Department of Industrial Engineering and Management

Supporting service innovation via evaluation: a future oriented, systemic and multi-actor approach

Kirsi Hyytinen

Aalto University

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Supporting service innovation via evaluation: a future oriented, systemic and multi-actor approach

Kirsi Hyytinen

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Abstract

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Abstract

The most urgent problems of our times – the environmental sustainability for example – are complex and systemic in nature. They cannot be solved via individual technologies or services but a combination of technological and service-based novelties, and collaboration between multiple actors, is required. It is also necessary to understand that the creation and dissemination of innovations depend on the dynamics of the system in which innovation efforts are carried out. This systemic nature of innovation and the complex societal problems in the background are the starting points of the dissertation.

This dissertation studies evaluation as a supporting practice in the context of innovation. It responds to the current evaluation challenge which has been noted within both general and service-based innovation research, and within evaluation research. The core problem is that traditional evaluation practices do not support innovation because the systemic perspective is neglected in the targets, and the implementation of evaluation does not take into account its dynamic nature. The dissertation suggests an alternative with two main aims. Firstly, it broadens the view on innovation as a target of evaluation:besides technological novelties, service, social and system innovations are included. Secondly, it develops a new type of evaluation approach which supports innovation in the systemic context.

The new evaluation approach builds on the basic ideas of developmental evaluation, and strengthens it with three broad perspectives: futures view, systems view and multi-actor view. A futures view links evaluation with innovation, whose essence is 'making something for tomorrow'. A systems view helps to identify the dynamic interlinkages between different factors in the target of evaluation. Finally, a multi-actor view creates understanding of the forces that make innovations to happen, spread and gain foothold.

The approach is further developed in the empirical context of energy and the environment. A Finnish innovation policy actor – a Strategic Centre for Science, Technology and Innovation (SHOK) – and its programmes, is used as a case example. The methodology of the dissertation is qualitative. The empirical application concretises how the approach can be implemented in practice and how the different perspectives and related methodologies support innovation. A futures view, concretised with foresight methodology, provides understanding of the future prospects of innovative energy services. A systems view, concretised with the integration of multi-criteria analysis and dynamic modelling, brings to the fore the multifaceted impacts of a new environmental data platform. A multi-actor view reveals the collaborative and interactive process in the development and implementation of innovation programmes.

Keywords Service innovation, evaluation, impact assessment, social innovation, systemic change, combining methods, environmental and energy sector

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Tiivistelmä

Aikamme isot yhteiskunnalliset haasteet – kuten kestävä kehitys – ovat luonteeltaan monimutkaisia ja systeemisiä. Niitä ei voi ratkaista yksittäisillä teknologioilla tai palveluilla. Haasteisiin vastaaminen edellyttää uusien teknologioiden ja palveluiden yhdistämistä, ja eri toimijoiden välistä yhteistyötä. Innovaatioiden kehittäminen, levittäminen ja käyttöönotto puolestaan edellyttävät laajan toimintaympäristön ja sen dynamiikan tuntemusta. Nämä yhteiskunnan monimutkaiset haasteet, ja niihin liittyvien innovaatioiden systeeminen luonne, ovat lähtökohtana tässä väitöskirjassa.

Väitöskirjassa tarkastellaan arviointia innovaatioiden kehittämisen tukena. Nykymuotoisen arviointitoiminnan ongelmallisuus on havaittu sekä innovaatio- ja palvelututkimuksen että arviointitutkimuksen piirissä. Perinteiset arviointikäytännöt eivät tue innovaatioita systeemisessä ympäristössä. Tämä johtuu yhtäältä siitä, että arvioinnin kohteena olevat innovaatiot on ymmärretty kapea-alaisesti. Toisaalta arviointien toteutuksessa ei ole otettu huomioon innovaatioiden dynaamista luonnetta. Tässä väitöskirjassa tarjotaan vaihtoehto, joka laajentaa ymmärrystä innovaatioista: teknologisten uutuuksien rinnalla keskiöön nostetaan sekä palvelut että sosiaaliset ja systeemiset innovaatiot. Toiseksi, työssä kehitetään uudenlainen arvioinnin lähestymistapa, joka tukee innovaatioita systeemisessä toimintaympäristössä.

Esitetty uusi lähestymistapa nojautuu kehittävän arvioinnin periaatteisiin. Väitöskirja ehdottaa kolmea näkökulmaa näiden periaatteiden vahvistamiseksi ja laajentamiseksi: tulevaisuusorientaatiota, systeemisyyttä ja monitoimijaisuutta. Tulevaisuusorientaatio yhdistää arvioinnin innovaatiotoimintaan, jonka tavoitteena on synnyttää 'huomisen ratkaisuja'. Systeemisyys auttaa ymmärtämään innovaatioihin liittyvien tekijöiden monimutkaisia vuorovaikutussuhteita. Monitoimijaisuus puolestaan tekee näkyväksi eri toimijoiden välisen yhteistyön merkityksen innovaatioiden syntymiselle ja leviämiselle.

Lähestymistapaa kehitetään ja konkretisoidaan energia- ja ympäristöpalveluiden kontekstissa. Tutkimuksen empiirisenä kohteena on suomalaisen innovaatiopolitiikan instrumentti: strategisen huippuosaamisen keskittymät (SHOK). Väitöskirjan tutkimusmenetelmänä on laadullinen case-tutkimus. Arvioinnin lähestymistavan käytännön soveltaminen osoittaa, miten eri näkökulmat ja niihin liittyvät menetelmät tukevat innovaatiota.

Avainsanat Palveluinnovaatio, arviointi, vaikuttavuuden arviointi, sosiaalinen innovaatio, systeeminen muutos, monimenetelmällisyys, ympäristö- ja energiasektori

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The most part of this dissertation has been carried out in SOPPI-project (Service and social innovations – policy needs and potential impacts) which was led by Marja Toivonen. My special thanks go to Ms. Hannamaija Määttä and Mr. Sampsa Ruutu who has been my closest colleagues in that project. They are both intelligent and creative researchers, and they have given me new valuable insights into research work. Together we learned the practices of academic research, visited multiple conferences and dived deep into the empirical work; and we always had so much fun and laughter when working together. Sampsa as my co-author has been extremely patient when teaching me the secrets of system dynamic modelling. My sincere gratitude goes to him: without his help and support my dissertation would have been incomplete.

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being present despite my 'long-lasting absence': being able to share the moments of enthusiasm and despair with you all has been extremely important. I'm particularly grateful for my mother Pirjo and father Pekka for their everlasting trust and encouragement. I highly appreciate their way of guiding me and my brothers Mikko and Tuomas to be independent and responsible. They have wisely encouraged us to follow our own hearts and values in life choices by providing back-up whenever needed. My brothers and their families, as well as Vili and Veeti, I thank for giving me so much joy and for reminding me of the life outside my research bubble. I'm grateful for my godmother Ulla for being there whenever I needed: our regular and insightful discussion gave me joy, faith and perspective to life. My parents-in-law, Seija and Heikki, I thank for being there for my family and for helping with our daughter.

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"He who is different from me does not impoverish me – he enriches me. Our unity is constituted in something higher than ourselves – in Man... For no man seeks to hear his own echo, or to find his reflection in the glass."

Helsinki, 1 January 2017

Kirsi Hyytinen

List of publications

The dissertation consists of the summary chapter and the following original publications. The publications are reproduced with the kind permission from the publishers.

Article 1*:* Nieminen M. & Hyytinen K. (2015), Future-oriented impact assessment: Supporting strategic decision-making in complex socio-technical environments. *Evaluation*, 21 (4), 448–461.

Article 2: Hyytinen, K. & Toivonen, M. (2015), Future energy services: empowering local communities and citizens. *Foresight*, 17 (4), 349–364.

Article 3: Hyytinen, K., Ruutu, S., Nieminen, M., Gallouj, F. & Toivonen, M. (2014), A System dynamic and multi-criteria evaluation of innovations in environmental services. *Economics and Policy of Energy and The Environment*, 3/2014, 29-52.

Article 4: Hyytinen, K. (2015), Multi-actor collaboration for the development of service innovations. *XXV International RESER conference*, 10.–12.9.2015, Copenhagen, Denmark. Accepted to be published in the European Review of Service Economics and Management (ERSEM), 22 pages.

Contributions of the author

Article 1: Nieminen M. & Hyytinen K. (2015), Future-oriented impact assessment: Supporting strategic decision-making in complex socio-technical environments. *Evaluation*, 21 (4), 448–461.

The theoretical analysis and the conceptual model included in the article were developed jointly by Mika Nieminen and Kirsi Hyytinen. They also wrote the article together. Kirsi Hyytinen was the responsible author for the following sections: introduction, traditional evaluation culture, multi-method approach, and implementation of the approach. Nieminen had the main responsibility for the sections 'societal change', 'understanding of complex socio-technical change', and 'conclusions'. The authors revised the article jointly based on the comments of anonymous reviewers of the journal 'Evaluation'. Kirsi Hyytinen presented an initial version of the article in the Early Career Research Conference (ECRC), EU-SPRI (European Forum for Studies of Policies for Research and Innovation), 2013.

Article 2: Hyytinen K. and Toivonen M. (2015), Future energy services: empowering local communities and citizens. *Foresight*, 17(4), 349–364.

The article was written collaboratively by Kirsi Hyytinen and Marja Toivonen. Kirsi Hyytinen developed the structure of the paper and was the main author in the analysis of socio-technical change, social innovation and service innovation. She also carried out the empirical analysis. Marja Toivonen was responsible for the foresight approach; she also participated in the formulation of the final results and conclusions. The authors revised the article jointly based on the comments of anonymous reviewers of the journal 'Foresight'.

Article 3: Hyytinen K., Ruutu S., Nieminen M., Gallouj F. and Toivonen M. (2014), A System dynamic and multi-criteria evaluation of innovations in environmental services. *Economics and Policy of Energy and the Environment*, 3/2014, 29–52.

Kirsi Hyytinen was the main author of the article. She was responsible for the theoretical analysis, methodological development, multi-criteria analysis, and discussion. System dynamic modelling was carried out in tight collaboration with Sampsa Ruutu, who generated the causal loop diagram included in the article. Sampsa Ruutu and Kirsi Hyytinen wrote jointly the empirical analysis of the modelling part. Marja Toivonen, Faiz Gallouj and Mika Nieminen contributed to the development of the theoretical analysis and provided comments on the paper. Kirsi Hyytinen presented an initial version of the article in the Annual Conference of RESER (European Association for Research in Services), 2014. She revised the article based on the scientific feedback of the conference.

Article 4: Hyytinen, K. (2015), Multi-actor collaboration for the development of service innovations. *XXV International RESER conference*, 10.–12.9.2015, Copenhagen, Denmark. Accepted to be published in the European Review of Service Economics and Management (ERSEM), 22 pages.

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Table of contents

1 Introduction

1.1. Background and the main aim of the dissertation

During the past 40 years, the most striking characteristics in the societal development have been the accelerated pace of technological and social changes and the increase of global interdependence (Lundvall, 2007). At the same time, it has become evident that major societal problems – concerning for example environmental issues – are complex and systemic in nature (Harrisson et al., 2010). The role of innovations has been emphasised when tackling these problems. Because of their systemic nature, it is impossible to find solutions through individual product or service innovations only, but large scale changes are required (Rubalcaba et al., 2013). Prerequisites for these kinds of changes are combining technological innovations and service-based novelties with the social support and engagement of various stakeholders (Djellal & Gallouj, 2010, 2013a; Hochgerner, 2009). The following three perspectives have been emphasised when dealing with system level problems and challenges:

- Innovations needed are multiple in nature: technological and service-based novelties are interlinked with broad social and systemic changes (Harrisson et al., 2010; Djellal & Gallouj, 2010, 2013a; Rubalcaba et al., 2013).
- Collaboration between multiple actors and stakeholders, representing different sectors of society, is required. The complementarities and synergies between public, private and third sector organisations are essential (Windrum, 2013; Lévesque, 2013; Moulaert et al., 2005).
- Developing innovations and disseminating them at the systemic level requires understanding about the whole socio-technical system, including the dynamics and interplay between parts of the system (Geels, 2010; Geels & Schot, 2007; Kemp & Rotmans, 2004; Kemp et al., 2009).

The viewpoints described above have significant implications to public policies. Novel approaches that support the development and implementation of innovations, strategic planning and evaluation have become necessary (Hartley, 2005; Lévesque, 2013; Smits & Kuhlmann, 2004; Kuhlmann et al., 2010). Services, which are often manifestations of the changes, are shaped through new types of governance mechanisms that include the rise of networks and partnerships, innovation as democratic practice, the development of 'choice', and co-production -based delivery models (Langergaard, 2011; Newman & Clarke, 2009; Sørensen, 2002). In practice, this necessitates new kinds of methods, which strengthen horizontal approaches and steering mechanisms and are adaptive to enable to respond to the rapidly changing situations. A challenge is how to take into account the increasing complexity

and pace of change in order to guarantee robust and real-time information in decision-making. While there is an increasing number of individual tools to generate and handle information and to use it in strategy and management (Kuhlmann, 2003; Kuhlmann et al., 2010; Rotmans & Loorbach 2009; Smits et al., 2010), there is an apparent need for more integrative approaches.

Service innovation studies, as an established area in innovation studies (Miles, 2016), provide a fruitful starting point for the analysis of the need and opportunities for social and system innovations, which are emerging research fields (Rubalcaba et al., 2012). Several common points can be identified. The outcomes of society level innovations and changes usually include new services or take place in service sectors. Also the empowerment and the participatory processes typically needed in systemic and social innovations resemble co-production practices recognised as an essential characteristic of services (Sundbo & Gallouj, 2000). The interplay between technological ingredients and immaterial aspects has been a study target in service innovation research right from the beginning (Miles, 2002) and is essential for understanding today's societal challenges and their solution opportunities. Finally, service offerings are systemic in nature, requiring the integration of a concept, process and resources (Edvardsson et al., 2006) – thus, service innovation studies have a long experience about the examination of systemic interactions.

In the context of innovation, the evaluation of the outcomes is an essential task. However, the current evaluation practices are largely based on the linear input-output-outcome -thinking, which does not correspond to today's complex development processes and the multiple relationships between the contributing actors (Arnold, 2004; Kuhlman, 2003; Patton, 2011; Rip, 2003). The increasing 'servitization of society' (Gebauer & Friedli, 2005; Neely et al., 2011) has created additional pressure to develop a more advanced approach to evaluation. Service studies, and specifically the studies on service innovation, have revealed the one-sidedly techno-economical nature of the indicators used in evaluation. These traditional tools and measures do not describe properly the innovativeness, impacts and performance of services (Djellal & Gallouj, 2010, 2013a; Metcalfe & Miles, 2000; Sundbo, 1998). More generally, they are not able to capture the immaterial, interactive and systemic characteristics of innovations.

Recently, *new approaches and supplementary methods have been sought within both general and service-focused innovation research, and within evaluation research*. In general innovation research, systemic approaches and the use of evaluation as a strategy tool have been emphasised (Kuhlmann, 2003; Rip, 2003). Foresight exercises and participatory approaches have been recommended to analyse the future prospects of innovations and to feed the strategy development (Arnold, 2004; Georghiou et al., 2008; Kuhlmann et al., 1999, 2010;

Kuhlmann, 2003; Rip, 2003; van der Knaap, 2006). In line with the above-described critique, service innovation scholars have suggested broader definitions for innovation and performance[1]. To capture the multi-faceted nature of innovation and to offer versatile perspectives to decision-making (Rubalcaba et al., 2013), they have highlighted the need for 'pluralistic and flexible evaluation' with multiple criteria (Djellal & Gallouj, 2010).

Also the evaluation scholars have raised the importance of a systemic perspective to the discussion. *Developmental evaluation* suggested by Patton (2011) reflects this approach. It has been designed to conduct evaluation in complex environments in a way which supports innovation. Other researchers have developed further Patton's ideas (e.g. Hargreaves & Podems, 2012). Partially the question is of systems researchers who have come to the field of evaluation and highlight the need for integrating systems thinking with evaluation: this integration is seen necessary in order to make visible the dynamic interrelationships and feedbacks in the entire system of innovation (Cabrera et al., 2008). Another group among the 'modernizers' of evaluation are the researchers who emphasise a multi-perspective approach, achieved via participatory practices. These scholars rely on the research stream which highlights empowerment and learning (Cousins & Earl, 1994; Fetterman, 2001; Torres & Preskill, 2001).

While the recent literature includes elements that respond to the evaluation challenge of the current society, the approaches and perspectives are dispersed in various research fields. Developmental evaluation – which is an effort towards a more integrative approach – is still at quite a general level of argumentation (Hargreaves & Podems, 2012). The representatives of this approach have themselves stated that there is a lack of framework which would both aggregate the recommendations for the improvement of evaluation and give concrete examples of them. Integration of the perspectives of social sciences and systems thinking, and the use of a multi-method approach, is urgently needed (Hargreaves & Podems, 2012; Patton, 2011).

The aim of this dissertation is to respond to the need for an integrative evaluation approach. It builds on the basic ideas of developmental evaluation, and strengthens and concretises it with

[1] 'Performance' is a concept that some service scholars have considered possible to be re-interpreted more easily than the concept of 'productivity', which is tightly linked to straightforward input-output considerations. For instance, Djellal and Gallouj (2009, p. 11) define performance as 'the improvement in the "positions" or "operating efficiency" relative to the various outputs'. They highlight that the performance of a given economic activity is not an objective category but is considered in different, even contradictory terms depending on the actors concerned (individuals, firms, political authorities). In addition to services, the subjective nature of performance also applies to tangible goods. It is particularly pronounced in the information and knowledge economy, which is based on intangible, abstract and socially constructed factors of production.

the following elements: a futures view concretised with foresight methodology; a systems view concretised with the multi-criteria analysis and dynamic modelling; and a multi-actor view concretised with participatory practices (societal embedding; Heiskanen et al., 2009; Kivisaari et al., 2004). Further, the dissertation examines how the development and implementation of innovations can be supported via this new type of evaluation. As regards the nature of innovations, the need for service, social and system innovations – in addition to technological innovations – is highlighted as a way to tackle major societal problems. In other words, evaluation is studied in the systemic context in which services and social phenomena play a central role.

Evaluation can be applied to many purposes: societal programmes, projects, and policies are typical application areas (Patton, 1997, 2011; Rossi et al., 1999). In this dissertation, *the focus is on the evaluation of innovation*, which has also been a common target but often narrowly concentrated on R&D -based activities. Because R&D is rare in services, the evaluation of innovation has a broader meaning in this dissertation: it also encompasses practice-based innovation (Russo-Spena & Mele, 2012; Toivonen, 2010).

The development of innovations is examined empirically in the area of energy and the environment. The selection of this focus is justifiable due to its topical nature: environmental sustainability is one of today's 'grand societal challenges' (Pope et al., 2004; Smith et al., 2010). Sustainable energy systems are generally considered one of the most efficient ways to achieve sustainable development (Haas et al., 2008). Energy is central to cope with major concerns of the 21st century: equitable economic development, human wellbeing and the avoidance of health risks, and environmental pressures caused by air pollution and climate change (Dincer, 2000; Kahn-Ribeiro et al., 2013). In addition to the topicality of the empirical focus, there is an apparent research gap that this dissertation aims to narrow. Service innovation studies in the area of environmental sustainability are rare (Gallouj et al., 2013); service economy has developed independently of the sustainability question (Gadrey, 2010). The implicit hypothesis that services are environment friendly because of their intangible nature has been questioned only recently (Djellal & Gallouj, 2016; Fourcroy et al., 2012). Even rarer are studies combining the social and systemic views and the evaluation perspective to the whole.

1.2. Research questions and specific perspectives

The aim of this dissertation is to examine service, social and system innovations and the related evaluation practices in the context of complex societal problems. *The dissertation opens up both the new types of targets of evaluation and aims to find a framework for a new type of an evaluation approach.* In order to tackle the former aim, it focuses on the issues of

how societal challenges can be answered via service, social and system innovations. In order to fulfil the latter aim, it examines which central elements are needed in an evaluation approach that supports the creation and implementation of these new types of innovations. Based on the analysis of literature, three broad categories have been selected as the starting point. A futures view is seen necessary for linking evaluation with innovation, whose essence is 'making something for tomorrow'. A systems view is seen necessary for the identification of the dynamic interlinkages between different factors in the target of evaluation. Finally, a multi-actor view is seen necessary for understanding the forces that make innovations to happen, spread and gain foothold.

The main research questions are:

> *RQ1 – Broadening the target of evaluation in the context of innovation: How should the view on innovation be broadened to tackle the current societal challenges, and how do service, social and system innovations contribute to this broader view?*
>
> *RQ2 – Developing a new approach for evaluation of innovations: How could a new integrative evaluation approach be constructed on the basis of recognised needs for futures thinking, systemic views and multi-actor approach?*

The central concepts included in the research questions are defined as follows:

- *A service innovation* is a new or renewed service which is put into practice, provides benefit to the provider and customers, involves some repeatable element(s), and is new in a broader context than the organisation which has developed it (Toivonen & Tuominen, 2009).
- *A social innovation* is 'social' in both its means and ends. Social innovations tackle social challenges – environmental and social sustainability in the first place – and they are based on participatory processes in a multi-actor environment (Harrisson et al., 2010; Rubalcaba et al., 2012).
- *A system innovation* – also used in the form 'systemic innovation' – is a new operational model which is based on the simultaneous development of organisations, technologies, services, and multiple network and partner relationships (Kemp et al., 2009; Saranummi et al., 2005).
- *Evaluation* refers to the procedures which systematically investigate the structure, results and value of an activity, and make visible the process towards them to enable a better orientation forward (Rossi et al., 1999; Vedung, 2006). The analysis increases the understanding of the role, rationale, contribution and performance of organisations or policy instruments (Patton, 2011).

- *Impact assessment* is linked to evaluation but has narrower contents: it refers to a purposeful evaluative study aimed to answer questions about the intended outcomes and impacts (of a specific intervention) in a defined societal context (Rossi et al., 1999).
- *Foresight* is an action-oriented and participatory process to analyse and identify the potential and alternative developments in the future from medium to long-term. It takes a comprehensive perspective to change and fosters an interactive process between multiple levels of a system (Dufva & Ahlqvist, 2014; Georghiou et al., 2008; Martin, 2010).
- *System dynamic modelling* is a methodology focusing on the underline feedback structure of a system. The models incorporate causal loop diagrams that map connections between system elements and reveal how the interactions of various feedback loops create certain dynamic behaviour (change over time in the variables of interest) in the system (Sterman, 2000).
- *Societal embedding* addresses the challenge of steering change through networked decision-making and 'co-creation' (Rotmans & Loorbach, 2009). Its core is a multi-actor perspective (a participative and interactive process between various actors) in setting the conditions for social development and in generating and scaling up innovations (Kivisaari et al., 2004, 2013).

1.3. Content of the dissertation

The dissertation consists of four articles and a summary chapter. The first article is conceptual and introduces the central idea and methods of the new approach to evaluation[2]. Three latter articles develop the elements of this approach: a futures view with foresight methodology (the second article), a systems view with the multi-criteria analysis and dynamic modelling (the third article), and a multi-actor view with participatory practices (the fourth article). These articles examine empirically the target of evaluation: service, social and system innovations. All of them concern innovation in the area of energy and the environment. A new Finnish innovation policy actor – a Strategic Centre for Science, Technology and Innovation (SHOK) – and its programmes, is used as a case example. Particular SHOK is Cleen, which operates in the area of energy and the environment. In the empirical articles, the new evaluation approach is applied, i.e. they aim to show how the new evaluation methods can support the development

[2] The concept used in the first article differs from the concept adopted in the other articles and in this summary. The first article applied the concept of 'impact assessment', which later was found to be too narrow and was replaced with the concept 'evaluation'. Even though there are narrower and broader approaches within this concept, too, it is better compatible with the future oriented, systemic and multi-criteria perspective applied in this dissertation.

and implementation of innovations. The contents of the four articles can be summarised as follows:

Article 1 'Future oriented impact assessment: Supporting strategic decision-making in complex socio-technical environments' (Nieminen & Hyytinen, 2015) examines the evaluation challenge in the context of complex societal problems. It introduces a future oriented and systemic evaluation approach, which integrates the methods of impact assessment, foresight, system dynamic modelling, and societal embedding under a single framework. The combination of different methods facilitates the accumulation of an extensive information base to support the strategic decision-making in complex situations. By developing a horizontal and holistic understanding, this approach responds to the current societal challenges – such as complexity, interdependence of societies and interconnectivity between technological, economic and societal developments – and aims to meet the challenges of changing evaluation standards. The approach provides a generic and flexible framework that can be utilised in different kinds of policy contexts.

Article 2 'Future energy services: empowering local communities and citizens' (Hyytinen & Toivonen, 2015) studies the future prospects of innovative energy services by utilising foresight. It applies qualitative trend analysis as the foresight method to create analytical understanding of the system level drivers and interdependences that influence the development and implementation of energy services. Two groups of trends were identified: the trends driven by technological development and the trends focusing on societal, managerial and consumer issues. The former consist of renewable energy sources, hybrid solutions, smart grids, and smart energy markets. The latter involve distributed energy production, demand response, optimisation of sustainability, and the role of energy as an opportunity and as service. The study reveals that energy should be increasingly understood as a comprehensive and tailor-made service solution for communities and individual households. Further, it highlights the significance of macro-level drivers and social and collaborative processes in the development of energy systems.

Article 3 'A system dynamic and multi-criteria evaluation of innovations in environmental services' (Hyytinen et al., 2014) analyses the challenge of evaluation in the context of systemic innovations in which services are a core element. The article argues that the traditional evaluation methods and measures are not able to capture either the diversity of innovations in services and systems or the multifaceted dimensions of performance resulting from these innovations. In order to contribute to a more purposeful evaluation practices and methods, it suggests a new combinatory approach to evaluate dynamic and multifaceted performance of services. This approach integrates the multi-criteria perspective of services (Djellal & Gallouj,

2010) and the system dynamic modelling (Sterman, 2000). The application of the approach is illustrated using an environmental data platform as a case example.

Article 4 'Multi-actor collaboration for the development of service innovations' (Hyytinen, 2015) studies the participatory and interactive process in the development and implementation of innovation programmes. Many ideas of societal embedding are applied in this article, even though the concept is not explicitly used. To understand how the collaborative arenas for a variety of actors may be organised, the article applies the concept of ServPPIN: public-private innovation networks in services (Gallouj et al., 2013). This concept concretises the collaborative mechanisms in which solutions to societal problems are sought via the integration of novelties in technology and services. It emphasises partnerships, negotiation and trust between multiple actors – highlighting the equal relationship between public, private and third sector organisations. The empirical results, based on experiences of the stakeholders taking part in the collaboration, confirmed the importance of versatility of the actor network but also revealed the complexity of participatory processes. These are essential characteristics in tackling the system level challenges and co-constructing solutions.

1.4. Research process

In the research process of this dissertation, the focus has been on the concept development on the one hand, and on the empirical work on the other. In the conceptual part, the main aims have been to understand service, social and system innovations as answers to 'grand societal challenges' (Cagnin et al., 2012; Smith et al., 2010), and to develop a new future oriented, systemic, and multi-actor evaluation approach to support the creation of innovations. The empirical work has verified and further developed the conceptual ideas concerning the nature of these innovations and the evaluation concept that could support them in the best possible way.

The actual research work was carried out in two research projects. The first conceptual article was elaborated in a strategic research project (STRADA, Future oriented impact assessment to aid strategic decision-making in complex socio-technical environments) of VTT Technical Research Centre of Finland Ltd. The project was carried out between the years 2013 and 2014. It aimed to develop a future oriented evaluation approach to support the decision making and implementation of systemic changes in the complex socio-technical environments. The studies providing material for the three latter articles were conducted in a research project (SOPPI, Service and social innovations – policy needs and potential impacts) funded by the Finnish Funding Agency for Innovation (Tekes) between the years 2013 and 2015. The project focused on the service, social and system innovations in general, and the specific part used in this

dissertation was carried out in the context of energy and the environment. Identifying policy needs and developing new evaluation methodologies to support the development and dissemination of innovations was a core interest in the project.

In the first phase of the dissertation process, the topic of complex societal problems and evaluation practices was analysed. This analysis resulted in the recognition of the need for a new type of evaluation and in the identification of elements that should be included in it: a futures view with foresight methodology, a systems view with the multi-criteria perspective and dynamic modelling, and a multi-actor view with participatory practices (societal embedding). In the second phase, these were examined in more detail. The general development of the new integrative approach for evaluation took place hand in hand with the application of the specific perspectives and methodologies.

However, the extent to which the development of the evaluation approach was explicitly linked to empirical studies, and discussed in the respective articles, varies. In the first empirical study, applying foresight, it was discussed only shortly because this study focused on the other main substance of the dissertation: it opened up the concepts of service, social and system innovations and analysed their roles as the manifestations, engine and drivers of societal changes. This study also introduced the empirical topic of the dissertation: services in the area of energy and the environment. The second study contributed more directly to development of the new evaluation approach. Its starting point was the multi-criteria analysis of Djellal and Gallouj (2010) which broadens the technology- and market-based evaluation of outputs and outcomes of innovation to the realms of relations, responsibility and reputation. In this study, system dynamic modelling was added to the Djellal-Gallouj analysis as a new element. The third study complemented the whole by transferring the multiple perspectives to the actor level; it was based on the ideas of societal embedding but did not apply its action research-procedures due to the restrictions of the research setting. In terms of innovation, the second and third articles focused on service innovations – however, the system view and social processes were also included: they influenced the problem formulation and can be identified in the results. In the present summary part, the three types of innovations (service, social and systemic) are again explicitly taken into account. Similarly, the three new constituents of evaluation (a futures view in the topic area, systemic interlinkages in the target innovation, and multiple perspectives of the actors that develop the innovations) are integrated to analyse the way in which evaluation can support innovation. Figure 1 illustrates the implementation of the research process.

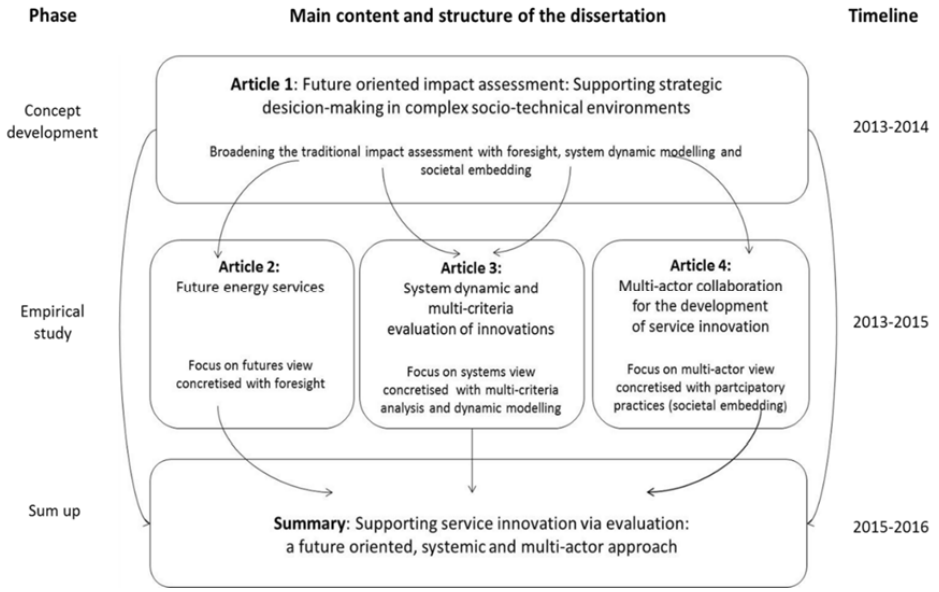

Figure 1. Research process in this dissertation

After this introduction, the summary part of the dissertation proceeds as follows. The second chapter includes the literature review, presenting the central theoretical perspectives applied in the dissertation: the framework of socio-technical change, theories on innovation and service innovation, and approaches of evaluation; it also describes theoretical starting points for the improvement of evaluation practices. The third chapter introduces the methodology and context of the empirical studies carried out in this dissertation. The main method has been case study and the context has been a novel policy actor and its innovation programmes in the area of energy and the environment. The fourth chapter summarises the results of empirical studies and reflects them in regard to the research questions. The final, discussion chapter collects the results into a new evaluation approach that supplements and enriches the approach of developmental evaluation. This chapter also includes the analysis of the theoretical contribution and managerial implications of the dissertation, as well as discussion on its scientific quality and limitations, and suggestions for future studies.

2 Literature review

The literature review discusses the theoretical topics on which this dissertation is based. The first sub-chapter starts with the presentation of systemic views to tackle complex societal problems and introduces the perspective of socio-technical change as a generic analysis framework. Systemic views are supplemented with the concept of social innovation, discussed as an engine of change. The second part of the literature review focuses on service innovations. It examines first the broad view of innovation as a prerequisite for the identification of innovation in services. Thereafter it discusses similarities and dissimilarities between service and technological innovations and introduces three basic approaches in this area of research: assimilation, demarcation and synthesis. Service innovations are also examined in the network context, which in this dissertation has been important in the study of public-private partnerships in particular. The third part of the literature review examines the evaluation challenge in the present society, presents three different evaluation approaches – summative, formative and developmental – and positions this dissertation within the last mentioned approach. In order to support and enrich this approach, the necessity of a multi-criteria perspective is brought to the fore and a model to apply this perspective is introduced. The developmental approach of evaluation is also deepened in three aspects that are included in it (either explicitly or implicitly) but should be strengthened: orientation towards the future, systems view, and multiple actors. They are further concretised in approaches that include both theoretical and methodological ingredients: foresight, dynamic modelling, and participatory practices (societal embedding). All of them are used in the empirical studies of this dissertation.

2.1. Societal challenges and the systemic view

The significance of innovation activities for economic growth has become more and more pronounced during the past few decades. Innovativeness increases competitiveness, and the growth strategy based on innovation makes it possible to foster employment and welfare on a larger scale. At the same time, it has become evident that the current social, economic, and environmental challenges are too big to be solved through individual product and service innovations created in individual organisations. The challenges require multiple innovations at different levels: the simultaneous development of organisations, technologies, services and network relationships (Gallouj, 1994, 2002; Harrisson et al., 2010; Rubalcaba et al., 2012; Windrum & García-Goñi, 2008). A crucial question is how to combine various innovations effectively and disseminate them rapidly on the basis of continuous interaction of different organisations.

Developing and examining innovations at the systemic level has come to the fore. While innovations are increasingly combinations of many technologies, organisational changes and services, they are also embedded in a wider social environment which supports or restrains their development. This wider context can be described as a socio-technical system, which provides a general framework to understand the creation and dissemination of innovations in a complex environment (Cabrera, 2006; Geels, 2002, 2004; Geels & Schot, 2007). In essence, this framework emphasises that the development of new innovative solutions to pursue a systemic change is a complex process that cannot be explained or analysed as simple causal relationships. The complex interaction between various actors, resources, institutionalised practices and regulations is a promoter of a systemic change (Geels, 2004; Lundvall, 2007; Vargo et al., 2015).

2.1.1. Socio-technical change as a generic framework

During the last decades, the framework of socio-technical system has been actively developed by the transition management approach (Geels, 2002; Kemp & Rotmans, 2004; Kemp & Loorbach, 2006). It is based on the work of a group of Dutch researchers (Kemp et al., 2001; Rip & Kemp, 1998). Originally the aim has been to describe changes in technological systems but later the framework has been applied to understand wider socio-technical changes in various contexts, such as electric systems (Verbong & Geels, 2007), urban development (Hodson & Marvin, 2010), and health-care systems (Kivisaari el. al, 2013). Socio-technical approach has also been used in the context of work, to analyse the interdependences of primary work system to whole organisation and macro-societal phenomena (Cummings, 1978; Tris, 1981).

In the core of the framework is the so-called multi-level perspective (Geels, 2002, 2004), which distinguishes three analytical levels to understand the dynamics of a socio-technical system. They are socio-technical landscape at the top level, socio-technical regime at the middle level, and niche-innovations at the bottom level. An essential argument is that a change of the system is possible only through the interaction between all three levels. Figure 2 illustrates the analytical levels of the socio-technical system.

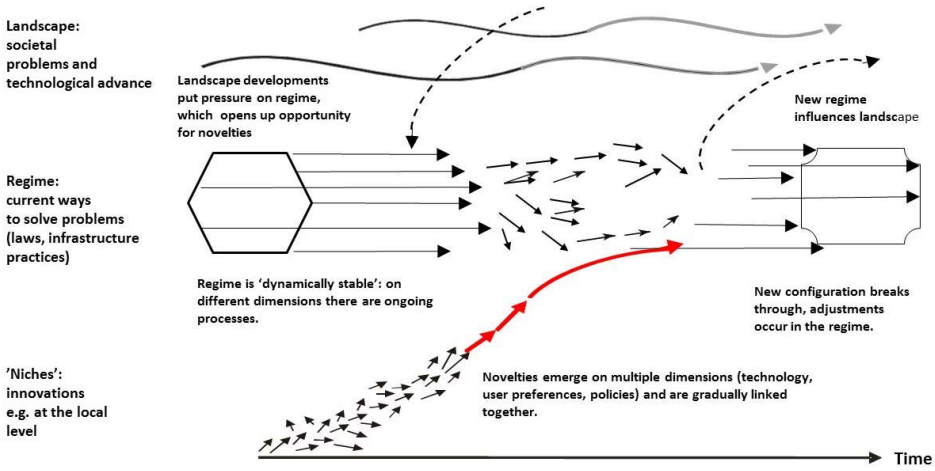

Figure 2. Multi-level perspective to socio-technical change (Geels & Schot, 2007, 401)

Socio-technical landscape refers to an exogenous environment encompassing large-scale and long-term societal trends (e.g. strive for sustainability), cultural and normative values, policy beliefs and worldviews as well as economic developments (e.g. depression, resource scarcity), which are quite stable and slow-changing factors in the society. Changes in the landscape may give rise to a pressure for change in the system. (Geels, 2002, 2004; Kemp & Rotmans, 2004)

In the middle of the model is *regime level*, which refers to well-established practices, structures and self-evident action patterns in the existing socio-technical system. It consists of five dimensions: available and used technologies, scientific institutions and paradigms, politics and administration, socio-cultural values and symbols as well as users and markets. Regime is an analytical concept which can be applied at various empirical levels from macro to micro levels; it can, for instance, be a certain industrial or societal sector. The regime level is the conservative element in the model: typically the institutionalised practices and structures are characterised by the stability which may cause 'path dependency' and 'lock-ins' in the system. The stability and constancy are maintained as long as there is 'compatibility' between the landscape and the regime. However, if the structures and action models in the regime are not compatible with the landscape, the regime confronts pressure from the landscape to change. This, in turn, may open up a window of opportunity for attempts to reform the regime itself (Berkhout et al., 2004; Geels, 2002, 2004; Geels & Kemp, 2007; Geels and Schot, 2007; Kemp et al., 1998).

The third level in the framework is '*niche',* which generates radically new innovations coming outside of the existing regime and protected from the normal market selection. The innovations generated at the niche level have the potential to reform or even transform the

existing regime. The niche level provides a 'protected' location for local initiatives, experiments and learning processes as well as a space to build social networks which support innovation. Radically new innovations often need protection because it takes time to improve their functionality, usability and performance. (Geels, 2002, 2004; Geels and Schot, 2007; Rip & Kemp, 1998; Kemp et al., 2001)

According to Geels (2002, 2004), innovations can break out from the niche level when the external circumstances are favourable to them. Ongoing processes at the landscape and regime levels may create a 'window of opportunity' for innovation and change. Landscape level changes (like climate change) or pressures in the existing regime (like changes in user preferences) may cause tension which may lead to the opening of new opportunities and the emergence of new solutions (ibid.)

In this dissertation, socio-technical change creates a generic framework to understand the wide societal context around the development of innovations. It helps to understand the system level challenges arriving from the operational environment and creating the pressure to develop and disseminate novel solutions in the context of sustainable development. Furthermore, socio-technical change offers a framework to analyse the long-term and dynamic process of a system level change by making visible the multiple actors, technologies, practices, resources and regulations that influence the development process. In addition, the framework points out that one actor or innovation cannot promote a systemic change alone. Instead, a prerequisite for scaling up local and delimited solutions and pursuing a system level change requires interaction of many actors and interconnections between parallel efforts to push through the change. (Elzen et al., 2004; Geels 2002, 2004; Kemp et al., 2001; Kivisaari et al., 2004; Rip & Kemp, 1998) That interlinks the system change with social innovation emphasising the latter as an 'engine for a change'.

2.1.2. Systemic change through social innovation

In addition to the description of the basic 'structure' of the socio-technical system, an essential question is how to intervene in ordinary practices and dynamics to accelerate the systemic change (Shove & Walker, 2010). The perspective of social innovation has been developed to improve understanding on the participatory and networked processes that are in the core of creation, implementation and diffusion of innovations (Harrisson, et al., 2010; Harrisson, 2012, Mulgan, 2007; Moulaert et al., 2013). The approach of social innovation highlights that collaboration between different actors and actor groups is essential: a prerequisite for the realisation of system level changes is the active engagement of various actors. Thus, system innovations are interlinked with social innovations. Many of them include the public, private,

and third sector organisations – not forgetting the central role of citizens as an engine for the change.

Social innovations are characterised by two different aspects of 'social': social by the ends and social by the means (Rubalcaba et al., 2013; Mehmood & Parra, 2013; Moulaert et al., 2013; Pol & Ville, 2009). The first aspect refers to the societal challenges (e.g. environmental sustainability) that innovations are aiming to solve, and the second aspect refers to the importance of engagement and participation (Harrisson et al., 2010; Kahnert et al., 2012). In addition, research into social innovation considers society a 'horizon of action' (Jessop et al., 2013, 124): society is not pre-given but it is co-constructed and defined by the multiple actors and multiple competing visions and preferences. This aspect of social innovation highlights the fundamental role of collective social practices and processes when developing new innovative solutions for societal transformations. Within this approach, particular attention is given to the relations and collaborative practices that promote the societal development, empowerment of the variety of actors, and governance of social structure (Jessop et al., 2013; Moulaert et al., 2013).

The integration of bottom-up and top-down perspectives is essential in social innovations (Rubalcaba et al., 2013). They may emerge at the grassroots level among users and employees, be produced in the collaboration of private, public and third sector organisations, or be initiated by policy makers and regulatory bodies. Bottom-up grassroots activities are an 'engine of social innovations'. The process of creation and implementation of social innovations highlights empowerment: citizens and their organisations are active co-developers of innovation (Sundbo, 1998). The importance of bottom-up processes is clearly observable in the sustainability context. The behaviour of consumers has a crucial impact on the achievement of the goals set. For instance, a change in user preferences is necessary in order to avoid undermining the improvements in the production and delivery of energy by consumption patterns (Weber & Hemmelskamp, 2005).

Equally important are the top-down processes which translate the general objectives into concrete policies and practices in the circumstances characterised by societal and political dispute (Meadowcroft, 2009; Pol & Ville, 2009). They are needed for the materialisation and dissemination of social innovations. Community decision makers and company managers have to support, recognise and organise bottom-up processes in order to make ideas implementable and scalable (Høyrup, 2012; Kivisaari et al., 2013). Policy actors have to enhance society's innovation capacity by revitalising innovation institutions and by fostering the innovation activities of public, private and third sector organisations (Rubalcaba et al., 2013).

The active role of citizens is a new emphasis in innovation research. Research into social innovations has also changed our notions on more traditional innovation activities – those taking place within and between firms and public organisations. This point of view has focused on new types of organisations and on the integration of initiatives in existing organisations (Moulaert et al., 2005; Mulgan, 2007). Research has been active concerning the third sector in particular (Osborne, 2009). Also private firms are entering the field of social innovation; corporate social responsibility and concern on sustainable development are more and more often a part of their strategies (Lapointe & Gendron, 2004).

The way in which the striving for social innovations changes innovation processes concerns all types of organisations – both public and private. Unlike innovations in the market sector, which traditionally have been kept outside competition as long as possible, social innovations call for imitation and diffusion (Rubalcaba et al., 2013). In them, open innovation is not an alternative strategy but the primary strategy, i.e. forming alliances and networks is essential. The governance and management of these networks have to support both the creation and dissemination of innovations. Dissemination is a challenging task due to two characteristics of social innovations: local nature and the lack of codification. The contribution of social innovations is typically manifested as the density of local networks and as local vitality that may result in new jobs and market activities. Scaling up innovations from this limited context requires the strengthening of their systemic features. It also requires new types of R&D practices that can facilitate the codification of social innovations and the procedures applied. (Harrisson et al., 2010; Moulaert et al., 2013; Pol & Ville, 2009; Rubalcaba et al., 2013)

2.2. Services as a challenger of the traditional view on innovation

Since the mid-1990s, interest in services and service innovation has rapidly accumulated among scholars and policymakers (Carlborg et al., 2014; Miles, 2016). This interest is linked to the increased importance of services in the economic and societal development: in Western countries, more than 70 per cent of the jobs and GDP are accounted directly by the services (Eurostat, 2015; OECD, 2014). Also the broadening of understanding about the nature of innovation and the discovery of the specificities of services has contributed to the growth of interest (Sundbo & Toivonen, 2011).

Research into service innovation has common theoretical roots with the so-called broad view of innovation (Lundvall, 2007): both rely on the work and definition of innovation by Schumpeter (1934, 1942) – the 'grand classic' in the field of innovation. This chapter discusses the central views on service innovation in more detail, also showing that the development of these views has proceeded partially hand in hand with the general innovation theory.

Describing the development phases of general innovation studies explains how the broad perspective has essentially contributed to the 'discovery' of innovation activities in services. However, because of the technological bias in innovation studies, services were for long regarded as secondary from the viewpoint of innovation (den Hertog, 2010; Toivonen & Tuominen, 2009). This biased view makes it understandable why the technological perspective still dominates the innovation policy discussion and the related approach of evaluation.

2.2.1. A broad view as a prerequisite for the analysis of innovation in services

The first theories on service innovation included a strong bias towards technology push (Barras, 1986; Soete & Miozzo, 1989). The theories which argue that service innovations are not necessarily linked to technology, usually rely on Schumpeter's (1934, 1942) classic work on the economics of innovation (Toivonen & Tuominen, 2009). According to the Schumpeterian definition, innovation can have several forms: 1) introduction of a new good or a new quality of a good, 2) introduction of a new method of production, including a new way of handling a commodity commercially, 3) opening of a new market, 4) conquest of a new source of supply of raw material or intermediate input, and 5) the establishment of a new organisation (Schumpeter, 1934). Schumpeter regarded new combinations of existing things – referring to incremental renewals – as the most general form of innovations, but also acknowledged the significance of radical discontinuities. Further, he raised entrepreneurs to a central position as innovative agents. In this way he laid the grounds for the studies that examine innovations emerging in everyday business activities (ibid.).

Schumpeter's definition of innovation was much broader and more open than the paradigm which became dominant after him along with the systematisation of innovation activities and generalisation of R&D laboratories of companies (Dosi, 1988; Kline & Rosenberg, 1986; Lundvall, 1992, 2007). The view – known as the linear model of innovation – put the focus on the provider's push and science-based technological inventions developed in institutionally and organisationally distinct R&D units (Kuhlmann et al., 2010). Further, it emphasised innovation development as a systematic and serial process, in which the different stages have different functions: basic research produces theories and findings that are redefined in applied research, thereafter theories and findings are tested in development processes, and finally innovations are launched to the markets and taken into use (Saren, 1984). The approach remained prevalent until the latter part of the 1980s, and its influence is still perceivable in the so-called stage-gate models of innovation (Cooper 2001, 2008).

Starting from the study of Kline and Rosenberg (1986), the linear model met critique and alternative models gained ground. Empirical studies revealed the complex, uncertain and

iterative nature of innovation activity and put emphasis on learning, using and interacting (Lundvall & Johnson, 1994). A broader perspective about the nature of innovation highlighted that radical technological innovations are not the only types of innovation, and R&D organisations are not the only way to generate innovations. Incremental and less tangible improvements became appreciated and the role of everyday business was acknowledged as an important arena for generation of innovations. (Lundvall, 1992; Lundvall & Johnson, 1994; Lundvall et al., 2002; Schienstock, 1999) These new thoughts gave a birth to 'the neo-Schumpeterian' theory of innovation or 'the broad view of innovation' (Dosi, 1988; Freeman, 1991; Lundvall, 1992, 2007; Nelson & Rosenberg 1993), leading to the recognition of the interactive nature of innovation (Shapira et al., 2010; Smits & Kuhlmann, 2004), which further led to the systemic perspective of innovation (Kuhlmann et al., 2010).

The paradigmatic change in mainstream innovation theories was a prerequisite for the emergence of research into service innovation (Howells, 2004; Toivonen & Tuominen, 2009): without the change from the linear to the broad view of innovation, the majority of service innovations would have remained hidden (Miles, 1993). On the other hand, research into service innovation has contributed to the further development of general innovation theories and the neo-Schumpeterian view on innovation (Smits & Kuhlmann, 2004); in these studies, the incremental and multi-faceted nature of innovations as well as the role of users, interactions and feedback in the innovation process have been highlighted (den Hertog et al., 1997; Gallouj & Weinstein, 1997; Smits & Kuhlmann, 2004).

Today, the majority of innovation related concepts and theoretical constructs criticise the linear model and emphasise the systemic nature of innovation, uncertainty of the innovation process, and the close linkage of innovation to learning (Kuhlmann et al., 2010; Smits & Kuhlmann, 2004). These prevailing thoughts affect not only the theory of innovation but also the innovation related policy and practice (Shapira et al., 2010). However, many policy instruments are still founded on the linear model (Boekholt, 2010; Shapira et al., 2010) and many policy-makers use them as 'cognitive maps of the innovation process' (Shapira et al., 2010, p. 451). Recent studies (Flanagan et al., 2011; Kuhlmann et al., 2010; Shapira et al., 2010; Smits & Kuhlmann, 2004) have suggested that both research into innovation policy and the actual policy processes should acknowledge a systems approach. In addition, science and technology as sources of innovation should be supplemented with numerous other aspects – such as variety of engaged actors and multi-level and multi-governance patterns – in order to achieve success.

2.2.2. Characteristics of service innovation

The dominance of technologically and materially biased views in general innovation studies has affected the conceptualisation of innovation in services (Gallouj & Savona, 2009). The literature on service innovation applies three main approaches: assimilation, demarcation and synthesis (Coombs & Miles, 2000); also called technologist, service-oriented and integrative approaches (Gallouj, 1994, 1998, 2002)[3]. These approaches offer a framework to classify, analyse and understand service innovation (Carlborg et al., 2014; Drejer, 2004). Each of the three perspectives takes a fundamentally different view on service innovation and its relationship to technology. Together they represent the evolution of service innovation research (Carlborg et al., 2014; Gallouj & Savona, 2009). However, instead of replacing the earlier one, the other perspective has supplemented it with radically new insights (Janssen, 2015).

The assimilation approach represents the earliest line of thinking about service innovation. According to it, services are supplementary to manufacturing, and technological and industrial innovation should be set as an ideal in them (den Hertog, 2010; Toivonen & Tuominen, 2009). Thus, this approach suggests that models and theories based on the technological definition of innovation are applicable also in the context of services (Coombs & Miles, 2000; Gallouj 1994). 'The reverse innovation cycle' -model by Barras (1986) – often mentioned as the first innovation theory which concentrated specifically on services – represents the assimilation approach. According to the model, a service innovation process is converse of the traditional innovation cycle in manufacturing, meaning that process innovation precedes product innovation. Despite the pioneering nature of the model, it does not contribute much to the understanding of innovation in services. Instead, the model analyses primarily the diffusion of innovations and describes the impacts that the spread of technological innovations causes in service sectors (Gallouj & Weinstein, 1997). The assimilation approach is identifiable also in other early studies; for example, the first innovation-based taxonomy of services, presented by Soete & Miozzo (1989), relies on this approach.

'Assimilationists' overlook the non-technological aspects of novelties, which is why the majority of service researchers have considered this view too narrow to create understanding

[3] Concepts relating to these three theoretical approaches vary in the literature. Gallouj (1994, 2002; Gallouj & Savona, 2009) separates between technologist (industrialist), service-oriented (differentiation) and integrative (synthesising) views. Coombs and Miles (2000) utilise the concepts of assimilation, demarcation and synthesis. There are even some contents-based differences in emphases in addition to the different concepts. Some authors (Droege et al., 2009) see that the technologist perspective refers to technological progress and competence gains generated by services; the assimilationist perspective, instead, claims that innovations in services are fundamentally similar to those in manufacturing. Partially, the differences are explained by the fact that the concepts have been developed in the different language traditions (Miles, 2016).

of services. As a counter-reaction, there emerged the demarcation approach (also known as the service-oriented approach) which resolves many of issues included in the assimilation perspective: it seeks to identify hidden forms of innovation (Coombs & Miles, 2000; Gallouj 1994, 1998). It focuses on the identification of specific characteristics of service innovations and pays attention to implications following from the intangible and co-produced nature of services (Preißl, 2000). An important implication of intangibility is the difficulty of recognizing the 'newness' and defining the unit of output (Djellal & Gallouj, 1999; Preißl, 2000). Interaction with customers makes it implausible to separate between product and process innovations: services are immaterial products whose core is an act or activity (Gadrey, 1996). Interaction also increases the general complexity in the development of services innovations (Gallouj et al., 2013). 'Demarcationists' argue that new service specific theories of innovation are required to understand the nature and the dynamics of innovation in services (Gallouj & Windrum, 2009).

The third approach is synthesis, which highlights the production and consumption of integrated solutions and systems (Coombs & Miles, 2000; Gallouj 2002; Gallouj & Weinstein, 1997). The approach has become increasingly relevant due to the 'servitization' of the economy, and the blurring boundaries between goods and services (Gallouj & Savona, 2009; Carlborg et al., 2014). In addition to service sectors, service innovations appear increasingly in manufacturing, where the forming of product-service bundles is essential (Kindström et al., 2013). Services are an integrated part of the change process in individual products as well as in the transformation of entire industries, value chains or other major elements of socio-technical systems (Janssen, 2015). Therefore, rather than seeing service innovation as fundamentally similar or different from innovation in goods, the synthesis approach aims to create a common framework, which pays attention to varying aspects of novelty as well as to the multi-dimensional and heterogeneous nature of innovation, and is applicable in both services and manufacturing (Carlborg et al., 2014).

The synthesis approach shares the broad view on innovation (Lundvall, 2007); in accordance with the renaissance of Schumpeter's (1934, 1942) views – known as the neo-Schumpeterian approach (Windrum & García-Goñi, 2008) – it considers innovation as a cumulative (sometimes radical) change that can result in novel products, but also in novel processes, organisational forms or market openings. Important aspects are the complexity and uncertainty of innovation processes, the unfinished nature of outcomes due to their 're-invention' in the use context, and the multiplicity of actors taking part in the creation and dissemination of innovations (Lundvall, 2007). The neo-Schumpeterian view has been the basis for the definition of service innovation by Toivonen and Tuominen (2009, p. 893): 'A service innovation is a new service or such a renewal of an existing service which is put into

practice and which provides benefit to the organisation that has developed it; the benefit usually derives from the added value that the renewal provides the customers. In addition, to be an innovation the renewal must be new not only to the developer but in a broader context, and it must involve some element that can be repeated in new situations; i.e. it must show some generalizable feature(s). A service innovation process is the process through which the renewals described are achieved.'

To analyse systematically the characteristics of services on the basis of the synthesis view, some specific approaches have been developed. The most well-known model has been developed by Gallouj and Weinstein (1997). It is widely applied and it has also been supplemented after its introduction (de Vries, 2006; Gallouj & Toivonen, 2011; Windrum & Garcia-Goñi, 2008). Its main purpose is to provide a theoretical model to take into account the specific innovation dynamics in services in a way that is compatible with innovation in material products. According to the Gallouj-Weinstein model, both services and goods are constituted of technical, process, and final characteristics – final characteristics describing the benefits for users. In services it is difficult to separate between the technical and process characteristics, and in addition individual competences play a central role. Thus, the model adopts a very broad view on technical characteristics, which are defined to include all tangible and intangible systems used in the production of services (also the process characteristics). The only group of characteristics that have to be analysed outside them are competence characteristics, which are the composition of individual skills of the service provider and the customer. (Gallouj & Weinstein, 1997)

The Gallouj-Weinstein model specifies different types of service innovations. Basically, it defines innovation as any change affecting one or more of technical (X), competence (C) or final (Y) characteristics. Six different types of innovations are identified: 1) improvement innovation, 2) innovation by addition or substitution, 3) architectural (or recombinative) innovation, 4) formalisation innovation, 5) radical innovation, and 6) ad hoc innovation. Improvement innovation means the increase in the value of certain Y by the enhancement of certain X or certain C. Innovation by addition or substitution occurs when one or more new element is added to or replaced in X (that also causes changes in C and Y). Architectural innovation refers to services, which are developed either by recombining the characteristics of two or more existing services or by dividing up existing services. Formalisation innovation occurs when a service is improved by clarifying the relationships between technical and final characteristics. Radical innovation refers to a completely new service – a change in all of its characteristics (X*, X*, Y*). Finally, ad hoc innovation refers to the tailored solution to a particular problem posed by a certain client. Even though the solution as such cannot be

transferred to new situation, the elements and expertise developed in connection to the solution are reproducible. (Gallouj & Weinstein, 1997; Gallouj, 2002)

The Gallouj-Weinstein model and its modifications have been applied when searching better indicators for innovation and performance in services. The peculiar characteristics of services that specifically have been pointed out in this context are intangibility and the central role of interaction; the latter refers to the co-production between the provider, customers and partners. An important implication of intangibility is the difficulty of defining the 'unit of output' and differentiating the product from the process. These aspects challenge the definition of innovation and quality improvements in it (Djellal & Gallouj, 2010). Interactivity increases the complexity of the development of services innovations (Gallouj et al., 2013). Ignoring these complex and dynamic relationships is often linked to the traditional technologic measures and the linear innovation model (Ahrweiler, 2010; Edqvist, 2005; Smith, 2000). It may lead to the oversimplification of the reality and to the biased understanding – not only of the impacts of services and innovations – but also of their drivers and dynamics (Arnold, 2004).

Recently, there has emerged a new approach to bridge service innovation and system innovation. This approach is the service-dominant logic (SDL), which has been developed by Vargo and Lusch (2004, 2008). Taking one step further in the service-orientation, it states that all economic activities consist of service, exchanged between actors. Compared to the view in which services (plural) are analysed as units of output, SDL understands service (singular) as a ubiquitous, collaborative process in ecosystems. In service innovation, it highlights the role of institutions and social structures that guide the action and interaction between multiple actors, i.e. it relies heavily on the systemic perspective of innovation (Vargo et al., 2015; Wieland et al., 2012). Its basic postulation is that irrespective of the amount of interaction, the value of both material goods and services is always co-created. This is because individual goods and services become meaningful only when they are linked to other goods and services, i.e. the value-in-use is essential and always defined by the user. The emergence of use value as a result of the integration of resources from many sources implies the importance of the broader actor network. In this network, different stakeholders have different perspectives to the novelties emerging, some of them being technological or financial but others including relational and social values. (Vargo & Lusch, 2004)

SDL is one of the perspectives that emphasise the significance of networks in service innovation. These perspectives have increasingly gained ground in recent research. In the next sub-chapter, network-based service innovations will be discussed in more detail from the viewpoint of this dissertation.

2.2.3. Network-based service innovations

Dealing with complex and continuously changing systems and 'wicked' societal problems requires flexibility, interconnectivity and cooperation. That drives the emergence of networked structures. Innovations and solutions to tackle system level challenges require collaboration between multiple actors representing different sectors of society. The complementarities and synergies between public and private and third sector organisations are essential (Gallouj et al., 2013). However, the networked structures of innovation are understood only partially (Rubalcaba et al., 2013). While there is an extensive literature on innovation networks (Callon, 1992; Edqvist, 1997; Tuomi, 2002), there are also biases. These biases are technological, industrial and market-based. In many cases, the focus is on technological innovations and less attention is given to the networks promoting non-technological ones (Djellal & Gallouj, 2013b; Edqvist, 1997). In the literature analysing innovations from the organisational perspective (Moore & Hartley, 2008), private and public innovations have been typically studied in isolation (Rubalcaba et al., 2013). In addition, understanding the different logics of innovations in private and public sectors is insufficient, which produces partial and incomplete understanding of the drivers and dynamics of innovations and services (Hartley, 2005; Levesque, 2013). What is needed is a more comprehensive understanding of the collaborative development processes between the variety of actors providing societally important innovations (Moore & Hartley, 2008; Windrum, 2013).

The multi-actor perspective has been proposed as an analytical framework to better understand the collaborative structure and complex interaction between decision makers, public and private service providers, and users (Windrum & Garcia-Goñi, 2008; Windrum, 2013). A recently introduced network concept ServPPIN (public-private innovation networks in services; Gallouj et al., 2013) aims to bridge the existing research gap by focusing on the complementarities and synergies between public and private service providers (Di Meglio, 2013; Rubalcaba et al., 2013). It concretises the collaborative mechanisms which seek solutions to complex societal problems through the integration of novelties in technology and services, and which appreciate partnerships, negotiation and trust between a variety of actors (Hartley, 2005; Levesque, 2013; Moore & Hartley, 2008; Voß et al., 2006). As an organiser of the development, production and delivery of new innovative services, ServPPINs have been seen as a practical way to create cooperative and interactive arenas to tackle the challenges posed by the increasing societal fragmentation, complexity and dynamism (Di Meglio, 2013; Gallouj et al., 2013; Sørensen & Torfing, 2007).

The collaborative relationship between public and private sector partners is in the heart of the ServPPIns. Deviating from the traditional innovation networks (Djellal & Gallouj, 2013b), ServPPINs highlight the equal role of public service providers and manufacturing firms. Instead of having a limited role as the provider of infrastructure, financing and institutional framework, public organisations may be real co-producers of service innovations by initiating, organising and propagating new ideas (Di Meglio, 2013). Moreover, to facilitate better matches between the technology and demand, ServPPINs involve consumers, intermediate users and third sector organisations to be active collaborators (Rubalcaba et al., 2013).

ServPPINs embody flat and flexible types of organisations which aim to develop synergies between different knowledge, competences, interests, objectives and services that different partners bring into the network (Di Meglio, 2013; Gallouj et al., 2013; Rubalcaba et al., 2013). Based on the empirical studies (Cruz et al., 2015; Cruz & Paulino, 2015; Rubalcaba et al., 2013; Weber & Heller-Schuh, 2013), the potential of ServPPINs is in credibility, dissemination and speeding up the process of agenda setting and decision making, provision of a more comprehensive view of the problems, legitimacy, resources and efficiency, learning capacity and knowledge transfer.

There are some key features which help to understand how ServPPINs operate. Firstly, they are grounded on the broad concept of innovation brought about by evolutionary economics (Dosi et al., 1988; Dosi, 1999; Kline & Rosenberg, 1986; Nelson & Winter, 1982) that highlights the dynamic nature and integrative perspective of innovations, i.e. both technological and non-technological aspects have a crucial role. Secondly, they are formed as multi-agent frameworks (Windrum & Garcia-Coñi, 2008; Windrum, 2013) in which the variety of actors from the public, private and third sectors are involved both in the innovation process and in the delivery of the final service, and in which each of the actors incorporate their specific competencies and interests into the innovation process. By engaging various actors in the different phases of innovation, ServPPINs may promote systemic change in the sectors concerned (Weber & Heller-Schuh, 2013). The third aspect relates to the life-cycle perspective: the evolution of a ServPPIN through different phases. The phases are design, pilot and implementation, and consolidation; and all of them may affect to the dynamics and composition of the network. Fourthly, ServPPINs are characterised by the open, complex, uncertain and interactive trust-based process in which several driving forces influence the final outcome (Fuglsang, 2013). The level of 'formality' and structuring of relationships may vary, but a certain degree of formalisation in usually required (e.g. exploitation of intellectual property rights).

Typology of ServPPINs

Djellal and Gallouj (2013b, 39) have proposed a typology of ServPPINs. The criteria used for this typology pay attention to the nature of innovation (tangible vs. intangible) and the characteristics in its development process (planned vs. unplanned). Based on the typology, four types are identified: 1) simple ServPPINs set up to adopt a technology; 2) simple ServPPINs set up to produce a technological innovation; 3) simple ServPPINs set up to produce a non-technological innovation; 4) complex or architectural ServPPINs. Table 1 illustrates these different types. In this dissertation, the analytical dimensions of the typology have been applied in Article 4 in particular. They are used to characterise the empirical study context and to provide understanding of the participatory processes and experiences of multiple actors taking part in the innovation development. The focus is on the roles of different actors, on the type of innovation processes, and on the outcomes of innovations produced by these networks.

Table 1. ServPPINs according to their complexity (Djellal & Gallouj, 2013b, 39)

Type of innovation	Technological innovation	Technological innovation	Non-technological innovation	Complex, architectural innovation
Dominant type of innovation process	Planned innovation		Unplanned innovation	Planned/unplanned innovation
Type of ServPPIN	Simple ServPPIn to adopt technological innovation	Simple ServPPIN to co-produce technological innovation	ServPPIn to co-produce non-technical innovation	Complex ServPPINs to adopt/ produce complex architectural innovation
Theoretical perspective	Assimilation		Demarcation	Integration

The typology is related to the basic service innovation perspectives: 'assimilation – demarcation – synthesis' (Coombs & Miles, 2000); also used in the form 'technologist – service-oriented – integrative' (Gallouj, 1994). Djellal & Gallouj (2013b) apply a combination of them. Simple ServPPINs – the first category – adopt a technology that has been produced elsewhere. They include minimal collaboration between public and private actors; the aim is, for example, to make joint investments and to organise the common use of technology. Simple ServPPINs may, however, also co-produce technological innovation (the second category); various actors from public and private sectors are involved. The 'simplicity' here indicates that the objective of the development is limited and does not cover the integration of technological and non-technological novelties (the innovations developed may be relatively complex). In both the first and the second categories, the process is predominately based on planned

innovation. The third category includes simple ServPPINs set up to produce non-technological – organisational, social and methodological – innovations. They typically adopt an unplanned innovation process, such as bricolage (Fuglsang, 2010), ad hoc innovation (Gallouj & Weinstein, 1997), or a rapid application model (Toivonen, 2010). Their complexity derives from the large number and diversity of partners as well as tacit knowledge and technologies they bring into the network. The fourth category involves complex or architectural ServPPINs. Their objective is to solve complex organisational or societal problems by combining various forms of technological and non-technological innovations. Co-production is the central principle integrating both the bottom-up and top-down processes (Djellal & Gallouj, 2013b).

ServPPINs as a manifestation of modernisation trends in public sector governance

ServPPINs have mainly emerged as a result of the modernisation and reform trends in the public sector (Di Meglio, 2013). They reflect a further change in the focus of public service provision: from cost-efficiency, markets and consumers towards complexity, co-production and public value (Levesqué, 2013; Rubalcaba et al., 2013). This development manifests a broader change in the governance discourse (cf. Langergaard, 2011). In the literature (Hartley, 2005), three competing paradigms of governance and public management have been identified: traditional public administration, New Public Management (NPM) and network governance. These paradigms represent different approaches to the generation, adoption and implementation of innovation (Hartley, 2005; Levesqué, 2013; Moore & Hartley, 2008). Each paradigm contains a different 'world view': particular assumptions about societal needs and a diverse understanding of the means and roles of different actors in tackling the societal challenges.

Developments in the public administration and governance culture have influenced evaluation research and practices; they also give reasons to seek more advanced approaches in evaluation. Table 2 summarises the characteristics of the three paradigms on the basis of Hartley's suggestion (2005). (The order of the analytical dimensions has been slightly modified to follow the idea and structure of this dissertation.)

Table 2. Three paradigms in governance (Hartley, 2005)

	Traditional public administration	**New Public Management (NPM)**	**Network governance**
Context	Stable	Competitive	Continuously changing
Needs/problems	Straightforward, defined by professionals	Wants, expressed through markets	Complex, volatile and prone to risk
Innovation	Large scale national and universal innovations	Innovation at organisational level	Innovation at both central and local levels
Improvement	Large step-change improvement initially, less capacity for continuous improvement	Improvements in managerial process and systems. Customer focus produces quality improvements in services	Aiming for transformational and continuous improvement in front-line services
Population	Homogenous	Atomised	Diverse
Role of policy makers	Commanders	Announcers	Leaders and interpreters
Role of public managers	'Clerks and martyrs'	Efficiency and market maximisers	Explorers
Role of population	Clients	Customers	Co-producers
Strategy	State and producer centred	Market and customer centred	Shaped by civil society; co-production
Governance through actors	Hierarchies, public servants	Markets; purchasers and providers; clients and contractors	Networks and partnerships; civic leadership
Key concepts	Public good	Public choice	Public value

The traditional public administration paradigm is largely based on a bureaucratic, hierarchic and rule-based approach. Societal context is considered fairly stable; needs and challenges are defined by professionals. Authority lies with the government, and standardised services – for the homogenous group of citizens – are provided by the public sector. New Public Management, instead, emphasises the competitive state, efficiency in terms of the economy and market selection, and the replacement of public services by private actors. Further, it sees the role of citizens as customers or service users. (Hartley, 2005; cf. Di Meglio, 2013; Windrum, 2008) Due to the increasing societal fragmentation, complexity and dynamism, new forms of non-hierarchical, de-centralised governance mechanisms have been demanded (Di Meglio, 2013; Hartley, 2005; Lévesque, 2013; Moore & Hartley, 2008; Rhodes, 1997; Sørensen & Torfing, 2007; Voß et al., 2006). Network governance is seen as a possible answer; it includes the rise of networks and partnerships, innovation as democratic practice and co-production of services (Langergaard, 2011; Newman & Clarke, 2009). It is also seen as a useful mechanism that supports the creation of innovations along the continuously changing societal conditions (Voß et al., 2006).

While the networked forms of governance have aroused much interest (Levesqué, 2013; Moore & Hartley, 2008), there is no agreement whether they are becoming the dominant steering mechanism in the public sector. There are apparently phenomena that reflect a

paradigmatic change but there are other phenomena that show a merge of different paradigms. Currently, the public steering and decision making is still largely organised on the basis of bureaucratic administration or New Public Management (Levesqué, 2013; Moore & Hartley, 2008). This means that the focus is on economic and technologist views on innovations and services, which do not take into account their collaborative, interactive and dynamic nature. Due to the techno-economic emphasis on the current governance mechanisms, some authors consider governance rather a problem producer than a problem solver (Voß et al., 2006). It may hinder innovation activities in the complex and continuously evolving society.

Networks as a coordinating mechanism are argued to be superior to both markets and hierarchies in complex environments (Langergaard, 2011). From the perspective of network governance, the societal context is hyper-complex and continuously changing (Hartley, 2005; Sørensen & Torfing, 2007). In the light of increasing complexity, both markets and hierarchies have serious shortcomings as coordination mechanisms. The markets often fail to address externalities involved in situations that are distinctively complex and interdependent, which then leads to short-run, localised ad hoc responses to market opportunities. Top-down coordination does not deal with the growing complexity of society either (Sørensen, 2002). One of the most general explanations for the rise of network governance is the possible evolutionary advantages that it offers for learning and innovation in changing environments (Langergaard, 2011).

2.3. Perspectives to evaluation

The above described developments have put pressure to find more advanced approaches to evaluation. The current evaluation culture, influenced by the accountability tradition, simplifies the complex process of innovation; it does not correspond to the increasing need for systemic approaches and does not capture either the diversity of innovations or the multifaceted nature of their performance. This chapter describes the development of this evaluation culture in more detail and points out its challenges. Then it presents the so-called 'developmental evaluation' as an alternative which this dissertation uses as its starting point and which it aims to supplement with future oriented, systems and multi-actor views. These views are concretised with the foresight methodology; multi-criteria analysis and system dynamic modelling; and participatory practices (societal embedding). Multi-criteria analysis is examined directly after the discussion on evaluation challenges in the same sub-chapter (2.3.) because it is tightly linked to the development of evaluation: it brings to the fore the multifaceted and systemic nature of innovations and narrows the 'double gap' in the

examination of innovation and performance. The next sub-chapter (2.4.) includes the presentation of foresight, system dynamic modelling and societal embedding.

2.3.1. Evaluation challenge in the present society

Evaluation is a relatively new research area, but its historical roots are long: they can be traced back to the very beginning of modern science in the 17th century. Evaluation studies are both a theory- and practice-driven, and from the beginning, their central objective has been to generate understanding and provide solutions to societal problems with the social research methods. (Clarke & Dawson, 1999; Patton, 1997; Rossi et al., 1999; Weiss, 1998) For example, in the first evaluation studies, the aim was to provide numerical measures to assess social conditions and identify the causes of mortality, morbidity and social disorganisation. In the literature, evaluation has been described as systematic examinations of planned social interventions to provide information about their characteristics, activities and outcomes (Clarke & Dawson, 1999; Patton, 1997; Rossi et al., 1999; Weiss, 1998). The use of evaluation is typically linked to the reduction of uncertainties, to the improvement of effectiveness, to the provision of evidence for policy-making, and to the support of decision-making (Guba & Lincoln, 1989; Patton, 1997; Weiss, 1998).

The development of evaluation research reflects the emergence and increasing appreciation of social sciences in universities and increasing support for social research (Rossi et al., 1999). Also the launch of numerous social programmes to meet the contemporary societal needs (e.g. urban development and housing, technological education, occupational training, and preventive health activities) in the aftermath of world wars affected the development of rigorous evaluation methods. That led – by the end of 1950s' – to the development of evaluation research as an ordinary and systematic practice in social studies. During the 1960s, literature about evaluation grew dramatically, and by the early 1970s, evaluation research emerged as a distinct field in social sciences. (Patton, 1997; Rossi et al., 1999; Weiss, 1998)

Like the other social sciences, evaluation is characterised by a long-lasting dichotomy between quantitative and qualitative approaches. 'Paradigm wars' or 'paradigm problems' – described widely in the evaluation literature (Chambers et al., 1992; Gage, 1989; Guba & Lincoln, 1989; Weiss, 1998) – have resulted in the domination of quantitative methods (Clarke & Dawson, 1999). However, in 1980s 'a silent scientific revolution in evaluation' (Fetterman, 1988, 4) led to the use of qualitative methods (Clarke & Dawson, 1999; Weiss, 1998). The development has been summarised by Guba and Lincoln who introduced a new paradigm: 'the fourth

generation evaluation'[4] (Guba & Lincoln, 1981, 1989; Lincoln & Guba, 1985). This paradigm does not neglect the role of quantitative methods but argues for the significance of a diversified knowledge base, including qualitative approaches. Further, it highlights the role of evaluation as a continuous and collaborative learning process and emphasises participatory practices. Thus, in addition to the recognition of qualitative approaches, the paradigm gave rise to the research stream which includes empowerment and learning-oriented approaches (Cousins & Earl, 1994; Fetterman, 2001; Torres & Preskill, 2001) to support the implementation of the programmes[5].

In its early years, evaluation was shaped mainly by the interests of researchers. Later, in accordance with the empowering and participatory approaches (Cousins & Earl, 1994; Fetterman, 2001; Patton, 1997; Torres & Preskill, 2001), the users of evaluation have influenced significantly the development of the field: it has moved towards applied research and political and managerial activity. Evaluation research and practices have also reflected the development of public administration and governance culture (Clarke & Dawson, 1999; Rossi et al., 1999), i.e. the change in the paradigmatic assumptions described in the chapter 2.2.3. The focus has moved from accountability to policy planning and implementation and further to strategy work (Chelimsky, 1997; Kuhlmann, 2003; Rip, 2003; Rossi et al., 1999).

Evaluation in the context of research, development and innovation

Evaluation has played a particularly important role in the context of publicly funded research, development and innovation (R&D&I). With the increased emphasis on innovation activities as a source of economic growth, societal development and wellbeing, a greater interest towards their evaluation has emerged (Shapira & Kuhlmann, 2003). Since the early days, impact assessment has been a typical way to implement evaluation in this context. It has meant that evaluation has been understood in terms of performance-related steering and monitoring, i.e. accountability (Chelimsky, 1997; Rip, 2003). With the curtailment of the size of the public sector, it has become evident that the publicly funded R&D&I activities must be shown to decision-makers and taxpayers to be beneficial and justified as a good investment (Georghiou, 1998). The aim has been to provide transparent information about how well

[4] 'The fourth generation evaluation' is grounded ontologically on constructivist assumptions, which put emphasis on the 'socially constructed nature of reality'. Conventional evaluations rely ontologically on the positivist and natural science assumptions of the 'objective reality'. Because of the different philosophical groundings, also the evaluation methods are different: the former approach favours qualitative and participatory methods and the latter approach quantitative (experimental and quasi-experimental) methods. (Clarke & Dawson, 1999; Guba & Lincoln, 1989; Weiss 1998)

[5] The empowerment and learning oriented evaluation approaches have been developed typically for the formative purposes, meaning that the focus is on an individual programme or organisation.

different policy instruments[6] have performed and attained their originally stated objectives (Clarysse et al., 2009). This has led to the increasing production of indicator based and comparable data to prove accountability (Martin & Johnston, 1999) and to legitimate the existence of individual programmes, organisations or policy instruments.

Typically the benefits and usefulness of public interventions have been discussed in economic terms of input and output additionality (Georghiou, 2007). Input additionality deals with the effectiveness of R&D-instruments encouraging private research efforts. Output additionality refers to the proportion of outputs from an R&D process, which would not have been achieved without public support. As a third concept, 'behavioural additionality' has gained ground to emphasise the changes in organisations' behaviour resulting from the intervention. (Clarysse et al., 2009; Georghiou, 2007) Traditionally, the impacts and effects of policy interventions have been evaluated ex-post, i.e. after the implementation of the intervention. During recent years, also ex-ante evaluation – defining the strategic objectives for the policy instruments and evaluating beforehand the potential fulfilment of these objectives – has gained ground (Fahrenkrog et al., 2002).

In broader terms, applied also outside the R&D&I context, the basic principles of conventional evaluation have been crystallized in the 'logic model' (Kellogg Foundation, 2004). This model consists of a linear continuum in which resources (inputs), activities (process), outputs, outcomes and impacts are connected via logical and causal pathways (Chen, 2005; Dyehouse et al., 2009). Inputs are defined as resources (e.g. funding, personnel, facilities, time, material) dedicated to the implementation of a policy instrument. Implementation is dependent on inputs. Activities present the action component in implementation and include transformational processes aimed at attaining desired results. Outputs are defined as direct tangible products. Outcomes are directly related to the objectives of the policy intervention and describe the anticipated results of implementation. They can be considered from the viewpoint of short term objectives or medium-term objectives (e.g. knowledge, attitudes, and skills). Impacts are outcomes to be expected in the long term (institutional and societal changes). (Kellogg Foundation, 2004)

The 'logic model' dominates the current evaluation thinking (Patton, 2011). Most evaluation and methodological guidelines (e.g. Gertler et al., 2011; Technopolis group & Mioir, 2012) follow this model. The logic model serves two types of evaluation: *summative and formative*

[6] The concept of 'policy instruments' refers to techniques and concrete operational forms of interventions by which decision-makers and public authorities aim to influence the societal development and change. In the literature, policy instruments are typically divided into regulations, economic means (grants for programmes, networks etc.), and information (influencing people through knowledge transfer) (Bemelmans-Videc et al., 1998; Vedung, 1998).

evaluation. Summative evaluation is related to accountability oriented activity and focuses on the generation of overall judgement of the merit and worth of policy instruments. Formative evaluation refers to the improvement of policy instruments to shape them to perform better (Scriven, 1991); it helps them 'to get ready for summative evaluation by improving program processes and providing feedback about strengths and weaknesses that appear to affect goal attainment' (Patton, 1994, 312). It reflects the current situation in which there are a variety of other motivations besides accountability to evaluate public interventions. In addition to the improvement of policy instruments, also the needs for strategic thinking and decision making in public policy are coming to fore and set requirements to evaluation (Patton, 1997; Rip, 2003; Scriven, 1991).

Despite the new motivations, the pressure of accountability is still strong in the evaluation culture and fosters the linear approach in the implementation of evaluation. This linear approach does not take into account that the impacts emerge in a cyclic, complex and long-term process (Cozzens & Melkers, 1997; Hansson, 2006; Rip, 2003; Tait & Williams, 1999; van der Knaap, 2006). Linearity is reflected in the dominance of evaluation methods that emphasise indicators as the main tool. Besides the basic problem of oversimplifying the reality, the indicator-based approach has been carried out in a backward-looking and one-off way – longer-term, futures-oriented and continuously implemented practices have not been searched for (Kuhlmann et al., 1999; Kuhlmann, 2003; Saari et al., 2008; Valovirta & Hjelt, 2005). This has resulted in the 'dilution' of the new more strategically oriented approaches (Hansson, 2006; Kuhlmann, 2003; Patton, 2011; Valovirta & Hjelt, 2005; van der Knaap, 2006).

Another consequence of accountability is that evaluations are usually 'atomistic': focused on assessing the impacts and effectiveness of individual policy instruments. In the global scale, the impacts of individual R&D programmes and organisations have been studied broadly (Rip, 2003; Rossi et al., 1999). For example, the European commission has organised systematic assessments of the impact and effectiveness of research programmes since the early 1980s (Luukkonen, 1998). Many national governments started to implement impact assessments of national R&D programmes simultaneously (Georghiou, 1995; Kuhlmann, 1995).

However, it is becoming increasingly clear that the input-output-outcome models, accountability efforts and indicator-based approaches cannot make visible the transformation processes in which interventions are turned into outcomes (Chen, 2005; Dyehouse et al., 2009). Traditional practices work in simple and predictable circumstances, but have significant downsides in dynamic situations and in the context of systemic innovation, where the focus is emergent, evolving and adapting (Ahrweiler, 2010; Arnold, 2004; Edqvist, 2005; Patton, 2011; Smith, 2000). More developed approaches, including a strategic stance, can be acknowledged

as an attempt to understand systemic conditions but usually they, too, remain at a general level, not explaining the complex relationships and dynamics between the components of the system. Along with the adoption of systemic perspectives in the field of innovation (Arnold, 2004; Kuhlmann et al., 2010), individual assessments, indicating the impacts of single policy instruments, have been condemned to be unrealistic. It has been highlighted that impacts are always co-created and they are interlinked to broader societal targets, structures and developments (Rip 2003). Therefore, the need to develop systemic evaluation approaches has been emphasised (Arnold, 2004; Smits & Kuhlmann, 2004; Shapira et al., 2010).

Towards developmental evaluation

A promising evaluation type is *developmental evaluation,* identified by Patton (1994; 1997, 2011). It is the third option besides summative and formative evaluations and refers to activities which are designed to conduct evaluation in complex societal realities, i.e. in the current society that is characterised by continuous and rapid changes (cf. Todd & Wolpin, 2010; Weijermars & Wesemann, 2013). A main aim is to make sense of what emerges under conditions of a complex system, and to provide real-time responses to adapt to new conditions in the face of changes. Developmental evaluation documents and interprets the dynamics, interaction and interdependencies that occur when innovation unfolds; to do so, it considers both the top-down and bottom-up forces.

Table 3 summarises the main types of evaluation (summative, formative, and developmental). It describes these types in the light of six aspects: purpose, context, target, timeline, means, and results. In the characterisation of the contents of the aspects, Patton (1994, 2011) is a central source but the characterisation also includes own analysis carried out for this dissertation: main characteristics to describe the evaluation types have been selected in accordance with the focus area of this dissertation.

The Table 3 indicates that in the summative evaluation, the main purpose is to test, prove and justify the merit, worth and value of the actions taken. It provides information for decision-making in stable and manageable situations. Because of the pressure of accountability, the target is typically atomistic, i.e. a single programme or organisation. The means are measurable indicators following the logic model; as a result, the value of actions is expressed in terms of output, outcome, impacts or effectiveness. The formative evaluation, instead, supports the improvement of policy instruments for a better goal attainment in manageable decision-making situations. It can be seen as preparatory for the summative evaluation: based on data monitoring, it identifies the impacts and effectiveness at a pilot level and provides feedback and actionable recommendations for better performance in the course of the

activity (ex-ante, real-time and mid-term evaluations). Developmental evaluation has a different focus: it aims to support innovation and development and to help their adaptation in changing conditions, especially in the context of complex environments. The target is a system: by the means of anticipation, adjustment, reflection, multiple perspectives and continuous implementation, it increases understanding of the innovation dynamics in it, and helps to identify potential outcomes and implications of innovations. The information resulting from that type of evaluation is especially relevant in complex and dynamic situations to support strategy building, development and continuous learning.

Table 3. Summary of the evaluation types (cf. Patton, 1994, 2011)

Type of evaluation	**Main characteristics from the viewpoint of this dissertation**					
	Purpose	**Context of application**	**Target**	**Time perspective**	**Means**	**Result**
Summative evaluation	Test, prove and validate; judge the merit, worth, and success or failure; determine the future of instrument	Decision making in manageable and stable situations	Atomistic	Ex post	Measurable indicators, linear cause-effect, 'logic model'	Value in terms of outputs, outcomes, impacts and effectiveness
Formative evaluation	Improvement for a better goal attainment; preparing the summative evaluation	Planning and decision making in manageable and stable situations	Atomistic	Ex-ante, real-time; mid-term	Indicators, monitoring, feedback, actionable recommend-dations	Impacts and effectiveness at the pilot level to establish readiness for the summative evaluation
Develop-mental evaluation	Supporting the ongoing development; adaptation to changing conditions	Strategy, development and continuous learning in complex and dynamic situations	Systemic	Ex-ante, real-time	Anticipation, adjustment, reflection, continuous implementation, multiple perspectives	Dynamics and inter-connections of the system, potential outcomes and implications

This dissertation is grounded on the basic ideas of developmental evaluation and supplements it with the futures, systems and multi-actor views. The futures view is concretised with the foresight methodology to show how and by what means it is possible to approach future developments. The systems view is concretised with multi-criteria analysis and dynamic modelling: the former broadens the definition of innovation and performance to include their immaterial and systemic characteristics. The latter makes visible the complex dynamics and interdependences within the system. The multi-actor view is concretised with participatory practices (societal embedding); it provides understanding of the actors and factors that make

innovations to happen and diffuse. The examination of these concrete approaches is started from the multi-criteria analysis, which is tightly linked to the views on innovation and evaluation.

2.3.2. Invisible innovation and performance: towards the multi-criteria perspective

The increasing 'servitization' of society (Gebauer & Friedli, 2005; Neely et al., 2011) has put pressure to develop more advanced approaches to evaluation and brought to the fore an additional problem linked to the traditional approach: the indicators have been one-sidedly technological and financial. These kinds of indicators do not capture the immaterial and interactive aspects that are central characteristics of services, and therefore the diversity of innovations and the multifaceted nature of their performance are not taken into account (Hipp & Grupp, 2005; Metcalfe & Miles, 2000; Rubalcaba et al., 2013; Sundbo, 1998). Today services are also increasingly forming systemic wholes – especially the most urgent problems in the present society cannot be solved via the development of individual services, but a systemic view is needed. While innovations are increasingly combinations of many technologies, organisational changes and services, they are also embedded in wider social environment (Geels, 2002, 2004) which affects the development and performance of innovations.

Djellal and Gallouj (2010, 2013a) have crystallised the above-described challenge in the concept of 'innovation and performance gap', which emphasises the need for a broader definition of both innovation and performance and highlights their interaction. It responses to the critique towards traditional innovation measures and provides basis for a more diversified evaluation approach and evaluation criteria: besides the technological and financial aspects, the evaluation of innovations should take into account their quality and societal value and the interrelationships of different aspects. This kind of an approach is important in the context of this dissertation: in services linked to environmental sustainability, the technological perspective dominates the discussion, even though the solutions found are typically multidimensional and integrative, including both technological and non-technological aspects (cf. Carlborg et al., 2014).

According to Djellal and Gallouj (2010, 2013a), a central background reason for the existence of the gap is the old dominance of the technologist perspective in the analysis of service innovation. Although a broader view and integrative perspectives have increasingly gained ground, the technologist origin of the view on innovation is still influential: in particular, the measurement and indicators of innovation are largely based on technologist definitions (see also Edqvist, 2005; Rubalcaba, 2006; Smith, 2000; Smits & Kuhlmann, 2004). In addition to this narrow understanding of innovation, the dominating view on performance is also mechanical

and narrow. It is usually linked to the concept of productivity which refers to the linear input-output function (Djellal & Gallouj, 2010, 2013a; cf. Patton 2011). This linkage prevents the recognition of the 'hidden performance' concerning the societal aspects of innovations: equality, ecological sustainability and societal well-being.

The analysis of the 'innovation and performance gap' (Djellal & Gallouj, 2010, 2013a) is based on the dichotomy between visible and invisible nature of innovation and performance. Whereas technology-based innovations are visible, non-technological innovations are invisible. As regards performance, the authors link the visible-invisible dichotomy to short-term vs. long-term influences. Both in scientific and the managerial discussions, short-term influences of performance are often analysed in terms of productivity and growth. Longer-term influences are increasingly analysed in terms of social impacts or environmental sustainability. There are four possibilities in the relationship between innovation and performance as Figure 3 illustrates (Djellal & Gallouj, 2010, 668). The most apparent relation is between visible innovation and visible performance (relationship 1), but visible innovation may also lead to hidden performance by promoting the long term environmental sustainability or societal well-being (relationship 2). Correspondingly, invisible innovation may be a source of visible performance, i.e. growth and productivity (relationship 3), or promote social and environmental sustainability (relationship 4).

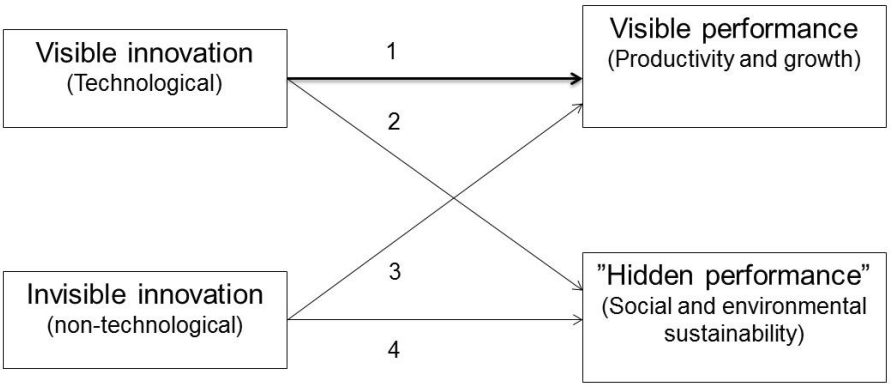

Figure 3. Innovation and performance gap (Djellal & Gallouj, 2010, 668)

The 'double gap' (Figure 3) – favouring the relationship 1 – has significant implications to public policies: they are still very technologically oriented and set to promote visible, technological innovation. Policy analysis and decision making – including the measurement, target setting, steering and policy planning – do not take into account invisible innovation and hidden performance. Further, they do not perceive the integrative nature of services. This neglect

may cause inaccurate analysis and interpretations and lead to inappropriate policies (den Hertog, 2010; Rubalcaba, 2006). In order to improve policy making, both the visible and invisible aspects in innovation and performance have to be included in the evaluations on which the decisions are based. This requires sensibility to the specificities and the integrative and multidimensional nature of services (den Hertog, 2010; Djellal & Gallouj, 2010; Rubalcaba, 2006; Rubalcaba et al., 2010).

The above described analysis of the 'double gap' has been the basis for the suggestion of an alternative: a multi-criteria evaluation approach which takes into account different perspectives on the outputs and outcomes of innovation and considers the respective performance in short and long terms (Djellal & Gallouj, 2010, 2013a). This Djellal-Gallouj approach analyses the diversity of innovations and the multifaceted nature of their performance by linking them to the idea of different 'worlds of services'. The concept of 'a world' is derived from the 'economics of convention', developed by Boltanski and Thévenot (1991), and refers to different justificatory criteria used in society in the definition of different values. Djellal-Gallouj approach (2013a) identifies six different 'worlds' that provide criteria for evaluation: *the industrial and technological world, the market and financial world, the relational and domestic world, the civic world, the world of innovation, and the world of reputation*. The outputs and outcomes of innovation can then be evaluated from the perspective of different goals or target areas: besides the traditional technical and financial aspects of innovation, the complex societal challenges and the specific characteristics of services linked to quality and social value can be taken into account (Djellal & Gallouj, 2010, 2013a; cf. Rubalcaba et al., 2013). In addition to the different target areas, the approach pays attention to the time-scale in the generation of impacts through the division into direct, short-term outputs and indirect, long term-outcomes. Table 4 illustrates the different worlds and the specific justification criteria related to the each of them. It also indicates that the same justification criteria can be applied both in the evaluation of short-term outputs and long-term outcomes. (Djellal & Gallouj, 2013a)

Table 4. A multi-criteria perspective to the evaluation of services (Djellal & Gallouj, 2013a)

	Industrial and technical world	**Market and financial world**	**Relational and domestic world**	**Responsi-bility world**	**Innovation world**	**Reputational world**
Output (direct, short term) ***Performance related***	Volumes, flows and technical operations; (perfor-mance, efficiency, scientific principle)	Value and monetary and financial transact-tions, money, savings	Interpersonal and organisational relations, trust, quality of relationship	Values like sustainabl e develop-ment, response-bility, equal treatment, fairness and justice	Creativity and inspiration	Brand, image
Outcome (indirect, long term) ***Performance related***						

On the other hand, the researchers are unanimous that the existing innovation and performance measures and indicators should not be abandoned. What is needed is a more diversified analysis framework that is able to take into account the multiplicity of innovations and the increase of their social and systemic nature (cf. den Hertog, 2010; Rubalcaba, 2006). From the viewpoint of this dissertation, a suggestion for a *'pluralistic and flexible evaluation system*' (Djellal & Gallouj, 2013a, 662) is valuable. This suggestion highlights the need for broadening the view, not only from technology to services, but also from the economic concepts like productivity and narrowly defined performance to social innovation, system innovation and use value. This view is in line with the arguments that put emphasis on the multi-method evaluation instead of mere measurements (Djellal & Gallouj, 2010, 2013a; Rubalcaba et al., 2010).

2.4. The perspectives of foresight, system dynamics and societal embedding

In addition to the multi-criteria approach, researchers have suggested the supplementation of traditional evaluation with other approaches and methodologies (Dyehouse et al., 2009; Kuhlmann et al., 1999; Kuhlmann, 2003; Williams & Imam, 2007). A primary motivation has been to strengthen the futures perspective in the decision making and strategy, and to answer the increasingly complex societal problems with systems thinking. Further, to ensure the development and diffusion of innovations, the multi-actor view has been highlighted. In this dissertation, these perspectives and views play a central role in the empirical studies. Within the vast literature discussing futures studies, system theories, and participatory (actor-based) thoughts, this dissertation focuses on the following approaches. Firstly, in order to find an alternative to the predictive stance in the analysis of future options, *foresight* is taken as the

starting point; its 'multiple futures' focus is considered important for 'wiring up' innovation efforts (cf. Georghiou et al., 2008; Kuhlmann et al., 1999; Kuhlmann, 2003). Secondly, in order to understand the dynamic interrelationships in societal systems (including the context of innovation), *dynamic modelling* is applied (Cabrera et al., 2008; Sterman, 2000). Thirdly, to highlight the engagement of actors, participatory approaches and the concept of *societal embedding* are introduced (Kivisaari et al., 2004, 2013; Rotmans & Loorbach, 2009).

2.4.1. Foresight

The concept 'foresight' originated in the context of science and technology in 1980s (Martin, 2010). Based on the early definitions by Coates (1996), foresight is a process which increases *understanding of the forces which shape the futures in the long-term*, and which should be taken into account in policy formulation, planning and decision-making. The concept was adopted first in the Anglo-Saxon countries but had a counterpart in the French tradition right from the beginning: this approach is called 'la prospective' (Godet, 1986). An essential characteristic in foresight is the difference compared to forecasting[7]. Whereas forecasting aims to extrapolate the most probable future, foresight emphasises that there are many alternative futures (Martin & Irvine, 1989; Martin, 2010). The French futurists had emphasised the importance of multiple futures even earlier: the concept of 'futuribles' referring to this idea originates from one of the most significant pioneers of futures research, de Jouvenel (1967).

Irrespective of the tradition, the overall aim of foresight is to influence the future development so that it better meets the long-term societal needs characterised by the increasing complexity and faster cycles (Martin & Johnston, 1999; Toivonen, 2004). As described by Miles (2013), the accomplishment of that aim requires the combination of prospective analysis, participation, and practical relevance. A prospective analysis consists of systematic studies to increase understanding of potential future directions and forces to shape them (Martin & Irvine, 1989; Martin, 2010; Miles, 2013). It promotes the identification of priorities for the future development and recognition of the uncertainty factors that may affect them; it also helps to anticipate the consequences of long-term decisions and to evaluate their importance, desirability and acceptability (Ahlqvist et al., 2012; Bell, 2003; Havas et al., 2010). Participatory approaches favour an active stance to future developments (Dufva, 2015; Miles, 2013). They

[7] Forecasting, and more specifically, technology forecasting originates from the US where it was developed in the late 1940s and in the 1950s in the military sector (Martin, 2010). As defined by Wills (1972, p. 263), forecasting is a set of specific techniques 'to make a probabilistic statement, on a relatively confidence level, about the future'. Despite the growing popularity of the foresight perspective, also forecasting belongs to the basic repertoire of organisational strategy work, both in the private and public sectors.

consist of the empowerment of multiple actors with differing perspectives to 'make the future together' and to build momentum for necessary changes (Dufva & Ahlqvist, 2014; Godet, 1986; Kivisaari et al., 2013; Martin and Irvine, 1989; Martin, 2010). In order to shape the future developments in reality, the practical relevance of foresight is essential. It means the integration of foresight with the actual decision-making process in a way which supports strategic choices and increases the capacity to adjust them to the requirements of the changing operational context (Auvinen et al., 2014; Dufva, 2015; Miles, 2010). In accordance with the definition of Miles (2013), comprehensive foresight approaches (which aim to reach variety of objectives and which go beyond narrow methods) have also been denominated as 'fully-fledged foresight' in the literature. Fully-fledged foresight emphasises strategic planning, participatory approaches and the combination of various futures studies as the three cornerstones. (Keenan et al., 2003)

Foresight has emerged as a key instrument in the development and implementation of research and innovation policy (Georghiou et al., 2008). Its significance in speeding up innovation efforts came to the fore in the large-scale foresight programmes carried out in the 1990s in several countries – United Kingdom, Australia and New Zealand, for instance. In these programmes, the rationale was summarised in the expression 'wiring-up the innovation system': they aimed to set priorities, to build networks between science and industry, and to encourage a structured debate with wide participation to foster a shared understanding of the long-term developments within the system. (Georghiou et al., 2008; Martin and Johnston, 1999) In addition to the system level programmes, which were carried out at both national and regional levels, organisation-specific foresight activities have gained ground during recent years. Their aim is to scan the relevant future developments and build capacity to respond them to ensure the survival of the company or organisation in question (Becker, 2002; Dufva, 2015; Rohrbeck, 2011; Saritas, 2013).

Future oriented knowledge, be it at the systemic or organisational level, can be acquired with a variety of qualitative and quantitative methods (Georghiou et al., 2008). Widely used foresight methods are scenario building, road mapping, trend analysis, and the analysis of weak signals (Holopainen & Toivonen, 2012; Martin & Irvine, 1989; Popper, 2008). In the elicitation of views on potential futures, expert based methods – such as expert panels and Delphi surveys – are commonly used; they are particularly popular in the policy context (Hjelt et al., 2001; Kuusi, 1999). Panels are dedicated to combine the knowledge of 'legitimate' experts with their creative, imaginative and visionary views in the specific area of interest (Popper, 2008). The Delphi method is a well-established technique that relies on anonymous interaction of experts. It involves several repeated survey rounds among a group of individuals.

Between the rounds, the respondents get feedback from the results of the previous rounds; this is a way to tests the persistence of their opinions under the group pressure (Kuusi, 1999).

Along with the spread of futures thinking to companies and organisations, scenario building and road mapping have gained popularity as they can be quite easily linked to the strategy work (Ahlqvist et al., 2012). Scenarios can be generated in two ways: starting from today and anticipating the different potential images for the future, or identifying the desirable and avoidable futures and analysing the respective paths to them. Scenarios may be produced by means of deskwork and workshops, or by using tools such as computer modelling. (Popper, 2008) Road mapping resembles scenario building but is more tightly linked to a specific theme area (policy, technology, markets, resources etc.) and to a specific societal context, for which it outlines the paths of future development (Phaal et al., 2003). It is widely used in companies, where it serves as a tool for idea exchange, for the development of shared visions, and for the communication of expectations about the futures to other parties (Popper, 2008).

Trend analysis can be carried out both quantitatively and qualitatively. Quantitative trend analysis is one of the established tools of forecasting, whereas foresight exercises usually apply *qualitative trend analysis* (Coates, 1996). This is also the case in this dissertation (see sub-chapter 4.2.). Trends refer to the potential future directions which are known and recognized broadly by several experts (Toivonen, 2004). Their analysis provides a rough idea of how present developments may look like in the future, and what are their potential impacts on systems, regions, policies, people etc. (Godet, 1994). In order to analyse future paths, understanding the past development is essential; thus, the trend analysis usually includes analysis of the past, present and future (Popper, 2008). In some future oriented studies, the concept of driving force (or 'driver') is used as a synonym with the concept of trend. Usually the concepts are, however, kept separate because the objective is different: when a phenomenon is studied as a trend, the emphasis is on the direction of its own development in the long term. In the study of driving forces, the focus is on the current situation and on the direction to which these forces push other phenomena. (Toivonen, 2004)

The concept of weak signals originates from Ansoff (1975, 1984), who developed the concept to supplement strategic planning in companies with the analysis of improbable phenomena. Later researchers have extended the use of the concept to broader societal contexts. Weak signals are first indications of change: they are phenomena or a group of phenomena that have no history (ibid.). When occurring, a weak signal does not necessarily seem important, but it may have a decisive impact on the formation of the future (Holopainen & Toivonen, 2012; Mendonça et al., 2004). Weak signals are linked to trends in several ways. They may play a role in breaking trends or they may be starting points for totally new trends. If a weak signal

does not die out, it becomes gradually a strong signal and finally a trend (Wygant & Markley, 1988). Trends may also emerge from a combination of several weak signals. Linking together the analyses of trends and weak signals enables mapping the future from opposite perspectives: trends indicate the most probable phenomena while weak signals warn about improbable but important surprises. Weak signal analysis is, however, used more rarely than trend analysis because it requires specific efforts to encourage non-conventional thinking among respondents.

In foresight activities, an action-oriented mode towards the future is more and more present (Havas, 2007). Foresight offers a facilitated arena to stimulate communication and collaboration between relevant stakeholders to catalyse the desired developments (Dufva & Ahlqvist, 2014; Eerola & Jørgensen, 2008). It highlights the involvement of a variety of experts. They should represent science, industry and government, and also the 'demand side' concerning the future technologies and economic and societal solutions should be included. The exercise itself should combine bottom-up and top-down processes. (Martin, 2010) In practice, foresight activities have mainly focused on technology-intensive sectors, even though the emphasis on technology has diminished when the importance of the development of the entire innovation system has been realised (Hjelt et al., 2001). Some foresight projects have included themes outside the technology realm – for example, culture-related issues or social problems. Foresight exercises in services have, however, been rare despite the rapid accumulation of research into service innovations (Miles, 1999).

The futures perspective is to some extent present in the current approaches to evaluation, especially in formative and developmental evaluation. However, there is need to include foresight in evaluation more systematically and more concretely. Two benefits can be especially pointed out. Firstly, foresight expands the timeframe in evaluation. Currently, the futures perspective in evaluation covers the duration of the programme or the implementation of the innovation in question. However, the impacts often require a longer time to become visible. Thus, the usual timeframe of foresight, which is five to ten years in minimum, helps to take into account – not only the direct outputs – but also the indirect outcomes (cf. Djellal & Gallouj, 2013a). Secondly, foresight provides systematic methods to analyse alternative futures. The review above has briefly introduced the methods of scenario building, road mapping, trend analysis, and weak signals analysis. The latter two methods focus on the mapping of potential future developments in the changing operational environment, while the former two methods are often more directly used to plan the activities of an organisation, policy maker or another stakeholder.

In this dissertation, potential future directions and changes in the operational environment have been a central issue; thus, trend analysis is applied as the futures method. As regards the development of the new evaluation approach, the qualitative trend analysis provides understanding of the long-term changes and conditions in the society. It emphasises the need to understand the long-term needs as a basis for innovation. As an ingredient of the new evaluation approach, it highlights the strategic stance: in accordance with the basic ideas of developmental evaluation, it emphasises the openness and multiplicity in future development directions. Compared for example to the road mapping, which provides a tool to support the strategic development towards a given direction, trend analysis is targeted to understand the multiplicity of alternative futures and to systematically analyse the potential future paths.

2.4.2. Systems thinking and system dynamic modelling

The roots of systems thinking reach back to ancient philosophers, such as Aristotle, but as an actual research area its start is usually dated to the first half of the twentieth century (Cabrera, 2006; Meadows, 2008; Williams & Hummelbrunner, 2011). Systems thinking encompasses multiple schools of systems theory. It includes, for example, general systems theory, cybernetics, system dynamics, complexity theory, studies on soft and critical systems, network theory, and analysis of learning systems. System scholars also represent many disciplines, such as physics, biology, anthropology, psychology, sociology, environmental studies, cognitive science, and studies on public policy. (Cabrera et al., 2008; Hargreaves & Podems, 2012)

A general feature in systems thinking is viewing the world in terms of wholes and relationships, rather than breaking it into component parts and looking each of them in isolation (Hargreaves & Podems, 2012; Ramage & Ship, 2009, Sterman, 2001). In the words of Meadows (2008, p. 1): 'once we see the relationships between structure and behaviour, we begin to understand how systems work, what makes them produce poor results, and how to shift them into better behaviour patterns'. Understanding the structure and dynamics of the 'whole' helps to identify the root causes of problems and see a variety of opportunities to solve them. Thus, systems thinking helps actors to adapt themselves to the complexity and rapid changes of the modern world (ibid.).

There is a variety of methods to generate understanding of a 'system'. Agent based models, social network analysis, and system dynamic modelling are broadly known in the analyses of complex societal situations (Hanneman & Riddle, 2011; Helbing, 2012; Holz et al., 2015; Williams & Hummenbrunner, 2011). Each of them has its own 'justification', and the choice of a specific method depends on the purpose of its use (Helbing, 2012; Williams & Hummenbrunner, 2011). In this dissertation, system dynamic modelling (Forrester, 2007;

Sterman, 2000) has been selected as the method to tackle systemic phenomena. It provides a means to analyse the nonlinear complex behaviour and the dynamic nature of systems (cf. Dyehouse et al., 2009; Merril et al., 2013), and helps to reveal and understand what phenomena promote or hinder the emergence of impacts. Thus, it is a particularly suitable methodology as a system oriented evaluation framework is the goal of the dissertation. Compared to the Soft System Methodology, which is more applicable in the organisational and managerial contexts and in purposeful and managerial problem solving situations (Lane & Oliva, 1998; Williams & Hummelbrunner, 2011), system dynamic modelling is more illustrative in the case of broad societal systems which are analysed in this dissertation.

System dynamics is an approach that is grounded on the theory of nonlinear dynamics and feedback control developed in mathematics, physics, and engineering (Sterman, 2001, 2002). It is an interdisciplinary approach: in order to enhance understanding of the behaviour in a complex system – including both the human and technical aspects – it draws on cognitive and social psychology, organization theory, economics, and other social sciences (Sterman, 2001). The conceptualisation of system dynamics has much in common with the general systems thinking, but its specific aim is *a model formulation*. The model focuses on the underlying feedback structure in a system and provides understanding of how the structure of the system creates complex dynamic behaviour over time (cf. Giddens, 1987). Modelling relies on the following basic arguments about the nature of systems (Senge, 1990; Sterman, 2000):

- Systems are tightly coupled, i.e. the actors interact with another and with the outside world. Feedback is a central characteristic: decisions of the actors trigger others to act, which again alters the next decisions of the original actors.
- The central position of feedback makes systems history-dependent: taking one path precludes many others.
- A system consists of interrelationships and causal circles rather than of cause-effect chains; a cause and its effects are often distant in time and space, which makes it difficult to identify immediate relationships between them.
- Systems are nonlinear (effects are not proportional to cause) which means that what happens locally in a system does not apply in its distant parts.
- Systems are dynamic, i.e. constantly changing at many scales that interact. They are also self-organising and adapting: small, random perturbations are often amplified by feedback, and capabilities of actors change as a result of learning.
- Systems are policy-resistant: the complexity makes it difficult to understand the system and as a result many seemingly obvious solutions fail. Time delays in feedback often mean that the long-run response is different from the short-run.

In modelling, interconnections between the elements of a system are visualised using causal loop diagrams (Sterman, 2000, 2001). Figure 4 exemplifies the main elements of the causal loop diagrams[8]. In the figure, the arrows indicate the direction of causality. A minus sign (-) next to arrows indicates a change in the opposite direction in the dependent variable when independent variable is changed. For the other arrows, the dependent variable changes in the same direction as the independent variable. Further, each diagram consists of individual feedback loops which can be either reinforcing or balancing. A reinforcing loop (noted with R in the diagram) refers to the vicious or virtuous circle: it means accelerated growth or accelerated decline in the system. A balancing loop (noted with B in the diagram) is goal-seeking or stability-seeking; it refers to self-correction that attempts to maintain a certain goal or target in the system. Rectangles in the figure indicate stock variables that change through flows. (Meadows, 2008; Senge, 1990; Sterman, 2000, 2002) Complex systems contain many loops of both types, coupled to one another with multiple time delays, nonlinearities, and accumulations. The dynamics arise from the interactions of the networks of feedbacks. (Sterman, 2001) Other means to illustrate the dynamics in complex systems are stocks and flows, which refer to the accumulation and dispersal of resources. A stock can be described as a store, a quantity, and an accumulation of material or information. Stocks change over time through the actions of an inflow or outflow (Meadows, 2008; Sterman, 2001).

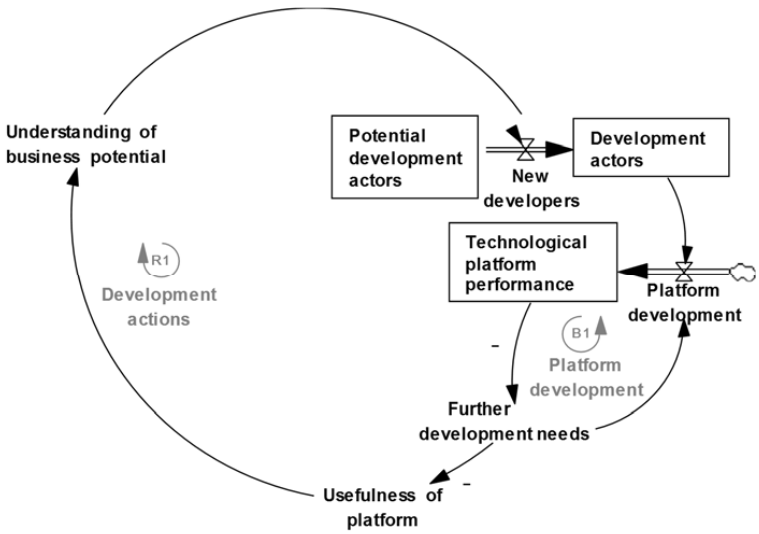

Figure 4. Example of a causal loop diagram

[8] The figure derives from the article 3 of this dissertation, but it follows the visualisation suggested by Sterman (2000, 2001). More detailed causal loop diagram (applied in article 3) is represented in Figure 6, chapter 4.3.

System dynamic modelling can be qualitative or quantitative. This dissertation applies the former. Qualitative models, visualised in causal loop diagrams, reveal nonlinear relations between causes and effects and show the delayed feedback. Further, they depict that unintended effects often arise in distant parts of the system in a way that cannot be easily anticipated (Senge, 1990; Sterman, 2000). Qualitative diagrams increase understanding of the complex structure and interaction within the system, and show how different actors and factors affect the system development (Senge, 1990; Sterman, 2000; Vennix 1996). They are useful tools to design better operating policies and to guide effective changes: because of their clarity and accuracy, they help to understand complex structure and to see potential behaviour scenarios, and to communicate them to the experts with different backgrounds (Holz et al., 2015; Ylén et al., 2014). Qualitative diagrams also form the basis for quantitative modelling: rigorous mathematical analysis and effective computer simulation (Forrester, 2007; Sterman, 2000, 2002; Williams & Hummenbrunner, 2011).[9]

Systems thinking and system dynamic modelling offer an alternative to the traditional evaluation approach which relies on the logic model and input-output analyses. They make visible the *'transformation processes that turn interventions into outcomes'* (Chen 2005, p. 231). In this way, they tackle the challenge of 'black-box evaluations: things go in and things come out, but what happens in between is a mystery' (Dyehouse et al., 2009, p. 187). By paying attention to the interaction between various actors and to the longitudinal, dynamic behaviour, system dynamic modelling helps to explain how the complex interactions reduce, change or even hinder the emergence of impacts (Merrill et al., 2013).

Although there has been an increasing interest towards systems thinking in evaluation during recent years (Cabrera et al., 2008; Dyehouse et al., 2009; Mayne, 2012; Funnel & Rogers, 2011; Patton, 2011; Williams & Hummelbrunner, 2011), systems approaches do not form the 'mainstream' in the field; actually, they are still unfamiliar to many evaluators. The plurality of systems approaches and methods (even the existence of numerous conflicting ones) is an important background reason for this situation (Hargreaves & Podems, 2012). Also the basic differences and traditional barriers between research traditions – in their epistemological groundings and research strategies, for instance – cause methodological and lexical variety. This has hindered the simultaneous utilisation and integration of different approaches, especially among the evaluators qualified in social sciences (ibid.). Despite these challenges, it would be important that evaluators familiarise themselves in systems thinking and then select

[9] In quantitative models aim is to show, how different parameters affect the evolvement of the system, and how the interaction of various feedback loops creates certain dynamic behaviour i.e. change over time in the variables of interest (Sterman, 2000, 2002; Williams & Hummenbrunner, 2011).

the appropriate concepts and methods for the purpose of their specific evaluation effort (Cabrera et al., 2008; Williams & Imam, 2007).

2.4.3. Participatory practices and societal embedding

Many different approaches in innovation research have highlighted and promoted the emergence of participatory practices. At the micro level, the emphasis on the central role of customers (Alam & Perry, 2002; Edvardsson et al., 2006) and users (Sundbo & Toivonen, 2011; von Hippel, 1988, 2005) has been influential. Recently, user-based approaches have been combined with the approach of employee-driven innovation: it has been realised that grassroots employees usually act as transmitters of the ideas of users into the innovating organisation (Brandi & Hasse, 2012; Kesting & Ulhøi, 2010). Also the 'practice turn' in innovation research has contributed to the striving for broad involvement and engagement. Originally, practice theories focused on organisations' internal routines that consist of a set of activities and material arrangements (Schatzki et al., 2001). Today, it has become increasingly clear that the analysis has to be extended outside the organisation, too (Russo-Spena & Mele, 2012). With the growing complexity of products and services, the organisations no longer have all the diverse knowledge in-house to be successful and competitive in research and production (Contractor et al., 2010).

Actor networks that include other stakeholders besides customers have come to the fore (Tuomi, 2002). Well known approaches applying the networked view are open innovation (Chesbrough, 2006) and service-dominant logic (Vargo & Lusch, 2004, 2008). Broadening the analysis from the dyadic relationship between the provider and the customer has been important both in the market and in the public sector; in the latter context, it has led to the discussion about broad engagement of citizens in various innovation activities (Reddel & Woolcock, 2004). The introduction of the concept of social innovation (Harrisson et al., 2010; Klein & Harrisson, 2007; Mulgan, 2007) has supported this development by emphasising that the solution of broad societal challenges requires networked and participatory processes between multiple actors, actor groups and organisations.

A broad perspective is inherent at the macro level, where the innovation systems approach[10] has highlighted the necessity of involving multiple actors (Freeman, 2002; Lundvall, 2007). This

[10] The so-called 'innovation systems approach' differs from the studies of system(ic) innovation – for example, from the studies on socio-technical change (Geels & Schot, 2007). In the former approach, the primary focus is on the institutional fabric that *supports innovation*, even though views on the nature of innovation are also included. The approach emerged in the late 1980s and continued strong until the end of 1990s (Dosi, 1988; Freeman, 1991; Lundvall, 1992; Nelson 1988). Its influence is visible in several streams of today's innovation studies even though studies titled as 'innovation systems studies' are minor in quantity compared to earlier decades.

approach focuses on the institutional arrangements linked to innovation. These arrangements and the processes by which particular institutional contexts foster or hinder patterns of innovation are at the heart of the studies. Both the public policies supporting directly or indirectly innovation and the strategies of innovation networks have been actively examined (ibid.). Because innovation is seen as a collective undertaking, the skills and competences of different actors require attention. Thus, collaborative learning plays a central role and helps the actors to find jointly the solutions to the problems at hand. The practical forms of learning – learning by doing, using and interacting (so-called DUI model)[11] – are considered especially important in the framework of the innovation systems approach (Lundvall & Johnson, 1994; Lundvall, 2007).

In practical applications, participatory views have been inspired by action research (Lewin, 1948). It is not a specific method or theory, but rather an umbrella term for approaches that emphasise the empowerment of variety of actors, shared knowledge and collective actions (Andersen & Bilfeldt, 2013; Hasu, 2001; Reason & Bradbury, 2008). In these approaches, a diversity of actors is involved not only in knowledge creation but also in actual development processes and the related decision-making. Participation takes place in multi-voiced forums through systematically facilitated processes. This enables actors to affect directly and efficiently to the problem solving and societal change (Andersen & Bilfeldt, 2013; Fontan et al., 2013). A central principle in the development is continuous reflection. It refers to a cumulative spiral which encompasses multiple phases of problem definition, of the development and application of a solution, and of evaluation and amelioration (Kivisaari et al., 2004). The many phases included ensure the hearing of multiple perspectives, improving the quality, and supporting the acceptability and scalability of the solution developed (Kivisaari et al., 2004; 2013).

The so-called 'societal embedding of innovations' follows the above-described principles (Heiskanen et al., 2009; Kivisaari et al., 2004, 2013). In this dissertation, it is applied as the particular perspective to participatory practices. It is an action oriented approach which highlights the inclusion of views of multiple actors in innovation and in the related evaluation. Studies based on societal embedding have been carried out since the late 1990s. They use the theories on socio-technical change (Geels, 2002, 2004; Kemp & Rotmans, 2004), transition management (Geels, 2002; Kemp & Loorbach, 2006) and strategic niche management (Kemp et al., 1998). A primary motivation for its development has been to facilitate and speed up the generation and diffusion of system level innovations. Local experiments are emphasised as an

[11] The concept of 'learning by doing' originates from Arrow (1962), the concept of 'learning by using' from Rosenberg (1982), and the concept of 'learning by interacting' from Lundvall (1985).

engine for systemic changes; the engagement of multiple actors, co-creation and networked decision-making are seen essential for their emergence and implementation (Rotmans & Loorbach, 2009). Studies have been carried out in several innovation contexts (e.g. ICT, health care and energy) to extend local actors' understanding of the importance of integrating their innovations with the broader societal needs (Heiskanen et al., 2009; Kivisaari et al., 2013).

Striving for impactful innovations with high 'social quality' is in the core of societal embedding. In order to achieve this goal, the involvement and commitment of multiple actors – and the appreciation of their needs, perspectives and values – are required. The actors set the conditions for the development and create a forum for the generation and scaling up of innovations (Kivisaari et al., 2004). The key actors to be included in the process are: technology and service providers, users of the novel technologies and services, developers (including researchers and development partners from the third sector), and a variety of other societal actors (including decision-makers, lobbyists, payers or purchasers etc.). Moreover, to attain a broad understanding of the impacts and quality of innovations, at least the following characteristics need to be considered: clear value to a variety of users, progressiveness and efficiency in the service production process, correspondence to the local needs, transferability to other contexts, and a wide range of impacts. (Kivisaari et al., 2004, 2013)

As an action oriented approach, societal embedding aims to enhance and facilitate learning by doing, learning by using, and learning by interacting (see footnote 9) in a continuous dialogue between the key actors (Kivisaari et al., 2004, 2013; cf. Kemp et al., 1998). The actual learning process comprises the following elements: building a dynamic network between the key actors; identifying their needs, interests, expectations and visions; enhancing shared learning; and creating a deep understanding of the problem to be solved and of the possible solutions. Learning is based on a cyclic view of the innovation process, which means that several fundamental questions have to be continuously reconsidered. The first question concerns the identification of the required characteristics of innovation. Second is important to specify whose expertise or approval is needed for the generation and diffusion of innovation. Third makes visible the interests of key actors and the way in which they become committed to the development. Typical means to acquire answers to these questions are multi-voiced seminars. (Kivisaari et al., 2004, 2013)

Although societal embedding is not an evaluation approach, it has commonalities with participatory, collaborative and interaction-oriented evaluation practices (Cousins & Earl, 1994; Fetterman, 2001; Patton, 1997; Torres & Preskill, 2001). These practices aim to enhance collaborative learning and increase the quality of actions by involving multiple perspectives and criteria in the evaluation process. On the other hand, they have been developed for the

purposes of formative evaluation which focuses on a single programme or organisation (see chapter 2.3.). Because this dissertation is based on developmental evaluation with systemic considerations, a broader perspective is needed in the analysis of participation, too. Societal embedding offers a concrete complementary constituent in the developmental evaluation to analyse this kind of a perspective: it emphasises multiple views, engagement of a variety of actors and continuous reflection and development in order to make innovations happen, spread and gain foothold in societal systems at different levels. Earlier it has been used mainly for the promotion of innovations, but in this dissertation it is brought to the context of evaluation: the third – multi-actor – element in the new evaluation framework is analysed based on it. Besides the engagement of multiple actors, the emphasis is on the collaborative process and continuous reflection embedded in the innovation activities.

3 Methodology and empirical context

3.1. The approach of the dissertation

Basic scientific paradigms are classified into a variety of categories. One of the most commonly used classifications is between the positivistic approach, interpretative approach, and critical theory (Bryman, 2004; Merriam, 2009; Willis, 2007). The positivist paradigm is based on the ontology[12] that approaches reality as 'objective'. From the epistemological[13] viewpoint it advocates the use of methods of natural sciences also in social sciences, and assumes that only knowledge gained through measurement and objective identification can be seen as truth (Bryman & Bell, 2011; Creswell, 1998; Guba & Lincoln, 1994). Based on these epistemological assumptions, the researcher is seen as independent from the reality of being researched (Creswell, 1998). The quantitative inquiries are traditionally having their roots in the positivist paradigm; seeking regularities and causal relationships are the typical target of the study (Burrell & Morgan, 1979).

The interpretative approach has developed as a criticism of positivism in social sciences. It groups together a variety of intellectual and philosophical approaches such as hermeneutics, phenomenology and socio-constructivism (Bryman & Bell, 2011; Deetz, 2009; Denzin & Lincoln, 2005; Guba & Lincoln, 1994, 2005; Merriam, 2009). Based on the relativist ontological assumption, the interpretivist paradigm assumes that the reality that we know is constructed inter-subjectively through the meanings and understandings developed socially and experientially (Guba & Lincoln, 1994). Epistemologically, it is based on subjectivist assumptions emphasising the interlinkage between the researcher and the research subject in sense-making and knowledge generation. Qualitative inquiries are typically grounded on the interpretivist tradition. (Denzin & Lincoln, 2005; Guba & Lincoln, 2005; Merriam, 2009)

Critical theory is a school of thought that stresses the reflective assessments and critique of society and culture (Willis, 2007). Ontologically, it is based on the historical realism aiming to understand the reality shaped by social, political, cultural, economic, ethnic and gender values (Guba & Lincoln, 1994; Merriam, 2009; Willis, 2007). It goes beyond uncovering the interpretation of people's understanding of the world: 'its goal is to critique and challenge and to transform and empower' (Merriam, 2009, 10). Research based on critical theory highlights power issues, asking: who has power, how it is negotiated, and what structures does society

[12] Ontology refers to the basic questions about the nature of reality and nature of the human being in the world (Bryman & Bell, 2011; Creswell, 1998; Denzin & Lincoln, 2005)

[13] Epistemology is about a theory of knowledge. It asks 'what is the relationship between the knower and the known' and 'how do I as a researcher know the world' (Bryman & Bell, 2011; Creswell, 1998; Denzin & Lincoln, 2005)

reinforce in the current distribution of power (Guba & Lincoln, 1994; Merriam, 2009; Willis, 2007).

The basic assumptions of this dissertation rely on the interpretivist paradigm and more precisely on the socio-constructivist approach (Berger & Luckmann, 1966). This approach emphasises the socially constructed nature of reality and the importance of collaboration and negotiation when creating understanding of the studied phenomenon. It challenges the ideas of objective and independent existence; instead, it states that the world is complex and it is in a constant state of change and revision. The approach recognises that a certain material world and the reality exist irrespective of the perception of the researcher. However, from the epistemological viewpoint – concerning the ways to acquire scientific knowledge of the reality – socio-constructivism emphasises the interdependence between researcher and the target of the study in the sense-making. Based on these assumptions, artefacts can embody knowledge but they cannot be understood and interpreted in one single way. Rather, there are multiple realities and interpretations of the studied phenomenon. (Bryman & Bell, 2011; Gherardi, 2008; Merriam, 2009) This means that the findings exist because of the interaction between the observer and the observed (Guba & Lincoln, 1989); the role of the researcher is to be an orchestrator of the negotiation process, whose essence is the generation of versatile and sophisticated information (Denzin & Lincoln, 2005).

Besides the socio-constructivist approach, this dissertation reflects some ideas of critical theory. It challenges the conventional – economically and technologically biased – values in evaluation (cf. Patton, 2011) and suggests a more versatile approach to capture the diversity of service innovations. Following the leading scholars in the socio-constructivist research stream, the central aim is to provide versatile understanding and interpretations – including analysis and critique – for the continuous dialogue. This dialogue is carried out in the social processes between a variety of actors, and results in the emergence of joint construction and reconstruction of the reality (Guba & Lincoln, 1989). These basic assumptions have directed both the theoretical development of the future oriented and systemic evaluation approach and the implementation of the empirical studies in this dissertation.

In addition to the distinction between the basic paradigms, there are more specific discussions about different scientific approaches and methodological choices. There are, among others, dichotomies separating objective and subjective, quantitative and qualitative, and 'hard and soft' approaches (Bryman, 2004; Buchanan & Bryman, 2009; Creswell, 1998; Deetz, 2009; Patton, 2002a). In social sciences, these dichotomies include tensions which are based on the long-standing view on the 'scientific approach' (lasting until 1960s). The imitation of natural sciences included in this view caused counter-argumentation and led to favouritism of

qualitative approaches (Guba & Lincoln, 1989). More recently, several scholars have remarked that differences in worldviews and scientific paradigms should not mean confrontation between methodological approaches (Denzin & Lincoln, 2005; Eskola & Suoranta, 1998; Willis, 2007). Actually, the paradigmatic and methodological diversity has become a general trend in social sciences, leading to the widening of boundaries and to the adoption of a range of orientations and methodologies (Brewer & Hunter, 1989; Bryman, 2004; Buchanan & Bryman, 2009).

The recent methodological literature emphasises 'methodological appropriateness rather than paradigm orthodoxy' (Patton, 2002b, 265). The increasing paradigmatic diversity derives from the multi-disciplinary nature of social sciences with their own perspectives and traditions to the research field. The fundamental aim is to examine the research problems by combining methods to compensate their particular weaknesses and limitations and to benefit from their specific strengths (Brewer & Hunter, 1989). That has led to the advancement of mixed and multi-method approaches (Denzin & Lincoln, 2003, 2005; Sechrest & Sidani, 1995), which have the potential of providing greater insights of the increasingly complex research contexts than a single approach (Buchanan & Bryman, 2009; Patton, 2002).

In this dissertation, the central principle in selecting the methods has been the relevance and responsiveness to the unresolved claims, concerns and issues in the research topic. Different tools and methods are applied to create a comprehensive picture of the examined phenomena; the dynamic complexity is analysed and elaborated to uncover the actors and factors that influence it (Kincheloe & McLaren, 2005). The multi-method approach also suggests that if the crucial elements do not exist in the conventional domain, the researcher has to look for them outside (cf. Nelson et al., 1992). This has been the situation of this dissertation: the construction of a new framework for evaluation in order to support new types of innovations – with services and systems as their core constituents – has required an 'out-of-box' attitude in the selection and combination of the methods. The multi-method approach adopted also means an inter-disciplinary perspective: methodological frameworks and tools have been sought from sociology, evolutionary economics, organisation science and systems sciences, among others.

In line with the socio-constructivist approach, the methods applied in this dissertation are qualitative in nature. The main aim in qualitative research is to understand and interpret phenomena in terms of meanings people bring to them (Creswell, 1998; Denzin & Lincoln, 2005). Its strength is richness and holism with a strong potential of revealing the complexity and nature of 'real life' (Miles & Huberman, 1994). Further, the qualitative approach is helpful in addressing emergent phenomena that require reflective thinking from the researcher

(Alvesson & Sköldberg, 2009; Smith et al., 2010). In this dissertation, the qualitative approach is combined with the multi-method view in two ways. In the data acquisition, it has meant the 'traditional' striving for methodological triangulation (Arksey & Knight, 1999; Denzin & Lincoln, 2005; Stake, 2005) through the combination of interviews, observations and documentary material (see 3.4.1.). In the data analysis and presentation of the results, it has meant the introduction of new types of tools (system dynamic modelling) that also serve as illustrations of the elements of the new evaluation framework.

The research process has followed abductive reasoning (Kelle, 1995; Peirce, 1931); it has been the way in which the theoretical views and empirical studies have been inter-linked in this dissertation. Abduction is the third form of inference process which bridges between the inductive and deductive research logics[14]. Alvesson and Sköldberg (2009, 4) define it as follows: 'Abduction starts from an empirical base, just like induction, but does not reject theoretical preconceptions and is in that closer to deduction. The analysis of empirical fact(s) may very well be combined, or preceded by, studies of previous theory in the literature; not as a mechanical application on single cases but as a source of inspiration for the discovery of patterns that bring understanding.'

Many researchers have perceived abduction especially useful in social sciences (Coffey & Atkinson, 1996; Dubois & Gadde, 2002). Abductive reasoning is typical in exploratory case studies; it highlights the iterative and dynamic interaction between data and theory, and allows a central role for the empirical research in the generation of ideas (Coffey & Atkinson, 1996; Dubois & Gadde, 2002). When applying abduction, the researcher goes 'back and forth' between empirical observations and the theory, acquiring new insights of both of them. Thus, abduction enables the consideration of both theoretical and practical (including developmental) needs simultaneously (ibid.). In this dissertation, the abductive reasoning process has been applied both in individual articles and in the iterative and cumulative process which synthesises the findings. In the latter phase, the research results have been integrated to create a comprehensive picture of the examined phenomena. This understanding has been used to elaborate the theoretical and conceptual views that have formed the starting point of the dissertation.

[14] Inductive-logic is based on the presumption that theories and generalisations can be accumulated based on empirical observations and cases, deductive logic – in turn – is founded on the presumption that empirical research can only be used to test theories (Coffey & Atkinson, 1996).

3.2. The case study methodology

In order to verify and elaborate the framework of the conceptual paper (Nieminen & Hyytinen, 2015), case study methodology was applied in the empirical part of this dissertation. Case studies have been suggested to be preferable when the research context is complex and the aim is to provide in-depth understanding of the phenomenon in question (Eisenhardt, 1989; Yin, 2009). They are also a beneficial methodology when the research area is new or there is a need to have a 'fresh perspective' and to create novel insights. As a phenomenon-driven approach, it is a purposeful choice when the existing theories are not capable of explaining the research questions (Eisenhardt & Graebner, 2007). In other words, case studies are the preferred method when 'how' and 'why' questions are asked, when the researcher has little control over the events, and when the focus of the study is on an emergent phenomenon within a real-life context (Yin, 2009).

Many researchers link case studies to the interpretative, ethnographic and field-study traditions, which differ distinctly from the experimental and quantitative research traditions and from the deductive reasoning aiming at producing statistical generalisations (Dyer & Wilkins, 1991; Eriksson & Kovalainen, 2008). There are, however, different emphases among the researchers as regards the qualitative and quantitative nature of the case methodology. In this dissertation, the qualitative research strategy with exploratory aims is prevailing. To improve the validity and reliability of the research, a variety of data sources and multiple data collection methods – interviews, observations and document analysis – are used. In this way, the data triangulation is achieved and a comprehensive picture of the phenomenon in question is pursued to draw conclusions that show required scientific quality (Eisenhardt, 1989; Yin, 2009)

The case study approach can involve either multiple cases or a single case (Eisenhardt, 1989). The former is useful if the aim is to make comparison or find common patterns; the latter highlights the search for insightful findings and their interpretation. An important benefit of using a particular case is that it enables learning and understanding the interaction between a phenomenon and its context (Dubois & Gadde, 2002). In a single case study, a multi-level analysis deepens the examination (Yin, 2009). In this dissertation the aim was to create in-depth understanding of the studied phenomenon and therefore the methodological choice was a single case study with multiple analytical units or levels[15] (cf. also Yin, 2009).

[15] Case study context of this dissertation is Cleen SHOK and the different analytical levels and units are the particular programmes. 'Case study' refers to Cleen SHOK, whereas the studies focusing on specific programmes are referred as empirical studies.

According to Eisenhardt (1989), data collection and data analysis are overlapped in the case study research. This interaction allows a researcher to make adjustments during the research process and give a rise for the novel and particular themes which emerge during the data gathering. It also affects the conduct of data collection: questions may be added to the interview protocol or additional data sources may be acquired (ibid.) Flexible and iterative data collection and analysis is a central characteristic in systematic combining (Dubois & Gadde, 2002), applied in this dissertation. The emergence of valuable themes, highlighted by the informants, has led to the additional interview questions regarding, for example, the systemic change in the area of energy and the environment, and the challenges in the governance of the examined policy instrument. As regards additional data sources during the implementation of the case study, there emerged an opportunity to observe the planning of new activities (new innovation programmes) in the case organisation. The observations generated interesting information of the collaborative processes in the context of service innovation and thus provided valuable insights from the theoretical viewpoint (cf. Eisenhardt, 1989; Dubois & Gadde, 2002).

3.3. Description of the case context

The empirical context of this dissertation is energy and the environment. The case study carried out examines service, social and system innovations in this context and analyse the ways in which these innovations could be purposefully evaluated. The studies have been conducted in Finland and focus on a new innovation policy instrument: SHOKs (Strategic Centres for Science, Technology and Innovation). One of the SHOKs – Cleen Ltd. (from now on Cleen) – operates in the area of energy and the environment. Its development programmes are the specific target of the empirical studies. Before describing the SHOK concept and the Cleen programmes in more detail, the research topic of energy and the environment is discussed in the following. Within this vast topic, the discussion has been restricted to the views that are most tightly linked to this dissertation: the need for systemic understanding and the need to include the service perspective to the development of technological solutions.

3.3.1. Sustainability in the context of energy and the environment

The concept of sustainability emerged in research, policy and organisational strategies in 1980s as an attempt to explore the relationship between the economic development and environmental protection (Banerjee, 2008; Pope et al., 2004). While there is variety of definitions for sustainability (Holmberg & Sandbrook, 1992), the most common is that of Brundtland Commission (Banerjee, 2008; Mickwitz et al., 2011). According to it, sustainable development is ‘a process of change in which the exploitation of resources, direction of

investments, orientation of technological development, and institutional change are made consistent with future as well as present needs' (WCED, 1987, p. 9). In the recent literature (Banerjee, 2008; Gendron, 2013; Komiyama & Takeuchi, 2006), the definition has been broadened to cover the balance between economy, society and the environment.

The main concern linked to environmental sustainability is the global climate change, which is one of the so called 'grand societal challenges' (Pope et al., 2004; Shrivastava, 2013; Smith et al., 2010). It is a broad topic that includes different domains: the use of natural resources, environmental pollution, the production and consumption of energy, traffic and transportation, water supply and waste disposal, economic equity, health and well-being, lifestyle etc. (Kajikawa, 2008). *Energy is central to cope with the sustainability challenge*: sustainable energy systems are generally considered one of the most efficient ways to tackle this challenge (Haas et al., 2008). Different forms of renewable energy sources (biomass, wood, hydro, solar, geo, wind etc.) and hybrid solutions lie at the core of sustainable energy. Thus, energy solutions are tightly linked with technological development and industrial production. However, they are also dependent on the behaviour of consumers (Kahn-Ribeiro et al., 2013). Energy saving and energy efficiency, balance between energy production and consumption, and limiting the ecological footprint are essential (Wang et al., 2009).

Awareness of the importance of the behaviour of actors – from the resource extraction to the final consumption – is gaining ground and has promoted the inclusion of the service perspective in sustainability issues. It has been understood that from the viewpoint of consumers, the core is the use value that various technologies produce: healthy and comfortable homes, safe and fast traffic, and balance between natural and built environment. In the case of energy, for instance, this value derives from the ability of technology to convert sources and flows of energy into heating, cooling, and lighting (Haas et al., 2008). A change in user preferences is necessary in order to avoid undermining the sustainability efforts by consumption patterns (Weber & Hemmelskamp, 2005). This raises *the need for many types of information and advisory services* that facilitate the decision making and practical operations among citizens. Corresponding support is also needed among organisational stakeholders both in the private and in the public sectors. The number of environmental consultants has been increasing. These 'agents of greening' (Evers & Menkhoff, 2004) provide consultancy in the areas of waste disposal, emissions and discharge monitoring, remediation and clean-up, environmental auditing, environmental impact assessment, and eco-design.

Boosting the development with *new solutions based on digitalization*[16] has gained popularity during the recent years (Caragliu & Nijkamp, 2011). Opening the public data reserves is one example: certain data is made freely available to everyone to use and republish (Davies, 2010; Zuiderwijk & Janssen, 2014). Public authorities develop new collaborative ways of working with data users, including commercial users – and where necessary engage in the market to stimulate demand for data. Open energy data and meteorological data are examples that are directly linked to the sustainability topic. Another example is the concept of smart city that is applied in many countries today. It refers to practices in which the digital technology is used for linking together the aims of environmental and social sustainability (Kahn-Ribeiro et al., 2013; Mcdonalda et al., 2008). The efforts include dealing with issues of urban ecology, solving problems in public services, and strengthening the social management. The goal is to promote sustainability via effective governmental operations, advanced industries, and an efficient information infrastructure.

Because of the complex nature of the sustainability challenge, a broad perspective has been called for in the problem framing: in the recent literature, systemic views have gained ground. These include the analysis of innovations at the system level; more specifically, the transition towards more sustainable socio-technical systems has aroused increasing interest (Geels, 2010; Elzen et al., 2004; Mickwitz et al., 2011; Kivimaa & Mickwitz, 2011; Smits et al., 2010). The perspective of socio-technical systems acknowledges the difficulty in solving sustainability challenges as isolated technologies and services, and provides a framework for their analysis in the context of societal changes. It points out strong interdependencies between various elements of the systems which impede new ways of organising the provision of renewable energy, for instance (Geels, 2005; Smith et al., 2010). *Multiple network relationships* are an essential characteristic of systems. The composition of networks needed for the promotion of sustainable development is versatile: they include public authorities, industrial firms, financial service providers, consultancies, universities etc. (Mickwitz et al., 2011; Smith et al., 2010).

System innovations in the area of sustainability imply major changes along the entire production-consumption chain: its flows, its multi-level architecture and its institutions and structures (Smith et al., 2010; Weber & Hemmelskamp, 2005). In the markets, central issues are the integration of clean technologies in safety standards and market rules, and the promotion of effective and prospective market demand. The institutional framework is

[16] The current era of digitalization means that the growth of data is no longer limited to active human creation, but computers, mobile phones and other digital devices and sensors collect, store and transfer data automatically. The concept 'internet of things' refers to communication between machines, and the concept 'big data' refers to the huge, unstructured mass of data created via digital devices. 'Big data' is characterised by increasing volume (amount of data), velocity (speed of data in and out), and variety (range of data types and sources). (Chen et al., 2014)

essential in order to go beyond technical aspects and include the enabling environment, which covers social mobilization and acceptance, institutional arrangements (e.g. laws and stakeholder roles), and financial and operational requirements (Van de Klundert & Anschütz, 2001). It highlights the role of policy-making and governance processes in sustainability efforts.

Corresponding to the existing need, many activities in different sectors and countries all over the world are striving for sustainability, and respective policy initiatives, instruments and research programmes have been launched to find innovative solutions to the problems. Development towards more sustainable environments is directed by international agreements and directives on the one hand, and by national visions, strategies and regulations on the other (Berger-Douce & Schmitt, 2013; Cruz et al., 2015). Striving for the cleaner environment is not the only motivation: new 'green' innovations are also seen to be a source for new business opportunities and economic growth (Gendron, 2013). In the case studies of this dissertation, the national endeavours in Finland are in the spotlight.

3.3.2. A Strategic Centre for Science, Technology and Innovation

As mentioned above, the case study examines the development programmes of the Cleen SHOK – a Strategic Centre for Science, Technology and Innovation in the area of energy and the environment in Finland. SHOKs were launched in 2006 by the decision of Research and Innovation Council (that time called Science and Technology Policy Council) chaired by Prime Minister. SHOKs operate as non-profit limited companies built on public-private partnerships and aim to enhance a new type of collaboration between business life and academia. The organisation of the practical activities in SHOKs is based on the research agenda (SRA), which is operationalized through long-term research programmes lasting approximately five years. During the implementation of the case studies, there were six SHOKs in operation: in addition to Cleen, they were Digile (in the ICT and digital services sector), Fimecc (in the metal and engineering industry), Salve (in the health and well-being sector), Rym (in the area of built environment) and Fibic (in the bio-economy cluster).

The main goals of SHOKs are to renew Finnish industries by crossing the conventional sectoral and organisational borders, and to create innovations that meet the needs of the Finnish economy and society within five-to-ten-year period. To reach these goals, SHOKs aim at generating top-level expertise on a global scale and accumulating a critical mass of resources and actors in the strategically selected fields. Testing and piloting the creation of innovative environments and the building of ecosystems constitute an essential part in their operations. SHOKs apply the idea of open knowledge sharing that includes open access to results and

shared IPR (Intellectual Property Rights) among the parties involved in a specific research and developmental task. These features have been considered unique in the Finnish innovation system (Ministry of the Employment and the Economy 2013).

Cleen Ltd. was established in 2008 to collect together the actors in the area of energy and the environment into a new cluster and to promote the competiveness of this cluster. The main driver behind the establishment of Cleen is the global environmental challenges; answering these challenges nationally is high on the governmental agenda. The creation of collaborative forms of innovation is essential to the effective operation of the new cluster and to the competitiveness of individual companies in this cluster. When the case studies were started in 2013, the actor network of Cleen included 44 shareholders, encompassing 28 company partners (many of them globally operating) and 16 partners from universities or public research organisations. In addition to the shareholding partners, also other companies and academic actors participate in the programmes. In the final stage of the study in 2014, altogether 93 companies (of which 42 per cents SMEs) and 25 research organisations were engaged in this way.

Funding for the programmes comes from multiple sources: 36 per cents is co-funded by partner companies and 11 per cents by universities and research organisations; the rest 53 per cents comes from the governmental budget allocated via Finnish Funding Agency for Innovation (Tekes) and Academy of Finland. For example, in 2014 there were eight collaborative research programmes going on in Cleen and their yearly volume was 28 million euros in total.

Cleen has various organisational bodies for the operational management, steering, and scientific counselling. Board of Directors is the main strategic forum that directs the operations; it consists of representatives of the shareholder companies and organisations. R&D council directs the research activities and has a central role in implementing Cleen's strategy. It consists of members representing shareholder organisations and other public and third sector stakeholders. It has two working groups, one focusing on the development of SRA and the other on the financial structure. In addition, the scientific excellence of Cleen and its programmes are supported and developed by Science Council and Scientific Advisory Boards (SAB); the latter are designated for individual programmes. The employees in Cleen's office consist of CEO, Chief Technology Officer, Development Manager and Controller. Together with other SHOKs, Cleen also employs a Legal Counsel. In addition, each programme has a manager, employed part-time by Cleen.

In principle, Cleen – like the other SHOKs – is operating as an independent legal entity. However, its activities are steered indirectly by the national research and innovation council.

This council monitors and evaluates the mission accomplishment and success of SHOKs. Monitoring data is based on key performance indicators provided by Cleen. The public funding criteria (including terms and conditions of funding) are also a powerful steering instrument; they are set by Tekes. Tekes is responsible for practical steering which plays an important role in Cleen's day to day management (Ministry of the Employment and the Economy 2013). It coordinates the thematic direction, enhances the collaboration between different thematic areas and supports the development of operations. Based on the funding criteria, and associated reporting, Tekes monitors the progress, quality and impacts throughout the programmes.

As in other SHOKs, the focus areas of Cleen are based on strategic research agendas (SRA), defined jointly by the partners (shareholders). This collaborative practice means that the targets are a combination of heterogeneous competences and goals of industry partners and public sector partners. The first SRA was compiled in 2008 to give directions for the establishment of Cleen and to support the planning and implementation of the first generation programmes. In this research agenda, the focus was on eight main areas: 1) carbon neutral energy production, 2) distributed energy production, 3) sustainable fuels, 4) energy markets and smart grids, 5) efficient energy use, 6) resource efficient production technologies and services, 7) recycling of materials and waste management and 8) monitoring, measurement and assessment of environmental efficiency. Significant renewal of the first SRA was carried out in 2014 to provide guidelines for the second generation programmes. In that work, four thematic areas were defined: 1) an architecture for the future energy system, 2) healthy urban living, 3) sustainable production, handling and use of gases for energy production and 4) sustainable use of natural resources in local, regional and global scale. The programmes are implemented in virtual networks, which consist of industrial and academic shareholders, and non-shareholders as described above.

In this study, the particular focus is on three ongoing programmes and on the preparation of two second generation programmes of Cleen[17]. The ongoing programmes are *'Distributed Energy Systems'* (DESY), *'Smart Grids and Energy Markets'* (SGEM) and *'Measurement, Monitoring and Environmental Assessment'* (MMEA).

- DESY aims to increase the production of renewable energy and to promote the use of hybrid energy technologies by developing for example the efficient sizing, optimization and simulation tools for hybrid energy solutions. In addition, its goal is to foster the emergence of local energy systems and energy self-sufficiency by the

[17] Two second generation programmes of Cleen were in their preparation phase during the implementation of this dissertation

improvement of energy efficiency, town and infrastructure planning, and by the development of more efficient measurement and analysis for environmental solutions (e.g. life cycle and environmental impact analysis). Compared to other programmes, DESY is small-scale in volume and duration: it was primarily launched for the preparation of more comprehensive programmes to renew energy system.

- SGEM aims to create international smart grid solutions practically demonstrated in a Finnish R&D infrastructure environment. The programme develops smart grid architectures and distribution infrastructure, and intelligent management and operation of the grid; it also includes solutions for smart consumption and customer interface for the smart grid. The goal is the promotion of efficient and uninterruptable use of electricity. Interaction between ICT systems and energy systems is a central innovation behind the advancements in this area.
- MMEA develops environmental information systems – including technologies, tools and services – to monitor and evaluate the environmental efficiency of various industrial processes, products and infrastructures. A specific focus is on inter-operational measurement systems and new online and remote sensing systems. In the core of the programme is the MMEA-platform, which is interoperable, modular, quality controlled measurement and monitoring platform and which aims to enhance the development and marketing of new end-used applications in the area.

Table 5 presents the programmes in nutshell, crystallising their goals, key research areas, partner network, duration and total volume.

Table 5. Description of the examined SHOK programmes according to their goal, key research areas, partner networks, duration and total volume

Programme	Goal	Key research areas	Partners	Duration	Total volume
DESY - Distributed Energy Systems	To increase the production of renewable energy and to promote the use of hybrid energy technologies by developing, for example, the efficient sizing, optimization, and simulation tools for hybrid energy solutions	Hybrid energy solutions and energy storing Business concept analysis for sustainable energy Local sustainable energy and self-sufficiency	12 companies and 6 research organisations Brings together energy users, producers, technology providers, engineering and consultancy companies, and academic and applied researchers.	2012–2014	1 M€
SGEM – Smart Grids and Energy Markets	To develop internationally acceptable smart grid solutions that can be demonstrated in a real environment utilising the Finnish R&D infrastructure	Smart grid drivers and scenarios, market integration, new business models Future Infrastructure of power systems Active resources of the smart grid Customer interface for the smart grid Intelligent management and operations of the smart grid	19 companies and 8 research organisations Brings together energy technology companies, local distribution system operators, energy retailers, the Finnish national transmission system operator, ICT companies; engineering and consultancy companies, and academic and applied researchers	2010–2014	52 M€
MMEA – Measurement, Monitoring and Environmental Assessment	To develop new technologies, methods, tools and services for environmental observation both in industrial processes and in the surrounding environment	Interoperable environmental measurement systems Management system for environmental energy efficiency New online and remote sensing technologies Business applications	27 companies and 13 research organisations Brings together weather observation providers, air quality measurement and monitoring companies, automation technology and service companies, data operators, ICT companies, environmental data providers (incl. authorities), and academic and applied researchers	2010–2015	54 M€

The second generation programmes (which were in the preparation phase during the implementation of this dissertation) are 'sustainable energy system'-programme and 'healthy urban living'-programme. The former programme continues the research and development work started in DESY, SGEM and MMEA and aims to provide a comprehensive perspective to

the transition towards sustainable and flexible energy systems. The focus is on the optimal integration of centralised and decentralised energy resources and production, and on the flexible use of various energy sources. The latter, 'healthy urban living'-programme aims to enhance sustainable development and well-being of citizens in the urban context. It focuses on the dynamic interlinkages within the urban system and puts emphasis on the following elements in particular: energy chain, environmental and meteorological data, air quality and its effects on human well-being, human behaviour, citizen empowerment, new business models and co-creation. The programme integrates and further develops the topics of the first generation programmes. It also collaborates closely with other SHOKs in the areas of built environment and digital services. During the empirical studies, these two programmes were in their preparation phase, due to which detailed information of their volume and duration was not available.

3.4. Data acquisition and analysis

This sub-chapter describes the collection and analysis of the empirical data for the case study carried out in the sector of energy and the environment (and examined in detail in three articles of this dissertation). As the case study share the same data to a great extent, data acquisition is presented as a whole; those points where the data sources differ are mentioned. The analysis methods vary much more between the different empirical studies and therefore they are described separately study by study.

3.4.1. Data acquisition

Data gathering followed the principle of methodological triangulation (Arksey & Knight, 1999; Denzin & Lincoln, 2005): application of multiple data sources and data gathering methods. This adds the rigour, breadth, complexity and richness of the study, and therefore increases its validity (Arksey & Knight, 1999; Stake, 2005). In this dissertation, triangulation means that the data has been derived from four types of sources with respective methods. Primary data consists of interviews and observation. Secondary data includes two types of documentary materials: 'traditional' written documents (e.g. annual reports, strategic research agendas, programme descriptions and newsletters) and a digital working space. Interviews were used as a primary data source in the first two empirical studies. Interview data was complemented with the written documentary material. The third empirical study utilised interviews and observation as a primary data source; documentary material and the material accumulated in the digital working space have been used as secondary material to complement it. The author herself had the main responsibility for designing the data collection. She also carried out all

interviews and collected the documentary material; the observations were partially carried out by a group of three researchers (see below).

The primary method in data collection was face-to-face interviews (35 in total). All the interviewees represented the shareholding partners of Cleen. Detailed list of interviewees is presented in Appendix A. The main part of them was conducted between February and June 2013 (30 interviews); they concerned general issues in the programme work of Cleen and specifically the on-going programmes. These interviews were utilised in all empirical studies. A small number of interviews (5) were carried out in spring 2015; they concerned the planning of the second-generation programmes and were utilised as supplementary interviews in the third case study. To identify the interviewees in the on-going programmes, snowball sampling (Biernacki & Waldorf, 1981) was applied: in an initial phase of the data gathering, a small number of respondents were selected to nominate other informants who could potentially contribute to the empirical study. The first respondents were Managing Director of Cleen and the programme managers. Thereafter, based on their suggestions, the other interviewees were selected among the members of the programmes. The final sample represented actors in the areas of sustainable energy and environmental measurement in a versatile way. It consisted of representatives of both small and medium size companies (SME's) and large companies. In addition, experts representing universities and other public research organisations were interviewed. All interviewees were managers, professors or senior experts in their background organisations, and they had a significant role in the preparation and implementation of the research programmes – including the writing of the strategic research agenda and the building up of the research network. Typically they were acting as programme managers, work package leaders, or as leaders of the service demonstration development which was part of the programme implementation. As regards the second generation programmes, the interview sample consisted of the technology and development managers of Cleen and of the key shareholding partners who were involved in the core group developing the new programmes.

A semi-structured interview method was applied: the topics were planned beforehand but within them the respondents were given a great deal of freedom (Bryman & Bell, 2011). The topics were derived from and structured according to the theoretical analyses that form the basis of this dissertation: systemic change, service innovation, networks and collaboration, evaluation and analysis of impacts, future developments etc. The same topic list was used in both interview rounds. The detailed list of the interview topics is presented in Appendix B. In the implementation of the interviews, attention was paid to the balance between openness and structuring so that the respondents were encouraged to express their opinions but the discussion was simultaneously directed so that all essential issues were covered (cf. Kvale,

1996). The duration of the interviews ranged from one and a half to three hours. With the exception of four cases, all interviews were recorded and transcribed in order to prevent the loss of information and increase reliability. In the four interviews that were not recorded[18], the notes were made very carefully and in detail.

The second source of material was non-participatory observations. This method was applied concerning the preparation process of the new programmes (the third empirical study). Observations took place in seven collaborative workshops in which the participants were from companies, universities and research organisations and which aimed to plan the themes of the second generation programmes. The collaborative workshops were organised by Cleen[19]. In the workshops, aim was to create multi-voiced forum for the variety of programme participants; interaction between partners was promoted by different interactive workshop tools. The author took part in all of the workshops; in the first two workshops, two colleagues were also present and supported data gathering and the increase of reliability. The workshops took place during the spring 2014 (February-June). The possibility to gather data in the workshops provided a privileged access to the participatory process of the programme preparation. The timing of observations in the later stage of this study was also good, because the author had more than one year's experience on examining the topic on the basis of the interviews. Thus, she had preparedness to apply the demanding method of observation in which it is important to avoid the personal bias as much as possible and to consider the ethical aspects relating to the method (Angrosino & Mays de Pérez, 2003). During the meetings, the author made careful field notes. The field notes were complemented by the 'official' meeting notes provided by the case organisation. In the two first workshops – in which two other colleagues were also present – all three observers made their own field notes. Similarly to interviewing, the observed topics were based on the theoretical background of the study; systemic change, service innovation, networks and collaboration, evaluation and analysis of impacts etc. A particular focus was on the multi-actor nature of innovation: the phenomena reflecting the roles of and dynamics between the actors, and interactivity within the process. After the workshops, the field notes were integrated. The researchers also discussed carefully their observations to avoid misunderstandings, and to ensure the reliability of the data. This careful discussion helped the author to conduct the analysis of the integrated field notes which also includes observations of other researchers.

[18] A central reason for interviewing without a recorder was that these interviews were carried out in public places where the background noise made recording impossible.

[19] Due to the restrictions of the research setting, action oriented research was not possible (this is stated in section 1.4.): researchers neither had a role in the organisation of the workshops, but all seven workshops were organised and implemented by Cleen.

The third and fourth data sources consisted of documentary material. The former source included the strategic planning and the follow-up material provided by Cleen: strategic research agendas, guidelines and criteria for the programme preparation, guidelines for funding applications, annual reports, material on programme results and success cases, and official evaluation reports. This documentary material was used in all empirical studies as background material to complement interviews and observations. It helped to build detailed understanding of the research objectives, organisational structure and operational principles of Cleen and its programmes. The latter source included the digital working space (Google Docs) that was taken into use to support the preparation of the second generation programmes. All shareholding partners, who took part on the programme preparation, had access to the digital working space. The author of this dissertation had that access, too. The programme documents and other material provided in the course of the programme preparation were saved in this working space. It included, for example, idea papers and background reports relevant for the planning of the programmes. This documentary source was used in the third case study. It helped to build detailed understanding of the different target areas of different partners, and it provided outlook for the generation of the common research objectives between the collaborative workshops. Table 6 provides a detailed list of the data types, the period in which data was gathered, the quantity of each type of data, and the source of the original data.

Table 6. Description of the data of the case study (data inventory)

Data type	Time period	Quantity	Original data source

Interviews	February – June 2013 (main part of interviews); April – May 2015 (supplementary interviews)	• 35 interviews
		• 3075 minutes of interviews
		• 420 pages transcribed
		• 222 pages research notes
			• Cleen organisation
			  ○ 8 interviews
			  ○ 408 minutes of interviews
			  ○ 51 pages of transcriptions
			  ○ 23 pages of research notes
			• SGEM-programme
			  ○ 9 interviews
			  ○ 865 minutes of interviews
			  ○ 110 pages of transcriptions
			  ○ 65 pages of research notes
			• DESY-programme
			  ○ 11 interviews
			  ○ 1015 minutes of interviews
			  ○ 142 pages of transcriptions
			  ○ 83 pages of research notes
			• MMEA-programme
			  ○ 7 interviews
			  ○ 787 hours of interviews
			  ○ 117 pages of transcriptions
			  ○ 51 pages of research notes

Observations	February – June 2014	• 7 workshops
		• 25 hours
		• 32 pages of field notes
			Meetings to prepare the second generation programmes
			• The 'sustainable energy system' -programme
			  ○ 5 workshops
			  ○ 19 hours
			  ○ 26 pages
			• The 'healthy urban living' -programme
			  ○ 1 workshops
			  ○ 4 hours
			  ○ 4 pages
			• R&D-council meeting
			  ○ 1 workshops
			  ○ 2 hours
			  ○ 2 pages

Documentary material on strategic planning and follow-up	February 2013 – April 2015	• 71 documents • 1956 pages in total	• General SHOK documents (incl. annual reports, SRA documents, newsletters) • Programme descriptions • Documents presenting results and success cases • Documents on the funding criteria and indicators of programmes • Evaluation reports

Documentary material on planning the second generation programmes	February – September 2014	• 30 documents
		• 317 pages
		• 40 e-mails
			Reports to support the programme planning
			• The 'sustainable energy system' -programme
			  ○ 15 documents
			  ○ 209 pages
			  ○ 22 e-mails
			• The 'healthy urban living' -programme
			  ○ 15 documents
			  ○ 108 pages
			  ○ 18 e-mails

3.4.2. Data analysis

In the analysis and interpretation of the empirical data, a coding tool was not used; instead, the realisation of scientific rigor was secured via a qualitative and systematic multistep process. This process was carried out separately for each of the three empirical studies because the theoretical background included specific frameworks and the methodological approach was different. Data analysis and presentation of the results followed the principle of analytical triangulation: the introduction of many types of analysis tools that also serve as illustrations of the elements of the new evaluation framework. Different empirical studies applied specific analytical frameworks, which are described below separately study by study. The analysis procedure followed the steps introduced by Bryman and Bell (2011). The set of interview transcribes and observation field notes were handled four times. In the first round, all the material was read through to get a general picture. The second round focused on picking up the material directly linked to the specific framework of the empirical study at hand (a future-oriented approach, a systemic approach, and a multi-actor approach respectively). In this way, the huge amount of material was handled to reduce it, and to derive meanings from it (Huberman and Miles, 1994). The third round included a systematic creation of linkages between the theoretical and empirical materials: in addition to the specific frameworks, also the more general theories on innovation and evaluation were utilised at this stage. Finally, in the fourth stage, the results were structured using the specific methods of empirical illustration (trend analysis; the multi-criteria framework and system dynamic modelling; and the ServPPIN -framework combined with the participatory and networked processes).

The dialog between the theoretical frameworks and empirical material played a central role in data analysis. The results were summarised in a table form in the first two empirical studies (the second study also includes the dynamic model); in the third empirical study, the interview quotations illustrate the core results. In the following, the 'theoretical – empirical' dialog is described in more detail concerning each empirical study and the use of the different methods for structuration and illustration of the results is presented.

The first empirical study (reported in article 2) focused on future energy services and applied the basic idea of foresight – more specifically, *qualitative trend analysis* (Coates, 1996). The aim was to create understanding on the role of services in the development of the energy sector and identify forces that shape it (cf. Martin & Irvine, 1989). The main empirical data analysed in the study, consists of interviews (20) carried out in SGEM and DESY programmes. Documentary material has been used as a supplement to provide understanding of the development of energy technologies and markets, and the objectives of the programmes. The qualitative trend analysis (ibid.) was carried out in a dialog between the empirical results and

the theoretical perspectives. Analysis started from a preliminary survey of the interview material and continued with the literature analysis, which took place as follows: to reveal the technological novelties and uses of energy as service, the perspective of innovation was applied; a particular interest was in social innovations and empowerment phenomena that link the roles and activities of citizens and local communities to the development of sustainable energy. Thereafter, the empirical data was re-examined to crystallise the main trends. To separate trends from other futures phenomena, three criteria were used: a trend has a history, it has an identifiable direction, and it shows continuity in the future. The history, even it might be short, is necessary for the identification of the direction (Toivonen, 2004). Broad recognition among interviewees was an additional criterion in the analysis: the selection criterion of the main trends was that they came up in the most of the interviews. This phase of the analysis started from the identification of the main trends linked to sustainable energy and continued to the description of their main contents. Thereafter, the impacts of the trends on the development of services and the empowerment phenomena were examined. Finally, the factors that promote the continuation of the trends or indicate their discontinuity were mapped. The last-mentioned perspective links the future development of energy services to the broader perspective of socio-technical change.

The second empirical study (reported in article 3) examined the opportunity for new evaluation approaches using as an example the environmental data platform[20] developed by Cleen. The data consists of 30 interviews carried out with Cleen management and in all three programmes[21]. Documentary material on the programme results and the development of environmental technologies, services and markets has been used as a supplementary data to provide general understanding of dynamics of innovation and emergence of impacts in the field. Here, the same data has been analysed by applying two different analysis tools: *the multi-criteria framework* and *the system dynamic modelling*. The analysis started from the identification of the potential short term outputs and long term outcomes of the environmental data platform in the multi-criteria framework. This framework makes visible the multifaceted nature of innovations by applying the idea of different 'worlds' of services and in this way extending the evaluation criteria to include also other than the traditionally

[20] The environmental data platform is an example of an open data initiative. The core of this approach is that public service providers develop new collaborative ways of working with data users, including commercial users. The premise for growth is that public service providers do not charge users for their data, but enable users gain access to it. Individuals can use open data as a way to facilitate their everyday activities, businesses can benefit from it in innovation or entrepreneurial efforts. The idea of bidirectional contribution is also included: the users may provide information inputs to the platform based on their own observations, in our case, concerning the condition of the environment.

[21] Specific aspects of the environmental data platform were discussed in the interviews of MMEA-programme. Other interviews (including two other programmes and Cleen management) revealed more general aspects of evaluation of innovation.

used technological and economic criteria (Djellal & Gallouj, 2010). However, the analysis as such does not reveal the dynamics between the criteria and does not show how the outputs and outcomes representing different 'worlds' are interlinked and may reinforce or contradict each other. Therefore, the qualitative system dynamic modelling (Sterman, 2000) was used as a supplementary method. The model describes mutually dependent and co-evolving feedback loops between different phenomena and shows how the effects emerge in short and long term in a non-linear process. In the compilation of the model, the dialog between the theoretical and empirical material played again a central role: important phenomena identified in the case material were used together with the basic elements of the multi-criteria framework. The model was compiled as a desk study, because participatory techniques (e.g. Vennix, 1996) were not possible to use due to the restrictions of the research setting. To increase the reliability of the study (cf. Bryman & Bell, 2011), modelling was carried out in collaboration with a co-author who is an expert in the field of system dynamics.

The third empirical study (reported in article 4) focused on participatory processes in the development and implementation of the innovation programmes of Cleen. As in other empirical studies, the aim was to create holistic understanding of the research topic via systematic and thorough analysis rounds – in this case, specific requirements emerged from the use of observational data. Theoretical views on social innovations and public-private innovation networks (ServPPINs) formed the background to which the empirical data was linked. The empirical data consists of all the interviews (35) and observations of seven collaborative workshops. The 'traditional' documentary material on strategic planning and follow-up (including for example the funding criteria and indicators of programmes, and evaluation reports) was used to supplement the primary data. Similarly, the material generated in the digital working space (including the planning of the second generation programmes) supplemented the primary data. The analysis started from the description of the study context using the analytical dimensions of the ServPPIN framework (Djellal & Gallouj, 2013b). This approach concretises the multi-actor view which is the core of societal embedding. Specific interests in the analysis were to examine the structure of the network (including the different actors involved) as well as to reveal the functions of the network. This analysis of the network structure and functions is mainly based on the interview data. Thereafter, the participatory and networked processes were examined thoroughly with qualitative analysis methods. In this analysis, the data derives from the observations. Particular attention was paid to the processes of network formation, collaborative practices, relationships between the actors, and the integration of bottom-up and top-down perspectives.

4 Results

The present chapter summarises the results included in the four articles of this dissertation. Together they aim at broadening the view on the target of evaluation of innovations and developing a new integrative and concrete evaluation framework. Thus, the results aim at answering the two research questions set in the beginning: why should evaluation practices be broadened and how this broadening could be done. As regards the former question, the phenomena linked to the growing importance of service, social and system innovations are brought to the fore. Based on the latter question, the study examines the possibility of developing an evaluation framework in which futures thinking, systemic views and a multi-actor approach are central ingredients.

The first article serves the research purpose by analysing the topic conceptually. It proposes a way to integrate foresight, system dynamic modelling, and societal embedding to evaluation (in the article 'impact assessment' – see footnote 2 in section 1.3.). This common framework is suggested to be an approach that provides versatile information to increase the strategic view in decision-making. The three other articles demonstrate how the specific approaches and methods included in the framework can be applied to analyse innovations from a broad perspective and how they can be concretised as evaluation tools. All these articles describe the context of environmental and energy services. The second article creates an understanding of the broadening of the scope of innovations (the target of evaluation) in this traditionally technological area: it examines services linked to energy production and distribution. As regards the development of evaluation tools, the second article illustrates an application of foresight: a qualitative trend analysis. The results reveal trends, drivers and system interdependencies in services in the energy sector. The third article describes the multi-faceted nature of service innovations using an environmental data platform as an example. Its contribution to understanding the target of evaluation takes place via the adoption of a multi-criteria framework that broadens the traditional evaluation criteria from the techno-economic world to the 'immaterial world' of relations, responsibility and reputation. The development of the evaluation framework focuses on the inclusion of systemic aspects: system dynamic modelling is used to illustrate the interlinkages of evaluation criteria. In the fourth article, the focus is on multi-actor collaboration (societal embedding) in the context of service innovation. Again, the results increase understanding both of the target of evaluation and of the way in which evaluation should be carried out. They highlight that the generation and scaling up of innovations requires collaborative networks and participatory processes. If a new type of developmental evaluation – with ex-ante and real time perspectives, i.e. embeddedness in innovation activities – is pursued, the broad participation of stakeholders (including policy makers, other decision-makers and financing

agents) is essential. Continuous reflection by the stakeholders during the process is an important element in participation.

4.1. Article 1: Future oriented impact assessment: Supporting strategic decision-making in complex socio-technical environments

The first article (Nieminen & Hyytinen, 2015) in this dissertation is conceptual in nature. It initiates the development of the new evaluation framework and utilises to a great part the same theoretical literature that is examined in the dissertation's summary part. However, the summary part analyses the background theories broader and deeper, elaborates the elements of the new evaluation framework further, and contextualises it in services. On the other hand, some aspects of evaluation are discussed in more detail in the article – in particular, it includes an 'exercise' to link the new evaluation framework to the theory of socio-technical change (Geels, 2002, 2004, Geels & Kemp, 2007). Also the context of the article differs from the summary; it focuses more generally on science, technology and innovation policy – not particularly on service innovation.

A central argument in the article is that the integration of foresight, system dynamic modelling and societal embedding to evaluation ('impact assessment' in this article – see the explanation below) offers *an extensive and versatile information base* to support strategic planning, management and governance in complex decision-making situations. By developing horizontal and holistic understanding, this framework responds to the current societal challenges such as complexity, interdependence of societies, and interconnectivity between technological, economic and societal developments. The need for the creation of a new evaluation framework is argued to derive from shortcomings of the traditional approaches which are still largely based on linear views of the target of evaluation: the traditional innovation process, which emphasises innovation development as a systematic and serial process. These kinds of approaches are not able to capture the complex relationships and dynamics in the development and implementation of innovation and in the emergence of impacts (Arnold, 2004; Patton, 2011; Rip, 2003).

The article introduces the view that evaluation should support innovation. In this regard, traditional evaluation is problematic in many ways. Firstly, the 'atomism' included, i.e. the focus on individual organisations and policies, results in overlooking the systemic and collaborative nature of innovation (Rip, 2003). Secondly, the mechanistic and quantitative indicators generally used lead to the over-simplification of the complex, dynamic and long-term nature of innovations and their impacts (Hansson, 2006; Van der Knaap, 2006). Thirdly, the emphasis on ex-post evaluations makes the perspective backward looking: the futures view and strategic orientation are less considered. Due to these challenges, which are opened

up in more detail in chapter 2.3.1. of this summary part of the dissertation, the prevailing evaluation practices do not provide accurate and real-time inputs to support innovation. They are particularly weak in the analysis of the phenomena in current society that is characterized by complex development processes, multiple relationships and rapid changes (Arnold, 2004; Patton 2011; Smits & Kuhlmann, 2004; Todd & Wolpin, 2010; Weijermars & Wesemann, 2013). The suggested new framework aims to meet these challenges of the changing innovation environment and the related evaluation practices.

In the article, the new evaluation framework is linked to the theory of socio-technical change (Geels, 2002, 2004; Geels & Kemp, 2007) – discussed more broadly in chapter 2.1.1. of this summary part. The theory emphasises the dynamic and complex interaction between different levels of the system: socio-technical landscape at the top level, socio-technical regime at the middle level, and niche-innovations at the bottom level. In the article, it is argued that the analysis of socio-technical change from this multi-level perspective provides a fruitful starting point to the improvement of evaluation practices. In addition to multiple perspectives, it highlights that comprehensive understanding of the system and its development – and the creation of preconditions for innovations – requires the integration of different methods (cf. Dyehouse et al., 2009; Williams & Imam, 2007).

The new framework is presented in a preliminary form in the first article. The biggest difference compared to the later elaboration is the application of the narrower concept 'impact assessment' instead of evaluation. Another difference is that the model is constructed of four equal elements: impact assessment, foresight, system dynamic modelling and societal embedding; in the later modifications, evaluation is used as the basis to be improved via the approaches of the other three elements. The linkage between the new evaluation framework and the theory of socio-technical change was created by locating each of the above-mentioned approaches in the multi-level model (Figure 5). The location was based on the analysis of the way in which each of the approaches supports the information base for the development of the system.

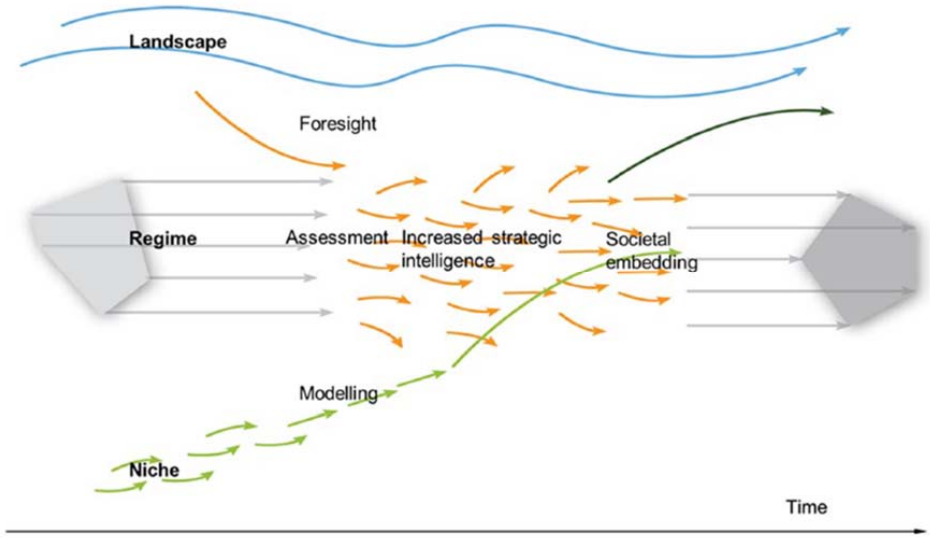

Figure 5. A multi-level framework for future oriented impact assessment (Nieminen & Hyytinen, 2015, 456; originally modified from Geels, 2002)

As the Figure 5 shows, foresight was located at the landscape level in the multi-level model: it was seen to contribute to the understanding of broad phenomena in the innovation environment, e.g. demographic change, new social movements, shifts in political ideology, economic restructuring, emerging scientific paradigms, and cultural developments (Geels, 2005). System dynamic modelling, on the other hand, was regarded as a way to reveal the complex interactions at the micro level where innovations originate and are combined to become more influential – thus, this method was located in the sphere of niches. Impact assessment and societal embedding were located at the regime level because the institutional factors belong to this level and affect on the recognition, 'stabilisation' and spread of innovations. These factors include knowledge, objects, infrastructures, values and norms, and show the dominant way of realising societal functions (Späth & Rohracher, 2010). The possibility that individual innovations gain success depends on the activities that frame and interpret them (cf. Smith et al., 2010) – in these activities, evaluation and societal embedding play a central role.

After the location of the methods in the model of socio-technical change, their contribution to the creation of sufficient and purposeful information base was analysed in more detail. The results are summarised in the following text. Thereafter they are presented in Table 7 in which they are structured according to the rationale of data accumulation on the one hand, and according to the outcome of data on the other.

- *Impact assessment* refers to a purposeful evaluative study aimed to answer questions about the intended outcomes and impacts. It provides understanding of the past and current state of the prevailing system, including its structure and operations. The assessment generates ex post evidence about how the actions taken have affected on the development of the system. It helps to redirect policy instruments, i.e. to set ex ante operational targets for better performance and for better responses to the needs of the changing environment.
- *Foresight* increases understanding of the forces that shape the future developments. It provides a comprehensive and long-term view on potential changes in the system: their drivers and trends. Future oriented data helps to formulate scenarios for the development of the system and set targets to reach the most favourable vision. In this way, it supports strategic choices for policy formulation and related decision-making. A central characteristic of foresight is an active stance: shared views in order to 'make the future together' (Martin & Irvine, 1989).
- *System dynamic modelling* (Forrester, 2007; Sterman, 2000) provides a formal and detailed analysis of the system structure, including the interdependencies between system elements. It enables understanding of the complex interactions and feedbacks that affect the innovation dynamics. Improved understanding of the factors that enhance or hinder the emergence of opportunities for innovation helps to design robust policies, and to find solutions to particular policy problems. As an illustrative methodology, system dynamic modelling also fosters the emergence of 'systems thinking' among the actors included.
- *Societal embedding* (Kivisaari et al., 2004, 2013) offers a multi-actor perspective to evaluation and supports the dialogue among various actors to set the conditions for societal development. As it emphasises the engagement of multiple actors, co-creation and networked decision-making (Rotmans & Loorbach, 2009), it is beneficial for the implementation and diffusion of innovations.

Table 7. Rationale and outcome of the data produced through different methods in the new evaluation framework (a simplified version from article 1, Nieminen & Hyytinen, 2015)

	Rationale of the data	**Outcome of the data**
Impact assessment	• To operationalise the long term targets • To analyse the system elements and their dynamics with a special view on impacts. • To analyse the impacts (inc. potential impacts) of policy instruments and decision-making	• Analysis of current status of the system • Strategic and operational targets to support policy implementation • Future-oriented impact assessment of policy measures • Follow-up of system development
Foresight	• To provide wide landscape understanding; affect on regime level changes • To generate scenarios of potential changes • To ensure dynamic, shared knowledge creation processes	• Strategic choices of alternative development trends • Insights and shared visions of future developments; consequent consensus of and commitment to future investments
System dynamic modelling	• To explain system behaviour through feedbacks • To illustrate dynamics between system elements	• Design for good and robust policies • Solutions to particular policy problems
Societal embedding	• To facilitate development and introduction of innovations • To facilitate diffusion of innovations	• Networking of experts • Active and continuous dialogue among actors who set conditions for development and diffusion of innovations

The experience of the application of the multi-method approach in the context of socio-technical change was positive: it increased understanding of the information base required in the different levels of the system to support strategic decision-making. In addition to the analysis of the structure and status of the current system, it is sensitive both to potential future developments and to complex dynamics in them. However, the model of socio-technical change in its present form (Geels, 2002) is general in nature, whereas the development of a new evaluation framework requires much more detailed analyses. The preliminary location of the different approaches and methods in the model also turned out to be too straightforward. During the work, it became apparent that system dynamic modelling is also needed at the broader levels in addition to the analysis of niche-innovations. Correspondingly, it became apparent that societal embedding is not only a meso (regime) level issue but should be introduced into the framework at the micro (niche) level, too. Thus, a conclusion was made about need to strengthen and deepen the understanding on the improvement of evaluation – regarding both its target (innovation) and methods – via more versatile theoretical analyses. This work has been continued in the other articles and in this introductory part of the dissertation.

As a practical implication of the study, it should be highlighted that the application of the multi-level and multi-method framework is context specific: the decision making situation and the

related policy challenges define the specific approach and methods. Thus, the framework should not be regarded as a 'locked model' but as a generic and flexible approach that should be tailored according to the context. The following three articles illustrate how the framework and the related methods can be applied to support the development and implementation of service innovations in the context of energy and the environment.

4.2. Article 2: Future Energy Services: empowering local communities and citizens

The second article (Hyytinen & Toivonen, 2015) studies the futures of services linked to energy systems. A starting point for the study is the observation that the role of service innovations is poorly understood in the energy context. In the evaluation of innovations in the energy sector, *the target of evaluation* has usually been restricted to technological novelties. However, what customers actually need and purchase is heating, cooling, lighting etc., i.e. services provided by the energy system that converts energy sources and flows into these services (Haas et al., 2008). Thus, even though the energy production focuses on industrial activities, the distribution is service by nature. In addition, along with the development of smart energy systems, the role of consumer behaviour becomes crucial and creates demand for different kinds advisory and consultancy services (Smith et al., 2010). Both of these aspects – energy as service and services supporting new energy systems – are analysed in the article.

Besides the aim to broaden the view on the target of evaluation, the article shows how *the perspective of foresight* can be concretely applied and which kinds of new insights it can generate. This application serves the construction of the new evaluation framework in one of its three aspects: future orientation. Even though the research setting has not enabled an actual evaluation process in which the foresight approach could have been tested, the exercise shows its usefulness and paves the way for further research in which foresight is explicitly linked to evaluation. The specific foresight methodology selected for this study is qualitative trend analysis (Coates, 1996). As mentioned in chapter 2.4.1., trend analysis is a suitable foresight method when the conditions in the operational environment are the focus of the study. With a trend analysis, it is possible to create 'a big picture' about the central phenomena under study – in this case about the need for innovative services linked to future energy systems.

Three theoretical frameworks form the starting point in the study: socio-technical transition, social innovation and service innovation. Socio-technical transition represents a macro-level driver for the promotion of sustainable energy. Social innovation provides a framework to analyse the bottom-up and top-down activities that function as an engine for the change.

Service innovations are a manifestation of the change; they show the outcomes of innovation efforts.

In the framework of socio-technical transition (cf. chapter 2.1.1.), sustainable energy is analysed as a systemic issue, meaning that innovations fostering sustainability require the understanding and critical re-consideration of entire systems of production and consumption (Smith et al., 2010). Changes in consumer behaviour and markets are particularly important. In addition, the success of novelties in the energy sector depends on the governance structures that promote their institutionalisation as general practices. Social innovation (cf. chapter 2.1.2.) highlights the empowerment of citizens to be active co-developers of innovations (Harrisson et al., 2010; Rubalcaba et al., 2013). This empowerment is urgently needed to motivate citizens to utilise smarter energy systems (Weber & Hemmelskamp, 2005). Users and citizens as active resources in innovation are also brought to the fore by service theories (cf. chapter 2.2.) – by the approach of service-dominant logic in particular (Vargo & Lusch, 2004, 2011). It emphasises the contextual and interactional nature of value creation and the necessity of integrating resources from various sources. In this way, it comes near to the systemic views in the development of the energy sector.

Empirical data for the trend analysis consists of interviews and documentary material, and focuses on two research and development programmes of Cleen SHOK (Strategic Centre for Science, Technology and Innovation). The programmes are smart grids and distributed energy systems (see chapter 3.4. for data acquisition and analysis). The identification of trends is based on the dialog between empirical data and theoretical perspectives (see section 3.4.2. data analysis). It was started from the preliminary survey of the interview material and continued with the literature analysis. To reveal the technological novelties and the use of energy as service, the perspective of innovation was applied. Further, to link the roles and activities of citizens and local communities to the development of sustainable energy, the perspectives of social innovations and empowerment phenomena were applied. Thereafter, the empirical data was re-examined to crystallise the main trends. At this stage, the broad recognition among interviewees was an important criterion in the selection of trends: all the interviewees raised same or similar observations. Other related phenomena were collected around these main trends. Based on the analysis, eight main trends of two types were identified: trends driven by technological development and requiring the advancement of technological systems, and trends focusing on societal and managerial issues and requiring profound changes in consumer behaviour. The technology-related trends are: increasing use of renewable energy sources, increasing use of hybrid solutions, development of smart grids, and development of smart energy markets. The trends including strong societal and behavioural aspects are: distributed and local production of energy, demand response,

optimisation for overall sustainability, and strengthening the role of energy as an opportunity and as service.

After the identification of the trends, they were analysed regarding their central contents. Next, the impacts of the trends on services development were examined. The analysis continued to the empowerment phenomena that link the activities of citizens and local communities to energy issues. It turned out that while the non-technological trends include the active participation of citizens in energy management, also the technological trends significantly influence the use of energy as service, foster the emergence of new service offerings, and include empowering social phenomena. Finally, the factors that support the trends or indicate their discontinuity were mapped. The landscape phenomena of socio-technical development are one important group of supporting factors that was included in the analysis. They function as driving forces that push forward new solutions to tackle the challenge of sustainability (Späth & Rohracher, 2010). Table 8 summarises the results of the trend analysis.

Table 8. Summary of the trends linked to the future energy services from the viewpoints of technological and societal issues (Hyytinen & Toivonen, 2015)

The trend	The main contents of the trend	Impacts on energy as service, new services	Empowerment phenomena	Factors supporting the trend	Sources of discontinuity
Increasing use of renewable energy sources	Diversity of energy sources Mass production of new technological devices linked to renewable energy sources (e.g. solar panels)	Increasing the combined provision of heat and power as service (incl. small power plants) New service concepts (e.g. solar energy concepts) including technology, design, usage, control and support	Increasing knowledge among citizens about the practical solutions applicable in individual households Fostering citizens' social responsibility	Efficiency and effectiveness of new energy technologies Increased social acceptability; regulation and subsidies favour renewable energy Decreasing prices of new technology revitalise markets	Short-sightedness in the selection of energy forms among average consumers Slow development of service concepts; continuing focus on technology Energy storage as a challenge
Increasing use of hybrid solutions	Combining different energy sources (solar, wind, biofuels) Optimising the hybrid solutions (well-designed, functional, reliable and cost-effective entity) New business models (e.g. risk transfer to the service provider)	Energy as a comprehensive and tailor-made solution service Consultancy in designing hybrid solutions New services in surveillance and monitoring	Customer-oriented solutions; design based on customer needs and desires Solutions based on community needs and co-developed with community actors	Emergence of company networks for the provision of hybrid solutions Simultaneous and interactive development of different technologies needed for comprehensive hybrid concepts	Small number of providers qualified in comprehensive solutions - today the focus is still on technology Ambiguity regarding the stakeholder who should take the role of integrator
Smart grids	Bidirectional grid Distributed information production; ICT as a means to gather and act on information Improved reliability of grid and uninterrupted energy usage	Broad service concepts based on smart grids, e.g. 'smart home', 'smart suburbs' and 'sustainable urban living' New services for the management of energy systems	Using information about consumers' behaviour to develop grid operation Embedding energy distribution in the improvement of living in local communities	Energy efficiency regardless of time and place Economic efficiency in the construction and use of smart electricity; possibility to use existing infrastructure and grids Support from advances of ICT	Difficulties of including small scale production in grid Absence of common device standards
Smart energy markets	Open energy markets, many actors in the markets (e.g. European-wide energy market) Open energy and information networks 'Super grid' connecting different locations of production	Multiple types of service agreements, e.g. solutions-based agreements and individual service agreements Market-based service structure; enabled by an automatic system for energy control	Smart users participate actively in the energy market, reacting to energy prices Surplus of individual production is fed into the grid	Plans for common European energy markets are readymade Plans for smart grids exist	National energy systems and protectionist politics slow down common plans Inefficient steering: e.g. different kinds of subsidies for different energy forms Fragmented energy markets

The trend	The main contents of the trend	Impacts on energy as service, new services	Empowerment phenomena	Factors supporting the trend	Sources of discontinuity
Distributed and local production of energy	Local energy production (e.g. in residential areas, cooperatives, energy villages) 'Island power system' - not connected to the grid Small scale energy production	Comprehensive service concepts for local energy production, heating and cooling New services in energy storage	Potential for cost-effective energy production even in single households Balancing the local supply and demand of energy	Functionality of the bidirectional grid Business potential observed in forerunning energy companies	Centralised municipal systems that restrict the freedom of choice Resistance of big energy companies (lobbying force) Lack of standards linked to bidirectional grid
Demand response	Production adjusted with consumption Transfer from production management to demand response Decreasing the electricity consumption or shifting it from on-peak to off-peak periods	Smart metering and home automation systems for energy management New types of flexible services that combine the follow-up and management of the load by the provider and/or the user	Citizens as information providers and influential actors Continuous measurement information promotes energy planning in households.	Remote electricity metering via ICT exists widely and enables timely follow-up of energy use Balance between supply and demand of energy	Poor awareness of the average consumer: changes required in electricity usage compared to earlier consumption patterns
Optimisation for overall sustainability	Multi-target optimisation: reconciling sustainable solutions with technological functionality and cost-effectiveness Integrating and balancing centralised and distributed energy production: also centralised production is needed	Consultancy for general optimisation of sustainability Optimisation (calculation) in designing the new infrastructure for energy production Environmental impact assessment	Strengthening of the role of municipalities as service providers: integrating energy solutions in town planning Designing locally tailored services and targeted concepts	Environmental impact assessment based on lifespan analysis is a general practice and documented in legislation and regulation	Dichotomy in energy markets still persists: a genuine combination of distributed and centralised markets is unsecure
Strengthening the role of energy as an opportunity and as service	Enhancing sustainability as a value in energy investments Moving the focus from separate technologies to the entire energy chain: sources, production, distribution and consumption	Linkage of service innovations to social innovations and systemic change in energy issues Comprehensive solutions provide potential for exportation as conceptualised services	Distributed proprietary in energy production Citizen as an energy producer: from consumer to producer	Increased understanding of system level transitions (consumer behaviour, new business potential and energy policy are core questions) Demonstrative regions and local pilots are essential for further development	Contradictory opinions among policymakers Insecurities concerning views of future decision makers Insufficient activity in concrete demonstrations that would enable the scaling up

The results indicate that irrespective of the focus of the trends, they have important impacts on the use of energy as a service. These impacts should be taken into account as an essential part of evaluation which concerns innovations in the energy sector. The study reveals that energy should be understood as a comprehensive and tailor-made service solution for communities and individual households. This requires careful development of service concepts and a skilful configuration of service offerings. Renewable sources or smart grids are not yet broadly used in the provision of novel services but they form an important infrastructure for future service innovation. In addition to energy consumption, new services are needed for design, management and consultancy of energy production and distribution, supported by services for follow-up, metering and monitoring. Optimisation and impact assessment are growing areas, in particular.

A significant new focus is the empowerment of citizens and local communities, without which many goals of sustainable energy remain unattainable. Consumers will increasingly enter the energy market as active participants. This raises the need for many types of services that support the citizens in decision making and practical operations. The more the citizens themselves manage their own energy systems – or even act as small-scale energy producers – the more important is the availability of services that provide knowledge and help in skills development. Growing demand for knowledge-intensive services can also be anticipated in the public sector when the smart energy concepts are increasingly integrated in town planning and suburbs are renovated according to the concept of 'sustainable urban living'. The continuation of the trends is supported by socio-technical transition towards sustainability. Challenges are linked to the shortage of new types of companies which would be skilful in integrating solutions and business networks. Also the inflexibility of consumption patterns, contradictory interests of big companies and contradictory political opinions may slow down the development.

4.3. Article 3: A System dynamic and multi-criteria evaluation of innovations in environmental services

The third article (Hyytinen et al., 2014) develops the systemic element in the new evaluation framework. It applies the multi-criteria approach developed by Djellal and Gallouj (2013a) and system dynamic modelling (Forrester, 2007; Sterman, 2000) as its theoretical and methodological approaches. These approaches are used for broadening the view on the target of evaluation (service innovation) and for the development of system methodologies applicable in evaluation. The multi-criteria framework serves the former purpose in particular, whereas dynamic modelling reveals the interlinkages between different evaluation criteria. It

brings to the fore the systemic nature of innovation and provides a method to examine the system as a whole.

The empirical example in this article is the environmental data platform developed by Cleen SHOK (cf. chapter 3.3.2.). It is an example of an open data initiative, which includes a complex combination of technological and non-technological ingredients. It illustrates how a technological innovation has many non-technological impacts. It provides analytical material about complementarities and contradictions between these impacts and shows, how the different evaluation criteria are interlinked and may reinforce or contradict each other. Research material consists of interviews and documents (see chapter 3.4. for data acquisition and analysis).

The multi-criteria framework includes two dimensions: short-term outputs and long-term outcomes and the respective performances (see footnote 1, chapter 1.1.) on the one hand, and different societal spheres on the other (Djellal & Gallouj, 2010, 2013a). The societal spheres ('worlds' in the original analysis) provide evaluation criteria from six perspectives: industrial and technical, market and financial, relational and domestic, responsibility, innovation, and reputational perspectives. Their multiplicity ensures that in addition to the traditional technological and financial measures, a broader perspective, including essential new criteria – such as responsibility and reputation – are taken into account (see chapter 2.3.2. for a detailed analysis). In this study, the original criteria have been slightly modified. In addition to small clarifying modifications in wordings, a separate sphere for innovation has been removed. As the whole study is targeted to the evaluation of innovation, the aspects of creativity and inspiration (included in the innovation sphere in the original approach) are considered to be an embedded criterion throughout the analysis.

Table 9 summarises the results of the application of the multi-criteria analysis in the environmental data platform. It illustrates the short-term outputs and long-term outcomes (and the respective performances) evaluated from the perspectives of the different spheres. From the industrial and technical perspective, the most essential short-term output is the technological solution that enables the gathering, visualisation and upkeep of data. In terms of the short-term performance, the integration of dispersed environmental data is the main improvement. In the longer term, the development of the environmental data platform is interlinked with the development of big data management and open data policies, which will set new demands for the environmental data platform architecture. The multiplicity of data essentially increases opportunities for end-user applications, but on the other hand highlights the reliability and usability of data as a critical issue for success.

From the financial perspective, the main outputs of the environmental data platform are free access to data and economic efficiency in the provision and sharing it. When the data is no more in the silos of different providers, the users find it quickly and the providers can link their own data generation with other sources. Both public and private actors can develop new services based on the raw data – knowledge-intensive business services are one promising area. A longer-term prospect is the creation of a centralised market place for environmental monitoring, analysing and reporting. Based on the analysis, it would support the emergence of start-ups and new value networks and even foster the full realisation of an environmental cluster that exists in policy programmes. International trade of these services would enhance the revenues generated.

Especially interesting are the non-technological impacts. From the relational perspective, the main output of the environmental data platform is the creation of connections between multiple data sources and users. The interaction between public and private data providers is important in particular. In terms of performance, the environmental data platform increases common understanding about the needs for environmental data and improves knowledge sharing. As long-term outcomes, the integration of citizens to the data generation and the personalisation of environmental data are pursued. This development removes the clear distinction between the production and use of data: in addition to public and private organisations, citizens make environmental observations and transmit this data to the environmental data platform. This change is one crucial phenomenon in the systemic change of the environmental sector. From the performance viewpoint, the development necessitates deep collaboration and trust building in actor networks, which fosters the further opening of data reserves.

From the responsibility perspective, the easily understandable and accessible data promotes awareness raising about the condition of the environment and the consequences of pollution. Increasing activity for the promotion of sustainable development among citizens and policy makers can be anticipated as a result. On the other hand, the platform is an important manifestation of the citizens' equal rights to have access to important information. Increased transparency and usability of public data are manifestations of the short term performance. In the longer term, the platform may enable environmental education that increases the awareness of environmental issues among young people in particular. Better database for responsibility strategies in private companies is a significant effect, too.

In terms of reputation, the brand benefit gained by the developer is an immediate output. The developer is not only seen as an innovator, but also as a professional sensitive to ecological problems, equity and fairness. The environmental data platform also improves possibilities to

‘market’ concrete activities in the area of sustainability. In the longer term, other actors in addition to the original developer – public bodies and private companies participating in the application and further development of the environmental data platform – gain visibility for their sustainability efforts. Simultaneously, the environmental sustainability as an important value becomes more visible in the society at large.

Table 9. The multi-criteria approach (Djellal & Gallouj, 2013a) applied in the evaluation of an environmental data platform (Hyytinen et al., 2014)

	Industrial and technological world	**Market and financial world**	**Relational world**	**Responsibility world**	**Reputational world**
Output (direct, short term)	A technological solution for gathering data from various sources and sharing it Processing mechanisms for the continuous upkeep of data Tools to visualize data Volume and variety of data	Free access to data Economic efficiency in the provision and sharing of environmental data New cost-effective environmental services in public and private sectors	New connection to data for professionals and partially to general public New networks between public and private data providers Increased connectivity between various data sources	Awareness about the condition of environment and the consequences of pollution based on easily understandable and accessible data Open and equal access to public data	The developer gains reputation as a pioneer in the enhancement of sustainable development
Performance related to output	Integration of dispersed environmental data Efficient processing of data for various purposes Increase of the volume and variety of data	Increased understanding of the business potential of environmental data Emergence of new market openings based on environmental monitoring	Improved understanding of needs for environmental data Increased knowledge and competence sharing in environmental issues Increased trust in the reliability of data	Increasing activity in environmental issues among citizens and policy makers Increasing transparency and usability of public data	Increased attractiveness of platform and it's developers
Outcome (indirect, long term)	An advanced architecture based on the big data management open data policies End-user applications Quality control of the data	Centralized market place for environmental monitoring, analyzing and reporting – additional monetary gains	Free access to general public End-users and commercial users as a data providers Personalized environmental data	Environmental data applied in educational services Environmental data for entertainment – integrated into games, for instance	Public bodies and private companies gain visibility for their sustainability efforts by participating in the application and further development of the platform
Performance related to outcome	Versatile environmental information, resulting in improved warnings, for instance Increased reliability of environmental data Improved usability of data	Opportunity for the development of a new competitive cluster: start-ups, value networks, new jobs etc. New export possibilities with the related income flows	Deepening collaboration and trust in actor networks fosters the opening of data reserves The emergence of 'expert amateurs' (user communities) supports the acquisition of real time environmental data	Better database for responsibility strategies in established and critical business sectors (e.g. energy companies)	Environmental sustainability as primary societal value becomes more concrete

In addition to the generation of new insights about the multiple perspectives from which the impacts of an innovation can be considered, the multi-criteria analysis shows that the impacts emerging in different spheres are mutually interdependent. For instance, some changes in relational and responsibility 'worlds' are prerequisites to effects in the technical and financial spheres. Open access to public data as a precondition for the development of the environmental data platform is an apparent linkage. However, a more detailed analysis about the complex relationships between different factors is not possible on the basis of the multi-criteria table (Table 9), but system tools are needed to show how the performances representing the different 'worlds' reinforce or contradict each other. In this article, system dynamic modelling (Forrester, 2007; Sterman, 2000) has been applied as such a tool. A specific method has been qualitative modelling that focuses on the underling feedback structure of a system (see chapter 2.4.2.). Figure 6 shows the model created to describe the system of the environmental data platform. Detailed causal loop diagram is presented in Appendix C.

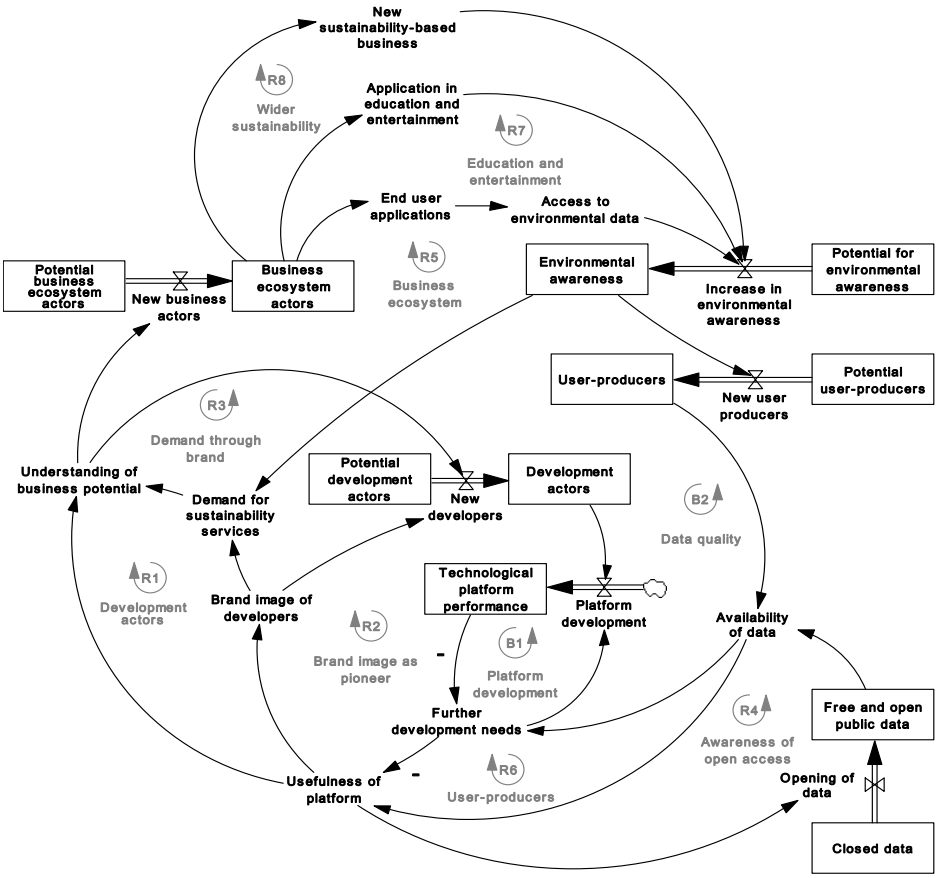

Figure 6. A system dynamic model of the environmental data platform (Hyytinen et al., 2014)

In the figure, the arrows indicate the direction of causality. A minus sign (-) next to the arrows indicates a change in the opposite direction in the dependent variable when the independent variable is changed. For all other arrows, the dependent variable changes in the same direction as the independent variable. Feedback loops are indicated by R (reinforcing) and B (balancing). Rectangles indicate stock variables that change through flows.

The model depicts how the different factors related to the environmental data platform form co-evolving feedback loops and how the effects emerge both in short and long term in a non-linear and dynamic process (cf. Senge, 1990; Sterman, 2000; Vennix, 1996). The factors belonging to different 'worlds' are marked in the text with the following abbreviations: TECH - industrial and technological world, FIN - market and financial world, REL - relational world, RES - responsibility world, and REP - reputational world. The first feedback loop relates to the formation of actor networks (R1 in causal loop diagram; Figure 6). These networks foster a new type of collaboration between public and private data providers (REL), which increases knowledge sharing in environmental issues. The actors start to develop the platform (TECH), which allows the integration of different data sources and the creation of better data processing mechanisms (TECH). It also enables data provision and sharing at reduced costs (FIN). The technological solution improves the usability (RES) of environmental data based on the integration of dispersed data and user-friendly visualisations. This improves the usefulness of the platform, shows its business potential (FIN) and attracts new actors (REL), which further accelerates the platform development (R1: 'development actors') to reduce the gap between needs and the current performance. The development slows down when the needs have been fulfilled (B1: 'platform development').

The model also shows how the new innovation in the area of environmental sustainability makes the developers to gain reputation as pioneers (REP) and how this attracts more public and private actors to the network (R2: 'brand image as pioneer'). Having a better brand for the platform also supports the marketing of concrete activities (REP and FIN). This increases demand for new services which again reinforces the understanding of the business potential of environmental data (R3: 'demand through brand'). The usefulness of the platform depends on the availability of open (RES) and free (FIN) data. Once the first data sources are opened and the platform is deemed useful, the demand for transparency increases and political pressure concerning free and open public data grows (R4: 'awareness of open access').

Once the technological platform is sufficiently developed, includes an advanced architecture (TECH) and a centralised market place (FIN), and has a good reputation regarding its business potential, new actors start forming value networks and business clusters (FIN) that use the platform. These actors, which also include start-ups, develop new end user applications (TECH)

through which the wider public's access (REL) to environmental data improves. This increases environmental awareness (RES) that generates new demand for services and fosters the emergence of a business ecosystem (R5: 'business ecosystem'). Furthermore, the increased awareness and the availability of new applications attract citizens to become active producers of data (REL). As a result, the data in the platform accumulates (R6: 'user-producers'). The data produced by users requires further development of the platform, e.g. quality control mechanisms (TECH). Problems in this development may cause reduction in the usefulness of platform (B2: 'data quality').

In addition to services that directly use the platform, start-ups in the ecosystem (FIN) may develop applications on a broader scale. Examples include applications that support schools in environmental education and applications that can be exploited for entertainment purposes (RES). Integrating environmental data into games improves the usability of the data through various channels which again increases citizens' awareness and responsibility from a young age (R7: 'education and entertainment'). Environmental awareness directs people to make more sustainable choices (RES) and fosters environmental sustainability as a primary societal value (REP). This compels policy makers to take it into account in decision making and firms to create sustainability strategies (RES) (R8: 'wider sustainability').

The combined multi-criteria and modelling exercise illustrated concretely that it is possible to broaden the basic concepts and criteria of evaluation to make them suitable in the context of system innovation in which services are a core element. The case example showed that the impacts of innovation emerge as a result of complex behaviour and dynamics: the factors representing different societal spheres are mutually interlinked. Understanding and making visible the social nature and hidden performance of innovations are essential in the development of evaluation – also in the case of apparently technological novelties.

4.4. Article 4: Multi-actor collaboration for the development of service innovation

The fourth article (Hyytinen, 2015) develops the multi-actor perspective in the evaluation framework. It studies the structure of collaborative networks, and the participatory and interactive processes in the development and implementation of service innovations. The article utilises the approach of societal embedding (Kivisaari et al., 2004, 2013), in which the multi-actor collaboration is the core idea (cf. chapter 2.4.3.). Two other theoretical concepts supplement this approach: public-private innovation networks in services (ServPPIN) (Gallouj et al., 2013) and social innovation (Harrisson et al., 2010; Mulgan, 2007; Moulaert et al., 2013; Rubalcaba et al., 2013). The former examines the ways in which collaborative arenas for a variety of actors can be organised (Di Meglio, 2013). It concretises mechanisms in seeking

solutions to societal problems via the integration of new technologies and services, and highlights the role of partnerships, negotiation and trust (Hartley, 2005; Levesque, 2013; Moore & Hartley, 2008; Voß et al., 2006). The latter responds to the need of understanding the interactive and participatory processes and the experiences of multiple actors taking part in the collaboration (Harrisson et al., 2010; Rubalcaba et al., 2013; Toivonen, 2014).

The empirical study discussed in this article concerns the multi-actor collaboration in the development and implementation of the programmes of Cleen SHOK: three ongoing programmes and two programmes in preparation. The on-going programmes are 'Distributed Energy Systems', 'Smart Grids and Energy Markets' and 'Measurement, Monitoring and Environmental Assessment'. The programmes in preparation are 'Sustainable energy systems' and 'Healthy urban living'. The programmes are built on a public-private partnership and they aim to enhance interaction between the business life and the academia. The empirical data consists of interviews, observations of collaborative workshops, and documentary material (see chapter 3.4. for data acquisition and analysis).

In the first phase of the study, the typology of ServPPINs (public-private innovation networks in services) developed by Djellal & Gallouj (2013b) was used to gain understanding of the nature of the multi-actor network of Cleen (see Table 1 in chapter 2.2.3.). This typology demonstrates the structure and the objective of the network and consists of two dimensions: the nature of innovation (tangible vs. intangible) and the characteristics of the development process (planned vs. unplanned). Based on these dimensions, it identifies four types of ServPPINs: 1) simple ServPPINs set up to adopt a technology; 2) simple ServPPINs set up to produce a technological innovation; 3) simple ServPPINs set up to produce a non-technological innovation; 4) complex or architectural ServPPINs.

Based on the analysis of the interviews and the observational material, the multi-actor network of Cleen was defined as a complex, architectural ServPPIN. Its purpose was to develop new competences and to promote the creation of new business and industrial competitiveness in the sector of energy and the environment. The innovative work carried out in the development and implementation of the programmes aimed to promote systemic change and industrial renewal. The solutions sought were integrative in nature, including both technological and non-technological elements. For example, the new programme 'Sustainable energy systems' included – in addition to technological innovations – the promotion of new environment-friendly patterns in the production and consumption of energy. The innovation process included both top-down bottom-up activities in the adoption, generation and implementation of novelties. Top-down activities included strategy work, for instance, and bottom-up activities various experiments, among others.

In the core of the programmes was the collaboration between the actors representing different sectors of society. This multi-actor collaboration reflects the fact that systemic change requires innovation at different levels of society. From the theoretical viewpoint, the ServPPIN of Cleen is an illustrative example of the need to understand innovations in terms of the synthesis view, which does not see technology and services as opposites but highlights the necessity of integrating them (Coombs & Miles, 2000; Gallouj, 1994, 2002). Table 10 describes the case context according to the analytical dimensions of ServPPIN.

Table 10. Cleen SHOK as a ServPPIN (Hyytinen, 2015)

Analytical dimensions	**Description**	**Cleen as a ServPPIN**
Type of ServPPIN	Complex ServPPINs to adopt, produce and enhance implementation of complex architectural innovation Multi-actor network	Co-production of various forms of technological and non-technological innovations 44 shareholders representing private and public organisations and different parts of the system Multi-actor collaboration is essential to co-develop new competences, to promote the creation of new business and industrial competitiveness, and to enhance the implementation of complex innovations in the sector of energy and the environment
Type of innovation	Broad perspective to innovation; complex, architectural innovation including various forms of technological and non-technological innovations	Complex innovation to promote systemic change and industrial renewal in the sector of energy and the environment; e.g. 'architecture of sustainable energy systems'. System renewal requiring a variety of technological and non-technological innovations; e.g. new patterns in production and consumption of energy
Dominant type of innovation process	Planned/unplanned innovation requires both bottom up and top down processes and both formal and various informal models (e.g. bricolage and rapid application)	Systemic change in the sector of energy and the environment requires innovations at every level of society and is based on top down strategies and activities as well as bottom up activities and experiments. The systemic change is promoted by both by formal and informal models of innovation.
Theoretical perspective	Integrative	Renewal of the sector of energy and the environment is based on the collaboration of multiple actors representing different sectors of society and on the integrative solutions combining many types of technological and non-technological innovations.

In the second stage of the study, the planning and implementation of Cleen programmes were examined in more detail in order to understand the participatory and networked process linked to complex innovation. Using the conceptual framework of social innovation (Harrisson et al., 2010), the interaction of top-down and bottom-up activities were examined in particular (Rubalcaba et al., 2012). The results highlight the role of heterogeneous competences and goals in the innovation dynamics of ServPPINs. The empowerment of actors with varying views

and opinions is essential for the creation of a comprehensive picture of the transition in question. Further, the integration of multiple competences is required to develop solutions that correspond to the needs of this transition.

It turned out that the Cleen programmes have fostered network generation across the traditional organisational boarders. Consequently, they have enabled the emergence of strategic understanding and the development of new competences supporting systemic change. For example, in the programme focusing on smart grids and energy markets (SGEM), the interaction between the systems of energy and ICT was a central innovation behind the advancement of the smart energy infrastructure. However, the results reveal that the current network consists mainly of organisational representatives from academia and private companies. What is lacking is the representation from municipalities and the participation of citizens. This shortcoming may slow down or even hinder the acceptance of novel solutions. Broadening of the collaboration is crucial for the spread of better and viable solutions: the real success of SHOKs depends on the possibility for nationwide spread of the innovations developed in the programmes.

The results also indicate that a network's capacity to create novel competences is to a great extent based on the informal trust between partners. Building trust is based on the will to foster open, collaborative culture and continuous interaction. Cleen has strived for this kind of development systematically: open calls to take part in the generation of the research agenda in collaborative workshops is an illustrative example. The aim has been to give voice and responsibility to multiple partners in strategy formulation and to match companies and researchers across traditional borders. The results show that setting the common targets and planning the practical implementation in an interactive and collaborative process weld the partners together from the beginning and form a good starting point for open knowledge sharing and trustful relationships. The trust-based collaboration has been a stone foundation – and a prerequisite – for the generation of new combinatory competences and for the creation of integrative service solutions. The programmes have supported service co-production between experts from the energy and ICT sectors. This has enabled the development of more comprehensive energy architecture: the new combinatory competences have made possible the coexistence of centralised and distributed energy systems and guaranteed the safe energy flow in the system. In addition, the programmes have created knowledge to design, construct, steer and use the smart and flexible energy system in the networks of multiple actors.

The new collaboration requires changes in typical ways of working: the 'mindset' and organisational boundaries have to be opened up to integrate competences and divergent

goals. New competences are needed not only in the grassroots networks, but new ways of communication, coordination and steering have to be developed at every level of the system. This highlights the need for good measures and evaluation mechanisms which are suited to support and enhance the co-production of innovations, and which are capable of capturing their integrative nature and dynamic development process. The study confirmed that the current evaluation criteria do not take into account the complex and systemic nature of development programmes and do not pay attention to the different objectives in them. Coordination is based on the linear view of innovation, which emphasises short term results such as publications, patents, computer software and new products. Moreover, the current evaluation criteria are set top-down, which is against the need for dialogue and shared vision in target setting in a continuously evolving operational environment. Thus, there are factors that threat the realisation of good targets in the networked programmes: ignoring their dynamic and long term performance is such a threat in particular. Summarising, the study confirmed that the methods and practices of evaluation need to be developed to enhance co-production in the networked world characterised by diversity and horizontality.

5 Discussion

This dissertation has studied evaluation as a supporting practice in the context of innovation. It responds to the current evaluation challenge which has been noted within both general and service innovation research, and within evaluation research. The results reveal that evaluation problems manifest in two ways in particular. *Firstly*, *innovation as a target of evaluation is defined narrowly*: the focus is on material, i.e. technological and financial aspects, whereas immaterial, social and systemic characteristics are neglected (Harrisson et al., 2010; Djellal & Gallouj, 2010; Rubalcaba et al., 2013). *Secondly, the implementation of evaluation follows the idea of linear input-output-outcome -thinking*: it does not correspond to the complex development of innovations and the multiple relationships between the contributing actors (Arnold, 2004; Kuhlmann, 2003; Patton, 2011; Rip, 2003).

Together these problems lead to biased evaluation criteria and indicators: they are one-sidedly techno-economic and do not capture properly the diversity of innovations and the multifaceted nature of their impacts. Further, the linear thinking does not take into account that impacts emerge in dynamic and long-term processes which are interlinked with broader societal targets, structures and developments (Arnold, 2004; Dyehouse et al., 2009; Patton, 2011; Rip, 2003). Linearity is reflected in the 'atomistic' evaluations and in the dominance of methods that emphasise indicators as the main tool. Besides the basic problem of oversimplifying the reality, these methods typically lack a strategic orientation: they are backward-looking and one-off, i.e. long-term and future-oriented practices with continuous implementation have not been searched for (Kuhlmann, 2003; Kuhlmann et al., 2010; Patton, 2011).

In order to tackle these problems, this dissertation suggests an alternative approach based on the principles of developmental evaluation (Patton, 1994, 1997, 2011; cf. also Todd & Wolpin, 2010; Weijermars & Wesemann, 2013). This section provides a summary discussion of this approach, crystallising its main elements in three perspectives: the futures view, the systems view and the multi-actor view. The research questions are answered using these perspectives as a lens to analyse how the target of evaluation on the one hand, and the implementation of evaluation on the other, should be developed. The identification of the basic characteristics of the new approach relies on the theoretical examinations carried out in the dissertation. The empirical case study has been used as verification for the approach. It illustrates the application of the approach in the topical area of sustainability: service innovations linked to energy and the environment are the evaluation target which has been empirically examined.

After the summarising discussion of the research substance, the latter part of this section focuses on the scientific credibility and the usability of the results, and on the theoretical and practical implications of the dissertation. Suggestions for future research are also included.

5.1. Seeking answers to the research questions based on the theory

The contribution of this dissertation to developmental evaluation (Patton, 1994, 1997, 2011) is in strengthening and concretising its basic ideas. The three perspectives mentioned above – the futures view, the systems view and the multi-actor view – are used to fulfil this aim. Table 11 summarises the views as the core of the new evaluation approach. It crystallises the ways in which they broaden the perspective of innovation as the target of evaluation, and the methods which are suggested as ingredients of the new evaluation approach in this dissertation.

Table 11. Three perspectives to broaden the view on innovation and to provide ingredients for a new evaluation approach

	Innovation as a target of evaluation	**Ingredients of a new evaluation approach**
Futures view	Innovation as 'making something for tomorrow'	Foresight
Systems view	Diversification of innovations: technological, social, service and system innovations	Multi-criteria analysis
	Multi-layered and non-linear nature of innovation	System dynamic modelling
Multi-actor view	Collaborative nature of innovation, social innovations	Participatory practices; societal embedding

The futures view orients towards long-term societal challenges, system level drivers, and forces that shape future directions. It emphasises the possibility of many alternative futures (Martin & Irvine, 1989; Martin, 2010; Miles, 2013) and an active stance in relation to the development (Miles, 2013). A central implication is empowerment of multiple actors with different perspectives to 'make the future together' and to build the momentum for necessary changes (Dufva & Ahlqvist, 2014; Martin & Irvine, 1989; Martin, 2010). *The systems view* understands the world in terms of wholes and relationships, rather than breaking it into component parts and looking them in isolation (Hargreaves & Podems, 2012; Sterman, 2001). By emphasising the structure and dynamics of the 'whole', it increases understanding of the complexity of the problems and of the variety of opportunities to solve them (Meadows, 2008). As regards solutions, the systems view emphasises their integrated nature. *The multi-*

actor view aims to promote flexibility, interconnectivity and cooperation. It drives the emergence of networked structures, and highlights that the solutions to systemic problems require collaboration between multiple actors representing different sectors of society (Geels, 2002, 2004; Windrum & Garcia-Goñi, 2008). A central implication is an improved understanding on the participatory processes that are in the core of creation, implementation and diffusion of innovations (Harrisson, et al., 2010; Harrisson, 2012, Moulaert et al., 2013).

In the following, these three perspectives are used to seek answers to the two research questions posed for this dissertation. The discussion on the first research question focuses on innovation as the target of evaluation (phenomena in the second column of the Table 4); the discussion on the second research question is linked to the new evaluation approach (methods and tools in the third column of the table).

The first research questions was how should the view on innovation be broadened to tackle the current societal challenges, and how do service, social and system innovations contribute to this broader view.

In order to enable a broad view on innovation, this dissertation has brought service, social and system innovations to the fore. It has applied three theoretical approaches that supplement each other. The theory of socio-technical change (Geels, 2002, 2004; Geels & Schot, 2007) provides a general view on the complex system level dynamics required to tackle the 'grand societal challenges'. The concept of social innovation (Harrisson, et al., 2010; Rubalcaba et al., 2013; Moulaert et al., 2013) supplements this view by emphasising social processes and the engagement of various actors as an 'engine of system level changes'. Studies on service innovation concretise how the systemic changes manifest themselves as practical solutions, characterised by the interplay between technological ingredients and immaterial aspects. In this dissertation, service innovation has been examined – in addition to the general analysis – specifically from the viewpoint of public-private innovation networks in services (ServPPINs; Gallouj et al., 2013). This topical perspective focuses on the collaboration between public, private and third sectors to form a concrete and interactive arena for the creation and dissemination of innovations.

All these theoretical approaches have emphasised the multi-dimensional and heterogeneous nature of innovation (Gallouj & Weinstein, 1997; Gallouj, 2002; Lundvall, 2007; Djellal & Gallouj, 2013a) and the central role of participatory and interactive processes in it (Sundbo & Gallouj, 2000; Windrum & Garcia-Goñi, 2008). The three perspectives – futures view, systems view and multi-actor view – crystallise the directions which the broadening of the innovation perspective should take. *The futures view* is tightly linked with innovation because the essence of innovation is 'making something for tomorrow'. In this dissertation, the framework of socio-

technical change (Geels, 2002, 2004; Geels & Schot, 2007; Kemp & Rotmans, 2004) has been used as a generic framework to understand the wide societal context around the development of innovations. It shows how system level challenges derive from the operational environment and create pressure to develop and disseminate novel solutions. Socio-technical change also offers a framework to analyse the long-term needs for innovation.

The systems view is important for the understanding of the diversified and multi-layered nature of innovation. It highlights the complex dynamics and interdependences within the system in which innovations are developed and disseminated, and broadens the view on innovation by emphasising the need to combine technological, non-technological and service-based novelties (Gallouj & Weinstein, 1997; Gallouj, 2002; Lundvall, 2007; Djellal & Gallouj, 2013a). Phenomena like the blurring of sectoral boundaries and the integration of goods and services are in line with the systems view (Coombs & Miles, 2000; Gallouj, 2002; Gallouj & Weinstein, 1997). These phenomena of diversification influence, not only the creation of innovations, but also the way in which they become accepted and institutionalised (Vargo et al., 2015). Innovations are embedded in the wider social environment, which means that there is a complex interaction and co-evolvement between various factors and actors, resources, practices and regulations (Geels 2002, 2004; Mitleton-Kelly 2007). The concept of socio-technical system, referred to in the former paragraph, provides a useful framework again here: it brings to the fore the multi-layered nature of the innovation environment and highlights that the question is often of a systemic change which cannot be analysed as simple causal relationships (Cabrera, 2006; Geels, 2002, 2004; Geels & Schot, 2007).

The multi-actor view extends the perspective of innovation by emphasising its collaborative nature and the participatory and interactive development process (Sundbo & Gallouj, 2000; Windrum & Garcia-Goñi, 2008). It is important for understanding the actors and social processes that make innovations to happen, spread and to gain foothold. The interaction between various actors representing different parts of the society is a prerequisite for the promotion of innovation (Elzen et al., 2004; Kivisaari et al., 2004; Windrum & García-Goñi, 2008). In this dissertation, the multi-actor view is included in the concept of social innovation in particular (Harrisson, et al., 2010; Rubalcaba, et al., 2013). At a more focused level, it is analysed as a core aspect in public-private innovation networks in services (ServPPIN; Gallouj et al., 2013). In social innovation, the empowerment of the different actors and actor groups, and the integration of bottom-up and top-down activities, is essential (Rubalcaba et al., 2013). Grassroots initiatives, collaboration between private, public and third sector organisations, and participation of policy makers and regulatory bodies are all important. The concept of ServPPIN concretises the collaborative mechanisms and networked structures. It shows how

different stakeholders – including citizens – function as carriers of ideas, competences and knowledge required for innovations (Di Meglio, 2013; Rubalcaba et al., 2013).

The second research question was, how could a new integrative evaluation approach be constructed on the basis of recognised needs for futures thinking, systemic views and multi-actor approach.

The new integrative evaluation approach suggested in this dissertation is grounded on the basic ideas of developmental evaluation (Patton, 1994, 1997, 2011), which is designed to support innovation and development and to help their implementation, adaptation and application in the context of complex and changing environments. By the means of anticipation, adjustment, reflection, multiple perspectives and continuous implementation, it increases understanding of the innovation dynamics and helps to identify potential outcomes and implications of innovations. The information resulting from that type of evaluation is especially relevant in complex and dynamic situations to support strategy building, development and continuous learning. The three complementary views suggested in this dissertation strengthen and concretise developmental evaluation with the following ingredients: the futures view has been concretised with foresight methodology; the systems view with the integration of multi-criteria analysis and system dynamic modelling; and the multi-actor view with participatory practices, societal embedding in particular. These concrete ingredients and their contribution to evaluation will be discussed below.

Foresight methodology has recently gained ground in the implementation of *the futures view*. Foresight is a process which increases understanding of the forces which shape the futures in the long-term. Its overall aim is to influence the future development so that it better meets the long-term societal needs characterised by increasing complexity and faster cycles (Martin & Johnston, 1999; Toivonen, 2004). The accomplishment of that aim requires the combination of prospective analysis, participation and practical relevance (Miles, 2013). Widely used foresight methods are scenario building, road mapping, trend analysis, and the analysis of weak signals (Holopainen & Toivonen, 2012; Irvine & Martin, 1989; Popper, 2008). In this dissertation, trend analysis has been applied as a concrete ingredient of evaluation because extensive changes in the operational environment have been the focus. To supplement evaluation, other foresight methods may be applied as well. The linkage between foresight and evaluation is apparent: foresight helps in identifying priorities and recognising uncertainty factors, and supports the anticipation of the consequences of decisions – their importance, desirability and acceptability (Ahlqvist et al., 2012; Bell, 2003; Havas et al., 2010). As the impacts of innovation manifest themselves in the long term, a strategic stance is essential and must be the core in policy formulation and decision-making.

The systems view is applied in this dissertation by combining the multi-criteria framework developed by Djellal and Gallouj (2013a) and the method of system dynamic modelling (Forrester, 2007; Sterman, 2000). The adoption of the multi-criteria framework is an important extension to the current evaluation practices: it helps to evaluate innovations and their performance from the short and long term perspectives on the one hand, and from the different societal spheres on the other hand. The societal spheres broaden the traditional evaluation criteria from the techno-economic world to the 'immaterial' world of relations, responsibility and reputation. They form the basis for criteria that can be used in the analysis of impacts of innovations. Dynamic modelling reveals the dynamics, interrelationships and multiple feedbacks between the different criteria. It makes visible the complex relationships between different societal spheres, and shows how different factors in these spheres reinforce or contradict each other. Modelling provides a concrete method to understand the systemic nature of innovation. Qualitative modelling – the particular method applied in this dissertation – provides deeper insights into co-evolving feedback loops and non-linear process through which the impacts of innovation emerge in short and long term.

The multi-actor view refers to participatory practices whose importance has been increasingly highlighted in innovation research. Partnership, trust and continuous negotiation and reflection, embedded in the innovation activities, are important elements in them. Societal embedding (Heiskanen et al., 2009; Kivisaari et al., 2004, 2013) is the particular participatory approach applied in this dissertation. Striving for impactful innovations with high 'social quality' is in its core. In order to achieve this goal, the involvement and commitment of multiple actors in innovation and in the related evaluation is required: the actors set the conditions for the development and create a forum for the generation and scaling up of innovations (Kivisaari et al., 2004, 2013). The concept of ServPPIN (Gallouj et al., 2013) illustrates the main characteristics of societal embedding and is used in this dissertation to make societal embedding more concrete. Besides concretising the structure of the collaborative networks, it specifies the ways in which the collaborative arenas for variety of actors can be organised (Di Meglio, 2013). Because the new evaluation approach is based on developmental evaluation with systemic considerations, a broad perspective is needed in the analysis of participation. Societal embedding concretised with the concept of ServPPIN offers this kind of a perspective: it emphasises multiple views and the engagement of multiple actors.

5.2. Verifying the evaluation approach in the empirical studies

The suggested evaluation approach has been illustrated empirically in the context of the development programmes of the Cleen SHOK – a Strategic Centre for Science, Technology and Innovation in the area of energy and the environment. The selection of this empirical context

is justifiable due to its topical nature: environmental sustainability is one of today's 'grand societal challenges' that requires radical response, systemic solutions, and the integration of technology and services (Pope et al., 2004; Smith et al., 2010). It offers a fruitful case context to study the increasing versatility in the nature of innovations, and to analyse the applicability of the systemic, future-oriented and multi-actor approach.

The empirical studies carried out in this dissertation exemplify how the approach can be implemented in practice and how the different perspectives and related methodologies support innovation. The futures view, concretised with foresight methodology (more specifically trend analysis), provides understanding of the prospects and challenges in the development of innovative energy services. The systems view, concretised with the integration of multi-criteria analysis and dynamic modelling, illustrates the multifaceted and interrelated impacts of a new environmental data platform. The multi-actor view, concretised with participatory practices and the concept of ServPPIN, reveals the significance of the collaborative and interactive process in the development and implementation of innovation programmes. Figure 7 summarises how each of these views and their related methodologies contributes to the understanding of innovation and to the implementation of evaluation.

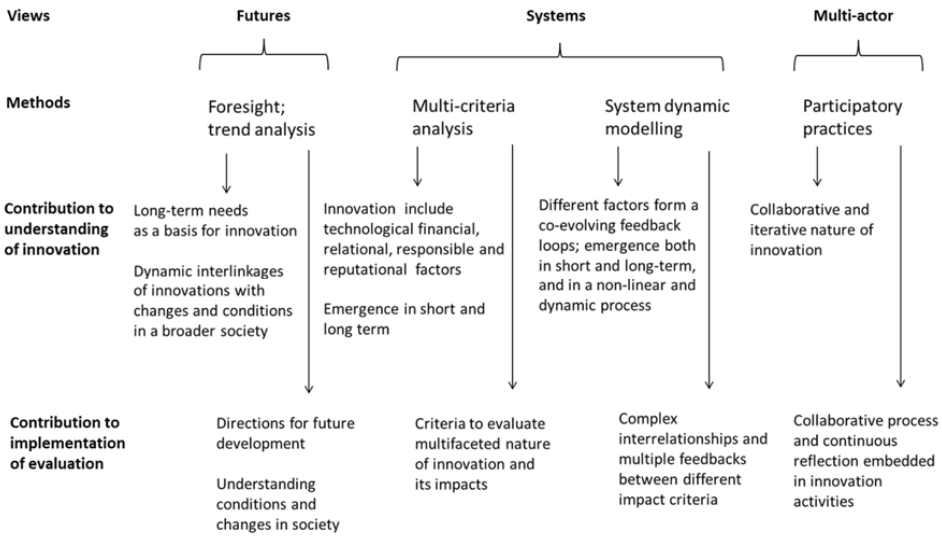

Figure 7. Contribution of the futures view, systems view and multi-actor view to the understanding of innovation and to the implementation of evaluation

In the concretisation of the *futures view* with the foresight methodology, this dissertation has applied qualitative trend analysis. This particular method has been used to provide anticipatory understanding on the nature of innovations in energy services. Information of the

long-term needs as a basis for innovation has also been pursued. The results confirm the theoretical argument (Elzen, et al., 2004; Geels, 2002, 2004; Kemp et al., 2001) that the creation and dissemination of innovations are dynamically interlinked with each other and with the changes and conditions in the broader society. The empirical analysis revealed the need for broadening the scope of innovation in the traditionally technological area of energy: also non-technological trends have important impacts on the functioning of energy systems. Further, both technological and non-technological trends affect policies, organisations and people. An essential finding is that services should be seen as a core part of the energy systems and thus as an important factor in the infrastructure of society. This highlights the significance of service innovations. Also the role of social innovations came to the fore in the study. Here, an especially important issue is the empowerment of citizens and local communities, because their behaviour is crucial in promoting or slowing down the strivings for sustainable energy solutions.

Even though evaluation process was not explicitly included in this empirical study, the study contributed to the development of the new evaluation approach. Besides the broadening perspective to innovation as the target of evaluation, the study confirmed the significance of the futures view as a constituent of the new evaluation approach. The role of the futures view within this approach is to create 'a big picture' of the long-term needs which direct the search for innovations. Further, as this view provides understanding of the conditions and changes in the broader society, it makes visible the dependences of the creation and dissemination of innovation on the institutional and other societal factors. These linkages should be taken into account as an essential part in the evaluation of innovation. Attention paid to them promotes the identification of priorities and the recognition of uncertainty factors; it also helps to anticipate consequences of long-term decisions and to judge their importance, desirability and acceptability (Ahlqvist., et al., 2012; Bell, 2003; Havas et al., 2010). To apply concretely the broad perspective, both systems and multi-actor views are required to complement the futures view.

In the empirical analysis, *the systems view* was concretised with the multi-criteria framework (Djellal & Gallouj, 2013a) and system dynamic modelling (Forrester, 2007; Sterman, 2000). The empirical study focused on an environmental data platform. The multi-criteria analysis aimed at generating insights about the multiple dimensions on which the impacts of an innovation can be considered. The analysis revealed that the impacts of the environmental data platform emerge in both short and long terms, and besides techno-economic dimensions they include relational, responsible and reputational factors. The relational sphere in the analysis focused on the social and collaborative nature of innovation. It brought to the fore the interaction between public and private data providers as a source of innovation, and showed the

significance of the engagement of citizens in the generation and the personalisation of data. The findings also confirmed the blurring of the production and use of data. Regarding the impacts, they highlighted the systemic change in the sector of energy and the environment. The analysis of the responsibility sphere supplemented the results by pointing out societal goals and value based aspects, which are a core in the impacts of innovations. All in all, the study showed that the multi-criteria framework forms a basis for setting criteria to analyse the impacts of innovations. The different spheres broaden the traditional evaluation criteria and the multiplicity of the criteria ensures that, in addition to the technical and financial aspects, other issues, such as relational and responsibility factors are relevant in the context of innovation.

However, without system modelling, the complex, dynamic interrelationships and multiple feedbacks between different criteria would remain invisible. Qualitative modelling – the particular method applied in this dissertation – shows that innovation related impacts emerge as a result of complex behaviour in which the factors from the different societal spheres are mutually interlinked and complement and contradict each other. The example of environmental data platform indicated that some factors in relational and responsible spheres are prerequisites to effects generated in technical and financial spheres. For instance, the generation of actor networks between public and private data providers accelerates knowledge and competence sharing and promotes the integration of various data sources and the development of better data processing mechanisms (a central element in the technological sphere). Also the technological aspects are important and affect the social and systemic factors in versatile ways. Besides the ability to process different types of data sources efficiently and economically, a technological solution improves the usability (an element in the responsibility sphere) of environmental data, and in the long term makes possible to create business based on that data (an important element in financial sphere). As shown in the empirical study, system dynamic modelling provides a concrete tool to analyse non-linear and dynamic processes between different criteria. It also facilitates the generation of new dynamic and systemic indicators to describe the complex process of impacts.

As a concrete constituent in the new evaluation approach, the combined multi-criteria and modelling analysis broadens the basic concepts and criteria of evaluation and makes them suitable in the context of systemic innovation, in which the services and social aspect are core elements. Understanding and making visible the social and systemic aspects of innovation is essential in the development of evaluation – also in the context of apparently technological novelties.

The social and systemic factors emphasise the collaboration between different actors as an essential ingredient of innovation. That raises the third perspective, *the multi-actor view*, to the fore. Here, the focus of this dissertation is on participatory practices – societal embedding (Heiskanen et al., 2009; Kivisaari et al., 2004, 2013) in particular. The empirical study has examined iterative and collaborative processes in the development and implementation of programmes. Like the above-described empirical studies, this study, too, increases the understanding of both the target of evaluation (innovation) and the way in which evaluation should be developed. As regards innovation, the empirical study highlights that the generation and scaling up of viable solutions requires collaborative networks and participatory processes. The empowerment of multiple actors with varying views and opinions is essential for the creation of a comprehensive picture of the challenges in question. Further, the integration of multiple competences is required to develop solutions that answer these challenges.

The empirical studies confirmed that the current evaluation practices and the related evaluation criteria do not support network-based innovation. This may threat the realisation of the targets in networked programmes: ignoring their dynamic and long term impacts is such a threat in particular. Thus, the formal mechanisms of evaluation need to be developed more adaptive: they should strengthen the diversity and horizontality in the context of innovations. As a contribution to the implementation of evaluation, the multi-actor view highlights the significance of the broad participation of stakeholders (including policy makers, other decision-makers, citizens, and financing agents). It aims to describe how the collaborative processes and continuous reflection embedded in innovation activities could and should be developed. Further, it emphasises the need for evaluation practices and criteria that are suited to enhance co-development of innovations in the networked world.

5.3. Theoretical implications

From the theoretical viewpoint this dissertation contributes to the current evaluation challenge which has been noted within both general innovation research (Arnold, 2004; Georghiou et al., 2008; Kuhlman, 2003; Kuhlmann et al., 2010; Rip, 2003) and service-based innovation research (Djellal & Gallouj, 2010, 2013a; Metcalfe & Miles, 2000; Rubalcaba et al., 2013; Sundbo, 1998), and within evaluation research (Cousins & Earl, 1994; Fetterman, 2001; Guba & Lincoln, 1989; Patton, 1994, 1997, 2011; Torres & Preskill, 2001). The core problem is that the current evaluation practices do not support innovation because the target of evaluation does not tackle the topical service social and systemic issues. Further, the implementation of evaluation does not take into account its dynamic nature.

Recently, new approaches and methods have been sought within the above-described research fields. Systemic approaches and the use of evaluation as a strategy tool have been emphasised in general innovation research (Arnold, 2004; Georghiou et al., 2008; Kuhlmann et al., 1999, 2010; Kuhlmann, 2003; Rip, 2003; van der Knaap, 2006). Service innovation scholars have suggested broader definitions for innovation and its impacts, and have highlighted their multifaceted nature (Djellal & Gallouj, 2010; Rubalcaba et al., 2013). Also the evaluation scholars have raised the importance of a systemic perspective to the discussion. *Developmental evaluation* suggested by Patton (1994, 1997, 2011) reflects this approach. It has been designed to conduct evaluation in complex environments in a way which supports innovation. Other researchers (Cabrera et al., 2008; Hargreaves & Podems, 2012) have developed further Patton's ideas by highlighting the need for integrating systems thinking with evaluation: this integration is seen necessary in order to make visible the dynamic interrelationships and feedbacks in the entire system of innovation (ibid.).

While the recent literature includes elements that respond to the evaluation challenge of the current society, the approaches and perspectives are dispersed in various research fields. Developmental evaluation – which is an effort towards a more integrative approach – is still at quite a general level of argumentation. The representatives of this approach (Hargreaves & Podems, 2012; Patton, 2011) have stated that there is a lack of a framework which would both aggregate the recommendations for the improvement of evaluation and give concrete examples of them. Integration of the perspectives of social sciences and systems thinking, and the use of a multi-method approach, is needed (ibid).

This dissertation aims to respond to the need by suggesting a new integrative evaluation approach. It is grounded on the basic idea of developmental evaluation (Patton, 1994, 1997, 2011), but strengthens and concretises it with three broad development directions: the futures view, the systems view and the multi-actor view. These three perspectives contribute both to the broad understanding of innovation and to the implementation of evaluation.

As regards the target of evaluation, three perspectives crystallise the directions which the broadening of the innovation perspective should take. *The futures view* is tightly linked with innovation because the essence of innovation is 'making something for tomorrow'. In this dissertation, the framework of socio-technical change (Geels, 2002, 2004; Geels & Schot, 2007; Kemp & Rotmans, 2004) has been used as a generic framework to understand the wider societal context around the development of innovations. It shows how system level challenges derive from the operational environment and create pressure to develop and disseminate novel solutions. Socio-technical change also offers a framework to analyse the long-term needs for innovation.

The systems view is important for the understanding of the diversified and multi-layered nature of innovation. In accordance with the theories of service innovation, it broadens the view on innovation by emphasising the need to combine technological, non-technological and service-based novelties (Gallouj & Weinstein, 1997; Gallouj, 2002; Lundvall, 2007; Djellal & Gallouj, 2010, 2013a). Phenomena like the blurring of sectoral boundaries and the integration of goods and services are in line with the systems view (Coombs & Miles, 2000; Gallouj, 2002; Gallouj & Weinstein, 1997). Further, it highlights the complex dynamics and interdependences within the system in which innovations are developed and disseminated. The concept of socio-technical system provides a useful framework again here: it brings to the fore the multi-layered nature of the innovation environment and highlights that the question is often of a systemic change which cannot be analysed as simple causal relationships (Cabrera, 2006; Geels, 2002, 2004; Geels & Schot, 2007).

The multi-actor view extends the perspective of innovation by emphasising its collaborative nature and the participatory and interactive development process (Sundbo & Gallouj, 2000; Windrum & Garcia-Goñi, 2008). In this dissertation, the multi-actor view is included in the concept of social innovation (Harrisson, et al., 2010; Rubalcaba, et al., 2013). It is important for understanding the empowerment of the different actors and actor groups, and the integration of bottom-up and top-down activities (Rubalcaba et al., 2013). At a more focused level, it is analysed as a core aspect in public-private innovation networks in services (ServPPIN; Gallouj et al., 2013). The concept of ServPPIN concretises the collaborative mechanisms and networked structures. It shows how different stakeholders – including citizens – function as carriers of ideas, competences and knowledge required for innovations (Di Meglio, 2013; Rubalcaba et al., 2013).

In the implementation of evaluation, three perspectives – futures view, systems view and multi-actor view – are concretised in the methods, which are required to construct the integrative evaluation approach. To provide *the futures view*, method of foresight have been applied. Foresight is a process which increases understanding of the forces which shape the futures in the long-term. Its overall aim is to influence the future development so that it better meets the long-term societal needs characterised by increasing complexity and faster cycles (Martin & Johnston, 1999; Toivonen, 2004). *The systems view* is applied by combining the multi-criteria framework developed by Djellal and Gallouj (2013a) to the method of system dynamic modelling (Forrester, 2007; Sterman, 2000). The adoption of the multi-criteria framework is an important extension to the current evaluation practices: it helps to evaluate innovations and their performance from the short and long term perspectives on the one hand, and from the different societal spheres on the other hand. The societal spheres broaden the traditional evaluation criteria from the techno-economic world to the 'immaterial' world

of relations, responsibility and reputation. Dynamic modelling, instead, reveals the dynamics, interrelationships and multiple feedbacks between the different criteria. It makes visible the complex relationships between different societal spheres, and shows how different factors in these spheres reinforce or contradict each other. *The multi-actor view* is concretised with participatory practices whose importance has been increasingly highlighted in innovation research. Societal embedding (Heiskanen et al., 2009; Kivisaari et al., 2004, 2013) is the particular participatory approach applied in this dissertation. The concept of ServPPIN (Gallouj et al., 2013) illustrates the main characteristics of societal embedding, and is used to make societal embedding more concrete. Besides concretising the structure of the collaborative networks, it specifies the ways in which the collaborative arenas for variety of actors can be organised (Di Meglio, 2013).

5.4. Fulfilling the scientific criteria

The methodological background of this dissertation is socio-constructivism and the main methodological approach is abduction; the empirical study has been carried out using a multi-method qualitative approach. In this kind of research, it is essential to evaluate the whole research process as an enabler of scientific quality (Kvale, 1996). A broader approach is needed than the traditional criteria that have focused on internal and external validity, reliability, and generalisability (Eisenhardt, 1989; Yin, 2009). These criteria are based on the positivistic view on science, because of which qualitative researchers have sought an alternative that will better match with this kind of methodology (Eskola & Suoranta, 1998; Patton, 1999, 2002b). Patton has suggested four inter-related dimensions to judge the quality and credibility of qualitative inquiry: a philosophical belief, a systematic and in-depth fieldwork, a systematic and conscientious analysis of the data, and a credibility of the researcher. As these dimensions are well in line with socio-constructivism and appreciate multi-method studies, they will be utilised as the framework for the quality analysis in this dissertation (1999, 2002b, 2015; cf. also Eskola & Suoranta, 1998).

The philosophical belief, which is the first dimension, focuses on the appropriateness of the selected inquiry and the appreciation of naturalistic inquiry, qualitative data gathering methodologies and holistic thinking thorough the research process. The philosophical belief of this dissertation relies on the socio-constructivist approach (Berger & Luckmann, 1966). This approach emphasises the socially constructed nature of reality and the importance of collaboration and negotiation when creating understanding of the studied phenomenon (Bryman & Bell, 2011; Gherardi, 2008; Merriam, 2009). Socio-constructivism emphasises the interdependence between the researcher and the target of the study. This means that the findings exist because of the interaction between the observer and the observed (Guba &

Lincoln, 1989); the role of the researcher is to be an orchestrator of the negotiation process, whose essence is the generation of versatile and sophisticated information (Denzin & Lincoln, 2005). Besides the socio-constructivist approach, this dissertation reflects some ideas of critical theory. It challenges the conventional – economically and technologically biased – values in evaluation (cf. Patton, 2011) and suggests a more versatile approach to capture the diversity of service innovations. These basic assumptions have directed both the theoretical development of the future oriented and systemic evaluation approach and the implementation of the empirical studies in this dissertation. This will be described – from the perspective of the latter three dimensions – below.

The second dimension highlights a systematic, in-depth fieldwork that yields high quality data. It corresponds to the traditional criteria of validity and reliability and pays attention to the triangulation of data (Arksey & Knight, 1999; Stake, 2000; Patton, 1999, 2015). In this dissertation, the multi-method approach aimed to secure an in-depth understanding of the empirical study context: data was gathered from various sources, combining interviews, observations and documentary material. To show the diversity of the data, a detailed list has been provided, including the data types, the period of the data gathering, the quantity of each type of data, and the source of the original data (Table 6). In addition, the data gathering process for each empirical study has been described in the articles and in the methodology section of the dissertation.

As interviews formed a central data gathering method, they were planned carefully. To ensure multiple perspectives, the interviewees with different backgrounds were selected and the interview sample was completed in a later phase of the empirical study to cover all relevant aspects. Complementary interviews were carried out in the spring 2015, to supplement the information carried out in the observations. The interview situations were designed to support the confidential and open relationship (cf. Patton, 2015), and the ethical aspects were taken into account: the researcher informed the respondents truthfully about the purposes and process of the research and took care about their privacy (cf. Fontana & Frey, 2003). In the interview sessions, the researcher paid attention to the balance between structuring and openness. She made questions from multiple angles, relying on the theoretical basis of the dissertation. Simultaneously, the purpose was to listen and understand the interviewees' own experiences of the studied phenomena (cf. Fontana & Frey, 2003; Patton, 2015). The researcher encouraged respondents to open reflection and description of various themes. In order to prevent the loss of data and to increase reliability, all interviews were recorded and transcribed.

Observations complemented the interview data in one empirical study the preparation of second generation Cleen SHOK programmes. They provided 'a real-life' experience which was not possible to capture via the interviews. The permission to observe the programme preparation was negotiated with the representatives of the case organisation. Observation took place in seven collaborative workshops: the researcher took part in all of them and made extensive field notes to cover the key topics and to observe the roles and dynamics between the actors within the programme preparation process. In the first two observation sessions, two colleagues were present to support the data gathering and to increase the reliability of the data. The field notes were completed by the official meeting notes, to ensure the full coverage.

The third dimension – a systematic and conscientious analysis of the data – focuses on the rigorous data analysis via the utilisation of alternative frameworks. In this dissertation, a multistep abduction process and the application of several frameworks, i.e. theory triangulation (Patton, 2015), were used to secure the rigorousness. Also, the thick description of the empirical data – including abundant quotations in the fourth article – provided a foundation for scientific analysis (Denzin, 1989). The analysis procedure was based on abductive reasoning that emphasises iterative and dynamic interaction between data and theory, and allows a central role for empirical research in the generation of ideas (Coffey & Atkinson, 1996; Dubois & Gadde, 2002). The analytical rounds included four phases (Bryman & Bell, 2011). In the first phase, a general picture of the phenomenon was generated; the second phase included the selection of the material linked to the specific framework at hand; in the third phase, systematic linkages between theory and empirical material were created; and in the final phase, the results were structured using the methods of empirical illustration. In the interpretation, alternative and complementary analytical frameworks (theory of socio-technical change, concept of social innovation, studies service innovation concretised with the concept of ServPPIN, public-private innovation networks is services) were applied. Strength of this multi-phase and multi-perspective process was that it enabled a holistic view both theoretically and empirically about the complex phenomena studied in this dissertation. Details of the analytical frameworks, data analysis techniques, and of the 'theoretical-empirical' dialog are described in the articles and in the methodology section of the dissertation.

The fourth dimension concerns the credibility of the researcher. In the qualitative context, it includes experience, rigorous and holistic thinking, creative mind, self-awareness and ethical issues (Eskola & Suoranta, 1998; Patton, 2015). When the author of this dissertation started the process, she had more than ten years' experience in research work. In addition, she had a supportive research community – both at VTT Technical Research Centre of Finland and at

Aalto University – to boost learning and progression during the process. To ensure rigorous and holistic thinking, systematic data gathering methods and various analysis strategies and techniques were applied as described above. In addition, the use of different methods was planned carefully. The long experience in interviewing provided the researcher with quite a good ability to apply the method of observation, too. However, this demanding method – in which it is important to avoid the personal bias as much as possible (Angrosino & Pérez, 2003) – was implemented only in a later stage of the study. As described in the articles and in the methodological part of this dissertation, the empirical data was analysed carefully, critically and from multiple perspectives. To keep the critical mind, the researcher aimed at a high degree of self-awareness during the process. Also the dialogue with the co-authors and the scientific community supported self-reflection and, hence, rigorous and holistic thinking. A creative attitude was already included in the research purpose: the goals to combine data in new ways in order to see the interactions between separate findings, and to develop a new evaluation approach based on the findings, stimulated creative thinking throughout the research process (cf. Patton, 2015).

The usefulness of the results is interlinked with their credibility (Patton, 2015). Therefore, it is important to consider the generalisability of the results and discuss the possible limitations of the study (cf. Denzin & Lincoln, 2003; Eskola & Suoranta, 1989; Guba & Lincoln, 1994). As regards generalisability, qualitative case studies have been criticised to be subjective and difficult to replicate (Brymann & Bell, 2011). The critique has been typically based on the requirements of the positivist research tradition that emphasises statistical generalisability (Kvale, 1996). In qualitative research the purpose is different: in accordance with the concept of naturalistic generalisation, the emphasis is on in-depth and thorough understanding of a particular case and on the provision of new knowledge and insights for constructing new theories (Eskola & Suoranta, 1998; Patton, 2015; Stake, 2005). This dissertation provides rich data and a multi-perspective approach to analyse service, social and system innovations and the related evaluation practices. The main idea has been to find such phenomena that are relevant in a wider scope in similar contexts (cf. Kvale, 1996). The aim has been to affect theory building and the development of a new evaluation concept applicable in other corresponding situations. The rigorous description of the reasoning processes strengthens the applicability of the results (cf. Lincoln & Guba, 1985). It ensures an in-depth knowledge about the empirical context of the study and provides basis for the comparison with other contexts.

As regards the limitations of the dissertation, the study was carried out in one case organisation and the number of empirical studies (research programmes) was limited. Even though the selection of the empirical context – environmental sustainability – is justifiable due to its topical and complex nature, more empirical studies in corresponding societal contexts

are needed to test the generalisability of the results. Therefore, the application of the research approach of this dissertation in other service sectors and innovation development contexts is required. For example, social and health care services, which are under pressure due to the demographic changes and rising expenditures, or the educational system, which is changing due to the increasing digitalisation, are both the topical application areas. They would both provide corresponding phenomena to analyse service, social and system innovations and the related evaluation practices. Besides the context of public services, it would be useful to verify the applicability and generalisability of the results in the context of service business models at the entrepreneurial and managerial levels.

In this dissertation, the value and impacts of innovations were not analysed from the perspectives of different actors taking part in their development and implementation. However, the impacts and benefits of innovations are strongly related to the preferences and values of actors in a specific situation. To go deeper to these specificities would provide a more diversified and analytical picture of the impacts of innovations. Also the contexts which are characterised by even more complex network situations than in this study, and which include other actor groups such as policy makers and citizens, would provide an interesting research setting.

In order to gain 'real-life' experiences and to provide valuable information of the applicability of the new evaluation approach, it needs to be implemented in a 'de facto' decision-making: integrating it in 'real-life' decision-making processes would provide the required experimental knowledge about its usability and benefits. It would also reveal the main developmental targets – an aspect that will be discussed in more detail in the final sub-chapter about the future research needs. Additionally, the author herself was not involved in the participatory practices described in the empirical studies, due to which action research was not possible to carry out. Studying the phenomena with this kind of method might have provided a deeper perspective to multi-actor collaboration and hence, more profound results. However, while this dissertation opens up new questions for the further research, it has offered basic arguments for broadening the target of evaluation and for developing the new evaluation approach.

5.5. Suggestions for further research

Based on the theoretical and empirical analysis, this dissertation created a new evaluation approach to support innovation in the context of complex societal challenges. The suggested approach builds on the basic ideas of developmental evaluation (Patton, 1994, 1997, 2011; cf. also Todd & Wolpin, 2010; Weijermars & Wesemann, 2013), and strengthens and concretises

it with three perspectives: futures view, systems view and multi-actor view. These three perspectives have been used as a lens to analyse how the target of evaluation on the one hand, and the implementation of evaluation on the other, should be developed.

In order to enable a broad view on innovation, this dissertation has brought service, social and system innovations to the fore. It has applied three theoretical approaches that supplement each other: the theory of socio-technical change (Geels, 2002, 2004; Geels & Schot, 2007), the concept of social innovation (Harrisson, et al., 2010; Rubalcaba et al., 2013; Moulaert et al., 2013), and studies on service innovation (e.g. Coomb & Miles, 2000; Gallouj, 1994, 2002; Gallouj & Weinstein, 1997, Toivonen & Tuominen, 2009), which in this dissertation have been examined – in addition to these general analysis – specifically from the viewpoint of public-private innovation networks in services (ServPPINs; Gallouj et al., 2013). In order to concretise the ingredients of novel evaluation approach following methods have been applied: the futures view has been concretised with foresight methodology; the systems view with the integration of multi-criteria analysis and system dynamic modelling; and the multi-actor view with participatory practices, societal embedding in particular.

The empirical case study has been used as verification for the approach. It illustrates the application of the approach in the topical area of sustainability: service innovations linked to energy and the environment are the evaluation target which has been empirically examined. The selection of this empirical context is justifiable due to its topical nature: environmental sustainability is one of today's 'grand societal challenges' that requires radical response, systemic solutions, and the integration of technology and services (Pope et al., 2004; Smith et al., 2010). Therefore, it offers a fruitful case context to study the increasing versatility in the nature of innovations, and to analyse the applicability of the systemic, future-oriented and multi-actor approach.

Regarding to the further studies, more research would be useful to test the generalizability of the results. The generated approach could be applied to the other type of complex societal situations, and in the other innovation contexts. Besides the other societal contexts such as health care and education, an interesting research direction is to examine whether the approach functions in the context of business model innovation (Chesbrough, 2010): a strategic perspective to innovation and change at the entrepreneurial and managerial level. Business models are vehicles of innovation and a source of competitive advantage; they allow companies to commercialise their services and to create better value (Amit & Zott, 2001; Demil & Lecocq, 2010; Korhonen, 2016). The value aspect is equally relevant in public organisations in order to adequately serve citizens and achieve desired long-term impacts. Also, the context of even more complex network situations, including other actor groups such as policy makers

and citizens, would provide an interesting research setting. Further, in order to gain experiences of the new evaluation approach, it must be implemented in a 'real-life' context: integrating it in 'de facto' decision-making processes would provide the required experimental knowledge about its usability and benefits. It would also reveal the main developmental targets of the new evaluation approach. To continuation with this research line requires stronger interlinks between evaluation and strategy and managerial activities (see Kallio, 2015). To direct evaluations towards continuous development, the stronger integration with learning theories and strategy approaches is beneficial (Kallio, 2015; Saari & Kallio, 2011).

To go deeper to the networked relations, and to evaluate the value and impacts of innovations from the viewpoint of different actors is also an interesting research avenue. In the recent literature the multi-actor perspective (Gallouj et al., 2013; Windrum & García-Goñi, 2008) has been proposed as an analytical framework to better understand the complex interaction between policy makers (society), public and private service providers as well as users of the services, and to evaluate the benefits of the services from the different perspectives. To integrate the actors' perspective to the evaluation emphasizes the subjective nature of evaluation; i.e. the interaction of various actors and their values creating an evaluation situation (cf. Giddens, 1987). Analysing the impacts from the perspective of different actors makes visible that the impacts and benefits of innovations are strongly related to the preferences and values of actors, and that there may be (value and motivation based) contradictions between different actors. Also considering the impacts crosswise from the perspective of multiple actors and different societal spheres (technological, financial relation, responsible and reputation; Djellal & Gallouj, 2010, 2013a) would give a more diversified and analytical picture of the impacts of innovations.

As regards the concrete ingredients of integrated evaluation approach, 'testing' the usability of other methods would be interesting as well. To provide the futures view, this dissertation has applied trend analysis as a concrete ingredient of evaluation approach. However, other foresight methods could be applied as well. For example, the concrete tool of road mapping is useful in the situations in which there is a need to plan the future activities of an organisation or decision-making situation. Further, besides the qualitative approach of this dissertation more formal methods of foresight such as the Delphi method could be the next step. In addition, to analyse the dynamics, interrelationships and multiple feedbacks between the impact criteria, this dissertation applied qualitative system dynamic modelling. To provide new quantitative information about the dynamic behaviour of innovations and impacts, and changing strengths and feedback loops over time, the simulation model is useful. Implementing the simulation model would also provide a basis for the generation of new type of dynamic and systemic indicators. Generation of new dynamic and systemic indicators which

describe that complex and non-linear nature of innovation would be both interesting and useful, also from the viewpoint of management and decision making.

5.6. Managerial and policy implications

Evaluation has played a particularly important role in the context of publicly funded research, development and innovation (R&D&I). With the increased emphasis on innovation activities as a source of economic growth, societal development and wellbeing, a greater interest towards their evaluation has emerged (Shapira & Kuhlmann, 2003). Impact assessment has been a typical way to implement evaluation in this context. It has meant that evaluation has been understood in terms of performance-related steering and monitoring, i.e. accountability (Chelimsky, 1997; Rip, 2003). With the curtailment of the size of the public sector, it has become evident that the publicly funded R&D&I activities must be shown to decision-makers and taxpayers to be beneficial and justified as a good investment (Georghiou, 1998). This has led to the increasing production of indicator based and comparable data to prove accountability (Martin & Johnston, 1999) and to legitimate the existence of individual programmes, organisations or policy instruments.

Following the use of public resources is important. Moreover, in the context of innovation, the evaluation of their impacts is an essential task. However, it is becoming increasingly clear that the input-output-outcome models, accountability efforts and indicator-based approaches do not correspond to today's complex development processes and the multiple relationships between the contributing actors (Arnold, 2004; Kuhlman, 2003; Patton, 2011; Rip, 2003). They cannot make visible the transformation processes in which interventions are turned into outcomes (Chen, 2005; Dyehouse et al., 2009). The results of this dissertation reveal that they may work in simple and predictable circumstances. However, they have significant downsides in dynamic situations and in the context of innovation, where the focus is multifaceted, evolving and adapting (Ahrweiler, 2010; Djellal & Gallouj, 2013a; Patton, 2011).

In addition, the increasing 'servitization of society' (Gebauer & Friedli, 2005; Neely et al., 2011) has created additional pressure to develop a more advanced approach to evaluation. Service studies, and specifically the studies on service innovation, have revealed the one-sidedly techno-economical nature of the indicators used in evaluation. These traditional tools and measures do not describe properly the innovativeness, impacts and performance of services (Djellal & Gallouj, 2010, 2013a; Metcalfe & Miles, 2000; Sundbo, 1998). More generally, they are not able to capture the immaterial, interactive and systemic characteristics of innovations.

The viewpoints described above have significant implications to public policies. Current analytical tools and policies are still very technologically oriented and set to promote visible

technological innovations. The impacts are still typically evaluated in terms of monetary value. Biased analysis may lead to inaccurate analysis and interpretations, and may cause inappropriate policies. That may even hinder or misdirect the innovation development and problem solving. Therefore, novel evaluation approaches that support the development and implementation of innovations, strategic planning and evaluation have become necessary (Hartley, 2005; Lévesque, 2013; Smits & Kuhlmann, 2004; Kuhlmann et al., 2010).

In practice, this necessitates new kinds of methods, which orients toward future, are able to capture the dynamic and multi-faceted nature of innovations, and considers the role of multiple actors in generation and implementation of innovations. Further, evaluation should be seen as supportive mechanism for innovation: as a mechanism to provide an arena for multi-voiced and continuous reflection strengthen it would work as an adaptive mechanism able to respond to the rapidly changing situations. As a practical implication, this dissertation suggests that in the decision making the evaluation practices could be tuned to perceive the systemic, social and service innovations. These innovations are in the essential role when seeking the solutions to complex societal challenges and aiming to industrial renewal. However, social, service and system innovations do not emerge without policy measures and evaluation mechanisms that support their creation. Therefore, the evaluation criteria could be updated to perceive their significance and 'hidden performance'. Implementation of the evaluation approach suggested in this dissertation would help in broadening the perspective to evaluation in decision-making. Further, it would support the development of new evaluation criteria and indicators fitted to the context of innovation.

In the companies and organisations there is also an urgent demand for the development of more diversified practices of innovation management. User-based practices, fostering of open innovation and collaboration across sectors and professions should be extended from the technology area to the realms of service, social and system innovations.

The perspectives examined in this dissertation should be taken into account in the evaluation of broad innovation and development programmes. In these types of context, it is very relevant to understand the diversified and systemic nature of innovations, and to take into account how the broader perspective to innovation affects the implementation of the evaluation. In practice, this requires the critical discussion about the traditional evaluation culture; for the discussion within policy makers, decision makers, funders etc. more knowledge and experiences of the new potential evaluation approaches is required.

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Appendixes

Appendix A: List of interviewees

Organisation /programme	Interviewee	Number of interviews	Time of interview
Cleen Ltd	Managing director of Cleen	2	Spring 2013
	Chief technical officer of Cleen	2	Spring 2015
	Development manager of Cleen	1	Spring 2015
	Representative of R&D council	1	Spring 2013
	Company representative; participant in second generation programme preparation	1	Spring 2015
	University representative; participant in second generation programme preparation	1	Spring 2015
SGEM-programme			
	Company representative, Large company in power and automation technology	1	Spring 2013
	Company representative, Large company in smart energy solutions	1	Spring 2013
	University professor, Technical university A	1	Spring 2013
	Senior scientist, Public research organisation A	1	Spring 2013
	Company representative, Small company in energy management (ICT)	1	Spring 2013
	Company representative, Large company in telecom operation	1	Spring 2013
	Company representative, Large company in energy production	1	Spring 2013
	Company representative, Small company in data monitoring, visualisation and control	1	Spring 2013
	Third sector representative; Organisation in environmental sustainability	1	Spring 2013
DESY-programme			
	Senior scientist, Public research organisation A	1	Spring 2013
	Professor, Technical university B	1	Spring 2013
	Company representative, Large company in renewable energy solutions	1	Spring 2013
	Senior scientist, Public research organisation B	1	Spring 2013
	Professor, University A	1	Spring 2013
	Company representative, Large company in energy distribution	1	Spring 2013
	Company representative, Large company in energy distribution	1	Spring 2013
	Company representative, Large energy company (energy production, power solutions, energy efficiency services etc.)	1	Spring 2013
	Professor, Technical university A	1	Spring 2013
	Professor, Technical university B	1	Spring 2013
	Company representative, Lange company in power and automation technology	1	Spring 2013
MMEA-programme			
	Senior scientist, Public research organisation C	1	Spring 2013
	Company representative, Small company in air quality measuring and monitoring	1	Spring 2013
	Senior scientist, Public research organisation A	1	Spring 2013
	Company representative, Large company in environmental and industrial measurement	1	Spring 2013
	Professor, Technical university B	1	Spring 2013
	Senior scientist, Public research organisation B	1	Spring 2013
	Principal scientist, Public research organisation A	1	Spring 2013

Appendix B: Interview topics

Background information:

- Background and role of interviewee in Cleen/programme
- Description of the programme; mission and main targets

Systemic change as a driver for innovation

- Societal challenges the Cleen/programme aims to tackle
- Trends and potential directions for the future development (related to the programme targets)
- Required solutions to tackle the identified challenges
- Mechanisms to collect the information about the societal challenges and to take them it into account in the programme implementation and in the creation of innovations

Multi-actor collaboration in setting targets for the programme and innovation:

- Process for setting targets
- Actors taking part in the target setting
    - Actors and competences required (decision-makers, companies, researchers, third sector parties, citizens)
    - Different targets of different actors
    - Different roles of different actors
    - Process to take in to account the different (even contradictory) targets of the different actors
    - Top-down and bottom up –collaboration; role of decision-makers and citizens in target setting
- Success factors in collaboration
- Challenges in the collaboration

Innovations and solutions:

- Innovations and solutions; detailed descriptions of innovations
    - Characteristics of innovations; combination of technological and non-technological characteristics
- Challenges the innovations aim to solve
- Roles of different actors in creation of innovations; including decision-makers and users
- Process to develop innovations
    - Success factors and challenges in the development process
- Implementation of innovations
    - Process to implement innovations
    - Success factors and challenges in the implementation
- Systematic mechanisms to support creation and implementation of innovation
    - Success factors and challenges
    - Potential needs

Multi-actor collaboration in the implementation of the programmes:

- Actors participating in the programme (decision-makers, companies, researchers, third sector parties, citizens)
- Different roles and functions of different actors; division of labour between the actors
- Top-down and bottom-up collaboration
- Interaction in implementation of the programme
    - Trust building between actors
    - Factors that support interaction
- Missing actors; missing competences
- Changes in the actor network during the programme implementation
- Success factors and challenges in the collaboration
- Benefits of the collaboration
    - New or deep inter-organisational collaboration between partners

Program operations

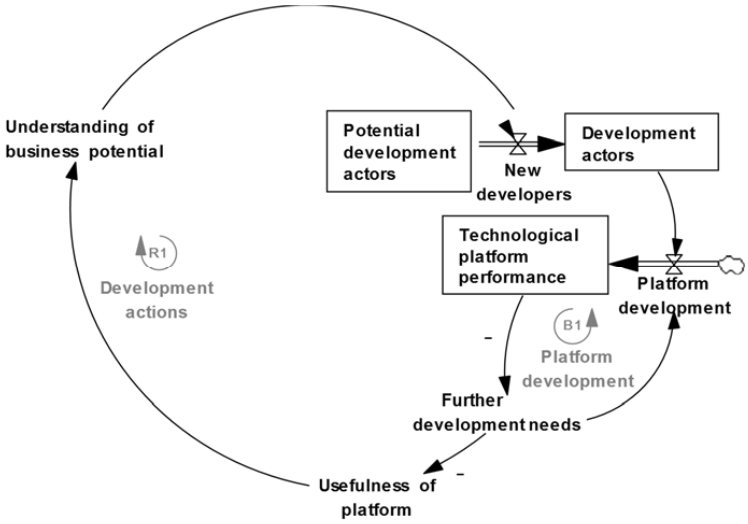
- Generation of the programme; detailed description of emergence of the programme
    - Factors affecting the programme generation
    - Mechanisms to support programme generation
- Implementation of the programme
    - Programme management
    - Programme administration
    - Mechanisms to support programme implementation and collaboration
    - Information delivery between actors
- Programme evaluation; systematic methods to follow up and support programme implementation

Evaluation and analysis of impacts

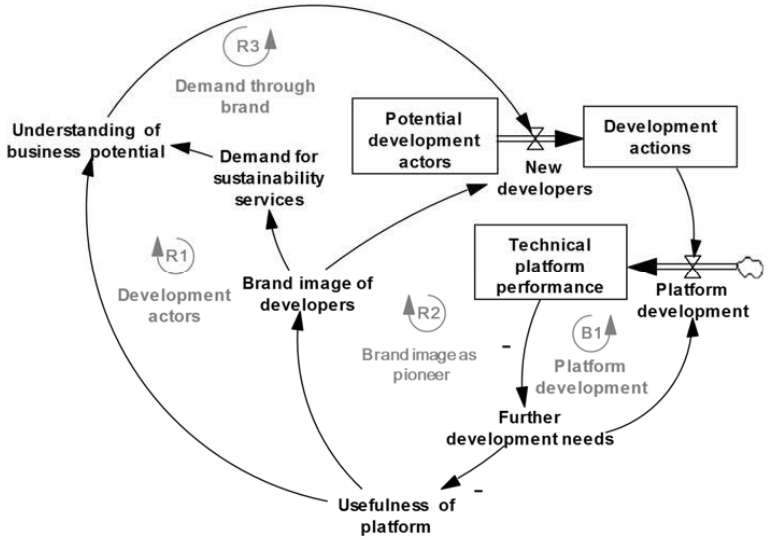
- Impacts of programme and innovations;
    - Detailed descriptions of the impacts and the potential impacts
    - Time frame for the emergence of impacts
    - Impacts from the viewpoint of different actors taking part in the collaboration
    - Impacts from the viewpoint of broader society and citizens
- Mechanisms/processes to evaluate the impacts of the programme/innovations
    - Evaluation mechanisms of different organisations (funding agency, SHOK, companies, research organisations)
- Success factors and challenges in evaluation
- Potential needs for evaluation to support innovation and programme collaboration

Appendix C: Detailed causal loop diagram

R1: 'Formation of actor networks'

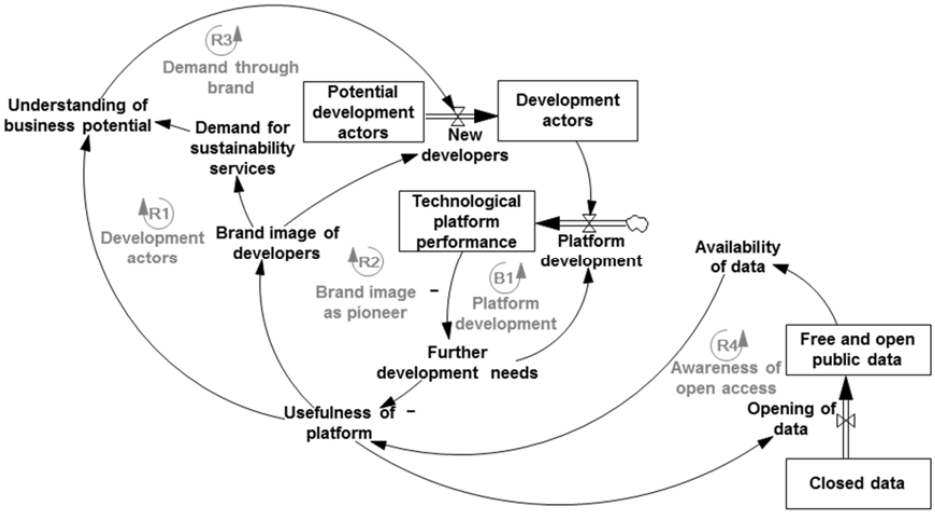


R2:' Brand image as pioneer'



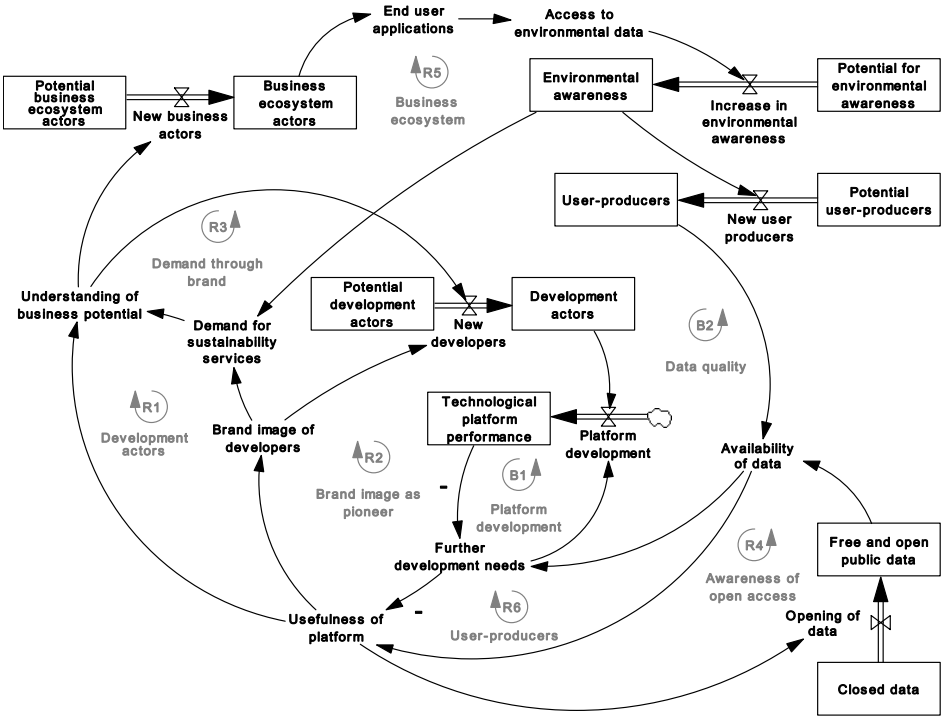
R3: 'Demand through brand'

R4: 'Awareness of open access'



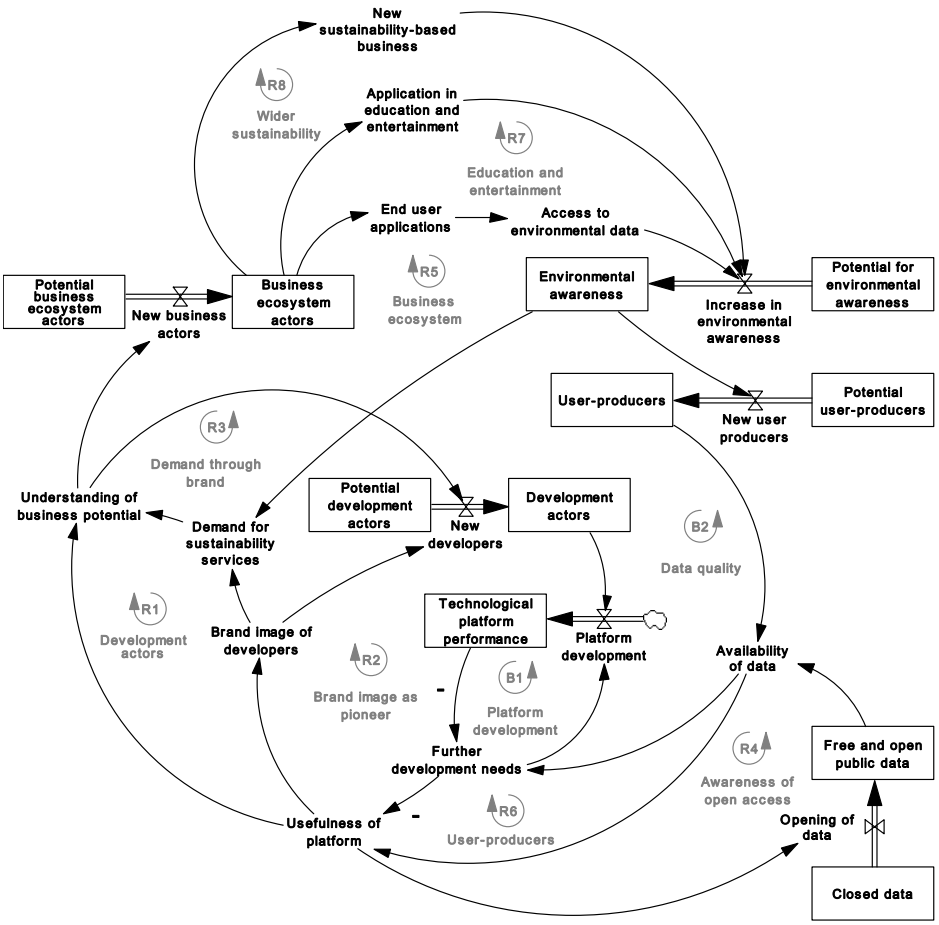
R5: 'New business ecosystems'

R6: 'User-producers'



R7: 'Education and entertainment'

R8: 'Wider sustainability'



ARTICLE 1

Future-oriented impact assessment: Supporting strategic decision-making in complex socio-technical environments

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Future-oriented impact assessment: Supporting strategic decision-making in complex socio-technical environments

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Abstract
The article proposes a systemic and future-oriented evaluation approach designed to support decision-making in complex socio-technical environments. The approach integrates established methods of evaluation, foresight, impact assessment, system dynamic modelling and societal embedding within a single framework to provide versatile information to increase strategic intelligence in decision-making. This generic and flexible framework aims to support decision-making in various policy and decision-making situations. It is designed to meet the challenges of the changing innovation environment.

Keywords
combining methods, complexity, evaluation, impact assessment, science, socio-technical, strategic decision-making, systems thinking, technology and innovation

Introduction

The article proposes a systemic and future-oriented evaluation approach designed to meet the challenges of a rapidly changing and increasingly complex modern society. The approach seeks to integrate foresight, impact assessment, system dynamic modelling and so-called societal embedding into a systematic framework in order to support strategic decision-making in networked and complex socio-technical environments. The approach is a proposal for a research agenda piloted in some empirical context.

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Current evaluation methods and monitoring practices are still largely based on linear ideas. In spite of various attempts and discussions to include systemic and complexity perspectives in evaluation research and practice (Forss et al., 2011; Patton, 2011; Williams and Hummelbrunner, 2011), most evaluations and methodological guidelines (Gertler et al., 2011; TECHNOPOLIS GROUP and MIOIR, 2012) still follow a linear inputs-outcome-outputs-impacts logic, which tends to oversimplify the complex relationships between human actors and other forces contributing to innovation (see Arnold, 2004).

Most evaluations are backward looking (*ex post*) despite the development and application of *ex ante* evaluation methods, especially in program evaluations (Weijermars and Wesemann, 2013). Traditional *ex post* evaluation is slow to provide guidance for policy making. Socio-economic changes take place fast and often on a global scale. As the context of policy making is in constant flux, recommendations based on past and current experiences may not be valid in future.

The acceleration of change, growth of social complexity, inter-linkages between the local and global and inter-dependencies between various systems (Castells, 2000; Ritzer, 2011) make policy making more complex and require new approaches to support strategic planning, management and governance (Smits and Kuhlmann, 2004).

Policymakers need accurate and real-time input in order to assess socio-economic problems and propose effective strategies for tackling them. The challenge is how to take into account the increasing complexity and pace of change so as to guarantee robust information for decision-making.

One possible response is to complement evaluation with *foresight* activities. While the future perspective is always more or less present in any evaluation, foresight is a more systematic method for analysing future possibilities. Foresight can be seen as 'a systematic, participatory, future intelligence gathering and medium-to-long-term vision building process aimed at present-day decisions and mobilising joint action' (Georghiou et al., 2008: 11). It is especially important to recognize that foresight is a participative process, in which various stakeholders identify possible futures and strategic choices as well as increase their capacity to adjust to the requirements of a changing operational context. Foresight is not forecasting, a practice which is based on assumptions of linear societal development (Koivisto et al., 2009). To some extent foresight resembles approaches that have been developed to strengthen the participatory, interactive and strategic elements of evaluation (Cousins and Earl, 1994; Fetterman, 2001; Patton, 2011). Whilst there are overlaps, foresight differs from other evaluation approaches at least in one important respect: its timescale is often more extended. Foresight activities may span anything from five to 20 years or longer. Furthermore, in the context of complexity, systems may evolve in many potential directions, which gives a further impetus to the use of methods that identify alternative futures.

In addition to analysis of the current situation, future prospects and visions, we also need a robust theory of change (e.g. Mayne, 2012) able to unpick effective causal relationships. However, as complex and dynamic systems are constantly in flux and involve a number of within-system feedback loops, we need a dynamic approach which is able to address this complexity (see Hargreaves and Podems, 2012). To this end we advocate *system dynamic modelling* (Forrester, 2007; Sterman, 2000).

All approaches to strategic decision-making and management have their pros and cons. The overall approach suggested here aims to combine the essential characteristics of evaluation and foresight methodologies, complemented by system dynamic modelling and societal embedding. This combination provides both high-level 'visionary' inputs together with specific and detailed information for decision-making. Since *societal embedding* incorporates the implementation perspective into the mix (Kivisaari et al., 2013), the overall approach therefore includes both developmental and steering capabilities necessary when dealing with change in complex social contexts (see Rotmans and Loorbach, 2009).

The proposed evaluation approach has aspects in common with some other approaches, especially those aiming to strengthen participatory and collaborative elements, as well as to support the building of a culture of learning through evaluation processes (e.g. Cousins and Earl, 1994; Fetterman, 2001; Patton, 1997; Rossi et al., 1999). For example these approaches also have as their goal to empower multiple stakeholders and to support shared learning through the process of evaluation. Our approach has also much in common with developmental evaluation (Patton, 2011), intended to support development, scalability and adaptation of innovations, policy instruments and policies.

While there have been attempts to create more comprehensive information generation and management tools for strategic decision-making (see e.g. Cousins and Earl, 1994; Fetterman, 2001; Guzman et al., 2014; Mavrommati et al., 2013; Merrill et al., 2013; Patton, 1997, 2011; Rossi et al., 1999) they typically rely on specific approaches and methodologies. Moreover decision-making is still based on fragmented information. Comprehensive information on the operational environment and its propensity to change, as well as an understanding of wider societal impacts, are usually lacking (e.g. Auvinen et al., 2015; Loorbach and Rotmans, 2010). Hence the need for more systemic and integrative methods.

This article aims to contribute especially to the discussion on new systemic and development-oriented evaluation approaches (e.g. Dyehouse et al., 2009; Patton, 2011). The central question that this article poses is: With what kinds of evaluation methods should we analyse a complex and rapidly changing society and its interconnected systems?

In the remainder of this article, we first discuss the need for a new framework. Approaching the challenge from a 'science, technology and innovation policy' perspective, we highlight two challenges to current evaluation practice: societal change; and traditional evaluation culture. Second, we discuss how the model might tackle changes in socio-technical environments through a holistic understanding and analysis of the complex interactions and changes in socio-technical systems. A model is put forward based on a theory of socio-technical change (Geels, 2002, 2004; Geels and Kemp, 2007). In the conclusions we summarize the special characteristics of our approach.

Need for a new framework

Societal change

Some of the most striking characteristics of societal change over the last 30 years are probably the accelerated pace of technological and social change, increasing global interconnectivity and the resulting growth of social complexity. The policy and environmental challenges we now face demand more strategic and horizontal policies better able to deal with this complexity. These secular trends and the challenges they pose for evaluation methodologies are possible to summarize as follows.

Interconnectivity. Our societies are highly networked and interlinked. While networks are not a new phenomenon, the rapid development of ICT technology and infrastructure means that global networks based on modern communication technologies increasingly affect all aspects of our lives (Castells, 2000; Castells and Cardoso, 2005). Various man-made systems as well as natural and environmental systems are also interlinked. For instance, systems such as transportation, health, food, education, communication and electricity are highly dependent on each other. It has been estimated that approximately 50 percent of each system's outputs depend on inputs from other systems. This 'hyper-connected world' also creates 'hyper risks' as vulnerabilities in various systems are coupled. For instance, our food and water system is affected strongly by ecosystems, global supply chains and communication and financial systems (Helbing, 2013). Any impacts in this kind of interconnected world are highly challenging to analyse and we would argue requires a new generation of comprehensive evaluation methods.

Complexity. Our comprehension of the nature of major societal and environmental challenges has also changed. As noted, we now understand that various systems are interconnected and solving major problems cannot take place by focusing solely on one system at a time: their systemic interlinkages have to be taken into account. This perspective has been especially visible recently in the debates on so-called 'grand challenges', with regard to such phenomena as the ageing of society, financial system failures, climate change and migration. Common to these challenges is, usually, a high degree of complexity and the fact that their solution requires transformation of entire systems, including changes in the technological, economic and social spheres as well as simultaneous development of organizations, technologies, services and multiple new network relationships. Together with growing interconnectivity, this complexity requires a more systemic perspective and methods which aid the analysis and management of these complex societal changes.

Technological, economic and social changes are interlinked. Interlinkages of the kind described emphasize the significance of complexity in the area of science, technology and innovation. The history of technology and innovations provides us with a number of examples of how technological development interconnects with social and economic development (e.g. Bijker, 1997; Freeman and Louca, 2002; Hughes, 1983; Perez, 1983). While all the technologies cannot be 'game changers', it is an ongoing challenge to analyse, assess and predict socio-technical developments and their wider social consequences. This perspective is further emphasized because of *technological convergence*. Technological convergence can be understood as the development of previously separate technologies into functional wholes (Olawuyi and Mgbole, 2012). Convergence may involve various sciences and technologies like nanotechnology, biotechnology, information technology, and cognitive sciences (Science & Technology Foresight Directorate, 2005). Technological convergence may have far-reaching societal consequences including, for instance, impacts on human identity, biodiversity, sustainable development and civil rights (Science & Technology Foresight Directorate, 2005). This, in turn, is increasing the need for assessment of the social, ethical and political aspects of emerging technologies (Guston and Sarewitz, 2002; Schot and Rip, 1997).

Need for horizontal decision-making and policy planning. All the changes described above necessitate new kinds of methods that strengthen horizontal policy approaches and steering mechanisms, able to respond to rapidly changing situations. Policy itself has to become more systemic. Decisions on societal development can no longer be made in separate administrative 'silos' as the problems and consequences of decisions are cross-cutting and touch various administrative sectors. These developments put more emphasis on strategic leadership and management of policy and related decisions. The changes highlight the need for holistic perspectives and methods to understand and analyse the complex interaction in networked socio-technical systems (Flanagan et al., 2011; Hajer and Wagenaar, 2003).

The societal trends and increasingly complex operational environment we have described, require policy making to become increasingly horizontal and network-based. This, in turn, requires new approaches to evaluation (Arnold, 2004; Edquist, 2005, 2006; Georghiou, 1998).

Traditional evaluation culture

The evolution of evaluation has been strongly driven by the need for strategic thinking and decision-making in public policy. This has been linked both to the general development of organizations and to more specific tasks and functions. It has played a particularly important role in the context of innovation and R&D. In public interventions – often carried out in the form of policy programs – evaluation has been an embedded practice whose purpose has been to support decision-making. Since the early days of evaluation, impact assessment has been a typical way to implement

evaluation. This has meant that evaluation has been understood in terms of performance-related steering and monitoring (Chelimsky, 1997; Rip, 2003). The primary purpose of this assessment process has been to produce indicator-based information to demonstrate accountability and to legitimate the role and justify the existence of individual organizations and policy instruments. These motivations and connections to policy making have been major factors influencing how evaluation has developed.

Typically evaluations are based on logic-model thinking – indeed some have claimed that such thinking dominates current evaluation approaches (Patton, 2011: 18). Logic models are widely used, especially in program evaluations, and employing concepts such as input, activities, output, outcome/impact and effectiveness[1] in order to assess the contribution, relevance and performance of policy instruments. Logic models assume a linear relationship between program resources, activities and outcomes, these different components being connected through pre-determined pathways (Dyehouse et al., 2009). Typically logic models will articulate 'assumptions' that are the basis for the intervention achieving its goals as well as 'risk' factors that may interfere with the achievement of anticipated outcomes and impacts (Kellogg Foundation, 2004)

This evaluation traditional creates its own challenges. First, it is backward looking and does not work well as a guiding instrument in a society characterized by rapid change (Todd and Wolpin, 2010; Weijermars and Wesemann, 2013). Second, the approach is 'atomistic': it focuses on individual organizations or policies and ignores the fact that 'impacts' are co-produced by more than one actor and are located in a broader context (Rip, 2003). Third, indicator-based assessments risk over-simplification. Indicators assume a simple causal relationship between intervention and impacts, incompatible with some important theories, e.g. with the contemporary understandings of the emergence of innovations (Cozzens and Melkers, 1997; Hansson, 2006; Van der Knaap, 2006). While logic models can be recognized as a first attempt to understand a 'system', they do not explain the complex relationships and dynamic between system components. The logic model approach works in simple and predictable situations, but it has significant downsides in complex and dynamic situations (Patton, 2011: 18).

Systems thinking offers an alternative and complementary framework to the traditional logic evaluation models. Compared to input–output evaluation (or 'black-box evaluations') where things go in and things come out but what happens in between is a mystery (Dyehouse et al., 2009: 187) – system approaches make visible the 'transformation processes that turn interventions into outcomes' (Chen, 2005: 231). By paying attention to the interaction between various actors and to longitudinal complex dynamic behaviour it is possible to explain how the complex interactions reduce, change or even hinder the desired outcome (Merrill et al., 2013). Considering complex dynamics discourages false cause and effect conclusions and helps to create a deeper understanding of the role of various factors promoting or hindering intentional change (Dyehouse et al., 2009: 187−8; Merrill et al., 2013; Sterman, 2000).

Systems thinking builds on a number of disciplinary and methodological traditions such as general systems theory, system dynamics, complexity science or specific methodologies such as system dynamic modelling. The focus is on 'a whole and its parts to form a more complete understanding of the system' (Cabrera, 2006). Some years later Cabrera and colleagues (2008) suggest that there are four patterns that all systems thinking theories and methods share: making distinctions, recognizing interrelationships, organizing part–whole systems, and taking multiple perspectives. Essentially systems thinking is an approach that pays attention to the interrelationships between the whole, its parts and the environment with which they interact.

Some system paradigms are well known in the evaluation field (see e.g. Guba and Lincoln, 1989) and there has been much debate and increasing interest in systems thinking in evaluation during recent years (e.g. Cabrera et al., 2008; Dyehouse et al., 2009; Funnel and Rogers, 2011; Mayne, 2012; Patton, 2011; Williams and Hummelbrunner, 2011). However, it is not yet a

'mainstream' approach and remains obscure to many evaluators (Hargreaves and Podems, 2012). A possible reason for this may well be the plurality of system approaches and methods not all of which are in agreement. In the face of this challenge many evaluators end up advocating 'mixed methods' or 'combining a plurality of methods' drawing from a limited repertoire (Dyehouse et al., 2009; Williams and Imam, 2007). Evaluators need to go deeper into systems thinking to be able to select the appropriate concepts and methods for the purposes of evaluation (e.g. Cabrera et al., 2008; Williams and Imam, 2007). At present evaluators who are sympathetic to these approaches tend to draw on a limited methodological repertoires. Moreover, epistemological differences and traditional barriers between research traditions, which have themselves fuelled methodological and lexical differences, have hindered the simultaneous utilization and integration of different approaches, even by evaluators qualified in social sciences (Hargreaves and Podems, 2012: 463).

While interest in systems thinking has increased there is still a need to emphasize more holistic and comprehensive strategic thinking as well as future-oriented approaches. This has to include questioning the direction of new policy initiatives from the outset as well as judging policies once implemented.

A multi-method approach to understanding systemic change

We are proposing an evaluation framework that addresses the systemic and complex characteristics of policies for socio-technical change. Like others (e.g. Dyehouse et al., 2009; Williams and Imam, 2007), we also suggest a multi-method approach. We first introduce these methods and how they complement each other. Then we locate these methods in relation to theories of socio-technical change, which gives us conceptual tools to understand change in complex systems and helps us to specify which aspects of systemic change the overall approach is able to address.

The approach does not aim to address a specific policy context or innovation policy instrument. It is a generic and flexible framework that may be utilized to support decision-making in various policy contexts and decision-making situations. However, as all systems – and thus decision-making situations – are context-specific the tools that are used (and how they are combined) need to be tailored to that specific policy context (Ahlqvist et al., 2012).

Multi-method approach

The approach includes the combination of evaluation, foresight, system dynamic modelling and societal embedding, each of which makes its own distinctive contribution.

Evaluation including qualitative and quantitative approaches of *ex ante*, *ex post* evaluation and monitoring provides information on the past and current state of the system, its structures, operations and historical development. It provides evidence of 'path-dependencies', i.e. established innovation trajectories that follow from actions taken in the past; and 'lock-ins', i.e. the dynamics that prevent systems diverging from existing trajectories even when these are recognized to be inefficient or otherwise counter-productive. Evaluation also supports redirecting policy instruments to better respond to the needs of a changing operational environment; and show how results feed-back to target setting and decision-making. By utilizing a systems theoretical perspective, evaluation can address the challenge of analysing interdependencies and interactions within the system, and between the system and its environment.

Foresight generates information about future transformations in a system and endorses the setting of long-term targets. It is an action- and participatory approach (Dufva and Ahlqvist, 2015) focusing on providing options for alternative futures and analysing trends and drivers causing change in the system. It is uses various techniques (e.g. scenario work, stakeholder analysis, trend extrapolations, roadmaps etc.) and a combination of qualitative and quantitative approaches (see

Georghiou et al., 2008). Evaluation approaches can be combined with foresight to generate detailed information on the development of a system. It supports operational target setting by providing information of the potential impacts of planned actions and the strategic applicability of the policy instruments. Foresight addresses the challenge of making sense of rapidly changing decision-making contexts and aiding formulation of commonly shared future visions among central actors in the system.

System dynamic modelling and simulation allows formal analysis of interdependencies and feedback loops among system elements and helps to explain how complex interactions reduce, change or hinder the desired outcome. System dynamic models incorporate causal connections between system elements that can be mapped using causal loop diagrams. Simulation modelling is used to understand how the interaction of various feedback loops creates change over time (Merrill et al., 2013). Even though the role of simulation is emphasized in system dynamics methodology, straightforward qualitative diagrams, that show interactions and feedback arrows, can also increase understanding of longitudinal complex dynamic behaviour (see Forrester, 2007; Sterman, 2000). System dynamic modelling has considerable potential to enhance policy learning and affect decision-making (Forrester, 2007). For example, if it is connected to social scientific methods, it may support sense making in the 'big societal issues' and policy-making contexts. Models can, for example, be used as a scenario generator to study the potential effects of different policies or they can be used when assessing dynamics in the generation of system-level impacts.

Societal embedding is an approach to initiate dialogue among various stakeholders and key actors who set conditions for social development and for the diffusion of social or technological innovations. The aim is to mobilize stakeholders to commit themselves to action and increase the 'social quality' of reforms and innovations. Quality increases if the reform or innovation: 1) has clear value to users, 2) indicates a future direction, 3) encompasses a societally wide range of impacts and 4) is likely to be transferable to other contexts. Embedding seeks to build a dynamic network of key actors; identify the needs, interests, expectations and visions of these actors; enhance shared learning; and create a deeper understanding of the problem to be solved as well as facilitate possible solutions (Kivisaari et al., 2013). Societal embedding supports and can be seen as an application of foresight. Its specific target is, however, more the implementation of reforms and innovations and practical steering of change. Societal embedding addresses the challenge of steering change through networked decision-making and 'co-creation' (see Rotmans and Loorbach, 2009).

Understanding complex socio-technical change

The above approach and methods are located within a theory of socio-technical change. This serves as a general framework to understand change in complex systems. The theory is useful for analysing systemic processes at macro, meso and micro levels, and provides the necessary heuristic tools for understanding the dynamics affecting the possibilities of social and technological change. While it necessarily simplifies complex reality, its comprehensiveness makes it possible to simultaneously analyse the whole and its interaction with its parts (see Cabrera, 2006).

Originally this theory was developed to describe changes in technological systems and most of the studies using this framework deal with socio-technical changes in specific contexts - electricity system in the Netherlands (Verbong and Geels, 2007), factory production in the U.S.A. (Geels, 2006a) and aviation technology (Geels, 2006b). There are also examples from other contexts like urban development (Hodson and Marvin, 2010) and health-care (Kivisaari et al., 2013). The well-established work of an important group of transition management researchers (e.g. Kemp et al., 2001; Rip and Kemp, 1998) underpins this body of theory. In essence, the theory emphasizes

complex interactions between actors, resources, institutionalized practises and regulation in a system. At the core of the theory is a so-called multi-level perspective, which distinguishes three analytical levels through which to analyse the dynamics of socio-technical change

At the centre of the model is the so-called *regime level*, which combines institutionalized practices, structures, and self-evident action patterns. The regime level itself consists of five dimensions:

1. available and used technologies;
2. scientific institutions and paradigms;
3. politics and administration;
4. socio-cultural values and symbols etc.; and
5. users and markets.

Regime is an analytical concept, which can be variously applied empirically (Geels, 2002, 2004; Geels and Schot, 2007). For example a regime can be an industrial sector or a segment of society.

The regime level is the conservative element in the model: institutionalized practices and structures may create 'path-dependency' and 'lock-ins' as previously observed. The pressure to change comes from the second level, described as the *landscape level*. Landscape is the wide socio-technical context surrounding the regime. It consists of general societal values and norms, political changes, economic fluctuations, society's infrastructure etc., i.e. factors the actors at the regime level can affect a little or only indirectly. The status quo is maintained so long as there is 'compatibility' between the landscape level and regime. However, if the structures and action models in the regime are not compatible with the landscape, the regime confronts pressure from the landscape to change. This, in turn, may open up a window of opportunity for attempts to reform the regime itself (Geels, 2002, 2004; Geels and Schot, 2007).

The third level in the framework is 'niche innovations' which refers to innovations and experiments taking place outside the regime. These innovations have the potential to reform or even transform the existing regime. Niche could include a small niche market, or a protected and publicly supported segment where new innovation can be developed without fierce market competition which might destroy it (Geels, 2002, 2004; Geels and Schot, 2007).

Within this it is assumed that change in the system is possible only through the interactions of all three levels. However, the levels may have different weights depending on the mechanisms of change. Change can be, for instance, more or less potent, when regime actors dominate and changes are incremental. More radical change takes place when the regime actors need to find radical innovations to solve contradiction between the regime and landscape levels. The most radical change occurs when the regime actors are unable to find viable solutions and there opens up a true opportunity for niche actors to transform the entire regime.

The interaction between the three levels and how our multi-method approach can be positioned within the framework is depicted in Figure 1. Each of the methods has a complementary function in making the systemic change understandable and in increasing strategic intelligence (Kuhlmann, 2003; Kuhlmann et al., 1999; Maccoby, 2001) in the decision-making context. The figure simplifies the division of labour between methods as each of them has overlapping elements and they can be utilized simultaneously at different system levels. Whilst it is an empirical question to test the methods in relation to each other, we would see foresight best suited to address the overall development of the system and its interaction with the wider context. For instance foresight can be used to anticipate, potential crisis points which may challenge and modify the existence of the regime. Evaluation is more concerned with the current dynamics and complex interaction at regime level and may focus more on individual policy actions and their impacts. Modelling, in turn, is especially useful when the complex multilevel interaction is analysed from the perspective of emerging

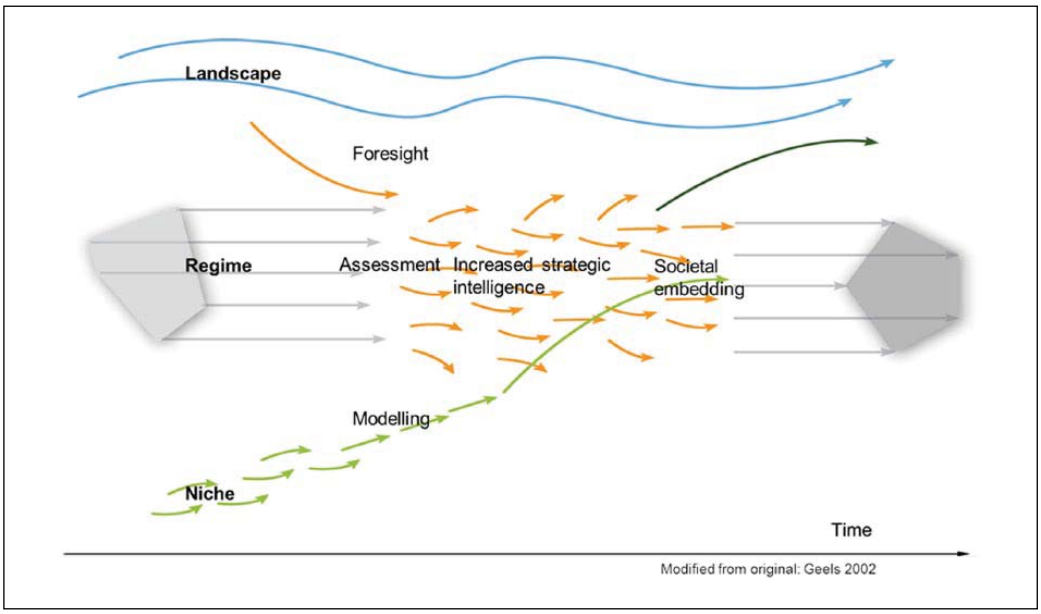

Figure 1. Multi-level methodological approach for future oriented impact assessment.

new innovations and action patterns. In general, it is a complementary method to understand the development of the system in greater detail. Societal embedding relates more to the support for innovation development and dissemination of new ideas and innovations. Such an innovation may, for instance, be a new way to produce specific health care services or to (re)organize a health care system (Kivisaari et al., 2013). It has to be emphasized, however, that methods and their combinations are always context-specific. The way they are used and their specific relation to each other or the issue of whether some of the methods are used at all depend on the situation and case that is being analysed.

Implementation of approach

The approach and its various tools all have a track-record of application and development. The approach has been piloted in different case studies, examining complex decision-making and systemic change in different policy contexts e.g. emission-free transport, customer-oriented health care services, and environmentally sustainable energy services (Nieminen and Hyytinen, 2015; Auvinen et al., 2015; Hyytinen et al., 2014; Hyytinen and Toivonen, 2015; Kivisaari et al., 2013, 2014). Regarding the transport system, a stepwise methodological process was introduced to support the decision-making situation in a complex socio-technical system. The process has also been demonstrated in a theoretical case study to explore vision building for 'emission-free transport in cities by 2050' (Auvinen et al., 2013). Differing case-related needs have contributed to the selection of the approaches as well as the development and utilization of the specific tools. Table 1 below summarizes the roles of complementary approaches by explicating the rationale for the data collection and the outcomes of the approaches. In addition, it gives some examples of the tools in the different case studies and policy contexts.

The approach and its 'toolbox' have been piloted but there is a need for further research and testing. As the examples indicate, the current development phase has mainly focused on the

Table 1. Rationale of the different approaches in the framework and examples of approach-related tools.

	Rationale for the data	Outcome	Examples of tools applied and their outcome
Foresight	- Wide landscape and regime level changes - Scenarios of potential changes - Forward looking data - Dynamic, shared process for knowledge creation	- Support strategic choices of alternative technological development paths - Promotes networking of experts - Contributes to insights and shared vision of future developments and consequent consensus over and commitment to future investments	*Vision path generation* by the support of 'system transition roadmap' (Auvinen et al., 2015) Identification of new potential sustainable services based on *trend analysis* (Hyytinen and Toivonen, 2015)
Impact assessment	- Operationalizing the long term targets - Analysing the system elements and their dynamic with the special view on impacts - Analysing the impacts (inc. potential impacts) of policy instruments and decision-making	- Analysis of the current status of the system e.g. path dependencies, windows of opportunities - Identification of system elements and their dynamic - Strategic and operational targets to support policy implementation - Future-oriented impact assessment of policy measures - Follow-up of system development	*Multi-criteria perspective in evaluation* and measurement of new sustainable services (Hyytinen et al., 2015)
System dynamic modelling	- The simulation model is a theory of system, explaining its behaviour endogenously through feedbacks - Model results are used to design good and robust policies - To solve a particular policy problem	- Models illustrating the dynamics between the system elements	*Identify interaction between system parts*: causal loop diagrams of the interactions in the system and feedback loops (Auvinen et al., 2015)
Societal embedding	- Facilitating development and introduction of new sustainable innovations; chosen technologies and social targets - Facilitating diffusion of new sustainable innovations	- Active and continuous dialogues among actors who set conditions for development and diffusion of innovations	*Interactivity in vision building*: involving relevant stakeholders to identify the challenges and to draft the common vision (Auvinen et al., 2015; Kivisaari et al., 2013)

development of combinatory or 'interdisciplinary' (Thompson Klein, 1990) methodologies. This means that different methodologies borrow and utilize issues from other methods and define common problems to be solved. The next phase should focus on the development of fully integrated or transdisciplinary tools, where the different tools are fully combined. In addition, further development of the methodology requires more studies in both theoretical and empirical contexts to improve the applicability of the approach. Ideally, future-oriented impact assessment would be implemented as an integrated part of real-life decision-making processes to provide information needed in different stages of decision-making.

Conclusions

In this article we have proposed an innovative evaluation approach designed to support decision-making in complex socio-technical environments. The aim of a future-oriented impact assessment approach is to meet the challenges of the changing innovation environment.

As policy making evolves in societies where inter-linkages between technological, societal and economic changes are increasing, traditional evaluation approaches are often unable to support decision-making in horizontal and complex situations. This includes the need to mobilize the commitment of key actors to problem solving, mutual learning and co-creation of shared visions. We have argued that traditional evaluation methods are not able to capture or help steer dynamic and complex systems partly because of the linear thinking that so dominates established evaluation practice. The multi method approach embedded in a socio-technical theory of innovation described in this article aims to support the responsiveness of the policy and decision-making system by increasing strategic intelligence.

The approach we have described is intended to contribute to the current discussion in the field of evaluation by building bridges between different methodological approaches and suggesting their combination for more appropriate and useful evaluation. It is especially important to integrate a 'future orientation' into evaluation with the help of foresight and detailed analysis of complex systems with the help of system dynamics modelling.

A question that remains is whether the proposed approach is sufficient to make decision-making more flexible and resilient in the context of rapidly occurring change. It might be that other non-information based dimensions of decision-making such as institutional 'lock-ins' or the way political power is distributed – are more important determinants of innovation in some circumstances. As evaluators already know providing more information and even conclusive findings does not always guarantee uptake and use.

Note

1. The scientific literature on innovation and evaluation reflects the existence of many disciplines and 'schools of thought' and consequently the conceptual apparatus varies. We refer to the most commonly utilized 'logic-model thinking' and follow their definitions in description. In this way of thinking, inputs are seen as resources (e.g. funding, personnel, time materials), activities as action components by which to attain the desired results, output as direct and immediately visible results, impact as an indirect result that becomes visible in the long term, and effectiveness as a broad societal change.

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ARTICLE 2

Future energy services:
empowering local communities and citizens

Foresight, 17 (4), 349 – 364

ARTICLE 3

A System dynamic and multi-criteria evaluation of innovations in environmental services

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A SYSTEM DYNAMIC AND MULTI-CRITERIA EVALUATION OF INNOVATIONS IN ENVIRONMENTAL SERVICES

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1. Introduction

The evaluation of innovations has been typically based on science and technology (S-T) indicators, highly oriented towards the technological aspects and economic impacts of innovations. This narrow approach has been criticized in service studies as it neglects the novelties based on immaterial values and interaction (Rubalcaba et al., 2012; Toivonen, 2010). In particular, researchers have pointed out that the traditional evaluation methods and measures are not able to capture the diversity of innovations and the multifaceted performance in service sectors (Djellal and Gallouj, 2013a).

The increasing "servitization" of society has put pressure to develop more advanced approaches to evaluation. In some recent studies (Dyehouse et al., 2009; Williams and Imam, 2007), a plurality of methods and starting points for new evaluation criteria have been suggested. According to them, impacts should be assessed on the basis of a multidimensional approach to take into account the issues of quality, reputation, social innovation and social value (Djellal and Gallouj, 2013a).

The reasoning is rooted in the "broad view on innovation" brought about by evolutionary economics (Nelson and Winter, 1982; Kline and Rosenberg, 1986; Dosi et al., 1988; Dosi, 1999), that highlights complexity, uncertainty and interactivity in the development and implementation of innovations. It directs the

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focus on the dynamic nature, interrelationships and feedbacks between multiple sources and actors in innovation establishing various types of systems and networks (Smith, 2000; Edquist, 2005; Lundvall, 1992; Malerba, 2002; Cabrera et al., 2008). In other words, it favors a systemic perspective. Recently, the systemic and network perspective has become topical – not only in terms of multiple actors – but also concerning the novelty itself. It has become apparent that that the most urgent problems in the present society cannot be solved via individual technologies or services, as these problems form systemic wholes and require systemic solutions (Harrison et al., 2010). This development puts additional pressure on the renewal of evaluation of innovations.

Environmental sustainability is an example of systemic issues and one of the grand challenges in today's society (Smith et al., 2010; Gallouj et al., 2014). There are important sustainability-supporting technological innovations in the areas of energy and waste management, for instance. However, in addition to the enabling technology, these innovations usually require a change in the consumer behaviour – in many cases community-wide. Technological advancement of ICT creates prerequisites for this kind of a change: internet of things, big data management and open data initiatives can be used to engage consumers in the common concern of environment. What is missing is the integration of technology development, support services, organizational arrangements and policy measures into a systemic whole. The evaluation linked to environmental innovations reflects this challenge: the technological core dominates the discussion and the relationship between services and environment is poorly understood (Gadrey, 2010).

This paper examines the above-described evaluation challenge in more detail and seeks a starting point for a more versatile approach. We suggest that a multi-criteria framework and system dynamic modelling provide a combination that can be used as such a starting point. The multi-criteria framework applied in this study evaluates innovations and their performance on two dimensions: from the short and long term perspectives, on the one hand, and from different societal spheres on the other hand (Djellal and Gallouj, 2010, 2013a). System dynamic modelling (Sterman, 2000) provides information on how the structure of the system creates complex dynamic behaviour over time (cf. Giddens, 1987). It helps to explain the role of feedback loops between different actors and factors and to understand phenomena that promote or hinder the emergence of various impacts.

We focus on the environmental sector as an area in which need for systemic innovations is apparent and in which new services play a crucial role but are typically considered secondary compared to technology. Our specific case describes an environmental data platform which shows the importance of the ICT-enabled development. This case illustrates how a technological innovation has many non-technological impacts in different societal spheres. It provides analytical material about complementarities and contradictions between these impacts and shows how the different evaluation criteria are mutually interlinked and may reinforce or contradict each other.

The following research questions guide our work:

– *How could a multi-criteria framework be used to evaluate a systemic*

innovation with services as a core part? How can this framework be applied in environmental services to evaluate their impacts both short and long terms?

– *How could the dynamic impacts of systemic innovations be modelled and what does this modelling tell about the dynamic impacts of innovative services in the environmental sector?*

The scientific literature on innovation and evaluation reflects the existence of many disciplines and 'schools of thinking', and consequently the conceptual apparatus varies. Because of our integrative approach, we combine concepts from several sources but aim to keep the definition of the central concepts clear. Our core concept is *evaluation*. It refers to the procedures which systematically investigate the results and value of what have been done, and make visible the path and process towards them to better orient forward (Rossi et al., 1999; Vedung, 2006). In our study, we specify this definition to refer to an assessment of the short term outputs and long term outcomes of innovations as well as the performance related to them. We prefer the use of the concept of performance in our analyses instead of the concept of impact because the former has a sound theoretical basis. However, the concepts of impact and impact assessment are generally used in practical (e.g. policy) contexts and we, too, apply them when we refer to these contexts. We define the concepts of innovation, output and outcome, and performance as follows:

– An *innovation* is a beneficial and replicable change in a good, service, process, organizational arrangement or a system. It can be an improvement, addition, subtraction, recombination or formalization in the elements of the former entity, or it can be a totally new entity (Gallouj and Weinstein, 1997; Toivonen and Tuominen, 2009).
– *Output* is a direct, immediately visible result of an innovation process. *Outcome* is an indirect result that becomes visible in the longer term. Gadrey (1996) uses this distinction to define the "product" of services, but this can be easily generalized to innovation.
– *Performance* is generally defined as the quantitative and qualitative evolution of the output and outcome. It reflects the improvement in the 'positions' or 'operating efficiency' relative to the various outputs and outcomes. In order to grasp the systemic view of innovation, we include the contextual change following from the outputs and outcomes: difference between the initial situation and final situation (e.g. Rossi et al., 1999).

The paper has been divided into six sections. The second and third sections after this introduction are based on literature. The former discusses the way in which the "discovery" of service innovations has challenged the traditional innovation paradigm; the ongoing transfer from the analysis of individual innovations towards a systemic view; and the implications of both these developments for evaluation. The latter presents the two main perspectives – the multi-criteria approach and the system dynamics modelling – that we combine as a starting point for a new approach in evaluation. The fourth section describes our case service – environmental data platform – and the methodology that we have

applied in data gathering and analysis. In the fifth section, we present our results concerning the empirical application of our combinatory approach. The final section sums up the study, provides some managerial and policy implication, and raises ideas for further studies.

2. Service innovation, system innovation and evaluation issues: the theoretical background

In this section we discuss the three theoretical approaches that form the starting point in our study. To begin we study the services as a challenger of the traditional view on innovation. Thereafter we adopt the systems perspective to studying innovations. To end this section we discuss what kind of implications both of these developments have for evaluation.

2.1. Services as a challenger of the traditional view on innovation

In the early stages of service innovation research in the late 1980s, the imitation of technological and industrial innovation was set as the ideal. This "assimilation" perspective was based on the traditional definition of innovation as an invention which results from an R&D project. The linear, stage-gate model of an innovation process – which was raised to the position of a norm and marketed as a prerequisite for success – increased the bias. Critique emerged first among "demarcationists", who emphasized the specific characteristics of services. Later on, a "synthesis view" gained ground. The representatives of this view have aimed at developing common innovation frameworks for both manufacturing and services. The blurring lines between goods and services and the growing significance of integrated solutions and systems have made this aim increasingly relevant (Coombs and Miles, 2000; Gallouj, 1994).

The synthesis view is strongly rooted in general innovation theories and based on Schumpeter's (1934, 1942) understanding of innovation as a cumulative (sometimes radical) change that can result in novel products, but also in novel processes, organizational forms or market openings. Important cornerstones are the complexity and uncertainty of innovation processes, the unfinished nature of outcomes due to their "re-invention" in the use context, and the multiplicity of actors taking part in the creation and dissemination of innovations (Lundvall, 2007). Traditional technologic measures and the linear innovation model often ignore these characteristics, which leads to the oversimplification of reality and to the biased understanding of the drivers, dynamics and impacts of innovations (Arnold, 2004; Ahrweiler, 2010).

The peculiar characteristics of services that specifically have been pointed out in this context are *intangibility and the central role of interaction*. An important implication of intangibility is the difficulty of recognizing the "newness" and defining the unit of output (Djellal and Gallouj, 1999g; Preissl, 2000). Interaction with customers makes it implausible to separate between product and process

innovations: services are immaterial products whose core is an act or activity (Gadrey, 1996). Interaction also increases the general complexity in the development of services innovations (Gallouj et al., 2013).

Regarding the organization modes of innovation, while many *complexities in innovation* have first been identified among service providers, they have later been perceived to characterize industrial companies, too, and among them even technology-intensive companies. An example is the intermingling of innovation activities with other organizational functions, e.g. marketing and training (Preissl, 2000). The central role of incremental innovations, which earlier was regarded as a specificity of services, has turned out to be essential in many high technology companies that create innovations by recombining existing pieces of knowledge (Henderson and Clark, 1990; Kim and Mauborgne, 1999). Research into service innovation has also raised questions about the relationship between customer-specific solutions and innovations. This has led to the specification of the definition of innovation: the visible change can be minor but the cognitive inputs behind it widely applicable (Gallouj and Weinstein, 1997).

During the last decade, the so-called service-dominant logic (SDL) has gained ground (Vargo and Lusch, 2004, 2008). Its basic postulation is that irrespective of the amount of interaction, the value of both material goods and services is always co-created. This is because individual goods and services become meaningful only when they are linked to other goods and services, i.e. the value-in-use is essential and always defined by the customer. The emergence of use value as a result of the integration of resources from many sources also implies the importance of the broader actor network. In this network, different stakeholders have different perspectives to the novelties emerging, some of them being technological or financial but others including relational and social values.

2.2. From service innovations to system innovations

A transfer from individual goods and services towards the analysis of systems is today taking place at several levels. At the most concrete level, the discussion about integrated solutions includes a system perspective. Integrated solutions are a bundle of physical products, services and information, seamlessly combined to provide more value than the parts alone. They address customer's needs in a holistic manner, are long-term oriented, and foster the emergence of a partnership relation between the provider and the customer. Due to their holistic nature, solutions usually require a broader network of suppliers around the main provider (Brax and Jonsson, 2009).

Today systems at higher levels are attracting increasing attention (e.g. Ahrweiler, 2010). In this context, the concept of systemic innovation refers to *the simultaneous development of organizations, technologies, services and multiple network relationships*. An important characteristic of system innovations is that the novelty is not restricted to the ways of operating, but also the knowledge sources and the ways to interact with other actors are new. A crucial question is how to combine various

innovations effectively and disseminate them rapidly on the basis of interaction of different organizations (Harrison et al., 2010; Rubalcaba et al., 2012).

A central driver for the adoption of systems view in innovation is the complexity of the issues that today most urgently need novel solutions. Environmental threats are one of the core issues. Today the challenge of sustainable development is increasingly understood as *a transition to more sustainable socio-technical systems* (Elzen et al., 2004; Geels, 2010). These systems comprise a whole set of infrastructures, networked supply chains, patterns of consumption, regulations, etc. Firm-level efforts continue to be important, but equally important are the organizations and institutions operating beyond the firm. The composition of networks needed is versatile: they include industrial firms, financial service providers, consultancies, universities etc. Institutional frameworks highlight the role of policy-making and governance processes. In markets, central issues are the integration of clean technologies in safety standards and market rules, and effective and prospective market demand (Smith et al., 2010).

Transition research provides a macro level perspective to analyze the prospective conditions under which sustainability might develop (Elzen et al., 2004). The concept of *socio-technical landscape* is used to describe the drivers that create pressures to break the current regimes, which are structures constituted of knowledge, objects, infrastructures, values and norms, and show the dominant way of realizing societal functions (Späth and Rohracher, 2010). These drivers also enable the emergence of innovations ('niches' in the terms of the transition literature). Landscape processes include environmental and demographic change, new social movements, shifts in political ideology, economic restructuring, emerging scientific paradigms, and cultural developments (Geels, 2004). Growing environmental awareness is a socio-cultural phenomenon that can be considered a landscape process; it is questioning multiple regimes, whilst generating opportunities for innovations (Smith et al., 2010).

Reconfiguration and reprioritisation of individual innovation activities contribute to sustainable development through the provision of greener goods and services. But the possibility of reconfiguration is structured – in both enabling and constraining ways – by wider contexts that frame, motivate and interpret innovation activities, and which may attenuate the benefits of individual innovations. Therefore, it is important to understand the broader societal transformations arising from the establishment of novel regimes. These transformations include technological developments but also institutional developments that select between possible would-be regimes and exert pressure on them to adapt or cause them to wither (Smith et al., 2010; Gallouj et al., 2014).

The perspective of socio-technical systems acknowledges difficulty in evaluating the sustainability of isolated technologies and services, if not analyzed as embedded in a broader context. It points out strong interdependencies between various elements of socio-technical systems. The analytical challenge is to understand these interdependencies as a dynamic system, and then to identify how innovation can induce a transition to other, potentially more sustainable, systems (Geels, 2002; 2004; Smith et al., 2010). Sustainable systems innovation implies

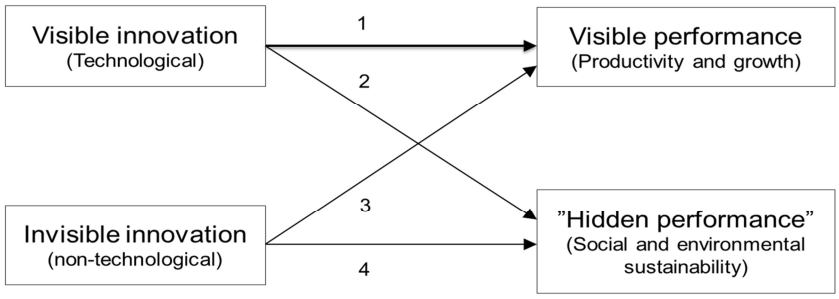
that major changes are required along the entire production-consumption chain, its flows, its multi-level architecture, its institutions and structures, and – not least – the behavior of the actors involved, from resource extraction to the final consumption (Weber and Hemmelskamp, 2005).

2.3. Implications for evaluation

Even though the broad view of innovation has gained ground among researchers both in general innovation research and service innovation research, its spread to the managerial or policy practices has been much slower. In the measurement and evaluation of innovations, the mainstream thinking is still more or less linear and simplifies the complex dynamics between actors contributing to innovation (Smith, 2000; Arnold, 2004; Smits and Kuhlmann, 2004; Ahrweiler, 2010; Patton, 2011). Consequently, *performance is usually analyzed in terms of productivity*, i.e. as an input-output function (Djellal and Gallouj, 2010, 2013; Patton, 2011). This means the neglect of the "hidden performance" that concerns the societal aspects of innovations: equality, ecological sustainability, and societal well-being.

In search for an alternative, Djellal and Gallouj (2010, 2013a) have described the interaction between innovation and performance by referring to both the visible and the invisible nature of these phenomena. Technology-based innovations are visible to our traditional economic lense (R&D intensity, patents, industry standards, number of start-ups, for instance) whereas non-technological innovations are invisible. Another new aspect is the inclusion of the time dimension. Time highlights the dynamic nature of innovations, focusing on their evolution: the short-term outputs and the medium and long-term outcomes. The time dimension is crucial in performance, too, and refers to short-term and long-term influences. Both in scientific and the managerial discussions, short-term influences are often analyzed in terms of productivity and growth, whereas long-term influences are increasingly analyzed in terms of environmental or social sustainability. Figure 1 illustrates these dichotomies.

Figure 1 - Innovation and performance gap in the measurement of services



Source: Djellal and Gallouj (2010, p. 668).

The most apparent relation is between visible (technological) innovation and visible performance (productivity and growth) (relation 1), but visible innovation may also lead to invisible performance (relation 2) by promoting the long term ecological sustainability or societal well-being. Correspondingly, invisible (non-technological) innovation may be a source of visible performance (growth and productivity) (relation 3), or lead to more "hidden" impacts in terms of sustainability (relation 4). If the first relation is the only one to which the attention is paid, there is a "double gap" in evaluation: an innovation gap and a performance gap. This double gap is the source of a gap in public policies. The invisible innovation and performance are neglected, which causes problems in target setting and in steering and planning (Djellal and Gallouj, 2010).

From the viewpoint of the present study, this framework is interesting in two respects. First, it provides a useful theoretical basis for the analysis of the short-term and long-term influences of innovations. Second, our specific research context – environmental sustainability – is a core element in the "hidden performance". As we focus on sustainability-linked services in particular, the innovation aspect of the "double gap" is also a forefront issue.

3. Towards a multi-criteria and system dynamic approach to the evaluation of service innovation

The new approach we suggest to address the question of the evaluation of innovation is compounded of two building blocks, which we intend to combine: 1) a multi-criteria framework that will be used to evaluate various dimensions of the innovation, and 2) a system dynamic modelling which will make possible to study the interactions between the different factors in the innovation process and in the emergence of impacts.

3.1. A multi-criteria framework to evaluation

The above described analysis of the "double gap" in evaluation has been a basis for the suggestion of an alternative: a multi-criteria framework which takes into account different perspectives to outputs and outcomes of innovation and considers the respective performance in short and long terms (Djellal and Gallouj, 2010). The starting point in the development of this framework is the observation that any innovation needs – not only the original idea – but also accommodations to other interests (cf. Windrum and García-Goñi, 2008). The "economics of convention" (Boltanski and Thévenot, 1991) is then applied to identify the main criteria (conventions) that individuals and groups use to justify actions and express opinions. Drawing on this approach, Djellal and Gallouj (2010) identify six "worlds" of justificatory criteria for evaluation:

– the industrial and technical world whose outputs are described and estimated mainly in terms of volumes, flows and technical operations;

– the market and financial world whose "output" is envisaged in terms of value, and monetary and financial transactions;
– the relational world in which interpersonal relationships, empathy and trust are valued; the quality of relationships is a key factor in the estimation of the "output";
– the civic world which is characterized by social relations based on a concern for equal treatment, fairness and justice;
– the world of innovation (the world of creativity and or inspiration);
– the world of reputation (the world of brand image).

The use of the six "worlds" in evaluation ensures that in addition to the traditional measures, the new criteria emphasized in the knowledge society are taken into account. In the multi-criteria framework, these "worlds" form one dimension. The other dimension consists of the direct, short-term outputs and indirect, long term-outcomes as well as of the respective performances. Table 1 illustrates the framework in a slightly modified form. We have replaced "the civic world" with the concept "responsibility world". It includes the original ethical issues linked to equal treatment and fairness, but also the new emphases on social innovation and environmental sustainability (Rubalcaba et al., 2012), which is a part of the hidden performance mentioned previously (figure 1). Another modification concerns the "world of innovation". As the whole framework is targeted to the evaluation of innovations, we consider that creativity and inspiration are an embedded criterion of the output and outcome irrespective of the "world". They represent the "moments of creation" independent of all the other worlds (Gallouj, 2002).

Table 1 - A multi-criteria framework for the evaluation of outputs and outcomes of innovation, including the related performances

<table>
<tr><th></th><th>Industrial and technical world</th><th>Market and financial world</th><th>Relational world</th><th>Responsibility world</th><th>Reputational world</th></tr>
<tr><td>Output (direct, short term)
Performance related to output</td><td rowspan="2">Volumes, flows and technical operations</td><td rowspan="2">Value and monetary and financial transactions</td><td rowspan="2">Interpersonal and organizational relations, trust, quality of relationships</td><td rowspan="2">Social and environmental sustainability, equal treatment, fairness and justice</td><td rowspan="2">Brand image</td></tr>
<tr><td>Outcome (indirect, long term)
Performance related to outcome</td></tr>
</table>

Source: Djellal and Gallouj 2010, p. 664, modified

Analyzing the performances from the perspective of different "worlds" makes visible the multifaceted nature of innovations. However, an analytical table does not reveal the dynamics and complex relationships between different factors. It

does not show how the performances representing different "worlds" are mutually interlinked and may reinforce or contradict each other. Therefore a supplementary framework is needed. In this paper the system dynamic modelling serves as such a framework.

3.2. System dynamic modelling of innovations

A key insight behind systems thinking is that inter-linkages between different elements in a system create complex behavior. This complex behavior and the non-linear nature of evaluation remain unnoticed if the different outputs, outcomes and related performances are analyzed separately. A systemic view and system oriented methods are needed when the dynamics of a multidimensional phenomenon is evaluated. The focus on individual technological or service innovations has to be supplemented with a view that takes into account the context and interactions within it.

System dynamics (Sterman, 2000) is a methodology that focuses on the underlying feedback structure of a system. System dynamics models incorporate causal connections between system elements that can be mapped using causal loop diagrams. Simulation modelling is used to understand how the interaction of various feedback loops creates certain dynamic behavior (i.e. change over time in the variables of interest). Even though the role of simulation is emphasized in the system dynamics methodology, also qualitative diagrams that show the interactions and feedback loops in a system can increase the understanding of a system. In this article we use system dynamics in a qualitative way, but our approach could be supplemented also by quantitative simulation modelling.

Systemic problems involve dynamic complexity that makes them counter-intuitive. The following features are important in particular (Sterman, 2000):

- Systems are tightly coupled, i.e. the actors interact with another and with the outside world. Feedback is a central characteristic: decisions of the actors trigger others to act, which again alters the next decisions of the original actors.
- The central position of feedback makes systems history-dependent: taking one path precludes many others.
- Systems are non-linear, i.e. effect is not proportional to cause. It is also difficult to identify immediate cause-effect relationships – instead of that cause and effect are often distant in space and time.
- Systems are constantly changing at many scales that interact. They are also self-organizing and adapting: small, random perturbations are often amplified by feedback, and capabilities of actors change as a result of learning.
- Systems are policy-resistant: the complexity makes it difficult to understand the system and as a result many seemingly obvious solutions fail. Time delays in feedback often mean that long-run response is different from the short-run.

In the evaluation of innovations, simulation modelling can be used to analyze potential effects of renewals ex-ante, and to explain ex-post how and why a system has behaved in a certain way (cf. Auvinen et al., 2014). Some authors analyze how the innovator is dependent on other actors in its activities (Adner, 2012). Others highlight the dynamic dependencies using the eco-system concept – an analogy with natural systems (Heller, 2013), and still others apply the systems theory and use concepts like co-evolution, co-specialization and co-opetition (Carayannis & Cambell, 2009). The way in which we examine systems in the present paper is a combination of the two latter views: we focus on a mutually dependent and dynamically co-evolving structure of elements.

4. The system dynamic and multi-criteria evaluation framework applied to an innovation in environmental services

Our purpose in this section is to apply our theoretical framework to a case of innovation, namely the evaluation of an environmental data platform. Before presenting our empirical results, we shortly describe the case context and the methodology.

4.1. Case context and methodology

Our empirical analysis focuses on innovations in the area of sustainability and related environmental services. The specific innovation that we examine is *an environmental data platform* that supports continuous data gathering and real-time environmental monitoring, analysis and reporting in a comprehensive manner. It includes a complex combination of both technological and non-technological ingredients and has been constructed in collaboration between multiple actors.

The innovation has been created in Finland within a research and development program carried out by a Strategic Centre for Science, Technology and Innovation – a new Finnish innovation policy instrument. The centres (abbreviated 'SHOK') operate in various industrial and service sectors as limited companies and are built on public-private partnerships. The specific SHOK (Cleen Ltd) that has developed the environmental data platform focuses on the promotion of sustainability and the program within which the platform was constructed concerns environmental measurement.

The so-called 'big data' (Chen et al., 2014) – the huge masses of data created today via digital devices with and without human beings – has been a prerequisite for the construction of the platform. Big data is characterized by volume (amount of data), velocity (speed of data in and out), and variety (range of data types and sources). The utilization of big data means a transfer from the analysis of past trends to detailed real time information. It makes the growing data reserves as the core of innovation resources. The so-called open data (e.g. Kalambokis et al., 2012; Zuiderwijk and Janssen, 2014) initiatives are linked to big data. They include the idea that certain data is freely available to everyone to use and republish,

without restrictions from copyrights, patents or other mechanisms of control. Open public data in particular is an important resource: many governmental organizations and cities collect a broad range of different types of data in order to perform their tasks.

The environmental data platform is an example of an open data initiative. Key to this approach is that public service providers develop new collaborative ways of working with data users, including commercial users – and, where necessary, actively engage in the market to stimulate demand for data. The premise for growth is that public service providers do not charge users for their data, but enable users gain access to it. Individuals can use open data as a way to facilitate their everyday activities and businesses can benefit from it in innovation or entrepreneurial efforts. The idea of bidirectional contribution is also included: the users may provide information inputs to the platform based on their own observations – in our case observations concerning the condition of the environment.

We have applied a qualitative research approach and the case study methodology in our study. The data was gathered via face-to-face interviews (30 in total). The interviews were carried out between February and June 2013. We applied snowball sampling in the identification of interviewees: the first respondents were Managing Director of Cleen Ltd and the program managers. Based on their suggestions, we thereafter selected the other interviewees among the members of the program consortium. The final sample represented actors in environmental technology and services in a versatile way. It consisted of representatives of private companies, universities and other research organizations. All interviewees were managers or experts in their organizations and had a significant role in the research program. Typically they were work package leaders or leaders of the service demonstration development.

We applied a semi-structured interview method: the topics were decided beforehand but within them the respondents were given a great deal of freedom (Bryman and Bell, 2011). The main topics focused on the manifestations of new innovative solutions within the program, factors that promote or slow down their generalization, impacts of the innovations and their evaluation. The duration of the interviews ranged from one and half to three hours. All interviews were recorded and transcribed. Documentary data on the general development of environmental technologies, services and markets were used as supplementary material.

In the analysis and interpretation of empirical data, we applied the multi-criteria framework and the system dynamics methodology. We started the analysis by studying how the environmental data platform is performing in short and long terms from the perspective of different "worlds" of justification criteria. Thereafter we moved to system dynamics modelling in order to describe interactions between the elements of the environmental data platform and the effects related to the different "worlds"– including reinforcing and balancing (counter-acting) feedback loops. The model is based on the different factors identified in the multi-criteria framework. Some factors were also included in the model based on the empirical case material that does not appear in the multi-criteria framework.

4.2. Multi-criteria evaluation of the environmental data platform

In this section, we describe how the innovative ingredients in the environmental data platform can be evaluated in the multi-criteria framework introduced in Table 1. We analyze both short term outputs and long term outcomes, and related performances, from the perspective of the different "worlds". The results are summarized in Table 2.

From the industrial and technical perspective, the most essential short-term output is the creation of a technological solution that enables the gathering of data from various sources together and keeping it continuously up-to-date. Measurement data acquired both via satellites and via on-the-ground monitoring activities is visualized with maps that facilitate the use. These visualizing tools are another illustration of outputs within the industrial and technical world. The data includes, for instance, water quality and the general condition of environment and atmosphere. In terms of the short-term performance, *the integration of dispersed environmental data* is the main improvement. Based on this integration and the advancements in data processing, the data volume and variety increases and can be flexibly used for various purposes.

In the longer term, the development of the platform is interlinked with the development of big data management and open data policies. Currently, the opening of the public data reserves has been quite slow in Finland, concerning primarily meteorological data and land survey data. When data reserves in other sectors become open, the amount of data may accumulate rapidly and demands for the development of the platform architecture grow. At that stage, the requirements for the quality control of data become more topical, too. On the other hand, the multiplicity of data essentially increases opportunities for end-user applications. In terms of the longer-term performance, versatile environmental information results in improved weather forecasts and warnings, for instance. Simultaneously, the significance of *the reliability and usability of data* becomes an increasingly critical issue for success.

From the perspective of markets and the financial world, the main outputs of our case innovation are the *free access to data and economic efficiency in the provision and sharing it*. When the data is no more dispersed in the silos of different providers in different sectors, the users find it quickly and also the providers can link their own data generation with other sources. Both public and private actors can develop new cost-effective services based on the raw data. Knowledge-intensive business services are one promising area. In terms of performance, this means that data which has been underutilized until now becomes a target of business development: *new market openings* can be expected based on effective environmental monitoring.

A longer-term prospect is the creation of a centralized market place for environmental monitoring, analyzing and reporting. This prospect promises additional monetary gains. In terms of performance, it would support the emergence of start-ups and new value networks and even foster the full realization of *an environmental cluster* that exists in policy programs but is not yet recognizable as a strong entity in practice. This performance effect is related to the overall industrial

change and new opportunities provided by data based services. The international trade of these services would enhance the revenues generated.

From the relational perspective, the output of environmental data platform is crystallized in creating connections between multiple data sources and users. In the short term, the access in our case is limited to the platform developers, but even in this restricted form, it is an important promoter of connectivity between various actors. The interaction between public and private data providers should be pointed out in particular. In terms of performance, it increases common understanding about the needs for environmental data, it improves the practices for knowledge and competence sharing and it also increase the trust in the reliability of data.

When the technologically readiness and usability are ameliorated, the platform will be opened to the general public. As long-term outcomes, also the integration of citizens to the data generation and the personalization of environmental data are pursued. This development *removes the clear distinction between the production and use of data*: in addition to public and private organizations, citizens make environmental observations and transmit this data to the platform. This change is one of crucial phenomena in the systemic change of the environmental sector. From the performance viewpoint, the development necessitates deepening collaboration and trust building in actor networks, which fosters the further opening of data reserves.

The responsibility world focuses on two different outputs in our case context. On the one hand, the platform promotes *awareness raising about the condition of environment* and the consequences of pollution based on easily understandable and accessible data. Increasing activity among citizens and policy makers can be anticipated as a result. On the other hand, the platform is an important manifestation of *the citizens' equal rights* to have access to important information. A manifestation of the short term performance is increased transparency and usability of public data. In the longer term, the platform may enable broader applications in the form of environmental education or new games that increase the awareness of environmental issues via entertainment and are targeted to young people in particular. Better database for responsibility strategies in private companies is a significant effect, too, and particularly important in established and critical business sectors (e.g. energy companies).

In the reputational world, the brand benefit gained by the developer of the innovation is an immediate output. Indeed, the developer is not only seen as an innovator, but also as a professional sensitive to ecological problems, equity and fairness. However, even in the short term the environmental data platform has much broader effects, too, in terms of reputation. It increases attractiveness of platform and it's developers and thus improves possibilities to 'market' concrete activities in the area of sustainability. In the longer term, other actors in addition to the original developer – public bodies and private companies participating in the application and further development of the platform – gain visibility for their sustainability efforts. Simultaneously the environmental *sustainability as an important value becomes more visible and determinant in the society at large*. All in all, the reputational "world" is however more tightly linked to specific actors than the other "worlds".

Table 2 - A multi-criteria framework applied for the evaluation of an environmental data platform

	Industrial and technological world	**Market and financial world**	**Relational world**	**Responsibility world**	**Reputational world**
Output (direct, short term)	A technological solution for gathering data from various sources and sharing it Processing mechanisms for the continuous upkeep of data Tools to visualize data Volume and variety of data	Free access to data Economic efficiency in the provision and sharing of environmental data New cost-effective environmental services in public and private sectors	New connection to data for professionals and partially to general public New networks between public and private data providers Increased connectivity between various data sources	Awareness about the condition of environment and the consequences of pollution based on easily understandable and accessible data Open and equal access to public data	The developer gains reputation as a pioneer in the enhancement of sustainable development
Performance related to output	Integration of dispersed environmental data Efficient processing of data for various purposes Increase of the volume and variety of data	Increased understanding of the business potential of environmental data Emergence of new market openings based on environmental monitoring	Improved understanding of needs for environmental data Increased knowledge and competence sharing in environmental issues Increased trust in the reliability of data	Increasing activity in environmental issues among citizens and policy makers Increasing transparency and usability of public data	Increased attractiveness of platform and it's developers

Outcome (indirect, long term)	An advanced architecture based on the big data management open data policies End-user applications Quality control of the data	Centralized market place for environmental monitoring, analyzing and reporting – additional monetary gains	Free access to general public End-users and commercial users as a data providers Personalized environmental data	Environmental data applied in educational services Environmental data for entertainment - integrated into games, for instance	Public bodies and private companies gain visibility for their sustainability efforts by participating in the application and further development of the platform
Performance related to outcome	Versatile environmental information, resulting in improved warnings, for instance Increased reliability of environmental data Improved usability of data	Opportunity for the development of a new competitive cluster: start-ups, value networks, new jobs etc. New export possibilities with the related income flows	Deepening collaboration and trust in actor networks fosters the opening of data reserves The emergence of 'expert amateurs' (user communities) supports the acquisition of real time environmental data	Better database for responsibility strategies in established and critical business sectors (e.g. energy companies)	Environmental sustainability as primary societal value becomes more concrete

To summarize, our case illustrates that relational, responsibility and reputational "worlds" are equally important as the technological and market views for the understanding of complex system innovations that include service aspects. In addition, our case indicates that the impacts generated in the different "worlds" are often interdependent and complementary to each other. For instance, some changes in relational and responsible "worlds" are prerequisites to effects generated in the technical and financial spheres. Open access to public data as a precondition for the development of the environmental data platform is an apparent linkage. However, there are many other linkages and in the following we study them via the system dynamic modelling.

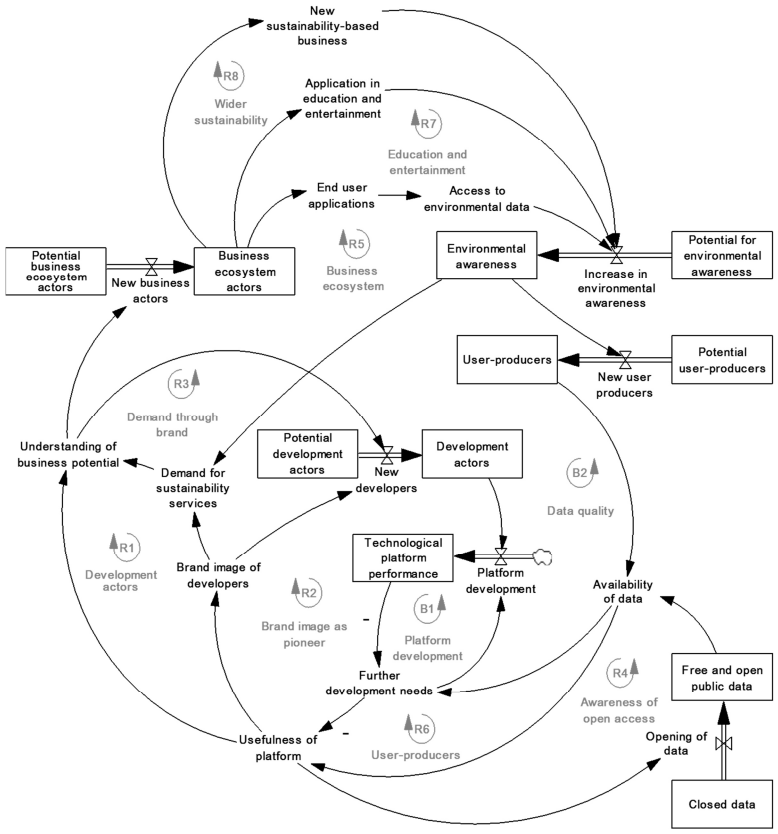
4.3. Dynamic model of impacts of the environmental data platform

In this section we analyse from the system dynamic perspective the complex behaviour and non-linear nature of innovation process and emergence of impacts of innovation. In the model we aim to understand dynamic and change by describing how the different factors related to the environmental data platform "in different worlds of services" form mutually dependent and co-evolving feedback loops. Our model also shows how the effects of innovation emerge both in short and long term long in a non-linear and dynamic process. Figure 2 crystallizes the complex feedback structure of the system.

In the figure arrows indicate the direction of causality. A minus sign (-) next to the arrows indicates a change in the opposite direction in the dependent variable when the independent variable is changed. For all other arrows, the dependent variable changes in the same direction as the independent variable. Feedback loops are indicated by R (reinforcing) and B (balancing). Rectangles indicate stock variables that change through flows.

Next, we explain the structure of the system one feedback loop at a time. We illustrate the factors belonging to different "worlds" using the following abbreviations: TECH: industrial and technological world, FIN: market and financial world, REL: relational world, RES: responsibility world, REP: reputational world.

Figure 2 - System perspective to environmental data platform



Actor networks and platform development: The first feedback loop of the model relates to the formation of actor networks that develop the environmental data platform. The creation of new development actor networks accelerates new type of collaboration between public and private data providers (REL), which increases knowledge and competence sharing, in environmental issues in general, and regarding platform development. These actors start to develop the environmental data platform (TECH), which allows the integration of different data sources and development of better data processing mechanisms (TECH). It also enables data provision and sharing at a reduced cost (FIN). Besides the ability to process different type of data sources efficiently and economically, the technological solution improves the usability (RES) of environmental data because of the integration of dispersed environmental data sources and user-friendly visualizations. All of these issues improve the usefulness of the platform, which makes it possible to form a clearer understanding its business potential (FIN). Understanding of future business potential attracts new developers to the actor network (REL), which further accelerates platform development (R1: "Development actors"). The platform is

developed to reduce the gap between the development needs and current technological platform performance. The platform development slows down after development needs have been fulfilled (B1: "Platform development").

Effects of brand image: Development of a new innovative solution in the area of environment and sustainability makes the developers and platform to gain reputation as pioneers (REP). This attracts more public and private actors to participate in the development network. (R2: "Brand image as pioneer"). Having a better brand for the environmental data platform also aids in the marketing of concrete activities (REP and FIN). This increases the demand for new sustainability services which again reinforces the understanding of the business potential of environmental data and related services (R3: "Demand through brand").

Awareness of open access: The usefulness of the platform depends crucially on the availability of open (RES) and free (FIN) data. Once the first data sources are opened and the platform is deemed useful, the demand for transparency of data increases and there is political pressure to open up further data sources, and eventually the availability of free and open public data can increase even more (R4: "Awareness of open access").

New business ecosystems: In the longer term, once the technological platform is sufficiently developed and includes an advanced architecture (TECH) as well as a centralised market place (FIN) and a good understanding of business potential has emerged, new actors start forming new value networks and business (FIN) clusters that use the technical platform. These business ecosystem actors, including new start-ups, start to develop end user applications (TECH). Through these end user applications the wider public's access (REL) to environmental data increases. This also increases general environmental awareness (RES) that generates new demand for sustainability services (R5: "Business ecosystem"). Furthermore, the increased environmental awareness and the possibility to use new end-user applications attract citizens to become active producers of data (REL). This increases overall availability of data in the platform (R6: "User-producers"). However, the availability of user produced data also requires further platform development, including data quality control mechanisms (TECH). Before these further developments are made, the usefulness of platform can be reduced (B2: "Data quality").

Wider applications and sustainability based business: In addition to environmental data based services, start-ups within the business ecosystem (FIN) start to develop new applications and services on a broader scale. These include applications in schools to support environmental education and applications that are exploited for entertainment purposes (RES). Integrating environmental data into games improves the data usability through various channels which again increases citizens' awareness and responsibility from a young age (R7: "Education and entertainment"). In addition, environmental awareness directs people to make more sustainable choices (RES). Environmental sustainability as a primary societal value (REP) becomes more visible which again directs policy makers to increase sustainability in decision making and firms to create sustainability strategies (RES) and establish them in critical business sectors (R8: "Wider sustainability"). In the long term, new competitive clusters and ecosystems based on sustainability are also formed (FIN).

5. Concluding discussion

In this article we have studied the challenge of evaluation in the context of the systemic innovation in which the services form the core. Our central argument is that the traditional evaluation methods and measures, originating from the science and technology indicators, are not able to capture neither the multifaceted dimensions of performance resulting from the innovations nor the complex dynamic behaviour in their generation and diffusion. We ground our argumentation on three different theoretical approaches: service innovation, system innovation and evaluation.

In this paper the solution to the evaluation challenge of systemic innovation is to combine of multi-criteria framework to systems dynamic perspective. In the new type of combinatory approach the multi-criteria framework evaluates the innovation and their performance from the short and long term perspective from the one hand and from the different societal spheres on the other hand. However, without the systems perspective the complex dynamic, interrelationships and multiple feedbacks between the different impact criteria remain invisible.

We have illustrated the usability of the approach in the context of environmental services in which the need for systemic innovation is apparent. We have used the environmental data platform as a case example. To understand and make visible the multifaceted nature of innovation and it's performance, the perspective of relational, responsible and reputational "worlds" are equally important as the technological and market views. Our analysis indicates that the impacts generated in the different worlds are often interdependent. Some factors in relational and responsible worlds can be seen as a prerequisite to effects generated from the viewpoint of technical and financial worlds. For instance increasing role of citizen's in data provision and increasing environmental awareness are particularly important in renewing sector.

Systems perspective in our analysis showed deeply that innovation related performance emerge as a result of complex behaviour in which the factors and elements from the different societal spheres are mutually interlinked and complement and contradict each other. For example one of the central feedbacks relates to the generation of new actor network between public and private data providers. That development accelerates the knowledge and competence sharing, which is important in relational world. These actors start to develop the environmental data platform including the integration of various data sources and development of better data processing mechanisms (central element from the perspective of technological world). Besides the ability to process different type of data sources efficiently and economically, the technological solution improves the usability (element in responsible world) of environmental data, and in a long term makes it possible to form a clearer understanding of business potential of new solution (important element from the perspective of financial world).

As a practical implication of our study we want to point out that in the decision making the evaluation concepts and criteria could be updated based on the current understanding of system innovation in which the services is a core element. The evaluation frameworks could be tuned to perceive the systemic and social nature of

innovations and industrial renewal. Also to understand and make visible the hidden performance of innovations, the profound discussion of the basic concepts and indicators of evaluation would be useful.

Regarding to the further studies more research would be useful to test the generalizability of our results. To go deeper to the dynamic relations, evaluating the value and performance of innovation from the viewpoint of different actors, could be the next step. Furthermore, generation of new type of dynamic and systemic indicators to describe that complex and non-linear process in the generation of impacts would be both interesting and useful also from the viewpoint of management and decision making.

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ARTICLE 4

Multi-actor collaboration for the development of service innovations

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Multi-actor collaboration for the development of service innovations

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Abstract: This article studies the multi-actor collaboration in the service innovation using the concept of ServPPINs. It concretises new collaborative mechanisms in which the solutions to societal problems are based on the integration of novelties in technology and services, and which appreciate partnerships, negotiation and trust between multiple actors. The specific focus is on interactive and participatory processes, required for the development of innovations in a multi-actor environment. The study examines service innovations tackling sustainability issues in the environmental and energy sector.

1. Introduction

The objective in this article is to study the collaborative forms of service innovations, and to illustrate the networked and participatory processes by giving the floor to the multiple actors taking part in the collaboration. The focus is on *service and social innovations in the environmental and energy sector*.

Environmental sustainability is one of the so called "grand societal challenges", referring to complex and global societal problems. They are systemic by nature and cannot be solved via individual product or service innovations created in individual organisations. Conversely, the challenges require the combination of various innovations and their effective dissemination on the basis of continuous interaction and dynamics between different organisations and parts of society [Gadrey (2010), Geels, (2002), Rubalcaba et al. (2013), Toivonen (2014)]. Thus, besides the combination of technological and service innovations, system and social innovations are required. *System innovation* refers to a renewal of a whole set of networked supply chains, patterns of use and consumption, infrastructure, regulations etc. that constitute the socio-technical system providing basic services such as energy provision [Smith et al. (2010)]. To develop system innovations, new operational models based on the simultaneous development of organisations, technologies, services and multiple network relationships are required [Gallouj (1994), (2002), Harrisson et al. (2010), Rubalcaba et al. (2012), Windrum & García-Goñi (2008)].

A prerequisite for the realisation of these system level changes is the active engagement of various actors in the creation, implementation and diffusion of innovations. Thus, system innovations are interlinked with *social innovations,* characterised in the recent literature by the two different aspects of "social": social by the ends and social by the means. The first aspect refers to the societal challenges (e.g. environmental sustainability) that innovations are aiming to solve, and the second aspect re-

fers to participatory and networked processes without which it is not possible to create innovation in a multi-actor environment [Harrisson et al. (2010), Toivonen (2014)].

However, the networked structure of innovation has been understood only partially. Large amount of literature is focused on the analysis of innovations from the organisational perspective [Moore & Hartley (2008)], and typically private and public innovations have been studied in isolation [Rubalcaba et al. (2013)]. In addition, examining the different logics and drivers of innovations in private and public sectors is insufficient. That may produce a partial and incomplete understanding of the dynamics and impacts of innovations and services [Hartley (2005), Levesque (2013), Moore & Hartley (2008), Rubalcaba et al. (2013)]. What is needed is a more comprehensive analysis of the collaborative and interactive development processes between multiple actors providing societally important innovations [e.g. Moore & Hartley (2008), Windrum (2013)].

In the literature, the multi-actor perspective has been proposed as an analytical framework to better understand the collaborative structure and complex interaction between decision makers, public and private service providers and users [e.g. Windrum & Garcia-Goñi (2008), Windrum (2013)]. Specifically, the recently introduced network concept "ServPPIN" (public-private innovation networks in services; Gallouj et al., 2013) aims to narrow this gap by emphasising the complementarities and synergies between public and private service providers in a complex service innovation process [Di Meglio (2013), Rubalcaba et al. (2013)]. ServPPINs can be seen as a practical way of organising a cooperative and interactive arena for diverse actors, competences and knowledge and thus for driving the systemic change in a flexible, cooperative and interconnected way [Di Meglio (2013)]. Currently, the studies on ServPPINs have mainly specified the concept and defined its role and nature – compared, for example, to the traditional innovation networks [Djellal & Gallouj (2013), Gallouj et al. (2013)]. In the analysis, the focus has been on the roles of different actors, on the type of innovation processes, and on the outcomes of innovations produced by these networks. The importance of public sector organisations both in the formation of ServPPINs and in the promotion of service innovations has been highlighted in particular. In addition, the role of policy as an enabler of ServPPINs and service innovations has been highlighted [Gallouj et al. (2013)]. On the other hand, the bottom-up perspective in the collaboration has not been emphasised so far. Especially, the actors' experiences of ServPPINs and actual collaborative processes in the development of societally important innovations have not been examined in depth.

This article studies the multi-actor collaboration in environmental services using the concept of ServPPINs [Gallouj et al. (2013)]. It concretises the new collaborative mechanisms in which the solutions to societal problems are based on the integration of novelties in technology and services, and which appreciate partnerships, negotiation and trust between multiple kinds of actors [Hartley (2005), Levesque (2013); Moore & Hartley (2008), Voß et al. (2006)]. A specific aim is to increase the understanding of the interactive and participatory processes and the experiences of multiple actors taking part in the collaboration. To understand the social process, the concept of social innovation is applied.

Empirical data of the study was collected in Finland and describes a new policy instrument "Strategic Centers for Science, Technology and Innovation" (abbreviated in Finnish "SHOK"). The aim of this instrument is to accelerate service, system and so-

cial innovations. The specific SHOK examined in this study operates in the area of environmental sustainability. Data has been gathered from face-to-face interviews (35 in total), observations of six collaborative workshops, program documents and other documentary material on the SHOK strategy.

The article is structured in five sections. The second section after this introduction presents the central theoretical approaches: social innovation to create understanding of the participatory and networked processes when tackling the system level challenges, and ServPPIN to illustrate a practical mode of organising the multi-actor collaboration to solve societal challenges. The third section presents the case context in the energy and environmental sector, and the research methodology applied in the data gathering and analysis. The fourth section describes the results. The final section sums up the study and provides some practical implications.

2. Theoretical background

2.1. System change through social innovation

Today the challenge of sustainable development is increasingly understood as a transition towards more sustainable socio-technical systems [Elzen et al. (2004), Geels (2010)]. The perspective of socio-technical systems acknowledges difficulty in studying the sustainability of isolated technologies and services, if not analysed as embedded in a broader context. It points out strong interdependencies between various elements of the systems which impede new ways of organising the provision of renewable energy, for instance. The analytical challenge is to understand these interdependencies in a dynamic system, and then to identify how innovation can induce a transition to other, potentially more sustainable, systems. [Geels (2005), Smith et al. (2010)] Sustainable systems imply that major changes are required along the entire production-consumption chain from resource extraction to the final consumption of goods and services. These changes concern material and knowledge flows, the multi-level architecture, institutions and structures including policy and governance processes, and – not least – the behaviour of the actors involved (Smith et al. (2010), Weber and Hemmelskamp (2005)].

The current literature on systemic change concentrates on the introduction of new technologies and solutions and obscures the discussion and questions of how to intervene in ordinary practices and dynamics to accelerate the systemic change [Showe and Walker (2010)]. However, a fundamental problem lies in understanding the interaction between top-down and bottom -up approaches. Co-creation with different actors and actor groups is essential and includes the public, private, and third sector organisations – not forgetting the central role of citizens as an engine for the change. The perspective of social innovation is needed to create understanding of the participatory and networked processes, without which it is not possible to create and implement innovations in a multi-actor environment [Harrisson, et al. (2010), Toivonen (2014)].

As stated in the introduction, the literature on social innovation recognises two different aspects of “social”: social by the ends and by the means [Harrison et al. (2010), Toivonen (2014)]. In addition, research into social innovation approaches society as

a “horizon of action“ [Jessop et al. (2013), p. 124]: society is not pre-given but it is co-constructed and defined by the multiple actors and multiple competing visions and preferences. This aspect of social innovation highlights the fundamental role of collective social practice and processes when developing new innovative solutions for societal transformations. Within this approach, particular attention is given to the relations and participatory and collaborative practices that promote the societal development, empowerment of the variety of actors, and governance of social structure [Jessop et al. (2013)]. In this process, the integration of bottom-up and top-down perspectives is essential [Rubalcaba et al. (2013)]. Social innovations may emerge at the grassroots level among users and employees; they may be produced in the collaboration of private, public and third sector organisations; or they may be initiated by policy makers and regulatory bodies.

Bottom-up grassroots activities are seen as an “engine of social innovations”. The process of creation and implementation of social innovations highlights empowerment: citizens and their organisations are active co-developers of innovation [Sundbo (1996)]. The importance of bottom-up processes is clearly observable in the sustainability context. The behaviour of consumers has a crucial impact on the achievement of the goals set. For instance, a change in user preferences is necessary in order to avoid undermining the improvements in the production and delivery of energy by consumption patterns [Weber and Hemmelskamp (2005)].

Equally important are the top-down processes which translate the general objectives into concrete policies and practices in the circumstances characterised by societal and political dispute [Meadowcroft (2009)]. They are needed for the materialisation and dissemination of social innovations. Community decision makers and company managers have to support, recognise and organise bottom-up processes in order to make ideas implementable and scalable [Høyrup (2010)]. Policy actors have to enhance society’s innovation capacity by revitalising innovation institutions and by fostering the innovation activities of public, private and third sector organisations [Rubalcaba et al. (2013)].

2.2. Public-private innovation networks (ServPPINs) conducting the change

ServPPINs [Gallouj et al. (2013)] can be seen as a practical way to create cooperative and interactive arenas to tackle the challenges posed by increasing societal fragmentation, complexity and dynamism [Sørensen & Torfing (2007)]. In the heart of ServPPIN is the collaborative relationship between public and private partners. Deviating from the traditional view on innovation networks, the ServPPIN concept highlights that the public service providers have an equal role in innovation with the manufacturing firms. Instead of being limited to the provision of infrastructure, financing and the institutional framework, public organisations may be genuine co-producers of service innovation by initiating, organising and propagating new ideas [Di Meglio (2013)]. Moreover, to facilitate better matches between technology and demand, ServPPINs involve consumers, intermediate users and third sector organisations as active collaborators [Rubalcaba et al. (2013)]. Non-technological innovation – which is often overlooked in the literature – is a central target of development [Gallouj et al. (2013)].

ServPPINs embody flat and flexible types of organisations which aim to develop synergies between different knowledge, competences, interests, objectives and services that different partners bring in to the network [Di Meglio (2013), Gallouj et al. (2013), Rubalcaba et al. (2013)]. Based on the empirical studies (e.g. Rubalcaba et al., 2013), the potential of ServPPINs is in credibility, dissemination, speeding up the process of agenda setting and decision making, provision of a more comprehensive view of the problems, legitimacy, resources and efficiency, learning capacity and knowledge transfer.

These new mixed organisational arrangements have emerged as a result of the modernisation trends in the public sector [Di Meglio (2013)]. They reflect a further change of the focus in the public service provision: the earlier modernisation from bureaucracy to cost-efficiency, market imitation and consumer choice has proved to be incompatible with the current development stage characterised by complexity, co-production and public value [Levesque (2013), Rubalcaba et al. (2013)]. The new trends reflect a broader paradigmatic transfer gaining ground in the governance system [Newman & Clarke (2009)]. Instead of hierarchical top-down coordination (e.g. new public management), there is a tendency towards non-hierarchical and self-regulated practices [Hartley (2005), Lévesque (2013), Sørensen & Torfing (2007)]. They include the rise of networks and partnerships, innovations as a democratic practice, the increasing choice of consumers, and co-production of services [Langergaard (2011), Newman & Clarke (2009)].

There are some key features which help to understand how ServPPINs operate. *Firstly*, they are grounded on a *broad concept of innovation* brought about by evolutionary economics [Dosi et al. (1988), Dosi (1999), Kline & Rosenberg (1986), Nelson & Winter (1982)]. This concept highlights the dynamic nature of innovations and the need for an integrative perspective which takes into account both technological and non-technological aspects. *Secondly,* ServPPINs are formed as multi-agent frameworks [Windrum & Garcia-Goñi (2008), Windrum (2013)]: a variety of actors from the public, private and third sectors is involved both in the innovation process and in the delivery of final service. Each of the actors incorporates their specific competencies and interests into the innovation process. The engagement of various actors in different phases of innovation promotes a systemic change in the sectors concerned [Weber & Heller-Schuh (2013), Windrum (2013)]. *Thirdly*, ServPPINs evolve through various phases that may affect their dynamics and composition; this kind of evolution makes a life-cycle perspective suitable in their analysis. The phases can be characterised as design (1), pilot and implementation (2), and consolidation (3) [Green et al. (2013), Weber & Heller-Schuh (2013)]. *Fourthly*, the development of ServPPINs follows an open, complex, uncertain and interactive trust-based process [Fuglsang, (2013)], in which the several driving forces influence the final outcome. The level of "formality" and structure of relationships may vary, but typically a certain degree of formalisation is required (e.g. exploitation of intellectual property rights).

Djellal and Gallouj [2013] have proposed a typology of ServPPINs according to their complexity. The criteria used for this typology pay attention to the nature of innovation (tangible vs. intangible) on the one hand, and to the characteristics of the development process (planned vs. unplanned) on the other. These ServPPIN types are also related to the main perspectives on service innovation: assimilative (or technologistic), demarcative (or service-oriented), and integrative (or synthesis) [Coombs & Miles (2000), Gallouj (1994), (2002), Gallouj & Weinstein (1997)]. The assimilation perspective analyses services innovation as an imitation of technological and manu-

facturing innovations, whereas the demarcative perspective focuses on the specific characteristics of service innovation. The integrative perspective has become increasingly relevant due to the blurring lines between goods and services: it highlights the production and consumption that focus on integrated solutions. Simple technologically focused ServPPINs have been considered as a manifestation of assimilation, simple non-technologically focused ServPPINs as a manifestation of demarcation, and complex ServPPINs as a manifestation of synthesis.

For the purposes of this article, the original typology has been slightly modified. The phenomenon of multi-actor collaboration has been pointed out explicitly in the characterisation of complex ServPPINs. In addition, the analytical dimensions have been ordered differently. The type of ServPPIN has been set as the first dimension, to emphasise it as a core analytical perspective of this article. The modified typology is presented in Table 1.

Table 1. ServPPINs according to their complexity (modified by the author from Djellal & Gallouj, 2013)

Analytical dimensions	**ServPPINs according to their complexity**			
Type of ServPPIN	Simple ServPPIN to adopt technological innovation	Simple ServPPIN to co-produce technological innovation	Simple ServPPIn to co-produce non-technical innovation	Complex ServPPINs to adopt, produce and enhance implementation of complex architectural innovation Multi-actor collaboration
Type of innovation	Technological innovation		Non-technological innovation	Broad, complex innovation including various individual technological and non-technological innovations
Dominant type of innovation process	Planned innovation		Unplanned innovation	Planned/unplanned innovation including both bottom up and top down innovations
Theoretical perspective	Assimilation		Demarcation	Integration

As shown in Table 1, four types of ServPPINs can be identified. The table represents them in the increasing order of complexity. Simple ServPPINs – the first category – adopt a technology that has been produced elsewhere. They include minimal collab-

oration between public and private actors; the aim is, for example, to make joint investments and to organise the common use of technology. Simple ServPPINs may, however, also co-produce technological innovation (the second category); various actors from public and private sectors are involved. The "simplicity" here indicates that the objective of the development is limited and does not cover the integration of technological and non-technological novelties (the innovations developed may be relatively complex). In both the first and the second categories, the process is predominately based on planned innovation. The third category includes simple ServPPINs set up to produce non-technological – organisational, social and methodological – innovations. They typically adopt an unplanned innovation process, such as bricolage [Fuglsang (2010)], ad hoc innovation [Gallouj (2002)] or a rapid application model [Toivonen (2010)]. Their complexity derives from the large number and diversity of partners as well as tacit knowledge and technologies they bring in to the network. The fourth category involves complex or architectural ServPPINs. Their objective is to solve complex organisational or societal problems by combining various forms of technological and non-technological innovations. Co-production is the central principle integrating both the bottom-up and top-down processes [Djellal & Gallouj (2013)].

This study applies the different analytical dimensions of ServPPINs to create understanding and concretise new innovation instruments based on co-production. These dimensions are used as the basic structure in the description of the empirical case and they are also utilised in the analysis of the results. The type of a ServPPIN demonstrates the structure and the objective of the collaborative network. The type of innovation highlights the integrative nature of the solutions developed to tackle the complex system level problems. The dominant type of innovation process, for its part, refers to the integration of top-down and bottom-up processes required for the adoption, production and implementation of complex architectural innovation.

3. Research context and methodology

3.1. Case context

In recent years, different types of networks have become one of the primary policy mechanisms to create and speed up innovations. Especially the strategic importance of public private partnerships has been highlighted. The approach to partnerships has varied in different countries. However, a typical aim has been to accelerate industrial renewal by enhancing the collaboration between the state and business actors. The case selected for this study provides information about how the Finnish policy instrument "Strategic Center for Science, Technology and Innovation" (abbreviated in Finnish "SHOK") promotes a systemic change and industrial renewal. SHOKs operate as not-for-profit limited companies built on a public-private partnership and aim to enhance collaboration and interaction between business life and academia in a cross-sectoral way. Their main goal is to renew industry clusters and to create system innovations to meet the needs of Finnish industry and society within a five-to-ten-year period.

In this study, the specific SHOK studied is "Cleen" which operates in the area of energy and the environment and aims to promote the competiveness of the companies

clustered around the sustainability issues. Cleen has currently 44 shareholders, including companies (28 in total) and universities and public research organisations (16 in total). The focus areas and operational activities are based on a strategic research agenda (SRA) jointly defined by the partners. The targets of the research agenda are operationalised through long-term research programs carried out in collaboration with shareholders and partners. Funding for the programs comes from multiple sources. On average, fourty per cent is co-funded by partner firms, ten per cent by public research organisations and the rest by the public funding providers such as Finnish Funding Agency for Innovation (Tekes) and the Academy of Finland. The SHOKs also apply to EU research programs for funding.

This study focused on three ongoing research programmes and the preparation of two "second generation" programmes. The first ongoing programme is *"Distributed Energy Systems"* (DESY), aiming to increase the production of renewable energy and to promote the use of hybrid energy technologies. The second programme is *"Smart Grids and Energy Markets"* (SGEM), aiming to develop smart grid architectures and intelligent management and solutions for smart consumption and customer interface. Interaction between ICT systems and energy systems is a central innovation behind the advancements in this area. The third programme is *"Measurement, Monitoring and Environmental Assessment"* (MMEA) that aims to develop an environmental information system to monitor and evaluate the environmental efficiency of various industrial processes, products and infrastructures.

Two programmes in preparation relate to the development of *"architecture of sustainable energy systems"* and *"healthy urban living"*. The former aims to provide a holistic view needed for the energy system revolution towards a sustainable and flexible system. The focus of the programme is the optimal integration of centralised and decentralised energy resources and production on the system level, and the flexible use of various energy carriers (electrical networks, gas, heat, cool). The latter programme aims to increase urban resilience and the well-being of citizens. It focuses on the interaction and interlinkages in urban systems, taking into account the energy chain, human behaviour, environmental and meteorological data, and air quality and its effect on human well-being. It engages the citizens and enhances the co-production of urban systems between different societal actors.

Table 2 describes the case context using the analytical dimensions of ServPPINs [Djellal & Gallouj (2013)]. Cleen can be characterized as a complex ServPPIN, as it is focused on architectural innovations and a multi-actor network has been formed to produce these innovations. Further, the innovations created are both technological and non-technological in nature and the innovation processes reflect both bottom-up and top-down approaches. All these aspects emphasise the integrative nature of service innovation.

Table 2. Cleen SHOK as a ServPPIn

Analytical dimensions	Description	Cleen as a ServPPIN
Type of ServPPIN	Complex ServPPINs to adopt, produce and enhance implementation of complex architectural innovation Multi-actor network	Co-production of various forms of technological and non-technological innovations 44 shareholders representing private and public organisations and different parts of the system Multi-actor collaboration essential to co-develop new competences, to promote the creation of new business and industrial competitiveness and to enhance the implementation of complex innovations in the area of energy and environment
Type of innovation	Broad perspective to innovation; complex, architectural innovation including various forms of technological and non- technological innovations	Complex innovation to promote the systemic change and industrial renewal in energy and environment sector and to define e.g. "the new architecture of the future energy system". System renewal requires variety of technological and non-technological innovations; e.g. new patterns in production and consumption of energy.
Dominant type of innovation process	Planned/unplanned innovation requires both bottom up and top down innovations developed both within formalized models and various informal models (e.g. bricolage & rapid application models)	Systemic change in energy end environment sector requires innovations in every level of society and is based on top down strategies and activities as well as bottom up activities and experiments. The systemic change is promoted by both by formalized and informal models of innovation.
Theoretical perspective	Integrative	Renewal of energy and environment sector is based on the collaboration of multiple actors representing the different sectors of society and on the integrative solutions combining multiple types of technological and non-technological innovations.

The characteristics of Cleen as a complex ServPPIN will be revealed in more detail in the results section. The case description can be summarised by stating that Cleen aims to tackle prominent societal challenges, among which environmental sustainability is primary. It accelerates new system level innovations and industrial renewal through a new type of interaction and co-creation.

3.2. Data collection and analysis

In order to gain an in-depth understanding of the activities under study, we gathered data from four types of sources. The author of this article had the main responsibility for designing the data collection and for analysing the data. The actual data was collected by the group of three researchers. *The primary instrument for data collection* was face-to-face interviews (35 in total). The interviews were gathered between February and June 2013. Some complementary interviews were conducted in spring 2015. We applied snowball sampling in the identification of interviewees: the first respondents were the Managing Director of Cleen Ltd and the Programme Managers. Based on their suggestions, we thereafter selected the other interviewees among the members of the programme consortiums. The final sample represented actors in the area of sustainable energy and environmental measurement in a diverse way. It consisted of representatives of small and medium size companies (SME's) and large companies in the field of environmental measurement and sustainable energy. In addition, a number of experts representing universities and other public research organisations in the same fields were interviewed. All interviewees were managers or senior experts in their background organisations and they had a significant role in the preparation and implementation of research programmes. Typically they were acting as programme managers, work package leaders or they were leading the service demonstration development as a part of the programme implementation. Interviews were complemented during the spring 2015 by the interviews of technological and development managers of Cleen.

We applied a semi-structured interview method: the topics were decided beforehand but within them the respondents were given a great deal of freedom [Bryman & Bell, (2011)]. The topics were structured on the basis of our theoretical analyses of the systemic change and innovation in the area of energy and the environment, governance and management of the innovation process in ServPPINs, and roles and responsibilities of network actors in innovation processes. The duration of the interviews ranged from one and a half to three hours. All interviews were recorded and transcribed.

The second source of material gathered were observations of the preparation process for new programmes. We took part in six collaborative workshops which collected participants from companies, universities and research organisations. Workshops took place during the spring 2014 (February-May). During the meetings, the author and her colleagues wrote up field notes based on the discussions. The official minutes of meetings were utilised to complement the field notes.

The third source of information was the material provided during the preparation phase of the new programmes. The digital working space of Cleen, to which we had access, enabled us to follow the proceeding of the programme: documents and other material provided in the course of programme preparation were continuously updated. *The fourth information source* was the strategic documentary material provided by the case organisation. This included, for example, the strategic research agendas, guidelines and criteria for the programme preparation, annual reports and programme results material.

In the analysis and interpretation of the data was made in a dialog between theory and empirical findings. In the analysis of empirical data any computer-assisted coding tool was not used, but several rounds of analysis were carried out to derive

meanings from data and to reduce the amount of data [Huberman and Miles (1994)]. While reading the interviews, observation notes and the other documentary material we uncovered the most common and typical themes, and classified and structured them. Aim was to create holistic understanding of the research topic via systematic and thorough analysis rounds of interviewees' responses. The quotations in the results sections illustrate the level at which extracts were picked from the material. The empirical observations were linked to the theoretical views on ServPPINs and social innovations. The analysis was started by describing the study context using the analytical dimensions of ServPPINs [Djellal & Gallouj (2013)]. Thereafter, the participatory and networked processes were examined thoroughly. Particular attention was in the relations and empowerment of variety of actors as well as the integration of bottom-up and top-down perspectives.

4. Research results

This section represents the main results of the study. The structure follows the central analytical dimensions of the study. The first section characterises in details the type of multi-actor network required for the development and implementation of complex innovations. Thereafter the focus is in collaborative and social processes: second section focuses to the central characteristics in bottom-up process and third in the top-down interaction.

4.1. Tackling the societal challenges in the collaboration of multiple partners

Cleen SHOK is one of the central actors in the Finnish innovation system to tackle environmental challenges and enhance a systemic change in the energy and environmental sector. The data of this study indicates that the role of research programmes is especially important in the creation of a comprehensive picture of the transition required. They are also crucial for the definition of strategic research questions and for the identification of the central actors who are needed to solve the problems and thus to enhance system level change.

According to our interviews, the empowerment of multiple actors representing a variety of sectors, competences and world views is essential both in creating a holistic understanding of the requirements of the system level change and in developing solutions that correspond to the comprehensive needs. It turned out that the novel programmes have accelerated network generation over the traditional organisational boarders. Consequently, they have enabled the generation of strategic understanding and the development of completely new competences required for the systemic change. For example in the SGEM programme, the interaction between energy and ICT systems is a central innovation behind the advancement of a novel smart energy infrastructure. The following interview quotes illustrate that in the face of complex and systemic problems, actors are running out of competence and are not capable of handling systemic problems without the support of a broad network:

> "Understanding the ongoing change is anything but a linear process. To create general understanding, we need multiple organisations, multiple actors, multiple backgrounds. One actor understands this and other actors that, and together we are able to create a holistic view of the on-

going changes. Without the collaboration of many actors, the creation of a strategic view is not possible. For that reason, we did not have strategic understanding of the ongoing changes in the energy sector before the first SHOK programme period". (Representative of university A)

"If we are alone, we are running out of competence regarding the systemic transition in the energy and environmental sector. Thus, we need to have a variety of players who have different types of competences required for the creation of holistic understanding of the ongoing change" (Representative of large company A)

Besides, the collaboration with different types of companies was emphasized. Most of the actors affirmed that the active participation of companies – and the entire value networks – ensures the development of practical service solutions. Companies carry out pilots and demonstrations in a real-life context, which is a prerequisite for the dissemination of the results. Moreover, particularly the role of large companies was seen to be very powerful in society-level vision building. Like the citation below illustrates, companies' ability to enhance the system level objectives through their strategies was important. Therefore, having them inside the collaborative networks was highly valued.

"To really make systemic change happen it is important to have large companies in these networks. They are also capable of enhancing the transition through their organisational strategies and programs" (Representative of large company A)

However, compared to traditional research and development programmes, collaboration between multiple partners and over traditional sectoral boarders also complicates the structure of networks. For example, SGEM encompasses in total 21 industrial partners from the energy sector, including energy technology providers, power production companies, energy distributors, and energy service providers. From the ICT sector, it includes software developers, network providers and network safety consultants. In addition, eight partners representing universities and public research organisations are in the core of the network. Correspondingly, in the first preparatory workshops of the healthy urban living -programme, approximately one hundred participants representing a variety of public, private and third sector organisations took part. Although the structure is complicated, the following interview quotes show that the extensive participation ensures both system level problem solving and real co-creation.

"On the one hand, traditional research programmes are clearer and simpler in their structure, but on the other hand, they have not managed to incorporate all the actors needed for the system level problem solving. In addition, traditional research programmes lack of genuine will and capacity of co-creation. By empowering all central national partners, the SHOK programmes have managed to create a forum for real collaborative innovation" (Representative of public research organisation A)

While the multi-actor collaboration between universities and companies was commended as a central notion in all the interviews, the absence of other public sector authorities, municipalities and citizens was also highlighted. The interviewees unanimously stated that the focus of the first generation programmes has primarily been in the development of new technologies and solutions. A broader understanding of citizens' needs and societal aspects has been lacking. They admitted that to create comprehensive understanding of healthy urban living conditions or the requirements of novel comprehensive energy architecture, new actors and competences – including the political and sociological perspective – need to be incorporated into the programme networks. The following quote points out that understanding the function of political and social systems, including the power relations and consumer needs and

behaviour, are in a crucial role in order to support the acceptance of novel solutions and enhance the systemic change.

> "To tackle the ongoing transition in energy sector, we need to incorporate the competences and perspectives of multiple actors. Technology is the easiest part of the transition. To be really able to tackle the complex needs of a system change, we need to incorporate new actors and competences into our network. We need to have understanding of the energy as a political issue. In addition, we need to understand what customers really need and how they behave. When we have comprehension of these societal aspects of energy and their dynamic interaction in the system, we may be able to develop viable and comprehensive service solutions and novel business concepts." (Representative of university A)

Based on our observations, the preparation of the "second generation" programmes has evolved into the desired direction: attention has been paid to the centrality of citizen centric approaches and participation of public authorities. For example in the preparation of the healthy urban living programme, the strategic research agenda highlights the centrality of citizens' needs in the urban planning and the role of municipalities as service development "platforms". Further, in the actual collaborative projects the aim is to integrate citizens and municipalities in the bottom-up experiments. According to the interviewees, broadening the collaboration is crucial both for the development and for the implementation of better and more viable solutions: acceptance of citizens and support of public sector actors are prerequisites for the scaling up of the results.

However, the success of SHOK-programmes is manifested only if new knowledge and innovations developed in the programmes can be executed as nationwide decisions. Some of the interviewees regretted that the current dissemination of the research results is too slow. According to them one potential reason is the inadequate communication with decision-makers and other interest groups. Although single programme actors were active in collaborating with national and local policymakers - they for example met politicians frequently and took part in EU and national level working groups- the most of them did not have any direct contact to decision makers. As the interview quotes below reveal, in order to affect on the national and EU-level strategies, and to have an impact on a societal development a more systematically organised and continuous interaction with decision makers is needed.

> "Currently the programme actors have produced lot of paper. But nothing is really changing, if we don't have courage to implement the results. Now the research is going round in circles; we are mainly communicating with companies and other researchers. Instead we should be thinking how and with whom we implement the results as concrete solutions and changes" (Representative of a small company A)

> "We should be more active in communicating our research results to decision-makers. Single actors have been active in contacting local and national decision-makers and politicians. This is very important if we want to have an influence and impact on society. Hoverer, we should be much more active in national and EU-level strategy and vision work to really influence on the future developments." (Representative of large company B)

4.2. Creating new competences and business solutions in a trust-based collaboration

Interviewees emphasised that the programmes have managed to create a model example of the network that integrates a variety of actors from multiple sectors and develops completely novel competences and innovations. As interviewees pointed out,

these are the central features when aiming for the industrial renewal. According to our empirical data, the collaborative ability of the network is based on formal agreements. For example partners' role as a formal shareholder and contracts on intellectual property rights (IPR) commit the partners to collaboration. However, these official agreements are only a starting point for partnership. Much more important is the informal trust. According to all the interviews, the role of trust was highlighted in the creation of open and profound collaboration. Like one of the interviewed representative of the university (B) pointed out: *"without trust, the collaboration is limited only to the exchange of informatio*n".

Informal trustbuilding has been systematically facilitated by Cleen and programme managers from the beginning of the programme planning. According to our observations, Cleen has an active role in promoting new partnerships and in creating a forum for open and trust-based discussion. They have organised an open call, for multiple stakeholders, to take part in the generation of the research agenda in the series of collaborative workshops. The aim is to give voice and responsibility to multiple partners in strategy formulation and to match up companies and research actors across traditional sectoral borders. According to our informants, setting the common targets and planning the practical implementation in the interactive and collaborative process weld the partners together from the beginning and form a core for open knowledge sharing and a trustful relationship.

The operational principle of Cleen defines that programmes are industry driven. That means that the industry needs are high on the research agenda and the targets are mainly set by the stakeholder companies. As the quote of one large company (B) representative reveals, the company needs are heard in the programme design: *"thanks to the novel programmes company targets are high on the agenda, whereas in the traditional research programs funding is directed to research done in ivory towers".* The informants emphasised that the companies' will and ability to sit in "a driving seat" commit them to programme targets and the partner network. From the company perspective it is a core issue when aiming for a profound collaboration, especially with the other companies. However, the programmes, which aim to tackle complex societal challenges, cannot be built solely on business needs. The interviewees highlighted the research partners' role in balancing the short term business opportunities to long term societal needs. Like the following quotes show, the interviewed actors believe that the combination of different type of objectives enhances the understanding the complementarities of different actors and thus benefits the collaboration.

> "This new policy instrument has created condition for true and open collaboration over company boarders. Partners sit in the same meetings to set targets for the common development and they implement targets collaboratively. Companies are actually affecting the target setting and thus the company and user needs are taken into account in research and development work. Also our research partners have benefitted from the collaboration – they have said that now they understand better what company needs are and what the challenges that need to be solved. In the best case this operational model generates an innovative platform for a variety of organisations willing to tackle collaboratively our common societal problems." (Representative of large company A)

> "The programme includes a variety of actors from research and industry and it has managed to combine the long term visionary research work and concrete short term business objectives. The combination of different types of targets is essential for good trust-based collaboration and is relevant in tackling system level problems." (Representative of large company B)

According to the interviews, profound and trust based collaboration has been a stone foundation – and a prerequisite - for the generation of new combinatory competences and for the creation of integrative service solutions. Programs have, for example, facilitated the emergence of a new type of co-production of services between experts from the energy and ICT sectors. This has been a starting point in the development of comprehensive energy architecture: the new combinatory competences have, for example, made possible the coexistence of centralised and distributed energy systems as well as guaranteed the safe energy flow in the system. In addition, by combining ICT in the energy system, programs create knowledge to design, construct, steer and use the smart and flexible energy system in the networks of multiple actors. As the interviewees revealed, these combinatory competences are required for industrial renewal in the energy sector. The quote of one large company (A) representative illustrates that the novel combination of competences helps tackling the challenges in the energy and environment sector: *"we have generated completely new competences with completely new partners. This creates the ground for a completely new industrial sector".*

Novel combination of competences generates new strategic partnerships and gives room for practical pilots and demonstrations. It benefits both companies and research partners. For example actors who develop a platform for sharing environmental data witness that the program has given rise to a new knowledge cluster; the development has both ameliorated the scientific base in the area and supported the development of concrete business solutions. The interview quotes below illustrate that close collaboration in developing common business solutions has led to interdependence between partners, which again has opened new doors for the actors. It has changed the way of thinking and doing business and has given rise to novel ecosystems. In addition, it is seen to be of strategic importance in ensuring the long-term business opportunities, in strengthening companies' competitiveness and in facilitating their entrance into the international markets.

> "SHOK programs have generated a new type of collaboration between company partners. We have learned to collaborate fluently and openly with other companies. That is not a typical way of action in business. This new way of action is of strategic importance and gives us a competitive advantage in markets in five or ten years. In the future, the firms who do not have the same capacity, will stay alone and focus on their own narrow activities. These company networks are extremely important in the internationalisation of business. We cannot fight the Chinese alone, but we can compete with them in the well-functioning company networks. Collaboration strengthens our competiveness domestically and internationally" (Representative of large company A)

> "For our company this programme has been extremely important. It has especially supported our internationalisation into China. In Europe it is easy to operate for our type of small company. On the contrary in China operating alone is not possible. Without the support we get from this public-private innovation network if would be impossible to create business in China." (Representative of small company B)

Building a trust based relationship, and creating a completely new collaborative way of working, is essential but not a simple issue. On the contrary, it is time consuming work, which is based on systematic and open interaction, and recognition of common interest and the additional value of each party in the development. Learning to speak a common language and having shared working methods cannot be adopted immediately by the partner organisations. On the contrary, it requires changes in mindset and in ways of working. Single organisations need, for example, to adopt the idea of shared value, which affects the current operational model and business logic in entire organisations and business networks. Although the needs for change are ambitious,

almost all the participating actors know that the creation a partnership network requires give-and-take. As the interviewees underlined, the baseline for the co-production has been created: the first generation programs have managed to generate shared working methods and to increase understanding of the collaborative nature of value generation, when tackling complex societal challenges.

4.3. Supporting the multi-actor collaboration by the mechanisms of top-down coordination

Programmes are steered by multiple mechanisms and varyingly in different phases of their implementation. The primary organisation carrying out the top-down coordination is the funding organisation Tekes: it both sets the criteria for funding and follows the success of programmes based on continuous reporting and evaluation. In addition, Cleen is monitoring the success of the programmes. According to the interviews, the double steering only increases bureaucracy and does not improve the programme results. However, it was seen as a small and bureaucratic snag. The bigger problem, according to our informants, is the governance criteria and mechanisms of funding the organisation. The problem manifests as contradictory and mechanistic targets of evaluation, a bureaucratic preparation process and restrictive consortium rules.

When the programme consortium is setting programme targets, there is paradox to match them up with funding criteria. Current criteria do not take into account the complex and systemic nature of the programmes. Further, they do not pay attention to the different types of objectives in the programmes. Instead, top-down coordination is based on the linear view of innovation, which emphasises the short term results such as publications, patents, computer softwares and new products. The systemic changes, which require for example new combinatory competences, collaboration between variety of actors and the long time scale have not been considered. As the following interview quotations reveal, the problems in steering reflects the absence of good measures which are suited to the co-production of service solutions, and which are capable of capturing their integrative nature and dynamic development process.

> "The traditional steering is based on concrete outputs of programmes, such as publications and software. But what we are actually developing in the programmes is comprehensive and holistic understanding to support the societal transition in the energy sector. Programmes support the new ways of thinking and new societal structure. But how we can measure these types of changes? It is paradoxical that there are no good measures for these systemic innovations. At the same time it is understandable that good measures do not exist yet. The changes would not be innovative and revolutionary if there were already measures for these changes". (Representative of University representative B)

> "The problem in steering of the programmes is the traditional measures and indicators. Funding organisation is still focusing, for example, on the numbers of developed products or reviewed articles. We must report how many new products we have launched during the programme's period and how many articles we have written. But the answer is none. This is because it has not been a target in our development. The targets for the programmes are something completely different, but the current measures are not able to capture the programme targets. Current programme targets are much more holistic than these current measures. (Representative of large company C)

The problems described above are, according to programme participants, manifest as contradictory targets. On the one hand programs are supposed to be risk taking

and revitalising industrial structures in the long term. On the other hand, the indicators, for example, expect short term readiness to launch new products and services into markets. However, according to the codes of funding, concrete service and technology development in the programmes is denied. As interview quotes below illustrate, the conflicting criteria make the preparation of the programmes schizophrenic and causes uncertainty about the role of different actors in governance of the network.

> "The problem is the contradictory funding criteria set by Tekes. On the one hand we are expected to promote export activities, but on the other hand we are not allowed to do any service or project development. Steering is schizophrenic because of contradictory and over-mechanistic targets (Representative of small company C)."

> "Current steering is based on conflicting targets. On the one hand the programs need to be long term and risk taking, and on the other hand programs should provide concrete short term results. I don't know if I should laugh or cry when thinking which targets to follow. The funny thing is that Tekes has forbidden us to develop concrete products. Anyhow, they are using it as a success indicator because they do not have any better indicators. But how can you get something which has not been set as target? Furthermore the steering culture is very much dependent on the personal opinions of the person in charge in the funding organisation. During our programme preparation the person has changed three times and every time that has affected the emphasis of our program. The former one stressed completely different things to the current one." (Representative of university A)

Also the timescale in steering was criticised by the programme's actors. Enhancement of systemic changes, such as the integration of user communities to provide real time environmental data, and the development of business solutions for environmental reporting, is a complex and long term process. The timeline for these changes is much longer, which cannot be captured by the current steering mechanisms. Therefore the reported results do not tell the truth of the attained results. Like the following interview quote reveals, they may even lead to the misevaluation conclusion of the success of the programmes:

> "The current indicators in steering may lead to the completely wrong conclusion of the success of the programs. They may even show that companies have not achieved anything in these programs. The reason for the wrong conclusion relates to the different time scales of steering and product development in companies. Launching the new products is a long term process. Companies publish the information of new solutions when launching them. A problematic thing is that steering in the funding organisation is based on targets which do not take into account different timescales. We have, for example, started several the product development processes based on the program results, but we won't tell about these results in public before launching the new products." (Representative of a large company D)

Current criteria are set top-down. Instead of top-down target setting, programme actors are begging for better interaction with funders during the programme preparation and implementation. According to interviewees, it would be essential to have a dialogue between top down and bottom up processes to create shared vision and to set targets for the development. In addition, the operational environment is continuously evolving. Therefore the targets and operations of the programmes need to be adapted to the changes in operational environment. That again emphasises a need for a continuous interaction. According to the interviews, the role of the funders should be as a supportive and collaborative partner, not a controlling administrator. Like the following quote reveals, continuous collaboration between top-down and bottom up processes, would promote the success of the programmes.

> "The bureaucracy and control do not enhance good quality research, business impacts or industrial renewal in this country. On the contrary, when we are aiming at radical and long term

> change the objectives should be defined in the collaboration of multiple actors including the funding organisation. This can not be done via a traditional bureaucratic process. Together we should set targets and identify the steps to reach targets." (Representative of large company E)

Interviewees believed that open interaction with funders would also improve the programme preparation. Currently the preparation processes are typically prolonged because of the bureaucracy, lasting in some programmes even for five years. Ineffective preparation has led to fatigue of company partners, and some of them have decided to opt out from the consortium. The loss of the central partners has led to the absence of the required competences.

Not only the poor interaction, but also the consortium rules are limiting the formation of an agile network and collaboration. Current rules are inflexible; they do not correspond with the modern way of development, which is based on continuously evolving networks. Currently, permanent participation in the consortium is a necessity: and network evolvement in the course of the programme is denied. That may, according to the interviewees, slow down programs activities. For example, programme actors perceived the need to empower the citizens and residents' associations into the development of energy solutions in the course of the "first generation" programmes. However, the integration of new actors into the ongoing programme was not possible, which, for example, prevented the collaborative development with citizens. In addition, in some companies – such as in start-up and high growth companies – the operations are fast and cyclic. As one large company (D) representative described: *"flexible entry into and exit from programmes is denied by the old-fashioned consortium rules".* That may prevent the some potential partners to take part in the collaboration, which again may cause the loss of required competences.

5. Concluding remarks

In this article, the first aim has been in examining the collaborative forms of service innovations in the environment and energy sectors. To describe the central characteristics of multi-actor collaboration, the concept of ServPPIN [Gallouj et al. (2013)] has been applied. The concept concretizes forms of co-production, in which the solutions to complex societal problems are based on the architectural innovations that integrate technological and service based novelties, trustful partnership between variety of actors and interaction between bottom-up and top-down processes. The second aim has been to increase understanding of the interactive and participatory processes – including the interplay between top-down and bottom-up approaches – without which it is not possible to develop innovation and scale them up in a complex system. Therefore the approach of social innovation has been applied [Harrisson (2011),Toivonen (2014)].

The study illustrates the new Finnish innovation policy instrument, SHOK, according to the analytical dimensions of ServPPIN. Results show that the SHOK can be characterised as a complex ServPPIN. It develops architectural innovations in a multi-actor collaboration to promote systemic change and industrial renewal in the area of energy and environment. For example, one of the targets is to define "a new architecture for a future energy system", and to achieve that a variety of technological and

non-technological innovations, such as new patterns in production and consumption of energy, have been developed.

Innovation dynamics within ServPPINs are the result of complex interactions between various actors having heterogeneous competences and goals [Djellal & Gallouj (2013)]. According to our results, the empowerment of multiple actors representing a variety of sectors, competences and world views is essential in creating the comprehensive picture of transition required. Further, integration of the variety of competences is needed to develop the solutions that correspond with these comprehensive needs. The novel innovation policy instrument has managed to create a forum that accelerates the creation of novel partnerships. However, in the current collaboration the representatives of public and private sectors are dominating. What is lacking is the broader understanding of citizens' needs and societal aspects. That may hinder the acceptance of novel solutions and hamper the sectoral renewal. Broadening the collaboration is crucial not only for the development but also for the implementation of better and viable solutions: the success on SHOK is manifested only if the new knowledge and innovations developed in the programs can be executed as nationwide decisions. Therefore more collaboration with users and better communication with decision-makers, is required.

A network's capacity for the creation of novel competences is mainly based on the informal trust between network partners. As the results show, building trust is based on a will to create an open, collaborative culture and a continuous interaction between partners. That requires changes in typical ways of working: mindset and organisational boundaries need to open up to integrate competences and divergent goals. These capabilities are not required only on the level of bottom up networks. Besides, new competences, new ways of communication, coordination and steering need to be developed at every level of the system.

From the viewpoint of the current governance system, the study reveals factors that threat the realization of targets in networked programs: ignoring their dynamic and long term performance is such a threat in particular. As a practical implication, the formal mechanisms of governance need to be developed to be adaptive, to strengthen diversity and horizontality in the development and to enhance co-production in networked world.

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