Experiences and challenges in data from WAMS for stability and control in the Dutch and the Colombian Power Systems

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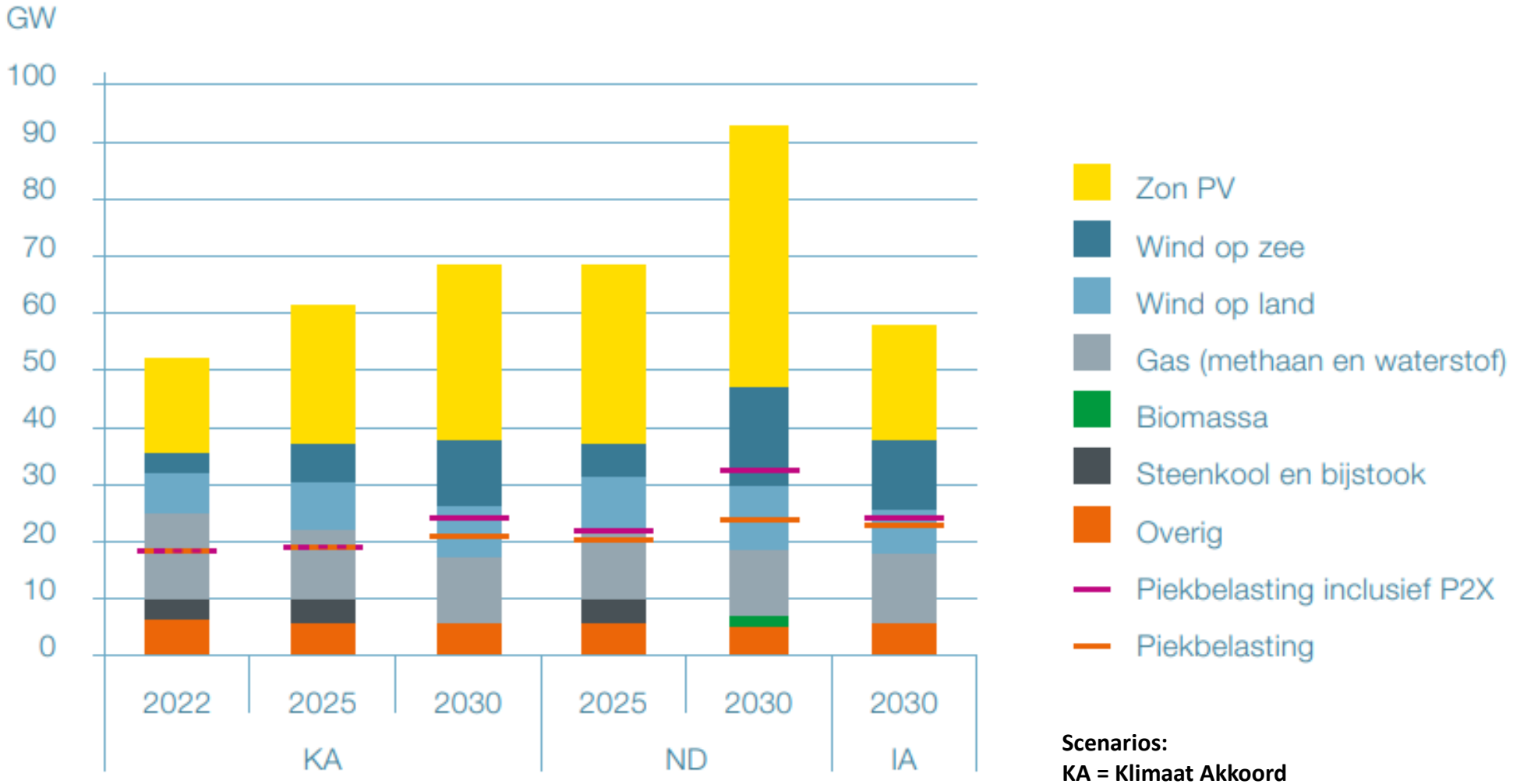
The Dutch Power System

The Dutch High-Voltage Network

- 380 kV connection/substation
- 380 kV connection/substation project
- 380 kV interconnection
- 380 kV interconnection in planning
- 220 kV connection/substation
- 220 kV interconnection
- 150 kV connection/substation
- 110 kV connection/substation
- 110 kV connection project
- Onshore DC connection in planning
- Subsea interconnector
- Subsea interconnector in planning
- Offshore connector
- Offshore connector in planning
- Offshore convertorstation/substation
- TenneT head office
- TenneT office
- Power plant
- Meeden — Name substation

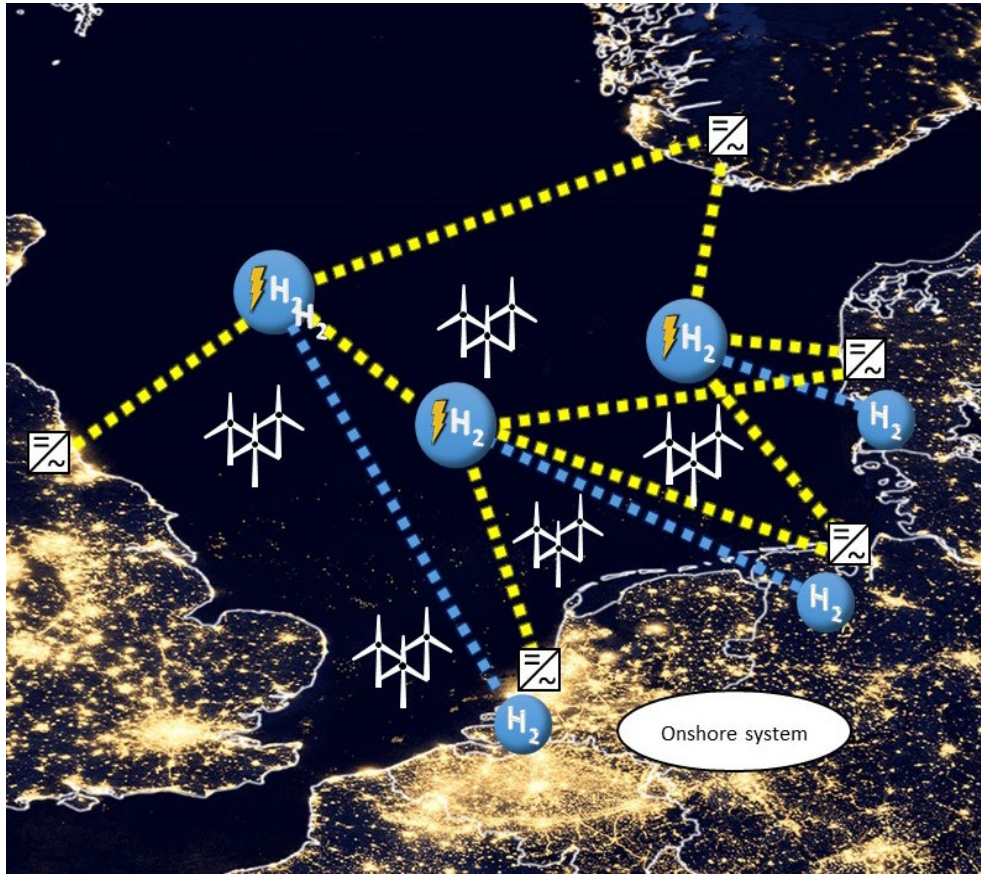
Development of RES



Scenarios:
KA = Klimaat Akkoord
ND = Nationale Drijfveer
IA = Internationale Ambitie

Stability challenges due to high RES

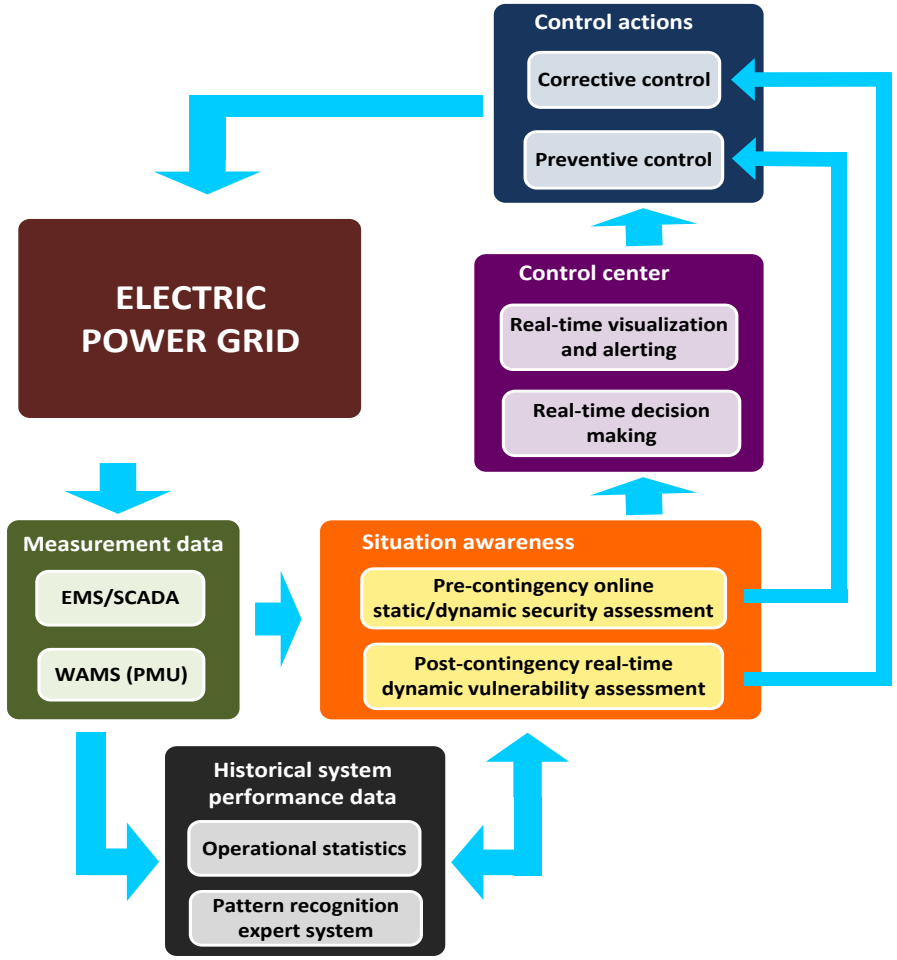
Towards 100% clean power supply



- Changing (time-variant), faster, and complex dynamic properties due to higher penetration of power electronic converters.
- Instability risk due to unprecedented adverse multi-controller dynamics.
- Limitations of existing tools for offline and online dynamic security assessment, control design, and decision making.

PMU data in power system operation

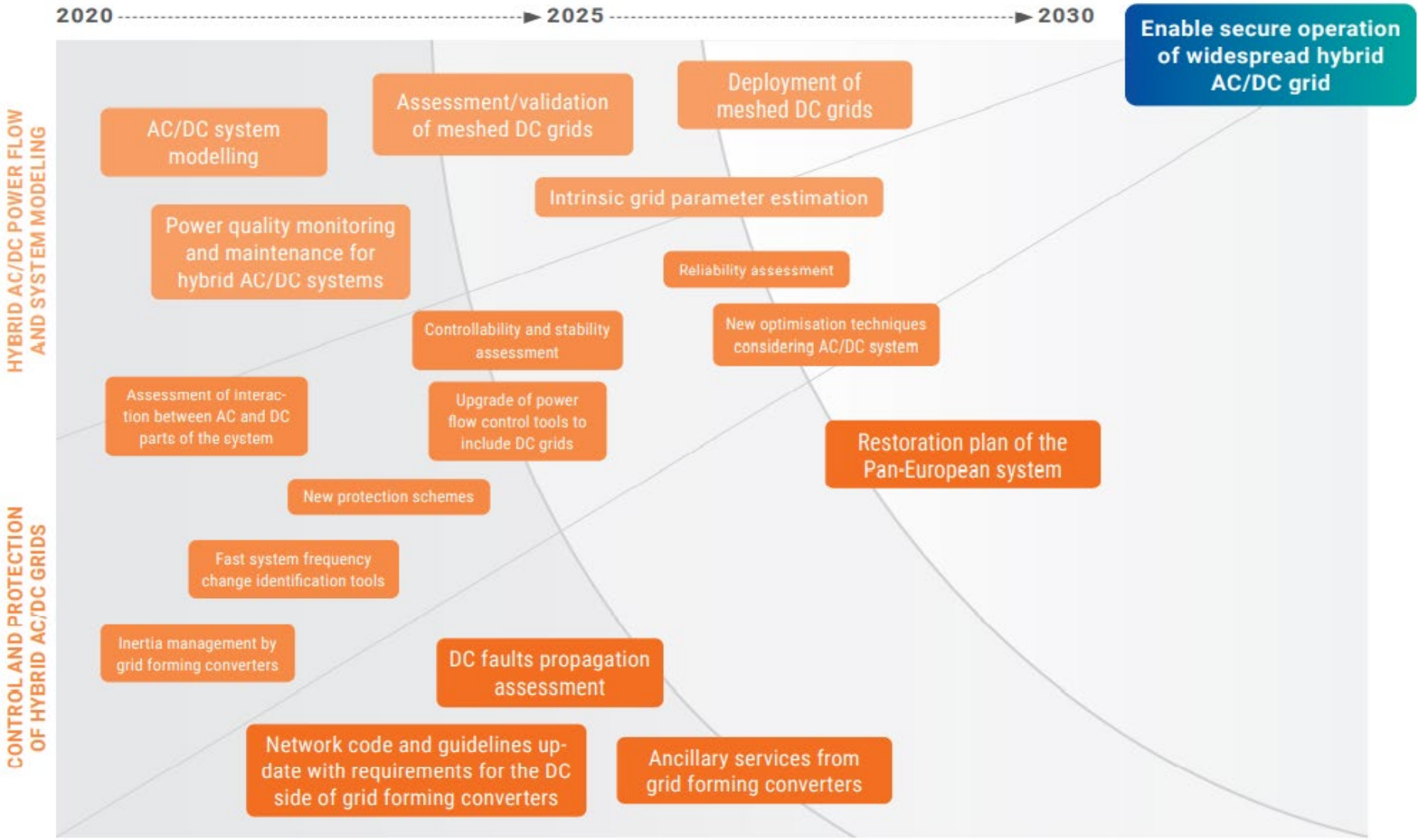
Example WAMPAC vision



Challenges

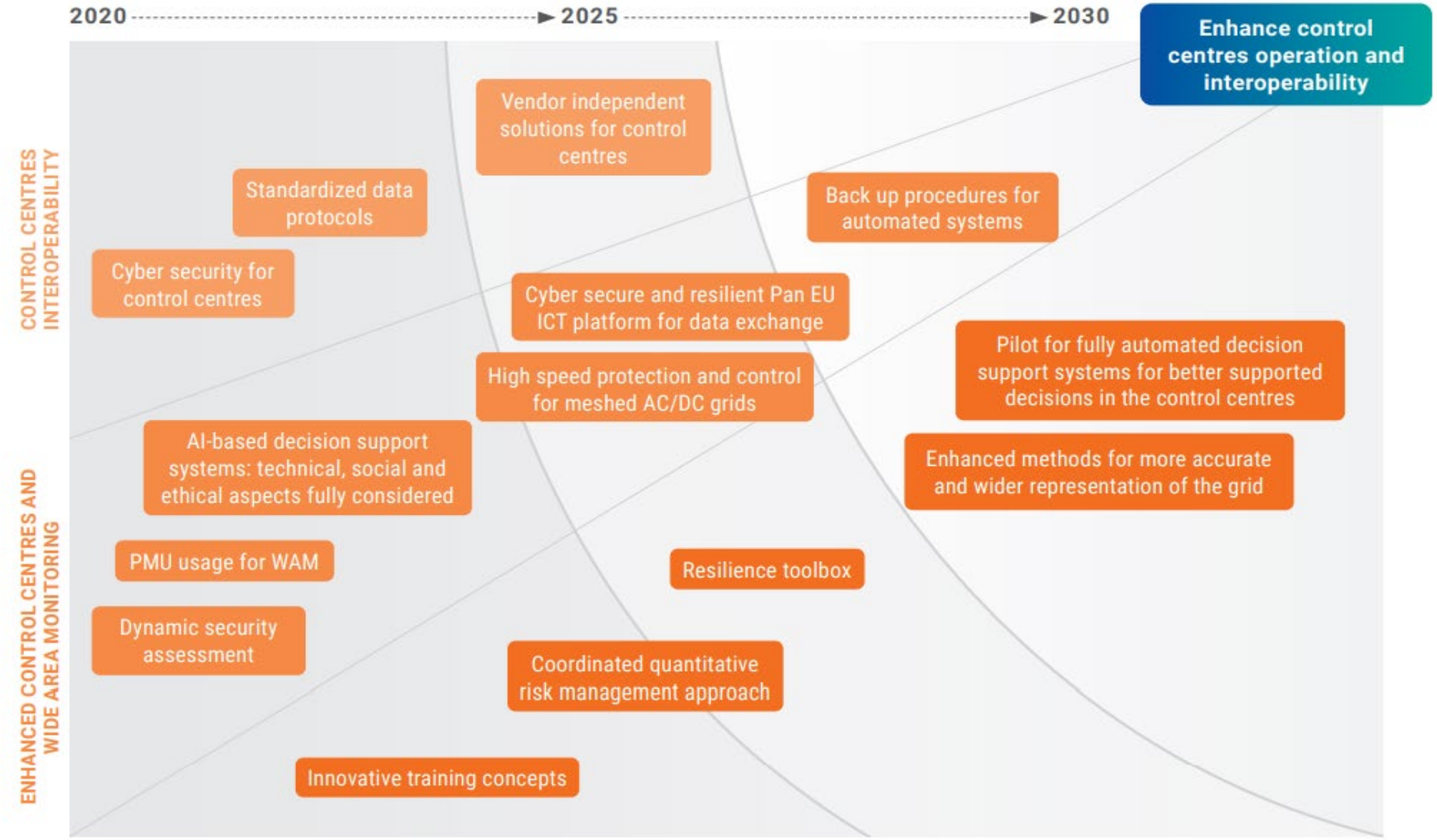
- Increasing the number of PMU devices (currently 6 PMUs deployed offline).
- Optimal handling and storage of large amounts of data.
- Continuous evaluation of data quality and its influence on models and functionalities of EMS.
- Effective tools for real-time resiliency assessment and enhancement and decision making.

Relevant R&D topics



Source: ENTSO-E

Relevant R&D topics

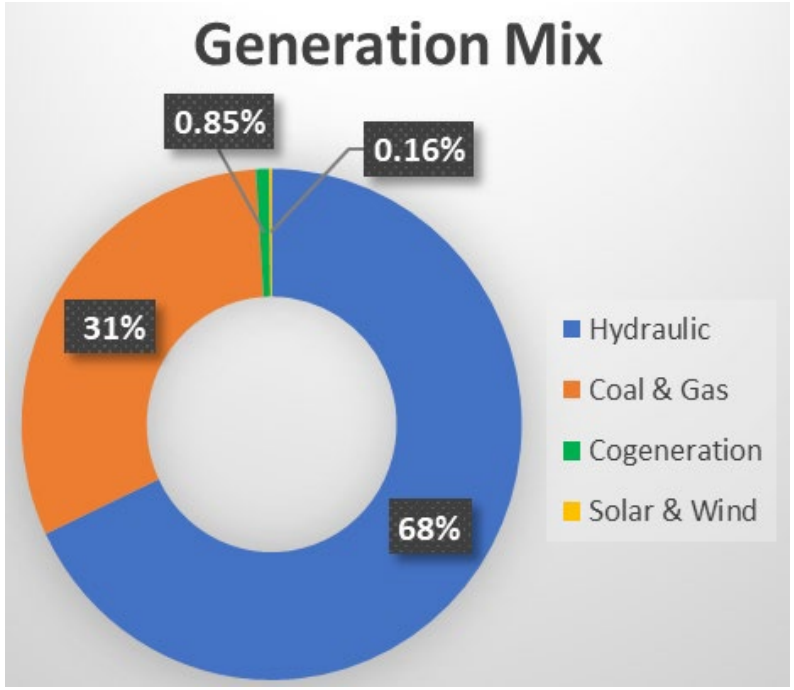


Source: ENTSO-E

The Colombian Power System

The Colombian High-Voltage Network

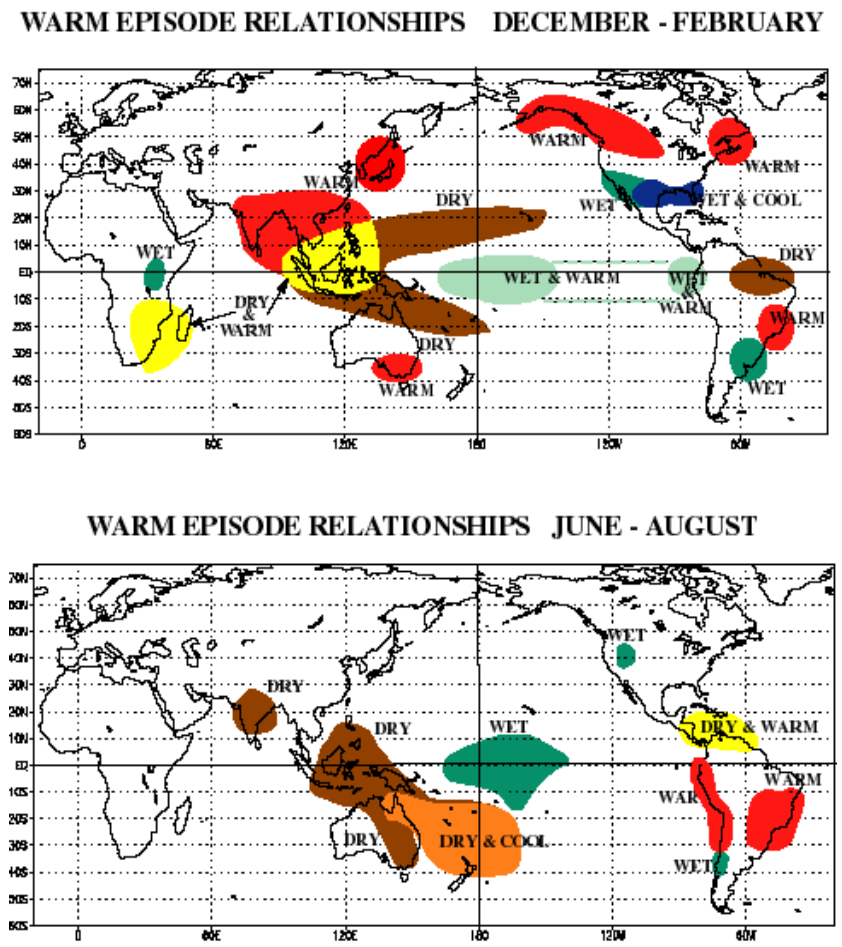
Electrical grid from 66 kV to 500 kV [dotted lines means expansion plan]



- 1400 buses
- 364 synchronous generators (mostly hydraulic)
- 900 transmission lines
- 17.6 GW maximum generation capacity
- 10.6 GW maximum active power demand.

PMU data in power system operation

Climate impacts of “El Niño”



Challenges

- Resiliency jeopardized by climate patterns (e.g. El Niño)
- Unprecedented dynamic phenomena due to technological upgrades (e.g. growing integration of power electronics).
- Increasing the number of PMU devices (currently 100 PMUs installed across the system and used in online applications like state estimation and network analysis).
- Application of PMU data for uncertainty modelling and reliability assessment and enhancement in different time horizons
- Deployment of big data analytics and advanced artificial intelligence.

Any Question?