SMART ENERGY TRANSITION

What are the rate, direction and impacts of the technological transition?

Review of megatrends in Energy Sector

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Published: 4.11.2016

Smart Energy Transition Project (293405), funded by The Strategic Research Council at the Academy of Finland tackles the global disruption of energy markets by creating pathways for Finland to profit from the energy disruption.

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Executive summary

This study is a part of the Smart Energy Transition Project funded by The Strategic Research Council at the Academy of Finland that provides funding of long-term and program-based research aimed at finding solutions for the major challenges, which meets Finnish society. (www.smartenergytransition.fi)

The report is also a part of the work package 1 focusing on answering the question “What are the rate, direction and impacts of the technological transition?” For this purpose, this report reviews the spectrum of global megatrends affecting energy sector development in Finland.

The megatrends have a significant impact on demographical, economical, technological, and political development of Finland. They dictate rules of development for society, organizations, and individuals. From the energy and climate perspective, the megatrends should be utilized as the indicators for allocating the resources to act in order to reconfigure existing market systems and suggest the perspectives for progress to all the Finnish stakeholders. Investigating existing megatrends facilitate the better understanding of opportunities and threads for a country.

In addition to most dominant trend climate change, the increasing populations and trend on urbanization provide new types of challenges for energy sector. In this perspective, for example, energy consumption is also concentrating in large urban areas along with the people and industries. On the other hand, the urban areas are often not the best locations for energy production. Consequently, energy transition put forward the renewable energy production concept and expect it as the next approach to achieve the cost-efficiency level of fossils energy systems in order to remove barriers for the energy transformation. By means of smart networking the new energy paradigm provokes continually increasing level of interrelation and interpenetration between of millions of energy consuming and energy generating units in the World varying from large to micro level ones.

Renewable Energy System in Lappeenranta, Finland (www.one1.fi).

However, globalization provides challenges for all the actors and especially for smaller countries as Finland. Globalization brings all the areas of human activity like business, social, or even regulative area closer together and become interconnected. All those activities should serve to local and personal needs at the same time being globally scalable and acceptable.

Contents

1 Introduction

The motivation of this report stems from the desire of Finland to become a carbon-neutral society by 2050. This report provides insights on global megatrends for the larger research project “Smart Energy Transition SET” aiming to analyze the ongoing transition of energy sector and its impacts on Finnish society, in particular the potential benefits for cleantech, digitalization and bioeconomy.

The disruptions that SET examines are driven by a convergence of several technologies, with cascading consequences in multiple industries (Hacklin et al. 2009). Although there is research on the impacts of individual technologies such as renewable energy sources (Richter 2013), or smart grids (Erlinghagen and Markard 2012) on the energy sector, there is a lack of studies that analyze the smart energy transition beyond energy production and distribution and examine the opportunities and challenges for the wider economy.

The main objectives of the SET project are 1) to analyze the disruptive technologies behind smart energy transition and their impacts on society and its growth spearheads: cleantech, digitalization and bioeconomy, 2) to explore how different sectors can benefit from the transition, and 3) to co-create and test solutions by articulating the impacts of the disruptive technologies and the opportunities and threats for the key stakeholders in energy sector.

This report is part of the work package 1 that is aiming to answer the question “What are the rate, direction and impacts of the technological transition?” For this purpose, this report reviews the spectrum of global megatrends affecting energy sector development in Finland and discusses some potential interest areas for business and society as a whole. The key aim of the review is to enhance leaders’ ability to recognize patterns of behavior that may differ from conventional view spread in their operational environment.

The megatrends have a significant impact on demographical, economical, technological, and political development of Finland in particular being a relatively small country. They give the ultimate limits for societies, organizations, and individuals in their actions. There is very limited possibilities to influence on their development. However, recognizing and understanding power of megatrends to change existing environments, e.g. large cities, regions and even a nation, an individual actor can find their effects on businesses, availability of resources, and technologies. From the energy and climate perspective, the megatrends should be utilized as the indicators for allocating the resources for actions in order to reconfigure existing market systems and give the perspectives for progress all the Finnish stakeholders. Even though, the global megatrends can be seen, their development and related impacts will be recognized and better understood over time. Also, they can be perceived in different ways depending on the type of stakeholders, e.g. urbanization can be seen as a growing pressure for environmental and economic ecosystems, or as an opportunity for more resource-efficient lifestyles. These, divergent perceptions, create pluralism in decisions taken and variety in actions providing either opportunities or threats for the broad variety of stakeholders.

The insights of this report provide, firstly understanding on megatrends as a phenomenon of global change. Secondly, depending on perspective, through this review, the competence gaps in the future commercial, social, and technological opportunity arenas can be recognized, e.g. in the field of energy industry transition. Thirdly, this report opens up some interest areas for further research. It also serves as an intervention tool to attract and connect stakeholders into the project activities.

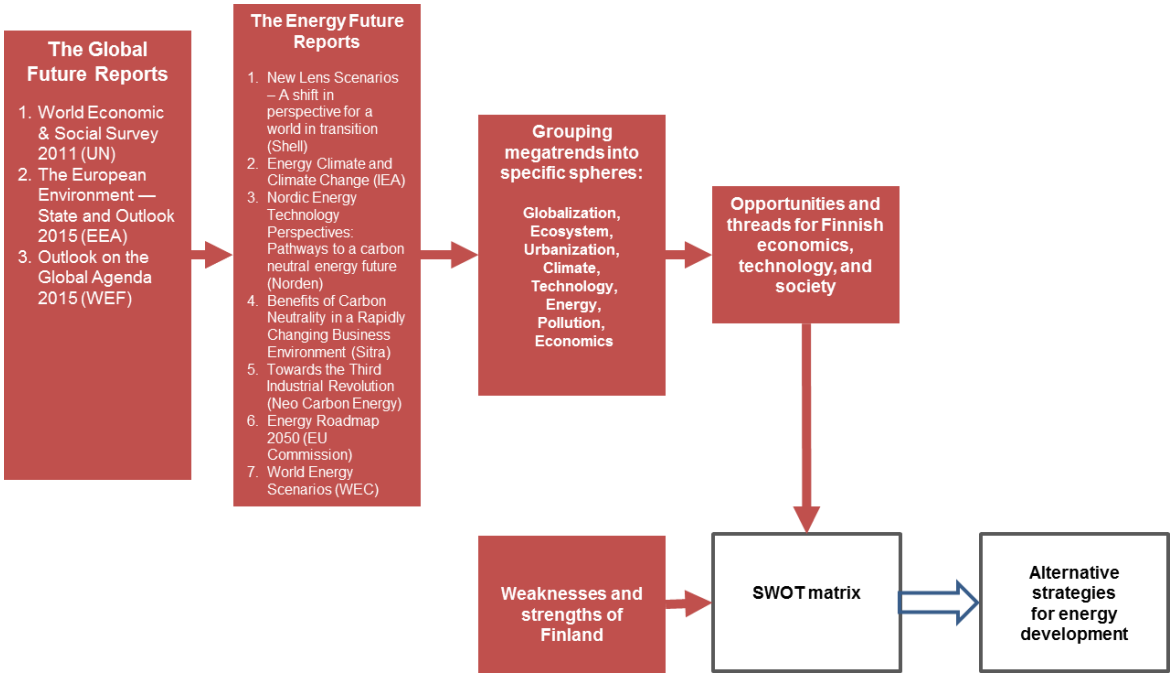

Figure 1. The process of analysis

This report begins with the review of the selected global future reports to recognize the relevant megatrends affecting the general development of the Finland and, in particular, the energy sector. The megatrends are then categorized and the key elements of them explained. Next, the review provides the concluding remarks and suggestions for further examination. Finally, the report provides some comments on the Energy and Climate Roadmap 2050 and the latest basic scenario of the national energy and climate strategy process.

2 Review of the upcoming megatrends

megatrends are seen as transformative, global forces that define the future world with far reaching impact on business, societies, economies, cultures and personal lives" (Sitra, 2015). The megatrends capture number of forces that have more limited impacts on a certain situation, e.g. industry or market development.

2.1 Globalization

Globalization is seen as a phenomenon of interconnectivity of people via information exchange making the world more transparent and shared. In this process, the fast developing digital technology and its diffusion into the everyday practices plays a central role. Globalization has been democratizing knowledge and interconnecting organizations and individuals globally. Growing global connectivity stimulates creativity but also puts intellectual property at risk. Connectivity facilitates individual expression and empowerment, but also encourages herd behavior and amplifies swings in confidence and demand. Globalization is forcing the existing institutions to change their behavior from top level decision making to the local community level. New countries and locally operating interest groups are taking leaderships from the global organizations and governments. There is increasing need for new forms of public-private collaboration across the countries and industries.

The deployment of information and communications technology has been a driver of economic globalization, extending and deepening trade, financial, and research links, spreading prosperity, and generating leadership challenges.

Global connectivity. Growing global connectivity stimulates creativity but also puts intellectual property at risk. Connectivity facilitates individual expression and empowerment, but also encourages herd behavior and amplifies swings in confidence and demand. The burgeoning availability of information has the capacity to bring insight and transparency, but data overload is equally likely to generate confusion and obscurity (Shell, 2013). The deployment of information and communications technology has been a driver of economic globalization, extending and deepening trade, financial, and research links, spreading prosperity, and generating leadership challenges. This unprecedented degree of connectivity is contributing to unusual intensity in part because growth in connectivity empowers individual players. Most countries are not fully self-sufficient in the interconnected Stress Nexus of food, energy, and water (Shell, 2013).

Leadership. In the context of globalization, governments are struggling with a mismatch between the increasingly long-term, systemic challenges facing society and their more limited focus and powers (EEA, 2015). Nevertheless, the World got a leadership crisis in the world today. The international community has largely failed to address any major global issue in recent years. It has failed to deal with global warming, and then barely dealt with the failure of the global economy, which has caused such severe problems in North America and Europe. Meanwhile violence has been left to fester in the Middle East (WEF, 2014). Addressing global stresses requires co-ordination among increasing constituencies of decision-makers. But the more diverse the groups that are involved, the more that vested interests tend to block progress. An often-cited African proverb suggests that to go fast, go alone – but to go far, go together. Grappling with growing stresses requires that we go fast and far – implying a paradoxical need to go alone and together. Fresh forms of collaboration are required that cut across familiar national, public–private, and industry-sector boundaries, but there are no strong models for such collaborations, and they are immensely difficult to get off the ground

because different parties remain focused on their individual foreground issues and responsibilities (Shell, 2013). The need for coordinated action at the global scale is reflected in the proliferation of international agreements, as well as the increasing role of business and civil society in governance. This diversification of governance approaches is necessary. But it raises concerns about coordination and effectiveness, and the replacement of government authority with less accountable or transparent non-state actors (EEA, 2015).

As a whole, globalization itself raises a paradox for government leaders: the greater the forces of globalization, the less the autonomous power of national governments (Shell, 2013). Governments will develop policies in all areas of the Stress Nexus even without a full understanding of the interdependencies and possible unintended consequences (Shell, 2013). Today renewed competition between key actors is a concern. While the old Cold War is not making a resurgence, recent developments have led to tectonic shifts in state interaction. Geopolitics – and real politic – is once again taking center stage, with potential wide-ranging on sequences for the global economy, politics, and society (WEF, 2014).

Nationalism. As the reaction on globalization processes for just as in the years of the Industrial Revolution people turned to political nationalism to protect and shelter their communities against the uneven and inequitable patterns of growth so, too, people seem to be turning back to – and mobilizing around – old loyalties and traditional identities as they seek to insulate themselves; whether it be in Catalonia or Belgium or Lombardy, they are demanding protection against what seems to be the economic disruption and social dislocation of globalization, which threatens to sweep aside long-established customs, values and ways of life (WEF, 2014).

2.2 Ecosystem

The global ecosystem is a complex cause-effect system connecting humans and its environment tightly together. Due to human activities the global ecosystem has been stressed over its capacity to recover. During the past decades and especially the latest ten years, international collaboration has been providing concrete endeavors to decelerate the overuse of natural resources and changes of the global ecosystem.

The world population may rise beyond 9.6 billion by 2050 exposing countries to overuse their natural resources.

As megatrends show, continuing and until resent years fastening overuse of natural resources has been driving large areas in Africa, Middle East, and some areas of in India, Afghanistan, Bangladesh into the water crises. This along with the uneven growing population between the regions is heading the ecosystems to damage regionally and exposes them epidemics. The effects of continued ecosystem generates degradation on poverty and inequality in regions

outside Europe and may lead to increased immigration movements, economic and political challenges.

Population. The world population may rise beyond 9.6 billion by 2050, despite the rate of growth slowing . (EEA, 2015). In combination with climate change, these changes also raise concerns about current meat-heavy diets and strategies for bioenergy production (EEA, 2015). With growing food demand, the resource footprint (land, water, energy) of food can increase significantly as proteins take over from carbohydrates in diets (Shell, 2013). The population growth in developing regions with natural resources is challenging existing industrial structures globally and especially in Nordic countries (NER, 2015).

Health. Health presents a challenge for all nations. Effective public health systems are essential for providing care for the sick, and for instituting measures that promote wellness and prevent disease. Tobacco, for instance, is one of the greatest scourges we face. In working to combat diseases such as lung cancer and heart disease, we have to fight the causes; there's a clear need for educational campaigns and other mechanisms to discourage people from smoking in the first place (WEF, 2014). The global burden from non-communicable disease now outweighs that from communicable disease. This has been influenced by increased ageing, and by rapidly changing economic and social conditions. Nonetheless, the threat of global pandemics continues, partly driven by increasing mobility. Around a quarter of the burden of disease and deaths are attributable to environmental causes. The effects of climate change are likely to exacerbate this (EEA, 2015). Europe has achieved major improvements in public health. However, an ageing population and the impacts of climate change may necessitate additional public health interventions and adjusted environmental policies (EEA, 2015).

Inequality. Inequality is one of the key challenges of our time. Income inequality specifically is one of the most visible aspects of a broader and more complex issue, one that entails inequality of opportunity and extends to gender, ethnicity, disability, and age, among others. This affects all countries around the world. In developed and developing countries alike, the poorest half of the population often controls less than 10% of its wealth. This is a universal challenge that the whole world must address (WEF, 2014).

Trust. Since the global economy crashed in 2008, there has been an erosion of trust in political institutions and processes. Citizens now place more faith in companies than in their own leaders, and even then they don't particularly trust the private sector, with the latest Edelman Trust Barometer showing global trust in business at 58% while trust in government has sunk to 44%. In the last two years, citizen protest has dominated the headlines in many countries around the globe. Greece and Spain have seen unrest in the aftermath of the Eurozone crisis. Ukrainians occupied central Kiev. Few nations from North Africa to the Middle East remain unaffected by the fallout from the Arab Spring, as citizens of the digital age grow ever more confident to mobilize in the face of a democratic deficit. Hong Kong is the latest place to experience large-scale protest (WEF, 2014).

Water stress. The open and fastening information flow has been democratizing the knowledge. Right here are the two main components of water crisis: water resource and water access. Even where resources are plentiful, there are millions of people who lack access. While the United Arab Emirates has very little in the way of water resources, for example, they have the financial means to ensure the provision of clean water. Ethiopia, on the other hand, is known as the water tower of Africa, but more than half its population does not have access to a safe and reliable source. In Asia, resource constraint may not be the key driver, but those resources can be depleted quickly given high population density. Crises emerge where there is poverty and a lack of financial resources to combat the problem. In India, there are more than 100 million people without access to improved water supplies, and this is primarily due to poverty. Climate change will undoubtedly be a big factor in the future, as it will have a dramatic effect on water distribution. As sea levels rise in Bangladesh, salt water intrusion is going to be very problematic for the significant number of people living in areas of low elevation – especially as there is little capacity for treating water (WEF, 2014).

Exacerbated by climate change and continued pollution, rates of global habitat destruction and biodiversity loss are predicted to increase, including in Europe. The effects of continued ecosystem degradation on poverty and inequality in regions outside Europe may lead to increased immigration to Europe (EEA, 2015).

2.3 Urbanization

Urbanization is not a new phenomenon. Since the beginning of the era of industrialization, people and their activities have been concentrating in the economic "hot spots". Continuously fastening trend is dividing people to the fast developing urban areas and the stagnation of their surrounding areas. This movement is generating some mega-cities in some regions that attract intelligence and economic activity leaving other areas the role of provide resources for this process. In this process, Europe suffering ageing population is loosing its economic power and fore running position in innovations to countries having younger and growing population. However, the Urbanization is requiring new forms of transportation, energy production and transmission systems, and sustainable use of resources and waste management systems.

50% of the world's population lives in urban areas. This will increase to around 70% by 2050.

Unequal developments. 50% of the world's population lives in urban areas. This will increase to around 70% by 2050. This mass migration to urban areas is transforming cities into enormous economic hubs creating the phenomenon of 'Mega Cities' (Sitra, 2015). Powering the global economic growth, urbanization and expanding populations in a sustainable manner is one of the biggest challenges and opportunities of the world today (Sitra, 2015). Most of the population increase will occur in developing world urban areas. Growing and younger populations in the developing world, the global growth of an affluent middle class, and ageing

populations in developed countries will affect resource use and the environment. Such unequal developments are likely to increase migration. Europe, with an ageing population, could face pressure for and from immigration. Through its environmental policies and international dialogue, Europe is persisting with efforts to decouple resource use from economic development (EEA, 2015).

Urban areas in developing countries will absorb most of the global population increase, with 67% of people living in cities by 2050. Most of the growth is expected to be in megacities, particularly slums. Compact cities are the most efficient and environmentally sustainable way to secure the welfare of a growing population (EEA, 2015).

Investments. Eventually cities, rather than countries, will be targeted as hubs of investment with each city becoming a unique customer with untapped opportunities in key industries such as mobility. Partnerships between city governments, solution providers (businesses), and academia will become the working model for most future city projects (Sitra, 2015).

Smart approach. Smart planning provides for the efficient re-use and mixed-use of urban space. Urban growth is driving land-use change in Europe, with peri-urban areas developing at four times the rate of towns and cities. Integrated urban management could increase the environmental resilience of Europe's cities, particularly in the east and south (EEA, 2015).

2.4 Climate

As the need for energy drives the use of fossil fuels alongside other carbon intensive activities, the amount of CO2 will continue to rise

The human influence on the environment is accelerating the increase of temperature of *climate system*. The increasing CO2 emissions and other waste are damaging the ecosystem dramatically. Climate changes are threatening regional ecosystems differently. Some regions in Africa, Middle East, China, India are already suffering weather extremes and erosion. Despite of positive effects of globalization, climate change is threatening human well-being and increasing inequality between regions and people.

Climate change. Recent changes in the global climate are unprecedented over millennia and will continue. Climate change is expected to increasingly threaten natural ecosystems and their biodiversity, slow economic growth, erode global food security, threaten human health and increase inequality. The risks of pervasive and irreversible impacts are expected to increase. (EEA, 2015).

Temperature. The global and continuous increase of temperature of the climate system due to human influence and recent anthropogenic emission of greenhouse gas are framing human's life dramatically.

Greenhouse gas. Climate change is a long-term shift in the planet's average temperatures and resultant weather patterns. There is a growing body of evidence that the warming is due to the accelerating quantities of greenhouse gases in the atmosphere. As the need for energy drives the use of fossil fuels alongside other carbon intensive activities, the amount of CO2 will continue to rise (Sitra, 2015).

Severe weather. Extreme weather events are a major consequence of climate change, and are becoming more frequent, powerful and erratic. What is needed is not just relief when disaster strikes, but adaptation to the massive effects these phenomena produce, including disease, political unrest and economic stress. It's obvious that adapting to – or ideally, preventing severe weather events –results in a better outcome for everyone (WEF, 2014). Key risks for Europe include flood events, droughts and other weather extremes, threatening human well-being and infrastructure as well as ecosystems and biodiversity (EEA, 2015). The extreme weather and climate events will increase and cause differing regional needs, e.g. in Nordic Countries shorter cold and longer warm periods influencing fragile and crude northern nature (NER, 2015).

2.5 Technology

5G will increase wireless capacity by 1,000 times

Fast technology development in digital and bio-technologies is accelerating changes in different technologies that are using applications provided by ICT and bio technologies. Technology development increases the use of sustainable energy sources, changes the roles actors in global business, blurs the industrial ecosystems. Also, innovations and their diffusion are becoming more unpredictable. Technology development is increasing the knowledge intensity of products and services. It is also intensifying the competition between the countries in new knowledge and highly educated workforce driving them to search for innovations from new sources to sustain their economic growth.

Technological change. The pace of technological change, particularly in the fields of information, communication, nano- and bio-technologies, is unprecedented. This provides opportunities to reduce humanity's impact on the environment and reliance on non-renewable natural resources, while improving lifestyles, stimulating innovation and green growth (EEA, 2015). The risks associated with technological innovation will be minimized using the precautionary principle and regulatory frameworks. By recalibrating its institutions, policies and environmental knowledge base, Europe will support better risk management, while enhancing innovation and the diffusion of new technologies (EEA, 2015).

5G. The development of 5G is another game-changer in infrastructure. 5G will increase wireless capacity by 1,000 times. It will be the enabler of connected solutions such as autonomous vehicles and will offer an average of 90% energy saving on a typical consumer

service such as video downloads, Internet-enabled telephone calls or remote computer updates (Sitra, 2015).

Smart products. Green products and services will be increasingly enhanced and traditional products replaced by smart products and services, with intelligent sensing technology and internet connectivity driving better optimization. Enabled by the internet of things (IoT), machine to machine (M2M) (Sitra, 2015). This is leading to the growth in development of smart cities using the latest intelligent and green initiatives to reduce energy and resource consumption and improve efficiencies in all facets of human life (Sitra, 2015).

Mobility. Developing transportation corridors (e.g., Trans- Siberian Railway and high-speed rail corridors in the United States) will lead to mushrooming of economic and technology clusters along these corridors (Sitra, 2015). In the near future, high speed rail will connect not only cities and countries but also continents (Sitra, 2015). Trends like connectivity and urbanization will have a profound impact on personal and freight mobility and on the car/truck and transportation models of the future which will lead to new mobility business models (Sitra, 2015). It will be more intelligent transport networks, integrated fare structures moving towards personal credit cards and even mobile phones, to make the future of connected living as seamless as possible. Future intelligent platforms will connect the car to numerous functions and devices at home and the office (Sitra, 2015).

2.6 Energy

The sustainability of energy generation determines the future of energy. Renewable energy sources are increasing continuously their share in global energy generation. Decentralization of the power system and heat generation increases due to more implementation of renewable generation. The technology development and international climate agreements are accelerating the energy transformation. digitalization is providing opportunities for integration and control of global energy networks. At the same time, the energy security is increasing its role in energy systems. However, energy transition towards sustainable forms of energy generation is happening along with the obsolescence of the existing systems. The final pace of energy transition is depending on global agreements and national decisions on implementation of them.

Primary energy demand drops in a range of 16% to 20% by 2030 and 32% to 41% by 2050 as compared to peaks in 2005-2006.

Energy savings. Very significant energy savings will be achieved in all decarburization scenarios. Primary energy demand drops in a range of 16% to 20% by 2030 and 32% to 41% by 2050 as compared to peaks in 2005-2006. Achieving significant energy savings will require a stronger decoupling of economic growth and energy consumption as well as strengthened measures in all EU Member States and in all economic sectors (EU, 2011).

Future of energy. The future of energy is expected to witness a shift in regional and fuel balance, addressing the global energy demand with new technologies such as smart grids and sustainable energy sources. Renewable energy is expected to continue to show strong growth in investment and account for approximately 40 to 65% of total global electricity generation by 2050 (Sitra, 2015). According to the Neo Carbon Energy project (2014-2019), industrialized societies are heading to the post-industrial era, where services are replacing increasingly production activities. The Futures from the energy industry perspective are framed by the integration of digital technology and renewable energy systems. This is leading us to the third industrial revolution. The third industrial revolution is now being paved by renewables, such as solar and wind, and the internet (VTT, 2015). All scenarios show electricity will have to play a much greater role than now (almost doubling its share in final energy demand to 36-39% in 2050) and will have to contribute to the decarbonisation of transport and heating/cooling (see fig. 6). Electricity could provide around 65% of energy demand by passenger cars and light duty vehicles, as shown in all decarbonisation scenarios. Final electricity demand increases even in the High energy efficiency scenario. To achieve this, the power generation system would have to undergo structural change and achieve a significant level of decarbonisation already in 2030 (57-65% in 2030 and 96-99% in 2050). This highlights the importance of starting the transition now and providing the signals necessary to minimize investments in carbon intensive assets in the next two decades (EU, 2011). Energy intensive industries are moving their production to the rapidly growing regions and countries, e.g. South America and Asia (NER, 2015).

Decentralized. Decentralization of the power system and heat generation increases due to more renewable generation. However, as the scenarios show, centralized large-scale systems such as e.g. nuclear and gas power plants and decentralized systems will increasingly have to work together. In the new energy system, a new configuration of decentralized and centralized large-scale systems needs to emerge and will depend on each other, for example, if local resources are not sufficient or are varying in time (EU, 2011). All this has a great impact on democratization of innovations, manufacturing, and energy production and distribution. Thus, the third industrial production paradigm promotes a decentralized society. In the third industrial phase, the household and communal level will be the main area of production, as citizens produce goods, services and energy by themselves, utilizing digital production technologies, such as 3D-printers, and distributed renewable energy resources. Citizens and micro-businesses use the internet to organize their productive efforts, and societal and economic power is redistributed from large organizations to small-scale actors (VTT, 2015). The relevance of the third industrial revolution for Neo-Carbon Energy is that locally produced and consumed energy affects not only the energy sector, but also the whole of society. Neo-Carbon energy system could provide the energy building block for the third industrial revolution society, in which energy, goods and services are produced locally and small-scale (VTT, 2015).

Renewables. Renewables accounted for nearly half of all new power generation capacity in 2014, led by growth in China, the United States, Japan and Germany, with investment remaining strong (at $270 billion) and costs continuing to fall. The energy intensity of the global

economy dropped by 2.3% in 2014, more than double the average rate of fall over the last decade, a result stemming from improved energy efficiency and structural changes in some economies, such as China. Around 11% of global energy-related CO2 emissions arise in areas that operate a carbon market (where the average price is $7 per ton of CO2), while 13% of energy-related CO2 emissions arise in markets with fossil-fuel consumption subsidies (an incentive equivalent to $115 per ton of CO2, on average). There are some encouraging signs on both fronts, with reform in sight for the European Union's Emissions Trading Scheme and countries including India, Indonesia, Malaysia and Thailand taking the opportunity of lower oil prices to diminish fossil-fuel subsidies, cutting the incentive for wasteful consumption (IEA). Renewables will become the leading source of electricity by 2030, as average annual investment in nonhydro renewables is 80% higher than levels seen since 2000, but inefficient coal-fired power generation capacity declines only slightly. The share of renewable energy (RES) rises substantially in all scenarios, achieving at least 55% in gross final energy consumption in 2050, up 45 percentage points from today's level at around 10%. The share of RES in electricity consumption reaches 64% in a High Energy Efficiency scenario and 97% in a High Renewables Scenario that includes significant electricity storage to accommodate varying RES supply even at times of low demand (EU, 2011).

Digitalization and renewable energy. In the overall perspective energy system of the future is characterized by volatile wind and solar renewable energies. The IT and energy sectors are growing together. Only a combination of both will make reliable the energy supply and demand at all times. The rapid cost digression in the storage technology, particularly for small and large battery banks, opens up the possibility of reliable energy supply at any time, finally even with a 100 per cent transfer to renewable energies (WWF, 2015).

Nuclear energy. Nuclear energy will be needed to provide a significant contribution in the energy transformation process in those Member States where it is pursued. It remains a key source of low carbon electricity generation. The highest penetration of nuclear comes in Delayed CCS and Diversified supply technologies scenarios (18 and 15% in primary energy respectively) which show the lowest total energy costs (EU, 2011).

2.7 Pollution

Climate change and pollution are tightly connected together. CO2 emissions are increasing continuously. They are increasingly coming from developing countries causing serious environmental problems in these countries. At the same time, Europe and Northern American countries are decreasing their emissions as well as other waste. Developing countries are still building infrastructure based on the use of fossils to sustain their economic growth.

The economy grows by 88% from 2013 to 2030 and energy-related CO2 emissions by 8% (reaching 34.8 gigatonnes). Nevertheless, the global economy grew by around 3% in 2014 but energy-related carbon dioxide (CO2) emissions stayed flat, the first time in at least 40 years.

However, developed countries are struggling with the low economic growth and existing investments that are producing pollution. The development of emissions is depending on global political decisions and international consensus.

Pollution increase. Globally, levels of air pollution and releases of nutrients from agriculture and wastewater remain high, causing soil acidification, eutrophication of aquatic ecosystems and losses in agricultural yield. In the coming decades, overall pollution levels are projected to increase strongly, particularly in Asia (EEA, 2015).

Carbon capacity. The industrialization of the developing world is creating unsustainable pollution levels. The solution requires a technological and an intellectual revolution; an alternative route to economic prosperity that preserves resources and limits carbon emissions has to be developed before it's too late. The developing world has learned a lot about commercial models, infrastructure and technology from Europe and North America. Those patterns worked well economically, but the world's carbon capacity cannot allow to continue on this path (WEF, 2014).

Carbon Capture and Storage (CCS), if commercialized, will have to contribute significantly in most scenarios with a particularly strong role of up to 32% in power generation in the case of constrained nuclear production and shares between 19 to 24% in other scenarios with the exception of the High RES scenario (EU, 2011).

CO2 dynamic. The link between global economic output and energy-related GHG emissions weakens significantly, but is not broken: the economy grows by 88% from 2013 to 2030 and energy-related CO2 emissions by 8% (reaching 34.8 gigatonnes). Nevertheless, the global economy grew by around 3% in 2014 but energy-related carbon dioxide (CO2) emissions stayed flat, the first time in at least 40 years that such an outcome has occurred outside economic crisis (IEA). Globally growing population and changing industrial structures increase CO2 emissions in developing countries and reduction of them in countries as Nordic countries. Globally, the increasing need for energy will influence climate change, CO2 emissions and development of well-being of people requiring new approaches for energy systems. Energy-related emissions have considered to be provided mainly by OECD countries. This has been changing rapidly in recent years. The share of the non-OECD countries is increasing from less than 60% to over 70% in 2030. In the EU, energy-related C02 emissions will decrease due to EU's climate and energy policies. They are also framing the energy systems in Nordic countries (NER, 2015).

Decarbonisation. The scenarios show that decarbonisation of the energy system is possible. Moreover, the costs of transforming the energy system do not differ substantially from the Current Policy Initiatives (CPI) scenario. The total energy system cost (including fuel, electricity and capital costs, investment in equipment, energy efficient products etc) could represent slightly less than the 14.6% percent of European GDP in 2050 in the case of CPI compared to the level of 10,5% in 2005. This reflects a significant shift of the role energy plays in society. Exposure to fossil fuel price volatility would drop in decarbonisation scenarios as

import dependency falls to 35-45% in 2050, compared to 58% under current policies (EU, 2011). Europe. Although the release of pollution may continue to improve in Europe, its ecosystems are likely to be affected by developments beyond the region's borders. Despite a fall in emissions, for example, there have not been equivalent reductions in air pollution partly as a result of the trans-boundary transport of pollutants (EEA, 2015).

2.8 Economic

Global economic development is increasingly depending on environmental issues and sustainable usage of natural resources. The investments in production capacity or new technology does not accelerate economic growth as in the past. The ageing population in developed countries is decreasing economic activity. The volatility in global economy is increasing and is becoming more and more unpredictable. Globalization has tended to reduce income inequality between nations yet increase inequalities within them. Beyond a point, increasing prosperity does not raise subjective wellbeing, which can even decline. There is growing need for new measures for well-being and economic development. Despite of the very minor share of global economy, the grassroots activities on sustainable and social innovations are providing new initiatives for global economy as well as they are challenging the existing institutions to renew themselves to serve individual "global citizens".

The global investment in infrastructure development is expected to cross US$ 27 trillion by 2025, with Asia-Pacific (APAC) accounting for 37% share and with expected investments of US$ 11 trillion from 2010 to 2025.

Energy pricing. All decarbonisation scenarios show a transition from today's system, with high fuel and operational costs, to an energy system based on higher capital expenditure and lower fuel costs. This is also due to the fact that large shares of current energy supply capacities come to an end of their useful life. In all decarbonisation scenarios, the EU bill for fossil fuel imports in 2050 would be substantially lower than today. The analysis also shows that cumulative grid investment costs alone could be 1.5 to 2.2 trillion Euros between 2011 and 2050, with the higher range reflecting greater investment in support of renewable energy. The average capital costs of the energy system will increase significantly - investments in power plants and grids, in industrial energy equipment, heating and cooling systems (including district heating and cooling), smart meters, insulation material, more efficient and low carbon vehicles, devices for exploiting local renewable energy sources (solar heat and photovoltaic), durable energy consuming goods etc. This has a widespread impact on the economy and jobs in manufacturing, services, construction, transport and agricultural sectors. It would create major opportunities for European industry and service providers to satisfy this increasing demand and stresses the importance of research and innovation to develop more cost-competitive technologies (EU, 2011).

Most scenarios suggest that electricity prices will rise to 2030, but fall thereafter. The largest share of these increases is already happening in the reference scenario, and is linked to the replacement in the next 20 years of old, already fully written-off generation capacity. In the High Renewables scenario, which implies a 97% share for renewable sources in electricity consumption, the modelled electricity prices continue to rise but at a decelerated rate - due to high capital costs and assumptions about high needs for balancing capacity, storage and grid investments in this "near 100% RES power" scenario. For example, RES power generation capacity in 2050 would be more than twice as high as today's total power generation capacity from all sources. However, substantial RES penetration does not necessarily mean high electricity prices. The High Energy Efficiency scenario and also the Diversified Supply Technology scenario have the lowest electricity prices and provide 60-65% of electricity consumption from RES, up from only 20% at present. In this context, it has to be noted that price in some Member States are currently artificially low due to price regulations and subsidies (EU, 2011).

In all scenarios, including current trends, expenditure on energy and energy-related products (including for transport) is likely to become a more important element in household expenditure, rising to around 16% in 2030, and decreasing thereafter to above 15% in 205013.This trend would also be significant for small and medium-sized enterprises (SMEs). In the long term, the rise in investment costs for efficient appliances, vehicles and insulation becomes less important than the reduction of expenditure on electricity and fuels. The costs include fuel costs as well as capital costs such as costs of purchasing more efficient vehicles, appliances and refurbishments of housing. However, if regulation, standards or innovative mechanisms are used to accelerate the introduction of energy efficient products and services, this would reduce costs (EU, 2011).

Resources. Global use of material resources has increased ten-fold since 1900 and is set to double again by 2030. Escalating demand may jeopardize access to some essential resources and cause environmental harm. Uneven geographical distribution of some resources could further increase price volatility, undermining living standards and even contributing to geopolitical conflict.

For Europe this is a major concern as its economy is structurally dependent on imports. Although growing scarcity and rising prices should incentivize investments in technologies to alleviate supply risks, such innovations will not necessarily reduce environmental pressures (EEA, 2015).

Economic output is projected to treble between 2010 and 2050, although growth is expected to decelerate in many countries as they become more prosperous. Rapid economic growth has brought reductions in global poverty and increases in well-being but it is also linked to growing inequality and escalating environmental pressures. In Europe, slowing growth is straining public finances for environmental protection and increasing inequality (EEA, 2015).

Driven by structural change, fast-growing workforces and trade liberalization, developing regions are rapidly increasing their share of global economic output, trade and investment. For Europe, this rebalancing presents competitive threats but also economic opportunities in meeting the demand of a fast growing global middle class (EEA,2015).

The emergence of a larger and more diverse mixture of major economic powers may, however, complicate global efforts to coordinate governance. And growing economic interdependence will make it harder to manage the social and environmental impacts associated with production and consumption systems (EEA, 2015).

Persistent jobless growth. The term “persistent jobless growth” refers to the phenomenon in which economies exiting recessions demonstrate economic growth while merely maintaining – or, in some cases, decreasing – their level of employment. The scale and significance of this problem is evident in the high placing of this trend, an increase even over last year’s report, when persistent structural employment was ranked as the third most concerning trend. The transformations and job displacements associated with technological progress are happening faster, and may even be more dramatic in their impact than anything we’ve experienced before, and the task of providing a meaningful, substantial role for everyone is going to be hugely important. This presents us with a huge opportunity to take advantage of current low costs of borrowing and under-utilized labor resources, and embark on large-scale projects to build and repair essential infrastructure in our developed and emerging economies (WEF, 2014).

Green economy. In the UN report the “green economy” is seen as the key concept of the radical new economic strategy — the concept embodies the promise of a new development paradigm having the potential to ensure the preservation of the earth’s ecosystem along new economic growth pathways while contributing at the same time to poverty reduction. There is broad agreement on the basic idea underpinning it, namely, that enhancing economic growth, social progress and environmental stewardship can be complementary strategic objectives and that the need for possible trade-offs among them route to their realization can be overcome (UN, 2011).

In this sense, the focus of the concept is fully consistent with that of the sustainable development concept elaborated by the United Nations, which perceives the economic, social and environmental dimensions as the three pillars of development. The concept is stressing the importance of intergenerational equity in development, i.e. ensuring that meeting the needs of the present generation does not compromise the ability of future generations to meet their own needs (UN, 2011).

Further, the “green economy” concept is based on the conviction that the benefits of investing in environmental sustainability outweigh the cost of not doing so, as much as it outweighs the cost of having to protect ecosystems from the damages caused by a “non-green” (brown) economy. Growth of the world population, per capita income, energy and resource use, waste and the production of pollutants (including greenhouse gas emissions) have all increased

exponentially since the first industrial revolution. The overall objective of the "green economy" will be to ensure that those limits are not crossed. With the frames of the "green economy", one option for achieving this would be to limit income growth, as it would also, given existing production methods, limit the growth of resource use, waste and pollutants (UN, 2011). However, doing so would complicate efforts to meet the development objective and would thus not be in the interest of developing countries, which are home to the vast majority of the world's population. Reducing population growth could be another option; but this could be achieved more effectively by improving living standards. Reducing non-renewable energy and resource use, reducing waste and pollutants, and reversing land degradation and biodiversity losses would then seem key to greening the economy in the Future (UN, 2011).

Living standards. Economic development is raising living standards for people. Economic development is raising living standards for hundreds of millions of people. But it also imposes environmental, resource, financial, political, and social stresses that can undermine some of the benefits of prosperity. Private gains can flourish while public costs mount, and greater comforts today can lead to greater risks tomorrow. Globalization has tended to reduce income inequality between nations yet increase inequalities within them. Increasing efficiency can stimulate increases in consumption. Beyond a point, increasing prosperity does not raise subjective wellbeing, which can even decline. For example, the more people prosper or see others prosper, the greater their desires and expectations for themselves and for their children – and the greater their possible discontent (Shell, 2013).

Infrastructure investments. The global investment in infrastructure development is expected to cross 27 trillion USD by 2025, with Asia-Pacific (APAC) accounting for 37% share and with expected investments of 11 trillion USD from 2010 to 2025 (Sitra, 2015). According to IEA (2014), between 2000-2012 57% of all global investments in power generation has been made in renewable energy being 153 billion USD per year.

3 Finland in the light of global megatrends

3.1 Overall perspective

The megatrends give the operative frames for global institutions as well as for grassroots-level actions. The effect of megatrends on the society vary depending on the actions taken by that society against or along with those megatrends. More than that, the actions can be reactive or proactive. Ignoring the megatrends is also an action that would most likely lead increasing lag in the society development. In other words, megatrends determine the directions of

economy development. Thus, Finland should develop itself in the way that takes in account the global megatrends. This can only happen if Finland sustains and foresees competencies of the future demand. These competences are difficult to identify in advance. In particular regarding to the SET project concept Finland should benefit from the smart energy transition.

As in the report published by the United Nations, the global megatrends can be summarized under the “Shifting Paradigm” of our lifestyle. The world is seen to be in the turning point either making step by step our living environment inviable or taking actions to change radically our behavior to move into the sustainable “green” economy. However, the megatrends, which are considered to have the strongest influence on energy sector globally, are quite visible. Those are, for instance, climate change, unequally growing population, urbanization, increase in CO2 and other GHG emissions, enlarging multi-polarity in the World, unbounded information sharing and connectivity, accelerating technology change. Obviously, the effects of megatrends should be employed in order to make Finland and its energy sector benefit from the external environment change. In its turn the impact of energy sector development upon Finnish society and individual actors is, to a certain extend, determined by some EU and international agreements and acts. This is an important issue that is not always taken into account in public discussions as well as by the business. We believe the question “What should we do as the Finns?” should be raised as soon as possible.

Finland is on its way exploiting the opportunities and avoiding the threads of megatrends in terms of sustainable society. For example, in 2014, Finland has joined the prestigious group of countries that have exceeded the 2020 renewable energy targets, according to Eurostat. Finland, with a target of 38%, is however leading the pack in being the only country to both overachieve its targets while also exceeding the EU average increase in renewables share for 2014. It is very important for the country not to lose the dynamics of this process. The renewable energy directive setting a 38% target for renewable energy in Finland by 2020 was a big incentive for the government to review existing legislation, which also shows government expectations for the growth of wind energy in the country: from the existing 170 MW (which provide 0.3% of Finland’s power) up to 2,500 MW (which would provide 6% of its power) (EWEA, 2010).

Each of the global megatrends provides opportunities and threads for the given society. In the appendix 1, the preliminary construct of a general SWOT table is introduced to demonstrate some opportunities and threads for Finland as the result of megatrend analysis. The long-term goal of Finland is to become a carbon-neutral society by 2050 (MOEAE 2014). Based on the SWOT technique those opportunities and threads should be confronted with strong and weak areas of the country. The government of Finland has determined a set of recommendations for actions based on particular advantages of Finland as a modern and highly educated society (Energia, 2016). The recognized strengths of Finland are relying on the developed energy infrastructure, high level of expertise in energy, IT technologies, developed infrastructure in urban and rural areas, relatively new and energy efficient buildings, as well as on bioenergy resources. In addition, the long-term investments in cleantech R&D, active collaboration between the public and private sectors, wide public agreement, and positive attitude for

sustainable society are considered as essential constructs for achieving the goals of the carbon-neutral society. In the SWOT table, we put some preliminary results on strengths and weaknesses for the energy sector of Finland, that have been derived from MOEAE 2014 as well as from SET 06.06.16 workshop dataset.

3.2 Finland in the light of globalization

Finland should consider its competences to become a global market player within the very specific areas. Globalization as a megatrend has two opposing general elements: the world is becoming an open and interconnected community and it is becoming increasingly divergent with the multiple interest groups. Globalization provides a challenge for all actions including business, social, or even regulative actions that they should be serve local and personal needs being globally scalable and acceptable at the same time.

Globally, small countries as Finland can be seen having a "mindset of personalization" creating solutions for small populations of users. The challenge and the opportunity is to scale them globally. For example, solar and wind energy offer potential business in two levels: domestic and export business. Locally, in Finland, renewable energy business often means implementation of imported goods enabling, e.g. Finland to reach the set renewable targets of the EU. In some cases, local actions enable to test ideas and develop innovations relating the particular technology or service. To create new export business, Finland should focus on very specific knowledge intensive areas in renewable technologies and services.

Finland have still some distinguishing strengths providing competitive advantages in energy sector, e.g. in ICT, power machinery, energy transmission, and wooden biomass processing. Finland cannot beat the competitors in "bulk" products like solar panels, heat pumps, and wind turbines. Finland's resources are extremely limited when considering workforce intensive scalable production. On the other hand, the brain drain in Finland should be stopped in the strongest areas of expertise and even probably reversed into the process, which allows Finland to attract high-level intellectual capital.

SWOT constructs: Scalable personalized solutions, expertise in interconnecting ICT and Energy sectors, mindset of personalization, limited resources.

3.3 Finland in the light of ecosystem change

The changes in global ecosystem generates increasingly local level extreme environmental events. In Finland, the long-term objective is to be a carbon-neutral society by 2050 (TEM, 2014). This gives the targets and limits for future decisions in Finland. As earlier mentioned, Finland is making its choices within the global and especially the EU boundaries. Despite of that Finland and Finnish actors have a wide spectrum of choices available regarding the

Energy Sector. The key strategic choices in Finnish Energy and Climate policy that made by the Parliament and other decision makers are mainly framed by the global megatrends as climate change, increasing CO2 emission, and the accelerating energy related technology development (TEM, 2014; YMM/TEM, 2015).

As its nature, Finland has always operated in extreme environments having expertise in such environments as arctic climate and forest, and clean water environments. This can provide some expertise areas in energy generation and transmission technologies and services in extreme environments, e.g. mobile hybrid emergency energy solutions, energy efficiency solutions for buildings, special equipment for extreme conditions as robotics and energy storage. In addition, emission related technologies in energy generations offer potential areas for management services and cleaning technologies. The ecosystem change generate increasing need for renewable energy solutions to reduce the usage of natural resources without decelerating the economic growth and well-being.

SWOT constructs: Extreme environmental events, artic expertise, technologies and services for artic environments.

3.4 Finland in the light of urbanization

People and activities tend to concentrate in the most favorable environments. The urbanization is not a new phenomenon but the accelerating development of urbanization provides new types of challenges for energy sector. In this perspective, energy consumption is also urbanizing along with the people and industry. At the same time, an urban area often is not the best one for energy production. Urbanization changes also the needs for transportation increasing short distance mobility and concentrating the long distance links to exist between the urban cities. The interconnected decentralized renewable energy systems enable to produce energy in the “hot spots” of consumption where cannot build (anymore) large centralized systems.

Finland is a wide and sparsely populated country with long distances between the urban areas supported by the well-established centralized energy systems, long-distance electricity and regional energy transmission systems, and well-developed transportation networks as well as the secure data transfer infrastructure. Finland is following the global trend creating its economic and social activities around the several urban areas. As the urban areas are relatively small and recently developed compared to other European countries, they could provide a fertile environment for utilization of new energy systems integrating them into the existing systems. This would mean that Finland should prioritize development activities in smart gridding, energy storage, digitalization of energy systems that enable

SWOT constructs: Interconnected decentralized energy systems, renewable energy systems within the urban areas, smart grids, ICT.

decentralized renewable energy production and transmission in urban areas.

3.5 Finland in the light of technology development

The energy sector development is driven by the interconnected megatrends of Climate change, Unequally growing population, Urbanization, Increasing CO2 and other GHG emissions, Increasingly multipolar World, Unbounded information sharing and connectivity, and Accelerating technology change.

The energy transition has been developing the renewable energy production to achieve cost-efficiency level of fossils energy systems removing a barrier to the energy transformation. The energy is increasingly produced in interconnected networks of millions of plants varying from large utilities to micro level units. This is enabled with digitalization of the energy systems and transmission grids. The fundamental distinguishing properties and challenge of energy produced with renewable technologies from traditional ones is volatility and their ability to decelerate the climate change.

Fast developing ICT technologies gives a particular chance for Finland to elaborate country competences in the new area of renewable energy, thus to become a World leading expert in modern technologies. Another opportunity for Finland as one of the most highly educated country lies in social sphere is in lifting the society on the new stage of understanding and knowledge of upcoming modernization in the energy sector.

Finland could develop it competences in arctic type of renewable technologies, energy storage technologies, prosumer concept development, mobility concepts, and smart gridding with long-distance electricity transmission, and other IT solutions related to energy generation and storage control. In addition, the competencies in ICT provide potential areas for Finnish actors, e.g. analysis of big data from machines, security of global energy networks, optimization of production processes, personalized energy services, intelligent control of energy generation and consumption.

SWOT constructs: Energy future is digital, scarce competencies, increase of knowledge of upcoming modernization in the energy sector.

Nevertheless, there are some challenges that the upcoming energy era put in the forefront for Finland, for example, aging of population, growing unemployment rate, brain drain, international regulation as an EU member, as well as its neighboring countries decisions on energy transformation.

3.6 Finland in the light of economic development

Global economy is diversifying and existing institutions are struggling with their roles in relation to new actors due to fastening Globalization and open information exchange and flow across the countries. These changes requires new approaches in regulation and governing structures. Finland could take very active role in those activities enhancing the development of new "world order" in technologies, markets, and even in legislation. Finland has an opportunity to learn from the near history how to influence global processes for own benefit. NMT and GSM technologies and forest industry's green certificates are the good examples.

The economic development is increasingly getting speed from grassroots-level innovations and actions[1] Especially, renewable energy and digital innovations have very often their origins in small-scale endeavors. From global perspective, Finland is a "grassroots-level" actor. Finland is extremely small market having very limited but focused resources to compete in global markets. Finland could see itself as a grassroots-level innovation platform for new initiatives examining, testing, and supporting the future solutions and their diffusion among the small communities and early adaptors. This means that the whole country and society could be seen as a single small-scale community that generates continuously new globally scalable innovations. This requires a new "mindset" for Finnish actors seeing themselves as born global.

SWOT constructs: Energy future is digital, scarce competencies, increase of knowledge of upcoming modernization in the energy sector.

3.7 Potential approaches

This report provided insights on megatrends that are driving the global economic, technological, and environmental development and actions in the field of energy. As noted, the megatrends are available and they are noticed but their influence on future development can be recognised and understood over time. The energy transition is turning into a global movement. The transformation to a sustainable energy system needs efficient and smart energy policy to be progressed in Finland.

Finland has created the energy and climate roadmap 2050 to achieve the EU targets for reduction of greenhouse gas emissions and the share of renewable energy of all energy production. The road map presents several key recommendations to achieve those goals based on the particular strengths of Finland. The recommendations stress the social aspects

[1] Korjonen-Kuusipuro et al. (2016). The emergence and diffusion of grassroots energy innovations: Building an interdisciplinary approach. Journal of Cleaner Production.

and sustaining the national competitive advantage in global markets. The key activities should focus on renewable energy, energy efficiency, and cleantech solutions.

It will be important to allocate the actions that are the most efficient for Finnish national-level policy. As the roadmap 2050 and the basic scenario propose, the goal is to achieve the targets of the EU's energy and climate strategy set for Finland. For that purpose, *Finland can select either adaptive or progressive approach for future actions in energy sector. The former approach would adapt* national policy activities into the frames the Future scenario given by the EU. This approach enables Finland to follow the main stream of the EU and gain support for own decisions and operations from other countries. In the *progressive approach,* Finland is determining the future operative environment and the goals for Finnish energy sector by itself in the first place. Striving for the Future of Finland, the EU level targets would be achieved then based on the country primary interests.

Therefore, it is important to elaborate the Future to understand the megatrends providing opportunities as well as threads for Finland. On the other hand scrutinizing the internal environment of the country in respect of future energy strategy development will produce strong and weak points of Finnish economics, technological level, and society. Thus, a comprehensive analysis of internal and external environment of Finland is needed to be carried out.

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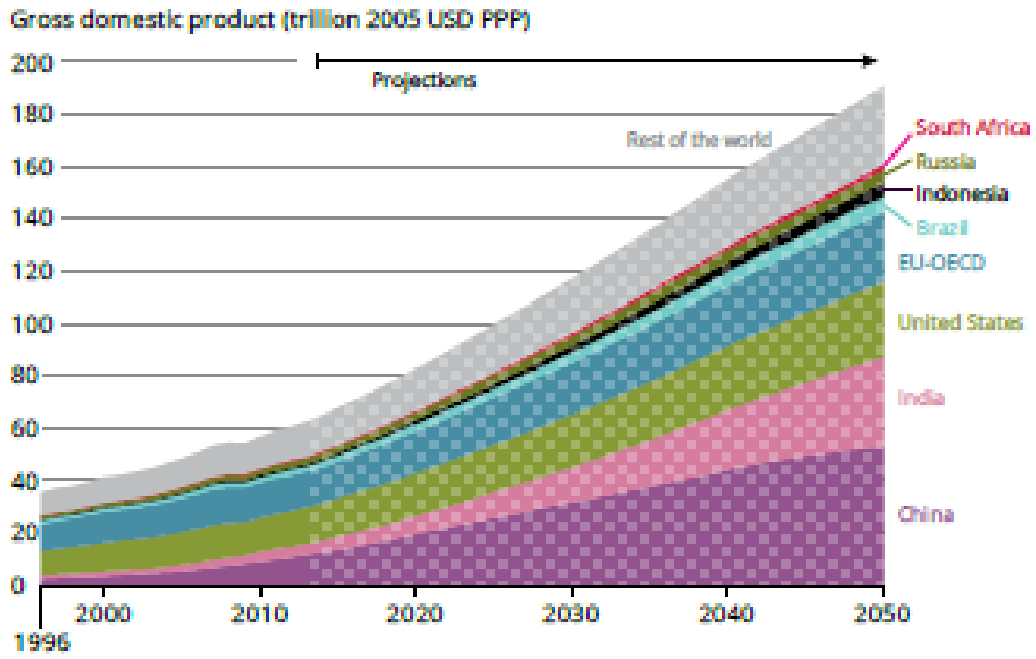
Appendix A – SWOT construct

The following SWOT analysis is compiled from the megatrend analysis of the report, MOEAE 2014 and SET Delphi survey 2016 for further discussion and analysis in the project.

OPPORTUNITIES	THREATS
The trend on development of distributed energy generation The trend on solar and wind energy generation development The active role of prosumer is increasing The number of Cleantech-sector jobs and export opportunities may increase in the nearest future New type of transportation is coming Demand for digitalization approach in general and in particular smart technologies is increasing worldwide Internationally operating cleantech companies benefit significantly from international obligations under the climate change agreements different countries	Conditions for market-based investments are currently weak as wholesale price level of electricity is low Combined heat and power production replacement investments may be compromised (may be threaten) European plans for capacity mechanisms may threaten the common market activity Global development and the sustainability of biomass related to carbon neutrality, particularly international and EU-level rules for calculating the greenhouse gas could change **Co**ntinuous growth of energy consumption in transport sector Climate policy focuses only the promotion of the use of biofuels Urban settlement structure development is not firmly planned The competitiveness of public transport decreases Lack in comprehensiveness of in life cycle management Carbon leakage and cleantech sector demand new jobs and skills that differ from the existing ones in the society at the present Lack of sense that the high energy consumption of Finland does not always have the energy inefficiency

STRENGTHS	WEAKNESSES
Finland is part of the competitive wholesale electricity market in Nordic countries Reliable and strong connections to the grids of neighboring countries Versatile electricity production A high proportion of combined heat and power production Biomass usage is a good backup for Finland in terms of costs, efficiency, raw material resources Potential for the wind and solar energy generation is high in terms of nature conditions and intellectual capital Finland does not depends much on fossil fuels or peat Advanced transport infrastructure as well as large bank of continually increasing know-hows in transportation industry The level of energy efficiency of the building stock generally reasonably good In Finland, the energy generation price is still competitive compare to other European countries In Finland, the industries are already relatively energy efficient High competitiveness in a number of cleantech technologies areas, especially in biotechnology and energy technology sectors Several global companies in cleantech sector are based in Finland Finland got knowledge, research and development as well as cultural knowledge base for the assessment and development Municipalities have responsibilities and expertise to make decision on many crucial issues Municipalities have active connections and the possibilities for cooperation with local residents	Dependency on electric power import The difference in the EU "mainstream": Finnish forestry, wood processing industry, as well as integrated bio-energy production are not typical for the EU The Government is not possible to finance many of renewable energy related projects Lack of strong management in wind energy generation projects Lack of domestic and foreign investments because of various reasons The global competitiveness of Finland in some energy technology sectors is not strong enough.

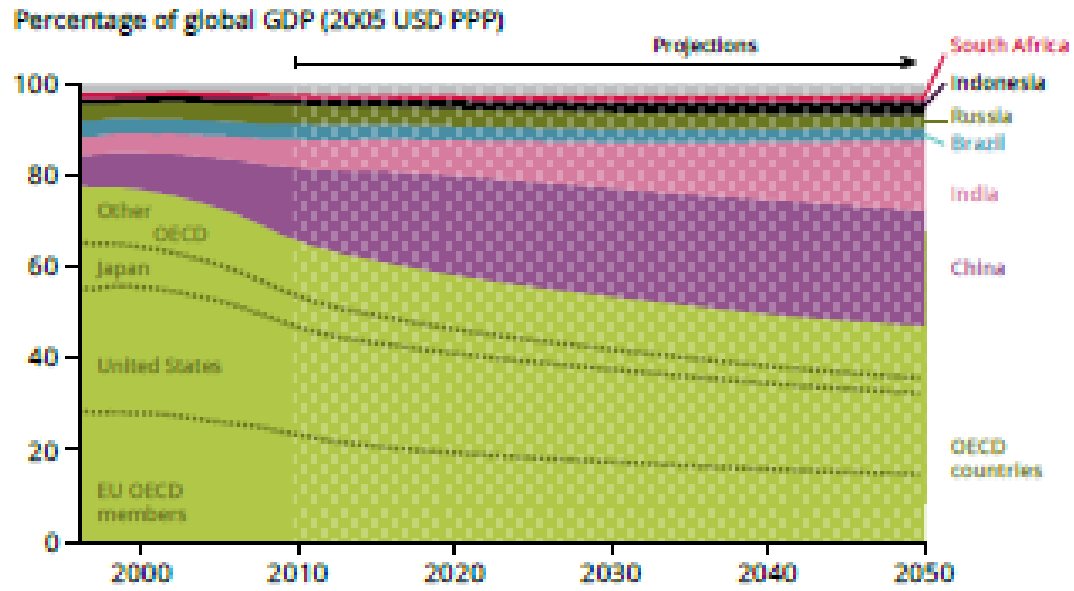
Appendix B – Global Economy



Note: EU-OECD refers to the EU Member States that are also members of the OECD. These countries accounted for approximately 97% of EU-28 GDP in 2012.

Source: OECD, 2014a.

Figure A1. Global economic output 1996-2050 (SOER 2015, EEA).



Source: OECD, 2014a.

Figure A2. Contribution of major economies in global GDP (SOER 2015, EEA).

Appendix C – Population

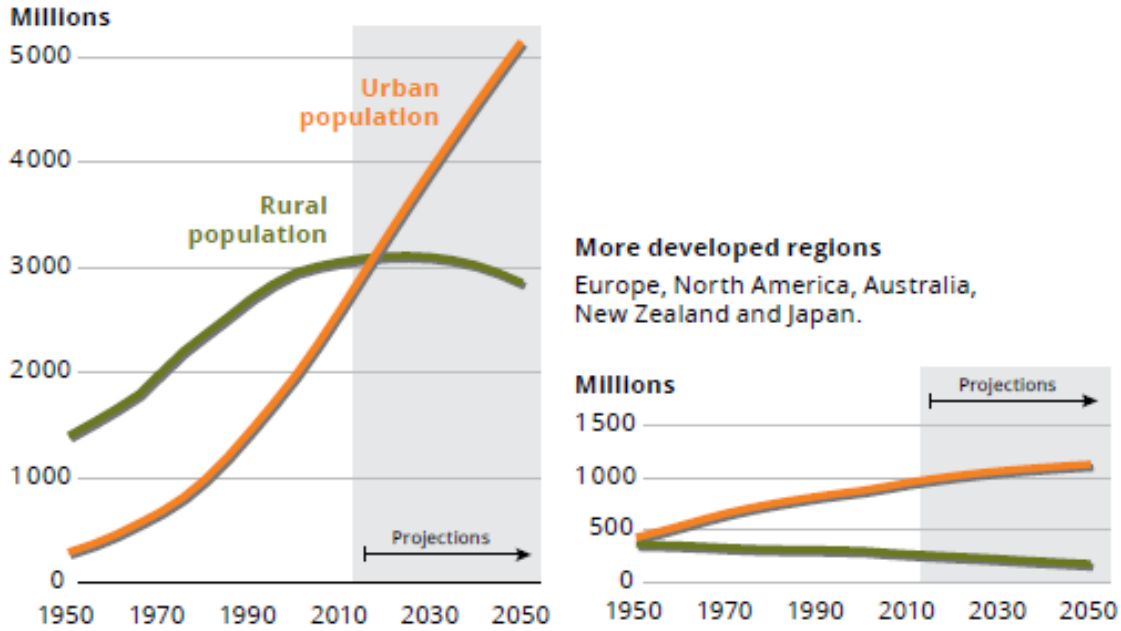


Figure B1. Urban and rural population in developed and less developed world regions, 1950-2050. (United Nations, 2012).

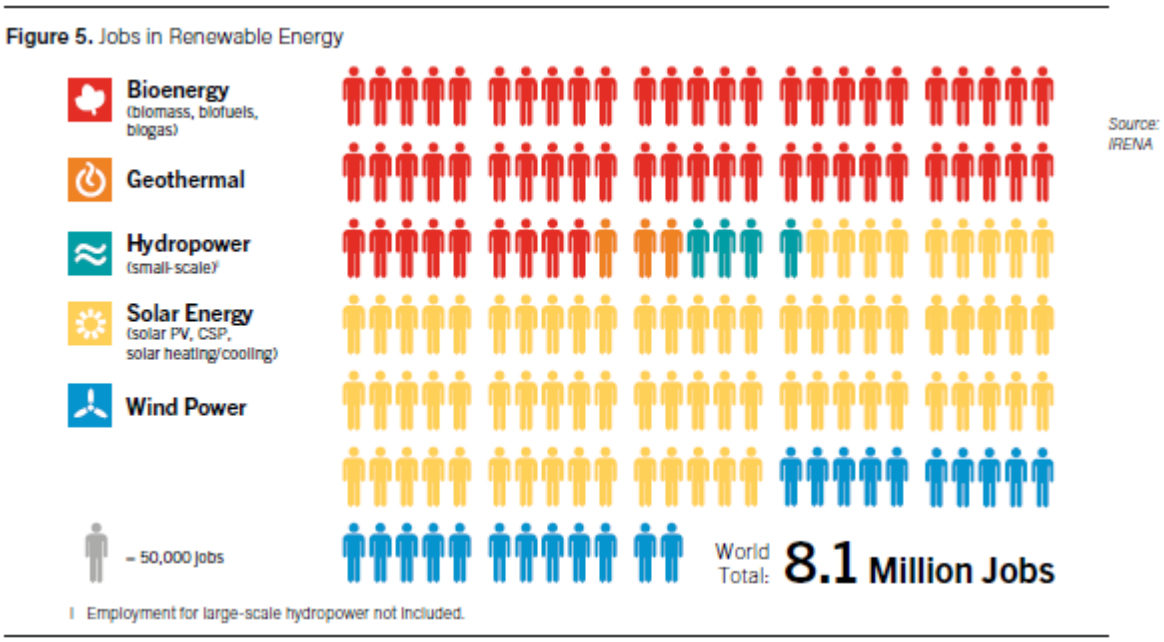


Figure B2. Jobs in renewable energy 2014-2015. (REN21).

Figure B3. Population pyramids for Europe, Africa, and Asia for 2000 and 2050 by age, sex, and education attainment. (Samir, K. C. et al., 2010. *Demographic Research* 22(15)).

Appendix D – Global energy

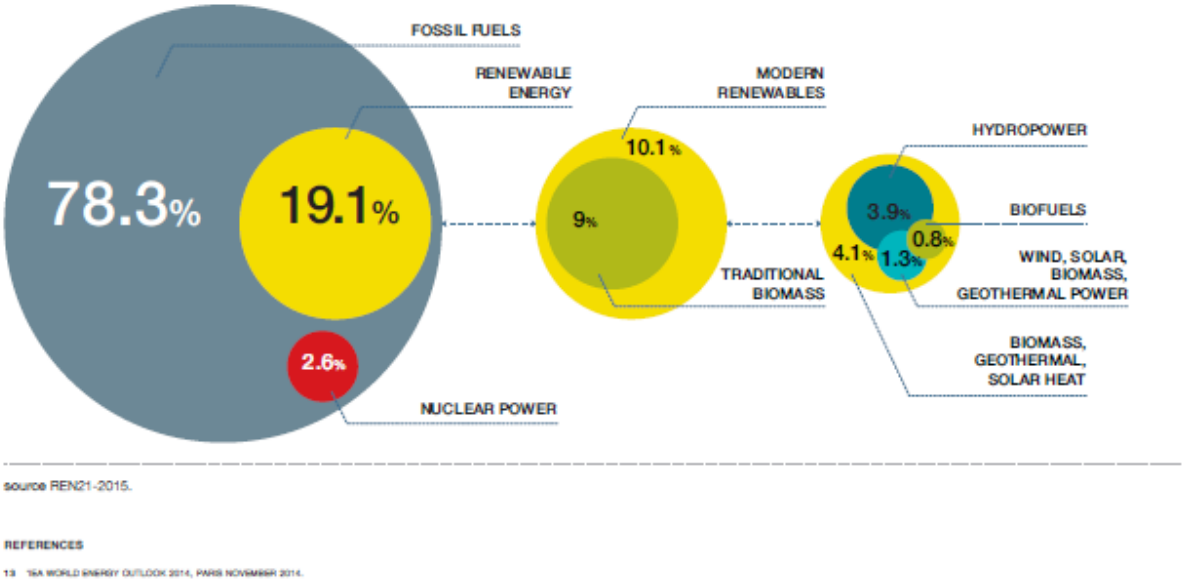


Figure C1. Estimated renewable energy share of global final energy consumption 2013 (Energy revolution a sustainable world, energy outlook 2015, Greenpeace International).

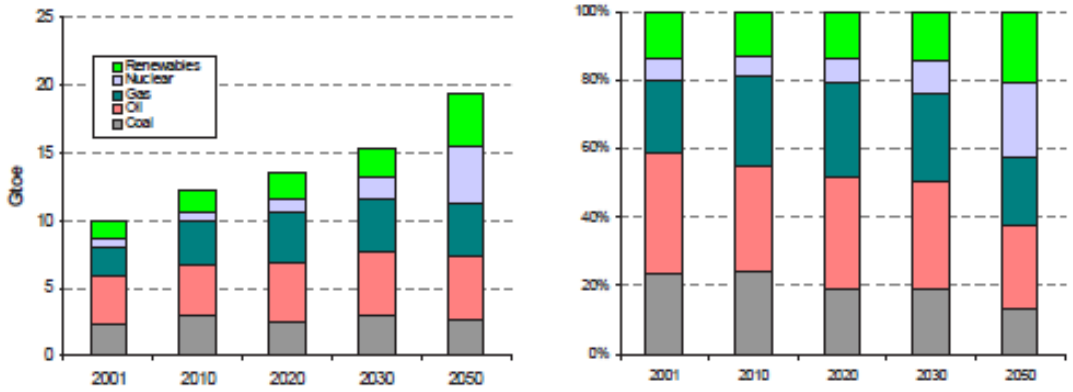


Figure C2. World primary energy demand – CCC (World energy Scenarios, WEC, 2013).

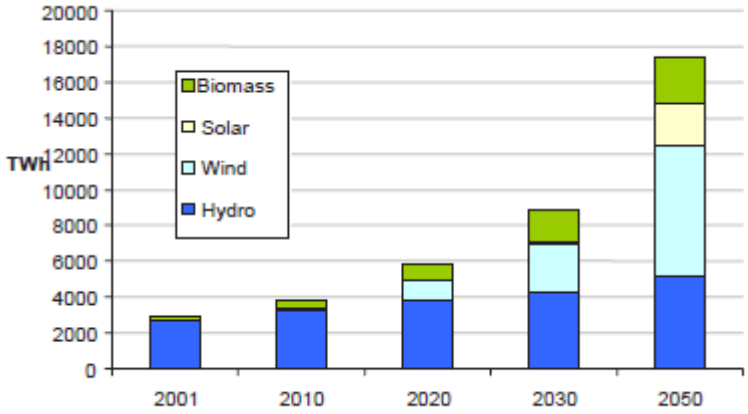


Figure C3. World renewable electricity (World energy scenarios, WEC, 2013).

Figure C4. European energy final energy supply / production – CCC (World energy scenarios, WEC, 2013).

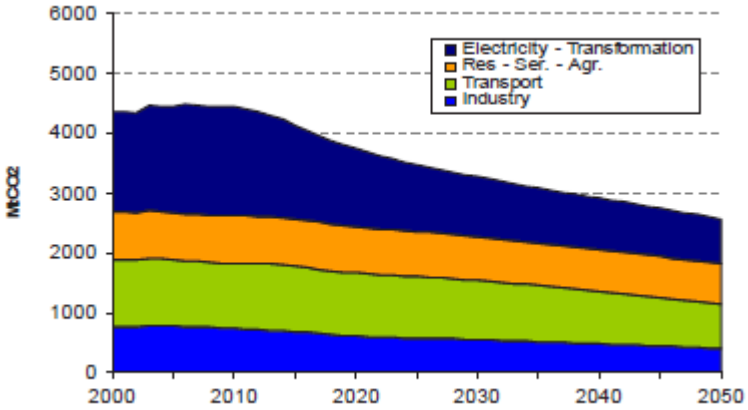
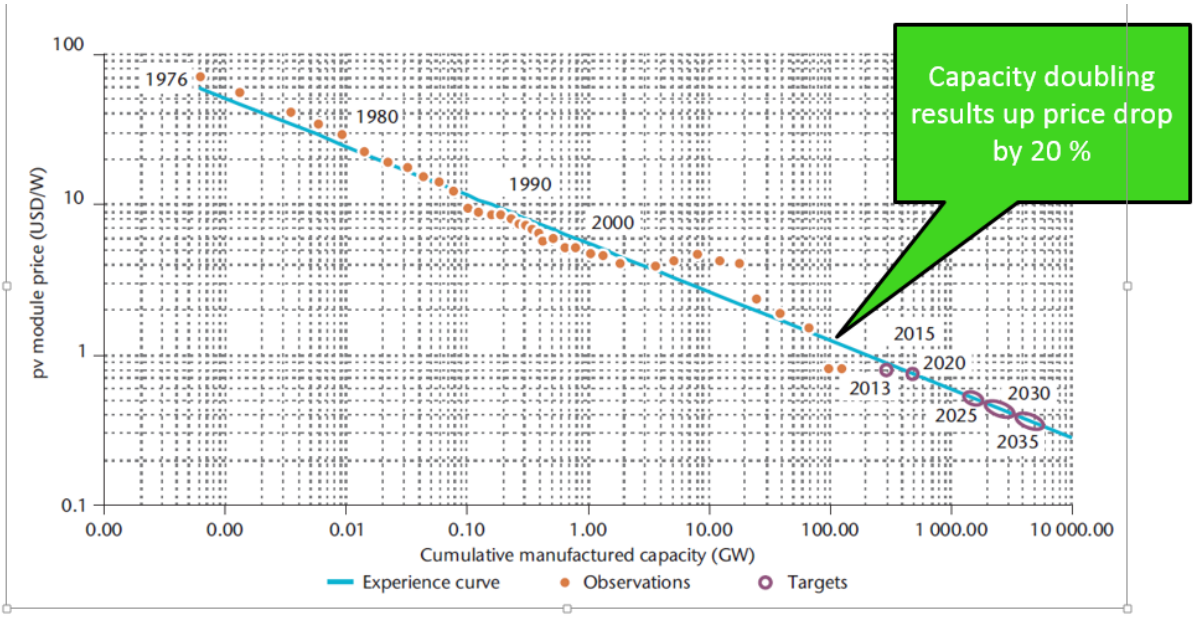


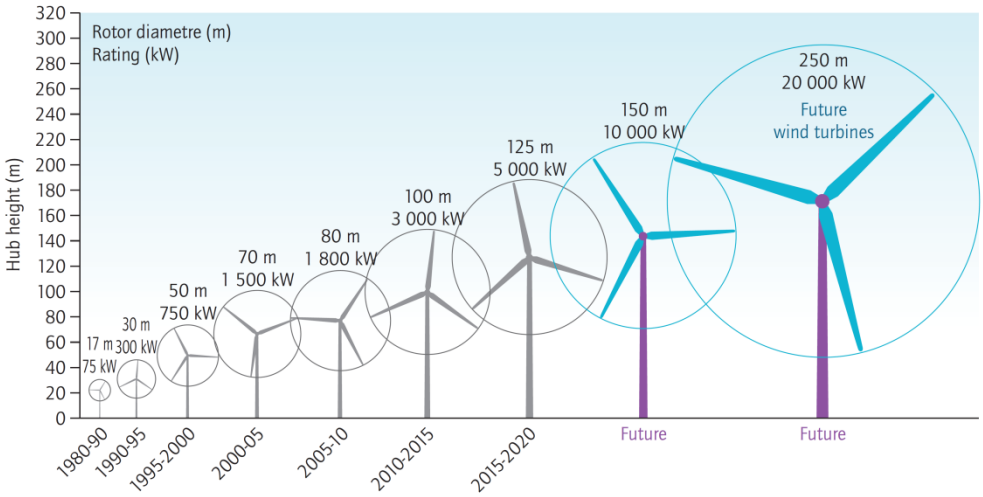
Figure C5. European energy related CO2 emissions – CCC (World energy scenarios, WEC, 2013).



Source: *IEA Technology roadmap solar photovoltaic energy 2014.*

Figure C6. Unit price (USD/Wp) development of PV panels (Ahola, J., 2015).

Figure 14: Growth in size of wind turbines since 1980 and prospects



Source: adapted from EWEA, 2009.

KEY POINT: scaling up turbines to lower costs has been effective so far, but it is not clear the trend can continue forever.

Figure C7. Future prediction of technology development in wind mills (EWEA, 2009)

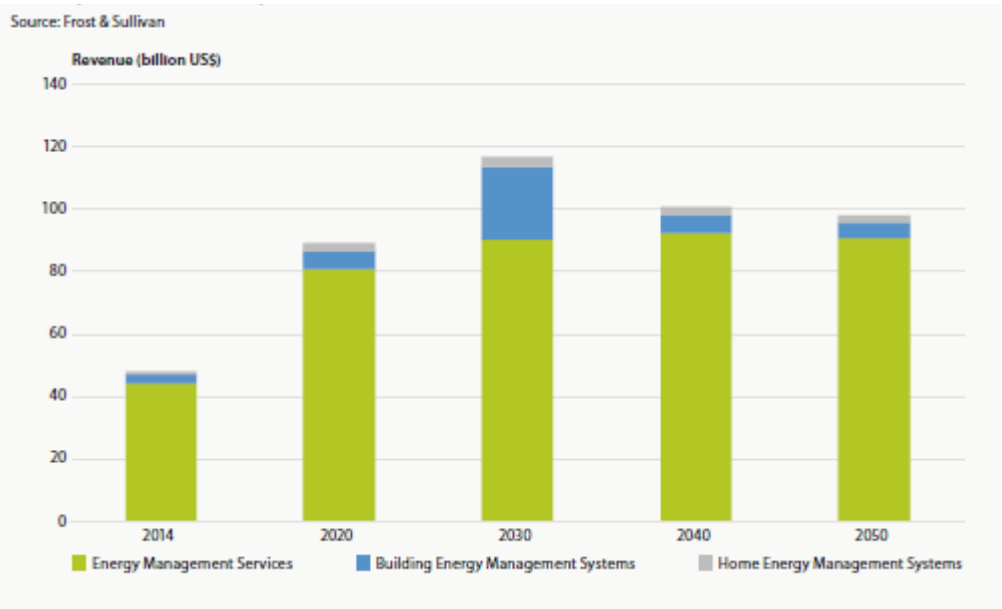


Figure C8. Energy Management and Service market: revenue forecast (Sitra, 2015).

Investment in energy generation	267 billion USD	100.0 %
Fossil energy	106 billion USD	39.7 %
of which coal	55 billion USD	20.6 %
of which natural gas	46 billion USD	17.2 %
Nuclear energy	8 billion USD	3.0 %
Renewable energies	153 billion USD	57.3 %
of which hydropower	52 billion USD	19.5 %
of which wind energy	43 billion USD	16.1 %
of which photovoltaic	37 billion USD	13.9 %
of which bioenergy	17 billion USD	6.4 %

Figure C9. Average annual global investments in the energy generation sector in 2000-2012 including larger hydropower (IEA, 2014).

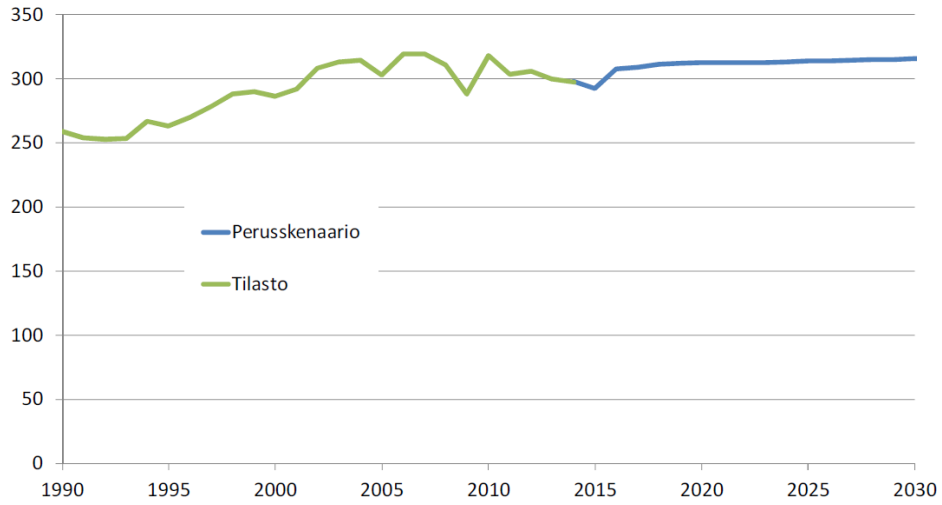


Figure C10. Total energy consumption in Finland, TWh (TEM, Perusskenaario, 15.6.2016).

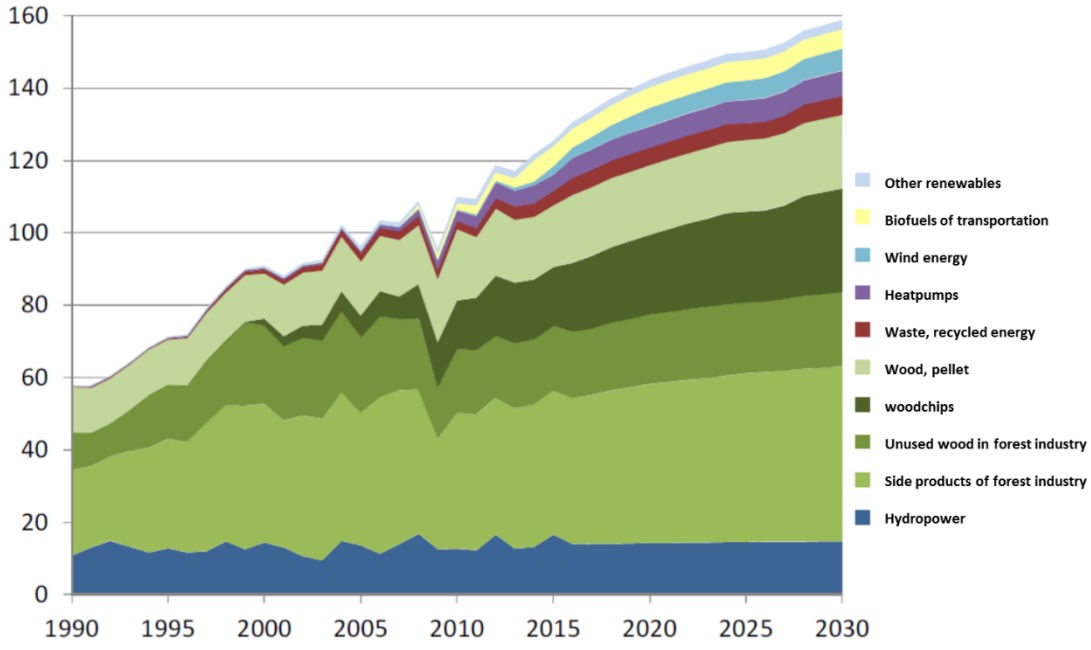
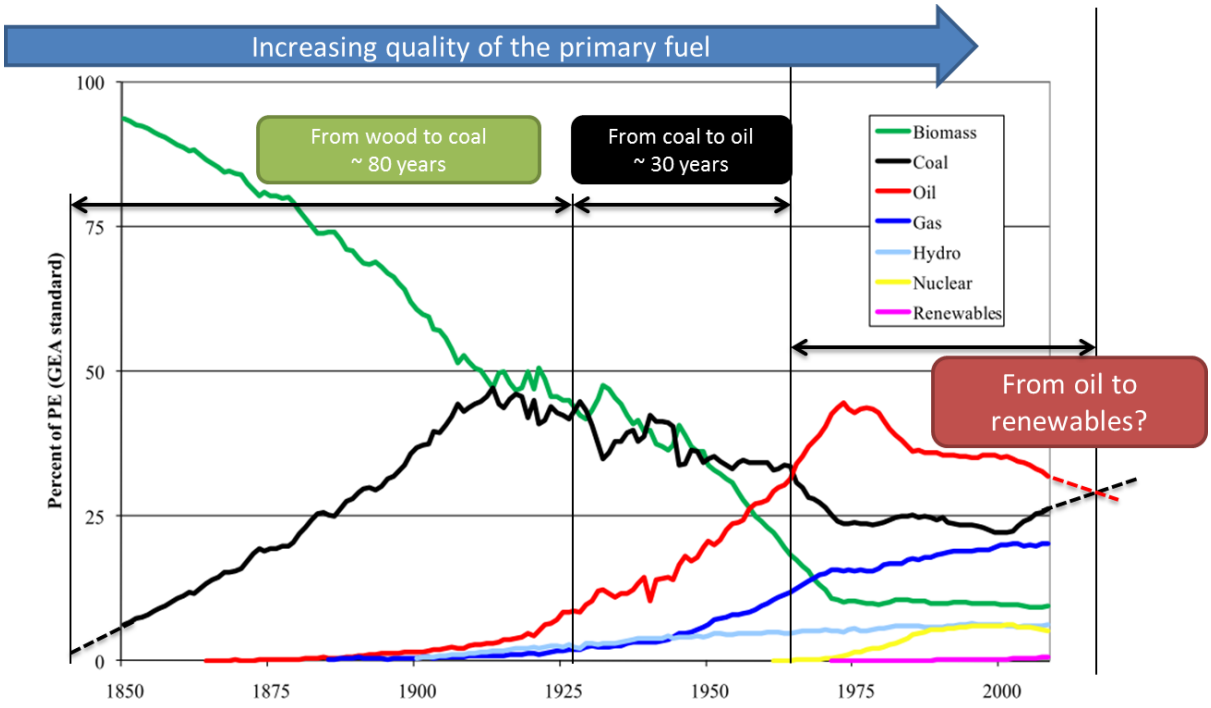


Figure C11. Renewable energy production in Finland, TWh (TEM, Perusskenaario, 15.6.2016).



Source: GEA Summary 2011, available at http://www.iiasa.ac.at/Research/ENE/GEA/index.html.accessed 6.8.2012

Figure C12. World energy transition 1850-2011 (Ahola, J., 2015).