Annual Report 2016

Ensuring Operational Safety on the European interconnected Grid

coreso

Enhancing operational security

Every day, every hour

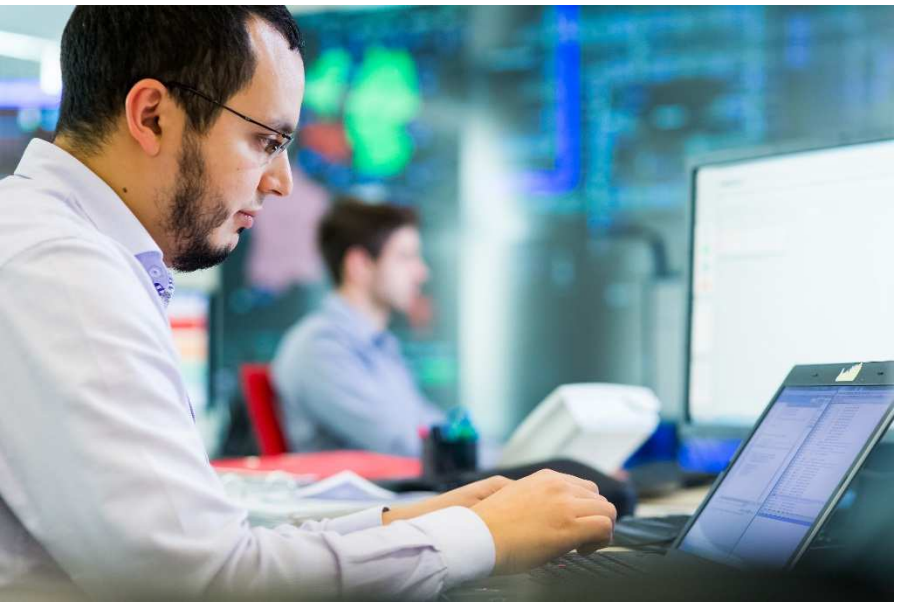
Every day at Coreso, a multicultural team of over 40 experts strives to offer the best possible service to the transmission system operators[1] on the European interconnected grid. By working closely together with the various European energy actors, Coreso aims to proactively help them face the challenges posed by Europe's energy transition.

The main challenge involves ensuring that substantial decentralised renewable generation, which is increasing every day, replaces the dwindling capacity of conventional power plants. Having an efficient, comprehensive, single European energy market characterised by extensive cross-border power flows is vital for ensuring security of supply. These changes are requiring TSOs to adopt a more regional approach in their daily operations, looking beyond national borders.

Since its establishment in 2008, Coreso has taken on the role and responsibility of applying such a regional approach to European grid security. First as a Regional Security and Coordination Initiative[2], and since the end of 2015 as a regional security coordinator[3] within the regulatory framework of the European Network of Transmissions System Operators for Electricity. This framework clearly outlines 5 mandatory services that each RSC should provide to its shareholders and requires that every TSO within ENTSO-E[4] should be a member of an RSC.

These 5 services are the driving forces behind Coreso's daily activities, which are tailored to meet the specific needs of its shareholder TSOs and in which continuous improvement, reliability and effectiveness are key to ensuring the best possible end results.

This annual report presents an overview of Coreso's efforts and accomplishments in 2016, offers insights into its future development and summarises the year in key figures.



[1] Transmission system operators (TSOs)
[2] Regional Security and Coordination Initiative (RSCI)
[3] Regional Security Coordinator (RSC)
[4] European Network of Transmissions System Operators for Electricity (ENTSO-E). Visit its website on www.entsoe.eu

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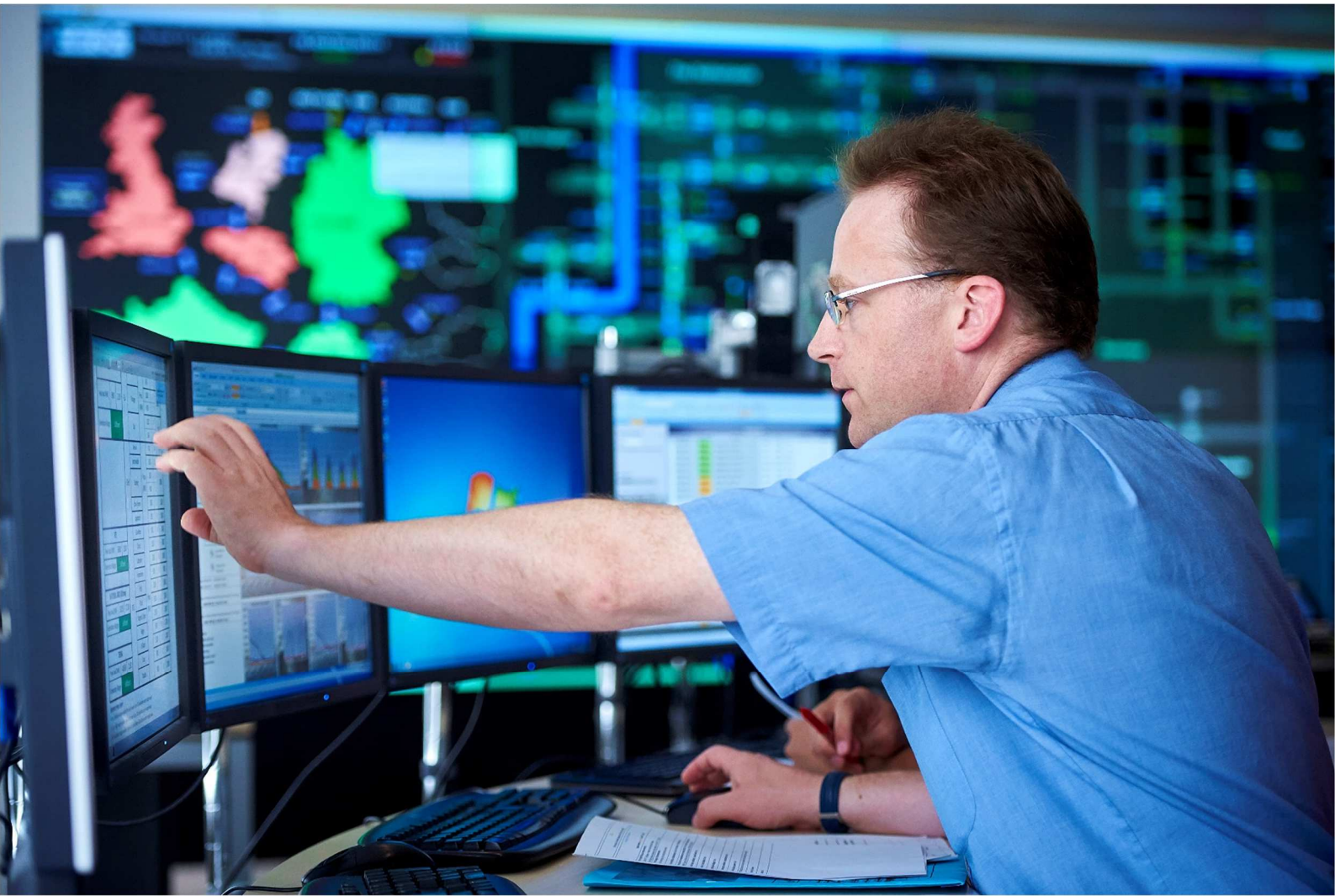


5 Mandatory Services

Service I - Coordinated security analysis

Analysing and identifying operational security risks in areas close to national borders.

Service II - Coordinated capacity calculation

Calculating available capacity for transmission across national borders.

Service III - Short and medium-term adequacy forecasts

Providing market participants with consumption, production and grid status forecasts starting from several weeks ahead.

Service IV – Coordinated outage planning

The creation of a coordination process for the outage of grid assets.

Service V - Common grid model Delivery

Providing an improved regional dynamic view of all major grid assets.

Letter from the CEO

Jean-Francois Gahungu

Dear reader,

The mission of Coreso, as a regional security coordinator (RSC), is to coordinate services for transmission system operators (TSOs), proactively helping them to ensure security of supply on a European regional basis.

We also collaborate with other RSCs to enhance the services we provide to TSOs and reduce the risk of large-scale events.

Throughout 2016, Coreso maintained the tireless commitment it has shown since its early days to improving the coordination services it offers.

All year long, we worked on new processes, improved existing ones and contributed to numerous projects. During the cold spell in the winter, we proposed some extraordinary measures to bolster short-term adequacy of supply.

Over the past year, we also took up a number of challenges regarding the management of projects related to the deployment of our 5 mandatory services, to meet shareholders' expectations and improve efficiency.

Of course, we will face some daunting challenges in the coming years, but feel sure that together we will succeed in making the best out of the situation where regional coordination is concerned.

This annual overview presents Coreso's achievements in 2016 regarding its five mandatory services, provides information on additional projects and gives details of the transmission system and power exchanges in Europe.

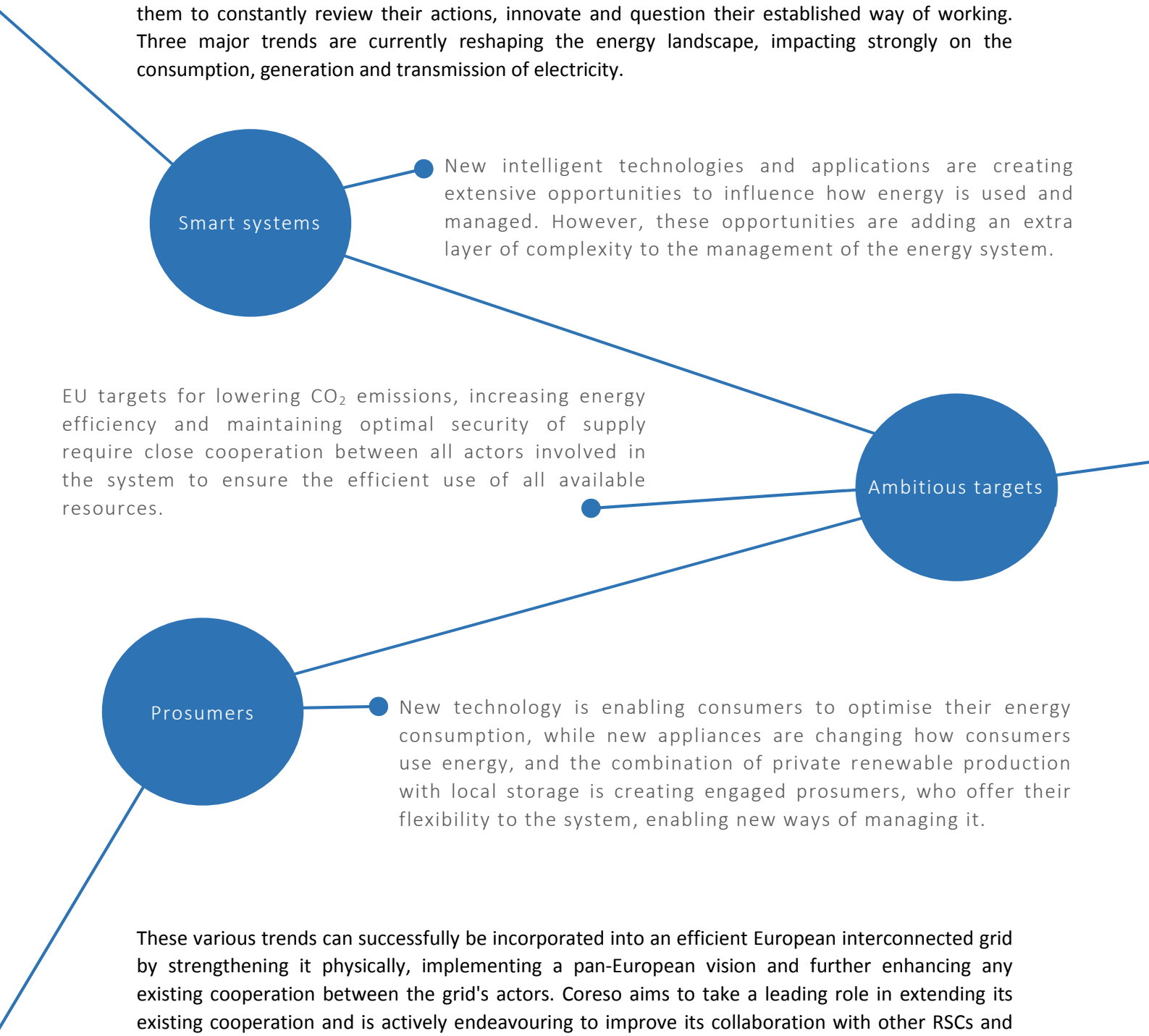
We hope you will find the information useful and enjoy reading it!

Jean-François Gahungu

Vision of the future

New technologies, ambitious targets and shifting consumer needs are the driving forces behind changes in the electric system

The European interconnected energy grid is constantly evolving, with new concepts being introduced all the time. Consequently, all actors need to maintain an agile approach to change that challenges them to constantly review their actions, innovate and question their established way of working. Three major trends are currently reshaping the energy landscape, impacting strongly on the consumption, generation and transmission of electricity.



These various trends can successfully be incorporated into an efficient European interconnected grid by strengthening it physically, implementing a pan-European vision and further enhancing any existing cooperation between the grid's actors. Coreso aims to take a leading role in extending its existing cooperation and is actively endeavouring to improve its collaboration with other RSCs and work with new partners.

A word from our external partners

Sonya Twohig
System Operations Manager

"ENTSO-E's Regional Coordination Strategy will become a reality in around mid-2017 as soon as the System Operations Guideline enters into force. Collaboration with Coreso and all RSCs for the successful implementation of regional tasks, pan-European tools and the Common Grid Model (CGM) platform has become a top priority for all TSOs and ENTSO-E. We look forward to continuing our excellent working relationships and reaping the fruits of our combined efforts during 2017 and coming years."

Siem Bruijns
Managing Director

"During 2016, Coreso and TSCNET Services worked hard together to create a strong, shared vision about our cooperation. As of 2017, this cooperation will become more visible through jointly developed and operated services clearly impacting positively on power grid efficiency and security."

Mario Princip
Head of Business Development

"It used to be inconceivable, but since 2016 has been indisputable: TSCNET and Coreso have been jointly exploring new development horizons. Cooperation on service enhancement started out as an initiative designed to effectively rise to the challenges associated with developing 5 services for the regions where both RSCs are active. In 2017, and in years to come, the TSOs using these services will benefit from the results of this shared development, while TSCNET and Coreso keep up-to-date with the latest power system management technology and IT."

A word from some of our shareholders

"Coreso plays a major role in the operational coordination between TSOs: its services to TSOs in a transversal regional context perfectly complement TSOs' local overview. The key elements behind Coreso's success are its experienced and dedicated staff and its excellent collaboration with all stakeholders. These strengths make its service invaluable for anticipating real-time situations and ensuring security of supply."

Patrick Deleener
Chief Customers,
Market & System Officer

Tomás Domínguez Autrán
Head of Operations

"In my view, strong coordination between TSOs is crucial for achieving a deeply integrated European electricity market without jeopardising the security of supply for European citizens. In this context, Coreso is, and will remain, an efficient tool for TSOs to successfully rise to this challenge."

Carlo Sabelli
International Cooperation
with Grid Operators

Pier Francesco Zanuzzi
Chief Executive Officer

"Several years of cooperation on an extremely wide range of operational challenges, the continuous experience-based improvement of processes and IT infrastructure, and professional governance have given the most important contribution to TSOs mission: to ensure reliability. Terna depends on Coreso."

Phil Sheppard
Director of System Operator

"Coreso is a key player in enabling TSO coordination. Coreso uses the experience gained over the last few years cooperating with other RSCs and TSOs on behalf of the shareholders. Coreso is making an important contribution to the security of the European power system with a lower cost. The added value for shareholders will increase with the implementation of the Network Code requirements, for example, provision of the Common Grid model and capacity calculation services."

Dirk Biermann
Chief Markets & System Operations Officer

"The TSOs founded Coreso around 10 years ago to deal with security issues. Today, Coreso and TSC are the role model for the RSC concept, offering a wide range of coordination services. TSOs will continue to enhance our cooperation, for this is in our DNA. And RSCs have become part of it!"

Brigitte Peyron
Project Director for Power System 2025

"TSOs are facing news challenges at European level and coordination is a necessity. Coreso, as a RSC, plays a key role in the new landscape of power system. Skills of the dedicated staff, continuous improvement of the services provided to the TSOs, close relationship with the shareholders are the pillars of its efficiency and of the added value of its broader analysis. The role of Coreso is clearly complementary to that of the TSOs for the security of the European power system."

Coreso in 2016: highlights

January: REN[1] – Coreso workshop

The managements of REN and Coreso met in Lisbon to take the first steps towards collaboration between both entities.

March: European Merging Function (EMF) working group

Using its tool Convergence, at the beginning of April Coreso supported the European Merging Function (EMF) working group by running tests with a new set of CGMES files provided by 20 TSOs for one business day. Coreso was able to import and run load-flows on 18 of the 20 TSO CGMES files.

April: Expert group on Core region capacity calculation started work

The expert group for day-ahead flow-based capacity calculation in the core region began. The new project will benefit from Coreso's previous experience with flow-based computation and input from TSCNET and the 15 TSOs involved.

May: System Operation Guidelines (SO GL)

The EU Member States adopted the modified System Operation Guidelines on 4 May 2016, which are expected to enter into force early in 2018 (in February).

June: Go-live of the new capacity calculation process in the Italy North region

The new two-day-ahead capacity calculation process jointly developed by Coreso, TSCNET and the five TSOs from the Italy North region went live. Since then, Coreso has performed daily calculations for this process.

Coordination services provided by a

[1] REN, Redes Energéticas Nacionais is the TSO responsible for the Portuguese grid. Visit its website at www.ren.pt/en-GB.

[2] PSTs, Phase-shifting transformers (PSTs), enable TSOs to better control energy transmissions along power lines.

[3] HVDC links, High Voltage Direct Current links, are cables on which energy is transported in DC.

[4] TSCNET is the RSC of 13 TSOs who are members of TSC (TSO Security Cooperation). Visit its website at www.tscnet.eu.

[5] REE, Red Eléctrica de España, is the TSO responsible for the Spanish grid. Visit its website at www.ree.es/en.

October: a new CEO for Coreso

After 4 years at Coreso, Patrick Deleener returned to Elia, handing over to incoming CEO Jean-François Gahungu from Rte.

October: Coreso operational workshop in Lisbon

The second operational workshop of 2016 brought together colleagues from the shareholder TSOs and an ENTSO-E representative to discuss crisis management.

December: Cooperation to face up to a tense winter situation

Low generating capacity prompted Rte and Elia to raise concerns about adequacy risks during the winter. A working group composed of Coreso and 8 TSOs cooperated to implement 4 operational procedures to anticipate and resolve these issues, using adequacy forecasts, adaptions of capacity calculations and agreements on cross-border redispatching.

July: Intraday congestion forecast (IDCF) process for continental Europe launched

The IDCF process was due to enter into force for all TSOs in continental Europe at the beginning of July. All TSOs in this region pledged to provide daily IDCF files.

team of experts

November: Cooperation principles between Coreso and TSCNET[4]

Jean-François Gahungu, CEO of Coreso, and Siem Bruijns, Managing Director of TSCNET, proposed new principles governing cooperation between their two organisations on the development of common tools, paving the way for closer collaboration and greater efficiency, especially in the regions where both RSCs are active.

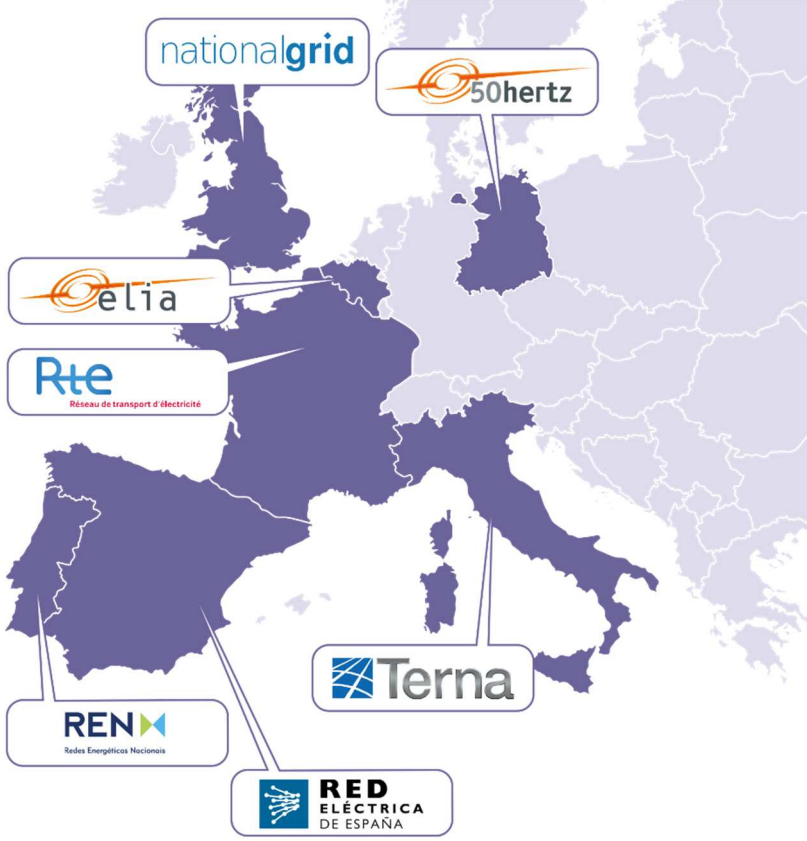
June: Coreso operational workshop in Reading

Together with colleagues from shareholder TSOs and an ENTSO-E representative, Coreso held a workshop on capacity calculation, PSTs[2] and HVDC links[3], focussing on their operational aspects.

November: REE joins Coreso

Spanish TSO REE[5] joined Coreso and become its shareholder on 28 October. REE's involvement is an important milestone as it will enable an efficient approach to cooperation on services in the Iberian Peninsula.

Key figures



7 shareholder TSOs since REE joined Coreso in 2016

Coreso now helps its TSOs to cover more than 1,800,000 km² and ensure the security of supply for more than 274,428,000 people.

To provide this level of service, Coreso relies on a team of around 40 professionals from 7 different nations, working around the clock 365 days a year.

In 2016, Coreso was 100% successful in coordinating day-ahead processes, proposed around 2,000 remedial actions in its coordinated security analysis studies, submitted 41 extra studies for system modification advice requests[7] and intraday studies, and completely overhauled 3 major processes to ensure the most agile approach towards our changing environment.

[7] TSOs may request System Modification Advice Requests, or SMART studies, to investigate specific grid situations in close to real time.

Service I: Coordinated security analysis

Identifying operational risks and proposing solutions

The development of the electric system over the past few decades has resulted in a strongly interconnected European grid with high volumes of cross-border energy flows. The number and intensity of these international energy trades is rising every year, and TSOs are making substantial efforts to increase the import and export capacities on their national borders. However, to ensure security of supply for all European citizens, the changes that have occurred are calling for a more regional approach to security calculations, beyond and across national borders.

This is where Coreso generates added value. Whereas TSOs are experts in securing the grid within their own borders, Coreso is ideally placed to detect issues linked to cross-border flows and to study the mutual impact of TSOs' actions on either side of borders. Coreso's global overview of the grid and its expertise in border areas enables it to propose coordinated responses to such risks and thereby prevent incidents with large-scale, cross-border effects.

The process

The process starts at D-1 with all TSOs providing their best possible forecast of the grid situation for the following day. Coreso merges these hypotheses and draws up an overview of the expected grid situation the next day in continental Europe.

This merged model is used to simulate the loss of various grid elements, the aim being to produce a comprehensive overview of security-of-supply risks on the grid for the following day. Whenever such risks are detected, the Coreso operator analyses the situation, seeks a solution and works in close collaboration with the TSOs and RSCs involved. Communicating these risks is key, and information is shared across all TSOs in a daily teleconference.

The process continues intraday with all TSOs sending hourly updates of their hypothetical grid situation for the rest of the day. Additional studies are conducted to detect fresh operational risks and monitor the development of constraints detected in day ahead. If stressful situations arise, TSOs can ask Coreso to conduct specific intraday studies and to answer system modification advice requests.

Areas of interest

Central Western Europe

In the CWE area, Coreso provides this coordinated security analysis to Elia[8], Rte[9] and National Grid[10]. Due to the progressive energy market mechanism, flow-based market coupling and a high concentration of renewable energy generation in northern Germany, combined with a high level of conventional generation in France, this area is characterised by substantial north-south (or south-north) flows throughout the zones covered by the various TSOs in CWE.

[8] Elia is the TSO responsible for the Belgian grid. Visit its website at www.elia.be/en.

[9] Rte, Réseau de transport d'électricité, is the TSO responsible for the French grid. Visit its website at www.rte-france.com/en.

[10] National Grid is the TSO that operates energy systems in the United Kingdom. Visit its website on www.nationalgrid.com/uk/.

Central Southern Europe

In the CSE area, the same service is provided to Terna[11] and Rte. This area is characterised by high imports across Italy's borders throughout the year. Incidents on one of these borders can significantly impact the country's other borders and security of supply in the region.

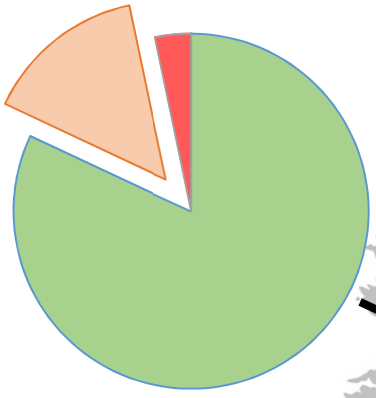
Central Eastern Europe

In the CEE area, Coreso serves 50Hertz[12]. The *Energiewende*[13] has created significant renewable energy production here. However, the fluctuating, less predictable nature of such renewable production necessitates close coordination between the different actors in the area.

Facts and figures

CWE

15% orange situations

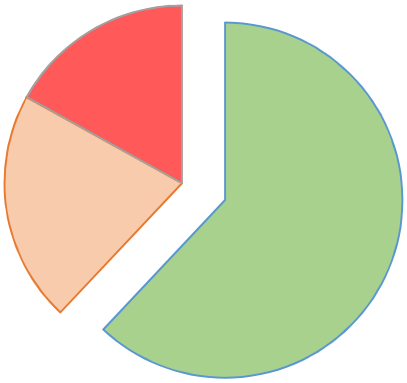


Red situation: a highly stressed grid situation, requiring close coordination between TSOs to manage it, as well as significant amounts of cross-border re-dispatching or the cancellation of outages.

Orange situation: a stressed grid situation, requiring coordination between TSOs, though security issues can be managed via internal re-dispatching and classical topological actions.

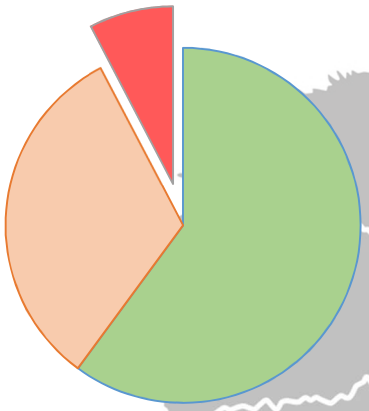
Green situation: few constraints detected on the grid, so the situation can be managed by classical topological actions.

[11] Terna is the TSO responsible for the Italian grid. Visit its website at www.terna.it.
[12] 50Hertz is one of the TSOs responsible for the German grid.
Visit its website at http://www.50hertz.com/en/.
[13] German energy transition



CSE

62% green situations



CEE

8% red situations

Service II: Coordinated capacity calculation

Calculating the available transmission capacity on borders to maximise market welfare, while ensuring grid safety

Energy imports and exports across Europe are vital for ensuring that grids use all generated energy efficiently and offer it at the best possible price. So electricity is bought and sold every day on European energy exchanges, and energy can be traded anywhere between months in advance and on an intraday basis.

The maximum capacity on every border limits the number of possible trades, resulting in price fluctuations when all the available capacity is used up. The available capacity on a border is influenced by seasonal limits, grid topology and the availability of network elements, internal stability restrictions and other factors. The high number of relevant factors means capacity can fluctuate from day to day and from hour to hour.

Coreso currently carries out

4 capacity calculation processes

on a daily basis

To optimise market welfare, every day the calculated maximum capacity should be as close as possible to the actual, physical maximum capacity, but not exceed it. Excessively high capacity leads to unacceptably high flows and to security constraints that can impact the entire interconnected area. Excessively low capacity limits the amount of possible trades and leads to unnecessarily high prices on the energy market.

Coreso plays a central role in different operational capacity calculation processes and provides know-how in the development of new processes in other regions, all in close collaboration with TSOs and other RSCs.

Operational processes

D-2 capacity calculation in the CWE area

Since May 2015, the flow-based market coupling model[15] has been implemented in the CWE area to calculate the available day-ahead capacity on the cross-border transmission lines of the TSOs active in the area (Rte, Elia, TenneT NL[16], TenneT DE[17], Amprion[18] and Creos[19]). The implementation of this advanced market coupling model has been the target mechanism since 2007, when the Pentalateral Energy Forum in Central Western Europe signed a memorandum of understanding (MoU).

Unlike conventional calculation methods, the FBMC model allocates transmission capacity while taking account of interdependencies between borders, creating the highest possible social welfare on the coupled electricity markets. This makes it the model best suited to the highly meshed system in the CWE region, where physical flows within each TSO's grid are determined by cross-border regional dynamics.

Since the FBMC process went live in 2015, Coreso has been a valued player in the process, providing a number of key services necessary for successful day-to-day operation.

Coreso's role in the FBMC process

The process takes place two days before the business day in question and aims to calculate the transmission capacity available to market players on the day-ahead market.

To start the process, all CWE TSOs provide their best forecast of the grid situation for the respective business day, the 2-day-ahead congestion forecast[20]. The latest day-ahead congestion forecast[21] files are used as input for TSOs outside the CWE area.

11 October 2016

was the date on which Coreso started operating as the single merging entity for calculating the capacity of day-ahead market coupling in the CWE area. Whereas Amprion used to provide a pre-merge of the individual German D2CF data sets (from Amprion, TenneT De, Transnet BW and 50Hertz), Coreso now directly integrates individual data (provided in the D2CF files) from the different German TSOs during the merge of the CWE area's D-2 common grid model. This change improved the efficiency of the merging process.

[15] Flow-based market coupling (FBMC)
[16] TenneT NL is the TSO responsible for the Dutch grid. Visit its website at www.tennet.eu.[17] TenneT DE is one of the TSOs responsible for the German grid. Visit its website at www.tennet.eu.
[17] TenneT DE is one of the TSOs responsible for the German grid. Visit its website at www.tennet.eu.
[18] Amprion is one of the TSOs responsible for the German grid. Visit its website at www.amprion.net.
[19] Creos is the TSO responsible for the Luxembourg grid. Visit its website at www.creos-net.lu.
[20] 2-day ahead congestion forecast (D2CF)
[21] Day-ahead congestion forecast (DACF)

Coreso has the major responsibility of providing a daily 'reference grid model' by merging all the individual grid models and uploading the resulting model into a central system that performs flow-based calculations, known as the flow-based common system[22].

The CWE TSOs upload two extra files to the FBCS: one describing the available generation in their area along with the modularity of the units involved, and another describing the limits of critical network elements in their grid and on their border(s). These files constitute major input for the flow-based capacity calculation.

Alternating with TSCNET, Coreso is responsible for hosting and operating the FBCS. The FBCS operator is there to ensure that the process runs smoothly through the various intermediate steps of the calculation up to final validation of the results by the respective TSOs.

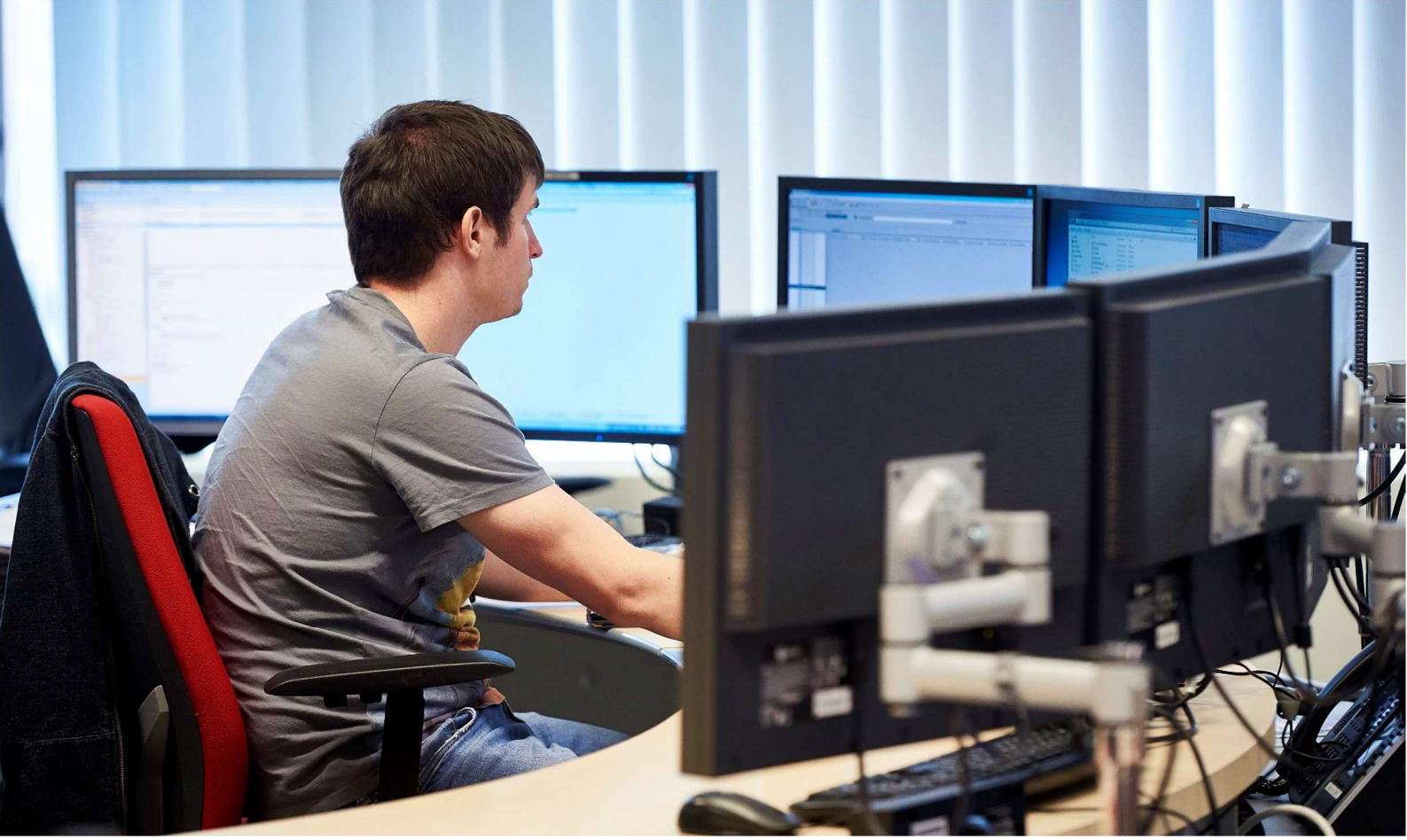
100%

Flow-based merged datasets were provided to the common system 100% of the time, meaning that the merging process ran successfully on all 366 business days in 2016.

82.4%

In 82.4% of cases, the merged grid models were uploaded to the FBCS before the target time (20:00 D-2). Possible reasons for delayed uploading include issues relating to the quality of individual input files or divergence during the merging process. These problems require additional investigation by Coreso's operators.

[22] Flow-based common system (FBCS)



Intraday capacity calculation in the CWE area

The capacities offered by the CWE D-2 calculation process enable market players to trade energy on day-ahead energy exchanges in the CWE area. The results of these trades, together with long-term allocations on borders, provide a clear picture of expected cross-border exchanges between TSOs.

During the first few hours of the business day (between 01:00 and 04:00), Coreso evaluates the resulting exchanges and serves Elia by conducting an additional study aimed at increasing the available capacity for the intraday market during from 09:00 to 24:00). The specific goals of the study are to assess the possibility of increasing available capacity by 100 MW on the Belgian-Dutch border and by 200 MW on the Belgian-French border, whilst ensuring grid security for any given timestamp.

D-2 capacity calculation in the CSE area

The CSE area, around Italy's northern border, is characterised by substantial imports into the Italian grid. To maximise market welfare and ensure safe grid operation, the 5 TSOs and 2 RSCs active in the area have set up a coordinated D-2 capacity calculation process.

First steps towards developing this coordinated process were taken in 2012, and Coreso has been a key project participant since the start and throughout the various

1 February 2016

The process officially went live on 1 February 2016 with calculated capacity results used for allocation on day-ahead energy exchanges.

phases of the project. In summer 2015, the project reached the external dry-run stage, which involved disclosing the calculated transfer capacities to all stakeholders, but not using them for actual capacity allocation.

During 2016, the process ran in parallel in Coreso and TSCnet, with both RSCs independently submitting their results to Terna.

The process uses the input files from all the TSOs concerned in the CSE area, describing the best forecast of their individual grid situation from 2 days in advance in D2CF files. The latest day-ahead congestion forecast files are used as input for TSOs outside the CSE area and merged to create a forecast of the grid situation on the respective business day.

An algorithm is applied to the merged grid model to simulate different import levels and optimise the use of remedial actions in the area to achieve the highest possible secure level of imports on Italy's northern border.

5 timestamps

At the start of the process, capacity was calculated for 2 timestamps. In the course of 2016, this increased to 4 and later 5 different timestamps, producing more accurate results.

Intraday capacity assessment in the CSE area

During the early hours of the night, an extra intraday assessment of the available capacity on intraday markets is submitted to Terna. For the latter part of the day (from 16:00 to 24:00), a simulation is carried out to show what the grid situation would be if the market parties used all the available capacity and ascertain whether any extra safety measures or actions need to be taken on an intraday basis to ensure Terna's security of supply.

Projects

In addition to its daily operational processes, Coreso puts significant effort into further extending its existing processes, expanding its activities related to service II, and sharing its internally accumulated knowledge and know-how with shareholders, TSOs and other RSCs involved in European projects.

6 capacity calculation projects

are currently being developed or extended by Coreso's project team together with the TSOs involved

D-2 capacity calculation in the CWE area

The flow-based D-2 capacity calculation process has been in operation for over one year, but every day Coreso and all the TSOs and RSCs involved are striving to achieve better results and improve its operational efficiency. Two major projects designed to improve this in 2016 are described below.

Net position forecasts

The goal of this project, initiated in 2015 together with RTE and Elia, is to devise a net position forecast (NPF) algorithm that accurately predicts the net position in the CWE area, i.e. the difference between imports and exports by countries inside the region. A second phase of the project will aim to refine the algorithm and expand the NPFs to European countries outside the CWE area.

NPFs are key to the flow-based process, since they indicate market trends and can be used to forecast the grid situation. This input can be used to optimise the grid situation, ultimately resulting in higher potential transfer capacities in the likely market directions.

The model was designed by Coreso, Rte and Elia and is implemented in an IT system called iNProve. Experimental application of the tool began in November 2016.

Remedial Action Coordination Tool

The Remedial Action Coordination Tool[23] is an instrument designed to be used in the flow-based qualification process to more efficiently coordinate remedial action by the TSOs and RSCs involved. It enables operators in the different entities to share information about potential remedial actions and test how such measures taken in neighbouring grids would affect the outcome of the capacity calculation process. This gives them a broader overview, enabling agreements on a set of remedial actions to be reached more efficiently. Application of the RACT and the operational procedure for flow-based qualification was approved by CWE TSOs in September 2016.

[23] Remedial action coordination tool (RACT)

Intraday capacity calculation in the CWE area

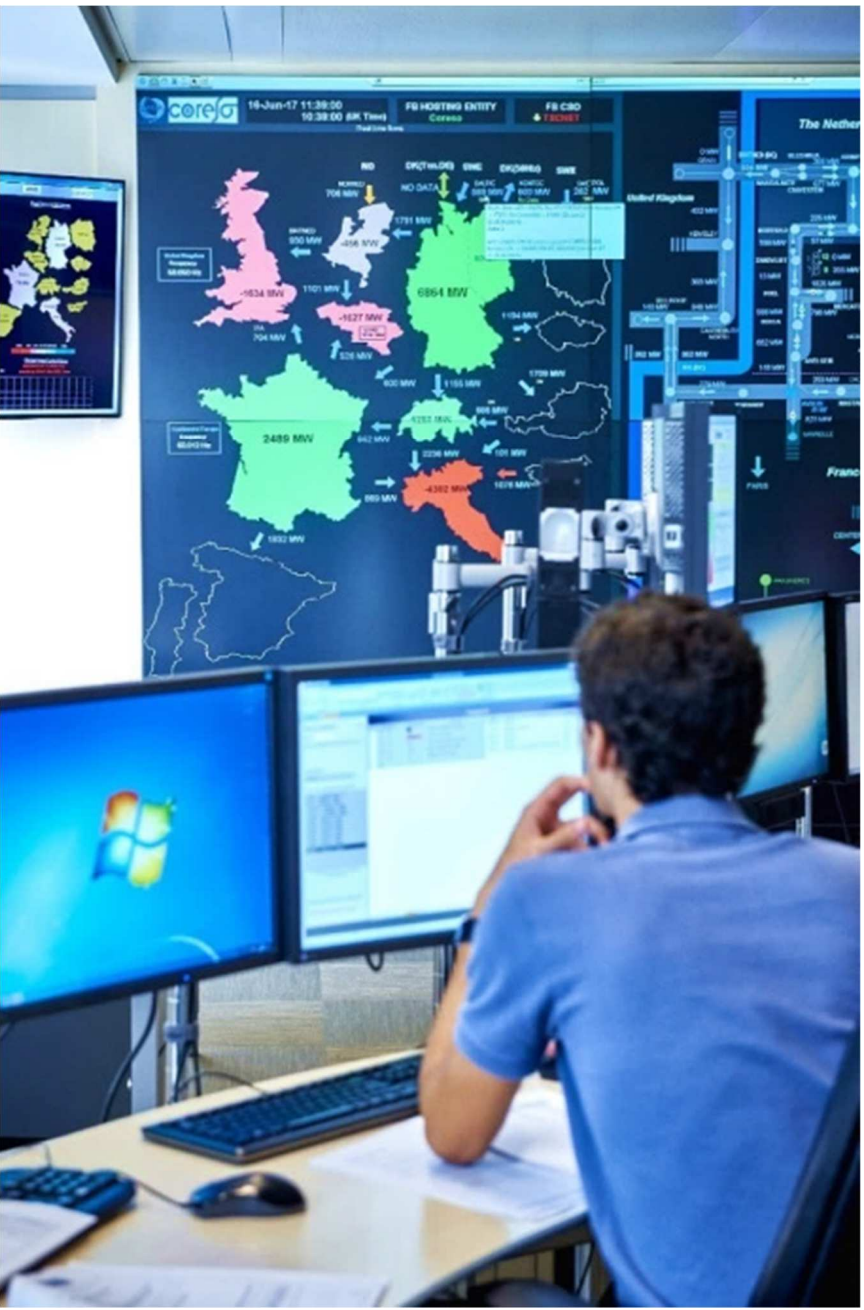
A process for analysing the intraday situation regarding available capacities on Belgium's borders and assessing possible ways of further boosting them for intraday trades has already been implemented and is running on a daily basis, with the results submitted to Elia. However, at present the process only analyses the timeframe between 09:00 and 24:00.

In 2016, a project was started to further extend this service and perform a second analysis covering the day's first business hours, from 00:00 to 09:00.

Intraday capacity calculation in the CSE area

September 2015 saw the launch of a project designed to improve and implement intraday capacity calculation and allocation on Italy's northern border. The aim is to provide maximum transfer capacities to the CSE market on an intraday basis without jeopardising security of supply.

The intraday timeframe enables a more accurate forecast of the real-time grid situation, the results of which can be passed on to the market. An additional aim of the project is to monitor the discrepancies between calculated intraday results and the outcomes of D-2 capacity calculation so that the causes of these differences can be pinpointed and both processes can be improved.



The first phase of the project entails installing an intraday process to boost capacities for the last 8 hours of the day (between 16:00 and 24:00). The timeline set for this first project phase aims at going live in early 2018. The second phase will consist of further developing and extending the process to review capacity around the clock.

To prepare the way for a successful go-live of the first phase in 2018, 2016 was a year of preparations, studies, analysis and development. All these efforts resulted in the successful launch of the qualitative experimentation phase in September 2016.

As a partner closely involved in the D-2 capacity calculation process, Coreso not only offered highly appreciated support to the TSOs involved by designing the new process, but was also responsible for identifying and detailing any discrepancies between the D-2 CSE capacity calculation process and the new intraday process.

Coreso's participation in and commitment to this project gives it an opportunity to improve and achieve better results in two processes: one future and one operational (D-2 capacity calculation in the CSE area). Coreso's involvement also gives it a chance to expand its inside knowledge of and know-how regarding the CSE grid and capacity calculation processes.

2017 will continue to be a challenging year, with the implementation of the full operational process inside the control room and hopefully successful performance in the scheduled test phases and parallel runs.

Capacity calculation in the SWE area

REN's affiliation in 2015 and REE's membership in 2016 expanded Coreso's area of activity into South Western Europe. In 2016, first steps, namely describing high-level business needs and launching the experimental phase, were taken towards offering the TSOs in the area a coordinated capacity calculation service and developing a new process designed to meet their expectations.

Challenges in SWE include the presence of a high-voltage DC cable between France and Spain and the different method used to select variable power units there.

Capacity calculation in the Channel area

In 2016, Coreso shared its experience in capacity calculation processes with the TSOs in the Channel and UK-Ireland regions. In in November 2016, the national regulatory agencies (NRAs) validated the Channel and UK-Ireland capacity calculation regions. The TSOs in these regions have started developing a capacity calculation method, while Coreso is providing support and will implement the method they devise. Coreso's support for the project will include experimentation and external/internal trials. Ultimately, it will take on the role of capacity calculator, though possibly not as the sole entity responsible for the Channel region.

The next step in 2017 will involve devising capacity calculation methods for both regions, with the process scheduled to go live during the fourth quarter of 2018.

D-2 flow-based capacity calculation in the Core region

In February 2016, 16 TSOs active in the CWE and CEE areas signed an MoU on merging the two capacity calculation areas. The resulting Core region, spanning from France to Romania, covers 13 countries and will play a crucial role in the integration of the European market.

Cooperation in the new region started with the preparation of two-day-ahead flow-based capacity calculation. Coreso has been actively involved in this work alongside the TSOs and TSCNET since a dedicated working group was set up in April 2016. Coreso's experience with flow-based calculations in the CWE area will be a major asset in this vast and complex project.

One of the challenges regarding flow-based capacity calculation in the Core region will entail determining every day, two days in advance, a set of remedial actions designed to optimise cross-border capacities across the entire region. This currently manual process in the CWE area will have to be automated in the Core region owing to the high number of potential remedial actions and the complex interdependencies its various grids. So Coreso will draw on the experience it gathered in optimising automatic remedial actions during the D-2 process for the CSE area and the IDCC project for the CWE area.

Service III: Short- and medium-term adequacy forecasts

Identifying adequacy issues in advance to prevent scarcity on the European grid

The tense situation in Belgium in the winter of 2014-2015 underscored the need to implement a process capable of detecting adequacy issues, so in its wake an ENTSO-E working group was launched to develop a process for short- and medium-term adequacy forecasts[24]. Coreso took the lead in this group, working in close cooperation with other RSCs (TSCNET, SCC[25], Nordic RSC[26] and Baltic RSC[27]) and TSOs throughout Europe.

32 TSOs **5** RSCs

Process goal

The SMTA service is designed to provide a regional update of short- and/or medium-term active power adequacy, in line with agreed ENTSO-E methods, on shorter timeframes than seasonal outlooks.

Adequacy is reviewed by considering local data together with the grid's capacity to accommodate cross-border exchanges. The update can include recommendations such as specific remedial actions aimed at optimising cross-border exchanges and requesting the activation of balancing-service providers.

When needed, for instance when a regional scarcity issue is detected and cross-zonal capacities are insufficient, a dedicated complementary security analysis can be performed and coordination can be extended to other regions or RSCs. The resulting recommendations may entail adapting cross-zonal capacities in addition to the measures outlined above.

Headway in the SMTA experimentation project

After intensive and fruitful collaboration between Coreso, TSCnet, the relevant TSOs and ENTSO-E, it was decided to base the initial concept of the project on ENTSO-E's expertise on seasonal outlook studies. Data definition and the set-up are handled in close cooperation with ENTSO-E, while representatives of Coreso and TSCNET's TSOs formed the sub-group that specified the concept to be developed for the dry run.

[24] Short- and medium-term adequacy (SMTA) forecasts

[25] SCC is the communal security service centre of Amprion, TenneT NL, TenneT DE. Visit its website at www.securityservicecenter.eu.

[26] Nordic RSC is an RSC active in the Nordic countries. Visit its website at www.nordic-rsc.net.

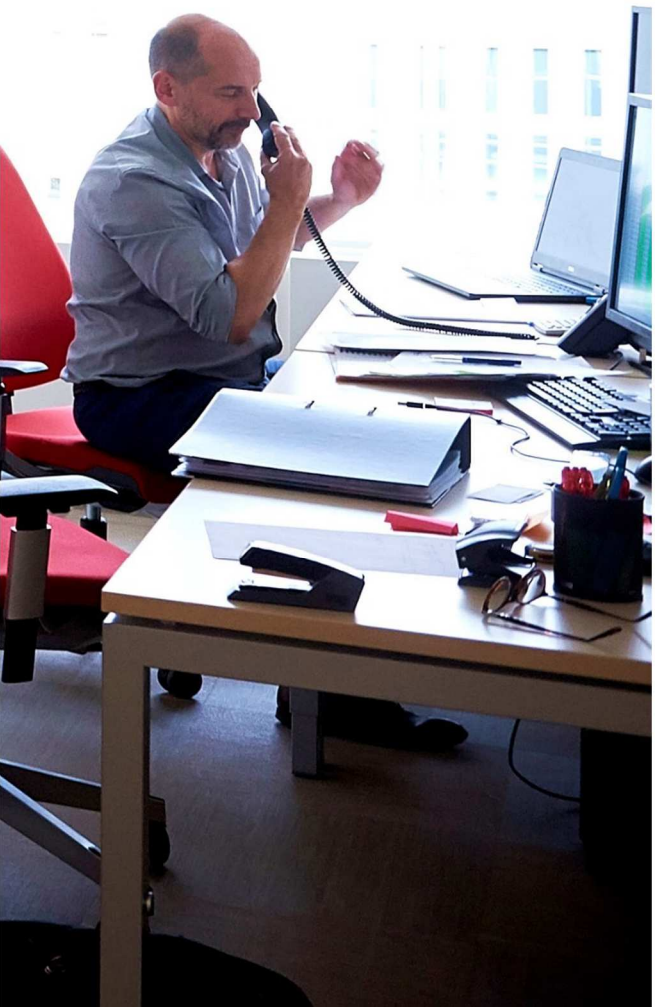
[27] Baltic RSC is an RSC active in the Baltic countries. Visit its website at www.baltic-rsc.eu.

At the start, the concept was limited to a simple deterministic approach, comparing available generating capacity with the various TSOs' demand for energy and ascertaining whether it was feasible to transfer the required volume taking account of grid capacity. The prototype IT concept used in the dry run was developed by Coreso in close collaboration with TSCNET.

The participating TSOs provide input by submitting their remaining capacity forecasts on a weekly basis. Week-ahead transfer capacities on the grid are derived from the ENTSO-E transparency platform. The dry run focussed on data quality and detecting inconsistencies. A weekly report presented the results of the adequacy forecast together with feedback on input data quality.

In a second phase, to comply with ENTSO-E adequacy methods the initial process was complemented by two other approaches: a probabilistic approach that takes account of possible fluctuations in wind energy, solar energy or load, and a more complex deterministic approach comprising a simplified simulation of the market.

The probabilistic approach was developed internally. Its methodology is based on a calculation of spatial (for all countries together) and temporal (for each hour) correlation factors between wind, solar and load data from the past 14 years. Data is extracted from the Pan-European Climatic Database (PECD), containing all measurements for wind and solar for all countries, and ENTSO-E's historical load database, detailing the load for all countries. The calculated factors are matched with a large band of week-ahead forecasts for wind, solar and the load in each country. The remaining capacities, which the TSOs provided as input, are adapted to represent these newly matched values for wind, solar and the load. Using these new values, an updated calculation is performed in which 500 different scenarios are considered for each timestamp and the percentage of scenarios not marked by adequacy shortfalls is counted.



This approach complements a deterministic one by providing robust deterministic results.

The complex deterministic calculation uses a driving function algorithm linked to a simple simulation of market flows. The approach and methodology applied, which is the same as used to generate the seasonal outlook report, contains a merit order classification for generating units, meaning a different price for each type of generation and application according to economic precedence.

A dedicated dry run was performed to test the new approach. The results proved more realistic where energy flows originated from TSOs known to have a more export-oriented production profile, due to high availability of advantageous energy sources like renewable production.

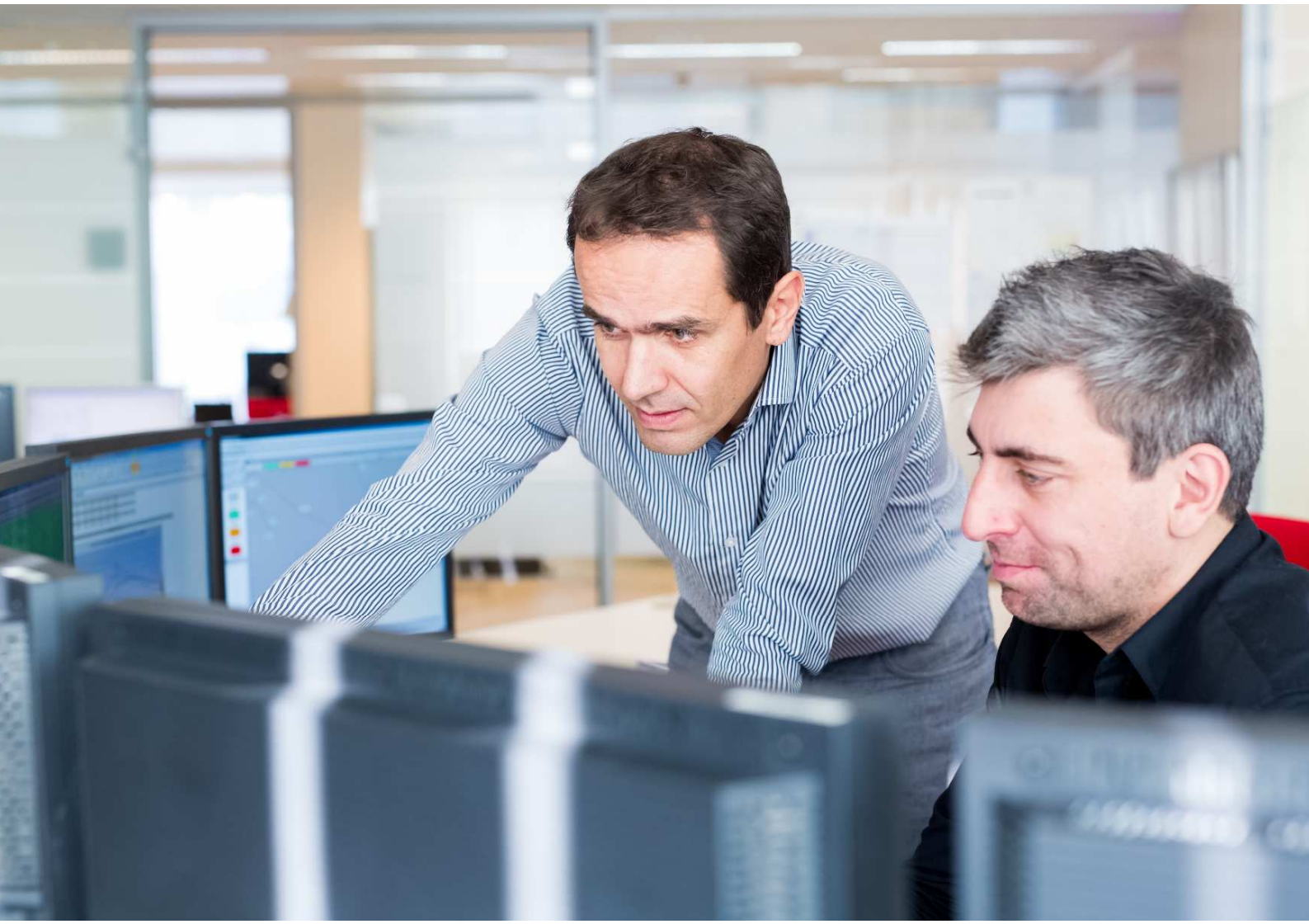
In a first practical application of this process, during the forecast tense situation for France in the winter of 2016-2017, Coreso performed an additional special winter adequacy calculation every Friday morning, to forecast the lack of adequacy on a week-ahead basis.

Every week, the results of the process are discussed with all the relevant TSOs at a week-ahead outage planning teleconference28 meeting.

Future developments

The dry run of the process will continue to adopt the week-ahead timeframe. In addition, a new format will be implemented to launch the probabilistic calculations with TSO data and test the complex deterministic approach with the market driving function.

In the meantime, the methodology will be continuously improved to enhance the results of the regional adequacy assessment.



[28] Week-ahead outage planning teleconference (WOPT)

Service IV: Outage planning coordination

Optimising the maintenance planning of grid elements to guarantee grid security

Within the framework of the outage planning coordination[29] project, ENTSO-E network code operational planning and scheduling requires TSOs to establish a common medium- and long-term outage planning processes based on pre-set standards with the key objective of harmonising regionally diverging outage planning processes on an ENTSO-E-wide basis.

All TSOs in the various capacity calculation regions will jointly appoint set up a regional security coordination body and establish rules governing its operations or appoint another RSC to perform regional outage coordination.

TSOs already successfully plan outage-related activities for areas defined over years of experience, but there was no commonly agreed methodology for implementation by RSCs in the outage coordination process that all ENTSO-E TSOs should apply. To bring this about, ENTSO-E set up a project, “TSO coordination strategy implementation with RSCs”, with a view to implementing the future TSO coordination strategy set out in the ENTSO policy paper published in November 2014. The aim of the project is to establish an outage planning and coordination process based on the existing coordination of outage planning by TSOs and the experience gained during the pilot phases.

Coreso is working closely together with TSCNET, the leader of the working group for this coordination service. The TSOs and RSCs involved in the project are collaborating to design common practices and help to develop a method for coordinating outage planning that will form the basis for a dry run.

5 RSCs **26** TSOs

In the beginning of 2016, the TSOs involved in TSC started a dry run, consisting of merging outages for weekly and monthly process to enable a systematic check of planned outages and facilitate coordination between TSOs. Coreso and its shareholder TSOs joined this experimentation phase at the end of 2016.

Furthermore, the process was enriched by developing new approaches, checking potential tie-line inconsistencies[30] in the outage plan and detecting potential outage planning incompatibilities, i.e. resulting states of the grid in which a combination of the available grid assets, including grid elements, power-generating modules and/or relevant demand facilities, combined with the best estimate of the forecast situation on the electricity grid, leads to a violation of operational security limits, taking account of the inexpensive remedial actions that TSOs can take.

[29] Outage planning coordination (OPC)

[30] Mismatched outage information on lines between 2 TSOs

These new approaches were tested during two month-long dry runs, in October and November 2016. Drawing on the experience gained from them, the methodology was improved and a realistic timeframe was proposed.

Future developments

In 2017, the week-ahead experimentation will be extended in the following three phases:

- Phase 1: TSOs will test the sending of week-ahead outage planning[31] and use the OPC prototype template to create and distribute a merged version thereof to all the project participants.
- Phase 2: In addition to the measure outlined in phase 1, each RSC will carry out a tie-line inconsistency check for its respective TSO(s) with a view to eliminating all tie-line inconsistencies from the final version of the outage plans.
- Phase 3: The resulting, merged outage plan will be used to detect any OP incompatibilities, resulting in definitive OPs that respect operational grid limits.

In the meantime, the methodology will be further improved to set a realistic timeframe for aligning the TSOs' internal outages planning with the coordinated process.

[31] Outage planning (OP)

Service V: Common Grid Model

Creating an improved overview of the interconnected European Grid

Coreso is involved at ENTSO-E level in the Common Grid Model[32] project team. The CGM project details all aspects of the future exchange of individual grid models, the future format for exchanging these models[33], the future exchange platform[34] and the merge function necessary to build a CGM.

Coreso will be one of the entities hosting this future OPDE network and associated archive database. It will also be one of the providers of the European merging function, having been assigned to serve as convenor of its design.

The switch to CGMES was decided by all ENTSO-E TSOs in 2013, the target set being to use the new standard when exchanging IGM files daily by the end of 2017. With a view to meeting this deadline, all of Coreso's tools comply with the new exchange format. Furthermore, the interoperability of the TSOs' IGMs with the tool has been extensively tested.

31 out of **34** IGMs

successfully delivered by TSOs using CGMES during the test phase

[32] Common Grid Model (CGM)
[33] The new data exchange format will be the Common Grid Model Exchange Standard (CGMES)
[34] The future exchange platform will be the Operational Planning Data Environment (OPDE)

Cross-border flows in 2016

A close-up on three different regional dynamics

In the highly interconnected European grid, cross-border flows require constant coordination between neighbouring grids. The physical flows on tie-lines mainly depend on the grid topology and the commercial exchanges that result from price differences on wholesale markets. Depending on the structural differences in the electric systems of neighbouring countries, the dynamics of cross-border flows vary from one region to another.

The present overview aims at illustrating these differences to which Coreso needs to adapt in order to provide the most adequate and relevant services to its shareholders.

98%

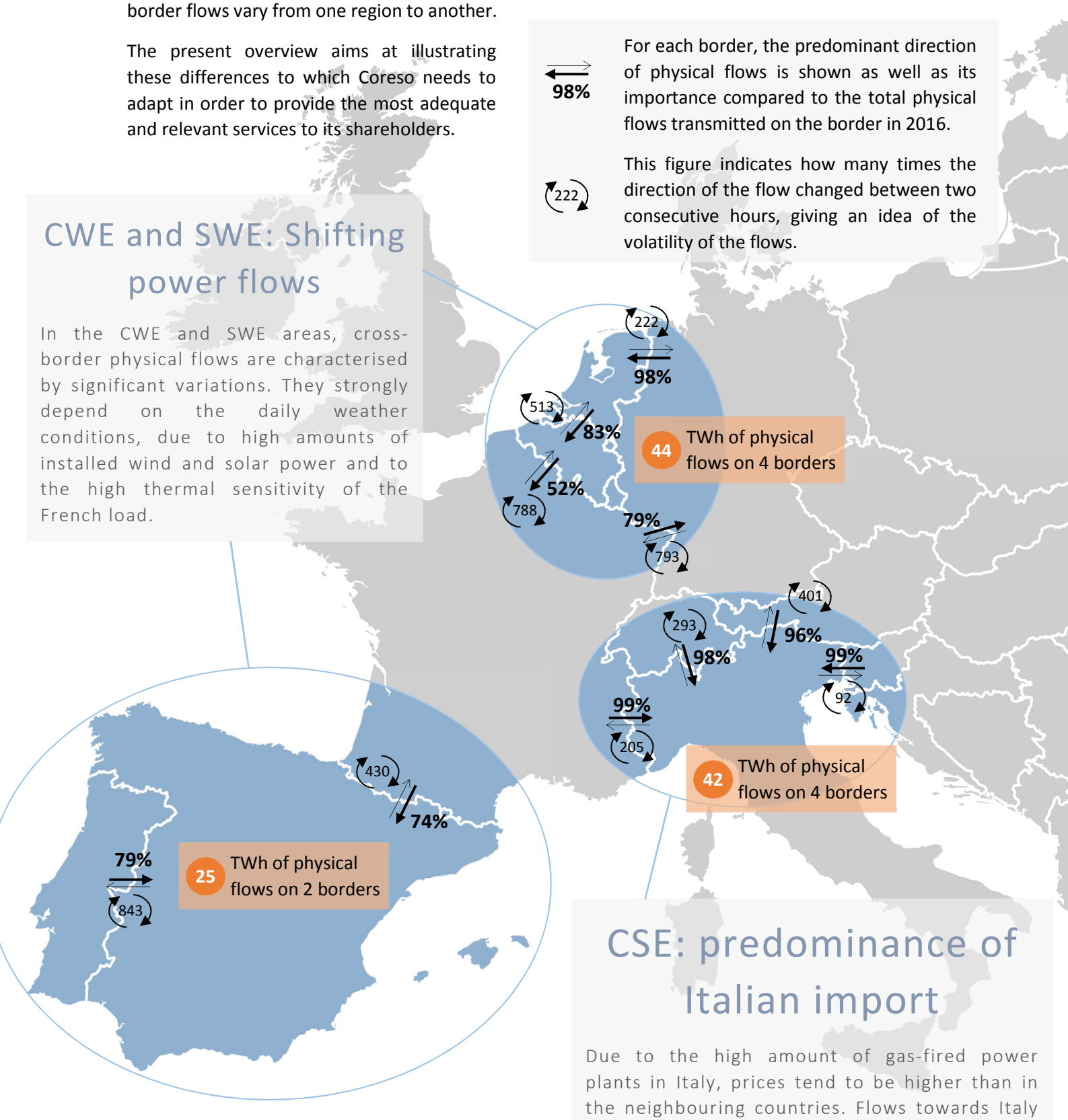
For each border, the predominant direction of physical flows is shown as well as its importance compared to the total physical flows transmitted on the border in 2016.

222

This figure indicates how many times the direction of the flow changed between two consecutive hours, giving an idea of the volatility of the flows.

CWE and SWE: Shifting power flows

In the CWE and SWE areas, cross-border physical flows are characterised by significant variations. They strongly depend on the daily weather conditions, due to high amounts of installed wind and solar power and to the high thermal sensitivity of the French load.



CSE: predominance of Italian import

Due to the high amount of gas-fired power plants in Italy, prices tend to be higher than in the neighbouring countries. Flows towards Italy are therefore almost constantly observed.

Data from Vulcanus platform

Glossary

50Hertz is one of the TSOs responsible for the German grid. Visit its website at http://www.50hertz.com/en/.

Amprion is one of the TSOs responsible for the German grid. Visit its website at www.amprion.net.

Baltic RSC is an RSC active in the Baltic countries. Visit its website at www.baltic-rsc.eu.

CGM: Common Grid Model

CGMES: Common Grid Model Exchange Standard, the new data exchange format

Creos is the TSO responsible for the Luxembourg grid. Visit its website at www.creos-net.lu.

D2CF: 2-day ahead congestion forecast

DACF: Day-ahead congestion forecast

Elia: Elia is the TSO responsible for the Belgian grid. Visit its website at www.elia.be/en.

Energiewende: German energy transition

ENTSO-E: European Network of Transmissions System Operators for Electricity. Visit its website on www.entsoe.eu

FBCS: Flow-based common system

FBMC: Flow-based market coupling

HVDC links: High Voltage Direct Current links are cables on which energy is transported in DC.

National Grid is the TSO that operates energy systems in the United Kingdom. Visit its website on www.nationalgrid.com/uk/.

Nordic RSC is an RSC active in the Nordic countries. Visit its website at www.nordic-rsc.net.

OPC: Outage planning coordination

OPDE: Operational Planning Data Environment

PSTs: Phase-shifting transformers (PSTs) enable TSOs to better control energy transmissions along power lines.

RACT: Remedial action coordination tool

REE: Red Eléctrica de España is the TSO responsible for the Spanish grid. Visit its website at www.ree.es/en.

REN: Redes Energéticas Nacionais is the TSO responsible for the Portuguese grid. Visit its website at www.ren.pt/en-GB.

RSC: Regional Security Coordinator

Rte: Réseau de transport d'électricité is the TSO responsible for the French grid. Visit its website at www.rte-france.com/en.

SCC is the communal security service centre of Amprion, TenneT NL, TenneT DE. Visit its website at www.securityservicecenter.eu.

SMART study: TSOs may request System Modification Advice Requests, or SMART studies, to investigate specific grid situations in close to real time.

SMTA: Short- and medium-term adequacy forecasts

TenneT DE is one of the TSOs responsible for the German grid. Visit its website at www.tennet.eu.

TenneT NL is the TSO responsible for the Dutch grid. Visit its website at www.tennet.eu.

Terna is the TSO responsible for the Italian grid. Visit its website at www.terna.it.

TSCNET is the RSC of 13 TSOs who are members of TSC (TSO Security Cooperation). Visit its website at www.tscnet.eu.

TSO: Transmission system operator

WOPT: Week-ahead outage planning teleconference

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