Massive Renewables uptake through enhanced grids

A Transatlantic Perspective

1 June 2021

WATT COALITION

CurrENT
Enabling Network Technology throughout Europe

Agenda

16.30 **Introduction to currENT and WATT** by Susanne Nies and Jenny Erwin

Presentation of the 'Unlocking the Queue' Report, Jay Caspary

16.55 **Industry Perspectives**

Rob Gramlich, Grid Strategies LLC, WATT, and ACEG
Oliver Koch, DG ENER
John Fitzgerald, SuperNode
Michael Jesberger, Transnet BW
Giles Dickson, WindEurope

17.30 **Q&A Session** **PLEASE SEND YOUR QUESTIONS THROUGH CHAT**

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Speakers

Susanne Nies
Board Chair of currENT

Jenny Erwin
Board Chair of WATT

Jay Caspary
VP of Grid Strategies LLC

Rob Gramlich
CEO of Grid Strategies LLC

Oliver Koch
DG ENER

John Fitzgerald
CEO of SuperNode

Michael Jesberger
CTO of TransnetBW GmbH

Giles Dickson
CEO of Wind Europe

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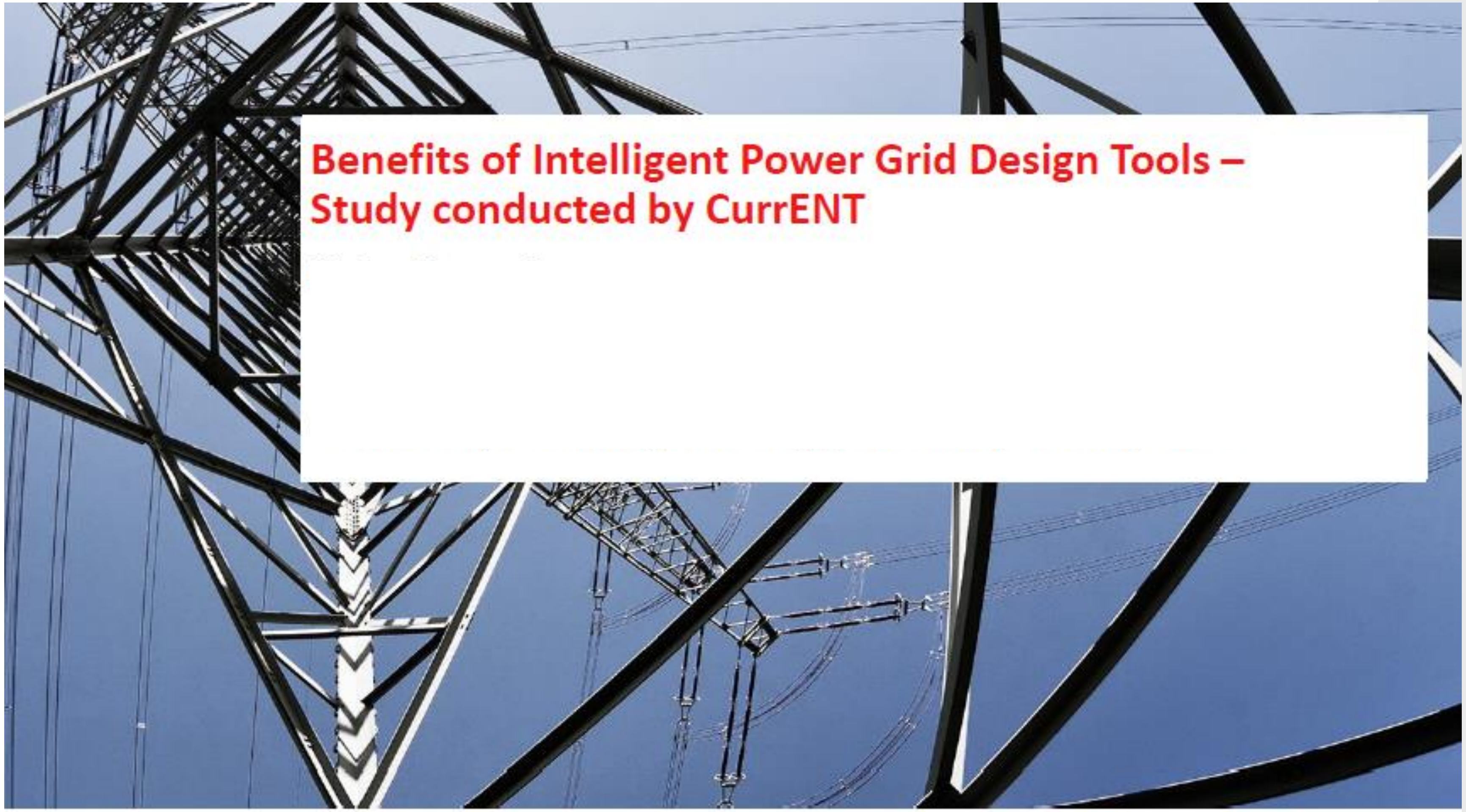
Forthcoming for the Infrastructure Forum 2021



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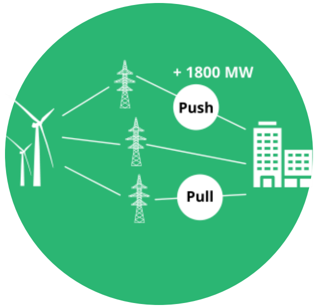
Grid Enhancing Technologies

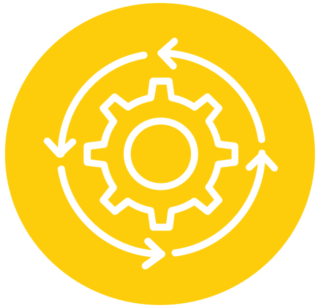
Hardware, software and associated protocols applied to existing transmission facilities that increase the network's operational transfer capacity, and maximise the efficiency of new grids



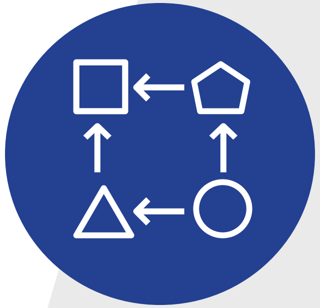
Modular Power Flow Control

Dynamic Line Rating

Superconductor Cable Systems



Innovative Sensors



Topology Control

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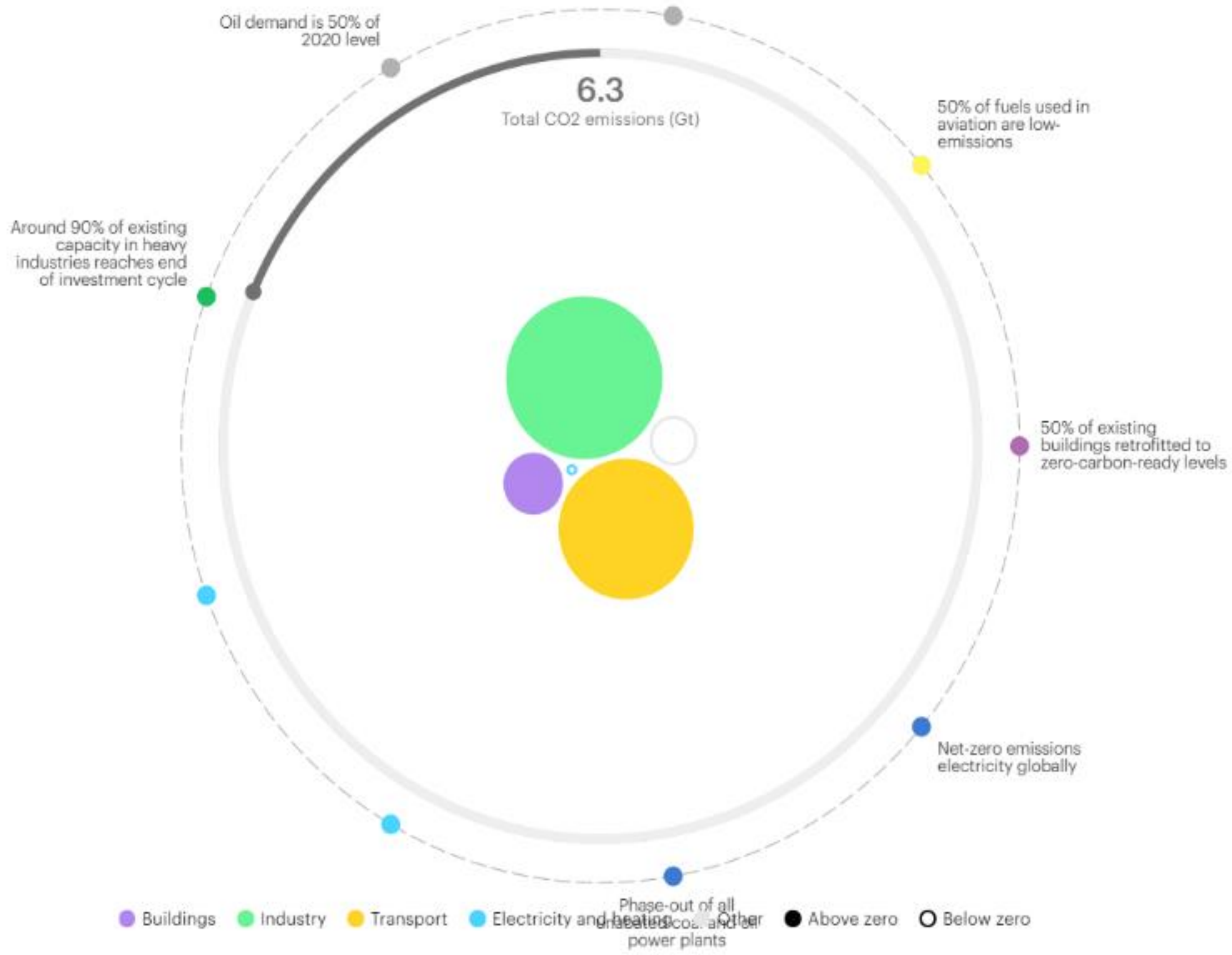
Why GETs are central? IEA Net Zero roadmap



Electricity becomes the core of the energy system

It will play a key role across all sectors, from transport and buildings to industry. Electricity generation will need to reach net-zero emissions globally in 2040 and be well on its way to supplying almost half of total energy consumption.

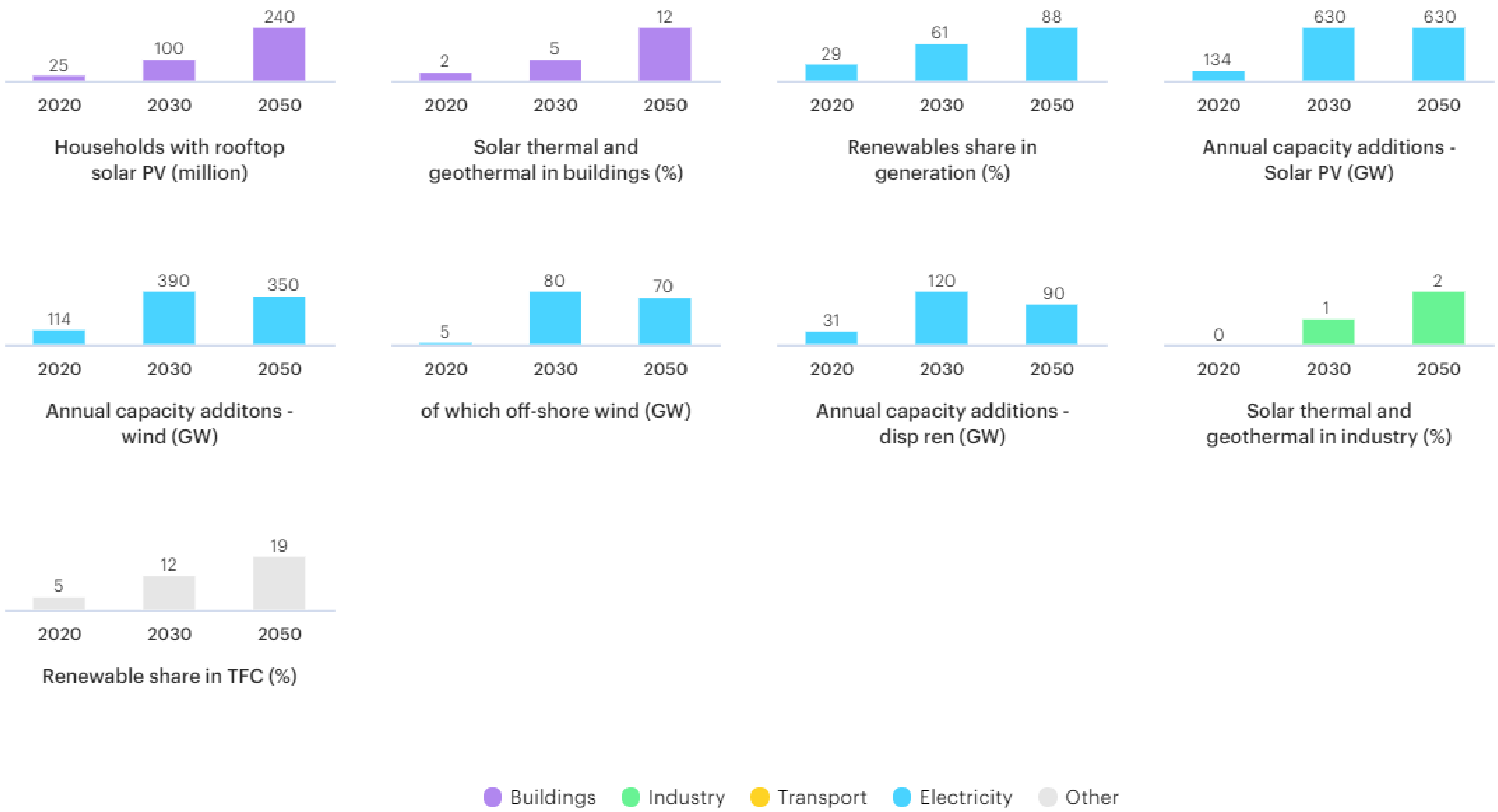
This will require huge increases in electricity system flexibility – such as batteries, demand response, hydrogen-

Why GETs are central? Renewables

Renewables

Renewable energy technologies like solar and wind are the key to reducing emissions in the electricity sector, which is today the single largest source of CO_2 emissions.

In our pathway to net zero, almost 90% of global electricity generation in 2050 comes from renewable sources, with solar PV and wind together accounting for nearly 70%.

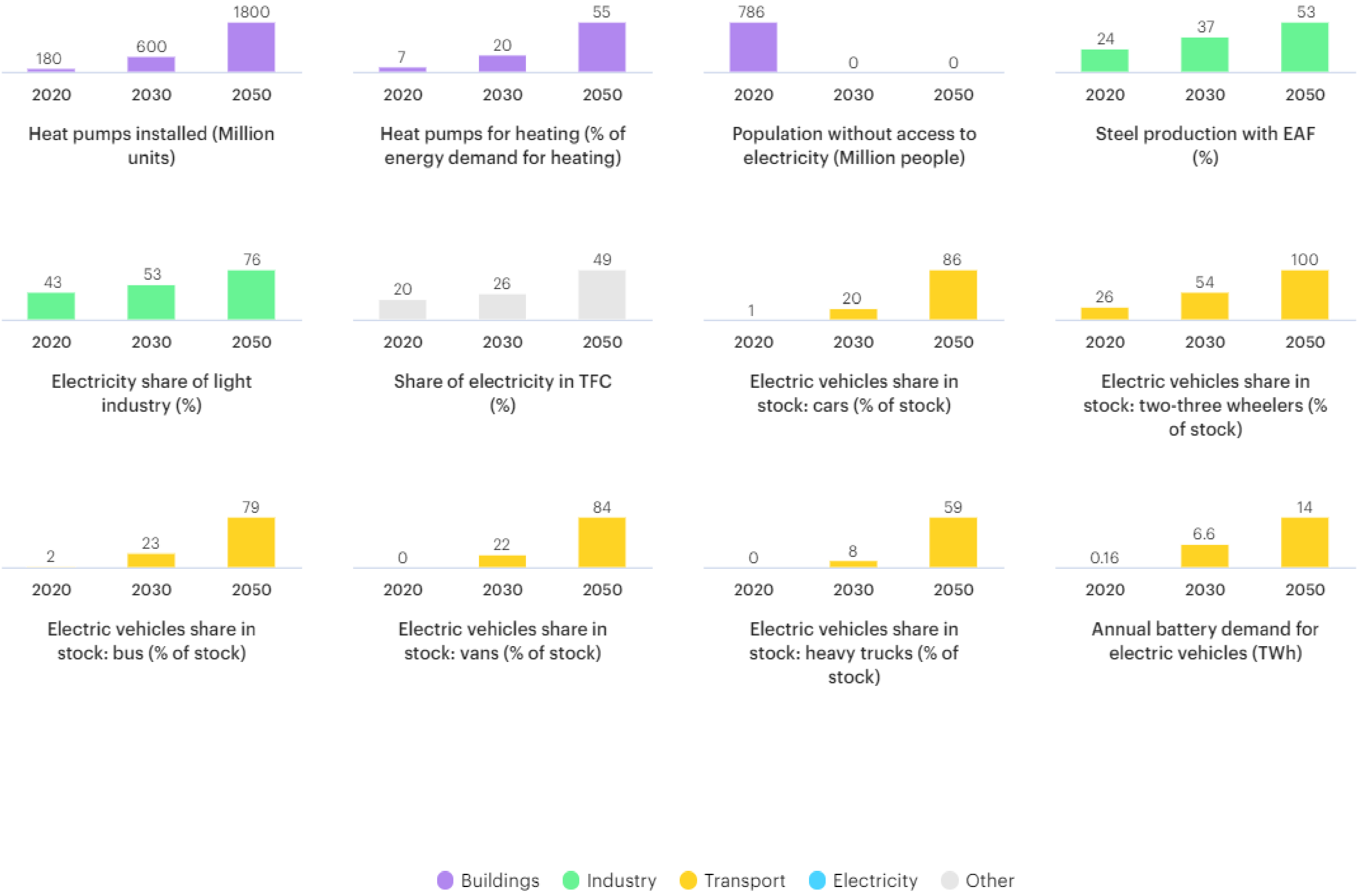


Why GETs are central? Electrification

Electrification

As electricity generation becomes progressively cleaner, electrification of areas previously dominated by fossil fuels emerges as a crucial economy-wide tool for reducing emissions.

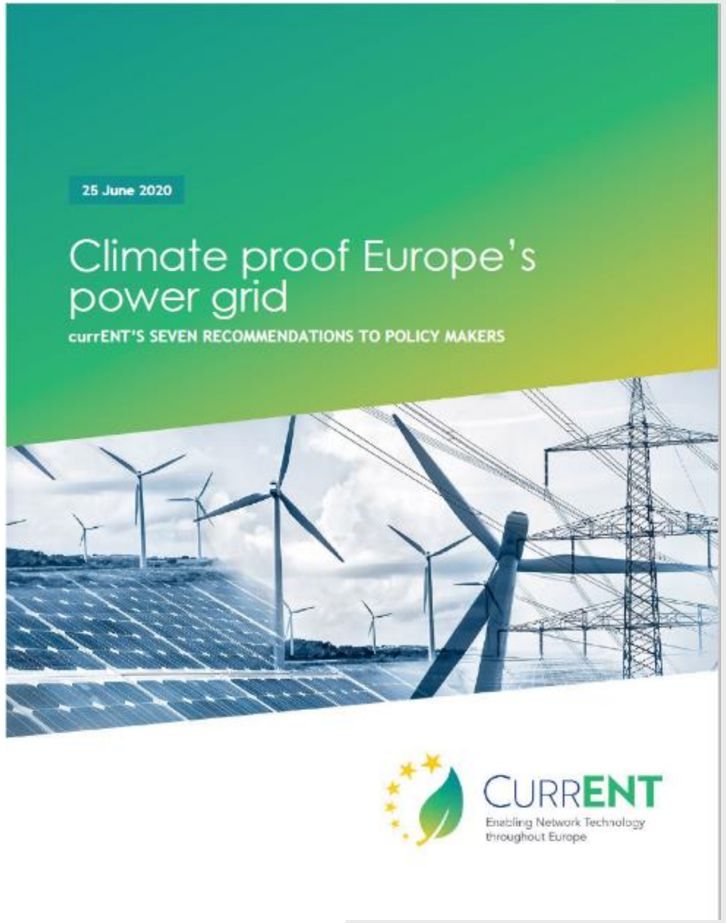
This takes place through technologies like electric cars, buses and trucks on the roads, heat pumps in buildings, and electric furnaces for steel production.



currENT : who we are

currENT is the key industry association representing innovative grid technology companies operating in Europe.

Our members are taking Europe’s power network to the next level – developing and supplying innovative technologies that optimise and maximise use of the existing grid.



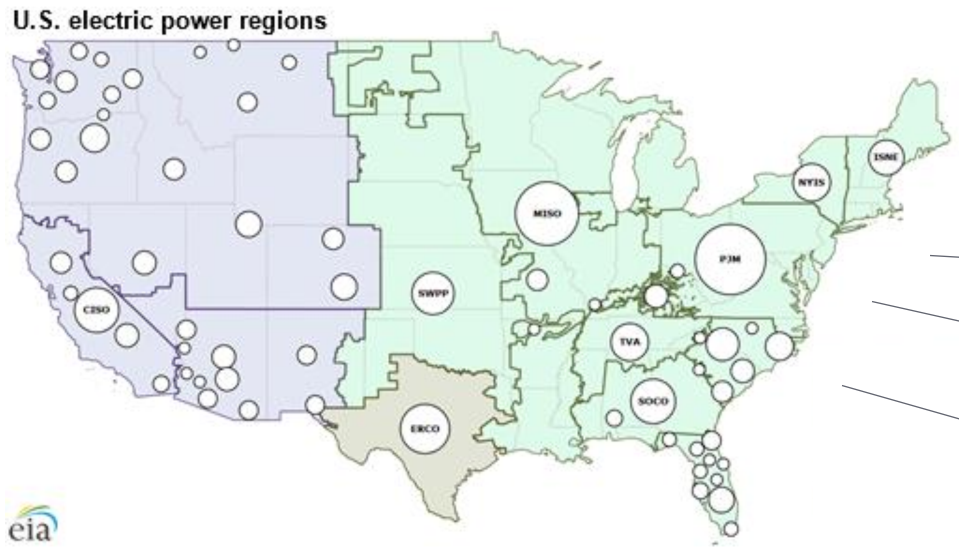
SUPERNODE™ amsc Ampacimon Smart solutions for a dynamic grid OTLM KNILL GRUPPE SMART WIRES GWP greenwood power HEIMDALL POWER LINEVISION

WATT: who we are

Get more out of the current grid.

WATT

The **Working for Advanced Transmission Technologies (WATT)** Coalition advocates for policy that supports wide deployment of Grid-Enhancing Technologies (GETs), to ***accelerate the clean energy transition and lower energy costs.***



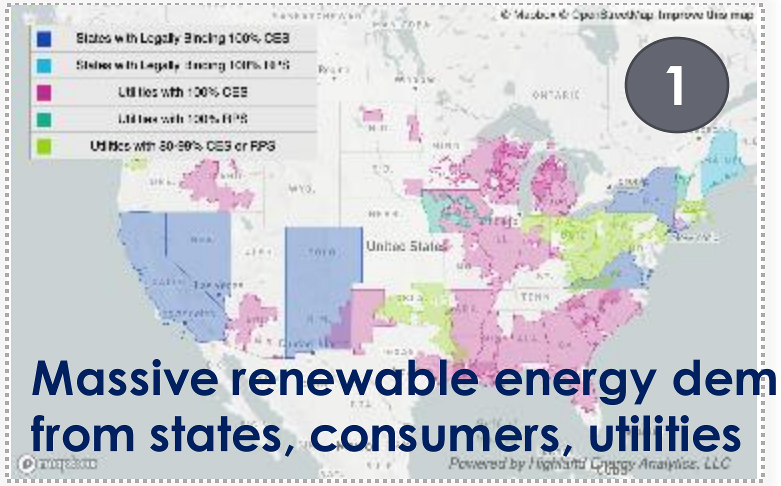
- FERC
- Congress
- State PUCs
- ISOs/RTOs
- Utilities
- Renewable Developers

Members

Infrastructure stimulus | **Transmission Policy Reform** | **Generation Connection Processes**

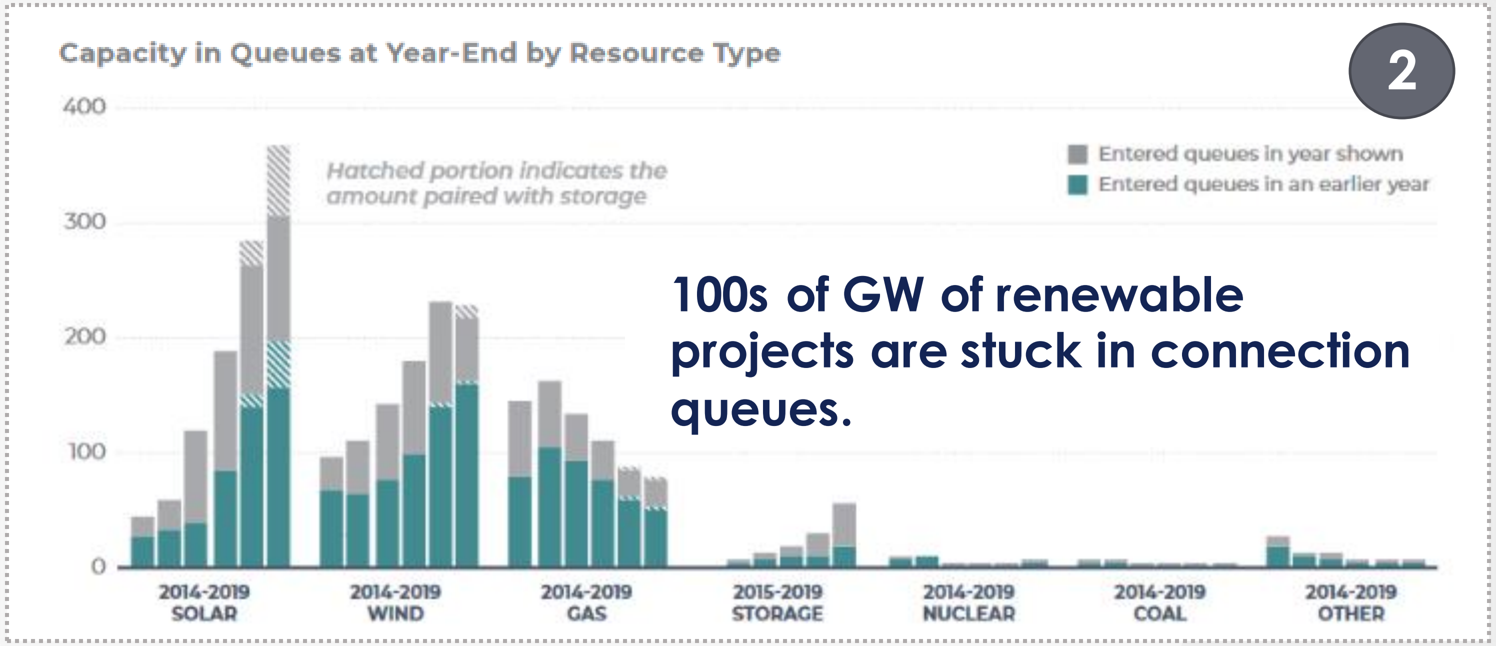
CurrENT
Enabling Network Technology throughout Europe

Study Launch



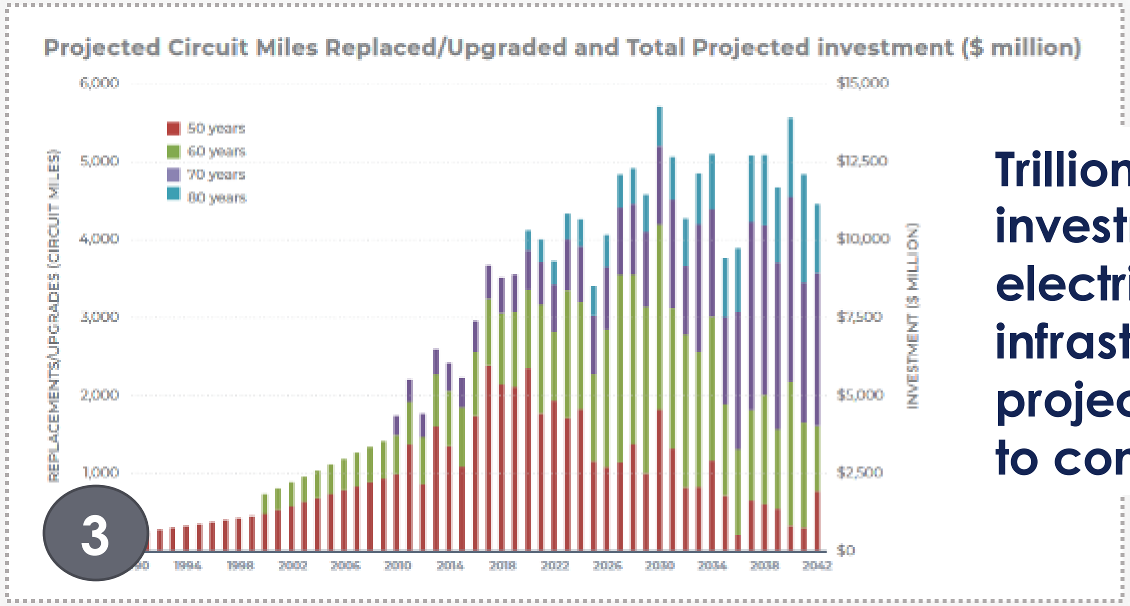
1

Massive renewable energy demand from states, consumers, utilities



2

100s of GW of renewable projects are stuck in connection queues.



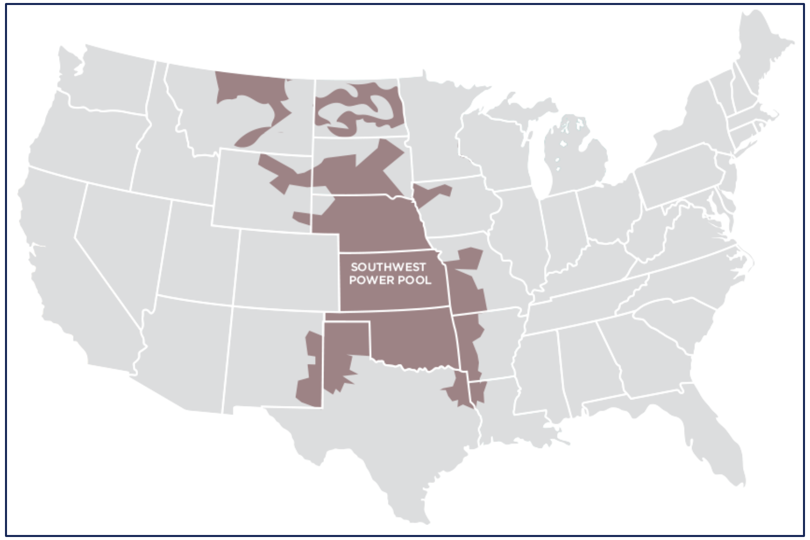
3

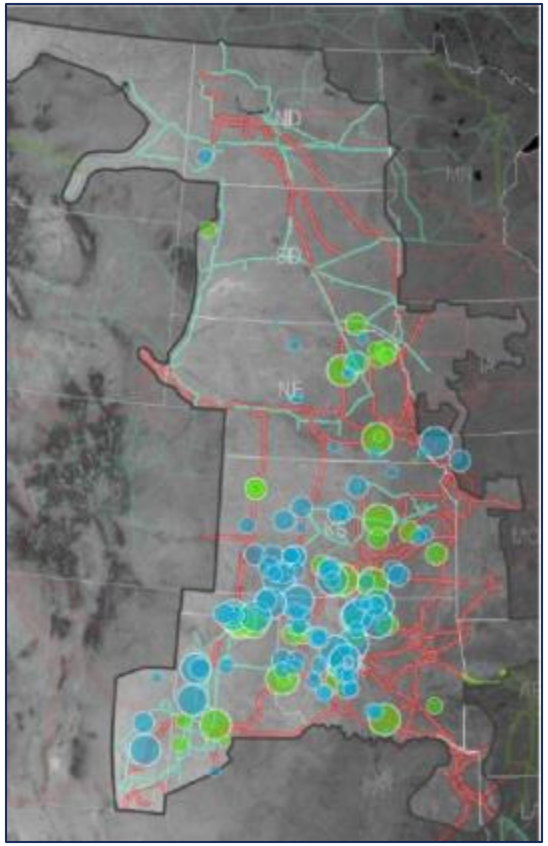
Trillions of $ of investment is planned in electric transmission infrastructure, but projects take decades to come to fruition.

Can we unlock the potential of today's grid?

Key Question

How many renewable projects can be added to the Kansas and Oklahoma grids by 2025?





SPP Generation Interconnection Queue

Impact:

↑ *MW, MWh*

↓ *$/yr consumer costs*

↓ *Tons CO2/yr*

↑ *Jobs*

Implications for the US and beyond: climate change is universal, and so are solutions

Kansas (KS) + Oklahoma (OK) land mass = Germany

KS + OK high voltage miles = TenneT Germany + Netherlands

10 GW of wind and solar seeking grid connections

+ 2.5 GW with Business as Usual

+5 GW with GETs

CurrENT
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Unlocking the Queue with Grid-Enhancing Technologies

Jay Caspary

currENT Webinar

June 1, 2021

Link to webpage with full report, recording of release event, etc.

WATT

Unlocking the Queue with Grid-Enhancing Technologies

CASE STUDY OF THE SOUTHWEST POWER POOL
FINAL REPORT – PUBLIC VERSION

PRESENTED BY
T. Bruce Tsuchida
Stephanie Ross
Adam Bigelow

PREPARED FOR
WATT (Working for Advanced Transmission Technologies) Coalition

FEBRUARY 1, 2021

Brattle

Disclaimer

- This report was prepared for the WATT (Working for Advanced Transmission Technologies) Coalition with support from GridLab, EDF Renewables North America, NextEra Energy Resources, and Duke Energy Renewables. The WATT Coalition includes Ampacimon, Lindsey Manufacturing, LineVision, NewGrid, Smart Wires, and WindSim. All results and any errors are the responsibility of the authors and do not represent the opinion of The Brattle Group (Brattle) or its clients.
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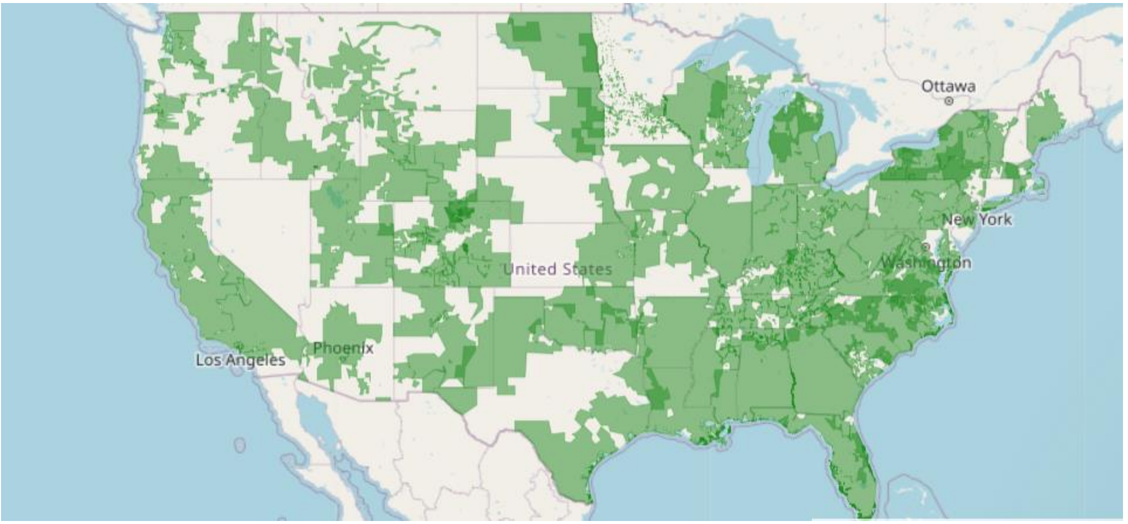
Issue at Hand - 1/2

Increasing renewable resources (often associated with carbon reduction) is a common goal.

- Many private entities including utilities, corporations, and academic institutes.
- Across jurisdictions from federal, state, to local (e.g., cities) levels.
- Increasing renewable projects provide jobs and other local benefits, and help boost the economy out from the current COVID-associated downturn.

Service Territories of Utilities With Announced Carbon Reduction Goals



Source: from Smart Electric Power Alliance Utility Carbon Reduction Tracker (Feb 2021)

Issue at Hand - 2/2

What are the roadblocks to integrating more renewables?

- Utilities and system operators have good understandings of the variability of renewable resources.
  - Wind became SPP's leading resource in 2020.
- Transmission availability is a major limiting factor.
  - Many renewable projects are locked up in the Generation Interconnection Queue.
  - There is a timing gap: renewables are developed (in months to years) much faster than transmission (in years to sometimes decades).
  - Utility-scale renewables are usually more cost efficient (on a $/MWh basis) compared to distributed resources.

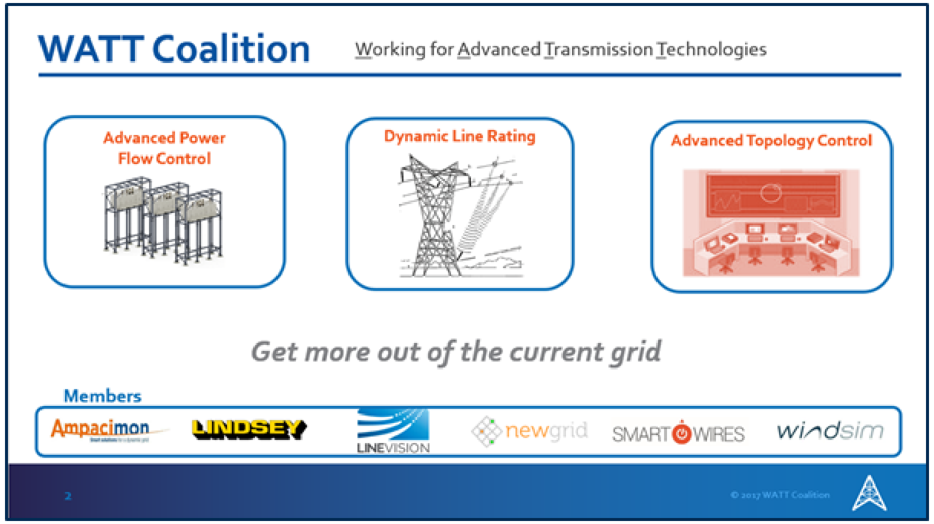
Can Grid-Enhancing Technologies (GETs) help integrate more renewables?

- GETs quickly and cost-effectively help maximize the capability of the existing transmission system

Study Overview - 1/2

Goal: Analyze how much additional renewables can be added to the grid using Grid-Enhancing Technologies (GETs):

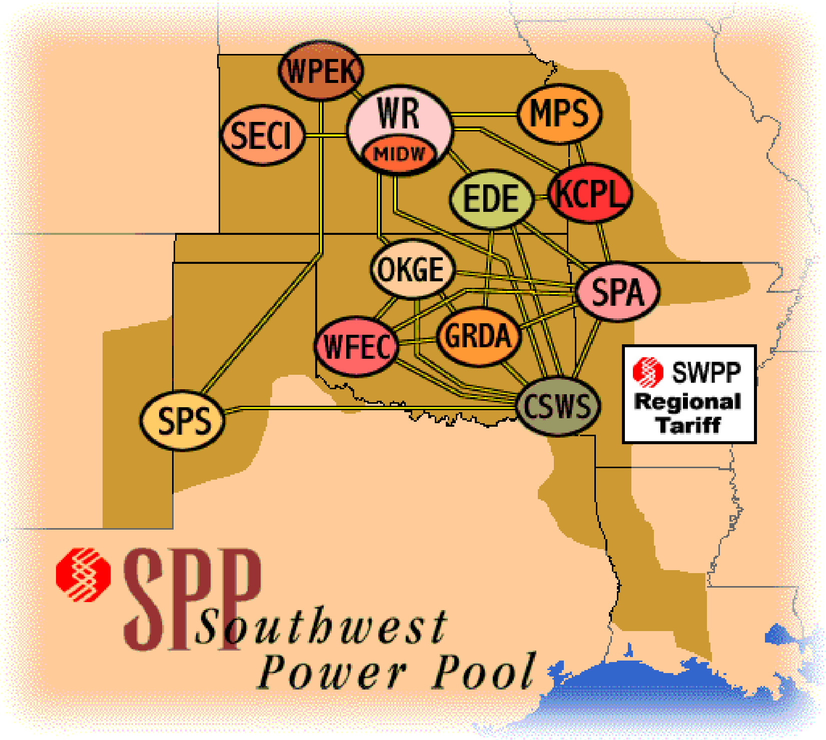
- GETs enhance transmission operations and planning.
- GETs complement building new transmission—they can bridge the timing gap until permanent expansion solutions can be put in place.
- While there are various types of GETs, this study focuses on the combined impact of the following three technologies:
  - **Advanced Power Flow Control**: Injects voltage in series with a facility to increase or decrease effective reactance, thereby pushing power off overloaded facilities or pulling power on to under-utilized facilities.
  - **Dynamic Line Ratings (DLR)**: Adjusts thermal ratings based on actual weather conditions including, at a minimum, ambient temperature and wind, in conjunction with real-time monitoring of resulting line behavior.
  - **Topology Optimization**: Automatically finds reconfiguration to re-route flow around congested or overloaded facilities while meeting reliability criteria.



Study Overview - 2/2

Goal: Analyze how much additional renewables can be added to the grid using Grid-Enhancing Technologies (GETs):

- Use the Southwest Power Pool (SPP) grid (focused on Kansas and Oklahoma, looking at 2025) as an illustrative case study.
  - SPP Generation Interconnection Queue* (GI Queue) shows ~9 GW of renewable resources with an Interconnection Agreement (IA) executed in Kansas and Oklahoma.
  - SPP Integrated Transmission Planning (ITP) Reports** show high congestion.
- Results metrics for the **combined** (not for individual) three GETs include:
  - Renewables added (capacity [GW] and energy [GWh]).
  - Economic benefits (production costs, investments, jobs, etc.)
  - Carbon emissions reduction.



SPP figure from http://opsportal.spp.org/Images/SPPMap.gif

* SPP GI Queue as of September 28, 2020

** 2019 Integrated Transmission Planning (available at: https://spp.org/Documents/60937/2019%20ITP%20Report_v1.0.pdf) and Q3 2020 Quarterly Project Tracking Report (available at: https://www.spp.org/documents/62710/q3%202020%20qpt%20report%20draft.pdf)

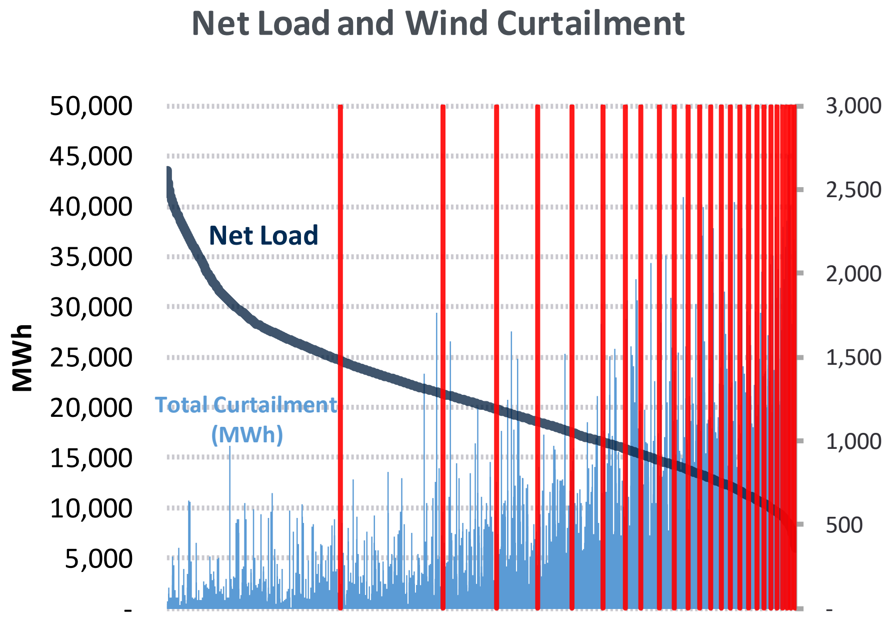
Study Approach - 1/2

Study purpose

- Quantify the benefits of **the three GETs combined** for integrating renewable resources (largely wind) using SPP as a test bed.

Analysis approach

- Select 24 representative historical power flow snapshots of SPP operations (2019 – 2020) that together reasonably represent a full year.
- Modify the snapshots to reflect new transmission upgrades, renewable projects from the GI queue, announced retirements, load change, etc.
- Find the maximum renewables amount (GW and GWh) that can be integrated under a business as usual scenario (Base Case) and then with GETs (With GETs Case), sequentially in the order of DLR, Topology Optimization, and Advanced Power Flow Control, by simulating the entire SPP system using the 24 power flow cases.
- Assess benefits of GETs including economic values (production costs, jobs, local benefits etc.) and carbon emissions reduction.



Areas between red line indicates the bins from which snapshots were selected, blue bars indicate curtailment of renewables. Each bin contains equal amounts of curtailment.

Study Approach - 2/2

Study purpose

- Quantify the benefits of **the three GETs combined** for integrating renewable resources (largely wind) using SPP as a test bed.

Finding the maximum amount of renewables that can be integrated

- Analysis is performed separately for the Base Case and With GETs Case for all 24 snapshots.
- Analysis is done using an iterative process:
  - Determine feasible reduction in thermal unit generation to accommodate additional renewable resources.
  - Dispatch wind and solar to their max output by running Security Constrained Optimal Power Flow (SCOPF).
  - Iteratively solve SCOPF (i.e., solve SCOPF, take out renewable projects with high curtailments, then resolve SCOPF, and repeat).
- Analysis assumes a 5% curtailment threshold for viability assessment (i.e., projects are viable if analysis indicates annual curtailments to be less than 5%).
  - Curtailment occurs largely for two reasons—transmission congestion (which the GETs will help solve) and minimum generation constraints of other generation resources.

Study Results - 1/5

GETs enable more than twice the amount of additional new renewables to be integrated.

- Potential Renewables Considered: 9,430 MW
  - Based on queue projects with IA executed.
- Integrated Renewables (without further transmission upgrades)
  - Base Case: 2,580 MW
  - With GETs Case: 5,250 MW
  - Delta (With GETs Case – Base Case): 2,670 MW

RENEWABLE POTENTIAL ASSUMED FOR KANSAS AND OKLAHOMA

State	Wind	Solar	Total
Kansas	3,410	120	3,530
Oklahoma	5,760	140	5,900
Total	9,170	260	9,430

[Rounded to the nearest 10 MW]

~1.5 times the amount of wind SPP integrated in 2019 (1.8 GW).

ADDITIONAL RENEWABLES INTEGRATED

State	Base Case			With GETs Case			Delta (GETs - Base)		
	Wind	Solar	Total	Wind	Solar	Total	Wind	Solar	Total
Kansas	1,710	0	1,710	1,910	0	1,910	200	0	200
Oklahoma	770	100	870	3,200	140	3,340	2,430	40	2,470
Total	2,480	100	2,580	5,110	140	5,250	2,630	40	2,670

X2

[Rounded to the nearest 10 MW]

Study Results - 2/5

GETs enable more than twice the amount of additional new renewables to be integrated.

- Additional renewables enabled by GETs: **2,670 MW / 8,776 GWh**.
  - 2,630 MW of **new wind** is assumed to produce over 8,640 GWh of energy per year.
  - 40 MW of **new solar** is assumed to produce about 60 GWh of energy per year.
  - GETs lower curtailment of **existing wind** by over 76,000 MWh per year.
- GETs installation cost is about $90 million.
  - Annual O&M costs is estimated to be around $10 million.
- GETs benefits (other than the value of additional renewables) include:

ANNUAL PRODUCTION COST SAVINGS

$175 million

ANNUAL REDUCED CARBON EMISSIONS

3 million tons

Additional Renewables enabled by GETs
2,670 MW / 8,776 GWh

LOCAL JOBS

650 long-term jobs and
11,300 short-term jobs

OTHER LOCAL BENEFITS

$15 million land lease and
$32 million tax revenues per year

Study Results - 3/5

GETs enable more than twice the amount of additional new renewables to be integrated.

- Estimated annual production cost savings: **$175 million**.
  - Pay-back for GETs investment (~$90 million) is about half a year.
  - $175 million conservatively assumes $20/MWh savings for 8,776 GWh of energy.
  - $20/MWh is at the lower end of the generation cost of a new natural gas-fueled combined cycle plant or coal plant and lower than average 2019 LMP (both day-ahead and real-time).
- Estimated job benefits associated with the increased renewables (2,670 MW):
  - Over 11,300 direct short-term jobs (largely construction of renewables).
  - Over 650 direct long-term jobs for operation and maintenance of the renewable resources.
- Estimated carbon emissions reduction: **Over 3 million tons per year.**
  - Conservatively assumes the renewables replace carbon emissions from natural gas-fueled combined cycle plants.
  - Less efficient resources with higher heat rates and emission rates are more likely to be replaced.
- Other estimated benefits include:
  - Local benefits estimated to be over $32 million annual tax revenues and $15 million land lease revenues (based on literature research).

Study Results - 4/5

Key benefits of GETs for Kansas and Oklahoma

- Enable more than **twice** the amount of additional new renewables to be integrated.
  - This is 1.5x the amount of wind SPP integrated in 2019.
- Estimated annual production cost savings: $175 million.
  - Payback for GETs investment is about 0.5 years.
- Estimated carbon emissions reduction: Over 3 million tons per year.
- Over 11,300 direct short-term and 650 direct long-term jobs.
- Over $32 million annual tax revenues and $15 million land lease revenues.

Potential Nation-Wide Benefits

Extrapolating these results to a nation-wide level* indicate GETs to provide **annual benefits** in the range of:

- Over **$5 billion** (~$5.3 billion) in production cost savings.
- **$90 million tons** of reduced carbon emission (more than enough to offset **ALL NEW** automobiles sold in the U.S. a year).
- About **$1.5 billion** in local benefits (local taxes and land lease revenues).
- More than 330,000 short-term (only for first year) and nearly 20,000 long-term jobs.
- Investment cost is $2.7 billion (only for first year). Ongoing costs would be around $300 million per year.

* EIA shows 2019 generation in Kansas and Oklahoma combined (136 TWh) was about 1/30 of the nationwide generation from utility-scale resources (4,100 TWh). EIA data, available at: https://www.eia.gov/electricity/state/kansas/, https://www.eia.gov/electricity/state/oklahoma/, and https://www.eia.gov/electricity/annual/html/epa_01_01.html

Study Results - 5/5

GETs utilized in this study include:

- **Hardware solutions**: DLR on 56 lines and Advanced Power Flow Control on 8 locations.

Hardware Solutions by Voltage Level	345	230	161	138	115	69	Total
DLR*	10	3	11	22	3	7	56
Advanced Power Flow Control	3	0	4	1	0	0	8

- **Software solutions**: 204 unique Topology Optimization reconfigurations, averaging 13 per snapshot.**

Software Solutions by Voltage Level	345	230	161	138	115	69	Total
Lines	20	10	31	75	4	30	170
Substations	4	0	1	1	0	0	6
Transformers (high voltage terminal)	10	1	4	13	0	0	28

- Estimated costs for implementing the above GETs: ~$90 million.
  - Initial investment costs is estimated to be around $90 million.***
  - Ongoing costs of around $10 million per year.***

* Every DLR installation requires 15 to 30 sensors.

** Average actions represent the average number of actions that remain per case, not actions per hour. Based on other studies the average number of actions per hour is expected to be smaller, typically less than the number of topology changes due to planned outages.

*** Costs can vary project by project, and also on how the GETs service is provided—for example, Topology Optimization can be provided as a software subscription service to reduce the initial cost. We also assume utilities can incorporate these technologies without large costs.

Rob Gramlich

President of Grid Strategies LLC, Executive Director of WATT, Executive Director of Americans for the Clean Grid (ACEG)

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Oliver Koch

Deputy Head of Unit, ENER C.3, DG ENER

CurrENT
Enabling Network Technology throughout Europe

John Fitzgerald

CEO, SuperNode

INNOVATIVE GRID TECHNOLOGY TO ENABLE DECARBONISATION WITH RENEWABLES

John Fitzgerald

SUPERNODE™

Why is new Transmission Technology Needed?

2050: Increased Electricity Demand – decarbonisation, electric vehicles, heat pumps, data centres

Electrical Demand to increase by 2-3 times by 2050

>>450 GW of offshore wind power will be needed

> 800 GW of new solar power will be required

Best Renewable Resources are found at the peripheries of Europe (km)

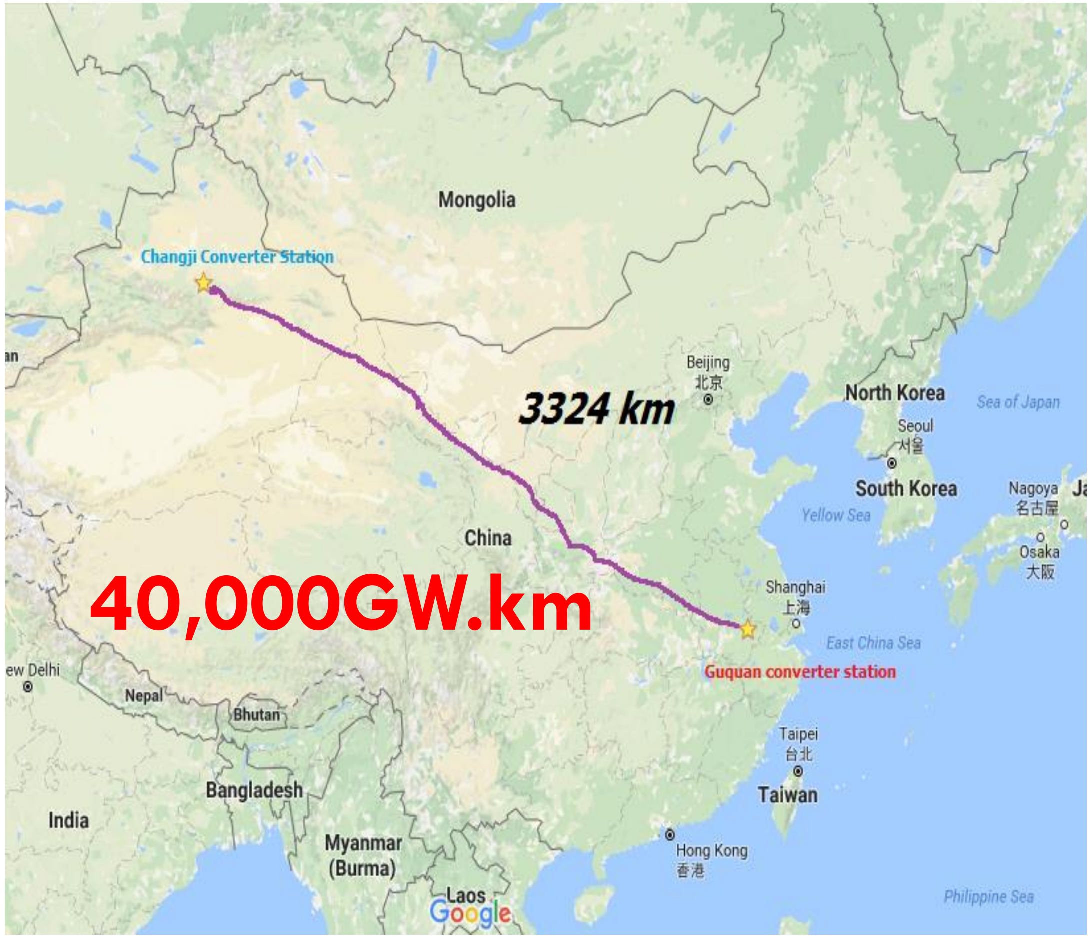
Transmission is a Major Constraint on the level of Renewables we need for deep decarbonisation

Low Public Acceptance and Supply Chain constraints with existing technology

Ambiguity on Transmission aspirations and plans for future beyond 2030

SUPERNODE™

Chinese Approach to new Grids



SUPERNODE™

Superconductivity - Innovation waiting to happen

"By its very nature, renewable electricity will be cheaper than zero-carbon hydrogen (which is a vector that stores renewable electricity). In the view of the authors, this gives rise to possibly the most important conclusion from this study. Aside from energy efficiency, the most important and immediate priority for the EU in ensuring a cost-effective decarbonisation of its energy system must therefore be to identify and eliminate infrastructure and other bottlenecks that are likely to constrain the cost-effective production and use of renewable electricity moving forwards"

Florence School of Regulation:, "*Cost-Effective Decarbonisation Study*" 2020

"Regarding HVDC cables, recurring to superconductivity technologies and namely High Temperature Cables (HTC) may be technically and economically convenient when the increase of transmission capacity need over a corridor requests the addition of more cables in parallel - It would be beneficial to develop HTC technologies for Superconducting Transmission Lines (STL) to explore its potential in situations where very high amounts of power need to be transmitted"
(…)
"to build the offshore energy production, and its connection to onshore consumption, an interconnected grid is needed"

Eur. Comm., "*Clean Energy Transition – technologies and innovations. (CET-TIR)*" 2020

'the commissioning dates for almost half of the PCIs have again been shifted into the future compared to the dates foreseen in previously reported schedules, adding up to the accumulated delays that are repeatedly noted in the Agency's annual PCI monitoring reports.'

ACER, 2019 PCI monitoring report

"In Best Paths, gigawatt-scale superconducting cables were investigated and shown to be technologically mature and cost-competitive for the transmission of large amounts of electricity. Thanks to their high efficiency, compact size, and reduced environmental impact, superconducting cables are likely to find higher public acceptance than overhead lines and conventional cables"

Best Paths, "*Advancing Superconducting links for very high-power transmission*" 2018

SUPERNODE™

Key Attributes of Superconductivity

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

Zero Electrical Resistance - When a superconducting material is cooled below its critical temperature, its electrical resistance reduces to zero.

High Power Density – Superconductors can carry significantly higher levels of current and thus are capable of the transmission of higher power levels than copper.

Smaller Right of Way – Superconducting cables have a smaller cross-section and thus the right of way required for their installation is much smaller than comparable copper cables.

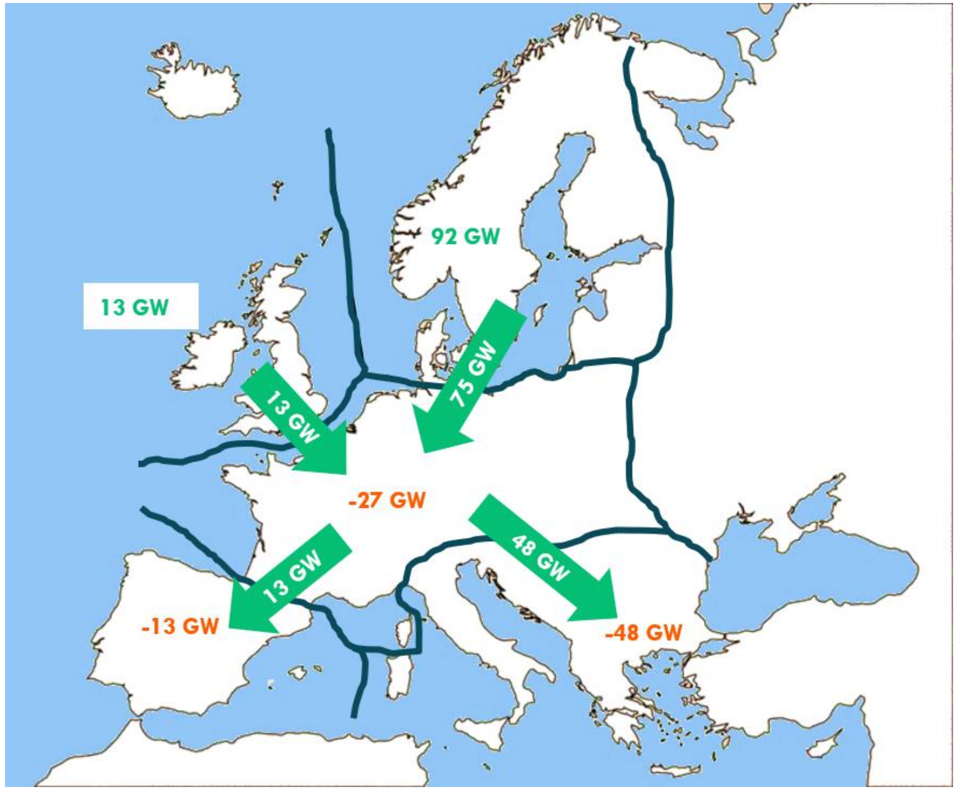
Lower Cost – The cost of the cables might be higher but the cost of a superconducting project can be significantly lower.

SUPERNODE™

Winter Afternoon/High Wind Case

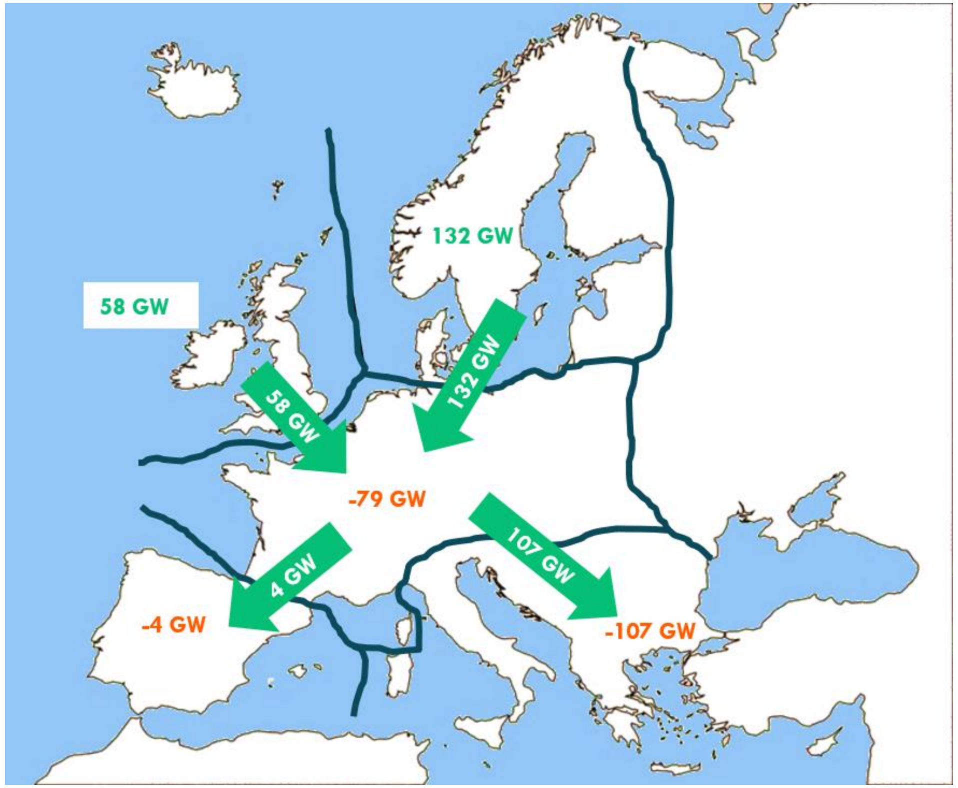
Business as Usual approach results in a cost of energy premium of €1.2 Trillion / 15% [1]

Business as Usual / Nationalistic Grids



3,180 GW of Generation and Storage

Pan-European Grid



2,900 GW of Generation and Storage

1 Based on Winter Summer Cases average Cost of Energy over 30 years

Michael Jesberger

CTO, Transnet BW

CURRENT
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TRANSNET BW

currENT-WATT webinar on 01st June

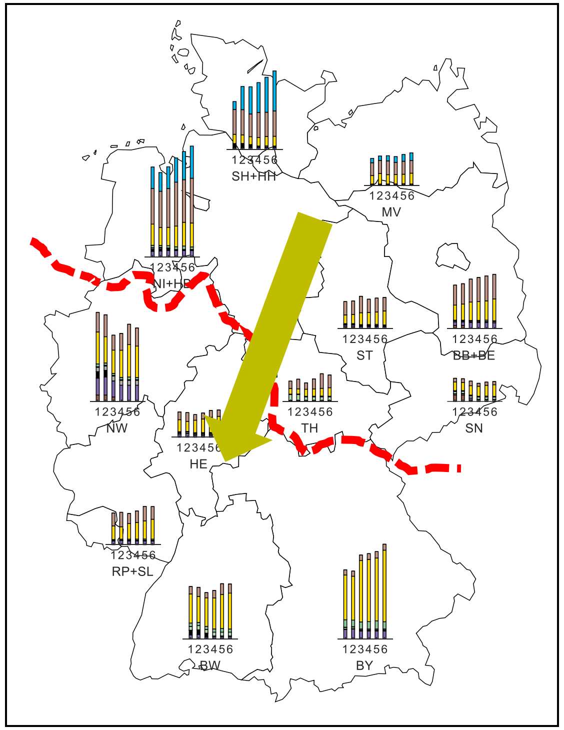
CHALLENGES OF THE ENERGY TRANSITION

MICHAEL JESBERGER, COO
Stuttgart

TRANSNET BW

Challenges of the energy transition

INCREASE OF TRANSFER DEMAND



/ **Estimation based on the increase in installed EE-capacity in Northern Germany**

NEP	19	19	21	21	21	21
[GW]	C2030	B2035	A2035	B2035	C2035	B2040
(offshore wind)	17	23	27	30	35	40
(onshore wind)	59	61	63	66	68	69

+ 27 GW

Expected consequences:

/ Additional system expansion with HGÜ and AC

/ Higher utilization of existing networks

/ Load flow regulating network elements

/ New operating concepts in connection with new operating resources

Grid Planning

FROM CONCEPT TO PROJECT: REGIONAL, NATIONAL AND EUROPEAN

EUROPÄISCHE PLANUNG

TYNDP
Alle zwei Jahre aktualisiert

NATIONALE PLANUNG

NEP
Alle zwei Jahre aktualisiert

REGIONALE PLANUNG UND REALISIERUNG

gemeinsame Zielnetzplanung
Alle zwei Jahre aktualisiert

Reactive power
General overview
380 kV till 2030
after NEP

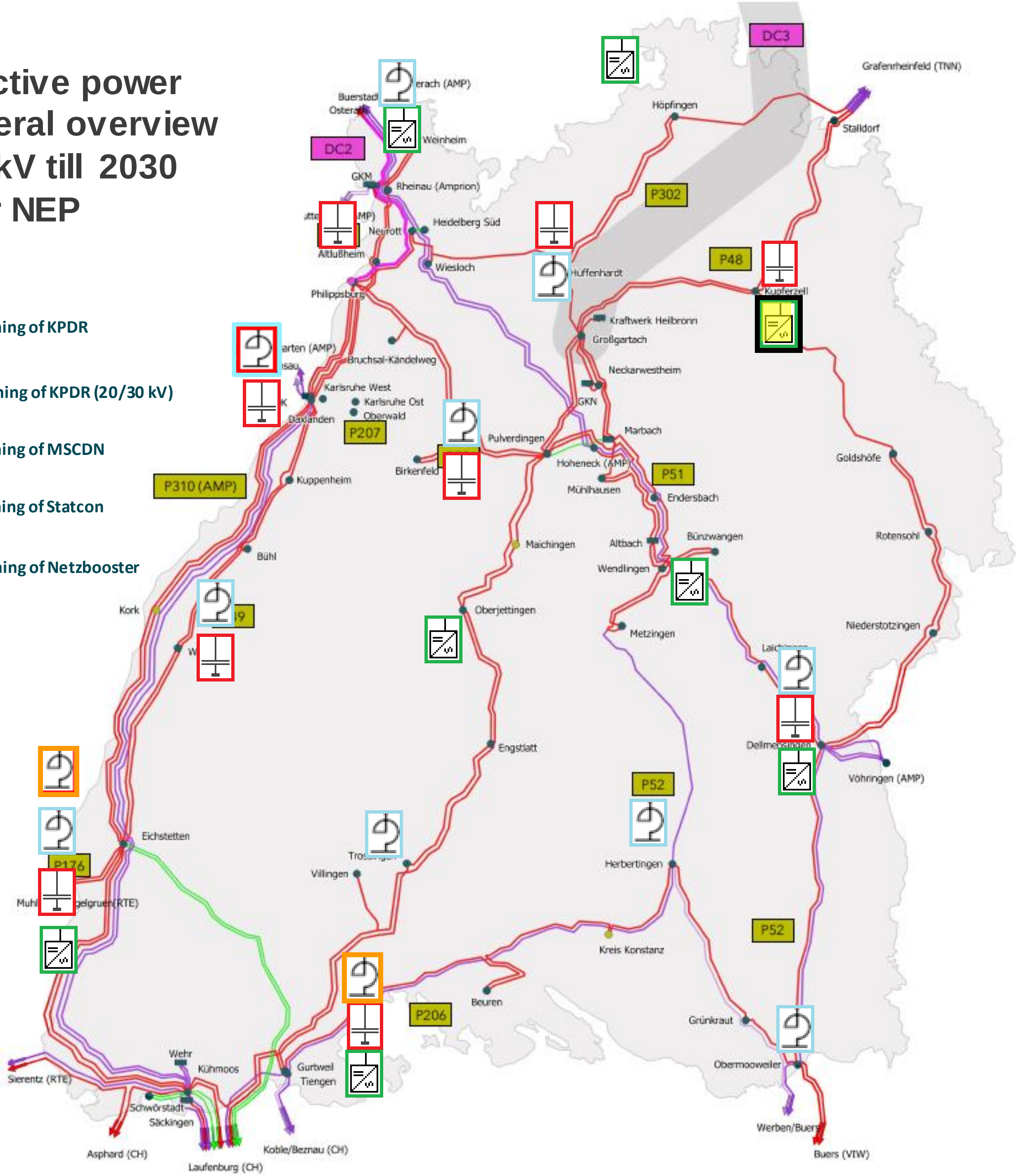
planning of KPDR

planning of KPDR (20/30 kV)

planning of MSCDN

planning of Statcon

planning of Netzbooster



Grid planning

SCENARIO B2025 OF NEP2030 (2019)

- Identification of ad-hoc measures to reduce redispatch volume
- Confirmed by the regulator:
  - 10 „ad-hoc“ PST + 1 TCSC
- Plus in B2030:
  - 2 „regular“ PST + 1 TCSC
- Complete grid optimisation of the existing grid for integration of renewable energy sources

Giles Dickson

CEO, WindEurope

Q&A Session

Please send your questions in the Q&A box

Thank you

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