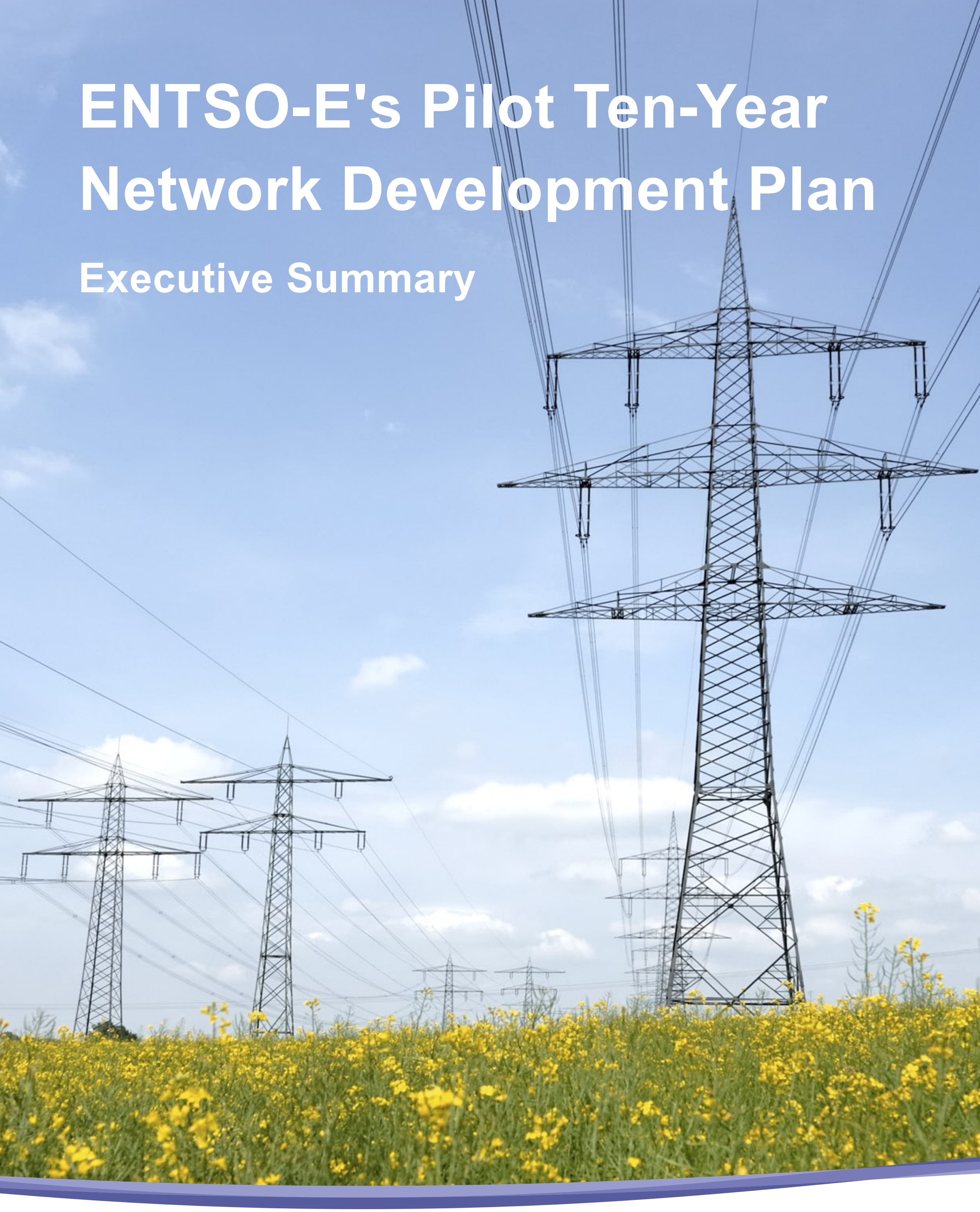
ENTSO-E's Pilot Ten-Year Network Development Plan

Executive Summary



European Network of
Transmission System Operators
for Electricity

entsoe

Content

Introduction

The development of the transmission network has undergone fundamental changes since the Electricity Directive 96/92/EC in 1999 for the liberalisation of the national electricity markets in Europe. Transmission System Operators (TSOs) had to develop their networks to accommodate European policy objectives without relying on a formal integrated planning of generation and network assets.

Ten years after the Directive, the Third Legislative Package for the Internal Market in electricity (hereinafter the Third Package) was adopted and will come into force in early 2011. The Third Package provides for institutions and tools that promote the strong coordination of the operation and development of the national transmission networks, as well as the harmonisation of the European regulatory frameworks. Regulation (EC) 714/2009 of the Third Package calls for the creation of the European Network of Transmission System Operators for Electricity (ENTSO-E) and according to Art. 8.3 (b) of the Regulation (EC) 714/2009, "ENTSO-E shall adopt a non-binding Community-wide ten-year network development plan" (TYNDP) with the objective to ensure greater transparency regarding the entire electricity transmission network in the Community and to support the decision making process at regional and European level.

According to Art. 8.10 of the Regulation, "The Community-wide network development plan shall include the modelling of the integrated network, scenario development, a European generation adequacy outlook and an assessment of the resilience of the system". Furthermore, the TYNDP must "build upon national investment plans" (the consistency with which is monitored by the Agency for the Cooperation of Energy Regulators, ACER), "and if appropriate the guidelines for trans-European energy networks". Also, it must "build on the reasonable needs of different system users". Finally, the TYNDP must "identify investment gaps, notably with respect to cross-border capacities".

The European TSOs, already familiar with the advantages of international collaboration through their experiences within long-standing associations [1], established ENTSO-E in anticipation of the Third Package in December 2008 as a fusion of the above mentioned organisations. The mission of ENTSO-E is to promote important aspects of energy policy in the face of significant challenges concerning the security of the operation of the network, the adequacy of the power system, the market integration and transparency, and the sustainability of development through the integration of renewable energy sources.

1) ATSOI (Association of the Transmission System Operators of Ireland); BALTSO (Baltic Transmission System Operators); ETSO (European Transmission System Operators); NORDEL (Association of TSOs from Norway, Finland, Denmark, Sweden and Iceland); UCTE (Union for the Coordination of the Transmission of Electricity); UKTSOA (UK Transmission System Operators Association).

ENTSO-E, having recognised that:

- the overwhelming response of European society to the climate change issue translates into massive investments in renewable energy sources whose efficient integration into the grid is a challenge that has to be urgently and adequately addressed;

- the wide scope and ambitious objectives of the TYNDP require a large number of dedicated resources, as well as the conception and implementation of processes and methodologies that have not been applied in a pan-European level before;

- the TSOs should continue to contribute towards the Internal Energy Market by ensuring the maximum transparency concerning the operation and development of their transmission grids;

decided to proactively release this report as the first TYNDP before the coming into force of the Third Package in the form of a pilot project.

This early release has four main objectives:

- to gain the feedback of stakeholders regarding the content and the collaboration they expect for the next releases of the report,

- to illustrate existing trends for attaining European energy policy objectives,

- to test the necessary processes and Europe-wide methodologies,

- to feed the political debate with an in depth review of existing trends.

ENTSO-E has also the ambition with this report to deliver a valuable input for the National Renewable Energy Action Plans (NREAPs) that Member States are committed to submit in June. The TYNDP also underlines the benefits power grid planning can derive from the Proposal of the EU-Council of a new Regulation concerning the notification to the Commission of investment projects in energy infrastructure within the European Community, repealing Regulation (EC) 736/96, and presently under discussion.

To achieve the above, the first release of the TYNDP:

- provides the most up-to-date and accurate information (to the TSOs' knowledge) of the planned or envisaged transmission investment projects of European importance.

- provides an outlook of the future condition of the electricity power system in Europe.

- discusses the development and evaluation of generation-demand scenarios, based on which analyses (such as the System Adequacy Forecast) will be performed.

- describes the challenges related to the development of the transmission network.

- initiates a "learning-by-doing" process to build TYNDP reports in an open and transparent manner, with the strong involvement of stakeholders, the European Regulators and the EC.

For this TYNDP pilot project, ENTSO-E has initiated at a very early stage a series of open discussions with major stakeholders and with the European Energy Regulators' Group for Electricity and Gas (ERGEG) aiming at receiving suggestions to its proposed content. These interviews were not held in the context of a formal consultation and ENTSO-E welcomes the stakeholders' feedback during the public consultation in Spring 2010 in written and during the workshop on March 2010, 19th, in which more than 100 participants could express their views.

In this report, network development means any investment in high voltage assets – either expansion or refurbishment – of European significance, i.e. addressing at least one of the three pillars of the EU energy policy: Security of Supply (SoS); tackling climate change and integration of Renewable Energy Sources (RES); economic efficiency and realisation of the Internal Energy Market (IEM). Although of key importance to monitor and operate the network, investments in IT, smart devices and appliances are not reported in the TYNDP so as to focus on transmission issues.

Challenges for Grid Development

Over the past hundred years, ever larger power systems developed, taking advantage of scaling effects and mutual support of generation and transmission components in case of failure. The outcome nowadays is the high reliability standard the grid offers in Europe to end-users, coping with defaulting system components (the so-called "N-1 criterion"), and, more generally, anticipating relevant risk and proposing mitigation measures.

Despite the ever changing context, drivers for grid development are primarily the same as they used to be for the last several decades, accommodating load and generation development. Changes in the legal and regulatory framework have induced major challenges for TSOs, such as:

- respond to the EU energy policy, especially market integration and connection large amounts of RES generation often in remote locations, while maintaining a high level of Security of Supply;
- deal with an increased number of uncertainties and a globally complex legal and regulatory context, especially for permitting procedures, stemming from a multitude of different authorities;
- secure the financial means to achieve the expected network developments in due time.

Still, the main concern is the lack of social acceptance that severely delays or jeopardises the realisation of transmission projects.

Although TSOs play a key-role, both as operators and as privileged observers of the system, they are not the only party with a major role in this respect. Meeting EU energy policy targets by 2020 and 2050 and also fulfilling the Article 194[1)] of recently ratified Lisbon treaty[2)] will demand coordinated efforts from all concerned stakeholders in order to mitigate uncertainties, harmonise the legal and regulatory framework, and enhance social acceptance of transmission assets.

Uncertainty is also a challenge which transmission system planner must address, with the following concerns:

- the inherent uncertainty in predicting the future location of generation and consumption and the limited availability and quality of this information available to TSOs;
- the changes over time in the way electricity is generated (from embedded generation to large off-shore wind-power clusters, etc.), transported, and consumed (new high-speed trains, heat pumps, electric vehicles, etc.);
- the medium and long term impact of separate policies (and also different policy implementation options) such as energy demand reduction and efficiency, renewable energy sources integration, CO_2 emissions reduction, decommissioning of polluting units, etc.

1) Setting the objectives of European policy on energy; ensure the functioning of the energy market; ensure security of energy supply in the Union; promote energy efficiency and energy saving and the development of new and renewable forms of energy; and promote the interconnection of energy networks.

2) Treaty of Lisbon amending the Treaty on European Union and the Treaty establishing the European Community, signed at Lisbon, 13 December 2007 and entered into force on 1 December 2009

Background Scenarios, Investment Needs, and Projects

The construction of multiple generation-demand scenarios for evaluating new transmission assets is an indispensable tool for dealing with uncertainties. The scenarios lay down technical and economic assumptions and identify possible solutions.

As expected from the Regulation, the core of the report focuses on the coming 5 – 15 years, divided into mid-term (until 2014 for the present release) and long-term issues. Within this timeframe, background scenarios are extensively described together with the contemplated investment in high voltage facilities, and the corresponding projects proposed by TSOs.

Background Scenarios

Scenario analysis intends to deliver a set of multiple diversified and plausible future environments for power systems. Scenario analysis gives decision-makers an overview of future perspectives and facilitates decision-making in complex, unpredictable situations. Stakeholders' involvement is required to sketch shared long-run perspectives accounting for different energy policies and national contexts.

As Member States are to submit their National Renewable Energy Action Plans (NREAPs) in June 2010, this report focuses on bottom-up scenarios, highlighting mainly mid-term trends, which are reliably proposed by TSOs, and suggests procedures to develop longer-run top-down background scenarios for further releases.

The two scenarios outlined in the present report are a conservative scenario and a best estimate scenario[3]. Generation adequacy and their overall consistency regarding the EU 2020 targets have been checked.

In summary, both Net Generating Capacity and Load are expected to moderately increase throughout the study period (2010 – 2025). Generation adequacy (i.e. the balance between generation and demand) in the best estimate scenario should be maintained during the entire monitored period; in the conservative scenario generation adequacy is maintained until 2020. After this period new generation capacity could be needed to achieve at least the same level of adequacy as exists in 2010.

Although data on how Member States plan to achieve their EU 2020 targets is not currently available, ENTSO-E sketched some overview:

– Power consumption is expected to grow, but rather moderately – at about 1.5 % per year in the coming decade.

– With about 933 TWh of RES generation[4] in 2020, compared to 3657 TWh of consumption, about 25.5 % of the power demand in the EU will be supplied by RES.

– Depending on macro-economic conditions, favouring coal-fired or gas-fired power plants, CO_2 emissions may vary between less than 800 to more than 1400 Mt CO_2/year, falling within or short of the EU target[5].

The moderate increase in power consumption takes into account increasing standards of living (and all the new electric devices involved) and end-use switch from oil and gas to electricity (for example in public and automotive transportation, heating, etc.), if electrical energy is seen as easier to decarbonise. This apparent paradox is explained by efficient enforcements of energy savings policies at national and EU level[6]. This increase is probably compatible with the overall decrease of energy consumption (and not only electricity) by 20 % compared to the business-as-usual scenario.

Also, according to some experts, the relative ease with which RES may be integrated in the power sector compared with others (transport or heating), means that this figure may need to be higher than 20 % (perhaps 30 – 35 %) in order to achieve EU 2020 targets.

Finally, the economic crisis may slow down consumption and investment in generation, and may sometimes result in reduced subsidies for RES. If the present economic downturn is quickly overcome, the EU targets would probably be within reach.

In any case, large grid investments must be undertaken at a quicker pace than during the last years so as to achieve the contemplated EU 2020 targets.

3) More information is available in the ENTSO-E System Adequacy Forecast 2010 – 2025 report released January 2010 and available at www.entsoe.eu.

4) Pure hydro: 118 GW; wind: 194 GW; solar: 38 GW; others: 23 GW.

5) which can be assessed in the range 800 – 900 Mt CO_2/year for an overall 20 % reduction compared to 1990.

6) Especially, the Directive EC 2005/32 "Eco-design requirements for Energy-using Products.

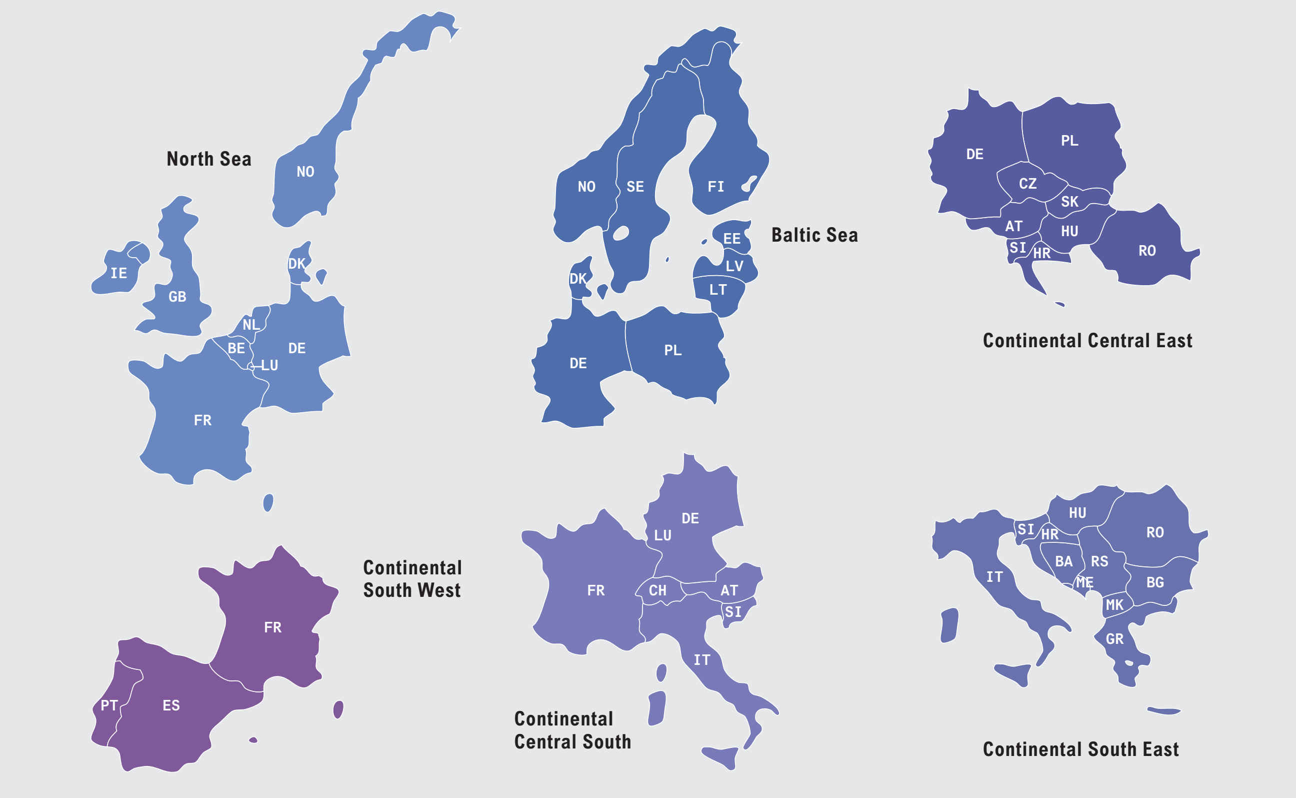


Figure 1:
ENTSO-E regions (system development committee)

Coming Investment Needs on the Transmission Grid

The report describes extensively, at the pan-European level, all investment needs with importance to the Security of Supply, the development of the European energy market and the integration of RES, i.e. every concern likely to trigger investments in high voltage assets, for the time periods under consideration.

ENTSO-E System Development Committee regional groups' perimeters were defined (as in Figure 1) so as to address most efficiently the challenges for grid development and integration in the coming years. The overview derives from common TSOs analyses at a regional level, accounting for up to date information regarding background evolution scenarios depicted above.

Cross-border congestion and market integration are important yet not the sole drivers for grid investment "of pan-European significance". ENTSO-E identified seven main investment clusters:

- **Massive renewable integration in the North part of Europe:** the connection of renewable sources, mainly wind, is one of the most important drivers of this plan as these plants are often located in remote areas of low load requirements inducing changing flow patterns within the concerned areas as well as the surrounding ones. Investment needs are threefold: connection to the network, increased onshore transmission capacity and efficient balancing of the system. For the latter, both offshore interconnections and optimized usage of available hydroelectric facilities will also trigger new investment requirements.

- **Massive renewable integration in the South part of Europe:** the connection and transmission of renewable sources, mainly wind, hydro and solar in the Iberian Peninsula, are major investments in the South-West and Central-South regions of Europe. For the same reasons as for the northern part of Europe, internal reinforcements and increased interconnection capacity with the rest of the continent and especially with France are required.

- **Important East-West and North-South flows in the South-East and Central South Regions:** these investment needs are dictated by the power balances and market prices of the member countries. The area including Greece, FYR of Macedonia, Albania and Italy is usually importing electricity. Strengthening of the Regional network in the predominant power flow directions, in order to assist market integration, is a main driver for transmission investments. North-South flow will rise in importance as new generation in Bulgaria, Hungary and Croatia will be connected to the network. A similar trend will be observed for the East-West flows but for different reasons, namely the interconnections of new systems with the continental synchronous system (possibly Turkey's system in the short term and possibly Moldova's and Ukraine's system later on). Also, the strong increase of generation and pumping capacity (new hydro pump storage power plants of several thousand MW) especially in the Austrian and Swiss Alps will have a strong influence on the power exchange in the region. A strong correlation with the wind power generation especially in North Germany is expected which will increase the need of transmission capacity between those two regions. A future increase of the wind generation in France and Italy will in a similar way lead to a need for investments to increase the exchange capacity between those regions.

- **Baltic States integration:** Two initiatives, namely the Baltic Sea Energy strategy from the Baltic Council of Ministers' Energy Committee in 1999 (which supports the results from the Multiregional plan) and the EU Commission Energy Market Interconnection Plan (BEMIP) launched in 2008 aim at the full integration of the three Baltic States into the European energy market, through the strengthening of interconnections with their EU neighbouring countries. The new connections to Finland, Sweden and Poland will create a need for internal investments in the Baltic countries.

- Complementary to RES integration, **the connection of new conventional power plants** totalling more than 100 GW is foreseen all over Europe in the next decade either to replace old, decommissioned plants or to cope with load growth and system balancing.

- **The power supply of some European cities and regions** will need reinforcements and could become an issue in Europe (Spain, France, Hungary, Slovakia, Poland, Czech Republic, etc.) as they could interact with other investment needs in the area, or limit the available cross-border capacity.

- With new locations and clustering of generation units, and greater variations of the generated power, efficient **market integration** is key to ensure that wherever power is available, it can be efficiently brought to consumption areas. Grid development and adaptation of grid access rules complement each other so as to propose the most appropriate market framework.

Project Technology	Total Lenght (km)	Lenght of the new connections (km)	Lenght of the upgraded Conections (km)
AC	32,500	25,700	6,900
of which > 300 kV	29,600	23,000	6,400
DC (mainly subsea)	9,600	9,600	0
Total	**42,100**	**35,300**	**6,900**
of which in mid-term	18,700		

Table 1:
Length of new and refurbished power lines until 2020 (projects of European Significance)

Grid Development Projects

All planned or envisaged transmission **investment projects** of European importance proposed by TSOs to address the above-mentioned investment needs are presented in this TYNDP pilot project. Almost all the reported projects are the result of regional, multilateral or bilateral cooperation between TSOs in order to address the requirements derived from users or European policies.

Only projects "of European significance", as defined above, are reported. They consist both of tie-lines and national projects, as all contribute to achieving European goals. These projects represent roughly 42,100 km of new or refurbished network routes, of which 18,700 km are expected in the mid-term. The economic crisis may delay some projects but is not expected to trigger significant changes in the above figures.

With about 23200 km, new 400kV AC overhead lines (OHL) account for slightly more than half of the total reported. On the other hand, about 25% of this total concerns new DC links (almost all sub-sea or underground cables). The refurbishment of 6,900 km of AC existing lines is also planned, i.e. more than 15% of the total. New 400 kV AC OHL projects are in technical, economic, and ecological terms the most efficient solution for long distance electricity transmission. Indeed, such reinforcements integrate straightforwardly into the existing grid since this technology has been the standard for a long time.

Given that the ENTSO-E transmission network consists of about 300 000 km of lines, it can be deducted from Table 1 that TSO investments correspond to more than 14% of the existing network in either new (12%) or refurbished (2%) power lines for the next ten years.

In Figure 2, the new or refurbished transmission lines are classified according to their contribution to the EU Energy policy objectives. It must be noted that the total number of kilometres of lines reported in Figure 2 is about 170 % of the number of kilometres physically constructed (as in Table 1) as a single project may respond to several needs at once. This is an illustration of the network effect (the value of the network is greater than the sum of the values of its components).

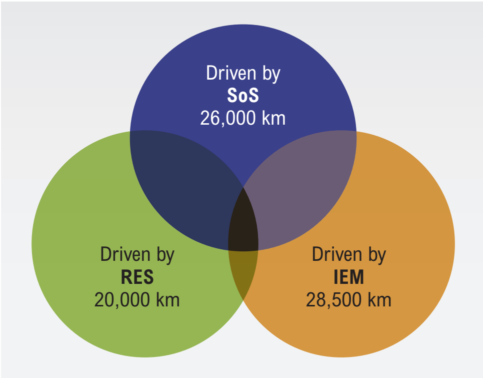


Figure 2:
Main drivers for investment in new or refurbished power lines (projects of European Significance)

Perimeter	**Investments** (Billion €)
RG North Sea	12 to 14
RG Baltic Sea	11 to 13
RG CCS	11 to 12
RG CCE	8 to 9
RG CSW	6 to 7
RG CSE	4 to 5
Total ENTSO-E	**23 to 28**

Table 2:
Investment costs of transmission projects of European Significance to be completed within the period 2010–2014

The assets due to be completed within the next five years represent investment costs ranging from 23 to 28 billion €, spread all over Europe, as depicted in Table 2. Although this range represents just a fraction of the total investment efforts of TSOs (i. e. it does not include all national or local investments on new/refurbished infrastructure, etc.) it demonstrates the magnitude of challenges ahead.

For the longer run, several projects are under study and costs are not fully known, or several options (route, technology, etc.) are still open. It is worthwhile noticing that with increasing lengths of DC, underground cables, and more demanding projects, the unitary cost of new power routes tends to increase significantly.

Moreover, unitary costs of individual projects depend largely on technical choices which are strongly influenced by public/local requirements. For instance, when it was proposed to implement the new France-Spain interconnection in the Eastern Pyrenees via a DC underground cable instead of double-circuit 400 kV OHL, an increase of the cost of the project by a factor 5.5 to 8 was observed[1]. Grid investment costs can thus sometimes compare to generation investment costs, when in the past they always showed a smaller order of magnitude.

In Figure 4 and Figure 5 (annexed), all investment projects of European significance for the mid-term and long-term horizons respectively are depicted.

1) European Coordinator Mario Monti Report – available at http://ec.europa.eu/energy/infrastructure/tent_e/doc/high_voltage/2008_06_high_voltage_report_fr.pdf

Assessment of Resilience

High voltage investments are expensive infrastructure projects, with a long lifetime, setting precedence of standards for coming projects, and require years to be carried out. To this aim, TSOs evaluate the resilience of their investment projects in order to avoid stranded costs, and to meet grid user's expectations over time with appropriate solutions.

The resilience of this set of projects has been addressed in the report, according to four main concerns:

- New grid components must at least maintain, and possibly improve, the high standards to which European end-users are accustomed. When planning, TSOs perform network and engineering studies to this aim taking into account new types of generating units and transmission equipment (with specific behaviour and possibly design constraints).

- Investments should positively address social welfare. To this aim, cost-benefit analyses are undertaken by TSOs according to market indicators where consistent and mature market frameworks have been implemented. Harmonisation concerns are also addressed for the coming years, accommodating structural differences between countries when justified.

- New technological advances are taken into account with consideration to the overall consistency of the interconnected system. TSOs strive to make the best use of existing assets implementing technologies such as FACTS, PST, HTLS[1] in order to optimise grid development or as an interim measure where grid extension cannot be realised in a timely manner; when grid extension is needed, novel and unconventional technologies can also be applied (DC connections, underground cables, etc.) to overcome barriers; TSOs also anticipate future challenges with live-testing of promising new technologies through pilot projects.

- Grid planning should anticipate long run perspectives beyond the coming ten years. Although shared and precisely defined scenarios are required to perform a more quantitative analysis, EU targets for Security of Supply, RES integration, and implementation of an Integrated Electricity Market set a clear blueprint. The future European power grid will probably be connected to neighbouring systems at its Southern and Eastern borders, extending in particular from north of the polar circle to the Sahara with a close network both onshore as today, but also offshore. Such a change of scale, with large amounts of climate-dependent RES will induce new operational limitations to mitigate disturbances over a wide perimeter and require reinforcements of existing high voltage networks onshore.

The set of projects proposed in the present report appear resilient in all these four respects. All these projects complement themselves to develop the overall transfer capability of the grid in all locations. Besides, with further RES development to expect in order to reach the EU 2020 targets, this set of transmission projects is only likely to be complemented. In such a context, project prioritisation is not an issue.

Achieving the integration of large amounts of offshore resources will require a significant amount of investment. Appropriate and shared technical standards (voltage level, operation principles if not procedures) and a consistent and harmonized regulatory framework for investors must be developed in order to anticipate the likely interconnection of initially separately developed assets.

ENTSO-E intends to play a key-role in paving the way for the coming decades, be it through large systems interconnection studies or its roadmap toward a North Sea off-shore grid released in November 2009.

1) Flexible AC Transmission System (FACTS);
Phase Shifting Transformers (PSTs);
High Temperature Low Sag conductors (HTLS)

Conclusions

Deliverables of the first TYNDP

This TYNDP pilot project marks progress in fulfilling the objectives set forth by the Regulation in the following ways:

- Bottom-up scenarios have been developed by TSOs describing mid-term trends.
- Investment needs and projects derive from coordinated modelling of integrated networks between TSOs, from numerous market and network studies, such as the EWIS study, the PLEF Regional Adequacy Forecast etc.
- A comprehensive assessment of resilience is presented synthetically. Principles are proposed as bases for future, refined and shared procedures for such assessments.
- A consultation of stakeholders has been performed to get feedback about the present report.
- This first release TYNDP will be the basis for seeking consistency with national and regional plans when the Third Package is enforced in early 2011.
- The detailed description of projects in Appendix 1 provides the necessary data to enable monitoring of the implementation of the plan as from the second edition.
- ENTSO-E is also presently setting up common procedures so that TSOs share the same methodological standards, enabling future TYNDPs to be based on consistent Regional studies. A consultation regarding scenarios will be launched to prepare the next issue of the TYNDP as soon as the implementation of the EU 2020 targets for the power sector is available.

The new context in Europe, with the extensive development of carbon-free generation facilities and their integration in the IEM, the amplification of free electricity trade, the connection of neighbouring systems, and the difficulties in grid development will certainly present significant challenges to operating reliably and efficiently the grid. TSOs' individual and combined expertise and experience safeguards the Security of Supply, and, through this report, demonstrates, not only the magnitude of the required collegial effort, but also their readiness to respond to these challenges.

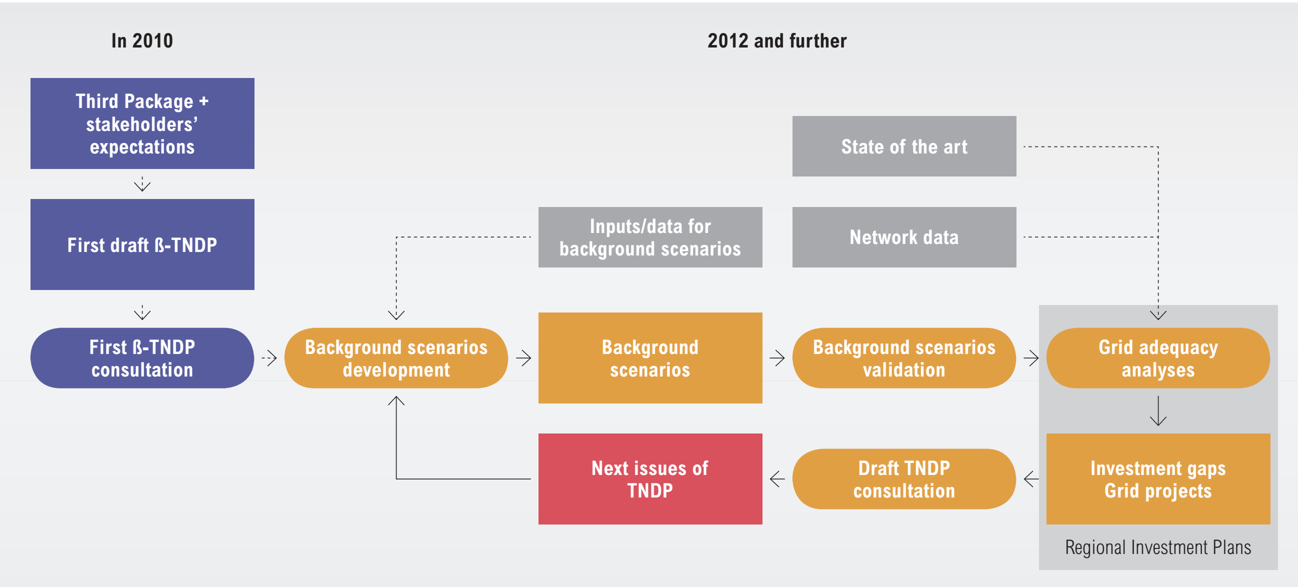


Figure 3:
Build-up process of the TYNDP

Towards the future releases of the TYNDP

By its nature as a pilot project, this first release of the TYNDP allows ENTSO-E to identify the main improvement areas and the best means for organising future releases. Figure 3 depicts a possible way this could be accomplished, starting an iterative process, involving stakeholders, that is based on this first TYNDP.

With two consultations planned, one on scenarios, the second on the final deliverable, and common studies to perform meanwhile, the loop is an extensive two-year process.

In order to meet a future release in June 2012, work on the next issue of the TYNDP must start immediately after the first report is published, in July 2010. Efforts presently concentrate on the three main concerns:

- to update present bottom-up scenarios, as well as developing shared, long-run, top-down, scenarios, involving ACER, stakeholders, policy and decision-makers. It will require the commitment and consensus of concerned parties, to define at least the 2020 horizon [1] and the completion of the EU 2020 targets based on the NREAPs, finalised by June 2010.

- to develop common ENTSO-E pan-European market modelling, reflecting as close as possible the forces which drive the commercial flow of electricity and its translation into physical power flows.

- to further develop an ENTSO-E wide common framework for the regional network studies, based on pan-European scenarios and integrated network model for mid and long term.

Stakeholders supported strongly these proposed priorities during the consultation process.

Work on other pending issues, especially shared resilience criteria, in whatever respect is also being prepared. These are however long-lasting concerns and the scope of coordinated work must first be carefully defined with stakeholders, ACER and National Regulatory Authorities, before completion deadlines can be proposed. Progress in this respect will enrich the next releases of the TYNDP.

1) If released in June 2012, the next release of TYNDP will look beyond 2020.

Critical to the above is the availability of data, especially concerning generation investment locations, to ENTSO-E in order to better forecast future needs. A clear framework on how reliable information reaches ENTSO-E needs to be set up and activated well before the second release of the TYNDP.

ENTSO-E intends to enrich the interaction with all stakeholders during the building-up of the next releases of the TYNDP (in constructing scenarios, obtaining/providing data, sharing methodologies), or through meetings and workshops. Each release of the TYNDP will be subject to public consultation. All these layers of exchange between ENTSO-E and stakeholders are meant to lead to the production of consistent, useful, and complete TYNDP reports.

Imprint

Publisher: ENTSO-E AISBL
Avenue de Cortenbergh 100, 1000 Brussels – Belgium

Design & Layout: Oswald und Martin Werbeagentur, Berlin

Printed by: Kehrberg Druck Produktion Service, Berlin

Photos: 50Hertz (p. 13), istockphoto.com (p. 1, 4, 6, 11)

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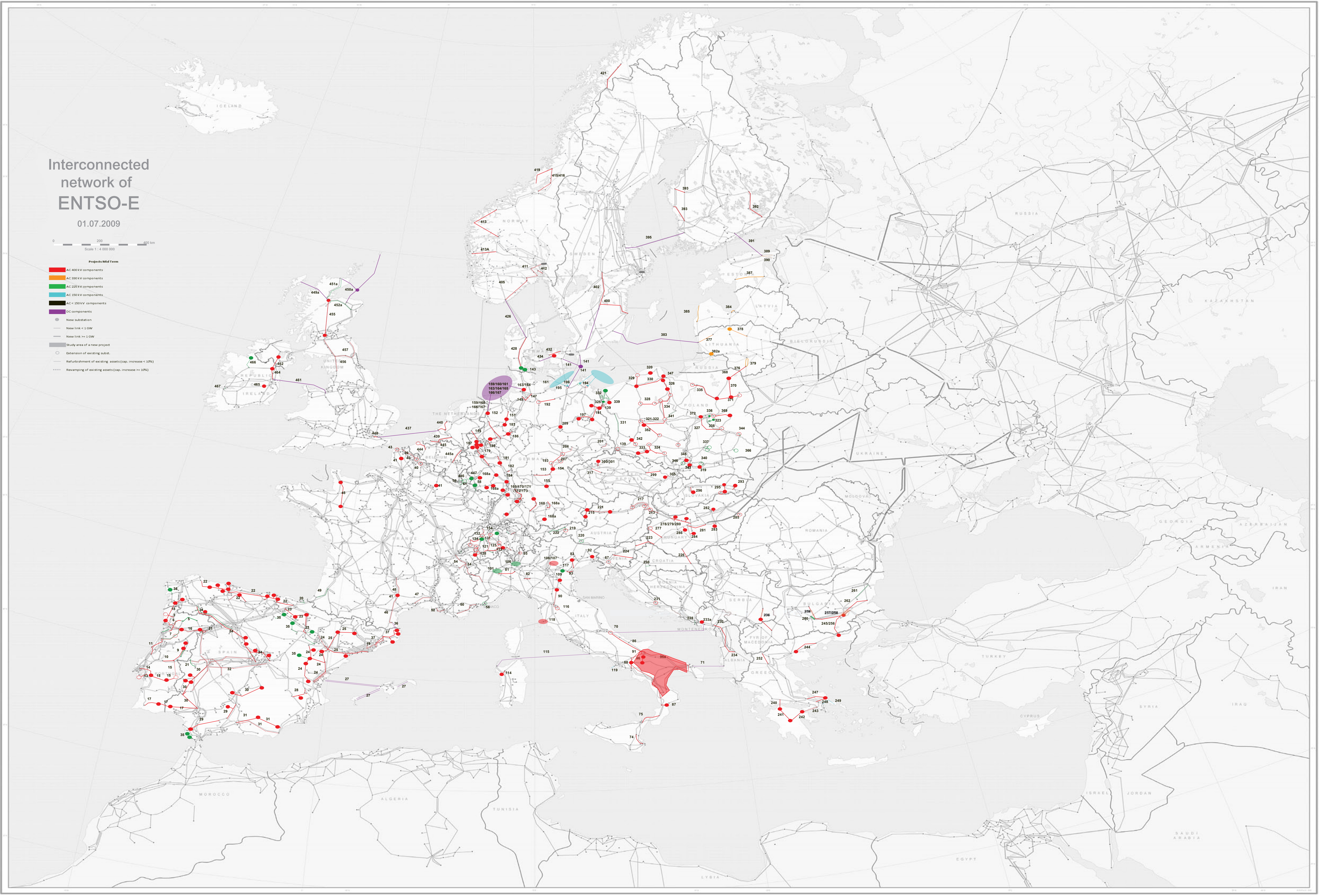

Figure 4: Projects of European Significance (2010–2014)

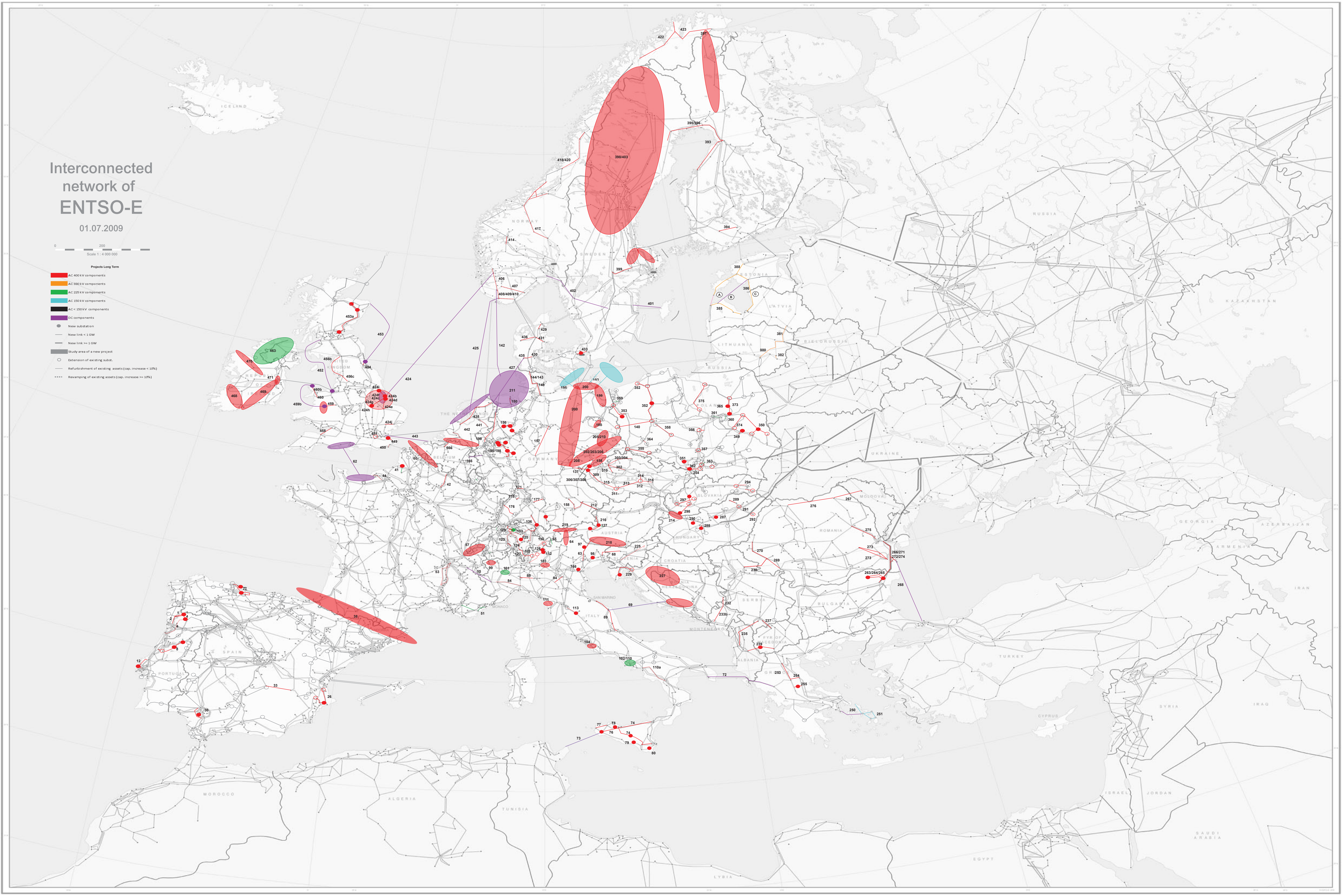

Figure 5: Projects of European Significance (2015–2020)