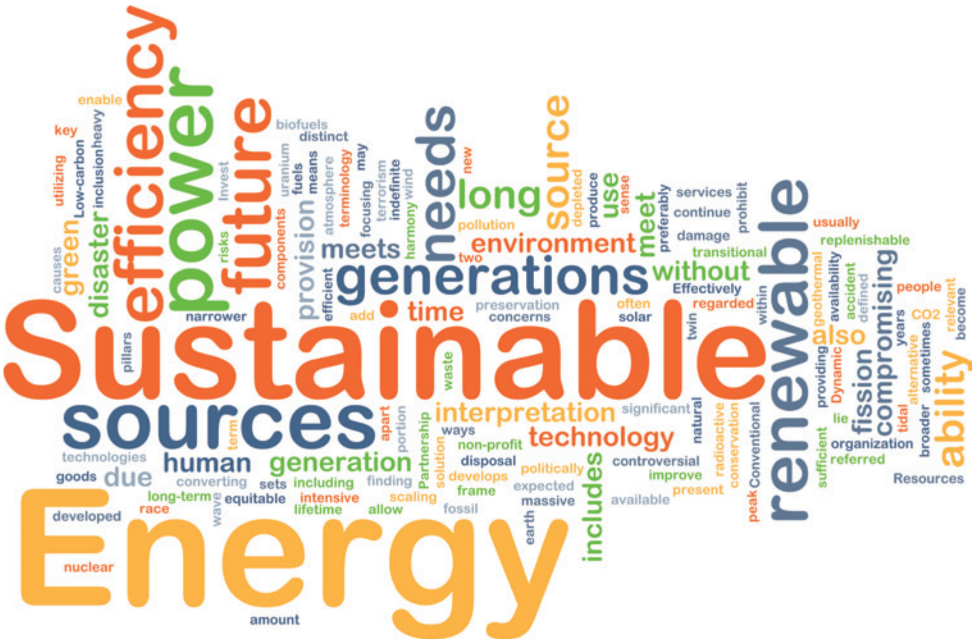

Our Electricity: What Really Lies Ahead?

Mechanisms of tomorrow's electricity system and its new regulatory framework – a Nordic perspective

A publication from Svensk Energi – Swedenergy
By Johan Lundqvist, Licentiate of Engineering

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SVENSK energi

FOREWORD

All aspects of operating and managing today's energy systems are in fact overseen to a large extent by authorities and politicians, at every level. Directly and indirectly, this has an impact on customers and on the community at large. In the electricity sector, Sweden and the Nordic region have a first-rate power generation and distribution system, which in many respects constitutes an international role model. The electricity market also functions efficiently. Sweden enjoys 97 per cent fossil-free electricity and 99.98 per cent security of electricity supply. In Europe as a whole, 30 per cent of electricity is likely to be renewables-sourced by 2020. The European Commission's goal for 2030 is a 27 per cent share of renewables within Europe's total energy consumption, with carbon dioxide emissions 40 per cent lower than in 1990.

Electricity constitutes a solid pillar in the building of a truly sustainable society for tomorrow. Huge strides ahead on climate and the environment can certainly be achieved through investment in electricity-based energy solutions. With electricity everything becomes possible!

But….. We see that rapid developments on the international scene are driving change, some of which is already with us. Many politicians see an increase in the market share of renewables as the solution for meeting climate goals. This can be regarded as Mega Trend No. 1.

Investment in wind and solar power, which in European terms are counted as the mainstream renewables, is already having a tangible effect on the operating of power systems, as well as on the electricity market. This is not surprising since renewables are weather-dependent and their use cannot be planned in advance. In the Nordic countries, it should be noted, hydroelectric power also counts as renewables-sourced.

In many countries, wind and solar power generating units are going to be given priority dispatch in the electricity grid, simply because there would otherwise be no ”green” transition. This is why existing large-scale production facilities – or those handling what we call “baseload” or ”capacity” generation – will play a different role in a future with more wind and solar power. In Germany, for instance, the impact of this can already be seen in the devastating effects on the profitability of the country's major generating facilities.

Prioritising renewables can certainly be viewed as logical because it will be impossible to achieve environmental and climate targets if such sources of electricity do not replace fossil fuels. Politically, however, it may well be hard to turn a blind eye to the notion that renewables-sourced power production without subsidies may be unrealistic, given that production costs are often significantly higher than when using other energy sources. And it should not be forgotten that the weather-dependent intermittency of renewables power generation calls for backup generation capacity, which, in turn, adds more cost to operating the system. We can nevertheless expect electricity grids and market mechanisms all around Europe to be affected significantly by efforts to meet European Union (EU) climate targets.

In Mega Trend No. 2, what we are seeing is a shift on the customer's side towards smarter solutions and more active involvement, i.e. more flexibility. At the EU level, a comprehensive regulatory framework – Network Codes, also known as Grid Codes – is emerging because of the new situation arising from the need to handle increasing volumes of weather-dependent power. Where customers' interests are concerned, this framework should also harmonise network operations and pave the way to a European internal market for electricity. The regulatory framework, designed along new lines to meet tomorrow's needs, can be seen as the starting point for what are known as “smart grids” and “smart” solutions.

Everybody needs to act in response to this transition, be they decision makers, officials within regulatory and other authorities or executives responsible for electricity companies, large or small. My aim in this paper is to describe what is going on in Europe, to outline how things will look tomorrow and to describe the mechanisms that need to be taken into account. In fact, most of these mechanisms are fundamental laws of physics that lay the groundwork for designing and operating power systems. These mechanisms cannot be ignored. The current and evolving situation in continental Europe could also become the future situation elsewhere in Europe, notably through the direct and indirect impact of future compliance of domestic power systems – and those of neighbouring countries – with various aspects of the Europe-wide regulatory framework under construction.

In addition to Network Codes themselves, more rules can also be expected in adjacent areas such as: support schemes for renewables and, most likely, capacity power; transparency in electricity trading; and rules governing the role and influence of customers within the system. In brief, the newly designed systems and regulations are certainly going to have an impact on everyone. Good or bad? We must all judge for ourselves. But the future has to be addressed.

At the end of the day, will there be a Union-wide EU solution? Or will there be many individual national solutions? In which case, what will remain from the past? And who will pay? And what about climate? Whatever happens, if the system is to adopt a new orientation, adjustments will be needed in most of its domains, bringing inevitable consequences. In this perspective, new rules and tools will doubtless be required. However, the whole picture will certainly have a strong continental European profile, which may perhaps not necessarily be beneficial for countries outside the continent.

The purpose of this publication is to share the experience of our Nordic countries and offer our viewpoint regarding what is happening in the electricity sector now and what we see approaching fast. Our aim is to inform the key players: industry employees, decision makers, the media and of course customers. It is therefore important to underline that this is not a position paper. We simply present a picture of how tomorrow's electric power system could evolve – or could need to evolve – as current policy objectives and near-term political vision become reality. This picture covers the mechanisms integral to the system, as well as the roles of customers and other involved parties. But much of what we sketch out is based also on developments in several European countries which are already experiencing the situation as it will be tomorrow. The changes will be far-reaching. We hope that what we outline will contribute to answering many of the questions now being asked, and that other prevailing concerns are addressed.

My colleague Kalle Karlsson, Swedenergy's Head of Communication, contributed much important expertise in helping me draft the description that follows of how tomorrow's power system could look. Valuable comments and drafting assistance with the Executive Summary were provided by Bengt Magnusson, long-standing European Correspondent and Editor-in-Chief of the magazine ERA.

I myself am Sweden's electricity industry representative and expert in the ongoing development of the new regulatory framework – Network Codes – in Brussels.

Your comments on this paper would be most welcome. Contact details can be found on the last page.

Spring 2014

Johan Lundqvist
Licenctiate of Engineering

EXECUTIVE SUMMARY

The financial crisis and severe economic hardship facing people in some EU member states are today setting the political agenda for Europe. In parallel, policy is driving vigorously towards an EU-wide electricity market. Simultaneously, we have seen considerable fragmentation between the respective energy policies of individual countries in recent years, especially during 2013. This process is totally at odds with the core ambitions of the EU.

Meanwhile, an entirely new set of rules for the European electricity system is materialising in order to facilitate integration of large new amounts of renewables-sourced power, all in accordance with the agreed objectives of what is known as the EU's Third Energy Package. At the same time, the role and influence of the customer are growing, as are calls for greater transparency. There is also much debate about subsidies for renewables power, as well as for capacity power that must be kept in place within the power system.

Against this backdrop, it is important to underline that any conclusions about the nature of tomorrow's electrical system that are based on how the system functions today would be hasty and ill-informed. Where risks are concerned, these certainly exist in relation to the current system, and they will still be there tomorrow. But tomorrow's risks are likely to be of much greater magnitude and will certainly be more complex to manage. New opportunities, however, will also open up in the short term. At all events, tomorrow's electricity market will certainly look different from today's.

One of the major reasons is how the system will be transformed to integrate renewables-based electricity generation. More, new types of marketplace will be needed, for instance introducing the innovative balancing markets under discussion, as well as capacity markets. One of the most important wide-scale changes will be a new, expanded range of flexible services where large and small electricity customers are also producers (known as "prosumers"), and where they become actors in the functioning of ”smart grids”. We can also expect to see exchanges of support services between grid owners and between customers and grid owners.

Clearly, everything points to increased costs on the horizon. But substantial, entirely new business opportunities are also part of the scenario.

Tomorrow's electricity system will be of dramatically greater complexity. Figuratively speaking, the system will be turned on its head: power and energy will flow upwards in the system, as opposed to the way it functions today. This is what is new and a major joint effort will be needed to ensure that the transition is a smooth one. The question is how to build a system that is sensible and sustainable from every angle. Responsibility for this lies with the politicians. And, because the significant climate dimension must be factored in, it will be a heavier responsibility henceforth than ever before in history.

The challenge is thus to solve the extremely tough equation embedded in the goal of enabling the system and its customers to meet environmental and climate targets in a long-term, sustainable and viable manner. In the resulting panorama of the future, we see various prominent features: new roles, new services, new patterns of behaviour, greater competition, larger financial risks, new tasks and widespread technical adaptation, as well as tomorrow's oversized production fleet. Each of these areas involves major, complex issues.

What is very clear is that electricity will play a significantly larger role in the modern society of tomorrow. **To what degree will the policy goals be met, and what will be the repercussions on the current energy market? We do not know. But, for sure, the most unlikely scenario is one where everything remains as it is today.**

ONGOING ISSUES

- How will tomorrow's electrical power system look? How will it function? Around the globe, the race is already on for big footholds in openings for renewables electricity production, harnessing solar, wind and tidal energy. This alone signals huge changes. The policy goal is to eliminate most of the emissions currently released into the atmosphere. As a result, because the share of renewables is expanding sharply around Europe, there will be increasingly stronger pressure on the traditional production technologies that constitute baseload power generation, using hydroelectric sources, nuclear power, coal or gas.
- While the objective at EU level is an internal market for energy, notably through the Third Energy Package, events seem to be moving in the totally opposite direction. More and more countries are facing internal challenges that they regard as higher priorities than EU-wide priorities. This is leading to electric power systems with increasingly national characteristics and regulations. The question is whether this is good or bad, or perhaps even whether it is a natural situation.
- We are at a crossroads for conceiving an electricity system for tomorrow that will maintain security of supply, freedom of choice for customers, new services, flexibility, and yet more. But where is this leading us? Do we really need to go this way? What will it cost? And how will the roles of customers and other stakeholders change?

A BIT OF HISTORY – the birth and expansion of the electricity system

Today's power system and its historical growth record will play a major role in future power systems for a long time to come.

Energy systems exist at all geographical and electrical levels. But they start at home, and with you and me. Way back in history, the original energy system took the form of heating for homes. Electrification from the early 1900s onwards opened the door to all sorts of new uses and applications, such as lighting, refrigeration or freezing, washing and cooking. Building on this throughout the 20th century, energy systems became increasingly complex, and increasingly nation-wide and global. An electric power system is of such intrinsic complexity that it is regarded as one of the most complicated systems created by mankind.

In the developing world, many populations have far to go in terms of energy, and they lack access to electricity or modern sources of heating. For them, day-to-day survival is the main concern. But in the industrialised world, the arrival of electricity has provided the key to today's industrially developed society, a far cry from the poverty of agrarian life. Electricity has brought a better lifestyle. It has been the passport to a warmer, brighter, easier, safer and more enjoyable existence. In short, with electricity, everything has become possible.

BALANCING OF CONSUMPTION AND PRODUCTION – an absolute must

An electric power system is a physically living system. If it is to function, consumption and production must be in balance at every second. This is fundamental.

If we look at Sweden, large areas to the north of the country were deforested during the late 1800s, as a consequence of growing timber requirements for emerging heavy industry and for people's use as an energy source. In those days, householders burned wood for heating and cooking purposes.

Every energy system is a closed system. At all times, there must be a balance between production and consumption. If there is too much wood in the stove, it becomes too hot and *vice versa.* In other words, if the temperature is to be just right, then the amount of wood must also be just right. Electrification provided solutions for numerous difficulties and needs.

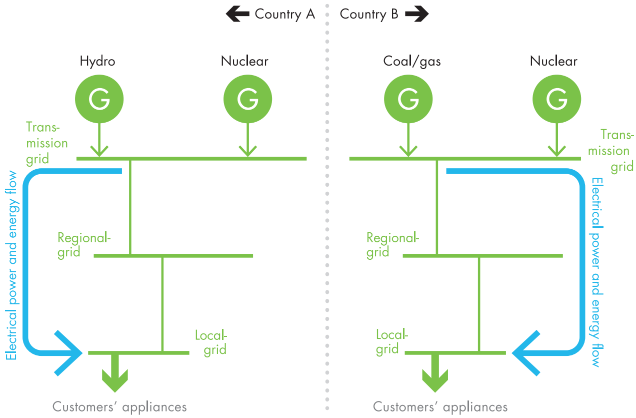
Electricity production and electricity demand kept pace with each other. Initially, requirements were met using biofuels, small hydro, coal and coke. Sweden, for example, went on to build large-scale hydropower, and later nuclear capacity. Electrical systems developed in stages, starting at local level and then expanding to regional scale. As customers' needs grew, increasingly large-scale facilities were needed, going beyond regional scope. Regional networks were connected together with areas adjacent to the national electricity system. A Nordic electricity system was thus created, bringing closer collaboration and a Nordic-scale approach to reserve capacity. The objective today is to link up more and more of Europe's electrical systems.

Even in the mid-1900s, when the Swedish electricity system was undergoing major development, blackouts were much more common than nowadays. Grids built earlier, usually with overhead power-lines, were rather more sensitive to bad weather conditions, which explained the frequency of power failures.

The production of electricity developed along a path similar to development of the networks, moving from small local and regional units to larger ones serving whole parts of a country. In the past, as today, the same basic conditions applied as with the wood stove: the balance between consumption and production had to be constantly monitored and maintained. Currently, indeed, this is even more necessary. The large-scale production solutions in Sweden (water and nuclear power) have been technically and economically advantageous because the prices they offer electricity consumers are more competitive than those elsewhere in Europe. Moreover, they have ensured stable production flow and security of supply. Where climate is concerned, large fossil-fired production units with advanced purification technology have proved more climate-friendly than smaller units.

In terms of how the electricity system has developed, different countries have different histories. The picture is not identical, for instance, from one Nordic country to another. In Norway, hydropower is an established strategic asset. Its hydropower resources, along with those of Sweden, today remain the backbone for maintaining equilibrium in the Nordic power system. It was during the 1940s that the concept of Nordic co-operation acquired the strong role it has held ever since.

Today's System



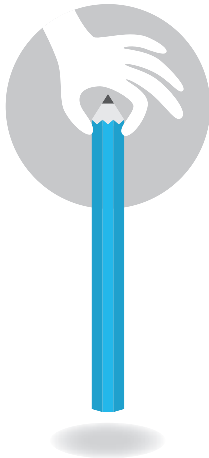


Figure 1

This is a simplified representation of today's system; electrical power and energy flow downwards in the system.

It is rather like a pen hanging from the grip of a hand.

The situation is stable and resistant to disturbances that could cause the pen to sway or fall, and this is exactly how it is with today's electricity system. By disturbances we mean short-circuits, for example, or exceptionally heavy fluctuations in demand, large momentary changes in generation output, or disconnections due to lightning.

During years of abundant water, Norway can export electricity to other Nordic countries. But it needs to import thermal-sourced power when water is less plentiful. The Nordic neighbours work together to meet their common electricity needs at the lowest possible cost. Finland has had a certain dependency on Russia in terms of energy supply. Denmark, for its part, has always been the smallest operator, making that country heavily dependent on its Nordic neighbours, and even neighbours farther south.

This Nordic co-operation was the foundation on which the Nordic electricity market model was built, a model that has long attracted interest around the globe.

The electricity system has been progressively fine-tuned to meet prevailing levels of electricity consumption. This applies to both electric power and energy, both of which are equally important.

As we continue below to describe how the power system works and how it is operated, it is important to note two key concepts and definitions. The term electrical power or "effect" (expressed in Watts) refers to what enables a light bulb to glow, and how strongly it emits light. When the light has been turned on for an hour, say, it has used a certain amount of energy, expressed as watt-hours (Wh). In an electricity bill, the units are kWh, that is, one thousand watt-hours. It is therefore important to understand both terms.

TODAY’S ELECTRICAL SYSTEM – stable and totally reliable

Today’s electricity supply is close to 100% reliable and customers have high expectations. Future expectations will be just as high and tomorrow’s system must be equally capable of meeting them.

In recent years, more and more of the power distribution system has been converted to underground cabling. If all the lines are not located underground, that is because it is not economically justifiable, as in the case of rural or mountainous areas, or cabling across wide open areas of fields. Expectations and requirements regarding the ability of today’s electricity networks to deliver are extremely high. Within most modern networks, the industry’s own efforts and evolving society have combined to bring security of supply very close to 100 per cent today. Moreover, the notion of quality in electric power has gained importance. Improved power quality is about avoiding power grid events or phenomena that cause customers’ machinery and apparatus to malfunction. Such voltage dips in the electricity supply can lead to wasteful use or damage to customers’ appliances or industrial equipment. But power quality must be handled in a pragmatic way to avoid excessive socio-economic costs.

Since the mid-1900s, Sweden’s robust electricity generation system, based principally on hydroelectric and nuclear power, has enabled the nation’s generating capacity to maintain excellent security of supply. This is a precondition for providing power to customers; it also enables the grid to honour its pledge of high-quality delivery. Power availability during winter, however, has made capacity in relation to customers’ demands increasingly tight over the past decade, in spite of hugely increased volumes of wind power in 2013. In other words, we are currently close to a problem known as power shortages, which are most likely to occur during the coldest days of winter. As yet, such power shortages have not been experienced in Sweden. It is worth noting in this context that, statistically, only six per cent at most of today’s approximately 4,000 megawatts (MW) of wind power capacity could contribute to alleviating a power shortage event. The real probability however, would be zero per cent on a windless winter’s day.

From the above, it is clear that power production and distribution must operate in tandem if customers’ needs are to be met

CONVENTIONAL WISDOM IS NO LONGER A SAFE BET

Without electricity everything stops functioning. Nobody wants that.

We have lived with the system described above for generations. It is taken for granted. For today's modern customer, electricity is a prerequisite for practically everything. In our modern world, electricity is increasingly regarded as a human right, notably in such areas as:

- High-tech industry;
- Cutting-edge medical care;
- Advanced food-retailing systems such as seamless refrigeration chains in grocery stores;
- Modern, comfortable day-to-day life at home.

However, this is by no means a given. We are moving into a brand new era. None of the old-established certainties remains valid, with one exception: the power system is a physically living system that must be kept in balance. Electricity use must be matched at all times with adequate electricity generation.

Constructing power generation facilities and electricity grids involves large investments. So they are not built on a speculative basis. Investors need to know what kind of services and levels of customers' consumption need to be catered for. In line with environmental legislation, a permit is also required, establishing that the connection is socially justifiable. And the permitting process alone is lengthy, sometimes taking more than ten years.

Levels of electricity demand must therefore be known in order to ensure that both the electricity generation facilities and the electricity grids are designed on an appropriate scale. From now on, those assessments will become much more difficult, given the generation of more renewables-based electricity – which is moreover highly dependent on the weather – and given that customers' consumption patterns will evolve due to increased cost. Another factor will be the physical requirements of the power system itself.

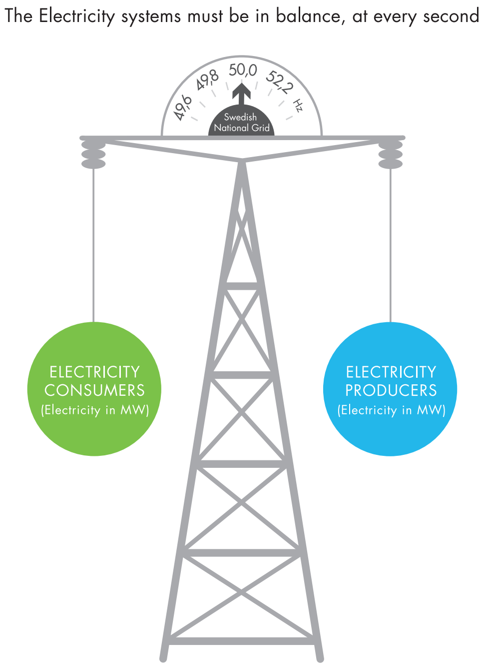


Figure 2

How balance is maintained today in Sweden – a typical winter week, 2013

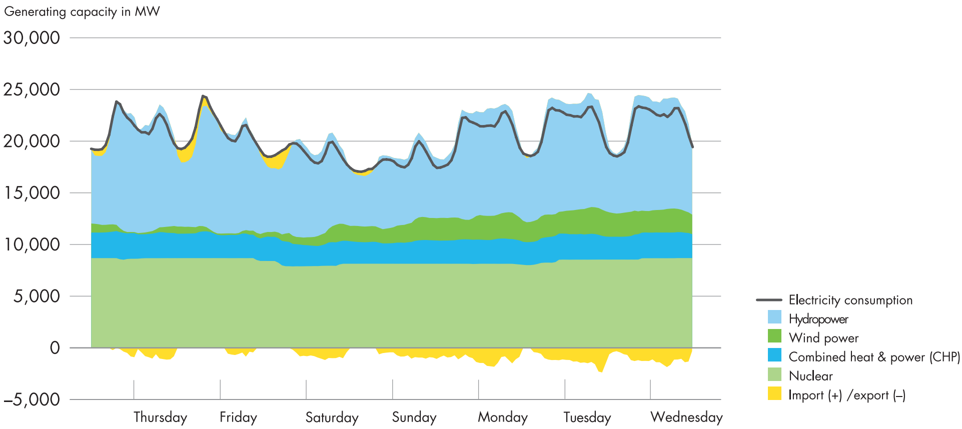


Figure 3. Maintaining a balance, each second, between power consumption and a corresponding amount of power generation is rather like using a set of scales. During Swedish winters, for example, we have nuclear and thermal power as baseload and hydroelectric power to provide for variations in demand during the daylight hours. Occasionally, we import or export electricity, according to the situation in Sweden and in neighbouring countries.

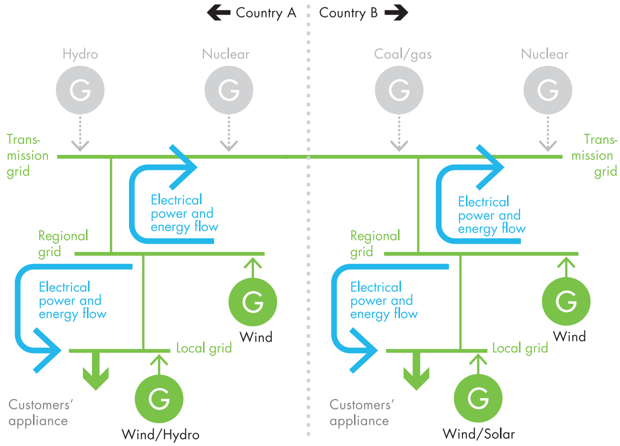
TOMORROW'S ELECTRICITY SYSTEM = today's system turned on its head

Does it matter from which direction the power comes? Yes, it certainly does when it comes to controlling the system's ability to remain in balance and not collapse.

While energy systems are today increasingly nationwide and cross-border, the local systems where it all started will retain their role. They will become even more crucial. But we shall see significantly more development of wider-spanning parts of the power system with names like "super grids" or "electrical highways". The system will grow and develop at both its upper and its lower levels. This is why we must consider what lies ahead from four different perspectives:

- Electricity grids: more transmission capacity is needed at all levels.
- Established electricity generation, base-load: this will undergo the most significant changes. Polices aimed at re-shaping the system will trigger spectacular transformations. As always, generation will have to match consumption. But existing generation capacity must now interact flexibly with new weather-dependent power as this is gradually integrated into the system.
- New sources of energy - solar, wind and wave power: these will be given precedence in the system because generation from these sources is regarded by politicians as indispensable if climate change issues are to be addressed; and this means transitioning from fossil to renewable energy. The marginal production cost of power generated from these sources is also the lowest, so it will take priority over others. Most of this power will be fed into the system at local or regional level. Seen against what we have today, the electrical system will thus have been turned on its head, with the lion's share of generating capacity relegated to a subsidiary role. Increasing shares of renewables will lead to new market design that will affect consumers, generators, electricity traders and grid-owners.
- Electricity customers: consumers will be given opportunities for getting directly involved in entirely new ways. Customers are likely to play a very different role in tomorrow's electricity market; the physical functioning of the system will require this. For example, household appliances will actively support the system. The daily consumption patterns of consumers will change. For instance, private customers will make lifestyles adjustments like switching to night-time use of dishwashers or clothes washers, while large industrial consumers of electricity will modify production schedules.

Tomorrow's System



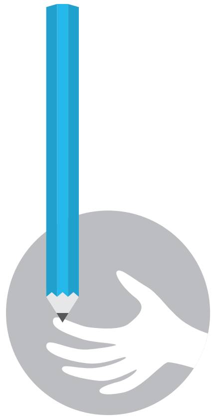


Figure 4

Tomorrow's world turned on its head – power and energy will flow upwards in the system, but only when the wind is blowing or the is sun is shining.

Balancing a pencil on your fingertip. It is very hard to maintain the balance and fend off disturbances simultaneously. This is just how it will be in tomorrow's electrical system.

POLICY ORIENTATION ON ENVIRONMENT AND CLIMATE IS DECISIVE

Electricity is the ultimate energy carrier. It is important to produce electricity and feed it into the system with a minimum of emissions, notably of carbon dioxide. In Sweden today, this is 97 per cent the case. The generation facility itself must also be designed to meet system-balancing requirements.
All this calls for a long-term perspective – indeed a very long-term view – in order to shape a system that is sensible and sustainable throughout. Responsibility for this lies with the politicians, working with the industry to find solutions together.

Under the impetus of climate considerations – albeit recently overtaken by pressing economic issues – the direction in which policies are heading will have a direct impact on energy systems and customers, and specifically on the electrical system. All around the world, societies are moving towards fossil-free solutions. Electricity generation in Europe is expected to be fossil-free by 2050, and 20 years earlier in the Nordic countries. For several years now, the European Union has had its climate and energy goals, and similar initiatives now exist in much of the western world. Sweden has set the objective of freeing its transport sector from fossil fuels by 2030. Today, a 97 per cent share of Sweden's electricity generation emits no carbon dioxide. Denmark is targeting 50 per cent renewables by 2020. Finland is building nuclear power as its response to the climate issue. Norway is building direct new grid connections to Great Britain and Germany in order to sell carbon-dioxide-free hydroelectric power by the shortest route to the continent and import electricity, notably wind-sourced power.

Policy objectives are thus crucial factors heralding major consequences where Swedish and Nordic electricity systems are concerned. In order to meet our goals, politicians envisage vigorous expansion of renewables-generated electricity. More wind power. More solar power. More bio-based power technologies, and ultimately more wave power.

It is this additional renewables-generated electricity that must be accommodated in the system alongside power from traditional generation technologies, and in such a way that supply continues to match customer demand. Because it is highly weather-dependent, as well as geographically dispersed, renewables-based electricity generation involves some specific extra challenges and opportunities. For instance, the scattered geographical location of generation capacity offers certain advantages due to variations in weather conditions between different parts of a country or region. The electrical system we see on the horizon will therefore be different from today's. But only when the wind is blowing or the sun is shining, which means that all the available production capacity – for the power that will be needed – must remain readily available in the system as backup. At other, windless and cloudy times the system will function as it does today. This is also a key point to bear in mind.

The EU's Climate Roadmap to 2050

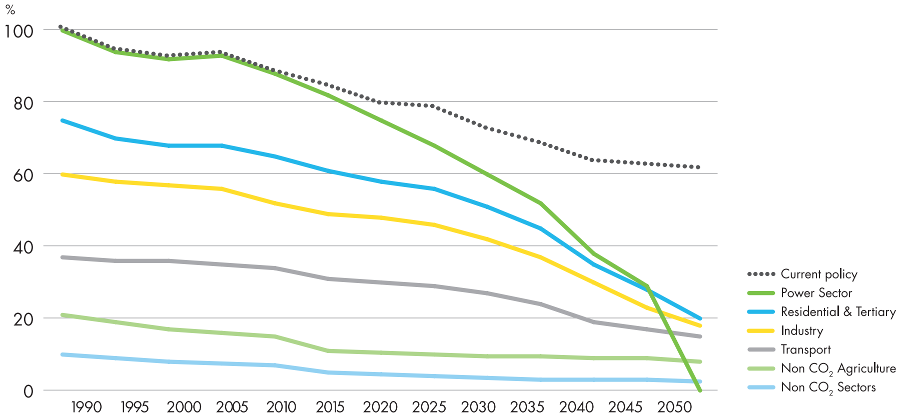


Figure 5. In the EU's roadmap for climate to 2050, the energy sector's greenhouse gas emissions will have fallen to zero.

Installed capacity in Sweden and different energy-mix scenarios

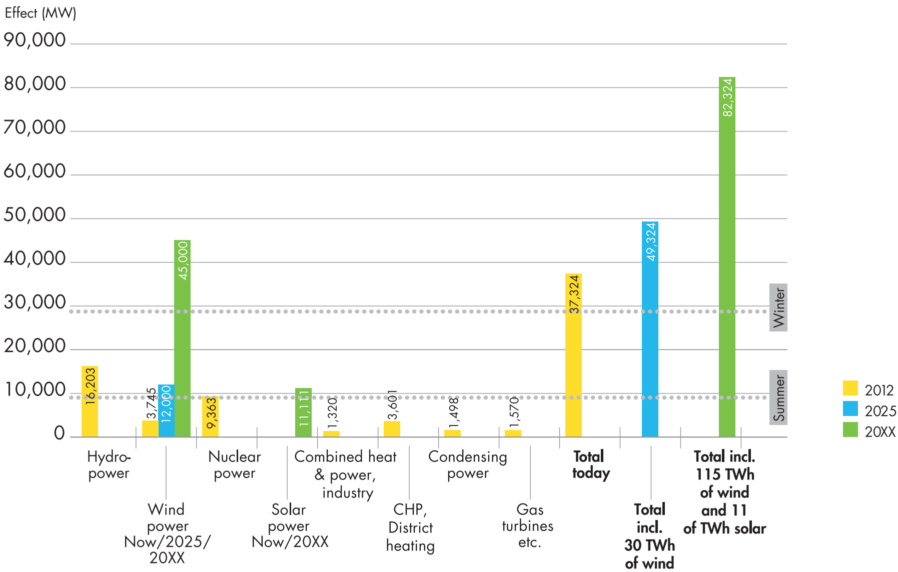


Figure 6. This chart shows relative shares of installed capacity in Sweden and various scenarios based on targeted integration of 30 TWh of wind power and known projects accounting for 115 TWh of wind power and for 10 TWh of solar power. This data is based on historical summer and winter consumption levels.

Annual amounts of energy produced, by type of installed capacity (energy density)

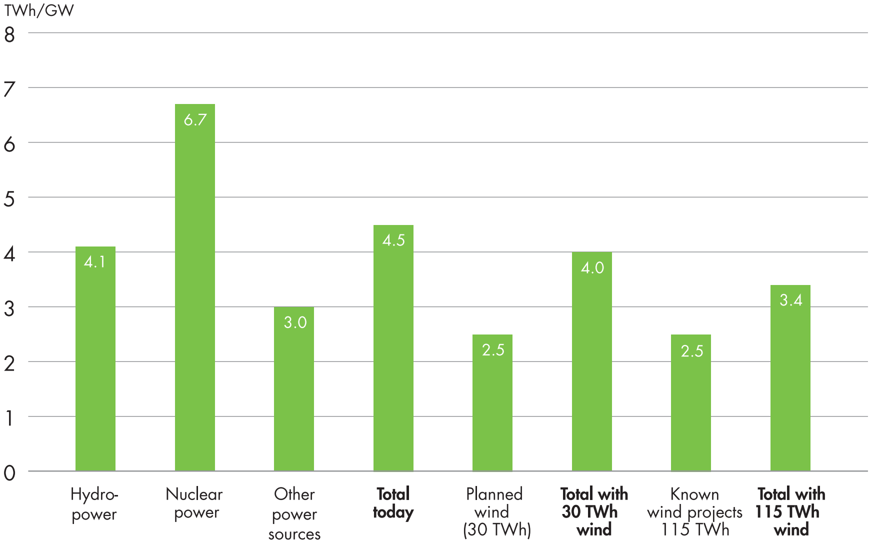


Figure 7. The chart shows the year's output of energy generated by different types of installed power capacity in Sweden in 2012. This means the amount of energy produced by each energy source for a given unit of installed power capacity. Comparing wind and nuclear, for example, roughly three times as much energy is produced from nuclear as from wind, using the same amount (level) of installed power capacity. This way of presenting the ratio can usually also be a gauge of full-capacity hours, but using a different scale on the y-axis.

HOW DOES A LIVING ELECTRICAL SYSTEM REACT – collapse or disconnect?

In addition to today's potential winter power shortage problems, a new situation will emerge that brings a summer problem, too. In some ways, this will be a larger, more difficult situation to address, not least financially.

If electricity is to reach its customers, the power grid must be intact – locally, regionally and at the transmission level – and production capacity must be adequate. At each moment, generated output must be equal to electricity demand, taking account of demand fluctuations. Meeting these two network and production requirements is the very foundation of a functioning electrical system. In such a functioning electrical system, which of course carries alternating current (AC), the frequency is close to 50 Hertz (Hz). This applies in most countries around the world, one exception being the United States, where the frequency is at 60 Hz.

If the amount of electricity generated exceeds power demand, then the frequency rises. Exactly the opposite occurs when demand exceeds the amount of power generated. If matching supply and demand is not possible within a very tight timeframe of minutes, there are three alternatives:

- Electricity generation is decreased or increased;
- Electricity demand is disconnected, or connected; or
- The system collapses; i.e. a disconnection occurs at the level of a generator or an industrial consumer, leading to what is known as a cascading failure. As a result, the lights go out and everything is in darkness.

In tomorrow's power system, if large volumes of renewables electricity production are integrated as planned, potential over-production will often become reality, mainly in spring, summer and autumn. Over-production occurs when large amounts of renewables electricity – by nature intermittent because weather-dependent – are fed into the system because of weather conditions and not because of current levels of electricity demand. This new situation can be regarded as a "summer problem", by analogy with the existing "winter problem". When the "summer problem" arises, generation from renewables must be partially cut back or totally disconnected in order to preserve the balance between consumption and production. If the export situation so permits, then some of the power and energy can of course be channelled away via that route.

Energy storage facilities could address such a situation to some degree, but because very large volumes of power and energy are involved, that is not a total solution. Moreover, energy storage connected to a local electricity grid cannot provide the same technical system support as today's large-scale power-generation sources.

Energy storage also involves major energy losses – 10 to 15 per cent losses or more are not unusual – and these must be added to other losses during transmission within the system. Other forms of energy conversion can of course come into play, such as electricity-to-gas or electricity-to-heat. But all these entail energy losses in the conversion process; and it costs money to build and maintain the facilities.

A further very important aspect of future systems using large volumes of wind and solar energy, as well as other components like energy storage, is that a certain amount of baseload generation, known as "must run" generation, is likely to remain necessary to maintain system stability (the hanging pen, as opposed to the pen balancing on the fingertip). This is why renewables generation, and to some extent energy storage, must operate on a limited basis, while a certain amount of baseload generation must be operating at all times.

WHAT WILL BE REALLY NEW IN TOMORROW'S SYSTEM?

The challenge is to solve the difficult equation of meeting environmental and climate goals in a way that is sustainable and viable long-term for the system and for customers.

- On the generation side, 90 per cent of the electricity in Sweden's system is currently produced from hydroelectric and nuclear sources. Large units supply the system with power and energy from "top-down". The remainder consists of electric power from heat and industrial production. It is consumed regionally and locally, i.e. "downwards" within the system.

- With tomorrow's system, which cannot yet be visualised in detail, large volumes of renewables-generated electricity from smaller units (wind and solar) will be connected from "bottom-up" regional and local sources. In the view of the politicians, this renewables power should be given priority by means of support or regulatory requirements and in the long term replace the majority of established fossil-fuel power generation. The implication here is that existing large production units must adapt their output accordingly. But they must remain available for when there is no wind or no sun. The economics of running large production units thus suffer a dramatic blow. Additional power obtained from renewables generating plant during windy and sunny weather will also call for new solutions. Another consequence is that electricity networks must cope with these new operating conditions (capacity and security of supply to customers). Electricity customers themselves will take on a somewhat new, more active role where more consumption will still take place at lower levels in the system. This will most likely lead to new market solutions.

- It is very important to be clear that the service life of renewables-sourced electricity generation units is still far from that of today's other technologies. Wind power plants have an estimated lifetime of approximately 20-25 years and solar power plants around 20 years, or slightly longer. Nuclear energy and hydropower technology have 50-100 years of service life or more, albeit incorporating upgrades. All generation plants of course require maintenance during their service lives, but the lives of renewables units cannot be extended in the same way as those of other production units. This means that large shares of currently existing wind power capacity will start to be replaced or decommissioned as early as the year 2020.

- This state of affairs raises a number of important issues:
  – If plants are dismantled and removed, there must be compensation elsewhere in the system for their loss. And even if the cost of demolition is covered by the facility's owners, there will still be new or reinforced electricity grid installations that are destined to become redundant.

- If new facilities are built in the same location, the amount of power fed into the grid cannot change greatly because the grid was customised to meet the level of requirements at the time of the facility's construction. This will continue to be the case, even if technological advances endow units of equivalent physical size with significantly greater capacity.
- If turbines having greater capacity (power and energy) could be accommodated through grid upgrades, the question remains of how existing base/capacity production, on the one hand, and production for frequency control purposes on the other hand, are affected, and how yet larger amounts of energy and additional power in the system should be handled, as well as market aspects. In other words, we are back to square one, but on a larger scale.

It is certainly true, of course, that both grids and existing production facilities are affected by rising or falling amounts of installed electric power, whatever type of generation is concerned. But the impact of future volumes of solar and wind power on local and regional grids that are already handling capacity generation will be challenging to the highest degree.

The above describes the difficult equation of meeting environmental and climate goals in a way that is sustainable and viable long-term for the system and for customers. It should also be noted in this context that other new external factors such as new fuels like shale gas can totally overturn what may have been considered to be the sole solution to achieve environmental and climate objectives. That would likely result in major consequences for energy systems and society.

HOW WILL THE STAKEHOLDERS BE AFFECTED BY TOMORROW'S REALITY?

New roles, new services, new patterns of behaviour, tougher competition, more financial risks, new tasks, major technological adaptation and an oversized production fleet … these are some of the changes that lie ahead.

We are moving towards surplus generation, in both energy and power

The outlook certainly looks problematic for electricity generation as it stands today. Conditions for long taken for granted have now become uncertain. This is above all true for the large production units, but also for smaller facilities not classified as renewables-sourced generators. These may find themselves elbowed out by generation from renewables. But they all need to be available as a backup for renewables generation. When there is no wind or sun, the system needs conventional generation units. Building new baseload plants to replace units retired out of service will become difficult because the number of operating hours will be inadequate to motivate investment. But baseload units must nevertheless continue to exist within the system.

Additional electricity generated from renewables will also be affected because it will need to be cut back at times when total generation exceeds demand, most likely in spring, summer and autumn. On top of the current risk of output shortages in winter, another tricky production issue threatens to arise: potential overproduction. The guiding principle is that market-based pricing solutions would be the basic solution in such situations. If that were not good enough, transmission operators would be given the option to restrict output or to intervene at demand level, maybe in relation to individual electrical devices within households, for example, or in industrial units.

One might think, moreover, that it is easy to export surplus electricity when such situations arise. But this is not the case for the very simple reason that ability to export depends on three basic factors:

- The capacity of interconnections between countries to handle given amounts of power;
- The operational situation in the receiving country at the time of export, including the current state and nature of its domestic production and internal transmission capacity; and
- The kinds of power to be exported (e.g. from wind, solar or water sources).

That is why opportunities to export are reduced or totally eliminated if the recipient country's operational situation includes large amounts of wind and solar power. This can remain the case for hours, days or weeks. In the case of Sweden, it is easy to see that the nation's export potential via existing interconnections does not today allow for more than some 9 000 MW (nine million kilowatts), which is very small in relation to the solar and wind power capacity likely to be built in Sweden. Conversely, where importing electricity is concerned, the same issues arise.

Over coming years, new solutions for storing energy will become increasingly important, indeed crucial. But it will be hard to stretch their total capacity to meet total needs,

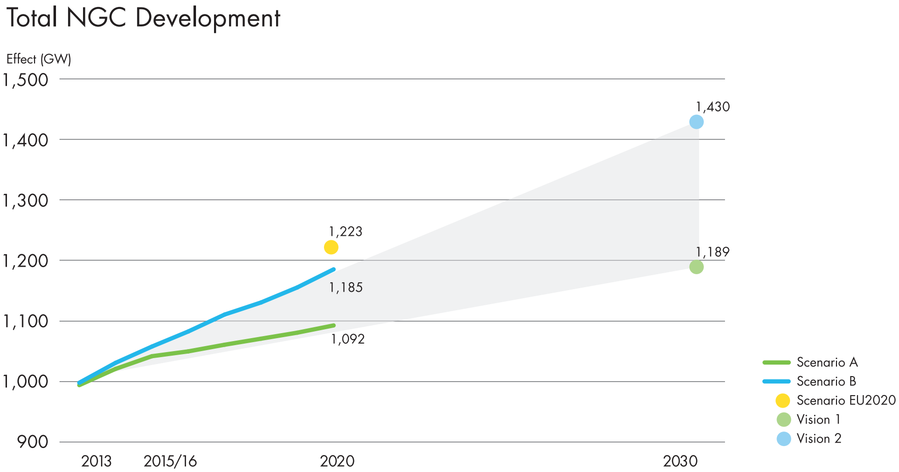


Figure 8

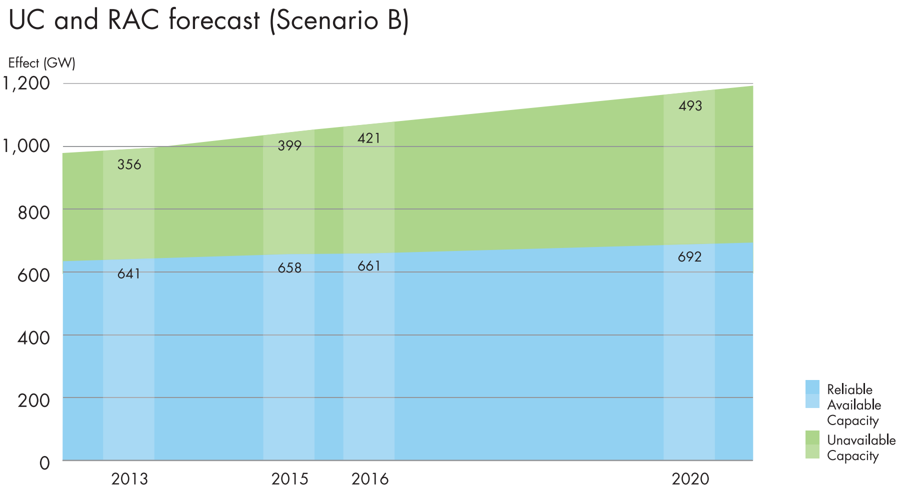


Figure 9. Installed capacity in Europe and the scenario to 2030 (Source: ENTSO-E Scenario Outlook & Adequacy Forecast 2013 to 2030). Today, out of roughly 1000 GW (one million megawatts), only some 640 GW come within the category known as "Reliable Available Capacity" (RAC), i.e. excluding wind and solar electricity (unavailable capacity, UC). In 2030, the share of RAC in the system is smaller, even though total installed capacity is greater.

and the role of storage cannot be compared to the technical role that large units play in today's system. Furthermore, neither the cost nor likely additional energy losses are negligible. The same applies to other methods of energy conversion.

From all this, an entirely new situation comes into focus, a situation that to some extent prevails already. It is creeping up on us in Sweden but is already perceptible on the continent. Examples can be seen in Germany, Italy, Spain, Denmark and their neighbouring countries. Surplus power (MWs) chiefly affects the domestic energy situation through volatile prices – in the short run lowering prices, in the long run increasing them – but it also has a knock-on effect across national borders. This surplus power primarily affects existing generation facilities, but also secondary renewables generation. The structures being designed for tomorrow's power generation system in Sweden and elsewhere in Europe will be several sizes too large. The cost will therefore be of corresponding magnitude.

Electricity use across Europe today totals some 510 GW in winter and about 420 GW in summer, i.e. about 50 and 40 per cent respectively of total installed capacity (power), or total Net Generating Capacity (NGC). The safety margin in relation to the so-called Reliable Available Capacity (RAC, without wind and solar) is considerably less than this, and the system has been tailored to this margin, which history has established as justified. But what about the future? In addition to installed capacity in 2020 – i.e. taking into account future unavailable capacity (UC) and plans still on the table for RAC – a further 38 GW of RAC needs to be added to the system in order to meet current safety margin forecasts established by the European Network of Transmission System Operators for Electricity (ENTSO-E). This raises a big question: who is willing to invest in this generation capacity, which will simply be a form of backup for UC (renewables) generation?

Electricity grids have a key role in the new system

Electricity grid owners will need to adapt their grids to the new situations. Large volumes of renewables generation must be handled. Increasingly active customers will all wish to generate their own electricity. Owners of electricity grids should be able to take this in their stride. But they must also provide for customers who have more flexible electricity consumption, which could consist in selling a service (disconnect or connect loads) in order to support local or regional grid owners, or upstream transmission system operators. These "support" services will be offered on a commercial basis, but could in certain cases also come into play as technical requirements.

New players known as third-party operators can be expected to enter the scene. These third-party companies are a totally new breed of partner, who will bring together small customers, aggregating their collective capacity (both generation and consumption) in order to sell this on as a service to power grid owners at any level in the system. For example, it could be a group of 500 customers who sell their freezers' power consumption pattern during a time slot of one hour, say, to a system operator (who is responsible for load balancing in the system), or during periods when the grid has bottlenecks at different levels. It could equally be a group of solar or wind power generators who undertake not to generate during a specified hour. Naturally, an aggregated service can also be offered by an electricity trader, existing or new.

Grid owners must also have the technical capability to handle a range of energy storage or energy conversion processes to which they are connected.

The new system underlines the importance of quality of service. Hence the accelerated development of ever more smart solutions, or what are known as smart electricity grids. This means more focus than today on what is happening in one's own grid and orientation towards automated operations and disconnection from the grid in the event of emergency. Smart grid solutions include smart electricity meters for both customers and generators, which enable both parties to be pro-active and smart, largely through automation. The service quality issue is likely to be resolved through customers' use of more robust and more durable appliances. This has in fact been a long-standing trend.

The electricity customer: winner or loser?

Tomorrow's electricity customers will have more freedom of choice than hitherto. But it will not come for free. He or she will play a clearer, direct and explicit role that entails both opportunities and a downside. The downside here is increased costs. The opportunities, however, will be ways to reduce electricity bills through a much wider range of services offering greater flexibility and lifestyle changes. More people will produce their own electricity. However, the role of energy customers will at certain times involve respecting the needs of the power system and using appliances in ways that support its stability and safety. The latter applies to automatic urgent connection or disconnection of fridges and freezers, for example, or heating equipment, i.e. equipment having thermal inertia. This could result in a rise or a drop in the temperature of the customer's appliance, but without prejudice to needs such as preserving food quality. Of course, for system safety and in emergency situations, other, more far-reaching remedies will be applied, including large-scale demand disconnection or a momentary stop in generation.

Electricity customers will in future join forces with new third-party operators. They may well also form partnerships with electricity traders via new products destined for electricity customers, who need to ensure marginal cost equilibrium between their own purchases and sales of electricity.

MARKET SOLUTIONS – many new challenges

Financial risks exist with today's systems and with those of tomorrow. But the risks ahead will be of greater magnitude and complexity.

The future electricity market looks different from today's. This is because systems will be carrying electricity generated from new kinds of source. Hence the discussion of introducing balancing markets and capacity markets. One of the major changes is a future new, larger and more flexible range of services offered by active customers and active producers. There are major dangers that interference (cross-wise impact) between existing market areas may cause them to encroach on each other. The reason for that is the greater complexity of tomorrow's electricity systems.

Another of the big challenges for electricity suppliers will be predicting actual output from weather-dependent power generation. Electricity trading companies may well need to create new solutions and work with new third-party operators to manage their own balancing responsibilities and risks.

A reasonable requirement would be that customers assume their own balancing responsibility, i.e. the cost of discrepancies in real consumption or production levels against what has been planned or announced. However, this may depend partially on system-related support services which need to be connected to consumers' devices and generation facilities and whose job is to autonomously activate or deactivate electricity consumption or production in harmony with conditions at system level. In comparison with the current market, one can list the following challenges that would arise for electricity trading companies:

- Considerably greater risks;
- A need for much more, increasingly complex IT systems;
- New roles to handle, for both electricity suppliers and third-party actors ("aggregators"). These roles imply interface with all parties: grid owners, electricity customers (as producers as well as consumers) and the system itself (for instance, in connection with new balancing and support services);
- Additional, increasingly complex services to manage.

HOW IS EUROPE PREPARING ITSELF FOR TOMORROW?

Vigorous efforts are under way to launch an internal electricity market. In parallel, new regulations are being created, in line with agreed objectives under the Third Energy Package, to enable the system to handle large amounts of renewables power. They also strengthen the customer's role and opportunities to influence, as well as ensuring greater transparency in the markets.
This comes against the backdrop of the financial crisis and difficult situations in certain member states. Major divergences between energy policies in different countries became clear in 2013, exposing situations totally at odds with the EU's ambitions and convictions.

As a member country of the EU, Sweden, for its part, is bound by decisions taken at EU level. Extensive work is in progress in the energy sector to set objectives and shift from fossil fuels to larger shares of renewables in the electricity and energy systems. The goal is a well functioning internal energy market, in which electricity can flow unhindered across borders and similarly within each country. Large amounts of time and resources are needed to bring all this about. Meanwhile, an ambitious effort is currently working towards greater energy-market transparency and stronger roles and influence for customers. The Nordic example illustrating this trend is the Nordic retail market, which features "one contact for the customer".

The electricity market's transition to tomorrow's systems requires new tools and rules. The major work in hand at EU level, which concerns all electricity market participants, focuses on what are called Network Codes (grid rules). Although the name suggests a focus on the power line component, the outcomes here will involve the entire electricity sector: generators, electricity suppliers, utility companies, new entrants or customers. Those outcomes will have a bearing on everybody's daily use of electricity. We should recall, moreover, that this work on the regulatory framework is built along the same lines, and with the same focus, as what we have highlighted and outlined in this paper, namely the shape and functioning of the system of tomorrow.

Over the next few years, the regulatory package is to be submitted for decision and there will be legislation in each member state. The detailed aspects of the task have been handled over the past couple of years within a tripartite partnership between the following:

- The European Commission, whose task is to ensure that this framework is developed and adopted;
- ACER (the European Agency for the Cooperation of Energy Regulators), which has been commissioned to write the Framework Guidelines for the Network Codes. ACER has 28 members;
- ENTSO-E (European Network of Trans-

mission System Operators for Electricity, with its 41 members). The European Commission has entrusted it with the mission to draw up a detailed design for the operation and management of the future systems, from the perspective of customers, generators, market participants and grid owners. This is what is expected to become law in the EU countries, starting in 2014, once the European Commission has completed its mission.

The new regulatory framework shapes the technical, commercial and legal rules for tomorrow's systems and will control much of the day-to-day business of electricity companies of every sort. The regulatory framework is very much based on a purely continental perspective, the Nordic views being of course in the minority. It is thus the interests and circumstances prevailing in continental Europe that have an impact. For example, the framework considers that the Nordic countries will need a dozen years or so to catch up because expansion of wind and solar power on the continent is ahead of us. Otherwise, the framework will not be at all necessary.

Further upcoming regulations affecting the industry come within the financial regulatory "REMIT" framework, which largely concerns the trading of electricity and notably rules on transparency. In addition to these new regulations, new rules are expected regarding customers' status and "clout", as well as smart grids and smart solutions.

The European Commission's Energy Efficiency Directive must also be considered as an important component in future systems. This involves measures to minimize energy consumption and promote its efficient use. Substantial work is also focusing on regulations establishing new requirements for energy-efficient components in the electricity grid, including transformers.

Much regulatory work is focusing on electricity grids' business revenue frameworks, quality of supply and other domains, all of which must take into account the multiple changes that tomorrow's systems will bring. Many of them are actually already here.

The danger that could threaten efforts to create a single European market for electricity is that member states set their own policy agendas, tailored primarily on their own domestic needs instead of the common needs of Europe. During 2013, signs became increasingly clear that this is now becoming the case. Where this will ultimately lead is difficult to assess as things stand at present.

NEW CONDITIONS FOR IMPORTING AND EXPORTING ELECTRICITY

You cannot draw conclusions about how electricity exports will function tomorrow by looking only at how today's electrical system works.

Opportunities for importing and exporting electricity will change in the systems of the future. Even today, we see many indications of this. Countries with large-scale wind and solar electricity generation have difficulty in exporting surpluses under certain conditions. This is because neighboring countries lack either grid capacity or the desire to risk disruptions to their own domestic electrical system that imported electricity could trigger (an example during 2013 was seen in Germany and Poland). On the positive side, however, export opportunities exist for countries which have the ”right” type of generation technology, notably hydro. This provides a glimpse of new mechanisms whose long-term effects are only just discernible today. What is new in all this is the large amount of over-dimensioning of production stemming primarily from renewables-sourced electricity and, of course, the newly evolving role of base/capacity-load generation. In this context, it is important to mention that stability has to be maintained to keep the system alive, so a number of crucial more deep-rooted technical parameters also come into play when considering which type of generation is needed in the system at a given time, and even geographical location.

The European Commission has for many years focused on the importance of increasing the capacity of transmission connections, both domestically and cross-border. The work takes place on three fronts. For its part, the EU Commission has identified relevant strategic projects to be treated as Projects of Common Interest (PCI). ENTSO-E is meanwhile working with the rolling ten-year network development plans (TYNDP) and in different parts of several countries on regional initiatives. Then there are a number of current projects in different parts of Europe.

In addition, the EU Commission is also working on the concept of ”super grids”, which are sorts of electricity highways running over and above existing transmission grids.

SELECTED CROSS-CUTTING ISSUES OF OVERRIDING IMPORTANCE

Under the headings below, we briefly address topics and issues that are important for consideration from a national competitive perspective in terms of the roles and functions of the various different actors, i.e. how their market positions might be affected by new developments or compulsory cost increases. These points are not developed further in the present publication.

- **Conflicting national / regional (Nordic, Baltic) / European issues**
  Support systems, types of generation/capacity, capacity between countries (cross-border capacity), new fuels (e.g shale gas).

- **Electricity system characteristics and features (at different levels of the grid)**
  Planning, capacity, operation, smart solutions.

- **Markets: existing and new market solutions/services**
  Distributed Energy Resources services, balancing market, capacity market, aggregation, other system-support services, tariffs, pricing models.

- **Technical requirements: existing, new and modified**
  Relevance to, and difference from, today's requirements, standardisation, type testing, real- time communication for information and data handling.

- **Roles and burden-sharing**
  Between transmission grid/regional grids/local grids/customer' self-generation and consumption, aggregators, relevance in distribution/assignment, regulations and regulatory frameworks.

- **Legal aspects**
  Subsidiarity, transparency, equitable treatment.

- **Social aspects, benefit for customers and climate**
  Cost-benefit analysis (CBA) of departures from today's practices, customer's role, electricity's role in environment and climate.

IMPORTANT POINTS FOR ELECTRICITY TRADERS TO CONSIDER

What advice should an electricity trader receive on gearing up for tomorrow's system?

- You must be on your toes and recognize that big changes are on the horizon. It is a question of properly understanding tomorrow's system and its underlying mechanisms, as well as the new roles and the need for new products. Conventional wisdom will be overturned. But much completely new knowledge will naturally emerge.

- For electricity traders, risk management is clearly rising steadily on the agenda. And it is becoming more difficult. Risk is now in a class of its own where electricity trading companies are concerned.

- Furthermore, the challenges will be compounded by the increasing complexity of future systems, with their IT component, new players and roles. And remember that higher costs must be expected. But also in the picture will be wide openings for new business opportunities.

IMPORTANT POINTS FOR POWER-GRID COMPANIES TO CONSIDER

- Because it will have the key function in the intended transition towards renewables, the grid will play a more vital role in tomorrow's system. Grid companies will have to measure up to their crucial task, while complying simultaneously with stiffer regulations. The grids and associated systems will have to undergo development and upgrading. Smart solutions are a part of this. New ways of working will be called for and there will be more work to do.

- Power grid owners will be involved in connecting all types of customer and managing their operations, but they will be more acutely affected by the new market reforms/mechanisms.

- It cannot be ruled out, moreover, that some support services will need to be provided to the upstream network owners and transmission system operators.

IMPORTANT POINTS FOR POWER GENERATORS TO CONSIDER

- When it comes to the generation sector, the most striking change to be seen in tomorrow's system will be an oversized production fleet with an excessive amount of generation capacity as a whole, due to the integration of renewables. It will be equipped on an extravagant scale, and this gets expensive. The economics of an electricity generator will look different. Conditions will likely evolve differently according to type of generation, and the most negatively where baseload generation is concerned.

- However, opportunities exist for power generators. The arrival of a balancing market and a possible future capacity market will create new prospects for power generation. Support schemes for renewables electricity generation can be expected to continue for quite a few years.

- Some uncertainty exists also over generation from renewables (wind and solar) because this could well be cut back sharply due to overproduction when the "summer problem" prevails.

- The writing on the wall is clear: tougher conditions for baseload production; a rosier outlook for renewables generation. Strong evidence of this is already very perceptible in certain continental countries.

IMPORTANT POINTS FOR ELECTRICITY CUSTOMERS TO CONSIDER

As for electricity customers, what is in store for them? What can they expect? They may see:

- More services to choose from.

- More market players to choose from, with stiffer competition.

- The obligation to foot the bill for the expanded generation capacity, enhanced grids, more trans-border connections, considerably more and increasingly complex IT, as well as support systems to manage operations. But will electricity bills be smaller in the long run because the additional costs are offset by stiffer competition?

THE FINAL WORD?
– No, this is an ongoing conversation!

So, the story ends here. Or does it? Perhaps you, the reader, will now step in and pose the questions you are asking yourself, or wish to put to others, or maybe to me? You are in all probability a long-established consumer of electricity who wishes to be certain that the grid operator will continue to deliver his product via the two holes in the wall, in conformity with what we might call your subscription with the electricity supplier.

Electricity concerns us all. It makes everything in our lives possible, as private individuals, as entrepreneurs or as employees. From the protected surroundings of the cradle to the sheltered housing of senior citizens, we are dependent on electricity. If you are young today, it will certainly not be long before you and yours are transported around courtesy of electricity. The revolution is already under way. As electric cars become smarter and cheaper, we shall be travelling in fossil-free fleets of vehicles within a few decades. And do I even need to add that the IT society is entirely dependent on electricity?

Environmental protection and safeguarding our climate are close to the hearts of us all, for ourselves and for future generations. Electricity is among the highest-rated carriers of energy, as you have probably gathered. Using electricity generated from clean sources, conveyed through efficient, rational distribution systems, is an insurance policy securing a benign environment and decent living conditions.

But how does it feel after reading this paper? Are you confident that you will continue to enjoy relatively clean electricity at a competitive price in your part of the world? Can you be sure of security of supply in the electricity panorama described on the previous pages? Moreover, did you know that 80 per cent of the legislation governing the operating practises of electricity companies is rooted in EU decisions? Never mind if you did not, but this fact is certainly something that people need to be aware of. We are all on a journey where everyone's efforts are needed to maintain the pace, be they politicians, the public at large, energy experts or other folk.

Your feedback on this publication from Swedenergy would be most welcome. You can contact me by email:
johan.lundqvist@svenskenergi.se.
To find out more about the organization I work for, take a browse through our web pages at www.svenskenergi.se.

We are all working for a better future. And your views are important to us.

Swedenergy is a Swedish trade association comprising some 380 companies in the electricity sector (generation, networks and trading/retail). It works on wide-ranging issues in order to enhance the conditions in which its members operate, to broaden understanding of electricity's important role in social development and in addressing such challenges as climate change.
See: www.svenskenergi.se.

Originally drafted in Swedish, this paper has been translated by Mary Harries Magnusson.

Svensk Energi – Swedenergy – AB
SE–101 53 Stockholm • Visiting address: Olof Palmes Gata 31
Phone: 08 – 677 25 00 • Fax: 08 – 677 25 06
E-mail: info@svenskenergi.se • Website: www.svenskenergi.se