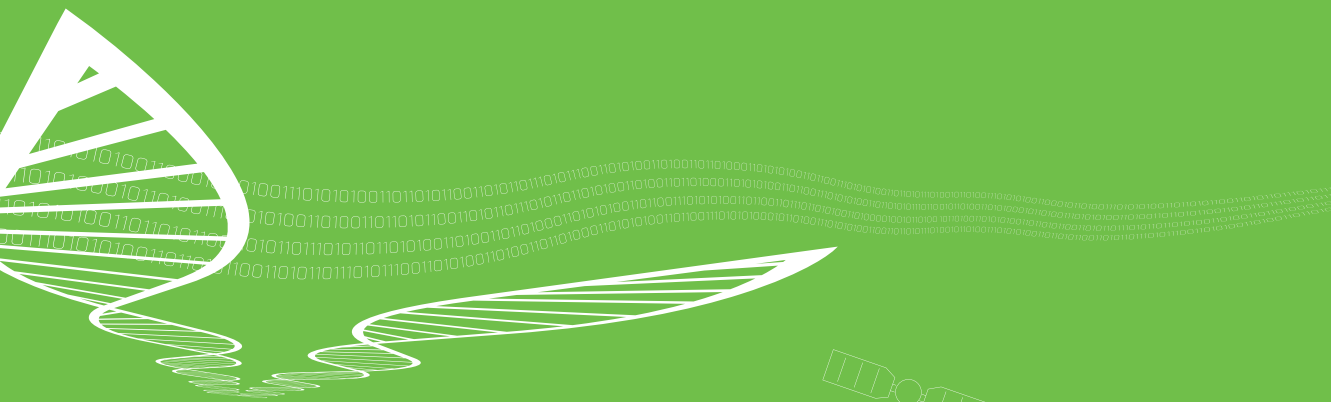


Smart sustainable mobility



A user-friendly transport system is a combination of intelligence, low carbon energy, and adaptable services



VTT VISIONS 5

**Smart
sustainable
mobility**

ISBN 978-951-38-8274-7 (print)
ISBN 978-951-38-8275-4 (online)

VTT Visions 5

ISSN-L 2242-1157
ISSN 2242-1157 (print)
ISSN 2242-1165 (online)

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PUBLISHER

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Printed in Kopijyvä, Kuopio 2014



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Mobility re-invented

Imagine a system based on actual user demand

Imagine a world in which people and goods can move with minimum impact on the local environment and climate. Imagine an intelligent transport system with smart infrastructure and smart connected vehicles powered mainly by renewable energy, and with enlightened end-users, private individuals and enterprises. Imagine a system that is actually based on user demand. That is what we would like to see.

Meanwhile, in the current world, emissions and other negative impacts of transport are on people's and policy-makers' lips. Transport accounts for some 20 % of greenhouse gas emissions and an even higher share of local pollution. Societal costs also arise from, e.g., congestion and traffic accidents.

We cannot stop transporting or moving. That is a fact.

The transport system performs vital services for the community by moving people and goods. Modern society depends on people going to work, goods being moved around and refuse being taken care of. People also like to travel in their spare time, in our case, typically, to their summer cottage for the weekend. In Finland, the transport sector represents more than 10 % of the gross domestic product and an equivalent share of employment.¹

In 2011, the EU Commission stated in its White Paper on Transport (European Commission, 2011) that "curbing mobility is not an option". The message

here is that we need mobility, of people and of goods, but we have to fulfil the mobility needs in a smarter and more sustainable way.

Will large, high-power, high consumption passenger cars become extinct?

Over the years, technology has been a wonder that has solved many problems of the day, but sometimes technology fit for today has created problems of tomorrow. In the early days of motoring, the car was seen as a blessing as it reduced the amount of horse dung in the streets. The number of cars and the need for infrastructure took off exponentially when oil was abundant and people were unaware of the long-term impacts of motorized mobility on climate change and air pollution. Oil was formed millions of years ago when the dinosaurs roamed the earth. The dinosaurs, some of them huge and clumsy, some of them fast and greedy, became extinct for one reason or another. Will the same happen to large, high-power, high consumption passenger cars? In the logistics sector, requirements for speed and just-in-time deliveries have increased transport work and the number of vehicles.

VTT's focus is on combining smart mobility with low-carbon energy.

So, we have to change things. It is no longer enough to make incremental improvements to

¹ *InfraExpo 2012 seminar in Helsinki, presentation by Juhana Vartiainen, available at http://portal.liikennevirasto.fi/portal/page/portal/ff/uutiset/2012/2012_9_10/12102012_seminaari/InfraExpo_Vartiainen.pdf*



SO, SIT BACK AND ENJOY A TOUR THROUGH OUR VISION OF SMART LOW-CARBON MOBILITY!

the vehicles we use in order to battle, for example, climate change. Mobility must be re-invented and considered as a whole. We have to convince people, as well as the commercial sector, to make sustainable choices that integrate all stakeholders in the actions that are needed. Today, we are at a crossroads for a paradigm shift that will encompass renewable energy, ultra-efficient vehicles, cooperative systems, smart mobility services and overarching optimization.

At VTT, we are reinventing mobility for the future. Our focus is on combining smart mobility with

low-carbon energy. That is, we study and improve the performance of renewable fuels including hydrogen, develop alternative power trains for vehicles based on fuel cells and electricity and bring ICT to transport by developing new services to make mobility more intelligent. To really create impact, we perform all of the above in close cooperation with other stakeholders and combine their views to obtain a truly holistic approach. With this publication we demonstrate our vision of safe, sustainable and energy-efficient mobility – a truly re-invented mobility that is fun and does not harm the environment.

Grand challenges and setting the stage

IN THE CASE OF IMPROVING THE TRANSPORT SYSTEM, IT MAY BE WISER TO DEFINE CRITERIA FOR PERFORMANCE RATHER THAN TO OPT FOR A CERTAIN TECHNOLOGY.

Global trends such as climate change, urbanization, urban sprawl, security issues, unfavourable demographics (aging), open markets and digitalization of the operating environment make it necessary to adapt and improve the whole transport system. As the system has significant inertia, it is important to react to early signals calling for change. Some people are envisioning a future society based on hydrogen. The decision-makers need wisdom in forecasting and creating roadmaps into the future. Betting on the wrong horse in the early stages of the race may turn out to be a costly mistake. Today, it is difficult to say which vehicle technology will win the race into the future: will it be the battery electric vehicle, the fuel cell vehicle or some other technology?

Balanced mix of technologies

We will most probably have a mix of technologies, a combination of electric propulsion and renewable fuels, in fact, not in competition but rather complementing each other. Figure 1 shows projections of energy use for transport to 2050.

One trend is beyond any doubt: ICT

One trend, however, is beyond doubt: information and communication technology (ICT) will definitely

revolutionize the whole transport system. Intelligence will be embedded at all levels of the systems: in the vehicle with its subsystems, in the surrounding infrastructure, in the energy supply, in the management systems and in the services delivered by the system. Internet of Things (IoT) will make communication between all components of the system possible, thus enabling a completely new level of optimization and automation.

Increasing vehicle numbers and transport work create challenges

The transport sector is highly regulated through international, regional and national rules and regulations. There are international regulations related to, e.g., vehicle exhaust emissions and vehicle safety features. The European Union has opted to limit the carbon dioxide emissions of passenger cars and vans. As of 2015, an automated emergency call system will be mandated for all new passenger vehicles. In Finland, there is a biofuels obligation law calling for 20 % biofuels in road transport by 2020.

Preliminary greenhouse gas emission (GHG) reduction targets have been set for the year 2050. It has been stated that transport should cut its GHG emissions by 60–80 %, depending on the framework. This will be a very demanding task as

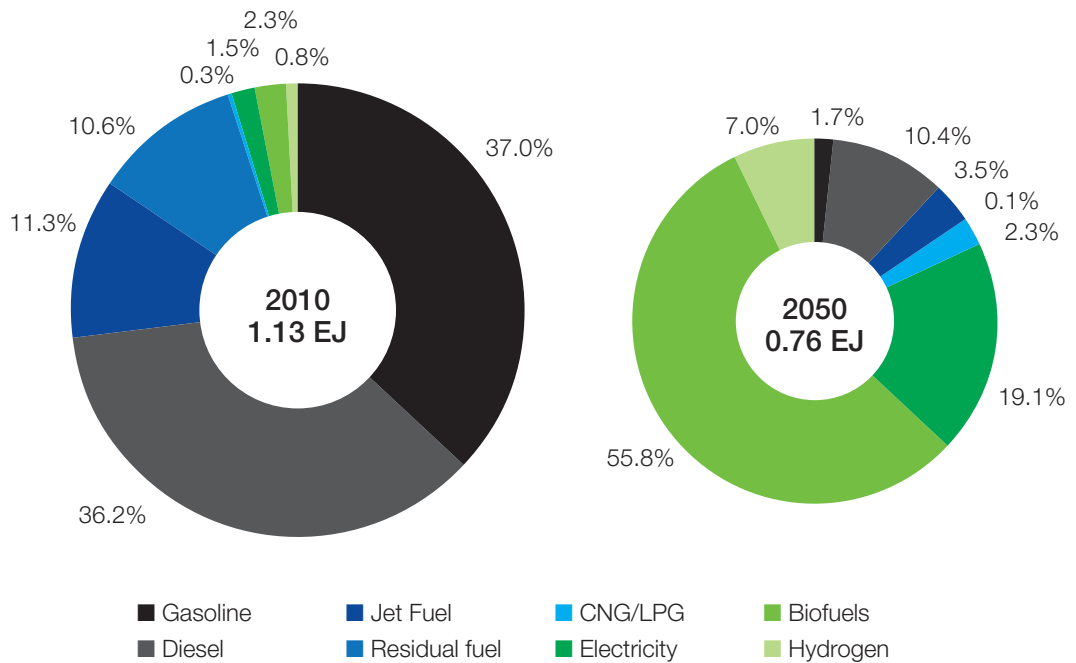


Figure 1. Projections for contributions of different energy sources to transport. According to the carbon-neutral scenario from Nordic Energy Technology Perspectives 2013 (IEA, 2013), a publication that includes input from VTT, we will see increasing shares of biofuels and electricity, and hydrogen will also find its way into transport. Compared with the situation we have today, we still have a long way to go!

vehicle numbers and transport work are expected to increase.

The European Commission has listed the following generic grand challenges (Horizon 2020, indented additions for implications on the transport sector added by the authors):

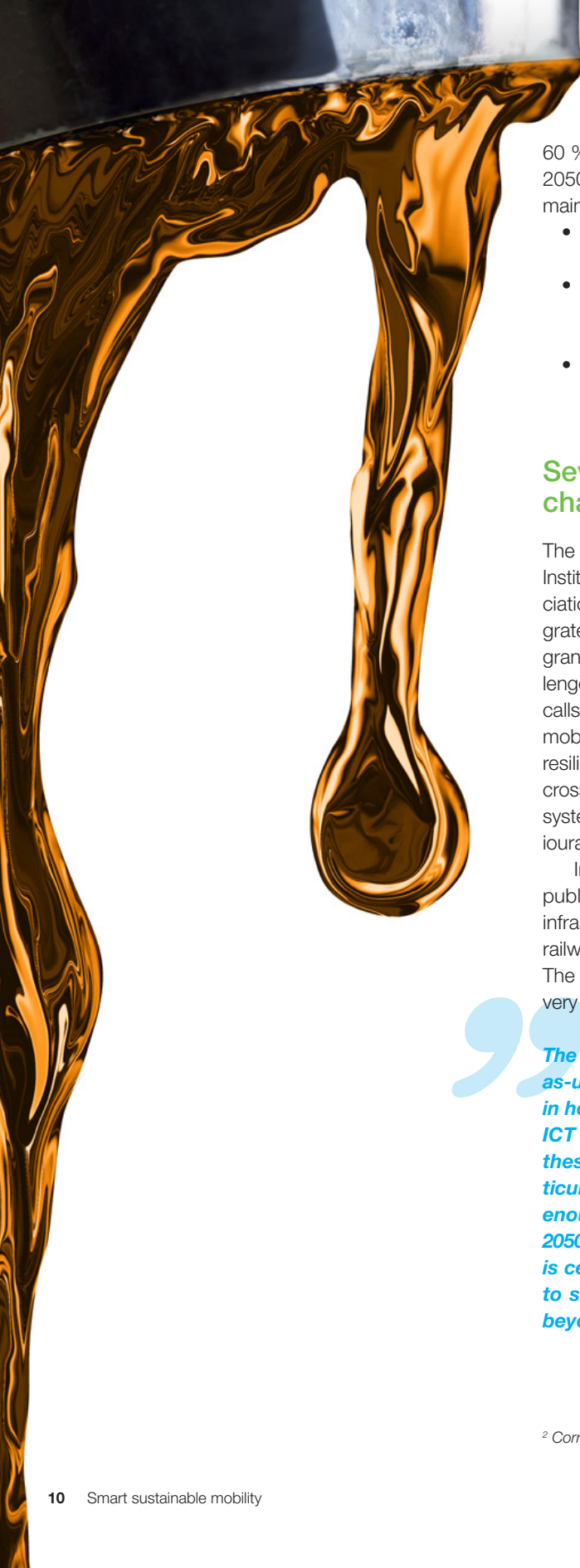
- Health, demographics and wellbeing
 - Control of local pollution, enabling mobility for elderly people
- Food security and sustainable bio-resources
 - Do not use food for fuel!
- Secure, clean and efficient energy
 - Move away from oil, increase energy efficiency and use low-carbon energy
- Smart, green and integrated transport
 - Think of traffic as a service, smooth

multi-modal services, integration of transport, infrastructure and energy

- Resource efficiency and climate challenge
 - Energy efficiency and low-carbon energy
- Secure and inclusive societies
 - Provide mobility for all.

Ten goals for a competitive and resource-efficient European transport system

The 2011 EU White Paper on Transport presents a roadmap for a competitive and resource-efficient European transport system (European Commission, 2011). The White Paper presents numerical targets for GHG emissions and energy (e.g. a



60 % reduction in GHG emissions in transport by 2050) and ten individual goals grouped into three main categories:

- developing and deploying new and sustainable fuels and propulsion systems
- optimizing the performance of multimodal logistic chains, including greater use of more energy-efficient modes
- increasing the efficiency of transport and infrastructure use with information systems and market-based incentives.

Several actors are calling for a change

The European Conference of Transport Research Institutes (ECTRI) is an international non-profit association. ECTRI stresses the importance of an integrated transport system in order to cope with the grand economic, environmental and societal challenges faced by society. According to ECTRI, this calls for an intelligent and adaptive transport and mobility system based on an interconnected and resilient infrastructure. ECTRI has identified seven cross-modal challenges for an integrated transport system. These include ‘soft’ issues such as behavioural aspects and socio-economic development.

In 2013, the International Energy Agency (IEA) published a report called ‘Global land transport infrastructure requirements: Estimating road and railway infrastructure capacity and costs to 2050’. The author of the report, John Dulac, has made a very clear statement²:

The world cannot support continued business-as-usual growth without some major changes in how we approach transport: either through ICT or mode shifting or some combination of these options. In developing regions in particular, it simply will not be possible to build enough roads to support 3 billion vehicles by 2050, electric, gas or conventional diesel... this is certainly a driver for finding real solutions to sustain long-term travel demand growth beyond vehicle and fuel technologies.

² Correspondence with John Dulac in 2013

Key point: de-carbonizing transport

Reducing CO₂ is not simple. CO₂ cannot just be captured from the tailpipe of the vehicle as is done for some regulated emissions. For example, eliminating particulate emissions from vehicles is quite simple: just add a particulate filter to the vehicle. There is therefore hope that technology will eventually solve the problems of local air quality. However, we still have to renew our vehicle fleet with new clean vehicles at sufficient pace, eliminating old high-emitting vehicles. The reduction of CO₂ emissions remains a challenge.

CO₂ formation is affected by system level issues as well as technical performance

To set transport on a track to sustainability, we have to reduce CO₂ emissions substantially. This is in fact the key challenge, and there is no simple way to do it. We cannot just hook a CO₂ catalyst onto the vehicle; it simply does not work that way.

In order to de-carbonize transport energy, we must first understand which factors and to which extent they contribute to the CO₂ emissions of

transport. The process of CO₂ formation is affected by system level issues as well as the technical performance of the components of the system.

Figure 2 explains the formation of CO₂ emissions. The amount of emissions depends on:

- the amount of travel/transport (transport work: in the case of people how many passenger kilometres, in the case of goods how many ton kilometres)
- the specific energy consumption of the means of transport (amount of energy needed per passenger kilometre or ton kilometre)
- the carbon intensity of the energy used (low, e.g. for renewable electricity, hydrogen and biofuels, high for conventional fossil fuels and electricity generated from coal).

Consumed energy has three main contributors

The amount of energy has three main contributors: the number of people and the amount of goods moved, the distance travelled and the specific

IN SIMPLE TERMS, THE AMOUNT OF CARBON EMITTED BY THE TRANSPORT SYSTEM DEPENDS ON THE AMOUNT OF ENERGY USED AND THE CARBON-INTENSITY OF THAT ENERGY.

energy consumption of the vehicles. The carbon intensity of the energy depends on the type of fuel or energy carrier and how it is produced.

Transport work is affected by factors such as:

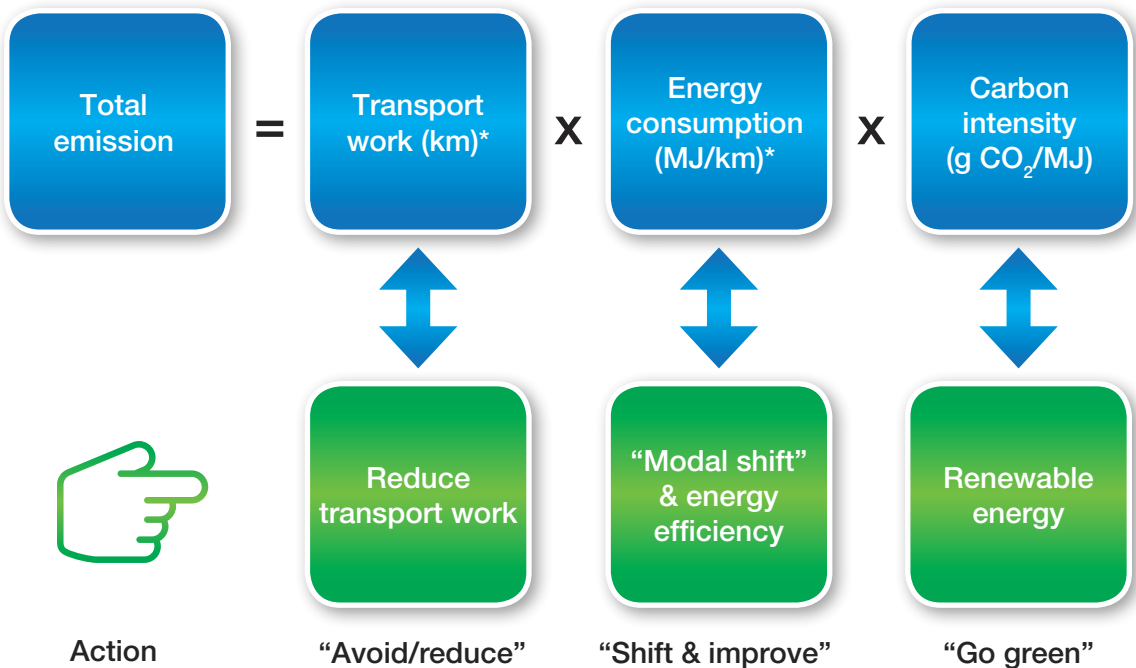
- land use planning and the location of various functions within society
- economic activity
- industry structure
- switching from physical to virtual travelling, e.g. teleworking.

In this context, the term modal shift is important. Modal shift means going for a more efficient means of transport. The most obvious modal shifts for reduced environmental impacts would be people switching from private cars to public transport

or to walking or cycling, when feasible. This would reduce energy consumption and emissions and also alleviate congestion. In addition, walking and cycling would promote health. In goods transport, rail and waterborne freight are generally more efficient than road freight.

Figure 3 shows the distance that can be travelled on one litre of fuel for different transport modes.

At vehicle level and when applied individually, hybridization, lightening and down-sizing can bring about fuel savings of some 25–30 %. When combined, even higher savings are possible. In some cases we can reduce CO₂ emissions by more than 50 % just by choosing our engine in a smart way (Figure 4).



*passenger km/ton km

Figure 2. Formation of CO₂ emissions and actions to reduce CO₂ emissions. The amount of transport work, the efficiency of operations and the carbon intensity of the energy used determine the CO₂ emissions. Emissions can be reduced by decreasing transport work, improving efficiency and using low-carbon energy – simple as that!

Using renewable energy does not remove the need to minimize consumption

The introduction of low-carbon or renewable energy is an efficient way to lower CO₂ emissions. However, the use of renewable energy does not take away the need to minimize energy consumption.

Energy efficiency and renewable energy should go hand in hand.

Substituting crude oil-based fuels with natural gas reduces CO₂ emissions by some 20 % at best. Synthetic natural gas-based fuels on a well-to-wheel basis (full fuel cycle from raw material extraction, fuel production, refining, and distribution to end use in vehicles) are roughly equivalent

IN EUROPEAN LEGISLATION, BIOFUELS PRODUCED FROM WASTES, RESIDUES, NON-FOOD CELLULOSIC MATERIAL AND LIGNO-CELLULOSIC MATERIAL ARE FAVOURED (DIRECTIVE 2009/28/EC).

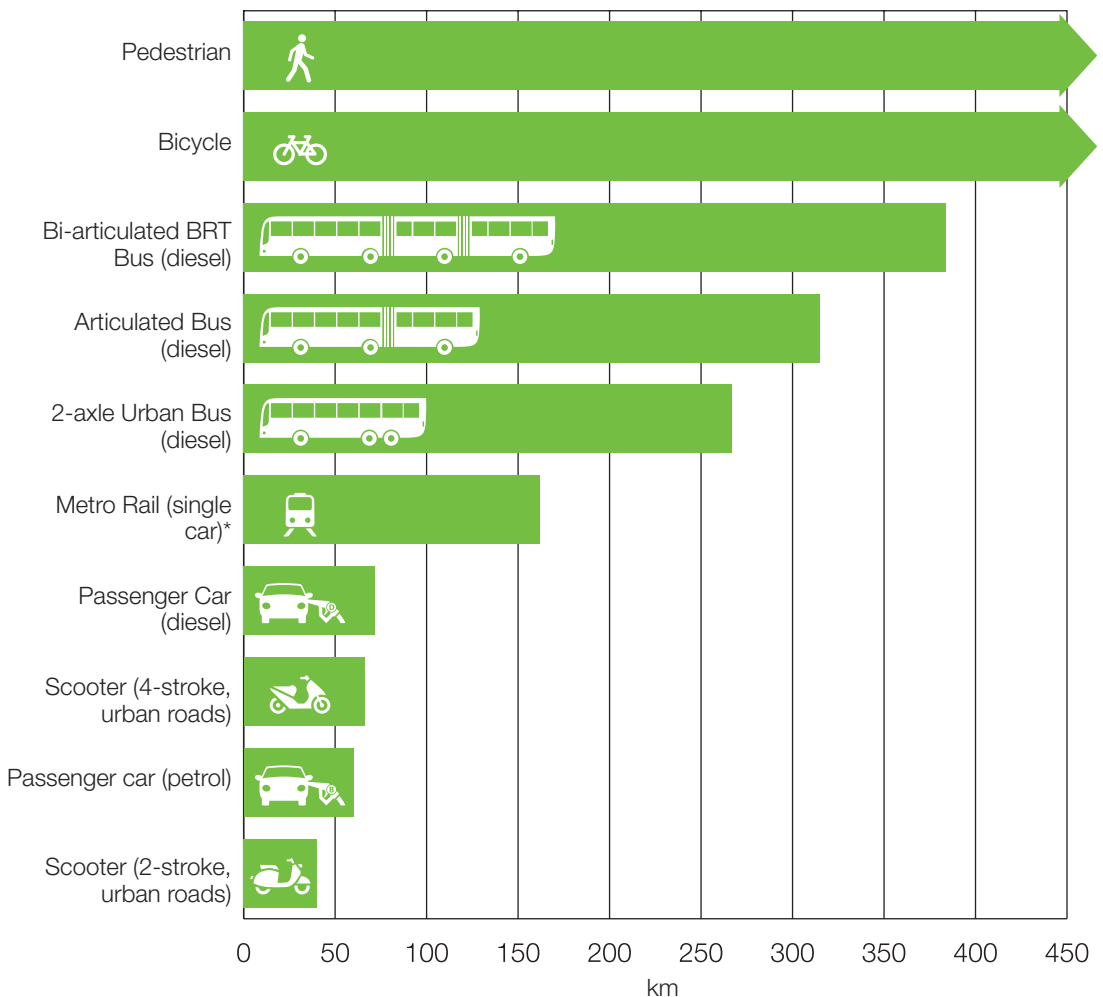


Figure 3. Distance travelled on one litre of fuel. Public transport will take you much further than motorized personal transport, while cycling and walking do not require any fuel. (Böhler-Baedeker and Hüging, 2012)

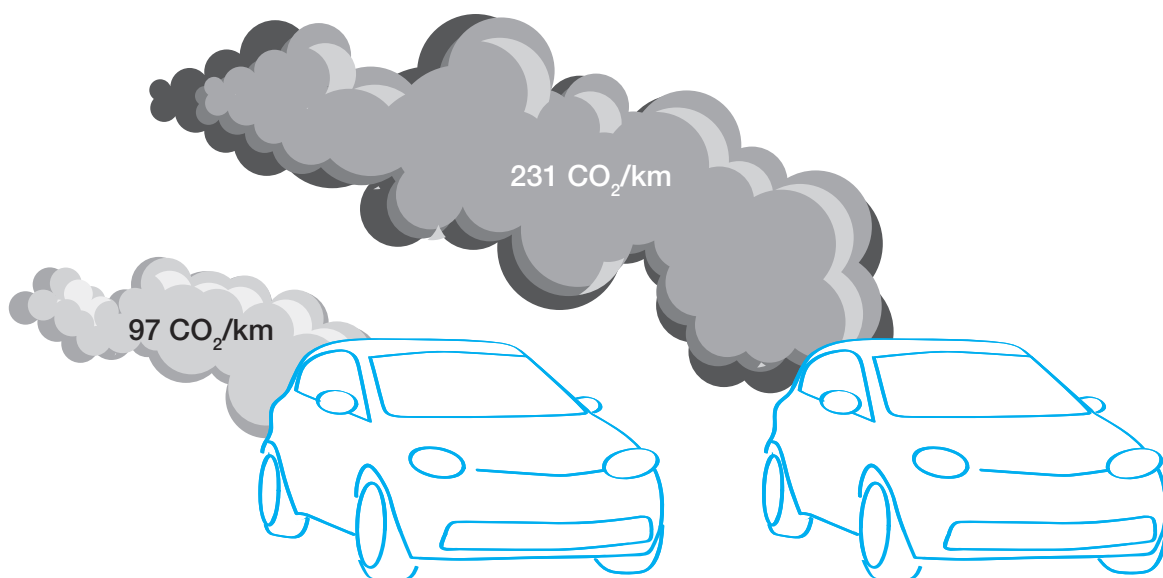


Figure 4. Choosing your engine in a smart way can reduce CO₂ emissions substantially. Numbers for a popular mid-size passenger car. For a certain vehicle model, CO₂ emissions can vary by a factor of more than two depending on the engine.

to petroleum products.

Substantial CO₂ reductions can be achieved through efficient biofuels or electricity and hydrogen from renewable sources. The best of the biofuels can reduce CO₂ emissions by some 80–90 % compared with petroleum products on a well-to-wheel basis. However, the use of edible feedstocks to produce fuel is not acceptable in the long run.

Electrification

Electrification *per se* is not a guarantee of low-carbon emissions; the overall climate effect is determined by the characteristics of the power generation. An electric car powered by coal-based electricity creates more CO₂ emissions than a conventional petrol or diesel-fuelled car. However, in Finland, electrification

of transport has favourable consequences and delivers significant CO₂ emission reductions, as the average Finnish electricity mix has fairly low-carbon intensity. This is even truer on a Nordic level, mainly because Norway and Sweden use a large amount of carbon-free hydropower. The Nordic grid is also very stable and dependable.

Figure 5 presents a comparison of full fuel cycle (well-to-wheel) greenhouse gas emissions for various passenger car technologies within the same vehicle model. The well-to-tank values are based on data from the Joint Research Centre-EUCAR-CONCAWE (JEC) collaboration (JEC, 2014) and the tank-to-wheel (i.e. emissions during end-use) data are based on VTT's own measurements.

As can be seen in Figure 5, diesel and natural gas deliver roughly equivalent CO₂ emission. Biofuel

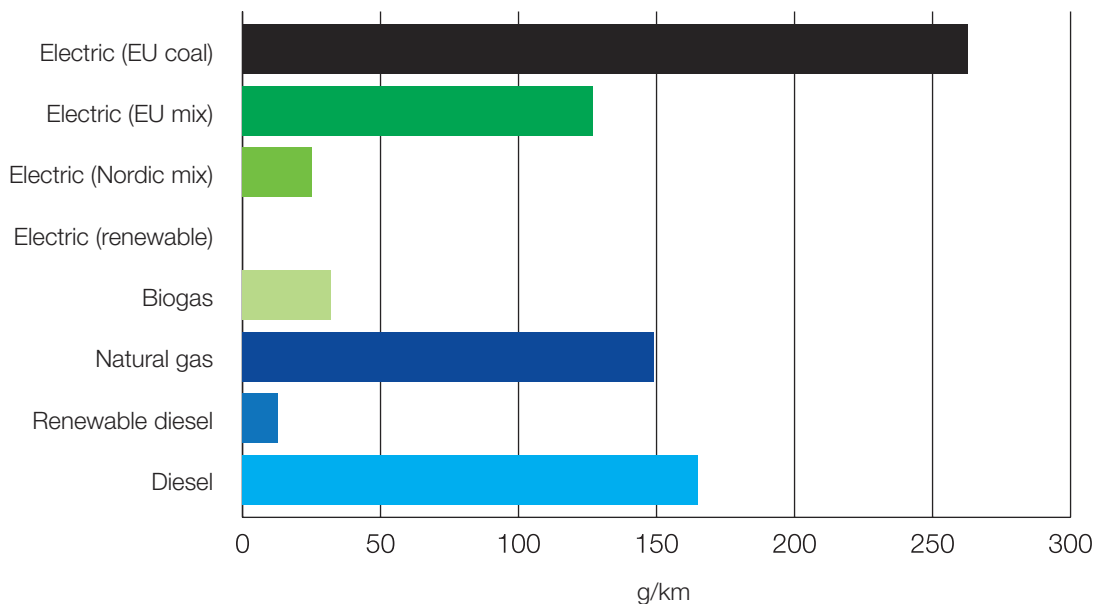


Figure 5. Full fuel cycle (well-to-wheel) greenhouse gas emissions for different passenger car technologies. Diesel and natural gas deliver roughly equivalent GHG emissions. To really make a difference, the best biofuels or low-carbon electricity (renewable, Nordic mix) must be used.

or low-carbon electricity is needed to achieve significant GHG emission reductions.

A fuel cell vehicle running on renewable hydrogen would give equivalent GHG emissions to those of an electric vehicle on renewable electricity. In fact, a fuel cell vehicle is an electric vehicle. The difference here is that a battery electric vehicle obtains

the energy from a battery, while the fuel cell vehicle generates the electricity on-board from hydrogen. In both cases, the tailpipe CO₂ emissions are nil and the well-to-wheel emissions are completely dependent on how the energy carrier (electricity or hydrogen) is produced.

OPTIONS FOR SIGNIFICANTLY REDUCED CO₂ EMISSIONS:

- RENEWABLE WOOD-BASED DIESEL AND BIOGAS FOR CARS EQUIPPED WITH AN INTERNAL COMBUSTION ENGINE
- RENEWABLE ELECTRICITY OR NORDIC MIX ELECTRICITY FOR ELECTRIC VEHICLES
- RENEWABLE HYDROGEN FOR FUEL CELL VEHICLES

Transport in numbers globally

The number of vehicles in operation surpassed the 1 billion unit mark in 2010

According to Ward's Auto³, the number of vehicles in operation worldwide surpassed the 1 billion unit mark in 2010 for the first time ever. The figure reflects the approximate number of cars; light-,

medium- and heavy-duty trucks; and buses registered worldwide, but it does not include off-road vehicles. There were some 700 million passenger cars and some 300 million commercial vehicles on the road, and the numbers are still growing. Some of the projections show up to 3 billion vehicles worldwide in 2050.

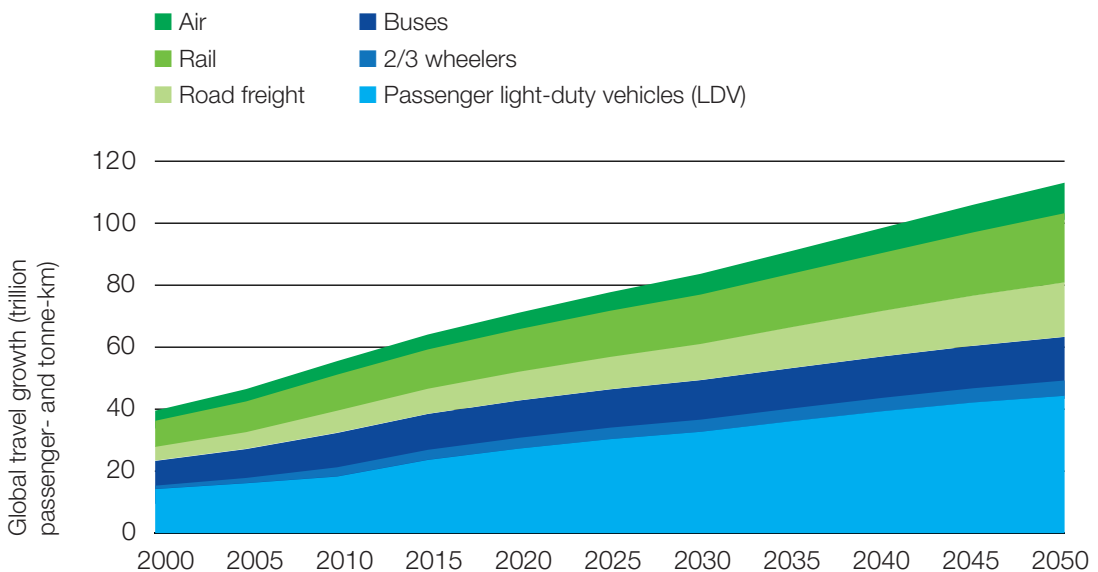


Figure 6. Projected global travel growth with no dedicated policies to reduce travel. If global travel doubles by 2050, we will have to make our transport system twice as efficient just to keep GHG emissions constant, if we continue using fossil fuels. (Dulac, 2013)

³ http://wardsauto.com/ar/world_vehicle_population_110815

Road travel is likely to double by 2050

Figure 6 shows a projection of the growth in passenger and freight travel. With no dedicated policies, road travel is likely to double by 2050, with most of the growth coming from passenger light-duty vehicles in developing countries.

Oil is still the dominating energy source

Figure 7 shows transport energy by source and by mode. At least two things are obvious:

- oil is the dominant energy source in transport (~95 %)
- road transport accounts for some 75 % of the total energy consumption in transport, and light-duty vehicles (cars) alone for more than 50 %.

At world level, transport accounts for some 25 % of final energy consumption

The world final energy consumption in 2010 was some 8700 Mtoe (IEA, 2012), which means that transport at world level accounts for some 25 % of final energy consumption. For the EU27, the corresponding figure is 33 %. Road transport is the dominating sector and, in the case of the EU27, road transport accounts for 27 % of final energy consumption (European Commission, 2013a).

Local emissions vs greenhouse gas emissions

The contribution of transport to greenhouse gas emissions is roughly equivalent to the share for transport of final energy consumption. However, the contribution of transport to local emissions is

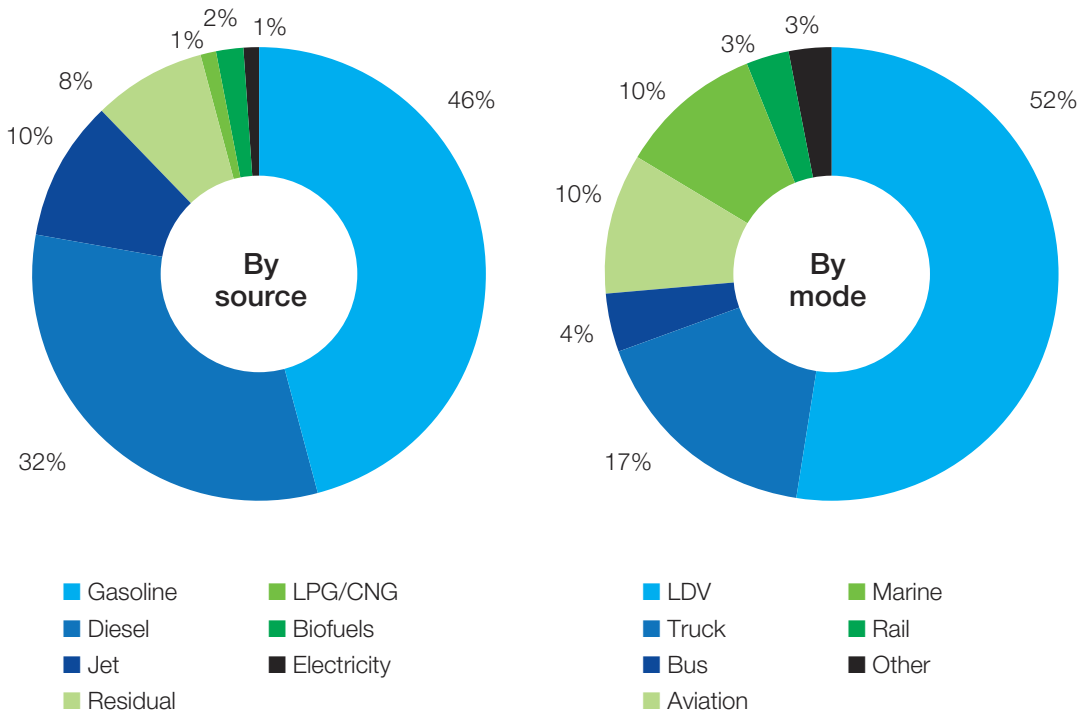


Figure 7. Transport energy by source and mode. In 2010, transport was more than 95 % dependent on petroleum. Radical changes will be needed to meet the future vision of a carbon-neutral transport system, as shown in the Figure. As for energy use by sector, road transport accounts for close to 75 % of the total transport energy. (Moavenzadeh et al., 2011)

substantially higher than its share to energy consumption or greenhouse gas emissions. This is due to the intermittent and cyclic combustion in internal combustion engines, which produces unwanted exhaust emissions, and the exhaust emissions from vehicles being emitted at ground level amongst people.

The good news is that improved engine and exhaust emission control technology combined with cleaner fuels has reduced the regulated emissions significantly on developed markets. The bad news is that despite some improvements in energy efficiency, the total carbon dioxide emissions from transport are still growing due to the increasing vehicle numbers and kilometres travelled. In addition, many

megacities around the world suffer from severe air quality problems. Given time, technology will eventually solve the problems regarding local air quality. However, the reduction of CO₂ emissions will remain a challenge.

Figure 8 shows the tremendous progress in reducing regulated emissions. If we only had brand new vehicles on the roads today, the air quality problems would be solved. Look at Figure 8 and the areas depicting the various emission classes. Euro I, which entered into force in 1992, only some 20 years ago, is big as a football field, whereas Euro VI, effective as of 2014, takes it down to the size of half a football goal.

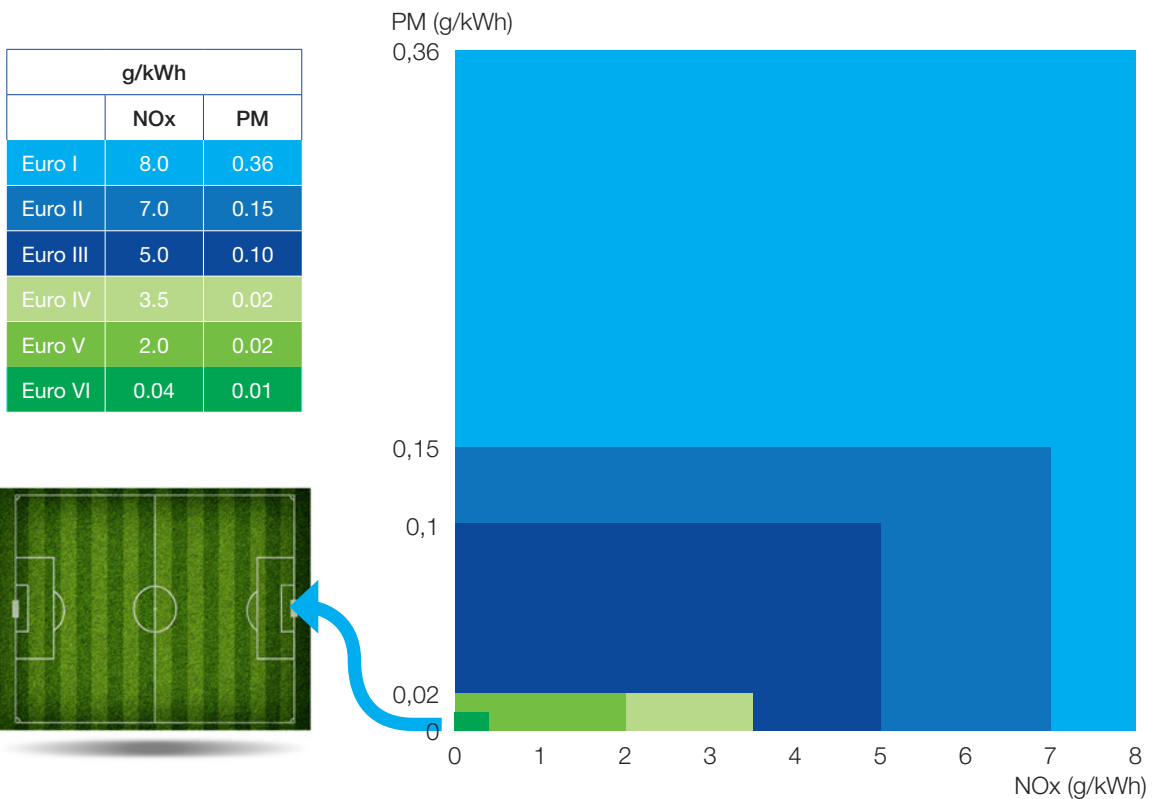


Figure 8. Cutting more than 90 % of heavy vehicle emissions of nitrogen oxides and particulates in 20 years. The progress in emission reduction is proportional to the areas depicting the different emission classes. The progress in just 20 years shrinks the whole football field to just half a football goal. Data from www.dieselnet.com.

Special characteristics of the transport sector in Finland

Key numbers

The total vehicle fleet in Finland is some 3 million units. A characteristic of Finland is its old vehicle fleet; it is one of the oldest in the EU, with an average age of almost 12 years, when the EU average is only 8.3 years⁴.

Finns make 5.2 billion domestic trips and travel 74 billion kilometres annually⁵. An average member of a Finnish household makes an average of three trips per day, spending around 66 minutes and travelling approximately 41 km.

In 2013, transport accounted for 16 % of final energy consumption. The share is lower than the EU average, mainly because of the energy-intensive industry (e.g. pulp and paper) in Finland. The road vehicles in Finland used some 2.4 Mt of diesel fuel and some 1.5 Mt of petrol, a total of about 1.5 % of the road fuel consumption of the EU27. Finland has a very progressive mandate for biofuels. In 2013, the target was a modest 6 % (as energy), but the mandate will gradually increase to 20 % by 2020. As the general EU target for renewable energy (biofuels, renewable electricity, hydrogen from renewable sources) in transport is 10 % by 2020, Finland basically aims to double this target with biofuels alone. Finland considers sustainable biofuels to be a great business opportunity for Finnish actors and, in addition, in its future scenarios, the Ministry of Transport and Communications

relies on a substantial share of biofuels as a way to reduce greenhouse gas emissions from transport.

Finns must be smart

We have certainly heard of OECD's PISA evaluation of students. The fifth volume of the PISA 2012 results (OECD, 2014) presents an assessment of student performances in creative problem solving, which measures students' capacity to respond to non-routine situations in order to achieve their potential as constructive and reflective citizens.

The study confirmed: Finns are the best problem solvers in Europe, and in the top three worldwide. So, how does this relate to the transport sector?

Finland is a large country situated above latitude 60°, and our capital Helsinki is at the same latitude as Anchorage, Alaska. So, we have to be smart to run a whole nation in such conditions. We have to be good at operating vehicles in cold conditions, and we certainly have 'snow-how'. A snowfall of 20 cm does not shut down the whole country; everything runs more or less normally.

Aiming for improved road safety in the challenging Finnish conditions

Transport work, that is, vehicle kilometres per capita, are high in Finland, a country with long distances

⁴ <http://www.acea.be/statistics/tag/category/average-vehicle-age>

⁵ National Travel Survey 2010-2011, http://portal.liikennevirasto.fi/portal/page/portal/e/fta/research_development/national_travel_survey/HLT_2010_2011_esite_ENG_0.pdf



and heavy goods, such as paper rolls, to transport. Energy efficiency is therefore very important. For improved energy efficiency, we recently increased the total permissible vehicle combination weight from 60 to 76 tonnes. But, are such heavy vehicles not a challenge for road safety? Yes, this is partly true, but at VTT, together with one of our industrial partners, we have developed a recommendation for tyres for heavy truck and trailer combinations as well as an automated system for slipperiness detection and alerting. All these help to alleviate the risks of driving.

Public transport ridership has been increasing steadily year on year

In a large, sparsely populated country arranging good public transport poses a challenge. Some 20 % of the Finnish population, about 1 million people, live in Metropolitan Helsinki where we have a good public transport system based on trains, metro, trams, buses and even a couple of ferries. Helsinki Region Transport (HRT), which is responsible for the transport system in the Metropolitan Helsinki area and for procuring public transport services, has a nice route planner system, making travelling and combining different modes of transport,

including walking, very easy. Public transport ridership has been increasing steadily year on year. Improved customer satisfaction is another indication of the popularity of public transport. In 2013, the HRT public transport also came out on top in the European BEST survey for the fourth time running.

Strong ICT competence supports development of intelligent transport systems

We also have a strong electronics and electrotechnical industry. This gives us a strong base for developing electromobility and smart mobility services. Some people who previously worked for the telecom industry now develop systems and applications for Intelligent Transport System (ITS). So, how about the energy sector? We have a balanced electricity generation mix, with a high share of renewable energy. The average CO₂ emissions are only about 200 g/kWh, so an electric vehicle in Finland is definitely good for the climate. The challenge, however, is to ensure and sustain sufficient range and reliability for battery electric vehicles when operating in a harsh winter climate or industrial applications in Finland, but we are working on that too.

Finland is at the cutting edge of biofuels...

We have a strong national fuel industry that provides Finland and markets around the globe with high quality transport fuels. Finland is at the cutting edge, especially in the development of sustainable biofuels, with VTT as an active player in the field. The Finnish government supports biofuels with special development funding and an ambitious national biofuels obligation of 20 % by 2020.

... and going strong in machinery

With regard to the manufacturing of vehicles and carriers, we have two leading engine manufacturers: AGCO Power for high-speed diesel engines used in mobile machinery and agricultural equipment, and Wärtsilä, which produces medium-speed diesel engines for ships and power plants. We have no large-scale manufacturing of trucks, but trailers and other special haulage equipment are built by several SME-size companies.

Marine transport is vital to Finland

Although Finland is connected to mainland Europe, for international transport, Finland is like an island in that it is totally dependent on marine transports. The Baltic Sea is also an emission control area, which is one more reason for us to develop clean technology for the marine sector.

New openings from electric commercial vehicles

The Finnish vehicle industry has specialized in mobile machinery and speciality vehicles rather than standard on-road vehicles. Wherever cargo is moved in ports or timber is harvested, you are bound to bump into Finnish machinery. Electric commercial vehicles, whether for on-road or off-road use, have recently been identified as a future possibility for Finnish industry.



Sustainable mobility is a mindset and an opportunity!

The transport sector is demonstrating a transition from a 'hardware-centred' approach (vehicles, roads, general infrastructure, etc.) to a user need-driven 'mobility as a service' approach. This can also be expressed as a shift 'from bitumen to bytes'. Why not switch to teleworking where applicable? It can reduce the amount of physical travelling.

Imagine a dialogue between two people representing different generations, an 'old-timer' born in the 50s/60s (Gen X) and a youngster born in the 90s (the Youth).

Gen X: I just got myself a nice new car. It's rather big, but it's a hybrid version, so I will help to save the planet. I could consider running it on renewable fuel. Recently, they opened up a fancy shopping centre some 15 km from my house. They have nice parking facilities, so I frequently go there with my wife for shopping or just to have a cup of coffee. My only complaint regarding traffic is that when I drive from the suburbs to work in the centre, there are traffic jams going in in the morning and out in the evening. I'm not the least attracted by public transport because it is a system that doesn't take me exactly where I'm going, not at a time that suits me and, worst of all, not in company I would care for.



The Youth: Come on you old-timer. Aren't you worried about the use of fossil fuels and climate change? I have opted not to get a driver's licence and I will never buy a car for myself. I want to live where I have access to a proper public transport system, preferably in the centre. Why should I be interested in owning the means of transport? I'm just after the service. I don't need to impress my neighbours with a fancy car. I always use public transport or my bike, or I walk. Cycling to work is good exercise. It saves you time and money and has no negative environmental impacts. Cycling is also relaxing, which helps you to cope better at work. As regards future public transport, I'm in favour of electrified transport for zero local emissions. I'm never stuck in queues because there are good bus and cycling lanes, and the intelligent traffic control system provides traffic light priority for public transport. I pay 500 EUR for an annual ticket. And, by the way, did you know that I can manage all my travelling on my smartphone? Most public transport vehicles provide free WIFI, so I can surf the Internet free of charge while travelling. When did you last board a bus or ride your bike? I would not dream of using my own car and drive to a shopping centre. I prefer to use the corner shop. I also do much of my shopping on the Internet. I have my purchase delivered to my door, whether it is food or clothes.






Gen X: Ok, you may have a point here. However, I have some questions. What do you do when you want to go to a place that is not served by public transport? I guess many Finns have a summer cottage in the countryside? Do you depend on your parents or friends and their cars for transport, or do you travel part of the way by taxi? You contest my way of shopping using my car. Have you realized that deliveries to your doorstep can be inefficient? In the worst-case scenario a single small package may be delivered by a big van or even a truck. And about saving the planet, I understand that you travel to the South and the sun a couple of times a year.

The Youth: You caught me out. Perhaps, I should get myself a driver's licence. Then I would be able to rent a car share car when going to the countryside. Naturally, the service provider should only offer low-emission vehicles running on renewable energy. And for booking the car, they should provide a really good app for my smartphone. Or even better, I could take the train to the city closest to the summer cottage, and then take a car sharing car or electric bike locally. Anyway, my travel apps should provide me with easy multi-modal travel planning. Alternatively, I can hope for a breakthrough of automated cars or people movers, and then I can have individual mobility without actually driving myself. As for shopping on the Internet, the packages do not need to come to my doorstep one by one, I can also collect them from the corner shop when I go there to get some fresh groceries. And couldn't I just require the service provider to have an environmental reporting system that reports the energy use and emissions of the product I have ordered all the way from production to delivery to my doorstep? I could then choose the most efficient service. By the way, creating good environmental reporting systems could be a good business opportunity for some skilled computer nerds. And as for travelling to the sun, I have heard that some airlines are experimenting with renewable jet fuel, so perhaps I can continue flying without contributing too much to global warming.



Gen X: This was a good discussion, and I think we both learned some things. The transport system as a whole is very complex, and it is sometimes easy to draw the wrong conclusions. I have to admit that I'm very impressed with how easily you are able to plan your travelling on your smartphone and its various apps. Even if I have a low-emission car, I have to admit that driving to work in it adds to congestion and takes up unnecessary space in the city centre. Perhaps, I should think about switching to public transport. Do you think that logistics could be made as smart as public transport? I think the telecom sector has laid off a lot of people. Could we perhaps get some good people together to think about green logistics? Could we make this a business case? Could we make tools for optimizing logistics and providing automated environmental reporting? And by the way, have you heard about the Internet of Things? It's something to do with machines talking to each other, to interconnecting systems. Do you think this could be useful in mobility and transport?

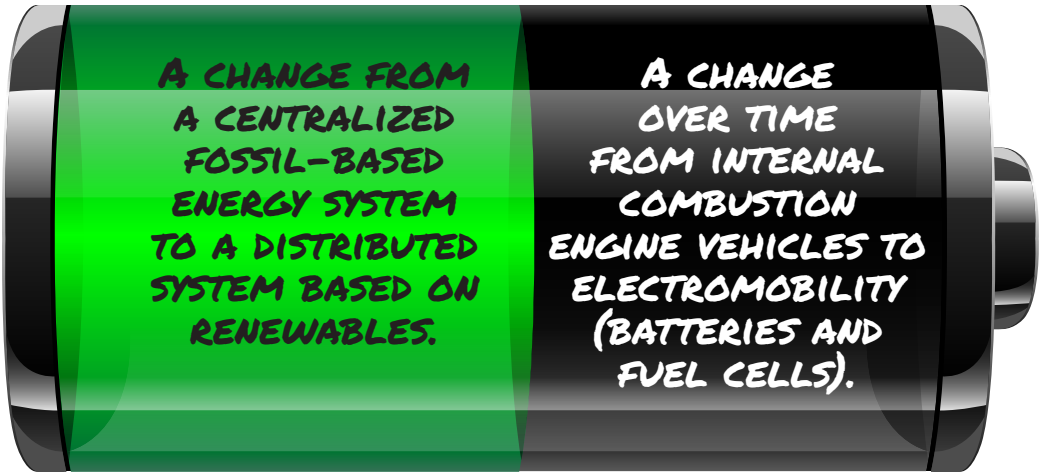
The game is changing!



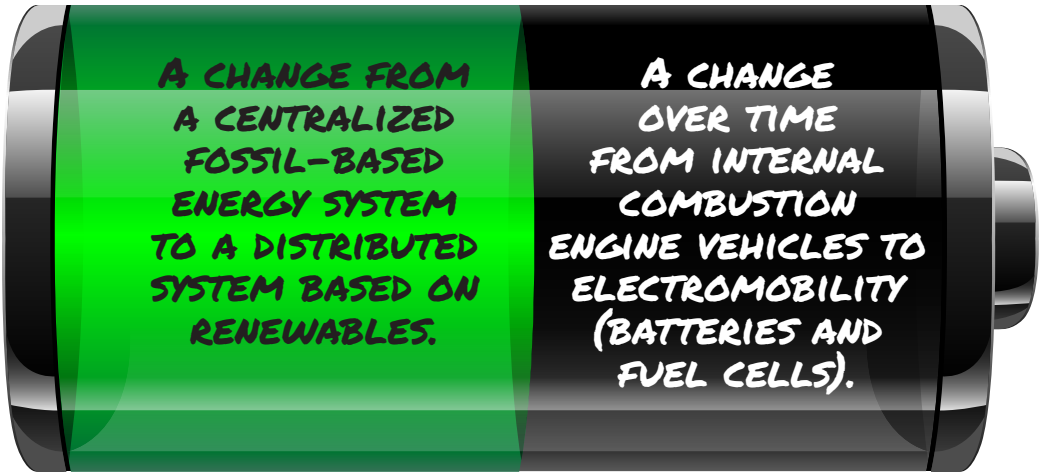
**BE PREPARED AND ALERT!
THERE ARE CHANGES
AHEAD. THERE MAY BE
HUGE OPPORTUNITIES FOR
YOU AND US!**




**A CHANGE FROM AN
INFRASTRUCTURE- AND
VEHICLE-CENTRED
APPROACH TO A CUSTOMER
AND SERVICE-CENTRED
APPROACH.**



**A CHANGE FROM
A CENTRALIZED
FOSSIL-BASED
ENERGY SYSTEM
TO A DISTRIBUTED
SYSTEM BASED ON
RENEWABLES.**



**A CHANGE
OVER TIME
FROM INTERNAL
COMBUSTION
ENGINE VEHICLES TO
ELECTROMOBILITY
(BATTERIES AND
FUEL CELLS).**



**A CHANGE FROM STAND-ALONE SYSTEMS TO
INTEGRATED SYSTEMS, E.G. THE INTEGRATION
OF BUILDINGS, ENERGY, MOBILITY AND ICT IN
THE SPIRIT OF SMART CITIES.**



**WE WILL BRIEFLY DISCUSS THREE GAME
CHANGERS, NAMELY MOBILITY AS A SERVICE,
RENEWABLE ENERGY FOR TRANSPORT AND
ELECTRIFICATION OF VEHICLES.**

From motoring to mobility

Transport systems are evolving continuously and rapidly. Today's transport system differs greatly from that only a few decades ago. The shift of the paradigm is also on its way. Transport is no longer seen as a value in its own right but rather as an enabler for people mobility and logistics. This shift of paradigm poses challenges but it also opens great possibilities for society and businesses. These possibilities create niches for new innovations and services that different stakeholders (public and private sector, transport users, etc.) should pursue from their respective perspective.

Traffic and mobility are more linked to services, economy and business than ever

The development of information and communication technologies (ICT) has contributed to the shift of paradigm. This not only applies to the development of traffic but also to people's everyday life in general. Traffic and mobility are more closely linked to services, economy and business than ever. Different stakeholders approach new traffic systems from different perspectives and have their respective needs. However, traffic systems need to be developed in parallel from perspectives in partnership with the public and private sector, as well as the people using it.

'Mobility as a Service'

In recent years, a more customer- and service-oriented approach has evolved in the field of transport. The concept of 'Mobility as a Service' (MaaS) has been predicted to change the transport system. A

push towards this kind of thinking has – at least partly – been induced by several challenges of the current traffic system and society. These challenges include an increasing demand for mobility and investments as traffic flows have grown along with economic activity. At the same time, the funding for traffic infrastructure has struggled to cope with increasing quality demands, also in Finland. In addition, economic, societal and environmental issues have been at the centre of the debate on traffic. More cost-efficient mobility can be achieved by means of intelligent services that allow less driving, less congestion, less idle time and optimized traffic services. At the same time, traffic has a key role in reducing emissions, as it corresponds to some 25 % of the CO₂ emissions in Europe. Finally, the concept can contribute greatly to improved traffic safety, which also has major economic and societal impacts.

Great economic potential in intelligent transport systems

Mobility as a service is closely linked to intelligent transport systems (ITS), which cultivate the shift of paradigm. The range of ITS services covers various transport modes and users. The core of these services is information, which may, among other things, enhance safety and consumer experience, increase efficiency of operations and productivity of the transport system as a whole or promote new value-added services. As an enabler of MaaS, the great economic potential of ITS has been recognized, and reports indicate significant growth projections for the ITS market as a whole. The total volume of the ITS industry has been estimated at

20-59 billion EUR on an annual basis with a growth projection of 20 % by BCC Research in their Intelligent Transport Systems Review. According VTT's study (Leviäkangas et al., 2012), the Finnish ITS industry had about 1700 employees with markets of approximately 300 million EUR in 2010. Recent developments have further increased the attractiveness of the industry and generated new business. Thus, new traffic services offer possibilities for new business, jobs and wellbeing. Finland has an advantage as a relatively small nation with high-quality infrastructure and technological expertise (especially in mobile services), providing an ideal environment for developing and piloting new services.

Cooperation is the only way forward!

So, the shift of paradigm towards considering traffic as a service and mobility as an enabler is on its way. This also requires participation by the public sector and research institutions together with industry. The Ministry of Transport and Communication in Finland published the world's first ITS strategy in 2009, and it was updated in 2013. The main themes in the strategy steer the development of the MaaS concept, including the following aspects:

- Customer-oriented mobility and improved service level
- Promoting the implementation of new transport policy
- Meeting the goals of the European White Paper for Transport
- Utilizing the possibilities of ICT in full.

Several megatrends promote mobility services

In addition to the above-mentioned aspects, several megatrends boosting the MaaS concept can be identified. As traffic is closely linked to global trends and the macro-economy, the following megatrends can be seen as promoters of MaaS:

- Increased awareness of environmental issues
 - traffic is responsible for some 25 % of all greenhouse emissions in the EU
 - the number of vehicles is high
 - the traffic system is rather inefficient with congestion adding to energy use and emissions
 - significant amounts of emissions are caused by people simply trying to find a vacant parking space.
- Changes in demographic structure (e.g. an aging population has different requirements for mobility including technology, vehicles, usability and safety)
- Urbanization (as the population is becoming increasingly concentrated in certain areas, new traffic services are needed especially in public transport)
- Reducing the number of people with a driver's licence and/or car (in capitals like Stockholm where the service level of public transport is high, young people do not necessarily obtain a licence or own a car; Copenhagen is another example of a city where cycling prevails)
- Technological developments (many technologies, whether related to mobile devices or vehicles, have had great impact on traffic).

This shift can be compared with the field of ICT in which cloud services have changed the scene towards a service-oriented approach (Software as a Service). The main technological developments that boost MaaS are related to the increase in the number of mobile devices, applications, location-based services, data connections and open data. The fact that a limited number of operating systems (mainly Android and IOS, and to some extent Windows) dominate the mobile device markets has eased the work of software developers. Device-independent applications based on, for example, HTML5, have facilitated the penetration of mobility services. These megatrends do not mean that all private traffic will definitely cease but change the paradigm towards thinking of Mobility as a Service.

Ensuring delivery of services to end customers in a convenient manner

However, the shift of paradigm towards MaaS thinking needs novel ecosystems that ensure delivery of services to end customers in a convenient manner. Three main parties of the MaaS ecosystem can be identified:

- Transport service providers (public transport, car rentals, taxis, vehicle suppliers, etc.)
- Service integrators (clearing houses for traffic services, yet to be fixed, e.g. mobile operators are one option)
- Value-added service providers (e.g. insurance companies, towing companies, security companies)
- Network providers (responsible for planning, investments, maintenance, etc.)

Mobility service packages – tailored to all needs

The MaaS concept is closely linked to end-users of transport services. One example of MaaS is the mobility service package, which would revolutionize people mobility. Based on their respective needs, different mobility service packages could be offered to people. For example, a 'light mobility package' could consist of free use of commuter transport with limited use of taxis and rental cars (e.g. 200 km/month) in certain areas, while a 'heavy user package' could comprise free use of public transport, taxis and rental cars in predetermined cities (or, for example, some European capitals). Crucial issues with end-user services are user friendly interfaces, data transfer (especially roaming abroad) and clearing between systems and areas.

Transport is a big expense that often goes unnoticed

At first glance, this kind of radical change to the existing system may seem like a massive one. However, it has been estimated that on average, in 2005, U.S. households spend approximately one-fifth of their income (or some 8,300 USD per year) on transportation (approximately 95 % of this is spent on self-provided transportation). This means that a single person spends 6000 EUR on traffic in a year. In other words, the average revenue per user (ARPU) on traffic in one month is 500 EUR⁶. This is a huge amount of money compared with, for example, what people spend on communication expenses.

In Finland, according to data from Statistics Finland⁷, in 2012, the average household spent over 5400 EUR annually on the purchase and use of private cars, second only to housing, which was about 10 000 EUR including the energy spent on lighting and heating, and more than food at 4500 EUR. Telecom was 900 EUR.

⁶ *The Transportation Challenge: MOVING THE U.S. ECONOMY* (https://www.uschamber.com/sites/default/files/legacy/reports/0804trans_challenge.pdf)

⁷ www.tilastokeskus.fi

From fossil to renewables

It is not often we think about the fact that almost all the energy we use on earth is derived from the radiation of the sun. Photovoltaic is the most obvious one, but wind power and hydropower, which are driven by the atmospheric climate, essentially also take their energy from the heat generated by the sun's radiation. Furthermore, biofuels use the radiation energy that plants have captured in photosynthesis. Even the fossil energy resources – oil, gas and coal – are essentially biofuels, originating from vegetation that grew billions of years ago. The only exceptions are nuclear and geothermal energies, and, to some extent, tidal power.

Until recently, oil was cheap and easy

The energy density of fossil fuels, especially liquids refined from mineral oil, is excellent, and that has been the main driver for their use from the beginning. The well-to-tank energy balance has also been fairly good. There is already primary energy in liquid form, and all that has to be done is to refine it a little. However, increasing product quality has taken its toll, and more energy is now needed to produce those sulphur-free, high-quality fuels that comply with current fuel standards and meet the needs of modern engines and emission control systems.

Today, the production of petroleum fuels is dominated by huge, multi-national publicly listed and owned companies. These international oil companies or 'supermajors', as they are often called,

track their roots to the very beginning of the oil industry. These companies hold most of the value chain upstream, from exploration and drilling to refining, and downstream, sometimes even up to the retail of the products for consumers, although the retail end is increasingly left to smaller, local marketing companies. There are, however, also smaller midstream companies, mainly in the refining and supply part of the chain, that buy their oil from national oil companies that are mostly only active in oil production.

Technology pushes the peak oil forward

Due to this structure, the global oil industry has quite a strong position and control of the market, and petroleum products dominate as transportation fuels. Most of the large companies also hold large reserves of oil in their fields for further development, and it is in their interest to capitalize those assets. Even if the debated 'peak oil' will come at some point, the fade-out will still take several decades. Lately, technological developments in shale oil and gas have also increased the reserves and pushed the peak further. As the companies have all the necessary downstream operations in place, they can afford to invest more in extraction and recovery and still be competitive against the new business in renewable fuels. Even though the supply of oil can be sustained for years to come, the negative impacts on climate remain.



Biomass resources for biofuels are more evenly distributed

The setup in the production of renewable fuels from different types of biomass is in many ways the complete opposite to that of the oil industry, and the new value chains are also very different. Whereas most of the known crude oil reserves are located in the Middle East and a few other countries like Venezuela, Canada and Russia, biomass resources are much more evenly spread. Of course there are differences in yields per hectare based on climate, soil and amount of sunlight, but most countries have exploitable biomass resources. Access to local and sustainable raw material is an essential prerequisite for successful biofuel production, as the exploitable energy density of most of the biomasses is low. Hence, the closer to the reserve the process starts, the better the overall cost competitiveness and total energy balance. Carrying low-grade raw material over long distances destroys both the economics and the ecology. This means that investments in production facilities need to be made along the value chain, rather than towards the end and close to the market, as with petroleum products. This inevitably means building a large and widespread supply chain.

Value chains of fuel production become diversified

The process and value chain of producing renewable biofuels also differs from that of oil refining. In an oil refinery, the chain is mostly a straightforward run from source to product. It has a singular entry point of raw material, and in the refinery process the raw material is split into various different fractions that have their end use mostly in transportation, either as an energy product or as part of the infrastructure, like bitumen, which is used for asphalt on the roads. Apart from the oil, the only major input is hydrogen, which is used in hydro-treatment processes that raise the quality of the product. Hydrogen is usually made from natural gas via a steam-reforming process. Water, electricity, steam, nitrogen, air and some chemicals are also used in the oil refining process.

With biofuels, the process and value chain entails multiple entry points of raw material, and it delivers side-streams and by-products that have value outside the transportation sector. For example, even the most basic process of producing conventional biodiesel takes in rapeseed and methanol and produces both motor fuel and animal fodder.

This kind of diversified value chain and process



concept involving multiple actors calls for an efficient quality management plan. It needs to ensure that the incoming feedstocks and outgoing products or commodities fulfil certain standards. When most of the production process takes place inside one organization, such as the oil industry, things are more straightforward, even if the activity has a global span.

The aim is for flexible production processes in terms of raw material

With the more advanced biofuel production processes, the value chain usually entails exploitation of a side-stream or by-product as the feed-in raw material, and the proliferation of heat energy that is a loss from another highly thermal-intensive process like pulping. The aim is also to develop production processes that are flexible with regard to the raw materials and still deliver high-quality products. The so-called drop-in fuels, i.e. biofuels that are completely compatible with the existing infrastructure and vehicles, are the most desirable.

Business opportunities are there to be exploited

Biofuels open up new business opportunities and bring forward new actors. Neste Oil, the Finnish national oil company is a relatively small actor on the international fuels market. Notwithstanding, Neste Oil is currently the word leader in the production of high-quality renewable diesel. Other Finnish actors in the field of biofuels are St1, which produces ethanol from waste, and the pulp and paper company UPM, which will soon be starting up production of high-quality renewable diesel from tall oil, a side-product of the pulping process. VTT for its part is a world-renowned expert in the field of biofuels, working in close cooperation with the industrial players. For example, St1 Biofuels Oy was a joint venture of St1 and VTT from 2006–2007 and the original de-centralised ethanol production method was based on technology developed by VTT.

The supporting framework for biofuels is in place in Finland. This means that we have a progressive biofuels obligation, financial support for the development of sustainable biofuels and a taxation system that treats biofuels fairly (based on energy content and CO₂ intensity rather than just volume).

Biofuels are not enough, energy consumption still needs to decrease

It is clear that biofuels cannot fully meet the energy demand of transport. Transport will therefore have to reduce its energy use overall and rely on a balanced mix of biofuels, renewable electricity, renewable hydrogen and fossil fuels.

Figure 9 shows some of the prerequisites for success in biofuels and Figure 10 shows the schematics for producing biofuels from solid biomass. In Finland, we are making good progress.

Not only biofuels

Biofuels are not the only option for vehicles equipped with an internal combustion engine: electricity and hydrogen are alternative energy carriers. Hydrogen can be produced using renewable electricity and electrolysis, thus rendering a totally carbon-free energy carrier. Electric vehicles are already on the market, and fuel cell vehicles are on the verge of market introduction (passenger cars, buses and working machinery).

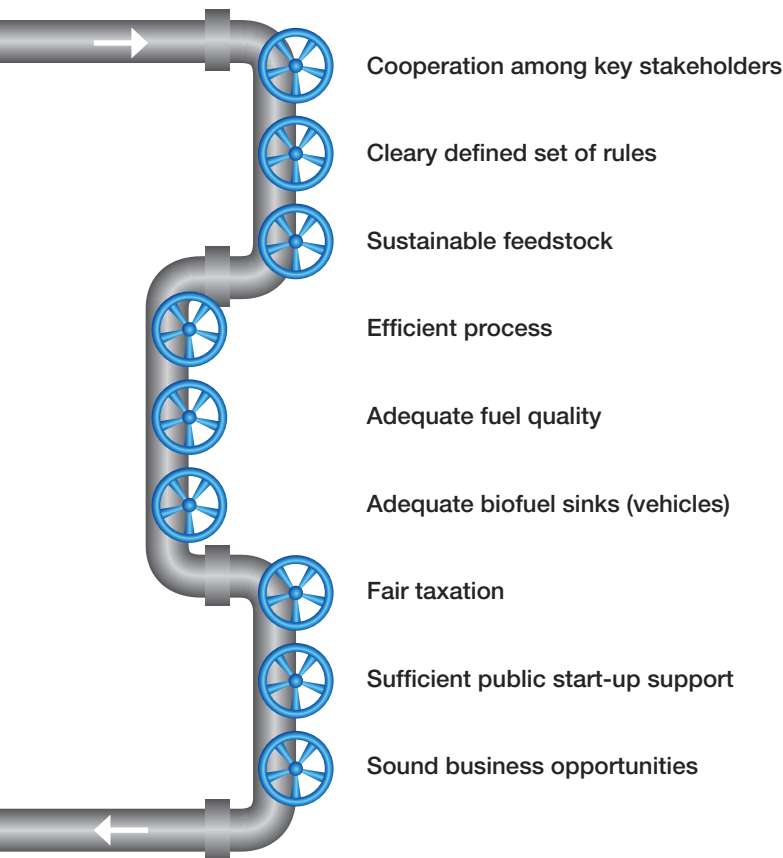


Figure 9. Prerequisites for success with biofuels.

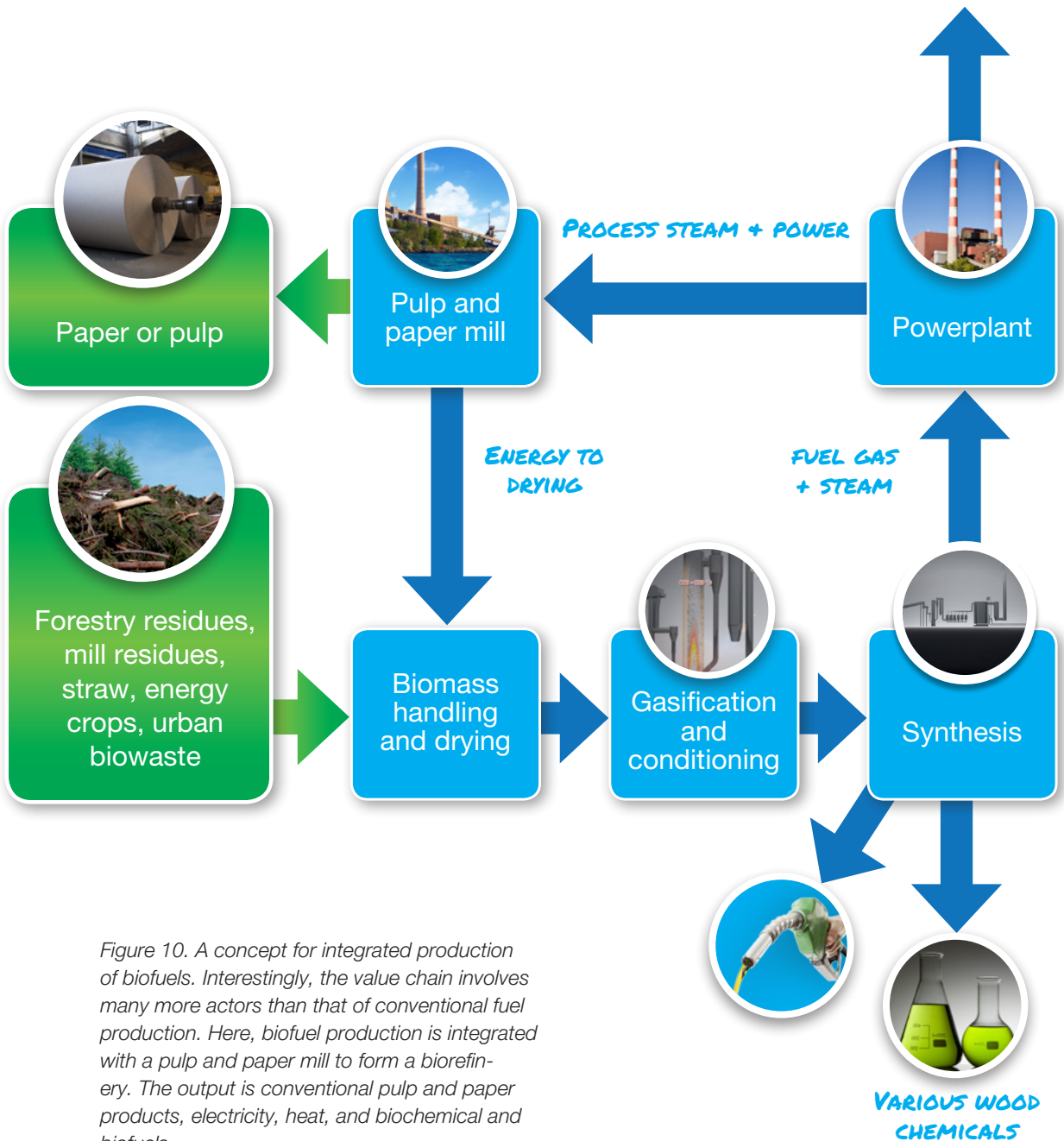


Figure 10. A concept for integrated production of biofuels. Interestingly, the value chain involves many more actors than that of conventional fuel production. Here, biofuel production is integrated with a pulp and paper mill to form a biorefinery. The output is conventional pulp and paper products, electricity, heat, and biochemical and biofuels.

Electrifying transport

In the past decades, electric vehicles have been seen as a solution to multiple challenges faced by the transport sector and society as a whole. Electric vehicles can offer benefits like lower pollution and noise in cities, reduced oil dependency and a cut in carbon dioxide emissions. In the early years of motoring, the electric car was a competitive option compared with cars powered with internal combustion engines. In their early years, electric vehicles suffered from poor capacity of batteries, a problem that remains to this day. Battery technology has improved with regard to capacity, power-to-weight ratio, costs and practicality, but so has its prime competitor, vehicles equipped with an internal combustion engine. The battery system remains the most expensive and also risky component in the electric vehicle – the battery cost constitutes a significant part of the total cost of an EV. So, electric vehicles have been a great promise for a century.

Electric vehicles are now more topical than ever

It now looks as if EVs really are coming and that the game is changing. Why is this? Batteries have finally reached a sufficient level of performance, reliability and cost-effectiveness, and, perhaps, even more importantly, some major auto manufacturers have started offering EV, both battery electric vehicles and plug-in hybrids. Figure 11 shows the development of EV sales in the U.S.

It remains to be seen what will happen with fuel cell vehicles. Some manufacturers have announced

a limited market introduction in 2015. In practice, fuel cell cars are electric cars equipped with hydrogen storage and a fuel cell system to provide electricity to run the car. Compared with battery electric, fuel cell electric cars offer an extended range and fast refilling. For range and performance, fuel cell vehicles can compete with conventional vehicles.

Electric vehicles have created a new market for a new ecosystem of components

What has actually brought EVs onto the market? Mainly the involvement of some major automotive players, but also smaller, start-up style companies trying to catch the early market. So, what lies behind this? One thing to notice is that forerunner countries for passenger EVs, such as Norway, heavily subsidize the purchase of the vehicles. This market pull, however, has been sufficient to activate the automotive players. Purely market-driven large-scale adoption of electric passenger cars is yet to be seen, but the vision is there and the implications of it are fascinating. From a technological point of view, battery technology has not taken a giant leap; neither have electric drivelines or power electronics. Even though technological concepts have existed, they have not been commercialized before. Previously, components specifically designed for electric vehicles and their drive trains were not available. Electric vehicles have created a new market for a new type of components and even an ecosystem of components, and this ecosystem is still developing

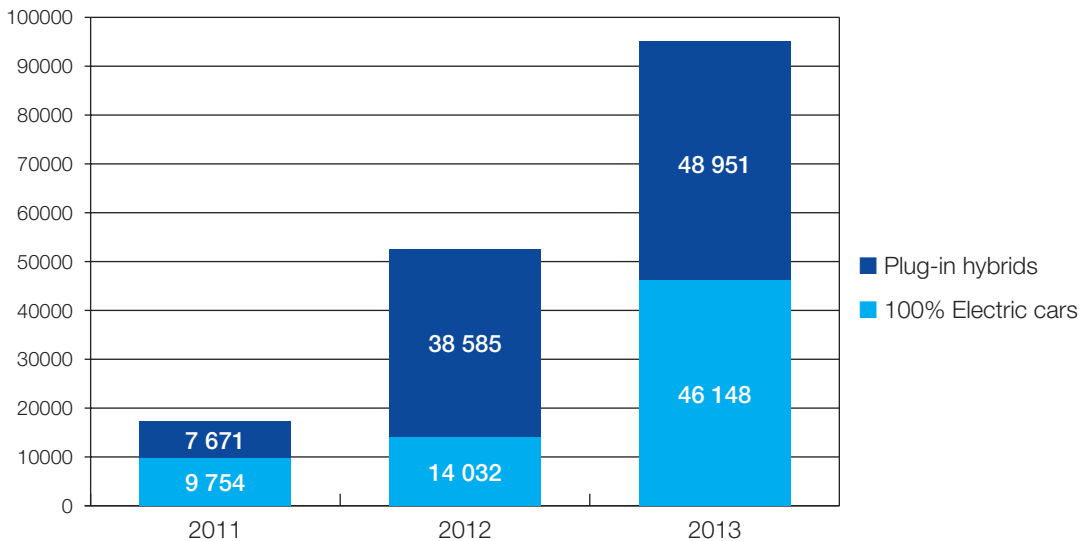


Figure 11. Electrified car sales in the U.S. 2011–2013, data from EV Obsession, <http://evobsession.com/electric-car-sales-increased-228-88-2013/>.

and is therefore only starting to gain cost savings through mass production. Value chains and actors in the car industry are facing changes, and new companies can find attractive opportunities in this evolving market, and, it is not only the car industry that is changing. Broad introduction of electric vehicles will obviously have an effect on the market of liquid fuels as well as impacts on the electric grid.

As for the drivers of electric vehicles, do not forget about policies calling for reduced emissions and oil substitution. Electric vehicles are part of the solution.

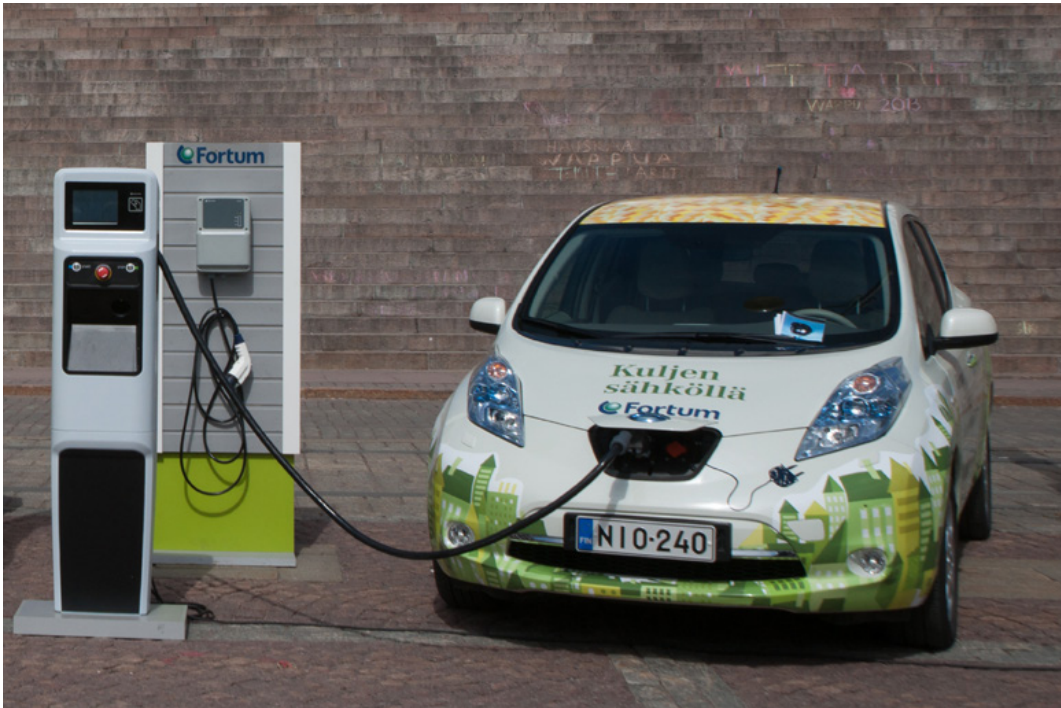
Sustaining widespread electromobility sets new requirements for recharging infrastructure

The electric vehicle will be a game changer in the automotive and energy sectors in many ways. For the workshops, there will be no more changing of motor oil and spark-plugs. At the filling stations, sales of conventional fuels will drop over time, but, at the same time, new markets and business opportunities

will open up. Electric vehicles require charging infrastructure, both private and public, and private consumers need charging devices that can be used in their own car parks. To enable widespread electromobility, public charging stations will have to be built in cities as well as along arterial roads, most probably in conjunction with existing filling stations.

Electric vehicles introduce a new parameter into the consumer decision process

The challenges and changes that are happening in the automotive and energy industries may not affect the motorist purchasing an electric car that much. The customer is looking for an electric car from a well-known manufacturer to suit his or her needs and is not that interested in knowing which company manufactured the battery packs or the new innovative air conditioning built specially for electric vehicles. In the case of conventional cars, consumers have become used to first choosing the type of car they want and then deciding between



petrol and diesel engines and balancing between costs, fuel consumption and performance. Electric vehicles introduce range as a new parameter into the consumer decision process.

How can the user needs be fulfilled?

The size of the batteries and the associated driving range vary from vehicle to vehicle, and some models even have different options for the capacity of the battery pack. For most users, any electric vehicle with an average size battery pack provides enough range for normal commuting. Even though a battery capacity of some 50 km of driving per day would cover the majority of needs, the driver will sometimes want to cover longer distances. One option is of course to go for a plug-in hybrid vehicle and thus curb range anxiety. In fact, a plug-in hybrid can, in principle, be based on either an internal combustion engine or a fuel cell.

So, how can a family that have opted for a pure battery electric car solve all their transportation needs? On weekdays, the battery capacity is enough for commuting and taking the children to their activities. But what happens when they want to go to their summer cottage for the weekend or make a road trip on their summer holiday? There are two answers to this question, both of which create a new kind of service business:

Mobility service

Mobility as a service concept, discussed previously, is one of the things that may make it easier to introduce electric vehicles. With today's technology, it would be both difficult and expensive to have an electric vehicle that fulfils all transport needs. A mobility service provider could sell a service that would give consumers an electric vehicle for their commuting and daily use and access to another car that could drive longer distances. This kind of approach would need a change in the ownership

of cars, but it would bring other benefits than just electrification. Today, consumers choose their vehicles to fulfil most of their transport needs, so cars are usually much larger than would be needed only for daily use.

National charging network

With today's average electric vehicles, the range on a full battery is about 150 km in optimal conditions. With quick charging of batteries, the distance covered can be extended. Quick charging stations offer interesting opportunities for electric companies and charging operators but also potential for many kinds of commercial services that consumers can use while their car is being charged.

Commercial passenger transport and local freight are also going electric

Private personal transport is not the only form that will face electrification; in fact, pure commercially driven electric transport is likely to start somewhere other than passenger cars. Commercial freight and public passenger transport may be easier to electrify. One reason for this is that commercial vehicles are usually bought for a specific and well-defined use or application. The easiest commercial service to electrify is city buses. City buses normally operate with a high utilization rate on fixed routes and schedules, and they usually serve the same route for between 5 and 10 years. A fixed route also creates possibilities for opportunity charging. The idea of opportunity charging is to minimize the battery capacity on board the bus by building charging devices along the bus route, typically at the end stops and, in some cases, also at intermediate bus stops. Opportunity charging at high power enables better optimization of batteries in buses and provides more flexibility in operation. Downsizing the battery capacity makes the bus (or other commercial vehicle) cheaper for the vehicle operator to purchase or lease and battery replacement will also not entail

an excessive cost. However, the drawback on the power system side could be that the electricity is then drawn from the grid in daytime when power consumption is heavy, rather than in the low-power hours usable for overnight charging.

Currently city buses offer good pay-back

As electric vehicles are currently expensive to buy but cheap to operate, commercial vehicles, especially city buses, offer much better pay-back than privately owned passenger cars that are normally only used for about an hour a day. As municipalities and public transport authorities set the rules for bus service procurement, they have the opportunity to create rules that favour low-emission vehicles, including electric buses. RATP, the public transport authority of Paris, recently announced that it will strive for a completely electrified bus fleet by 2025.

Electrifying the bus services is primarily not a vehicle technology issue but rather a system level issue: how to plan the services, how to arrange fast charging, impacts on the power grid, requirements on the infrastructure and so on. High-power charging of heavy vehicle fleets may require modifications to the local power grid and the use of stationary energy storage to support the grid. This offers attractive possibilities for integrated infrastructure and synergy with rail traffic and infra (especially trams and metro), smart grid, distributed renewable power generation and demand side management.

You often hear the counter-argument that large scale electrification of transport would deplete the power system. If all passenger cars in Finland (2.5 million) were electric, they would consume some 8.5 TWh of electricity, or some 10 % of the current total electricity consumption. With smart charging of the vehicles, electrification of the whole fleet would be doable, without much added generating capacity. Taking into account the foreseen and potential new grid-level benefits, businesses and services as well as domestic sustainable electricity production, the total impact on society can be very positive.

Smart Mobility Integrated with Low-Carbon Energy

Transport system services have been set challenging domestic and international objectives for quality, efficiency and environmental impact. To achieve these we'll need a systemic approach and close cooperation actors. VTT's TransSmart spearhead programme weaves together the needs of different actors and develops solutions to match.

Programme manager
Nils-Olof Nylund



**DRIVING THE TRANSPORT
SYSTEM TOWARDS
SUSTAINABLE DEVELOPMENT.
THIS CAN MAKE YOU
SMILE!**

TAKE A TOUR OF OUR ACTIVITIES AIMED AT SUSTAINABLE TRANSPORT AND A BRIGHTER FUTURE!

Our vision for 2030

The Finnish transport system successfully pursues sustainability in societal, economic as well as environmental terms:

- The transport system is mainly powered by electricity, biofuels and hydrogen. Where conventional fuels and powertrains still apply, the efficiency of using energy and other resources has improved remarkably. Energy systems for transport are well integrated into other infrastructures in terms of production, storage and delivery.
- Transport and mobility needs of people and goods are fulfilled by a wide range of transport services, characterized by advanced technologies, functionality and efficiency.
- Development and production of transport fuels, vehicles, mobile machinery, infrastructure and services generate business and profit for the Finnish entrepreneurs in the domestic as well as global markets.

The systematic, continuous work to evolve and adapt the transport system builds on information, knowledge and intelligence from both experts and users. Development, operation and governance are tasks shared in collaboration between the public and private sectors.

TransSmart, Smart Mobility Integrated with Low-carbon Energy, is one of VTT's spearhead programmes. It was launched in the beginning of 2013 as a platform for strategic research for transport at VTT Technical Research Centre of Finland. It has shared synergies with VTT's two other spearhead programmes, Productivity Leap with Internet of Things (ICT tools adapted to mobility services) and Bioeconomy Transformation (biofuel production).

Within the TransSmart programme, we have four main themes, namely: **low-carbon energy**, **advanced vehicles**, **smart mobility services** and the **transport system** itself. The foundation of the programme is based on:

- Understanding megatrends as well as identifying weak signals of change
- Understanding user demands
- Identifying business opportunities
- Providing solid data for decision-making
- A professional approach in foresight technologies.

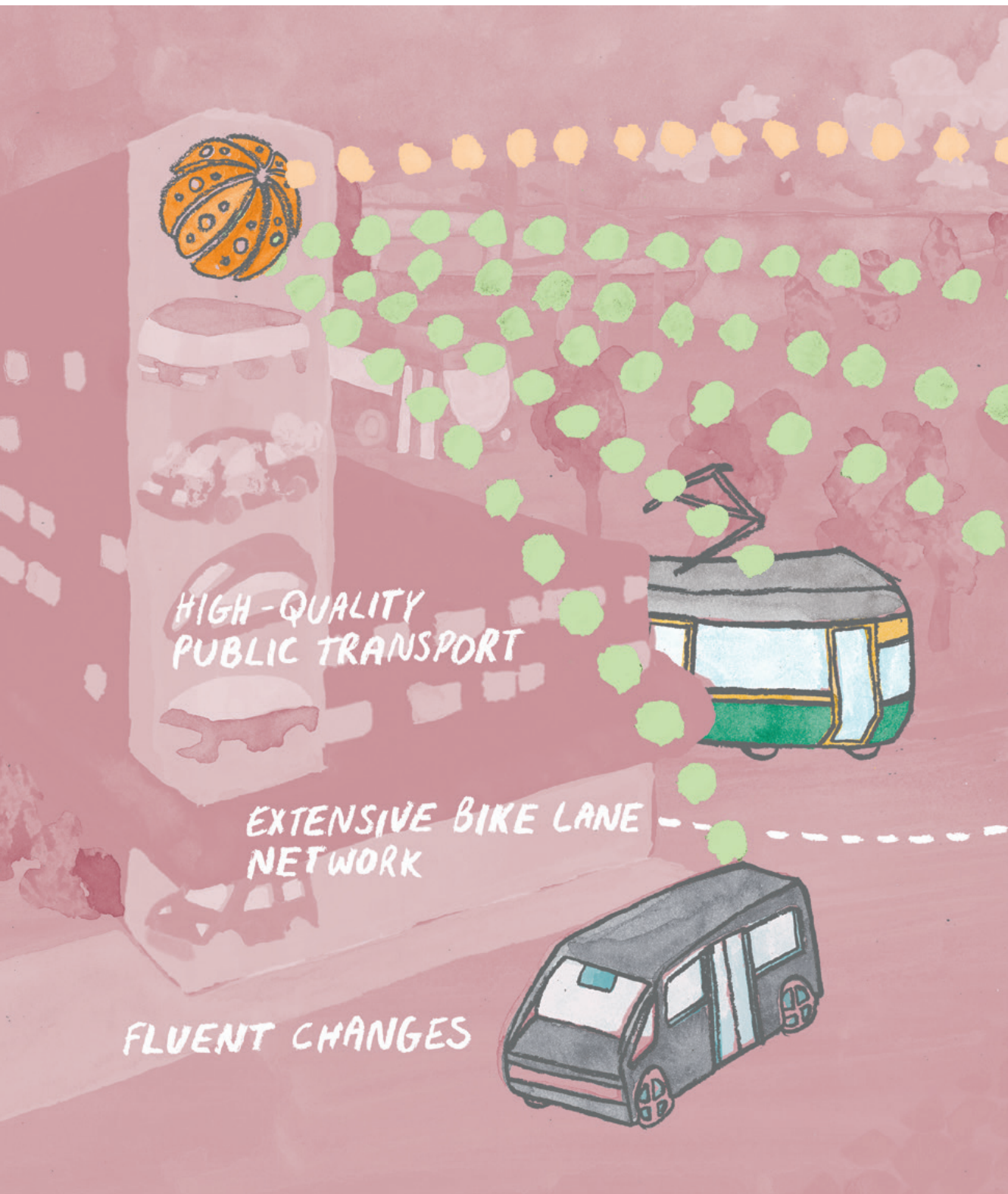
The future is shaped in cooperation

To secure good communication, relevance and impact, VTT opted for an external steering group for TransSmart. The group comprises representatives of four key ministries, governmental agencies, the municipal sector, industrial companies, interest groups and academia. With the guidance of this group, we can be sure to stay focused and on track. Our external communication is handled by Motiva, an affiliated Government agency providing companies, the public sector and consumers with information and solutions leading to resource-efficient and sustainable choices.

You can find up to date information on TransSmart at www.transsmart.fi and http://www.vtt.fi/research/spearhead_transsmart.jsp.

A systemic approach arises in interaction between technological and societal perspectives.

In the following sections, we will describe VTT's competences as well as the main activities within the themes, with the aim of fulfilling our vision of a smart low-carbon transport system.



HIGH-QUALITY
PUBLIC TRANSPORT

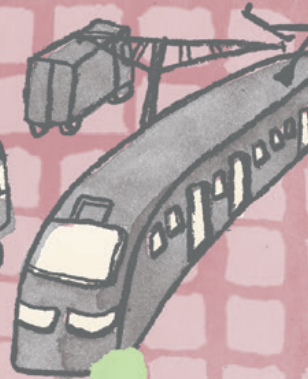
EXTENSIVE BIKE LANE
NETWORK

FLUENT CHANGES

Change on multiple levels is needed for smart, low carbon transport systems



DECISION
MAKING



REAL-TIME INFORMATION



Why should I be interested in owning the means of transport?



Understanding and supporting the socio-technical transition

Responding to the challenges mentioned earlier in the publication requires socio-technical change (transition) in the transport system. This means that along with technological developments, the political, economic, social, environmental and cultural dimensions of the system need to be considered and adjusted to promote the systemic change towards a smart, low-carbon future. Socio-technical transitions typically unfold over a long period and, thus, a long-term perspective is important in developing, assessing and making decisions on strategies and measures to promote the necessary transition.

Our approach integrates four main components of the transport system that are too often considered separately and in the short term: users (people and goods), vehicles, transport infrastructures and governance of the transport system. We therefore take a wider societal and long-term view to understanding the passenger and freight transport in modern society. Here, the transport system is also understood as a spatially scaled system with, for example, urban, regional, national, European and global dimensions.

Combining perspectives for a wider systemic view

Presenting alternative future visions and pathways based on a transdisciplinary and systemic research approach can support strategic planning and business development towards a smart, low-carbon transport future. New methods are available that combine a wider systemic perspective with deeper participation and policy support approaches. For example, the introduction, adaptation and acceptance of electric vehicles in the transport system requires co-operation between various stakeholders,

such as vehicle manufacturers, electricity companies, infrastructure providers, city planners, legislation and standardization bodies, etc., and, last but not least, acceptance by the end-users.

The changes arise at multiple levels

The socio-technical system of transport is a socially constructed entity that aims to fulfil the mobility needs of its users. The system also reshapes society over time through physical infrastructure and services provided to the end-users that further form user attitudes and values. The transport system consists of a wide range of interlinked dimensions such as: technologies, markets, users, science, policies, cultural meanings, etc. It is thus a web consisting of these elements and resources that support them, such as knowledge, capital and labour. A socio-technical system and its transition from one configuration to another can be studied using an established concept (Geels and Schot, 2007; Geels, 2012) that distinguishes between three analytical levels: the niche-level that accounts for the emergence of new innovations, the socio-technical regime level that accounts for the stability of existing systems and the socio-technical landscape that accounts for exogenous macro-developments, such as greenhouse gas pressures and fixed target levels. A major shift towards a smart, low-carbon transport system by 2030 is realized when structural changes take place in the dimensions of the system (Figure 12).

In Figure 12, landscape developments (blue) represent grand challenges and other major trends that drive the general development. The regime level (purple) represents the developments in the

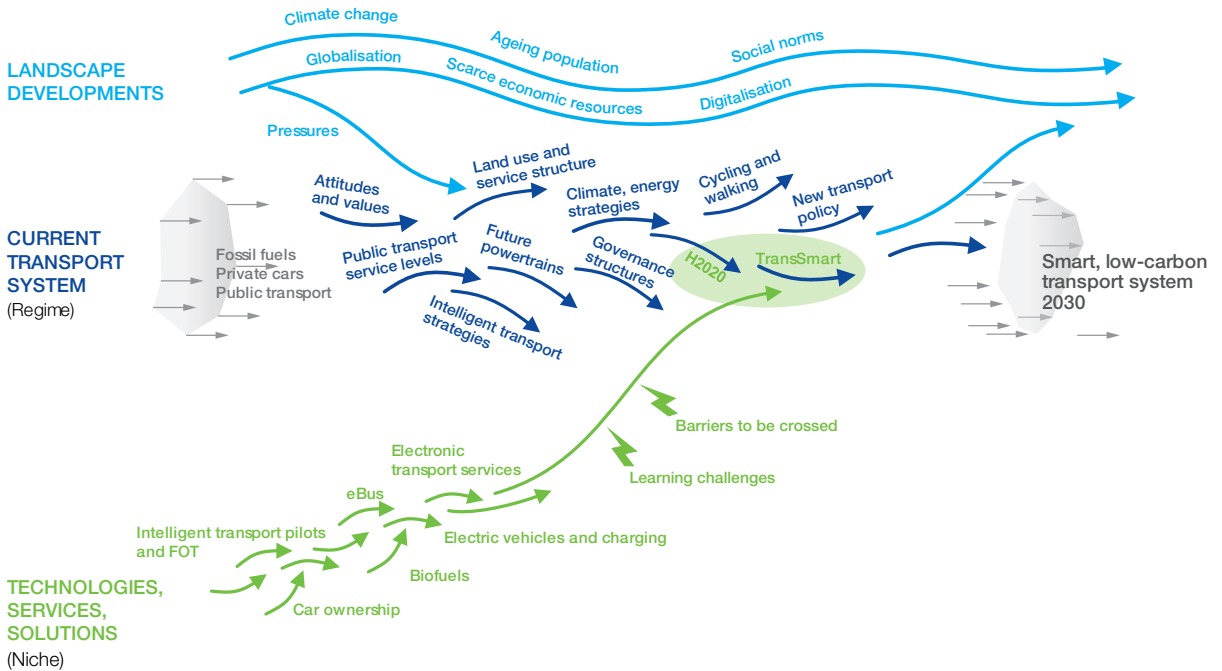


Figure 12. Developments and elements of socio-technical change at multiple levels towards a smart, low-carbon transport system 2030. (Adapted from Geels and Schot, 2007)

current transport system towards a smart, low-carbon future and reactions to the pressures from the blue trends. The niche level (green) represents technologies and new solutions that are slowly entering the transport system but face many challenges and barriers. The picture depicts how the system and its transition from one configuration to another need to be considered at various levels. In this context, the TransSmart research programme provides a platform for collaboration, strategic developments and innovations.

At VTT, we promote a major shift using methods and tools to support socio-technical transition, as follows:

1. We apply socio-technical foresight methods to build visions, scenarios and roadmaps in close collaboration with relevant stakeholders to support actions towards a smart,

low-carbon transport system.

2. We identify the most beneficial policy and market instruments and strategies towards a smart, low-carbon future and assess their impacts to support the selection and deployment of the 'fit-for-purpose' instruments by different transport system stakeholders.
3. We put together a transition toolbox of methods and tools to support policy and concept development by city authorities and businesses to promote co-operation and developments towards smart, low-carbon cities.
4. We analyse user values and activities, demands, acceptance and intention to use new technology and services for the basis of new smart, low-carbon technology and service development.

VTT contributes to the creation and implementation of a systemic view in three ways

Firstly, we provide new knowledge and methods for strategic planning, decision-making and emerging ecosystem actors to support socio-technical change towards smart, low-carbon transport systems. The knowledge will be produced in co-operation with public and private transport system actors for use as a basis for informed policy and business decisions.

Secondly, VTT's researchers have long experience and wide expertise in combining different approaches, such as field experiments in real use contexts, user acceptance studies and expert assessments to study the impacts of new systems and solutions. Impact assessments promote the selection of the most favourable measures or combinations thereof and thereby support efficient deployment of new technologies, systems and services.

Thirdly, we provide foresight and impact assessment methods, tools and knowledge for use by a wide community to support new research openings and businesses development.

Understanding the socio-technical change of the transport system is high on the European agenda

Research on socio-technical change and the related multi-level perspective is currently ranked high on the European research agenda. However, the orientation was mainly in the past and in theoretical discussions. Our perspective on the change provides a transdisciplinary, forward-looking approach that produces practical tools for policy and business support. VTT has strong competences in foresight, impact assessment, system-dynamic modelling and societal embedding, and these perspectives are tightly integrated to provide support for the stakeholders touched by the change.

Our research projects have covered, for example, the following subjects:

- To guide industrial strategies and governments in making the transition to sustainable Nordic energy and transport systems and enhance the competitive position of Nordic industries, a process was developed for

the creation of prospective value chains for renewable road transport energy sources up to 2050 in the Nordic Countries. The process was applied to three technology platforms: biofuels, electricity and hydrogen.

- To describe the deployment paths of electric vehicles until 2030, a scenario-based market model was applied. The model specifies consumer demand and market supply of electromobility in Finland, Germany and Poland.
- In order to contribute to the design and operation of seamless, smart, clean and safe European public transport, an integrated business model for intermodal public transport system interchanges was developed.
- Several impact assessments and user studies in EU-wide field operational tests, e.g. in the context of nomadic devices in vehicles and C2X communication technology in Europe, have been carried out.

Roadmap process – towards a smart low-carbon transport system 2030

In 2013 we completed a vision exercise aimed at building a shared vision among the programme stakeholders on 'Smart, low-carbon transport system 2030' and finding the programme strengths and future research priorities. The detailed results of the roadmap work are available at VTT Technology 146 (<http://www.vtt.fi/inf/pdf/technology/2013/T146.pdf>). The roadmap process provided a new approach – societal embedding of a research programme – that will be applied and further developed in future projects with customers. The key results of the project are Vision 2030, the Programme Roadmap (Figure 13) and the Research Theme Roadmaps. The roadmapping process proved a useful tool for communication (internal + external) between programme stakeholders.

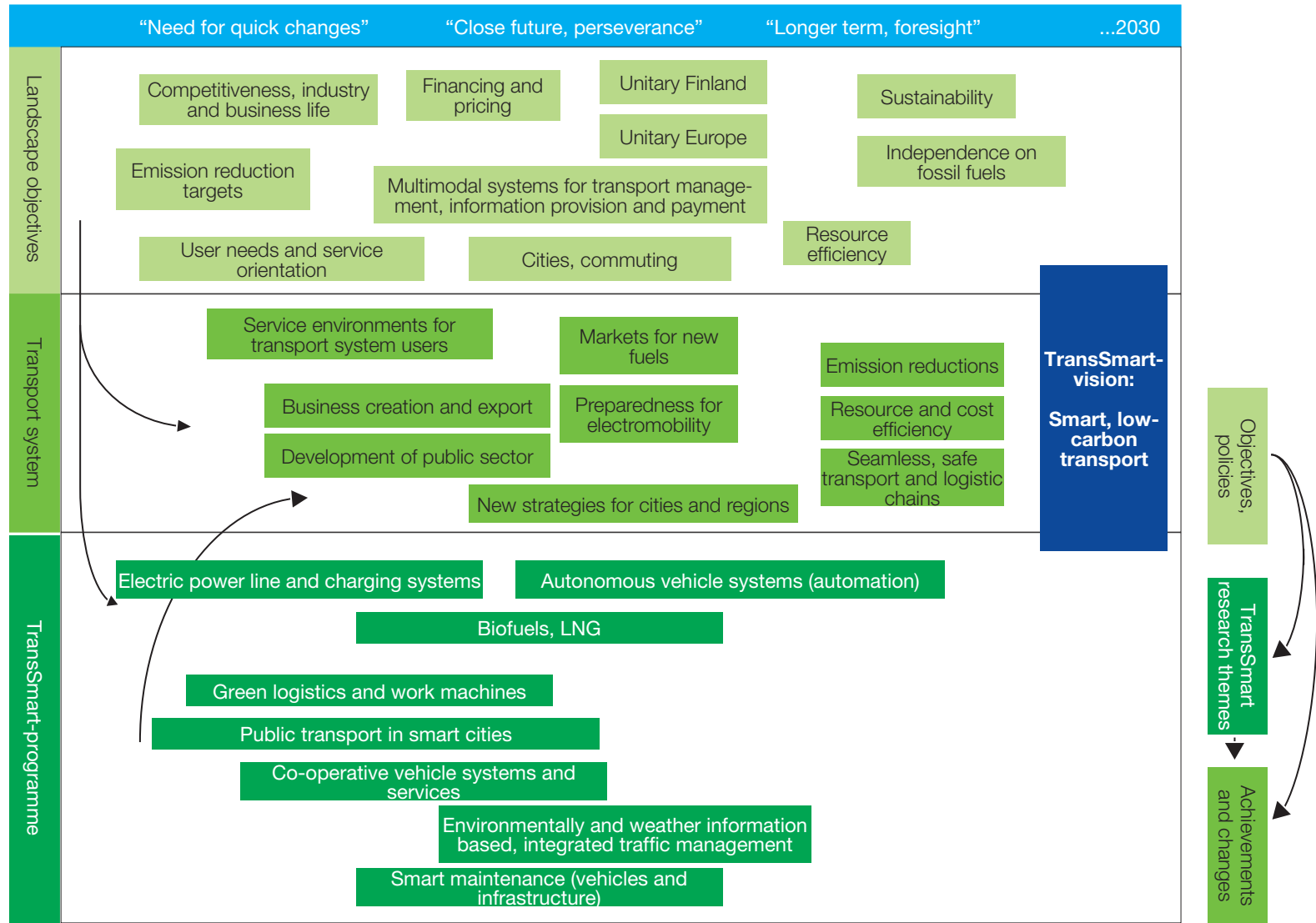


Figure 13. TransSmart key research themes linked and timed with transport system and landscape developments.

Tuominen, A. and Auvinen, H. 2013. TransSmart-kärkihjelman visio ja tiekartta. Älykäs, vähähiilinen liikennejärjestelmä 2030. Espoo. VTT Technology 146. <http://www.vtt.fi/inf/pdf/technology/2013/T146.pdf>. Available only in Finnish.



Do you know that I can manage all my travelling with my smartphone?



WASH

WAX

REFUEL

CAR SHARING CENTRE

MULTIPLE OPTIONS



ON-LINE SERVICES FOR YOU

“Mobility as a Service” is easy-to-use and affordable mobility



CONNECTIVITY

AIRPORT: 2 min delay
TAMPERE: fluent train services
TURKU: go to track

USER FRIENDLY
&
SEAMLESS

your train
leaves
in 10 min

Smart mobility is connected services

The transport network has limited capacity and is becoming increasingly overloaded, creating increasing disruption, congestion and emissions. In growing urban environments, these problems can no longer be solved by building more roads and streets, due to a lack of physical space and public funds. Environmental restrictions and objectives, such as CO₂ targets, also set further limitations on the viability of solutions. Scarcity and a clear need for change, however, often create a productive environment for new innovations and solutions.

Our vision is Mobility as a Service – but what does this mean and how do we achieve it? The aim is for the user to have various easy-to-use and affordable mobility options. Services must be available to address the user's mobility needs and be easy to combine; flying, private car, walking, cycling, public transport, taxi and ride sharing demand responsive solutions (e.g. dial-a-ride). Mobility services must provide reliable and timely information and guidance through different devices and means (such as smart phones and social media). Mobility as a Service reduces the need for private car ownership as well as parking spaces and road construction. It is also a platform for new businesses and new ways to tackle existing problems.

The transformation towards this vision is already happening. Businesses are co-creating and providing new and innovative services together with travellers. This is supported by research and common goals. Authorities are increasingly trying to solve transport-related problems by acquiring services and levels of services instead of building new roads. The development is supported by the digitalization of society, open public data, technological advancements, social network services and ecosystems, emphasis on environmental values, and a mindset regarding mobility, transport and car ownership.

Efficiency and fluency of mobility from the Internet?

It is crucial to increase fluency and ease across the whole travel chain from start to end from the end-user's point of view. One efficient way to achieve this is by Intelligent Transport Systems and Services (ITS) that utilize information and communications technologies. ITS helps achieve transport policy goals by shifting the focus from expensive transport infrastructure construction towards efficiency and fluency of mobility and logistics while creating and enabling new business.

Information and communication technology plays an important role as enabler in the transformation of mobility. The Internet of Things (IoT), for example, is an ecosystem in which objects and devices automatically collect, share and exchange information and utilize the information received. Vehicles can monitor their surroundings and the environment and provide information to other road users, infrastructure systems and managers. Information can also be processed along the way and provided to new vehicles and road users. This information can be used to build more advanced services and applications. As an example of this, drivers can be given localized and timely warnings about road conditions based on slipperiness detection sensors in other vehicles or road infrastructure. The same information can also be used for better road weather forecasts and to improve road maintenance efficiency. In addition to automatic sensors, some information, such as incident reports or gas prices, can be co-created by the users, creating new services and business opportunities.

Automated driving

The next step after vehicles communicating with one another is automatic driving. Automation is already available in, for example, driverless metros and car parking assistance, when the driver only needs to use the accelerator and brake while the car takes care of the steering. Increased automation will enable better utilization of road capacity by safely allowing smaller gaps between vehicles. Automation will shift the responsibility and liability from humans to machines, but the introduction and deployment of the systems will take much time and require extensive testing of the technologies involved. In this context, it is also clear that a thorough process for collecting and analysing the views of all stakeholders is necessary, as this is a change that is very sensitive in the public debate.

Will the mobile phone's data package soon include mobility?

In addition to new technology, the transformation of mobility requires new operational models, service concepts and business ecosystems. Here, the expertise, services and products of businesses and other stakeholders are needed to form competitive offerings. For the user, it is essential that there are alternative packages from which to choose the preferred services. The user should be able to select a flexibly priced mix of, for example, car-sharing, city bikes and public transportation that fills the personal mobility needs and, of course, user-friendliness, including simple and secure payment.

Intelligent cross-border services

New mobility services for cross-border passenger traffic between Helsinki and St Petersburg are a concrete example of an offering that is currently being developed. The objective of these services is to solve the fundamental issues that have been identified: mobile data transfer availability is unreliable and costs vary between countries, traffic and road weather availability is insufficient throughout the journey, and service usability and availability in different languages is lacking. The services developed in the first stage include automatic road weather services, automatic incident reporting and warning systems, real-time traffic and congestion information service, public transport information service, and a travel chain optimization platform. The services are based on a device-independent HTML5 platform and are therefore available to all mobile devices. In addition to transport information, the platform will have value-added services such as online translation, travel insurance and other applications that are useful for cross-border travel. The services will be presented at the ITS Europe 2014 Congress in Helsinki in June 2014.

At first, the services will be available for practical reasons for road and rail transport, but in the future they will cover travel chains that also incorporate other modes. The developed services will include safety improvements. For example, in a couple years, the service offering will include a commercial vehicle emergency service in Finland and Russia. Alongside safe and smooth transport, the aim is to generate new business by facilitating transport data and making them available. The services are currently being developed by a consortium of more than ten companies from Finland and Russia.

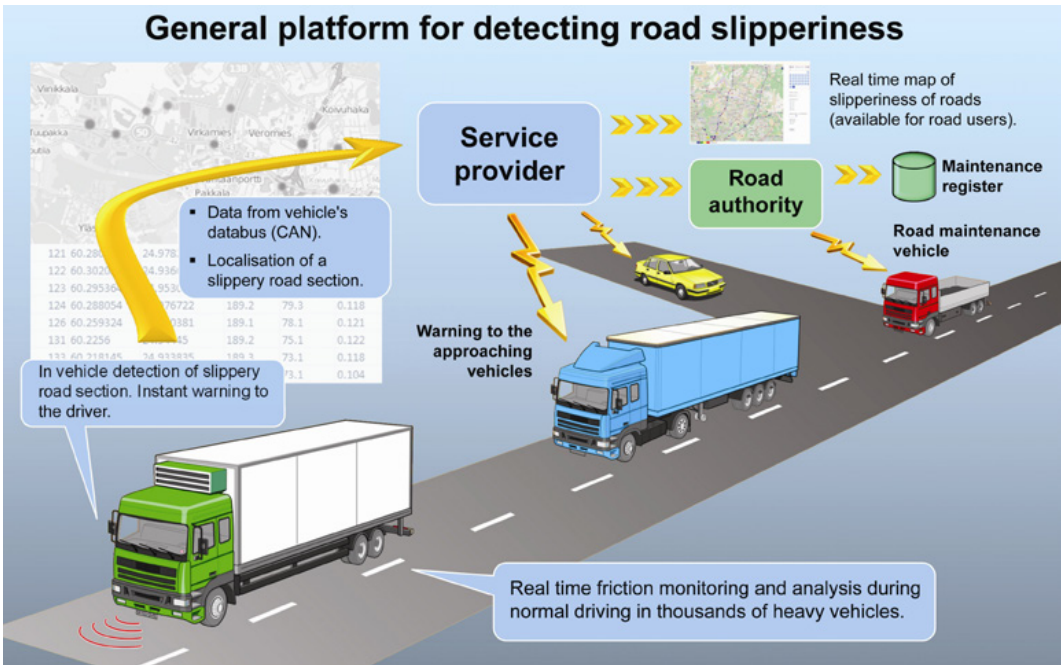


Figure 14. The developed system for detection of road slipperiness is device and vehicle independent. It also does not require particular actions from the user or installation of extra equipment. The system allows automatic, continuous measurements based on readily available in-vehicle data (wheel rotation). The collected data can be easily distributed to other road-users.

New business in sight

The ongoing structural change in the mobility and transport markets enables new business. Mobility is no longer seen as something that only generates costs; it is also an enabler of new services. The creation of new business, however, requires the services to fill existing needs or to provide value for the users. The technology readiness must also be there. To ensure and boost quick market uptake for new services and technologies, it is important to test them in an agile manner in real operating environments to verify viability. Reliable measurements and validation information are necessary to support business development. This applies to decision-making as well as regulation and legislation.

VTT and TransSmart work with the public and private sectors to develop and export services

supporting the Mobility as a Service vision. To speed up the structural change, contribute to transport policy goals and promote consumer markets, the Finnish Ministry of Transport and Communications has launched an experimental project on electronic transport services for 2014–2015 together with the Finnish Funding Agency for Innovation (Tekes). The project aims to promote consumer markets and to analyse the impacts of the services, and it tests new operating models and technological solutions as well as co-operation between the public sector, private enterprises and research institutes in developing services. VTT is actively participating in this project.

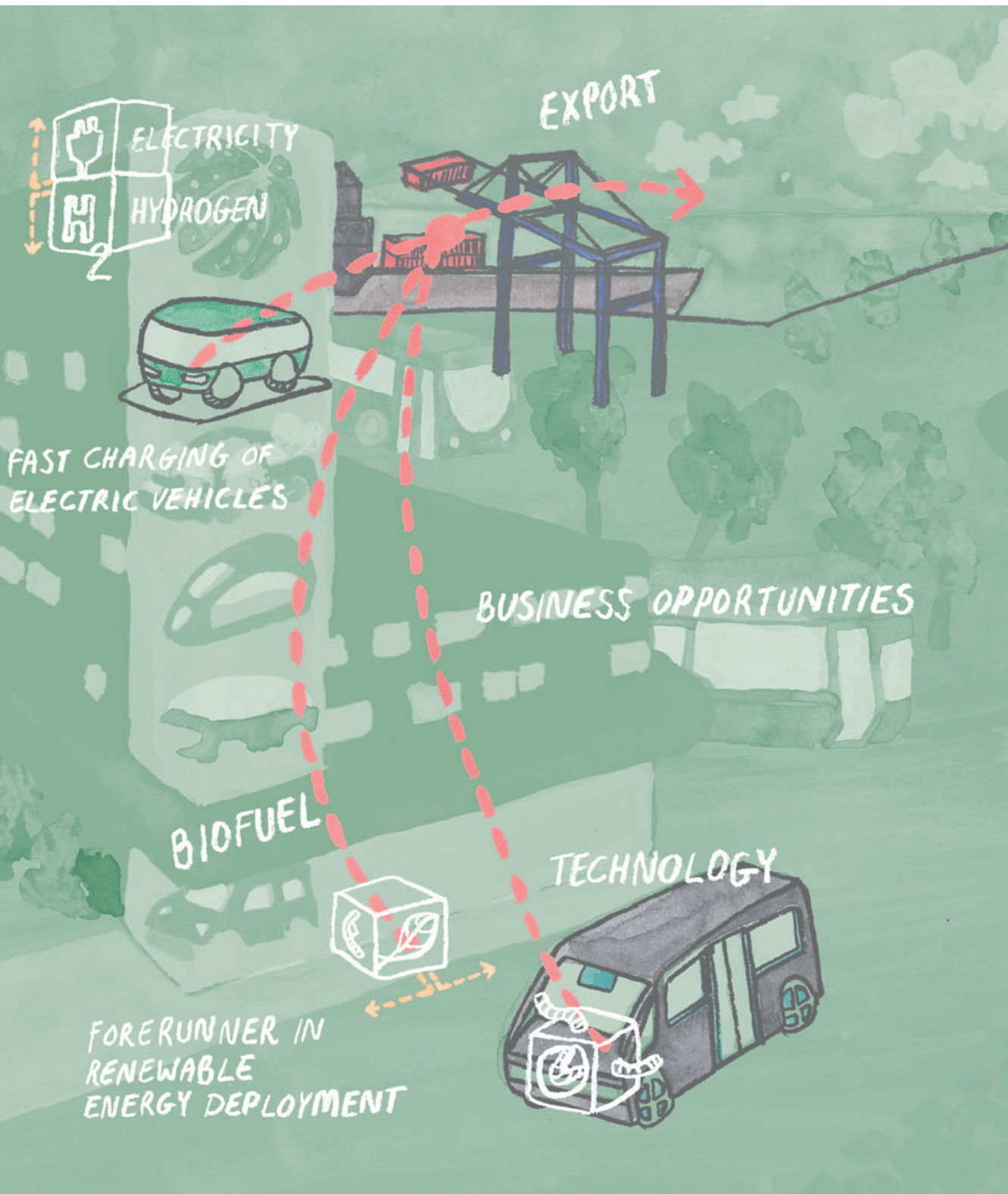
Case: Snowhow saves lives and money

Adverse weather conditions in wintertime result in significant loss of both life and well-being and generate greater material costs as a result of increased numbers of accidents. Road weather information services based on reliable and comprehensive measurement data help to mitigate these harms. According to VTT's study (*Hautala et al., 2007*), in Finland, the socio-economic benefits of weather information services for road transport amount to at least 120 million EUR annually in reduced accident and maintenance costs. It has been estimated that the benefits could be doubled by developing even more efficient and intelligent information services. A European Commission regulation (European Commission, 2013b) also calls for providing information on temporary slippery road conditions to drivers throughout the road network rather than only at fixed measuring points.

These technologies and services have been developed at VTT in close collaboration with key players in the field. One example is the ongoing FIRWE (Finnish Roadweather Excellence) collaboration, which includes Vaisala, Arctic Machine, Foreca and Teconer (with Tekes The Finnish Funding Agency for Innovation) as the main funding body). Two methods of providing slipperiness-related road weather information in a co-operative manner have been developed. One of the methods for detecting road slipperiness is based on image processing (Pyykkönen et al., 2013) whereas the other uses readily available in-vehicle information from the difference in the speeds of the wheels of the drive axle and of the freely rotating wheels in various driving situations⁸. In fact, this novel method offers significant new opportunities to obtain location-based slipperiness data from a much wider area of the road network and provide this information to other road-users automatically and easily (Figure 14).

⁸ See VTT's press release "VTT's technology makes driving on black ice safer". Available at: http://www.vtt.fi/news/2013/23012013_luukkautentunnistin.jsp?lang=en [accessed 30 January 2014].





VTT is working to increase renewable energy in transport

SUSTAINABILITY

REDUCTION OF GREENHOUSE GASES

”

I could think of running on renewable fuel.



Going for green energy

The four key aspects regarding energy supply and use in transport vehicles are, firstly, that we must be able to take on board sufficient energy to propel the vehicle over an acceptable distance. Secondly, it needs to be fairly quick to fill up the energy charge, and the on-board storage must not be very heavy or expensive to manufacture. Thirdly, depending on the type of fuel or 'energy carrier' we are using, a compatible conversion system is needed that turns the energy into mechanical work that drives the vehicle with adequate efficiency. Fourthly, each carrier must have a complete system for production, distribution and logistics that adequately supplies the needs of the users.

There is a reason that oil has ruled for a century

Seen from this angle, liquid fuels based on mineral oil are highly advantageous as their energy density is high and storage quite straightforward with low-cost technology. There is worldwide production, supply and distribution, the tank can be filled up in a matter of minutes and the vehicle can easily be driven for 1000 km or more before refuelling is needed. Today, the efficiency of the combustion engine is also reasonably good.

At the other end of the scale, we have electricity, which requires heavy and expensive batteries for storage that carry a limited amount of energy. The range is thus in most cases unacceptably short, even if the electric drive system inherently has quite high efficiency. The recharging times are also fairly long, even with rapid-charge technologies, limiting the battery-electric drive to shorter distances and not allowing longer journeys. Liquid biofuels, gaseous fuels and hydrogen for fuel cell vehicles all fall somewhere between these extremes.

Considering these overwhelming advantages, it is no wonder that mineral oil-based fuels have become the de facto standard in almost all vehicles, excluding rail, for which electricity is clearly the preferred option.

No time to wait for the 'next oil' – it will never come

However, the need to cut carbon emissions has become increasingly evident in order to battle climate change, and the use of fossil fuels is the major source of carbon release. We must therefore find and start using alternatives, even if the costs are higher, at least seen from a short-term perspective. We do not have time to wait and see what the 'next oil' will be, because none of the alternatives has the capability of replacing today's fossil fuels in a timeframe that is acceptable. Thus, we need to take advantage of several options in parallel.

Changing fuel is a systemic change

When assessing the potential of an alternative to oil, it is important to consider also the need to change the existing systems required for its use. If new cars and new infrastructure for the energy supply are necessary, we are suddenly talking about decades before a meaningful change can take place.

Thus, the introduction of new fuel options or energy carriers also needs to be supported by a decent supply and distribution networks. Otherwise, market acceptance will remain marginal. We therefore need to make use of incremental solutions that can be implemented widely in the short term but, at the same time, start the preparations for a more profound change that entails building a

new infrastructure and new vehicles. This is why it is crucial for research and innovation actors to have continuous and interactive communication with all the stakeholders, and VTT is well connected to industry and the decision-makers.

An open-minded approach

Someone stated that energy efficiency is alternative fuel number one. People should naturally pick the low-hanging fruit first. So, energy efficiency is one of the focal points of TransSmart. In addition, however, we have to look for alternatives to oil-based fuels. The options are not really that many, namely biofuels (liquid and gaseous), renewable or low-carbon electricity and hydrogen from renewable resources. All these options are covered by TransSmart. Hydrogen is one way of storing renewable electricity, and this probably means that the supply of renewable hydrogen will increase over time. As mentioned previously, the alternative energy carriers are not in competition but rather complement each other. In building the bridge to a sustainable future, we need a multitude of energy carriers in transport. However, we have to be smart about it and figure out in which applications to make the best use of the alternatives. It can be stated, with good reason, that 'one size doesn't fit all'.

TransSmart does not conduct research on biofuel production, power generation or large-scale hydrogen production. The emphasis is on the interface between the energy carrier and the vehicle. In the case of biofuels, this means ensuring that the biofuels work well in the vehicles without causing end-use problems. This is done either by modifications to the fuel formulation or adaptation of the vehicle itself. For EVs, the focus is on fast charge solutions and the implications of fast charging on

the grid. In the case of hydrogen, we look at fuel quality requirements in fuel cell vehicles as well as de-centralized local production of hydrogen.

Biofuels: promises and challenges

There are several Finnish energy companies investing in advanced biofuels. Some pulp and paper companies are even switching in the direction of biorefineries, thus becoming involved in the energy business. There are several challenges for biofuels, including sustainability of the feedstock, reaching desired end-use properties and cost-efficiency. With its vast biomass resources and advanced technology, Finland is well positioned to produce significant amounts of sustainable biofuels. VTT and TransSmart are cooperating with all the key players in the field of biofuels, fuel formulation, and engine and vehicle testing in lab conditions and large-scale living lab field testing. The objectives are twofold: firstly, to create a competitive edge for the Finnish industrial players in biofuels and, secondly, to enable high market penetration of biofuels in Finland, thus achieving substantial GHG emission reductions in transport in a cost-effective way.

Today, the EU Fuels Quality Directive (FQD) and fuel standards define the terms for the way biofuels are accepted by the car manufacturers. However, we should find ways to make the automakers not just accept biofuels but really want or need them. This should be possible, as the best renewable fuels have already shown that they can outperform mineral oil-based fuels, such as HVO (hydrotreated vegetable oils) fuels, which have a high cetane number that can be advantageous in view of combustion efficiency and engine-out emissions. If the use of renewable fuels were to benefit carmakers to fulfil

their obligation to lower the average carbon emission rate of their whole product line some way, they would most probably want to make use of that.

Battery electric or fuel cell?

As discussed previously, a fuel cell vehicle is, in principle, an electric vehicle: the traction motor is electric in both cases. Both technologies, batteries and fuel cells, deliver also significant benefits for local emissions and noise. Furthermore, if the energy carrier is derived from renewable sources, there are also significant climate benefits compared with conventional vehicles. The thing that differentiates the two technologies is the way energy is replenished and stored: in the case of an electric vehicle as electricity into a battery, and in the case of a fuel cell vehicle as compressed hydrogen into a gas store.

Battery electric vehicles need fast charging

For pure battery electric vehicles the challenge of range remains. To enable large-scale mobility with passenger cars as well as services by electrified commercial vehicles, fast charging is needed. VTT is actively working on electrifying the bus system. A battery electric city bus is not just a vehicle technology issue but more of a system level issue, involving factors like fast charging, grid and infrastructure implications and the need for detailed planning of everyday operations. VTT has updated its labs to incorporate equipment for testing and research of energy storage (batteries), with equipment for development fast charging systems to follow. So, we are well equipped to face the research need arising from electrification of commercial vehicle and mobile machinery systems.

Hydrogen and fuel cells – another zero-emission option

VTT is actively developing both low-temperature and high-temperature fuel cell systems. Low-temperature PEM (proton exchange membrane) fuel cells working on hydrogen are well suited to transport applications. VTT also has very well equipped labs for fuel cell technology.

VTT has already demonstrated a hybrid-type forklift equipped with a PEM fuel cell system acting as range extender. Considering the high peak loads needed in many types of working machinery, a combination of energy storage and fuel cells may be a good option.

Within TransSmart, the fuel cell-related activities focus on hydrogen quality issues and high-temperature electrolysis. In the case of hydrogen quality, the aim is to control impurities that shorten the life of the fuel cell stack and still have a hydrogen grade that is cost-effective in mobile applications.

The amount of intermittent renewable energy installed in Finland and Europe is increasing rapidly. The problem is that wind and solar electricity production do not match the electricity consumption pattern. There is therefore an acute need for a solution to store large amounts of electricity. Electrolyzing water to produce hydrogen from electricity can alleviate the problem, while at the same time delivering a carbon-free energy vector for, e.g., transport applications.

The electrolysis being developed at VTT is based on solid oxide electrolysis cell technologies, which is the most efficient electrolyser technology today. The hydrogen can be sold as fuel, added to the natural gas grid or stored to produce electricity during peak demand. The technology also allows co-electrolysis, delivering carbon monoxide and hydrogen at the same time; the components can then be converted into methane.

Hydrogen roadmap

The Finnish hydrogen roadmap, compiled by VTT and partly funded by Tekes – the Finnish Funding Agency for Innovation, assessed the export opportunities that may be available to Finnish businesses through international development. The report, published in spring of 2013, envisaged the kind of energy-, climate- and industrial-political opportunities offered to Finland through widespread adoption of hydrogen energy and it presents recommendations for gaining access to them.

Finland is already prepared for the construction of hydrogen refuelling stations through the gas company Woikoski Oy, which is using its own innovative technology to bring an exportable hydrogen refuelling station to Vuosaari in Helsinki.

Case: Cooperation and networking on new fuel options

Finland has made a political decision to promote the introduction of biofuels for transport on an accelerated schedule, because sustainable biofuels have significant profit potential for the industry. Furthermore, significant emission reductions can be achieved with the best of these fuels.

VTT has orchestrated a project integration that paves the way for increased deployment of sustainable biofuels. The project focuses on new biofuels that can replace conventional diesel fuel, as well as new ways to take advantage of biofuels. The project shall identify the most cost-effective methods and uses of the various biofuel options.

The project, which serves decision making as well as the creation of new business, brings together all the main stakeholders: energy companies, vehicle operators and decision-makers at municipal level and in ministries.

The modus operandi is the living lab model: putting new fuels and alternative-fuel vehicles into everyday operation to obtain feedback on real-life performance. In parallel, VTT carries out research in its versatile laboratories to refine technology and monitor the performance of the vehicles participating in the field testing. The technologies and fuels evaluated are ethanol for heavy-duty vehicles; renewable diesel from tall oil, a side product from the pulping industry; and biomethane in heavy-duty vehicles. Our partners include actors such as NEOT, St1, UPM Biofuels, Itella, City of Helsinki, Helsingin Bussiliikenne, Veolia Transport Finland and Helsinki Region Transport. We have linked this project internationally, as we are cooperating with the International Energy Agency programme on Advanced Motor Fuels (AMF).



ENABLING USE OF
RENEWABLE ENERGY

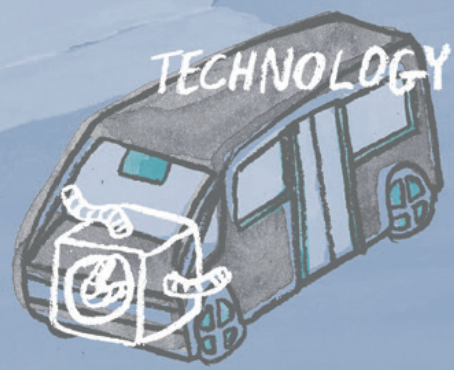


SMART VEHICLE SYSTEMS



CONTROL
SYSTEMS

ENERGY EFFICIENCY

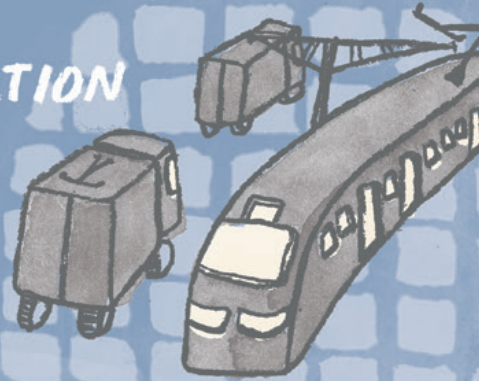


TECHNOLOGY

A smart vehicle is efficient and clean

ELECTRIC POWERTRAINS

EMISSION REDUCTION



It's a hybrid version,
so I will help save
the planet.



Cutting the energy use of vehicles in half

Look at the progress in reducing regulated exhaust emissions, oxides of nitrogen and particulates: a reduction of some 95 % over the past 20 years. Look at what has happened in fuel efficiency over the same period. Progress, yes, but not that spectacular. So, we have to admit that reducing fuel consumption is much more challenging, especially since significant reduction in regulated emissions, tends to increase fuel consumption through e.g. additional exhaust after-treatment devices. Actually, reducing fuel consumption by 95 % would be close to creating perpetuum mobile.

So, let us be realistic. How about, on an average, halving the energy consumption of vehicles in less than 20 years? This could be achievable. However, to achieve this we have to implement a wide range of measures. Let us think about the options. We have to consider the vehicle itself, the power line, meaning engine and transmission, and then all the auxiliaries, including systems to help the driver to drive in the most energy-efficient way.

Reduce driving resistances

The aerodynamic drag and the weight of the vehicle are decisive to the driving resistance of the vehicle. Power demand is the resistive force multiplied by speed. Reducing speed is an effective way to reduce energy consumption, as the power needed to overcome the aerodynamic drag is proportional to the third power of speed. On the other hand, reducing speed significantly from the current rather modest speed levels we have in Finland would mean either more time spent on the road or reduced transport capacity. So, let us look at aerodynamics instead. At VTT, we added relatively simple aerodynamic fairings to a heavy truck-trailer

combination and obtained fairly astonishing result – 30 % fuel savings in highway driving. Now we need to make sure this technology is widely adopted.

So, how about the weight? The curb weight of the vehicle is critical in transient operation, meaning city-type driving with many starts and stops. With our knowledge of materials technology, let us implement lightweighting on city buses – almost the same effect as with the aerodynamic fairing on the truck, close to 30 % fuel savings. Only 20 % to go...

Improve engine control and reduce friction

So, let us move ahead to look at the power line. Let us start with a traditional power line based on an internal combustion engine. Believe it or not, the internal combustion engine will be around for many decades to come. Our advanced sensor technologies enable better control of the engine itself and all the auxiliaries, including exhaust after-treatment systems. Naturally, we will optimize the combustion of high-quality renewable fuels, simultaneously decreasing greenhouse gas emissions and improving energy efficiency. By the way, did you know that at VTT we are experts in tribology?⁹ We can reduce friction losses within the engine itself, all the way from the piston ring/cylinder liner throughout the power line to the driving wheels. And, yes, naturally we will put tyres with low rolling resistance on the vehicle. However, in the case of tyres, we have to make sure that we are not compromising safety for energy efficiency.

Again, let us see what the savings in this sector add up to: 10 % easily. So, where do we find another 10 %?

⁹ See, for example, Holmberg, K., Andersson, P., and Erdemir, A., 2012, *Global energy consumption due to friction in passenger cars*, *Tribology International*, Volume 47, pages 221-234, <http://dx.doi.org/10.1016/j.triboint.2011.11.022>

Electrification helps out

The answer is obvious, naturally, we will include electrification. We can opt for different degrees and technologies of electrification; we can go for autonomous hybrids, battery electric vehicles and even fuel cell vehicles. In the case of the city bus, we will combine lightweighting with simple hybridization to recuperate brake energy. There we go, a 50 % reduction in fuel consumption compared with a baseline diesel bus. Great! Let us take this one step further, let us go fully electric. Lightweighting is good, also in this case, as a lightweight chassis and body compensate for the heavy batteries. We are not pulling your leg, together with our partners, we have already built an electric city bus that consumes less than 1 kWh/km. Converted into the diesel equivalent, this is some 10 l/100 km. A conventional diesel bus then? It consumes some 45 l/100 km. Hurray! We already have a vehicle that delivers a 75 % reduction in energy consumption. Alright, so it is not completely fair to compare diesel and electricity (diesel you have to burn to get useful energy, electricity again is energy in its best form, ready to use and versatile), but it is still a highly notable result.

To reduce the energy consumption of vehicles by more than 50 %, can we not just go for electrification? Unfortunately not, as full electric drive is not suitable for all applications. It is hard, for example, to envisage a battery electric timber truck. City buses, on the other hand, are an excellent target for electrification. Fixed routing makes operation predictable, high efficiency is appreciated as are zero local emissions and low noise. A high degree of utilization provides economic feasibility and short pay-back times.

So, the question stands: why do we not go to immediate electrification of buses? The answer is that we still have some homework to do. We simply cannot look at electric buses from a narrow

vehicle technology perspective; we have to take a systemic approach. Therefore, we are not only working hard on the vehicle but we are also figuring out how to best recharge buses and how to integrate the eBus system with the general infrastructure and the power grid.

Do not forget the driver

Oh, almost forgot, reducing energy consumption is not only about technology, it is also about people and their behaviour. It is our duty to inform the consumer about smart choices. Those who still want to have a passenger car of their own should be made aware that within the same vehicle model, the fuel consumption of a specific car model can vary by a factor of two, depending on the engine size and output. So, we can cut fuel consumption by 50 % just by choosing a smart engine.

VTT is also involved in the development of systems that improve driver performance, both in regard to safety and energy efficiency. We already have a cooperative system enabling communication vehicle to vehicle or vehicle to infrastructure. In our vision, we are moving towards automated systems.

The discussion above focused on road vehicles. Some of the principles are also applicable to other types of vehicles and even ships. All machinery equipped with internal combustion engines will benefit from advanced sensors and better control systems, optimized exhaust gas after-treatment systems and reduced friction. Finland is famous for its icebreakers. In fact, our icebreakers have already applied hybrid technology, i.e. internal combustion engine driven generators and electric propulsion motors, for a long time. Now, hybridization and even electrification are entering the segment of mobile machinery to enhance energy efficiency and reduce emissions. With our knowledge of electric motor design, power electronics and energy storage we are an integrated part of the process.

Case: Urban electric bus system in Metropolitan Helsinki

Together with our partners (Helsinki Region Transport, City of Espoo, Veolia Transport Finland, the Metropolia University of Applied Sciences, Fortum, and the Ministry of Transport and Communications, among others), we are going to electrify the bus system. A new west-bound metro line will open in the Helsinki area in 2016, and the aim is for the bus feeder traffic for the new metro line to run using electric buses. Helsinki Region Transport is determined to cut local pollution as well as greenhouse gas emissions.

Electrifying the bus system is not only about vehicle technology and the buses themselves but also about how electric buses fit into the transport system and how to charge them. Several years

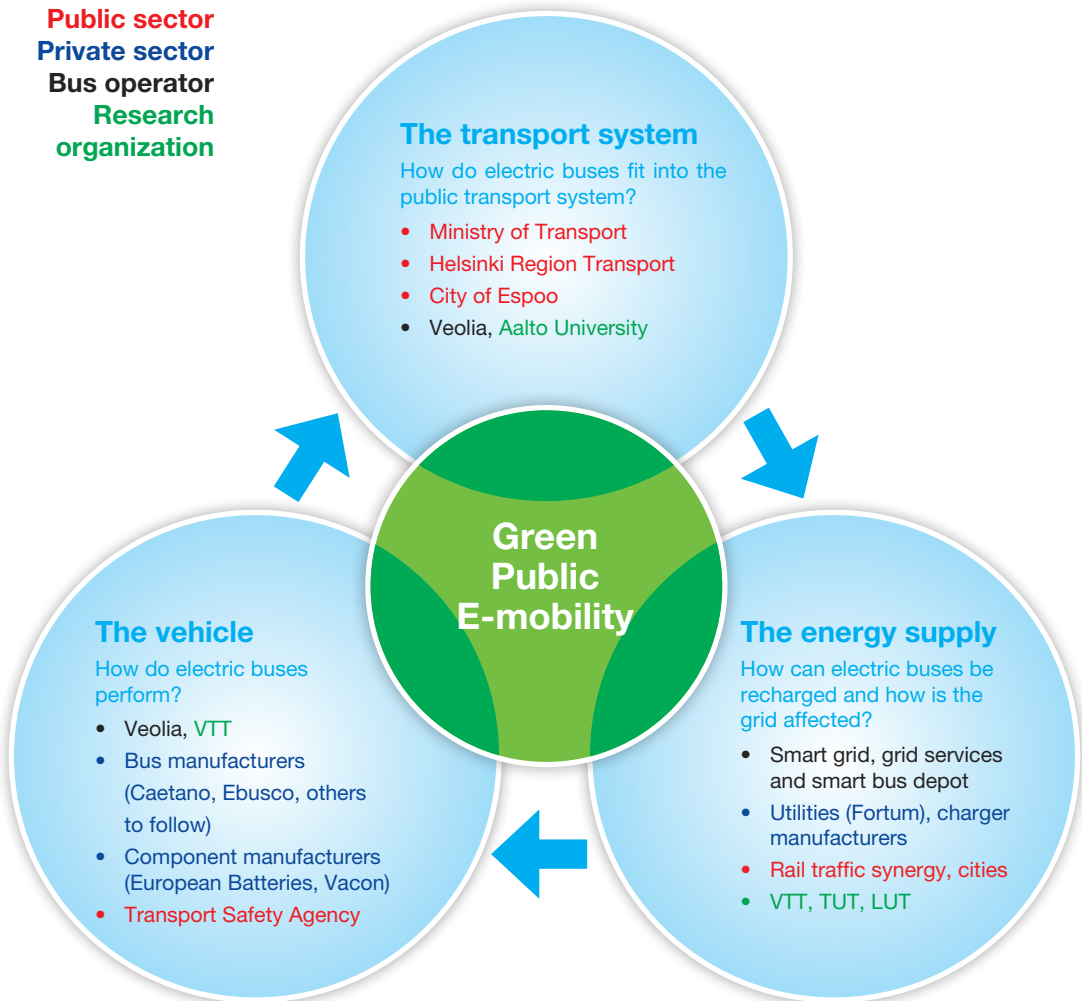
before the metro line is due to open, we have started benchmarking electric buses of various brands in everyday service, mimicking feeder traffic on an existing bus route. In cooperation with the Metropolia University of Applied Sciences, we have also built our own full-size battery electric bus to be used as a platform for electric power train development. Our excellent research facilities for electric vehicles make us an interesting partner in Finland and internationally. We are a partner in the huge European ZeEUS electric bus project, which is headed by UITP (International Association of Public Transport).

Test facility at VTT is used for measuring accurately the performance of the electric busses and breaking-down the energy use to driving and the contribution of each on-board sub-system.



The Metropolitan Helsinki eBUS & eBusSystem projects

Public sector
Private sector
Bus operator
Research organization



Cooperation with Helsinki Region Transport

Helsinki Region Transport (HRT) is a joint local authority whose member municipalities in Metropolitan Helsinki are Helsinki, Espoo, Vantaa, Kauniainen, Kerava, Kirkkonummi and Sipoo. In Finland, HRT is by far the most important player in public transport, procuring more than 60 % of all public transport in Finland. Some 345 million journeys are made on HRT's transport services annually.

HRT is actually doing well. In 2013, public transport ridership in the Helsinki region increased by 3.1 per cent from the previous year. The number of journeys made totalled some 355 million.

"Public transport ridership has been increasing steadily year on year. According to the traffic survey published last autumn, the share of public transport of all transport in the metropolitan area was also up for the first time in 50 years. This is a remarkable change that shows that new customer groups are also interested in HRT's services," says HRT's Executive Director Suvi Rihtniemi.

Improved customer satisfaction is another indication of the popularity of public transport. In 2013, The HRT area public transport also came out on top in the European BEST survey for the fourth time running.

HRT's basic task is to provide extensive transport options and create conditions for a viable and pleasant Helsinki region. The aim is for the Helsinki region to have the most efficient transport system and the most satisfied users of public transport in

Europe. In the new strategy for 2025, a number of strategic goals have been set:

1. The travel chain of the customer is based on the public trunk network and efficient feeder services
2. HRT provides its customers with up-to-date information before and during their journeys as well as clear, easy-to-use and reasonably priced tickets
3. HRT's transport system based on rail services creates a more compact urban structure and makes the region more attractive
4. HRT directs the increase in traffic to public transport, walking and cycling
5. HRT increases the share of low-emission public transport
6. HRT makes public transport more cost-effective and strengthens the funding base of the entire transport system.

In addition, HRT has set environmental goals. Compared with the year 2010, the targets for 2018 are

- 80 % reduction in emissions of oxides of nitrogen and particulates
- 50 % reduction in greenhouse gas emissions.

In 2013, HRT and the TransSmart programme signed a four-year framework contract. It could be said that HRT and TransSmart share the same values and objectives:

- to promote public transport and non-motorized transport instead of motoring
- to introduce new and clean technology, in the case of buses this means, e.g., the newest vehicle technology for reduced local emissions and the best biofuels and electrification for reductions of greenhouse gas emissions
- to make public transport more attractive by developing and refining smart mobility services.

VTT has been running a heavy-duty vehicle test facility since 2002. HRT and its predecessors were instrumental in creating the facility and have been loyal customers ever since. As a result of this long-standing cooperation, HRT now has access to the best database on bus performance in Europe. The information is used in, among other things, the tendering process of bus services.

HRT and VTT also look into the future together. Meeting the 2018 environmental goals requires implementation of new vehicles, sustainable biofuels as well as electrifying part of the bus fleet. A new westbound metro line for Espoo will be completed in 2016. The public transport in the western region of HRT's operating area will change from regional bus services into Helsinki to a combination of feeder traffic to nodal points and then rail-based transport. The ambition is that at least part of the feeder traffic will be serviced by electric buses.

HRT and VTT are working together to evaluate the performance of electric buses. However, the work on the formulation on the future electrified bus system is even more important. Electrifying the bus system has implications for, e.g., the infrastructure, the electric grid, traffic planning and the tendering system for bus services. Electrifying buses is more than just vehicle technology, it requires a system level approach, and this is where TransSmart will help HRT to build the future.



The four main themes of TransSmart: low-carbon energy, advanced vehicles, smart mobility services and the transport system as a whole, including foresight, are all focal points for HRT. We have a long tradition in cooperation with VTT, and the TransSmart programme has taken the cooperation to a new level. We are happy to be building future sustainable public transport together with VTT.

Reijo Mäkinen
Director of Transport Services
at HRT

Cooperation in competence building

Fintrip, i.e. the Finnish Transport Research and Innovation Partnership, is a platform for competence building and innovation in the transport arena. Fintrip, an initiative set up by the Ministry of Transport and Communications, is supported financially by the Ministry, the Finnish Transport Agency, the Finnish Transport Safety Agency and Tekes – the Finnish Funding Agency for Innovation.

The task of Fintrip is to enhance cooperation between those financing research and innovation in the transport sector and those providing and using research. The ambition is to strengthen networks at national as well as international level.

The aim of Fintrip is to develop spearhead competence, stimulate innovation and provide solid data for decision-making. In addition, Fintrip aims to improve dissemination of information, specifically for applied research in the transport sector.

The board of Fintrip recognized the ability of TransSmart to bring all the players in the field of transport together and to disseminate information in an efficient way. Fintrip therefore decided to create a partnership between Fintrip and TransSmart in the field of smart sustainable mobility rather than to duplicate efforts.

| SAFETY AND SECURITY | EFFICIENCY | SEAMLESS MOBILITY | SUSTAINABILITY |
|----------------------|------------|-------------------|----------------|
| Smart Cities | | | |
| Arctic | | | |
| Russia | | | |
| New transport policy | | | |

Goals and preliminary themes of transport research and innovation activities in Fintrip context

- All transport modes; passenger and freight traffic
- Productivity, effectiveness, competitiveness, foresight

Data Pekka Plathan/Fintrip 9.12.2013

The Fintrip – TransSmart partnership in smart and sustainable mobility comprises the following actions and tasks:

- enhancing cooperation between all stakeholders in smart and sustainable mobility
- efficient dissemination of information
- arranging joint workshops and seminars
- identifying and bringing forward research needs in a systemic way: Fintrip with a focus on the needs of the public sector and TransSmart with a focus on the needs of industry
- initiating pre-studies in areas where knowledge gaps have been identified, and by doing so involving relevant research organizations, building competence and laying the foundation for large research projects.

TransSmart was given the responsibility for nationwide coordination for research in smart sustainable mobility. This was the final confirmation that TransSmart, an initiative by VTT, had evolved into a national programme bringing all the relevant actors together.



Fintrip recognized that TransSmart and its predecessor TransEco had created a platform for cooperation, which was what Fintrip was looking for. Fintrip therefore decided to form a partnership with TransSmart in the field of smart sustainable mobility, which is one of Fintrip's main focal areas. The partnership is a win-win situation for the two parties, Fintrip and TransSmart. At the same time, we avoid duplicating efforts, something which is highly valued in harsh financial conditions like the ones we are experiencing now.

Pekka Plathan
Director General at the Ministry of Transport and Communications,
Chairman of Fintrip

VTT excels at making a change

In creating a better future and bringing the transport system on track to sustainability, VTT and the TransSmart programme are a key player on the national scene as well as internationally. Why is this?

At national level, we have the ability to bring all the key actors together: industry, the public sector and other research institutes. As regards the international perspective, we are scouting for best practices suitable for implementation in Finland.

We have long experience in the European research arena and consequently good international contacts, facilitating two-way communication. In the other direction, we help Finnish actors in the field of smart low-carbon transport to go international with the aim of opening up new business opportunities. The VTT TransSmart programme has been entrusted with national coordination for research in intelligent and sustainable transport, with the task to



Heavy-duty vehicle test facility at VTT enables simulation of driving in closely-controlled laboratory environment for maximum accuracy and repeatability.

involve all relevant research organizations in Finland.

VTT is a trusted and well-known partner with excellent contacts with industry. Our partnership also stretches to developing strategies for the Ministry of Transport and Communications (support for transport policy) and the Ministry of Employment and the Economy (support for energy technology policy).

VTT Technical Research Centre of Finland is the biggest multi-technological applied research organization in Northern Europe. VTT provides high-end technology solutions and innovation services. From its wide knowledge base, VTT can combine different technologies, create new innovations and a substantial range of world-class technologies and applied research services, thus improving its clients' competitiveness and competence. Through its international scientific and technology network, VTT can produce information, upgrade technology knowledge, create business intelligence and add value to its stakeholders.

In the case of sustainable transport, we have comprehensive expertise and critical mass in selected areas, i.e.:

- engine and vehicle technology
- electric motors and energy storage
- fuel cell technology
- modelling and measurements
- sensors, ITC and cooperative solutions for transport
- ITS service ecosystems and business models
- general transport system issues
- future-oriented activities, impact assessment and socio-technical change.

What differentiates VTT from consultants and many other research organizations is the combination of a wide knowledge base and unique research facilities. We have up-to-date research facilities for passenger cars and heavy-duty vehicles (up to 60 metric tonnes). In preparing for the future, the vehicle facilities have been updated with power supplies and battery simulators to cater for electric vehicle measurements. A new battery test facility complements our electric vehicle activities. As for internal combustion engine research, we have several engine dynamometers, all the way to a 1.6 MW medium-speed diesel-driven power plant unit.

Naturally, we have accreditation for our most important measurements on engines and vehicles. VTT's proprietary sensor technologies can be applied to engine and vehicle research, as well as to applications in everyday service.

When creating pathways into the future, it is not enough just to work in the lab. It is necessary to go into field testing, creating living lab environments. We have done this for advanced biofuels, electric buses and smart mobility services, as demonstrated in the above examples. Again, bringing all the stakeholders together for the transport system of the future is a key effort for VTT.

Speaking about the future, we also have a professional approach in foresight technologies. We integrate analytical and participatory methods from the fields of foresight, impact assessment and modelling to support strategic planning and decision-making. And, as mentioned before, in this we are a trusted partner of the government as well as industry.



VTT has several dynamometers for engine-only research and development.

Summary

As we have shown, we are committed to making a change. In our vision, we depict a sustainable transport system of the future. Three things are evident, as mentioned below.

First, when building the new system, we have to switch from the conventional hardware-centred approach (e.g. road infrastructure and vehicles) to a system based on user demand and mobility services.

Second, we need a systemic approach to mobility. To reach all the goals regarding climate, energy and service level, we cannot just work on a single element of the system, we also have to consider the system as a whole and, further still, the entire society beyond the system boundaries.

Third, we must be aware that one size does not fit all. By this, we mean that one single vehicle technology, energy carrier or even ICT service platform cannot cover all the mobility needs. We simply have to accept that we will have a mix of technologies, and we should have the knowledge to decide for which application a certain technology is best suited.

In our vision, the transport system is mainly powered by electricity, biofuels and hydrogen. Where conventional fuels and powertrains still apply, we

have succeeded in improving the efficiency of using energy and other resources remarkably. Energy systems for transport are integrated into other infrastructures in terms of production, storage and delivery. In our ideal system, the transport and mobility needs of individual people and companies are fulfilled by a wide range of transport services, characterized by advanced technologies, functionality and efficiency.

Naturally, at VTT we are working for the well-being of our nation. In addition to providing sustainable and efficient mobility services, we contribute to the development and production of transport fuels, vehicles, mobile machinery, infrastructure and services to generate business and profit for Finnish entrepreneurs in the domestic as well as global markets. The systematic, continuous work to evolve and adapt the transport system builds on information, knowledge and intelligence from experts and users. VTT's expertise in foresight and analysis of socio-technical changes gives us good tools to prepare for the future. We also constantly interact with the public and private sectors, as the development, operation and governance of the traffic system are shared tasks.

**TOGETHER WE CAN MAKE IT.
TEAM UP WITH US TO CREATE THE
MOBILITY SYSTEM OF THE FUTURE.**

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|-------------------|--|
| Title | Smart sustainable mobility – A user-friendly transport system is a combination of intelligence, low carbon energy, and adaptable services |
| Author(s) | Nils-Olof Nylund and Kaisa Belloni (eds.) |
| Abstract | <p>Imagine a world in which people and goods can move with minimum impact on the local environment and climate. Imagine an intelligent transport system with smart infrastructure and smart, connected vehicles powered predominantly by renewable energy, and with enlightened end-users: private individuals and enterprises. Imagine a system that is actually based on user demand. That is what we would like to see.</p> <p>To put mobility and transport on the track to sustainability, we have to improve energy efficiency, switch to renewable energy and more efficient modes of mobility, and, most importantly, increase smartness at all levels of the system. In practice, the last point means smart and efficient mobility services, cooperative systems, and intelligent vehicles and infrastructure.</p> <p>VTT has a toolbox and the expertise to tackle all the key challenges of smart low-carbon mobility. And, to really make an impact, we are cooperating with all the key stakeholders in the field. Let us re-invent mobility and co-create a better future together!</p> |
| ISBN, ISSN | ISBN 978-951-38-8274-7 (Soft back ed.) ISBN 978-951-38-8275-4 (URL: http://www.vtt.fi/publications/index.jsp) ISSN-L 2242-1157 ISSN 2242-1157 (Print) ISSN 2242-1165 (Online) |
| Date | June 2014 |
| Language | English |
| Pages | 72 p. |
| Keywords | Intelligent transport systems, smart mobility, mobility as a service, cooperative systems, low-carbon mobility, biofuels, electric vehicles, fuel cell vehicles, foresight |
| Publisher | VTT Technical Research Centre of Finland P.O. Box 1000 FI-02044 VTT, Finland Tel. +358 20 722 111 |

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Smart sustainable mobility

A user-friendly transport system is a combination of intelligence, low carbon energy, and adaptable services

Imagine a world in which people and goods can move with minimum impact on the local environment and climate. Imagine an intelligent transport system with smart infrastructure and smart, connected vehicles powered predominantly by renewable energy, and with enlightened end-users: private individuals and enterprises. Imagine a system that is actually based on user demand. That is what we would like to see.

To put mobility and transport on the track to sustainability, we have to improve energy efficiency, switch to renewable energy and more efficient modes of mobility, and, most importantly, increase smartness at all levels of the system. In practice, the last point means smart and efficient mobility services, cooperative systems, and intelligent vehicles and infrastructure.

VTT has a toolbox and the expertise to tackle all the key challenges of smart low-carbon mobility. And, to really make an impact, we are cooperating with all the key stakeholders in the field. Let us re-invent mobility and co-create a better future together!

New profitable
business within
the field of
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smart low-carbon
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ISBN 978-951-38-8274-7 (Soft back ed.)

ISBN 978-951-38-8275-4 (www.vtt.fi/publications/index.jsp)

ISSN-L 2242-1157

ISSN 2242-1157 (Print)

ISSN 2242-1165 (Online)