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# Preface

Sometimes writing is a challenging task when the target just doesn't stay still. Energy, especially renewables, is a good example of a constantly evolving topic. Today you write something, and tomorrow the news tells you that the game has changed. At the moment several regions in the world are unsafe and politically unstable, fracking is in a political turmoil in the EU but a bestseller in the USA, price of oil is below any predictions, nuclear power is making a comeback and Obama is pushing sustainability policies in the USA. The global economy is still in on a slow gear and Finland is trying to manage the stretched depression while pushing sustainability and local green energy. However, investors are making strong inroads into the renewables business due to developing technology and higher return expectations. This publication is published as part of the REmix – Renewable Energy Technology Mix research project 2011–2014. The project was managed by VTT Technical Research Centre of Finland Ltd.

REmix was co-funded by the participating companies, Tekes and VTT. The contribution provided by the companies was most valuable and fuelled the discussion and group work. A must for the REmix project was their expertise that did not only provide data for the calculations but directed the project from unrealistic goals to the realistic ones. For the small companies with new business and technology the networking activity with municipalities and more experienced companies provided new insights.

Tekes funding made REmix possible and enabled innovative collaboration around real cases. Organizations participating the project were (in alphabetical order) Aurubis Finland Ltd, Darrox Ltd, Elcon Solutions Ltd, GreenStream Network Plc, Janakkala Municipality, MW Power Ltd (owned by Valmet Corp), One1 Ltd and Senate Properties.

We would especially like to acknowledge Tuusula and Janakkala municipalities. This project would not have been possible without the activity and input from the case owners. The hands-on approach that made it possible for the company representatives and researchers to actually walk around in the case locations and discuss with case owners was most valuable. Grounding the discussion and proposed solution to the real world was the key to the rich debate.

# Contents

# List of acronyms

| | |
|---|---|
| CHP | Combined Heat and Power |
| COP | Coefficient of performance |
| DECC | Department of Energy and Climate Change |
| ESCO | Energy Service COmpany |
| ICT | Information and Communication Technology |
| IFRS | International Financial Reporting Standards |
| IIEA | Institute of International and European Affairs |
| ITER | International Thermonuclear Experimental Reactor |
| LNG | Liquefied Natural Gas |
| OFGEM | Office of Gas & Electricity Markets |
| PV | Photovoltaics |
| TTIP | Transatlantic Trade and Investment Partnership |

# 1. Introduction

Thanks to growing investments in research and development activities, energy technology is moving fast. Many interesting technologies, like better batteries and solar panels, are already working in labs and may become an even bigger game-changer. Futuristic ones like fusion in the ITER project and at the Skunk Works laboratory are at the proof-of-concept stage. However, the path of development of an individual technology is very difficult to predict.

These irregularities make it difficult for the energy industry, investors and public actors to outline long-term visions or roadmaps. Public initiatives following set political and economic priorities will guide energy market development. Legislation, subsidies and public procurement are a set of tools available to governments. Due to systemic complexity, finding a good enough combination is a process of trial and error that cannot be accelerated. Thus, countries leading the way may end up as either winners or losers due to the massive investments required and the long payback periods.

Renewable energy is growing in importance in area planning and development. The REmix project was based on the idea that renewable energy solutions have to become competitive on their own to be successful. Subsidies and other forms of public support that are pushing renewables nowadays will eventually be removed, and renewables will become a business among others. Companies with customer-oriented flexible offerings probably have a better competitive edge on international markets too.

The basic assumption was that the best total solution would be achieved by finding the best combination of several renewable energy technologies for each case. Collaboration would be sought to design the best business models and to reduce project costs. Workshops were held to find collaboration benefits, their conclusion being that the most important synergies were identified in the pre-planning and planning phases of a project, laying the foundation for successful and cost-efficient execution.

All this brings factors such as flexibility, collaboration, innovation, risk sharing and new business models to the forefront of business strategies. In this book, we will discuss many of these topics keeping this in mind. The aim is not to go into too much detail but to give an overview and to provide ideas for those involved in local and regional decision-making on energy.

We will also present calculations and business models through three case studies aiming at understanding the realities of regional development and its connection to energy. One of these cases was a large new residential area in planning and two were existing blocks in smaller conurbations. This approach made grounded group work possible by enabling us not only to sit around the same table but also to share the same cases.

## 1.1 Transition in energy markets

In the energy industry, globally renewable energy plays a small but growing role. Governments are putting pressure on non-renewables with sustainability demands, and this is changing the balance of the total environmental impacts and related costs of the various energy sources.

An example of this is the change in US LNG export policies, allowing more exports but adding an environmental requirement for companies. They also have to apply to the Federal Energy Regulatory Commission for approval and show that they comply with the requirements. Since this applies only for exports to countries with no free trade agreement with the US, and no EU countries are on this list of 20 countries, this has the effect of delaying potential plans of exporting LNG to Europe. Energy is probably one of the big topics in the ongoing TTIP (Transatlantic Trade and Investment Partnership) negotiations.

The share of renewables in gross final energy consumption in EU28 in 2012 was 14.1%, including the quite stable percentage of hydropower. In electricity production only, renewables accounted for 23.5%. (Eurostat, 2013)

World Bank statistics show that the share of hydropower in electricity generation (2012) was 23.9% in Finland, 1.6% in the UK, 3.5% in Germany and 6.5% in the US. The potential of hydropower is unequal and varies based on natural resources but also on legislation and environmental priorities. As in the Nordic countries, there is still unused potential, but that potential is not accessible for environmental and political reasons. This has a strong impact on renewables strategies and goals in various countries.

The impact of the development of standards and regulations for renewables may have a negative business impact in many countries. As in any other maturing industry with a wide range of competing solutions and services based on different technologies, the jungle of rules easily becomes too complex to manage. This 'jitter' creates unbalanced pros and cons for businesses based on different technologies.

Energy related business opportunities thus differ widely between regions and countries. Not only sources of energy but also legislation and regulations may vary, from the very strict to the flexible. Also, international organisations that govern prices and production volumes, for instance, have the power to change the economic and operating environment globally at very short notice. The decisions of individual countries usually have only a limited impact but potentially a strong local one. Natural disasters like hurricanes and earthquakes may have short-term market influences.

This development is not progressing in the same way in all countries and is thus also connected to the markets, politics and global business in general. The challenge for investors, both public and private, is to identify and understand the roots of the symptoms and to make decisions based on them. This uncertainty caused by complexity and rapid technological development can be seen in the tendency to invest only in projects with a short payback period of two to five years, unless secured by a public body such as a government.

Some examples of the complex cases with root causes that are difficult to identify or control include: shale gas economics and related political decisions, planned changes in federal Investment Tax Credits in the US combined with local policies, Ukraine, delays in Finnish nuclear energy projects, developments in the UK North Sea oil field, the Middle East situation, policies of African countries rich in oil and gas, the success of Germany's Energiewende, economic development in China and its impact on overseas investments, whether to drill for oil in the Arctic Ocean or the investment policies of the state-owned Norwegian Oil Fund with an estimated value of EUR 610 billion (2014).

The above represents only some of the factors making the energy business unstable and risky, especially for renewable energy companies not able to spread their risk. At the moment, the uncertain economic situation is also affecting not only decisions on direct energy investments but also subsidies and tariffs. On the other hand, more and more energy is needed to meet the needs of the growing economies in particular with competitively priced energy. This situation easily pressures governments, companies and investors to channel their energy investments into more predictable alternatives such as nuclear power and natural gas.

Recently, there have been worries about the decline of investments in renewable power, for instance in the Medium-Term Renewable Energy Market Report 2014 issued by the International Energy Agency (IEA).

A good survey of various energy production cost estimates may be found in Wikipedia (http://en.wikipedia.org/wiki/Cost_of_electricity_by_source), and attention is easily drawn to the fact that they do not agree.

## 1.2 Global energy – act locally, watch globally

Renewable energy is a hot topic almost globally. It is at the centre of heated political discussion, driven by both emission control and economy. In the 2013 Australian federal election, the opposition promised to cut spending on promoting renewables and won. In China, more and more is being done for the environment, but the sheer size of the problem and the growing demand for energy is undermining these efforts. In the USA, shale gas plays a significant role in replacing coal and reducing emissions but has its own challenges and is by no means a clean final choice. In Spain, an additional tax was introduced for private rooftop solar panels to secure funding for national grid maintenance after the cost of buying power from the grid was strongly reduced as a subsidy for installing solar panels.

A common theme in all discussion concerns the negative impacts on many existing energy companies and their profitability. Often the existing energy system and market is more or less disrupted by strong and fast subsiding actions and new legislation on renewables. In other countries, the slowness of political shift towards renewables is criticised, but this slow rate also allows time to better understand the impacts of actions and thus to make more informed decisions. Time will tell whether in the fast track or the slow lane was the better strategy.

According to the IIEA, the EU imported 54% of its energy in 2011. EU-level directives and consensus are needed to make the energy ecosystem transparent, predictable and coherent. Business will exploit local subsidies and go where the best deals and the highest profit are available. This is business as usual, but common frameworks and ground rules are required to ensure European-level value creation. There are always loopholes in legislation, and they are being investigated and eliminated by the authorities. The VAT "missing trader fraud" allegations in power trading and carbon emission trading, investigated by both EU and US authorities, are a case in point.

For companies, legal tax planning is important, and though legislation for limited liability companies is quite uniform in EU, limited partnership companies are taxed differently. Financial instruments such as leasing may be treated differently in national legislation and in IFRS, which affects balance sheets and thus taxation.

Next we will look more closely at two countries, the UK and Germany, to highlight challenges for the wider introduction of renewable energy.

### 1.2.1 UK

There is a strong political push for green energy in the UK. Several government actions have been seen, but their impact and especially their efficiency have been questioned. At the moment, the entire range of energy sources is being discussed in the UK, with choices ranging from nuclear to shale gas and renewables. The UK imports a large part of its energy (see e.g. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/556194/Total_Energy.pdf), and fossil fuels play a major role in the energy supply. Reducing energy imports and replacing them with domestic sources is a huge business opportunity and energy security topic, not only politically but economically too.

Oil and gas production in the North Sea fields has been decreasing thus raising discussion for example about tax reductions to keep the industry in the area. Nuclear power plants are growing old and need to be decommissioned. It has been estimated that by 2020 it will be a challenge for the UK to ensure a 100% electricity supply. Fracking is very unpopular in the UK. A survey by YouGov shows that 62% favoured wind and 19% favoured fracking in their council area. At the moment, political discussion is heating up about sharing the income from fracking wells between government, local communities and the oil and gas companies.

However, the million-dollar political question is not in the technology or energy sources but in the subsidies. For instance, the government has promised to pay over £90 per megawatt hour for 35 years for electricity produced by a new nuclear power plant if constructed. This was double the wholesale market rate. When at the same time also wind, wave and bio energy are being supported, the total bill is substantial.

Having said this, we must remember that if done right the new knowledge created will benefit the nation and especially in the long run give a competitive edge not only to the UK but to the EU as a whole. Also, the investments attracted to the UK and the employment created boost the economy.

The environmental targets set in a government paper in 2003 to advance sustainability were quite challenging. The subsequent 2008 Climate Change Act, followed by the 2011 Carbon Plan, aims to “reduce greenhouse gas emissions by at least 80% (from the 1990 baseline) by 2050”. However, the energy production industry does not have to meet these challenges alone, since reducing demand for energy has a strong role in these plans as well.

The conclusion from all this is that less power is needed. The distribution network in the UK has been built for an energy landscape with a few big power plants, using an extensive mileage of power lines to bring energy to customers. A challenge that the UK shares for instance with Spain is that the less power is transmitted the less income there is for maintaining the grid. This is where taxation comes to the rescue, making this politically correct and without making those people and companies angry who have just invested in solar panels to produce local energy at site.

All this is hugely expensive for energy users. The energy-intensive industry will have a hard time convincing owners and investors to keep running their businesses in the UK.

A transparent and clear framework in the energy ecosystem is required to attract investments. There are a lot of ifs and buts on the roadmap to economically competitive distributed green energy.

The DECC (Department of Energy and Climate Change) launched the Community Energy Strategy at the beginning of 2014. According to Local Energy (Local Energy 2014) the highlights of the strategy include:

- A new Community Energy Unit within the DECC to ensure that the potential of Community Energy is reflected in everything the Department does;
- The launch this spring of the Renewable Heat Incentive for domestic properties;
- Doubling the Feed-in Tariff maximum capacity ceiling from 5MW to 10MW for community projects (subject to consultation in spring 2014);
- A new £10 million Urban Community Energy Fund (complementing the £15 million Rural Community Energy Fund launched in July) to provide 'at risk' finance for community energy projects;
- Links to the £80m Green Deal Communities scheme, which provides a new opportunity for community groups to partner with their local authorities to get involved in improving energy efficiency in their local area;
- A commitment to work with OFGEM and community energy groups to seek to enable community energy groups to become direct energy suppliers.

Government activities supporting implementation of renewables in the UK are not a new thing. One of the challenges has been how to adjust a support mechanism with the available funds. Government has been forced in one instance to pull the plug since demand was higher than anticipated due to "too good a deal". This is an excellent example of the continuous learning process that is required to adjust support mechanisms to match the developing technology and the changing energy market.

### 1.2.2 Germany

In Germany, “Energiewende” officially started in 2010 when the energy reform plan was formed. This was a long-term political decision aiming to make Germany the leader in the new energy economy based on low energy consumption, low emissions and a high percentage of renewables in the energy production portfolio. After the Fukushima accident, Germany decided to abandon nuclear energy. As a result of these decisions, the available combination of energy production options was severely restricted.

The subsidy system in Germany is partly related to the amount of green energy produced. This means that the more green energy is produced, the more it costs the government. Renewables implementation in Germany has to slow down, since current progress is becoming too expensive and industry will go abroad looking for less expensive energy if rebates are cut. The alternatives to the renewables available in Germany are local shale gas, imported LNG and electricity imports from other EU countries.

The challenge of this change is to keep the price of energy competitive. The development of technology and energy systems is probably taking more time than was estimated. Also, the percentage of traditional energy sources such as coal-fired power plants has remained high, while it is becoming less profitable for the energy companies running them. It has turned out to be very expensive to keep the power infrastructure reliably running with such a high percentage of renewables in the system. One part of this package is that in 2015 Germany has decided to keep some of the coal fired power stations as a reserve and in a state of continuous readiness which means income to the energy companies and was seen as an increase in share prices.

One of the structural challenges in Germany is the scattered geographical location of heavy industry and the big wind and solar parks in the northern parts of the country. This has required and will so also in the future heavy investments into transmission lines and grid management.

However, if expensive, the change has been popular in Germany. Partly this is due to the ownership structure, where private people and cooperatives play a significant role. But also the general opinion in Germany is pro Energiewende.

But there are different opinions about Energiewende and UK energy policies that can be found on newspapers and on the internet. Arguments are good on both sides and so often “Time will tell” who is right and who is wrong. It is true that some part of discussion is about terminology, like are some interventions (e.g. feed-in tarifs) subsidies or not. The fact is that the energy scene is currently, and will be for some time, so complex that your guess is as good as anyone’s.

# 2. Renewable local energy as business

Renewable local energy has the power to change the whole energy landscape and infrastructure. This change is not going to happen overnight, and it may never happen in full scale, but we need to look into different scenarios as possible pathways. The change would not only be technological; the impact on business models and energy strategies would have extensive ramifications, and we need to understand them in order to identify the early signals of change.

The prerequisite is that the technology for local energy production must become as robust and economically competitive as large scale energy production. However, this is not enough. For any new technology to become popular, the mind-set of both decision-makers and the public at large has to change. At the moment, political discussion, lobbying and populism are dominant, and we need to see beyond this ‘support-driven period’ of the renewable-energy ecosystem.

At the moment, we see a market correction taking place after a lot of hype, and many clean-tech investments are losing value. Some argue that this is a lasting trend. However, cycles are short in emerging industries, and corrections characteristically restore the market to a sound footing. With many uncertainties on several levels, energy visions provide many new business opportunities for those who dare to take the risk. But both the probabilities and timespan of new technologies are difficult to predict.

All this makes the business and economy landscape very difficult for companies and investors in terms of making decisions about long-term investments. If an investment has a repayment period of no more than five years but a much longer operating life, the initial investment is low-risk and financing is easy to obtain at a reasonably low interest rate. With a longer repayment period, the cost of financing skyrockets unless scrutiny-proof securities such as long-term contracts with a municipality are available. However, all this is sharing, avoidance and transfer of risk, not a final solution.

All of the above means that in business concepts, things like alluring investors, benefiting from government incentives and cost sensitivity become important but may be in conflict in short-term and long-term planning and risk management.

From the national perspective, the profitability of business, though very important, is not the biggest challenge. If companies, funding organisations and research organisations are not certain enough about the near or middle future, investments and innovation activities will decrease.

## 2.1 Business concepts

There is a large number of potential business models for each case. The combinations can be very different or differ only in small details. Also, there is no single absolutely correct answer; some are better, some are worse. Thus, the final model will be a result of a joint iterative decision-making process influenced by real-life issues that emerge during this process.

Some distinct boundary conditions exist in every case, excluding some versions of business models. These may be budget limitations (too expensive), site limitations (no room for infrastructure), time limits (winter coming) or legislation (emission regulations).

There are two basic scenarios in building business concepts: the assumption that the 'energy universe' is expanding and the assumption that it is shrinking (fracturing).

If it is expanding, the energy system and infrastructure will continue to grow to support transmitting electricity, heat and cool typically from large production sites to end users. This is the common scenario that enables the pan-European renewable energy vision based on smart grids. In this scenario, local energy will play a smaller role and policies will aim to support large scale solutions. An example of this is the German vision for the north of the country, with large wind and solar farms producing energy for the energy intensive industrialised southern states transmitted via heavy power lines not yet constructed and objected to by residents.

If it is shrinking, energy will be produced near customers and the need for large-scale infrastructures such as 400kV transmitting lines will fall or mostly serve energy-intensive industries. This scenario requires local energy that is both economically feasible and reliable. At the moment, grid power is at the very least required as a backup to kick in when local energy has no wind or sunshine to utilise or when fuel runs out.

There has been a lot of discussion about off-grid electricity production by private households, especially in Spain and the UK. When customers need less power from the grid, less power is transmitted and less money is made. However, income is needed to maintain the grid and to secure the power transmission system. The answer to this has been to charge extra from those producing their own power, and thus you pay tax for the electricity that comes from your own rooftop. After major support for rooftop solar panel installations driven by emission reducing policies, this retraction has been a cautionary example of energy policies 'jumping the gun'.

### 2.1.1 Business concept framework

We have created a framework for generating and comparing business concepts (see Table 1 for further information). The selection of parameters is based on both literature study and the results of project workshops.

The starting point for the model is to assume that the company and partners have the technological core capabilities and competences required. This is thus excluded from the model, and the focus is on 'making business'.

Table 1. Business concept framework table

| **Parameter** | **Description** | **Options** |
|---|---|---|
| Customer | For local energy, many customers can be identified. These are often legal entities but may also be individuals. Often one energy provider has several types of customer. Customers can also be located outside the local area. | Municipality<br>Company<br>Private person<br>Association |
| Ownership | Ownership can vary greatly. The multitude of combinations and ownership of different parts of the production and distribution infrastructure and business adds dimensions. Only case-relevant options are included in this framework. | Municipality<br>Municipality + energy company<br>Limited company |
| Income | A steady income is required to make a solid business case. To convince potential investors and financing organisations, long-term contracts with sustainable customers are needed. | Cash flow<br>Price subsidies |
| Financing | Financing is required to cover both investments and working capital. Related to ownership and income. | Cash-flow<br>Own capital<br>Investor capital<br>Subsidies<br>Shareholders' equity<br>(Municipality, energy |

| | | |
|---|---|---|
| | | company, …) |
| Pricing | Pricing is the major procurement decision criterion. In renewables, qualitative criteria are gaining weight, but commonly these are also rooted in monetary mechanisms such as subsidies or market image. | Cost-based, market-based and/or value-based. |
| Fuel | Fuel has a major impact on the business concept. Predictability of availability and price development varies, and also its impact on branding and marketing. Also affects the area, thus selection of location. | Coal<br>Natural gas<br>Peat<br>Pellets<br>Wood chip<br>Ground heat<br>Solar<br>Wind |

Customer needs are the starting point for any modern service business. The power of customers, trends and public opinion has been the driving force behind most new successful business ideas. Is this also happening in the ‘old-fashioned’ and rigid, production-oriented energy industry? This is possible. However, it seems that price is still the number one decision criterion for both consumers buying energy and parties making investments in energy infrastructure.

Ownership is perhaps the single most interesting factor in the energy business. In energy, heavy infrastructure such as the main grid, gas pipes, production facilities and distribution networks create stickiness that slows down any change. On the other hand, many investments such as oil-drilling derricks have a surprisingly short average payback period of 2–3 years. After this, operation costs are the major decision criterion, and transferring to new businesses is not hindered by old capital but the power required to launch the new.

In municipalities, however, the situation is quite different. A municipality has a responsibility to provide basic services like heating and water. Therefore the requirements for the payback period are not necessarily the same as in a case of a private company.

Income can be generated by selling heat, cooling, added value services or power in case of a CHP plant. Price subsidies are seen as a part of income.

Financing is often the most challenging part of a project. See chapter “2.2 Financing” for more information.

Basically, there are three pricing mechanisms: cost-based, market-based and value-based. However, combinations are common and different pricing can be used for different parts of an offering. However, it is important to keep the pricing mechanism simple. All business parties need to understand the pricing principles and to be able to estimate and manage the related risks for their own business.

Cost-based pricing is an excellent choice for a small entrepreneurial company providing local energy as service to a reliable long-term customer such as a municipality. Costs need to be linked to an index or directly to the production costs. This has the effect for instance of transferring the risk related to the fuel price to the customer, but the motivation to make energy production more effective remains with the service provider. The 'Mankala' business model, a special case of cost-based pricing, is a type of cooperative where all energy production costs are paid by the owners.

Market-based pricing is basically price competition with other providers on the market. Whereas in cost-based pricing the margin sought is added on top of costs, in market-based pricing a price is given and the business is profitable if costs are less than that. The success factor in this case is targeting the right market segment and creating a competitive offering.

Value-based pricing is important for the renewable local energy business. However, coming to an agreement of 'value' is challenging, not least because of the customer's in-house difficulties to evaluate and put monetary value on qualitative values. A simple case is a consumer valuing sustainability and energy independence and thus being willing to install rooftop solar panels, which as yet are unprofitable. A complex case is a municipality developing a new residential area and considering the payback period of the investments in local energy and sustainability.

Costs can be seen as part of pricing logic and are thus not presented as a separate row in the table. Costs can include e.g. procurement, logistics, storage, waste management and facility management costs. Local employment, tax income and other direct or indirect effects on the local economy (both place of use and place of fuel production) may be included if necessary. Predicting future cost levels is vital but very difficult. Fuel is addressed separately because of its manifold role.

Fuel is needed to make power or heat. For simplicity, we use 'fuel' as a blanket term, also covering primary energy sources such as solar and geothermal. Fuel has three different top-level properties: cost, security and impact. Security includes both short-term and long-term availability of fuel. The energy system cannot be transformed overnight; this makes the fuel flexibility of the designed system important. It is very difficult to predict why and when any big change will take place in the open market-based system, although afterwards it is easy to see the path leading to the point. The change may be a sudden and surprising change in technology, an international crisis or a change in policy.

## 2.2 Financing

Local renewable energy and energy efficiency solutions are both major trends in the current energy sector globally, the main reasons being security of supply, self-sufficiency, environmental aspects and economic viability both for end users and at the national level. In theory, all investments that generate a positive net present value (i.e. the present value of discounted future cash flows is equal or larger than the initial investment) should be realised. However, in practice it can be seen that especially within these investment types, many economically justifiable investments remain unrealised. This chapter includes firstly a discussion of the several barriers to local renewable energy investments; secondly, a discussion of actual and potential ways to finance these investments, including end users, energy supplier and third-party financing; and finally, the practical main parameters determining the 'bankability' of a local renewable energy solution are identified and briefly discussed.

### 2.2.1 Local renewable energy investment barriers

There are many ways to categorise investment barriers for local renewable energy investments. One helpful way is provided by Cagno and Trianni (2013), who divide the barriers into two categories: company (or end-user) internal barriers and external barriers related to circumstances surrounding the company (or other end-users).

External barriers:

- Market barriers: Market structures and business models are naturally developed to support conventional solutions. However, they may not always be suitable for new solutions such as local renewable energy investments, creating shortcomings related to the efficient diffusion of technologies, information and risk management, for example.
- Government / regulatory barriers: In the same way as market structures, policies and regulations are not always in line with the specific needs of local renewable energy investments. Small investments may face unnecessarily burdensome and complex regulatory frameworks, and the technical requirements and standards may not have been designed having local renewable energy investments in mind, for example.
- Technology suppliers: This could also be generally called 'technology barriers'. New technologies often come with a real additional technology risk compared to conventional technologies. However, in many cases a lack of information, awareness, references etc. may cause additional 'perceived risk', preventing investments in local renewable energy.
- Energy suppliers: Due to the above reasons, but also due to concerns about market position and control, traditional energy companies face op-

erational and strategic barriers to implementing local renewable energy projects.

- Capital suppliers: From an external perspective, the capital supply barrier can be generally linked to (1) high real and perceived risks for the financial sector (due to above reasons), which make it difficult for financiers to evaluate and price the risks, and also high transaction costs due to the typically small size of local renewable energy investments and financiers' typically heavy investment appraisal procedures designed for conventional (and larger) investments.  These barriers may lead to a situation where there are no acceptable required returns or other terms of financing, and the investors cannot process the investment proposals at all and thus cannot provide financing on any conditions.

Internal barriers:

- Economic barriers: Some local renewable energy investments are not profitable at all, whereas some of them may be profitable but not profitable enough to overcome the investment barrier. In addition, there may be additional risks and transaction costs (due to novelty and small size), meaning that the profitability of such an investment must be clearly above the profitability of an alternative investment in order to be realised. Secondly, the availability of funding is usually restricted, and in such cases these investments (from the end-user internal perspective) may often be not realised as 'non-core' investments. Although more obvious in case of companies, this applies to households and public organisations too.
- Organisational barriers: Organisational barriers in end-user organisations affect all energy-related investments. There may be no separate responsibilities for managing energy issues, and they may have generally low status in an organisation (broadly this applies to companies, but also to the public sector and households). Also, decision-making may be complex, and there may be conflicting interests (for example between the public sector and housing companies) preventing investment decisions in local renewable energy investments even if economically justifiable.
- Behavioural barriers: Empirical behavioural investment research has shown that investments that may be labelled 'strategic' are often preferred over other investments such as replacement investments or investments in improving productivity (if this is not a core strategic target). In addition, research shows that expansion investments targeted at increasing the revenues and market share are preferred over other investments. Both these general findings explain why local energy solutions face a difficult competitive situation within an organisation. It is also a behavioural issue that it is generally easier to apply old routines than look for new solutions. it typically requires specific interest from

an individual to start planning a new solution instead of repeating the old one, unless specifically incentivised to do that.

- Technology-related barriers: Technology risk (real or perceived) may prevent organisations or households from implementing local renewable energy investments. Sometimes the references of these solutions are limited or controversial. It may also be that the technology supplier(s) are not able to provide technical, mechanical, performance and other guarantees satisfactory to the end-user, or the supplier is financially too weak to provide such guarantees in a credible way. Energy solutions in general often entail high initial costs and thus bind the end-user to the selected solution for a long time, which increases perceived technology risks and makes end-users more cautious about the performance of new solutions in the long term.
- Information barriers: In addition to their novelty and the information barrier related to that fact, local renewable energy solutions are currently also evolving rapidly. For example, the cost of solar PV has decreased dramatically several years in a row, and the reliability of many solutions has increased. It is likely that most end-users who are not experts in renewable energy are not aware of the current status and attractiveness of local renewable energy solutions. In case of conventional energy solutions developing more slowly, the information barrier is lower. This challenge also contributes to awareness and competence, as well as perceived risks of local renewable energy investments. It may also be more challenging to even find information about newer solutions compared to more conventional ones.
- Competence and awareness barriers: These barriers are related to the above barriers, especially the information barrier. In case of new solutions, there is typically lack of expertise to develop the project, evaluate alternatives, and in some cases to operate and control the solutions after the installation of the solution. The latter challenge is especially related to project types requiring active operations such as bioenergy-based investments (wood chip or pellet boilers, gasifiers, anaerobic digestion of biowaste, etc.). In case of centralised solutions, all operative issues may be left with the energy utility, but even in case the operation and maintenance of a local energy solution can be outsourced, it poses an additional risk for the end-user with insufficient expertise.

The above barriers are to a large extent overlapping and interrelated. Furthermore, of the above external and internal barriers only the capital supplier related (external) and economic (internal) barriers are directly linked to financing issues. However, all the other barriers have a remarkable indirect impact on the financing (and bankability) of local renewable energy investments, too.

As the local renewable energy generation assets are closely linked to the end-user (single household, residential area or municipal, industrial and commercial buildings) both physically and operationally, in many cases it would be the most natural alternative that the end-users finance and own the installations by themselves. Because of the above barriers, these investments, although often profitable and otherwise justifiable, remain unrealised. In addition to removing investment barriers from end-users, another increasingly important alternative is third-party financing. In a third-party financing structure, an external investor provides capital for the investment and receives the revenue generated (or part of it, enough to provide sufficient return on investment). Typically, there is a fixed term financing period, after which the equipment may or may not be transferred to the end-user, depending on the specific contract structure.

In some cases (although quite rarely), an investor may invest directly in a local renewable energy investment, but due to the typically small size of these projects, and due to the financial sector's appetite and need for scale, third-party financing is typically channelled through specific entities pooling financing and projects into larger portfolios, focusing on these investments and having also the needed specific expertise. As typical examples (not an exhaustive list), three models may be described:

**Installer / project developer financing model.** In this model, a company operating in the market as an installer and provider of local renewable energy systems pools funding to finance the projects delivered by it to its customers. Installers operate as normal limited liability companies and channel the funding through themselves or directly from the source of funding to the end-customer. The advantages of this model include that the installer / developer typically look to expand their business and building larger portfolios and customer base, creating the scale needed by the financial sector. In addition, these companies have the skills needed to identify, sell and implement projects, which often is needed (due to information, competence and awareness barriers within the customers). From installer / developer companies' point of view, this model is attractive, as financing can be used as an additional sales argument to sell projects to customers. As the installer can offer the whole package, there is little or no action left for the customer. The most successful such models can nowadays be found in the US solar PV market, where for example SolarCity and Vivint are the two leading residential PV installers controlling the entire value chain and being thus able to provide delivery of the project from the identification of the project to installation and financing, and even to operation and maintenance. In general, this model has turned out a winning concept in the US solar PV sector.

**Limited partnership model.** The LPM model means in practice an ordinary fund structure. In the structure, a limited partnership is formed to pool the funds. The fund is managed by general partner (a fund management company), which operates in an autonomous way within the partnership agreement and investment strategy agreed with limited partners (investors). The lifetime of such funds is usually clearly restricted to 10–12 years; the funds are collected at the beginning, and then no more new investments are taken in. The partnership itself is a tax neutral structure, and the investors manage the returns from the fund as part of their other income taxation. Such funds can in some cases have their own technical project development and implementation expertise, but quite often they only act as investors and rely on specialist project developers and or utilities / industry in lead generation. One potential limitation of such structures is that the typical lifetimes in case of holding energy assets is rather limited, whereas the investments typically have a long technical and economic lifetime. Also, in local renewable energy investments the needed holding periods can easily be 10–15 years or even more, and then some additional refinancing and/or ownership arrangements may be needed in the LPM. The LPM model may also limit the debt financing available for the portfolio. However, the legislation governing limited partnerships varies considerably between countries, and therefore the details can be very different in different countries.

**YieldCo model.** YieldCos are corporations / limited liability companies, holding a portfolio of generation assets aiming at providing stable long-term revenues for its investors. A YieldCo typically contains only de-risked operative assets, while the project development and construction phases of the projects are managed by other entities. Typically, a YieldCo is formed by transferring an already existing operative portfolio into it while raising new equity for new investments. The equity can possibly be raised at close to debt rates due to the low risk of the portfolio. In addition to the low risk portfolio, the required return can be lowered by providing liquidity for the shares through public listing of the vehicle. Such a trend was strong within renewable energy assets in USA and the UK in 2013–2014, as investors have been looking for stable long-term returns outperforming the currently low bond yields. This structure has so far been relevant mainly for larger scale renewable energy assets in the wind and solar PV sector, but recently there have been public listings of YieldCos containing and targeting smaller and more diversified projects such as energy efficiency and local energy solutions. YieldCos aim at active and stable ‘fixed income type’ dividend distribution to their investors.

The above structures involve raising and pooling funds – both equity and debt – for investments in renewable energy projects. These investment vehicles may apply various instruments to invest the funds at the project level. In principle, these instruments can be numerous, but the following three tend to be very typical in the context of local renewable energy (and also energy efficiency) investments:

**Hire-purchase financing:** Hire purchase means in practice providing credit for the customer on behalf of the seller / supplier and paying the bills on behalf of the end-user. In the arrangement, the financier pays the bills related to investment, so the technology providers and other parties in implementation stage are paid normally during the construction and commissioning process of the project. On the other hand, the end-user has to repay the credit during the operational phase of the project. The only risk the financier is taking is the counterparty risk of the end-user. Therefore providing such financing is much easier and less risky than financing which also covers certain operative, technological and/or market risks, for example. In the case of local renewable energy projects, the payback times of investments may be long, which may require long repayment periods. This creates a need for a special financing vehicle (such as a fund), as banks may not be able to provide such long-term loans at all or not at competitive rates, due to the aforementioned financing barriers. The special hire-purchase agreements designed on the solar PV market in USA, for instance, may have repayment periods of up to 20 years. In this arrangement, the equipment is shown as an asset of the end-user and the agreement is a liability of the end-user, therefore like a loan.

**Lease financing:** Leasing is an arrangement where the financier (lessor) owns the equipment and rents it out to the end-user (lessee). The latter then pays a rental payment (typically fixed) to the former during the leasing period. Typically, there are certain options for the lessee to cancel the arrangement during the contract period, but at the end of the leasing contract period the lessee should not have the obligation to acquire the asset or continue the contract period. Instead, the lessor has a real residual value risk of the equipment. Also, the leasing agreement is quite easy for the financier as far as it is comfortable with the counterparty risk, as leasing agreements (similar to hire purchase) in this sector typically do not include operational, technical or market risks. However, for the financier it is riskier than hire purchase, as the latter obligates the end-user to pay the whole price for the equipment including the cost of financing, whereas in leasing the financier has (at least in principle although not always in practice) the residual value risk, as the equipment will have residual value and not be fully paid for at the end of the contract period, and the end-user will not have the obligation to redeem the asset. In a leasing arrangement, the asset is shown on the financier’s balance sheet (and the lessor will also have the right to depreciation benefits), and the rental payment is a tax-deductible expense on the lessee’s income statement. Leasing may be difficult in a case where the equipment to be leased is not a clearly movable asset, as the case in energy generation assets often is. However, leasing works even in large power plant investments where the key components such as turbines and generators may be financed through leasing. Therefore, leasing should be an applicable alternative also in case of local renewable energy investments, at least for financing certain parts of the investments. Another source of uncertainty related to leasing agreements is related to accounting standards. For example, the Finnish accounting standards differ considerably from those of IFRS, and both of these are in constant change with regard to treatment of leasing agreements in financial statements. There are ‘mainstream’ leasing companies in the market, such as commercial banks’ leasing companies, car leasing companies, office equipment leasing companies, etc. However, all these mainstream leasing companies face difficulties in local renewable energy investments. The non-movable nature of parts of investments, lack of technological and market understanding, as well as often needed long leasing contracts provide a difficult challenge for these financiers. Therefore, specific leasing companies and funds have emerged that are specifically tailored for providing leasing agreements for local renewable energy investments.

**Power purchase agreement (PPA) model: The** PPA model is the most advanced and demanding form of financing from the investor's perspective. In contrast to hire purchase and leasing, the third-party investor assumes operational, technical and market risks related to the generation asset and effectively becomes an energy seller to the end-user. In this model, an installer, equipment supplier or similar party delivers the project to the end user, and the investor pays the investment costs. After the commissioning, the investor receives a return on the investment by selling the generated energy to the end-user. In this arrangement, the asset is obviously on the investor's balance sheet. Depending on the contract structure, the risks can be transferred more to the end-user's or investor's side, but generally these agreements should have higher cost of financing due to a higher risk for the investor. in the context of local renewable energy investments, the financier is often the installer company, which has the PPA structure as an alternative to be offered for customers who want to pay the investments in their energy bills rather than paying the upfront costs. This structure is therefore typically related to the 'installer financing model' described above, and this model has been very successful for example on the residential solar PV market in USA. The PPA model in local renewable energy investments is analogous to the ESCO financing model in energy efficiency investments.

The above examples (or principal financing structures) of third-party financing instruments in local renewable energy investments may each be competitive in different circumstances and within different customer segments. Some customers may for example prefer to have the assets on their balance sheet in order to have the right of depreciation, or for VAT reasons, in which case then hire purchase may be more attractive. Others may instead prefer to have minimal liability and balance sheet implications and are willing to pay a higher premium for that, in which case the PPA model is more attractive.

When evaluating the financing options in local renewable energy investments, there are certain practical characteristics in the projects that are the most crucial ones affecting the choice and design of the third-party financing. These parameters are listed and briefly discussed in the following. This is not an exhaustive list but rather a practical example of the basic issues that typically arise early in the evaluation process:

**Counterparty:** The counterparty is (normally) the end-user and the beneficiary of the investment who shall repay the financing including the cost of financing. The more creditworthy the counterparty, the easier the finance and the better the terms. On the other hand, even a good project may be rejected by financiers due to a weak counterparty. It is also possible to form a specific project company and finance that project separately, with no recourse to the owners' balance sheet. In this arrangement, the external financiers rely on the cash flows of the investment only. Also, all the physical, financial, contractual and other assets (anything that can have collateral value) are pledged as collateral. However, due to high transaction costs project finance is only suitable for large investments (tens of millions of euros), and therefore seldom a realistic arrangement in case of local renewable energy investments. Also, the collateral value of the project assets may not be sufficient as such to back the external financing, which again calls for a strong counterparty (typically the end-user).

**Investment cost:** Investment cost means the scale of business for the investors. The size of the investment defines for example the spectrum of potential investors. In case of a larger investment, the spectrum is typically broader, whereas smaller investments attract only a limited number of investors (possibly specialist funds and other specialist investors only). Third-party investors also do not usually want to assume any investment cost or construction risk (cost overrun, delay, etc.), and therefore either the supplier or end-user are required to take this risk and provide sufficient guarantees that they can credibly cover this risk.

**Revenues, operative costs and cash flow:** Operative cash flow (in relation to investment cost) is naturally the most important parameter defining the profitability and the amount of financing that can be available for the investment. Investors typically require fixed revenue streams in the form of long-term fixed-price energy sales and purchase contracts (with the end-user) and long-term fixed-price operation and maintenance agreements (with the technology company, operator company, etc.). Obviously, this risk is crucial in the PPA model, whereas it has more limited relevance in leasing and hire-purchase models. However, also in the latter structures the investors require a solid investment case.

**Technology / solution:** A technology must be proven in order to get third-party financing. In case of immature technologies and limited reference base, the financing is typically provided to a greater extent by the project owner / end-user or technology supplier, and to a lesser extent by third-party investors. It is also typical that third-party investors require technical and performance guarantees for the whole financing period.

**Technical and economic lifetime of the technology / solution:** The maximum length of the financing is determined by the technical lifetime of the investment. If the technical lifetime is 20 years, for example, it is not likely that a third-party investor (especially in leasing and hire-purchase arrangements) would commit to funding for the whole lifetime. Instead, the maximum length of the financing would probably be 10–15 years at the maximum.

**Direct payback time:** Although direct payback time is not a good indicator of the profitability of the project, it gives a good picture of the cash flow profile and also the required profile of the financing. If the payback time is three years, the project needs considerably shorter financing compared with a project with seven years' payback time. Investors typically know their requirements for the aforementioned risk profile issues and have thus also their targeted price for financing; based on this, they can quite quickly see from the payback time how long a financing contract is needed in the project to enable repayment with the cost of financing.

**Internal rate of return (IRR):** Internal rate of return is tightly linked to the payback time of a project. IRR calculation, however, it also involves a time variable: the IRR is the higher the longer the calculation period used is. From this perspective, investors may typically check how long a period is needed for the project to reach the IRR level required by the investor. The IRR is at the same time the maximum price for financing. If IRR is below the cost of financing, the project is not viable.

## 2.3 Risk assessment

### 2.3.1 Risk and risk assessment

Risk can arise wherever there is a potential source of damage or loss, i.e. a hazard (threat), to a target. Nowadays, the subject of risk plays a relevant role in the design, development, operation and management of components, systems and structures in many types of industry (Aven & Zio 2011). In the case of planning a new residential area, it is important to consider and manage a large range of risks related to planning and executing the construction project. The effects of the risks may concern people, environment, corporate finance or operations. When choosing energy sources and energy solutions for the planned area, the risks related to the various options should be carefully assessed beforehand. Risk-conscious decision making always requires systematic identification of risks.

Risk assessment provides a mechanism for identifying which risks represent opportunities and which represent potential pitfalls. It is a systematic approach to hazard identification and control. First, ideas should be brainstormed and grouped under the appropriate risk headings. Then, the impacts on people, environment, physical assets and finances should be considered and written down systematically. Typically, risks are analysed by determining the consequences and likelihood of each risk (Table 2). Then the current risk management strategies should be identified and their effectiveness, i.e. how well these strategies work, analysed. The actions needed to bring the risks to an acceptable level should also be considered and written down.

Table 2. Risk matrix (5x5)

| **Likelihood** | **Severity of consequences** | | | | |
|---|---|---|---|---|---|
| | No harmful consequences | Low | Serious | Major | Extreme |
| Almost certain | Minor risk | Moderate risk | Significant risk | Significant | Significant |
| Likely | Insignificant risk | Minor | Moderate | Significant | Significant |
| Possible | Insignificant | Minor | Moderate | Moderate | Significant |
| Unlikely | Insignificant | Insignificant | Minor | Minor | Moderate |
| Rare | Insignificant | Insignificant | Insignificant | Minor | Minor |

**Levels of action**

Risk management can be defined as a systematic application of management policies, procedures and practices to the tasks of analysing, evaluating and controlling risk. The risk management process includes the identification of risk factors, risk assessment and the execution of mitigating actions. A classical way to defend a system against the uncertainty of its failure scenarios is presented by Zio (2009). Three steps are important (see Table 3): 1) identifying the group of failure event sequences leading to credible worst-case scenarios, 2) predicting their consequences and 3) accordingly designing proper barriers for preventing such scenarios and mitigating their associated consequences. In some cases, checklists or keywords are used for guiding the risk assessment. The checklist for identifying threats and harms related to the renewable energy options of a residential area is presented in Appendix 2, and some examples for using joint forms to collect the risks assessed are presented in Appendix 3.

Table 3. Risk levels

| | |
|---|---|
| Level IV | Immediate action |
| Level III | Some action required |
| Level II | Monitor |
| Level I | Action not required |

The risk mitigation step involves the development of mitigation plans designed to manage, eliminate or reduce risk to an acceptable level. In some circumstances, risks can either be accepted or transferred from one party to another. When planning mitigation actions, emerging new risks or re-emerging risks should also be considered.

Becoming aware of different risks can help organisations to operate and make decisions in the presence of uncertainty. In order to perceive risks and manage them systematically, organisations are typically applying formal risk management practices. However, it can be argued that by formal risk management practices companies are actually trying to prepare for events that are not totally manageable. In addition to formal practices, it is often stated that organisations need to increase their flexibility to cope with unexpected events and also be prepared for uncertainties that cannot be assessed beforehand.

### 2.3.2 Examples of risks related to using renewable energy sources in a residential area

In the Rykmentinpuisto case of the REmix project, an example risk assessment was conducted to demonstrate the use of risk management practices in supporting renewable energy decisions in a residential area. The use of geothermal heating, CHP (wood chips), photovoltaics (PV), solar heating and small wind turbines were considered from the viewpoint of threats and consequences related to each available energy source option. Current actions to manage the identified threats were also described and new mitigation actions suggested. Novel opportunities arising from the adoption of the energy sources were also thought up and discussed.

To conduct the assessment in a systematic way, a keyword list was used to assure that the relevant aspects were taken into account throughout the assessment process. The keywords included the maturity and reliability of the technology, the availability of the energy source, technology and services, and the attractiveness and accessibility of the solution for the stakeholders (for the complete list of keywords, see Appendix 2). During the assessment session, the identified risks and mitigation actions were documented by filling in a template for each energy source option considered. The complete risk identification tables are given in Appendix 3.

The identified risks can be classified into three main categories: market risks, technological risks and regulatory risks. Market risks are related to the uncertainty of the energy and financial markets. In other words, uncertainty related to energy prices (both renewable and other energy sources), the availability of biofuels (wood chips, pellets) and the price and availability of funding on the financial market. Fluctuating market prices may, for example, increase the operating costs of geothermal heating and thus affect the expected revenues. A decrease in the fossil fuel prices may lower the comparative competitiveness of the renewable energy source options. Among other things, the use of external suppliers with long-term contracts as a risk mitigation action was suggested.

In the context of renewable energy sources considered in the Rykmentinpuisto case, the technological risks were mainly related to the maturity level of the adopted technology. In the context of relatively novel technologies that are developing at fast pace, there is inherent uncertainty about the exact energy output of the solutions considered. There is also some uncertainty related to the techno-economic lifetime of the solutions, and that has an effect on the expected long-term profitability. As mitigation actions, several proposals were made including the use of piloting as well as paying enough attention to the various renewable energy solutions in zoning (for example, by reserving enough space for geothermal heating wells and solar panels).

Governmental regulation plays a key role on the energy market, and there are policy instruments that support the use and development of renewable energy solutions. Governmental subsidies, taxes and emission standards can change the relative profitability of the energy solutions considered. Thus, depending on the instrument at hand, it can be seen either as a regulatory risk or an opportunity.

In conclusion, we may note that the preliminary threats and risks identified above seem to be in line with findings presented in the recent literature which emphasises the importance of improving risk-reward ratios for investors and the central role of policy incentives in promoting the use of renewable energy (see Wüstenhagen & Menichetti 2012; Couture & Gagnon 2010; Foxon et al. 2005). Also, several types of barriers to the adoption of renewable energy have been identified, including market failures and distortions, economic and financial challenges, lack of institutional support, technical barriers and social, cultural and behavioural aspects (Painuly 2001). The use of risk assessment, as conducted in the example above, can help to identify possible threats and their consequences as well as ways to find mitigation actions and to overcome barriers identified in the risk assessment conducted and elsewhere. However, the preliminary risk assessment shown here is intended as an example only. To support a real-world investment decision, a more thorough assessment should be made, with all the relevant stakeholders involved in the process.

# 3. Innovation networks

### 3.1.1 Local innovation network

For any local authority, an area development project like Rykmentinpuisto (one of the REmix cases) is a long-term commitment. It requires a significant percentage of available resources from both civil servants and council members. Planning and development can easily take ten years, and in bigger cases the last building in the area might be constructed 20 to 30 years after the first one. The whole lifecycle of the area may be hundreds of years. This makes the best knowledge, innovations and learning most valuable when it still counts.

The construction life cycle of an area such as Rykmentinpuisto is very long and has many stages. The area can be expected to be completed within c. 30 years. During this time, construction and its requirements will change, but energy technology and the related services, in particular, will evolve. Price trends and utilisation possibilities of energy sources are also difficult to predict. Changes in customer needs and trends affect demand, which requires regional development discussion throughout the entire life cycle of the area. For this reason, long-term regional development should take into consideration the flexibility of the alternatives, learning, and the active and networked innovation activities of the operators in the area.

The parts of Rykmentinpuisto will be built up from the direction of the city centre area that has already been built to some degree, which means that the area will have properties that are at very different stages of their life cycles. This must be taken into consideration in the activities of the innovation network and particularly its structure, which will be affected by changes in the profiles of the operators.

Continuity of the participating development of the area throughout the development stage that will continue for several decades and during the subsequent use and renovation stage will require active measures and active operators. This must be taken into consideration from the planning phase, and the necessary roles and operators must be established in the area. The local authority plays an important role in maintaining the activity, but it is even more important to establish the conditions, structures and potential for active operators. However, the local authority's resources are limited; attention should be paid both to developing the resources of the municipality and motivating the other operators in the area. The active inclusion of the operators in the area stems from the opportunity of influencing the process, which in turn depends on the flexibility of the alternatives and the possibility to adopt new technologies and services.

Area development partners have different backgrounds and viewpoints with regard to systems and services. This causes information 'stickiness' and requires investing time and resources into communication and collaboration to reach the best decisions. One partner cannot have enough knowledge and capacity to take into account all information and aspects for making an optimal decision.

Open innovation

Companies need to have a clear incentive to move from their own comfort zone to network-level development, which is needed in the competition with the traditional energy solutions. This requires a systematic process and facilitation often managed by a third party.

In the REmix workshops, several topics related to innovation collaboration during area development were identified. The main topics that emerged from the data were *operational coordination, information management, business network development* and *operating model development*. Parallel common topics that emerged included the *need for simplicity, decision making, training* and *image*. Similar findings also exist in other project-based industries. There were also topics more specifically related to renewable energy, such as *permits, customer decision making criteria*, and *profit and risk sharing models*.

Innovation discussions often lack sufficient emphasis on *financing,* which is a key part of the business concept and planning in any real-life case. Especially in the case of implementing novel solutions as with many renewables, obtaining financing is difficult. Local energy cases are also commonly too small to attract big and traditional financiers. For a successful case, financiers and financing expertise should be brought into the discussion right from the beginning.

The following is a discussion of the operators and their roles.

Developers and construction companies

The role of the developers and construction companies is to efficiently implement objectives determined on the market and to produce alternatives based on their own know-how. In a correctly implemented innovation environment, this know-how can be leveraged from the beginning of the planning phase; the competitive negotiated procedure is an example. In a partnership network, the suppliers of building technology and energy systems play an essential role.

Residents

Demand for the area ultimately depends on the residents. The current residents are ‘sellers’, and a strong identity for the area will support their activity in spreading their views both to the operators in the area and potential new residents. Reacting and responding to the needs of the customers requires cooperation between the operators in the area and flexible solutions.

Architects

The area as a whole must be both pleasant and functionally successful. The energy solutions must not play too large a role in the general image of Rykmentinpuisto, but the brand allows an image of sustainable development and, to a certain degree, demands its inclusion in the elevations and public areas. With regard to renewable, locally produced energy, the most important task of the architect is to successfully create a symbiosis between technology, visual image and practicality in interactive cooperation with the other members of the network and stakeholders.

Providers of energy services

Rykmentinpuisto is a major area with regard to its overall energy consumption and is certain to interest many providers of energy services. Energy (heat, electricity, cooling) in itself forms only a part of the services required in the area. In addition to energy, customer-targeted communications, planning, maintenance, finance, measurements and monitoring are required, among other things. Preferably, all of these should be available on the one-stop shop principle.

On the other hand, the development must be based on the totality of the area and the customer together; in other words, the synergies between services must be identified. Other services related to the area's energy solutions include transport and parking, ICT, business support services, municipal services (e.g. schools, day care centres, sports). Many of these use energy services, but, to take an example, the ground cabling required by ICT should be planned and implemented together with the infrastructure and property connections required by energy. In addition to these, it would be worthwhile to consider implementing the other customer services through a shared customer interface (a single service centre that can be contacted at any business in the area). Enabling such cooperation requires the area's innovation network to be capable and active right from the area planning stage.

Local authority

It is the task of the local authority to enable the activities of the area's innovation network and be an active member in it. During strategic decision-making, the development framework should be kept in mind, and engage in active dialogue with the other operators. The local authority reaps its benefits through the attractiveness of the area, which supports the development and marketing of new areas.

Research and development networks

Research in locally produced energy solutions is very active, both in Finland and internationally. The lack of good piloting possibilities may be considered a challenge, as there are numerous areas at the planning stage with renewable energy solutions playing a major role, but only a few at the implementation stage. For this reason, the research sector is particularly interested in areas entering the implementation stage. This interest should be leveraged, not only in the planning of the areas, but also in the financing and implementation of pilot projects and the follow-up and verification of the results. Comparisons between areas and solutions are also possible in international projects. In research projects, examination of the subjects can also continue over their life cycle through active participation, key projects being sought out for each stage.

### 3.1.2 Business co-innovation

Energy and especially renewables business ecosystem is developing rapidly. It becomes more and more difficult to achieve competitive edge and strategic partnership networks become the primary source of advantage. This is especially true for the small and medium sized companies. To achieve this, extensive collaboration over all of business network is required to identify synergies and connected activities.

Initiating collaboration is challenging as such. Companies need to have a clear incentive to move from their own comfort zone to the network-level development, which is needed to successfully compete on the constantly developing energy market. For this, companies are needed to take the role of not only a technology, but also a business and value integrator. This supply chain or network of companies is the one that is actually competing with the other networks and supply chains.

Companies focused on different technologies are not used to collaborate, for instance in system integration, market understanding or joint business model development. Different backgrounds require investing time and resources in communication and collaboration to pin down what are the main potential synergies between the partners of a business network delivering a technology mix based renewable energy solution. The goal is to identify the major possible areas of synergies in the area of energy solutions at different and different parts of business concepts and stages of the life cycle of an area development project.

Though it is possible for the companies to manage the process themselves, it is often practical and more effective to use external know-how and expertise to facilitate the innovation process. Companies, not least family businesses, have core competences and business critical know-how they are used to protect and be jealous about. However, to bring the network business to perfection, also these cards need to be put on the table. This often requires impartial and unbiased attitude provided by an external actor together with well managed facilitation methods.

There are many ways to do this but one method used for data collection is a set of facilitated workshops aiming to identify potential synergy areas. The workshops need to cover all phases of a project lifecycle and selected business topics. One often used framework of a business concept is the “business model canvas” by Alexander Osterwalder. This canvas was used in the REmix project and the total number of sticker notes with synergy ideas in the two workshops was over one hundred. The main challenges in the process were related to the classification of the ambiguous notes and group work management. This kind of innovative discussion can be very fluctuating and diverse, but it can also stuck into the most interesting or “easiest” elements of the canvas.

More information can be found in Chapter 4.4 and in the Springer publication “Smart and Sustainable Planning for Cities and Regions” (edited by A. Bisello et al., 2017), chapter “Collaboration in Regional Energy-Efficiency Development”.

# 4. Economic perspective of renewable energy solutions

## 4.1 Renewable energy solutions

### 4.1.1 Geothermal heat pump or ground source heat pump (GSHP)

An important thing to keep in mind is that geothermal heat pump solutions can also be used to produce district cooling. This is especially useful during warm seasons and for some processes that are dependent on cooling.

The actual initial investment cost depends on many factors (for instance, geological conditions) and is rather case-specific and therefore quite hard to estimate accurately. The larger the area, the harder the estimation process. There are some decent estimates for a single-family house or small apartment blocks, but not so much for the city block or area level. The actual initial investment paid by the customer is also dependent on the subsidy policies in effect during the investment. Therefore, these issues should be carefully studied before the actual investment decision.

The main, and basically only, source of operating costs is the electricity required to operate the geothermal heat pump system. This relation is expressed using the coefficient of performance (COP) number. If the coefficient of performance is 3, for example (quite normal), then 1 MWh of electricity is required to produce 3 MWh of heat. Thus, the economic feasibility of a geothermal heat pump is dependent on the price of electricity. Therefore, a great emphasis should be placed on the production or purchasing of electricity. On the other hand, the geothermal heat pump solution is not dependent on the market price of heat in general, which is largely governed by the price of burnable heat sources such as coal.

### 4.1.2 Combined heat and power plant (CHP)

A combined heat and power requires a large plot of land about the size of a football field. The logistics arrangements of the site and its vicinity must be carefully planned, because of the truck traffic and storage space needed for the fuel.

The initial investment for this type of energy production unit is rather high. Therefore, much emphasis should be placed on the timing of the investment. There has to be a demand for all the energy that will be produced. A temporary solution can be, for instance, to sell part of the production to some industrial consumers that are located near the actual market area.

Fuel cost is the most significant factor of the cost structure. The most feasible renewable fuel is wood chips. The problem is that if the demand is very high or rising constantly, the fuel has to be transported over long distances. This creates additional costs and raises a question: Can this kind of production still be called local renewable energy? This is in many cases the will of the decision-makers, especially in the public sector. A combined heat and power plant also requires electricity to operate. This electricity may be self-produced or bought from the grid, depending on the legislation. Service and maintenance is also needed as well as operating personnel.

### 4.1.3 Solar heating, solar photovoltaics and wind power

These three sources of renewable energy can be described in the same section because of their similarities when it comes to initial investment and operating costs.

With small-scale solar and wind power, the initial investment may not be very high in absolute terms. However, they are quite heavily priced in relation to their energy production capacity. This means that the payback time is long. On the other hand, these solutions are good additions to larger energy solutions and may be used, for instance, to produce the required operating power.

The operating costs are marginal, and these solutions are basically care-free, which means that after the initial investment almost all cash flows are positive, which is a huge difference when compared with a CHP plant, for instance.

Feed-in tariffs and investment subsidies play an important role when evaluating the economic feasibility of this kind of investment. Therefore, the current situation should be carefully studied before a large investment of this kind.

## 4.2 Opportunity cost

Especially in replacement investments, the opportunity cost is a very important factor when evaluating the economic feasibility of a certain local renewable energy solution. The payback time of an investment is heavily affected by the annual saving potential that forms the positive cash flows. The annual saving may be totally different when the opportunity cost is district heating instead of oil, for instance.

In addition, the price of district heating varies greatly within Finland. In the most expensive areas the price can be twice as high as in the least expensive areas.

Moreover, large customers, such as corporate customers and municipal customers, are paying significantly less for the energy (heat and electricity) than consumer clients. This means that the payback time, for example, is different for a large corporation and a household client.

## 4.3 Other factors affecting the investment decision

Especially in the public sector, investment decisions have many direct or indirect effects and aspects that should also be taken into consideration. These factors can be roughly divided into two sub-groups: hard and soft factors. Hard factors are usually quantitative and monetary. Soft factors are usually qualitative and non-financial.

Tax issues are probably the most important hard factors in public-sector decision making. This is about how the decision affects the local economy. If the investment would create jobs (and resulting taxable income) for locals, a somewhat longer payback period could be acceptable and would also make sense financially.

Soft factors include image, sustainability and the valuation of local energy. Despite their non-financial nature, these factors also have economic impacts, but these impacts are extremely hard to measure. The public image may have a positive impact on the number people as well as the real-estate prices. Relying on local energy may be a very good choice during a global crisis, for instance, but how much is this worth financially?

Therefore, it is evident that publics sector energy procurement decisions should not be based only on the direct costs and revenues/savings. The main problem is how to evaluate soft factors in a reasonable and fair manner.

## 4.4 Synergies resulting from co-locating different renewable energy technologies

During the project, two workshops were organised in order to identify possible synergies. In the first one, the case evaluated was Tapaila block; in the second one, it was Rykmentinpuisto. These two very different cases were chosen also because the point was to find out how synergies differ in different case scenarios. The method applied in the workshops was based on Alex Osterwalder's Business Model Canvas[1] (Figure 1), and our own project stage classification. In addition, we left out the financial parts of the Business Model Canvas (Cost Structure and Revenue Streams) in order to put more emphasis on the non-financial aspects. The Customer Segments part was also excluded, because in our workshops the customer was a local authority, and no segmentation was needed. The matrix we used is depicted in Figure 2.

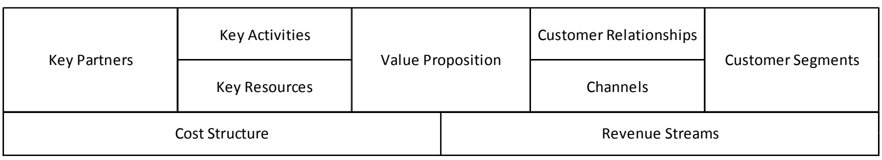



Figure 1. Business Model Canvas by Osterwalder

| | Dialogue | Planning | Design | Construction | Handover | Operation |
|---|---|---|---|---|---|---|
| Key Partners | | | | | | |
| Key Activities | | | | | | |
| Key Resources | | | | | | |
| Value Proposition | | | | | | |
| Channels | | | | | | |
| Customer Relationships | | | | | | |

Figure 2. Business Model Canvas matrix used in REmix project

[1] http://www.businessmodelgeneration.com/downloads/business_model_canvas_poster.pdf

### 4.4.1 Potential sources of synergy classified according to the Osterwalder model

- Key partners

The role of the coordinator is very significant throughout the process. At a very early stage, the coordinator should organise cooperation between the suppliers, officials, customer, financers and operator. At this stage, there a number of synergies that can be gained by cooperating: higher negotiating power, more efficient tendering, cooperating in permit issues, decreasing and dividing the risks and also increasing the assumed profit margin. At the design stage, the head designer has a key role and is responsible for the design in cooperation with design partners. The actual construction stage is carried out by local operators or own subcontractors. At this stage synergies may arise for instance from common supervision. The operator has a key role at the handover stage and especially at the operation stage.

- Key activities

A common commitment is important for the success of the project, and this should be emphasised at the very beginning. Thinking about the total solution is also an important early activity. Information and document management is very crucial throughout the project. By handling this task well, a great amount of errors and extra work can be avoided. At the construction stage, site management, especially material logistics, plays a key role. One way to gain synergies is to use the same mechanics. Before the handover, the system should be tested carefully. Service and maintenance during the operation may be either compulsory (statutory) or included in the guarantee conditions. Some operators want to keep the service business under their own control, while others allow other operators to provide the service. When the guarantee period is over, it is common to offer a service agreement or to lengthen the guarantee period.

- Key resources

The designer cooperates closely with the suppliers, and this network has a key role at the design stage. At the construction stage, logistics, timing and schedules are in focus.

- Value proposition

The client would usually like to buy an objectively offered overall solution. The client should also consider whether to buy the solution as a system or a service. However, the client's own expertise is usually insufficient, and there is thus a high demand for consultants in this field. The first thing is to decide where to invest.

Energy efficiency, for instance, can be improved by investment in the systems or in the buildings or both. The decisions should be based on the life-cycle costs, not on the initial investment. Public-sector clients in particular should also consider other factors besides price, such as safety, image and local impacts. The projects are usually rather large and built over a long time period. In these cases, emphasis should be put on the modularity aspects. The responsibilities should be clear so that the client always knows whom to contact. When considering the financing aspects, various subsidy options should be studied, and alternative pricing methods should also be considered where the actual price could be based on the energy saving, for example.

- Channels

Various networks play an important role in information transfer even before the actual project. Contacts and ideas may be found through these networks. The communication at the construction stage is carried out either through a coordinator or between designated persons in charge.

- Customer relationship

The information transfer between a client and operators should be further developed. Checkpoints play an important role in the information transfer during the project. These can be used to ensure that the budget and schedule targets are met. Overall project management is a huge challenge, especially in large projects.

### 4.4.2 Potential sources of synergy classified according to stage

- Dialogue

The role of external expertise is significant. This stage has a substantial impact on the success of the whole project. A coordinator must be appointed to handle the contacting. Networks play an important role in information-gathering. The initial plans for risk sharing should be discussed. The continuity of the project should also be ensured.

- Planning

Achieving a common commitment is very important. All parties should be motivated and committed to work towards a common goal. Synergies can be gained by efficient cooperation. These include permit processes, purchasing tendering, risk sharing and negotiating power. Together, these factors also result in a higher overall profit margin. An important decision is whether to invest in the systems or in the buildings. This is especially true in renovation processes. Even the best systems may not help if the building is not suitable for these solutions. The role of life-cycle costs should be emphasised at this point. The final decision should rely heavily on these calculations instead of the investment cost. Other important decision criteria include subsidies, safety, image and local considerations.

- Design

The role of coordination is again significant. This is usually the head designer's responsibility in cooperation with other design partners. The suppliers are also represented in the network. When the project progresses and the amount of information increase, the role of efficient information management becomes increasingly important. Enough time should be scheduled for this, because the permit process may be rather slow. When considering the life span of the whole area, modularity should be emphasised. The checkpoints should also be decided in advance in order to keep the project within budget and schedule.

- Construction

Construction is carried out by the subcontractors of the main contractor or local actors. Shared supervision and logistics arrangements are potential sources of synergy. The logistics arrangements are in many case carried out using the JIT (just in time) method, and the project manager has the main responsibility. Each actor should have appointed a contact person and all contacts should take place between these persons or through a coordinator (depending on the matter at hand).

- Handover

The operator has a key role at this stage. All service and maintenance issues are also addressed at this stage. Some of them are compulsory, others are not. It is also important to clarify which service and maintenance tasks are included in the guarantee agreement. How to proceed when the guarantee expires should also be considered already at this stage. The operator assumes the principal responsibility from the coordinator or head designer. It is very important to make sure that all information and documents are transferred smoothly. This applies to all discontinuity points, such as a change of operator or the end of the guarantee period. At this time at the latest, it should also be decided whether the client wants to buy a system or a service. If the pricing is even to some extent based on the resulting energy saving, these details should be finalised at this point.

- Operation

Some system suppliers want to keep the maintenance operations under their own control and not allow any other service providers to perform these tasks. Many system suppliers would like also to sell the client a service agreement or an extra guarantee period. This is also by far the longest stage of the project and has, therefore, a great impact on the life-cycle costs and overall profitability of the project.

## 4.5 Calculation tools

One calculation tool developed during the project was an area exploration and comparison tool that takes into account the energy needs (heat and electricity) and also other factors such as $CO_2$ emission. An example graphic is presented in Figure 3 (the tool is currently only in Finnish). The case analyses presented in Chapter 4 are largely based on the outcomes of this calculation tool.

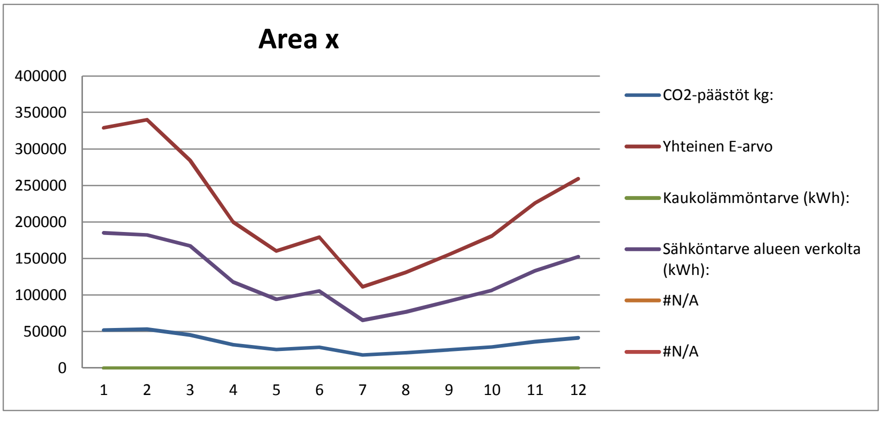



Figure 3. Calculation tool graphics example

The other calculation tool developed during the project was an overall economic impact calculation tool aimed to support renewable energy -related decision making especially in early stages of public sector projects. The main components of the model are depicted in Figure 4.

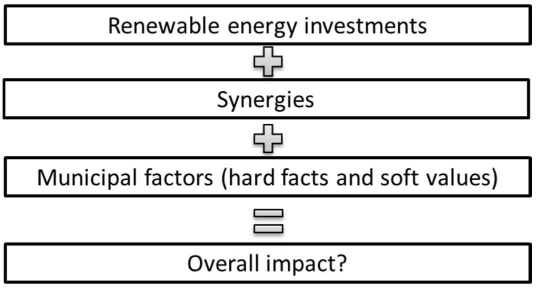



Figure 4. Main components of the overall impact

The tool can be used to calculate all the common investment evaluation indicators (payback time, net present value and internal rate of return) for all chosen energy forms and for the overall solution. An example calculation is presented in Figure 5. The model compares a solution that comprises of a mix of renewable energy technologies (and possible also some amount of grid electricity and district heating) to a "basic solution", where all energy is either electricity from grid or district heating. This assumption is, therefore, especially valid in energy replacement investments, where the current solution relies on grid electricity and district heating. The assumption is also relevant in new building areas, whether residential or industrial, where grid electricity and district heating are easily available.

| Year | 1 | 2 | ........ | 24 | 25 |
|---|---|---|---|---|---|
| Geothermal heat | 0,8 | x | ........ | | |
| Initial investment | -240 000 | | ........ | | |
| Operating cost | -2 400 | -2 448 | ........ | -3 785 | -3 860 |
| Residual value(+/-) | | | ........ | | |
| Depreciation time | | | ........ | | |
| Operating time | | | ........ | | |
| | | | ........ | | |
| Heat (MWh) | 800 | 800 | ........ | 800 | 800 |
| Electricity (MWh) | | | ........ | | |
| Consumption | | | ........ | | |
| Heat (MWh) | | | ........ | | |
| Electricity (MWh) | 267 | 267 | ........ | 267 | 267 |
| "Savings" (€) | 24 000 | 24 480 | ........ | 37 846 | 38 602 |
| NCF | -218 400 | 22 032 | ........ | 34 061 | 34 742 |
| NPV | -218 400 | 20 029 | ........ | 3 804 | 3 527 |
| NPV (cumulative) | -218 400 | -198 371 | ........ | 8 501 | 12 028 |
| IRR | -218 400 | 19 947 | ........ | 3 462 | 3 197 |

| 0 | | |
|---|---|---|
| Pay back time | 10,1 | Laske |
| IRR | 10,5 % | |
| NPV: | 7 788 | |
| -Discount rate: | 10,0 % | |

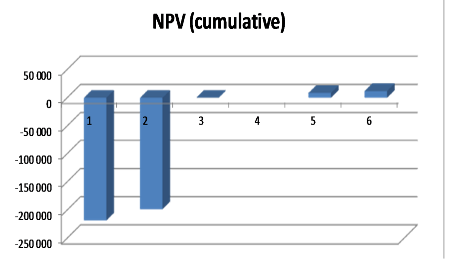



Figure 5. An example calculation, investment evaluation indicators

However, the main target of the model is to help to quantify the economic effects of synergies (arising from installing and using multiple renewable energy forms in a single location) and municipal factors (such as tax effects, energy subsidies, energy self-sufficiency, sustainability and image). These factors can, in fact, have a significant impact on the economic viability of a solution. Some of these factors can be calculated quite accurately. However, some are very hard to quantify (e.g. sustainability effects and image). Still, even these rough estimates are a lot better option than no figures at all and one purpose of the model is just to remind the users to pay attention to these viewpoints also.

## 4.6 Sensitivity analysis

The following Figure 6 illustrates how the payback time changes for a small wind power investment in various scenarios for technology price changes and energy price changes.

| | | | | |
|---|---|---|---|---|
| Price of electricity: | | **90** | €/MWh | |
| Initial investment: | | 35 000 | € | |
| Operation cost: | | 0 | €/v | |
| Electrity production: | | 10 | MWh/v | |
| Annual saving: | | 900 | € | |
| Pay back time: | | **39** | v | |
| | | | | |
| Investment year | | | | |
| | Technology price change (%/v) | | | |
| | | Energy price change (%/v) | | |
| | | 2 % | 4 % | 6 % |
| 2013 | | **29** | 23 | 20 |
| 2020 | -2 % | 23 | 18 | 14 |
| | 0 % | 26 | 19 | 16 |
| | 2 % | **29** | 21 | 17 |
| 2030 | -2 % | 19 | 11 | **8** |
| | 0 % | 22 | 14 | 10 |
| | 2 % | **29** | 19 | 13 |

New payback time

Figure 6. Payback time of a small wind power investment in different scenarios

The variations in payback time are considerable, and the actual payback time is greatly dependent on these factors. The payback time with current values is 39 years, but it will be significantly lower if energy prices continue to develop favourably in this respect. The energy price change naturally also affects the payback time of an investment already in place. The other demonstrated factor is the technology price change per MWh produced. If the positive trend continues in this manner, the payback times for future investment may be significantly shorter than nowadays. This does not affect the payback times of investments already made but should be taken into consideration when considering the energy solutions for a large area that is built in multiple phases.

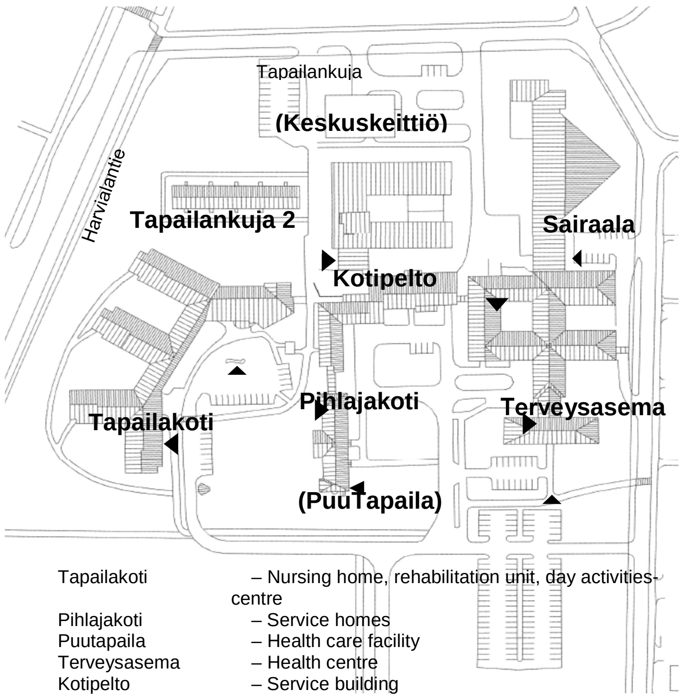
This clearly illustrates that there is a need to carry out investment calculations with different future scenarios and assumptions and to try to evaluate their probability. This kind of sensitivity analysis applies to wind power, solar heating and solar photovoltaic because of their similarities. Combined heat and power plants, on the other hand, are not so sensitive to energy price changes, since their demand for fuel dilutes this effect.

# 5. Demonstrations cases

In this chapter, three cases from Finland will be evaluated according to the topics discussed earlier in this document.

## 5.1 Case: Tapaila city block

Tapaila is a small area in the municipality of Janakkala. A city block consisting of several service buildings in Tapaila was chosen for demonstrating our business model analysis. The buildings included in the investigation and their descriptions are listed in Figure 7.




Tapailakoti – Nursing home, rehabilitation unit, day activities-centre
Pihlajakoti – Service homes
Puutapaila – Health care facility
Terveysasema – Health centre
Kotipelto – Service building
Tapailankuja 2 – Senior apartments
Sairaala – Hospital, Bed-facility, rehabilitation unit
Keskuskeittiö – Central Kitchen

Figure 7. Map and description of building the city block in the Tapaila case

These buildings are commonly occupied by around 200 residents/patients and 200 employees.

### 5.1.1 Energy demand and solutions

The Municipality of Janakkala signed an agreement where they aim to increase the use of renewable energy in their own buildings and additionally to reduce energy consumption by 9% from its current level. In this case, there exists a district heating network in the area to which the majority of the buildings are connected. The central kitchen, however, is newly built and heated by ground source heating. In all, of 3,100 MWh of district heating and 1,600 MWh of electricity were consumed in the buildings in 2011. In Figure 8, the monthly cumulative energy demand of all the buildings is shown.

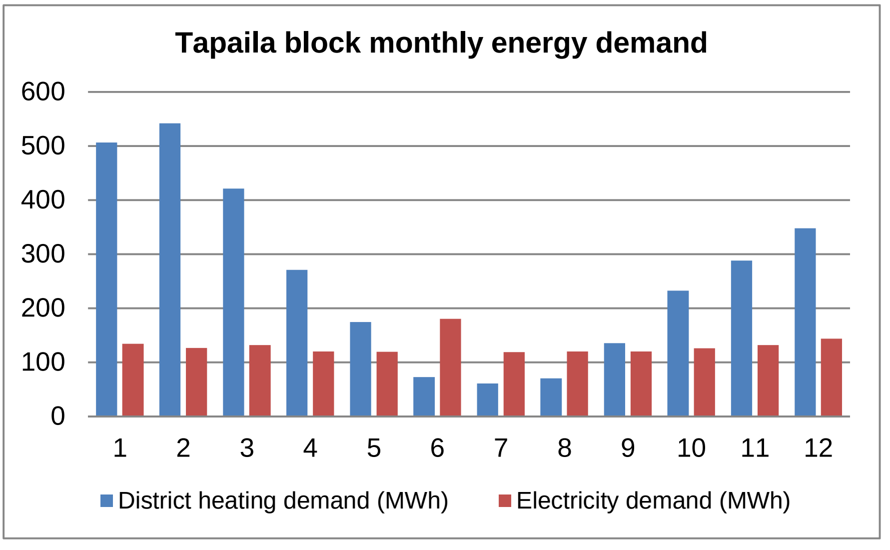



Figure 8. Total energy demand of buildings in the Tapaila case (measured during 2011, *municipality of Janakkala*)

Looking at the monthly energy demand, it can be concluded that the highest demand peaks for district heating is in winter. The electricity demand is otherwise close to constant except for peaks during the summer when extensive cooling is needed for the health centre and hospital.

The Tapaila case energy analysis will be given in three parts presented in the following order: energy savings, utilisation of excess energy and increasing use of renewables. This will be followed by a business model opportunity analysis of the renewable energy solutions presented.

**Energy savings**

Some of the buildings in the Tapaila city block are over 30 years old (Tapailakoti, Puutapaila and Tapailankuja 2) which means that there could be great potentials for saving energy by renovating these. Assuming that the thermal insulation of the buildings would be upgraded from their year of construction to present building standards (Table 5, Finnish building regulation D3, 2012), the expected savings in heating energy could be up to 881 MWh per year, or 28.5% of the total district heating demand of the whole block (see Table 4).[2]

Table 4. Energy savings after renovation of buildings in the Tapaila block

| Building name | Tapailakoti | Puutapaila | Tapailankuja 2 | Renovated values (2012) |
|---|---|---|---|---|
| Year of construction | 1958 | 1880 | 1974 | 2012 |
| U-Values | | | | |
| Wall | 0.81 | 0.81 | 0.7 | 0.17 |
| Roof | 0.47 | 0.47 | 0.35 | 0.09 |
| Basement | 0.47 | 0.47 | 0.4 | 0.16 |
| Outside windows | 2.8 | 2.8 | 2.1 | 1 |
| Outside doors | 2.2 | 2.2 | 1.4 | 1 |
| Energy savings after renovation | | | | |
| Yearly savings (MWh/y) | 696 | 114 | 71 | - |
| Yearly percentage (%) | 66% | 70% | 50% | - |

Table 5. Estimated building insulation values for some of the Tapaila buildings before and after renovation

| Building name | Tapailakoti | Puutapaila | Tapailankuja 2 | Renovated values (2012) |
|---|---|---|---|---|
| Construcion year | 1958 | 1880 | 1974 | 2012 |
| U-Values | | | | |
| Wall | 0,81 | 0,81 | 0,7 | 0,17 |
| Roof | 0,47 | 0,47 | 0,35 | 0,09 |
| Basement | 0,47 | 0,47 | 0,4 | 0,16 |

[2] Calculations made according to the Finnish building regulations D5, only concerning the items listen in Table 4.

| | | | | |
|---|---|---|---|---|
| Outside windows | 2,8 | 2,8 | 2,1 | 1 |
| Outside doors | 2,2 | 2,2 | 1,4 | 1 |
| Energy savings after renovation | | | | |
| Yearly savings (MWh/y) | 696 | 114 | 71 | - |
| Yearly percentage (%) | 66 % | 70 % | 50 % | - |

Another energy-saving measure would be to install mechanical ventilation with heat recovery. The savings from this measure would require further investigation of air leakages and the air demand of the buildings. The benefit would furthermore depend on factors such as installation costs (in old buildings, the entire distribution system would need to be replaced, including ducts and vents) and additional electric consumption of the system. According to current building regulations, heat recovery from exhaust air in new ventilation systems (Finnish building regulation D3, 2012) averages at 45%. An additional benefit from mechanical ventilation would be better indoor air quality.

On the electricity side, energy savings can easily be made by installing low-energy lighting (e.g. LED lamps and utilising natural lighting) and replacing old electronic devices with new energy-efficient ones. According to statistics, lighting accounts for only 8% of the total electricity consumption in a Finnish home (Motiva 2013). However, in the case block the situation would be different, since the majority of the buildings are service buildings with special equipment for serving hospital patients and elder people.

The hospital and health centre have a cooling demand which consumes a considerable amount of electricity. An option for reducing electricity needed for cooling is to switch from air-source to ground-source cooling. This would require investments in the construction of the ground loop (horizontal) and connecting it to the existing system.

**Excess energy**

There is an ice-cream factory (Valio) to the south of the Tapaila block generating 377 MWh/month of excess heat during the heating season and 176MWh/month in the summer.[3] This excess heat could be transferred (possible temperature adjustments done by heat pumps) to the district heating network to be used in the buildings, thus improving energy efficiency in the area. In order to optimise the utilisation of this excess energy, a thermal storage unit might be needed to match the heat production with the demand.

[3] Information provided by the Municipality of Janakkala.

**Renewable energy**

Regarding the energy demand of the Tapaila block, it can be seen that the electricity demand increases in the summer due to the intensive cooling demand of the hospital and health centre. As mentioned earlier, this electricity demand could be reduced by utilising ground-source cooling; however, solar photovoltaic could also be used for matching the demand curve (the sunnier the day, the more cooling is needed). Estimating the roof surface available for solar panel installation of the two integrated buildings to be 800 $m^2$, the total solar gains would cover up to 11% of the current electricity demand on a yearly basis (see Figure 9).[4]

The cooling demand curve of Kotipelto is similar while the solar photovoltaic installation potential (700 m2 of panel surface) would result in 58 % coverage of the yearly demand (European Commission, Joint Research centre, Institute of Energy and Transport (IET) 2013). The solar photovoltaic system might include storage capacity (batteries) in order to cover for peaks of demand and production peaks and also provide for backup power during blackouts.

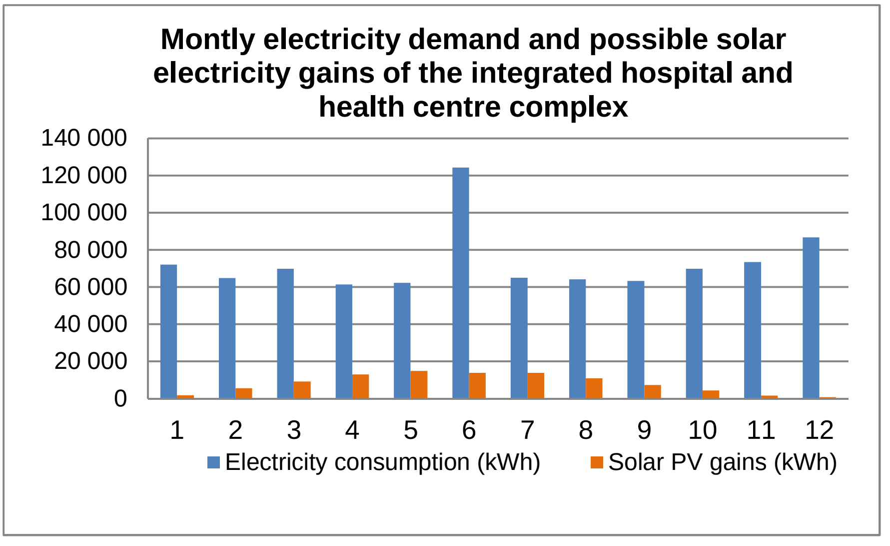



Figure 9. Monthly electricity demand and Solar PV production, Tapaila block

There is a pellet production factory (Vapo) about 300 m from the Tapaila block. Pellets, which are considered to be renewable energy source, could be used for heat production during times of peak load. This would be an option if the excess energy from the Valio factory is utilised, since the heat generation would otherwise

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[4] For numeric values, see Appendix 1.

not cover all demand during the winter months. Another benefit from producing heat locally is shorter transfer distances and less heat loss.

Since it is possible to drill vertical boreholes close to the central kitchen area, one option would be to construct a borehole or aquifer storage system which would enable seasonal storage of heat. The storage capacity and losses of such systems are dependent on several factors (e.g. soil properties, ground water amount and properties, temperature differences), which make it difficult to predict the feasibility. However, this should be considered as an option for the Tapaila block

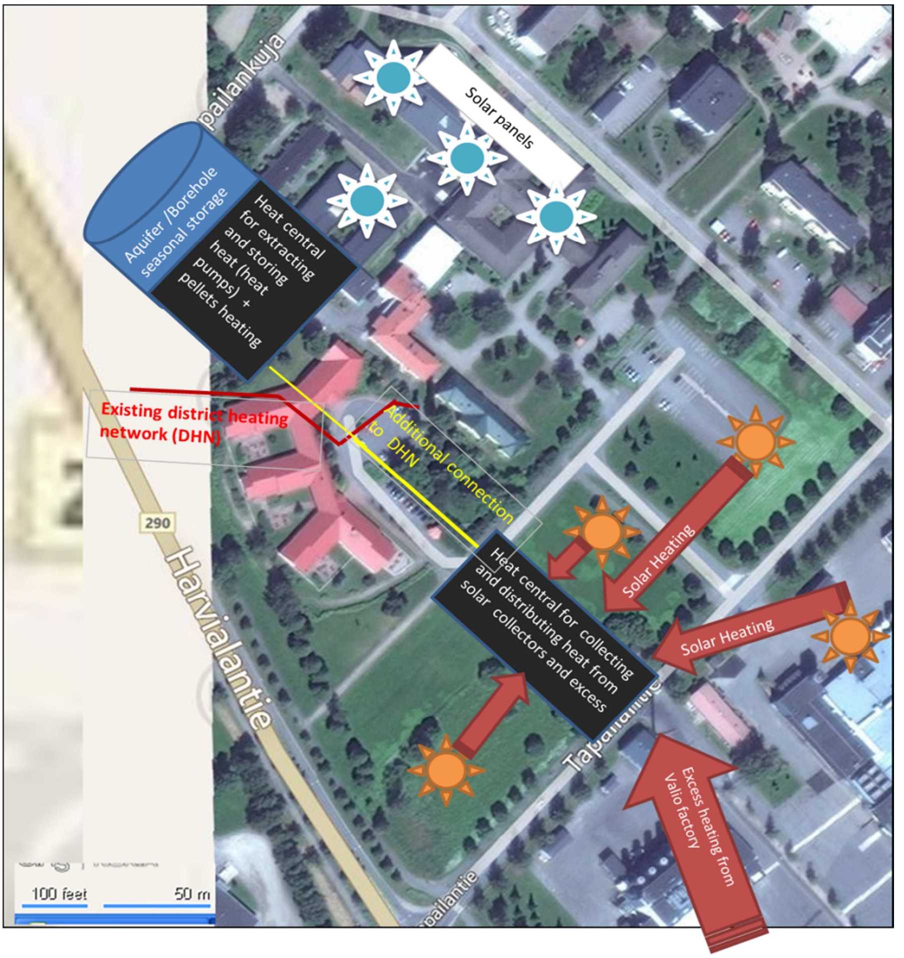


Figure 10. Map of proposed renewable energy solution for the Tapaila block

since excess heat (from the Valio factory, solar collectors and cooling systems) during overproduction (summer) can be stored for later use when the demand is high (winter). Figure 10 contains all the solutions mentioned for the Tapaila block.

### 5.1.2 Business opportunities and models for the Tapaila case

The Tapaila block features a notable number of municipal properties that are currently using district heating generated using natural gas. The properties include, for example, a health care centre hospital, nursing home and a rental building for the elderly. There are also a library and a gymnasium in the vicinity, but they are not included in this discussion. In the same vein, the two dairy product refineries located next door are excluded, although they could be potential heating customers.

There is empty space next to the properties, currently covered in grass. A heating station using either wood chips or pellets could be located there. Wood chips are favoured by their low price, while pellets require less storage space. The possible noise disturbance from the wood chip plant's conveyors should also be carefully assessed due to the central location and taken into consideration in the agreements as noise limits.

The likely heat supplier would be a heating entrepreneur who would assume the business risk. As in the Tervakoski case, in this case also a long-term heat purchasing agreement made with the municipality and a distribution of risks related to production costs taken into consideration through pricing form a prerequisite for arranging financing.

Another alternative is to increase the size of the facility by acquiring the library/gymnasium and the adjacent plants as customers. In this case, the ownership base could be expanded by involving the municipality and plant owners. At the same time, new financing solutions could also be found amongst both customers and investors. In this model, the risk structure and the agreement portfolio would change significantly and would be much more difficult to anticipate. This, in turn, would make implementation-related decision-making slower and more difficult for both the municipality and the other parties.

It is unlikely that developing added-value services for one customer would be feasible in the narrower alternative. Were the case to expand in both size and ownership base, it would present a fine opportunity for developing usage optimisation and energy-efficiency methods in cooperation with the parties. External development and research bodies could then also be assumed to take an interest in this fascinating project.

In the Tapaila case, the focus is on energy production. The distribution network is largely already in place, only ownership of different parts has to be agreed on. The energy efficiency of the buildings is mostly fine and not an issue here. The energy storage is needed to minimise buying power from the grid but has to be scaled correctly to optimise lifecycle costs. Energy services are related to production system running, maintenance and fuel logistics, thus added services are not part of the offer.

Fuel procurement and logistics can have a positive local impact if the supplier is local. There is a wood pellet factory in the region.

The big business question in the Tapaila case is who will do what. The two opposite ends are to purchase the whole system from just one supplier or to divide it between several suppliers. Both have their own problems, such as “does one have enough knowledge to provide everything” and “how to manage several suppliers and divided maintenance contracts” or “complex bidding process”. This decision is made by the customer based on the customer’s own resources and procurement strategy. In this case, the diversified technology mix led us to select the “one-stop shop” strategy. See Table 6 for an overview.

Ownership is the second biggest question. Where to draw the line between the ownership of the municipality and the supplier? Here we drew the line between the distribution infrastructure that is required to make any solution possible and the production technology including pipelines required for collecting heat and power from the different sources. In practice, this takes place in the heat centre.

Table 6. Business concept framework table for case Tapaila

| **Parameter** | **Description** | **Options** |
|---|---|---|
| Customer | In Tapaila case the municipality is the only certain customer. In the future also other customers (companies, residents) are possible but uncertain. | Municipality |
| Ownership | The heating plant is owned by the service company. The existing heat distribution network is owned by the municipality. | Private company |
| Income | A steady income is secured by the long term contract with the municipality. | Cash flow |
| Financing | Financing is required to cover the initial investments. Bank loan is likely to be granted because of the long term contract with the municipality. | Loan |
| Pricing | Both low and high limit of the price are deter- | Cost and market-based |

| | | |
|---|---|---|
| | mined. Low limit is cost based and relational to a fuel basket index. The high limit is based on an index determined by prices of several regional district heat providers. | lower and higher limits. |
| Fuel | In principle the service provider has freedom to choose the fuel. However the location sets limitations to the space available and thus e.g. the wood chip option requiring storage space is not an option in this case. | Pellets |

## 5.2 Tervakoski public buildings

The background of this Tervakoski case is the need to replace the current heating solution of a few public buildings with a new one that offers better prices and contract flexibility. The four public buildings included in the Tervakoski case area: a swimming hall, a community centre, Tervakoski School and Kettukallio day-care centre and school. The objective in this case was to find alternative solutions and their requirements for heating in the case area. The current heating solution is based on district heating, utilising the excess heat from the local paper factory, which has been considered costly. Other interesting aspects would also be the ecological and economic benefits of the current solution to other renewable energy solutions. The current monthly energy demand curves of the Tervakoski buildings are shown in Figure 11 (monthly curve estimated). On a yearly basis, the buildings consume around 2,000 MWh of heat and 800 MWh of electricity.

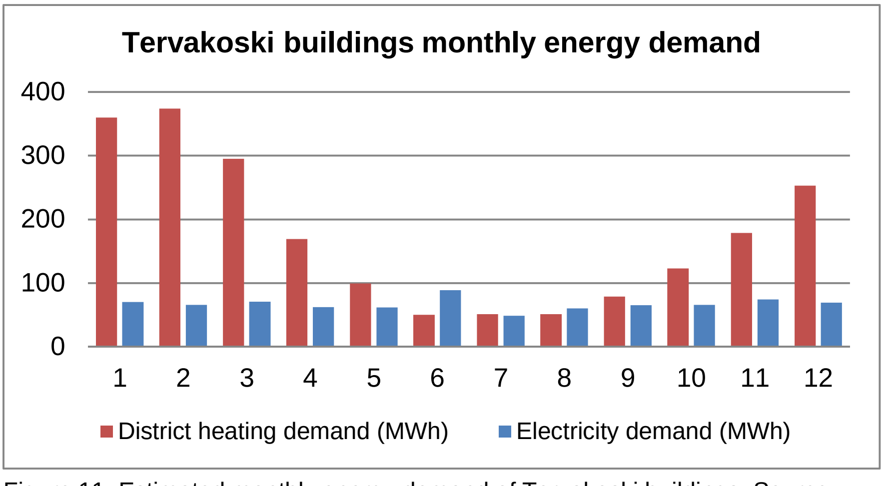


Figure 11. Estimated monthly energy demand of Tervakoski buildings. Source: Municipality of Janakkala

There were two heating solutions analysed for the Tervakoski buildings. The first alternative was a centre with combined wood chip and solar heating connected to the district heating network. The second alternative was to install a combined solar photovoltaic and ground source heating system for each building separately.

**Woodchip and Solar heated district heating**

In this case, we assumed that the solar collectors would be sufficient to cover nearly all demand during the summer, while a wood chip boiler would cover for the rest of the demand. This system would require additional heat storage units to better match production to demand.

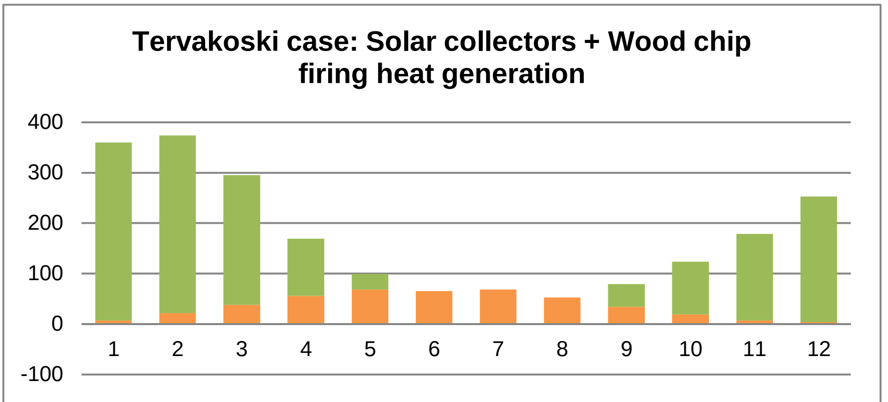


Figure 12. Solar heating and wood chip firing solution for Tervakoski buildings

Assuming that 1,000 $m^2$ of vacuum tube solar collectors are installed,[5] the system would generate 350 MWh of heat annually, or 17.5% of the yearly demand (58% of the yearly domestic hot water demand). This means that the remaining heat demand of 1,650Wh would have to be generated from wood chip firing (see Figure 12). Assuming the heat value of wood chips to be 770 kWh/$m^3$ and the efficiency of the boiler to be 75% (Finnish building regulation D3), we get a yearly wood chip demand of 2,860 $m^3$.

The volume of wood chips must be considered, since it has to be transported from elsewhere and will affect the running costs and environmental impact of the final solution. The storage space for wood chips needs to be optimally designed to keep construction costs low but at the same time be large enough to reduce the need of transport and ensure sufficient capacity during colder periods. In order to deliver the annual amount of wood chips needed, 24 truckloads would be required

[5] Solar collector efficiency of 40%, source (Solar Simulator Finland Ltd. 2009)

(double trailer) and with an estimated travel distance of 100 km per delivery; this would result in a consumption of 1,600 l of diesel fuel annually[6].

*+ In case the heating centre can be placed closer to the Tervakoski case buildings, transfer losses in the district heating network could be kept lower than at present.*

*+ Wood burning is considered to be $CO_2$ neutral in Finland.*

**Individual ground source heat pumps and solar photovoltaic**

Installing a ground source heating system to each building separately would have the benefit of production flexibility, relatively cheap energy and lower transfer losses. However, the installation would require space inside the buildings and land area close to the building. Since heat, in this case, is generated by the expense of electricity, solar panels are added to this solution in order to partly make up for the increased demand for electricity.

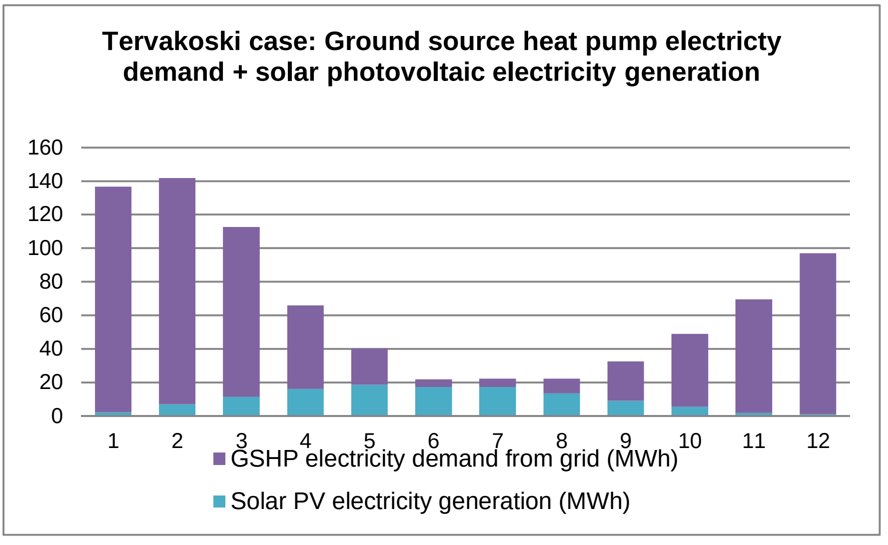


Figure 13. Ground source heating and solar power solution for Tervakoski buildings

Dimensioning the solar panels to generate the corresponding amount of electricity needed for heating during the summer months, we get a panel surface area of 1,000 m$^2$. Annually, the electricity generated by these panels annually would be

[6] Density 350 kg/m$^3$ (Ranta 2010), 45 l/100 km (Kytö ym. 2009).

120 MWh, or 16% of the electricity needed for the heat pumps (see Figure 13).[7] The coefficient of performance (COP) of the heat pumps was set to 2.3 for domestic hot water production and 2.7 for space heating (Finnish building regulations D3). Ground source heating systems (closed loop) can be connected to either vertical pipes inside boreholes up to over 200 m deep or horizontal pipes in shallow ground (1–1.2 meter). The depth and the length of pipe in the loop installation is mainly dependent on the energy demand and the soil properties. Assuming the ice-forming heat value of the ground to be 55 kWh/$m^3$ and the maximum depth of one borehole to be 200 m, the land area required for boreholes in the Tervakoski case would be around 14,000 $m^2$. The corresponding area for installing horizontal pipes would be 36,500 $m^2$ (1.5 m spacing, source SULPU 2012).

+ *Ground source heating systems can also be used for effective cooling for the buildings.*

+ *Individual heating systems have less heat transfer loss than district heating.*

+ *Solar photovoltaic systems with storage capacity (battery) would also provide backup power during blackouts.*

**Comparison of the solutions to the current case**

With reference to energy prices in 2011, it may be considered that the option of using ground source heat pumps and solar panels would be the most beneficial in terms of consumption (see Appendix 1). However, this option would, according to Finnish standards, contribute to most $CO_2$-equivalent emissions, since biofuels and biomass are regarded to be $CO_2$ neutral. The E-number (kWh/$m^2$/a) is used in Finland for denoting the energy efficiency of buildings and is calculated by multiplying energy demand with a specific factors related to the source of energy used. The lower the E-number, the more environment-friendly the building (see Table 1 - 7 and Table 1 - 8 in Appendix 1). According to this method, the GSHP + Solar PV option resulted result in the lowest accumulated E-number (kWh).

Table 7. Tervakoski case comparison

| Cases | Yearly heating costs (k€) | E-Number | $CO_2$-ekvivalents [t/a] *Source: *Motiva* |
|---|---|---|---|
| Current | 131 979 | 1 470 730 | 1,3 |
| Solar + Wood chip heating | 93 009 | 1 188 072 | 1,7 |
| GSHP + Solar PV | 63 288 | 1 174 553 | 145,1 |

[7] Calculations with PVGIS application by IET.

**Business opportunities and models for the Tervakoski case**
In Tervakoski case the ground source heat pump is selected for the business opportunities review.

Table 8. Business concept framework table for case Tervakoski

| Parameter | Description | Options |
|---|---|---|
| Customer | In Tervakoski case the municipality is the only customer. | Municipality |
| Ownership | The plant and panels are owned by the service company. The heat distribution network is owned by the municipality. | Private company |
| Income | A steady income is secured by the long term contract with the municipality. | Cash flow |
| Financing | Financing is required to cover the initial investments. Bank loan is likely to be granted because of the long term contract with the municipality. | Loan |
| Pricing | Both low and high limit of the price are determined. Low limit is cost based and relational to the electricity price index. The high limit is based on an index determined by prices of several regional district heat providers. | Cost and market-based lower and higher limits. |
| Fuel | In the case of a heat pump and solar PV no fuel as such is needed. However, from the risk point of view, availability of “fuel” has to be secured by sizing the system properly. | Ground heat<br>Solar<br>Power |

The municipality's investment comprises the construction of a district heating network that covers these properties. Keeping the network in the municipality's ownership will ensure that, if necessary, the heating for the properties can also be acquired through solutions other than subcontracting from the original supplier. In this way, the long-term risks of the municipality can be reduced, while the entrepreneur's investment is specifically targeted to the profit-generating part of the operations, the heating plant.

Financing required for the investment and the operating capital is arranged by the company offering the service. The district heating agreement made with the municipality is the decisive factor as it provides a sufficient guarantee to the lender. This makes it possible for the heating entrepreneur to procure financing that is sufficiently affordable and long-term for profitable business operations.

A wood chip plant utilising local wood chip production acts as the starting point. In this way, the benefits of the business remain within the municipality to the extent possible, if competitive operations and pricing level can be maintained.

With regard to risk management, the pricing of the heating power can be used to influence the distribution of risk between the entrepreneur and the municipality. Here, the risks to be managed comprise the price development of the fuel and labour costs. The agreement will allow the cost of the purchased heating power to fluctuate within a kind of a pipe, where the customer assumes a larger part of the costs exceeding the upper limit through an increased price. On the other hand, the price of the heating power will decrease below the lower limit. The principle of the distribution of risk is that it is not fiscally sensible for the municipality to drive a local business to bankruptcy. On the other hand, with this model it is most profitable for the entrepreneur to keep the costs at the lower limit of the agreed price pipe, which promotes efficient operations.

Naturally, the company can also offer added-value services to the customer. In the local heating entrepreneur scenario this is, however, not as much of a given as in the case of larger companies, because the added-value services require both additional capital and personnel with the right skillsets. Indeed, it is likely that only heating would be purchased from the company, and the municipality would handle activities such as monitoring and optimising the energy consumption of the properties itself or through outsourcing.

## 5.3 Tuusula Rykmentinpuisto case

The Rykmentinpuisto area in Tuusula is being planned for 9,000 residents and hundreds of jobs. The detailed plans are under development, which means that our analysis for this case was more to estimate energy consumption and production, and on this basis to give suggestions for energy solutions and systems in order to increase the use of renewable energy and make the area more energy effective. A draft version of one of the suggested detailed plans is shown in Figure 14.

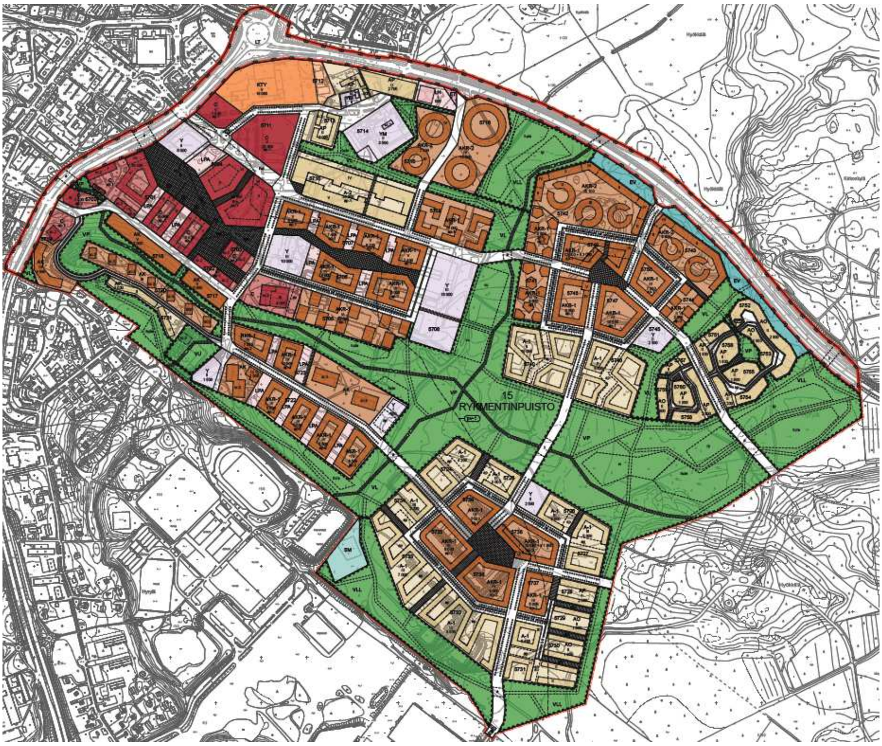


Figure 14. Conceptual general plan for Rykmentinpuisto*, Akkitehtuuritoimisto B&M OY*

It was assumed that the area was to be developed in four phases where energy efficient buildings were used for the design. As for the energy consumption of the buildings, most residential buildings would achieve energy class C–B according to today's standards (no domestic energy production). The energy demand of the office buildings would correspond to energy class E–C (see Table 1 - 8 in Appendix 1). The amount of residential and office/commercial floor area was consistent with the planning directives of Arkkitehtuuritoimisto B&M OY (Arkkitehtuuritoimisto B&M OY 2012).

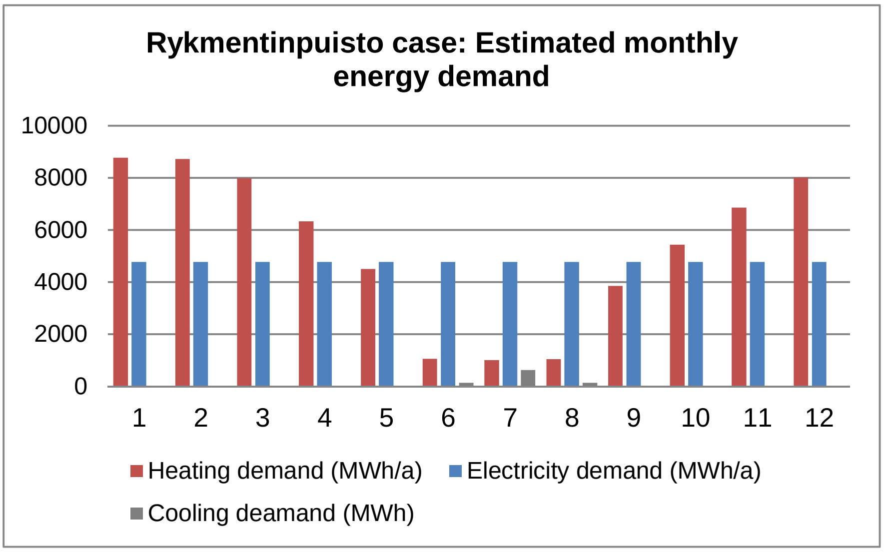


Figure 15. Estimated monthly energy demand, Rykmentinpuisto

Figure 15 shows the anticipated heating, cooling and electricity demands in the Rykmentinpuisto area when the plans have been implemented. Regarding energy production in the area, we prepared two alternative cases for demonstration. The first case consists mainly of ground source heat pumps (coefficient of performance: 3) with some additional renewable energy production (GSHP + R). The second case is a combination of a bigger percentage of combined heat and power production with some ground source heating and renewable energy production (CHP + R). These cases are described in more detail in Table 9. The amount of renewable energy was regarded to be the same in both cases, and the required surface area for the energy systems can be found in Appendix 1, Table 1 - 10.

The GSHP+R and the CHP+R cases were compared through economic, environmental and political values, all from the perspective of the residents. By estimating a linear progression of average consumer prices for electricity and district heating (over the period 2000–2013; Tilastokeskus 2013, Energiateollisuus 2012), the results showed that the GSHP+R alternative would be more beneficial from the end-consumer perspective. By using an energy factor of 0.7 for district heating and 1.7 for electricity, we found once again that the GSHP alternative would be more preferable from the end-consumer perspective. Average values of 2011 were used for calculating $CO_2$ equivalent, which also showed that the GSHP+R case had the advantage.

Even though the comparison performed showed that the GSHP+R option would be the most favourable, there might be additional factors that should be considered in order to find the optimal solution. The comparison was done considering the most beneficial alternative when looking from a more holistic perspective (stakeholders, subsidies, financial solutions, technical solution, maintenance, logistics, etc.). For example, the economic benefits of a solution might be different from the perspective of an investor, system provider or the end consumer, or the environmental assessment would favour the CHP+R alternative if biofuels were to be used.

Another important issue affecting the choice of an optimal energy solution or combination of solutions for the Rykmentinpuisto development is the possible synergies that could arise. For example, opportunities for synergies could be provided by the involvement and collaboration of various stakeholders from the beginning of the planning phases. In this way, synergies could be leveraged in planning, implementation, permit applications and logistics.

Table 9. Rykmentipuisto energy production cases

| | GSHP + R | CHP + R |
|---|---|---|
| **Energy demand [TWh/a]** | | |
| Heat | 63,6 | 63,6 |
| Electricity (includes cooling) | 79,2 | 62,2 |
| **Local energy production [TWh/a]** | | |
| Ground source heating | 60,9 | 14,8 |
| Solar heat | 1,8 | 1,8 |
| Solar electricity | 15,8 | 15,8 |
| Wind power | 17,8 | 17,8 |
| **Energy Balance [TWh/a]** | | |
| Bought heat | 1,6 | 47,0 |
| Bought electricity | 45,6 | 28,6 |
| **Comparison** | | |
| Consumer Energy price M€/a | 13,55 | 18,36 |
| Energy number [-] | 77,48 | 81,59 |
| $CO_2$-equivalents emissions [t/a] | 9 572 | 16 218 |

### 5.3.1 Business opportunities and concepts

The location of the Rykmentinpuisto area, in the middle of existing residential and business areas, makes this case a most interesting one from the business perspective. The energy providers already supplying heat to the surrounding areas are in a good position to provide services for Rykmentinpuisto too. However, this together with the local energy potential within the area, creates an interesting portfolio of energy options that the municipality needs to assess carefully.

Here, we chose to form and evaluate an imaginary business concept based on the aforementioned GSHP+R option. The energy production in this concept is local district heating based on a ground source heat (GSH) field that grows together with the area following the park, but supplemented with other local renewable energy options (+R) where needed and wanted. Also a connection for external heat procurement should be implemented.

A key part of this concept is an actor who provides comprehensive energy services for the area – residents, businesses and municipal services like schools and day care centres. This can be the energy producer but could also be a separate body. The point is that if local energy solutions are to be implemented widely in the area, this has to be made not only profitable but easy for those making the property investment decisions.

The starting point of the Rykmentinpuisto case is a new energy company to be established in the area, Rykmentinpuiston energia Oy (RPe Oy). Its ownership base would comprise the Municipality of Tuusula together with the regional energy company. In addition to them, there could be other minority shareholders. Distributing the ownership ensures the municipality's perspective as a customer and developer of the area, and the inclusion of the energy company's competencies in the operations.

RPe Oy will deliver district heating to the customers in the Rykmentinpuisto area via the local district heating network it owns. The company either produces the heat itself or purchases it from a third party. The starting point is to offer the customer district heating that is as affordable and reliable as possible.

RPe can also produce electricity in the area, either to be sold to the grid or for its own use (for example, to power the district heating network). Although these other alternatives are not discussed here, they constitute an interesting part of a possible future service portfolio and must be taken into consideration during planning.

RPe Oy can also produce other services it wishes. These are not, however, financed with profits from district heating; here; they are considered to be separate for-profit operations with market-driven pricing. Such services could include customer support, energy management, information services and the development of the area's energy use. The customers of the services could include private citizens, real estate companies, constructors, developers and public agents. The market area of the additional services is not geographically limited. They could also be targeted, for instance, at offering electricity and the storage and saving of energy. Indeed, it should be considered whether it would be better to establish a separate company for these for-profit service operations. This should then be taken into account when defining RPe's role in the area.

In the beginning, the company will finance its investments and operations with its own capital and loans it has taken. The loan management expenses are included into the price of the energy. The ratio of the technical lifetime and the required replacement investments to the payback period plays an essential role in the investments. It has a great impact on the risks inherent in the operations and their management.

Retaining flexibility should lie at the root of the company's operations and the solutions it has chosen. In practice, this can be achieved by binding the company to individual energy suppliers in a considered manner and for limited agreement periods. In practice, RPe Oy is a buyer, distributor and seller of heating power that does also have the possibility of producing energy in the Rykmentinpuisto area. From the perspective of risk management, however, the share of own production should be kept sufficiently small with the capital tied up for a sufficiently short period of time. The reliable anticipation of costs, such as the price development of fuel, is essential for the investments.

A local energy company that offers a distribution channel for different energy producers through its open district heating network will enable the diverse development of energy production in the area. The planning of the operations must take into account the objectives of the municipality concerning, for instance, local energy entrepreneurship and fuel production. Optimally, such an operating environment will create a functional environment for experimentation and innovation that is sure to attract wider interest from operators in the sector, other municipalities and researchers.

The energy demand estimates for any greenfield area being developed are based on historical statistics and future predictions. Every real-life area is different; energy efficiency regulations are changing, and the number of customers correlates with the rate of area development that correlates with the overall market situation. These leveraged uncertainties have an impact on the investment willingness of any energy provider. Thus it is important, especially in the case of capital-intensive district heating solutions, to come to an agreement about risk sharing.

To make local energy a viable choice in area development, right from the beginning, all planning must include this option in the design and decision-making processes. This requires integration of all interest groups within and outside the local authority into a well-planned and well-designed open innovation process that is actively executed and managed.

Table 10. Business concept framework table for case Rykmentinpuisto

| **Parameter** | **Description** | **Options** |
|---|---|---|
| Customer | In Rykmentinpuisto case almost all customer types are present. | Municipality<br>Businesses<br>Housing cooperatives<br>Households |
| Ownership | The biggest owners of the RPe company are municipality and regional government-owned energy company. Minority shareholders would bring into business additional knowhow and different perspective. | Municipality<br>Government-owned company |
| Income | Income is related to the development phase of the area and the market share of RPe. The income additional to the heat sales are dependent to the potential service portfolio of RPe. | Cash flow from heat and service sales |
| Financing | Financing is required to cover the initial investments and district heating network development. | Loan<br>Own capital<br>Subsidies |
| Pricing | RPe has to be competitive in the area since other energy providers can also provide services in the area. | Market based pricing |
| Fuel | RPe has own energy production facilities in the area. The technologies are not fixed since the area will develop over the next 30 years. RPe can start e.g. by procuring heat from external providers combined with a local ground source heat pump field and a small scale heat plant. | Various |

## 5.4 Economic evaluation of the cases

The financial indicator used in these example calculations is payback time. It was chosen because it is the commonly used investment indicator and is easy to apply and understand. The calculated payback time (as well as all other possible indicators) is very highly dependent on the applied calculation assumptions. Main assumptions used in the calculations are the following:

- Value added tax (VAT) is excluded

    - Therefore, the prices used in the calculations reflect the price paid by an operator that uses VAT 0% prices. This assumption is used to simplify calculations. However, each operator should take into account the actual VAT interpretation of each case.
- The price of electricity from grid is 90 €/MWh
    - Including energy, transfer and monthly fees
- The price of district heating is 60 €/MWh
    - Including energy and monthly fees
- There are different scenarios for energy price development
    - 2% increase per year
        - This is the moderate scenario where energy price development follows closely the inflation development of recent years
    - 4% increase per year
        - In this scenario energy price is increasing faster than general price level
- Operating expenses of renewable energy solutions increase 2% per year
- Investment prices of renewable energy solutions decrease 2% per year
    - The overall price trend of renewable energy solutions has been mainly decreasing during the last 10 to 15 years. This applies especially to solar photovoltaic solutions. Therefore, the annual price decrease for solar PV is assumed to be 5% per year. In Tapaila and Tervakoski cases these assumptions are used for a period of 5 years. In Rykmentinpuisto case, the same assumptions are used for a period of 10 years. This longer time horizon also increases the uncertainty related in calculations.
- No investment subventions, other subsidies or feed-in tariffs are taken in account
    - The amount and availability of these should be carefully studied in each case
- The calculations horizon applied is 25 years

Using a longer calculation horizon (up to 50) would have been possible, but the uncertainty related to the applied assumptions would have been significant in the later years. In addition, the payback times of various energy solutions are generally less than 25 years, so the effect on the results would have been minimal.

- The possible residual value at the end of the period is not taken into account

It's very hard to predict what will be the residual value after 25 years in a field where technological development is generally fast. And again, the payback times of various energy solutions are generally less than 25 years, so the effect on the results would have been minimal.

In Tapaila and Tervakoski cases these price change assumptions are used for a period of 5 years. In Rykmentinpuisto case, the same assumptions are used for a period of 10 years. This longer time horizon also increases the uncertainty related in calculations.

The prices and other assumptions used in the calculations are mainly based on the discussions, workshops and interviews carried out during the project. The actual prices may differ greatly from these prices. Mainly because of the following uncertainty factors: Which part of the existing infrastructure can actually be used to support the new renewable energy solution? What are the actual conditions (wind, sun, soil) on the site? (Regarding wind and solar solutions as well as GHSP) What will be the scale or volume of the actual solution? (Changes in investment price are not usually linear if the scale or volume of the solution changes). When will the actual investment take place? (Prices of energy and renewable energy technologies change over time so depending on the market situation the price environment may be totally different). Because of this high level of uncertainty, the payback times are presented using a price range of +/- 25% for the renewable energy solutions. Further, the main idea of the graphs is to provide a view of the possible order of magnitude and also provide information on how sensitive the values are for changes in calculation assumptions.

### 5.4.1 Tapaila case

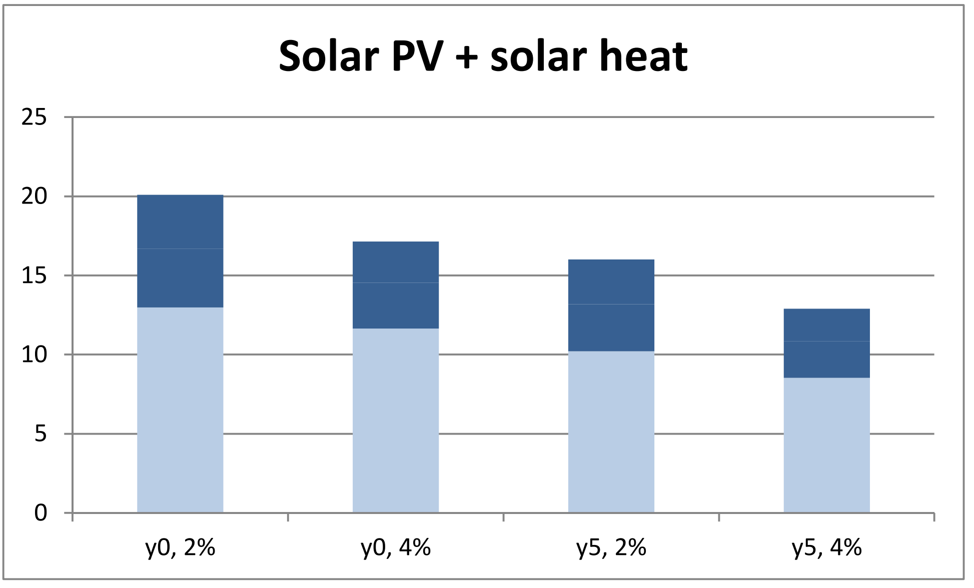


Figure 16. Payback time of the Solar PV + Solar heat solution (dark blue, investment price range +/- 25%)

In this solution the amount of produced solar electricity and solar heat are equal (in MWh/y). Figure 16 also implies that delaying the investment for 5 years with 2% energy price increase assumption results in more favorable solution than investing now using the 4% energy price increase assumption.

The payback time of the total energy solution is highly dependent on the cost of excess heat from the nearby factory. Even though there is a pellet factory very near, building a pellet heating plant just to cover the peak hours of heat consumption may not be a good choise, because of the low utilization rate. Therefore, this option should preferably include a possiblity to sell heat also to some other buildings around the area. Another option would be to use district heating to complemet excess heat of the factory.

### 5.4.2 Tervakoski case

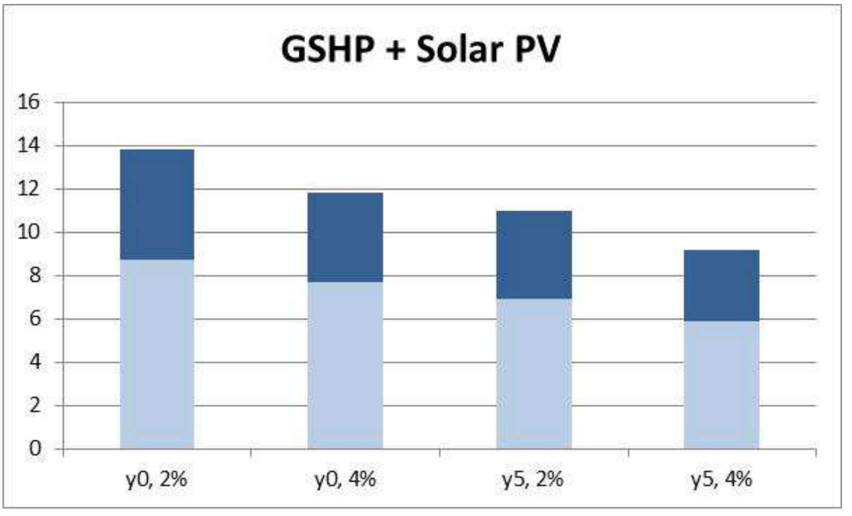


Figure 17. Payback time of the GSHP + solar PV solution (dark blue, investment price range +/- 25%)

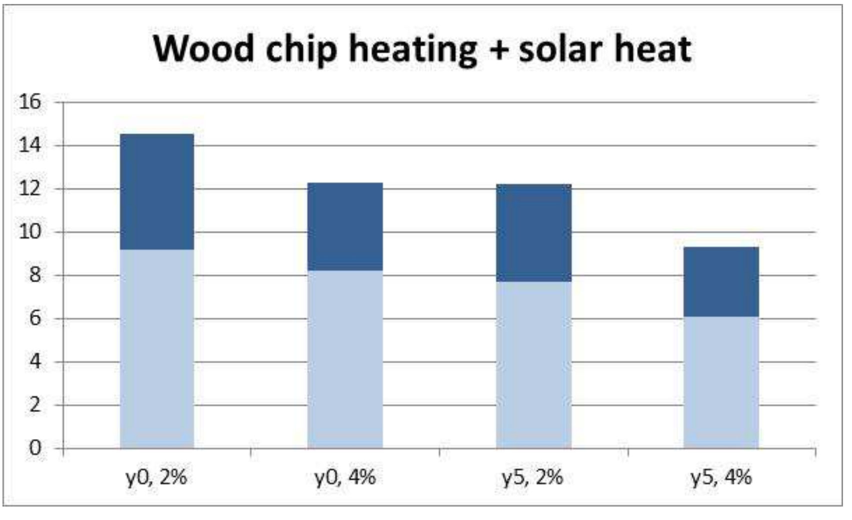


Figure 18. Payback time of the Wood chip heating + solar heat solution (dark blue, investment price range +/- 25%)

Figure 17 and Figure 18 depict roughly the payback time of two different heating solutions. What can be concluded is that in both options delaying the investment for five years will result in lower payback time, because the investment can be made in more favourable conditions (lower investment cost, higher energy price). This is especially true in GSHP + Solar PV solution, since the technology price decrease was assumed the highest with Solar PV. In this case delaying the investment for five years (keeping the 2% energy price increase assumption intact) will result in better payback time figure than doing the renewable energy investment now with a 4% energy price increase assumption. When considering Wood chip heating + solar heat solution delaying the energy investment for five years (keeping the 2% energy price increase assumption intact) or doing the energy investment now with a 4% energy price increase assumption will result in very similar numbers. Tervakoski case is also a replacement investment site. Whether the investment can be delayed for five years or even more is, therefore, linked to the condition the current energy system. The price of the energy investment is also dependent on the old energy system and infrastructure and to what extent they can be utilized in the new solution.

The annual operating costs of the GSHP + solar PV solution are closely linked to the price of electricity, since only around 15% of the electricity required by GSHP is produced by solar PV system. The annual operating costs of the Wood chip heating + solar heat solution, on the other hand, are dependent mainly on the price and availability of wood chips.

### 5.4.3 Rykmentinpuisto case

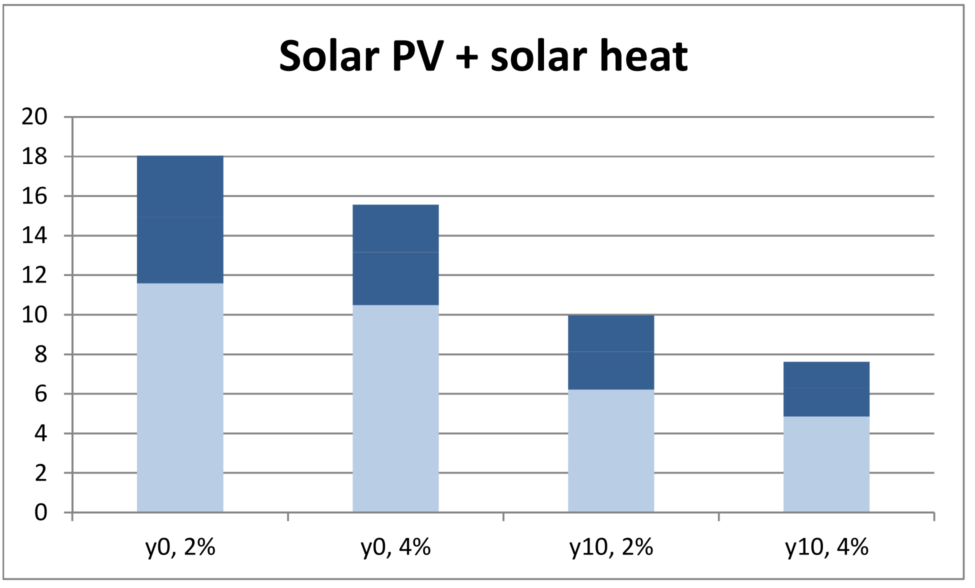


Figure 19. Payback time of the Solar PV + Solar heat solution (dark blue, investment price range +/- 25%)

Rykmentinpuisto differs greatly from the two replacement investment cases. Time horizon is the longest, because the full construction of the area will take around 20–30 years. This has to be taken into account when considering the payback times of the solutions. Further, there are basically no current energy solutions so there is no need to consider which parts of the old energy infrastructure can be utilized in the new solution. It is hard to estimate whether the economic impact of this is positive or negative. Depends greatly on condition of the old energy infrastructure. Another major difference is that because the construction of the area takes very long time, also the total energy investment will be carried out in many parts. Therefore, calculating the payback time for the total investment provides rather misleading information.

In this case it's best to calculate the payback times for annual investments carried out in certain years. In this case years one and ten were chosen for calculations. The average payback time for all annual investments carried out during the first the years is somewhere in between these two extremes depicted in Figure 19. In this case delaying the investment seems to be a lot more profitable than in two previous cases. This is the result of 2 main factors: 1) delaying the investment for 10 years is more profitable than delaying the investment for 5 years because of the calculation assumptions. 2) Solar PV has a major role in this solution (almost 9 times the amount of solar heat in terms of MWh/y. This latter combined with the assumption that the initial investment price for solar PV solutions decreases 5 percent annually explains a lot. When comparing the two extreme values (y0, 2% and y10, 4%), the investment price is almost 40 % lower and energy price is around 50 % higher (already at the investment time and the annual increase will be calculated on top of this). This gives a very good view on the impacts calculation assumptions have on final result.

When considering the overall energy investment of the Rykmentinpuisto case, there will be also wind power together with GSHP or CHP plant. The payback times for very large scale wind power solutions will be quite close to the figures of the depicted solar PV + solar heat solution. So it has only a minor effect on the payback time of the total investment. Small scale wind power solutions, on the other, hand have currently considerable longer payback time so it would have a negative impact on the payback times. What kind of wind power solutions can and will be applied, depends on many factors.

Both, GSHP solutions and CHP plant have considerable lower payback times than the depicted solar PV + solar heat solutions (on current prices), so this component will lower the payback time in both cases. One main difference is that GSHP solutions can be built annually following the development of the whole area. A CHP plant on the other hand is a large one-time investment that can be carried out when there is already enough demand for the produced energy. If a CHP plant is built in the very beginning of the area development the excess energy should be sold to other energy users nearby in order to realize the full potential of the plant.

# 6. Discussion

As from the demonstration cases, we experienced that there were incentives from part of the cities/municipalities to involve renewable energy and energy efficiency in the urban development. However, there was usually lack of knowledge or a holistic vision amongst the decision makers regarding for the development. The main problem here is that there are many interests that has to be taken into consideration which is not solely bound to solutions regarding energy demand and production but also other technological (e.g. waste management, water and wastewater, industrial) and social (services, need of residents, political incentives) interests. Another problem is also limited monetary resources that drive cities/municipalities to reorganise services and use of resources which increases the risks of investing in renewables or energy efficiency (buildings might become vacant in future).

Involving the utilization of renewables and energy efficiency in urban development might also be challenging for smaller municipalities due to the marginal market. Subcontractor coordination and stakeholder negotiations are necessary in order to find synergies (business opportunities, subsidies, installation etc.) and reduce potential risks (building permits, funding, expertise). One way this could be overcome is if there would be a larger company that withholds all the necessary services and products for necessary preparation process (stakeholder involvement, applications, pre-evaluations) and implementation of solutions. Another similar opportunity would be through a network of solution providers that would deliver the same service to the municipality.

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# Appendix 1: Energy calculations, numeric values

Table 1 - 1. **Tapaila block energy demand and solar photovoltaic production (MWh)**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| District heating demand (measured) | 506,5 | 542,1 | 421,4 | 270,7 | 174,4 | 73,1 | 60,9 | 70,2 | 135,3 | 232,7 | 288,3 | 348,2 | 3 123,9 |
| Electricity demand (measured) | 134,1 | 126,7 | 132,0 | 120,4 | 119,4 | 180,2 | 119,0 | 120,0 | 120,0 | 126,3 | 131,7 | 143,6 | 1 573,4 |
| Hospital Solar PV gains | 1,7 | 5,6 | 9,2 | 12,9 | 14,9 | 13,9 | 13,9 | 10,9 | 7,4 | 4,3 | 1,6 | 0,9 | 97,0 |
| Kotipelto Solar PV gains | 1,4 | 4,6 | 7,8 | 11,2 | 13,1 | 12,4 | 12,3 | 9,6 | 6,4 | 3,6 | 1,3 | 0,7 | 84,4 |

Table 1 - 2. **Tervakoski case, current energy demand (MWh)**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| District heating demand (yearly measured) | 360,0 | 374,2 | 295,1 | 169,3 | 99,4 | 50,4 | 51,4 | 51,4 | 79,2 | 123,4 | 178,9 | 253,2 | 2 085,7 |
| Electricity demand for heating | 1,1 | 1,1 | 0,9 | 0,5 | 0,3 | 0,2 | 0,2 | 0,2 | 0,2 | 0,4 | 0,5 | 0,8 | 6,3 |

Table 1 - 3. **Tervakoski case, Solar collectors + Wood chip firing (MWh)**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Solar collector production | 5,5 | 17,2 | 30,5 | 44,4 | 55,0 | 52,3 | 54,9 | 41,9 | 27,3 | 15,2 | 5,3 | 2,9 | 352,3 |
| Wood chip firing | 354,5 | 357,0 | 264,7 | 124,8 | 44,5 | 0,0 | 0,0 | 9,5 | 51,9 | 108,2 | 173,5 | 250,3 | 1 738,9 |
| Electricity demand for heating | 1,6 | 1,7 | 1,2 | 0,6 | 0,2 | 0,0 | 0,0 | 0,04 | 0,2 | 0,5 | 0,8 | 1,2 | 8,1 |

Table 1 - 4. **Tervakoski case, Ground source heat pumps + Solar Photovoltaics (MWh)**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GSHP electricity demand from grid | 131,4 | 136,7 | 114,6 | 56,4 | 33,1 | 16,8 | 17,1 | 17,1 | 26,4 | 41,1 | 59,6 | 91,9 | 742,4 |
| Solar PV electricity generation | 2,2 | 7,0 | 11,5 | 16,2 | 18,6 | 17,3 | 17,4 | 13,6 | 9,2 | 5,4 | 2,0 | 1,1 | 121,3 |
| Difference (bought from the grid) | 129,3 | 129,7 | 103,1 | 40,3 | 14,6 | -0,5 | -0,2 | 3,5 | 17,2 | 35,7 | 57,7 | 90,8 | 621,1 |

Table 1 - 5. **Tuusula Rykmenttipuisto case, design of energy demand of blocks**

| Schedule | Block name | Total floor area m2 | Average heat demand [MWh/m2] | Average electricity demand [MWh/m2] | Average cooling demand [MWh/m2] | Total heat demand [MWh] | Total Electricity demand [MWh] | Total Cooling demand [MWh] |
|---|---|---|---|---|---|---|---|---|
| Phase 1 (2020) | KESKUSTA + | 114000 | 70 | 45 | 0,5 | 7980 | 5130 | 57 |
| Phase 2 (2025) | HYÖKKÄLÄ + | 103400 | 80 | 65 | 2 | 8272 | 6721 | 206,8 |
| | OLYMPIAKYLÄ ++ | 28000 | 65 | 50 | 0,5 | 1820 | 1400 | 14 |
| Phase 3 (2033) | HUVILAKYLÄ +++ | 105800 | 55 | 40 | 0,5 | 5819 | 4232 | 52,9 |
| | PUISTOKYLÄ +++ | 82800 | 55 | 40 | 0,5 | 4554 | 3312 | 41,4 |
| Phase 4 (2040) | SAMMALKALLIO ++ | 63000 | 65 | 40 | 0,5 | 4095 | 2520 | 31,5 |
| | ONKAKALLIO ++ | 59800 | 60 | 40 | 0,5 | 3588 | 2392 | 29,9 |
| | RYKMENTINVUORI+++ | 56100 | 55 | 60 | 0,5 | 3085,5 | 3366 | 28,05 |
| | KORPIVUORI ++ | 46200 | 60 | 60 | 0,5 | 2772 | 2772 | 23,1 |
| | MÄYRÄKORPI + | 110050 | 75 | 100 | 2 | 8253,75 | 11005 | 220,1 |
| | MYRTINKAARI + | 63000 | 75 | 100 | 2 | 4725 | 6300 | 126 |
| | VIHERMÄKI ++P | 107100 | 60 | 55 | 0,5 | 6426 | 5890,5 | 53,55 |
| | MYRTINOJA +++P | 18900 | 55 | 55 | 0,5 | 1039,5 | 1039,5 | 9,45 |
| | UUSIKYLÄ +++P | 21000 | 55 | 55 | 0,5 | 1155 | 1155 | 10,5 |
| SUM | | | | | | 63584,75 | 57235 | 904,25 |

Table 1 - 6. **Tervakoski case, Ground source heat pumps + Solar Photovoltaics**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GSHP electricity demand from grid (MWh) | 136,7 | 141,9 | 112,6 | 66,0 | 40,1 | 22,0 | 22,3 | 22,3 | 32,6 | 49,0 | 69,6 | 97,1 | 812,2 |
| Solar PV electricity generation (MWh) | 2,2 | 7,0 | 11,5 | 16,2 | 18,6 | 17,3 | 17,4 | 13,6 | 9,2 | 5,4 | 2,0 | 1,1 | 121,3 |
| Diffeerence | 134,5 | 134,9 | 101,1 | 49,8 | 21,5 | 4,7 | 5,0 | 8,7 | 23,4 | 43,6 | 67,6 | 96,0 | 690,9 |

Table 1 - 7. **Residential building E-number classification**

| Energyefficiency class | Total energy consumption, E-number (kWhE/m² year) | Source: Finnish building regulations D3 | | | |
|---|---|---|---|---|---|
| A | | | E-number | ≤ | 75 |
| B | 76 | ≤ | E-number | ≤ | 100 |
| C | 101 | ≤ | E-number | ≤ | 130 |
| D | 131 | ≤ | E-number | ≤ | 160 |
| E | 161 | ≤ | E-number | ≤ | 190 |
| F | 191 | ≤ | E-number | ≤ | 240 |
| G | 241 | ≤ | E-number | | |

| Table 1 - 8. **Commercial building  E-number classification** | | | | | | |
|---|---|---|---|---|---|---|
| Energyefficiency class | Total energy consumption, E-number (kWhE/m² year) | Source: Finnish building regulations D3 | | | | |
| A | | | E-number | ≤ | 80 |
| B | 81 | ≤ | E-number | ≤ | 120 |
| C | 121 | ≤ | E-number | ≤ | 170 |
| D | 171 | ≤ | E-number | ≤ | 200 |
| E | 201 | ≤ | E-number | ≤ | 240 |
| F | 241 | ≤ | E-number | ≤ | 300 |
| G | 301 | ≤ | E-number | | |

| Table 1 - 9. **Residential multi-storey building** | | | | | |
|---|---|---|---|---|---|
| Energy efficiency class | Total energy consumption, E-number (kWh/m² year) | | | | |
| A | | | E-number | ≤ | 75 |
| B | 76 | ≤ | E-number | ≤ | 100 |
| C | 101 | ≤ | E-number | ≤ | 130 |
| D | 131 | ≤ | E-number | ≤ | 160 |
| E | 161 | ≤ | E-number | ≤ | 190 |
| F | 191 | ≤ | E-number | ≤ | 240 |
| G | 241 | ≤ | E-number | | |

Table 1 - 10. **Rykmentinpuisto case, proposed surface occupation of renewable energy systems**

| | Total surface [ha] | % of corresponding available surface |
|---|---|---|
| Roof surface for solar energy | 8,50 | 23,7 % |
| Ground surface for solar energy | 18,46 | 4,6 % |
| Roof surface for wind energy | 1,65 | 6,9 % |
| Ground surface for wind energy | 72,78 | 27,4 % |

# Appendix 2: Risk assessment check list

**Risk assessment – step by step**

1. Define the target for assessment
2. Use the relevant keywords for identifying the risks (harmful situations, threats)
3. Describe who might be harmed and how
4. Evaluate the risks with the help of matrix
5. Describe precaution (current actions and mitigation actions suggested)

After the assessment make sure that all is recorded and inserted to the joint form. Implement actions and utilize the information. Review and update if necessary.

**Keywords**

Use keywords and questions in order to identify risks. Insert description of the risk in the joint form.

**Maturity** and **reliability** of the technology – Are there references of the technology, how long it has been used and how it has been tested?

**Resilience** of the solution

**Replaceability –** How easily the solution can be replaced later with another technology or energy source?

**Availability** of the energy source, technology or services

**Dependence** – Which dependences the solutions involve?

**Ownership** – Are there some risks related to the ownership of the area, plant, technology etc.?

**Investment –** Are there some risks related to the size or the type of the investment required?

**Attractiveness** and **accessibility** of the solution for the investors, client companies, users etc.

**Political factors** – Are there political factors supporting the use of particular energy source, technology or services?

**Planning -** Are there some avoidable risks emerging during the town planning process?

**Environmental impacts** – What are the environmental impacts of each solution?

**Safety** – Are there safety aspects that should be taken into consideration (e.g. safety of residents or operators/workers)

**Economic losses** – Are there any risks affecting financial loss to a business (e.g. property damage or destruction caused by the negligent acts of a third party)

# Appendix 3: Examples of risk identification

**Hazard and harm identification** Area: Rykmenttipuisto
Project: Remix
Date: 3.4.2014, Duration: 3 hours Participators: Tapani Ryynänen, Ari Jussila, Marinka Lanne

1. Geothermal heating

| Threat | Consequence | Risk | Current actions | Mitigate actions |
|---|---|---|---|---|
| Energy losses in the power distribution system. The area of geothermal heating is restricted causing long distances to the heated buildings. | Increased energy losses of the heating network, lost revenues. | | The geothermal heating area will be located near to the first premises. | Enough space reserved for the geothermal heating in zoning (a low temperature district heating network) . |
| The price of electricity increases. | Rise of the operating costs of the geothermal heating system due to the increased electricity costs. | | Efficient tendering of the electricity. Buying the heat from an external supplier. The capacity of the solar panels should be dimensioned to be sufficient in summer. The energy addition needed at the winter will be bought from an external supplier. | Producing the electricity independently from external suppliers, for example with the help of solar panels. In some cases the geothermal heating could be replaced with a new energy source (e.g. pellet plant). |
| The exact energy output is not known before the solution is executed. | The geothermal heating wells generate less energy than expected. More drills are needed, which increases the costs. | | Some geotechnical investigations are made, but not from the viewpoint of the geothermal heating. | Test drillings and measurements. Calculations with variable expected outcome. Decent margins when zoning the field, enough space for extra wells. |
| Funding from financial market is too expensive to enable profitable business. | Using other sources of funding (cooperatives, loans taken by the municipality). If other financing methods are not available, other energy sources should be selected. | | | Selecting a suitable business model. One option is that the municipality takes the risk, which usually belongs to the investor. |
| **Opportunities** | | | | |
| Opportunities to generate ”district cooling”<br>Relatively inexpensive energy solution (in addition, economies of scale in tendering)<br>Flexible solution when executed as decentralised<br>Reliable and robust | | | | |

Figure 3 - 1. Rykmentinpuisto Workshop outcomes

Series title and number

VTT Technology 281

| | |
|---|---|
| Title | **How to mix renewable energy technology, area development and business** |
| Author(s) | Tapani Ryynänen, Aleksi Lumijärvi, Ari Jussila, Ha Hoang, Markku Mikkola, Marinka Lanne & Markus Jähi |
| Abstract | In the REmix – Renewable Energy Technology Mix research project the focus was in the potential benefits and challenges of colocating different renewable energy technologies.<br>Strategic points of view were business, innovation and collaboration partnerships, project synergies, energy demand and supply, and costs.<br>In the center of the project were three real life cases. The ideas and models were innovated in the context of these cases together with the case owners who participated the group meetings. For this work researchers provided initial data, energy calculations and general descriptions of the cases. All this grounded the work to the cases that were also visited at the place.<br>In this publication we will first take a look into the nature of renewable energy markets and also the situation in Germany and Great Britain. Next we will discuss about the characteristics of renewable energy as business, like potential risks and investment related issues, emphasizing the financing models.<br>An important part of the REmix project was the analysis and group discussions about the potential supplier network synergies. The findings have been presented over the project lifecycle phases.<br>The case presentations are divided into four topics: introduction, energy demand, technological solution and business opportunities.<br>Some observations made during the project are shortly discussed at the end of this report. |
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Julkaisun sarja ja numero

VTT Technology 281

| | |
|---|---|
| Nimeke | **Miten yhdistää uusiutuva energia, aluekehittäminen ja liiketoiminta** |
| Tekijä(t) | Tapani Ryynänen, Aleksi Lumijärvi, Ari Jussila, Ha Hoang, Markku Mikkola, Marinka Lanne & Markus Jähi |
| Tiivistelmä | REmix – Renewable Energy Technology Mix -tutkimushankkeessa tarkasteltiin mahdollisuuksia ja haasteita, jotka liittyvät uusiutuvan energian tuotantoteknologioiden paikalliseen, verkostomaiseen toteutukseen. Tarkastelunäkökulmina olivat lähinnä liiketoiminta, innovaatioyhteistyö, projektien synergiat, energian tuotanto ja kysyntä sekä kustannukset.<br>Keskiössä oli kolme käytännön casea. Hankkeessa ideoituja kuvitteellisia ratkaisuita caseihin analysoitiin osallistujien yhteisissä työpajoissa. Niissä oli käytettävissä tutkijoiden laatimat casejen kuvaukset ja niihin liittyvät laskelmat, jotka perustuivat mahdollisimman pitkälle aitoihin tietoihin. Näin päästiin yhdessä konkretian tasolle. Lisäksi kävimme aidoissa kohteissa.<br>Julkaisun alussa on tarkasteltu lyhyesti uusiutuvan energian markkinoiden luonnetta sekä esimerkkinä tilannetta Saksassa ja Isossa-Britanniassa. Tämän jälkeen kuvataan uusiutuvan energian piirteitä liiketoimintana, siihen liittyvien riskien tarkastelua ja investointiin vaikuttavia seikkoja. Oleellinen osa on rahoituksen tarkastelu ja rahoitusmallien kuvaus.<br>Tärkeä osa hanketta oli ratkaisun toimittajaverkoston yhteistyömahdollisuuksien tarkastelu, joka toteutettiin osallistujien ryhmätyönä. Siihen liittyvät havainnot on esitetty toimitusprojektin osa-alueisiin ja elinkaaren eri vaiheisiin sijoitettuina.<br>Case-tarkastelu tehtiin eri näkökulmista: yleisesittely, energian kysyntäprofiili, tekninen ratkaisu yleisellä tasolla ja liiketoimintamahdollisuudet.<br>Julkaisun lopussa on nostettu esille hankkeessa havaittuja erityisiä huomioita. |
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| Julkaisija | Teknologian tutkimuskeskus VTT Oy<br>PL 1000, 02044 VTT, puh. 020 722 111 |

VTT TECHNOLOGY 281

How to mix renewable energy...

# How to mix renewable energy technology, area development and business

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