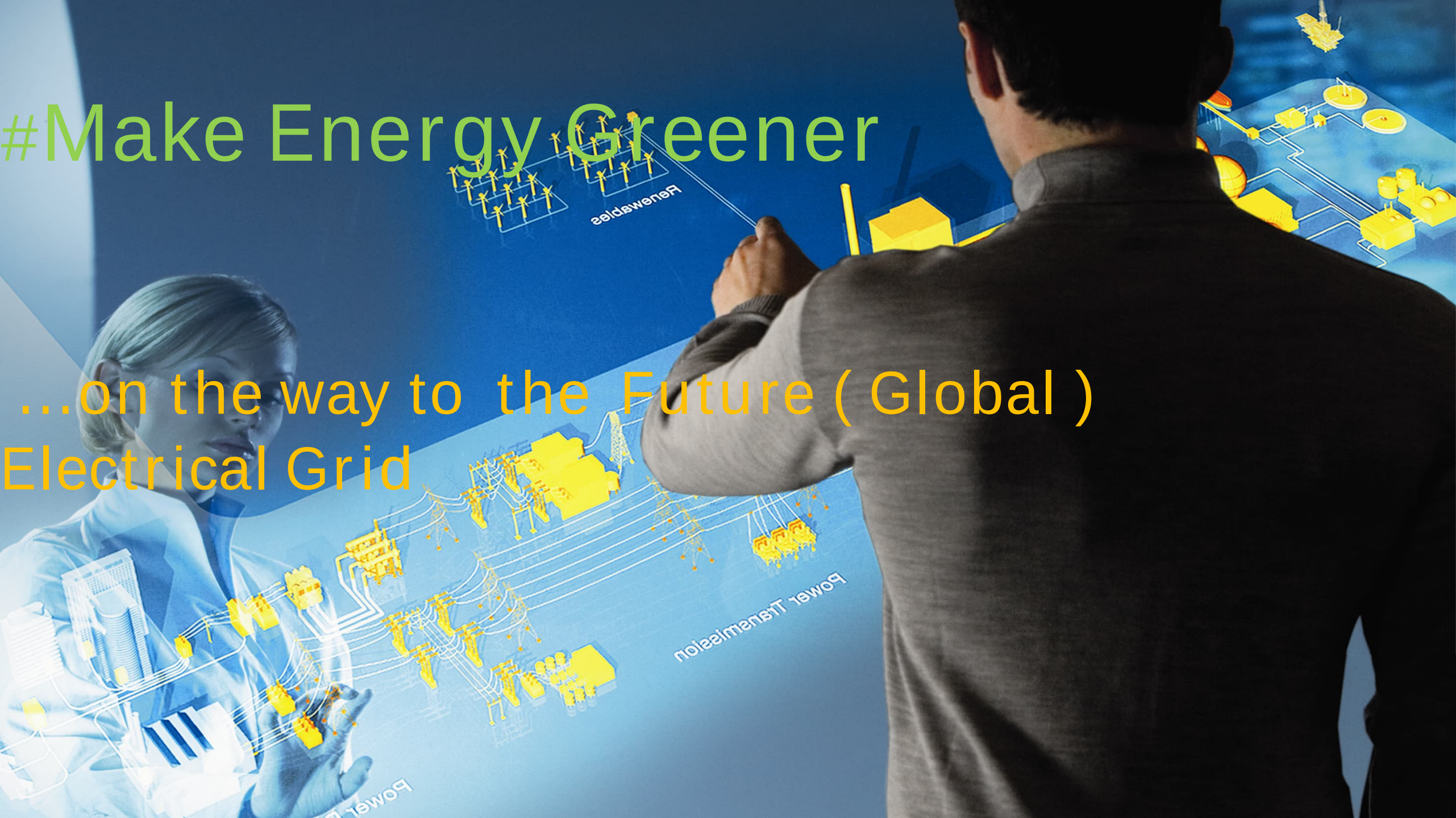

#Make Energy Greener
...on the way to the Future (Global)
Electrical Grid

Les différentes sources d'énergie

QUESTIONS SCIENCES

L'approvisionnement énergétique est un facteur clé de notre niveau de vie. Le changement climatique et l'épuisement des ressources fossiles nous poussent néanmoins à modifier nos habitudes. De nombreuses technologies existent et notre capacité à nous orienter efficacement vers un développement durable dépend en grande partie de notre connaissance de l'approvisionnement actuel.

Ressources naturelles

Energie primaire (715 TWh)

Approvisionnement

Entrée en transformation (682 TWh)

Utilisation directe (33 TWh)

Transformation physico-chimique

Pertes de transformation (198 TWh)

Sorties de transformation (484 TWh)

Distribution

Pertes de distribution (4 TWh)

Energie finale (513 TWh)

Consommation

L'unité légale pour la mesure de l'énergie est le joule mais on utilise souvent le kilowatt-heure (kWh) qui correspond à 3,6 millions de joules. L'unité utilisée ici est le tera watt-heure (TWh) qui vaut un milliard de kilowatt-heure (kWh).

A l'état naturel, l'uranium est le plus souvent extrait du sol sous la forme d'un minerai appelé l'uranite (ou Pechblende)

Le charbon, le pétrole et le gaz naturel constituent les combustibles fossiles qui se sont formés par la décomposition des plantes et des animaux morts il y a plusieurs dizaines de millions d'années

L'énergie solaire provient de la réaction de fusion nucléaire de l'hydrogène en hélium au sein du noyau de notre étoile

L'interaction Terre-Lune provoque les marées

L'énergie géothermique est le résidu de l'énergie thermique laissée depuis les origines de la planète Terre

Combustible nucléaire | Gaz naturel | Charbon | Pétrole | Biomasse | Le vent | Les fleuves et rivières

Les centrales nucléaires | Les centrales thermiques classiques | Les raffineries | Les centrales biomasses | Les centrales solaires | Les éoliennes | Les centrales houlomotrices | Les centrales hydroélectriques | Les centrales marémotrices | Les centrales géothermiques

Réseau de distribution de gaz

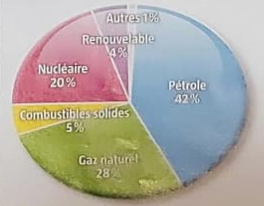
Réseau de distribution de combustibles liquides (mazout de chauffage, essence, diesel, LPG,...)

L'énergie électrique est distribuée par le réseau de transport et de distribution électrique vers les points de consommation

L'énergie électrique n'est pas toujours produite lorsque nous en avons besoin. Elle doit alors être convertie en une autre forme d'énergie pour être stockée (ex. conversion en énergie hydraulique à la centrale de Coo)

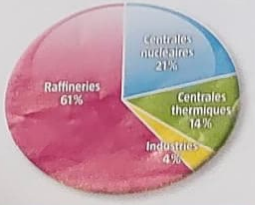
Industrie | Transport | Ménages | Agriculture | Commerces et services publics

RÉPARTITION de l'énergie primaire (Total = 715 TWh)



CONSOMMATION de l'énergie finale (Total = 513 TWh)

TRANSFORMATION de l'énergie primaire (Total = 682 TWh)



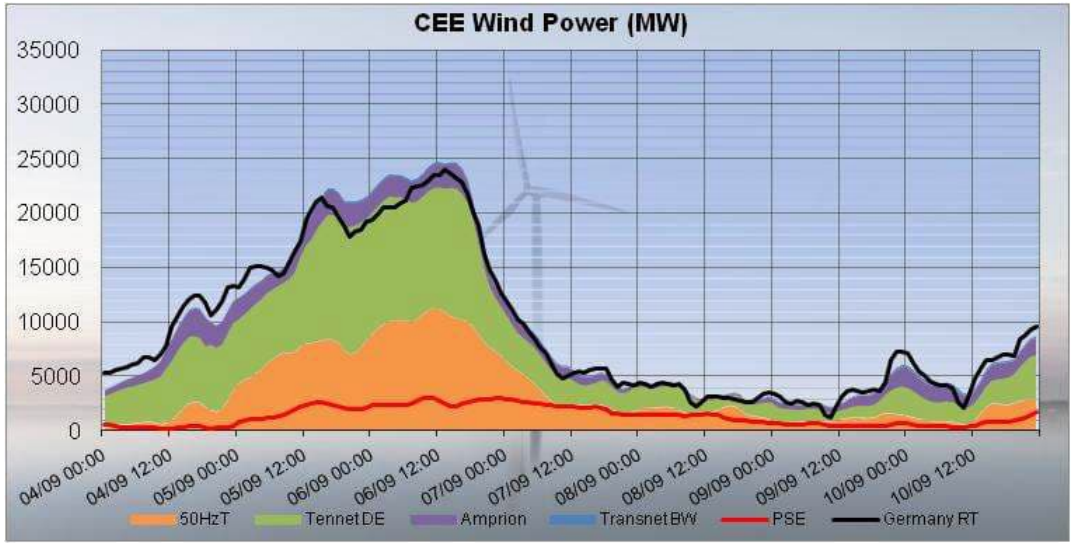
PRODUCTION électrique annuelle brute (Total = 95 TWh)

Les énergies renouvelables sont produites et consommées localement. L'énergie excédentaire est rejetée sur le réseau de distribution électrique.

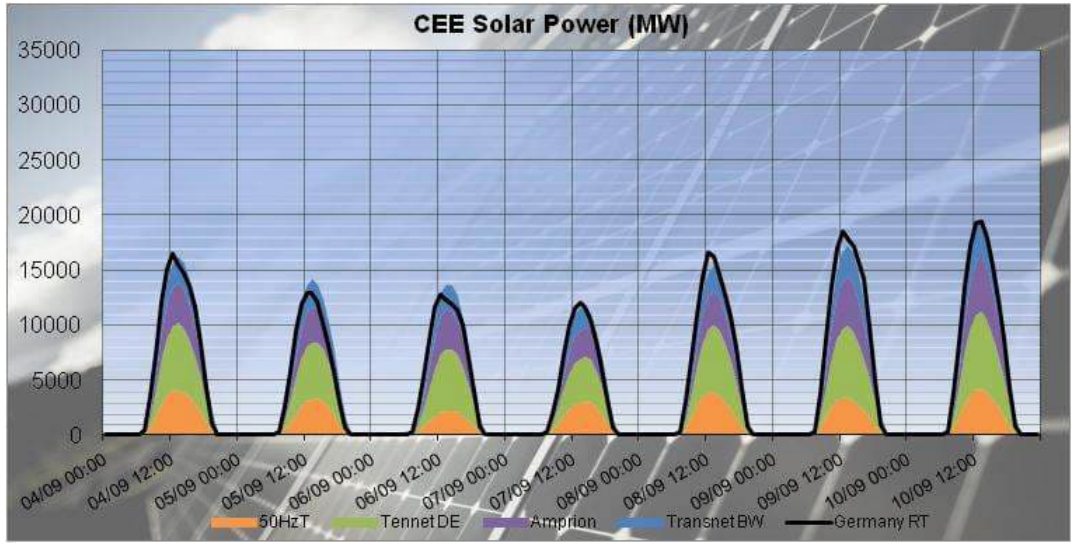
Auteur : Pierre Dewallef, Département d'aérospatiale et mécanique/ Systèmes de conversion d'énergie pour un développement durable, Université de Liège
Pour en savoir plus : www.ulg.ac.be/sciences/postersQS

Renewable Energy in Germany (during one week)

- **WIND**



- **SOLAR**



Available theoretical wind power

The available wind power P_{vent} is equal to:

$$P_{vent} = \frac{1}{2} \rho A . v_{vent}^{3} \quad [W]$$

- ρ = Air density (kg/m^3)
- A = Area swept by the blades (m^2)
- v_{vent} = Wind speed [m/s]

Example :
Wind speed: 10 m/s, Rotor diameter: 82 m

Wind power: 1/2 x 1,225 x 5.281 x 10^3 = 3.235 x 10^3 W ou 3.235 kW

Captured power by the wind turbine = Wind power x cp
Cp : performance coefficient, theoretical maximum = 0,59

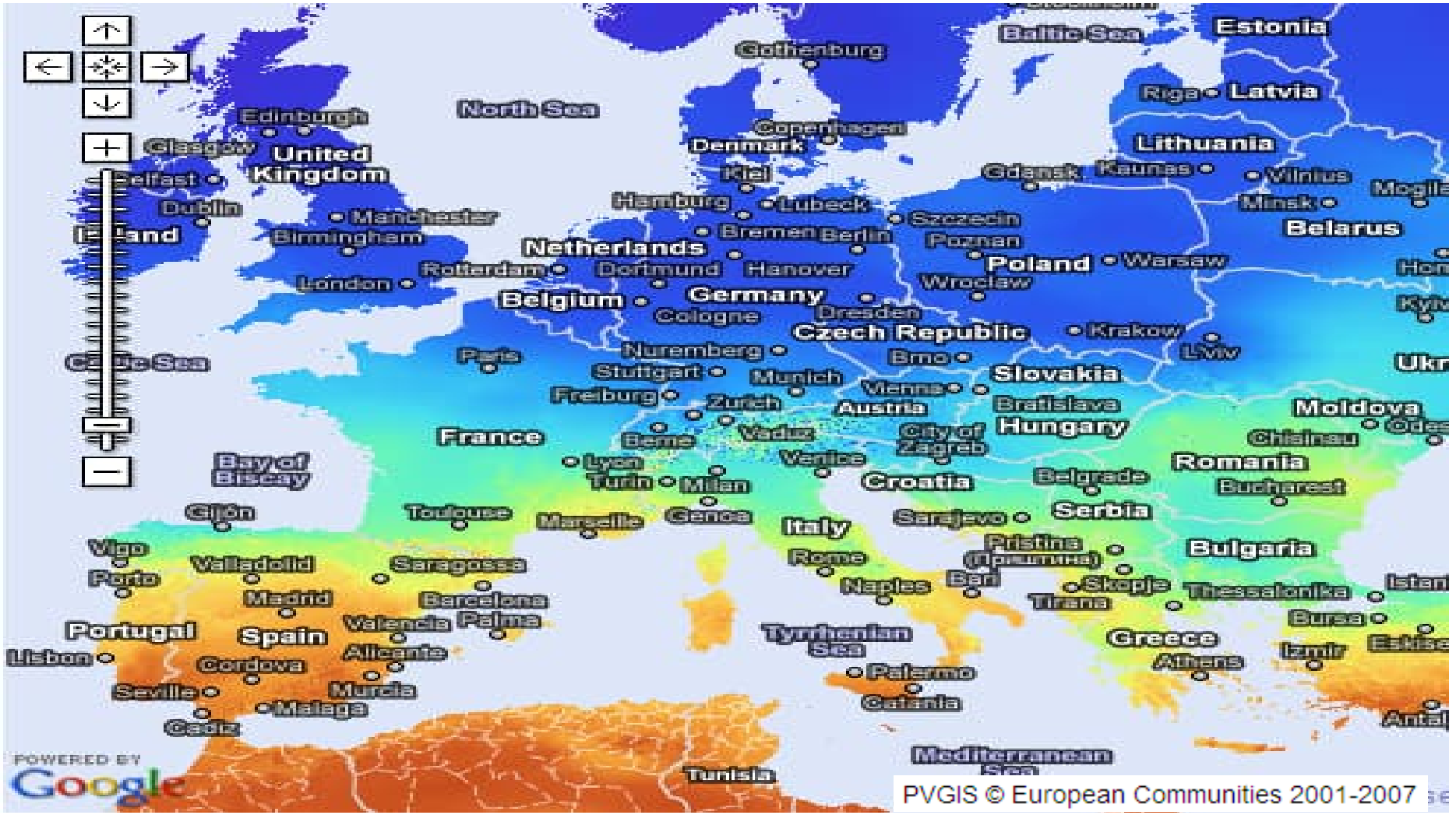
Offshore Wind turbines in 2024

Puissance nominale :14 MW

Diamètre du rotor :236 m

Longueur de pale :115 m

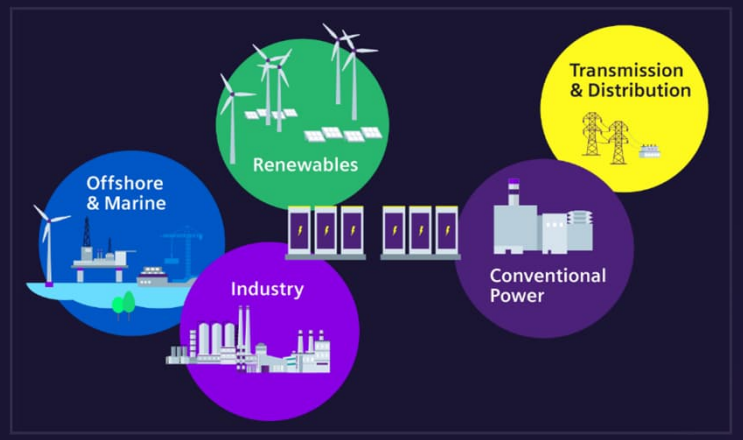
Solar Power Potential in Europe

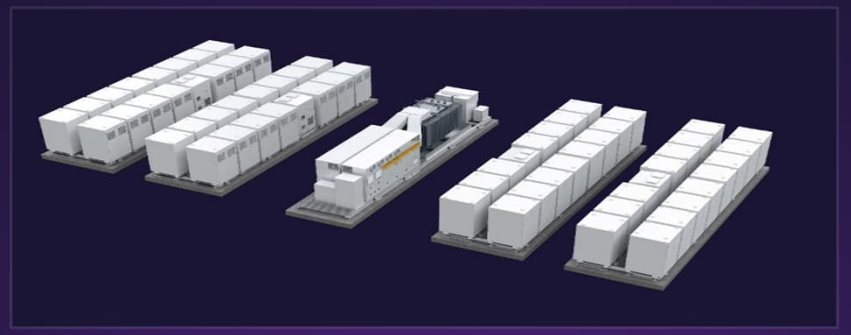


Yearly total of global irradiation on horizontal surface

200 500 800 1100 1400 1700 2000 [kWh/m²]

Les projets de stockage d’énergie par batteries (BESS) poussent comme des champignons en Belgique





Battery energy storage systems (BESS)

BESS consist of one or more batteries and can be used to balance the electric grid, provide backup power and improve grid stability.

Battery Energy Storage System (BESS) de Luminus à Navagne

150MW net power capacity during 2h or 4h

Connected to the grid 150 kV of ELIA

With their inherent flexibility, energy storage assets can play a critical role in renewable energy shifting to peak demand times and supporting grid stability.

Partenariat franco-allemand joue un rôle central dans le développement d'une économie hydrogène durable nécessaire pour réussir la transition énergétique.

8/11/2023 : Siemens Energy et Air Liquide inaugurent leur gigafactory pour faire décoller l'hydrogène vert

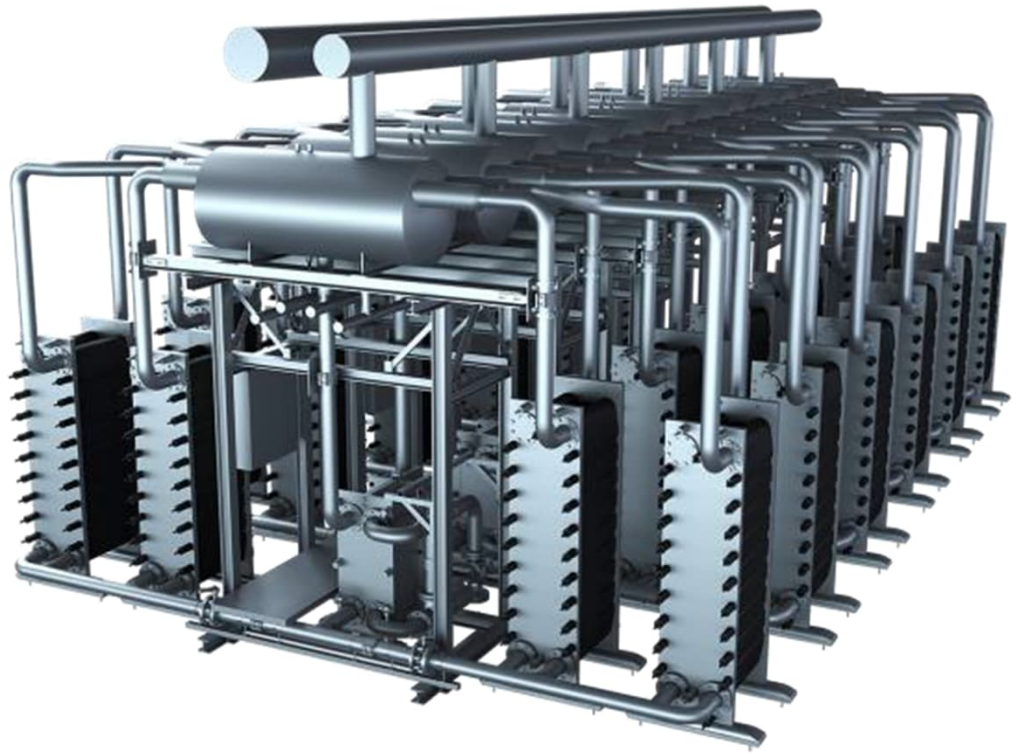
L'usine géante de Siemens Energy et Air Liquide est un pari sur l'avenir. Les deux partenaires vont mettre sur le marché les plus gros électrolyseurs à technologie PEM (membrane échangeuse de protons).

Les modules PEM présentent un haut degré d'efficience et sont particulièrement adaptés à l'intermittence des énergies renouvelables. Air Liquide et Siemens Energy prévoient de porter la capacité de production annuelle de l'usine, actuellement d'un gigawatt, à trois gigawatts d'ici 2025. Une fois produits, l'assemblage des modules pourra être réalisé au plus près des sites où ils seront installés.

Silyzer 300
The next paradigm in PEM electrolysis

17.5 MW	Power demand per full Module Array (24 modules)
>76 %	System efficiency[1] (higher heating value)
24 modules	to build a full Module Array
335 kg	Hydrogen per hour per full Module Array (24 modules)

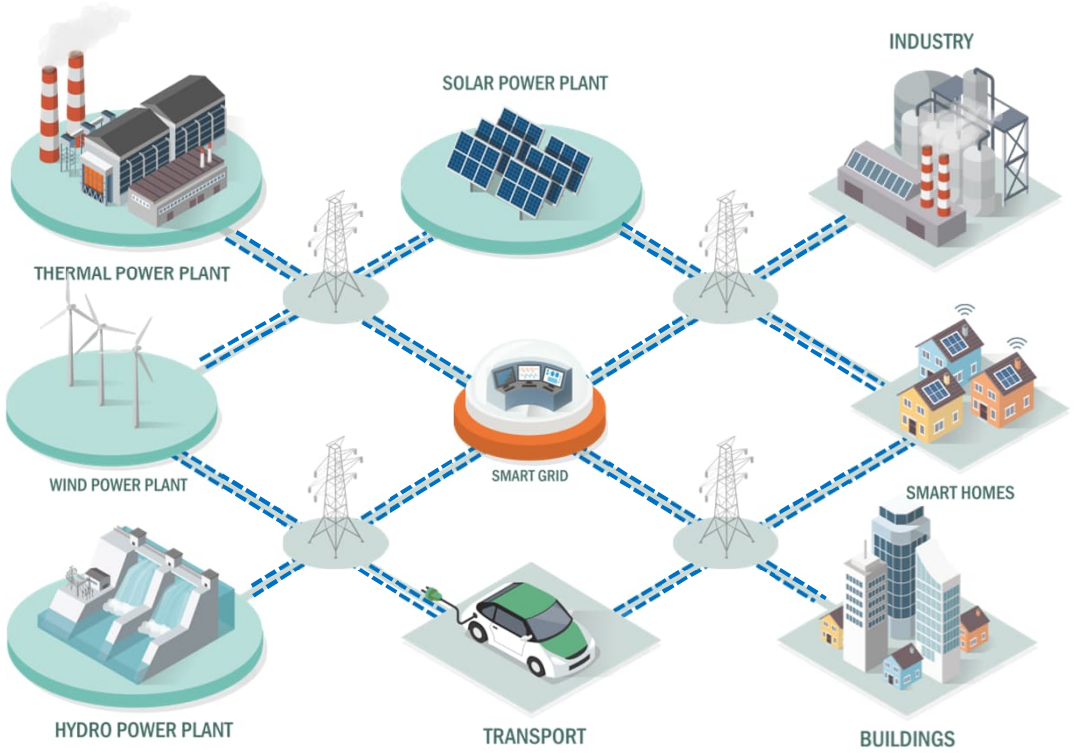
Silyzer 300
Module Array (24 modules)



Our new world

A Complex and Interconnected Energy Landscape

The power sector landscape is changing dramatically



Traditional system

Centralised / Dispatchable generation

High inertia and stability

Central Planning

One way flows of energy and communication

Closed networks, few devices

New system

Decentralised / Variable generation

Multiple actors / Competitive markets

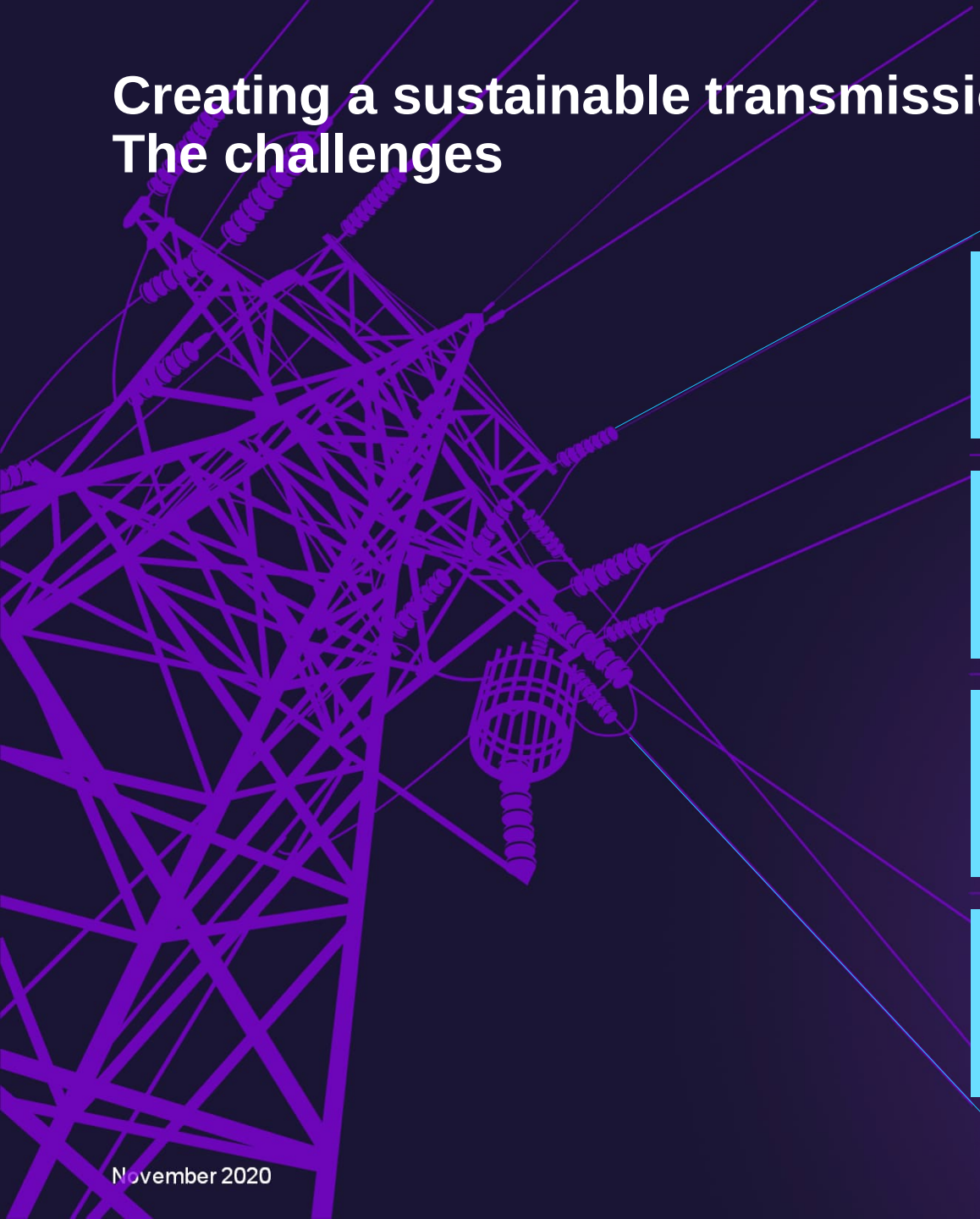
Two way flows of energy and communication

Open networks and many devices

Distributed resources offer flexibility and provide energy

Changing climate patterns

Creating a sustainable transmission grid
The challenges



Rising global demand for electricity

DEMAND GROWTH
Maintain reliable power supply

Increasing focus on environment across energy transmission

DECARBONIZATION
Make energy greener

Monolithic and centralized energy systems

DECENTRALIZATION
Embrace system complexity

Improving asset performance & grid management

DIGITALIZATION
Adopt digital solutions

Qu'est-ce qu'un poste électrique haute tension?

Le monde ne peut fonctionner sans électricité. Nous dépendons de l'électricité pour une multitude de choses, des ordinateurs aux feux de circulation, des appareils ménagers aux téléphones mobiles. Au cours des prochaines années, la consommation d'électricité augmentera en raison, entre autres, de la progression des voitures électriques et des pompes à chaleur. Voilà pourquoi Elia investit dans le bon fonctionnement et la fiabilité des infrastructures, comme les postes électriques haute tension.

814

POSTES ÉLECTRIQUES HAUTE TENSION EN BELGIQUE

L'électricité est de plus en plus générée par des sources d'énergie renouvelable comme les éoliennes et les panneaux photovoltaïques. En tant que gestionnaire de réseau de transport, Elia joue un rôle clé dans l'intégration des **énergies renouvelables** dans le réseau électrique. Elia contribue à l'approvisionnement en électricité jour et nuit de **11 millions de consoammateurs finaux en Belgique**.

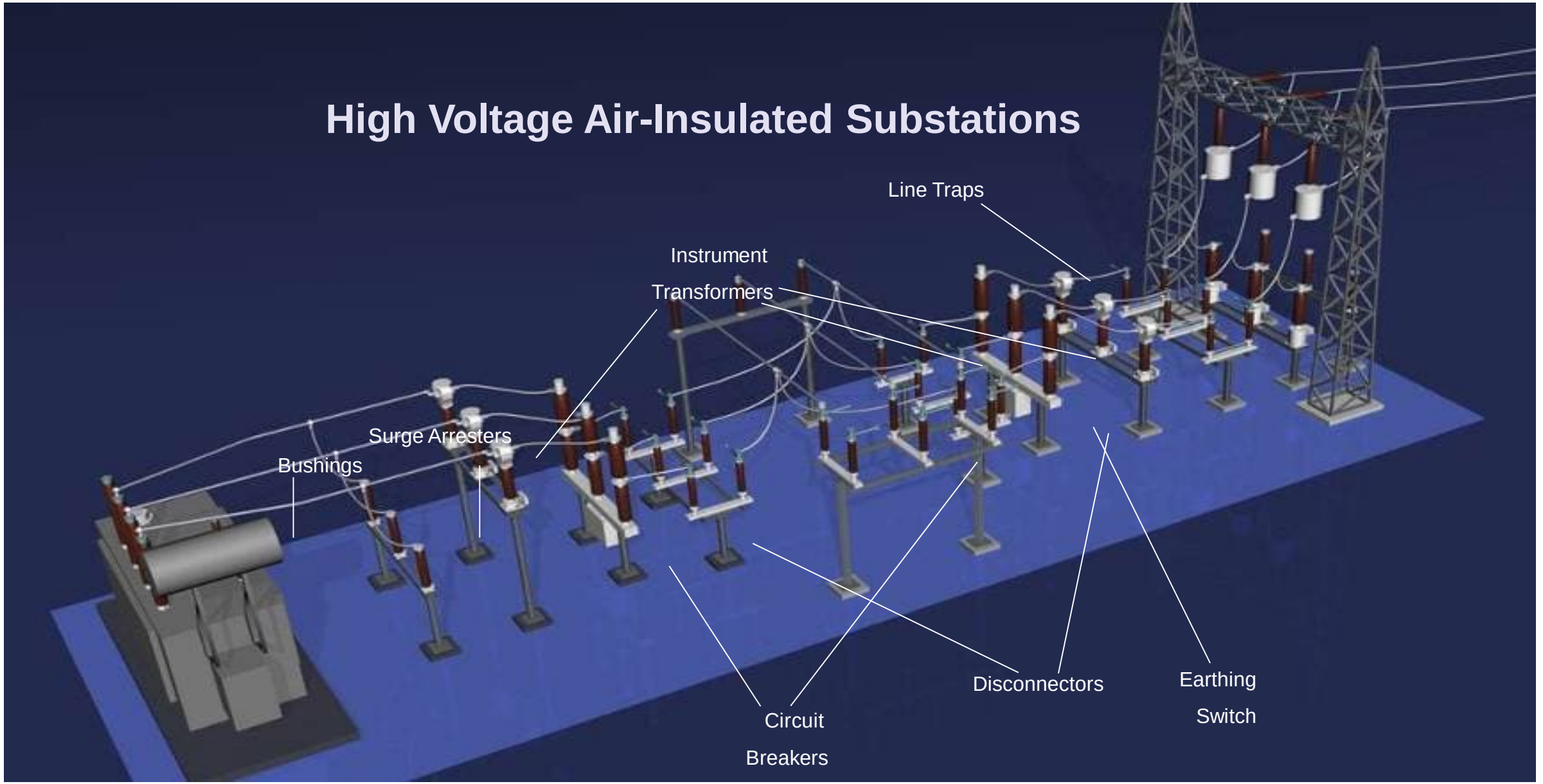
Une infrastructure fiable est donc requise. Elia pose de nouvelles liaisons électriques et améliore les liaisons existantes. Par ailleurs, Elia construit et renouvelle également des postes électriques haute tension.

La présente brochure détaille la fonction d'un poste électrique haute tension, le fonctionnement d'un poste et les types de postes existants.

Poste d’Aubange 220 kV

Air Insulated Switchgear (AIS)

High Voltage Air-Insulated Substations

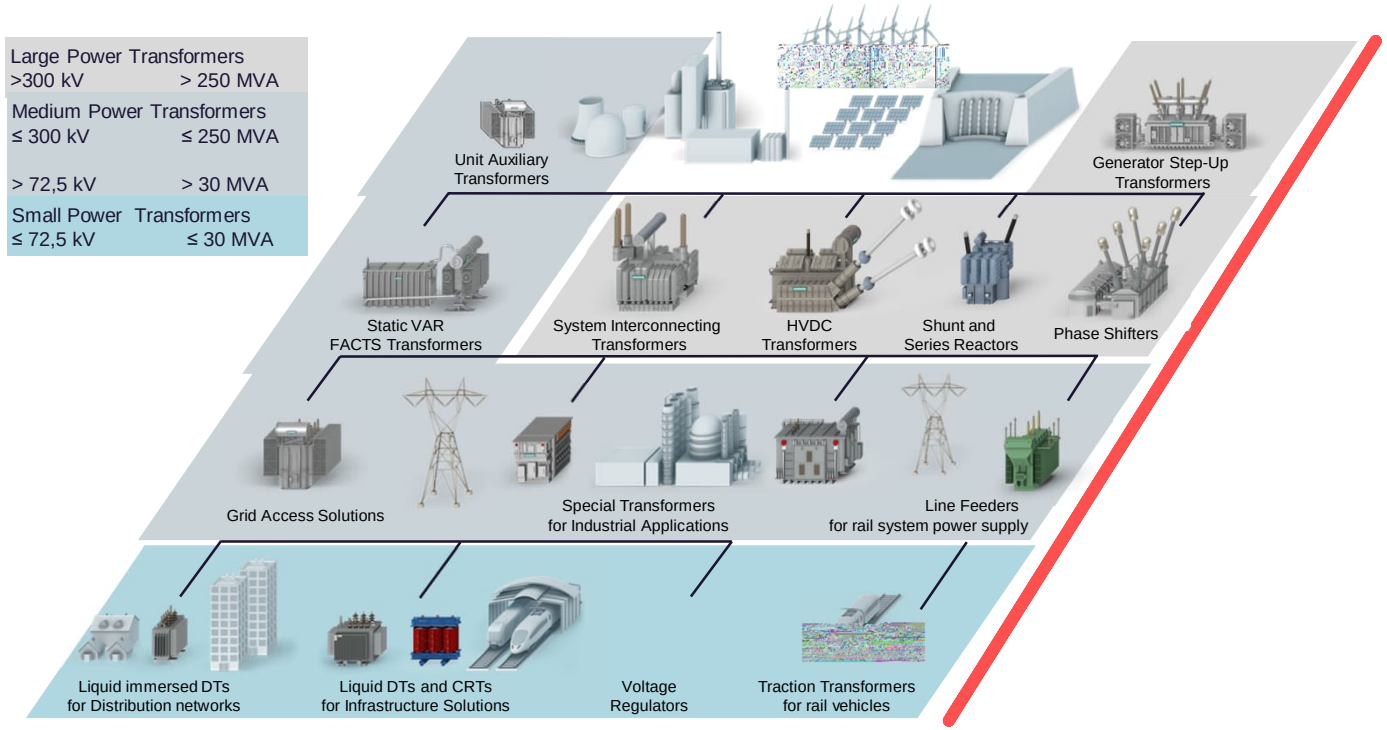


Gas Insulated Switchgear (GIS)

- **Gas-Insulated Switchgear (GIS) integrates all necessary functions like switching, disconnecting, earthing, measurement and surge protection, required for ensuring a reliable and safe supply of electricity in a very compact and highly efficient way.**
- **All of the above mentionned components are housed in a grounded metal enclosure and filled with SF6 (Sulphur Hexafluoride), a gas known for its good insulation and arc-quenching properties.**
- **The modular structure of the switchgear permits flexible designs and problem-free extension.**

Power Transformers

at all levels of transmission and distribution



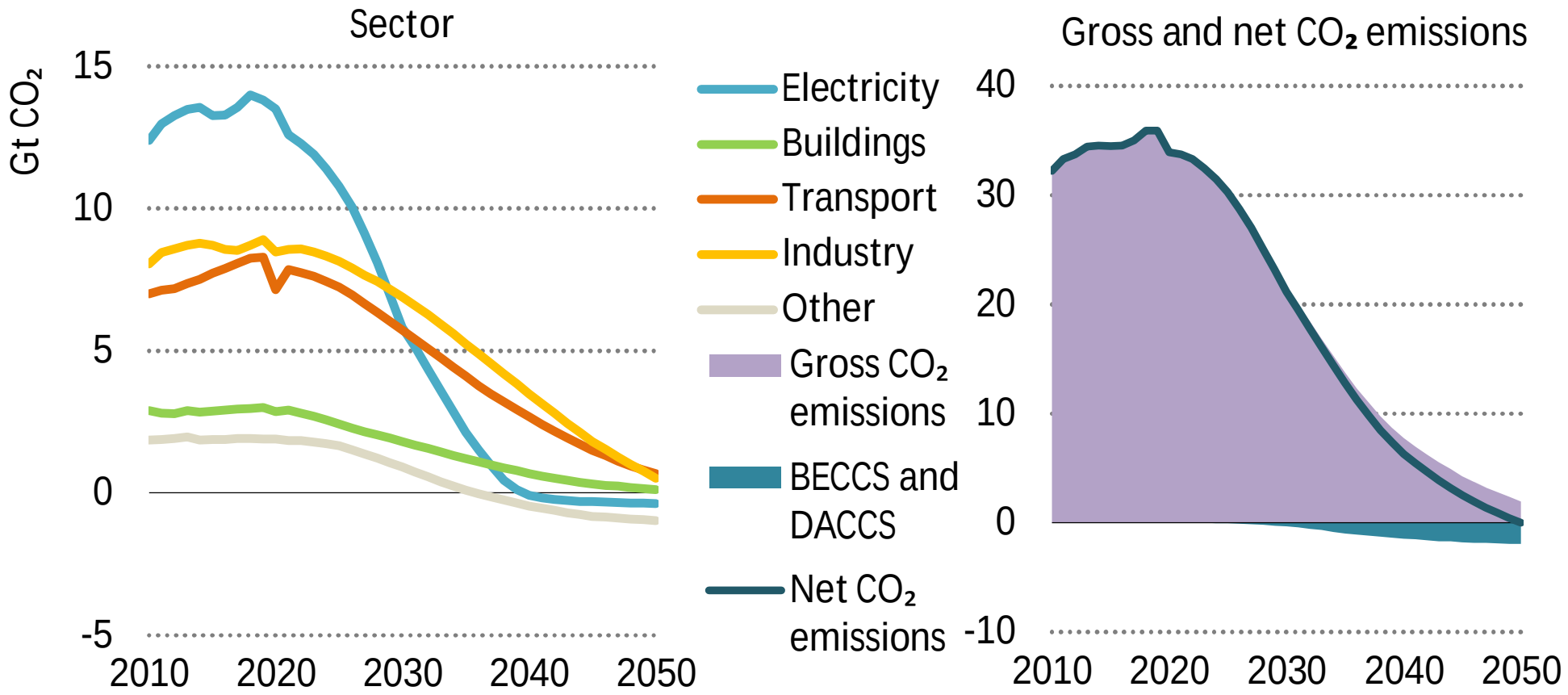
DECARBONIZATION

Make energy greener

Together, shaping Industry to achieve Net Zero

The power sector as the first mover and enabler of decarbonisation

Global net-CO2 emissions by sector, and gross and net CO2 emissions in the NZE



Make energy greener
What’s needed: evolution, not revolution

LIMIT GLOBAL WARMING POTENTIAL (GWP)

Ensure zero greenhouse gas emissions

ENVIRONMENTALLY SAFE MATERIALS

Use only materials and substances that meet highest health & safety standards (e.g. REACH, RoHS in Europe)*

SUSTAINABLE PRODUCTS

Enable durable products with long operational life, low maintenance, and low recycling requirements

* RoHS: Restriction of Hazardous Substances
REACH: Registration, Evaluation, Authorization and Restriction of Chemicals

PFAS making headlines

Rainwater everywhere on Earth contains unsafe levels of 'forever chemicals' linked to cancer and other illnesses, study finds

- Unsafe levels of man-made PFAS have been found in rain across the world
- Maximum concentrations of the chemicals have been decreasing for decades
- This is because knowledge of their dangers to human health has increased
- However their environmental levels have not changed, according to researchers

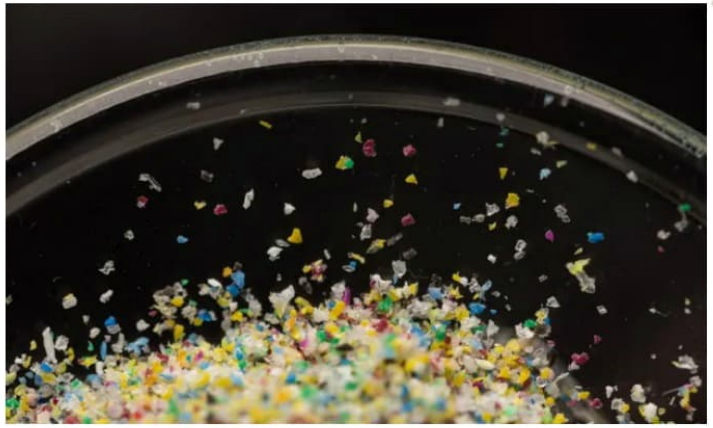
By FIONA JACKSON FOR MAILONLINE
PUBLISHED: 16:43 BST, 2 August 2022 | **UPDATED:** 17:00 BST, 2 August 2022

US news

Exposure to environmental toxins may be root of rise in neurological disorders

Doctors warn exposure to omnipresent yet poorly understood chemicals such as microplastics could play a role in dementia

Nina Lakhani *in New York*
@ninalakhani
Sun 23 Oct 2022 11.00 BST



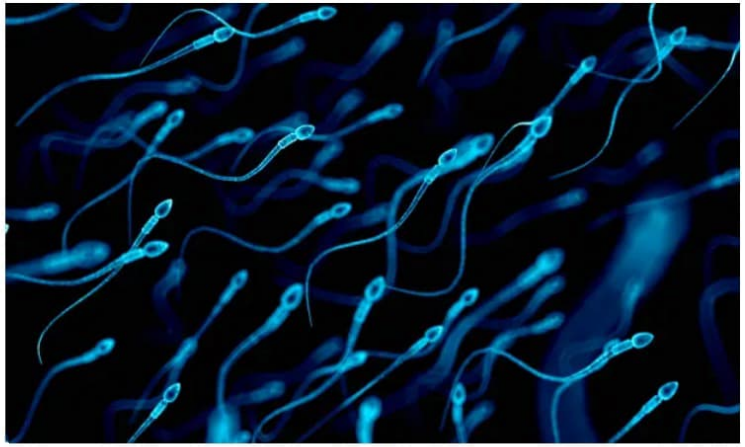
Microplastics, pesticides and other toxins could be causing increase of neurological disorders. Photograph: David Kelly/Photograph David Kelly/The University of Queensland

Fertility problems

Study links in utero 'forever chemical' exposure to low sperm count and mobility

PFAS, now found in nearly all umbilical cord blood around the world, interfere with hormones crucial to testicle development

Tom Perkins
Wed 5 Oct 2022 05.01 BST



Photograph: Sebastian Kaulitzki/Science Photo Library/Getty Images/Science Photo Library RF

State Department of Health to Issue Proposed Regulations for PFAS in Drinking Water Systems

ALBANY, N.Y. (October 4, 2022)

JUNE 30, 2022

European teenagers are high – on PFAS

Teenagers in Europe have high levels of PFAS in their blood, especially Swedish, French and Norwegian ones, an EU human biomonitoring study shows. The reason for these high levels? A large intake of egg, fish, animal intestines – and locally produced food.

Deutsche Umwelthilfe

Equipment free of fluorinated gases for sustainable, climate-neutral power grids

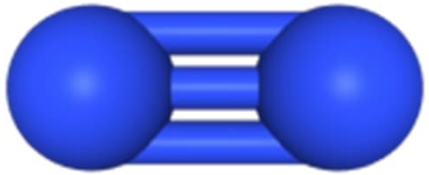
The electrical transmission and distribution (T&D) industry has an opportunity to lead society's response to deliver infrastructures that are targeting climate-neutral objective to underpin the transition to net zero emission economies. The clean transport of low-carbon electricity is an essential element of national decarbonization plans, which will underpin the sustainable economies of the future. In conjunction with decarbonized power generation using renewable energy sources, it is vital to do the same for T&D power grids upon which the system relies..

For over 50 years, the recognized insulation and switching performance as well as proven and stable characteristics of SF6 have contributed to the reliability, efficiency, and resilience of power network facilities, enabling compact equipment for all voltage classes. However, because SF6 has a global warming potential over 25,000 times greater than CO2, action is now required to achieve truly sustainable power grids. To enable this change, we need to limit the SF6 emissions and install new electrical equipment using clean reliable and non-toxic alternatives.

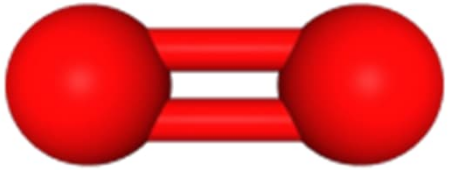
The phase-out of fluorinated and PFAS-gases (per- and polyfluoroalkyl substances) in electrical T&D equipment, where alternatives are available, would accelerate progress toward a more sustainable future.

The first F-gas free products are successfully in operation, and each of the signing companies is committed to close the remaining portfolio gaps in the upcoming years in order to deliver on science-based net zero targets (SBTI) that companies are setting.

SF_6 Alternative: F-gas free



Nitrogen + Oxygen



- natural origin, non-fluorinated, non-toxic
- GWP < 1 → climate friendly
- no degradation products → environmentally safe

Clean Air insulation technology

- No Global Warming Potential: GWP = 0
- No Ozone Depletion Potential: ODP = 0
- Non-toxic (no known toxicological effects: LC50, TLV-TWA, CMR)
- Non-flammable
- High stability
- Low boiling point and no liquefaction of insulation medium
- Clean air with well-known and proven material compatibilities
- F-gas free insulation with lowest requirements on training, transport, installation, operation, reporting and recycling
- C-gas free with no risk of C-decomposition
- No documentation and reporting duties for clean air gas
- No CO_2 compensation costs or risk of future tax or compensation
- No gas recycling required

Make energy greener

BLUE Products

Wind tower GIS
up to 72.5 kV

Blue GIS
up to 145 kV

BLUE GIS®

Live Tank
up to 145 kV

Dead Tank
up to 145 kV

BLUE CIRCUIT BREAKER®

Station Service VT
up to 420 kV & 167 kVA

Instrument VT
up to 420 kV

BLUE VOLTAGE TRANSFORMER®

with its zero GWP, it is the **most environment-friendly switching technology** of the world

is **non-toxic, non-hazardous** and does not require special safety systems like CO-monitoring in the GIS building

offers **highest short-circuit switching capability** without degradation and is completely **maintenance-free**

can be operated in a **wide temperature range** and is specially suitable for very low temperature applications

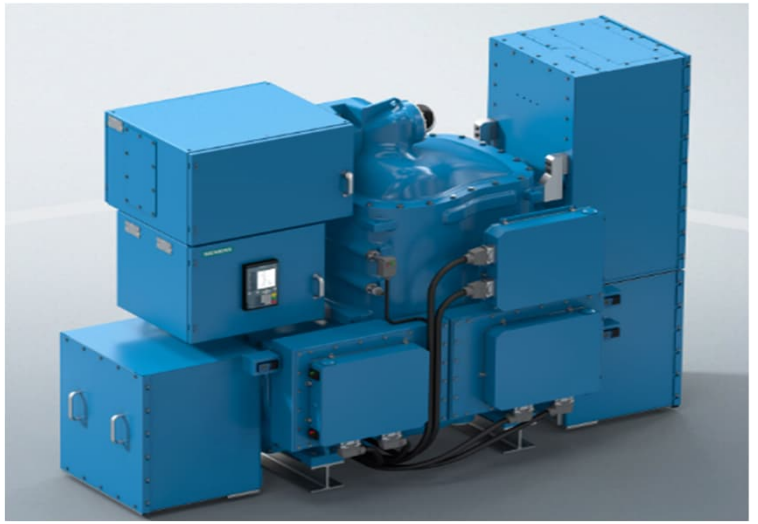
is based on **40+ years experience** in design & manufacturing of vacuum switching & clean air insulation technology

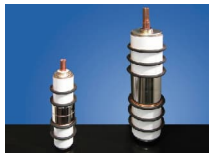
Blue Gas-Insulated Switchgear

CO_2 NEUTRAL

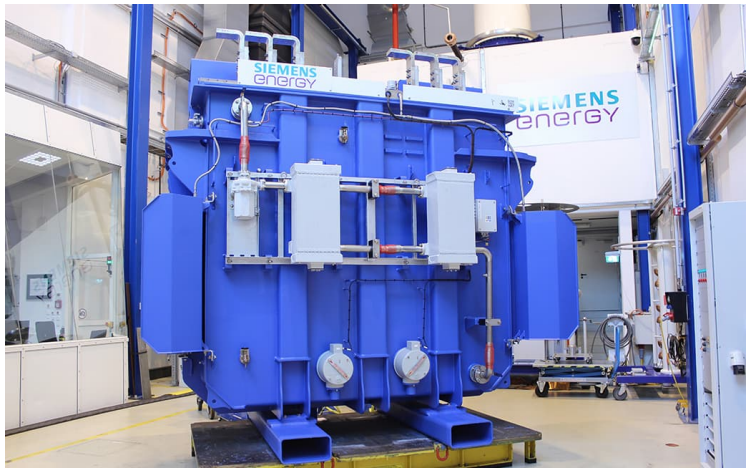
The blue GIS uses clean air as insulation medium. Clean air **is a composition of 80% N_2 and 20% O_2, cleaned and free from humidity (technical air).**

The clean air Global Warming Potential GWP is 0. Clean air is and will not be part of the EU-F-gas regulation





Make energy greener



ESTER OIL FILLED TRANSFORMERS

Environmentally friendly fire safe transformers with fully bio-degradable insulating oil for enhanced operation at high temperatures

ESTER OIL FILLED ARC SUPPERESSION COILS

Ideal compensation equipment with resonant earthing technique to protect electrical power distribution network from single phase to earth-fault

CAST RESIN GEAFOL® DISTRIBUTION TRANSFORMER

Maintenance-free, flame resistant, self-extinguishing, completely recyclable with high overload capacity for reliable power supply to load centres

On the way to the future grid …

FIGURE 1: THE 5 PRINCIPLES FOR THE ELABORATION OF THE FEDERAL DEVELOPMENT PLAN

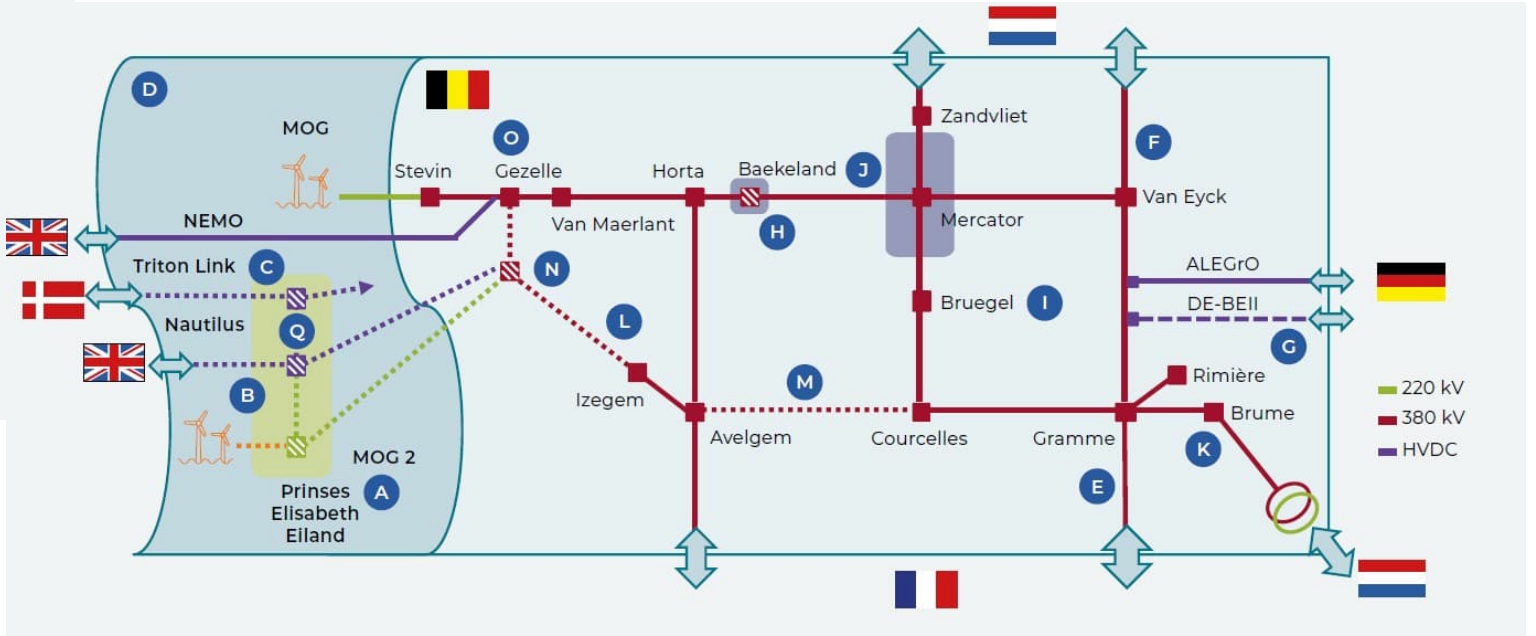
1. Maximum integration of domestic renewable energy potential in the electricity system

2. Realization of a first offshore energy hub as a gateway to the North Sea

3. Enabling a far reaching electrification of our society on the road to net zero

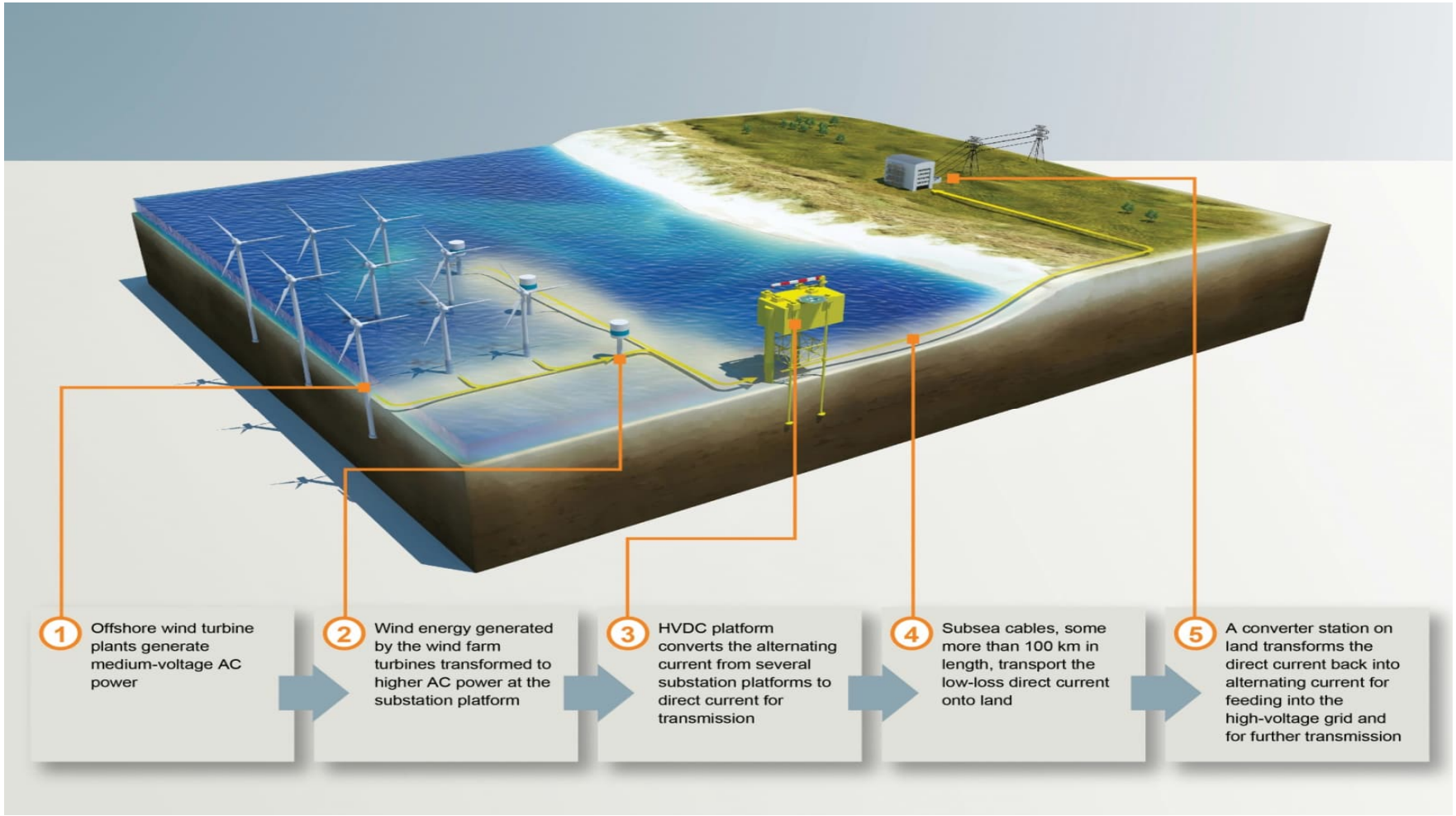
4. Maximum integration within the European electricity market to smooth out fluctuations in renewable generation and to get access to competitive prices

5. Make optimal use of the existing stucture and making it more robust

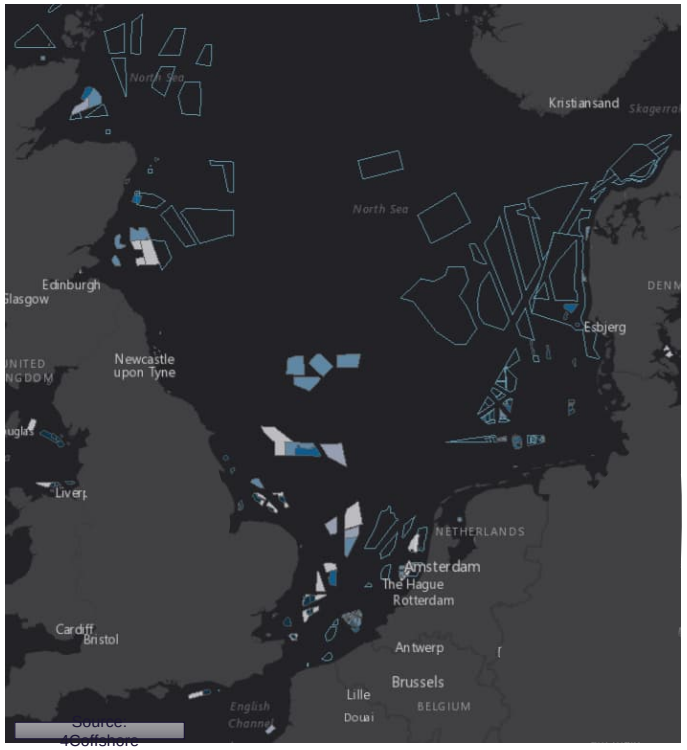


Simplification

Ramener l’ énergie éolienne offshore vers les réseaux on-shore



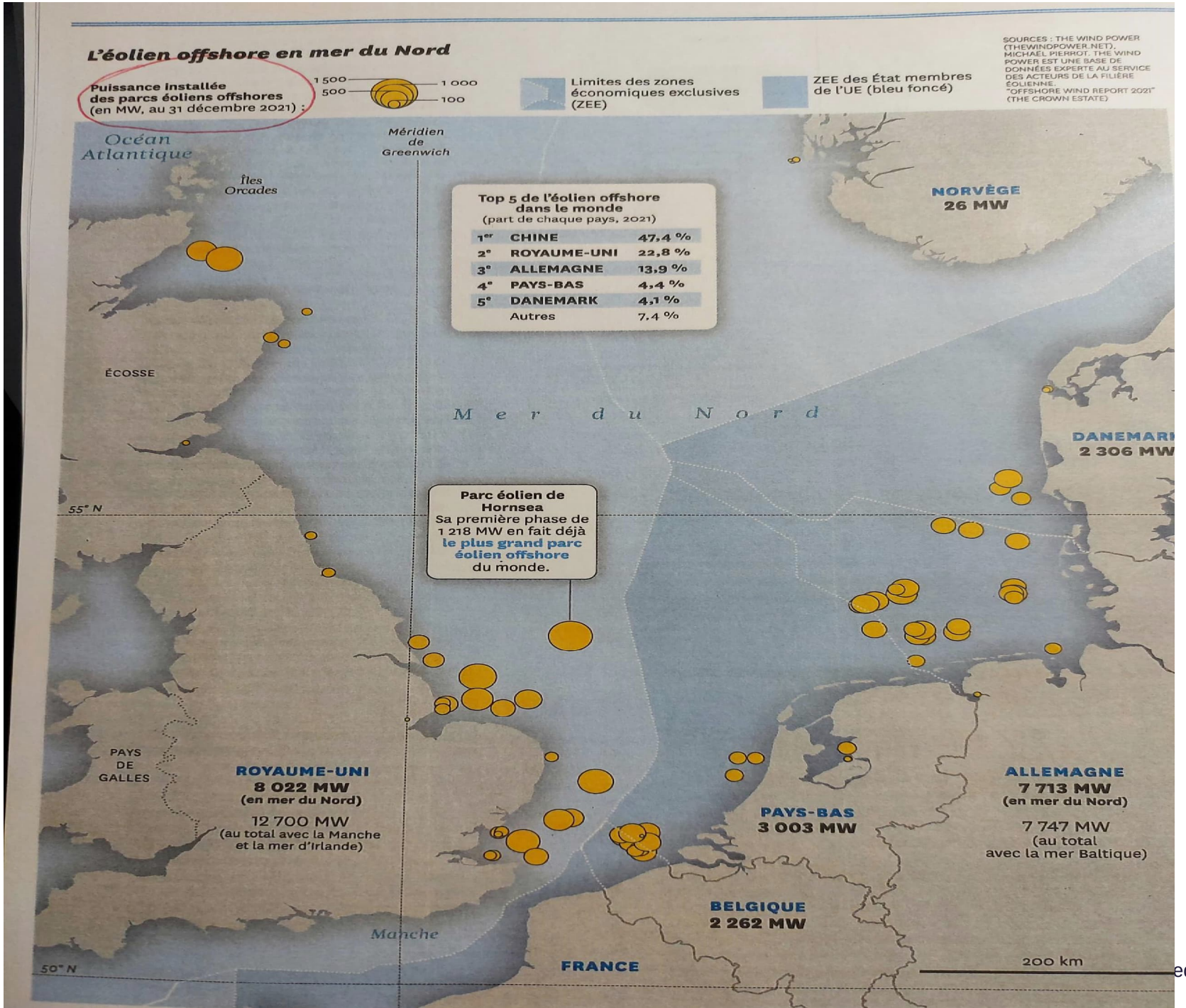
The North Sea has an energetic wind potential of more than 250 GW



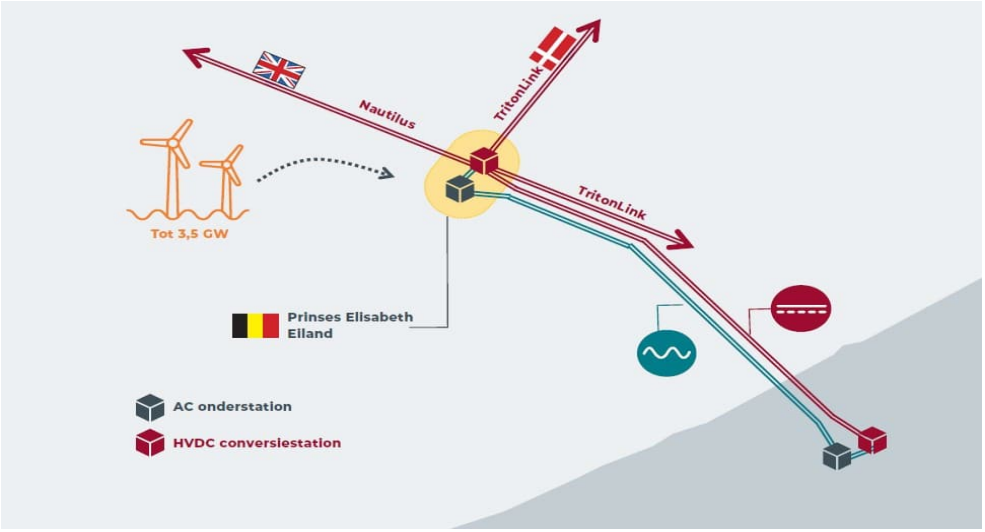
Offshore wind capacity North Sea

Installed capacity in the North Sea is increasing rapidly

							North Sea
Constructed[1] (GW)	1.2	1.1	5.5	0.9	5.7	0	~ 15
Planned by 2030[2] (GW)	4	11.5	17	3.5	20	2.7	~ 60
Potential (GW)	250 – 600 (?)						

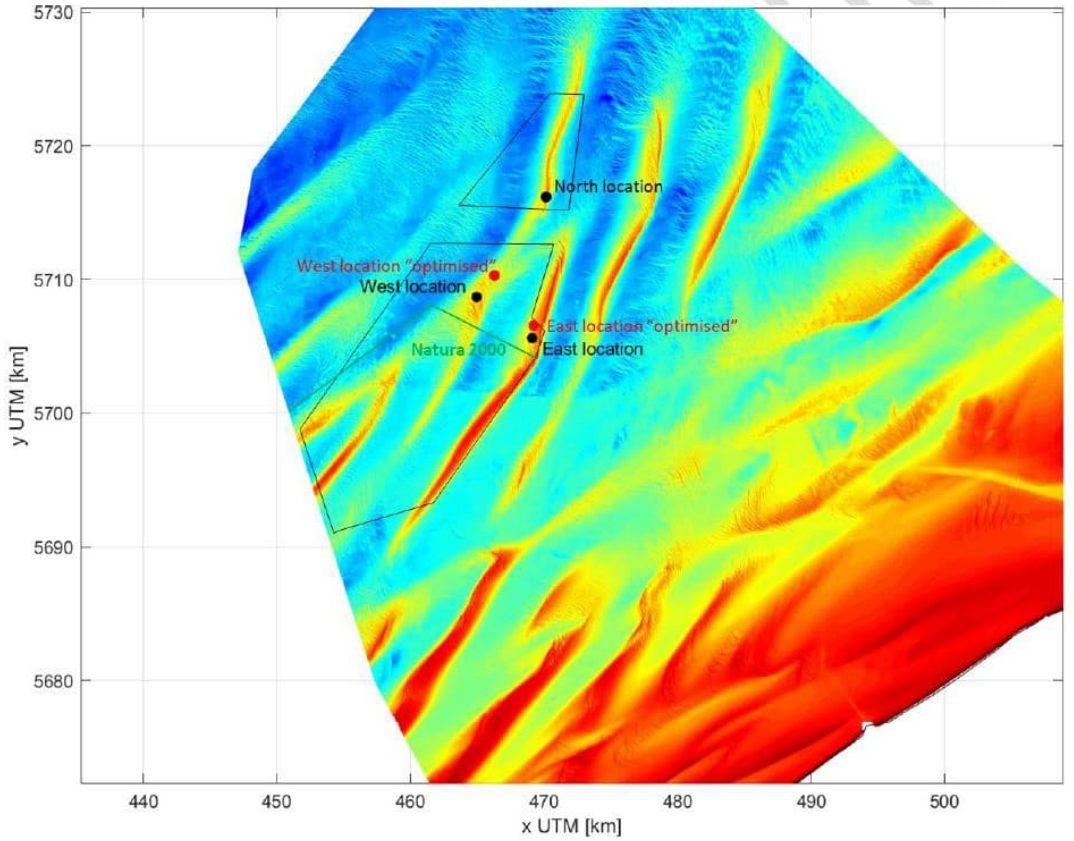


The Princess Elisabeth Island will house the transmission infrastructure to connect up to 3.5 GW of offshore wind from the Princess Elisabeth wind zone and to provide a connection point for interconnectors (such as Nautilus and Triton Link). Therefore, a mix of AC (alternating current) and HVDC (high voltage direct current) is envisaged to achieve these goals.

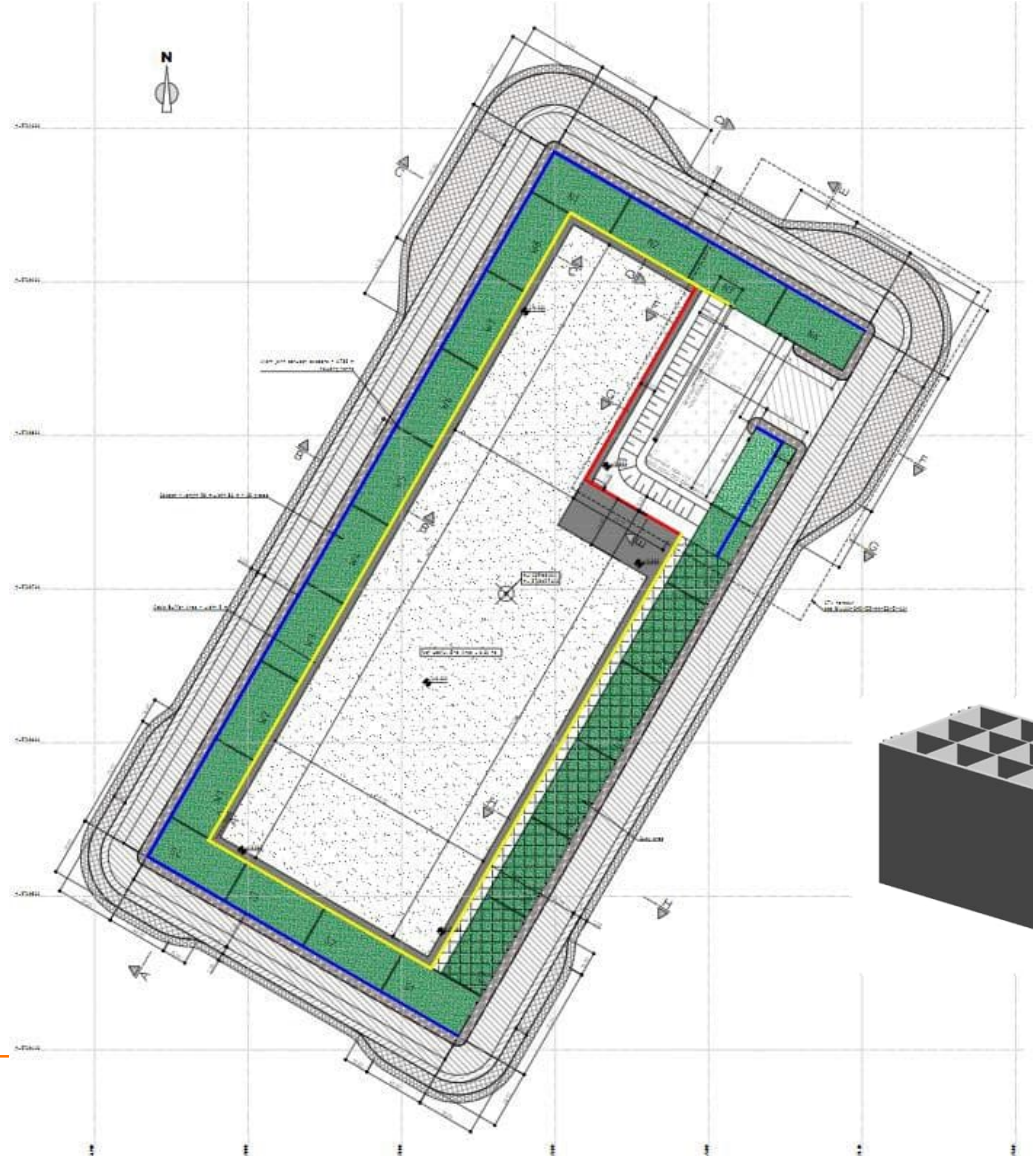


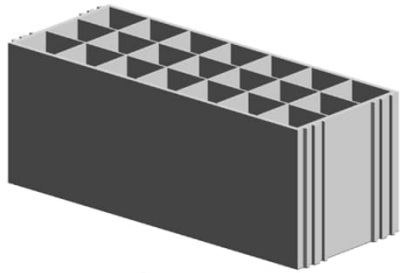
Island location

1. Limite impact on neighboring gravel beds
2. Volume of sand needed for the island
3. Cable lenghts (inter-array and export)
4. Impact on shipping traffic
5. Operational impact (cable corssings, interfaces between TSO and producer, acces possibilities, ….)
6. Impact on powerdensity of the Prinses Elisabeth zone (fex. Limitations due to helicopter flight paths).
7. Impact op de costs



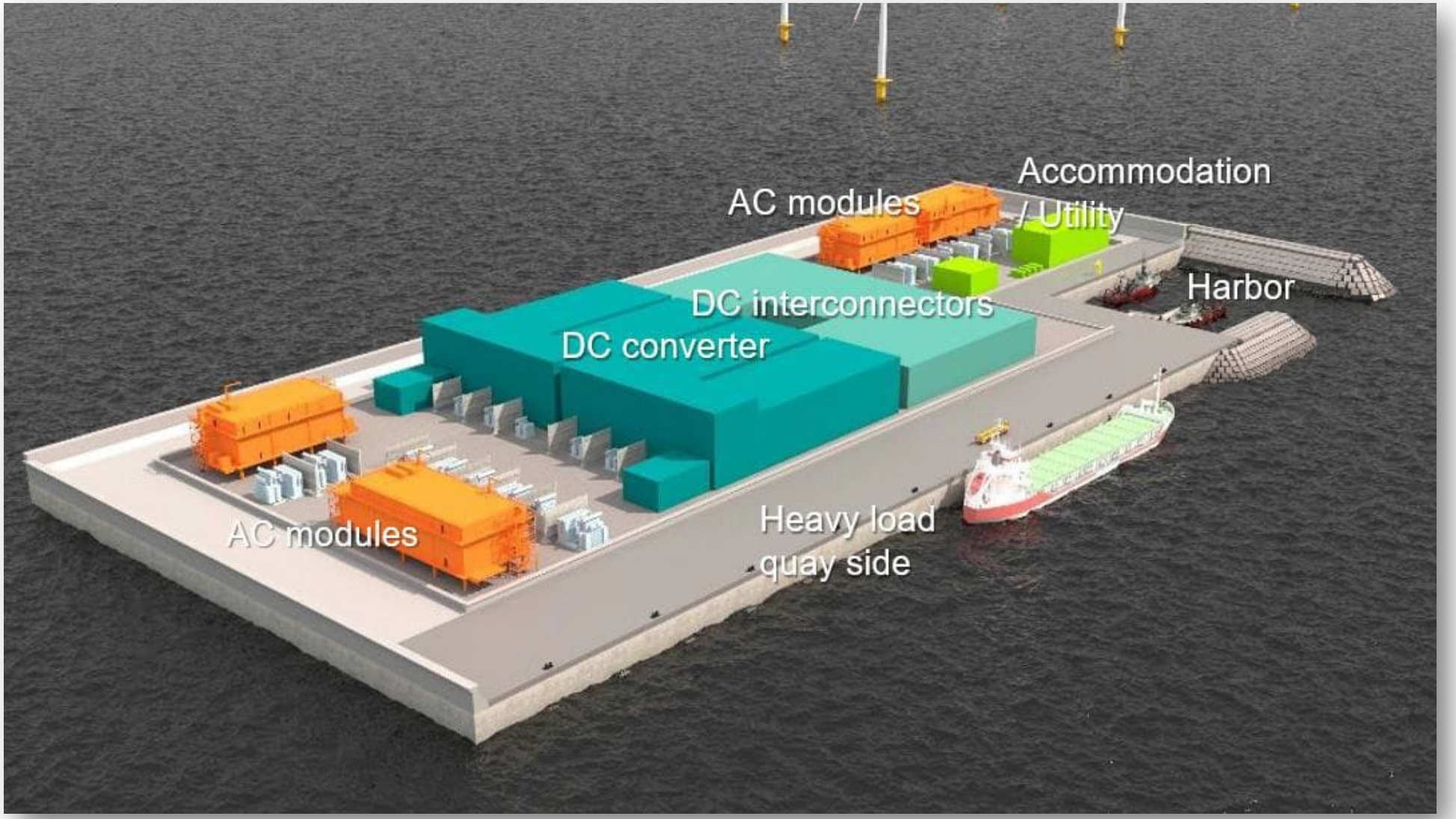
General layout



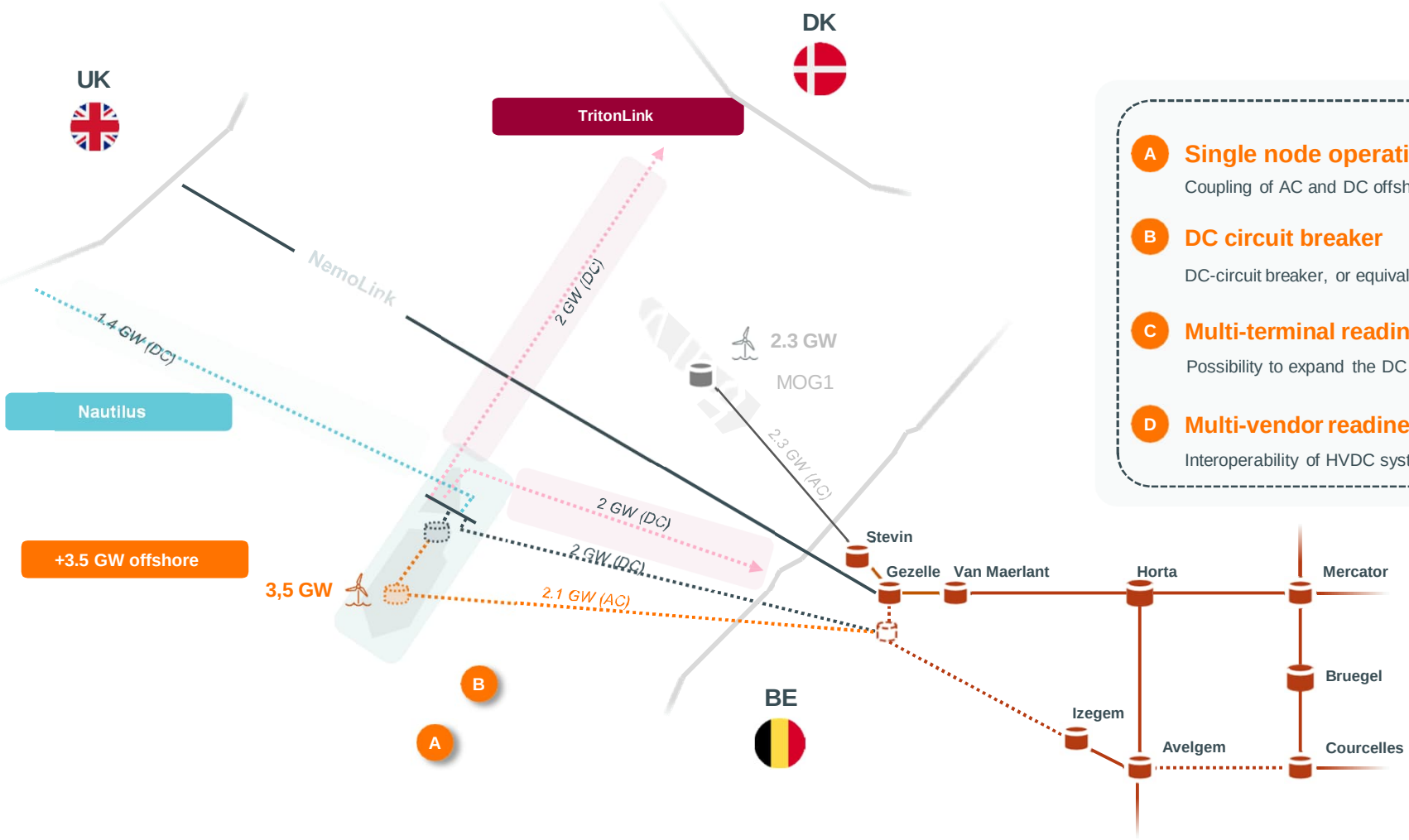


- Dimensions at water level
  - Width ~230 m
  - Length ~520 m
- Dimensions including rock protection
  - Width ~350 m
- Length ~620 m
- Net Useful Grid Area
  - 6.00 ha
- Highest point island perimeter
  - +18,5 m above low water level
- 23 caissons
  - Length 58 m
  - Width 28 m
  - Height including sea wall 32 m
  - Height excluding sea wall 22 m

Electrical Concept



Towards meshed offshore grid / challenges



A Single node operation

Coupling of AC and DC offshore substations on the Princess Elisabeth Island

B DC circuit breaker

DC-circuit breaker, or equivalent technology, to allow partial protection selectivity in the DC grid

C Multi-terminal readiness

Possibility to expand the DC grid to additional terminals and couple additional interconnectors

D Multi-vendor readiness

Interoperability of HVDC systems from different vendors

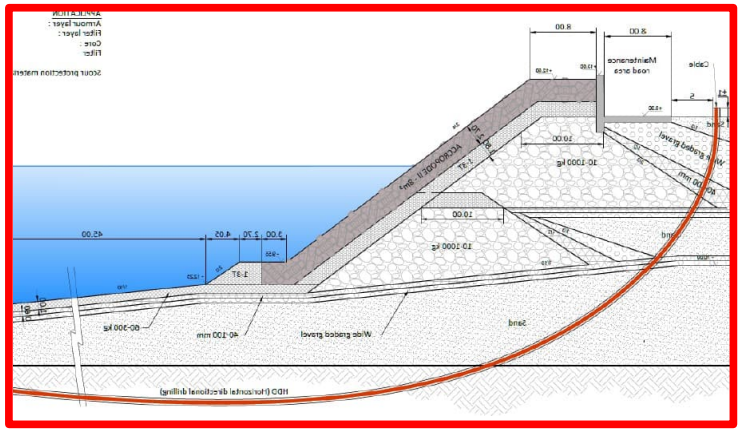
Legend

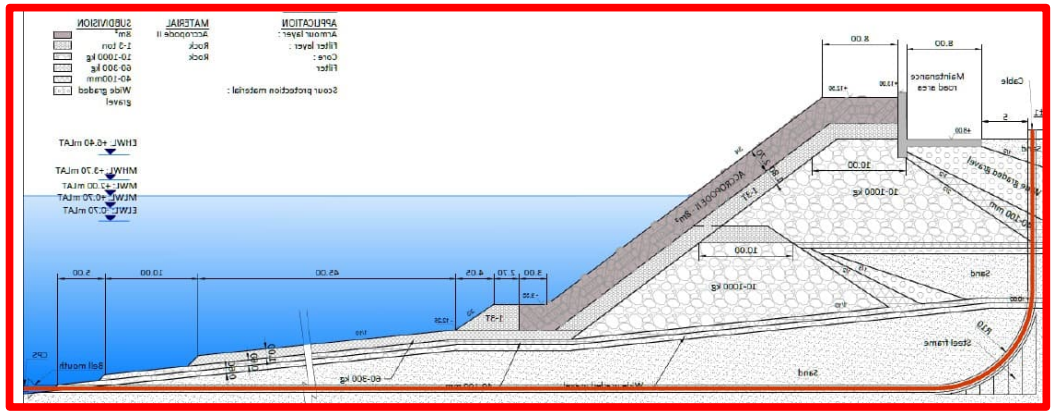
- AC - 220 kV
- AC - 380 kV
- DC

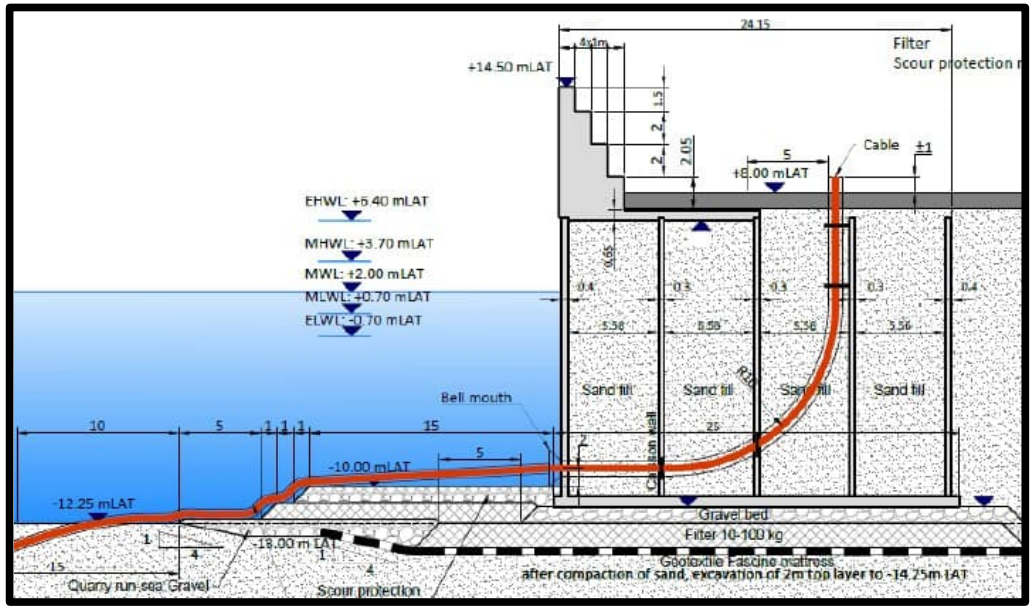
Lots of novelties and even world premieres

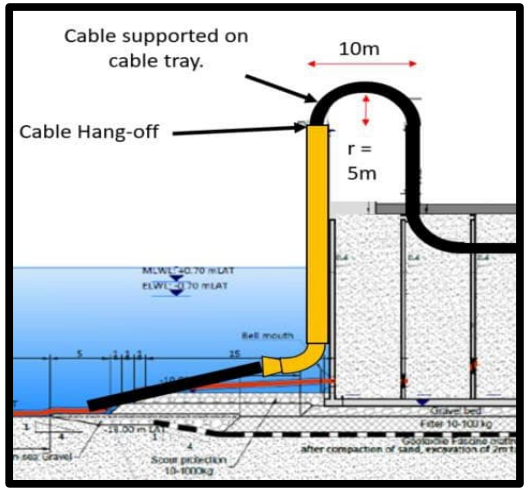
Top Technology skills

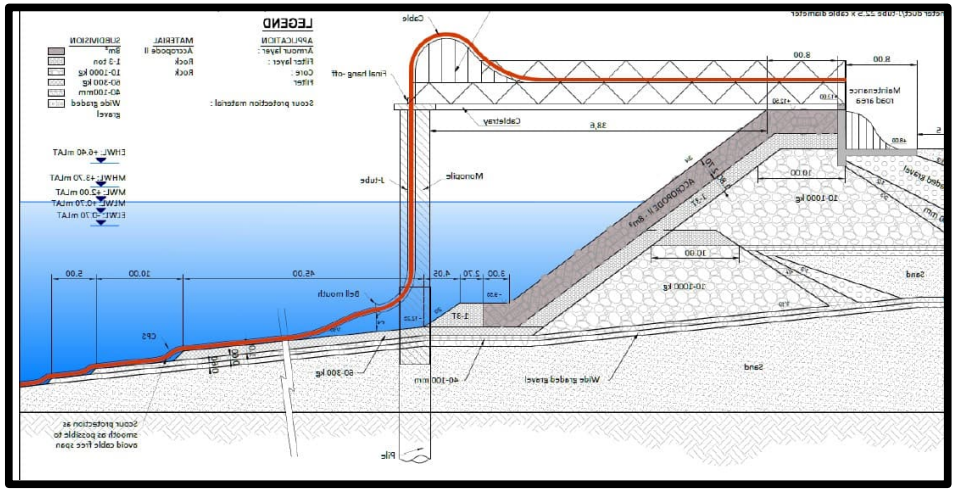
Offshore Cable challenges





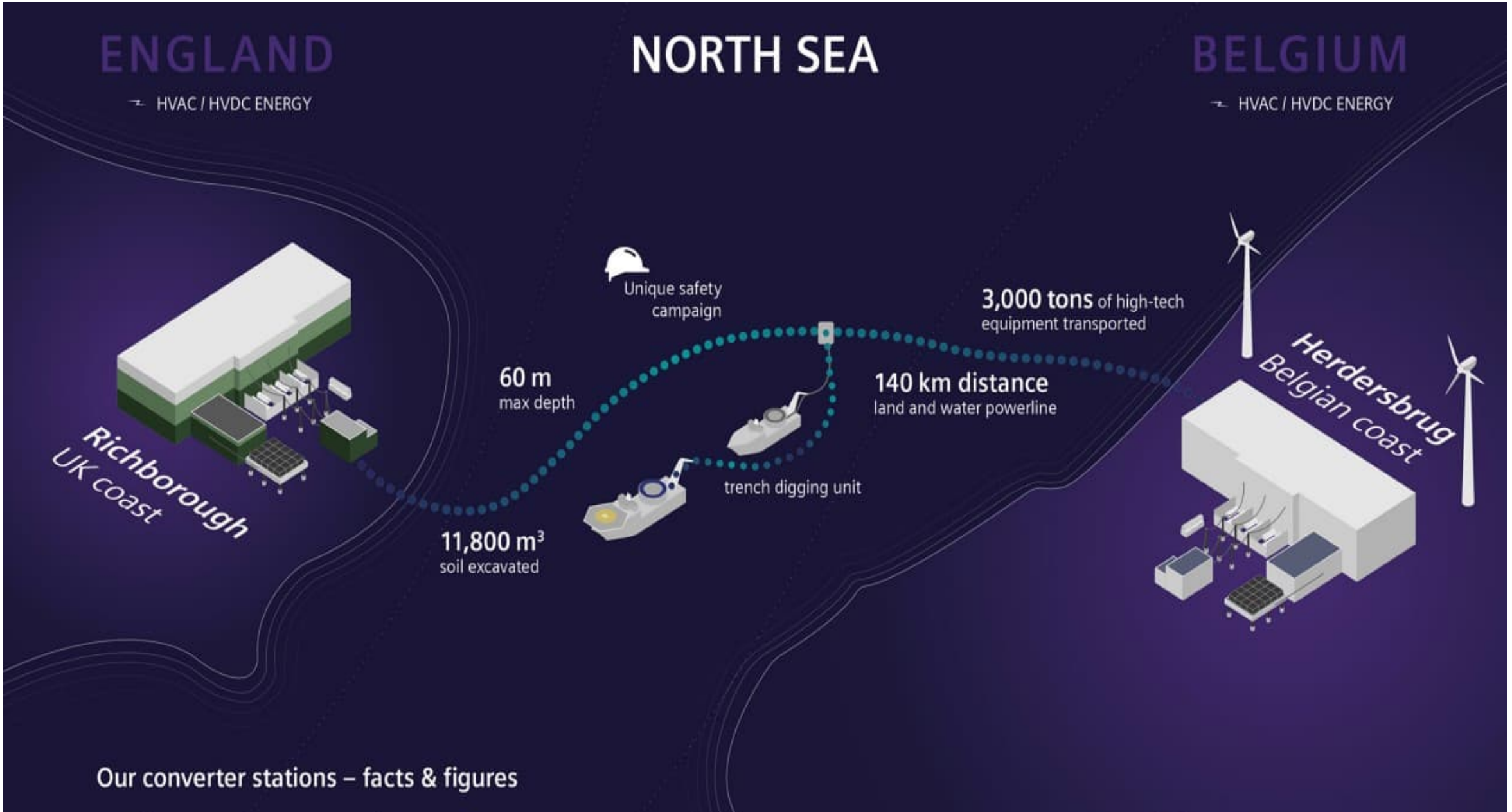






Creativity

NEMO (HVDC link BE-UK)



ALEGrO , un “pont électrique enterré ” entre la Belgique et l’Allemagne .

A project of Amprion and Elia

First electricity link between Germany and Belgium

Customer reference: ALEGrO

Challenge

- ALEGrO increases energy security for Germany and Belgium and supports the integration of renewable energy to encounter bottlenecks in the grid
- The link provides the highest degree of controllability of the power flow

Solution

- Using state-of-the-art converter technology and 90 km long underground cables, ALEGrO is connecting the Belgian and German high-voltage electricity systems with a transmission capacity of 1,000 MW

Benefit

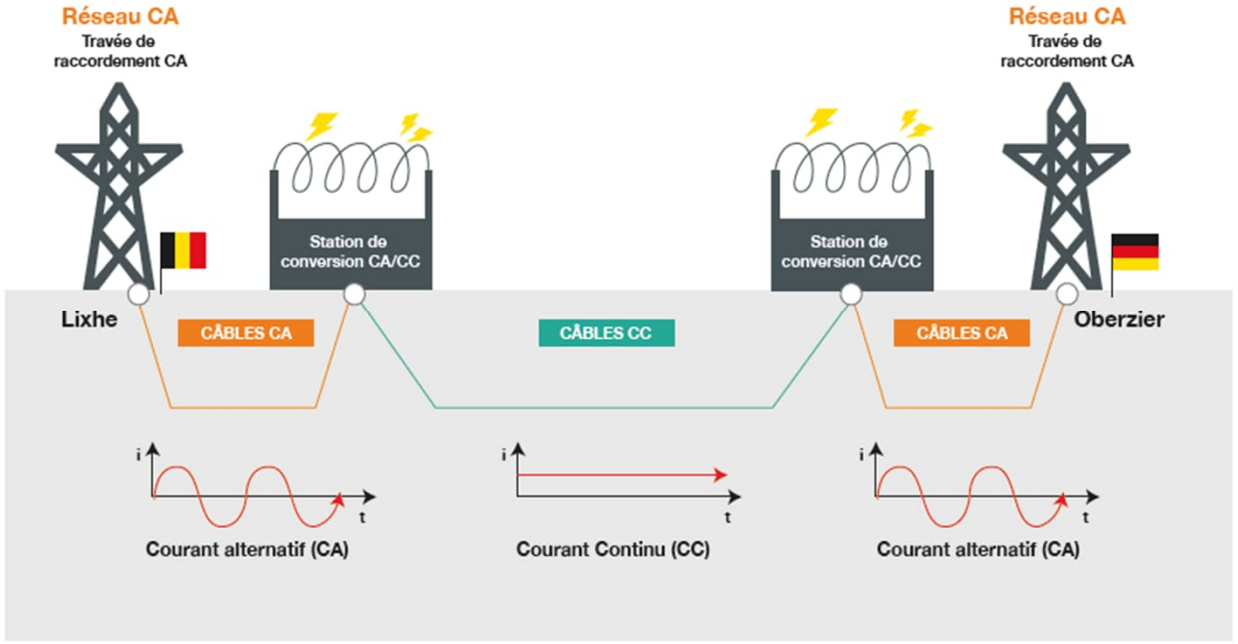
- Proven HVDC Plus technology for highest reliability and efficiency
- Converters with fast control and protective intervention allow to flexibly adjust the power flow ensuring stable grid operation conditions

Customer
Amprion & Elia Group

Location
Belgium – Germany

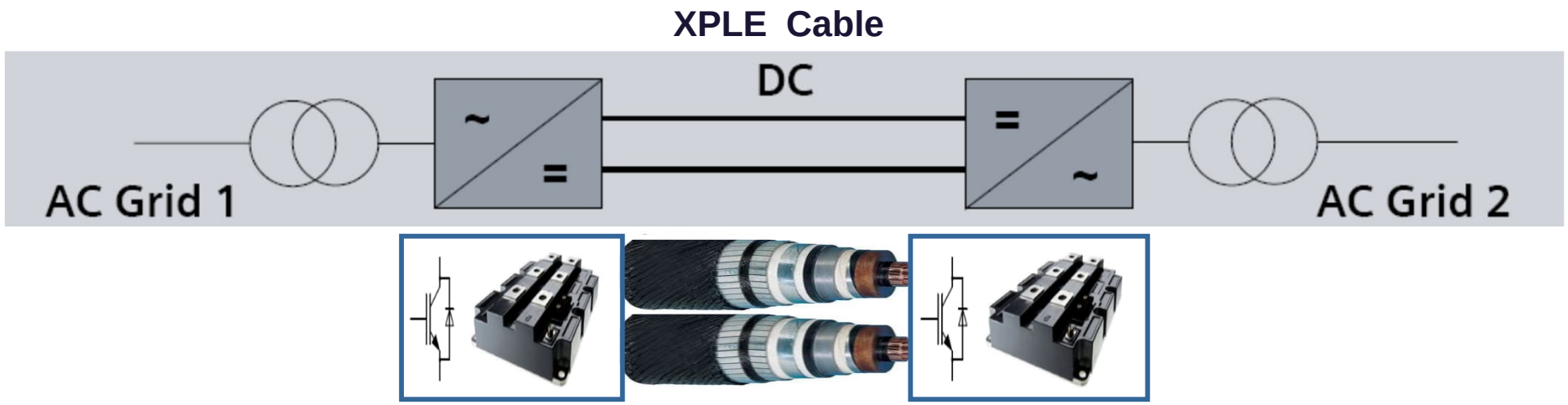
Completion
2020

What’s ALEGrO



Power Rating	1000 MW, Symmetrical Monopole
Type of Plant	HVDC PLUS in half-bridge topology
Voltage Levels	DC : ± 320 kV DC AC : 400 kV, 50 Hz
Semiconductors	IGBT

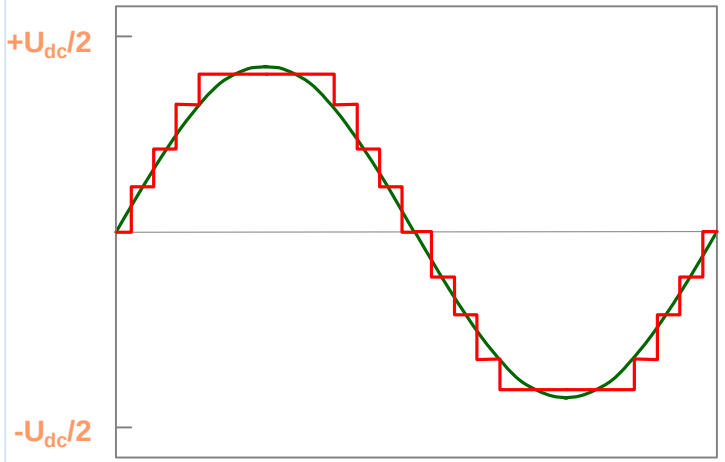
HVDC Plus Interconnection
Voltage Sourced Converter (VSC)



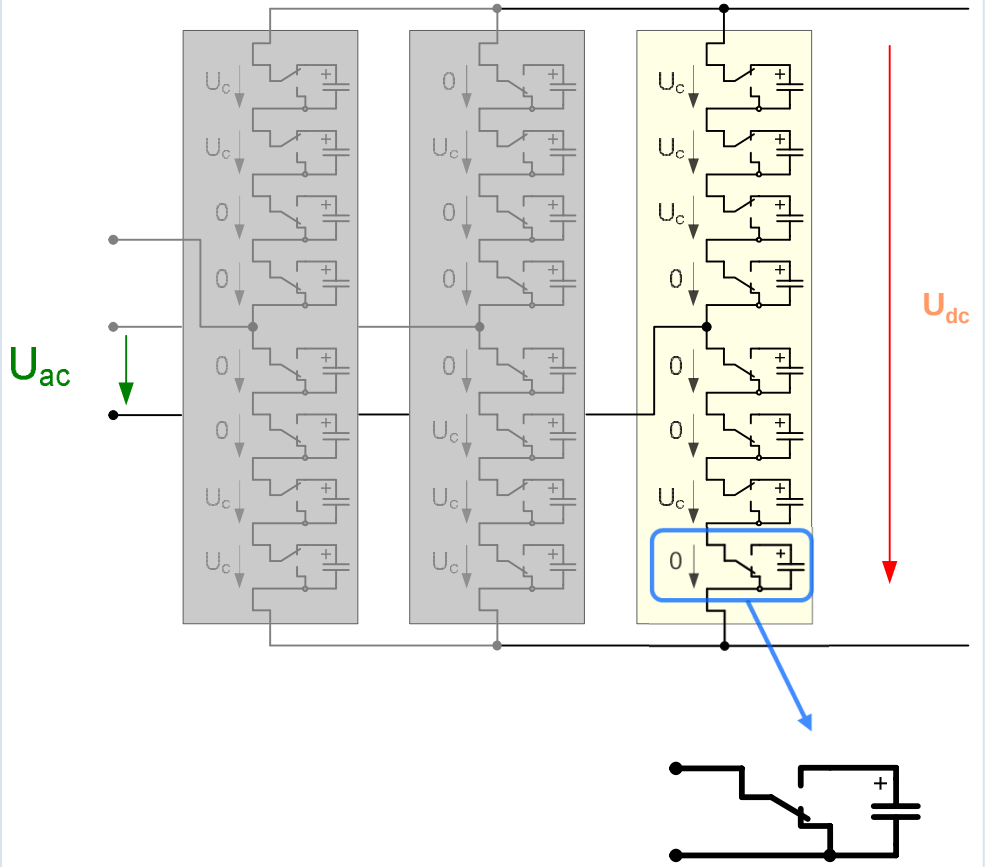
IGBT : Semiconductor Switches with turn-on and turn-off Capability

Basics of HVDC PLUS
Modular Multilevel Converter - MMC

Examples Half Bridge



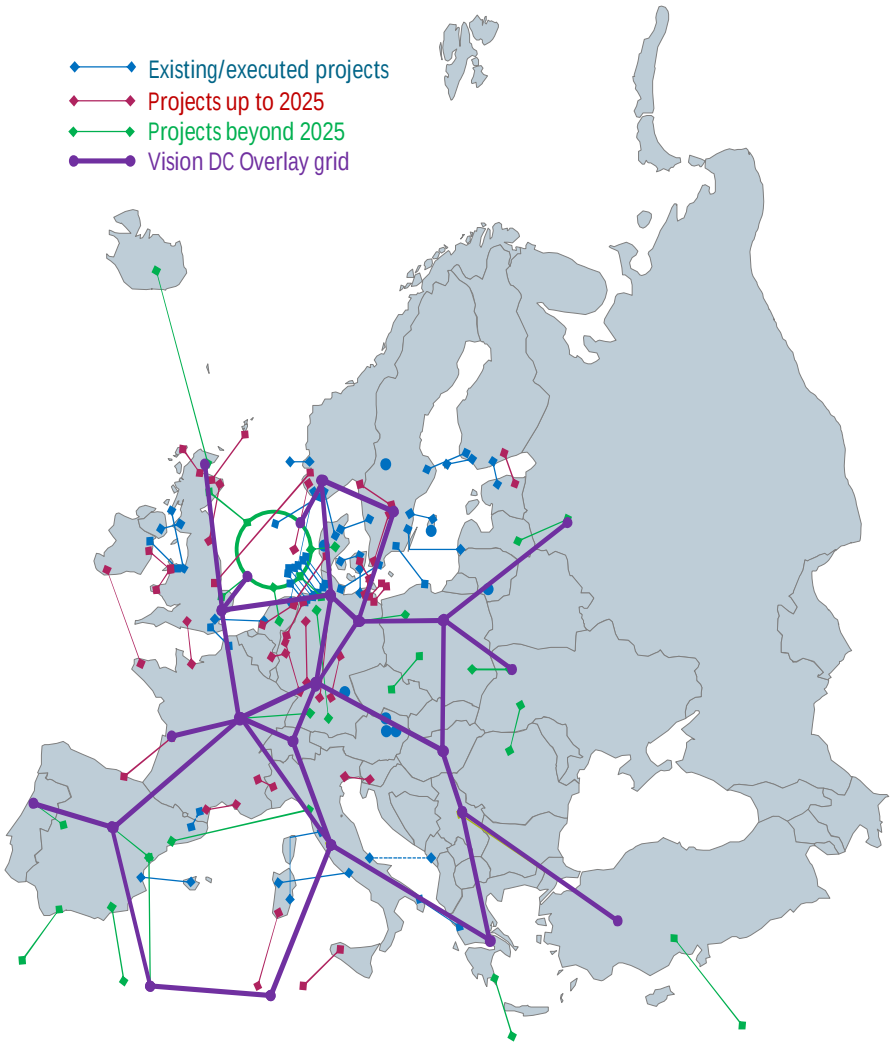
- Low level of harmonics and HF noise
- Low switching losses
- Modular arrangement with identical two-terminal power modules



Much better performance of the grid with HVDC transmission systems

- Supporting the integration of renewable generation and enhance the transmission grids (grid stability, voltage support, losses reduction)
- Improving the security of supply (re-energizing of blacked-out networks)
- Contributing to the public acceptance (lower visual impact , less space requirements , constant magnetic field)
- Facilitating the operation of the electricity market (impact on the price) by independent control of active and reactive power in both directions

HVDC Grids
Look into the future



Energy Transition
Industrialize and Deploy

How can we deploy at Speed?

Social Acceptance
- Communicate: work with what we have

Government Support
- 2030/2050 goals need longer term view

Overcome Regulatory Constraints
- Regulation for future networks, rather than legacy models

Build Industry standards
- 15 MW offshore turbines
- 2 GW HVDC connections, bipolar (offshore), scalable

Le développement des réseaux de transport d‘ électricité en Belgique est aujourd’hui , extrêmement freiné , par manque de :

1) cadres politiques et régulatoires “ favorables à l’électrification “

2) délais de réalisation des projets d‘ infrastructure des réseaux , définissables et suffisamment courts (étude , permis , recours , réalisation,…)

3) personnel compétent sur le plan technique et multidisciplinaire

Merci pour votre attention

Arlon , le 1er décembre 2023

Ir. Alain Belvaux
Be Ohm Consult