WHEN TRUST MATTERS

Challenges in the energy transition

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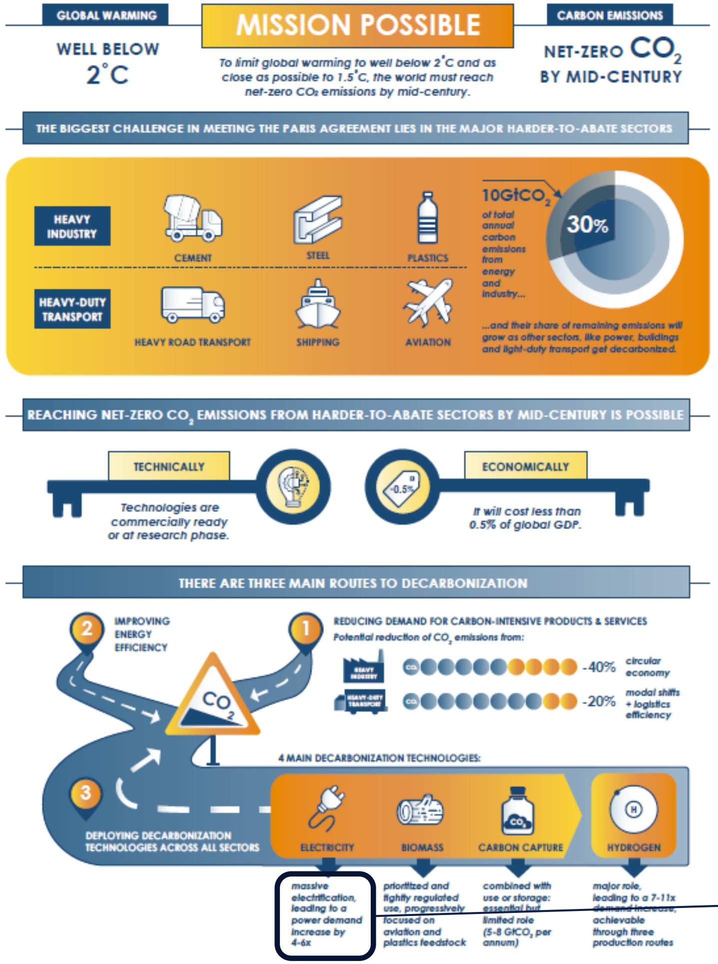
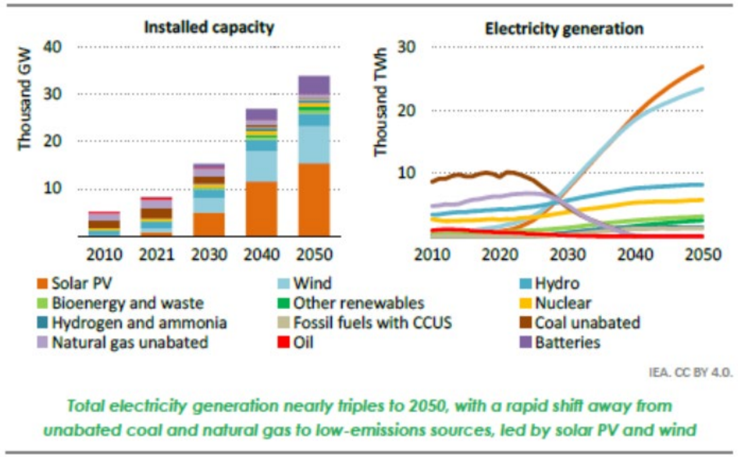
SUSTAINABLE
SECURE

FUTURE ENERGY SYSTEM

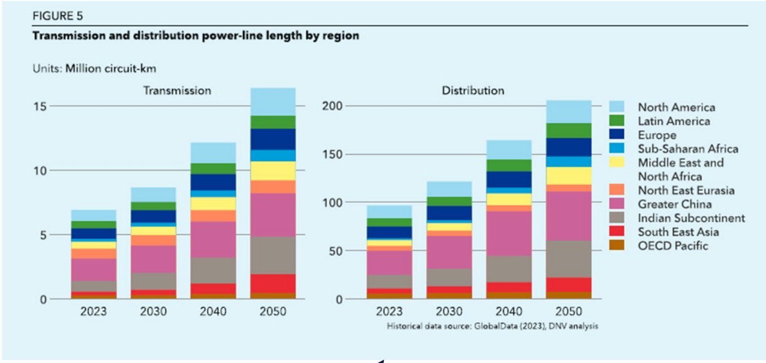
Energy Transition: What does it mean for the grid?



Source: Energy Transitions Commission 2018 and IEA Energy outlook 2022



Source: Energy Outlook 2022



Source: Energy Outlook 2024

Massive electrification, leading to an electrical power demand increase in Europe by a factor 4 to 6 and internationally by a factor of 2 to 7

Increased demand requires:
1. increased power production
2. increased transmission

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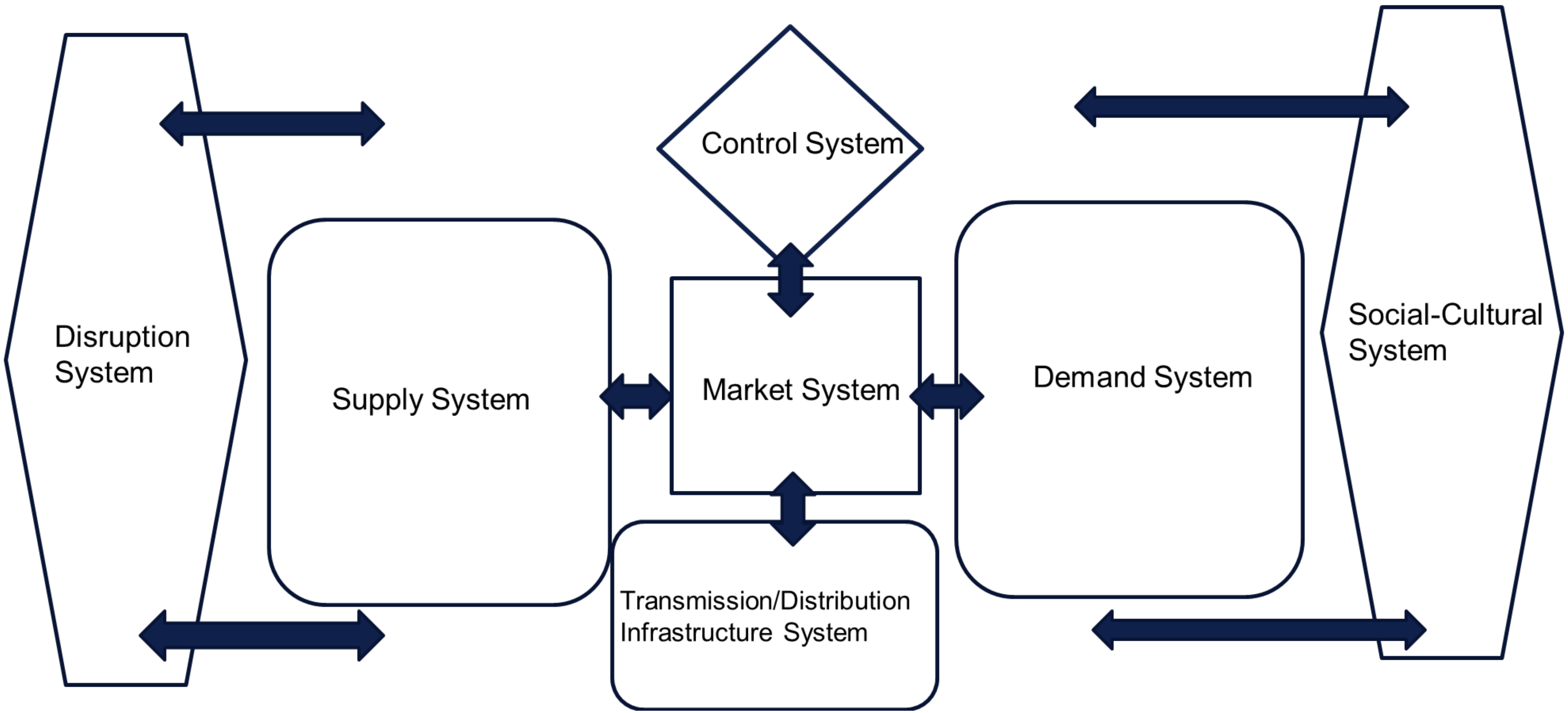
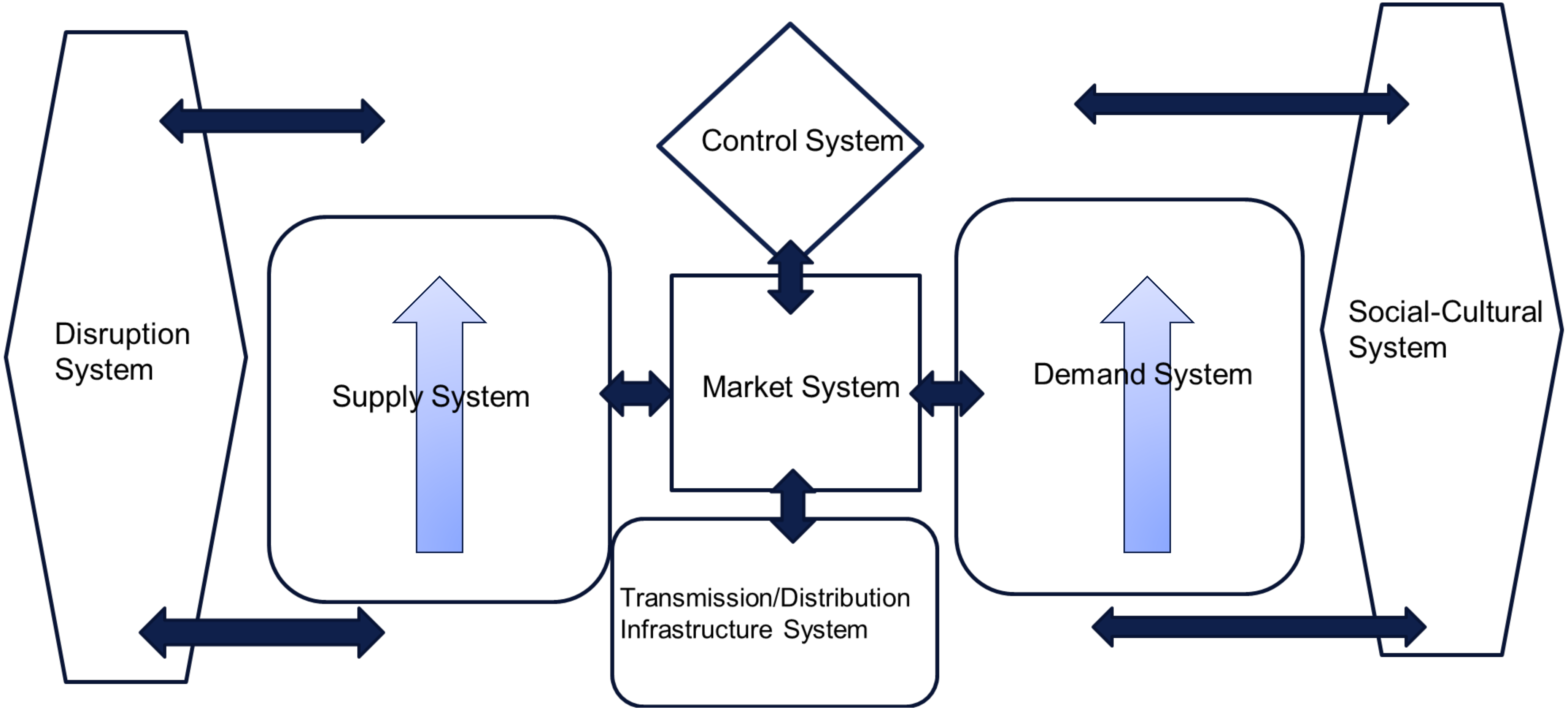
The electricity system – explained



‘No transition without transmission’

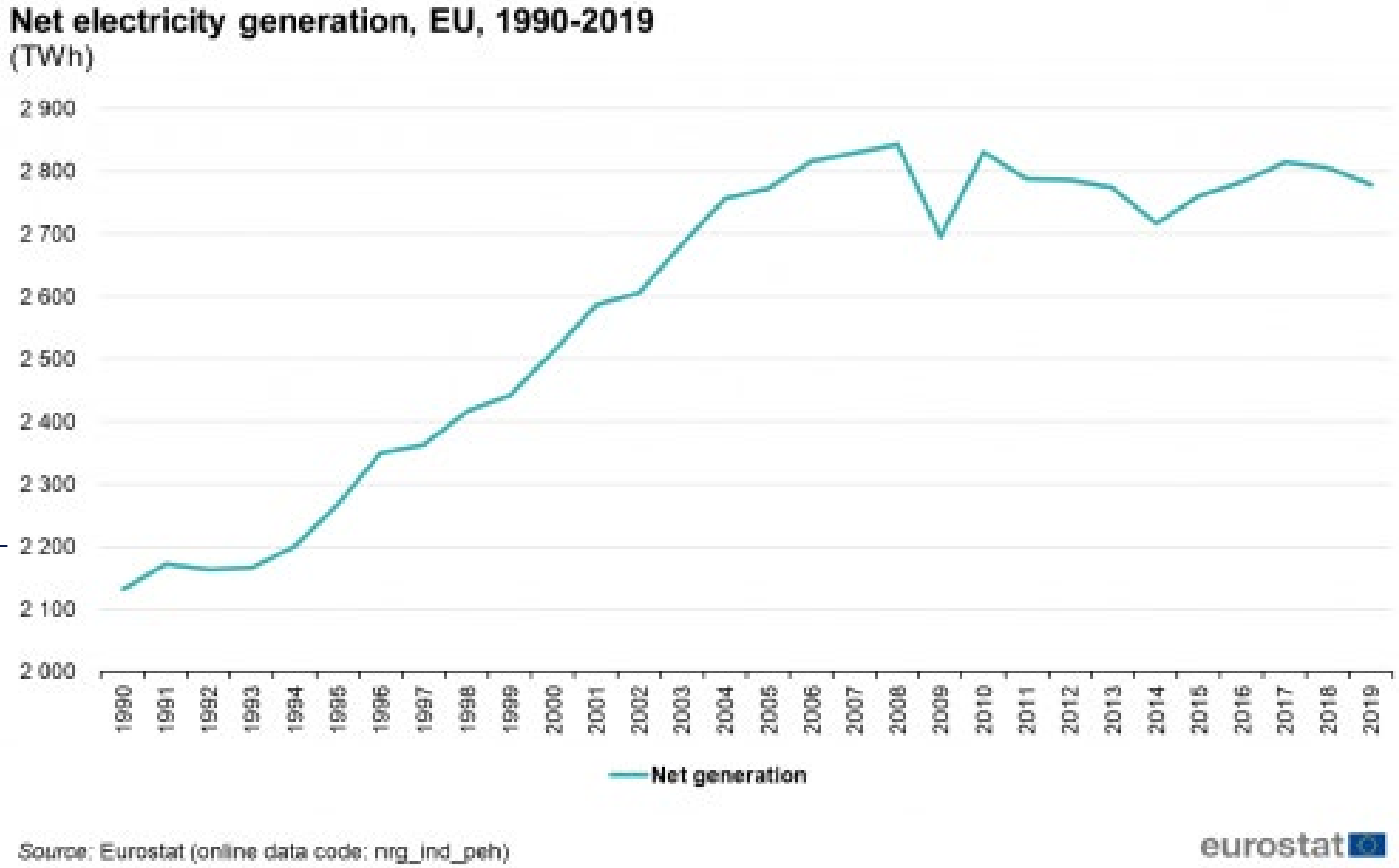
The electricity system – Trends



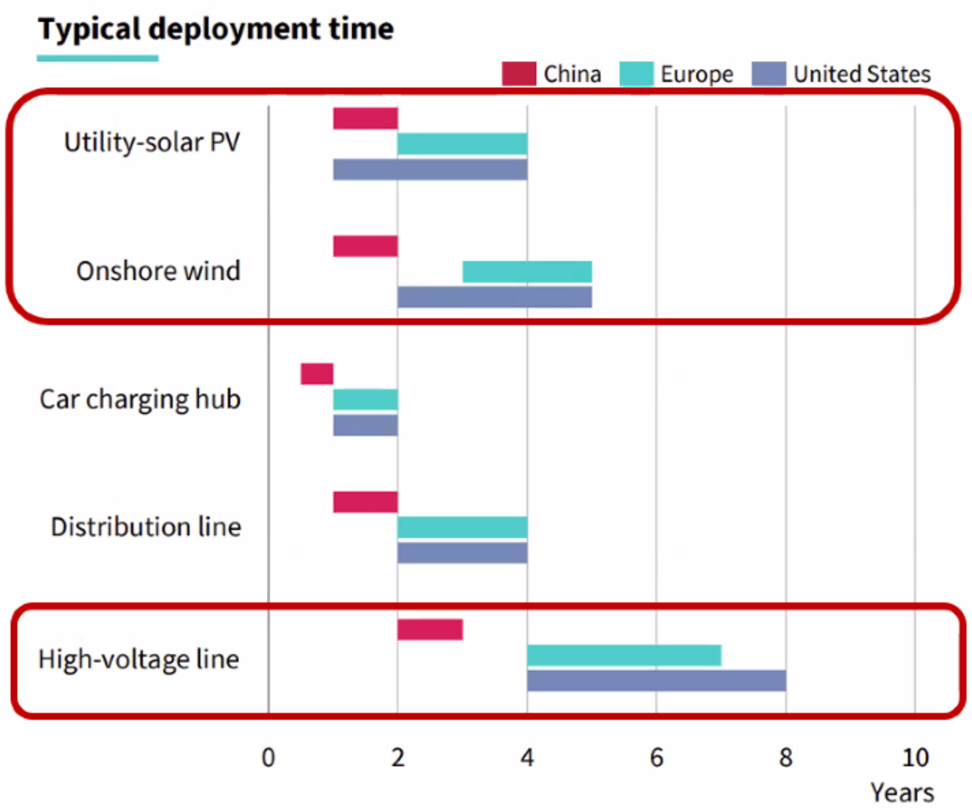
Net Electricity Generation in Europe

30% increase in
20 years time

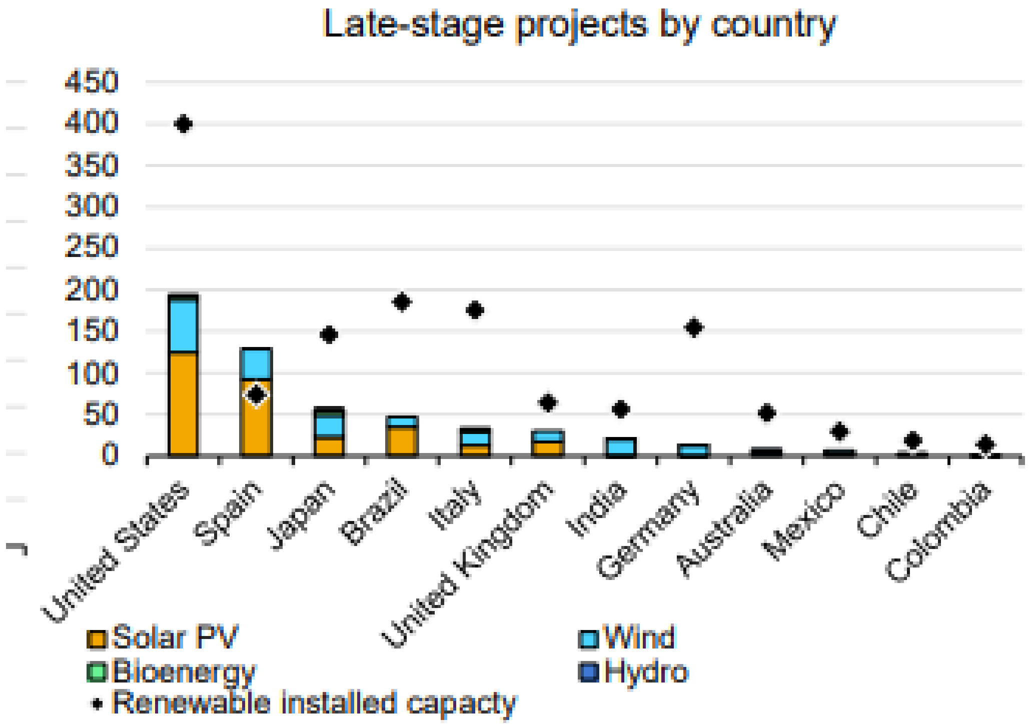
Now we need an at
least 300% increase
in 30 years time



It takes longer time to build new grid than it takes to build new production and transform the different sectors



Source: RMI, Kingsmill Bond, Sam Butler-Sloss, and Daan Walter. 'It's Exponential, Disruptive, and Now', 2024.



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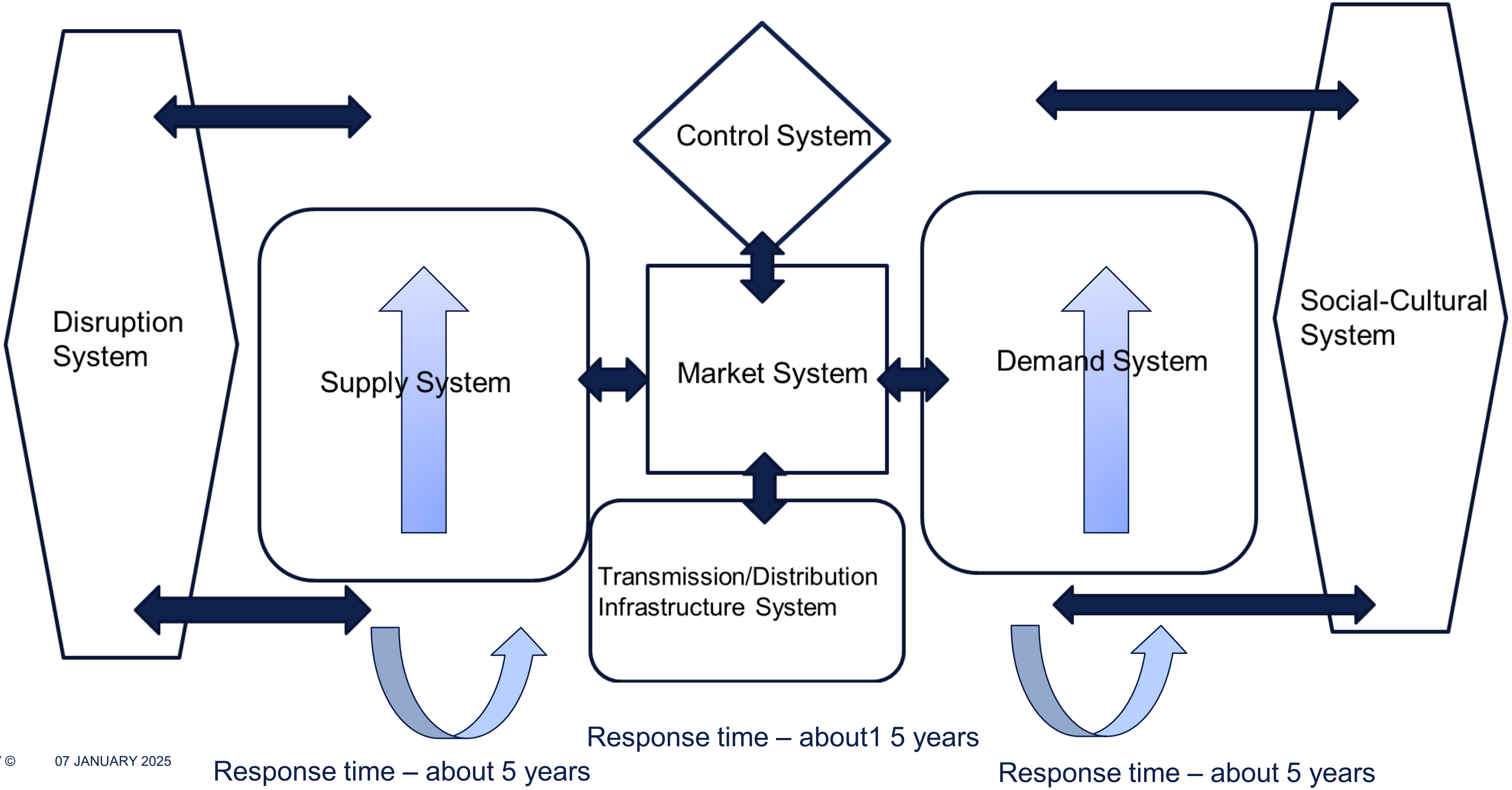

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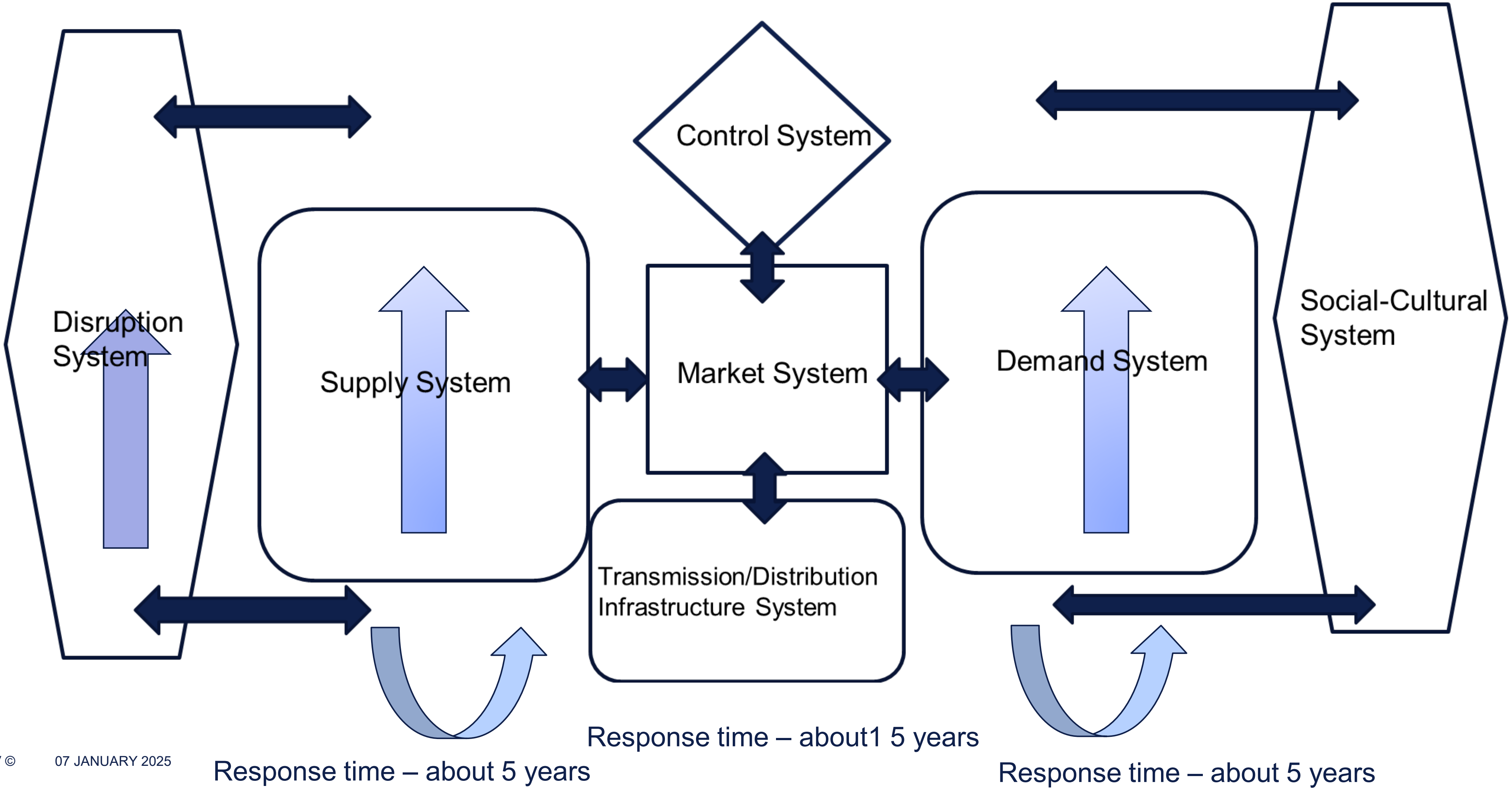
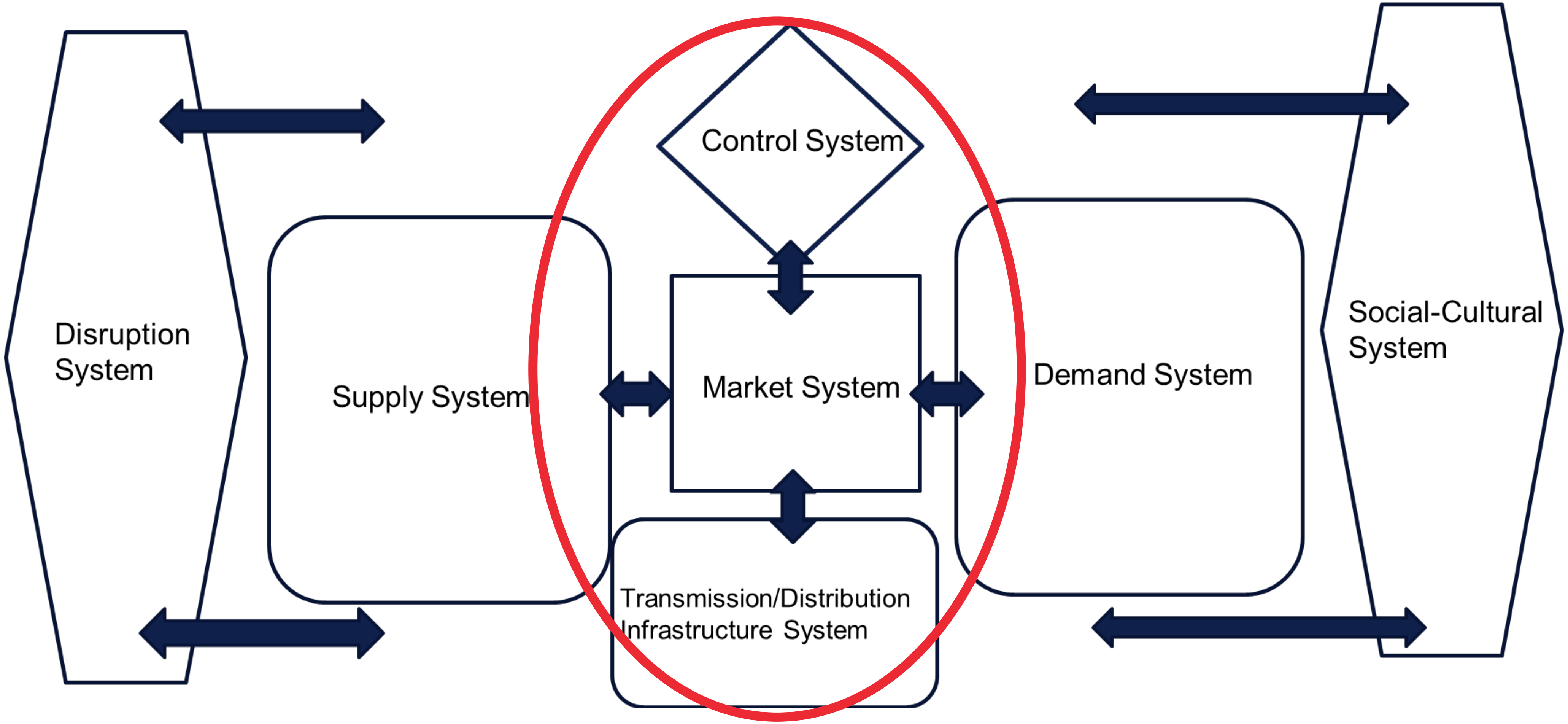
The electricity system – Trends



The electricity grid is being challenged



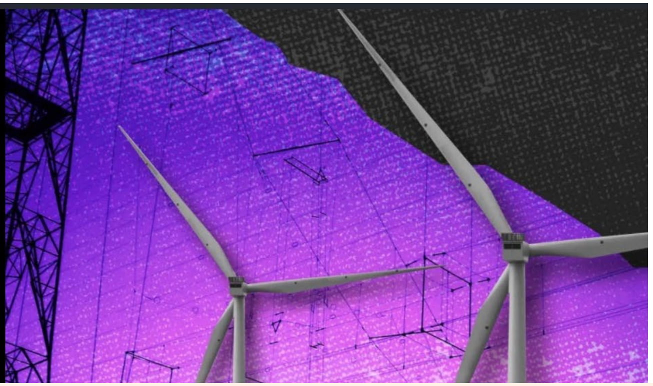
'No transition without transmission'

Grids risk becoming the weak link of the energy transition

The Big Read   Electric power   + Add to myFT

Gridlock: how a lack of power lines will delay the age of renewables

A backlog of wind and solar projects is waiting to connect to infrastructure built for another era, threatening net zero plans



The project's developer BayWa RE says the wind farm is facing an eight-year wait before it can obtain a connection to the grid — the network of cables, substations and transformers that takes electricity around regions, countries and across borders to power our homes, offices and factories.

It is a lengthy delay, but not exceptional. Around the world, developers of renewable energy infrastructure are being told they must wait anything from a couple of years in parts of the US to up to 15 years in the UK before they can plug projects into grids that are struggling to keep pace with shifts in electricity generation.

iea

Electricity Grids and Secure Energy Transitions

Enhancing the foundations of resilient, sustainable and affordable power systems

Grids risk becoming the weak link of clean energy transitions

At least 3 000 gigawatts (GW) of renewable power projects, of which 1 500 GW are in advanced stages, are waiting in grid connection queues – equivalent to five times the amount of solar PV and wind capacity added in 2022. This shows grids are becoming a bottleneck for transitions to net zero emissions. The number of projects awaiting connection worldwide is likely to be even higher, as data on such queues is accessible for countries accounting for half of global wind and solar PV capacity. While investment in renewables has been increasing rapidly – nearly doubling since 2010 – global investment in grids has barely changed, remaining static at around USD 300 billion per year.

Delays in grid investment and reform would substantially increase global carbon dioxide (CO_2) emissions, slowing energy transitions and putting the 1.5 °C goal out of reach. For this report, we developed the Grid Delay Case to explore the impacts of more limited investment, modernisation, digitalisation and operational changes than are envisioned in the IEA's climate-focused scenarios. The Grid Delay Case shows transitions stalling, with slower uptake of renewables and higher fossil fuel use. Cumulative CO_2 emissions from the power sector to 2050 would be 58 gigatonnes higher in the Grid Delay Case than in a scenario aligned with national climate targets. This is equivalent to the total global power sector CO_2 emissions from the past four years. It would also mean that the global long-term temperature rise would go well above 1.5 °C, with a 40% chance of it exceeding 2 °C.

At a time of fragile natural gas markets and concerns about gas supply security, failing to build out grids increases countries' reliance on gas. In the Grid Delay Case, global gas imports are over 80 billion cubic metres (bcm) a year higher after 2030 than in a scenario aligned with national climate targets – and coal imports nearly 50 million tonnes higher. Delayed grid development also increases the risk that economically damaging outages would multiply. Today, such outages already cost around USD 100 billion a year, or 0.1% of global GDP.

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We are experiencing grid lock

- Consequences – just to name a few
  - Risk of not reaching climate goals in time, this will cost more than costs for energy transition and will lead to more political instability
  - Reduced or delayed creation of new job opportunities
  - Loosing our competitive advantage
  - Increased project costs, and increased uncertainties for both project developers and investors, thus potentially decreasing the flow of capital
  - Lost opportunities

It is getting rapidly a bigger challenge

- More threats and attacks to the power system
- Electricity infrastructure is becoming the number one critical infrastructure
- Increased requirements to resilience and availability
- Data centers are huge new loads
  - with a very intermitted load that introduce disturbances
- Both new generation and new supply are ‘nervous’

There is just one way out

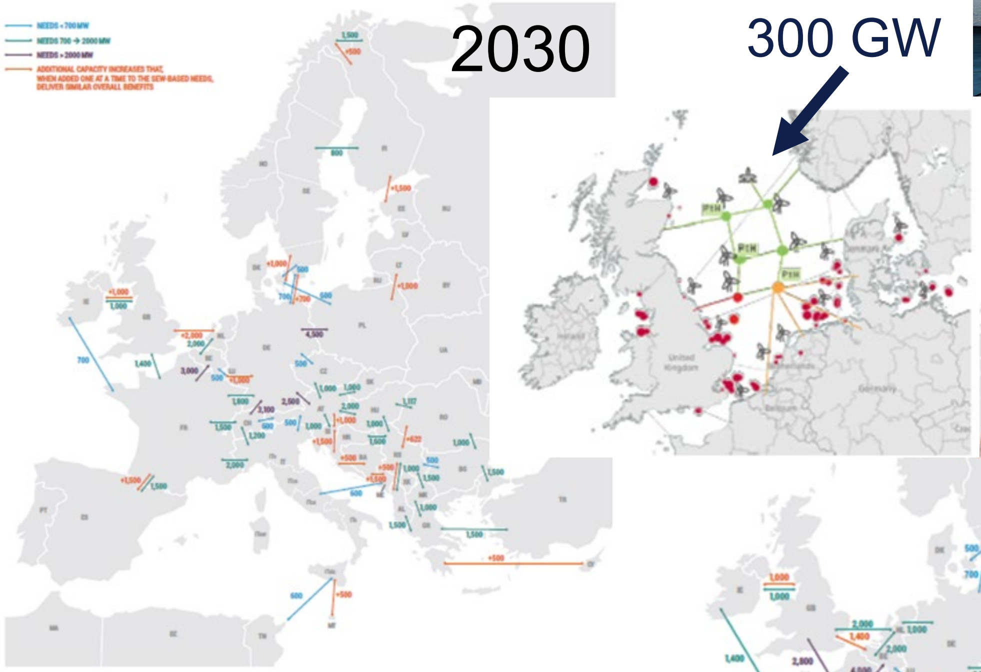
- We need more grid and we need to develop and build it faster than before (expanding grid capacity)

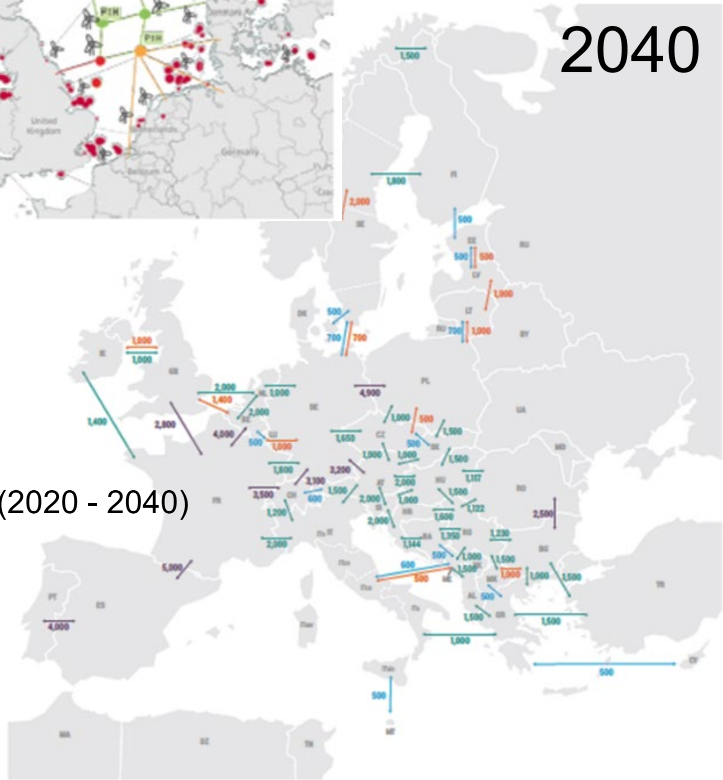
- We need to utilize the grid we have better (increasing grid capacity)

Source - www.rac.co.uk

Everyone is planning

- Planning is complex and has to be done under large uncertainties
- The system becomes more complex
- New connections don’t solve all issues
- Many questions are unanswered
    - Life time – vs – life time
    - Reality – vs – prognosis
    - Energy need – vs – energy efficiency





Grid investments in the magnitude of 45 bn€ (2020 - 2040)

Source: ENTSO-E TYNDP 2020

Technology response to challenges – new grid

Investments in new grid

- European Grid investments on TSO level in the magnitude of 45 bn€ (2020 - 2040)
- IRA → US transmission growth, new HVDC lines
- Items around financing of new transmission corridors (TenneT split), new players in investment market (windgrid)
- Long lead times from need to in service line/cable, supply chain challenges
- Standardisation, container based solutions

Establishment of Energy Islands

- Connect country to country
- Connect off shore wind and hydrogen and other storage solutions
- Island design
- MVDC design of platforms (hydrogen and oil)

Long distance transportation - HVDC

- Supply chain squeeze
- Multi-terminal, DC breakers, Interoperability
- Costs of HVDC stations for short corridors
- Mixed AC /DC grid challenges (stability and modelling, protection and control)
- Cyber Physical Security and Resillience

Sustainable materials and environmental concerns

- SF6 free GIS
- Lead free cables
- Sustainable transformers
- Eco design and life cycle management
- Environmental impact

Also here we see challenges

- System integration
- Co-dependencies
- Product maturity
- Conservatism
- Vendor lock-in
- Human resources
- Regulations and policies

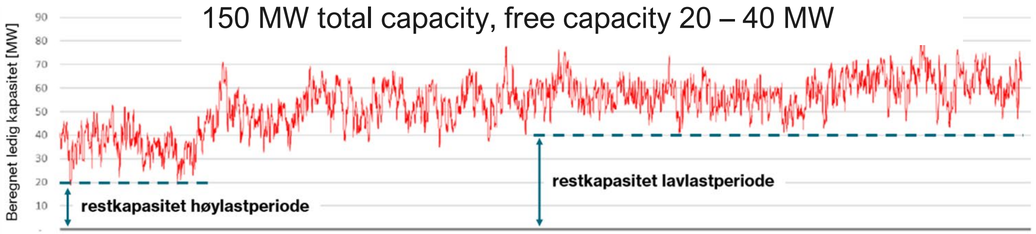
Increasing grid capacity without new infrastructure?

- Technical solutions
  - Better operational control
  - Updating algorithms and formulas
  - N-x
  - Dynamic line rating, voltage and temperature upgrading
  - Dynamic system protection
  - etc etc
- Market solutions
  - Flexibility markets
  - Price adaptation
- Regulatory solutions
  - Different kinds of contracts
  - Don’t occupy more capacity than needed
- Right incentives for grid owners and operators

- Most of the solutions require though a large investment in IT systems

By how much can we increase capacity?

- Studies have shown that grid capacity can be increased with 10 – 50 %
- Background
  - Dynamic line rating can in some cases free up 30 – 40 % capacity
  - Grid is planned, maintained & operated according to the N-1 principle
  - Power lines are operated (very) conservatively (old formulas from the 1950's)
  - Protection settings are static
  - More possibilies for grid stabilisation are available
  - More insight in the system is available (digitalisation)



- When one combines the potential that exists in components and the system, the whole system can be utilized better

The operational control is the bottle-neck

- Every new connection will lead to a new situation for the operational control
- More expected and unexpected events will occur - With less time to act
- A control based on manual processes will be impossible or lead to high risks in the future
- We need to fully automatise protection, control and operation
- We need to automatise flexibility

Photo from Statnett

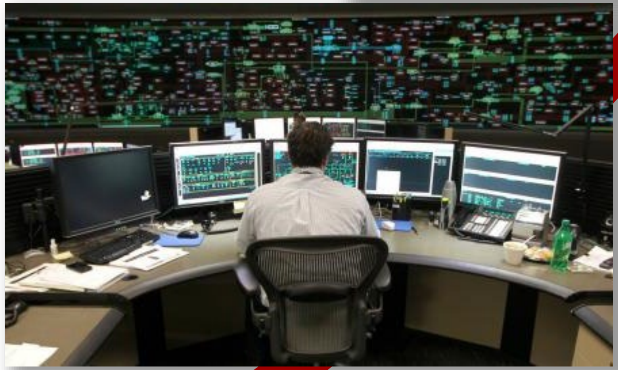
Complicating factor is that there are really high expectations and requirements towards high security of supply and operational security

A possibility is that these requirements are based on conservative rules made for ’old’ technology

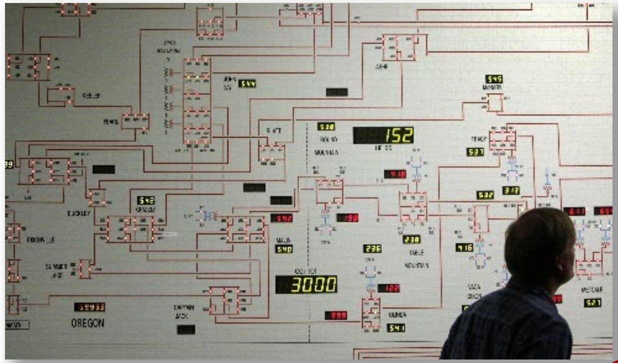
Development of the control center

Digital Transformation

- Novel use of digital technology to solve traditional problems.
- Enable new types of innovation and creativity, rather than simply enhance and support traditional methods

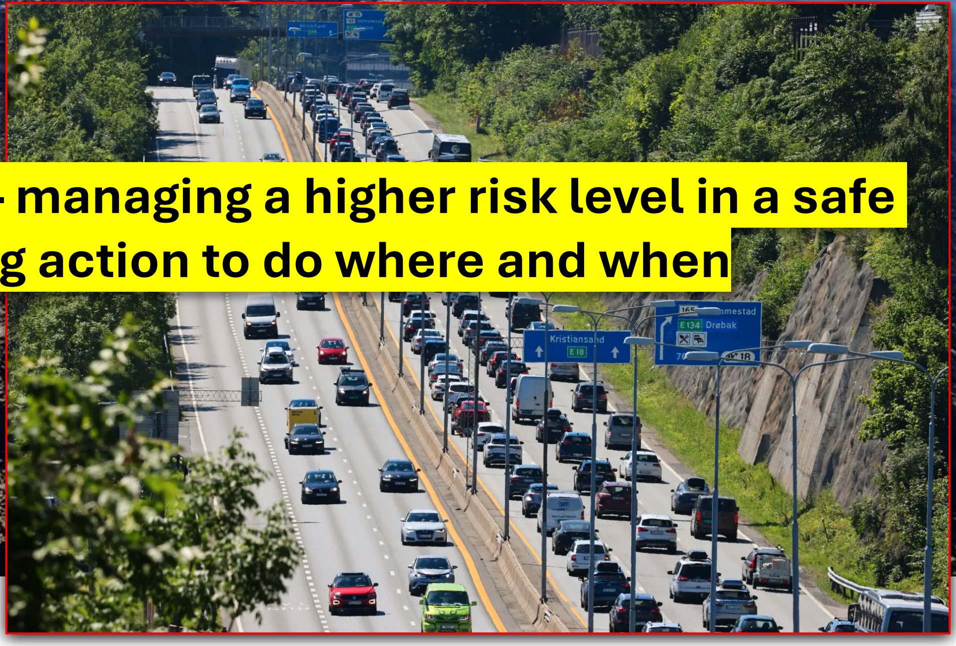


5-10 years!?

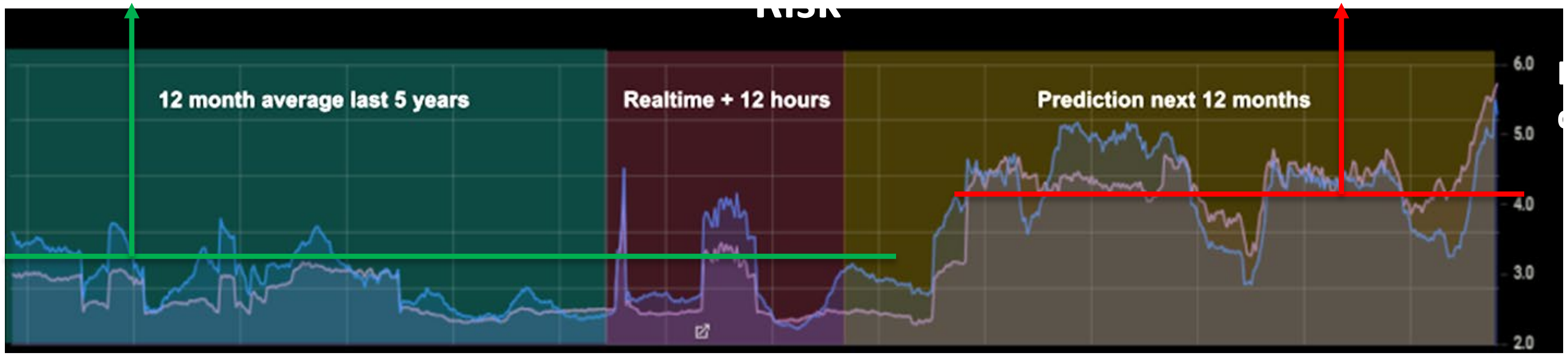


N-1

N-X

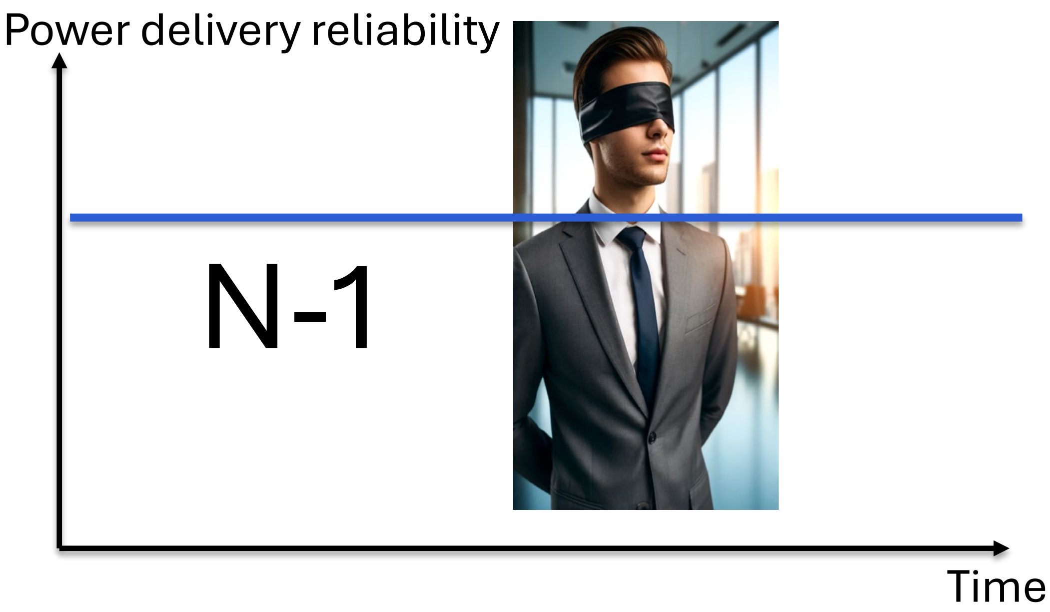


Use more of the spare capacity in time of need – managing a higher risk level in a safe way by understanding what risk mitigating action to do where and when



Today

Deterministic N-1 security of supply

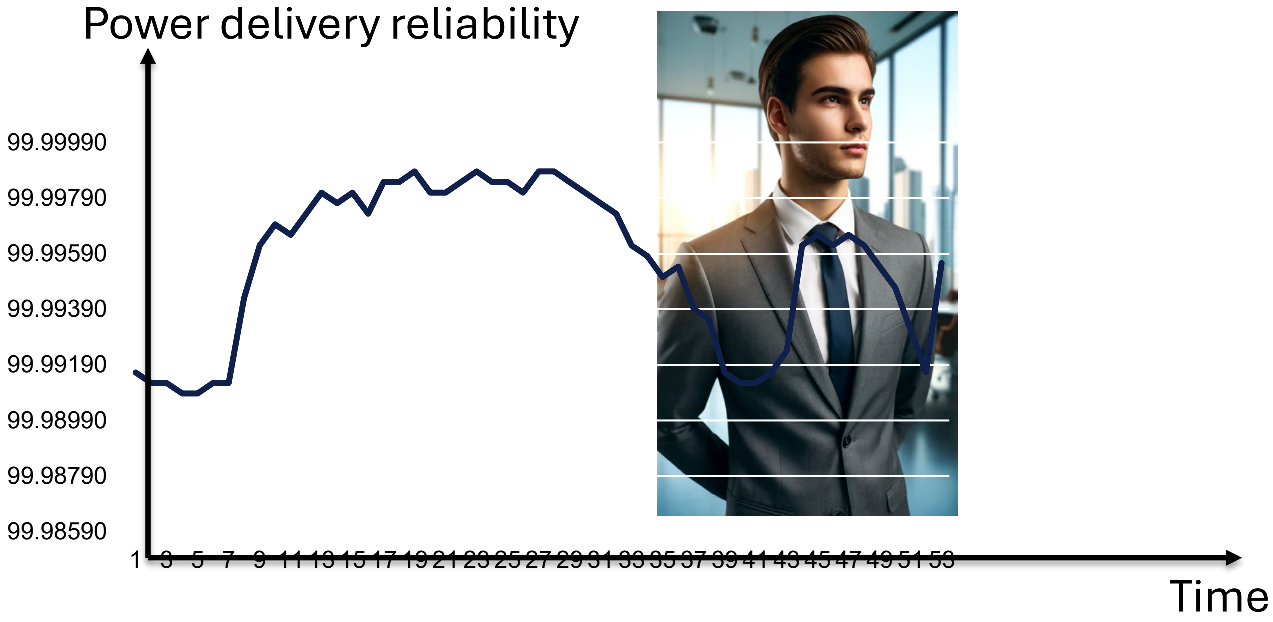


Interruptions summarized – the answer at the end of the year – do not know what the risk picture is along the way – cannot change course

Tomorrow

Probabilistic N-X security of supply

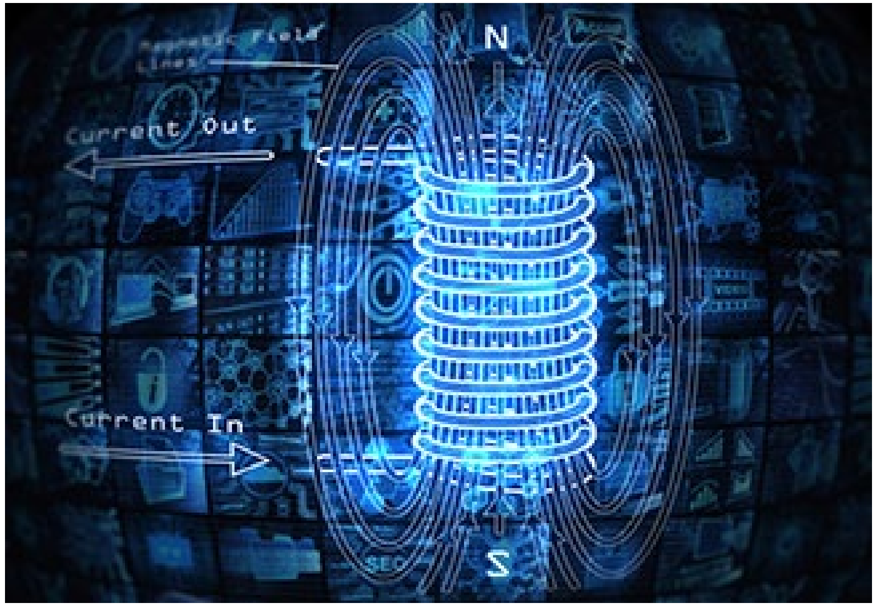
(N-1 as the goal – N-x is the tool)



The probability of outages is assessed, risks are monitored, and risk-reducing measures are implemented - change course in time

Better control of infrastructure

- Since the margins in the power system will be challenged, we need to have accurate real time information about the status and condition of the infrastructure
- We need to know every single second of the day if there are unexpected outages to be expected and if we can utilise the infrastructure at an optimum



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More AI and data transfer/interaction

- Measurement Data streams will be humongous
  - Quantity
  - Speed
- Fast and automatic decisions with better precision are needed
- Need for more AI
- Need for better data transfer, sharing and interaction

Cyber secure and digital and cyber resilient

- Full digitalisation and automation increases the quality of supply
- Adds a new risk:
  - Cybersecurity risk
  - Digital resilience
- Cyber security, cyber and digital resilience are a must

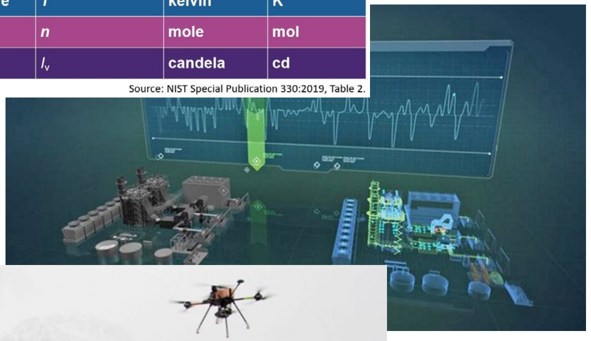
Enormous amounts of reliable and accurate measurements are needed

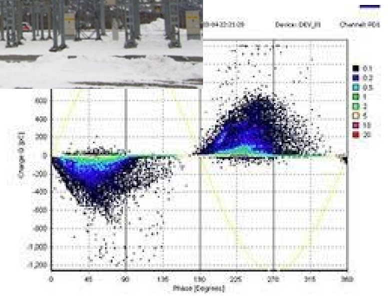
- No other sector has similar measurement challenges
  - Voltage, Current, Power, Losses
  - Time, Location/Position (e.g. height)
  - Temperature, Pressure
  - Vibrations, Moisture content
  - Solar radiation, ice accretion, precipitation
  - Wind velocity and speed
  - Gas detection, UV, IR
  - Magnetic field, flux, inductance, resistance, capactitance
  - etc

SI Base Units

Base quantity		Base unit	
Name	Typical symbol	Name	Symbol
time	*t*	second	s
length	*l*, *x*, *r*, etc.	meter	m
mass	*m*	kilogram	kg
electric current	*I*, *i*	ampere	A
thermodynamic temperature	*T*	kelvin	K
amount of substance	*n*	mole	mol
luminous intensity	I_v	candela	cd

Source: NIST Special Publication 330:2019, Table 2.





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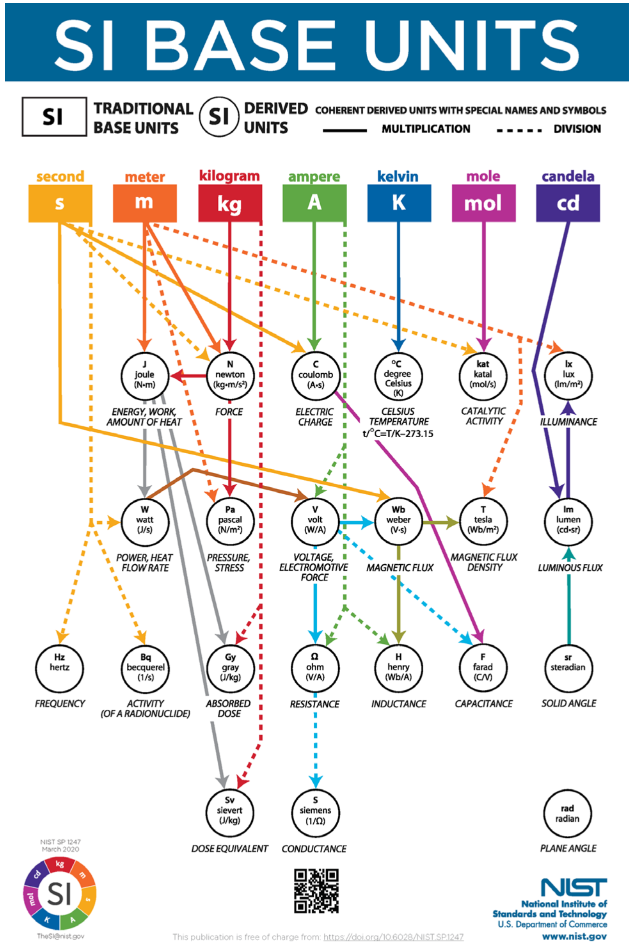
Enormous amounts of reliable and accurate measurements are needed

- The challenge is to measure:
  - Small (n) and fast signals (ns)
    as well as the large signal (T) and slow signals (s)
  - On remote locations under extreme conditions
- Challenging to transmit fast and accurate



Laki Power

Openelectrical.org

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Take ways

- Our common goal is to create a sustainable planet
- A sustainable, digital, carbon neutral energy system, with the ’digital’ electricity grid as a backbone, is one of the enablers
- To be able to tackle the challenges with the transition on short term – measurements of all kinds on all places with good accuracy become more and more important

Thank you!

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