A Grid to Decarbonise Europe

Conference presented by:

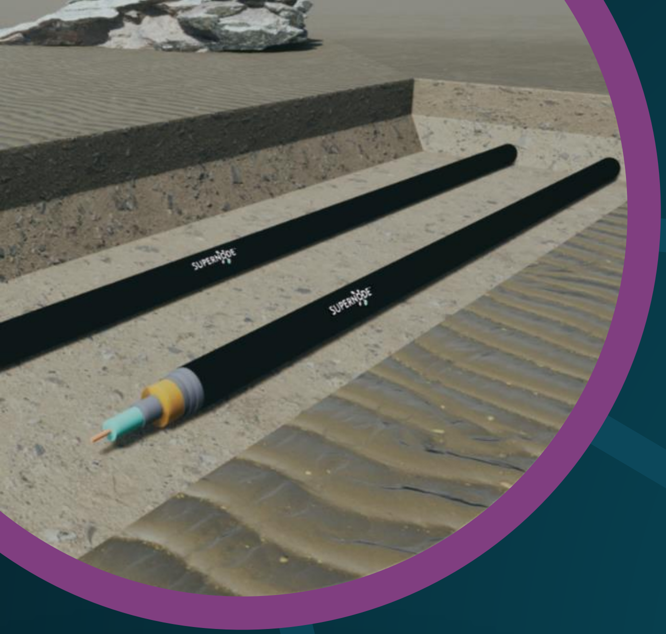
currENT

SuperNode Ltd

University of Strathclyde

KU Leuven

CurrENT
Enabling Network Technology throughout Europe



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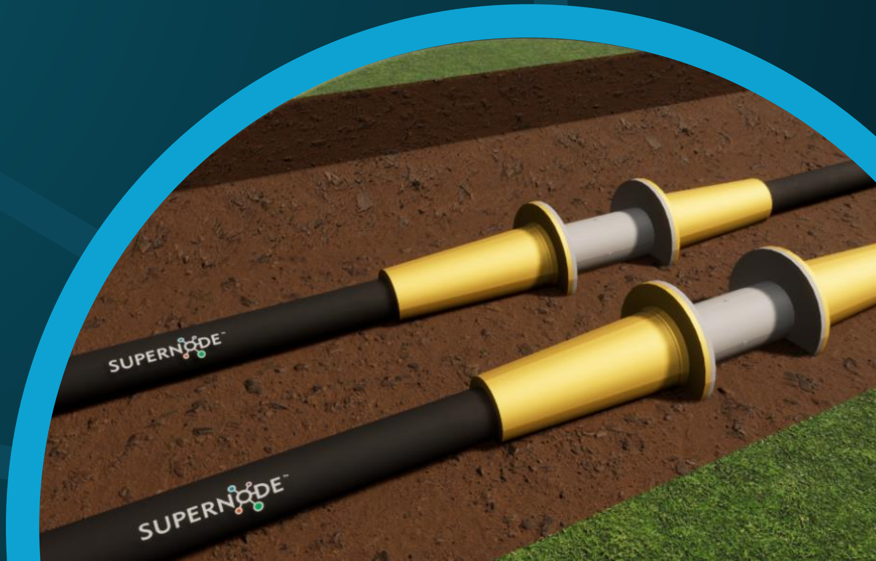
A GRID TO DECARBONISE EUROPE



INTRODUCTION

1. Secure, Sustainable and Affordable energy is really important to maintain our Wellbeing!

2. We have enjoyed this for the best part of 100 years, but the system only runs with fossil fuel (carbon) and we have a Global Climate Crisis!

✓ Game-changing 2050 Climate Policy and Targets adopted.

✓ Electrification is the major driver in combating Climate Change.
- PtG used where electrification is not practicable

✓ Generation technology is fit for purpose.

X Grids are the enabling backbone of our Energy future and the most significant challenge and constraint.

WORKING BACKWARDS FROM THE TRANSFORMATIONAL GOAL OF DECARBONISATION

Rather than just incrementing forwards to somewhere – work backwards from the goal and vision we share!

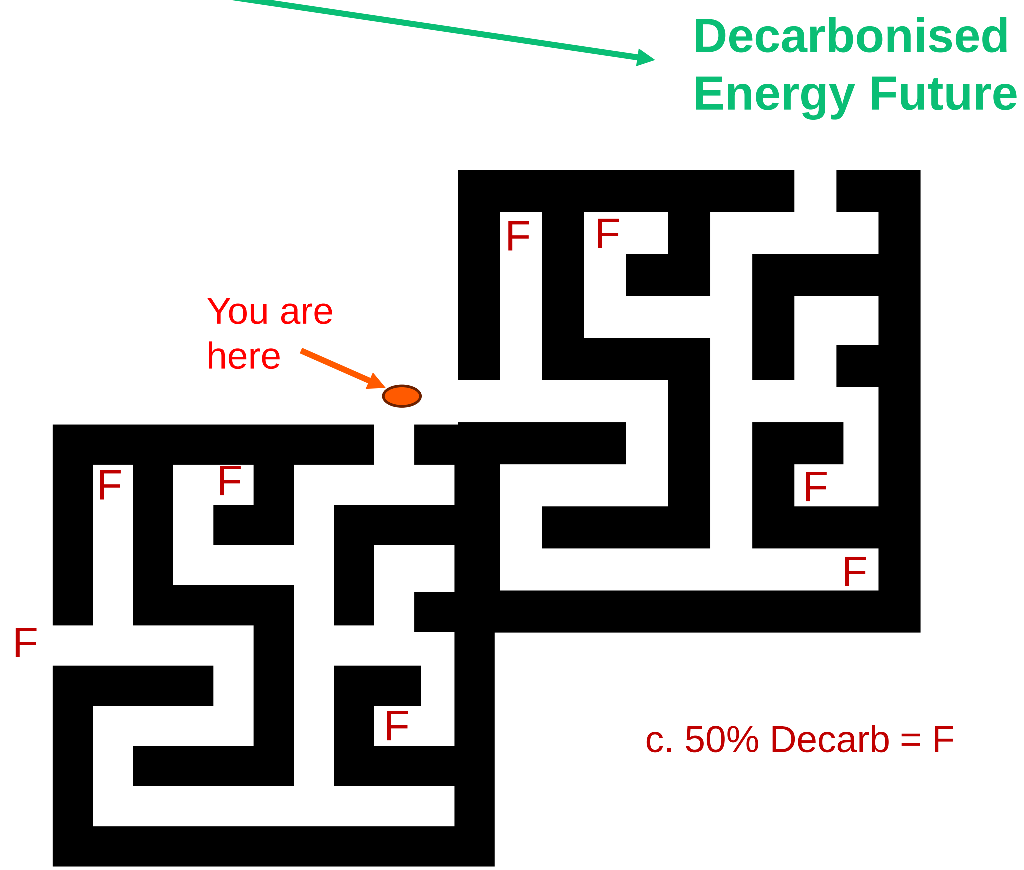
What does a System that can operate without Carbon look like?

What changes do non-fossil generation impose on 2050 Grid design?

How big is the Grid / how much Connectivity is needed?

What is the optimal circuit size?

Is current grid technology adequate?



TECHNOLOGY AGNOSTIC NETWORK MODEL TO KEEP THE LIGHTS ON WITHOUT CARBON

SETUP AND ASSUMPTIONS

- Network analysis is **Technology Agnostic**.
- **Nodes** have geographical locations and reflect national RES targets and demand.
- Each node is limited in size and connected by at least **2 power corridors**.
- **LSI of 3GW** for the continent and **2GW** for Ireland, UK and Scandinavia.
- **Max circuit size** is limited to **12GW**
- In a contingency event adjacent circuits will operate with **additional capacity**
- Existing Transfer Capacity between nodes is not modelled so within country corridor capacity and to a much lesser extent international corridor capacity requirements may be overstated.
- Model assumes **no interconnection outside of Europe.**

The 2050 RELAY Network Model

Objective:

Create an indicative pan-European network based on carbon free energy.

Energy scenario*:

Solar: 1,102GW
Offshore Wind: 740GW
Onshore Wind: 450GW
Total RES: c. 2,500GW

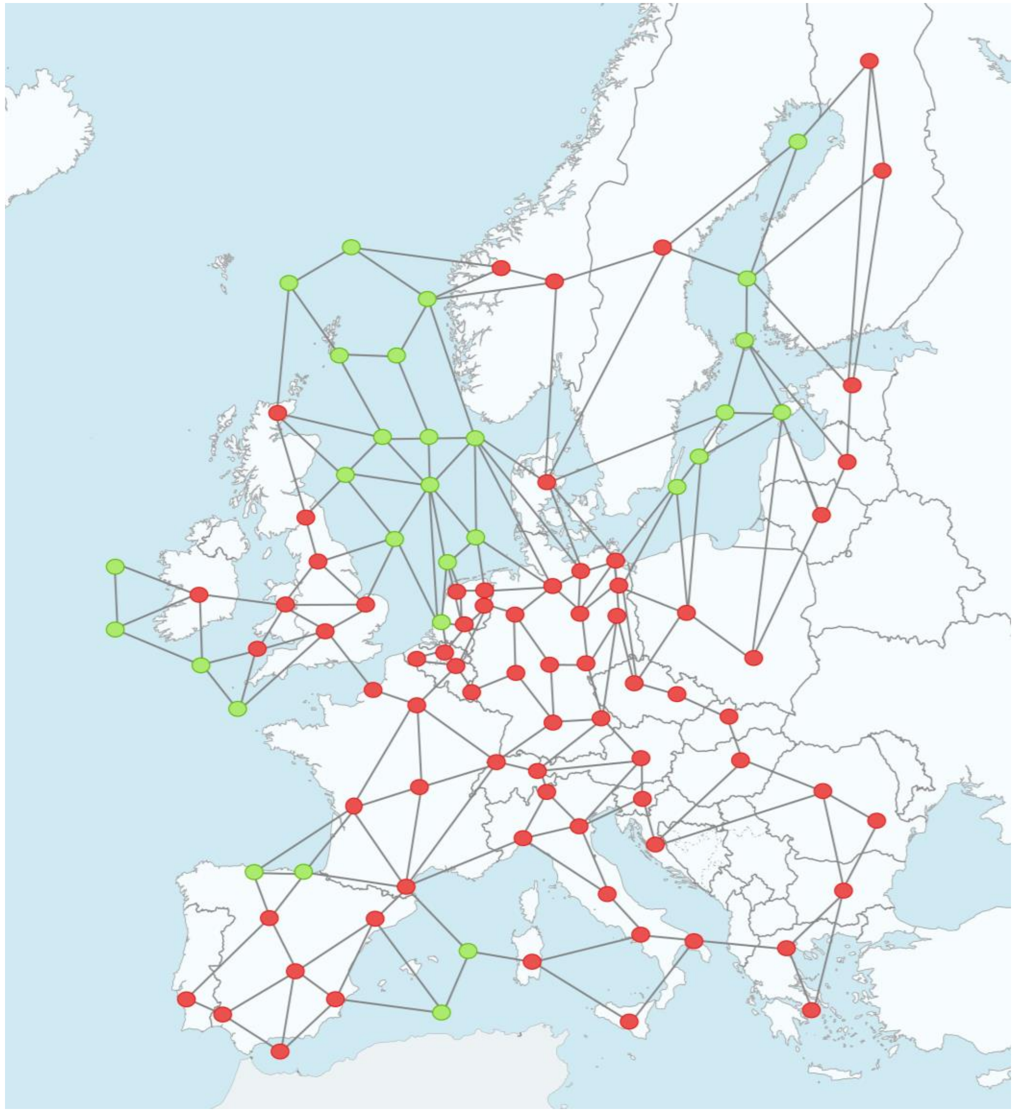
No. of Nodes: 103

No. of Corridors: 198

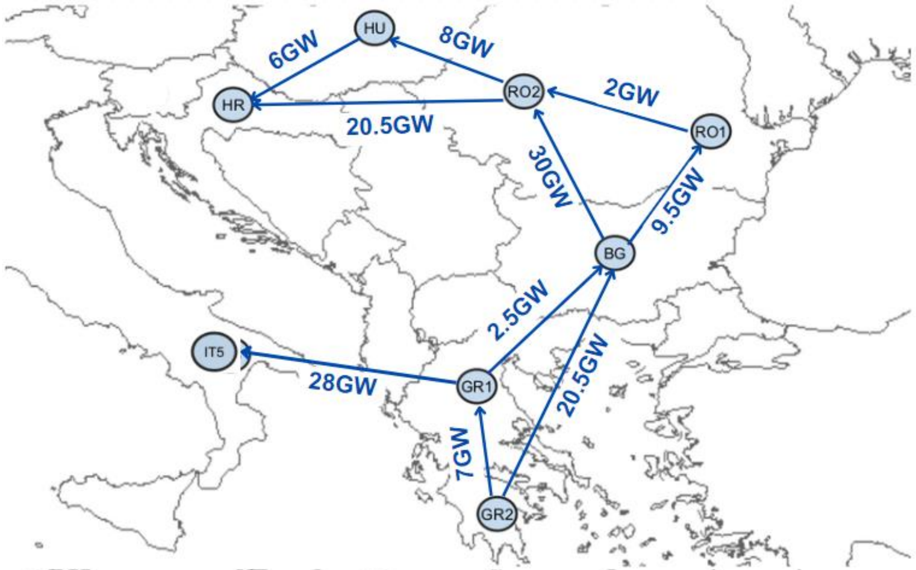
*Energy scenario used in line with ENTSO-E's TYNDP and Commission 1.5Tech - / Demand based on ENTSO-E weather data is 2019

METHODOLOGY

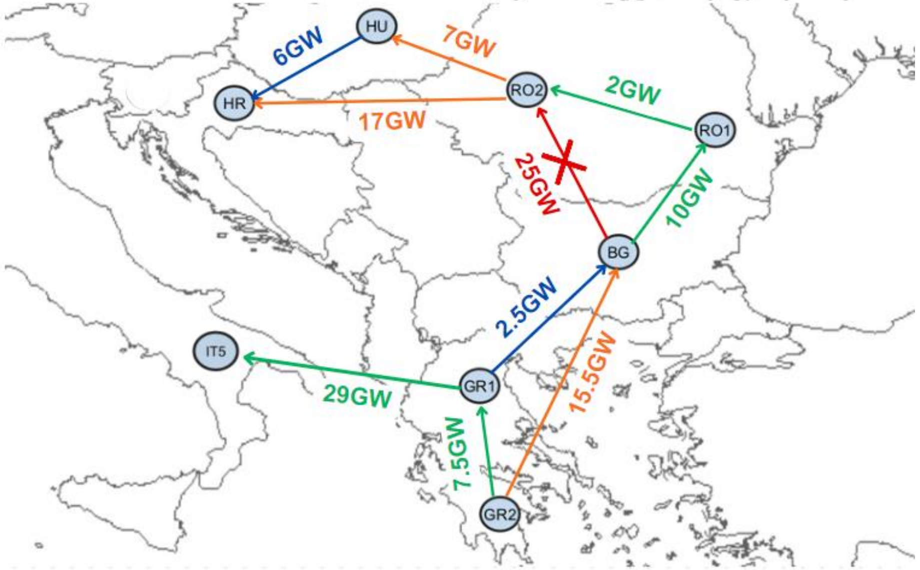
1. Ensured generation adequacy, including storage to support generation/demand deficit.
2. Developed heuristic initial network corridors.
3. Used modified max flow algorithm to size corridors and ensure the network supports internodal flows 95% of the time.
4. Identified the 8 most demanding hours for grid transfers.
5. Conducted contingency analysis on these 8 hours for all corridors, with reducing circuit sizes, to maintain stability.
6. Calculated the circuit sizes for corridors across the network.



CASE 1: BG-RO2 (STABILITY CRITERION NOT MET)



Before N-1 Event



After N-1 Event

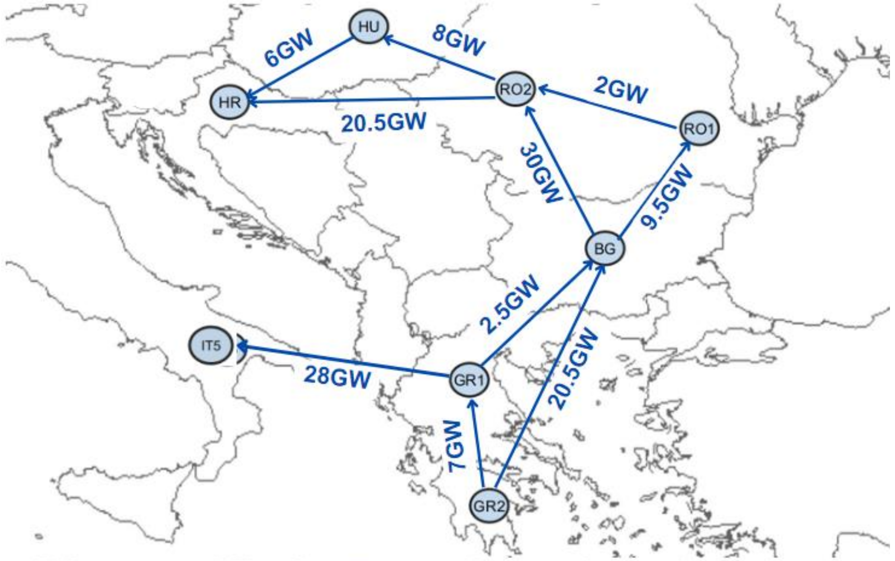
N-1 Corridor Analysis: (BG, RO2)

- **Original Capacity:** 30GW
- **Circuit Size Used:** 7.5GW
- **Adjusted N-1 Capacity:** 24.75GW

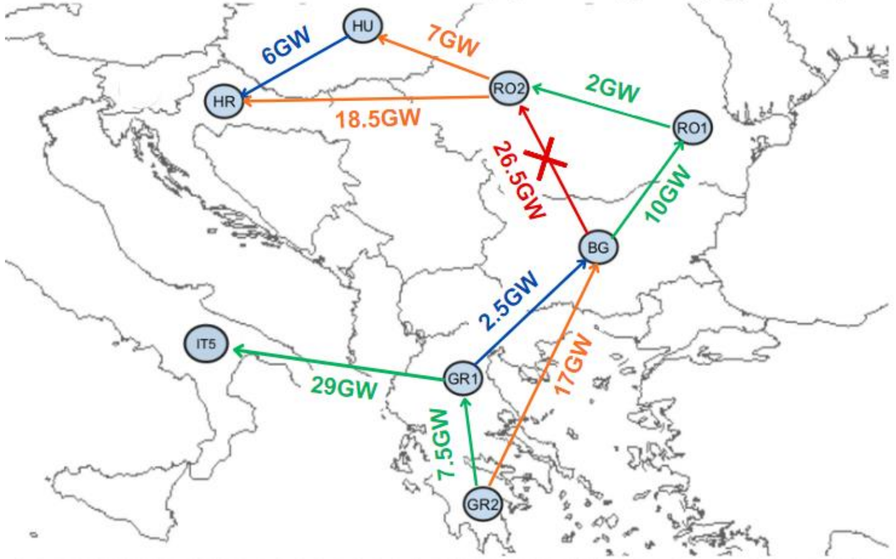
System Performance Metrics:

- **Stability Criterion:** 3GW
- **Active Loss:** 4.2GW
- **7.5GW** circuit size does not meet the criterion (4.2GW > 3GW)

CASE 2: BG-RO2 (STABILITY CRITERION MET)



Before N-1 Event



After N-1 Event

N-1 Corridor Analysis: (BG, RO2)

- **Original Capacity:** 30 GW
- **Circuit Size Used:** 6 GW
- **Adjusted N-1 Capacity:** 26.4 GW

Network Performance Metrics:

- **Normal Operations Flow**: 619.3GW
- **N-1 Event Flow**: 616.7GW
- **Stability Criterion:** 3 GW
- **Active Loss across the network:** 2.6 GW

6GW circuit meets the criterion 2.6 GW < 3 GW

CIRCUIT SIZING: SINGLE CORRIDOR

Corridor: ('BG', 'RO2'), Original Capacity: 30.00 GW

CIRCUIT SIZE (GW)	N-1 CAPACITY (GW)	ADJUSTED N-1 CAPACITY (GW)	REAL CAPACITY LOSS IN THE CORRIDOR (GW)	ACTIVE LOSS IN THE NETWORK (GW)
1 * 30	0	0	30	26.9
2 * 15	15	16.5	13.5	12.4
3 * 10	20	22	8	6.9
4 * 7.5	22.5	24.75	5.25	4.2
5 * 6	**24**	**26.4**	**3.6**	**2.5**
6 * 5	25	27.5	2.5	

Objective: Determine maximum circuit size for stability within an acceptable loss threshold

Example: 6GW circuit size meets < 3 GW criterion

Process:

- **Identify Potential Circuit Sizes:** Calculate corridor capacity divisors for potential circuit sizes
- **Adjust Capacity:** Subtract circuit sizes from corridor original capacity, then apply +10% adjustment
- **Evaluate Impact:** Compare network flow with normal operations to calculate active loss until circuit size is found

CIRCUIT SIZE ANALYSIS: FULL NETWORK

Objective: Identify optimal circuit sizes across all corridors and extreme demand hours.

Process Overview:

1. **All Corridors, Single Hour**: Extended single-corridor analysis to all corridors for a specific hour
2. **All Corridors, Extreme Demand Hours:** Conducted circuit size analysis for all corridors across eight extreme demand hours
3. **Optimal Circuit Size Determination:** For each corridor, identify the circuit size that maintains stability across all extreme hours

Table below showcases average circuit size by geographical region and for the entire network, including ranges

	AVERAGE CIRCUIT SIZE	MIN CIRCUIT SIZE	MAX CIRCUIT SIZE
Western Europe	6.5 GW	2 GW	12 GW
Scandinavia	4.5 GW	2 GW	12 GW
Eastern Europe	5.5 GW	2 GW	12 GW
Northern Europe	6 GW	2 GW	12 GW
Southern Europe	5 GW	2 GW	12 GW
Offshore	7 GW	2 GW	12 GW
NETWORK AVERAGE	**6 GW**		

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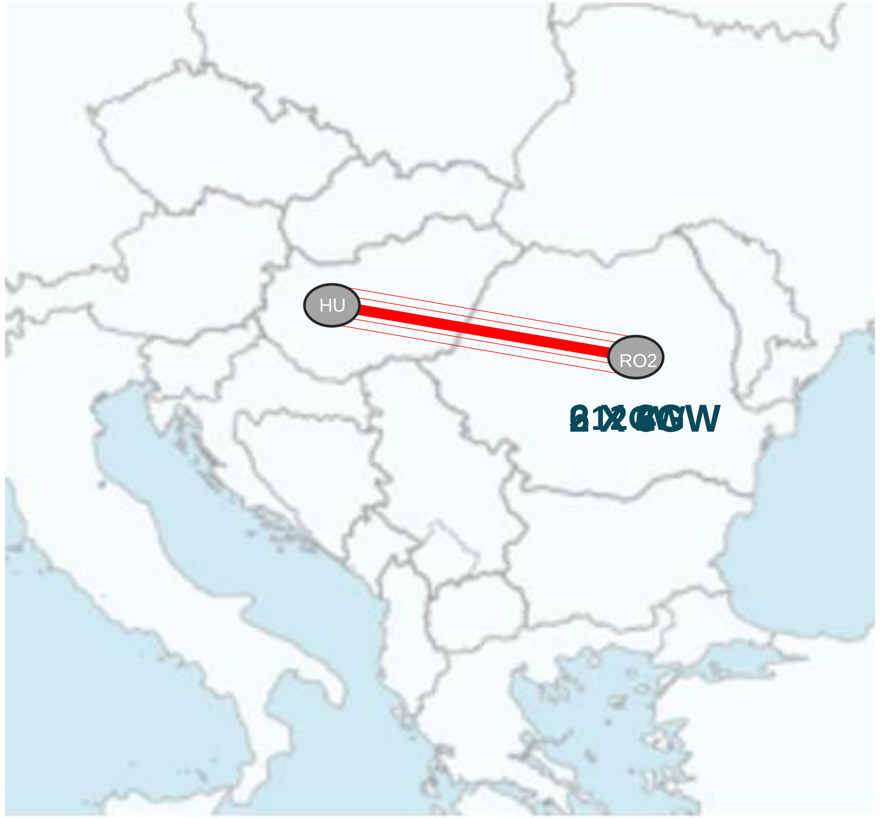
CIRCUIT KILOMETRES ANALYSIS – INDIVIDUAL CORRIDOR

Corridor	Distance (km)	Capacity (GW)	GW.km
Romania 2, Hungary	262	12	3,143

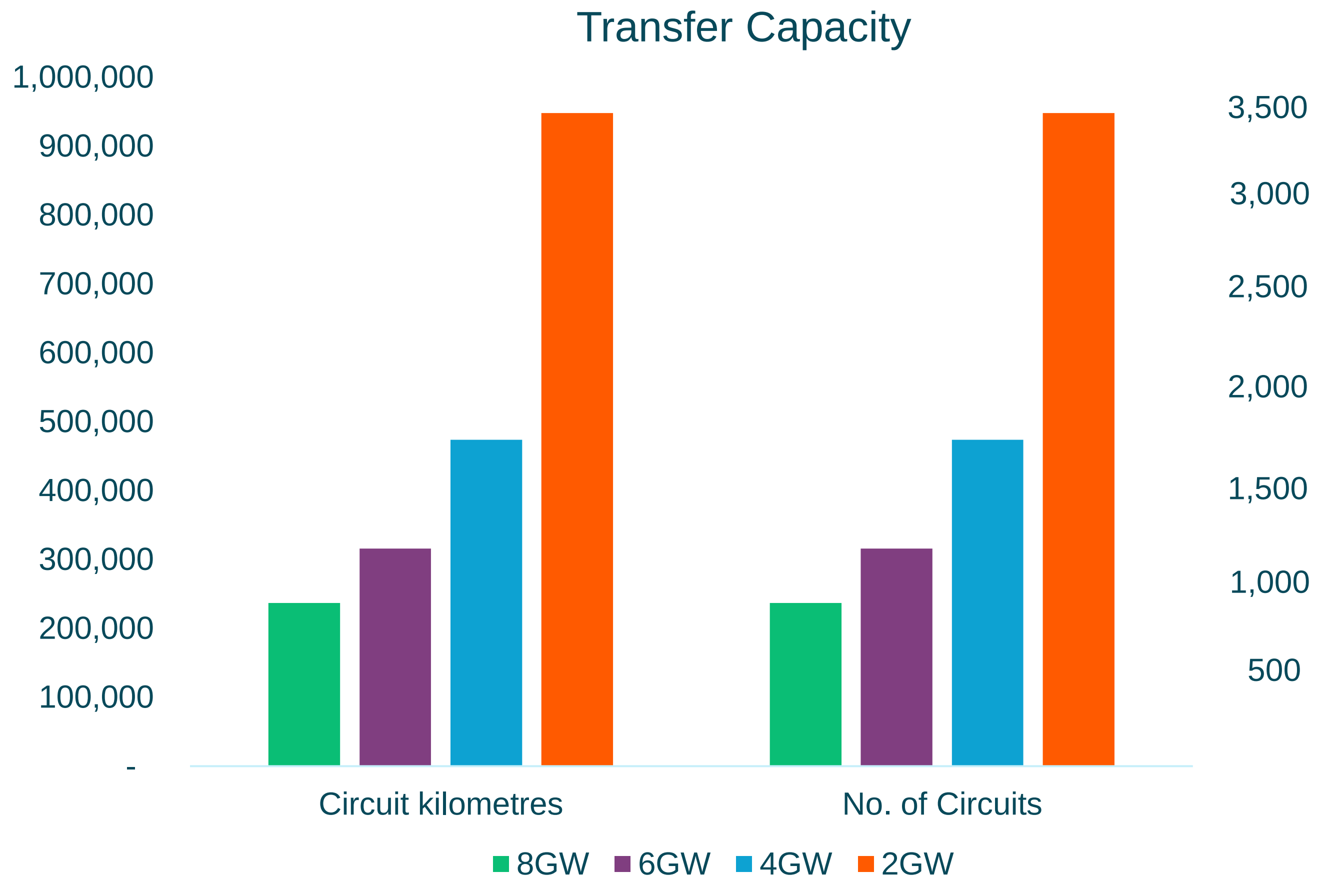
Technology Capacity	No. Circuits	Circuit-Kilometres
2 GW	6	**1,572**
4 GW	3	**786**
6 GW	2	**524**



CIRCUIT KILOMETRES ANALYSIS – FULL NETWORK

Total Network Size	
Corridor km	**GW.km**
~99,000	~1,900,000

Total Circuit-Kilometres		
Transfer Capacity	**Circuit km**	**# Circuits/ROW**
2 GW	~950,000	~3,500
4 GW	~475,000	~1,750
6 GW	~300,000	~1,100
8 GW	~250,000	~875



CONCLUSIONS

- **An average Circuit Size of 6GW minimises Circuit KMs and satisfies N-1 criteria**
- We need ~1,900,000 GWKMs of Transfer Capacity to keep the lights on without carbon.
- The cost and quantum of materials for infrastructure can be reduced substantially with an appropriate Circuit Size commensurate to the targets we have set ourselves.
- There is a significant gap between what we have and what we need from Transmission.

Innovation is Needed!!

THANK YOU

DC OVERLAY GRID PROJECT OVERVIEW

PROJECT INTRODUCTION

Overview

- Collaborative research & modelling project with KU Leuven, University of Strathclyde & SuperNode.

Objective:

- Demonstrate the **first ever** feasible approach to the architecture, operation and control of a continental-scale DC Overlay Grid.

University of Strathclyde Glasgow

KU LEUVEN

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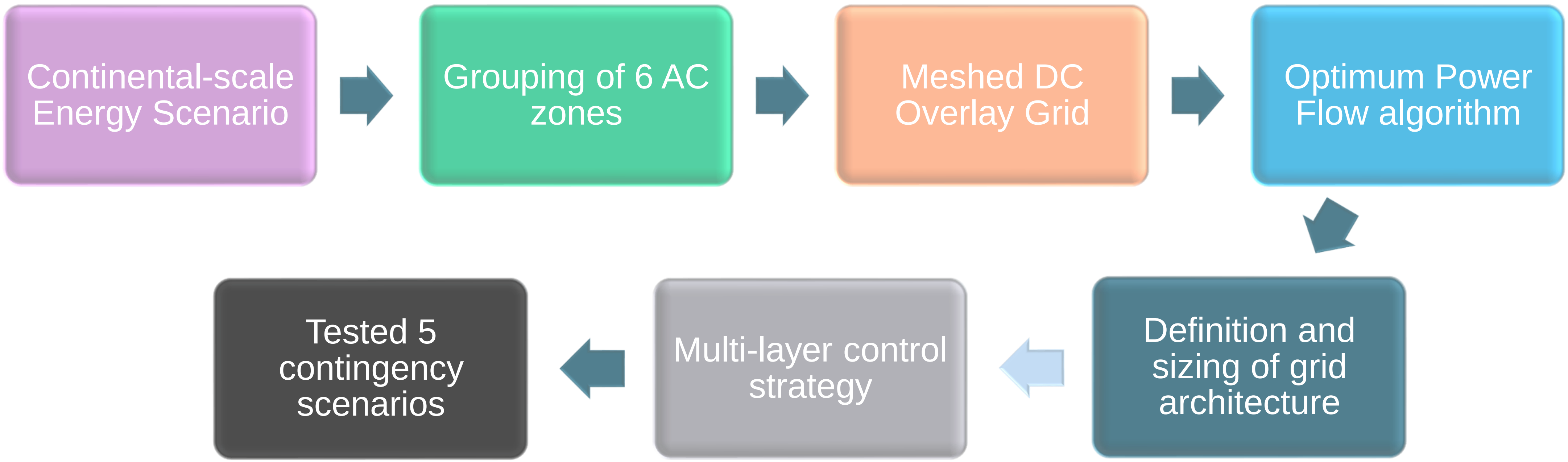
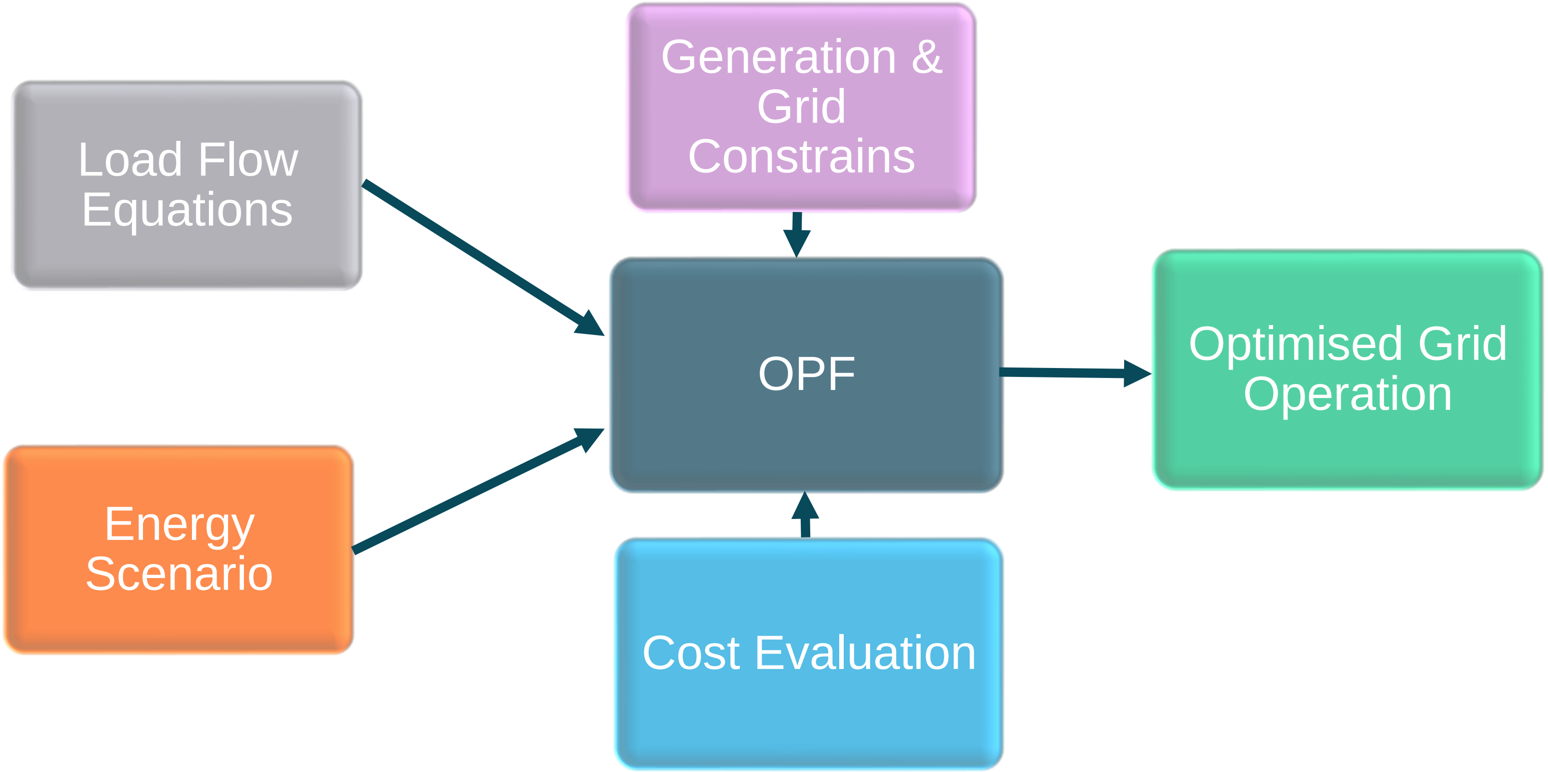
Connecting the Future

METHODOLOGY



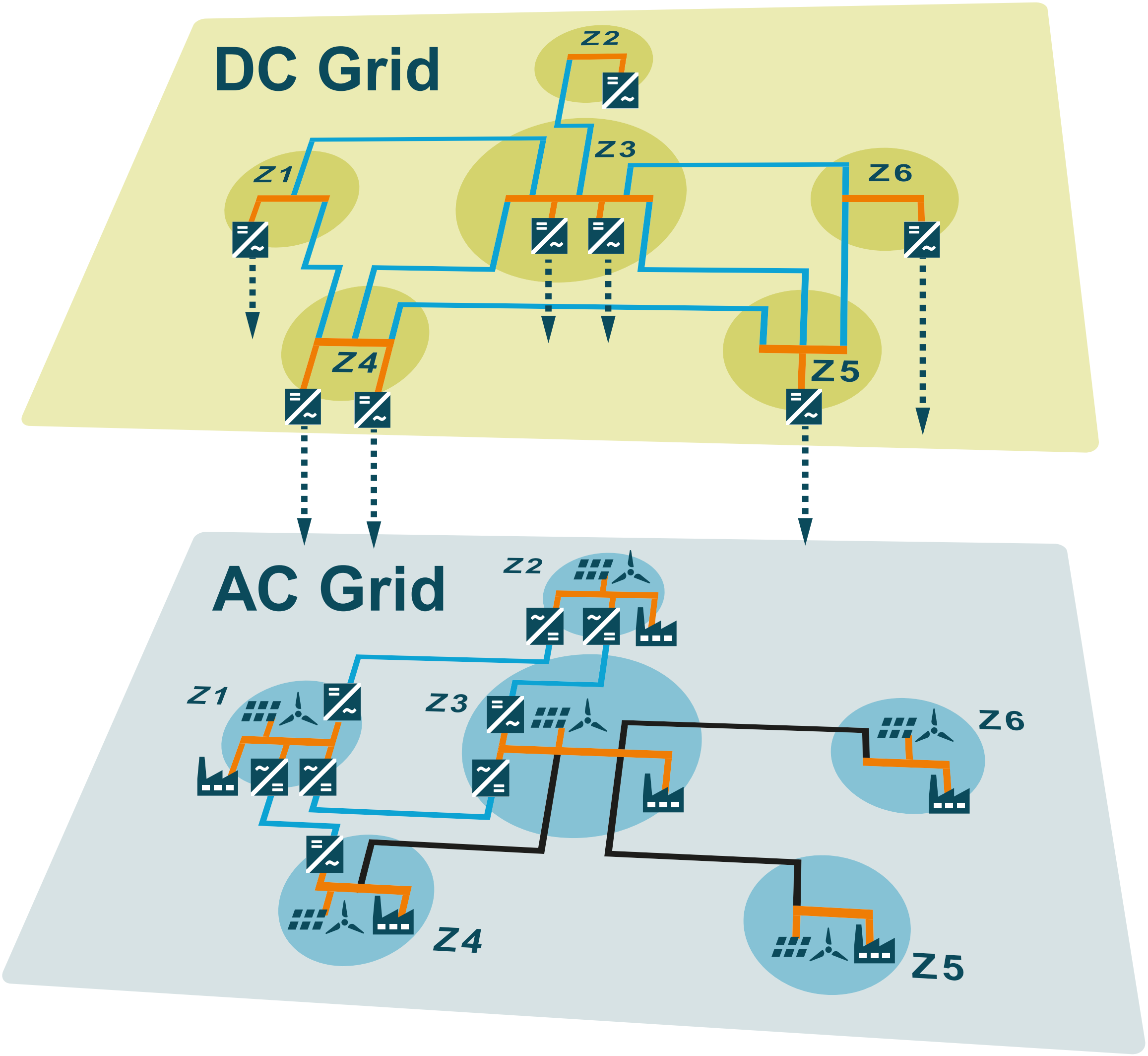
OPTIMAL POWER FLOW MODELS (OPF)

- OPF is an algorithm developed by KUL for AC/DC grids.
- OPF model calculates optimised settings for generators, converters, and power flow in AC/DC branches.
- Circuits defined set for balanced transmission across the time series.
- Continuous OPF iterations guide the control system on corrective actions during unexpected events through Control levels.



GRID ARCHITECTURE

- Mixed Generation & demand capacities for each zone.
- Six market zones defined for AC layer.
- Meshed DC layer directly reflecting AC architecture.
- Interlayer power transfers through high-capacity HVDC power converters.
- Interzonal power exchanges governed by OPF.



Blue Line = DC Link **Black Line = AC Link**

= Converter Station = Generation = Demand

MULTI-LAYER CONTROL STRATEGY

REDISPATCH POWER CONTROLS [mins to hrs]

- **Tertiary Control**
  - Optimal power flow solutions
- **Secondary Control**
  - Redispatch considering contingency
  - Generator Power Controller
  - Converter Power Controller

OPF establishes grid parameters and optimal power flow setpoints

DEVICE AND SYSTEM STABILISATION [ms to secs]

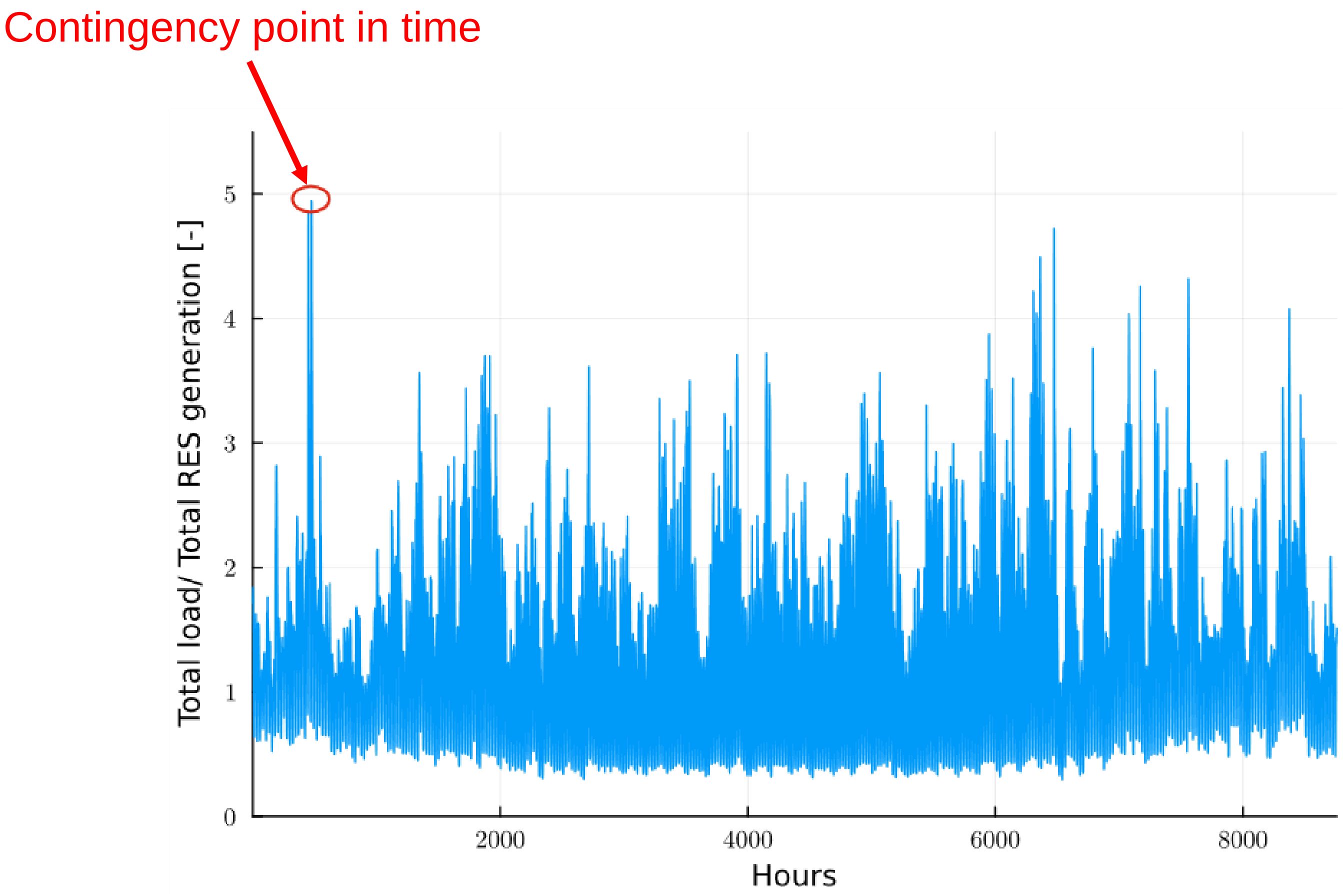
- **Primary Control**
  - Generator Droop
  - Converter Voltage Control
- **Local Control**
  - Generator Frequency Control
  - Converter Current Control

Distributed local controller to take immediate contingency action through DC Voltage & AC frequency control

CONTINGENCY SCENARIOS

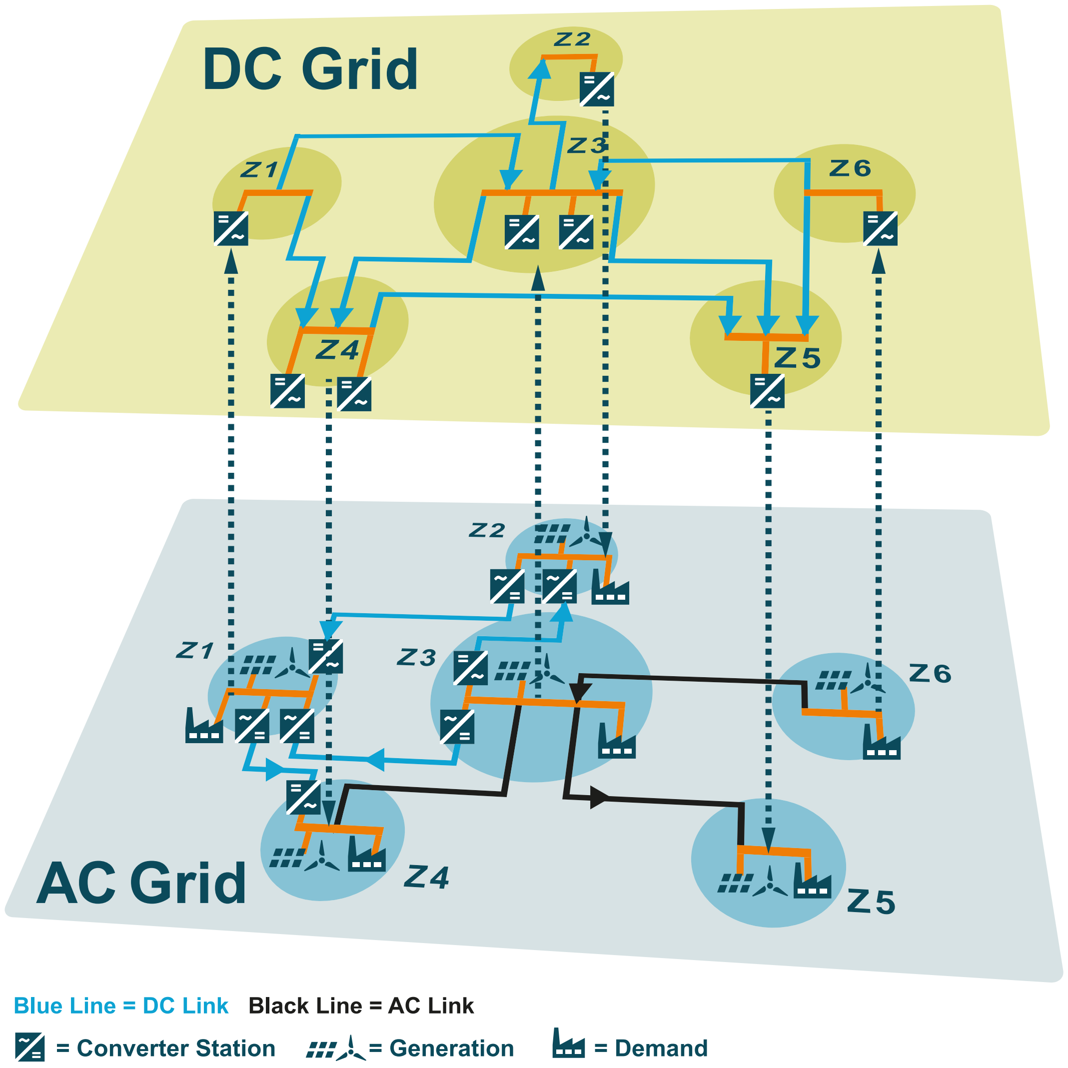
- All Scenarios are tested for the timestep with the highest ratio of total demand to RES generation

1. **Loss of converter on meshed DC Grid**
2. **Fault DC line on meshed DC grid**
3. Fault DC line on non-meshed DC grid
4. Loss of large AC generator
5. Loss of converters on PtP interconnectors



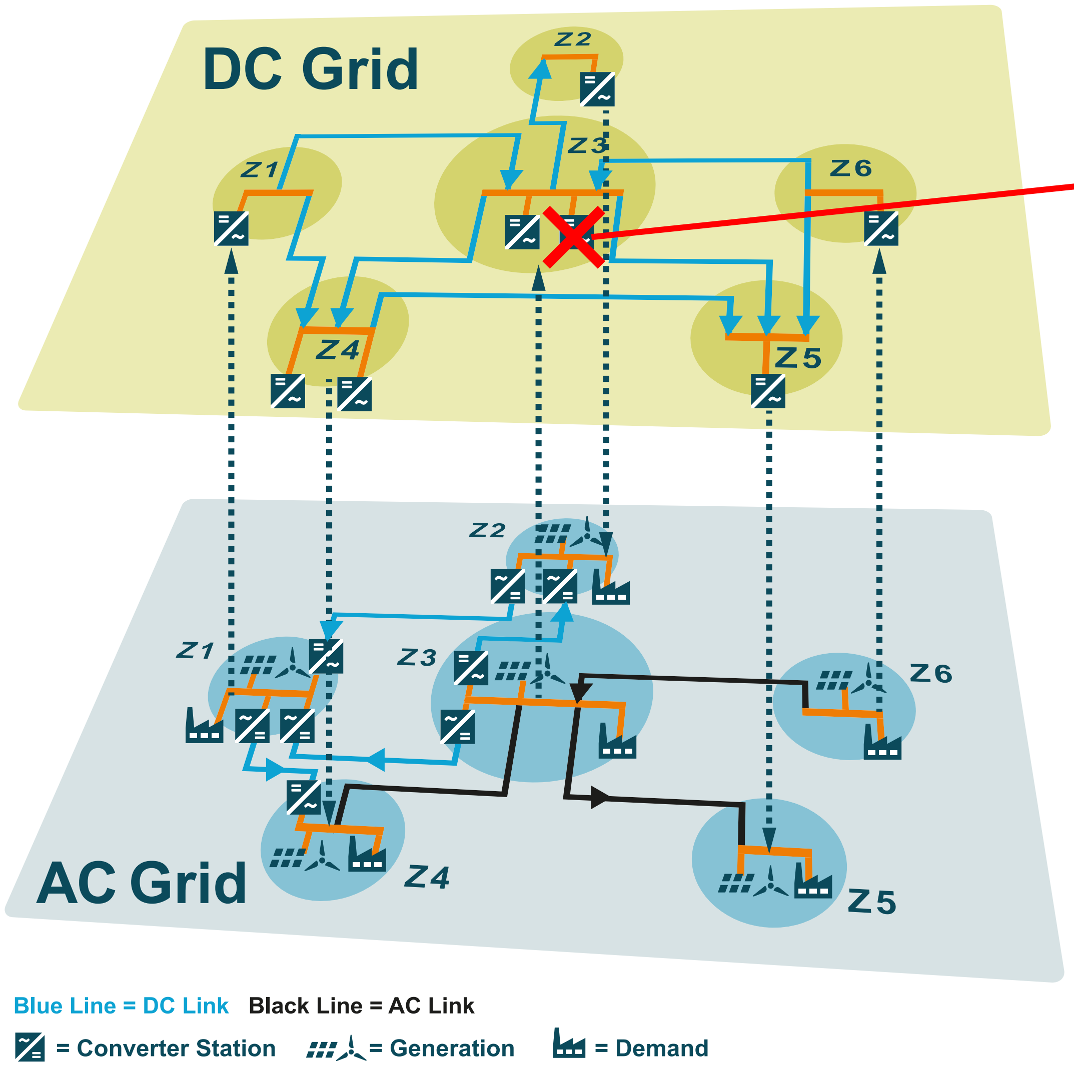
- PSCAD models used to investigate full system response through Contingencies

PRE-CONTINGENCY STABLE SYSTEM



- AC and DC power flows before contingency scenarios as calculated through the OPF.
- High AC generation in Zone 3.
- DC Zone 3 Converters are the master DC voltage controlling stations.
- The converters at other DC zones directly control active power.
- **Demonstrates optimal operation & stability**

SCENARIO 1- LOSS OF CONVERTER ON DC GRID



SCENARIO:

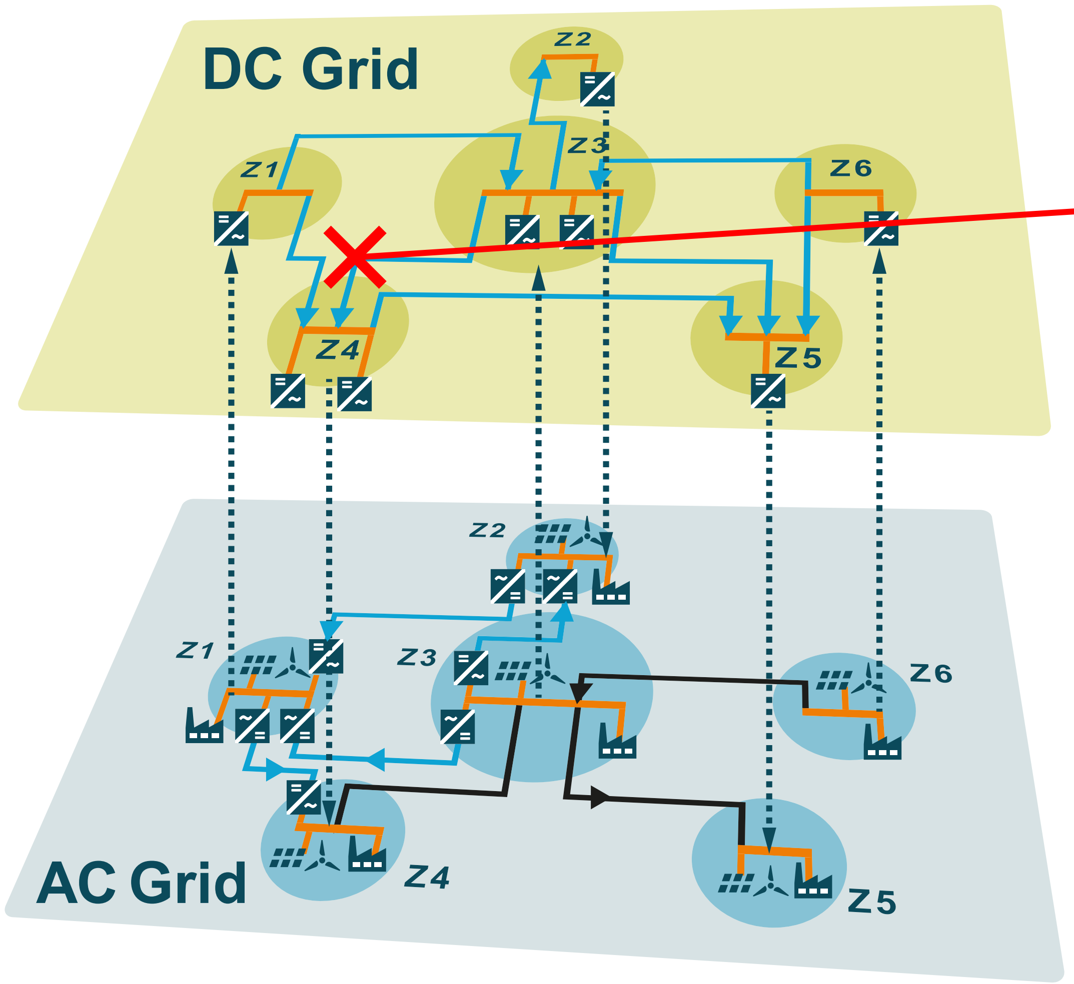
- A master DC converter in DC zone 3 is faulted, resulting in a transient loss of 3 GW power.

RESPONSE:

- Local Control layer response.
- Zone 3 converters have spare capacity
- The remaining healthy converters in DC Zone 3 compensate the lost 3 GW.
- The rest of the system is unaffected, and the overall power flow remains unchanged.
- No further action is required for this scenario.

The loss of master MMCs in the DC voltage control will not affect overall system stability.

SCENARIO 2: FAULT DC LINE ON MESHED DC GRID:



Blue Line = DC Link Black Line = AC Link

= Converter Station = Generation = Demand

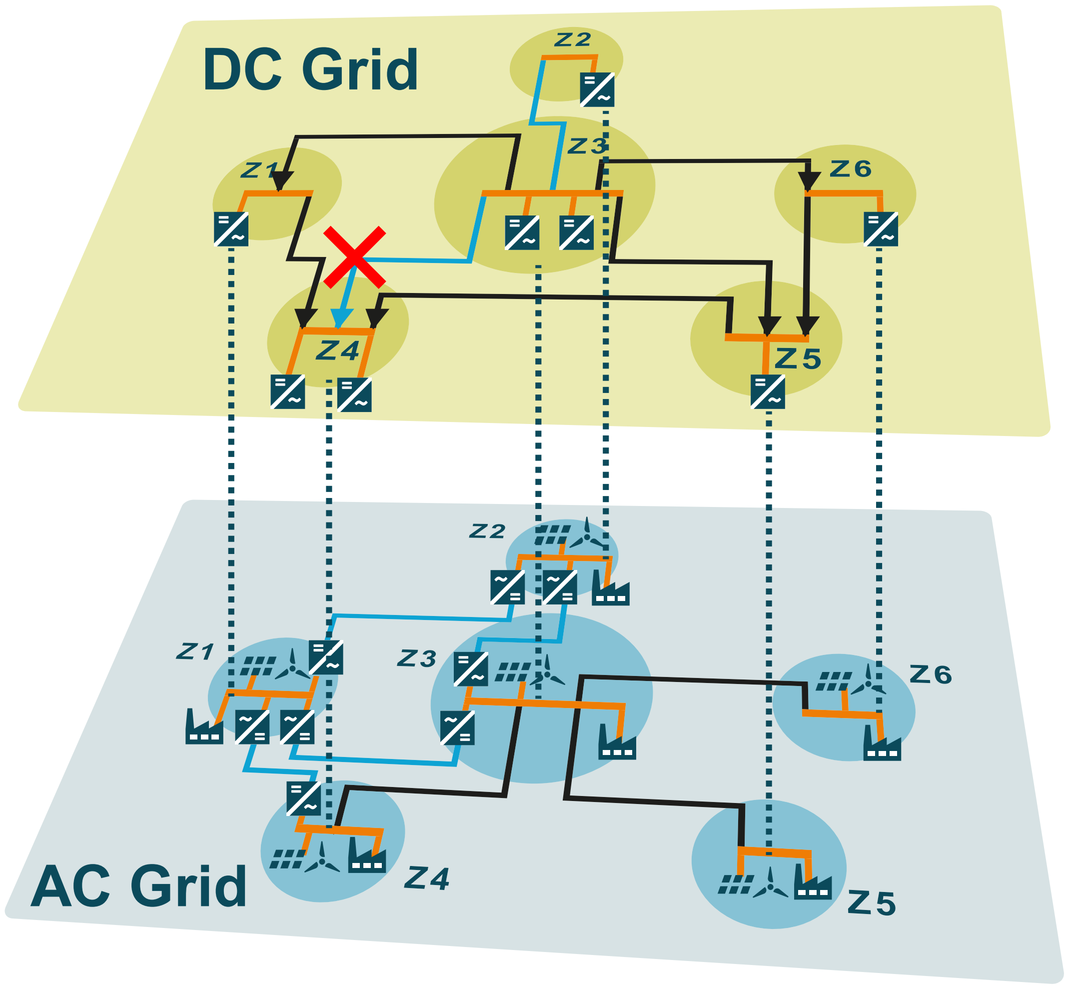
SCENARIO:

- Fault on DC overlay grid line transmitting 4GW from DC zone 3 to 4.

IMMEDIATE RESPONSE:

- Selective protection: Fast acting DCCBs immediately isolate fault & DC line.

SCENARIO 2: FAULT DC LINE ON MESHED DC GRID



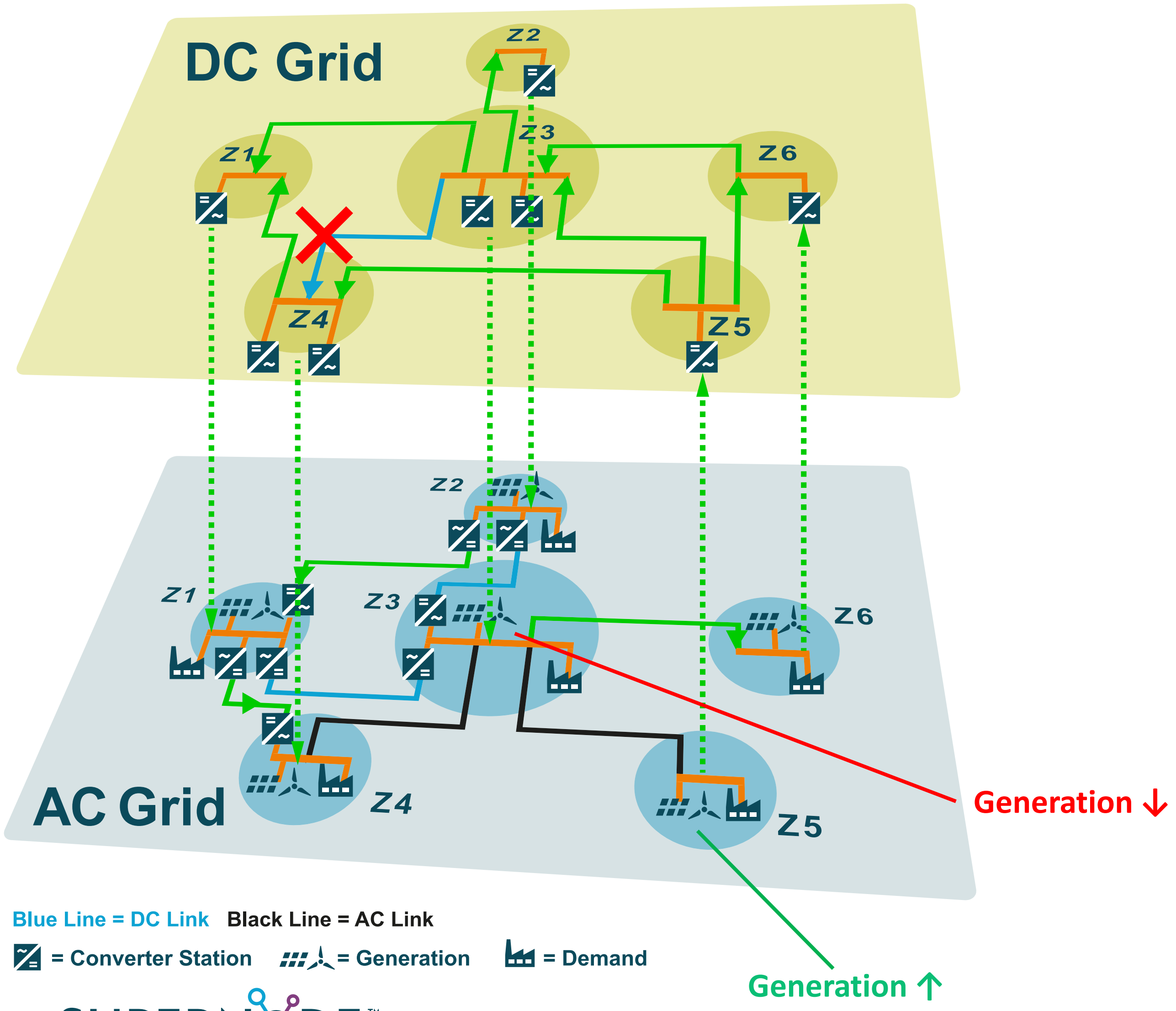
LOCAL RESPONSE:

- The active power carried by the faulty DC line is automatically / immediately redistributed among other DC lines.
- The AC lines and ptp HVDC systems in the AC grid remain unchanged as well as the active power transmitted from the DC grid to the AC grid.
- DC lines between zone 3 & 5 and between zone 6 & 5 are temporarily overloaded.

OUTCOME:

- Redistribution of 4GW active power through meshed DC grid is automatic.
- Power transmission through converters are unaffected (i.e. no converter overloading).

SCENARIO 2: SECONDARY RESPONSE TO OVERLOADED DC LINES



SECONDARY RESPONSE:

- OPF calculation to determine optimised power flows for the system (Secondary Control)

OUTCOME:

- All transmission capacities out from AC Zone 3 (both AC and DC) are fully utilized.
- To avoid overloading the lines, generation at AC zone 3 is reduced, while generation at AC zone 5 is increased.
- Less power needs to be transmitted from AC Zone 3 to the other zones.
- The DC overlay converter power setpoints are changed accordingly in accordance with the new OPF data.

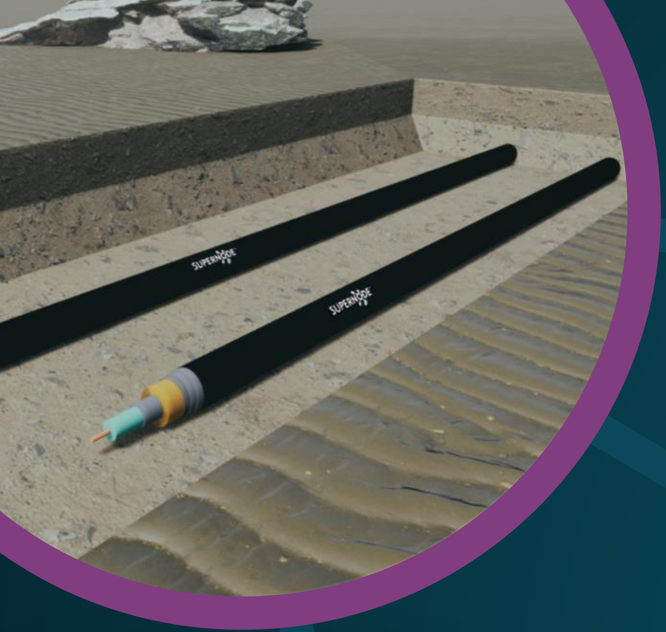
System stability has been maintained

CONCLUSION

- Demonstrated first ever feasible approach to the development, operation, protection & control of a continental-scale DC Overlay grid.

- Control Strategy enacted through the OPF model was effective, demonstrating;
  - Balanced power flow control in normal operation
  - System stability maintained in all contingency scenarios
  - Controllability of high-capacity DC grid with high volume power converter based-resources.

- Demonstrated that increased RES generation and transmission capacity can be achieved through increased system flexibility enabled by a **meshed DC Overlay grid**.



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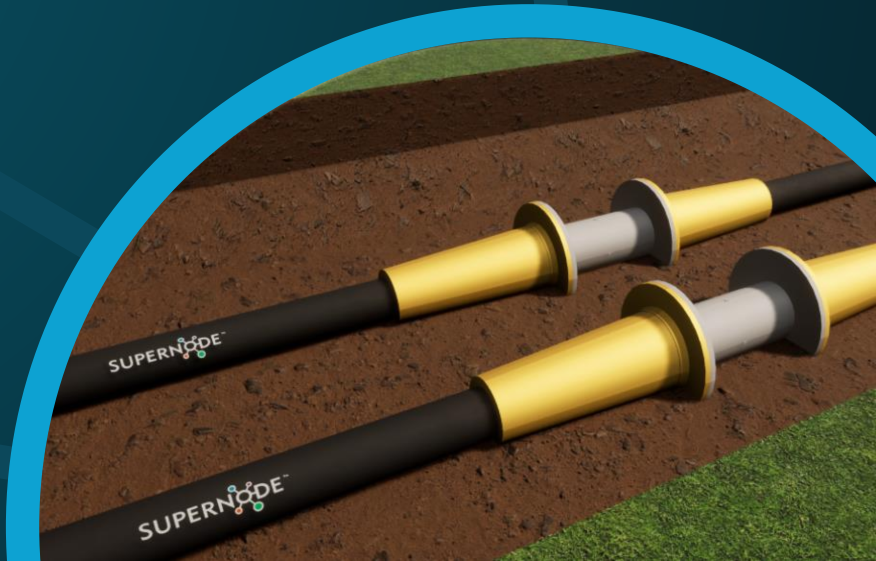
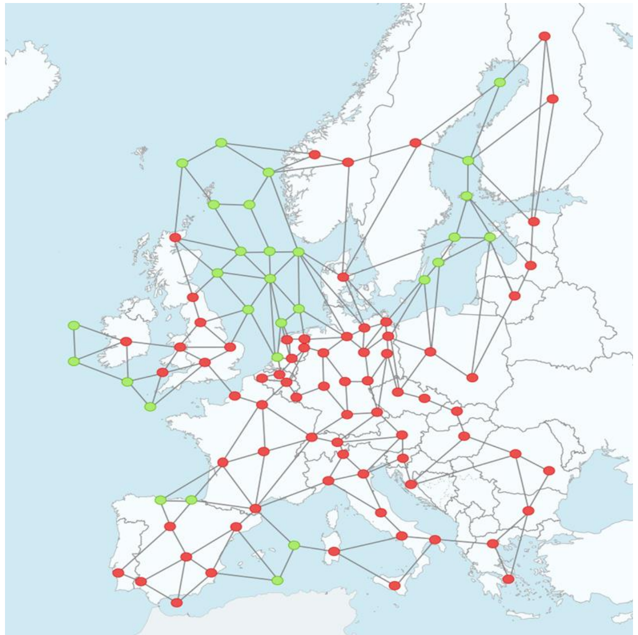
NEXT GENERATION
SUPERCONDUCTING
CABLES

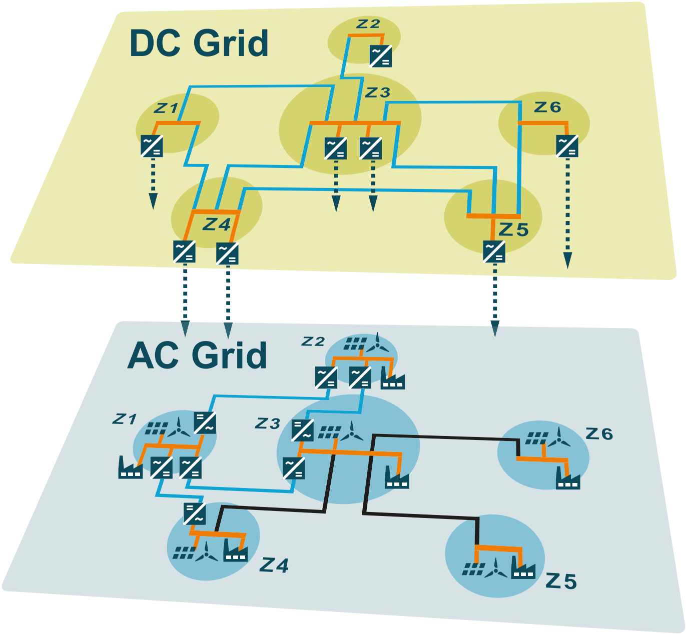


NEXT STEP FOR TRANSMISSION - HIGH-CAPACITY MESHED GRIDS

Relay Project: ~ 6GW power circuits



DC Overlay Grid



What transmission technologies can deliver a decarbonised grid?

TECHNOLOGY OVERVIEW

OVERHEAD LINES

- Not consentable in europe at scale

AC TRANSMISSION CABLES

- Not technically capable of long-distance bulk power transfer

TECHNOLOGY OVERVIEW – DC UNDERGROUND TRANSMISSION

CONVENTIONAL CABLES

- Capacity constrained, cost challenged with higher voltages

SUPERCONDUCTING CABLES

- Next generation Superconducting cables can deliver the capacity, scale & cost profile required

SUPERCONDUCTING POWER CABLES

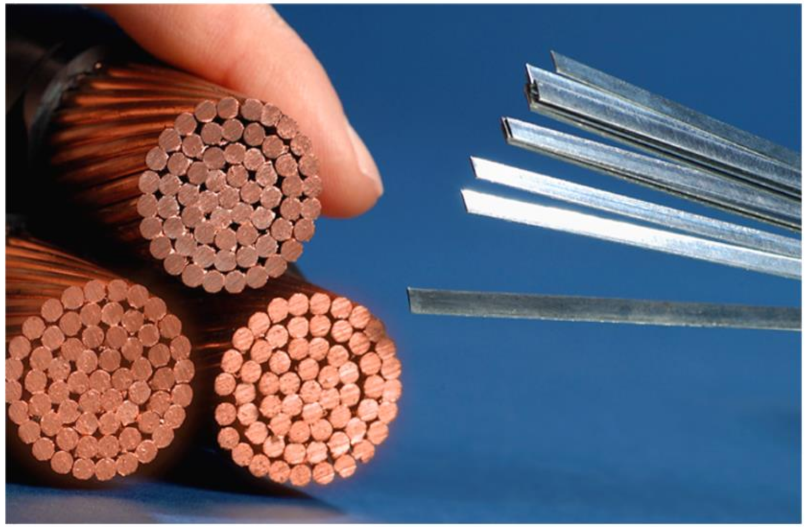
WHAT IS SUPERCONDUCTIVITY?

Superconductivity occurs in some materials, when cooled below a certain temperature, display unique characteristics:

- Zero electrical resistance
- High power density

How to achieve superconductivity:

- A material must be cooled to below its '*critical temperature*'.
- High temperature superconductors (HTS) are superconductive around -200◦c.



SUPERCONDUCTING CABLES IN PRACTICE

Recent Superconductor Projects				
2013	Nexans (ELECTRIFY THE FUTURE)	Ampacity, Essen	1km, 40MVA, 10kV, AC	- Innovative solution to ease urban congestion - Operated successfully at -200℃ for 7 years
2018	Best Paths	EU Horizon's 'Best Paths' Project	30m, 3.2GW, 320kV, DC	- High power density transmission level demonstration project
2019	KEPCO	Shingal, Seoul	1km, 50MVA, 23kV, AC	- Best strategic solution to ease urban congestion
2021	amsc	REG, Chicago	62MVA, 12kV, AC	- Best strategic solution for ringmain resilience
2023	NKT (We connect a greener world)	Superlink, Munich	12km, 500MVA, 110kV, AC	- Customer-driven by SWMunich - 3x power with no disruption

Nexans Cable, Ampacity 2013

Next Generation Superconducting cable

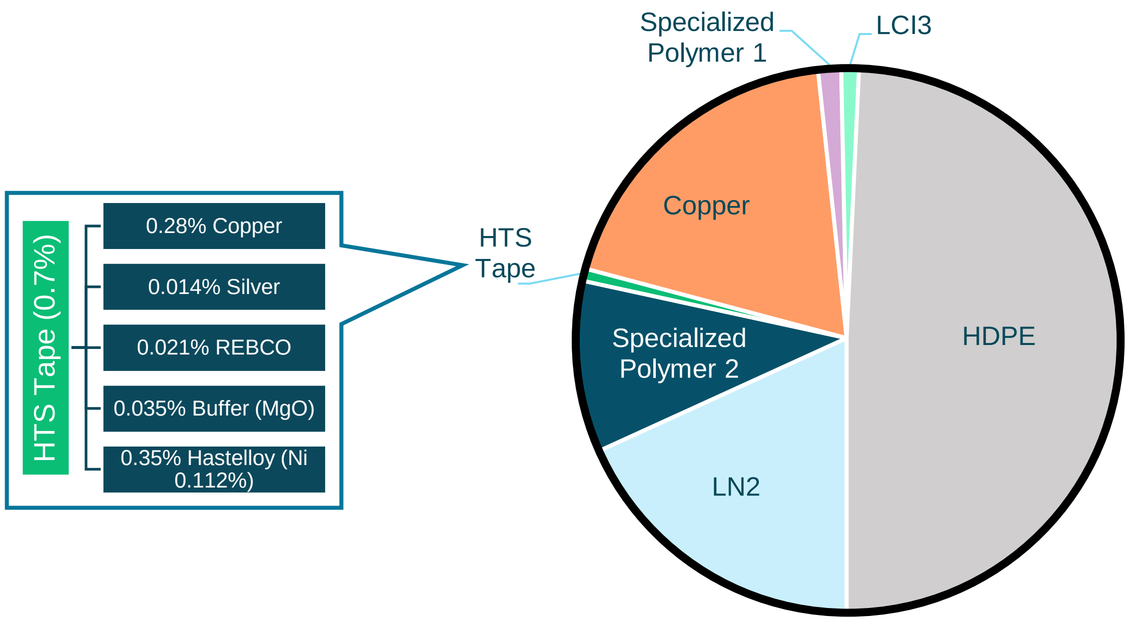
ADVANTAGES OF SUPERCONDUCTING TRANSMISSION

MATERIAL COMPARISON

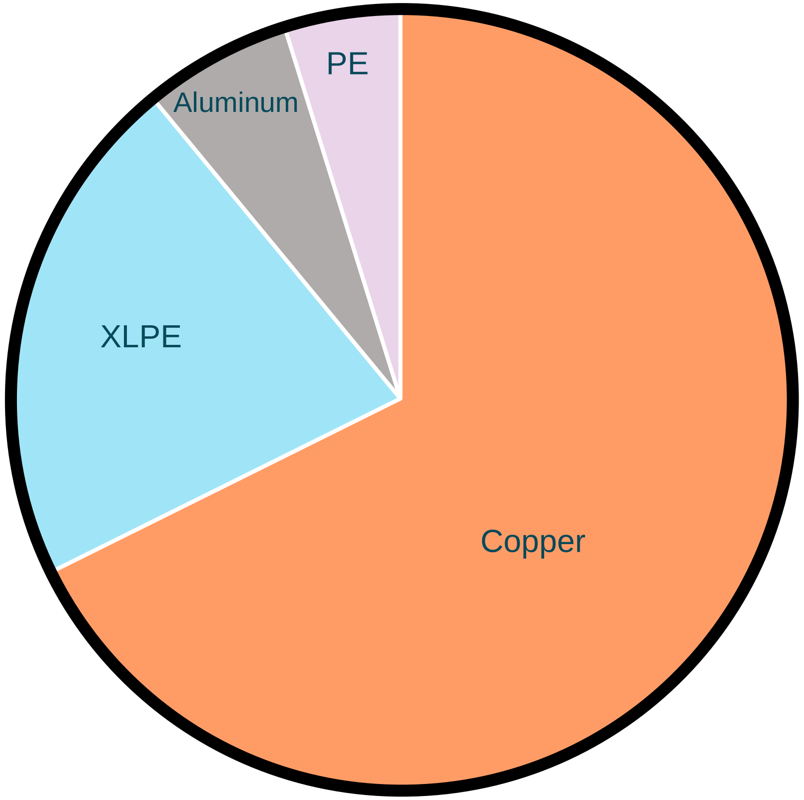
FOR 2GW EQUIVALENT POWER TRANSMISSION

- Superconducting cable is **57%** lighter than a conventional cable
- **19%** of superconducting cable is copper vs **68%** of a conventional cable

Superconducting Cable (17 ton per km)



Conventional Cable (40 ton per km)



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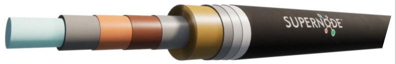
SCALABILITY: COPPER COMPARISON

6GW corridor: Superconducting cables

Cable



2GW Cable

+

HTS Tape

6GW corridor: Conventional cables

Cable

2GW Cable

+

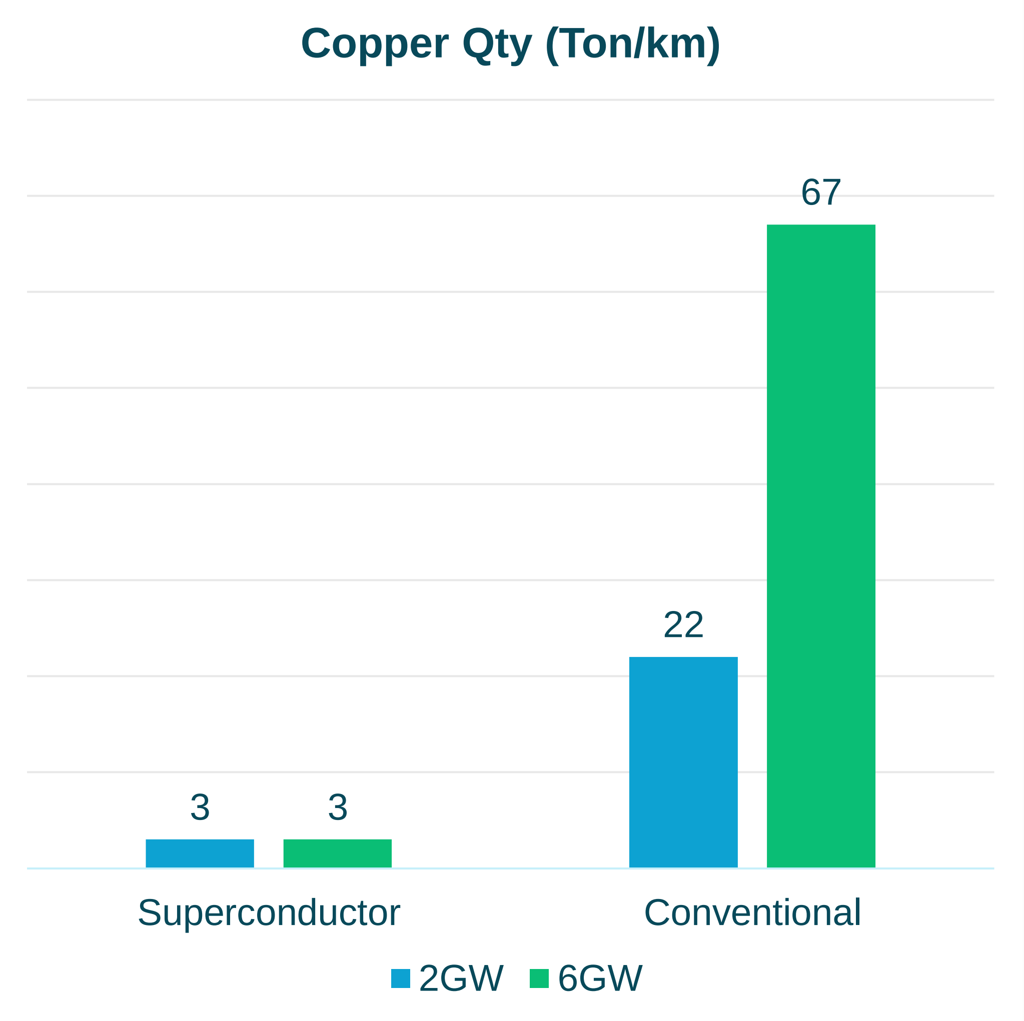
Cable

2GW Cable

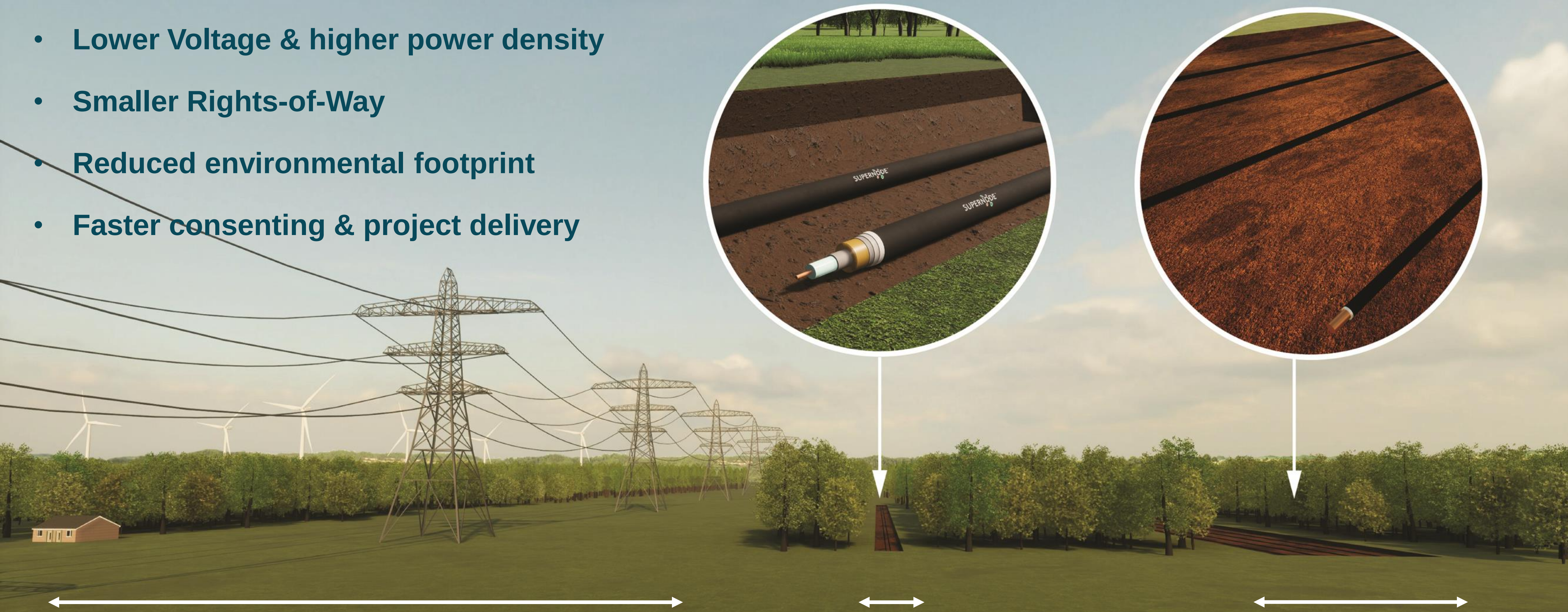
+

Cable

2GW Cable



- **Lower Voltage & higher power density**
- **Smaller Rights-of-Way**
- **Reduced environmental footprint**
- **Faster consenting & project delivery**



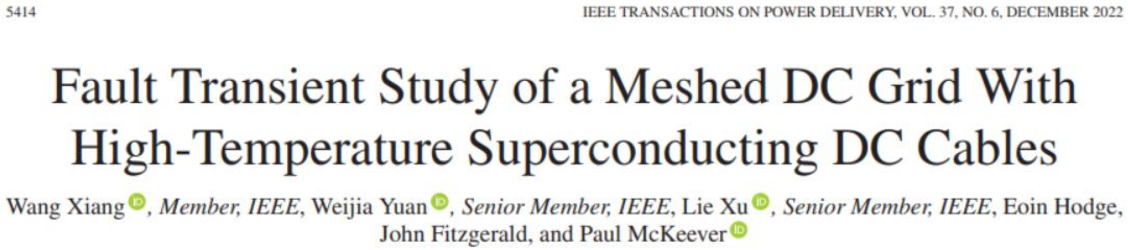
125m	1-2m	19 - 25m
+/- 800kV HVDC	Superconducting cable	XLPE Copper Cable
4 GW Capacity	4 GW Capacity (1 bi-pole = 2 cables)	4 GW Capacity (2 bi-pole = 4 cables)

MESHED GRID INTEGRATION ADVANTAGES - PROTECTION

- Superconducting transmission cables can be designed as **fault tolerant**

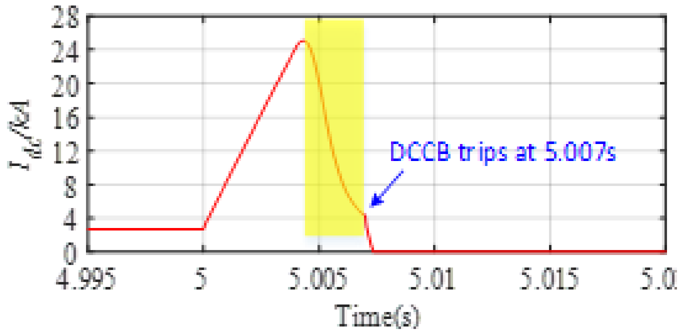
- Inherent **current limiting** capability can provide “firewalls” around the DC fault, **preventing grid propagation** around meshed system

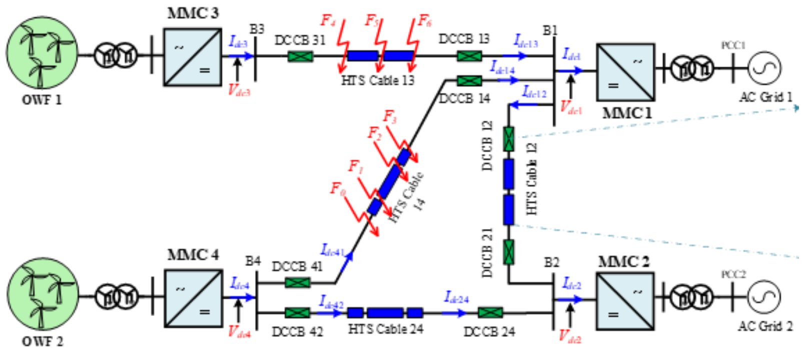
- Opportunity to use **cheaper DCCB technology** and ratings as Superconducting cables limit faults


5414 IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 37, NO. 6, DECEMBER 2022

Fault Transient Study of a Meshed DC Grid With High-Temperature Superconducting DC Cables

Wang Xiang, *Member, IEEE*, Weijia Yuan, *Senior Member, IEEE*, Lie Xu, *Senior Member, IEEE*, Eoin Hodge, John Fitzgerald, and Paul McKeever



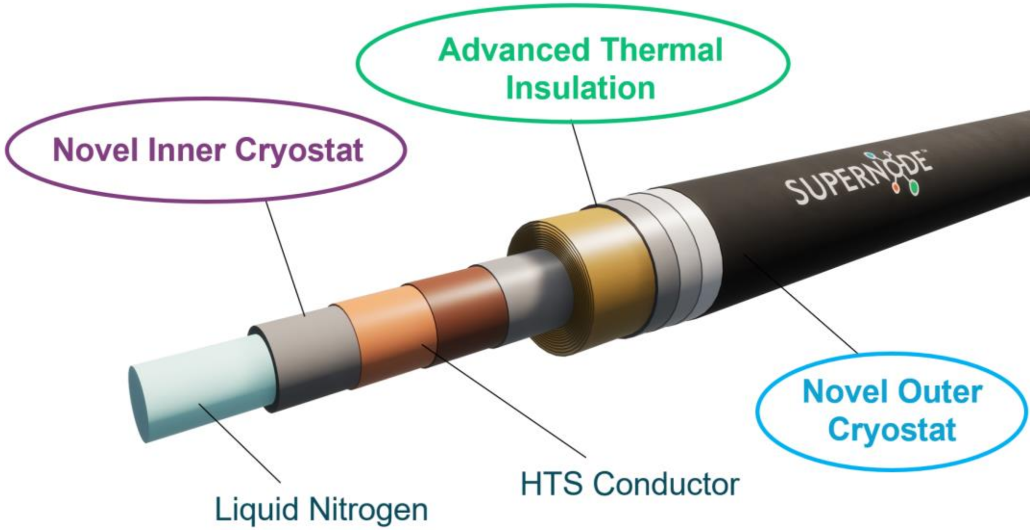


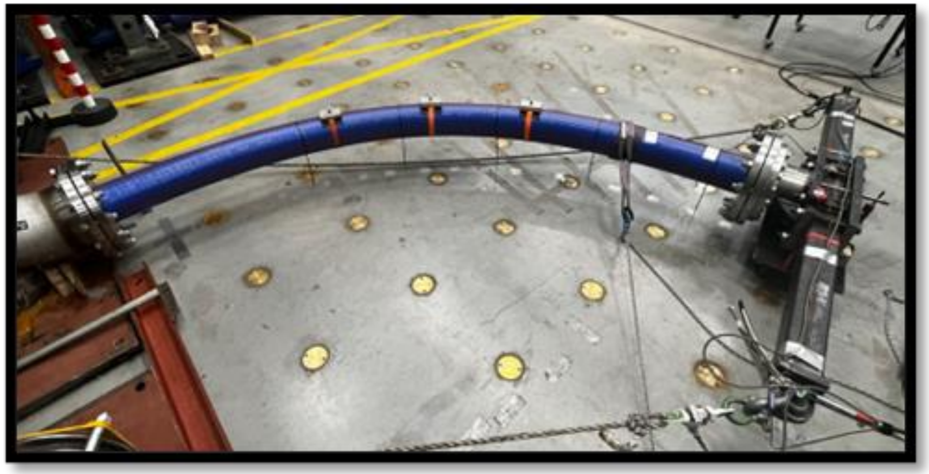
NEXT GENERATION SUPERCONDUCTORS

SUPERNODE'S NEXT GENERATION SUPERCONDUCTING CABLES

SuperNode Next Gen Cable Technology:

- Scaled **Capacity** for bulk power transmission
- Scaled **Transmission distance** enabling remote RES connection.
- Scaled for **Volume Manufacturing** to eliminate cost.
- **TRL 6 qualification** will be achieved in 2025.





PATH TO COMMERCIALISATION

2024 Demonstration at UK **TSO Innovation Centre**

2025 **TRL 6 Qualification** with DNV certification

2026 **Marine demonstration** with TSO & EU Offshore developer

2028 **Pilot Project** Medium Voltage & Power grid application

2030 **Commercial projects**

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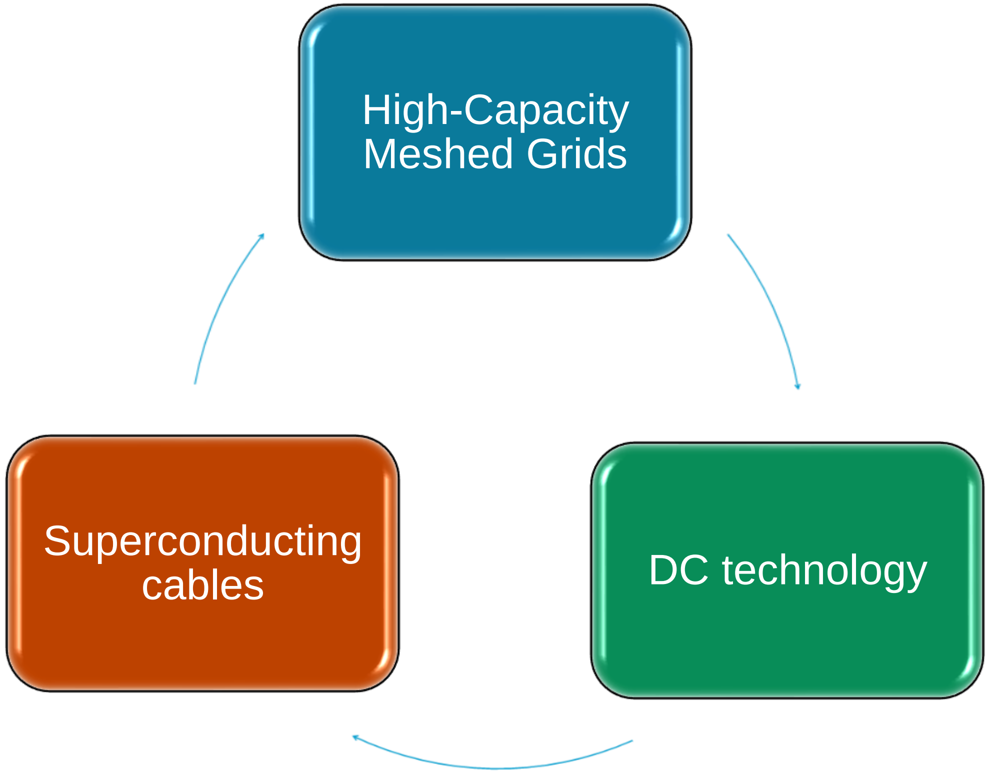
CONCLUSIONS

- High-capacity highly-meshed grids are required to deliver x9 more renewables.
- DC technologies required for bulk power, long distance transmission scale.
- Technology gap exists in DC transmission.
- Superconducting cables can deliver the scale, speed and efficiency required to decarbonise.

Optimal Steps to a Decarbonised Grid

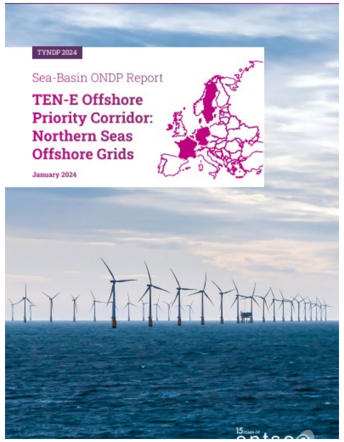


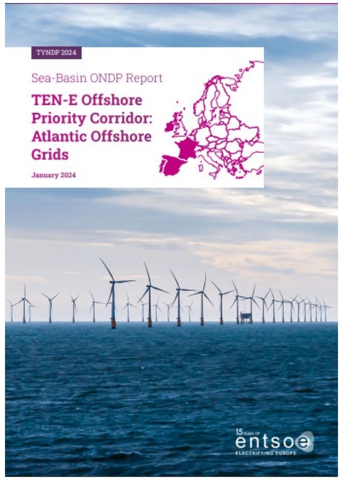
ENTSO-E's Offshore Network Development Plan 2024

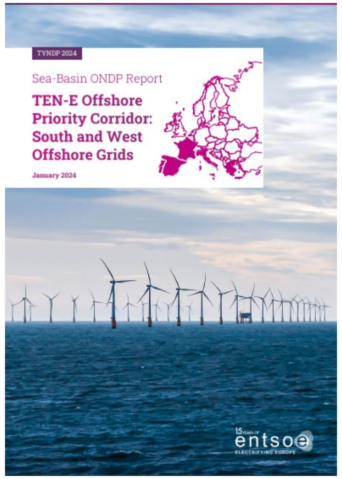
05 March 2024 - 'A Grid to Decarbonise Europe' - currENT Event, BXL/Hybrid

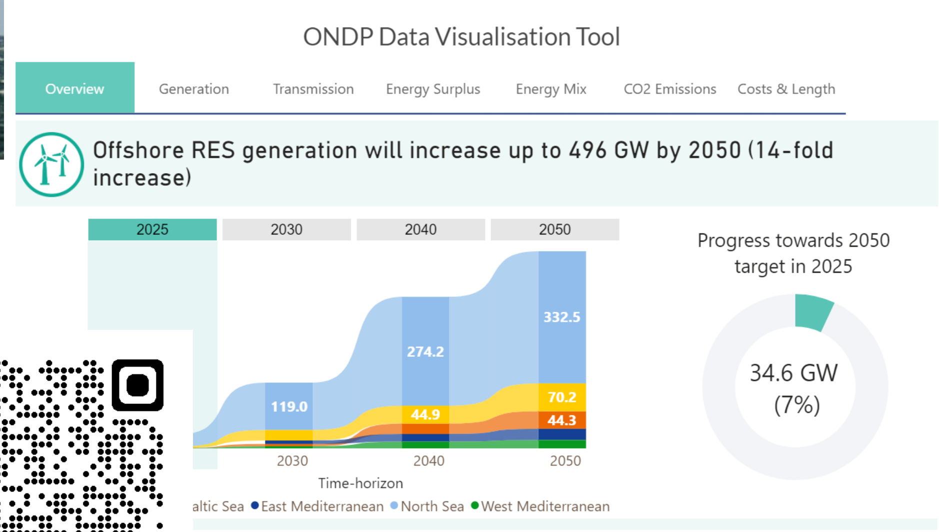
The ONDP Package

The Offshore Network Development Plan (ONDP) translates the MSs' non- binding offshore RES capacities into Network Infrastructure Equipment Needs and -Costs









Visit the online ONDP- site to find the reports, the interactive data platform, a film ….

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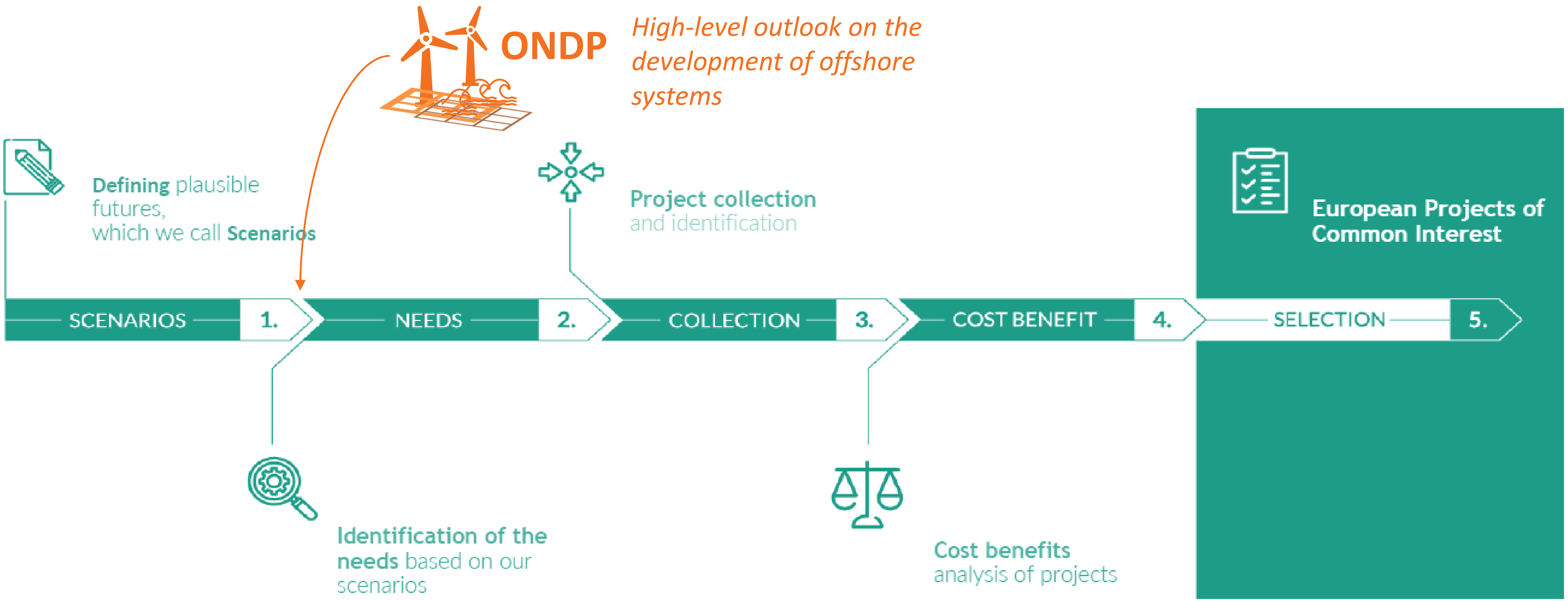
The ONDP is part of the TYNDP



The ONDP 2024 is the first version of a new product

The ONDP answers a different question compared to the Scenario building / Needs Identification:

ONDP 2024:
"What does it take to integrate 496 GW of offshore RES into the 'DE 2040/ 2050- environment'?"

The optimizer is can only invest in
offshore transmission infrastructure connecting RES.
All other parameters remain locked in this first edition.

Implications on the onshore systems will be part of the TYNDP24 IoSN process.

a) Scenarios / b) Needs Identification
"a) How could the European Energy System look like in the environment "Distrib. Energy" in 2040 / 2050? – and
b) where could the system be more economically efficient?"

The optimizer can invest in
a) generation, infrastructure, DSR, flexibility measures etc. All-in-one optimization starting from candidate links without capacity.
b) infrastructure, peaking units, storage – from list of candidate projects. Offshore hybrids so far not part of the identification process

..some simplifications had to be made to deliver on time:

- Usage of the TYNDP22 model, mounting MSs' offshore RES on it.
- No economic evaluation / adjustment of the overall production portfolio.
- Linear expansion of the demand by arbitrary increase of 8% across *all Europe* to better represent electrification.

Energy production - TYNDP 2022

Ambitious development of renewables across Europe

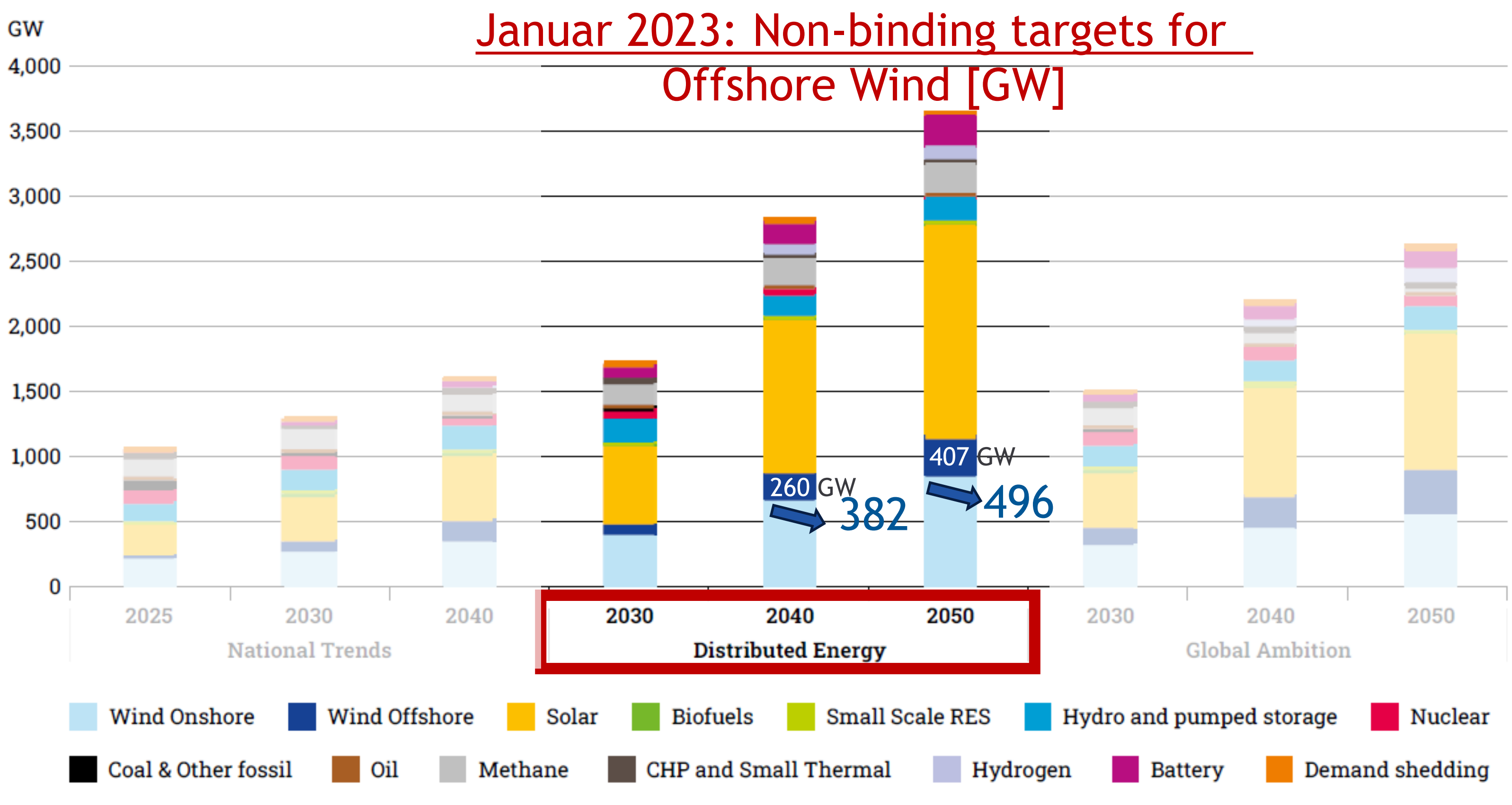


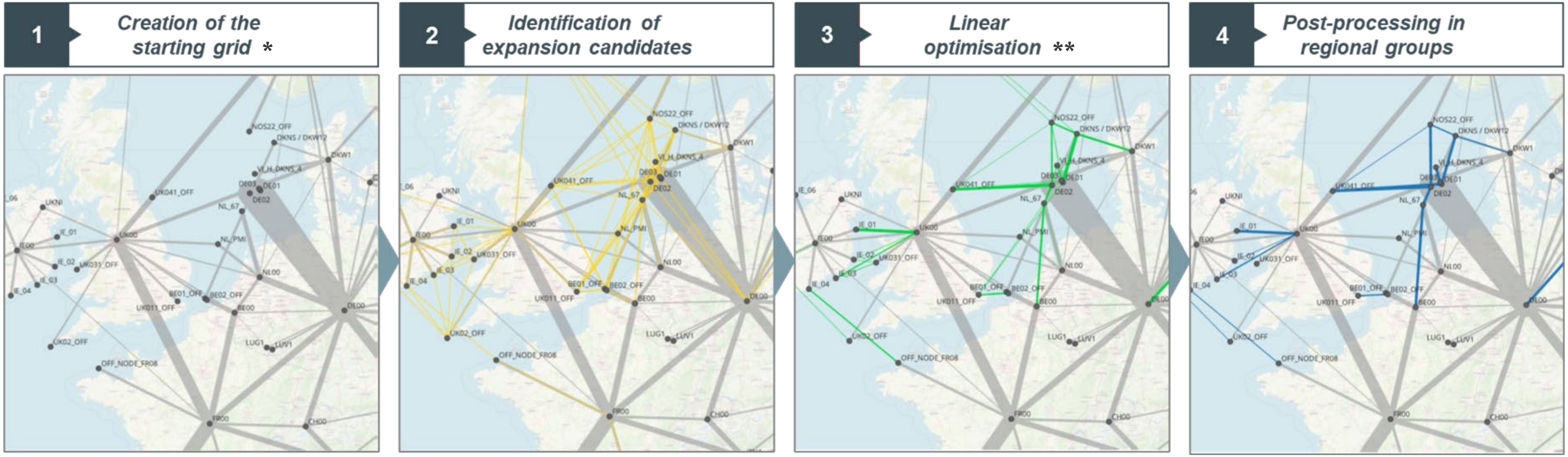
Figure 24: Capacity mix for EU27 (including prosumer PV, hybrid and dedicated RES for electrolysis)

Find the details of the TYNDP22 Scenarios here

The ONDP in four steps

Live DEMO of [Vizualisation Tool]

Schematic Visualisation:



* 2030 for 2040
2040 for 2050

** minimize TOTEX

*** check plausibility and adjust

The TYNDP22 model and Distributed Energy Scenario was used
Investigations focused on offshore infrastructure only. Onshore to follow

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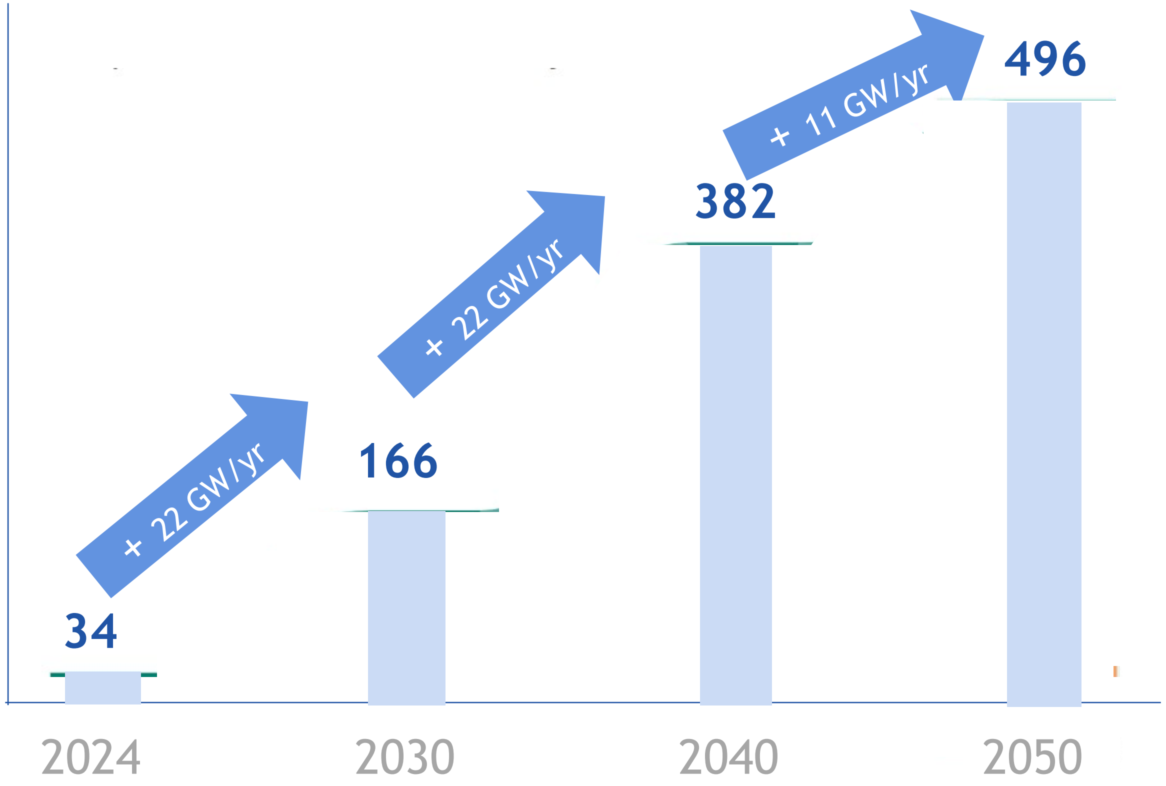
Need for Speed…for Generation and Transmission

Offshore RES Generation capacity [GW]



Today's offshore RES is only 7% of offshore RES foreseen in 2050

Annual installations of offshore RES and Infrastructure need to accelerate significantly => requires to be **9 times faster** than during the last decade!

…**BUT**: average speed last 10 years was

Live DEMO of Vizualisation Tool

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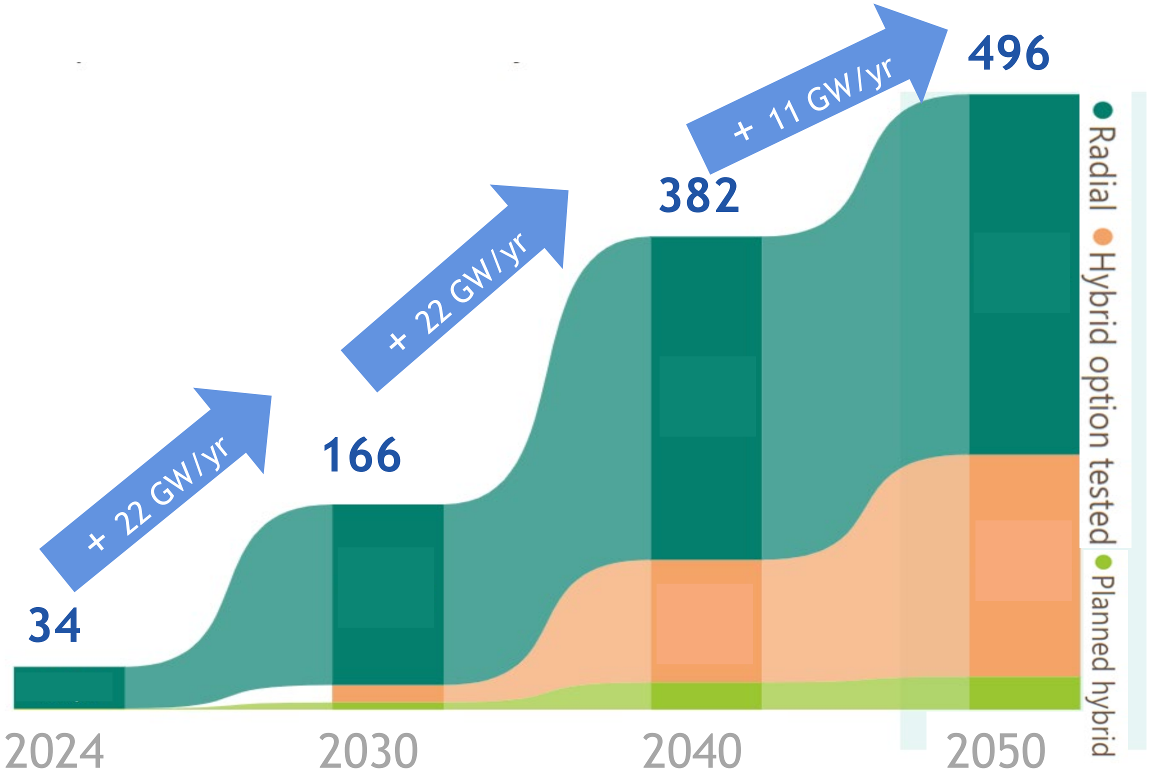
Need for Speed…for Generation and Transmission

Offshore RES Generation capacity [GW]



…BUT: average speed last 10 years was + 2.5 GW/yr

Today's offshore RES is only 7% of offshore RES foreseen in 2050

Annual installations of offshore RES and Infrastructure need to accelerate significantly => requires to be **9 times faster** than during the last decade!

To translate offshore RES capacities into Network Infrastructure Equipment Needs and –Costs, about half has been tested to be connected as via hybrid infra

Live DEMO of Vizualisation Tool

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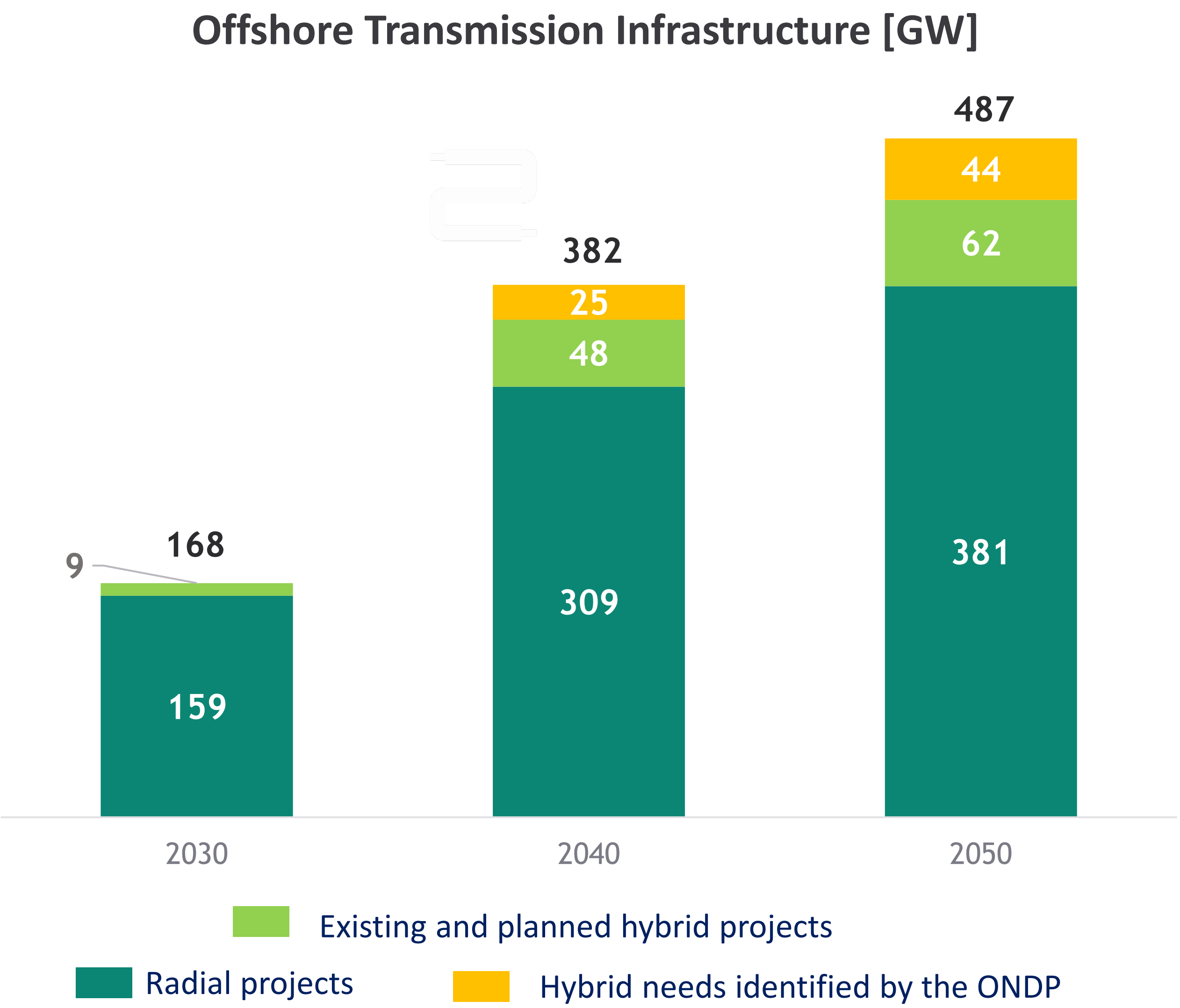
Results: Offshore Transmission Infrastructure Needs



Most offshore RES is expected to be connected via radial connections

The supply chain will be crucial for delivering the needed infrastructure in time

Need to balance the rapid deployment of offshore grid infrastructure with the imperative to preserve and restore our marine environment.

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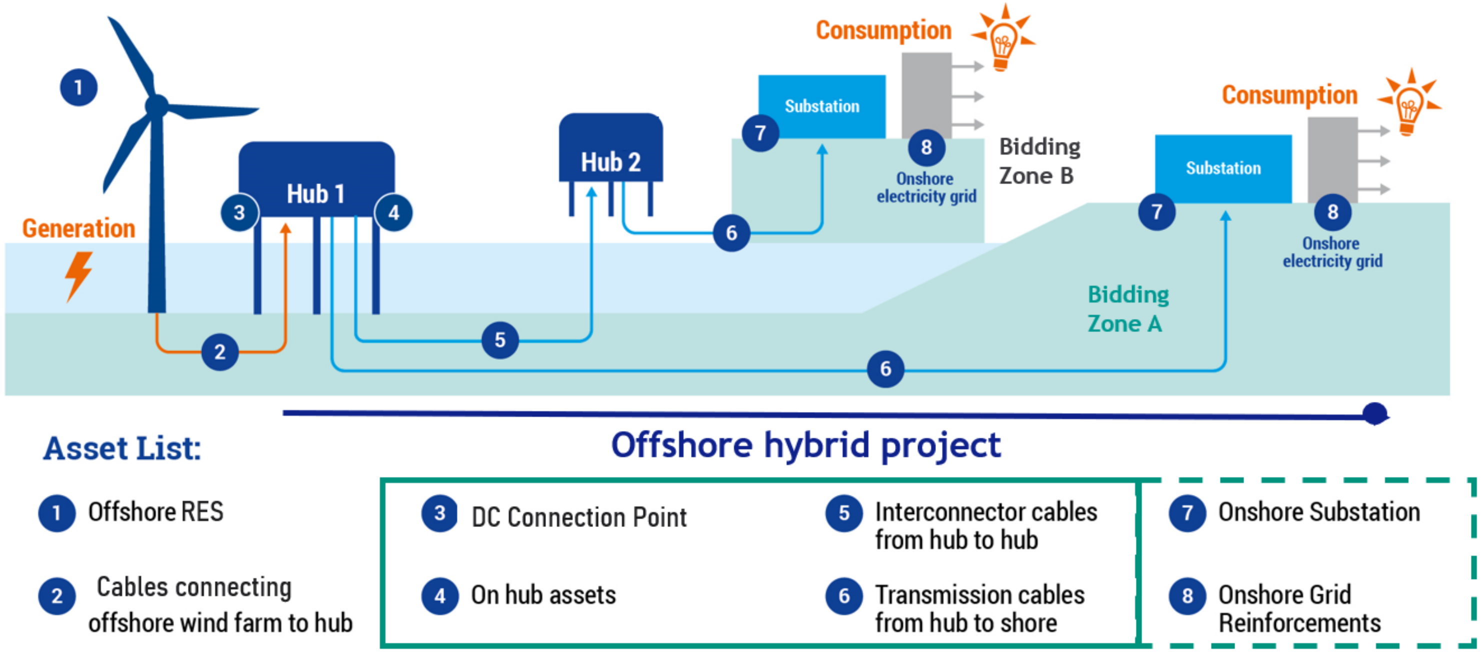
Hybrid Project - What is it?



Common terminology on- and offshore
=> same legislation applies

The term

"offshore hybrid project"

refers specifically to the **transmission infrastructure** connecting two countries (or bidding zones) and connecting the OWF to shore. Generation assets are out of scope.

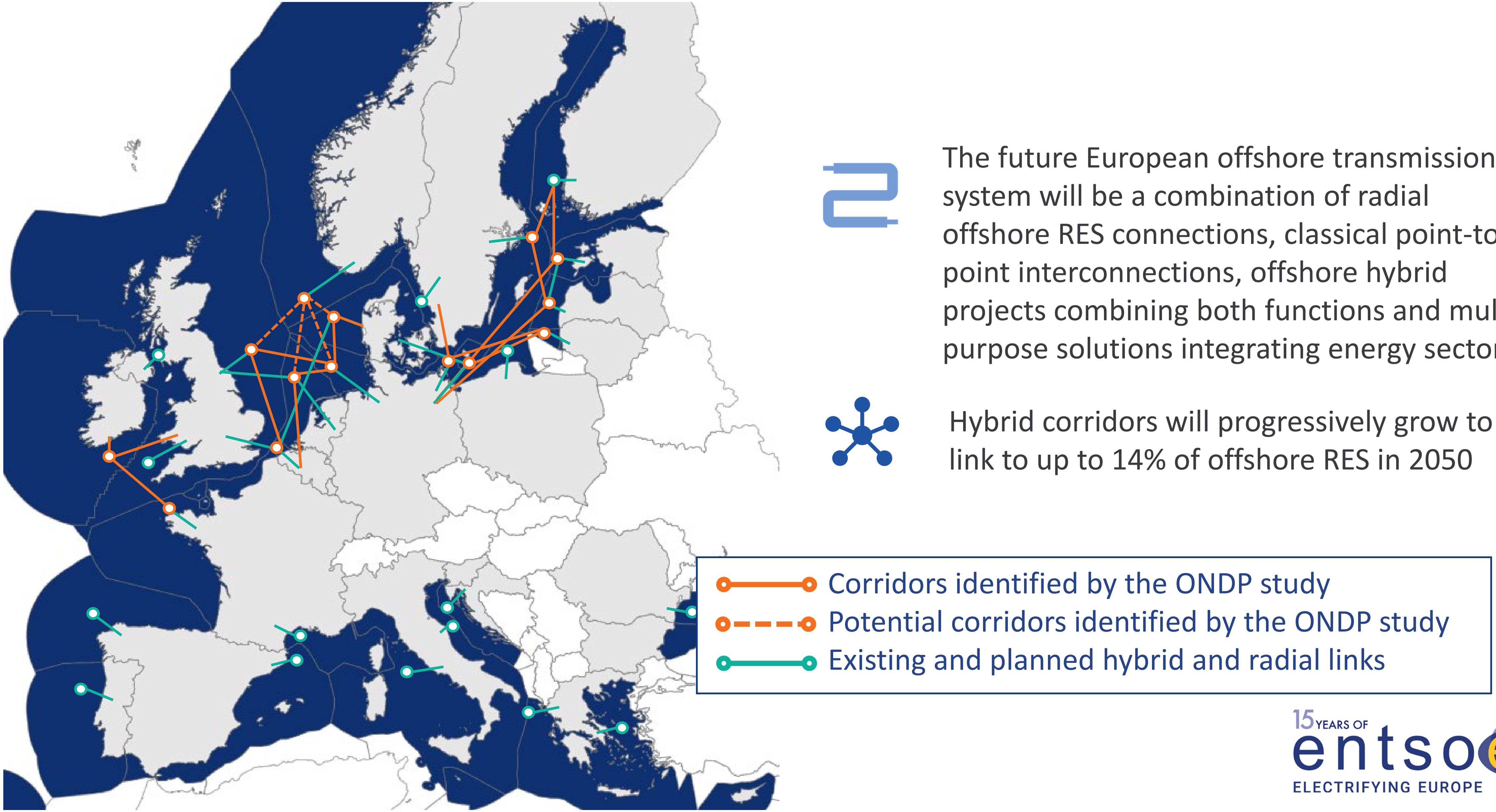
(also called "dual purpose project" or "hybrid interconnector")

"Multi-purpose": additionally crossing energy sectors

entsoe

Find various aspects about this category in our 6 position papers here

Up to 1 out of 7 GW will be connected via Offshore Hybrid Corridors



The future European offshore transmission system will be a combination of radial offshore RES connections, classical point-to-point interconnections, offshore hybrid projects combining both functions and multi-purpose solutions integrating energy sectors

Hybrid corridors will progressively grow to link to up to 14% of offshore RES in 2050

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Benefits and challenges of offshore corridor development

Energy Security Increase

Resulting from cross-border interconnections and increased redundancy

Price-convergence

Hybrid corridors would contribute to reduce price difference between market nodes

Better utilisation of offshore RES

Hybrid corridors reduce green energy surplus and help to avoid up to 5 to 8 Mton CO_2 annually

System risk

e.g. comply with reference incident measures as stated in network codes and guidelines

Operational challenges

No experience yet with operation of HVDC systems.

Offshore RES development

is at risk in case coordination across multiple actors fails - complex coordination is decisive

& General challenges with

- Infrastructure supply chain (incl. workforce)
- Ports availability
- Environmental impact
- Flexibility

The Shopping List is long...

Route length
Up to 54,000 km
up to 36,000 km (NS)

DC converter stations offshore
158 ..172 units
NS: 93 ..103 units
with .. .w/o

AC substations offshore
123..137 units)
NS: 30…40 units
with … w/o

403 bn€*
255 bn€ (NS)

DC converter stations onshore
167…176 units
100…104 units (NS)
w/o … with

DC circuit breaker sets
Up to 34 sets
Up to 21 sets (NS)

Credit mages top and bottom left: TenneT NL
Credit Image bottom right: Hitachi Energy

* low-cost assumption

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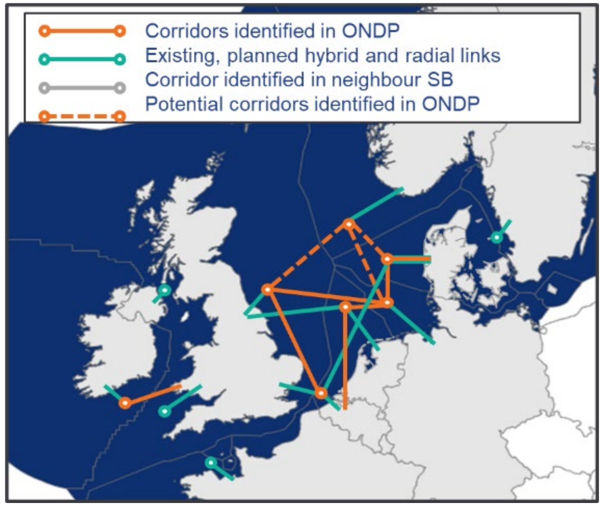
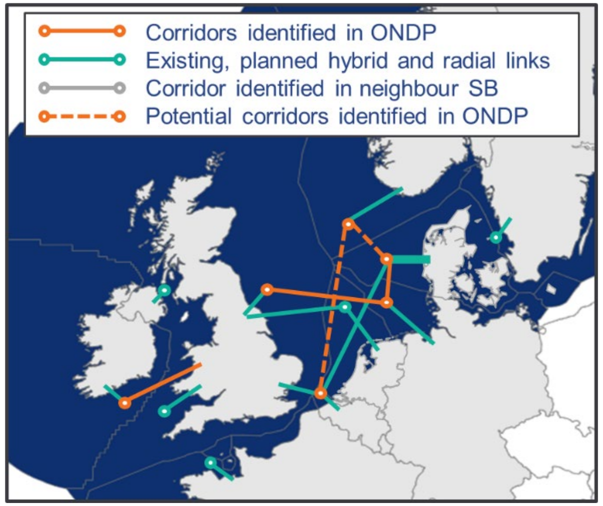
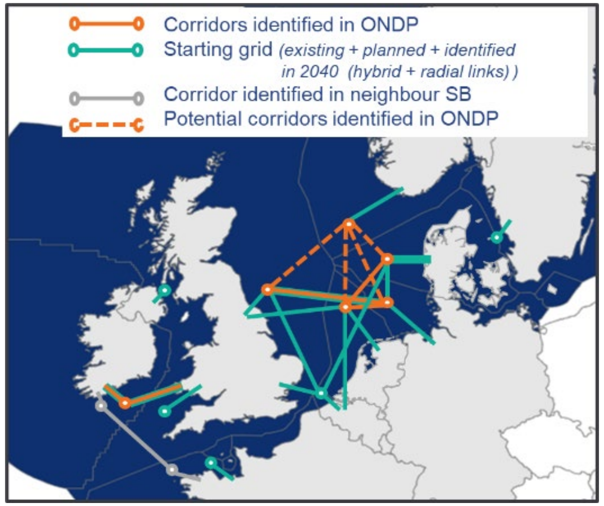
2040/2050 Offshore Infrastructure – with/ without HVDC-circuit breaker … Example Northern Seas

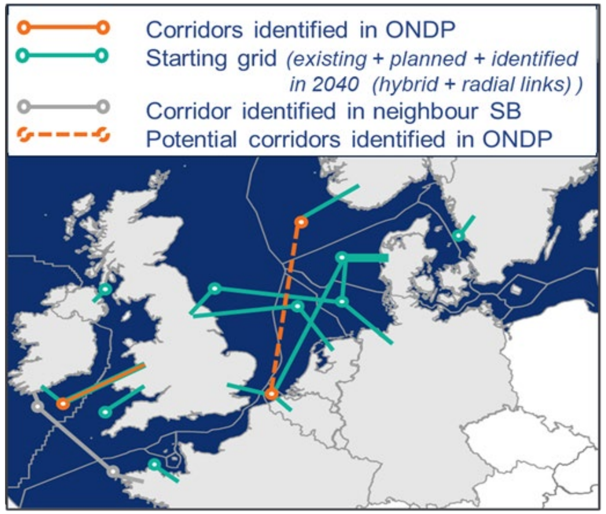
2040





2050





With DC-breaker — Without DC-breaker

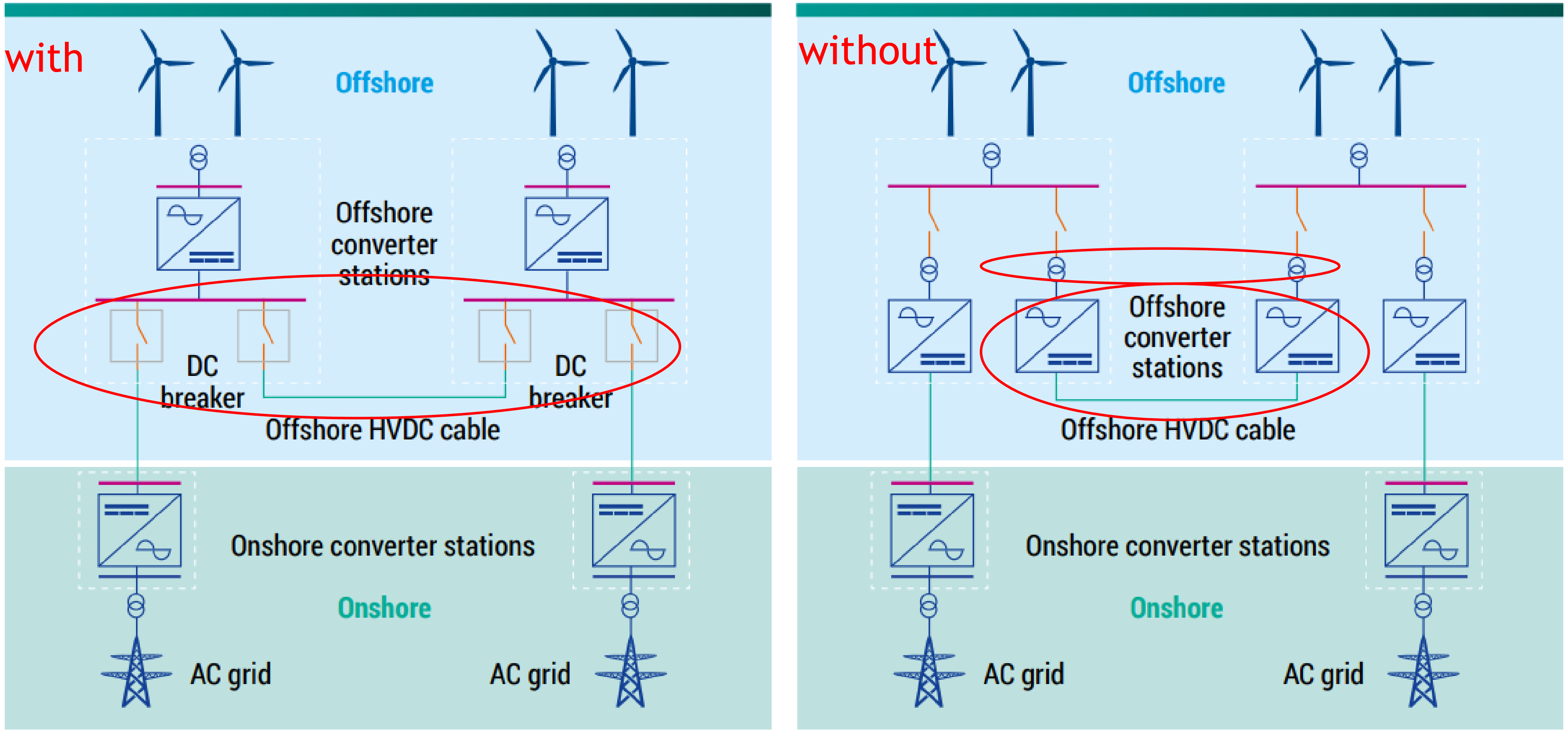
Selected corridors*

	With DC-breaker	Without DC-breaker
2031-2040	21.5 GW 4,300 / 21,000 km 148 bn€	7.5 GW 2,200 / 19,000 km 148 bn€
2041-2050	8.5 GW 1,900 / 8,000 km 59 bn€	3.0 GW 1,800 / 8,000 km 57 bn€

- DC Circuit breaker is not yet commercially attractive
- Without it, converter stations + AC substation instead
- **DC Circuit breaker facilitates three times higher cross-border connection capacity at similar costs**

*All costs refer to low-cost assumptions

The Mystery of the DC breaker



Adding a 2 GW link between two offshore nodes means…

Offshore Asset List
4 DC Circuit breakers à 330 M€ = 1.32 bn€
Total: **1.32 bn€**

Offshore Asset List
2 converter Stations à 1.1 bn € = 2.2 bn€
2 AC offshore stations à 882 M€ = 1.76 bn€
Total: **3.96 bn€**

+2.64 bn € (+200%)

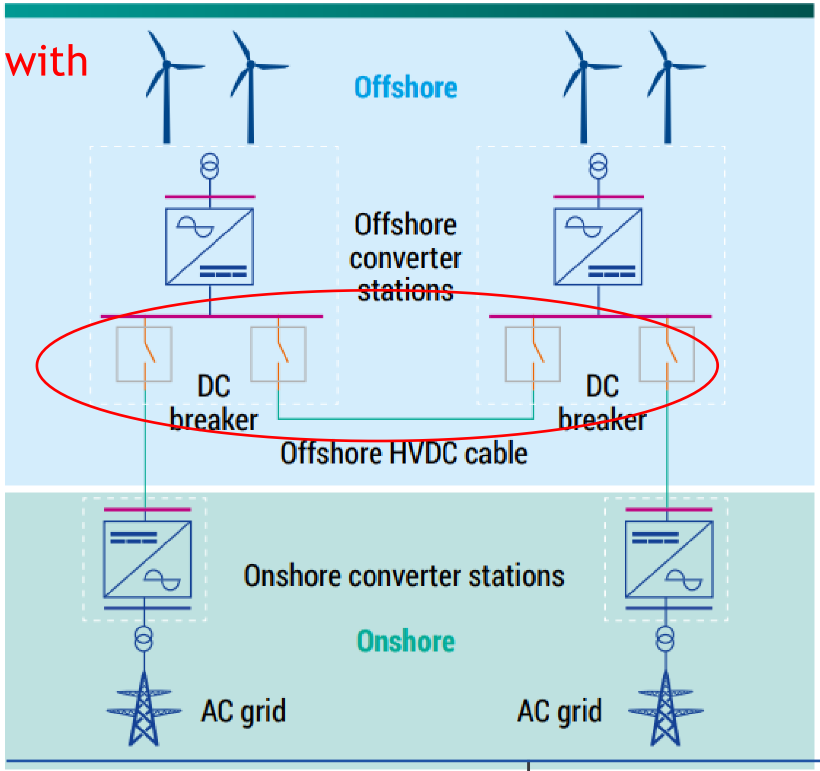
Why is it a game-changer?

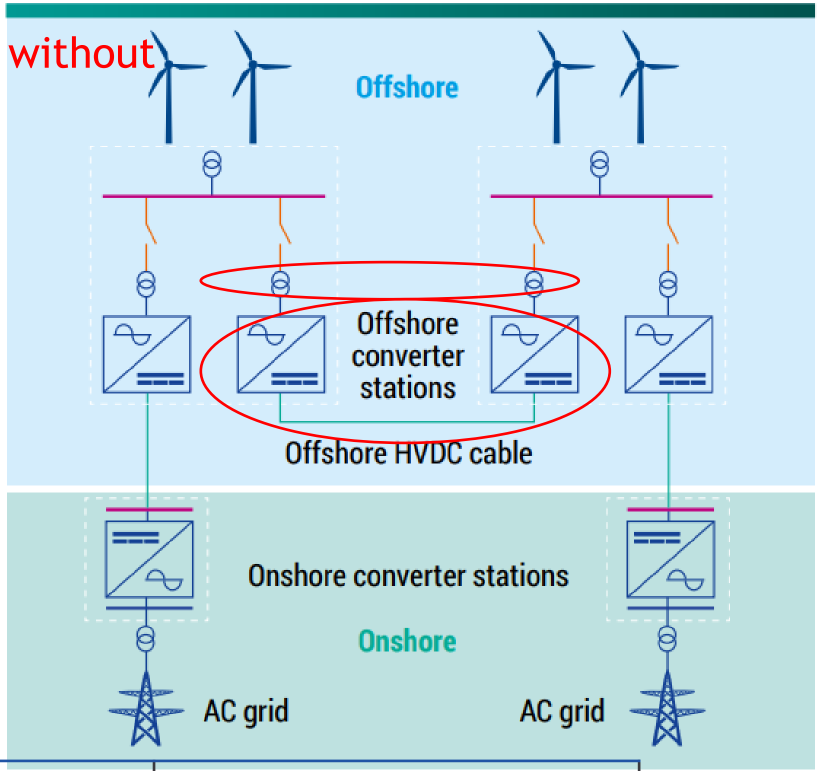
Due to triple costs per additional link between nodes, less links are identified.

For NSOG this resulted in
=> rather similar costs,
but 3 times less capacity to exchange electricity across borders.

(Low-cost-assumption)

The Mystery of the DC breaker





	With	Without
	NS / All SBs	NS / All SBs
Add. Hybrid Corridors [nr]	21 / 34	10 / 13
Add. Hybrid Corridors [GW]	30 / 44	10,5 / 14
Add. Costs [bn€]	1.6 / 10	N.A.
Total Costs [bn€]	254 / 403	253 / 393

Why is it a game-changer?

Due to triple costs per additional link between nodes, less links are identified.

For NSOG this resulted in
=> rather similar costs,
but 3 times less capacity to exchange electricity across borders.

TYNDP22 identified **88** GW cross border capacity for entire Europe. ONDP identified for…
=> ..All SBs either **16%** (without)
or **50%** (with) of that.
=> ..NS either **12%** (without)
or **34%** (with) of that.

Next Steps

- **Online Survey**
  -> YOUR opinion on the ONDP by 22 March
  -> Recommended improvements

- In ENTSO-E we'll now integrate the ONDP into the TYNDP 2024

- TYNDP 2024 release incl. onshore reinforcements in autumn 2024

- WATCH also our
  Public ONDP-Webinar on YOUTUBE!

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Thank you!

Antje Orths
Convenor ENTSO-E ONDP Central Group
ano@energinet.dk

EU Grid Action Plan

06 March 2024

Eric Lecomte, DG Energy
Research, Innovation, Competitiveness, Digitalisation

Importance of electricity grids

€584bn investment by 2030!

Capacity expansion (cables & substations), modernisation (40%) and smartening

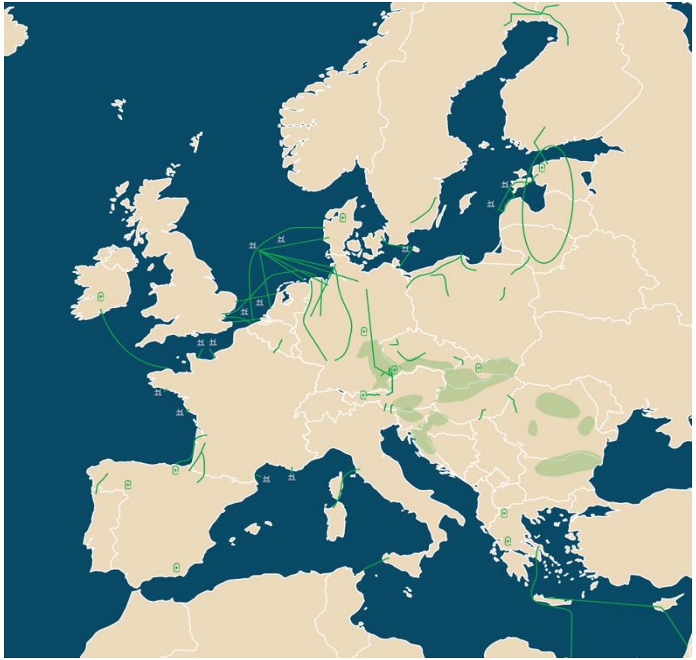
Transmission grids

- Transport of renewables across Europe:
  - Cross-border capacity (PCIs)
    - ✓ x2 by 2030
    - ✓ ↓ Annual €9M generation costs by 2040
  - Offshore ~317 GW
  - Industry electrification
  - Between distribution areas

Distribution grids

- ~70% new renewables (1,000 GW by 2030)
- 40M electric vehicles by 2030 (400 to 1000 GW)
- Heat pumps deployment rate x2
- Smart grids
  - Digitalisation → Digitalising the Energy Sector Action Plan 2022
  - Flexibility
  - Prosumer

First PCI/PMI list: Electricity C(2023)7930 - 28nov2023



PCI (Project of Common Interest)

- 85 electricity PCIs, incl:
  12 related to storage,12 offshore,
  5 smart grids

PMI (Project of Mutual Interest)

- 10 Projects: electricity
  interconnections with UK, Western
  Balkans, North African countries

European
Commission

EU Grid Action Plan

Accelerating PCIs implementation

1 Network planning

2 Regulatory incentives

3 Smart and efficient grids

4 Financing

5 Permitting & acceptance

6 Supply chain

European Commission

1 Network planning

HLGs reinforced monitoring, ministerials

COM to assess funding needs (CEF-Energy)

ENTSO-E to improve TYNDP

EU DSO Entity to support DSOs

2 Regulatory incentives

COM guidance on anticipatory investments

COM guidance on offshore cost sharing

European Commission

3 Smart & efficient grids

ENTSO-E and EU DSO Entity to enhance grid capacity transparency

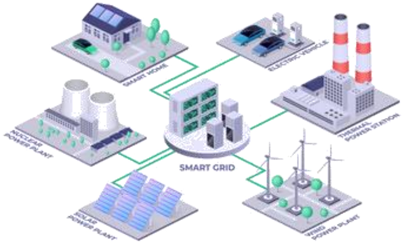
ENTSO-E and EU DSO to promote uptake of smart grids and innovative tech

ACER to recommend best practices on OPEX+CAPEX in tariff reports

4 Financing

COM –through Investors Dialogue– to address financing obstacles

COM to increase visibility on funding for distribution (ERDF, CF, RRF)



European Commission

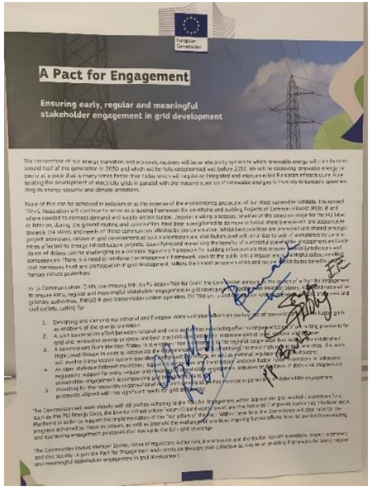
5 Permitting & public acceptance

MSs to use Emergency Reg + RED for grids

COM update ENV guidance for grids

National Competent Authorities platform

Pact for Engagement


European Commission

A Pact for Engagement

Ensuring early, regular and meaningful stakeholder engagement in grid development

6 Supply chain

PLANS AND PERMITTING

ENTSO-E, EU DSO and tech providers to develop standard specifications

Common tech requirements for connection of generation / demand

Net Zero Industry Act: manufacturing plants

European Commission

Thank you

Strategic Energy Technology- SET Plan

Implementation Working Group (IWG) on *Sustainable and Efficient Energy use in Industry*

ERIC LECOMTE

04/03/2024

AIDRES (European Parliament Pilot Project 32 027714)

Advancing Industrial Decarbonisation by assessing the future use of REnewable energies in industrial processeS

- Assessment of industrial technology **pathways to C-neutrality**
- Quantification of **future energy and feedstock needs**, and CO2 captured
- Geographical **mapping of facilities**
- **Mapping of the needs** at facility and NUTS3 levels

#SETPlan

European Commission

AIDRES (European Parliament Pilot Project 32 027714)

6 sectors and 16 products in scope

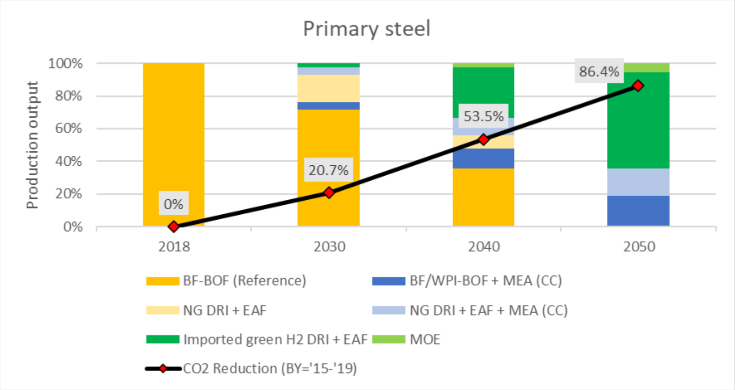
SECTOR	PRODUCT
Steel	Primary and secondary steel Excl. steel finishing sites
Fertiliser	Ammonia, urea, nitric acid
Chemical	Olefins, polymers and organic synthesis Excl. other basic chemicals and downstream products
Glass	Flat, container, fibre glass
Cement	Portland Cement II, LC3
Refinery	Light liquid fuel (63,8% of product out of crude oil) Excl. naphtha, heavy fuel, other

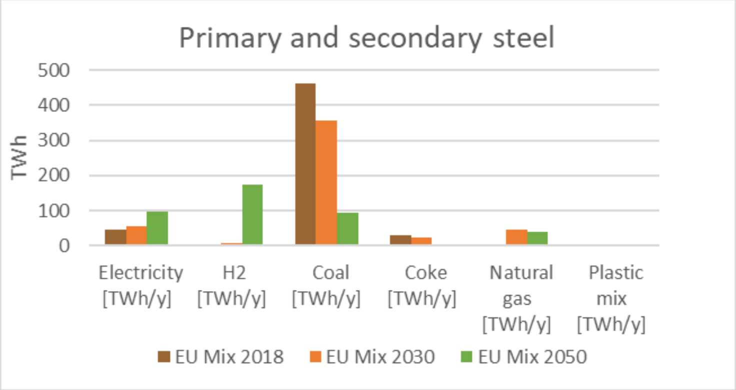
Source: Port of Antwerp and Bruges

AIDRES (European Parliament Pilot Project 32 027714)

sector results STEEL

- AIDRES EU mix primary steel production routes[1].
  - **Hydrogen** direct reduced Iron (H2-DRI): **59%**
  - **Carbon capture** based routes: **36%**
  - Other technologies e.g. **Molten Oxyde Electrolysis (MOE)**: **5%**





[1]Sources:
https://www.eurofer.eu/assets/Uploads/EUROFER-Low-Carbon-Roadmap-Pathways-to-a-CO2-neutral-European-Steel-Industry.pdf
https://www.estep.eu/assets/Uploads/D1.7-Decarbonisation-Pathways-2030-and-2050.pdf
https://iea.blob.core.windows.net/assets/eb0c8ec1-3665-4959-97d0-187ceca189a8/Iron_and_Steel_Technology_Roadmap.pdf

European Commission

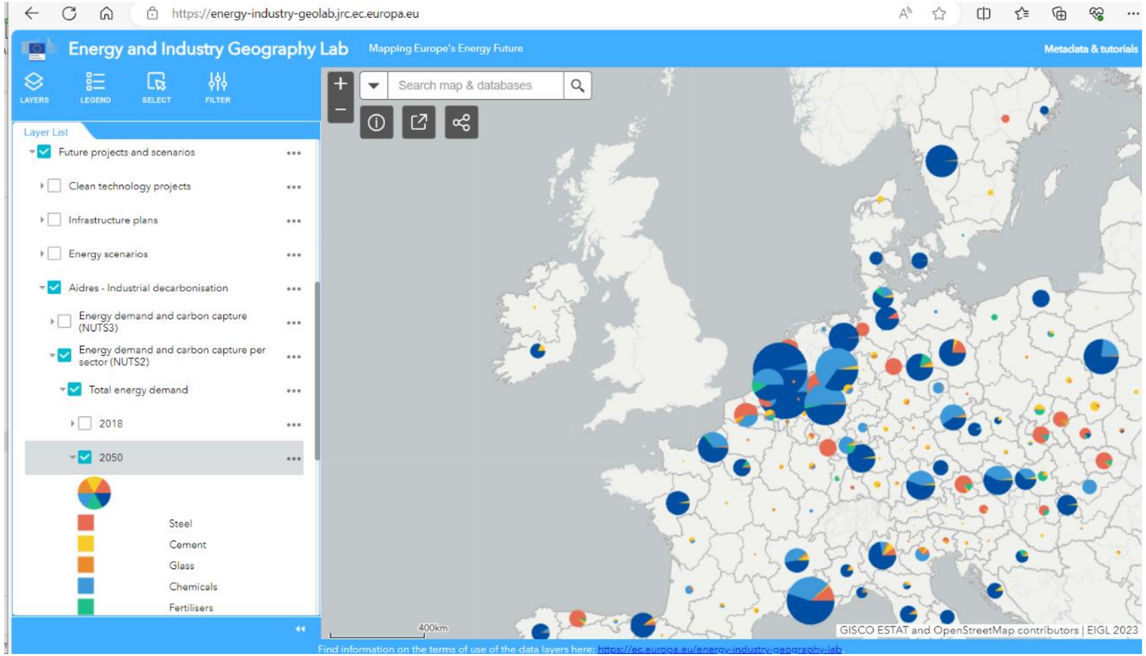
AIDRES (European Parliament Pilot Project 32 027714)

The AIDRES project final report *- Assessment and geo-mapping of renewable energy demand for technological paths towards carbon neutrality of EU energy-intensive industries :* [*https://op.europa.eu/s/yZuw*](https://op.europa.eu/s/yZuw)

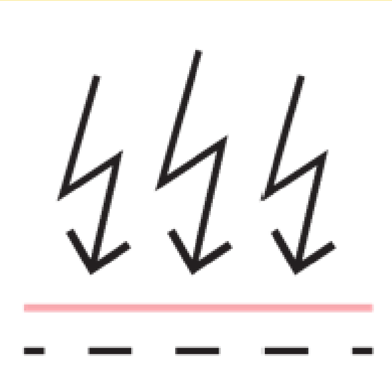
Database in SQL format*:* [*https://data.jrc.ec.europa.eu/dataset/14914982-70a9-4d1d-a2fc-cdee4a1d833d*](https://data.jrc.ec.europa.eu/dataset/14914982-70a9-4d1d-a2fc-cdee4a1d833d) *.*

Visualisation *in the JRC's EIGL (Energy and Industry Geography Lab)* [*https://europa.eu/!kTr9xT*](https://europa.eu/!kTr9xT)

Simplified version of the ***database in EXCEL format*** *:* [*https://energy.ec.europa.eu/publications/database-advancing-industrial-decarbonisation-assessing-future-use-renewable-energies-industrial_en*](https://energy.ec.europa.eu/publications/database-advancing-industrial-decarbonisation-assessing-future-use-renewable-energies-industrial_en)



SET Plan IWG – HVDC & DC technologies



LVDC Implementation Plan

Outline presentation

Content of the draft Implementation Plan

1. Why LVDC?
2. Benefits of LVDC
3. Status of LVDC / Examples
4. Challenges
5. Priorities and targets
6. Proposed activities

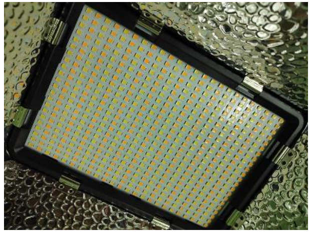
1. Why LVDC?

Most applications are DC-based or DC-ready

- **Renewable energy**: Solar PV, Wind, ocean energy,
- **Storage**: electrical battery (stationary and E-Vehicles)
- **Electronics**: LED-lighting, IT/office equipment,
- Variable speed **motor drives** in: motors, robots, heat pumps, washing machines, dishwasher, vacuum cleaner …

  include DC-link in frequency converters: AC->DC->AC
- **Resistive heating**: stove, oven, water boiler

Sources: https://commons.wikimedia.org/wiki/File:Mennoki_Wind_Power_station.jpg, https://commons.wikimedia.org/wiki/File:Solarpark_Jännersdorf.jpg



https://commons.wikimedia.org/wiki/File:Battery-Pack-Leaf.jpg
https://commons.wikimedia.org/wiki/File:Led_Lights_Panel.jpg

2. Benefits of DC

- **Converters: Less copper and material, higher efficiency**
- **Simple integration of renewables & storage:** higher self-consumption
- **Cables: Less copper, higher efficiency (lower losses)**
- **Motors' braking energy recovery**
- **Peak power shaving** – lower connection capacity needs

Thank you!

Eric.Lecomte@ec.europa.eu

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Horizon Europe – Running projects

Horizon Europe - Closed topics - Title	Budget	Type	Projects
HORIZON-CL5-2021-D3-01-02 - **Laying down the basis** for the demonstration of a Real Time Demonstrator of **Multi-Vendor Multi-Terminal HVDC** with Grid Forming Capability: Coordination action	1 M€ (1 pj)	CSA	READY4DC Getting ready for multi-vendor and multi-terminal DC technology Apr 2022 – Sep 2023
HORIZON-CL5-2021-D3-02-08: Electricity system **reliability and resilience by design**: **HVDC-based systems** and solutions	15 M€ (2 pj of 7-8 M€)	RIA	NEWGEN 7.6M€, Oct22-Sep26 New generation of HVDC insulation materials, cables and systems HVDC-WISE 6.6M€, Oct22-Mar26, HVDC-based grid architectures for reliable and resilient WIdeSprEad hybrid AC/DC transmission systems
HORIZON-CL5-2021-D3-02-10: Demonstration of **advanced Power Electronics** for application in the energy sector *(including HV and MV-HVDC)*	10 M€ (2 pj of 5 M€)	IA	AdvanSiC Advances in Cost-Effective HV SiC Power Devices for Europe's MV grids, 3.2M€, Jan23-Dec25 SiC4GRID (*) Next Gen Modular SIC-based Advanced Power Electronics Converters 3.8M€, Oct22-Mar26 FOR2ENSICS Future Oriented Renewable and Reliable Energy SIC Solutions, 4.4M€, Oct22-Sep26

European Commission

Horizon Europe – Running projects

Horizon Europe - Closed topics - Title	Budget	Type	Projects
HORIZON-CL5-2022-D3-01-09: Real Time Demonstrator of **Multi-Vendor Multi-Terminal VSC-HVDC** with Grid Forming Capability	55 M€ (topic)	IA	InterOPERA, (**) Enabling interoperability of multi-vendor HVDC grids, 50.7M€, Jan 2023 – Apr 2027
HORIZON-CL5-2023-D3-01-05: Critical **technologies for the offshore wind** farm of the Future	18 M€ (3pj of 6 M€)	RIA	**INF4INiTY** Integrated Designs for Future Floating Offshore Wind Farm Technology, 6M€, Jan 2024 -Dec 2027 **MADE4WIND** Innovative circular materials and design methods for the development of Floating Wind Turbine components for offshore Wind Farms of the future, 6M€, Dec 2023 - May 2027 **FLOATFARM** Developing the Next Generation of Environmentally-Friendly Floating Wind Farms with Innovative Technologies and Sustainable Solutions, 6M€, Jan 2024 - Dec 2027 **TAILWIND** Sustainable station-keeping systems for floating wind, 5M€, Jan 2024 - Dec 2027
HORIZON-CL5-2023-D3-01-11: Demonstration of **DC powered data centres, buildings, industries and ports**	18 M€ (2 pj 9 M€)	IA	**SHIFT2DC** SHIFT to Direct Current, 11.3M€, Dec 2023 - May 2027 DC-POWER Direct Current – Power flOws in megawatt-scale Energy gRids, 8.7M€, Jan2024 - Dec 2027
HORIZON-CL5-2023-D3-01-12: Development of **MVDC, HVDC and High-Power Transmission systems and components** for a resilient grid	22 M€ (2 pj of 11 M€)	IA	**MISSION** eMISsion-free HV and MV transmiSION switchgear for AC and DC, 10.4M€, Jan 2024 - Dec 2027

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Horizon Europe – Running projects

Horizon Europe - Closed topics - Title	Budget	Type	Projects
HORIZON-CL5-2022-D3-01-09: Real Time Demonstrator of **Multi-Vendor Multi-Terminal VSC-HVDC** with Grid Forming Capability	55 M€ (topic)	IA	InterOPERA, (**) Enabling interoperability of multi-vendor HVDC grids, 50.7M€, Jan 2023 – Apr 2027
HORIZON-CL5-2023-D3-01-05: Critical **technologies for the offshore wind** farm of the Future	18 M€ (3pj of 6 M€)	RIA	**INF4INiTY** Integrated Designs for Future Floating Offshore Wind Farm Technology, 6M€, Jan 2024 -Dec 2027 **MADE4WIND** Innovative circular materials and design methods for the development of Floating Wind Turbine components for offshore Wind Farms of the future, 6M€, Dec 2023 - May 2027 **FLOATFARM** Developing the Next Generation of Environmentally-Friendly Floating Wind Farms with Innovative Technologies and Sustainable Solutions, 6M€, Jan 2024 - Dec 2027 **TAILWIND** Sustainable station-keeping systems for floating wind, 5M€, Jan 2024 - Dec 2027
HORIZON-CL5-2023-D3-01-11: Demonstration of **DC powered data centres, buildings, industries and ports**	18 M€ (2 pj 9 M€)	IA	**SHIFT2DC** SHIFT to Direct Current, 11.3M€, Dec 2023 - May 2027 DC-POWER Direct Current – Power flOws in megawatt-scale Energy gRids, 8.7M€, Jan2024 - Dec 2027
HORIZON-CL5-2023-D3-01-12: Development of **MVDC, HVDC and High-Power Transmission systems and components** for a resilient grid	22 M€ (2 pj of 11 M€)	IA	**MISSION** eMISsion-free HV and MV transmiSION switchgear for AC and DC, 10.4M€, Jan 2024 - Dec 2027

Horizon Europe - Closed topics

Horizon Europe - Open topics - Title	Budget	Type	Projects
HORIZON-CL5-2024-D3-01-15: HVAC, HVDC and **High-Power cable** systems (incl. superconducting)	16 M€ (3pj of 5.5 M€)	IA	Open: 12 Sep 2023 DDL: 16 Jan 2024

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