Renewables Grid Initiative

Glossary of technical terms

Technical terms relevant to the "Need for Grids"

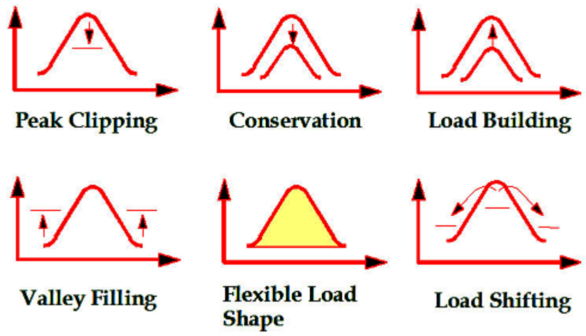
Aggregators	Aggregators are third party intermediaries who specialise in aggregating demand response from individual consumers to better meet industry parties' technical requirements for specific routes to market. They send signals to their consumers to modify their demand as a response to either the System Operator requirements and/or market price signals.
Balancing Market	Balancing refers to the period after electricity markets close (gate closure) where TSOs act to ensure that demand is equal to supply in order to secure the stability of the electricity system. The balancing market is the part of the electricity market that provides for meeting the needs through the trading of balancing services.
Base load	The base load is the minimum level of demand on an electrical grid over a given period of time (usually over the year, or over a season or day). Base load power sources are power stations that are capable of consistently generating the electrical power needed to cover this demand. They do not need to (but may have) feature control mechanisms that allow a fast adjustment of their output power, so that they have to run at a certain load for a specific amount of time once they are ramped up. Economically, they are therefore the units that feature relatively high fixed and low variable costs, and their operators try to have them run as close to full load as possible at all time. Typical base load plants are run-of-river, nuclear and lignite power plants. Base load is highly predictable and large power systems implement base load plants (hydro, fossil-fuel or nuclear plants) in order to minimise overall costs.
Capacity factor (aka load factor)	A power plant's capacity factor describes the ratio of its electrical energy output over a given period of time (in MWh or KWh) to the maximum possible electrical energy output of this unit (in kW or MW) and divided by this amount of time (in hours). It is a unit-free number expressed in % (e.g. 1MWh/1MW/1h = 1=100%). It is often computed over a year (i.e. a meaningful life-cycle). However, the division by 8760h (the number of hours per year) is often forgotten, so that the result is expressed in hours/year. It can then also be named ➚"full load hours".
Congestion	Congestion occurs when the level of electrical power that needs to be transported across a transmission line exceeds its transmission

	capacity. This situation is not sustainable, and depending on the magnitude of the excess current, it must be solved at best within a few minutes, or even a few milliseconds. In order to remedy the situation (i.e. to cure it ex post if time allows, or otherwise to prevent it from happening) the topology of the grid is adapted, generation in feeds are being adjusted and/or ↗demand side management (DSM) is being applied. All measures are implemented to reduce the excess flow. Basically, power plant infeed upstream (resp. downstream) of congestion must be reduced (resp. increased), and the same logic applies for DSM measures, if available. As competition would have ensured that the cheapest power plants would be generating, this adjustment leads to a decrease of cheap generation and activating a more expensive one, resulting in an increase of the generation price, causing a loss of ↗socio-economic welfare. If the market has not provided the TSO with the required options to adapt generation or load, then ↗load shedding (downstream) or ↗generation curtailment (upstream) are last resort options. A line or a grid's section that is regularly congested is often referred to as ↗transmission bottleneck.
Curtailment (of generation)	Curtailment is the reduction of electrical generation, used as a last resort to balance the system or solve congestion. (It is also sometimes used with respect to consumption, see ↗load-shedding or ↗demand side management).
Decarbonised power sector	The reduction of the carbon intensity of the power sector by increased use of technologies that result in a lower concentration of fossil fuels released into the atmosphere during power generation. Renewables like wind, solar and hydro but also nuclear power are all non-carbon. Considering nuclear power to decarbonise the power sector is, however, often debated, as many oppose it for safety reasons.
Demand Response / Demand side management (also: load management)	Demand response (DR) or demand side management (DSM) refers to the use of mechanisms that encourage consumers to adjust their electricity demand, e.g. to help adjust demand and generation or to reduce strain on the distribution or transmission grid. DSM can be static (with financial incentives through variable grid tariffs, e.g. time-based rates) or more dynamic (where consumers directly, or through ↗aggregators face dynamic market prices and opportunities to value their action on ↗balancing or ↗intra-day markets). Industrial customers specifically can take advantage of time-based tariffs (from their suppliers), or value their load adjustment options on the market, or enter a bilateral specific ↗interruptibility agreement

with their supplier.

Generally, DSM does not lead to an overall reduction of electricity demand (it basically shifts demand from one timeslot to another), but can lead to a reduced need of investment in grid infrastructure or power generation if the load profile can be reshaped in order to fit these constraints.

Forms of DSM can be:



Source: Interact Energia, available here

Distributed generation, embedded generation

Energy produced near the point of consumption rather than at a distance, usually small plants that provide power onsite. Examples of this include the installation of rooftop PV cells or municipal wind parks instead of a large centralised solar park or traditional thermal generation. The idea of distributed generation is sometimes accompanied with the assumption that decentralised systems automatically have a reduced need for grid infrastructure, implying that the energy produced is consumed directly without being fed into the distribution or transmission grid.

Distribution grid

The distribution grid is the group of power lines and associated equipment for the transport of electric energy at a lower ↗voltage to the vast majority of customers. Typically, distribution represents power grids from 110 kilovolt to 110 volt (or in France and Belgium from 110 kV to 20 kV only).

One can think of the distribution grid as the smaller ‘roads’ that allow electricity to flow to households. Following the same analogy, there are ↗transmission grids, comparable to federal roads and highways that transport the electricity over larger distances at higher ↗voltage levels.

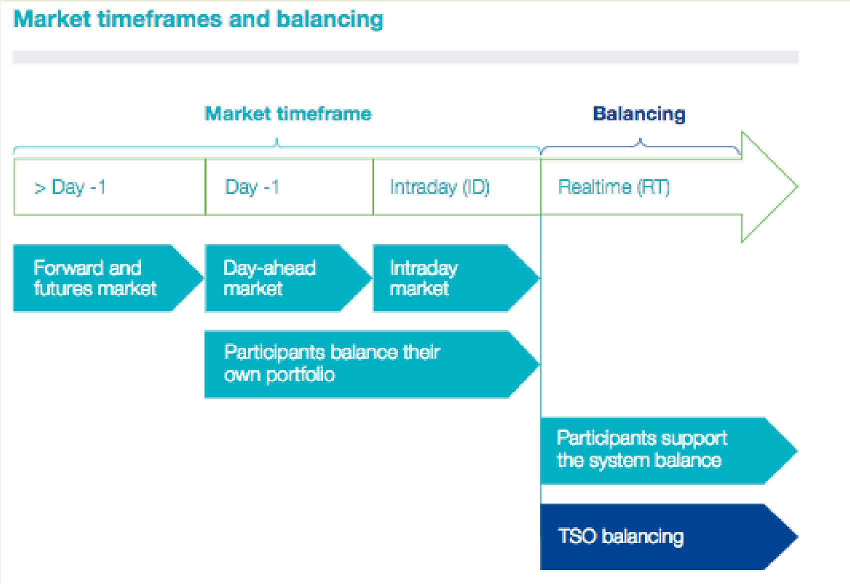
Energy

Energy is the capacity to do work. Energy is ↗power integrated over time. It can be either stored or consumed/produced over a period of time. The unit of energy is Joule or, more commonly in the power sector ↗watt hours (Wh).

Energy and ↗power are being confused often. To clarify the difference, you can consider the example of a light bulb powered by

	a battery: A light bulb draws 60 W from the battery at any given moment in time in order to provide the desired luminous intensity. If the battery cannot supply this much ➚power, the light bulb will remain dark or at least glow less intense. This state remains constant in time. In order to get the desired light intensity either a different light bulb that requires less power or a different battery that can supply more power has to be used. If, however, the battery can supply the required power and you want to have the desired luminous intensity for the duration of one hour, the battery needs to be able to supply 60 Wh of electrical energy. If less energy is stored in the battery, e.g. 30 Wh, it does not necessarily mean that you cannot power the light bulb. You could supply the light bulb with 60 W for the duration of half an hour instead and afterwards turn it off. If you can reduce the light intensity of the bulb, you can also power the bulb with the same 30-Wh battery at half its power for a full hour.
Energy efficiency	Providing the same service (or end-use, e.g. lighting, heating, transportation), with the same level of quality (or comfort), by utilising a reduced amount of energy. Overall electricity consumption (reported in ➚watt hours) is thereby reduced without affecting the quality of the services provided. It can refer to the improvement of devices as well as to providing a service by shifting to a more efficient technology. Using LED instead of older light bulbs is a leading example of this concept.
Frequency	Alternating current (AC) electricity periodically reverses its direction and therefore has a frequency (direct current doesn't). The frequency of an AC power system must be maintained at a constant level in order not to risk damaging all connected devices, from household appliances to power plants. These would disconnect if the frequency deviated too much from the nominal level. Operating a power system is in essence ensuring a stable frequency (with typical deviations less than 0.2%), sign of a balanced generation and demand. Frequency is measured in Hertz. Grids in Europe, Asia, Australia and parts of Africa and Southern America run at 50 Hertz, while the Northern American grid and half of Japan is operated at 60 Hertz.
Full load hours	Full load hours refer to the number of hours per year that a power plant would need to run at its rated power in order to produce the same amount of energy that it actually produces during a year (during which it does not always run at full load). Full load hours can be translated into ➚capacity factor by dividing through 8760h, the number of hours within a year.

Generation	Generation is the amount of electricity a generator has produced over a specific period of time. For example, a generator with 1 megawatt (MW) ↗generation capacity that operates at that capacity consistently for one hour will produce 1 megawatt hour ↗(MWh) of electricity. If the generator operates at only half that capacity for one hour, it will produce 0.5 MWh of electricity.
Generating capacity (also: installed capacity, rated power)	Generation capacity is the maximum electric ↗power an electricity generator can produce under specific conditions. It gives no information on how much ↗energy is generated by this generator over a defined period in time. This can be seen in the theoretical example of a coal fired power plant with a generation capacity of 1,000 MW. Under the assumption that this plant runs at full capacity during a whole year, it generates 8,760,000 MWh (operating 365 days * 24 hours * 100 MW). However, most generators do not operate at their full capacity at all times. A generator's output may vary according to conditions at the power plant (e.g. outages for maintenance), fuel costs, and/or as instructed by the electric power grid operator. Renewables based generation suffers from its volatility. For example, many wind parks only run at roughly 40% of the time due to weather conditions. If you assume a wind park which also has a generation capacity of 1,000 MW, but which runs only 40% of the time, the generated electricity would go down to 3,504,000 MWh (40% of 8,760,000). The same applies when the wind park produces only 40% of its installed capacity throughout the year because the wind is not strong enough to supply more.
Generator	The term generator refers to any machine that produces electrical power.
Interconnector	Interconnectors are transmission lines that allow the transfer of electricity across international borders.
Interruptibility	Interruptibility is an emergency reduction of electrical consumption from large industrial consumers who entered specific agreements with the transmission system operator for this specific service, with an incentive to shift power consumption out of a specific time of day. It is a last resort means, prior to ↗load shedding. It is sometimes considered part of ↗DSM schemes, sometimes not (because of its emergency aspect).
Load (also: demand)	Load is defined as the level of electricity consumption by the consumer. Load refers also to an element that consumes electrical power as opposed to a ↗generator which provides it.
Load curve	In a power system, a load curve or load profile is a chart illustrating the variation in demand/electrical load over a specific time. Electricity companies use this information to plan how much power one will

	need to generate at any given time.
Load shaving (also: peak shaving)	Where the demand for electricity exceeds the available power generation, organisations responsible for the electrical system need to consider the practicalities of ↗load management during peak demand times of the day. Peak shaving is a technique that is used to reduce the demand for electrical power consumption during periods of maximum demand.
Load shedding	Load shedding is the reduction of electrical consumption. It is used as a last resort method to balance supply and demand when generation cannot meet demand. As a last resort means, consumption is shed with no prior agreement of the concerned consumers.
Load shifting	Load shifting is another form of ↗load management, mainly used by utilities. It involves moving the electricity consumption of loads to different times within an hour/day. It does not lead to reduction in net quantity of energy consumed in electricity. It simply involves changing the “when consumed” rather than “how much consumed”.
Electricity Markets	Electricity generators compete in wholesale electricity markets to sell electricity to large industrial consumers and electricity suppliers. Suppliers compete in the retail electricity market to sell electricity to the final consumer. Electricity is a commodity with the property that generation has to equal consumption (plus grid losses) on an instantaneous basis. The design of electricity markets is adapted to deal with this particular property. Different types of electricity markets are arranged in a sequential order, starting years before the actual physical delivery and ending after the actual delivery:  *Source: TenneT Market Review 2016*

	The forward and futures markets span the time intervals from years before up to the day before delivery. In the day-ahead market, electricity is traded one day before actual delivery. The day-ahead market is of major importance and also the market with the highest trading volumes and number of participants. In the intraday market, electricity is traded on the delivery day itself. The intraday market enables market participants to correct for shifts in their day-ahead nominations due to better renewable feed-in forecasts, demand changes, unexpected power plant outages, etc. Unlike most commodities, electrical energy needs to be balanced at every point in time, due to the limited possibilities to store this electricity. Balancing capacity is procured to provide balancing capacity when needed.
Modelling	Modelling refers to the development and use of a computer model that represents a physical system by means of mathematical equations. One possible application is modelling of electrical transmission (or distribution) grids with the purpose of e.g. analysing their stability in specific situations or evaluating their adequacy for supplying electricity in the future in order to determine if and where grid development will be required. Typical modelling steps in the process of ascertaining the needs of future grids are: • Load forecasting aims at identifying the development of new and existing grid elements in the future to be able to satisfy future demand. • Market modelling answers the question 'which generation (location/type) is going to serve the demand in any future instant?' • Grid modelling as input for (static and dynamic) simulations that assess load flow results like the current flow and ↗voltage levels for all modelled elements in the system in order to evaluate the adequacy of the grid to fulfil its transmission (or distribution) task. In other words answering the question: is the grid infrastructure sufficient to secure that all demand can be met and the grid system remains stable or are more/other powerlines needed.
Node	The term node refers to a significant point in the grid where several elements, such as loads, generation, storage, transmission lines or external grids (e.g. a distribution grid when regarding the transmission grid) are connected. Depending on the scope of the respective study, a certain degree of aggregation is required. For national network development planning

	of transmission system operators, each substation is typically modelled as a node, whereas in pan-European studies, countries may be aggregated to a small number of nodes. For transmission system studies, consumption within the same distribution system may be aggregated to one load, whereas households may need to be represented individually when analysing e.g. system stability of a distribution grid.
Peak load	Peak load may refer to high levels of demand or to the time of maximum or very high demand. These peak demands are often only for short durations, e.g. the times (usually an hour or half hour) of very high demand during midday and/or in the evening. In mathematical terms, peak demand could be understood as the difference between the base demand and the highest demand. Peak load power plants are plants that can adjust their power output very quickly to follow fast changes in the demand. Typically, they feature high variable costs and are hence utilised for only few hours per day. Typical peak load plants are gas and pumped hydro.
Power	Power is the rate at which work is done, or the amount of ↗energy generated, transferred or consumed per unit time. The unit of power is ↗watt (W). Often, ↗energy and power are confused.
Residual load	Renewable sources (RES) like PV and wind energy are highly dependent on weather conditions, which limits the possibility to control their power. Furthermore, energy policies of many European countries prioritise power from RES, so that controlling them is even unwanted. For these reasons, the fluctuating and weather-dependent infeed is sometimes regarded as a negative load instead of as generation. The residual load is the actual load that needs to be supplied minus the generation from these fluctuating, weather-dependent renewable sources. It is the resulting load that needs to be supplied by steerable/controllable generation such as biomass, coal or nuclear and/or from storage.
Scenarios	The presentation of potential ‘paths’ through the uncertain energy landscape depicting a plausible range of possible future developments. Encompassing a coherent set of individual influencing factors and their defining assumptions, scenarios are used as an input to a quantitative market/grid modelling exercise with the aim of deriving measures that need to be taken in the future to ensure security of supply depending on the development of the addressed uncertainties. Each scenario has a number of drivers around which the narratives are built (e.g. high renewables and European focus). The scenarios do not represent forecasts, but show a range of plausible pathways for energy in the future, with the aim of aiding governments,

	customers and other stakeholders in making informed decisions.
Sensitivity analysis (also: parameter study)	Sensitivity analysis is the study of how the uncertainty in the output of a mathematical model or system can be apportioned to different sources of uncertainty in its inputs. In energy system modelling, it is used for various purposes, such as testing the robustness of the results of a model or system in the presence of uncertainty, understanding of the relationships between input and output variables, identifying model inputs that cause significant uncertainty in the output and should therefore be the focus of attention, and finding regions in the space of input factors for which the model output is either maximum or minimum or meets some optimum criterion. In case of calibrating models with large number of parameters, a primary sensitivity test can ease the calibration stage by focusing on the sensitive parameters. Not knowing the sensitivity of parameters can result in time being uselessly spent on non-sensitive ones. In the context of grid development studies, sensitivity analysis is often applied to identify how parameters like the development of load and generation influence the requirement of grid reinforcement in order to identify which uncertainties should be included in different scenarios. Furthermore, it is applied to validate the results by checking their robustness to various factors after identifying the final grid architecture.
Socio-economic welfare	Socio-economic welfare (SEW) or market integration is characterised by the ability of a project to reduce congestion and thus provide an increase in transmission capacity that makes it possible to increase commercial exchanges, so that electricity markets can trade power in an economically efficient manner.
Storage	The term storage refers to an element that stores energy. It allows to capture electrical energy produced at one time for a use at later time by converting it to a different form of energy, e.g. chemical energy in batteries or potential energy in pump storage power plants. Storage devices as part of an electricity system can provide a variety of different services to both energy providers/grid operators and end-customers. Some of these services can help to maintain the stability of the electricity system, they may allow to defer an investment of extra grid capacity or they may give opportunity to customers to savings on the electricity bill.
Transmission bottlenecks	Transmission bottlenecks are transmission lines that are frequently subject to ➚congestion. In this situation, the infrastructure may require an upgrade (increase of transmission capacity) to enable it to transmit the necessary power. An alternative approach to mitigate congestion can be the application of ➚demand side management. The term can also refer to a congested transmission line.

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Transmission capacity	The amount of electricity that is able to flow through a transmission line without compromising its functionality and system security. The term can also refer to the amount of electricity that can be transferred from one node or region to another via several transmission lines, e.g. when talking about the overall ↗interconnector capacity between neighbouring countries.
Transmission grid (also: transmission system)	The transmission grid is the interconnected group of power lines and associated equipment for transporting electrical power at high ↗voltage over long distances. Connected to transmission grid are usually large generation plants, ↗distribution grids and very large consumers. Following the analogy introduced for ↗distribution grids, the transmission grid would be the power line 'highway'.
Voltage	A quantitative expression of the potential difference in charge between two points in an electrical field. The greater the voltage, the greater the flow of electrical current (that is, the quantity of charge carriers that pass through a fixed area per unit of time) through a conducting or semiconducting medium for a given resistance to the flow.
Watt, megawatt, gigawatt, terawatt, petawatt	Watt is the standard unit to measure electrical ↗power. This can apply to power produced by a generator, consumed by a load or transferred via the grid. Multiples of the watt include kilo (KW), mega (MW), giga (GW), tera (TW), peta (PW).
Watt hour	Watt hour is the standard unit of energy, which can be produced, used or stored. Multiples of the watt hour include kilo (KWh), mega (MWh), giga (GWh), tera (TWh), peta (PW)h. If power is being transmitted or used at a constant rate over a period of time, the total energy in kilowatt hours is the power in kilowatt multiplied by the time in hours. For example, a generation unit runs constantly at 1 kW for one hour and produces exactly 1 kWh. People are often confused because of the reference to time in this measure. However, this is a measure of the volume of the produced electricity, not a measure of time. To give an example, a unit with 2 kW generation capacity that would run for half an hour would also produce 1 kWh of electricity (2kW*0,5h=1kWh).