Forecasting volatile behaviour in hydrogen grids: Network Control as key to long term network simulation

Or: How to build the Energy Infrastructure of Tomorrow

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DOINGTHE MATH

OGE

Our Vision

We are a cornerstone of the future energy system at the heart of Europe.

Our Mission

We plan, build and operate high-performance infrastructures for natural gas, hydrogen and CO_2.

This is how we create innovative and affordable solutions for our customers for a successful energy transition.

German Hydrogen Core Network

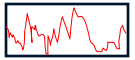
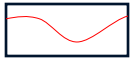
Key data on the core network:

Total length: 9,666 km, of which
- 5,047 km of conversions
- 3,561 km of new lines

Compressor stations: 291 MW

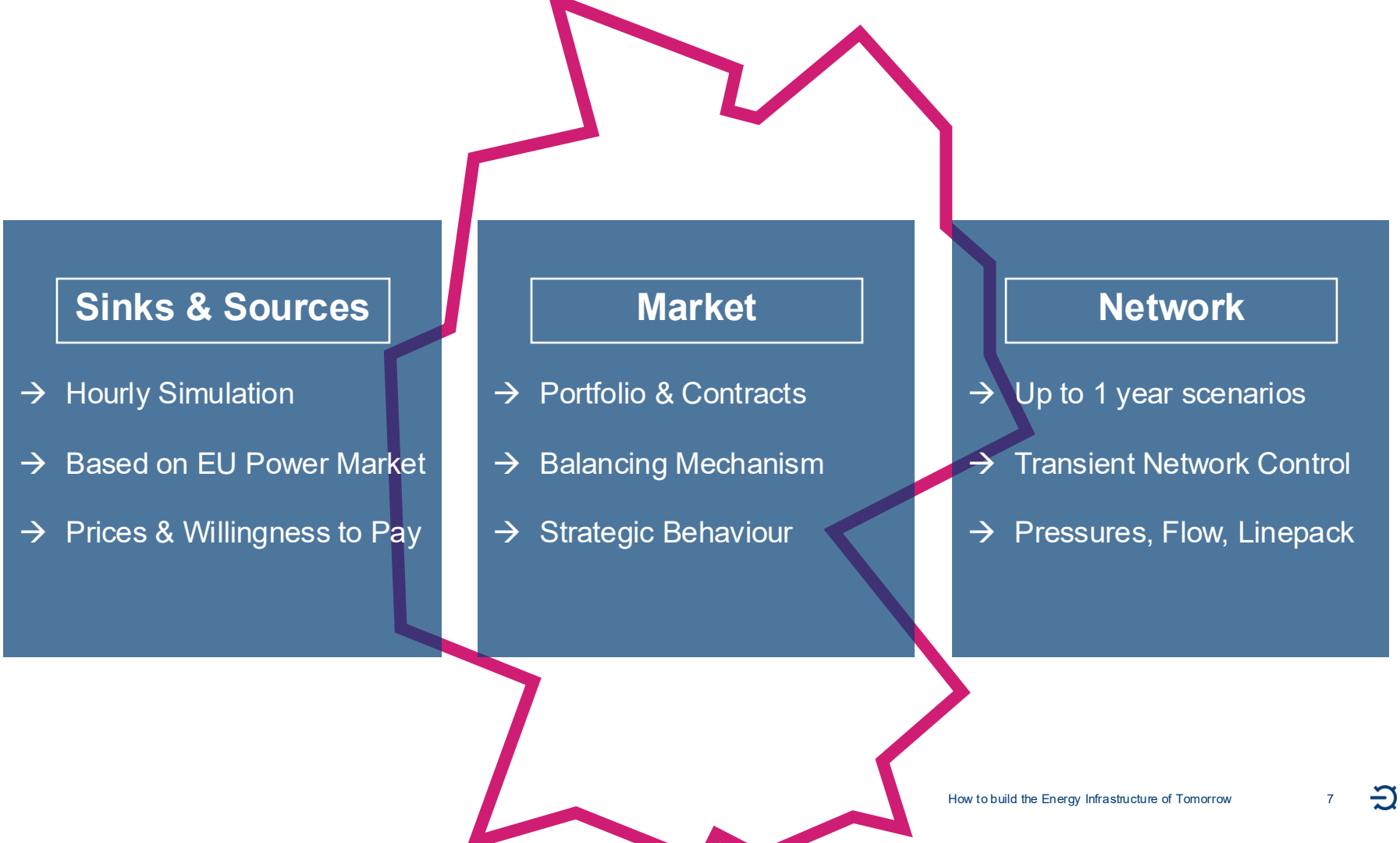
Total investment costs: € 19.7 billion

Hydrogen – Completely Different to Natural Gas

Feature	Natural Gas	Hydrogen
Supply Volatility	Predictable 	Weather-driven, volatile 
Demand Volatility	Mature, seasonal 	Emerging, uncertain 
Flow Direction	(Mostly) Uni-directional 	Multi-directional 
Storage/Line Pack	Sufficient, reliable 	Scarce, constrained 
Planning Needs	Daily, rule-based 	Predictive, dynamic 
Power System Coupling	Limited 	Deeply tied to electricity 
Pressure Load Monitoring	Not needed 	Needed 

Our Project

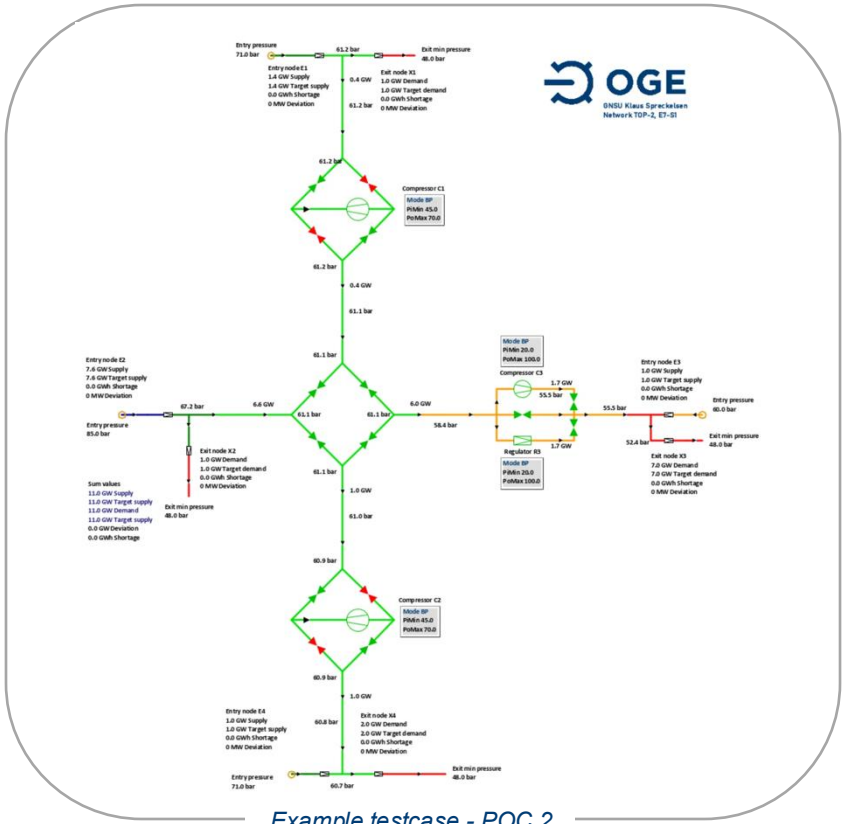
We develop a simulator to combine market foresight with physical network properties.


Sinks & Sources
→ Hourly Simulation
→ Based on EU Power Market
→ Prices & Willingness to Pay
Market
→ Portfolio & Contracts
→ Balancing Mechanism
→ Strategic Behaviour
Network
→ Up to 1 year scenarios
→ Transient Network Control
→ Pressures, Flow, Linepack

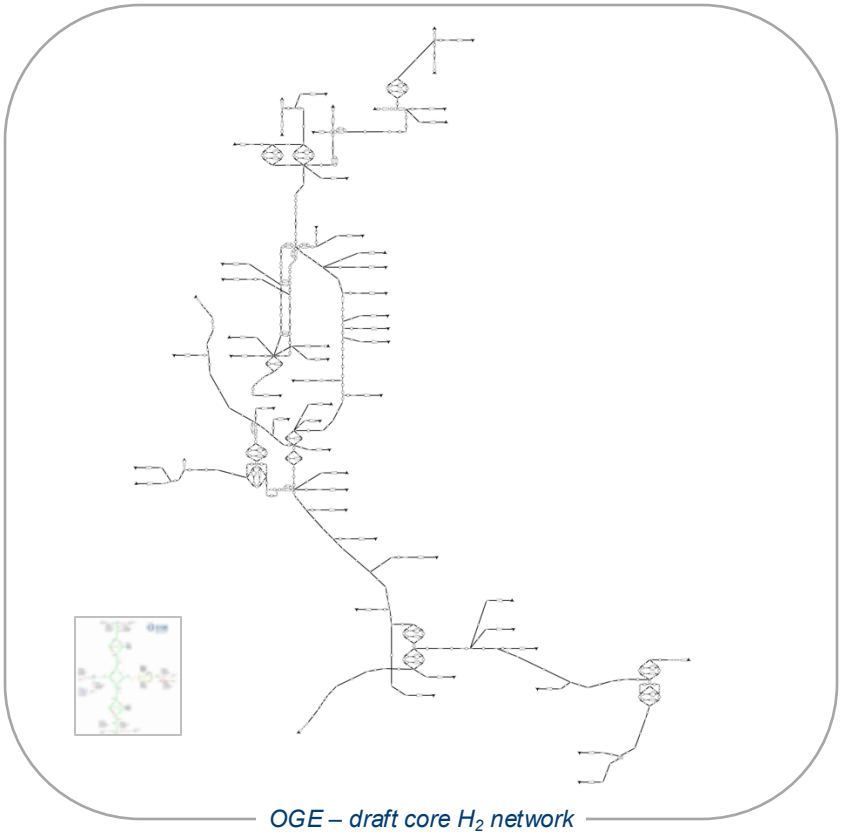
The Mathematicians That Could

DOING THE MATH

The Networks We're Controlling



Example testcase - POC 2



OGE – draft core H_2 network

Modelling Complexities of Gas Network Control

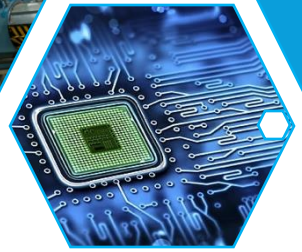
Network Reconfigurations

H_2 is not water or electricity

Compressors

Gas flow nonlinear

H_2 is slow



On the Edge

Optimising Hydrogen Network Control

Navigating Key Challenges

Active element mode switching

Highly complex combinatorial decisions introduce discrete optimization challenges

Modelling time & line pack

Pipes act as storage, time dynamics must be captured explicitly

Need for accurate pipe flow physics

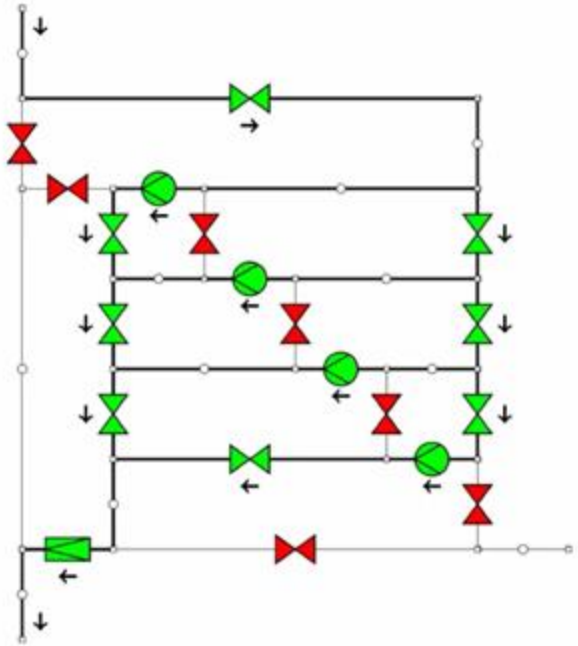
Controls must respect pressure bounds and flow feasibility

Complexity of year-long scenario evaluation

Thousands of transitions to consider

Complex optimisation problem

Mix of discrete & nonlinear (physical) models makes solving hard



The combinatoric complexity of a compressor station (ZIB, Mark Turner)

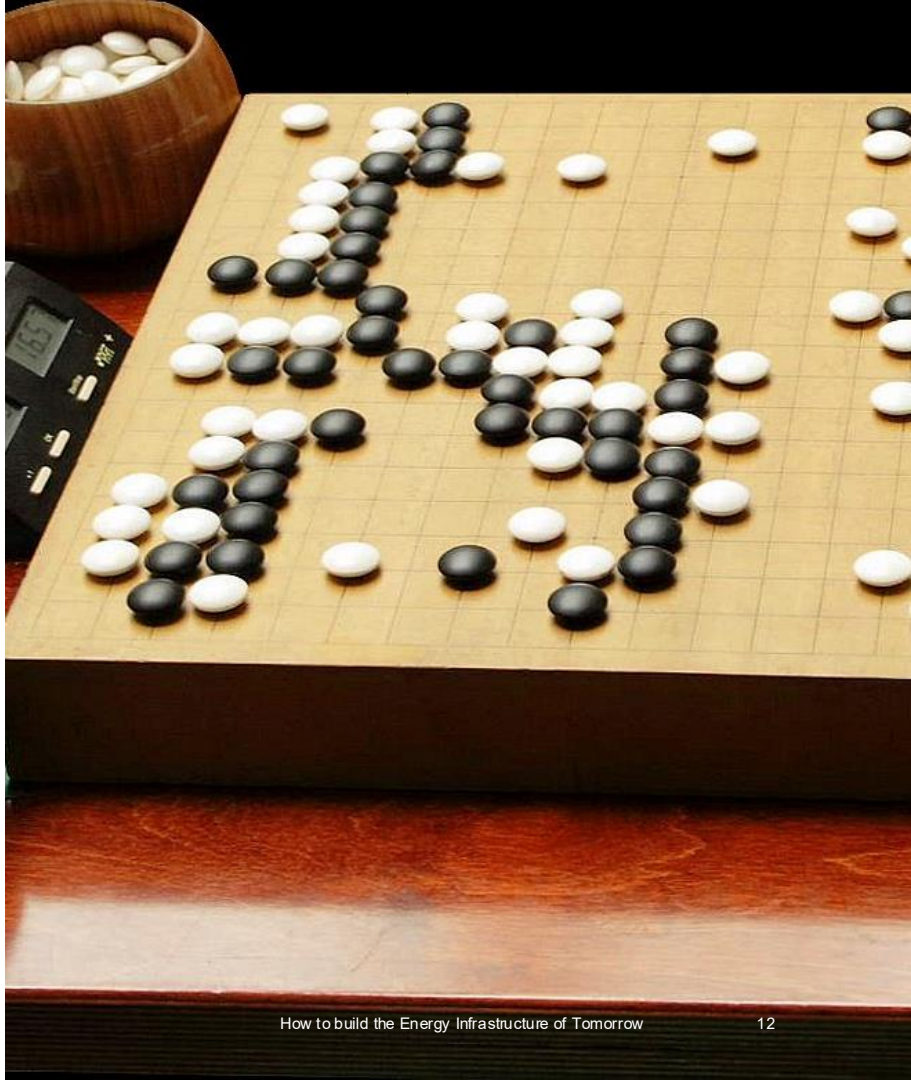
Optimised Network Control

Project Goals to be achieved

🎯 **Avoid curtailment of entries/exits**
Ensure reliable supply to customers

🎯 **Limit pressure load cycles**
Extend asset life by avoiding fatigue

🎯 **Find calm control strategies**
Minimize unnecessary changes to network controls



CORGI -“Divide and Conquer” on multiple levels

Control Optimisation for Resilient Gas Infrastructure

Sequential approach

Breaks down intractable optimisation into solvable subproblems

Linearisation

Approximate nonlinear physics (not relax)

Solve NLP with fixed controls

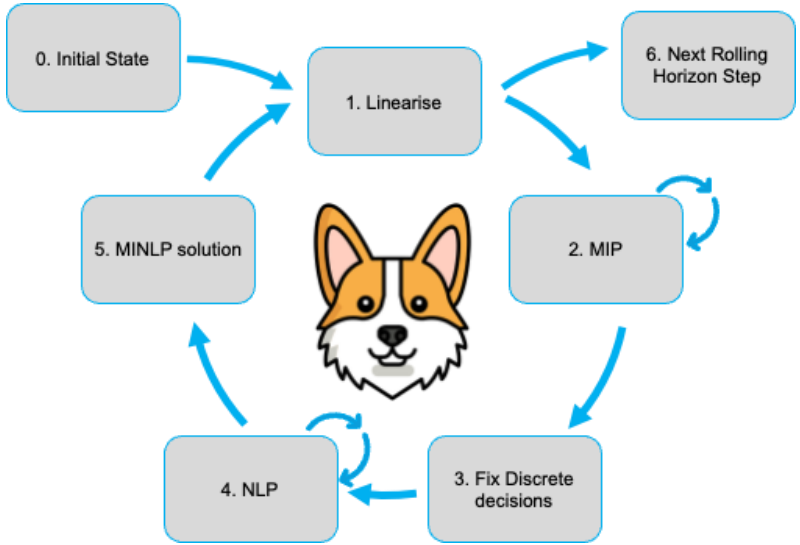
Use NLP solver to validate feasibility under fixed discrete control decisions

(Optional) Iterate with updated linearisation

Refines the model based on current solution

Rolling Horizon

Divide year-long scenario into time windows for tractability



What Made This Project Work?

✔ Having a competition works well, it helps to identify the right partner

👥 Involve all relevant disciplines: mathematicians, physicists, engineers

📚 Access to state-of-the-art research enables the design of cutting-edge algorithms

🔍 Model validation through simulation boosts trust in results

🧪 Testing under realistic scenarios reveals edge cases and robustness gaps

🚧 Early recognition of model limitations shapes better design and manages expectations

🤝 Close cooperation between Gurobi and DTM proved mutually beneficial


Optimisation controls
sustainable energy infrastructure
before it is even built!

We bring
the energy.

OGE