T&D europe

The European Association of the Electricity Transmission
and Distribution Equipment and Services Industry

Future proofing electricity grids[1] in the EU Green Deal age: Assessing and monitoring capabilities of European grids to deal with evolving future requirements

Position Paper by T&D Europe

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Executive Summary

Electricity networks are undergoing a fundamental transformation and will require to provide new services, such as enabling flexibility from distributed resources and facilitating all types of prosumer related services. Therefore, networks of the future will have to be much smarter than in the past; this certainly means more measuring, controlling and automation. While most parts of the transmission network are today equipped with smart digital solutions, the distribution level needs to undertake a complete transformation.

In this context, a supplement to the regulatory framework is needed to ensure the definition of future functionalities and to monitor the roll-out of these. The European Union's Clean Energy Package calls for a smartness monitoring process as a matter of principle and has introduced a specific provision in the revised Electricity Directive.

This paper describes a proposal for such process to be implemented by national energy regulators and involving the relevant stakeholder groups, that should at least include grid operators, grid users (generators and consumers) and regulators.

Content

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[1] Formerly titled “A smartness indicator for grids”, renamed because of broadening the concept.

Introduction

An important milestone in the process of European legislative initiatives aiming at reducing carbon dioxide emissions and to increasing the share of renewable energies in the energy mix is the Clean Energy for all Europeans package adopted in 2018-2019, and in particular the revised Electricity Directive[2]. Since 2020, we must look at how we produce, transport, distribute and use energy within the framework of the European Green Deal – in order to contribute to the objective of a climate-neutral EU by 2050.

Without electricity, everyday life is severely disrupted, creating massive impact on essential services such as transportation, water and food supply, communications, security and health services. Given its criticality, the EU has designated electricity generation, transmission and supply as European critical infrastructure[3]. Electricity networks are the backbone of Europe's energy system and facilitator of the energy transition. They are undergoing a fundamental transformation and will require to provide new services, such as enabling flexibility from distributed resources and facilitating all types of prosumer related services.

The networks of the future will have to be much smarter than in the past – and this certainly means more measuring, controlling and automation. However, although the concept of Smart Grids is under discussion since about 2005, not too much has happened yet, particularly not on distribution level, where most of the changes will happen.

Increasing dynamism and decentralization require new functions. Examples are voltage regulation in secondary distribution grids, congestion management on distribution level, digital connectivity of decentralized resources and fast market processes to benefit from intra-day markets. The prerequisites for these functions should be created pro-actively, since retrofitting is too slow and, most likely, more expensive. The basis for a pro-active design is a coordinated view of network operators, users and technology providers on the **future functionalities of the grid** and possible realizations. This means that a supplement to the regulatory framework is needed to ensure definition of future functionalities and to monitor roll-out of these. The European Union's Clean Energy Package calls for such a smartness monitoring process as a matter of principle; article 59.1 (l) of the revised Electricity Directive named national regulatory authorities as responsible for its design.

Introducing such a smartness monitoring process requires using the knowledge of all relevant stakeholder groups. T&D Europe has drafted a first set of ideas on how such an indicator could be created. This is presented by this paper. A longer version including further background

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[2] Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity

[3] COUNCIL DIRECTIVE 2008/114/EC of 8 December 2008 on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection

information and references to similar approaches in other parts of the world is also available[4]. We propose these papers to serve as a starting point for a development process to be implemented by national energy regulators and involving the relevant stakeholder groups. These should at least include grid operators, grid users (generators and consumers) and regulators.

1. Why monitoring and assessing grids in a Green Deal equation?

Electricity grids connect and coordinate all elements of power systems to serve their end users. Grids will play a crucial role in facilitating and enabling the energy transition to incorporate increasing levels of distributed generation, changing demand patterns and the implementation of new technology and solutions. As we move on from traditional energy systems, new, smarter solutions will be required in order to manage the changing generation mix, whilst maintaining affordability and ensuring security of supply. This means that not only the generation sector will have to undergo a fundamental transformation, but also the grids will have to change and develop accordingly in order to ensure value for money, a successful transition and to deliver value and quality of supply to consumers.

Moreover, electricity grids are long-term investments. We expect grid components to be in place, serving their purpose in good quality over several decades. Europe’s electricity grids have an ageing structure, as they are all originating from the time after World War II. Therefore, many of their components are close to end of their life time. Steady re-investments are very important in such situation to avoid reduction of reliability of supply because of synchronous failures of outdated equipment in future.

Both aspects can be summarised under the umbrella “state of the grid”: On one side this term addresses the state of existing installations as a basis of reliability of supply in future and on the other side it addresses the future preparedness of grids in a transitional period resulting in new tasks and challenges.

State of the grid	
State of **existing installations**	**Future preparedness** of grids in a transitional period
➢ basis of reliability of supply in future	➢ making networks ready to serve new tasks and challenges in a cost-efficient and pro-active way

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[4] T&D Europe, “Assessing, monitoring and future proofing European grids: Increasing transparency on the performance of electrical grids within the framework of the European Green Deal”, April 2020

Today's regulation does not reflect neither of these two topics

Regulation is primarily or in many cases even exclusively focusing on cost-efficiency of the grids and quality of supply. These output-oriented criteria are reflecting today's tasks of the grids and their current solution. They do not reflect the technical quality of grids nor do they address the preparedness for changes of these tasks resulting from the energy transition. Thus, today's regulatory schemes do not reflect the active contribution of grids to a successful (including cost-efficient) energy transition. There is a need to broaden this regulatory view on electricity grids in two directions:

1: Monitoring the **current state** of the grid	2: Monitoring the **future preparedness**
In addition to measuring the current quality of service, a monitoring process for the technical state of grids is needed. Its main purpose is **ensuring continuous re-investments and avoiding accumulation of outdated equipment.** Infrastructures can be operated over a long time with insufficient investments while maintaining quality of service, but beyond a tipping point quality of service may collapse and it takes a long time to restore it in such situation. A pragmatic approach for monitoring the technical state of grids would be looking at the age distribution of grid components. This part of monitoring the state of grids will not be elaborated in this paper, but it should be acknowledged as integral part of the proposed approach nevertheless.	This part is by far the more difficult one, as it somehow **requires monitoring and regulating an unknown future**, based on the fact that all new developments are connected to the grid (electric mobility, all types of distributed energy resources (DER), storage etc.), and this X-to-Grid brings uncertainty to the electrical network, and may fragilize it from the transmission and distribution angle or from the "last mile" perspective. However, as explained already, there is a need of a continuous and structured discussion on what needs to be done in order to make today's investments in grids as future-proof as possible. Ideas on realising this additional element of regulation are the main subject of this paper. Moreover, all future investments must be viewed and assessed within the framework of an increasingly circular economy approach.

Expert Group 4 (EG4, Smart Grid Infrastructure Deployment) within the Commission's Task Force Smart Grid has dealt with the "Monitoring the future preparedness" regarding projects proposed under the framework of Projects of Common Interest (PCI). A more detailed discussion how the framework for assessing projects proposed by this expert group[5] is linked to the approach proposed in this paper is subject of a longer version of this paper[6].

The assessment proposed by EG4 is addressing projects to be built, whereas our proposal is complementing this by monitoring the status of smart grid deployment in the installed base. In addition, it covers all investments in grids outside the scope of PCI, particularly including the distribution level. We propose the introduction of a grid smartness monitoring process as an additional element of regulation schemes for the grids, e.g. TYNDP. This new methodology would create transparency on the transition to smarter grids in Europe, increase the awareness of smart technologies and their potential and promote the use of best practices. By doing so it is expected to help Member States investing to reach their emissions reduction and energy efficiency targets while incentivising investments in innovative technologies.

Out of scope	In scope
Improving the regulatory framework with this regard is not subject of our proposal.	While our proposal is focussing on innovative solutions, it is important to keep in mind, that it is primarily **addressing new functionalities expected to be required in future**. Different from that, innovative solutions can also help improving present performance of grids.

The impact of the regulatory schemes on innovation in European grids as a means for performance improvement has been analysed for instance in a study for the European Commission published in March 2019[7].

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[5] Definition of an Assessment Framework for Projects of Common Interest in the Field of Smart Grids under the EC 'Proposal for a regulation of the European Parliament and of the Council on guidelines for trans-European energy infrastructure and repealing Decision No 1364/2006/EC' (COM(2011) 658), Brussels, July 2012

[6] Assessing, monitoring and future proofing European grids: Increasing transparency on the performance of electrical grids within the framework of the European Green Deal – working document, available on T&D Europe website, 21 April 2020

[7] Do current regulatory frameworks in the EU support innovation and security of supply in electricity and gas infrastructure? Final report, European Union, ISBN: 978-92-76-03384-4, 2018

2. Objective of the Green Deal monitoring smartness indicators of grids

The Grid Smartness Monitoring Process should provide information on the ability of a grid to serve its purpose in a changing environment. Traditionally there has been a triangle of expectations on power systems and on grids as an integral part of them. They should ensure cost-efficient, reliable and sustainable provision of electrical energy.

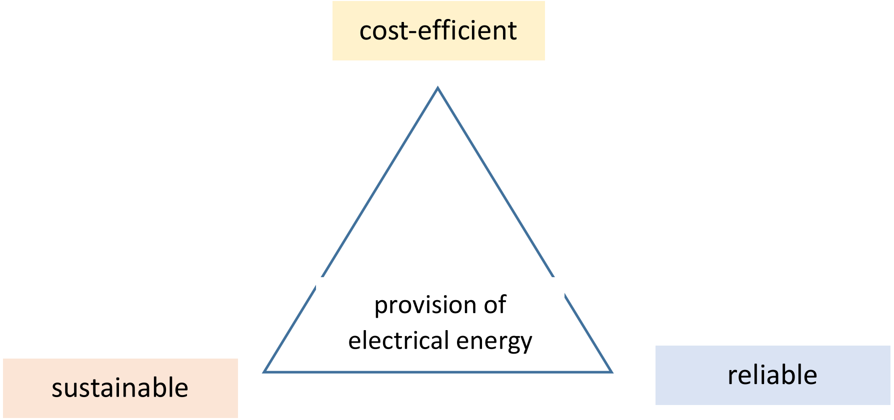

Fig. x: *Traditional expectations towards power systems and grids*

These three expectations are still in place, but they are applied in a different environment today.

Therefore, **monitoring the smartness should reflect the ability of the grid to enable the entire power system to ensure cost-effectiveness whilst supporting the energy transition and security of supply as well as the participation for all users known today and in the future (e.g. generators, consumers, prosumers, aggregators, etc.).**

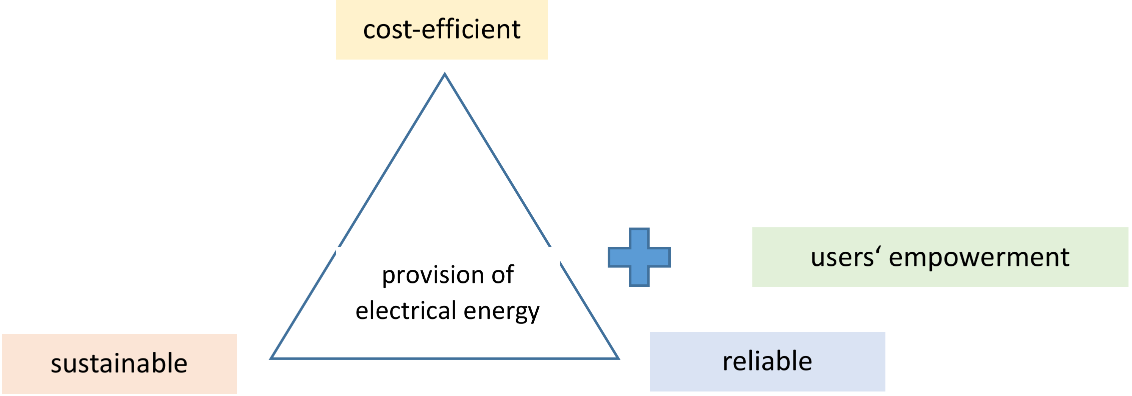

Fig. y: *Traditional expectations towards power systems and grids applied in a different environment*

3. Breakdown of the objective and the expectations on grids

Although expectations on power systems and grids seem to be the same as in the past from an end user point of view, the conclusions may be different in the context of the energy transition. This chapter therefore discusses the different elements of the objective more in detail.

Cost-effectiveness, **support of the energy transition and security of supply** are representing the traditional triangle of requirements, with the energy transition covering sustainability and security of supply addressing reliability and resilience.

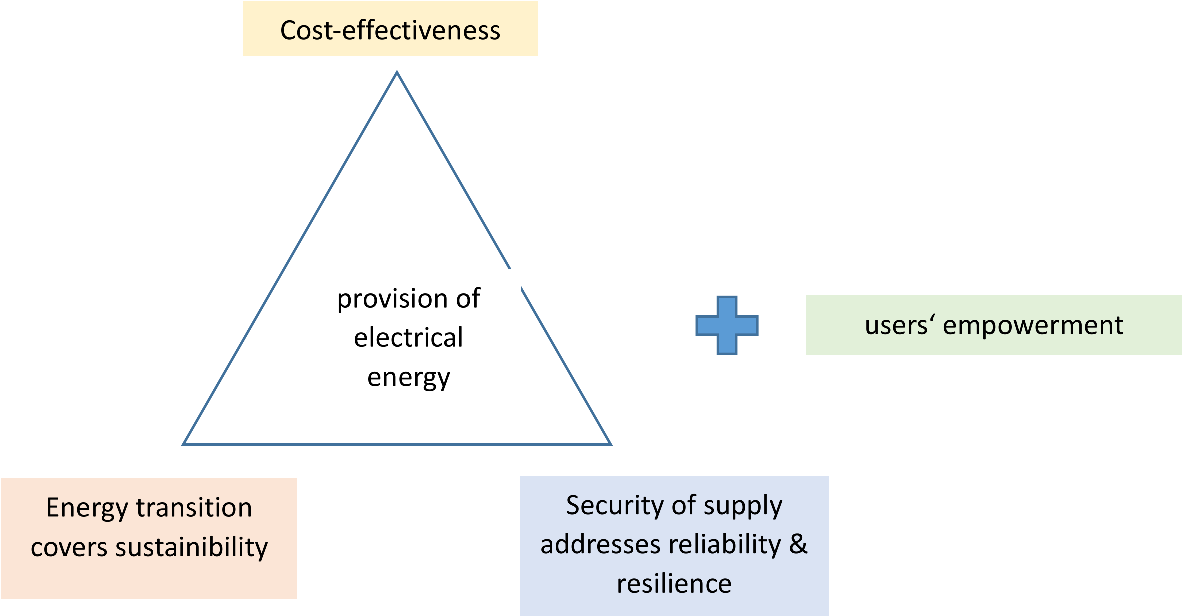

Fig. z: Traditional expectations towards power systems and grids in the context of energy transition

Cost-effectiveness in the context of the energy transition translates into other challenges and solutions than in traditional power systems. Wind and solar power as well as new types of load, in particular EV charging infrastructures, are rapidly evolving and are challenging the grids with high and rare peaks. Traditional design of the grid based on the peak load would result in decreasing utilisation due to changing demand patterns and projected increases in peak demand affected directly by consumer charging behaviour. Deferring investments in primary equipment and reinforcement by smarter operation of the grids therefore gains importance.

Future investments need to be assessed regarding their contribution to a more circular economy and their carbon footprint all over their life cycle.

Some examples of smarter operation are:

a) Dynamic loading of components
b) Increased ability to accommodate DER (generation and new types of load, such as EV charging infrastructures) by dynamic voltage control
c) Reasonable curtailment of rare peaks of RES feed-in or load - such as Active Network Management
d) Advanced asset health management, for a better life cycle management
e) Minimization of fuel and carbon cost of conventional generation by maximizing accommodation of renewables - increasing network capacity and headroom using smart techniques such as reactive power compensation

Examples for equipping and using the grids for supporting **sustainability and the energy transition** are:

a) Loss reduction by increasing energy-efficiency of the grids
b) Accommodating increasing levels of renewable generation
c) Support of electrification of new sectors based on sector coupling optimisation, e.g. electric vehicles (EV) charging and heat
d) Optimization of the grid load at all voltage levels including phase balancing, to increase the energy efficiency of the grid
e) Circular economy offers, based on end of-life management, recycling, for instance
f) Greener components, e.g. more efficient transformers or SF6 free switchgear, to contribute to climate neutrality of networks

Ensuring **security and quality of supply as well as resilience** of the system has become a quite different and much more challenging task in an environment with much more stochastic, volatile processes and significantly increased complexity due to highly distributed, active resources both on generation and consumption side. Examples for approaches for the grid to more effectively manage this are:

a) Advanced planning procedures and tools, reflecting distributed resources and new loads, in particular EV charging infrastructures, and consideration of operational measures (e.g. peak shaving) when assessing and planning the infrastructure.
b) Advanced asset management, reflecting condition and importance of assets and ensuring that critical components are identified and prioritised: Such approaches are

	becoming more relevant in a rapidly evolving environment, in which grid enforcements and extension have to be implemented much faster than in the traditional, quite stable European environment. Prioritization of limited investment and maintenance resources is a key success factor under such circumstances. Future asset management has also to consider a circular economy framework and end of life management and recyclability.
c)	Real-time dynamic security assessment on transmission level: Historically, the European interconnected power system has been engineered to share reserves and to allow portfolio optimisation in a regionally balanced power system. Additionally, the majority of generation was provided by large rotating machines, stabilizing the grid by their mechanically inertia. Today, with increasing regional imbalances caused by geographically constrained sources of renewable energy mainly connected via power electronics, the pan-European transmission grids are facing a fundamentally different task. The traditional way of operating the systems with strong focus on preventing emergencies and much less attention on curing such efficiently, which resulted in high reserve capacities in the transmission grid, is not adequate for this task any more. Instead, more real-time monitoring and network management should be applied to ensure best utilisation of the infrastructure, while at the same time maintaining security of supply. In doing so, also new grid elements based on power electronics need to be considered.
d)	Self-healing or re-configuring distribution networks: Rapidly changing load situations caused by volatile distributed generation are requiring more operational flexibility even in the secondary distribution level, which traditionally has not been controlled or monitored. This will contribute bot to the ability of networks to accommodate production from distributed sources and reliability of supply for citizens.
e)	Fast outage clearing: Reliability of supply can be improved not only by avoiding outages, but also by shortening the time of interruption of supply. Increased application of remote control and monitoring can support this and at the same time even lower costs.
f)	Increased resilience provided by on-grid micro- or nanogrids: Distributed generation, if equipped with adequate microgrid controllers, can run independent from the grid in case of regional or system-wide blackouts. Using this opportunity given by distributed generation would reduce the negative impacts of such blackouts significantly.
g)	Demand response programmes helping to avoid critical situations: Such programmes may help to balance load and generation, they may help accommodating renewable generation, but they may also give relief to the grids in critical situation and help the grid to manage changing demand patters and increasing connected loads in a more effective and efficient way.

h) Cyber security assessments: All the items above imply the use of more digital control and communication technologies. Moreover, integrating and coordinating highly distributed resources means a quantitatively much broader exposure of the system to cybercrime. Cyber security and cyber security assessments are therefore crucial for ensuring security of supply in future power systems.

Empowerment of all types of users of the grids and letting them participate more actively is a new, additional requirement complementing the traditional triangle. An important pre-requisite for such participation is transparency of the user's influence on the service received and on the system, both for the user and for service providers. Examples for implementation are:

a) Smart metering infrastructure and services providing information to users and grid operators

b) Time-of-use tariffs (enabled by time-based metering or smart meters)

c) Differentiation between applications with guaranteed supply and such, which may be switched off under certain conditions and get another (cheaper) tariff therefore

d) Facilitation of participation of all players even very small ones in markets by efficient and functional regulation for registration, qualification and settlement

e) Allowance for the grid operator to use reasonable curtailment of rare peaks as an alternative to grid extension based on economic decisions

There are two more elements in the objective, which suggest a broadening of the traditional triangle of requirements and a need for different solutions in future than in the past: The first is the requirement to serve all types of users of the grids. In addition to the classical users – bulk power plants and passive consumers – this addresses for instance distributed generators, prosumers and new service providers, such as aggregators. The second is to be accessible to all of these new users known already today, but also to those that may evolve in future and are not known yet.

This accessibility requires concepts that are capable of evolution and adaptation. Digitalisation, if properly applied, can be expected to be a key enabler to address this requirement.

4. First ideas on monitoring smartness Indicators of grids

Measuring the contribution of a particular grid to the energy transition	Monitoring the smartness of grids should reflect the feasibility that a grid is prepared to support the objective defined above.
e. g. by quantifying accommodated renewable generation, utilisation of assets, reliability of supply or curtailed generation from renewables. However, these outcomes will not only depend on the smartness of the grid, but at least as much on its structure inherited from the past, the situation of load and generation and many other factors. Therefore, we propose another view on the right-hand side of the table.	It should not be a precise measurement of what a particular grid is delivering by using smart technologies and solutions. With other words: **We propose to measure the capabilities of the grids do deal with tasks, which may evolve in future, and not their current performance.** This requires at first an agreement on functionalities expected from grids in future. Secondly, it may be sufficient to accumulate technologies or solutions obviously contributing to these functionalities. They should be weighted based on their role out in the grid or availability to the grid user, without the need for quantifying their contribution in a particular grid. This makes the process simple, robust – and will always allow the addition of new solutions in the future.

It should also be noted that there is not a one and only smart grid. Differences in the geographical structure of load and generation as well as different combinations of technologies and solutions may result in grids equally serving the requirements, although being quite differently equipped. This also means that some of the solutions proposed to be monitored may be overlapping, defining more a menu of alternatives than one consistent set of complementary solutions. This implies that not all monitored solutions need to be in place in a certain grid to make it smart.

We therefore understand the **proposed monitoring process** as a **principle defining a general direction of development but leaving freedom for its users (e.g. regulators) to be adopted to national requirements and to support national goals.** With other words:

We are not asking for the same path for all, but for a common direction with local freedom.

Looking at technologies and solutions to be monitored, we propose to structure them in three technological groups:

I: Smart grid infrastructure	**II: Smart grid functions**	**III: Smart actuators**
field devices, remote monitoring and control	operational features on network level, software	new non-conventional components to operate the network
Assuming that a common denominator of most, if not all smart solutions is to operate grids in a more precise and adaptive manner, getting information from the field and being able to control the grid remotely is a pre-requisite for increased smartness. This would be reflected by this first group: a smart grid infrastructure that supports cost-efficiency as well as reliability and by increasing the capability to accommodate RES generation – sustainability. Moreover, smart devices at the edge of the grid are the basis for all types of new consumer-oriented services and for consumer empowerment.	Using information provided by the infrastructure addressed by the first group is the second building block of smart grids, which contains primarily out of software functions applied on network level – either on parts of a network, such as lines (i.e. underground cables, overhead lines, gas insulated lines), or to entire grids.	Combining the first two groups means to operate conventionally equipped grids with more monitoring and remote control more smartly. This is an important first step towards smart grids. However, there are more opportunities if non-conventional elements are added, allowing faster adaptation of the grid to new situations and by that to increase utilisation without reducing reliability of supply. Such solutions are frequently based on power electronics.

Technologies and solutions contributing to the three areas of smartening grids

Examples of technologies and solutions representing the smart grid infrastructure are listed in the following table. The two right columns are indicating the areas of impact: Some solutions are relevant for the transmission level, others for the distribution level and some for both. Moreover, some are contributing to improved operation of the grids, while others are supporting consumer services and engagement. However, it should be recognized that advanced network operation in general is expected to improve the service quality for consumers, meaning that in the end all of the listed solutions are consumer oriented.

I: Smart grid infrastructure - Examples	**T/D**[8]	**g/c**[9]
Percentage of substations remotely monitored and controlled in real-time, itemised as transmission, HV/MV and MV/LV substations	T, D	g
Percentage of substations ready for predictive maintenance, itemised as before	T, D	g
Percentage of energy efficient transformers	(T), D	g
Percentage of underground and overhead lines remotely monitored in real-time, itemised as HV, MV and LV	T, D	g
Percentage of underground lines ready for predictive maintenance, itemised as before	T, D	g
Percentage of LV lines with efficiency monitoring (phase imbalance detection)	D	g
Percentage of smart meters installed (supporting transparency and time-of-use tariffs)	D	c
Percentage of smart meters with building automation gateways installed (supporting remotely controlled flexibility)	D	c, g
Percentage of the grid connected to smart buildings (according to the Smartness indicator for buildings)	D	c
…		

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[8] T: transmission (extra-high/high voltage, EHV/HV), D: distribution (high, medium and low voltage, HV/MV/LV)

[9] g: supporting grid operation, c: supporting consumer services

II: Smart grid functions – Examples (Smart grid functions are complementary modules to the smart grid infrastructure, these help to manage grid planning, operation and maintenance more effectively and efficiently)	**T/D**	**g/c**
Percentage of the number of underground and overhead lines operated under dynamic line ratings	T	g
Asset health monitoring, supporting controlled, temporary overloading	T, D	g
Percentage of networks prepared by local automation for remote reconfiguration through advanced distribution management systems	D	g
Number of micro- or nanogrids being able to operate autonomously during grid outages	D	c
Use of real-time dynamic security assessment on transmission level	T	g
Flow-based allocation of interconnector capacity in market processes	T	g
Share of load under demand response programmes	T, D	c
…		

III: Smart actuators - Examples (new non-conventional components to operate the network)	**T/D**	**g/c**
HVDC lines embedded into the AC grid being able to influence load flow	T	g
Fast (i.e. power electronics based) FACTS, optionally including storage	T, (D)	g
Smart distribution transformers with actuators or other equipment for distribution voltage control (e.g. line voltage regulators)	D	g
…		

Contribution of smart solutions to enabling grids to serve their purpose

Smart technologies and solution have been grouped using technical categories in the previous sections in order to reflect the technical structure of a grid. Doing so ensured that each solution could be counted only once. However, eventually it is also important to understand, to which of the objectives of a grid discussed in the chapter before the different solutions can contribute. The following table therefore maps solutions to objectives.

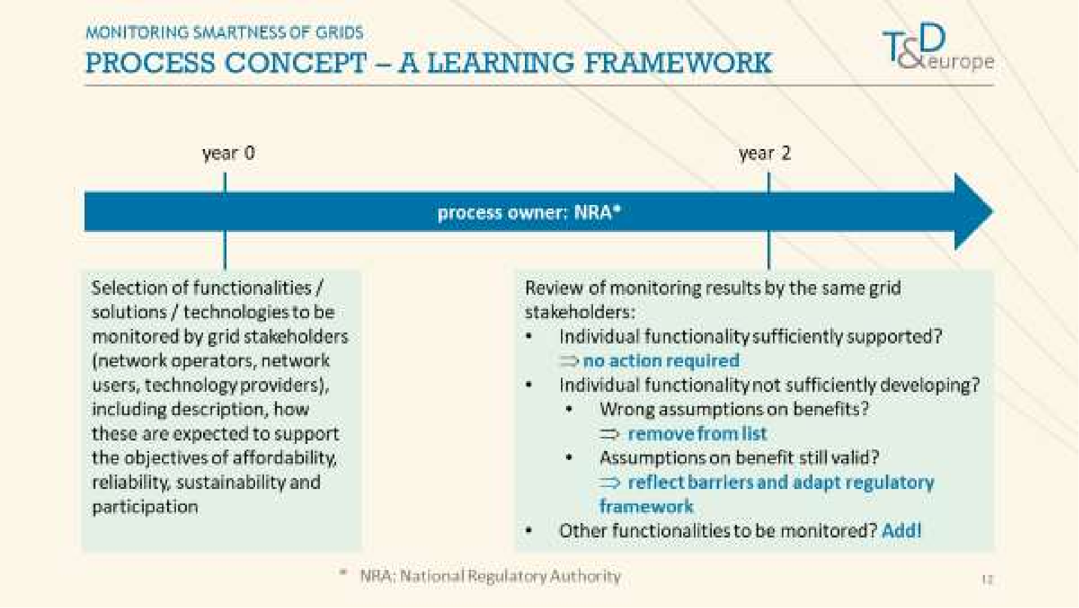
Smart technology or solution	Cost-effectiveness	Energy transition	Security of supply	Empowerment
Smart grid infrastructure				
Percentage of substations remotely monitored and controlled in real-time, itemised as transmission, HV/MV and MV/LV substations	●	●	●	
Percentage of substations ready for predictive maintenance, itemised as before	●			
Percentage of energy efficient transformers	●	●		
Percentage of underground and overhead lines remotely monitored in real time itemised as HV, MV and LV	●	●	●	
Percentage of underground lines ready for predictive maintenance, itemised as before	●		●	
Percentage of LV lines with efficiency monitoring (phase imbalance detection)	●	●		
Percentage of smart meters installed		●		●
Percentage of smart meters with building automation gateways installed		●	●	●
Percentage of the grid connected to smart buildings (according to the Smartness indicator for buildings)	●	●		●

Smart grid functions				
Percentage of number of underground and overhead lines operated under dynamic line ratings	●	●	●	
Asset health monitoring, supporting controlled, temporary overloading	●	●	●	
Percentage of networks prepared by local automation for remote reconfiguration through advanced distribution management systems		●		
Number of micro- or nanogrids being able to operate autonomously during grid outages			●	●
Use of real-time dynamic security assessment on transmission level	●	●	●	
Flow-based allocation of interconnector capacity	●	●		
Share of load under demand response programmes	●	●		●
Smart actuators				
HVDC lines embedded into the AC grid being able to influence load flow		●	●	
Fast (i.e. power electronics based) FACTS, optionally including storage		●	●	
Smart distribution transformers with actuators or other equipment for distribution voltage control (e.g. line voltage regulators)	●			

6. Monitoring and assessing grids in the Electricity Directive: process proposal

According to the Electricity Directive, article 59.1 (l) *"The regulatory authority shall have the following duties: (…) (l) monitoring and assessing the performance of the transmission system operators and distribution system operators in relation to the development of a smart grid that promotes energy efficiency and the integration of energy from renewable sources based on a limited set of indicators, and publish a national report every two years, including recommendations;"*

An initial proposal for such process, as shown below, has been developed by T&D Europe. At its core there is a forum of network operators, technology providers and network users who, under the leadership of the regulatory authority, agree on which future functionalities are considered necessary and which solutions should be used for this purpose. The installation of these solutions will then be monitored within the regulatory framework. In the next step of this rolling process the players will analyze whether these solutions have been sufficiently used and, if not, what may be causes of the deviation. In this way, a learning regulatory framework is created, with which the transition of grids into a widely unknown and uncertain future can be orchestrated and shaped.



MONITORING SMARTNESS OF GRIDS

PROCESS CONCEPT – A LEARNING FRAMEWORK

T&D europe

year 0

year 2

process owner: NRA*

Selection of functionalities / solutions / technologies to be monitored by grid stakeholders (network operators, network users, technology providers), including description, how these are expected to support the objectives of affordability, reliability, sustainability and participation

Review of monitoring results by the same grid stakeholders:

- Individual functionality sufficiently supported?
  ⇒ no action required
- Individual functionality not sufficiently developing?
  - Wrong assumptions on benefits?
    ⇒ remove from list
  - Assumptions on benefit still valid?
    ⇒ reflect barriers and adapt regulatory framework
- Other functionalities to be monitored? Add!

* NRA: National Regulatory Authority

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Conclusion

T&D Europe has drafted a first set of ideas on how an indicator could be created. In this paper, we propose a starting point for a development process under the leadership of national energy regulators involving the relevant stakeholder groups. These should at least include grid operators, grid users (generators and consumers) and regulators.