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Four Futures

The Swedish energy system beyond 2020

Explorative scenarios

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The future starts today

What you are now reading is unlike everything else you have previously seen from the Swedish Energy Agency. Our study "Four Futures" provides a starting point for a modern energy dialogue. It is a dialogue that adopts a holistic approach, a societal transition and demonstrates the importance of properly navigating the energy transition.

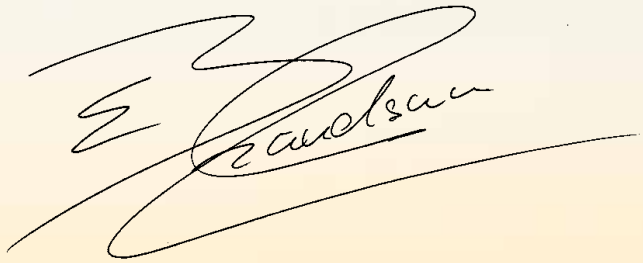
At the Swedish Energy Agency, we know a lot about the development of the Swedish energy system. But the energy industry will change more in the next five years than it has done in the past fifty years. Many external factors contribute to this pace and we believe we need to supplement the energy arena with a new approach. For this reason, we started our own study of the energy system after 2020.

This study has let go of the traditional supply perspective. We also clearly demonstrate that energy is not an isolated issue but is part of a context in which we think about the development of transport, housing, jobs and our landscape. Each future has a driving force dictating societal development, such as global justice, competitiveness, individualism or security of energy supply.

This way of describing societal development gives both us and actors in the energy arena a greater understanding of different perspectives in today's energy debate. We sketch an overall, holistic perspective. We describe without committing to any position. We present four possible energy futures.

I would like to thank all my energy colleagues who have poured their in-depth knowledge into a decidedly unusual project. There has never been a more gratifying time to work with the energy issues than today.

We are now taking the next step into Sweden's energy history.



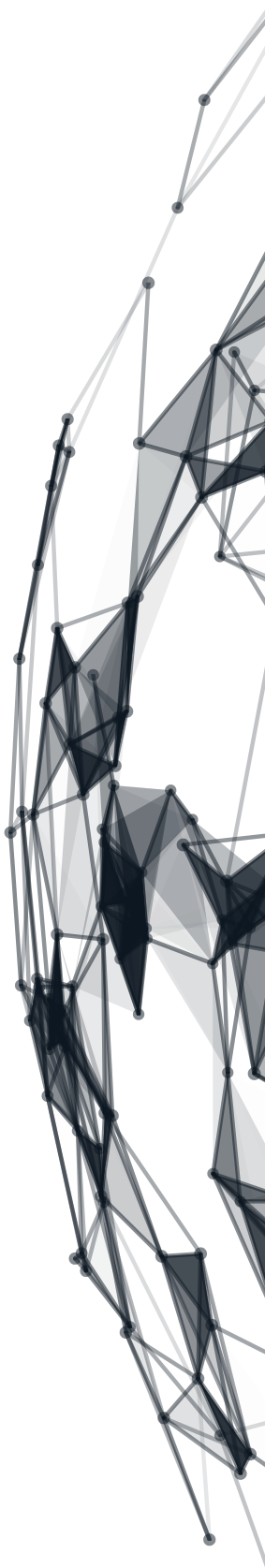
Erik Brandsma
Director General

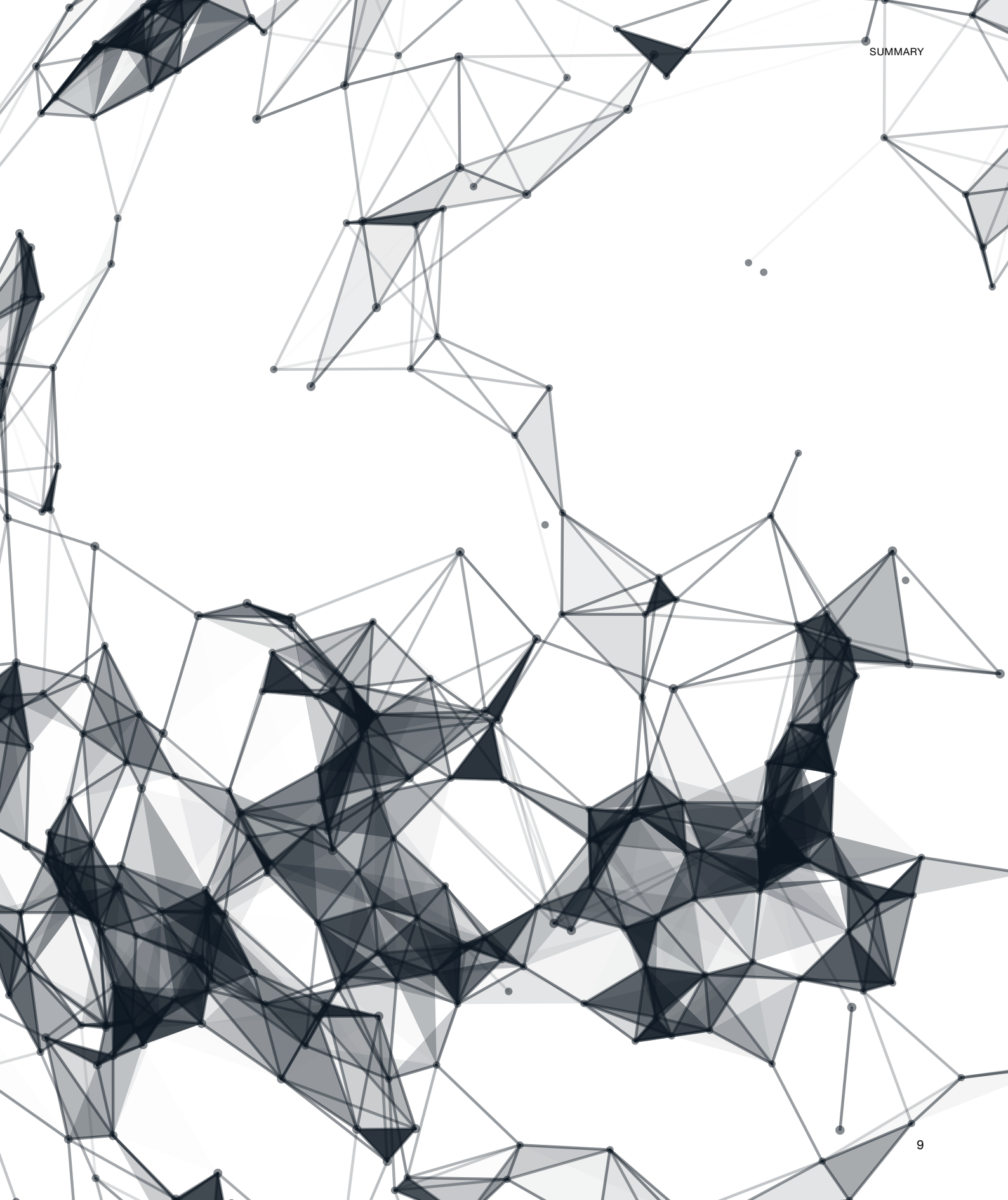
FORTE

Content

Summary

Investments in energy are long-term. Planning that begins today shapes society for decades to come. Nevertheless, Sweden has not had a discussion about the kind of future society in which energy will interact. How involved do households want to be in producing their own electricity? How do we want to link growth and energy? Is energy primarily an issue for Sweden or a global issue for the world?





In its work on the study “The Energy System after 2020”, the Swedish Energy Agency has had reason to think about these questions. We began by compiling the crucial issues we see in the energy area, difficult questions that must in some way be resolved in order to make progress in the transition of the energy system. We grouped these into the subjects: energy conservation, the electricity system, transport, bioenergy and the roles and responsibilities of different actors in the transition of the energy system. Here, we describe each subject in brief.

Many actors highlight energy efficiency and energy conservation as decisive for the transition to a sustainable energy system. They argue that energy efficiency is the first priority that politicians should set in order to achieve a sustainable energy system. Yet today, relatively little is happening in this area.

The Swedish electricity system today faces major changes since several production facilities are beginning to age. At the same time, changes are taking place in the use of the electricity system. More and more people now want to start producing electricity and are placing completely new demands on how the electricity system and electricity markets should function when a certain amount of production goes from being centralised to decentralised.

Today, the transport sector accounts for one third of Sweden’s total final energy use, and a lot of this energy is from fossil fuels. In order for transport to become fossil-free, the use of renewable electricity and biofuels must increase, but it will not be possible to replace all of it. Energy use for transport must also decrease. Biomass plays a decisive role in the transition to a sustainable society, partly in order to replace fossil energy. But there is discussion about how society best makes use of this resource since bioenergy competes with other benefits in society, such as food and raw materials for industry.

Sweden today has many different actors that together design the energy system. We see three main groups: the public sector, private for-profit actors and private not-for-profit actors, mostly households. All actors have a role to play in the transition of the energy system in a direction that is sustainable in the long term. Roles and responsibilities among different actors in the energy system are not obvious, and they also change over time. Those who are consumers today might be electricity producers tomorrow have the opportunity to store energy. We have discussed all these crucial issues in greater depth in the report **“Vägval och utmaningar för energisystemet”** [“Choices and challenges for the energy system”].

Another document we have produced is the report **"Industrins långsiktiga utveckling i samspel med energisystemet"** ["Industry's long-term development in interaction with the energy system"]. This discusses various strategies for Swedish industry to achieve near zero emissions of carbon dioxide and how it affects the energy system. Energy efficiency in industry is an important piece of the puzzle, but major transition and investments are necessary if industry is to be fully capable of being without fossil fuels. Both these reports form a knowledge base for continued work.

In "Four Futures", we have worked on scenarios in order to envisage what the future energy system might look like, depending on what society deems important with respect to energy. We paint four future pictures and call them Forte, Legato, Espressivo and Vivace. These names come from the world of music. Forte means forceful, Legato is tied together, Espressivo is expressive and Vivace stands for lively. The names indicate what the important priority is in each future. Energy that is used comes from different sources and is used in different ways.

How much energy is used also varies in the different scenarios. Common to all the futures is that energy is not an isolated issue, but closely interlinked with all aspects of society, such as how we live, what we work with and how we organise our society.

IN FORTE, it is important that society ensures that energy prices are low, especially for industry. Welfare is based on economic growth and the availability of jobs in traditional industry. Secure access to energy is also one of Forte's main priorities.

LEGATO involves reducing the energy system's environmental impact and helping to resolve a global issue. Important factors here are ecological sustainability and global justice, which characterise its solutions.

ESPRESSIVO is very much based on people's own initiatives and consumers who want to have individual solutions and flexibility. Here, green energy is a strong driving force. Decentralisation, small-scale private production and purchasing services are important elements in Espressivo.

VIVACE has a strong climate focus. Sweden has chosen to become a forerunner in green growth and develops the export market for environmental technology and bioindustry. This entails an investment in new types of jobs.

Priorities

Our four futures offer different routes to a robust energy system and are based on the view that energy has various roles in society. How we organise society is just as central to the scenarios as the question of which energy supply technologies we prioritise. The point is that the role assigned to energy and the energy system by societal actors can result in major changes in society[1], and this role controls the priorities and choices of energy policy.

The scenarios we have developed are explorative and give a broad perspective on possible routes of development for the Swedish energy system. The scenarios do not predict the most likely development and also do not need to fulfil existing environmental and climate objectives. Instead, they are intended to describe a development of the energy system derived from the priority that becomes most important in their respective futures.

The scenarios are not routes charted according to political considerations, but are a result of changes in society, supported by the population, politicians and the wider world. All the scenarios assume that Sweden is still a democracy, with the same constitution as today and with current levels of welfare. We set course for the year 2035 and also look ahead to the year 2050.

Although external changes also facilitate or reinforce the different lines of development, our focus nevertheless is entirely on Sweden's priorities.

1 In this context energy is not merely a physical entity, and should be perceived as a concept and sense creator in society.

Our four futures are:

Conditions that the four futures have in common

There are several global trends underlying the future scenarios. Such “megatrends” are mentioned and described with a relatively high degree of consensus by many sources, such as the EU’s European Environment Agency and the Copenhagen Institute for Futures Studies. These trends apply more or less strongly in all four scenarios.

Global warming continues

According to the IPCC's latest report[2], the warming of the planet and the increase in its average temperature are unequivocal. The atmosphere and the oceans have become warmer, the quantity of snow and ice has decreased, sea levels have risen and the concentration of greenhouse gases has increased. Extreme weather is becoming more common. Areas with little rain and a lot of sun are becoming drier and hotter, while areas closer to the poles are seeing a sharp rise in temperature and precipitation. How much Sweden will be affected depends on the magnitude of global warming, but climate scenarios from the Swedish Meteorological and Hydrological Institute (SMHI[3]) suggest that Sweden is also seeing a rise in temperature.

Our average annual precipitation is increasing. Climate change could hand Sweden a more significant role as a global producer of food since there is a worldwide decline in the proportion of arable land, while Sweden is gaining a more favourable climate for cultivation. We might see increased immigration from countries that are hit harder by climate change. Further consequences might include greater societal costs for flood management and a reduction in the potential area for building in coastal areas. On the other hand, there might be a reduction in the need to heat buildings.

Poverty decreases and education increases

The majority of the population of already developed countries and large groups in previous developing countries will become increasingly better off and more highly educated. More people will also have access to electricity, good housing and the opportunity to travel. This brings economic changes, but also increases energy use and environmental impact. The world is undergoing urbanisation, happening fastest in areas of rapid population development or industrialisation, mainly in Asia and Africa. This presents challenges to infrastructure, the environment and traditional patterns of living.

2 PIPCC fifth assessment report, www.ipcc.ch/report/ar5/wg1/
3 www.smhi.se/klimat/framtidens-klimat/klimatscenarier#area=eur&dnr=0&sc=rcp85&seas=ar&var=t

Issues of health, nature and the environment are becoming increasingly important

Issues related to health and the local environment are being assigned an increasingly higher value, and there will be a growing focus on issues such as clean drinking water, agricultural land and air quality, but also on lifestyle diseases such as obesity and stress. Many environmental and health problems are linked to the use of energy, especially fossil fuels. The future will place higher demands on the capacity of countries for sustainable resource management and the better management of natural resources and ecosystem services[4]. The need for environmental technology is great, but its development is controlled largely by the countries' own political priorities.

Digitalisation is developing completely new services

Electronics are becoming a more and more natural part of our everyday lives. Digital networks are becoming a central concept permeating our way of thinking. For energy, digitalisation can hasten a structural change in the industry. Smart grids, smart homes and smart gadgets, known as the internet of things, are creating conditions for improving energy efficiency and optimising the use of electricity and heat. At the same time, electricity use might increase when more or more things[5] are connected.

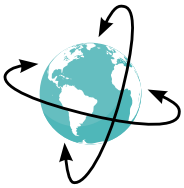
Digitalisation will lead to new opportunities, but also to challenges in terms of ethics and integrity due to more opportunities for both the government and businesses to monitor citizens.

Technological development continues at a rapid pace

Since the beginning of industrialisation, technological development has accelerated and there is nothing to indicate that it will slow down. Swedish industry and service sectors are investing in the development of competitive products and services for a global market.

4 Ecosystem services imply direct and indirect aspects of ecosystems that contribute to the welfare of people and society. Ecosystem services that entail products – such as forest resources – can generate direct economic profit.

5 Internet of things is the network of physical devices, such as refrigerators or heatpumps – embedded with electronicsand network connectivity that enable these objects to collect and exchange data.



Globalisation links countries together in new ways

There is a rapidly growing global interlinking of people, capital, goods and services. Trade between countries is made easier through the opportunity for companies to set up business where it is most profitable.

More people and more homes

Globally there is an expected population growth until 2050. After 2050, the growth rate will probably subside[6], and the global population is ageing. It is likely that there is a population decline in certain geographical areas, such as parts of Europe.

Statistics Sweden (SCB) has forecasted that the Swedish population will pass 10 million in 2016, reach 11.7 million in 2035 and 12.4 million in 2050[7]. A housing shortage and larger population will increase the need for new housing in Sweden. The assessment of the National Board of Housing, Building and Planning is that 705,000 dwellings[8] will need to be built by 2025.

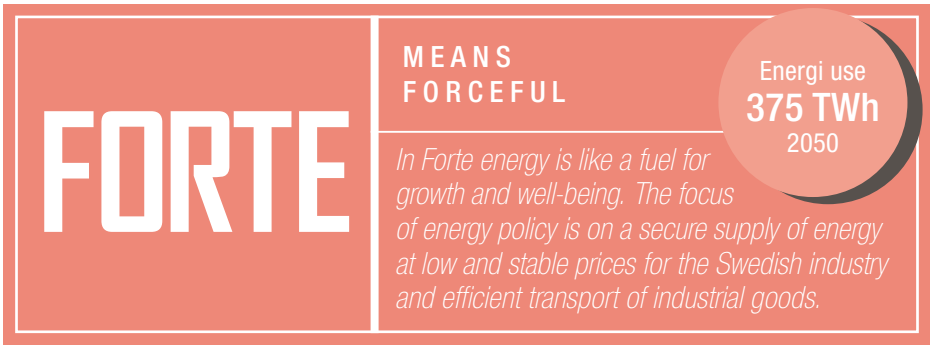
Increasing competition for natural resources

The combination of population growth, greater prosperity and the effects of climate change is leading to a more intense strain on important natural resources such as water, arable land and various commodities. Sweden, as an actor on the global commodities markets, is affected through the lack of its own fossil fuel resources, but enjoys great use and potential with respect to renewable energy, such as hydropower, bioenergy, wind power and solar power. Sweden also has major raw material assets in the mining and forest industries.

6 UN World Population Prospects: 2015 Revision.
7 Statistics Sweden 2015 Population projection.
8 National Board of Housing, Building and Planning 2015.

FORTE

Senario Forte – energy is like a fuel for growth and well-being



Forte's starting point is that secure access to energy at low and stable energy prices is important for energy-intensive industry as a means of Swedish prosperity. The focus of society is on responding to European industry's fierce international competition. Asia and Africa are taking more and more market shares on global markets. Swedish companies are already beginning to see the consequences of this shortly after 2020. The political parties see economic growth and job creation as paramount and listen carefully to industry.

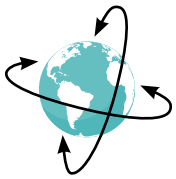
Voters also place great importance on existing industry as they fear that unemployment would otherwise increase. The energy debate focuses on security of supply and competitive, predictable energy prices from a large-scale, centralised energy system. Sweden's population believes that the government is responsible for acheiving this. The Swedish government wants to reduce the energy system's climate and environmental impact, but only as long as it does not impair the competitiveness of industry. For this reason, its climate and environmental measures mainly target other sectors, such as passenger transport and housing.

MAIN DRIVING FORCES

- Low and stable energy prices to the existent industry
- Economic growth
- Secure energy supply

GLOBAL TRENDS IN FOCUS

Technological development continues in a rapid pace



Globalisation links countries together in new ways

Increasing competition for natural resources

Spatial planning

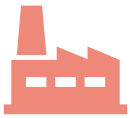
There is demand from trade and industry for efficient means of transport and the opportunity to establish new industries in strategic locations, such as near ports. This is allowed to take precedence over "nature" as a national interest and over regional and municipal interests. Spatial planning is based on the needs of industry for infrastructure and individual transport with a focus on roads for freight traffic and private motoring.

There is great demand for attractive housing environments, and this holds sway over spatial planning. Dwellings are built in green urban areas or in older summer cottage areas or in fields or woodland. Reducing transport by spatial planning is not a consideration in Forte.

Lifestyle and housing

The lifestyle in Forte is similar to that today, but there is a stronger belief in industry and the production sector as an engine for prosperity. We are increasing consumption, and income growth is a priority in Forte. Industry is growing, which means that smaller industrial towns are retaining or increasing their population and level of service.

Industry



In order to cope with international competition, Swedish industry is investing in specialisation and product processing, and this requires major investments in research and innovation. In Forte, industry is increasing both its production and its energy use compared with current levels, and this is mainly due to greater investments in the iron/steel and mining industries.

Transport

The strong growth of industry means an increase in freight transport. The government is therefore investing heavily in the infrastructure of all transport modes and is also supporting smooth transitions between modes, such as train, lorry and boat. Industry is initiating an infrastructure for natural gas for heavy vehicles and at ports. A large part of this natural gas is used in shipping.

The government is above all focusing on electricity-based transport solutions. Together with the government, industries are investing in industry shuttles and in electric roads in the road network in a triangle Stockholm–Gothenburg–Malmö–Stockholm, which will be ready by 2050. Traffic management prioritises freight trains ahead of passenger trains.

The government highly prioritises security of supply, taking greater responsibility for energy supply. Policy instruments make it possible to diversify the fuels used for transport. It is still important to reduce the climate impact of the transport sector, but measures mainly target passenger transport.

Energy supply

In the period 2025–2035, the government will stimulate a strong expansion of large-scale electricity production facilities, mainly nuclear reactors, that will be able to deliver large quantities of electricity at a stable level for a long time to come. Hydropower owners will modernise and maintain their power plants so that high production will continue to be possible. As 2050 approaches, climate change is becoming increasingly clear with more precipitation that will further increase hydropower production.

Global fossil fuel prices and carbon dioxide price have an effect on the use of fossil fuels, which in Sweden will decrease by 20 per cent from today to the year 2035. The growing industrial sector contributes greater quantities of waste heat that can be harnessed by some district heating systems. Imported and domestic waste is also a common fuel for district heating production.

Biofuel use will increase until the year 2035. This comes as a result of the growing industry and a certain level of ambition to reduce Sweden's climate impact. Industries use biofuels as a raw material in production, and homes use the majority of solid biofuels such as wood, pellets and wood chips for heating. Fuel companies are increasingly blending liquid biofuels into petrol and diesel.

Through the strong expansion of electricity production, Sweden's electricity customers are gaining greater access to electricity at a stable price. Electricity becomes an export commodity for Sweden, and the government overhauls Sweden's interregional and overseas transmission capacity.

Policy instruments

In Forte, the government prioritises the competitiveness of energy-intensive industry, and the supply perspective dominates energy policy. The climate is still a current issue, and to secure access to electricity with low carbon dioxide emissions, the government is investing in new nuclear reactors to replace those reaching retirement. The cost for this is passed on to electricity customers in the form of a newly created "atomic premium". However, industry does not participate in paying for this.

Property tax and nuclear power tax, which are deemed to inhibit major new investments in power plants, are abolished. The environmental adaptation of hydropower becomes more limited.

In 2050, the Swedish energy and resource-intensive industries have developed more effective process technology and refined their products, with the hope of remaining internationally competitive. In 2050, Sweden has an electricity and district heating system that is very much reminiscent of what exists today. The big change is for fossil fuels, which have gradually declined in favour of electricity and biofuels. Energy products are traded on a global market and at competitive prices.

The Swedish electricity system is dominated by large, central production facilities that generate electricity at a high and even level and that yield a surplus.

Looking ahead to 2050

Households will have to bear the higher cost of electricity
In order to prioritise electricity-intensive industry with a low electricity price, a higher price is passed on to the other categories of electricity customers – mainly households. What acceptance is there for this, and to what degree?

Climate work is slow
As Forte does not have an explicit climate focus, climate measures are implemented to the extent they are deemed profitable, which means that climate improvements move slowly.

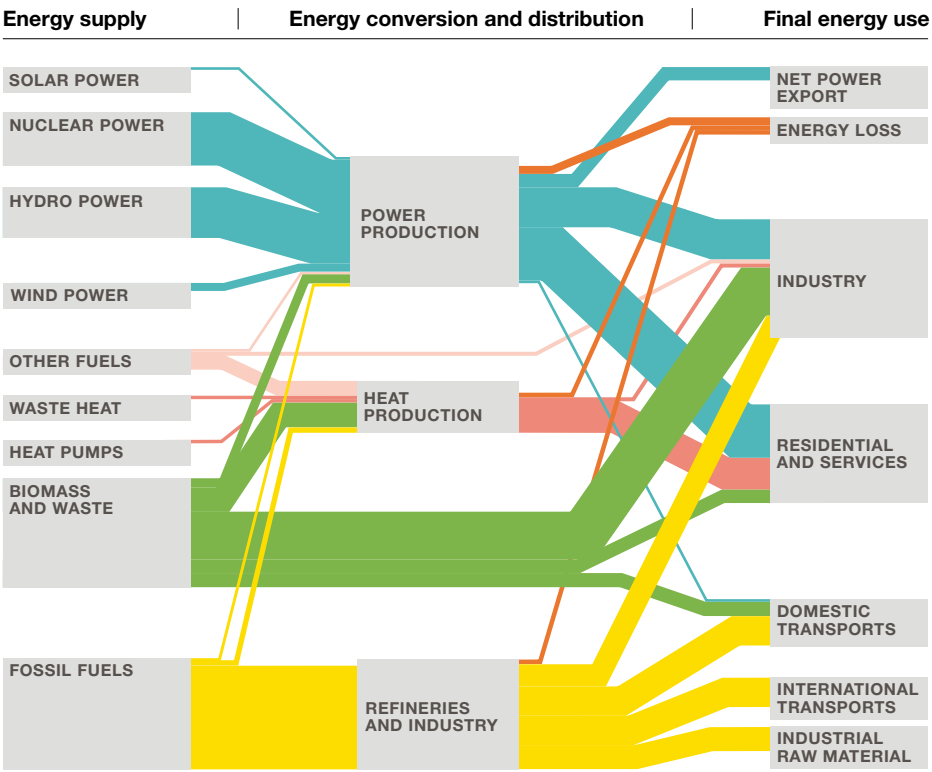
Research and innovation is partly slow
In areas not falling within the sphere of interest of energy-intensive industry, investments in research and innovation can be few or altogether absent.

Investment in traditional industry can be short-term
The investment in traditional industry can be short-term if the sectors themselves are ultimately unable to bear their own costs. This is comparable with Sweden's earlier textile and shipbuilding industries.

Energy efficiency in industry can stagnate
The low electricity price in Sweden for energy-intensive industry reduces the incentives for improving energy efficiency. This makes industry sensitive to large fluctuations in energy prices.

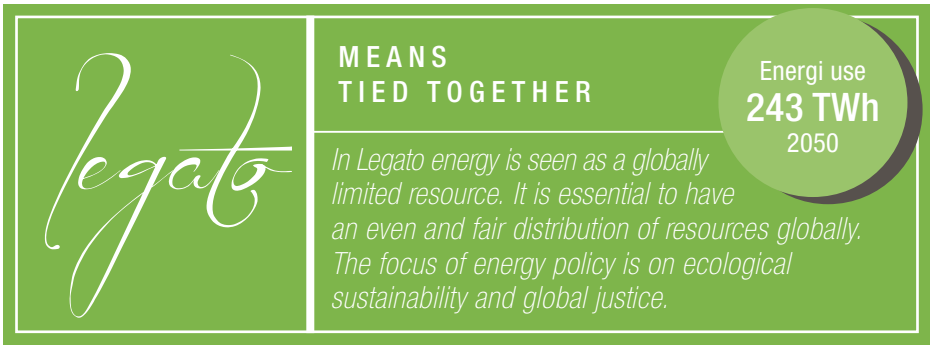
Challenges

The energy system in Forte 2050




Ego

Scenario Legato – energy is seen as a globally limited resource



In Legato, issues of global justice and long-term ecological sustainabilityare high on the Swedish and international political agenda. We are beginning to see the establishment of a view of global energy and natural resources as being common to the global population. In Sweden, many people are choosing to move into a simpler lifestyle, both for environmental reasons and for reasons of solidarity with the population of other countries.

A number of society's fundamental structures have undergone a change in Legato in 2035. The economy – a circular economy – is based on a recycling society and uses resource-efficient business models. Changes are seen at all levels of society, including the way in which people organise their everyday lives. Energy use has declined sharply. There are explicit policy instruments in the area of resource and energy efficiency.

Sweden's electricity customers prioritise flowing energy resources, such as sun, wind and water. Every year Sweden produces more biofuels, bioenergy and renewable electricity than the domestic market uses, and therefore seeks to export both electricity and fuels. Fossil energy is being phased out, as is nuclear power.

MAIN DRIVING FORCES

GLOBAL TRENDS IN FOCUS

Global warming continues

Issues of health, nature and the environment are becoming increasingly important.

Poverty decreases and education increases

Spatial planning

In order to increase accessibility, municipal planning prioritises a mix of housing, service, schools and workplaces. A densification of cities is taking place. Pedestrians, cyclists and users of public transport are priority target groups in urban planning. This development comes at the expense of private motoring, to which urban planning has given less space. Rural municipalities work with a combination of physical planning, behavioural measures and digitalisation to promote sustainable transport and greater accessibility to local service functions in rural areas.

Lifestyle and housing

More and more Swedes are choosing a lifestyle with less resource use, and voluntary simplicity is becoming a strong movement. "Ecological footprint" is becoming a frequently used term in the debate, and the residents of Sweden are striving to adapt their footprint to a globally sustainable level. More people reduce their working hours, increase their degree of self-sufficiency, borrow and exchange things, spend more time with their families, get involved in voluntary associations, hobbies and societal development.

Industry

Industry is being increasingly steered towards more of a recycling mentality, whereby it reduces its use of raw materials and reduces the generation of waste. This is facilitated by building more in clusters in order to maximise cooperation on energy and raw materials between different industries. The government is introducing more stringent requirements on energy audits and energy efficiency, which help industries to implement systematic energy efficiency improvements.

The government invests in research and innovation, and in state aid for the transformation of the energy system. Bioclusters are being formed that produce a variety of bio-based products, such as electricity, heat, fuels, chemicals, plastics and textiles. Agriculture is also being linked to these clusters in order to streamline the production of sustainable foodstuffs.

Transport

The demand for passenger transport has decreased. Sweden's five largest cities have introduced bans on private motoring in the city centre and have invested in more infrastructure for pedestrians, cyclists and public transport. The fossil-free transport system is powered by electricity and biofuels. Fossil fuels have been phased out since the early 2030s. Digital ride-sharing has reduced dependence on privately owned cars, even in rural areas.

The government makes no new major investments in either road or rail infrastructure, but instead maintains existing infrastructure. Domestic aviation remains for a few long routes, but has largely been replaced by train.

Energy supply

The government extends the electricity certificate system to allow for a resource-efficient expansion of renewable energy. The view of the general public is that it is important to be able to contribute to the export of electricity with low climate emissions and to share the resources available in Sweden. Major investments are being made in improving energy efficiency. Energy companies are investing in a major expansion of onshore wind power. Closer to 2050, a little wave power is also being built, and where profitable, offshore wind power. Citizens support the transition by themselves investing in solar cells that reduce their own use of electricity from the grid, thus increasing opportunities for export. As a consequence of low electricity prices and reduced electricity needs, nuclear power becomes unprofitable and is phased out prematurely.

Over the years, prices on the electricity market become more and more varied, opening the way for more energy storage. Electricity users are more flexible and plan their electricity use according to times of availability.

Policy instruments

In Legato, there are strong climate and energy policy instruments that influence industry towards more resource-efficient operations, which, among other things, has been favourable to the formation of industrial clusters. Carbon dioxide tax is central, which provides good conditions for more mature renewable technologies to compete without special support.

In 2050, energy-efficient technology is used on a large scale, and a changed lifestyle has reduced energy use and resource needs in Sweden. Industry has undergone major restructuring, and Sweden has a large export of renewable electricity and biofuels. Collective and individual, small and large-scale, and technical and behavioural energy solutions are combined and used on a large scale.

In 2050, Sweden has an energy mix that is largely based on flowing energy sources and bioenergy. Society already has long experience of being both almost fossil-free and largely renewable. The security of the energy systems is based on effective energy markets with a wide range, high flexibility and good preparedness to manage the consequences of any disruptions.

Looking ahead to 2050

Risk of stagnation in technological development
Since the changes in society are largely behaviour-driven, there is a risk of stagnation in the development of technologies to improve resource efficiency.

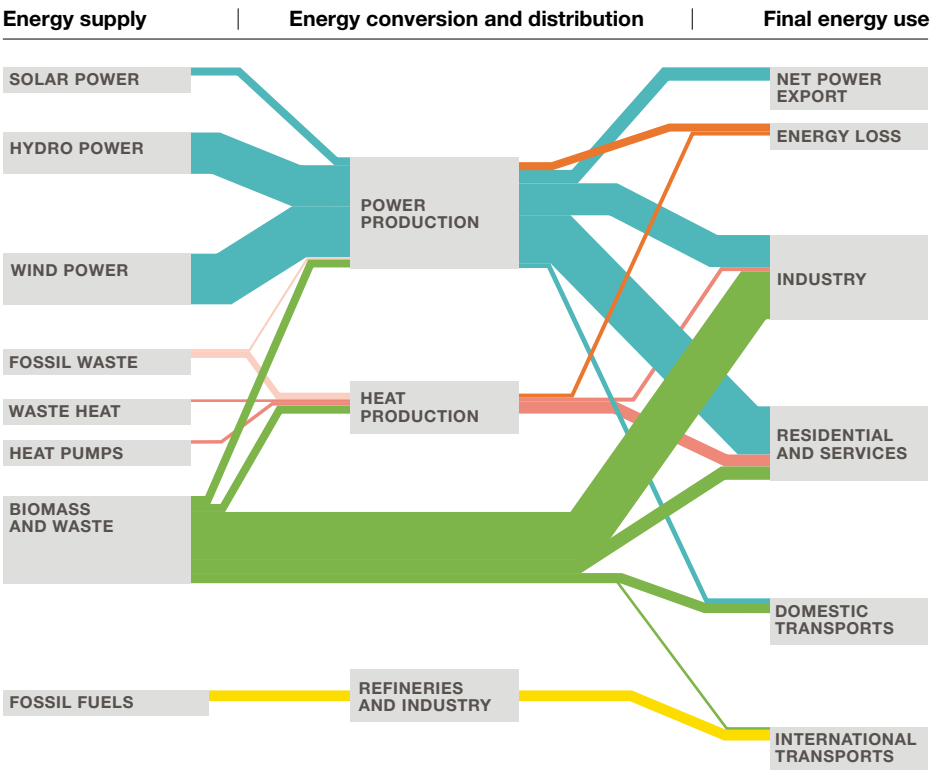
Secure research for the transformation to a bioeconomy
The government will need to invest large sums in research, development and demonstrations in order to convert industry to become bio-based. Research and development regarding the electricity grid is also important for Legato's opportunity to secure demand response.

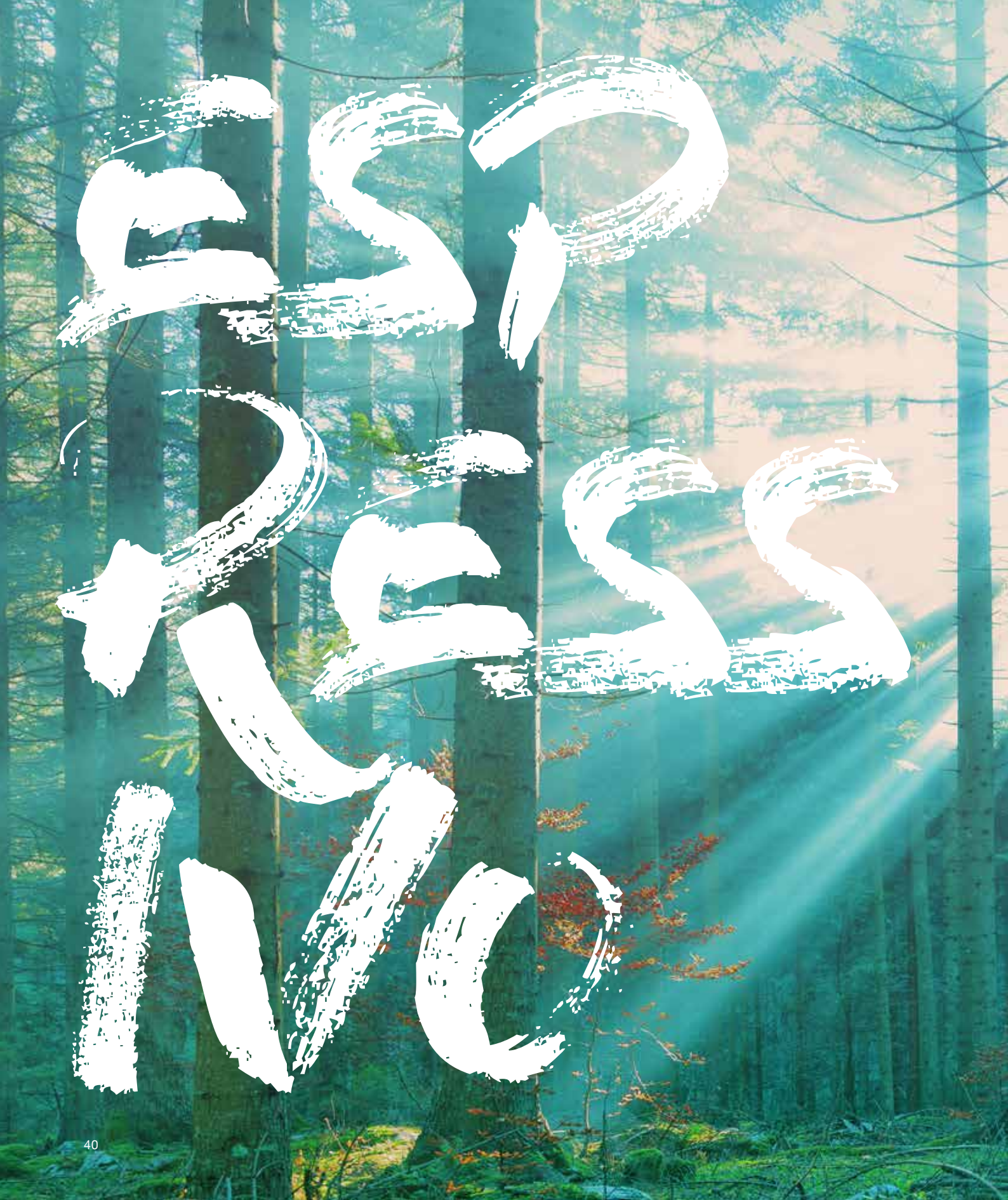
High demand response is important
Especially during the winter, the system with a high proportion of variable electricity production (solar and wind power) will require large flexibility in electricity use – a flexibility that does not exist today.

Potential need to change the treasury's revenue model
If parts of the tax revenue are based on environmental impact, this revenue will decrease as society becomes more environmentally friendly. If a large proportion of the population also begins to consume significantly less goods and instead utilise more services, the government must change its revenue model in order to maintain the welfare state that exists today.

Challenges

The energy system in Legato 2050




ESPRESSIVO

Scenario Espressivo – energy is a means of expression

In Espressivo, decentralisation and individual freedom are increasingly important ideals. The political climate is moving away from central governance, large-scale solutions and the idea of a homogeneous "Home of the People" to a greater focus on diversity and individual solutions. The focus is also on issues close to the individual person, such as health and local environmental values.

Private investments are increasingly frequent in infrastructure, electricity and heat production, as are research and innovation projects through public sponsorship and fundraising. Local residents and groups are also having a greater say, for example, in the establishment of energy and industrial facilities and in major infrastructure projects.

MAIN DRIVING FORCES

GLOBAL TRENDS IN FOCUS

Issues of health, nature and the environment are becoming increasingly important

Technological development continues at a rapid pace

Digitalisation is developing completely new services

Globalisation links countries together in new ways

Spatial planning

Society is developing in such a way that citizens have greater opportunity to influence the design of their living environment and as well as transport and energy solutions. The government supports this individualisation and in many respects allows local interests to take precedence over national interests. Spatial planning is flexible and sets only the administrative framework for the self-organised society.

More and more people have taken an interest in a form of urban and residential development where individuals and families come together to plan, build and later live in a building designed according to their own perceptions and ideas.

Lifestyle and housing

Many people want to produce their own energy. New construction often takes the form of low-energy houses, which use minimal energy and have solar cells installed on their roofs as standard. The design and organisation of housing is becoming increasingly important, and people are becoming more active in this.

Many combine a lesser degree of gainful employment with other activities, such as food production or the cultivation of energy crops.

Energy use continues to decrease until 2050, and fossil fuels in the service sector have now been completely phased out and replaced with biofuels.

Industry

The focus is on individual solutions and to make things easier for people regardless of where they live. Industries adapt in larger content products to different customer needs. Since this development is largely driven by customer demand, it is primarily companies offering consumer-related products and services that choose an environmentally conscious profile.

There is a strong entrepreneurial spirit. A great many smaller, start-up companies are emerging that offer products adapted for resource efficiency and, for example, independent electricity production. Research and innovation projects are largely financed through private investments.

Transport

Espressivo accommodates a wide range of different forms of transport, with varying comfort, technology and speed.

The opportunity to use individual transport vehicles, such as cars, biofuel-powered aircraft and electric mini-vehicles, continues to be important. Passenger traffic is becoming more dynamic and varied. Those who want to travel in their own compartment and work or spend their time on something other than driving, order a self-driving taxi to their door. Cycling fast is a means of expression, and new fast bike lanes have been built in the larger cities. Public transport is being expanded within and between major cities.

Electric vehicles are common in sparsely populated areas. Charging these vehicles using one's own electricity is becoming a new form of balancing service. In rural areas, public transport is size-adapted. It comes when ordered and can both deliver goods and collect people.

Energy supply

The supply of energy in Espressivo is driven with a focus on individual solutions and self-sufficiency. More consumers produce their own heat, and an increasing number of people sell residual heat from homes, premises and industry to the district heating network. With more local energy solutions and a reduced customer base for large district heating producers, trading in heat is becoming something between households and other customers rather than between the central district heating supplier and the heat user.

Industries buy shares in existing nuclear power plants to prevent the early closure of the reactors. However, due to the reduced electricity load on the central network, no new major nuclear power plants will be built. Therefore, after 2035, some industries will choose to invest in small nuclear plants, known as modular nuclear power.

To achieve a stable electricity supply for industry, combined with a desire for a low share of fossil fuels, the solutions will be large-scale wind power combined with industrial combined heat and power plants, where different industries can help each other to balance production and electricity use. Due to problems of acceptance, establishments of wind power are usually offshore.

New investments in the Swedish electricity network are being made at the local level, where there are private initiatives to make the networks smart and optimised for self-sufficiency or to be as independent from the central network as possible.

The new electricity markets

Up until 2050 there is an extensive expansion of micro-production, micro-storage, and micro-grids in Sweden. Nord Pool is extended to the whole of Europe, a European pool. Nordic hydropower is becoming an increasingly attractive regulation resource on the continental European electricity market.

The emergence of many micro-grids also leads to the formation of small, local spot markets. However, the markets are governed by common rules determined by a European electricity exchange committee.

More and more people are completely disconnecting from the network due to the development of their own seasonal storage. There is little interest in investing in new centralised production. One exception is reinvestments in hydropower and the national grid, which continue to be necessary for balancing power and supplying electricity to major cities and industries. Private actors also invest in hydropower and transmission capacity for export reasons as there is demand for electricity from continental Europe.

Policy instruments

The government's operational regulations has decreased in favour of regions and municipalities. Regulations and policy instruments are adapted and created in order to simplify and support individual solutions.

The position of consumers on the energy market is stronger than before. It is easier to come together in cooperatives to invest in the joint production of electricity. When actors try to find local solutions, there can be a risk of sub-optimisation, which can result in inefficient planning on the larger scale. Authorities and municipalities provide a large quantity of networks to reduce this risk.

In 2050, the energy system has a higher degree of decentralised organisation and that gives greater power to consumers. The total use of energy does not differ very much from today, but the distribution between different types of energy and how the energy market functions have undergone major changes. The energy system is characterised by a high degree of flexibility and individual solutions.

Looking ahead to 2050

Security of supply in small-scale, decentralised electricity systems

A development of the electricity network to include more small-scale and decentralised systems could lead to a lower security of supply at the system level (in the national grid) due to possible difficulties in predictability and the synchronised control of these smaller, autonomous systems.

At the same time, technology in the area is developing towards greater automation, digitalisation, new types of control and regulation and system architectures that are expected to provide the opportunity to maintain and even increase the security of supply in systems that have a greater number of decentralised and small-scale systems[9].

A development of this kind also presupposes the development of different types of energy storage solutions, which increases the opportunity to be self-sufficient when supply is disrupted. Power cuts also do not affect as many users each time.

Security of supply can be created regardless of the system if it is included in the planning at an early stage. It is thus even possible that security of supply from a societal perspective could improve with small-scale systems.

9 EcoGrid EU, http://www.eu-ecogrid.net samt Cell Controllers Architecture, http://energinet.dk/SiteCollectionDocuments/Engelske%20dokumenter/Forskning/Cell%20Controller%20pilot.pdf

Sub-optimisation – who has the overall perspective
If it is up to individuals or small groups to decide over their energy supply, there is an obvious risk that the system as a whole will not be optimised since it is difficult to have the overall perspective. Infrastructure and spatial planning might also lack the overall perspective, which could result in increased costs and require more resources.

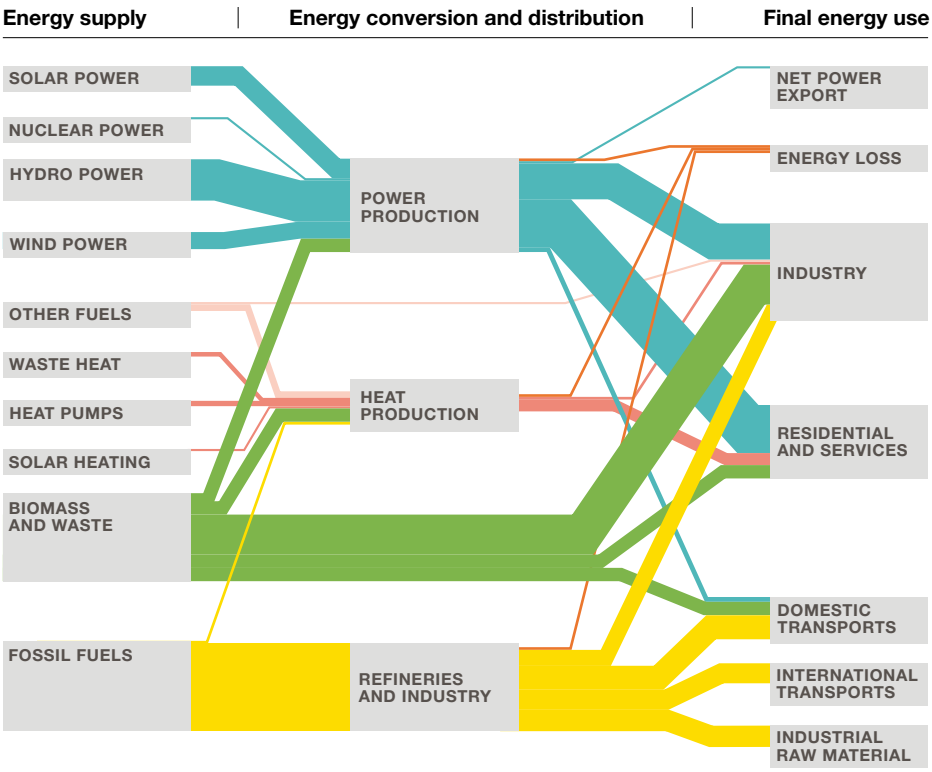
Individual freedom is perhaps not in the best interests of the public
In a society where individuals and individual needs have a central position, there is a risk that the solutions which are the best collectively are not prioritised, precisely because a comprehensive persepective is missing. This might occur not only as regards the electricity network (see the challenge above), but also in areas such as urban planning and establishing companies.

Climate work can be slow
Individual solutions without too much control could lead to the slow progress, or even complete halt, of climate improvement measures.

Great difference in energy use between different groups
In this scenario, lifestyles and energy use could become very different between groups in society, depending on personal finances and on interest in technology and entrepreneurship. This could lead to greater gaps in society.

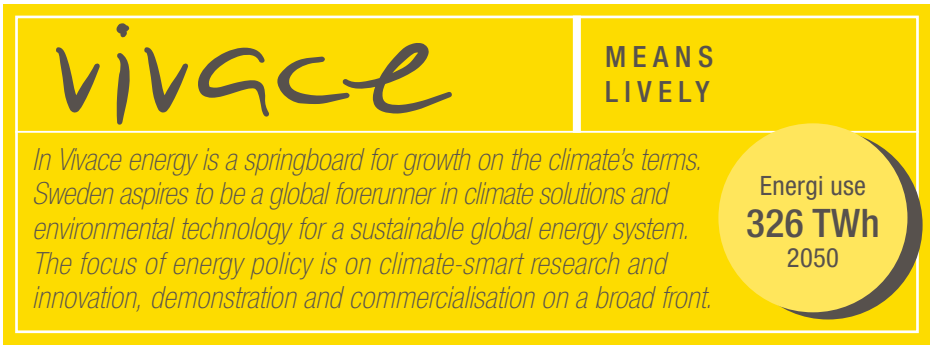
Challenges

The energy system in Espressivo 2050




vivo

Scenario Vivace – energy is a springboard for growth on the climate´s terms

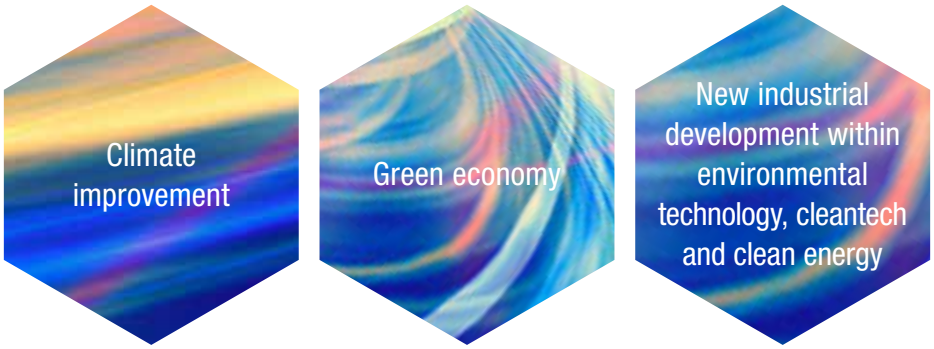


In Vivace, new, green technology and new services in the area of energy and the climate are an important engine for development in Sweden. Energy is viewed as a springboard for societal change and a facilitator of new technology industries that help to improve the climate.

Politicians have a strong mandate from the population to drive energy and climate issues internationally. The experience of being pioneers is used to inspire the development of new goods and services. The strategy creates many new jobs and operations.

The government invests in transport infrastructure in order to reduce the climate impact of transport and facilitate the emerging branches of industry. The green industries are growing. Forestry and agriculture are investing heavily in biofuels and processed food products.

MAIN DRIVING FORCES



GLOBAL TRENDS IN FOCUS

Global warming continues

Technological development continues at a rapid pace

Digitalisation is developing completely new services

Spatial planning

In order to secure major infrastructure projects, spatial planning prioritises the national interests of "energy and industrial production" ahead of regional and municipal interests. The aim of spatial planning is to create a technology and climate-smart environment for housing, leisure and work.

Information about most things in society flows and is available to all. This enables all citizens to keep themselves well informed thanks to innovative services, e.g. to find the best route and mode of transport at any given time. Self-driving vehicles, both buses and cars, have been allowed to take more space.

Lifestyle and housing

Life has not fundamentally changed compared with today, and travel and transport occurs to the extent permitted by climate objectives. In the building sector, architects and engineers are developing new technologies to construct energy and climate-smart plus-energy houses, a low-energy house that supplies energy to surrounding systems.

The government, municipalities and industry are collaborating on major investments to develop sustainable cities. The new construction of houses and premises is increasing as the Swedish population wishes to upgrade their housing with new technology and climate-smart solutions.

In Vivace, the total energy consumption of the residential and service sectors has decreased greatly leading up to 2035. Energy efficiency improvements and a strong technological development are fundamental reasons for this decrease, which will continue until 2050.

Industry

Trade and industry in Sweden is working actively to influence and drive research and innovation in order to convert industry into the most climate-smart in the world. It is undergoing a transformation to more circular business models and production. New industries are grouped in clusters so that they can collaborate and, for example, utilise each other's waste products.

In Vivace, a major structural change is taking place in industry, which among other things entails an extensive transformation to fossil-independent production. This increases the electrification of industry. Sweden is also becoming a hub in the growing global recycling industry, which means that the raw material base for industry consists of imports and of Swedish raw materials and waste products.

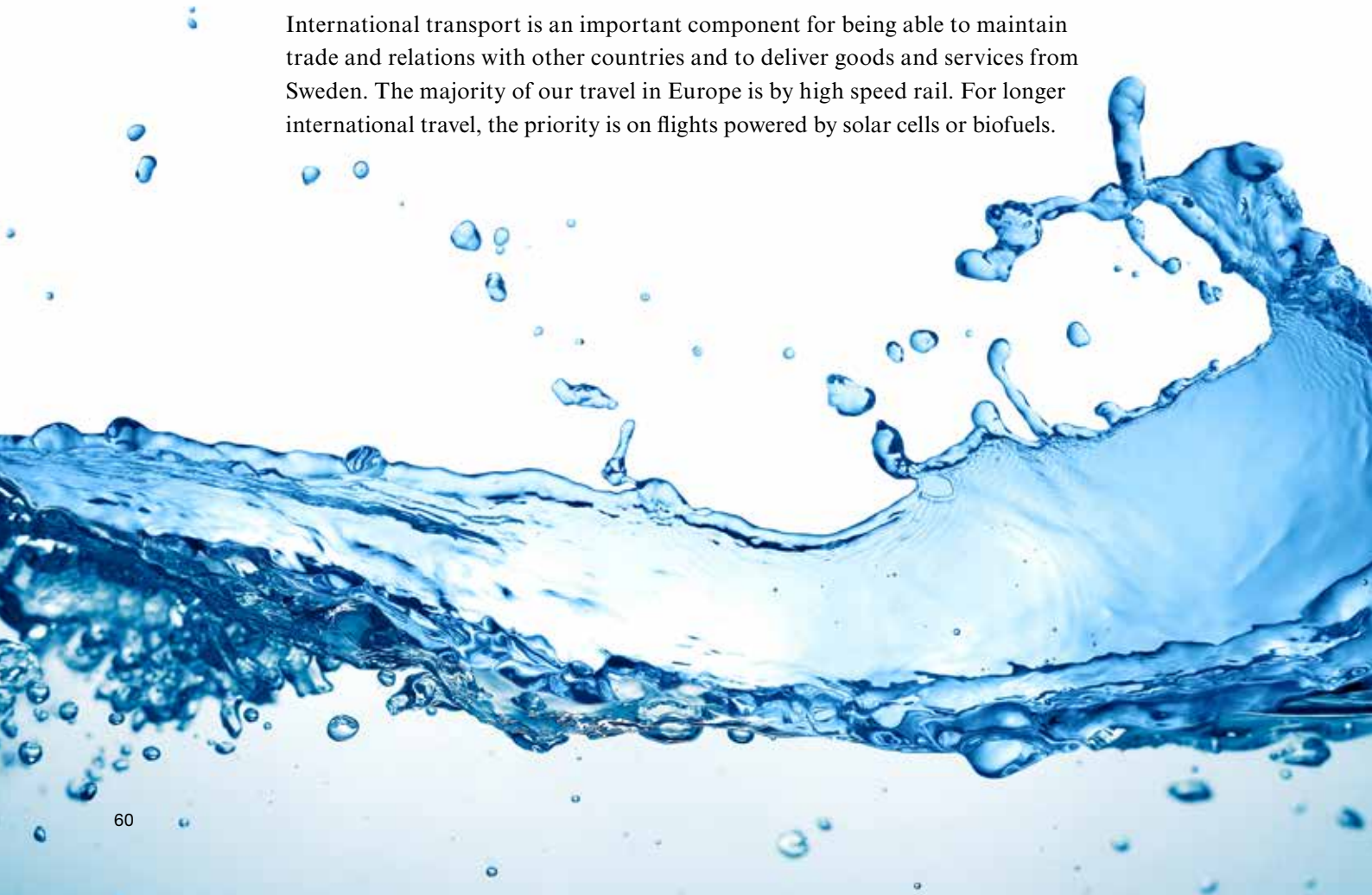
As climate change has significantly changed the opportunities for cultivation from a global perspective, former cotton farmers are now mainly using their land to grow food. This has boosted the Swedish textile industry by initiating close cooperation with the forest industry, and in 2035, they have identified energy-efficient and environmentally friendly processes for making textiles of both recycled and new cellulose fibres.

Transport

Transport based on electricity and various forms of advanced biofuels form the foundation. Public transport with a high degree of capability to handle individual transport needs is created in places where this is profitable. Rail traffic is prioritised, and the government, together with industry, is building high speed rail that connects Sweden with Europe and offers passenger and freight transport. The government is also investing in expanding electric roads on strategic routes of major industrial activity.

Vehicles are more energy-efficient, and longer and heavier vehicles are permitted. The government and industry have jointly invested in starting up domestic production of biofuels manufactured from waste products from agriculture and forestry.

International transport is an important component for being able to maintain trade and relations with other countries and to deliver goods and services from Sweden. The majority of our travel in Europe is by high speed rail. For longer international travel, the priority is on flights powered by solar cells or biofuels.



Energy supply

Using various incentives, the government is investing heavily in renewable electricity production, such as wind, solar and wave power. There are no new investments in existing nuclear power, which will be phased out gradually.

Vivace is characterised by a great enthusiasm for transition. In 2035, Sweden is a test arena for a series of market introductions in the area of renewable energy technology. A greater quantity of biofuels is produced in Swedish factories and shipped across the world.

The government and industry are together initiating several demonstration projects that present the supply, storage, transmission and use of energy as an integrated whole.

Many new branches of industry are emerging. These include the manufacture of power plants for waves and marine currents, new types of highly efficient solar cells and prefabricated house sections that integrate electricity production and storage. One state initiative results in hydropower owners increasing power, which means that the major hydropower rivers raise their maximum output by over 30 per cent.

New system services increase the flexibility of the electricity system, which contributes to a more economical electricity consumption. In connection with the increased share of solar and wind power in the electricity system, the price variations are passed on to the power exchange. This raises the value of regulating and balancing power.

In Vivace, the electricity grid is continuously developed with new technology for control and metering. This is to enable the export of new resource-smart network technology.

The electricity market is well connected with Europe, and "the European single market" is a reality. The temporal resolution on the market is approaching real time, and all trading is automated. The network companies are investing heavily in transmission capacity in the form of advanced DC cables[10] linking Sweden with the continent so that Swedish electricity customers can take full advantage of the European electricity market. This means that Swedish energy producers do not need to resolve all surplus and deficit situations on their own. As Sweden's supply to other European countries includes a large quantity of electricity from wave and current power[11], a greater transmission capacity also contributes to a greener mix in the European electricity system.

The increase in renewable electricity production reduces the proportion of nuclear power in the electricity system. In 2035, the three largest reactors remain, but will soon reach the end of their technical lifetime. However, research is in progress on the fourth generation of nuclear power because it is deemed an internationally important technology. This development mainly has an overseas market in mind, focusing on countries with less favourable conditions for wind power and hydropower than Sweden.

Policy instruments

Vivace is governed more by enabling policy instruments than by policy instruments of a prohibitive nature. However, there are instances of significant regulations to increase the cost of fossil fuel use and other environmentally harmful activities.

Investments in research, development and demonstration are several times greater than today. At the same time, society is characterised by the good ability of relevant actors in the energy and climate sector to harness innovations. The interest in innovative product development is great, and the government has promoted entrepreneurship by reducing limiting factors in legislation.

The system of policy instruments to promote renewable electricity production (electricity certificates) remains in place, and the government provides targeted support for wave power and offshore wind power. The government also supports development in the area of biopower.

10 High Voltage Direct Current Cables are especially efficient for long distance electricity transport.
11 Current power is generated by power plants in flowing water.

In 2050, energy companies produce large quantities of electricity from wind power and cogeneration from biofuels. Nuclear power has been completely phased out. In principle, all construction materials in new buildings can utilise of incoming sunlight, which means that solar electricity accounts for a relatively large share of electricity production. The use of fossil fuels has been almost completely phased out. Sweden has an electricity system with about as much use as production.

By 2050, the transport system has completely stopped using fossil fuels, except for overseas transport.

Looking ahead to 2050

Challenges

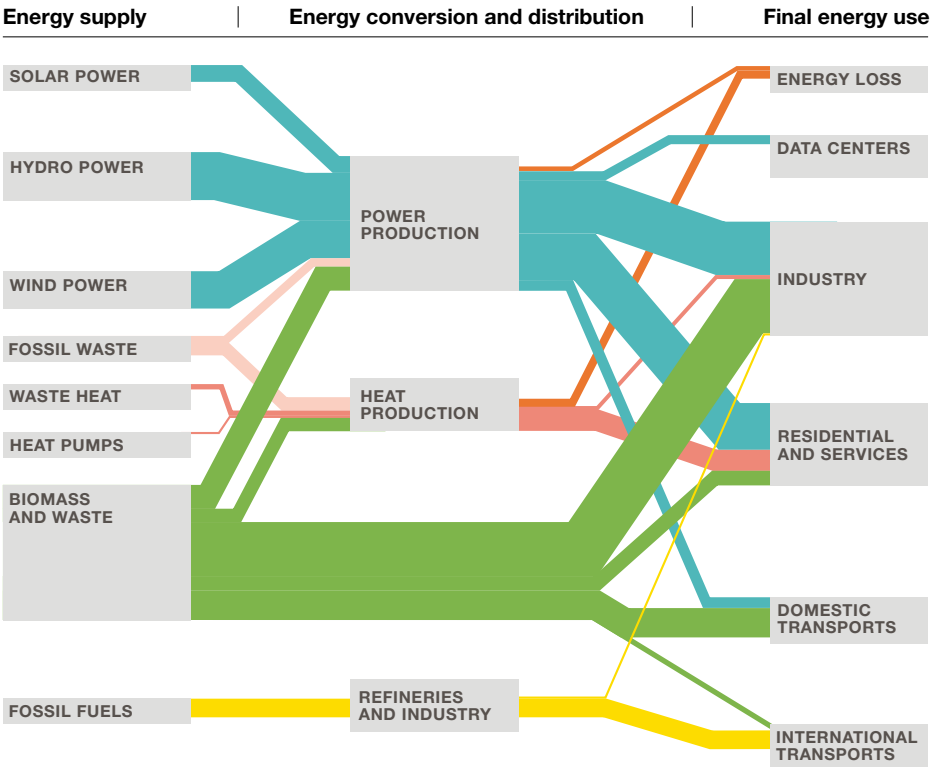
Massive upscaling of new technology
The government must fund major investments in research and innovation, demonstration and commercialisation. How is the government to ensure financing in all phases of the innovation process, for example, after the first pilot factory is ready until a company can begin selling products on a commercial basis?

Energy-intensive and high resource use
In Vivace, a lot of energy is still used, an approach that could be questioned in order to achieve objectives of a lower climate impact.

Use of land for biomass
The major production of bioenergy and biofuels requires large quantities of available biomass. The biomass that is available might not be sufficient to implement all production of bioenergy and biofuels.

High-tech employment strategy
All the development in the energy and manufacturing industries requires many people with the right skills. One challenge is to acquire skills, train people and get enough people into work.

The energy system in Vivace 2050



Comparisons between the four futures

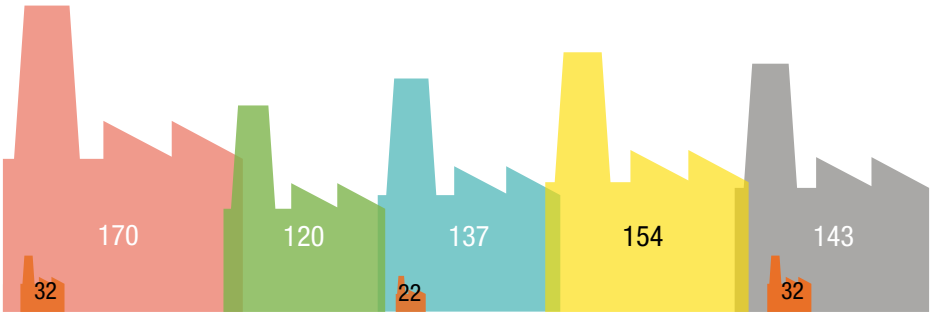
Table of comparisons

	Forte	Legato	Espressivo	Vivace
Main priority	Energy works as a fuel for growth and well-being	Energy is a globally limited resource to be justly shared	Energy is a means to express individuals' lifestyles	Energy is a trampoline for growth on terms dictated by the climate
State's focus	Needs of the industrial and commercial sectors	Fast climate adjustment	Individual solutions	Research and innovation
Energy system	Centralised	Renewable	Decentralised	High-tech
Share of renewables in the energy system	50 percent	Nearly 100 percent	75 percent	Nearly 100 percent
Demand-side flexibility	Limited	Medium to high	High in the own system	High and entirely automated
Solution to peak-load effects	Strategic effect reserves	Centralised governance of effect distribution	Individual/local responsibility for effect supply	The market solves effect situations

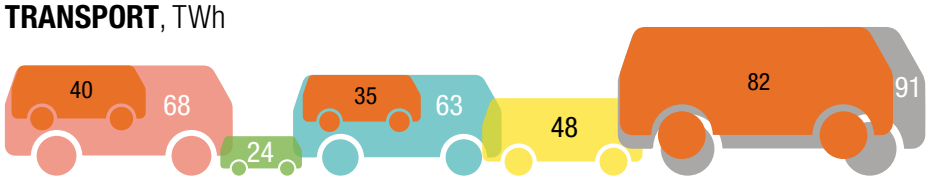
FINAL ENERGY USE 2050 INCLUDING DISTRIBUTION LOSSES

FINAL ENERGY USE 2050 PER SECTOR

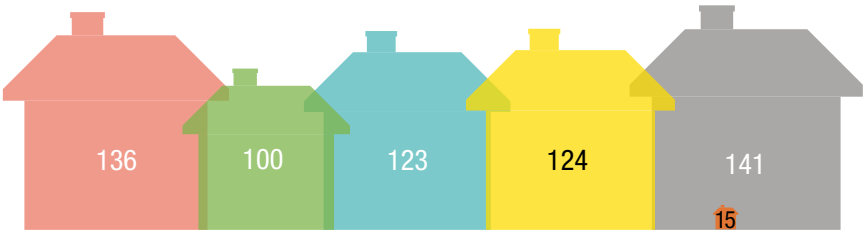
INDUSTRY, TWh



TRANSPORT, TWh

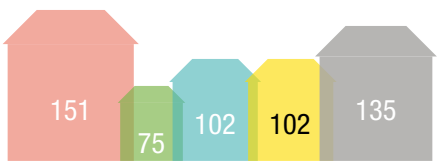


BUILDINGS AND SERVICE, TWh



(SINGLE FAMILY) HOUSES, kWh/m²

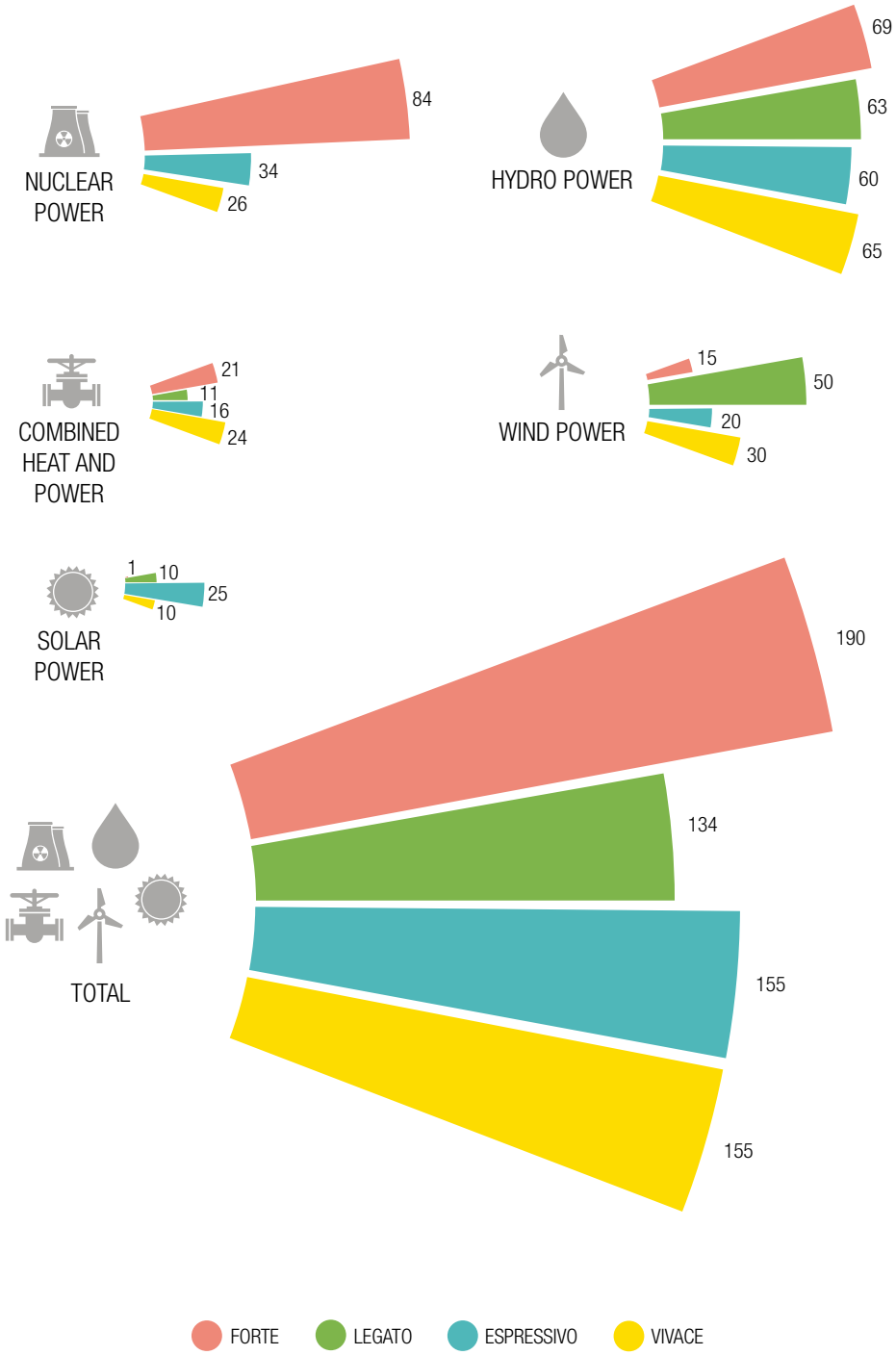
APARTMENT BUILDINGS, kWh/m²



FORTE LEGATO ESPRESSIVO VIVACE 2014 FOSSIL FUELS

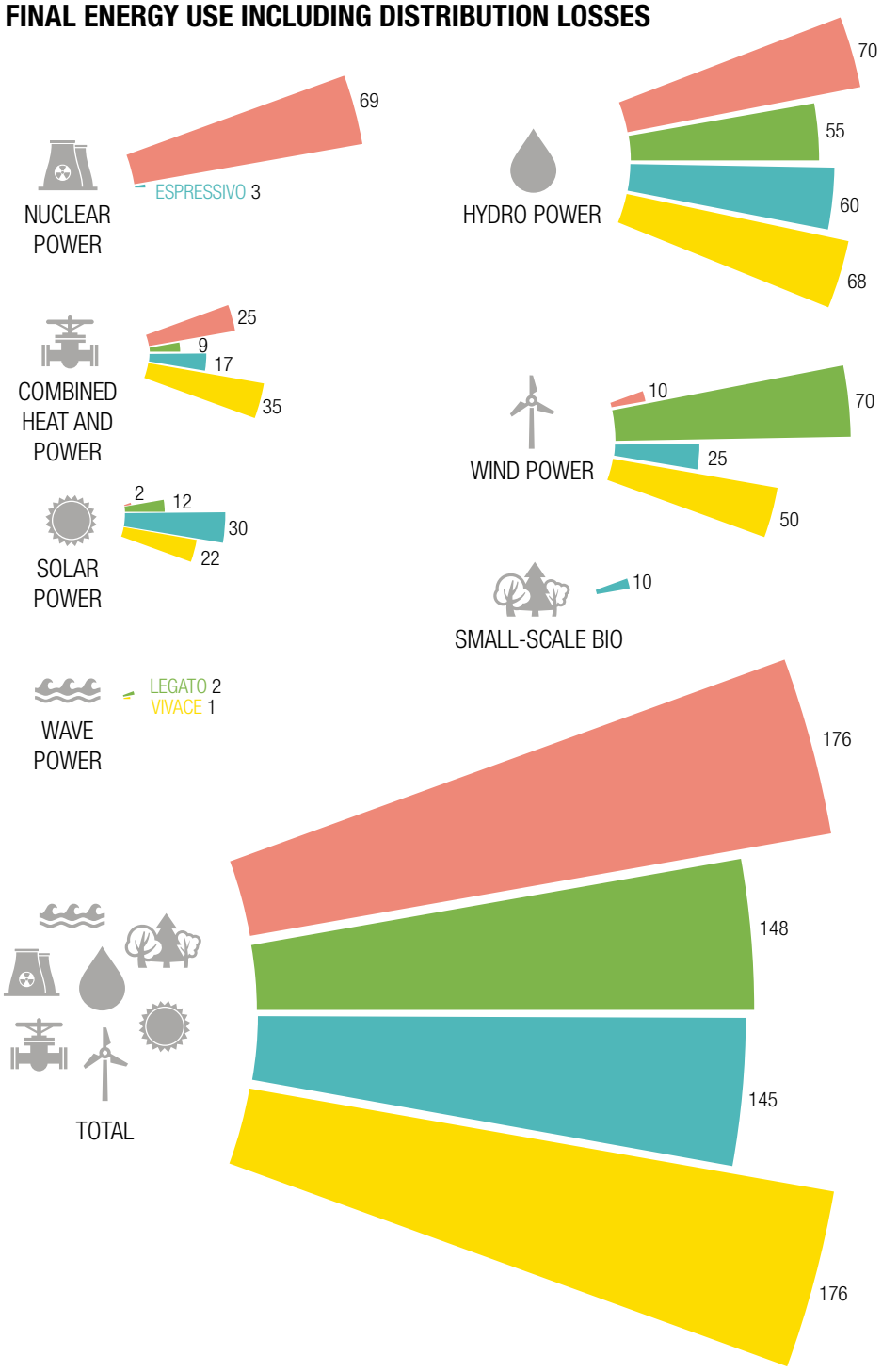
ELECTRICITY SYSTEM 2035, TWh

FINAL ENERGY USE INCLUDING DISTRIBUTION LOSSES



ELECTRICITY SYSTEM 2050, TWh

FINAL ENERGY USE INCLUDING DISTRIBUTION LOSSES



Analysis of the four scenarios

Assessment of electricity system investments and robustness

The scenarios are first estimated without the help of models. Model simulations have then been run in order to simulate the scenarios and to be able to perform impact assessments and identify needs in terms of policy instruments for the scenarios.

The electricity system is international

In order to perform an impact assessment of the electricity system's future development, we must first note that the electricity system is not only a Swedish matter. Sweden has a common Nordic electricity market with cables and lines to our neighbouring countries. For this reason, our project has used two international, existing simulation models for the electricity system, Markal[12] and Apollo[13]. These include the Nordic and European electricity systems in their calculations. The models are based on today's knowledge and market model.

When events in Sweden are tested in these northern European models, it means in practice that only a small part of the parameters in the model is changed. The results for our scenarios may therefore resemble each other despite the fact that Sweden is appearing to make major changes. This is because external factors have a major impact in the models, and these external factors develop in the same way regardless of scenario. All the simulations also have a good energy balance with a large transmission capacity.

The trade and exchange of electricity between different countries and bidding areas is done every hour. In recent years, Sweden has a net export[14] of electricity, and both Markal and Apollo also indicate good conditions for a large net export in the future.

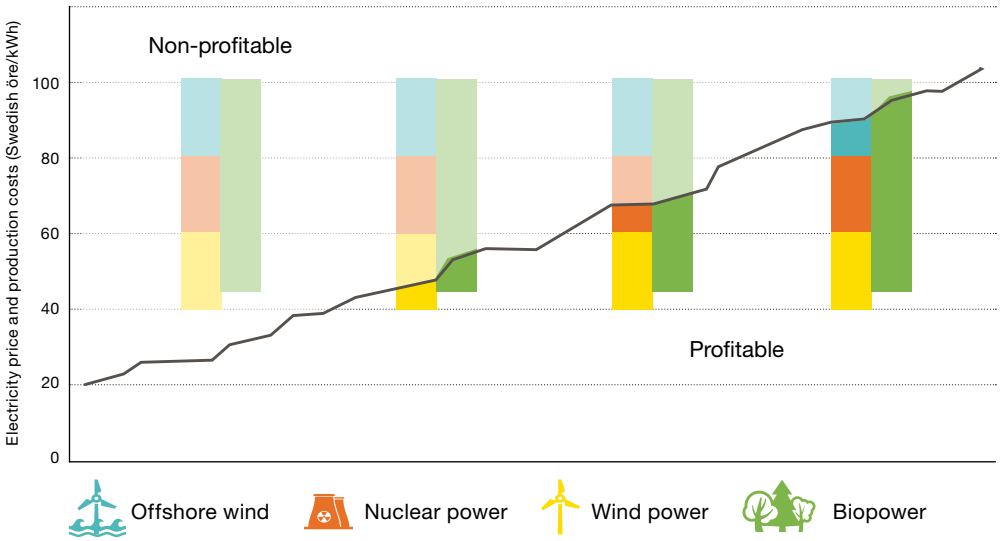
12 Markal is a Nordic energy system model with connections to Germany and Poland, which creates the economically most optimised production mix based on set conditions.
13 Apollo is an electricity market model that simulates the European power market up to the hourly level based on a predetermined production mix. It also gives the price of electricity.
14 Net export indicates an annual figure for how much more export than import of electricity Sweden has had.

All model runs show that in 2035 we will reach a net export of 20–40 TWh. It is above all Sweden's great potential for onshore wind power together with planned additional transmission capacity that will enable the major export in the scenarios.

Electricity prices decisive for investments

The price of electricity in the models is decisive for determining results regarding expansion and profitability the electricity system in the models results in. The figure below shows the production costs for some different types of power, according to our models. With a low electricity price, all production types to be built need some kind of support. When the electricity price rises to higher levels, more and more production types will become profitable to expand without support, only with the help of the electricity price. Solar electricity is not included in this particular comparison since a large part of the solar cells will probably be installed in properties and reduces the quantity of purchased electricity, which results in completely different economic conditions.

Approximation of costs for different power production technologies and showing how the electricity price will be decisive if different power production technologies will be built



Major impact of the price of carbon dioxide price

The simulation results show that the price of electricity will ultimately increase in all the scenarios[15]. Higher electricity prices make it profitable to roll out more electricity production in Sweden without support. Something that has a major impact on the development of the electricity price in the models is the carbon dioxide price that is adopted. Despite the scenarios' completely different production systems, the future price of electricity is at about the same level if the same carbon dioxide price is adopted.

A high carbon dioxide price does not mainly affect production facilities in Sweden, but fossil plants in surrounding countries. Due to extensive trade with surrounding countries, this also increases the price of electricity in Sweden. A rapid transition to renewables in all countries would therefore be able to yield lower electricity prices compared with the model runs, which do not take this into account.

15 Government Bill 2008/09:93 "Goals for future travel and transportation".

The models indicate challenges with the scenarios

The simulations run in the models Apollo and Markal have helped us to notice various challenges that exist for the different scenarios and the expansion of electricity production that the scenarios presuppose. Here we present some of these in brief.

Strong expansion of wind power when the electricity price rises

When electricity prices rise, this results in a strong expansion of onshore wind power of around 70 TWh in our simulations. One explanation is that the otential for onshore wind power with a low production cost is very high in Sweden. The conditions for rolling out a lot of production also exist on account of transmission capacity and the opportunity to export. One sensitivity case in Markal tested what happens if the transmission capacity is limited while other neighbouring countries roll out a lot of renewable electricity. The result was that investments in wind power decreased so that the net export was limited to 10 TWh per year.

Expansion of nuclear power requires support

The construction of new nuclear power to the extent described in Forte requires some form of support for nuclear power, according to our models. It would also require an active stop to the expansion of onshore wind power in Forte. Offshore wind power, which has an even higher production cost than nuclear power in the models, is not expanded without support in any of the scenarios.

Espressivo is a difficult scenario to simulate since many electricity customers choose to disconnect from the network. Our model runs have excluded disconnected production, and the market also appears to function with a smaller quantity of electricity in circulation. But what do micro-grids, batteries and independent electricity production solutions cost? Can the electricity customers remaining on the network expect higher network costs? Will there be less pressure on balance regulation if there are a lot of electricity customers and variable production outside the network? These are questions that we raise but have not been able to test in our model runs.

Plannable production can yield more revenue

For power types such as hydropower and biopower, there is an opportunity to obtain a revenue higher than the average price of electricity since it is possible to plan when these plants produce. According to our model runs, biopower does not produce as much electricity as some scenarios estimated. A decreasing demand for heat in several scenarios, combined with high competition from cheaper district heating production such as waste heat and waste cogeneration of heat and power, means that biopower heat does not become big without additional policy instruments.

The modelled market functions in all the scenarios

The electricity market helps us to match supply with demand for each individual hour in the electricity system. If a given hour has high demand and low supply, this results in a high hourly price. Low demand and high supply yields a low electricity price. It is therefore interesting to analyse how prices vary in the different scenarios in order to see whether the modelled market can cope with all situations.

Variable electricity prices are also considered to be an important driver of flexibility of different kinds. More variable electricity production usually increases variations in the price of electricity. The prices are more stable in Forte than in the other three scenarios. However, the differences between the scenarios are not as great as we had expected. Espressivo and Vivace have about the same number of hours with zero prices as Forte, and the number of hours with prices over SEK 1/kWh is about the same in all the scenarios.

That the prices do not differ more between the scenarios is probably because Sweden is only one part of the entire system, but it could also be due to the models underestimating the variations in a future price of electricity. Based on our results, we must nevertheless draw the conclusion that Nordic hydropower, together with high transmission capacity, provides great opportunities to roll out a lot of renewable electricity production in Sweden.

New production systems place new demands on robustness

One general conclusion from the simulations is that an effective electricity market is a guarantee of good security of supply. Through trading with other countries, there is balance during most hours of the year, regardless of scenario. However, a development with more variable electricity production places demands on the development of flexibility and other stability resources, such as electricity storage, in order for the system to function during all hours.

The four scenarios have handled peak loads in different ways. Forte has a capacity reserve that provides industry with an inexpensive insurance against electricity shortages. Legato's solution is based on demand response, where different electricity customers have signed up for subscriptions that allow central control of their power usage in difficult situations. In Espressivo, everyone takes responsibility for their energy supply and has some level of local collaboration, while Vivace with its automated demand response and rapid trading has a market capable of handling all power situations solely on the market's control signals.

Extreme surplus situations can also arise in several of the scenarios, which need to be managed using export, increased use and in some cases even wasting the surplus. In several scenarios, demand response is important, both in terms of increasing and decreasing consumption. The pattern of electricity use also changes in some of our scenarios, something which our simulations have not taken into account. Several different solutions will be needed in order to manage completely new operational situations.

With more intelligent control systems in the electricity grid, IT security will also become increasingly important. Svenska kraftnät has produced a report summarising possible threats and risks relating to the function of the electricity system[16]. Maintaining integrity also requires robust systems when our homes become increasingly smarter and more online. It is therefore highly likely that there will be a need for new regulations, products and incentives.

16 Svenska kraftnät, 2013 Reference number 2012/331 "Threats to the power sector. Threats to IT, information management, process control and automation." www.energisakerhetsportalen.se/media/1040/Hotkatalog-fo¦êr-Elbranschen-master.pdf

Security of energy supply can be resolved in new ways

Our society will always be dependent on the security of energy supply in order to maintain essential functions and to facilitate good access to electricity and heat. However, what constitutes security of energy supply varies on the basis of the specific needs and circumstances of different energy users. What is satisfactory for one energy user at a given time may, at another time or for another energy user, be completely unacceptable. This is also true in our scenarios. At relatively high costs, Sweden today has very few serious disruptions or power shortages. In the future, we might perhaps be able to accept another level of security of supply, in exchange for other investments or services.

Energy users might assume a greater responsibility for managing disruptions and outages through demand response, for example. This could either be voluntary by means of agreements with users (as in Legato) or of fully automated systems before the disruption reaches the customers (as in Vivace). In Espressivo, the users' own micro-grids with their own control and security systems could be another solution for ensuring a high security of supply.

Depending on the scenario, different methods and tools are needed to achieve the same level of security of supply, and it is necessary to work both strategically and operationally with prevention and mitigation in all four scenarios.

Greater electricity dependence in all the scenarios

All the scenarios show an increase in electrification, thus making society even more dependent on a functioning electricity supply. For this reason, trade and industry, the public sector and households need to increase their future ability to prevent and mitigate the effects of disruptions or cuts in the electricity supply. The more large-scale electricity production is, the greater the risk of more extensive consequences in society when there is a disruption.

Society's increased electrification brings a risk of an overall decrease in the diversification of the energy systems, which in different contexts could increase vulnerability. For example, a car that only runs on electricity is dependent on a functioning electricity supply for charging, while a hybrid car running on both electricity and biofuel will work as long as there is electricity or biofuel.

The effect of weather on electricity production

All the scenarios except Forte move towards an electricity system that has a higher degree of weather dependence. It is important to bear in mind that the models are based on a normal year with a given average temperature and a given precipitation. If a dry year is combined with a year of low wind intensity and a really cold winter, the system will face more challenges than those we have seen in the results. Solar energy corresponds well with electricity use on a daily basis, but less well on an annual basis. For wind power, it is exactly the opposite. Effective storage solutions can help to minimise the risks in years with weather that deviates from a normal year.

Assessment of environment and climate

The four scenarios are explorative and have not been designed to achieve a particular goal, such as reducing greenhouse gas emissions to a certain level. In some respects, the scenarios perhaps also fall short of already set targets and approaches. The scenarios give all actors in society the opportunity to deploy measures to achieve goals within the context of the scenarios, but the conditions for achieving goals, and the priority and effectiveness of the various measures, differ from scenario to scenario.

There are three common areas that are central to managing the environmental challenges in all the scenarios:

- closure of nuclear reactors
- housing construction and renovations, and
- use of biomass.

All the scenarios include both new construction and various degrees of renovation of existing buildings in Sweden. Materials for construction are needed, which results in construction waste. The expenditure of energy and resources in new construction is also a factor to be reckoned with. In several scenarios, there are high demands for energy efficiency in the new or renovated buildings. The health of residents and those otherwise occupying the buildings is a design priority.

Sweden has major resources in the form of forest and agricultural biomass, and also long stretches of coastline where aquatic biomass could be grown in the future. Biomass is a renewable but limited resource, where over-extraction could result in loss and changes in ecosystems, hydrology and climate.
At the same time, fossil resources can be replaced by biofuels. Fossil resources, besides adverse climate effects, have a number of environmental effects associated with extraction and refinement. The table **Opportunities and risks**, page 84, lists the main environmental risks and opportunities for each scenario.

The energy system's direct greenhouse gas emissions

To obtain a comparison between the scenarios' greenhouse gas emissions, we have converted their use of fossil fuels into carbon dioxide equivalents. In 2050, we can see a reduction in the fossil emissions in the energy system in all scenarios compared with the fossil emissions in 2014. In 2050, Legato has the lowest emissions, and Forte has the highest emissions, primarily from industry and the transport sector. Vivace has relatively low emissions as long as biogenic carbon dioxide emissions are excluded.

The scenarios' relationships to existing climate objectives and visions

Sweden has several objectives and visions that it wishes to reach in the medium and long-term perspectives. The scenarios will to varying degrees be able to fulfil these objectives and visions.

The EU's 2030 climate and energy goals

The EU is working to reduce climate impact in a variety of ways. New goals for the period until 2030 were adopted in 2014. Binding goals for 2030 are to reduce greenhouse gas emissions by 40 per cent and for the share of renewable energy to reach the level of 27 per cent compared with the level in 1990. Energy efficiency is to increase by 27 per cent relative to a reference scenario. This is not a binding goal, however.

The new goals have not yet been broken down into national goals. All the scenarios meet the overall requirements, but as Sweden with great certainty will have higher goals, we are instead looking at the already existing national goals in Sweden.

Fossil-free vehicle fleet

Since 2009, transport policy objectives have been in place with the aim to give Sweden a vehicle fleet independent of fossil fuels by 2030[17]. In the scenarios, fossil dependence decreases, but it is only in Legato that transport depends exclusively non-fossil fuels in 2035. Both Espressivo and Vivace have a driving force for good technical solutions. This means that there are great opportunities to further reduce fossil dependence in both these scenarios. Forte's challenges will lie in establishing economic incentives for transport fuels. This is in line with the idea of low energy prices for industry. Electric vehicles will become attractive as a result of technological development and an acceptable electricity price.

In Forte, Espressivo and Vivace, the vehicle fleet is not fossil-free in 2030. There is a need for further measures beyond those already found in the scenarios in order to stimulate new transport solutions based on non-fossil fuels in the near future. The biggest challenge to achieving this goal is found in the Forte scenario.

Net zero emissions in 2050

The climate policy debate has a vision of reaching a situation where Sweden has greenhouse gas emissions with a net zero load. This means in part that certain emissions from a sector can be balanced with a long-term sequestration of carbon, known as negative emissions, from another sector. Forestry has an important function due to this increased sequestration of carbon in biomass in the forest. The potential scope of these negative emissions in the future is difficult to assess, but they will play an important role in the scenarios.

The results for greenhouse gas emissions from the energy system show that Legato is the scenario exhibiting the greatest reductions directly linked to the energy sector. Vivace also exhibits major reductions compared to today's situation, and only limited further measures are needed in order to reduce direct emissions. On the other hand, Forte and Espressivo require significant measures for further emission reductions. The link to the transport sector is important since large parts of the emissions in these scenarios come from fossil fuels.

17 Government Bill 2008/09:93 "Goals for future travel and transportation".

All the scenarios show an increase in the use of biofuel relative to today's situation. Potentially, this could give rise to climate impact, both positive and negative, if carbon balances[18] and land use are affected. If more carbon is sequestered in biomass, for example through effective forest management, this will create a positive effect, but if carbon is instead released into the atmosphere, for example through a reduction in the total quantity of standing biomass, we will see a negative effect. Particularly in Vivace, the use of biomass-based fuels is higher than today, which will have an effect on carbon sequestration. If carbon sequestration in forest biomass also decreases in other scenarios, this will adversely affect the opportunity to achieve the net zero goal and vice versa if it increases. In all situations, fossil fuels give rise to a negative effect. The question of importing energy resources is central since the effects of extracting and producing these imported fuels do not affect emissions in Sweden, but in the country where they are extracted and produced. In Sweden, our forests are an important carbon sink, where carbon is sequestered in biomass.

The potential for various solutions for carbon dioxide sequestration, such as carbon dioxide capture and storage, is great, primarily in Forte and Vivace since in Forte point sources of emissions are more likely and Vivace has driving forces for applying new technological solutions and innovations. Various forms of carbon offsetting in other parts of the world are also a solution that can be utilised in all the scenarios to create negative emissions.

18 Carbon balances refers to how the cycle of the carbon atoms in the ecosystems is affected. If carbon is sequestered in biomass, the carbon becomes "stored".

The 2015 Paris Climate Agreement

The agreement reached in Paris, whereby the world's nations agreed to work to limit global warming to well below two degrees Celsius and to strive to limit it to 1.5 degrees Celsius of warming, places demands on the way in which Sweden develops its energy system in the future. In its interim report from 2016, the All-Party Committee on Environmental Objectives states that by 2045 emissions must be reduced by 85 per cent compared with the level of emissions that Sweden had in 1990[19] in order to approach the goals of the Paris Agreement, and that a system for creating negative emissions must be used to achieve a net zero situation.

On this basis, the Swedish energy system should demonstrate emissions of no more than 10 million tonnes of carbon dioxide equivalents per year in 2050. The Legato scenario is well below this level, and Vivace is in line with this level. Vivace may need to increase the pace of transition. Forte is the scenario that is furthest from the 85 per cent reduction. Measures can be taken in all the scenarios to further reduce emissions. Carbon dioxide capture is viewed as a key technology, both linked to fossil sources of emissions and to facilities that use biofuels. From the perspective of the Paris Agreement, the question of consumption and footprint in other parts of the world will become relevant. Our consumption could drive climate impact overseas, but might also act in the opposite direction if consumption patterns change.

In Forte and Espressivo, further measures will be required to approach the 1.5 degree target. A reduction of greenhouse gas emissions from the Swedish energy sector can be achieved through a shift in technology and a shift in fuel, further efficiency measures and various forms of carbon dioxide capture or storage. Changes to spatial planning, changes to habits and the steering of behaviours, e.g. in transport, and housing design can also yield important contributions.

Especially in the Forte and Espressivo scenarios, the fulfilment of existing goals and visions requires additional strong political initiatives. If we look at what a 1.5 degree target would mean for Sweden, it is Legato and Vivace that fulfil the requirements. However, Vivace must increase its rate of transition in order to achieve the target as early as 2045, which is the year the target is to be fulfilled under the political agreement[20].

19 Interim report of the All-Party Committee on Environmental Objectives "A climate policy framework" SOU 2016:21.
20 A climate and air strategy for Sweden SOU 2016:47, part 1.

The UN's 17 global sustainable development goals

Sweden's energy system affects ecosystems and society both nationally and in other countries. Previous sections of the environmental assessment have primarily focused on effects within Sweden's borders, but have not fully captured effects in other countries. In September 2015, the UN General Assembly adopted 17 global goals for sustainable development, which aim to drive and guide the work for sustainable development.

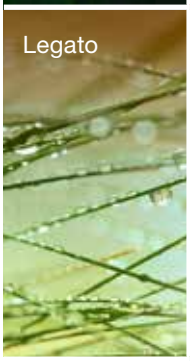
Our four scenarios are linked to the UN's sustainable development goals to varying degrees. Each scenario has driving forces that can be linked to specific sustainability goals. In Forte, economic growth is important, which is found in Goal 8 – decent work and economic growth. In Legato, justice and resource allocation are central, which links to Goal 10 – reduced inequalities and Goal 12 – responsible consumption and production. In Espressivo, there is less of a link to specific goals, but Goal 3 – good health and well-being is close to its driving forces. In Vivace, it is Goal 9 – industry, innovation and infrastructure and Goal 11 – sustainable cities and communities that link most to its driving forces. Goal 13 – climate action is also strongly linked with both Legato and Vivace.

The global sustainable development goals set up important frames to guide strategic choices and provide an opportunity to include effects outside Sweden's and the EU's borders. Sweden is a part of a global system where trade in goods and services takes place continuously. The energy systems described in the present report give rise to a demand for resources and services that not only originate in Sweden. Imports influence other parts of the world – an influence that both can have positive effects in the form of, for example jobs and tax revenues to the government, and negative effects in the form of, for example emissions of greenhouse gases and other negative environmental impacts.

Our scenarios' greatest opportunities for a positive global impact primarily involve the export of innovations, climate friendly products and environmental technology. When we convert to a fossil-free industry and transport sector, we are developing technologies for electricity production and societies with a low climate impact. New storage methods, climate-smart construction and resource and energy-efficient use could yield even more positive effects if the technologies are used globally. But questions concerning organisation and creation of sustainable spatial planning and concerning business models for sustainable trade and industry can serve as inspiration and have a global effect. These opportunities can all make positive contributions to several of the development goals, both directly and indirectly, if they are realised.

Comparison of environmental and climate-related aspects

Opportunities and risks

Scenario	Opportunities	Risks
 Forte	• Reduced risk that areas are exploited for wind energy, wave energy, etc. • Emissions from road traffic decrease with electrification.	• Increased amount of transport. • Increased need of uranium. • Increased amounts of nuclear waste. • Large discharges of waste to air and water as well as landfill waste.
 Legato	• Use of fossil-based resources in the energy sector reduces drastically as early as 2035. The impact on climate decreases. • Consumption declines, thereby reducing environmental impacts in Sweden and abroad. • Circular business models with a high degree of recycling, reusing and re-circulating of natural resources reduces the amount of waste and extraction of certain raw materials.	• New activities in biorefineries and the bioeconomy sector can entail new environmental problems around discharges of waste to air and water. • Land-based wind energy risks increasing the impact on birds, bats and insects. Constructing service roads impacts the landscape.
 Espressivo	• The sharing of products and services can contribute to reduced overall material consumption. • Enhanced livelihood in the countryside where areas rich with forests, soil and water in combination with communities and cities give value to residents.	• Risk for worse resource management and suboptimisation in the energy system with smaller power plants, smart systems and a more decentralised structure. • Increased risk for fossil fuel dependence and large discharges of waste to air as a result of individual decision-making in both the transport and housing sectors.
 Vivace	• Increased risk for fossil fuel dependence and large discharges of waste to air as a result of individual decision-making in both the transport and housing sectors. • With technology development comes the opportunity for technological breakthroughs that potentially could revolutionise resource management and energy systems. Storage opportunities, conversion of solar energy to manageable energy carriers, or nuclear power (fusion and next generation nuclear fission).	• Biomass represents an important resource for industry and the transport sector. Increased risk for negative impacts on forests and agricultural lands. • Increased risk for regulations and environmental legislation falling behind the development. • Risk for larger turnover of enterprises, increased need of ensuring that the liquidation of enterprises occurs while taking account of impacts on the environment.

Qualitative cost assessment

All the scenarios presuppose significant investments of various kinds. A quantitative estimate of total investments has been excluded since, in all cases, this involves complex scenarios with many parameters to take into consideration. The costs that are considered have a very direct link to the energy sector. Calculations of economic costs caused by factors such as inefficient resource allocation and reduced consumption have not been made within the scope of the present investigation.

In Forte, major investments are made in both new and upgraded nuclear power and in electric roads with their associated infrastructure. The costs for this development will largely be borne by the government, but there is also some product development through private actors. In Forte, investment developments are mainly state-driven and are generally reminiscent of developments in the first half of the 1900s, when the government participated very actively in the expansion of major infrastructure projects.

In Legato, developments are also state-driven, but in the form of reduced investments in certain existing structures. At the same time, there is an expansion of other structures, such as multi-lane cycle paths and a reshaping of urban planning. Both revenue and expenditure are decreasing, and a new revenue model for the government will probably have to be developed.

In Espressivo, there is a strong shift of financial responsibility from the government to regions, municipalities and individuals. It is likely that these actors will also be responsible for the local reinforcement of, for example, electricity grids that will be involved in the scenario, as well as other energy-related investments. Since such solutions are mainly local, it is difficult to try to assess their consequences for the picture as a whole. It cannot be ruled out that the total costs will be higher in this scenario than in the others, since similar investments will be made in several places at the same time and since the cost aspect can force actors to choose less suitable solutions.

Vivace is characterised by very extensive investments both from the government and from trade and industry. This scenario must also anticipate significant depreciations, since many new technologies will not see a breakthrough. Some form of state guarantees is needed, either for producers or for investors in infrastructure-related projects.

All the scenarios are thus associated with extensive and largely unknown costs. There is reason to point out that many of the costs would also arise if Sweden were not to actively follow any of the scenarios, but were to continue with today's plans.

Sensitivity analysis of critical external factors

One starting point in our scenarios is that the outside world is assumed to be more or less the same, while the causes of the differences between them are primarily opinion and policy. Common, but changing, external factors have been described in the section named **Conditions that the four futures have in common**. In order to assess how robust or sensitive the different scenarios are to external changes we have performed a sensitivity analysis for a number of variable external factors. The external factors we have analysed are the influence of global climate agreements, the EU's role and influence on Sweden in the four futures, the consequences of a global financial crisis and also how a serious disruption of the energy markets affects the scenarios. We have also tested how the political decision to re-regulate and re-nationalise the market affects our scenarios.

A changed security situation would seriously affect all the scenarios, for example, as regards trade, information security and production capacity. No detailed analysis of this is included in the present study, but it is an important external factor, and an in-depth analysis would be of interest in further work. On the following page there is a summary of the results.

Sensitivity analysis of critical external factors

	Forte	Legato	Espressivo	Vivace
Strong climate agreement	Weakens the scenario ↓	Strengthens the scenario ↑	Little effect on scenario	Strengthens the scenario ↑
Climate negotiations collapse	Little effect on scenario	Weakens the scenario ↓	Little effect on scenario	Weakens the scenario ↓
Strong European Union	Can both strengthen ↑ or weaken ↓ the scenario	Can both strengthen ↑ or weaken ↓ the scenario	Can both strengthen ↑ or weaken ↓ the scenario	Can both strengthen ↑ or weaken ↓ the scenario
Weak European Union	Weakens the scenario ↓	Weakens the scenario ↓	Little effect on scenario	Weakens the scenario ↓
Global financial crisis	Weakens the scenario ↓	Weakens the scenario ↓	Weakens the scenario ↓	Weakens the scenario ↓
Serious disruption of energy supply	Weakens the scenario ↓	Weakens the scenario ↓	Weakens the scenario ↓	Weakens the scenario ↓
Electricity markets are re-regulated and re-nationalised	Strengthens the scenario ↑	Weakens the scenario ↓	Strengthens the scenario ↑	Strengthens the scenario ↑
The electricity market is completely open	Strengthens the scenario ↑	Little effect on scenario	Little effect on scenario	Strengthens the scenario ↑

In the sensitivity analysis, society responds to an external change or disruption of some kind. How each scenario succeeds in managing this change depends on the scenario's previous development and focus. Some external factors have the potential to upend the development in one scenario, while another scenario is relatively unaffected or strengthened in its development. Identifying potential "game changers", producing action plans and adapting to the external changes is central to continuing to drive developments in the desired direction, even in a changing world.

Discussion

Each of the futures we have painted has its own challenges. Depending on the priority in the scenarios, our four futures have to handle different specific opportunities, but also specific challenges. We see the need to raise the following questions in the discussion we wish to start with politicians, decision-makers, energy actors and the general public.

Spatial planning is everything

The spatial planning that is done today and tomorrow has a central place in all our scenarios, as this determines the way in which we use energy in the future. How cities are designed for housing, how we organise transport and the accessibility of service all affect how much energy we use in the future.

How will Sweden convert to a fossil-free transport system?

Implementing fossil-free domestic transport in our scenarios will require major changes in the supply and use of energy in the transport sector in a very short period of time.

The transition of the transport system places great demands on all actors in the system, from politicians and other decision-makers to all the technology providers involved in the transition and individual consumers who also must contribute.

Energy use must decrease, partly through efficiency measures, but above all through various initiatives to reduce transport needs. In order to meet the objectives, a political decision must be made as early as 2020 to phase out all fossil fuels.

Domestic aviation and shipping presents a hard nut to crack

The use of fossil fuels in aviation and shipping today is virtually 100 per cent. These forms of transport represent an increasing part of the climate impact from the transport sector.

There are good opportunities for political influence, for example, by introducing a tax on domestic flights in order to even out the taxation on different domestic modes of transport.

In the case of shipping, the government could introduce national support to get the industry to reduce its emissions. Speed limits and support for biofuels in shipping could reduce fuel use and emissions.

Overseas aviation and shipping – primarily an international issue

Sweden can contribute by advancing research and innovation in ship design and the development of alternative fuels. Reduced transport on a global level is also a key to reducing dependence on fossil fuels.

How are we affected by electricity production in the rest of Europe?

The type and size of the energy supply system created in the rest of Europe is decisive for the optimal design of the Swedish energy system. If countries that are interlinked with the Swedish electricity market roll out a lot of renewable electricity, for example, this could result in a fall of the price of electricty so that it becomes less profitable to expand more expensive production in Sweden, such as offshore wind power or new nuclear power. This would also reduce export opportunities. All our simulations indicate a higher price of electricity in the long term during the period 2035 to 2050.

The future price of electricity affects the development of the energy system

A low price of electricity can result in production that is discontinued before the technical lifetime has been reached, and that investments in new facilities that do not materialise. High prices can cause electricity use to decrease or industries to relocate. It is not sustainable in the long term to have extreme price levels. With a low price of electricity, all the types of production to be built need some form of support to be economically possible. If the price of electricity rises to higher levels in the long term, more and more types of production will become profitable to establish using the price of electricity alone.

More flexible electricity network and electricity market part of the solution

Depending on future developments, the electricity network will vary in significance. In some cases, the local network might have a much greater significance than today, with the establishment of micro-grids and greater self-sufficiency.

The national grid might become less significant nationally but more significant internationally as a major exporter of electricity in the form of regulating power. It is an important challenge for the government to adapt to these changes, while also controlling and planning for major infrastructure investments, spatial planning and changes in regulations.

Systematic and increased energy efficiency part of the solution

Energy efficiency is increasingly portrayed as a "fuel" in its own right. The IEA's Energy Efficiency Market Report[21] shows that energy savings within IEA countries in 2011 were greater than supply from any other single fuel, and so energy efficiency is sometimes called "the first fuel".

There are multiple values to energy efficiency beyond the energy saving itself. For example, less fuel use in cars can contribute to better health in cities. An investment calculation should include all benefits in order to estimate the total value of the energy efficiency improvement.

Demand response gives stability in the electricity network

There is great opportunity to use electricity consumers to reduce the need for power during peak load. Developments within digitalisation make it easy to disconnect from everything but essential electricity use, for example, during peak load. Demand response traditionally means an electricity user postponing consumption, but properly applied can also save kilowatt-hours. The future may see progressive electricity contracts where customers agree to be disconnected from the network should the need for this arise. It is also possible to introduce national taxes on international aviation.

21 Energy Efficiency: Market report 2013: Market trends and Medium-Term Prospects. IEA, 2013.

The quantity of waste in the energy system can vary greatly

Even if a greater degree of recycling and better product design decrease waste, there is a certain fraction of waste left that probably cannot be used at all other than through combustion for electricity and heat production. In some scenarios, the quantities increase compared with today, and electricity and heat are produced from both domestic and imported waste. A certain proportion of this waste is fossil.

The scenarios can be fitted with other energy systems

In the models we have used, the price of electricity has steered the actual design of the electricity system; types of power that are inexpensive to invest in are built before those requiring greater investments. Different policy instruments, such as high carbon dioxide tax, greatly affect which type of production the simulation models will propose to be built in the future.

Security of energy supply in the energy system of the future

All the scenarios require secure energy supply in society, including for trade and industry, the public sector and households. The need is likely to grow with the increased integration of computerised control systems. But how the energy systems in our scenarios meet the new needs is determined by a combination of political decisions, the security situation, technological developments and how our behaviours and patterns of use evolve.

Research and innovation contribute to fulfilling climate objectives and global development goals

Without research and innovation, especially for the transition of the transport sector and industrial processes, the global development goals will not be met. The scenarios that meet the climate objectives and that want to retain and develop Swedish industry have made extensive investments in research and innovation.

Expertise contributes to research and innovation

Many of the scenarios are based on the fact that Sweden has strong research, innovation, demonstration and commercialisation. A strong trade and industry also develops the energy system. Sweden, a country with a small population from a global perspective, must harness the expertise found among our citizens, and there is perhaps a need for labour immigration.

Key findings

NO 01

Policy instruments are needed

In all the scenarios, it is clear that policy and various instruments are necessary to shape the future according to the priorities determined. The simulations also show that support is necessary for the technology that will be needed for electricity production. The simulations' most profitable choices do not always coincide with the scenario's chosen production technologies, which are based on a mix of economic and political priorities.

NO 02

Regional and spatial planning have great impact on future energy demand

The coordinated planning of infrastructure and building is of utmost importance for being able to fully adapt to a sustainable society. The whole of society is affected by a change in the focus of energy policy, which is most evident in the Legato and Espressivo scenarios. There, spatial planning has been actively designed according to new priorities for, e.g. people's transport needs and methods, which are different compared with today. In Forte and Vivace, there are major investments in infrastructure projects, such as electric roads and high speed rail. This strongly affects the energy use in these scenarios.

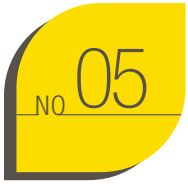
NO 03

Great potential for electricity export

Sweden has good conditions for producing electricity with low emissions and at low costs thanks to favourable access to natural resources. Several of our scenarios with different electricity production systems show a good potential for high electricity exports. It is above all Sweden's opportunity to build competitive wind power combined with hydropower and increased transmission capacity that could make major exports possible. Sweden might also assume a new role as an exporter of regulating power.

Sweden is greatly affected by the outside world

The energy system in Sweden is not isolated, neither from other energy systems nor from other events in the world around us. Our scenarios' energy systems are all more or less sensitive to external changes depending on which external change occurs. Identifying potential external factors that could be "game changers" and being able to adapt to the changes is central to continuing to drive developments in the desired direction, even in a changing world.



More diversified energy systems with more actors and services

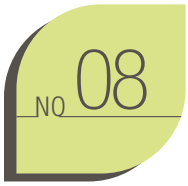
Many existing regulations and markets are, for example, adapted to large-scale electricity production. Some of our scenarios develop a more diversified energy system with more decentralised and small-scale electricity production. The energy systems in some of our scenarios are also becoming more integrated. The same actor can be a producer, user and serve as energy storage. Some examples of greater integration are industries that more actively help to balance the electricity network, buildings that store heat in their facades and district heating networks that store energy by converting electricity into heat in times of surplus production. More actors will be involved in the energy markets, and digitalisation gives rise to new services. Legislation needs to be adapted to these changes.

The transport sector gains a stronger connection to the rest of the energy system

In our scenarios, the transport sector gains a stronger connection to other energy sectors due to the increased electrification of the vehicle fleet, the establishment of electric roads and the greater use of biofuels. Converting the transport sector presents us with several challenges, such as replacing the vehicle fleet, building suitable infrastructure and creating political and economic incentives for change. This makes the transport sector a key in the design of a future sustainable energy system.

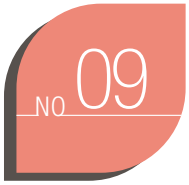
Electricity an increased part of energy use

In several of our scenarios, there is an increase in electricity dependence, and this increase takes place in several sectors. Some comes from industrial processes converting to electricity, and some from the establishment of electric roads and more electric vehicles. Greater digitalisation and IT development make our scenarios even more dependent on electricity. At the same time, electricity use can vary rapidly as more actors can more quickly adapt their consumption to the price of electricity, which may entail a need for new models to control and calculate electricity use.



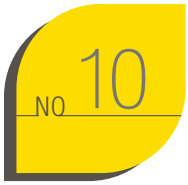
Energy efficiency facilitates a sustainable energy system

In our scenarios, the improvement of energy efficiency, for example in buildings and industries and the reduction of fuel use in vehicles, is an important factor in the transition to a sustainable energy system. Improving energy efficiency in all parts of the energy system can significantly reduce energy use and energy losses, which also helps to reduce the energy system's environmental impact.



Research and innovation for a globally sustainable future

Investments in research and innovation are fundamental in our scenarios. For example, innovations are needed to enable the scenarios' investments in bioclusters in order to expand our opportunities for reliable and renewable electricity production, a transition to sustainable transport systems, biogenic carbon dioxide capture and smart grids. It is clear from several of our scenarios how interconnected energy research is with the climate issue. Research in Sweden has a ripple effect overseas when technology is exported and used all over the world. More international research transition and exchange of experience can help to speed up, and reduce the costs of, the transition of the energy system, both at the national level and where Sweden wishes to contribute globally.



Robust measures are needed to achieve the climate goals

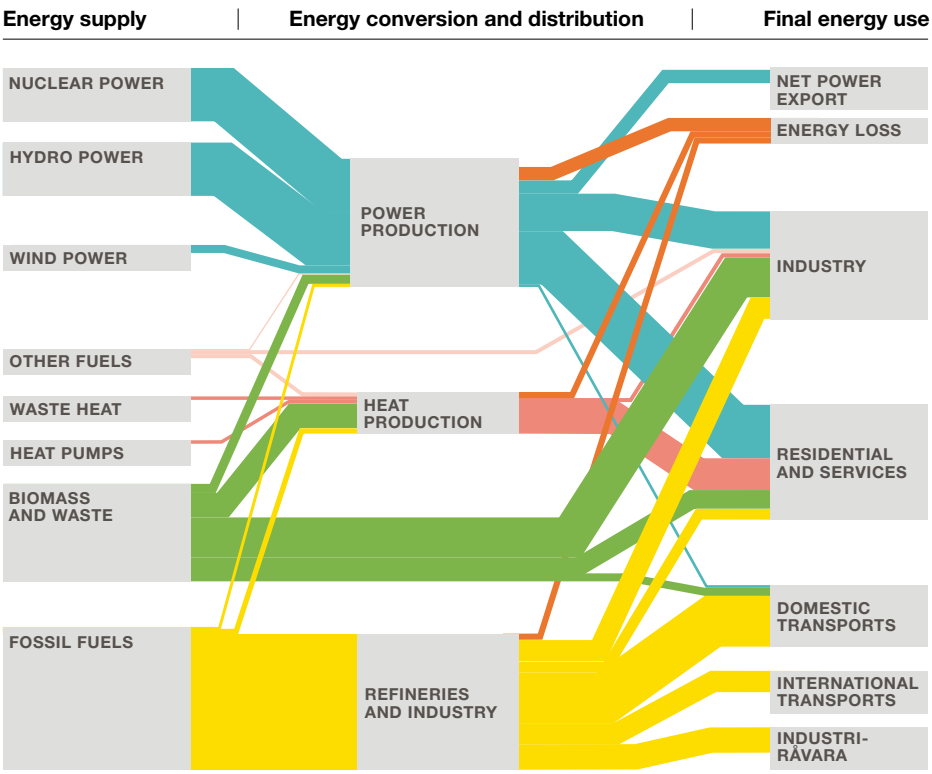
If we are to fulfil the terms of the climate agreements, robust measures are needed in all areas. Our scenarios are explorative and not performance-oriented. All the scenarios reduce emissions compared with today, but it is only two scenarios, Legato and Vivace, that reduce them sufficiently to fulfil the global climate agreements on reduced emissions by 2050 in accordance with the interim report of the All-Party Committee on Environmental Objectives. These scenarios include robust measures, large investments and a major transition from the society we have today.

Meeting the UN's global sustainable development goals is strongly dependent on the development of the energy system

Our future scenarios clearly show how developments affect the ability to meet the UN's sustainability goals in Sweden by 2030. It is important that the energy discussions are linked the energy discussions to Sweden's implementation of the sustainability goals, where twelve of seventeen are directly linked to the energy system. Viewing Sweden's energy systems, emissions and future growth as a national issue is of no interest if we want to operate in a global arena and contribute globally to climate and sustainability goals.

The Swedish energy system year 2014

Energisystemet 2014



We want to talk future energy

“Four Futures” represents our contribution to a modern energy dialogue that adopts a holistic approach and a societal perspective. We want to have a discussion about energy that points forwards.

So what does the future look like? There is not just one answer, but several. Here, we present four possible futures for the Swedish energy system. Each future has different driving forces that shape society, such as security of energy supply, global justice, individualism or climate improvement. We call them Forte, Legato, Espressivo and Vivace.

Welcome to a new and different conversation about the energy of the future.

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