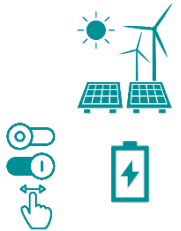

flexibility
forecast
frequency
industry
15min
valorise
ancillary
xborder
season
week
heat
infrastructure
energy
PHS
CCS
baseline
transport
transmission
flywheel
hydrogen
storage
ISP
HP
LNG
EV
gas
integration
persistence
harmonisation
PV
stability
power_quality
MW
efficiency
CHP
vision
prices
distribution
hour
market
network
load
barrier
imbalance
demand
process
P2H
battery
CO2hydrogen
MWh
CAS
access
position
response
action
wind
grid
portfolio
investment
outlook
consumers
BRP
system
discharge
charge
unlock
power
compressed_air
electricity
balancing
decarbonise
hybrid
interconnection
aggregator
roadmap
verify
day
asset
generation
variability
controller
emissions
P2P
decarbonise
stability
dispatchable

To realise

a renewable energy future a mix of new flexibility options has to be unlocked

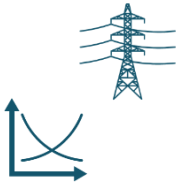
Summary



Flexibility assets such as demand response, storage and flexible generation are needed to complement wind and solar generation, if we want the role of conventional generation in flexibility to shrink.

1. While flexibility already plays a role to balance generation and consumption, the demand for it will evolve and grow substantially in the coming decades due to variable renewable generation, new electricity uses and changing flows in transmission and distribution grids.
2. Flexibility provided by fossil fired generation assets can be displaced by sufficient growth of the volume of other flexible technologies, such as demand response or storage. Increasingly this will include decentral resources connected to the distribution grid.

A broad mix of new flexibility options have to be unlocked because the most cost effective mix is difficult to predict. For this purpose, competition between and the efficient use of the flexibility options have to be enabled.



3. A range of technologies can supply flexibility and the optimum mix will evolve, depending on technology improvement and cost trends. Moreover, synergies with options to reduce emissions in industry, heat and transport will influence the potential and the competitiveness of key flexibility options. Flexible conventional generation (and possibly bio and synthetic fuels) will probably continue to be a competitive option as well.
4. While substantial investments are required in international interconnection, transmission and distribution grids in the coming decades, this infrastructure enables access to more diverse and a broader pool of flexibility resources at a cost that is relatively low, when compared to other flexibility options.
5. The electricity market model works as an efficient process for using flexibility by constantly matching demand and supply and allocating flexible resources to achieve this. It also enables consumers or market parties with flexible assets to sell these capabilities to the market.

While flexibility is already active in the market, some barriers still have to be removed to facilitate the growing and changing role of flexibility. This Flexibility Roadmap presents actions to achieve this.

6. While the Dutch electricity market already offers good opportunities to unlock and valorise flexibility, there are still some barriers in the market model and TenneT processes. TenneT will be addressing these through market pilots and internal projects and by working together with stakeholders.
7. Three priority action areas are:
   a. Facilitate the aggregation of decentral assets, enabling consumers and market parties to offer their flexibility in all markets.
   b. Further develop the market model and processes for congestion management in cooperation between TSO and DSOs.
   c. Improve understanding of the future role and value of flexibility through joint energy system studies with stakeholders in key sectors.

Contents

What role does flexibility play?

What is flexibility?

1. Flexibility in the electricity system are the means that enable it to transition from one state of **equilibrium between generation and consumption** to another.

2. It is an essential **second building block** of the future renewable energy system, that is necessary as a **complement to variable renewable generation**.

3. Flexibility makes it possible to maintain a stable electricity system, even with the growing role of variable renewable generation.

Scope and objective of this roadmap

The role of flexibility in the electricity system will evolve and grow. This Roadmap aims to remove remaining barriers so that existing and new flexibility potential can contribute to the electricity system, to the extent economically efficient.

1. While flexibility has always played a role, the demand for flexibility is expected to grow in different parts of the electricity system, including portfolio balancing by parties active in the wholesale market, the balancing market and for congestion management by TSO and DSO.
2. The means that can supply flexibility include the interconnected electricity grid, demand response, storage and flexible generation capacity. In addition to meeting the growing demand, new flexible means are needed to replace part of the traditional providers, as these fossil-based power generation are increasingly displaced by renewable generation.

This roadmap focusses on the electricity system, while considering a broad range of aspects that influence flexibility.

3. As the energy system is becoming increasingly inter-linked with other parts of the energy system (for instance heating, transportation, industry), other sectors are considered, including the relevant trends and essential stakeholders.
4. Flexibility is relevant in many parts of the electricity system and the electricity market, while a broad range of flexibility technologies can play a role. In part this is tied to the expected growth in electricity consumption that is driven by decarbonising applications such as transportation, heat and industry.
5. Flexibility is relevant both short-term (seconds, hours, days) to maintain system balance and long-term (months, years) to ensure that the necessary physical assets are available. It requires physical assets - the technical dimension - and a set of regulations and processes so that consumers, market parties and grid operators can actively use these assets to provide flexibility to the market - the commercial and regulatory dimensions.
6. This roadmap does not address a number of other requirements for a stable electricity system that is dominated by renewable generation, such as system adequacy during rate times with very little renewable generation, inertia, power quality, et cetera.

Numerous studies, and input from external stakeholders and TenneT colleagues provided the basis for this analysis.

7. A range of studies have already considered the topic of flexibility in NL and internationally in recent years. These have contributed to the assessment of the growth demand and supply potential sketched in this Roadmap, as well as the barriers identified.
8. Furthermore, the picture was completed based on a set of interviews and workshops with key stakeholders and experts from key TenneT departments. The authors would like to thank all market parties, DSOs, colleagues and other stakeholders that have shared their insights.

Decarbonising the Dutch energy system

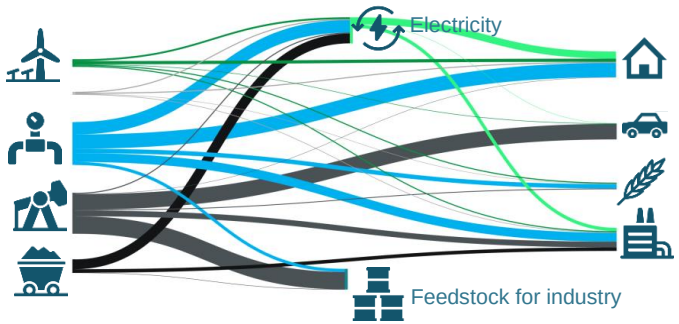
Setting the scene: accelerating decarbonisation of the energy system

1. The recent coalition agreement of the new Government provides clear direction for decarbonising the energy system in The Netherlands. Moreover, the EU Energy Roadmap 2050 and the Paris agreement in 2015 point to a largely carbon-neutral economy by 2050.
2. This requires an estimated a **national investment of the order of €10 billion per annum[1]**, including substantial investments in energy efficiency, electrification of demand, as well as grid infrastructure and flexibility to complement renewable generation.
3. **Solar and (offshore) wind power** generation are expected to play a dominant role in power generation, driven by a progressive cost reduction trend, through technology development, deployment at scale. In addition to the generation capacity to meet electricity demand, industrial input and feedstock will require substantial additional installed RE capacity.
4. Some other technologies such as biomass and CCS with fossil fired power generation can play a role, but their operating hours are constrained due to their position in the merit order with marginal cost well above that of wind and solar PV.
5. The relative size of the role of various types of energy assets (generation, storage, demand response) will depend on technology development and cost trends, as well as parallel investment in grid infrastructure and inter-connection.

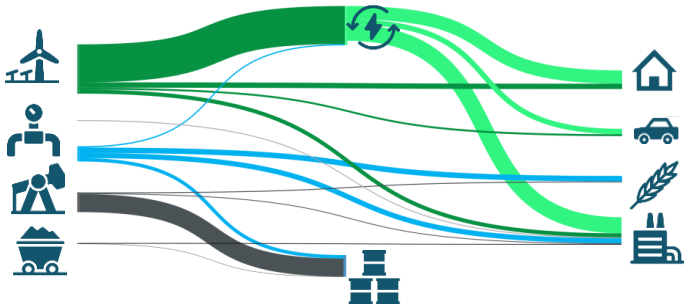
Energy efficiency , electrification of demand and variable renewable generation

6. **Electrification results in a substantial increase in total load**, as a route for decarbonising sectors such as transportation and heat (industrial and residential).
7. **Inter-linkages between the electricity system and other parts of the energy system** become stronger, both due to substantial new electricity demand in multiple sectors and the need to accommodate variable RE production. Policies and investments in many sectors influence the electricity system: heat networks and power-to-heat, geothermal energy energy storage inherent in EVs, renewable hydrogen and decarbonising industry, energy efficiency in buildings are important factors for the electricity system, both in terms of total load and flexibility.

Energy sources and uses in the Netherlands 2015



Scenario with 80% emissions reduction in the future 2040 ~ 2050



[1] McKinsey 2016, Versnellen van de energietransitie: kostbaar of kansrijk? and PBL, ECN 2017,Verkenning van Klimaatdoelen. Figures based on: McKinsey 2016, Versnellen van de energietransitie: kostbaar of kansrijk? and McKinsey 2017, Energy transition: mission (im)possible for industry?

Three key trends in electricity system

1. Rapid growth of installed capacity variable renewable generation

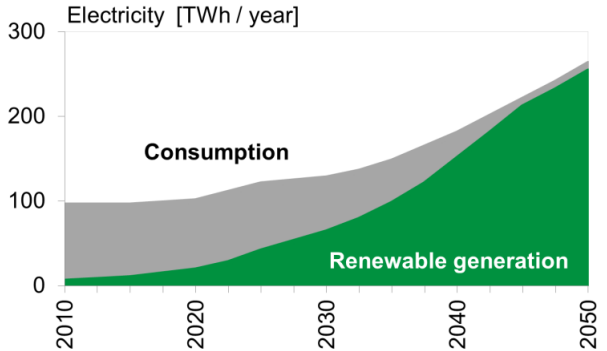
- Wind energy dominant in electricity generated
- Solar PV only contributes a little generation during winter months

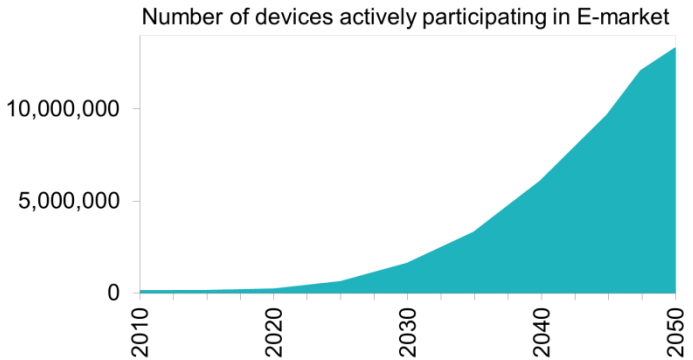
2. Substantial growth of load due to electrification

- Heat and transportation for households and businesses
- High temperature heat and hydrogen production for industry

3. Leap in number of devices and actors active in market

- From centralised generation to decentral consumer assets participating, including generation, demand response and storage devices at households and businesses.
- Smart meter allocation, data and innovative propositions from market parties make it possible to unlock flexibility and contribute to lowering electricity bills for end-users.
- This requires efficient aggregation of decentral and increasingly small scale assets.





TenneT analysis, building on data and scenario's from NEV2017, KCD2017 and McKinsey2016

Flexibility active in the current system

Substantial volumes of flexibility are already active in the Dutch electricity market, provided by industry, horticulture and conventional generation.

1. A substantial volume of demand response is actively being leveraged by BRPs as part of their trade portfolios in the wholesale market since the start of the liberalised electricity market in the early 2000s. This is part of portfolios of market parties and currently cannot be quantified precisely from the data available from the wholesale market.

2. An indication of volumes is provided by a 2004 study that quantified volumes of demand response participating in the market and came to a value of approximately 1000 MW, which included primarily industry, horticulture and other businesses. The current 2017 volume of demand response is believed to be substantially greater, in particular through the growth in participation of the sizeable horticulture sector.

3. The horticulture sector is an active participant in the market, relying on advanced energy management systems that respond to market prices based on a combination of demand response (some 500 MW potential believed to be largely unlocked) and CHP flexible generation. Substantial volumes of demand response in industry has been active for years and have been valorised by these businesses through commercial agreement with one or more BRPs.

A number of additional measures were implemented in recent years, aimed at enabling smaller scale or aggregated assets to participate in this market.

4. Smart meter role-out has reached a substantial % of small consumers and smart meter allocation is possible for small consumers since late 2016, while this has been in place for large consumers since many years. This enables these consumers to engage in flexible price contracts and to valorise their flexibility, for instance by shifting their demand to times when market prices are low.

5. TenneT has updated ancillary services product specifications for balancing and processes have been streamlined to allow shorter bid periods. This enables a broader range of flexible assets to play a role in this market.

Part I
Vision on future of flexibility

To realise a renewable energy future,
a mix of new flexibility options has to be unlocked.

Why we believe

unlocking a mix of new flexibility is necessary

Firstly

the role of flexibility will be growing and changing

Growing and changing role for flexibility

The Energy Transition leads to a changing and growing demand for flexibility in three domains

1. Today's electricity system already caters for a sizeable demand for flexibility to ensure that generation and net-imports adjust to match the demand variability: **Demand varies → Generation adjusts**
   This flexibility is mostly provided by gas-fired generation and a strongly interconnected grid, with some demand response.
2. The growth of variable wind and solar generation and electrification of energy demand will lead to an increasing demand for flexibility, because of (i) the variability of wind and solar generation, (ii) increasing load and generation connected to the distribution grid level and (iii) more pronounced coincidence of peaks in demand. This increase in the demand for flexibility materialises in three domains, described below.
   Increasingly, **Generation fluctuates → Demand adjusts**

Portfolio balancing by Balance Responsible Parties

3. First and foremost, it is the responsibility of each Balance Responsible Parties (BRP) to balance its portfolio of electricity produced /bought and sold/consumed by their customers over each 15 minute block (ISP). To this end, BRPs are trading in the wholesale markets (long-term, day-ahead and intra-day). The total volume handled matches the national consumption.
4. Parties with variable wind and solar generation in their portfolio and firm delivery commitment to their customers, need to procure flexibility from other parties or adjust their own generation when forecast RE production deviates from a forecast.

System balancing by TSO and Balance Responsible Parties

5. Unexpected deviations within each 15 minute time block in load or generation, are managed through the balancing market organised by TenneT. Market parties can offer flexibility through competitive bids, activated autonomously (FCR) or by the TSO (aFRR, mFRR).
6. BRPs also respond with flexible assets to published price signals (passive balancing), thus contributing to system balancing.

Congestion management in case of grid capacity constraints by TSO and DSO

7. Sometimes, the limit of the transfer capacity of parts of the electricity grid may be reached, typically due to (i) either rare generation or consumption situations or (ii) in cases where the TSO or DSO have been unable to reinforce the grid infrastructure in time. This can occur both in the transmission grid and in the distribution grid.
8. In such a case the problem can be mitigated through congestion management, where market parties are asked to offer location-specific flexibility bids that the relevant grid operator can activate so as to lower the network load locally.

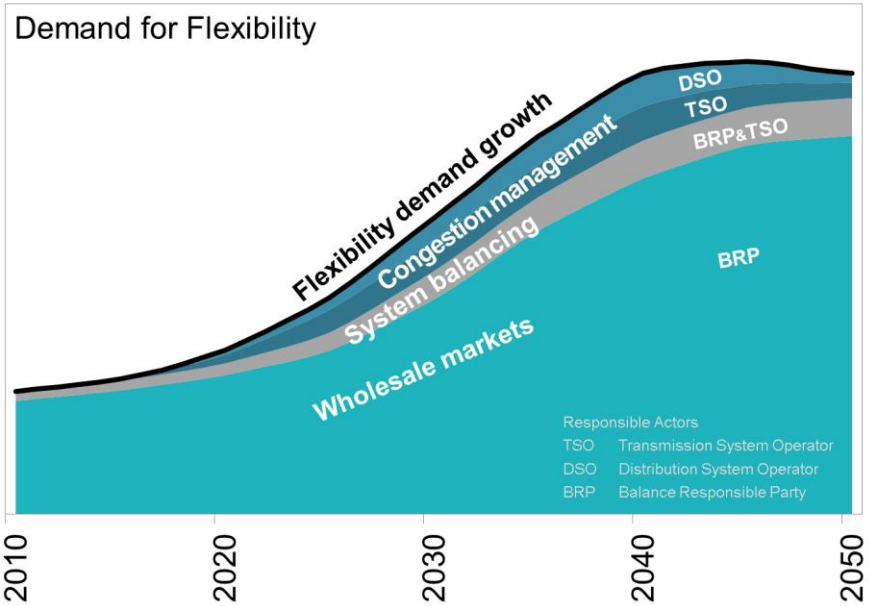
portfolio balancing

system balancing

congestion management

Growing demand for flexibility in 3 domains

- **Growth in demand for flexibility will be greatest in the wholesale markets driven by the need to balance solar and wind generation portfolios.**
- **Limited increase in system balancing demand driven by short-term forecast error.**
- **Congestion management is mostly driven by timing of grid reinforcement projects versus fast evolving needs of customers.**



Notes:

- Indicative chart, in which bi-directional and potentially dual-purpose demand represented as cumulative.
- In this figure demand for flexibility is intended to reflect a MWh volume, not MW installed capacity.

Secondly

we need to meet the growing demand for new flexibility and we need to reduce CO_2 emissions

Substantial new flexibility potential

Electrification of energy demand results in substantial new potential for flexibility, in addition to the existing potential

1. While a substantial volume of flexibility assets is already part of the existing system, a substantial growth in the supply of new flexibility will be required to meet the growing demand, while the available capacity of flexible fossil-fired generation is likely to diminish.
2. A big part of the new flexibility potential is concentrated in the following 3 areas: Industry, Heat and Transport. In addition, a wide range of applications offers additional potential, such as storage combined with PV, cooling and pumping systems.

Flexibility potential in Industry

3. Some industries already provide substantial volume of demand response where electrochemical processes allow. Existing examples include chloride and aluminium production. Future examples include novel processes for electrochemical production of steel.
4. Industrial heat is likely to be electrified in the future, possibly in hybrid systems with gas/biomass firing and/or heat buffering. This could unlock a substantial volume of demand response.
5. Large scale production of hydrogen based on electrolysis is part of most scenarios for decarbonising industry. This has strong potential to supply flexibility to the electricity system through a combination of (i) modulating production based on electricity prices , (ii) buffering / storage of hydrogen and (iii) reconversion of hydrogen to electricity when PEM systems are used for electrolysis.

Flexibility potential associated with Heat

6. Horticulture is already a major provider of flexibility through a combination of CHPs, heat buffering and demand response of lighting.
7. Residential heat pumps in well insulated houses combine a substantial consumption with demand response by time-shifting operation.
8. District heating systems with waste or geothermal heat, can absorb substantial volume power to heat when a heat buffer is included.

Flexibility potential associated with Transport

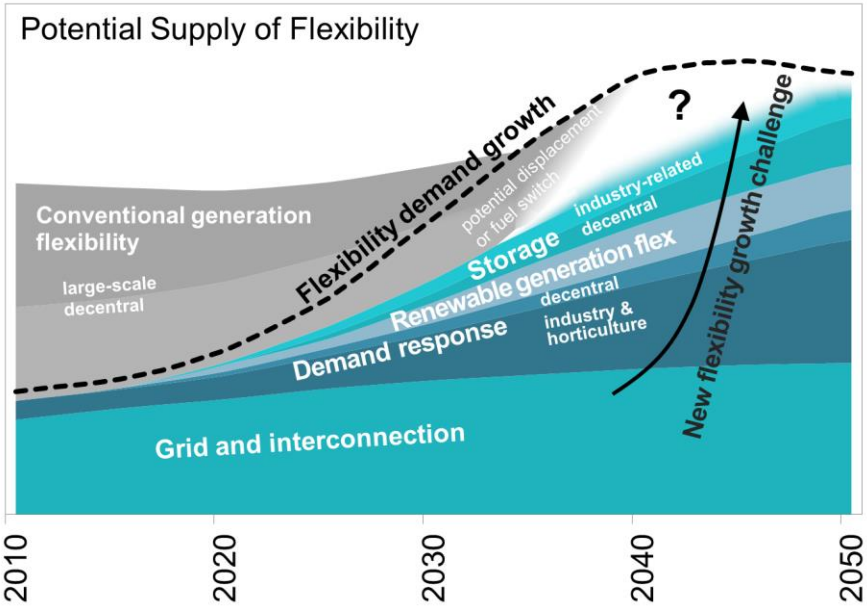
9. Electrical Vehicles can provide demand response by managing charging rates and times, as well as vehicle-to-grid flow of energy.
10. Hydrogen-fuel cell vehicles, could feed electrical power to the grid when stationary and connected, using hydrogen in the fuel tank.

Growing potential supply new flexibility

1. **The interconnected grid provides an important and growing “source” of flexibility.**

2. **Investment by market parties to unlock new flexibility potential in a range of technologies and sectors is necessary if the role of conventional flexibility is to shrink.**

3. **With flexibility resources competing in the market, conventional generation (and fuel-switching) also plays a role, based on existing installed assets.**



Notes:

- Indicative chart, in which bi-directional and potentially dual-purpose demand represented as cumulative.
- System adequacy or MW installed capacity were not considered in this analysis. In these figures, supply and demand of flexibility reflect a MWh volume.

Investments in new flexibility

Investments by market parties are key to create and unlock new flexibility assets

1. While a substantial volume of flexibility assets is already part of the existing system, a substantial growth in the supply of new flexibility will be required to meet the growing demand, while the available capacity of flexible fossil fired generation is likely to diminish.
2. Investment in new flexibility assets relies on market parties, that can best assess earnings potential, manage risks and choose between alternative technologies. Frequency, duration and height of price peeks and troughs are key drivers for this earnings potential. These will evolve over time depending on cost of RES, cost of flexibility technologies, CO2 price and/or other emissions constraints, amongst others.
3. Efficient functioning of the electricity market and a reliable policy outlook are important to enable this, including a consistent market design and transparent market information. Moreover, the role of gas and fuel-switching in the supply of flexibility has to be considered as part of this market.

TenneT invests in grid interconnection to provide access to flexibility from neighbouring countries

The growth in new flexibility has to be sufficiently large, if we want the role of conventional generation in flexibility to shrink.

However, today the value of flexibility is relatively low, as there is sufficient supply in the market.

Thus

a broad mix of new flexibility options has to be unlocked since the most cost-effective mix is difficult to predict

Unlocking a broad range of flexibility options

A broad mix of new flexibility options have to be unlocked because the most cost effective mix is difficult to predict

1. There is a broad range of technologies and applications for new flexibility sources, but their level of competitiveness will depend on trends in technical capabilities and costs

2. Synergies with options to reduce emissions in industry, heat and transport will influence the potential and the competitiveness of key flexibility options.

3. The role of flexible conventional generation (and possibly bio and synthetic fuels) in the supply of flexibility has to be considered.

Synergies of flexibility technologies

Synergies with choices in how to reduce emissions in industry, heat and transport will influence potential and competitiveness of key flexibility options.

1. As electricity will be playing a growing role across the energy system, the corresponding new energy assets can play a key role in supplying flexibility to the electricity system. However, in many of these areas, the primary driver for this investment is not electricity market per se, but policy drivers to invest in energy efficiency or decarbonising.
2. Moreover, the business case for investment in flexibility resources, relies on a clear outlook on the expected variability in market prices. This variability, in turn, greatly depends on policy choices that affect many different parts of the energy system, for instance:
   - Policies that affect coal fired power plants, in the Netherlands but also in neighbouring countries.
   - Investment and implementation strategies for strengthening transmission and distribution networks.
   - Policies that affect the rate at which large scale investments take place in renewables.
   - Policies on energy efficiency in households and small businesses.
   - Policies on decarbonising heat, including district heating networks.

Further system studies together with stakeholders from different parts of the energy system are essential to adequately quantify key interdependencies, robust and no-regret options.

3. While market parties can be expected to assess future costs of technologies and energy, this is hardly the case when it comes to changes in policies affecting in other energy sectors. Unexpected policy changes in other sectors have the potential to have significant impact on business case for any one specific investment in an asset that aims to earn revenues by selling flexibility to the market.
4. System studies can greatly help in gaining a better understanding of key interdependencies. These provide a basis for (i) identifying robust and no-regret investment options and (ii) seeking a specific understanding on trends in other parts of the energy system that are the most relevant.

And therefore

competition between and efficient use of flexibility options have to be enabled

Competitiveness of flexibility options

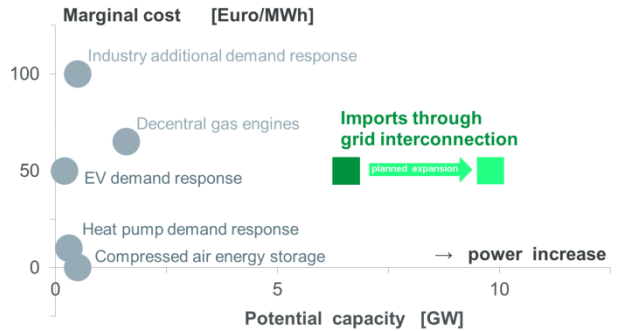
Flexibility competing in liberalised electricity market

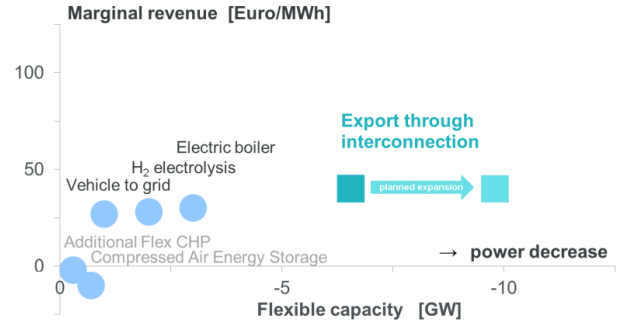
1. An efficient electricity market can play an essential role in continuously matching power in-feed and demand, as well as signalling a positive return on investment in assets that contribute to the economic efficiency of the system.
2. During periods in which the market price decreases, more electricity is exported, flexible consumption is switched on (for instance electrical heat pumps), EV batteries are charged and hydrogen is produced in industry. These different possibilities compete for absorbing the low cost electricity and options that generate most value are exhausted first.
3. At times of an increasing market price, more electricity is imported, battery storage is used, flexible generation is started up, first some and later more consumers postpone their consumption (for instance, EV charging is temporarily paused) and businesses switch to using stored hydrogen instead of produced. Again, these options compete and least cost options are typically used first.

Interconnection provides a cost effective means to access flexibility

4. The competitiveness of different flexibility technologies is governed by technical capabilities, investment and marginal operating costs. Furthermore, the combination of functions and business cases plays a role of many of these, for instance in the case of electrolysis of hydrogen as an industrial feedstock.
5. Depending on the effective cost associated with CO_2 emissions and fuels, flexible gas and biomass fired power generation will also compete to provide this flexibility.
6. One of the most competitive options, however, is to source flexibility from outside the Netherlands through electricity imports or exports. This is due to the fact that (i) wind and solar generation spread over a greater area tends to be less variable than for only a single country, and (ii) the variety of flexibility assets across Europe is greater than domestically.

Flexibility potential 2023 and marginal cost, with existing and planned international interconnection.





figures based on CE Delft 2016, Flexibiliteit en Markt, complemented with tenneT data on interconnection.

Enabling competition & efficient use of flexibility

1. **Because the most cost-effective mix of flexibility options is difficult to predict, competition between and the efficient use of the flexibility options have to be enabled.**

2. **The market competition is an efficient mechanism to coordinate the allocation and use of available flexibility resources.**

3. **Price signals from the market provide an incentive to invest in new flexibility resources in a way that can result in an optimum mix. This optimum mix is likely to evolve over time as technologies improve, cost reduction is achieved and synergies materialise.**

Grid enables access to flexibility

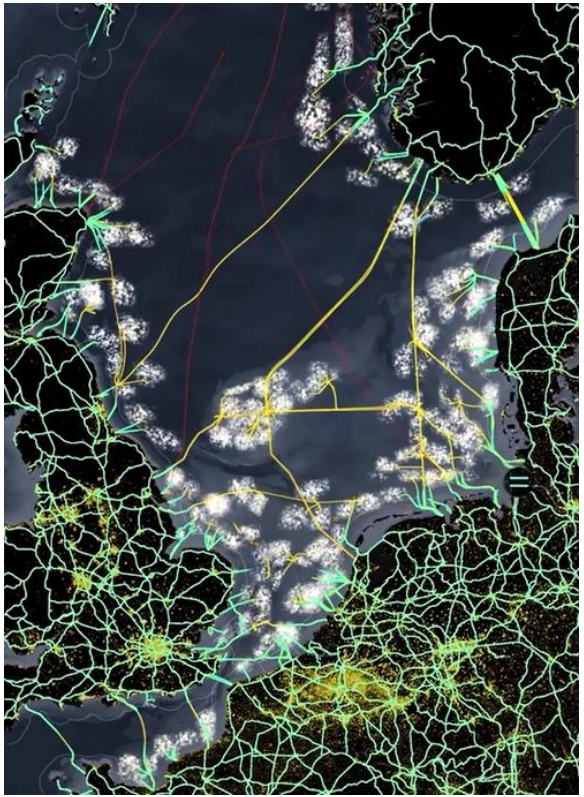
Electricity grid provides access to flexible resources spread over a wide region.

1. Substantial investments in electricity distribution infrastructure are required because of electrification of domestics heating and EVs, together with smart monitoring systems. Due to the scope of the transition and timeframe, a sizeable percentage of the distribution infrastructure will be strengthened in the period to 2050. The main question is not if or where, but rather when and how to do this cost effectively.
2. Along the same lines, TenneT continues to investment in transmission infrastructure, to connect offshore wind farms and transport electricity across the country, accommodating a growing load and interconnection.
3. Capacity utilisation of lines and stations both in distribution and transmission infrastructure are actively monitored. Combined with day-ahead load forecasts these provide a basis for congestion management.

Key role for data and efficient communication processes.

4. Smartly metered demand enables effective price signals to consumers:
   a. Energy intensive industry has strong ability to shape electricity consumption, together with own power generation assets ensuring electricity at known cost.
   b. Various businesses with a substantial energy bill will be actively planning and managing demand, carefully acting on market prices.
   c. Some households opt for flexible price contracts, in particular those with charging of EVs and heat pumps, with smart technology optimising use. Others choose to avoid price risk through fixed price contracts.
5. Data and efficient communication processes play a key role in managing of flexibility resources by market parties and in communication with network operators.
6. Accurate forecast and real-time data on flows in the electricity grid provide a solid basis for a focussed solution to managing congestion in any part of the transmission and distribution grids.

Artist impression of 2050 grid interconnection



source: H+N+S Landscape Architects, Ecofys and Tungsten Pro, 2015: IABR: 2050 - An Energetic Odyssey

Market coordinates efficient use of flexibility

The Dutch market model provides a solid basis for accessing new flexibility.

- The existing market model provides effective price signals that incentivise energy producers and consumers to manage their flexible energy assets, towards keeping generation balanced with load.
- The market offers consumers access to competitively priced combination of generation and flexibility. Flexible resources can generate revenues in this market by bringing this flexibility to the market. 100s of MW demand response and flexible generation are already actively doing so today.
- Renewable generation is an integral part of the market, competing and constraining the role of other technologies in the market due to the very low marginal cost of solar and wind generation. In the long term the market model will have to evolve to handle supply saturation with these type of assets.

A coherent approach by TSO and DSOs is important to manage congestion and to enable access to flexibility for that use where it is most valuable.

Peer-to-peer or local trading may appeal to some stakeholders, but should not restrict access to flexibility resources across regions and markets.

In this way, the available flexibility resources can be used for the most valuable purpose at any given time.

Part I Recap
Vision on flexibility

To realise a renewable energy future, a mix of new flexibility options has to be unlocked.

1. The role of flexibility will be growing and changing.
2. We need to meet the growing demand for flexibility and we need to reduce CO_2 emissions.
3. A broad mix of new flexibility options have to be unlocked because the most cost effective mix is difficult to predict.
4. Competition between and the efficient use of the flexibility options have to be enabled.
5. While flexibility is already active in the market, some barriers still have to be removed to facilitate its growing and changing role.

But

some barriers still have to be removed to facilitate the changing role of flexibility

Part II
Removing remaining barriers for flexibility

Removing barriers

While flexibility is already active in the market, some barriers still have to be removed to facilitate the growing and changing role of flexibility

Firstly, TenneT is already working on a set of initiatives to remove barriers that were identified before:

1. Digital Transformation programme.
2. Blockchain pilot project on balancing power (aFRR) in the Netherlands and on redispatch in Germany.
3. Intra-day Congestion Spreads project in cooperation with Stedin and ETPA.

But these are not enough…

Further barriers identified and prioritised

An overview of remaining barriers for flexibility in the Dutch electricity market model was compiled based on input from market parties and experts.

1. A comprehensive list of remaining barriers includes detailed issues and ongoing actions (if any) noted. This was done based on input from:
   - Numerous studies on flexibility, system balancing and decarbonisation of sectors of the energy system.
   - Interviews with market parties, including aggregators, flexibility asset owners , BRPs, Government bodies.
   - Input from TenneT colleagues on known issues in The Netherlands as well as lessons learned at TenneT in Germany.

The resulting list of barriers was prioritised considering two main dimensions:

2. **Impact** on economic efficiency or cost of national electricity system resulting from the barrier
3. **Timeframe** within this impact would occur if not appropriately mitigated.

An action plan was defined to address these barriers. These actions cover a range of aspects, including:

4. Elements of the market model.
5. TenneT processes:

IMPACT

Economic cost for electricity system

URGENCY

Timeframe for action to mitigate impact

	Short term < 2 years	Medium term 2 - 10 years	Long term > 10 years
Large	**High priority**		
Medium		**Medium priority**	
Small			**Low priority**

Three focus areas for new initiatives

In identifying actions to address the main barriers, 3 main themes emerge as a basis for an action plan including some examples of initiatives:

1. **Facilitate the aggregation of decentral assets, enabling consumers and market parties to offer their flexibility in all markets.**
   - Upcoming aFRR pilot projects focused on aggregators and decentral energy assets.
   - Evaluation of grid tariff structure, avoiding undue barriers for decentral assets to provide flexibility.

2. **Further develop the market model and processes for congestion management in cooperation between TSO and DSOs.**
   - Unlocking the participation of decentral assets to contribute to congestion management.
   - Refinement of processes for congestion management in cooperation with DSOs.

3. **Improve understanding of the future role and value of flexibility through joint energy system studies with stakeholders in key sectors.**
   - Joint projects with industry and energy stakeholders on potential and value of flexibility in the future.
   - Time series data CO_2 emissions generation mix, to account for consumption flexibility in emissions targets.

Part II Recap
Removing remaining barriers for flexibility

While flexibility is already active in the market, some barriers still have to be removed to facilitate the growing and changing role of flexibility in three main areas:

1. Facilitate the aggregation of decentral assets, enabling consumers and market parties to offer their flexibility in all markets.
2. Further develop the market model and processes for congestion management in cooperation between TSO and DSOs.
3. Improve understanding of the future role and value of flexibility through joint energy system studies with stakeholders in key sectors.

TenneT is looking forward to work together with our key stakeholders on these topics, as we are focused on further developing the electricity market model and grid infrastructure to enable the growing role for flexibility and to unlock the investments necessary in new flexibility potential.

Concluding remarks

The work towards this Flexibility Roadmap and by discussing the barriers identified and potential actions has proven to be a fruitful process to arrive at a shared understanding of key opportunities and issues.

- This provides a solid basis both for implementing the actions identified within TenneT and for pro-actively engaging stakeholders in the energy system on the key issues that are relevant for flexibility in the electricity system.
- It is productive to continue to strengthen this joint vision on flexibility within TenneT, by continued joint work among the key departments and across The Netherlands and Germany, for instance as part of the flexibility forum that was initiated in 2016.

While addressing remaining barriers for flexibility, due attention is required to maintain the consistent and efficient functioning electricity market.

- Continuing to ensure consistent price signals for energy consumers, owners of energy assets, balance responsible parties, across multiple sub-markets.
- Ensuring that the transmission and distribution infrastructure is in place whenever socio-economically sensible, in time to enable flexibility to act in well functioning markets.
- Warranting that flexibility can be offered across multiple markets so that it is procured where it generates greatest economic value, be it energy, balancing or congestion management.

This Flexibility Roadmap takes stock of the situation at the end of 2017 and is intended to be updated periodically.

- By that time, a significant number of the remaining barriers should be resolved, such that it is likely to focus on a reduced number of remaining challenges. At the same time new issues may emerge from the practical experience gained while renewable energy generation grows and electrification takes of in some sectors.
- Furthermore, more clarity on the market for flexibility will become available as time progresses and developments in the energy system materialise.

TenneT

is looking forward to
work together with you
to resolve barriers
for flexibility

Presentation flexibility roadmap document

Public version of this Flexibility Roadmap is available for download from

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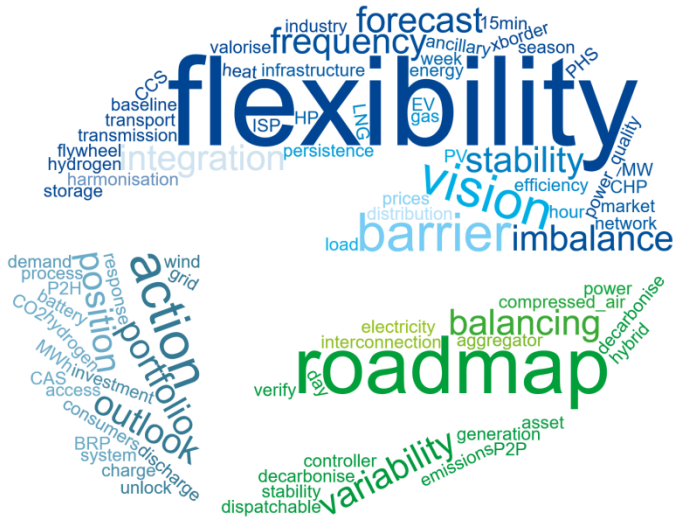

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Taking power further