Whole Energy System Planning

Thursday 20 November

For power system expertise

CIGRE UK Technical Committee
Whole System Task Force

A new taskforce within CIGRE

Whole energy system definition

Whole system building blocks

Whole energy system modelling

Whole energy system planning

Whole energy system opportunity

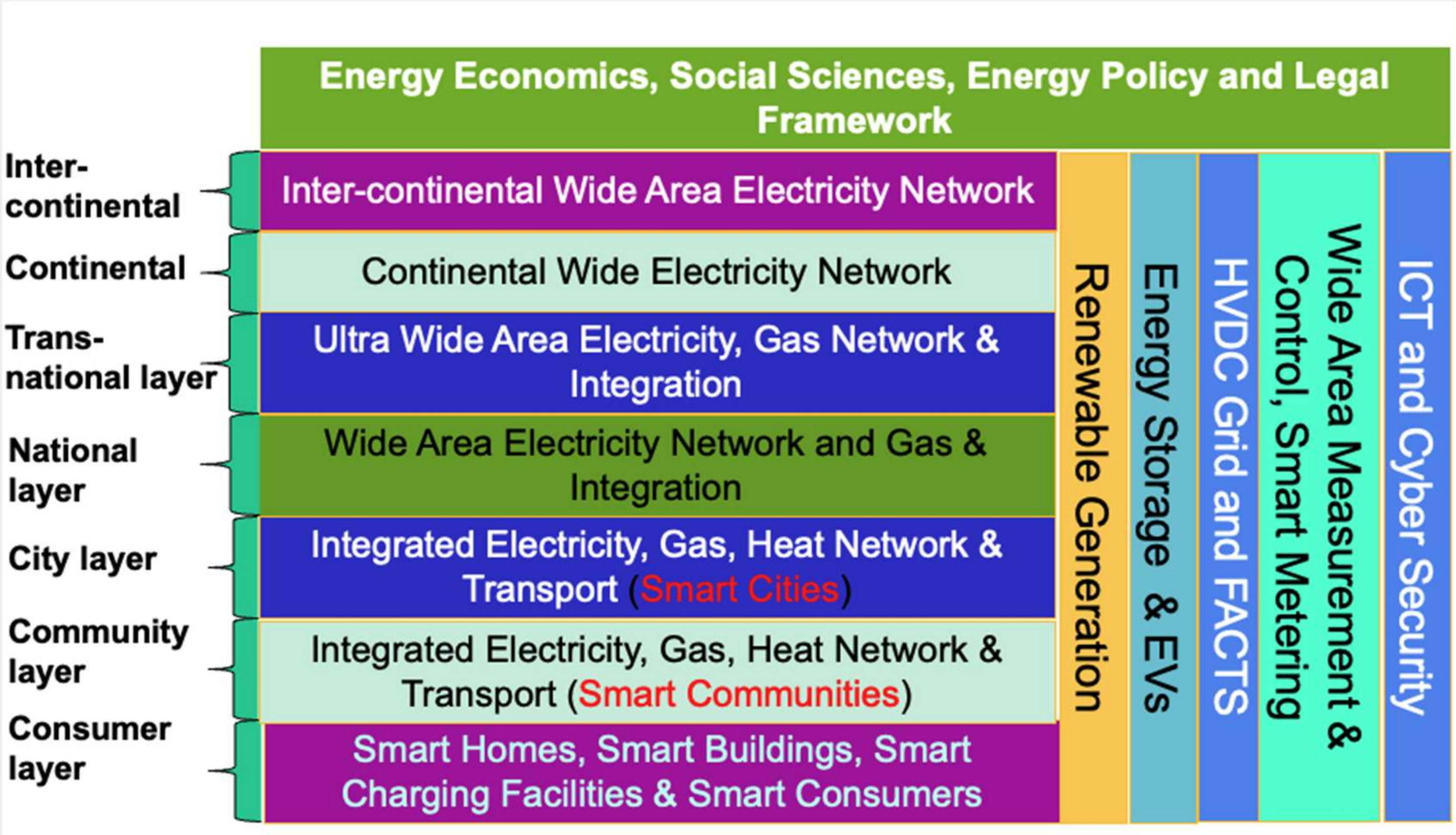
"To us: The whole energy system comprises electricity, gas, heat and transport networks and components that serve GB society."

Enabling whole energy system outcomes, SSEN Transmission, 2019

Whole Energy System refers to the intricate network of processes, infrastructure, technologies, markets, resources, licences and regulations involved in the generation, transmission, distribution, storage and consumption of energy across all sectors. There are multiple energy vectors that we should take into account to gain that holistic picture of the energy system, for example these would include natural gas, hydrogen and CCUS.

Whole Energy System Awareness, NESO, 2024

Global Architecture of Whole Energy System

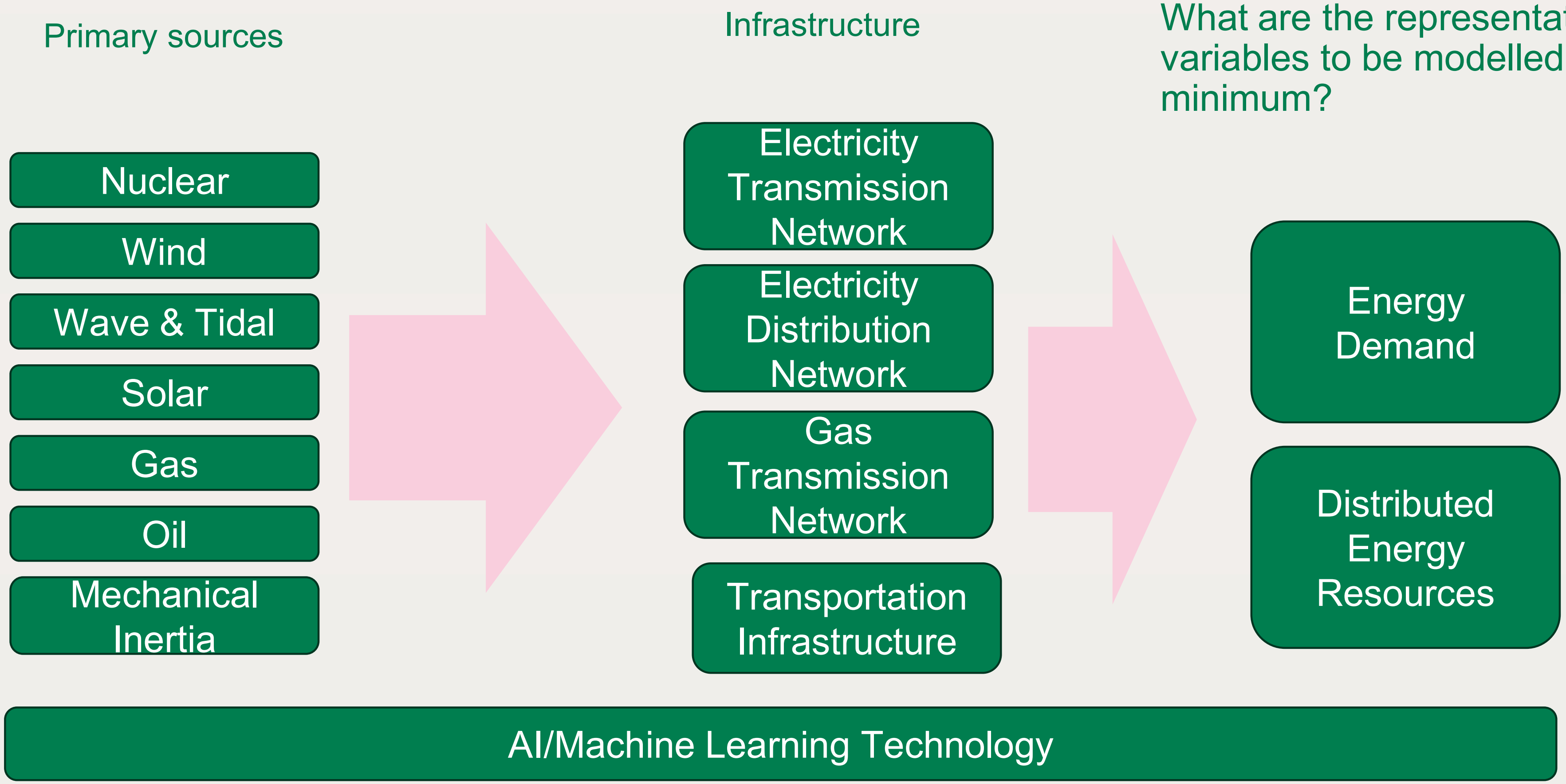


- The idea of an 'Energy Union' to oversee the governance of the Global Grid was introduced during a workshop held at the EU Sustainable Energy Week in the European Parliament in 2013.
- In 2015, the European Commission formally launched the 'Energy Union' initiative to spearhead Europe's energy transition.

Building blocks - Subsystems

How do we develop generic models for different functional parts of the energy system?

What are the representative variables to be modelled as a minimum?

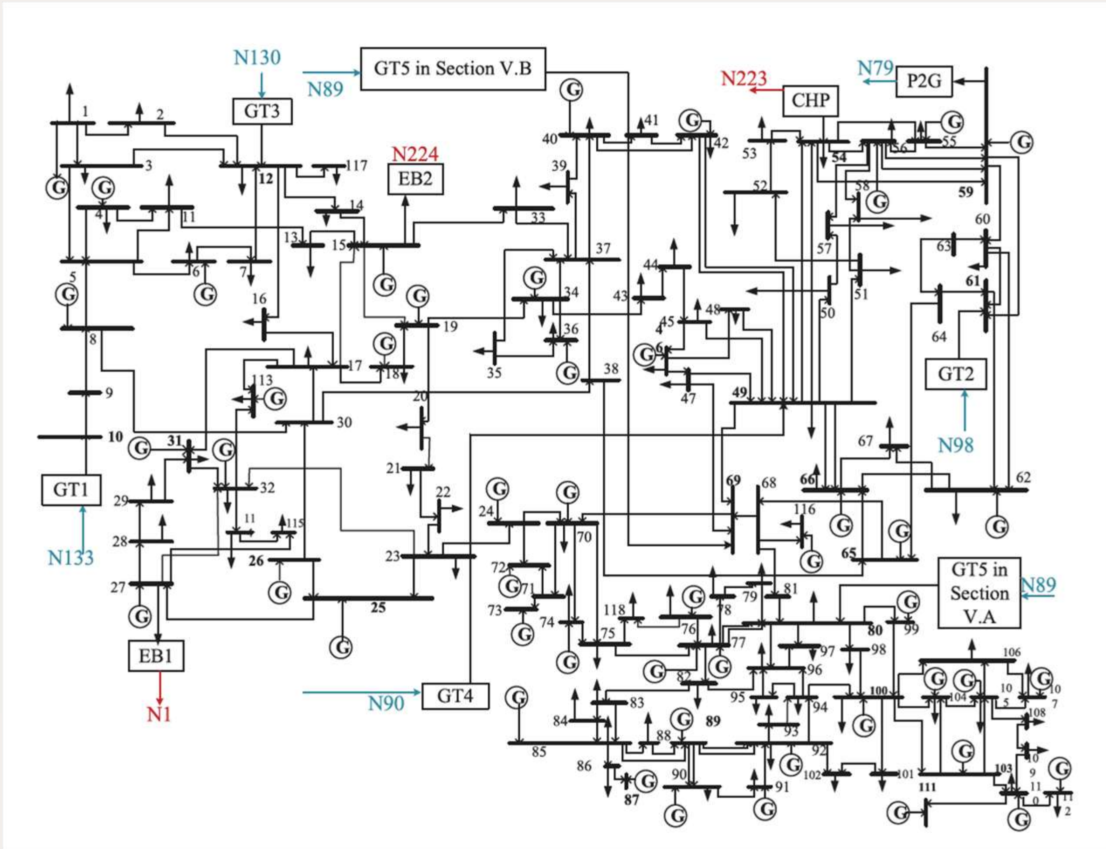


Challenges of Whole System Modelling

- Various levels of geographical coupling: Transnational, National, City, Community, and Consumers (industrial/domestic)
- Integration between different energy systems: Electricity, Gas, Heat, Hydrogen, Battery Storage, and Transport
- Diverse modelling approaches and tools are necessary for different energy system types
- A wide range of existing models and solutions are already available
- Research and development of innovative way of coupling sectors and vectors
- Reliable testing data sets are still very limited

Case Study 1: Coupling Gas, Heat and Electricity

- The analysis is performed in a large-scale whole energy system: 118-bus PS, 225-node HS, and 134-node GS.
- The 118-bus PS is modified from the IEEE 118-bus system
- Three systems are coupled with one back-pressure CHP unit, two EBs, five GTs, and one P2G
- The simulation period is 24h and Δt is 120s



Case study 1 conclusion

- Models of power systems, gas systems and heat systems have been presented.
- The presentation has been focused on how to benchmark the system models and test systems.
- Bidirectional intensively coupled and bidirectional weakly coupled system have both been simulated to verify the models.
- The data availability is still a big issue for real energy systems, in particular heat systems.

Case Study 2: Model Hydrogen in PowerFactory

Need Case
The UK government aims to produce **10GW** of low-carbon hydrogen by 2030 and to supply between **240-500 TWh** of low-carbon hydrogen by 2050.

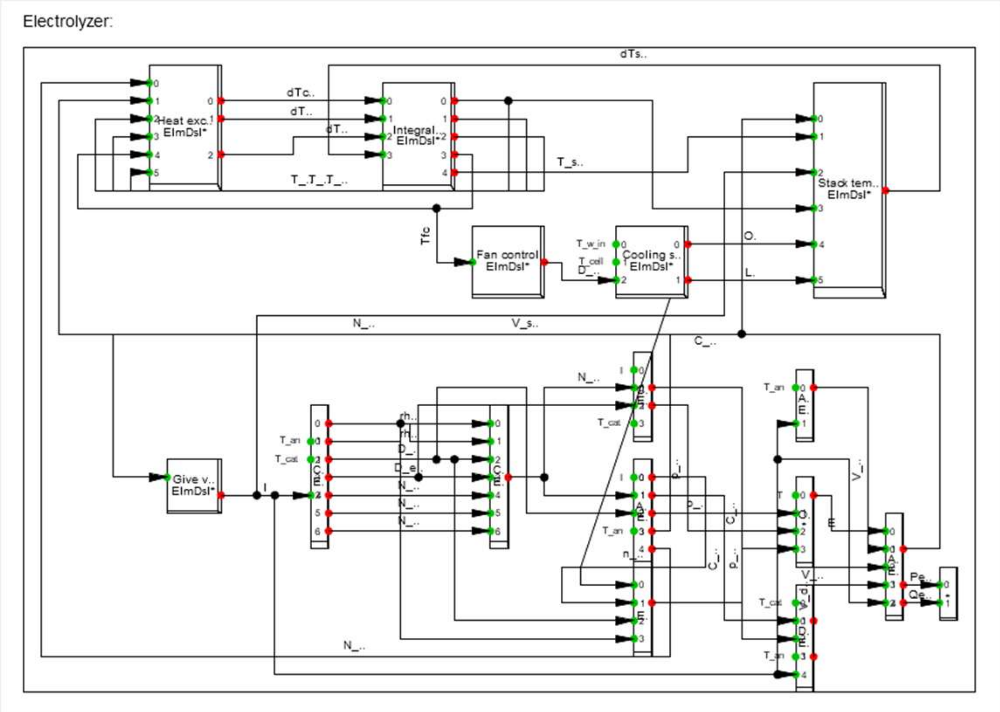
What we have today
Power Factory:
- Electrolyser model is implemented as a general PQ load, providing P and Q values
- Fuel cell model functions as a static generator, providing only P and Q values without detailed components

MATLAB:
- Uses a closed library structure
- No direct integration with other commercial software

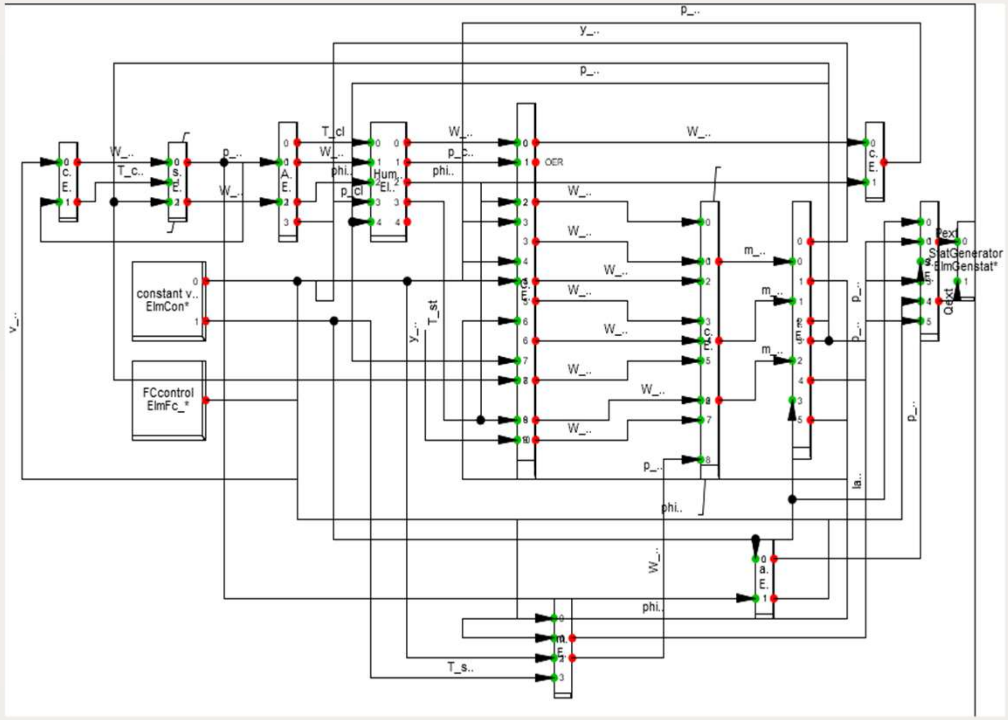
Why choose a dynamic model over a basic source/load model?
- A simple source/load model does not take real-time control inputs
- Compute dynamic outputs to pass to static generator block as PQ references
- Electrolyser, fuel cell and electricity system operate on very different time constants
- It lacks representation of dynamic, thermal, or gas-related effects

Case study 2 conclusion

Dynamic composite model of electrolyser

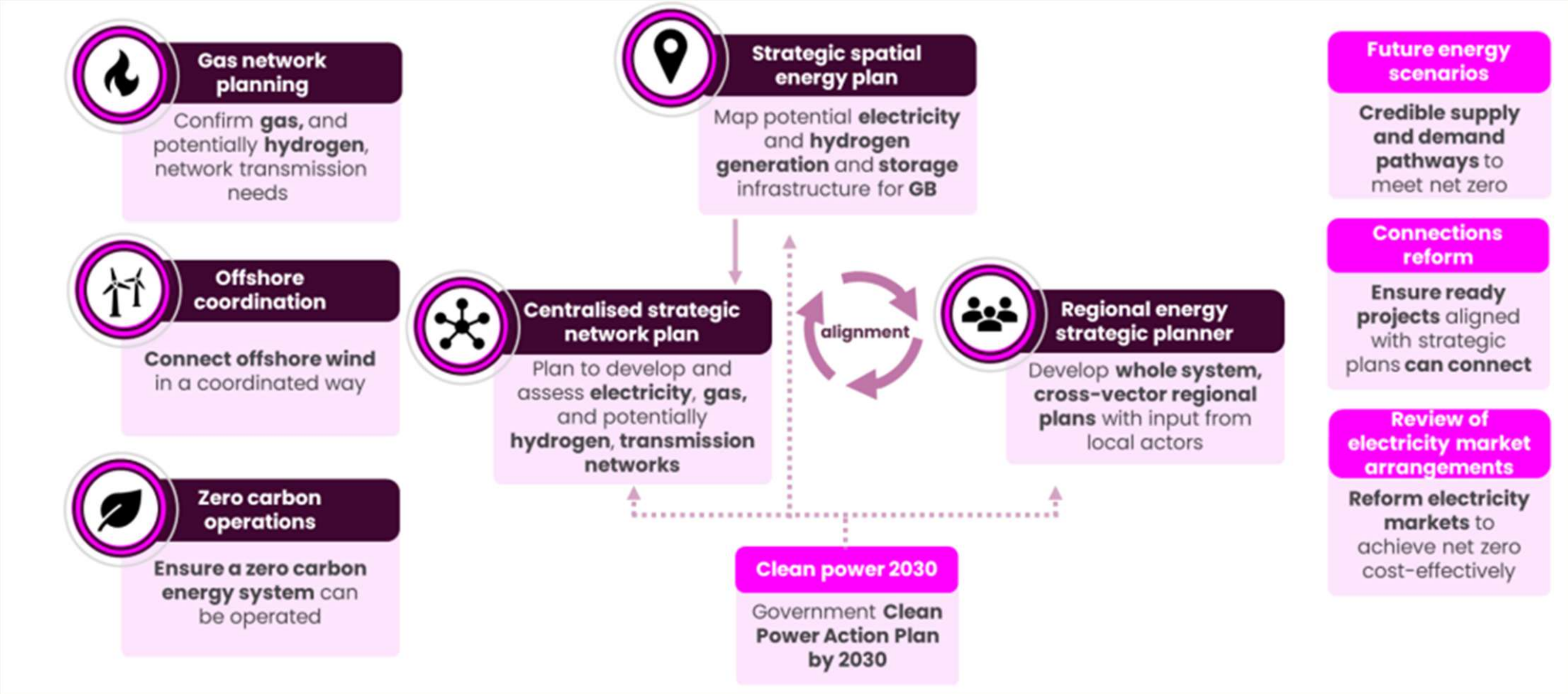


Dynamic composite model of fuel cell



When load/demand changes, the compressor and hydrogen flow control take time to adjust, and this affects the transient voltage and power behaviour which has been modelled correctly to enable a meaningful power system simulation.

Whole energy system planning

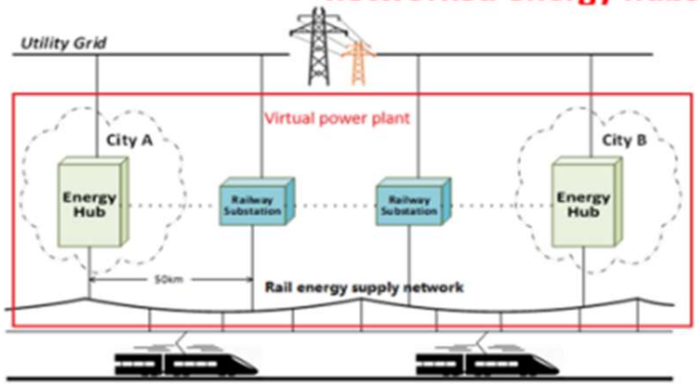


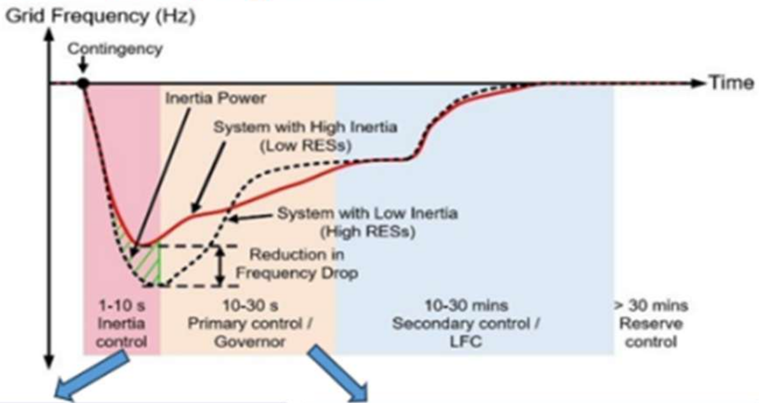
Planning Approach

Drive	An industry transformation led by regulator to plan the energy networks centrally required for the wider transfer of electricity, gas, and hydrogen.
Identify	Build an accurate baseline for the current capability and future needs of the networks to inform all relevant parties in each energy vector and sector.
Develop	Considering each vector and sector's system requirements, a range of network reinforcement/planning/operational options will be put forward by all industry parties, managed by a centralised platform.
Appraise	Options will then be assessed across multiple assessment criteria to determine the best solution across GB, such as consumer benefits, system security, net zero contribution and environmental impact etc.
Regulation Decision	A transparent plan could be published with a consultation window, which will provide an opportunity to shape the final solution. Proper regulatory funding and license will then be allocated accordingly.
Deliver	Following regulatory decision, the whole energy system solution will progress through detailed design, consenting and delivery. An ongoing change control process will ensure delivery in line with the plan.

Whole energy system opportunity - case 1

Coupling railway network with HV transmission network via networked energy hubs for frequency regulation





Victim ? → Potential Solution

- Massive, distributed kinetic energy store
- Regenerative braking
- Rapid, short term power boost

Inertia Support (IS)

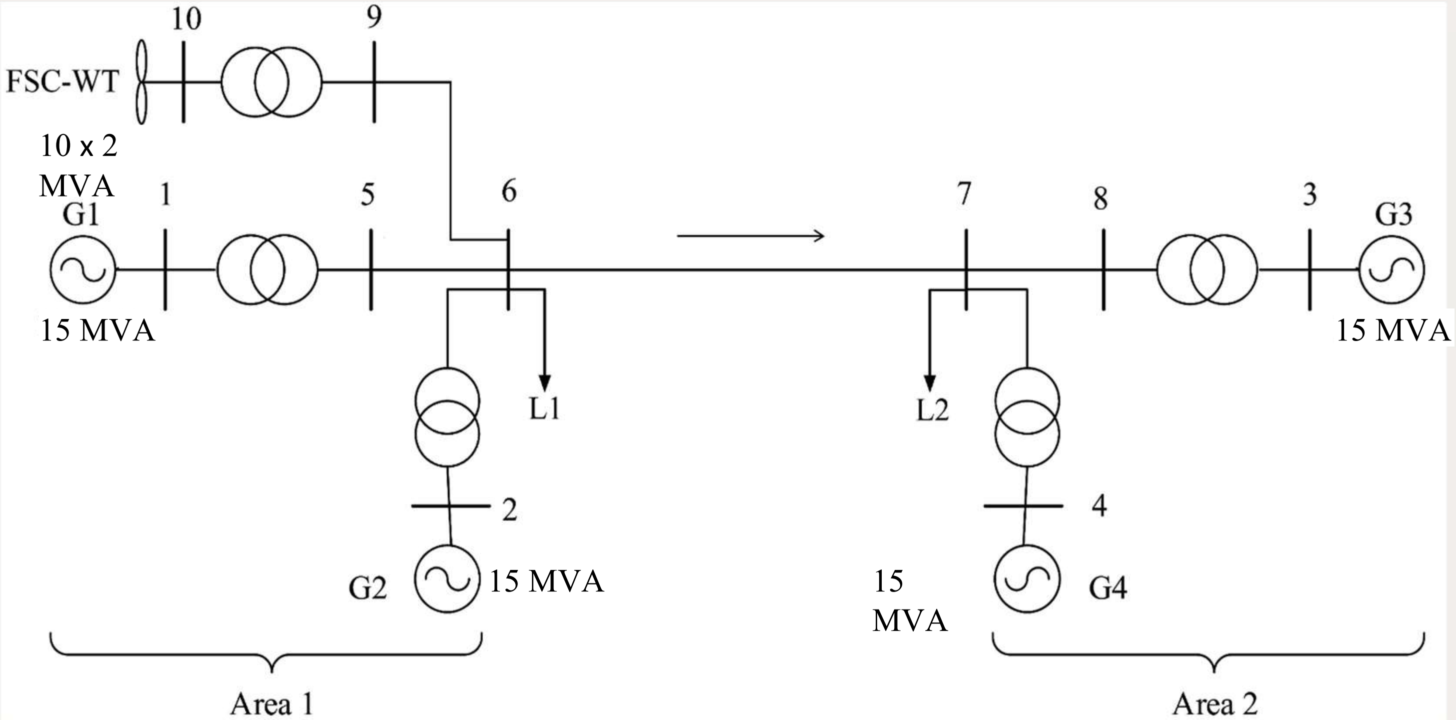
- Purpose: Instantaneous power injection to slow the Rate-of-Change-of-Frequency (RoCoF).
- Response: **< 100 ms**
- Power: Up to **~550 MW**
- Limited by converter current rating.

Frequency Support

- Purpose: Sustained power injection to arrest frequency fall and aid recovery.
- Duration: **60 seconds**
- Power: Up to **~400 MW** (with a 90% speed deviation)
- Limited by train kinetic energy and allowable speed drop.

Whole energy system opportunity - case 2

Wind farm with 10 x 2 MW WTs and a 4 MW Electrolyser



An AI controller coordinates wind turbines and electrolysers to provide fast frequency response and inertia support, improving frequency nadir by over 30% during disturbances - proved hydrogen and wind farm can enhance grid resilience through adaptive AI control.

CIGRE support, promote and champion this journey ..

Call for everyone to join our Whole Energy System Planning Taskforce!

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