TIME FOR A SECOND ELECTRICITY MARKET REFORM?

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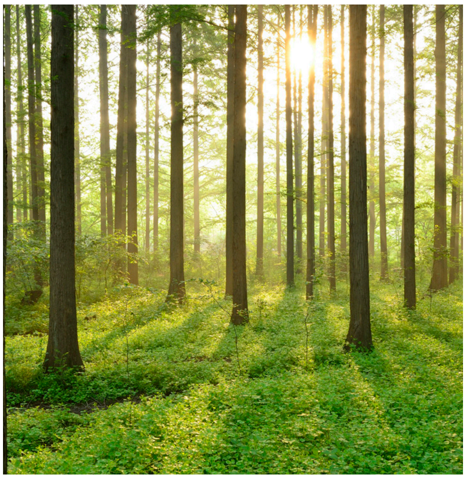

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Time for a Second Electricity Market Reform?

Conclusions of the EFORIS Panel Project

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Foreword

This project has been funded by EFORIS, a research program on electricity market design. The goal is to develop a better understanding of the electricity market and its role in society. It has been conducted by a panel of electricity market experts from academia, energy companies, consultancies and public agencies. The project has been led by Lars Bergman, with Mats Nilsson as deputy project leader.

Within the frame of the project the members of the panel have not represented the organizations to which they are affiliated. Thus they have participated in the project only in order to share their knowledge and insights about electricity market issues. Each and every panel member has approved the report, but does not necessarily agree on all the conclusions and recommendations put forward.

Sammanfattning

”Panelprojektet” är en del av forskningsprogrammet EFORIS. Det har genomförts av en panel bestående av forskare vid akademiska institutioner och företrädare för kraftföretag och andra företag och organisationer med anknytning till elmarknaden. Den centrala frågan i panelens arbete är om elmarknadens nuvarande organisation och regelverk förblir ändamålsenliga när en stor eller dominerande del av kraftproduktionen baseras på vind- och solkraft. Med andra ord: Är det dags för en ny elmarknadsreform?

Den pågående omvandlingen av elproduktionssystemet innebär en snabbt ökande andel intermittent kraft, i form av vind och solkraft. Dessa kraftslag har två unika egenskaper. En är att de i det närmaste saknar rörliga kostnader. Det betyder att närhelst ett vind- eller solkraftverk kan producera så producerar det el till en lägre rörlig kostnad än varje annat kraftslag (utom möjligen vissa kraftvärmeanläggningar). Den andra egenskapen är att produktionen beror på naturen, d.v.s. på tillgången på vind respektive sol, och är svårare att förutse än produktionen i konventionella kraftslag.

Vind- och solkraftens speciella egenskaper har skapad oro för de konventionella kraftslagens framtida lönsamhet och därmed om det framtida kraftproduktionssystemets leveranssäkerhet. Betyder detta att elmarknadens nuvarande organisation och regelverk måste förändras? Panelens svar är att flera mindre reformer är nödvändiga samtidigt som mer omfattande reformer kan behövas på längre sikt. De mindre reformer som panelen rekommenderar är:

- Den högsta tillåtna nivån för priserna på dagen-före (Elspot) och balansmarknaderna bör höjas till en nivå som reflekterar de bästa uppskattningarna av VOLL (Value of Lost Load).
- Priset på dagen-före marknaden (Elspot) bör sättas på den högsta tillåtna nivån närhelst den s.k. effektreserven aktiveras.
- Utnyttjandet av de nordiska ländernas effektreserver bör koordineras.
- Handelsperioderna på intra-dag (Elbas) och balansmarknaderna bör reduceras, d.v.s. bör vara kortare än en timme.
- Balanskraven bör avse kortare perioder än en timme.
- Handel på intra-dag marknaden (Elbas) närmare drifttimmen, d.v.s. mindre än en timme, bör tillåtas.

Även om dessa reformer genomförs kan det inte uteslutas att mer genomgripande reformer så småningom måste övervägas. Sådana reformer skulle sannolikt innebära att den nuvarande effektreserven ersätts av en mer utvecklad s.k. kapacitetsmekanism, då helst en Nordisk i stället för en svensk kapacitetsmekanism. Mot denna bakgrund föreslår panelen att:

- Ett kvantitativt mått på graden av leveranssäkerhet bör definieras och dess utveckling över tiden bör noggrant följas.

- Man bör också för detta mått fastställa ett kritiskt värde vid vilket en utvecklad kapacitetsmekanism behöver införas.

Vidare rekommenderar panelen att:

- Om och när en utvecklad kapacitetsmekanism behöver införas så bör denna utformas med målet att så långt möjligt bevara en elmarknad med konkurrens i produktion och handel.

På grund av den pågående integrationen av de nationella elmarknaderna, inte minst i de nordiska och baltiska länderna, har ”elmarknaden” nu en annan och större geografisk utbredning än tidigare. Men detta framgår inte särskilt tydligt i den statistik som publiceras av Energimyndigheten och andra organisationer inom energiområdet. Panelen rekommenderar därför att man gör en översyn av elmarknads- och kraftindustristatistiken. Närmare bestämt bör statistiken i fråga ge relevant information om elanvändning, elpriser och elproduktionskapacitet inom ett större geografiskt område än Sverige.

Det är ett prioriterat politiskt mål att utveckla ett hållbart elproduktionssystem. Målet för elmarknadsforskningen bör därför vara att identifiera den utformning av en elmarknad med effektiv konkurrens som är ändamålsenlig för ett sådant elproduktionssystem. Den framtida elmarknadens organisation och regelverk bör också stödja elhandel över nationsgränserna och utvecklingen mot en gemensam europeisk marknad för el. Dessutom bör man besluta om principer för utformningen, tillämpningen och utfasningen av subventioner till hållbara kraftslag.

Summary

The "Panel Project" is a part of the EFORIS research program. It is carried out by a panel comprised of academic researchers and practitioners in the power industry and related institutions and organizations. The key issue dealt with by the panel is whether the current electricity market arrangements are fit for purpose when a significant or even dominating part of total electricity will be based on wind and solar power. In other words: Is it time for another electricity market reform?

The ongoing transformation of the electricity supply system implies a rapidly increasing proportion of intermittent power, in the form of wind and solar power. These technologies have two unique features. One is that variable costs are close to zero. Thus, whenever a wind or solar power plant can produce, it produces at a lower cost than any conventional power plant (except some CHP). The other is that the level of output depends on nature and is more unpredictable than the output of conventional power plants.

These characteristics of wind and solar power have created concerns about the financial viability of conventional power plants and thus about the security of supply of the future electricity supply system in Sweden. Does this mean that a revision of the current electricity market design is needed? The conclusion by the panel is that several minor changes of the rules and regulations of the electricity market indeed are needed, while major changes may be considered in the future. In terms of minor changes the panel recommends that:

- The caps on day-ahead and balance market prices are raised to levels reflecting available estimates of VOLL (Value of Lost Load).
- The spot price is set at the cap level whenever the strategic reserve is activated.
- The strategic reserves are coordinated across the Nordic countries.
- Trading intervals on the intra-day and balance markets are reduced
- Balance requirements are referred to shorter than hourly periods
- Gate closure is closer to the time for delivery

However, it cannot be ruled out that some major changes of the electricity market design will have to be considered in the future. This would probably amount to replacing the current strategic reserve ("effektreserven") with an extended capacity mechanism, preferably a Nordic rather than a Swedish capacity mechanism. In view of this the panel proposes that

- A quantitative measure of supply security is defined and continuously monitored
- A trigger value at which an extended capacity mechanism is needed is determined

Moreover the Panel recommends that:

- If and when an extended capacity mechanism is needed, the choice of specific mechanism should be done with the goal of keeping as much as possible of the current competitive electricity market.

Due to the continuing integration of national electricity markets, not the least in the Nordic and Baltic countries, there is a new geography of the electricity market. But this is hardly visible in energy statistics published by the *Swedish Energy Agency* and other energy related institutions in Sweden. The Panel recommends that a redesign and revision of the electricity market and power industry statistics is implemented. More precisely the statistics should provide relevant information about wholesale electricity consumption, electricity prices and capacity adequacy in a wider geographical area than Sweden.

The political goal is to develop a sustainable electricity supply system. The goal for research on electricity market design should be to define the institutions of a competitive electricity market which are conducive to such an electricity supply system. These institutions should also be conducive for cross-border trade and continued development toward a single European markets for electricity. In addition principles for the design, implementation and phasing out of subsidies to preferred technologies should be developed.

List of content

1 The Panel Project

The ongoing transformation of the Swedish electricity supply system has caused considerable concerns about the design of the electricity market. The key issue is whether the current electricity market arrangements are fit for purpose when a significant or even dominating part of total electricity supply in Sweden and several neighboring countries will be based on wind and solar power. Several studies have addressed this issue[1], and many conclusions and recommendations have been put forward. The "Panel Project", which is a part of the EFORIS research program, has the same motivation but represents a slightly different approach to the study of electricity market design issues.

The basic idea of the Panel Project is to bring knowledge from both academic research and practical experience in various parts of the power industry and related institutions to the table. The overarching objective is to evaluate the need for another electricity market reform, and, to the extent such a reform is considered necessary, to outline the main features of a revised electricity market design in Sweden, the Nordic area, or even the EU as a whole. The members of the panel are introduced with brief biographies in the Appendix.

It should be pointed out that, within the frame of the project, the members of the panel have not represented the organizations to which they are affiliated. Thus they have participated in the project only in order to share their knowledge and insights about electricity market issues. Each and every panel member has approved the report, but does not necessarily agree on all the conclusions and recommendations put forward.

[1] For instance "*Electricity Market Design for a Reliable Swedish Power System*", by Copenhagen Economics, "*Framtidens elmarknad*" (*The Future Electricity Market*) by the Royal Swedish Academy of Engineering Sciences (IVA) and "*Electricity market needs fixing – What can we do?*" by Fingrid.

2 Background and motivation

In 1996, a major electricity market reform was implemented in Sweden. It was inspired by similar reforms in Norway and England & Wales a few years before. However, the Swedish reform process was also driven by anticipations about upcoming EU Directives aimed at liberalizing and integrating EU electricity markets. Behind these reforms was an internationally widespread belief that competition in liberalized markets, better than detailed regulation, would foster efficiency in network industries such as electricity, railways, airlines and telecommunications.

The Swedish electricity market reform not only implied liberalization, i.e. opening up for free price formation and market-based decisions about production and investments in the power industry. It also implied a first step toward internationalization of the electricity market. Thus, regulatory constraints on cross-border trade between Sweden and Norway were lifted, and a common Swedish-Norwegian market place, Nord Pool, was established. After the implementation of similar reforms in Finland and Denmark a few years later the "Nordic electricity market", internationally often referred to as "Nord Pool", was created.

While complaints about the functioning of the electricity market are voiced from time to time, analysts and power industry representatives throughout the world consider the Nordic electricity market a success. The lights have stayed on, power industry productivity has increased and pre-tax electricity prices have been close to the relevant marginal costs. Despite considerable consolidation of the power industry, there is no abuse of market power in the electricity market. Another sign of success is that the EU "Target Model", aimed at guiding the development of electricity market institutions in EU member states, is clearly inspired by the design of the Nordic electricity market.

However, the economic, technological and political environment of the electricity market is changing. In addition to the much slower growth of electricity demand, there are four ongoing, largely European-wide, processes with potentially significant impact on the electricity market. These processes are:

- The geographical extension of the electricity market has grown and continues to grow. Before 1996, domestic supply and demand conditions determined electricity prices in Sweden. In 2017, electricity prices reflect supply and demand conditions in a large part of northern Europe.
- Financial support schemes, which significantly affect the timing and structure of investment decisions in the power industry, have been implemented and are likely to be a long-term feature of energy policy.
- Large-scale introduction of intermittent power production is taking place. In Sweden and other North European countries this primarily has the form of wind power introduction, while solar power is playing an increasingly important role in the central and southern parts of Europe.

- Rapid technological changes coupled with "learning by doing" and scale-based cost reductions in wind and solar power production have paved the way for distributed electricity production. Also "smart grids" have opened up new possibilities for interaction between suppliers and consumers. At the same time energy storage is about to become economically viable.

There is also a fifth process with potentially significant impact on electricity market design in the Nordic countries. This process amounts to a shift of decision making about the rules and regulations of the electricity market from the national to the European level. Thus the DG Energy of the EU Commission currently has responsibility for the overall policy and regulatory framework while the Agency for the Cooperation of Energy Regulators (ACER) is responsible for regulatory oversight and has the possibility to intervene in certain areas.

It is fairly obvious that these processes will have implications for the power industry, in terms of business models as well as for the entire structure of that industry. Likewise system operators will face new challenges, and with more distributed generation the same will apply for distribution network operators. The key question, however, is whether the current design of the electricity market will remain appropriate and efficient in spite of these changes in the generation, transmission and distribution segments of the power industry. In other words, is it time for a second electricity market reform?

3 Purpose and scope of the report

The purpose of this report is to present the analyses, conclusions and recommendations of the Panel Project. The electricity market design issues dealt with in the project are seen in a Nordic and sometimes European perspective. Yet, the primary focus is on rules and regulations affecting power producers and electricity consumers in Sweden. The report is targeting energy policy makers, decision makers in the power industry and related organizations as well as media and people with an interest in electricity market issues. It is also intended to inspire researchers in economics and energy systems analysis to focus on electricity market research. The outline of the report is as follows:

In Section 4, the physical characteristics of electricity production and their implications for electricity markets are briefly discussed, while key features of the current electricity market are presented in Section 5. In Section 6, the four processes mentioned above are discussed in more detail, focusing on their implications for the functioning of the electricity market. In Section 7, a number of proposed minor and major changes of the electricity market design are presented and evaluated. In Section 8, the politics and economics of taxes and subsidies are discussed, and in Section 9 some of the long-term visions for the electricity supply system and electricity market are briefly discussed.

4 Physics and economics of electricity markets

Due to the laws of physics and the current level of technology the design of electricity markets must differ from that of other markets in certain respects. The key physical fact is that production has to continuously equal consumption[2]. The key technological fact is that trade in electricity on a second-by-second basis is not feasible. Instead the traded "products" are hourly (or half-hourly or even 5 minutes) loads or accumulated loads during longer periods.

As a result of this mismatch in time-scales there is a need for a "System Operator", i.e. an agent in charge of continuously balancing the power system (maintaining "security of supply"). This agent often also has the role of managing the transmission system, and is thus called "Transmission System Operator" (TSO). The need for a system operator also implies that security of supply is a public good, i.e. a good the provision of which simultaneously benefits all consumers connected to the network.

Another specific feature of electricity markets is that consumers do not take active part in short-term trading. The reason for this is basically technological. With the technology available to date it has not been possible for consumers to easily observe and react to electricity price information on an hourly basis, not to say a real-time basis[3].

As a consequence retail electricity contracts are typically designed as call options, i.e. within certain limits, consumers can buy as much electricity as they want at a given price during a specific period. From the point of view of the TSO this makes electricity demand less predictable, and increases the need for arrangements supporting the balancing of the system in real time. As will be discussed below, the system of "Balance Responsible Parties" is such an arrangement. However, as will also be discussed below, new technology may significantly increase the possibilities for active demand side participation in the electricity market.

[2] "Production"/"consumption" may then include power from/to storage facilities.

[3] In recent years it has become possible also for household consumers to buy electricity on an hourly basis, but due to relatively limited price volatility the incentives to do so have not been very strong.

5 Key features of the current Swedish electricity market

The power industry has a vertical structure with four distinct parts: Generation, Transmission, Distribution and Retailing (or Supply). In most countries the industry used to be organized in two segments, with Generation and Transmission in one and Distribution and Retailing in the other. The first segment typically had very few players—only one in many countries—while in most cases there were a large number of players, each one with a local monopoly, in the second segment. Central regulations of investment, production and prices were common. But in the 1980s, ideas and proposals about a new industry structure and more room for regular market forces began to emerge. This led to a wave of electricity market reforms all over the world, not the least in the Nordic countries. In some countries, privatization of the power industry has been part of the electricity market reforms.

The electricity market reform and the current market design
The electricity market reforms all implied vertical separation of the four parts of the power industry, although the details of the reforms differed across countries. Thus Generation was separated from Transmission, and in general Distribution was separated from Retailing. Moreover, the reform opened up for competition in Generation and Retailing, while Transmission and Distribution were considered "natural monopolies" and remained subject to regulation of prices and other key aspects of their operation. The most important regulation from an electricity market point of view was "Third Party Access" (TPA), i.e. the requirement that transmission and distribution networks be open for third parties at non-discriminatory prices.

Since its implementation twenty years ago, the new regulatory framework has led to major changes of the structure of the Swedish power industry. Thus, there has been significant consolidation both in the generation and distribution segments of the industry. In retailing, a number of new firms have entered the market, and by now consumers can choose between a wide range of different providers and contracts for electricity. At the same time, organized market places for electricity trade have been established.

The day-ahead (Elspot) and intra-day (Elbas) markets, together with financial markets based on day-ahead prices, have become key instruments for production planning and risk management in the generation and retailing segments of the industry. The price formation on the day-ahead and intra-day markets is transparent and price data is easily accessible. The regulation of Transmission and Distribution has been changed from an *ex post* to an *ex ante* model, implying that the regulator (*Swedish Energy Markets Inspectorate*) imposes a revenue cap for each transmission and distribution company. Thus the regulation of network prices is indirect via the revenue caps, which are revised every fourth year.

Reliability of the power system

The "Reliability" of a power system is generally considered to have three aspects. "Supply security" is a short term matter related to the system operator´s access to balancing resources in order to maintain frequency and voltage at target levels. "Flexibility" is about the possibilities to increase or decrease power production and/or consumption. "Capacity adequacy" is a long term matter related to the amount of available capacity in relation to peak demand. Needless to say, there is a strong relation between these three aspects of "reliability". With insufficient capacity adequacy, for instance, it may be difficult or even impossible to continuously maintain security of supply.

The electricity market reform has often been described as "deregulation of the electricity market". While it is true that prices and investments no longer are subject to regulation, a number of specific rules and regulations apply to the power industry and the electricity market. Yet, in one very important aspect the electricity market is not regulated: There is no regulation of available capacity in relation to expected peak demand, i.e. "capacity adequacy". Instead, the Nordic electricity market is an "energy-only market" where capacity adequacy is expected to be secured as a result of economic incentives faced by the market actors. But there is no pricing of capacity *per se*.

Rather, the remuneration to capacity comes from the difference between the market price of electricity and the variable cost of individual power plants. In general, the market price is equal to or just above the variable cost of the marginal plant, i.e. the plant with the highest variable cost of those that need to produce in order to satisfy demand. Thus the infra-marginal plants face a positive difference between the market price and the plant's variable cost. But in order for such a difference to exist for peak-load plants, producing only during a limited number of hours per year, there must be periods with so called "scarcity pricing". That is periods when demand tends to exceed the available capacity, and the market price thus has to be higher than the variable cost of the marginal plant in order to establish equality between supply and demand[4].

However, there is also a complement to the market-based provision of capacity adequacy in the form of a so called strategic reserve ("Effektreserven"). Thus the TSO, i.e. *Svenska kraftnät*, is mandated to procure access to production capacity and/or demand flexibility up to a maximum of 750 MW to be activated when a market-clearing price cannot be established on the day-ahead market (*Elspot*) by the regular bids. A key feature of the system is that the price of electricity provided by the strategic reserve is set just above the highest bid on the day-ahead market. This means that the existence of the strategic reserve implies an informal cap on the market price of electricity. In turn this means that the strategic reserve not only provides extra capacity but also weakens the incentives for market-based provision of capacity adequacy.

[4] From a competition policy point of view this feature of energy-only markets is problematic. On the one hand prices above marginal production cost is often seen to indicate that some producers are exploiting their market power, which is not acceptable from a competition policy point of view. On the other hands periods with prices above marginal production cost are necessary in order to maintain capacity adequacy.

From the point of view of maintaining security of supply the so called "Balance Responsible Parties" play a key role in the current market design. The system works as follows: Every producer and retailer[5] has a responsibility to, hour by hour, have access to exactly the amount of electricity that its customers consume, i.e. to be "in balance". Any difference between forecast and outcome implies selling or buying balancing power[6] on the real-time market operated by the TSO (*Svenska kraftnät*). Due to the pricing of balancing power the producers and retailers have quite strong financial incentives to be in "balance" each and every hour. If all producers and retailers are in balance, the system as a whole will also be in balance and supply security is maintained[7].

Consumption, production and prices

In terms of overall structure, the Swedish electricity market has changed considerably, both on the demand side and the supply side during the last two decades. On the demand side, the rapid growth up to the 1990s has been followed by a period of much slower or even negative growth. Thus, between 2006 and 2014, annual electricity consumption in Sweden fell by almost 12 TWh. Also in the Nordic area as a whole, there is a trend of falling demand, let alone with significant annual differences.

On the supply side, the trend is the opposite. Thus, between 2006 and 2014 electricity production in Sweden increased from 140.3 TWh to 150.3 TWh, essentially reflecting increased wind power production from 1.0 TWh to 11.5 TWh[8]. As a result Sweden´s net export of electricity increased quite significantly. More precisely from a net import of 6.1 TWh in 2006 to a net export of 15.6 TWh in 2014.

The combination of falling demand and increasing supply has put downward pressure on electricity prices. In the Stockholm area ("Electricity area 3"), for instance, the annual average price fell from 54 öre/kWh in 2010[9] down to 29 öre/kWh in 2014. In 2015, which happened to be a year with an exceptionally high level of hydro power production, the average annual price in the Stockholm area was only 21 öre/kWh. The Nord Pool "system price", which reflects supply and demand conditions in the entire Nord Pool area[10], exhibits the same pattern. Although prices have increased in the 2016-17 season, forward prices for the coming ten years are below 30 öre/kWh.

[5] Any producer or retailer can assume the role of "Balance Responsible Party", i.e. enter a contract with the TSO. Alternatively the obligation in question can be transferred to a firm that, at a price, aggregates the resources and obligations of several producers or retailers.

[6] To be precise these are not regular market transactions but part of an *ex post* settlement process.

[7] This is not exactly true. "Balance" refers to hours, while "supply security" is about continuously balancing the system in real time.

[8] The corresponding figure for 2015 is even higher, 16.6 TWh, but it seems that 2015 was a year with particularly good conditions for hydro and wind power production.

[9] The high price level in 2010 among other things reflected the unusually low temperatures during the winter period.

[10] The system price is calculated under the assumption that there is no congestion in the transmission system. Once such constraints emerge the price of electricity will differ between two or more "electricity areas".

Electricity prices at or close to the level experienced the last few years are much lower than what is needed to cover the full cost of any type of new power production plants. Moreover, low prices have reduced the operational surpluses of existing conventional power plants and put considerable financial pressure on power producers. This is a problem for the owners of power companies, but it may also have a social cost in terms of reduced innovation and technological development in the power industry. Needless to say, power companies have a key role in the transformation of the electricity supply system, and low profitability is likely to increase the cost of financing new investments. However, there are several new actors that innovates new solutions for power generation, storage and demand flexibility.

6 Major processes affecting the electricity market

As mentioned in the introduction, the electricity market is increasingly affected by four on-going processes. In the following section, each one of these is discussed in some detail, focusing on the implications for the functioning of the electricity market.

6.1 THE GEOGRAPHICAL EXTENSION OF THE ELECTRICITY MARKET

The creation of the Nordic electricity market in the late 1990s turned out to be just the beginning of a process of far-reaching electricity market integration in Europe. Since then, physical interconnections between European countries have been extended, and day-ahead markets, from the north to the south, have been coupled. Moreover the EU Commission has issued directives aimed at creating a single European market for electricity.

The market integration process is particularly visible in the Nordic area, where the electricity markets of the Baltic States, Poland and to some extent Germany by now are physically and institutionally connected to the Nordic electricity market. Against this background there is reason to ask whether "the Swedish electricity market" remains to be a relevant concept.

The answer depends on which perspective one adopts. In terms of power production and wholesale prices, Sweden is part of a well-integrated electricity market comprising all the Nordic countries and the Baltics (the "Elspot area"), and this market is coupled with the electricity markets in Germany and further southward in Europe. However, the size of the "relevant electricity market", i.e. the geographical area in which the wholesale price of electricity is the same, varies over time depending on the degree of interconnector congestion within and between countries. Thus, at times the wholesale prices in the four "electricity areas" in Sweden may differ, while the price may be the same in the whole Elspot area at other times[11].

Yet, Sweden as a geographical and legal entity remains relevant in several other electricity market perspectives. Retail prices are significantly affected by Swedish taxes and the electricity certificate system. Property taxes and subsidies to renewable energy (to be discussed in the ensuing sub-section) play a significant role for the cost of building and using different types of power plants in Sweden. Transmission and distribution network charges and operational conditions are subject to Swedish legislation. Although there is close cooperation between system

[11] For example, between 02 and 03 on January 2016 the spot price was the same and equal to 23.28 öre/kWh in the whole Elspot area except Latvia and Lithuania where the price was 33.54 öre/kWh. A few hours later the same day, between 08 and 09, there were three different price levels in the Elspot area. Thus, in SE 1 and SE 2 in Sweden and the northern part of Norway the price was 32.24 öre/kWh, while it was 34.43 in SE 3 and SE 4 in Sweden, Finland, the Baltics and the southeast of Norway. In the remaining parts of Norway the price was 41.94 öre/kWh.

operators in the Elspot area it is clear that *Svenska kraftnät*, the Swedish TSO, has a key role in managing and controlling the Swedish electricity supply system.

However, the new geography of the electricity market is hardly visible in energy statistics published by the *Swedish Energy Agency* and other energy related institutions in Sweden. As the integration of the national electricity markets is likely to continue a redesign and revision of the electricity market and power industry statistics would be desirable. More precisely the statistics should provide relevant information about wholesale prices and capacity adequacy in a wider geographical area than Sweden.

When it comes to prices the underlying supply and demand, conditions not only in Sweden but also in the other Nordic countries and the Baltics, Poland and Germany should be reported in a consistent way. When it comes to capacity adequacy the challenge is to develop and apply relevant quantitative measures, primarily for Sweden and for the Nordic area as a whole.

6.2 TAXES AND SUBSIDIES AFFECTING THE ELECTRICITY MARKET

Fiscal taxes on electricity consumption have existed for ages, and remain an important source of revenue for the government. There are also taxes on electricity production, primarily in the form of property taxes on hydro and nuclear power plants[12]. However, during the last two decades subsidies to power production based of renewable resources have been introduced. The main vehicle for subsidizing power production based on renewable sources in Sweden is the market for tradable "electricity certificates". These certificates are issued per unit of renewable electricity produced, and are demanded by electricity retailers who need to comply with legal requirements about the proportion of renewable electricity in the total consumption of electricity by their customers.

The goal of these policies primarily reflects EU environmental policy goals[13]. One of these is to make the electricity supply system sustainable and free of greenhouse gas emissions. Another is to increase the efficiency by which electricity is used and thus reduce electricity consumption. From the point of view of electricity market design consumption taxes are not very important, but production taxes and subsidies may affect the functioning of the electricity supply system and call for changes of the design of the electricity market.

[12] This includes a special nuclear power tax which is about to be phased out.

[13] Yet fiscal concerns also play a role. For instance, in 2016 the total revenues from the property taxes on hydro and nuclear power amount to around SEK 10 billion equally divide between the two technologies. Moreover, the design of the subsidy system to electricity from renewable sources, i.e. the electricity certificate system, implies that the subsidies are paid directly from the consumers rather than from the government budget.

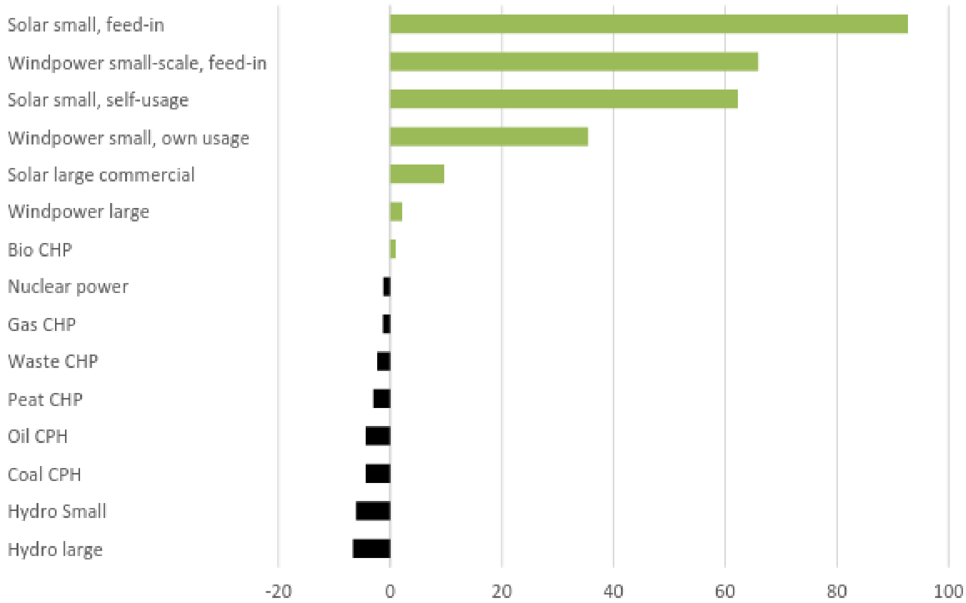

Table 1. Net effect from taxes and subsidies 2017, öre/kWh

Source: SWECO

As shown in Table 1, the combined impact of current taxes and subsidies varies significantly across different technologies. Thus, while some technologies are subject to taxation (negative numbers in the figure), the subsidies to small-scale wind and solar power are quite significant. Yet the tax/subsidy difference between large scale wind power and hydro power is only 9 öre/kWh, and the corresponding figure for nuclear power is 4 öre/kWh. However, these numbers are considerably lower than they were only a year ago (25 öre/kWh and 24 öre/kWh, respectively[14]) and have been for quite some time.

In the case of nuclear power, part of the reason for the much lower tax/subsidy difference in relation to large scale wind power in 2017 is the phasing out of the nuclear capacity tax. But the main reason is that the subsidy to wind power comes as revenues from selling electricity certificates and the certificate prices have fallen considerably. Thus, while the certificate prices have been in the range 16-19 öre/kWh for quite some time they have dropped significantly since the beginning of 2017. As a consequence, the certificate price behind the numbers in the table is 4.5 öre/kWh, which in a historical context is extremely low. A slight price increase has taken place, but the level is still low. Combined with the low prices of electricity this means that the economic incentives to invest in wind and solar power are not likely to be very strong unless additional support to such investments is implemented.

However, the set of production taxes and subsidies in place until the end of 2016 provided quite strong incentives for investments in wind and solar power. One effect of these investments is that the total capacity to produce electricity in Sweden has increased considerably, in spite of the stagnant demand. As a result,

[14] See *Framtidens Elmarknad*, IVA, 2015, p.21.

wholesale electricity prices have fallen to a level well below the full cost of new generation capacity. From a social efficiency point of view this means that the timing of the wind and solar power investments has not been "dynamically efficient". In order to be dynamically efficient, capacity additions should be done at a rate where market prices are equal to the long term marginal cost, i.e. the marginal cost that includes capital costs[15].

The other effect of the tax and subsidy system that has been in place during recent years is that the proportion of intermittent power in total power supply has increased significantly. This change of the structure of power production is most likely to have an impact on the functioning of the current electricity market design, which is the topic of the ensuing sub-section 6.3. The design and implementation of the electricity tax and subsidy system will be further discussed in Section 8.

6.3 ELECTRICITY MARKET CONSEQUENCES OF AN INCREASING PROPORTION OF INTERMITTENT POWER

Wind and solar power technology has two unique characteristics. One is that variable costs are close to zero. Thus, whenever a wind or solar power plant can produce, it produces at a lower variable cost than any conventional power plant (except some CHP). The second is that the level of output depends on nature and is more unpredictable than the output of conventional power plants. While the annual output of individual wind and power plants can be predicted with a reasonable degree of accuracy, wind power output during a specific hour is highly uncertain until a few hours before dispatch. Moreover, in an electricity supply system with a high proportion of intermittent power, the short term variations of aggregate wind and solar power may be quite significant.

The diagram below illustrates the magnitude of short term wind power production variations during the month of January in 2040/50, assuming that installed wind and solar power capacity is 18 800 MW and 12 00 MW, respectively[16]. This means that wind and solar power capacity are assumed to develop in accordance with current plans. The diagram is based on the assumption that wind, temperature and demand conditions are the same as during the corresponding period a during a so called ten year winter.

[15] It could be argued that the lower production in nuclear and fossil fuelled plants resulting from increased production of wind and solar power has benefits in the form of reduced generation of spent nuclear fuel and harmful emissions, respectively. However, as will be discussed in Section 8 the socially efficient way of reducing harmful externalities is to tax the emissions, i.e. not to subsidize alternative production technologies.

[16] The corresponding levels of annual production are 54 TWh for wind power and 10 TWh for solar power.

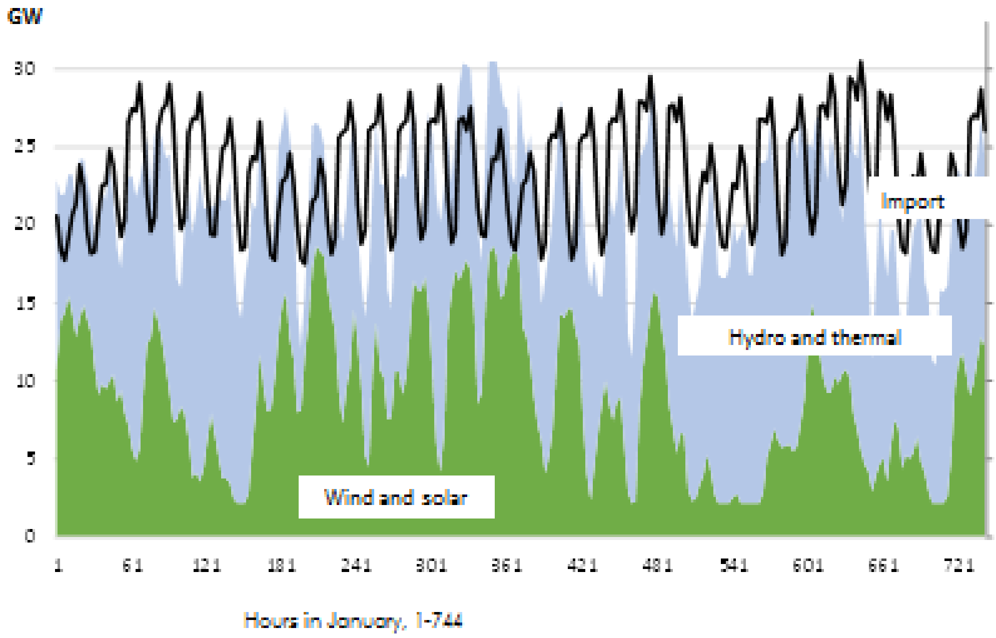

Diagram 1. Projected demand, production[17] and import in January 2040/50
Source: PROFU

As shown by the diagram, the wind and solar power production (mostly wind power in January) varies between approximately 2 000 MWh/h to 18 000 MWh/h within a few days. Given the need to continuously balance the power supply system, this means that conventional power or storage facilities must be available in order to compensate for the intermittency of wind and solar power. Alternatively more flexible instantaneous demand can substitute for reserve capacity in conventional power plants or availability of stored electricity.

However, Diagram 1 also illustrates another feature of an electricity supply system with a high proportion of non-schedulable power, namely relatively long periods of very low levels of intermittent power production. As shown by the diagram, the level of wind power production is at a very low level for 2-3 days at several occasions. In those cases, flexibility of demand is not likely to be an efficient alternative for balancing the short-fall of wind power production. Instead, schedulable power must be available to prevent rolling brown- or black-outs.

Adapting the electricity market design to a situation with a high proportion of intermittent power could require a two-step process. The first step is to adapt the energy-only market by implementing relatively minor changes in practices, rules and regulations. If that step is not sufficient, a second step would be to introduce a capacity mechanism (instead of the existing strategic reserve). Such a reform would mean that the energy-only model in effect is replaced by a different electricity market design. The specific measures that would and should be

[17] "Production" includes output from new thermal plants and batteries.

implemented within the frame of this process, and their likely consequences, will be discussed in Section 9.

6.4 TECHNOLOGICAL DEVELOPMENT AFFECTING THE ELECTRICITY MARKET

As briefly discussed in Section 4, the electricity market as an institution where producers and consumers of electricity interact have a few rather unique features. One is that a system operator is needed in order to maintain security of supply. Another is that consumers in practice are not observing and reacting to electricity prices in real time. These features have had significant impact on the design of electricity markets as well as on the thinking about methods to ensure capacity adequacy and security of supply.

However, technological developments are gradually changing the situation and opening up new options. Technologies for storing electricity are being developed and may soon play a role in the fine-tuning of the electricity supply system by providing additional supply or demand on short notice. More importantly, storage facilities in effect can move electricity from periods with high wind and solar power production to periods when that production is low, thus alleviating one of the key problems with intermittent power production.

Another effect of technological change is that distributed power production of significant scale is becoming a real possibility. Among other things this means that a new type of actor, the "prosumer"[18], is entering the electricity market. Technological development on the demand side includes development of devices enabling consumers to automatically observe and react to electricity prices in real time, thus increasing the short-term price sensitivity of electricity demand.

With increased flexibility of demand, the risk for insufficient capacity adequacy will be lower, particularly if electricity storage options also are available. The new technology also opens up possibilities for new consumer products on the electricity market, for instance individualized levels of supply security. It should be noted, however, that in order for these new technologies to be profitable electricity prices need to be volatile. Thus, storing of electricity can be profitable only if prices are low at certain times and high at other times.

In view of these developments, it is of utmost importance that the rules and regulations of the electricity market do not act as barriers to the implementation of new technologies and business practices. It is also critical that the impact of new technologies and business practices are carefully evaluated before major changes of the electricity market design are implemented.

[18] By "prosumer" is meant a customer with own production capacity, typically in the form of wind or solar power. The "prosumer" may alternate between being a net buyer from the grid or a net seller to the grid.

7 An electricity market design for the future

What is the appropriate design of the electricity market in view of the four processes of change discussed in this report? To answer that question, one needs a fairly specific idea about the characteristics of the Swedish electricity supply system a few decades into the future. As a point of departure for its deliberations, the Panel has taken a simulation of the capacity and demand conditions expected to prevail a year between 2040 and 2050. The numbers, presented in Table 2, should not be interpreted as a forecast, but as a reasonably realistic description of the future electricity supply system in Sweden.

As shown in the table, the growth of demand is assumed to be rather modest while a significant growth of wind and solar power capacity is projected. In terms of expected peak capacity, however, the contribution from wind and solar power remains limited[19]. Moreover, the additional wind and solar capacity does not fully compensate for the nuclear capacity that is scheduled to be phased out during the next couple of decades. This means that although wind and solar power plants are likely to supply a significant proportion of the total annual supply of electricity, a certain amount of other kinds of schedulable power is needed in order to balance the system during peak-hours. As indicated by the numbers in the table it may also become necessary to rely on imports during peak periods.

However, the table also illustrates the benefits of having ample access to hydro power in Sweden and the Nordic area as a whole. Hydro power is flexible both in terms of balancing short term variations in wind and solar power production and in terms of compensating shortfalls of wind and solar power production during several days. Without hydro power, the situation in the Nordic countries would be about the same as in continental Europe with respect to the problems associated with the expansion of intermittent power production.

[19] It is assumed that the capacity credit for wind and solar power in 2040/50 remains at the same level as estimated by *Svenska kraftnät* for the current system.

Table 2. Capacity and demand in the Swedish power system 2016/2017 and 2030/2050

	2016/2017		**2040/2050**	
	Installed capacity, MW	**Expected peak capacity, MW**	**Installed capacity, MW**	**Expected peak capacity, MW**
Hydro power	16 200	13 700	16 200	14 000
Nuclear power	9 100	8 200	0	0
Wind power	6 500	700	18 800	2 200
Thermal power	8 000	4 600	8 000	6 000
Solar power	0	0	12 000	0
Total capacity	**39 800**	**27 200**	**55 000**	**22 200**
Demand, MW		**27 400**		**30 000**
Deficit to be covered by import, demand response, thermal power and batteries		-200		-7 800

Source: Svenska Kraftnät (2016/2017) and Energiföretagen (2040/2050).

On the basis of the numbers in the table, two observations related to electricity market design can be made. The first is that the market design, in one way or the other, should provide incentives for generators to keep sufficient amounts of conventional power capacity and/or storage capacity available. What is "sufficient" depends on the degree of demand flexibility which is technologically and economically feasible a few decades into the future.

The other observation is that although the system will have a significant proportion of non-schedulable power with close to zero variable cost there will be a considerable amount of conventional power plants with variable costs well above zero. (In the case of hydro power the variable cost at a certain hour is the opportunity cost of using the stored water at some other time.) But this means that a key feature of the current market design, i.e. that generators make bids to the day-ahead and intraday markets on the basis of positive marginal (variable) cost, will continue to prevail. In other words, the current model for pricing electricity is likely to work also in the future. What may be problematic is the pricing of capacity, and the consequences of insufficient capacity adequacy.

7.1 WHAT IS AN "ELECTRICITY MARKET REFORM"?

The electricity market developments during the coming decades will be affected by the four processes discussed above. In addition "endogenous" adjustments to new circumstances by producers, consumers, balance responsible parties and institutions such as Nord Pool will affect the development of the electricity market. For instance, it cannot be ruled out that balance responsible parties secure access to capacity by entering contractual agreements with producers and thus in effect create a capacity market. Moreover, new actors may enter the electricity market and incumbent power companies may change their business models.

However, in the following such “endogenous” adjustments will not be regarded as “reforms”, even though they may play a significant role for the future development of the electricity market. What will be regarded as “reforms” are changes in rules and regulations under control by the TSO, as well as changes in electricity market legislation.

7.2 REVISIONS AND EXTENSIONS OF THE ENERGY-ONLY MODEL

Reforms of the current energy-only market design should be focused on the specific problems emerging from increasing proportions of intermittent power in the overall power mix. In particular two problems have to be addressed. The first is that the wind and solar power, due to the negligible variable cost, outcompetes every other kind of power plants whenever there is sufficient wind and sun, respectively. For “conventional” power plants this means that the annual number of hours in operation becomes lower than it used to be, and unless compensated by higher prices this will lead to lower revenues.

The other specific problem related to a high proportion of intermittent power is that total power production becomes less predictable in the short and very short term. This means that current (hourly) trading intervals and time before “gate closure” (one hour) may have to be revised. In addition wind and solar power plants differ from conventional power plants with respect to their provision of ancillary services such as inertia. Thus, methods for securing the supply of such services have to be established[20].

In the following sub-sections, a number of measures that address these problems are proposed.

Price caps and the use of the strategic reserve
In order to maintain conventional power revenues at a full-cost level when hours of operation are reduced, the electricity prices have to be higher during hours when the plants in question produce. This applies to all kinds of conventional power plants—not only to plants intended to serve peak demands. Thus, in order for the energy-only model to work properly, the regulated caps on the price of electricity need to be at a sufficiently high level. Moreover short periods with very high prices must be socially acceptable.

Current Nord Pool rules imply that day-ahead prices are capped at 3 000 EUR/MWh, while balance market prices are capped at 5 000 EUR/MWh. These levels are considerably lower than in other parts of the world, where the corresponding caps typically are related to estimates of VOLL, the Value of Lost Load. In Australia, for instance, the cap is 9 000 EUR/MWh. Needless to say the estimates of VOLL are uncertain and vary between groups of consumers, season and time of day. Yet, most estimates are well above 3 000 EUR/MWh.

[20] However, technological solutions such as virtual inertia may partly meet the requirements for ancillary services.

As mentioned, there is also an informal cap on the price of electricity, stemming from the rules for activating the strategic reserve. In accordance with these rules, the reserve is activated when equality between supply and demand on the day-ahead market cannot be established. The price is then set just above the marginal bid. That bid might be equal to the variable cost in peak load plants. But it could also be equal to a scarcity price, i.e. a price above the variable cost in the marginal plant. In case the strategic reserve is not sufficient to establish equality between supply and demand, the price is set equal to the formal cap, i.e. 3000 €/MWh, and the buyers only get a proportion of their bids.

It is unknown to what extent this informal cap affects expected revenues of peak load capacity. Yet, it is clear that there is uncertainty about which price that will prevail in scarcity situations, and it is likely that that uncertainty has a negative impact on investments in schedulable capacity.

In view of these observations, the Panel proposes that:

- The caps on day-ahead and balance market prices are raised to levels reflecting available estimates of VOLL.
- The spot price is set at the cap level whenever the strategic reserve is activated.

Since the electricity markets in the Nordic countries are so well integrated, there is a strong case for coordinating the use of the strategic reserves. Such coordination does not imply a common strategic reserve, but common rules about maximum price and under which circumstances the reserves are activated. Thus, the Panel proposes that:

- The strategic reserves are coordinated across the Nordic countries.

The parties in charge of implementing these proposals are the power exchanges (e.g. Nord Pool) and the TSOs in the Nordic countries.

Trading intervals and gate closure

The current hourly trading intervals and the time between the closure of intraday trading and the time for delivery (“gate closure”) were selected at a time when hydro and nuclear power plants were the dominating producers of electricity in the Nordic countries. Among other things, this meant that total power production was highly predictable in the short and very short term. Consequently, hourly trading and hourly balance requirements as well as a one-hour gate closure were appropriate features of the electricity market design. With a high proportion of wind and possibly solar power, this will no longer be the case. To this end, the Panel proposes that:

- Trading intervals are reduced
- Balance requirements should refer to shorter than hourly periods
- Gate closure should be closer to the time for delivery

The parties in charge of implementing these proposals are the TSOs in the “Elspot” area; TSOs should also decide on how much to shorten trading intervals, etc.

Pricing of ancillary services
As long as different types of power plants did not differ significantly with respect to their provision of so-called ancillary services, such as inertia, there was no reason to have specific markets or other methods for pricing of such services. With a high proportion of wind and solar power, the situation is different and payment for provided ancillary services may become an important source of revenue for conventional power plants. To this end, the Panel proposes that:

- Methods for pricing of ancillary services are developed and implemented

Again, the TSOs in the Nordic countries or in the Elspot area as a whole are in charge of detailing and implementing this proposal.

7.3 AN ALTERNATIVE ELECTRICITY MARKET DESIGN

Implementation of the reforms mentioned above would make the electricity market more fit to accommodate a significant proportion of intermittent power. However, although it is likely that the reliability of the electricity supply system will be maintained, such an outcome cannot be guaranteed. It may be the case that investments in schedulable load capacity will appear too risky when their profitability depends on very high prices during very few hours. Additionally, consumers' ability to hedge the risks associated with electricity price spikes may be insufficient, which could imply that price spikes become socially and politically unacceptable. As a result, additional reforms may be needed some years along the road.

The commonly proposed addition to the electricity market institutions is a "capacity mechanism". Such a mechanism is used for safeguarding a target degree of security of supply, either directly or indirectly through a target level for capacity adequacy. The key feature of a capacity mechanism is payment for available MWs, either in the form of production capacity, storage or flexible demand. When designing a capacity mechanism it is quite important that available capacity is provided in a cost-efficient way. If, for instance, there is a bias towards production capacity at the expense of less costly alternatives in the form of demand flexibility or storage the target security of supply will come at an unnecessary high cost.

Capacity mechanisms can be designed and classified in many different ways. However, the classification below has become standard in the electricity market design literature. It is also common to label the "Volume based, Market-Wide" mechanisms "Capacity Markets". As seen below, "Strategic Reserve" is one of the identified capacity mechanisms. Thus, the issue is not whether a capacity mechanism should be introduced in Sweden, but rather to what extent the existing strategic reserve is sufficient and fit for purpose.

Capacity Mechanisms				
Volume Based				**Price Based**
Targeted	***Market-Wide***			
Strategic reserve	*Capacity obligation*	*Capacity auction*	*Reliability option*	*Capacity payment*

Capacity mechanisms have been or are in the process of being implemented in many EU member states, and the design of these mechanisms differs across countries. For instance, in the UK a capacity auction system has been implemented, while several types of strategic reserves have been implemented in Germany. This process has created concern about the future integration of the national electricity markets in EU, i.e. the creation of "a single European market for electricity". The reason is that capacity mechanisms in effect can disturb cross-border trade and thus lead to a re-nationalization of electricity markets in EU.

A capacity mechanism may also undermine "endogenous" adjustments in the form of market based capacity contracts between producers and retailers, and between wind and solar power producers and conventional power producers. Yet, implementation of an extended capacity mechanism should be seen as an option if the promises of technological development and market based adjustments are not realized.

A natural first step toward keeping that option open would be to define and monitor a suitable measure of supply security, and to decide upon a trigger value for that measure, i.e. a value at which an extended capacity mechanism would be needed. In view of this the Panel proposes that

- A quantitative measure of supply security is defined and continuously monitored
- A trigger value at which an extended capacity mechanism is needed is determined

The party in charge of implementing this proposal is the Swedish TSO and, possibly, the legislator. However, defining a relevant quantitative measure of security of supply is not an easy task. Among other things import possibilities have to be included in a realistic way. The best way of handling that issue would be to opt for a Nordic rather than a Swedish capacity mechanism.

The trigger value is a way of determining the point in time when an extended capacity mechanism should be implemented or, at least, should be seriously taken under consideration. An equally important issue concerns the criteria for choosing such a mechanism. The Panel recommends that:

- If and when an extended capacity mechanism is needed, the choice of specific mechanism should be done with the goal of keeping as much as possible of the current competitive electricity market.

8 Economics and politics of electricity taxes and subsidies

The current set of taxes and subsidies affecting consumption and production of electricity should primarily be seen as instruments for achieving political goals such as increasing the proportion of renewables such as wind and solar power in electricity production as well as fostering "efficiency" in electricity consumption. The political goals in question reflect concern for the environmental damage caused by the use of fossil fuels, but even more a vision about a sustainable electricity system based on hydro, wind, sun and biofuels and free of risks associated with nuclear power.

In theory it would be possible to calculate the social costs and benefits of the intended transformation of the electricity supply system, and come to a conclusion about which system is preferable from a social efficiency point of view. But in practice such analyses cannot be done with a reasonable degree of accuracy. Moreover, the political goals clearly reflect other considerations than social efficiency as commonly defined. To this end, the Panel has not taken any position in relation to political goals, but considers them as given.

However, the design and implementation of policy instruments can and should be discussed from a social efficiency point of view. This discussion amounts to exploring to what extent the political goals could be reached at a lower social cost[21] by means of another set of policy instruments than those adopted. In particular, there are two of the policy instruments that need to be discussed: consumption taxes on electricity and subsidies to electricity based on renewables, in particular wind and solar power. The conceptual basis for the discussion is some key results in environmental economics and the economics of innovation and technological change. First the tax related issues are discussed.

The environmental damage caused by an economic activity is a real cost, but at the same time a cost that is "external" to the polluting firm or household. It is "external" because environmental resources typically are so called public goods and thus not tradable and priced on regular markets. A key result in environmental economics is that the external cost should be "internalized", either by means of a tax or a system with tradable emission permits[22]. Thus, it is not socially efficient to combat the pollution by subsidizing "clean" activities. Another key result is that the tax, or the tradable emission permit, should target the pollutant as directly as possible. For instance, to the extent possible it is the polluting substances in the flue gases from a thermal power station and not the fuels that should be taxed.

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[21] By "social cost" of certain activity is meant the total cost including external costs such as the cost of environmental damage. The calculation of social costs includes a number of issues about which monetary values should be put on market resources as well as on non-market resources. It is beyond the scope of this report to deal with these issues in any detail.

[22] The criteria for choosing between these two alternatives are elaborated in most textbooks in environmental economics.

Considering these factors, there is no reason, except fiscal reasons, to tax electricity *per se*[23]. From an environmental point of view, there is a big difference between electricity from hydro or wind power plants and electricity from coal power plants. Thus, in order to reduce CO_2 and other emissions at the lowest possible social cost, taxes should be levied on the emissions or, if that is not feasible, on the polluting fuels. With the same point of departure subsidizing wind, solar and bio power is not a socially efficient method to reduce CO_2 emissions. However, as is well known there is a European-wide system for reducing CO_2 emissions in place, the EU emissions trading system (ETS). This system has been widely criticized[24]; yet it appears to be the appropriate instrument for controlling CO_2 emissions in Europe.

However, there is another economic argument in favor of subsidies to wind and solar power, namely that these technologies are new and that early investments, through "learning by doing" and economies of scale in the production of wind and solar power plants, will become competitive. Factors such as those have played a significant role during the early phases of wind and solar power development, and have made the cost of wind and solar power competitive investment alternatives. Consequently, the subsidies in Sweden and many other countries have been effective. Yet, a couple of aspects of the system are questionable from a social efficiency point of view.

As mentioned, subsidies to wind and solar power[25] in Sweden are based on a tradable certificate system. A key parameter is the proportion of renewable electricity in total electricity consumption, i.e. the "percentage requirement". The numerical value of this parameter reflects political goals and has not been adjusted to prevailing supply and demand conditions on the electricity market. As mentioned this has led to overcapacity and very low prices.

The low prices imply redistribution of income from producers to consumers of electricity, and thus do not represent a social cost. But there is a social cost resulting from early retirement of nuclear power plants induced by the low prices. From a political point of view, this may be a desirable outcome. Yet, the nuclear power plants about to be closed could have produced electricity at a cost below the market price if the expansion of wind power had been somewhat slower, and that would have been beneficial from a social efficiency point of view. On the other hand the political goals about renewable power production would then not have been attained.

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[23] It has been argued that households, due to lack of information and suitable financing, do not implement energy efficiency increasing measures that would be privately profitable, and that extra incentives, in the form of taxes, thus are motivated from a social efficiency point of view. However, there is little evidence that households are less informed and rational when it comes to energy use decisions than they are in connection with other economic decisions.

[24] The criticism is primarily about the low prices of emission permits, not the functioning of the system in terms of keeping total emissions within target levels. However, the low prices of emission permits to a large extent reflect the impact of other measures, not the least the subsidies to wind and solar power, aimed at reducing CO_2 emissions. If these other measures would be phased out the EU ETS would most likely produce higher prices on emission permits and thus stronger incentives to reduce CO_2 emissions.

[25] Several types of electricity based on renewable energy sources are eligible for subsidies, but due to their intermittency characteristics and scale wind and to some extent solar power are the most important ones in an electricity market context.

Another concern is that the phasing out of the subsidy scheme is not explicitly related to the maturity of the subsidized technologies. It is fairly obvious that a technology which, due to "learning by doing" and economies of scale, has become competitive should not continue to be eligible for subsidies. Likewise, if the subsidized technology has not become competitive after a certain number of years, a further extension of the subsidy scheme should be seriously questioned. These views should be but have not been integrated in the subsidy scheme.

To this end, it appears desirable that a "subsidy strategy" is developed, aimed at introducing and expanding production from preferred technologies at a rate which is adapted to the retirement rate for existing power plants. Such a strategy would contribute to "dynamically efficient" investments in the power industry, i.e. capacity expansion at a rate that maintains electricity prices at the long run marginal cost level of the electricity supply system.

However, it is possible that the expansion of renewable power production resulting from such a strategy would not satisfy the political goals of the transformation of the electricity supply system. In that case, more subsidies—possibly designed in other ways than the current renewable electricity certificate system—would be needed. At the same time, such a development would imply an apparent conflict between the political goals about the structure of the electricity supply system and traditional goals of a cost efficient electricity supply system.

9 Concluding remarks

The Nordic electricity market has worked well, and the only reason for changing its rules and regulations appears to be that increasing proportions of intermittent power significantly changes the "playing field". However, it should be stressed that the ample supply of hydro power puts the Nordic countries in a favorable position in terms of the need for major changes of the electricity market design. Thus, such changes are more urgent in continental Europe.

In this report, several specific measures, aimed at improving the functioning of the electricity market in the emerging situation, have been proposed. The basic message is that reforms should be implemented if and when they are needed. Some reforms are urgent and should be implemented as soon as possible. Others, such as implementation of an extended capacity mechanism, are less urgent and can be put on hold. But rather than passively waiting to implement these reforms, a designated institution should work to define and monitor quantitative measures of supply security. If and when a critical value is reached there should be a plan for how to deal with the situation.

However, these conclusions are based on the assumption that the electricity supply system will retain some of its current basic features. These include a significant proportion of power production with non-negligible variable costs as well as essentially the same vertical structure (Generation, Transmission, Distribution and Retailing) of the power industry as today. But in a longer term perspective, the processes discussed in this report may lead to an electricity supply system, both in the Nordic countries and in large parts of Europe, which is very different from the system existing today.

This is the case if non-subsidized wind and solar power become the most competitive investment options, or if subsidization of these technologies continues, while conventional power in the form of nuclear and coal power is phased out. Consequently, the electricity supply system will be dominated by power plants with negligible variable costs. Moreover, a significant proportion of consumers may have access to advanced digital technology enabling them to observe and react to electricity prices and electricity supply conditions in real time.

The optimal design of a competitive electricity market will likely be different from the current design. Searching for a market design for a radically different electricity supply system amounts to answering several critical questions, including the following:

- What are the efficient mechanisms for maintaining security of supply, and what is the appropriate role of the TSO in relation to those mechanisms?
- What kind of pricing mechanism is efficient when electricity is produced without variable costs? Should prices be posted per unit of MW or per unit of MWh?
- Will the current vertical separation between Generation, Transmission, Distribution and Retailing remain appropriate?

- What will be the role of new actors such as Aggregators[26] and Prosumers?
- What are the efficient mechanisms for hedging price risks faced by producers and consumers?

These future-oriented issues form the basis for a research agenda, constituting a revival of research on "electricity market design". But this revival is already underway. One of several issues currently attracting attention is the relation between Distribution and Retailing. The argument is that total system costs could be reduced if the local network operator, i.e. the DSO (Distribution System Operator), could be active in Retailing and thus control the consumption of electricity in the distribution area in question. The upside is that it may be more efficient to implement measures that reduce peak demands rather than investing in more network capacity. The downside is that it most likely would give the local network operator a monopoly-like position on the local electricity market.

This is just one example of the trade-offs that have to be identified and analyzed in the search for an efficient electricity market design for an entirely new electricity supply system. The political goal is to develop a sustainable electricity supply system. The goal for research on electricity market design should be to define the institutions of a competitive electricity market which is conducive to such an electricity supply system. These institutions should also be conducive for cross-border trade and continued development toward a single European markets for electricity.

[26] "Aggregators" is a new type of actor on the electricity market, acknowledged and supported by the EU Commission. The role of the aggregator is to manage demand response by a group of customers without having to be a balance responsible party or to act in consent with other market participants.

10 Appendix

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TIME FOR A SECOND ELECTRICITY MARKET REFORM?

The ongoing transformation of the Swedish electricity supply system has caused considerable concerns about the design of the electricity market. The key issue dealt with in this report is whether the current electricity market arrangements are fit for purpose when a significant or even dominating part of total electricity supply in Sweden and several neighbouring countries will be based on wind and solar power. In other words: Is it time for another electricity market reform?

The ongoing transformation of the electricity supply system implies a rapidly increasing proportion of intermittent power, in the form of wind and solar power. These technologies have two unique features. One is that variable costs are close to zero. Thus, whenever a wind or solar power plant can produce, it produces at a lower cost than any conventional power plant, except some CHP. The other is that the level of output depends on nature and is more unpredictable than the output of conventional power plants.

These characteristics of wind and solar power have created concerns about the financial viability of conventional power plants and thus about the security of supply of the future electricity supply system in Sweden. Does this mean that a revision of the current electricity market design is needed? The conclusion put forward in this report is that several minor changes of the rules and regulations of the electricity market indeed are needed, while there is no immediate need for major changes.

However, it cannot be ruled out that some major changes of the electricity market design will have to be considered in the future. This would probably amount to replacing the current strategic reserve, "effektreserven", with an extended capacity mechanism, preferably a Nordic rather than a Swedish capacity mechanism.

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