Energy transition

Energy Research Strategy

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Electricity markets: the role of interconnection

As the percentage of renewable electricity in the energy mix increases, so too does the importance of flexibility. Interconnection capacity, in addition to demand-side management and storage, will play an important role in dealing with the increasing volatility of supply of energy resources. Differences in supply relative to demand for electricity in a given bidding zone create price differences relative to surrounding bidding zones. These are a trigger to import or export electricity, as long as it fits within existing transmission capacity.

The 2022 Supply Security Monitoring report by TenneT report shows that the importance of interconnection capacity is relatively high in the coming years. The report also shows that in a base case scenario the Netherlands will exceed the security of supply standard for electricity for the first time in 2030 if sufficient investments in storage and demand-side management are not made. Before the end of this year, there will be clarity on whether the number of bidding zones will be expanded. More bidding zones would lead to more efficient use of existing interconnection capacity. More bidding zones would also lead to welfare gains, reductions in CO2 emissions and a reduction in switching off renewable resources. At the same time, the liquidity of trade within a bidding zone decreases. This can lead to higher price volatility.

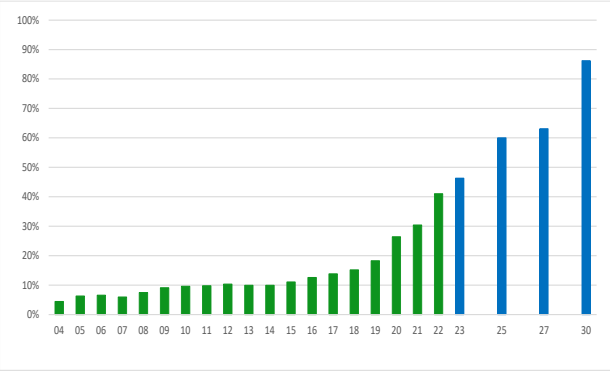
The next few years will therefore be exciting when it comes to investing in further expansion of interconnection capacity. In this update we look at the availability of interconnection capacity in the Netherlands and surrounding countries. We also look at expectations and developments in terms of policy in this area.

Electricity market mix changes; more flexibility desired

Electricity is going to play an increasingly important role in the energy mix. Electricity production - which currently still runs largely on fossil fuels - will have to further switch to a renewable system. In addition, the general demand for (renewable) electricity is growing due to electrification of fossil processes in sectors such as industry and mobility, for example. Finally, electricity will start to be used to make green hydrogen, for example, since some processes will also continue to require molecules. In short, the electricity market will become larger and more important over the years.

Percentage of renewable electricity NL growing

% realization and expectation



Source: Eurostat, PBL (IPCC definition)

In the electricity market, demand for and supply of electricity must be equal to each other at all times. This, in itself, is not a major problem when we can rely to a relatively large extent on the availability of fossil power plants. Provided the capacity of these fossil power plants is sufficient, electricity generation can be ramped up or down at any time, depending on the demand for electricity. This is

called controllable power. However, an electricity supply increasingly dependent on renewable energy generation (see chart above) also has to deal to a greater extent with the vagaries associated with it. The need for flexibility increases on both the demand and supply side.

Wind power is generated only when the wind is blowing, and solar power is generated only when the sun is shining. Thus, during a windless night or during any other period of twilight (or dunkelflaute), there is little or no generation of renewable energy from solar and wind. In other words, the share of controllable power in total power generation will decrease in the future. Controllable power plants will then run less, possibly resulting in closures. When power plants do remain available as backup, the effect will be limited. Whether a power plant will remain available depends on the owner's commercial considerations. If the revenue model declines too much, the owner may decide to close the power plant. Possibly, in the future, there will be a model where the fixed costs of keeping the power plant on standby can be passed on as fixed costs: a capacity market. Still, there are several ways to deal with less controllable power in the form of power plants. Electricity storage is one possibility, but so far this has proved relatively expensive, is difficult to apply on a large scale and does not solve the problem of seasonal bridging easily. Demand-side management is also a method in which part of the solution lies.

Another way to keep our electricity system robust as electricity generation becomes less stable is to use interconnectivity. These are international electricity links for the exchange, or trade, of electricity between countries and provide flexibility to export surpluses or import electricity during times of shortages. Through the use of these international connections, renewable electricity generation is not just dependent on weather conditions in the Netherlands but will further increase electricity imports and exports at the time of price differences due to surpluses and shortages. If the sun shines in Germany and the price of electricity falls there, the Netherlands can take advantage of that in part by increasing imports. In addition to Germany, the Netherlands has international electricity connections with Belgium, the United Kingdom, Denmark and Norway (see table below).

Overview of interconnections in 2021

Connection between	Name cable	Capacity in MW
NL – DE	N/A (multiple high-voltage networks)	5.000
NL – BE	N/A (multiple high-voltage networks)	3.400
NL – NO	NorNed-cable	700
NL – VK	BritNed-cable	1.000
NL – DK	Cobracable	700

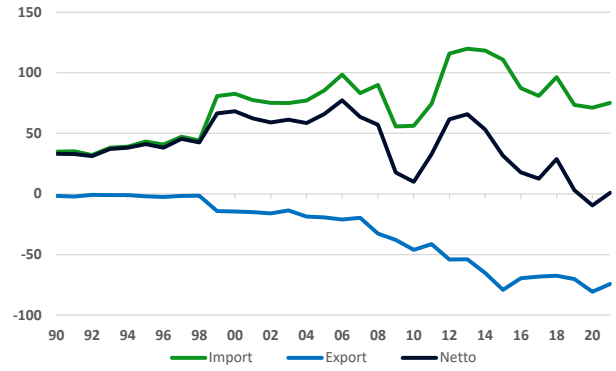
Source: TenneT (Report 'Monitoring Leveringszekerheid 2022')

The Netherlands exporter of electricity

The Netherlands imported about 20.9 TWh (75.2 PJ) of electricity in 2021. In the same year, it exported 20.6 TWh (74.3 PJ) of electricity. That makes the Netherlands a net importer of electricity (0.3 TWh). The total production of electricity in the Netherlands in 2021 was 122 TWh. Thus, the Netherlands exported almost 17% of the electricity generated.

Role of electricity imports and exports of The Netherlands increases

x 1.000 TJ



Source: IEA

Composition of bidding zones

In most cases, the boundaries of bidding zones correspond to country borders. Within a bidding zone, one price applies, and accordingly the same price usually applies to the entire country. However, there are a few exceptions. For example, Italy has six bidding zones, and Sweden and Norway also have multiple bidding zones. Germany and Luxembourg, on the other hand, share a bidding zone together. Ideally, the supply within a bidding zone is adjusted to the level of demand. However, some countries are so large that it is not feasible (or affordable) in terms of transmission capacity, for example, to shift electricity supply in the north to demand in the south of the country. Therefore, to better match supply and demand, some countries work with multiple bidding zones. Germany, on the other hand, does not want industry in the north of the country to face different prices than similar companies in the south of the country. Therefore, Germany is less enthusiastic about splitting bidding zones.

More bidding zones or not?

It is often argued that if "we" have shortages, these can be made up for with imports from surrounding countries. Here, however, two problems come into play. First, transport capacity must be sufficient. Further, if there are shortages in country A, largely the same weather conditions apply in neighboring country B. Yet trade between countries is increasing. In contrast, there is greater potential for utilization of interconnections with the United Kingdom and Norway because the electricity mix in those countries will be different from that of the Netherlands. Electricity from nuclear and hydropower will determine the electricity mix of these countries to a greater extent.

Trading between bidding zones occurs on the basis of price differences. Demand for electricity in bidding zone A may be higher than supply, thus creating a higher price than in bidding zone B, where demand is low and supply is high. By creating more bidding zones, the theory is that more space becomes available for renewable electricity, provided it actually fits within the capabilities of transmission capacity. Surpluses can then be shared more, and shortages can be made up between the different bidding zones.

According to a TNO study, the introduction of more bidding zones could be an important opportunity to use existing interconnection capacity more efficiently. In addition, more bidding zones would, among other things, reduce CO2 emissions and limit curtailment, or reduction of available renewable electricity. Also, less conventional generation would be needed to cover periods of lower renewable energy yields. The question is to what extent this argument still holds up now that the vulnerability of

over-reliance on energy imports has come back on the radar after the Russian invasion of Ukraine and local conventional generation has once again proven its worth.
TenneT is currently investigating whether the Dutch electricity market should be split into different bidding zones. A possible border would then divide Northeast, Central and South Netherlands, creating different electricity prices for the three areas. Just recently, the European Union Agency for the Cooperation of Energy Regulators (ACER) came out with a position paper advocating splitting the Dutch bidding zones into two parts. The results of this so-called Bidding Zone Review are expected to be there by the end of 2023. This Bidding Zone Review will be done simultaneously by all TSOs of European member states to test compliance with the EU Electricity Regulation. Indeed, as of 2025, there is a minimum of 70% of the capacity of critical network elements to be made available for electricity flows resulting from cross-border trade. The European Commission will then come up with the decision whether or not to go for unbundling.

The disadvantage of smaller bidding zones, however, is that trading within such a zone decreases, and thus actually causes larger price movements. Less liquidity carries the risk of higher volatility. Another issue is the availability of transmission capacity. In theory, electricity will be traded between bidding zones based on price differences. But in practice this only works if such trade (import or export of electricity) is actually possible. The moment that transmission capacity is not sufficient, the price difference will remain in place or electricity production from renewable sources will have to be switched off in case of excess supply.

Report Monitoring Security of Supply 2022 TenneT

TenneT's Supply Security Monitoring 2022 report also shows that the importance of interconnection capacity will increase in the future. Surrounding countries are, like the Netherlands, in transition to an electricity mix that will increasingly consist of renewable energy sources. Even though interconnection makes the electricity system more robust against local weather conditions that determine the supply of renewable electricity, differences remain in the potential of different interconnections.

Base load and peak load

Electricity consumption is distinguished into "base load" and "peak load. The base load is the minimum electricity demand throughout a day (in 24 hours). As part of the base load, you can think, for example, of a refrigerator that is on and thereby has a constant daily electricity demand. The peak load is the variable electricity demand that comes on top of the base load. Where a refrigerator is always on, an oven is used (actively) for an hour, for example.

So, there are certain times when the peak load on a day reaches its maximum. Often this is in the early evening, when most people come home and turn on all the lights and the furnace, for example. So peak load varies within a day, but there is also variation in peak load between days. Again, there are certain days of the year when peak load reaches a higher maximum than on other days, such as on a dark cold winter night.

Surrounding countries with a significantly different electricity mix from that of the Netherlands have greater interconnection potential than surrounding countries with a similar electricity mix. In particular, the electricity mix of the Netherlands, Germany, Denmark and Belgium will be largely similar and will consist largely of solar and wind, with backups from gas plants, as our neighbors close their coal and nuclear plants.

Possible power shortages in 2030

Another message from the report is that in the base case scenario, the Netherlands will exceed the security of supply standard for electricity for the first time in 2030 if sufficient investments in storage and demand-side management are not made. In other words, the "peak load" will exceed the

maximum supply of electricity in 2030 for several hours. This is referred to as Loss Of Load Expectation (LOLE). In the Netherlands, a LOLE standard of 4 hours is used. In other words, the security of electricity supply is tested against a standard of four hours per year in which electricity shortages are "allowed" to exist. As such, an electricity system with a LOLE below four hours is classified as reliable. Different countries use different LOLE standards. Belgium, for example, uses a LOLE standard of three hours. TenneT states in the report that the LOLE standard for the Netherlands will be exceeded by half an hour in 2030, bringing it to 4.5 hours. This 4.5 hours is an average of many different simulations with different assumptions. Simulations with assumptions that have a negative impact on the security of electricity supply result in a much higher LOLE. For example, the 95th percentile of these simulations gives a LOLE of 18 hours per year in 2030.

The monitoring report thus uses scenario studies that reason according to different assumptions, such as investments in electricity storage and demand-side management. The report assumes two scenarios. The Current Policy (HB) scenario uses the assumptions from the Climate and Energy Outlook (KEV) 2022 of the Netherlands Environmental Assessment Agency (PBL) and the Higher Ambition (HA) scenario uses an emission reduction of 55% in 2030. On the one hand, a decreasing ability to import in times of shortages and a decrease in controllable thermal power continues the trend of reduced security of supply. On the other hand, the trend is somewhat reduced in the Netherlands by an (assumed) increase in battery capacity. However, this second development is not enough to significantly reduce the continued Dutch dependence on foreign imports.

Increased ambitions also cause the electricity system to become increasingly weather dependent. In both scenarios, but mainly in the HB scenario, shortages may appear due to large differences in climate years. As a result, differences in climate years will become increasingly evident in supply security. According to the report, the security of supply risks for the Netherlands increase due, among other things, to the acceleration of declines in available regulating capacity in surrounding countries. This is further reinforced by increased security of supply dependence between northwestern European countries.

The importance of flexible deployment is further increased by reduced import flexibility from surrounding countries. This causes the LOLE level to depend to an increasing extent on available battery capacity. At the time of high battery capacity availability, the LOLE level decreases, but halving battery capacity could double the LOLE level. Finally, the analyses show that interconnectors with Norway and the United Kingdom, for example, could reduce a lack of flexibility due to shortages in surrounding countries.

Differences onshore and offshore interconnection

When transporting electricity, distance plays a role in the choice of direct or alternating current. Generally speaking, the longer the distance over which electricity is transported, the more attractive the use of direct voltage connections in combination with inverters becomes. This is because when electricity is transported over longer distances, direct-voltage connections produce less electricity losses. This therefore explains why the overland interconnections with Belgium and Germany run on alternating current, while the submarine interconnections with the United Kingdom, Norway and Denmark use direct current.

Thus, the Netherlands has a total of three of these direct current cables, with each of the latter three countries having one. In addition, the Netherlands also has a trio of converter stations that convert the direct current from the submarine interconnections into alternating current for feeding into the onshore grid.

Importance of interconnection capacity for security of supply

Finally, TenneT's Security of Supply 2022 Monitoring report makes clear the importance of interconnection capacity for the security of electricity supply. In the report, TenneT also analyzed the implications for security of electricity supply in an electricity market without the use of interconnections with other countries. In this analysis, the LOLE appears to increase from the 4.5 hours from the base scenario to a total of 72 hours. So that's about three days with serious power shortages. In the Security of Supply Monitoring a year earlier, the scenario without interconnection even showed an LOLE of 592 hours. This is mainly due to the increase in electricity demand accompanied by a decrease in regulable capacity abroad. As a result, the Netherlands has less ability to import electricity from abroad in times of shortages.

TenneT releases investment plans for the onshore and offshore electricity grids every two years. The most recent investment plans cover the time period from 2022 - 2031. Among other things, the investment plans reveal that interconnection capacity with Belgium will be strengthened in 2024. In addition, TenneT is making investments for the possibility of a WindConnector at the IJmuiden Ver wind project. The high-voltage installation being constructed for the wind farm will also be made suitable to serve as an interconnector in the future. This would allow it to serve as a so-called hybrid interconnector. The actual decision for this has not yet been made, but in this way a possible later decision for this has been anticipated. This is in line with the ambition of the Minister of Climate and Energy to have the offshore grid serve as an interconnector in the future when the various energy hubs in the international North Sea are connected.

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