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Coupling Energy Networks

USEA
United States Energy Association

The Need for Dynamic Hydraulic Gas Network Modeling & the Value of Planning Electricity & Gas Networks as an Integrated Energy System

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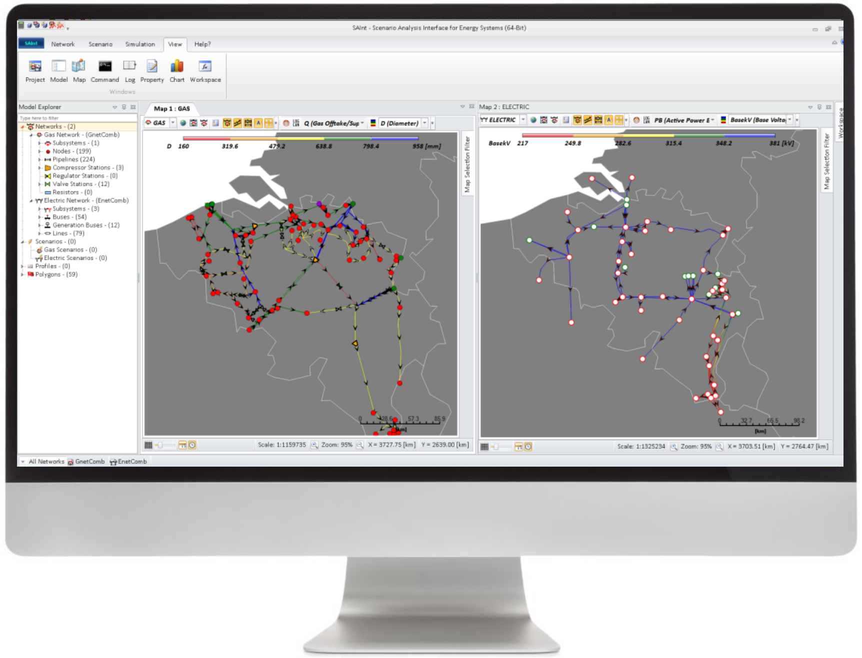

SAInt by encoord

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encoord in brief

- encoord is an American-German software company that provides tools to plan today's energy systems and their transition to a decarbonized future.
- Our core technology is the Scenario Analysis Interface for Energy Systems (SAInt), an intuitive, flexible and modular software platform to model energy networks and markets.
- Our clients include electricity and gas transmission network operators, utilities, investors, project developers, regulators, governmental agencies, market traders and analysts, consulting companies, research institutions, and universities.

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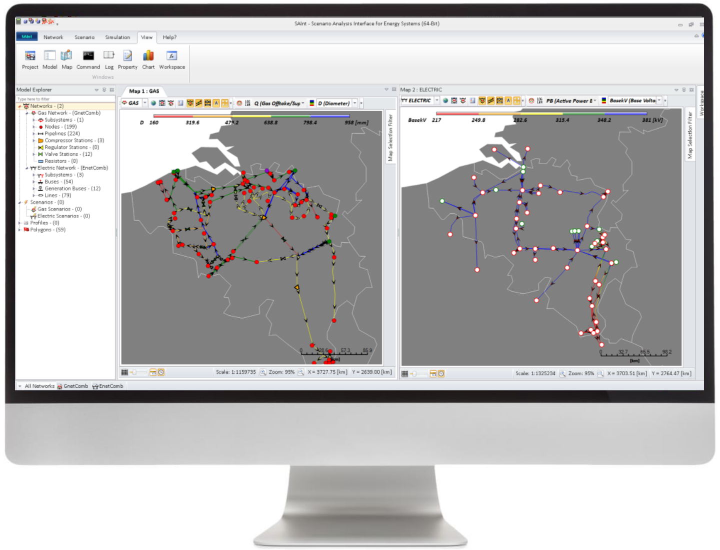


electricity

gas

heat

liquid

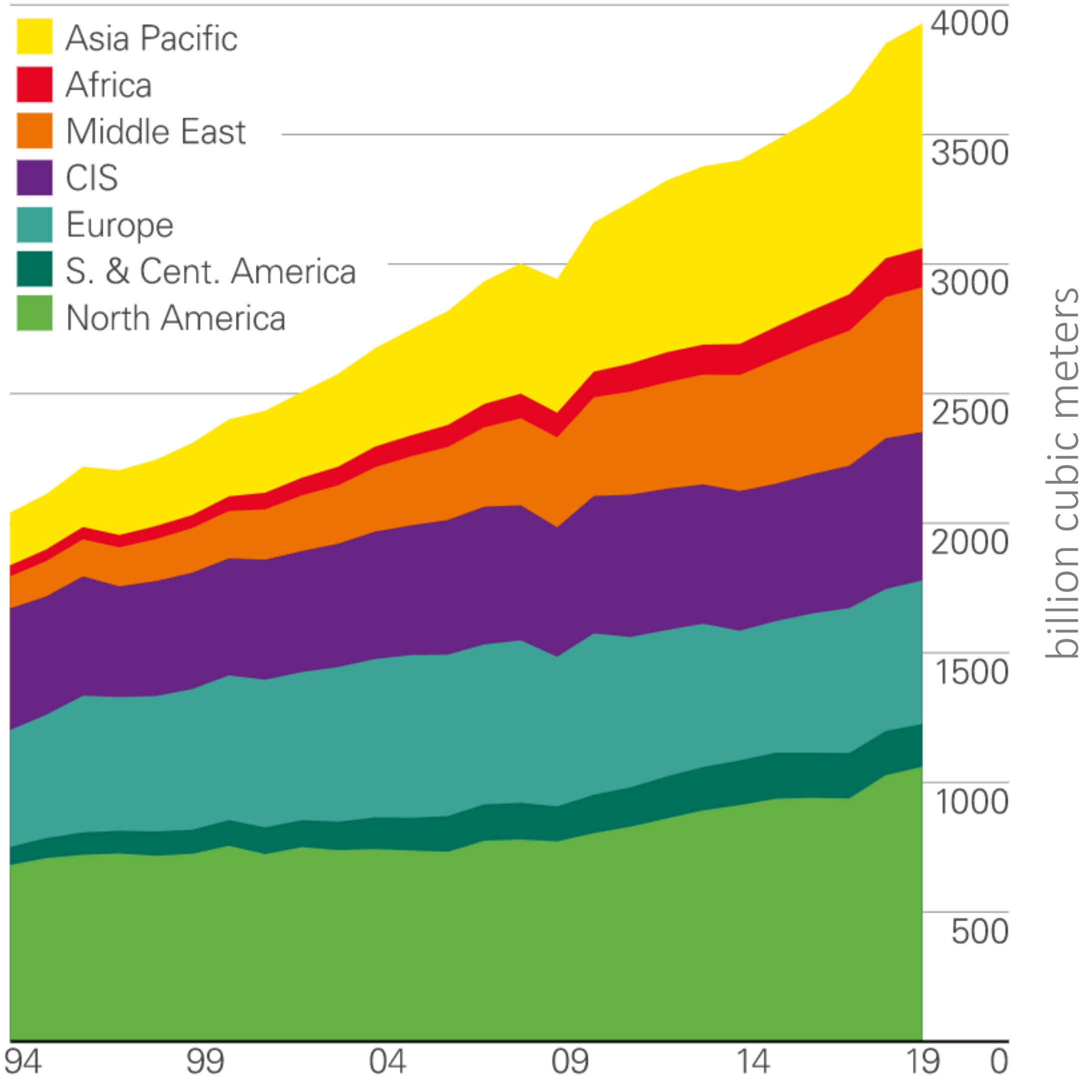
clients in 8 countries

Agenda

- Natural gas consumption & infrastructure
- Operation of natural gas pipeline networks
- Hydraulic gas network modeling
- Applications of hydraulic gas network models
- Example of a hydraulic gas network model application in SAInt
- The value of planning electricity & gas networks as an integrated energy system
- SAInt’s unique capability to model coupled electricity and gas networks
- Applications of coupled electricity and gas network simulations
- Example of a coupled electricity and gas network simulation application in SAInt

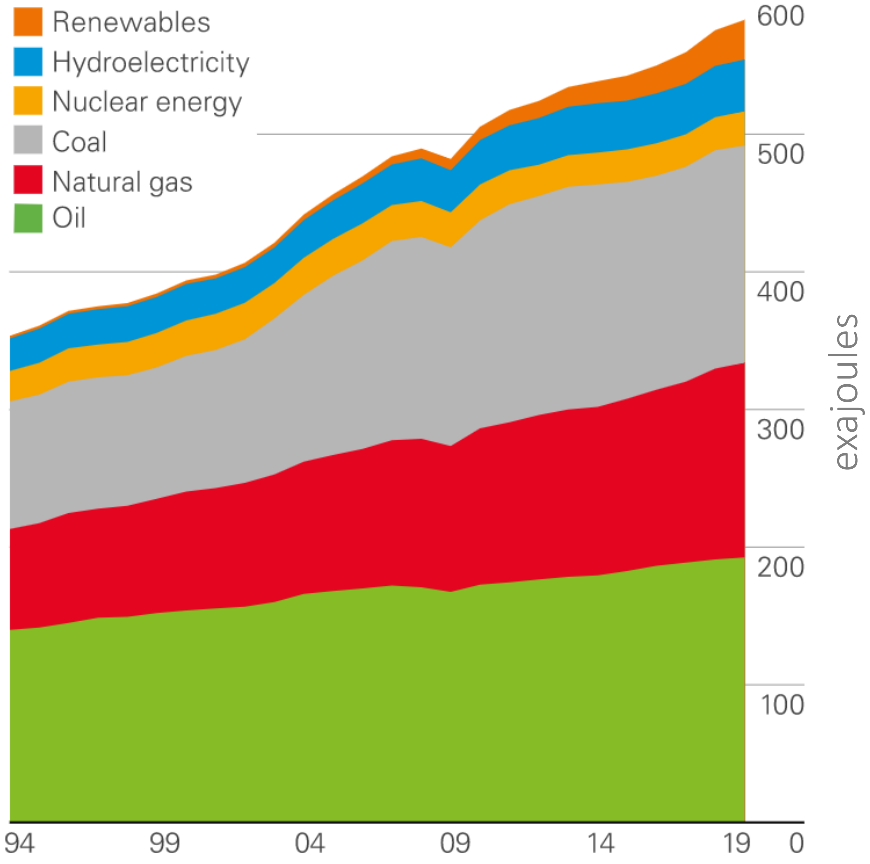
Global natural gas consumption

- Electricity generation
- Industrial production
- Heating
- Transportation



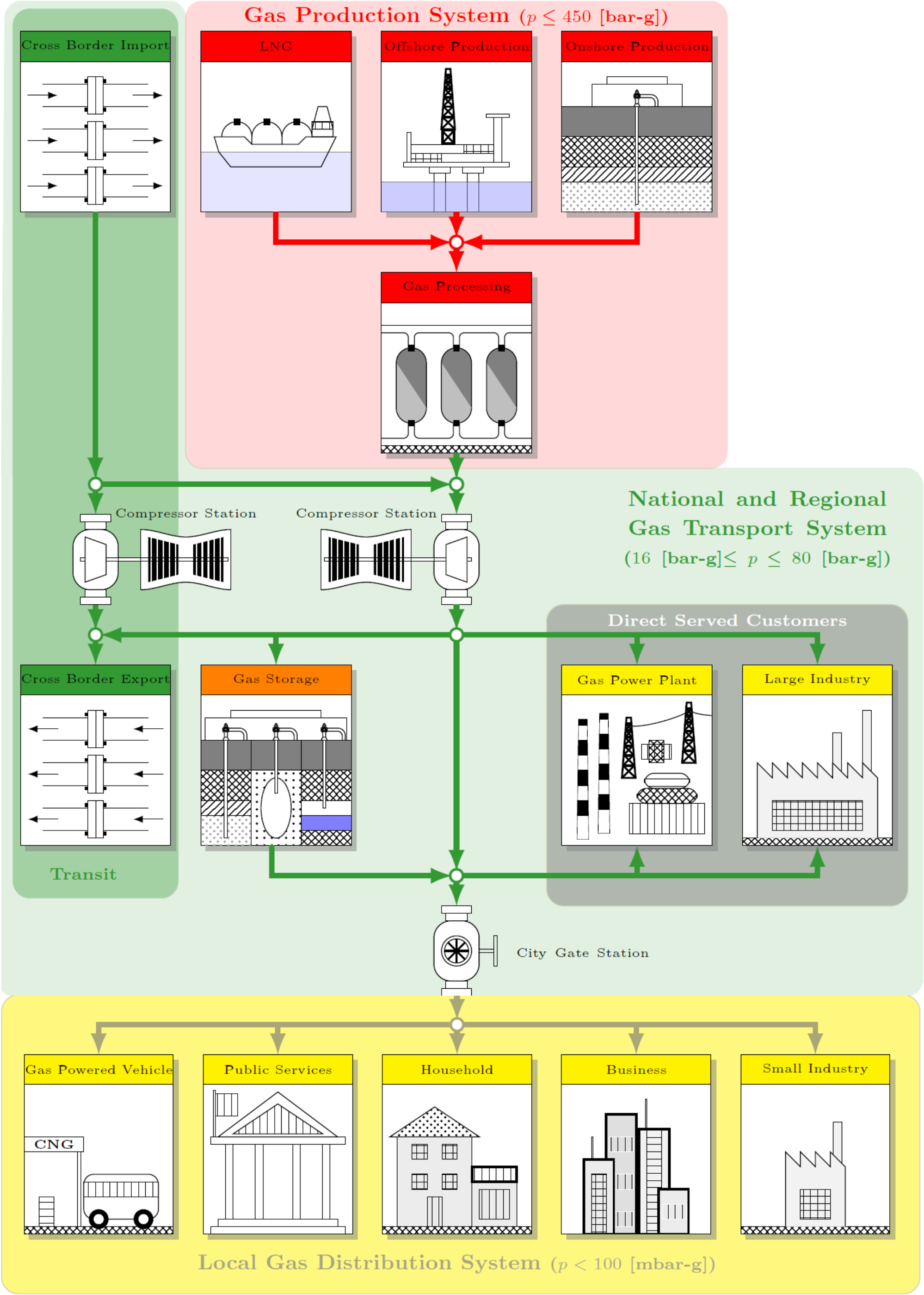
Source: BP

Global primary energy consumption



Source: BP

Natural gas infrastructure



Source: [Kwabena Pambour's Ph.D. thesis]

Operation of natural gas pipeline networks

Operation is restricted by physical, technical, and contractual constraints imposed by the facilities and stakeholders involved in the gas supply chain.

- Pipelines: maximum operating pressure
- Compressor stations: compression power
- Gas-fired power plants: minimum delivery pressure

Transmission system operators (TSOs) are equipped with Supervisory Control and Data Acquisition (SCADA) systems and software application to monitor and control the facilities and components of their transport system.

Controlling the system involves finding the most economical configurations and control set points that do not violate technical and legal constraints.

Modeling of natural gas pipeline networks

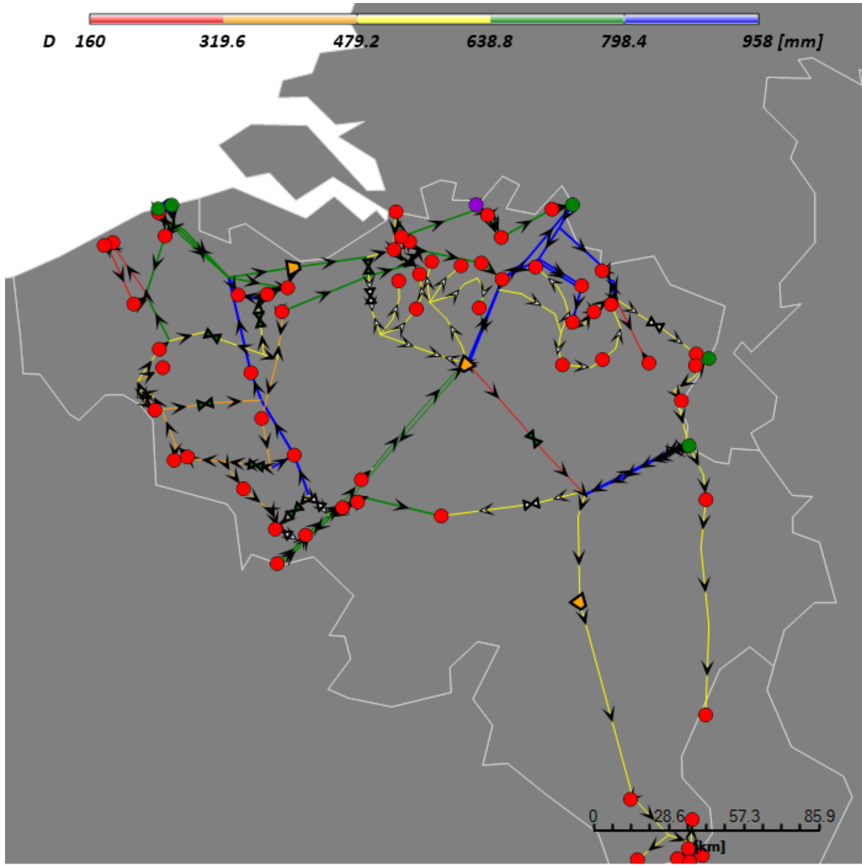
Gas TSOs (and DSOs) must be aware of potential operational challenges (or threats to security of gas supply).

The analysis of gas pipeline networks under potential future scenarios and operational conditions requires the use of numerical models that can reflect the behavior of gas transport systems under different scenarios and their reaction to different types of events in adequate and accurate manner.

The model should be able to capture accurately the reaction of gas pipeline networks to load variations and disruption events with reasonable computation cost, taking into account the physical laws governing its dynamic behavior.

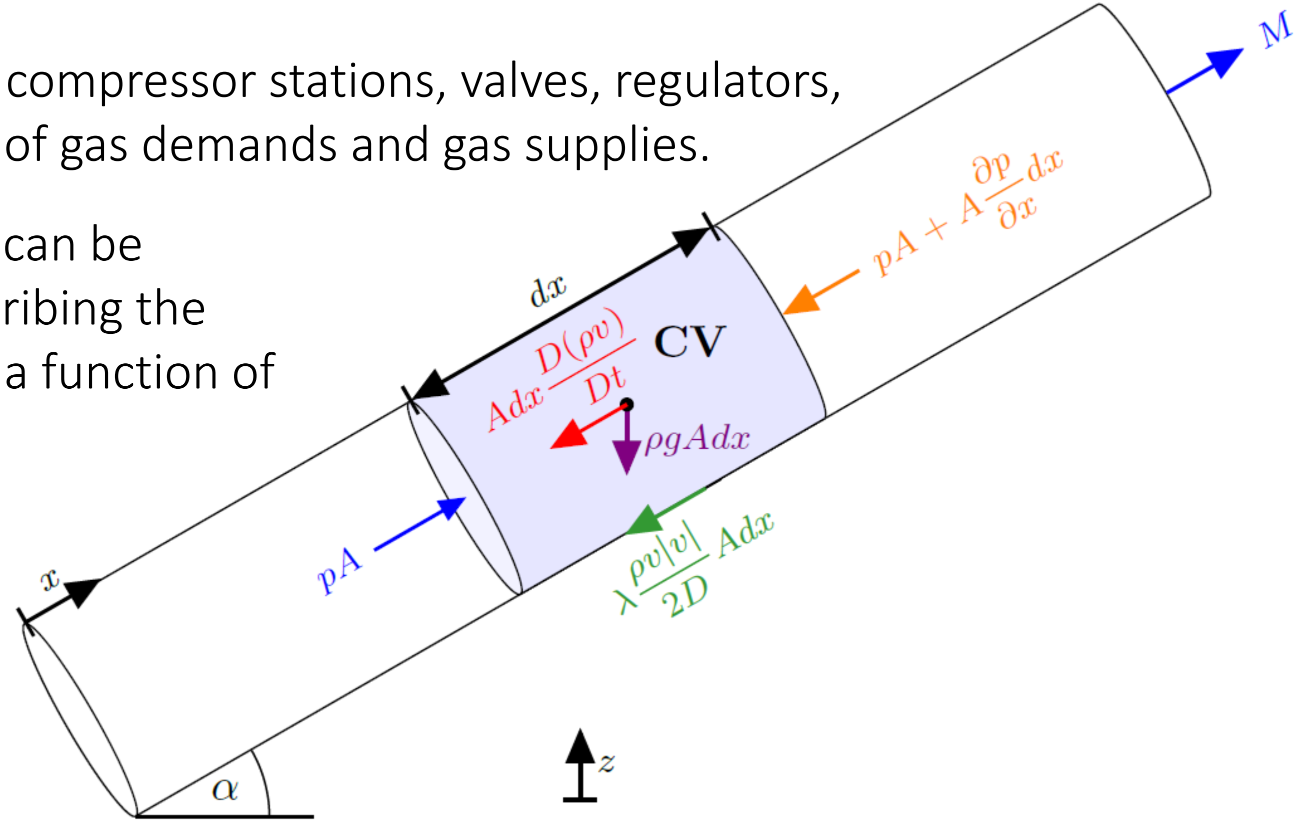
The model should include reasonable sub models of all important gas pipeline network facilities, such as pipelines, compressor stations, production fields, cross-border entry and exit stations, city gate stations, stations of direct served customers, LNG terminals and UGS facilities.

The model should appropriately consider the constraints imposed by the different network facilities and stakeholders.



Hydraulic gas network modeling

- Gas hydraulic network simulations are based on the one-dimensional continuity, momentum, energy, and state equations, derived from the laws of conservation of mass, momentum, energy, and the real gas law.
- Dynamic hydraulic models are used to correctly model the operation of gas transmission networks, as they can quantify the changes in pressure and linepack (which cannot be captured by mass balance or steady-state hydraulic models).
- Hydraulic gas network models include pipelines, compressor stations, valves, regulators, underground storages, as well as different types of gas demands and gas supplies.
- Different types of underground storage facilities can be modeled using different storage envelopes, describing the restrictions on withdrawal and injection rates as a function of working gas inventory.
- Gas compressibility is considered, and gas networks can be simulated with gas quality, composition, and temperature tracking.



Clarification of different gas network models

Mass Balance Flow Optimizations

- Physical equations ignored (pressure and linepack not considered)
- Used for market-based analysis where only gas flow between virtual connections are respected.
- Also used in low resolution investment models

Succession of Steady State Hydraulic Simulations

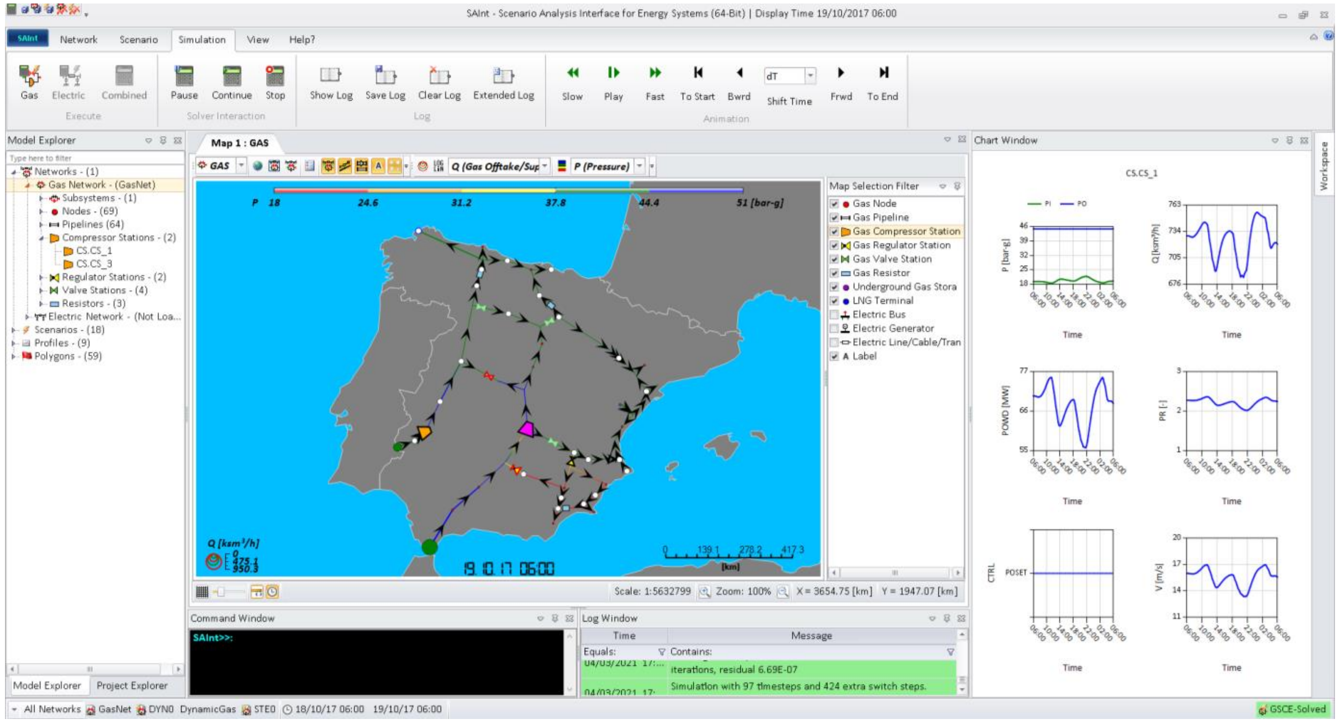
- Physical equations are considered, but physical properties (gas pressures) are assumed constant in time.
- Flow balance is assumed to be zero (inflow = outflow). This is a non-physical representation of the gas system. Linepack changes are incoherent with the zero-flow balance.
- Changes in nodal gas pressures are not correctly simulated. These are extremely important to know if a gas generator has enough pressure to start-up or to continue operation.
- Used for capacity expansion modeling.

Dynamic Hydraulic Simulations

- Physical equations are considered, and physical properties (gas pressures) may change in time.
- Time evolution of pressures and linepack is considered and coherent with the flow balance.
- Operation of gas generators is correctly simulated since correct linepack and pressure information is available, and it can be used to impose fuel offtake constraints on gas generators in power system simulations.
- Used for operational planning and real-time operations. Also used for linepack management and contingency analysis.

Applications of hydraulic gas network simulations

- Inform gas network planning decisions.
- Optimize investments in transmission and storage assets.
- Model gas network operations.
- Model and optimize underground gas storage facilities.
- Optimize the scheduling of LNG vessel arrivals to LNG regasification terminals.
- Perform contingency analyses.
- Identify potential harmful scenarios & estimate their consequences
- Analyze the effectiveness of countermeasures and mitigate the impact of disruptions.



Example of a hydraulic gas network model application

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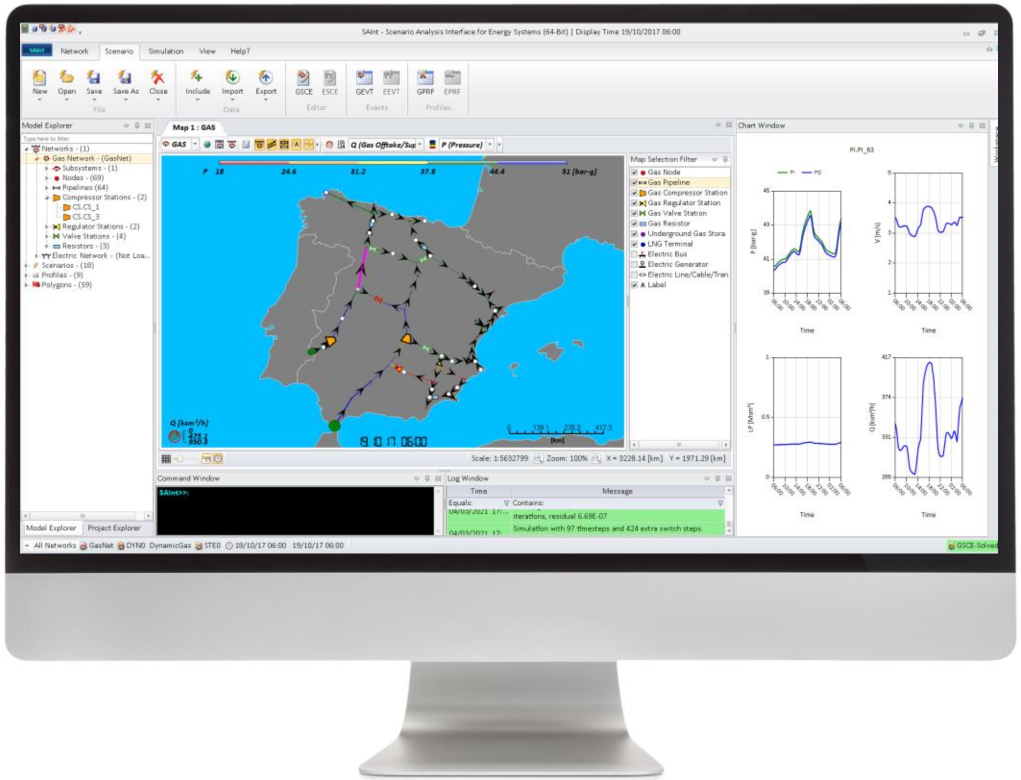
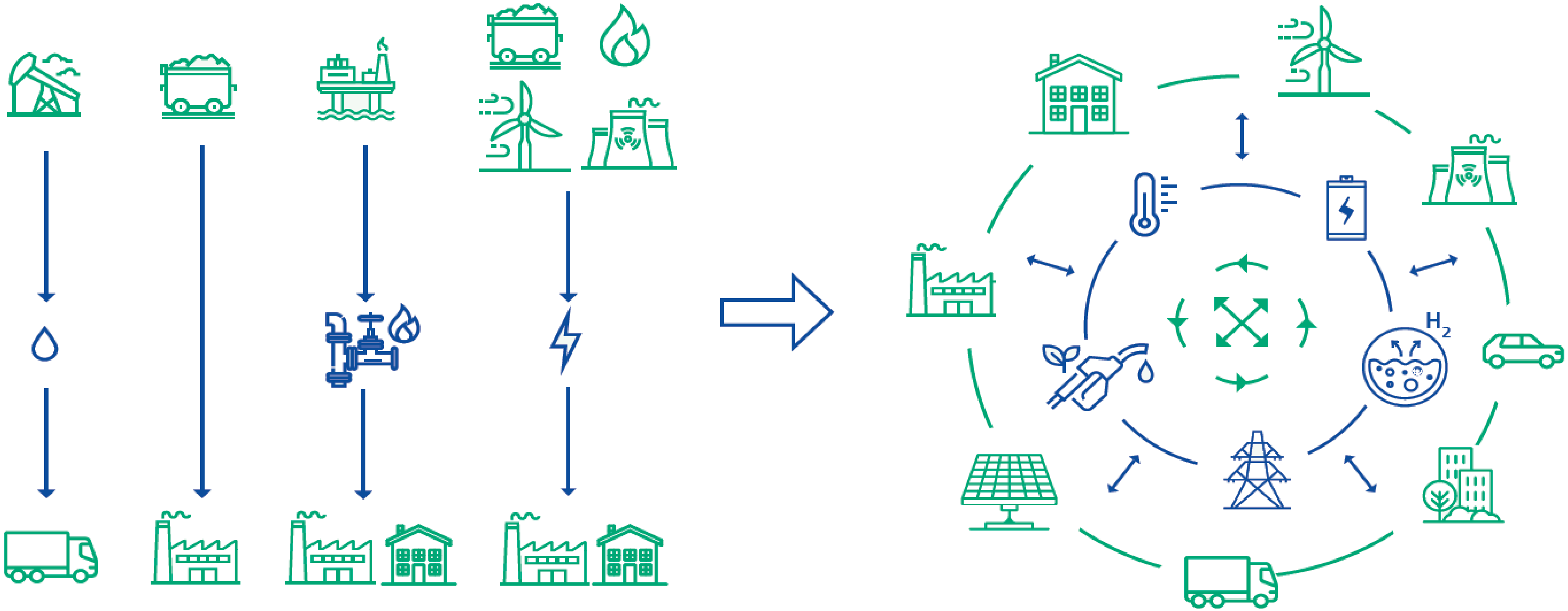


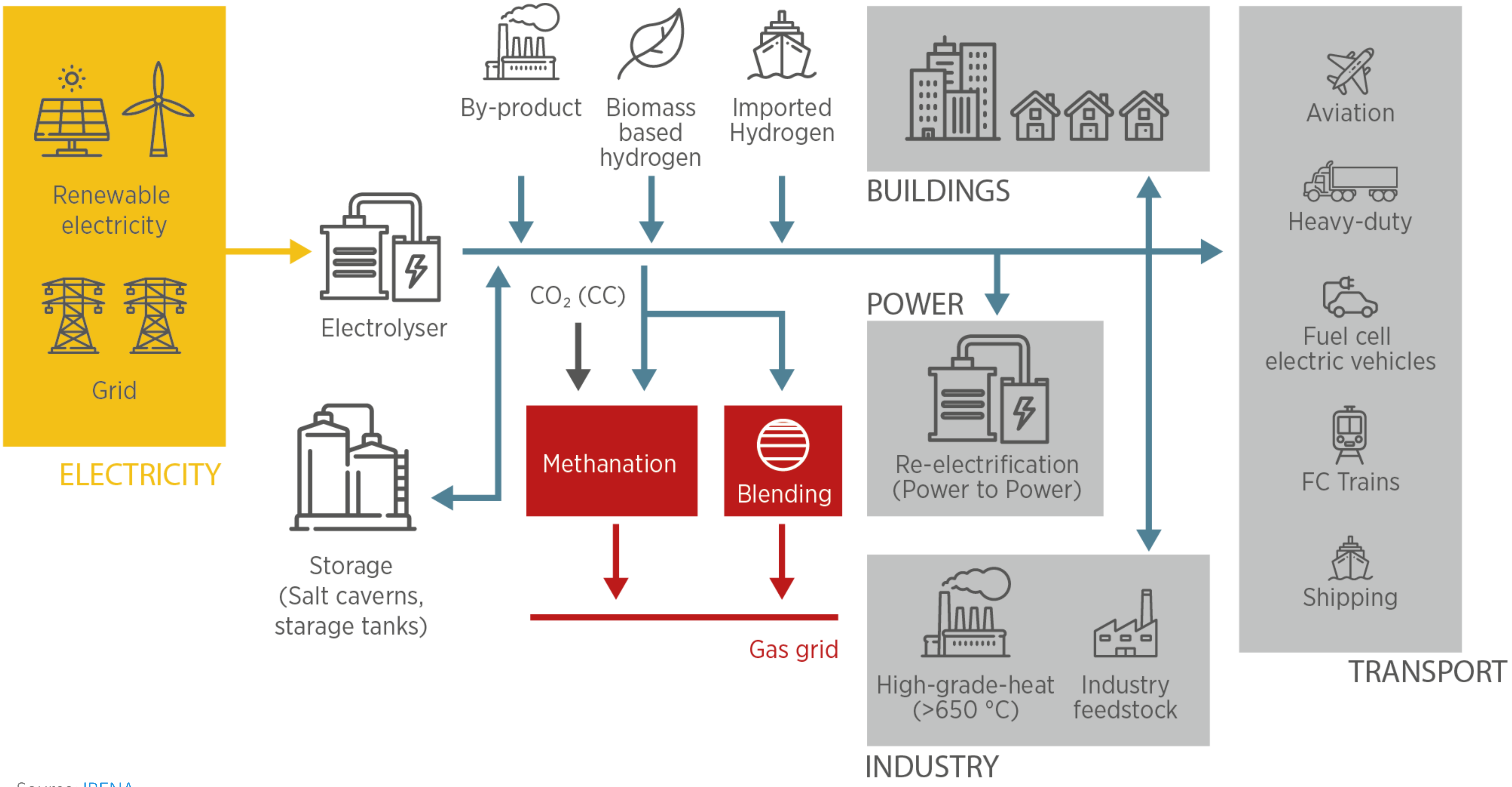
The value of planning electricity & gas networks as an integrated energy system



Source: European Commission, EU Energy System Integration Strategy

We need tools to couple energy networks

Hydrogen potential



Source: IRENA

SAInt's unique capability to model coupled electricity and gas networks

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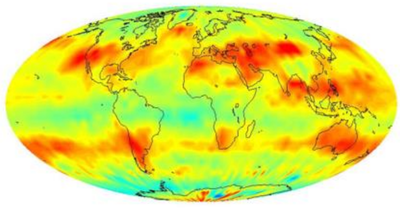
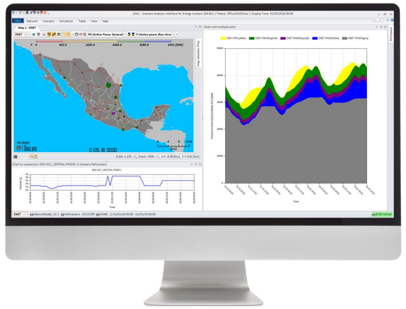
1. 

Combined simulations of electricity & gas networks

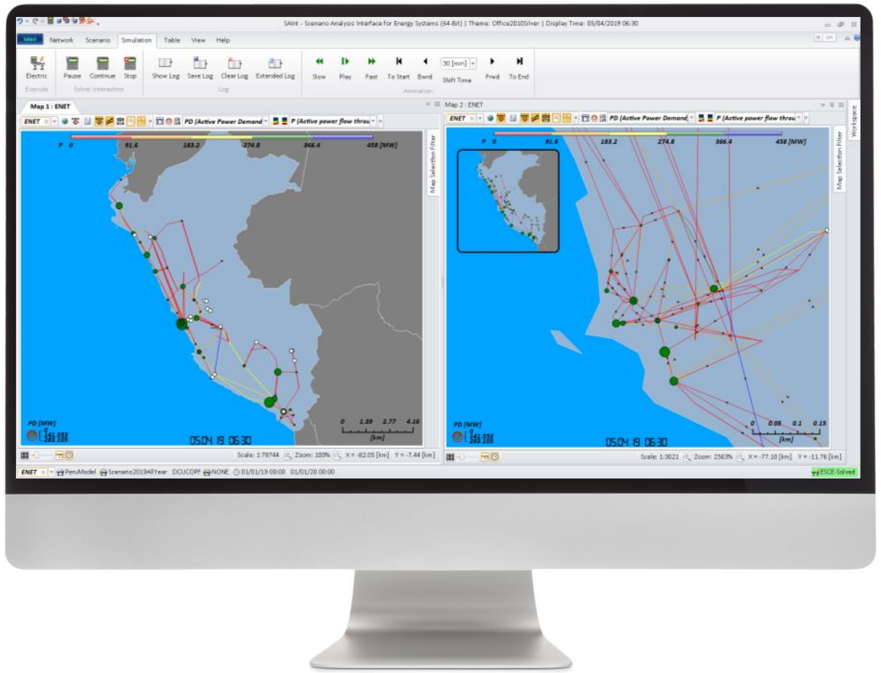
2. 

Integration with meteorological datasets to quantify weather impacts on energy networks

3. 

SAInt's flexibility and modularity for scalability & adaptation to new challenges

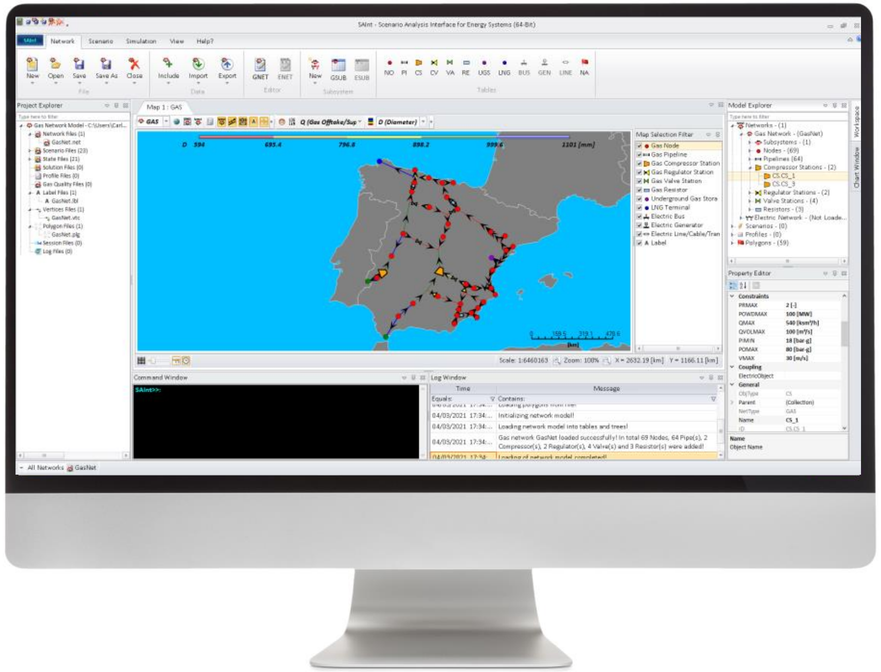
Electric Network Simulation



SAInt includes three electric network simulation modules:

- AC Power Flow Network Simulation
- AC Optimal Power Flow Network Simulation
- Security Constrained Unit Commitment & Economic Dispatch with DC Optimal Power Flow: Production Cost Model (PCM)

Gas Network Simulation

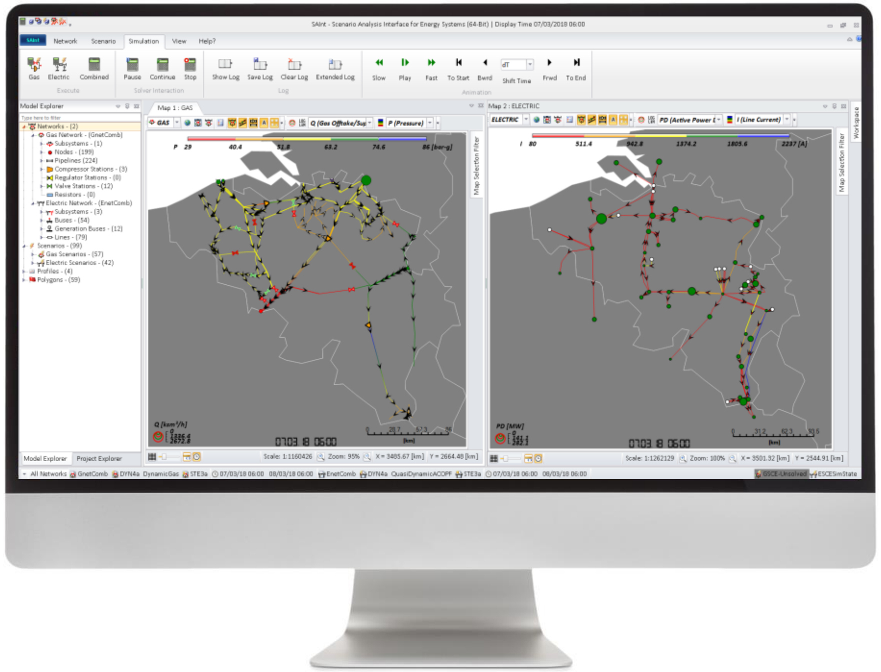


SAInt includes two gas network hydraulic simulation modules:

- Steady State Gas Network Simulation
- Transient Gas Network Simulation

Gas networks can be modeled with gas quality, composition, and temperature tracking. The user can model the injection and blending of different gases (e.g., hydrogen).

Coupled Electricity & Gas Network Simulation



The combined modeling of natural gas and electricity networks is the most unique feature of SAInt.

The equations describing the natural gas and electricity systems are linked through coupling equations reflecting the physical interlink between the two energy vectors. The resulting system of equations is solved simultaneously. The coupling between both vectors includes:

- gas fired power plants
- power-to-gas facilities (e.g., electrolyzers)
- electric-driven gas compressor stations
- electric-driven LNG regasification terminals

SAInt allows the user to model coordinated controls between coupled energy networks.

Examples of SAInt's Applications

European Commission
Joint Research Centre

Impact of the interdependency of electricity and natural gas networks on energy security

Coordination of electricity and natural gas network operations to integrate higher renewable energy penetrations

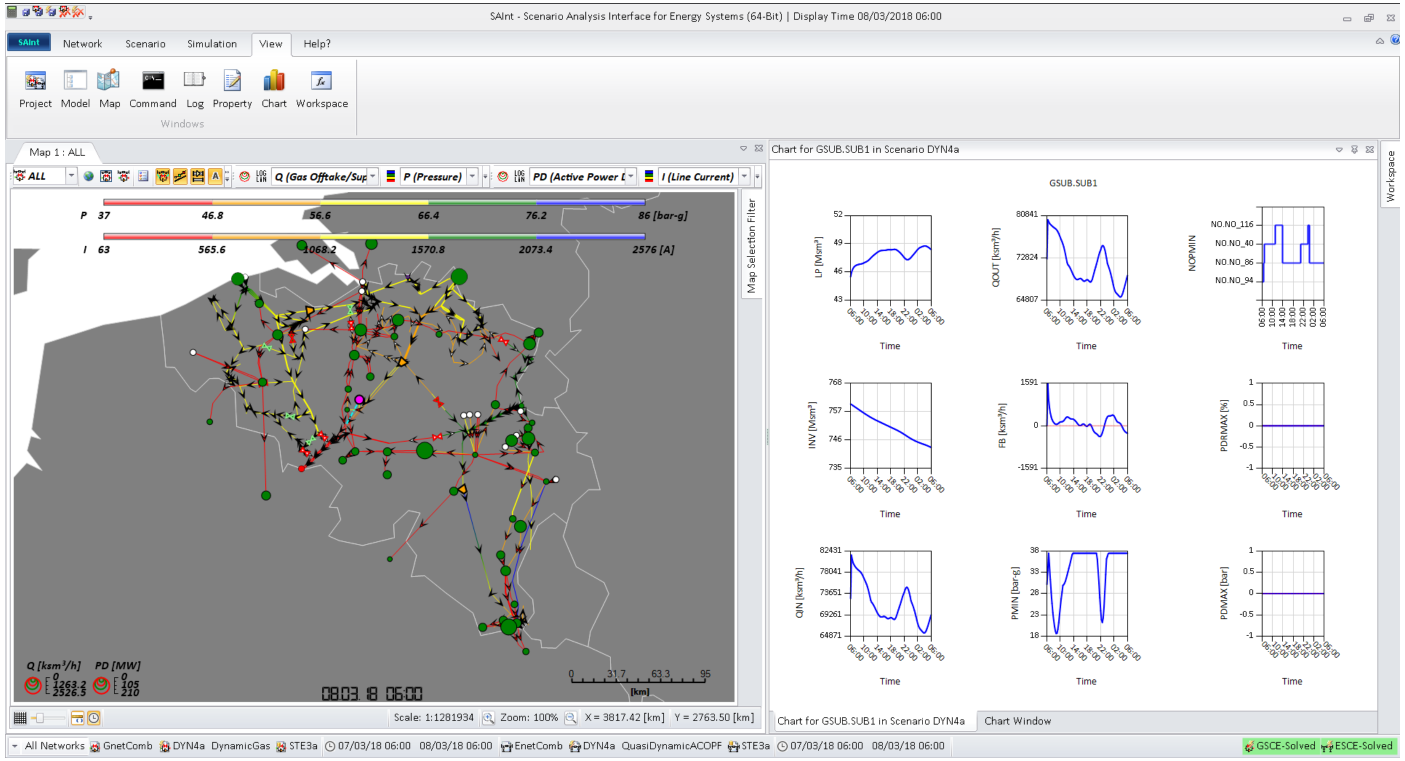
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

TenneT
Taking power further

Analysis of the optimal location and sizing of electrolyzers by modeling coupled electricity and gas network operations

Applications of coupled electricity and gas network simulations

- Study the coupling between electricity and gas networks.
- Analyze the flexibility and storage sources at the interface between electricity and gas networks.
- Plan the evolution of coupled electricity and gas networks.
- Optimize investments in power-to-gas facilities.
- Quantify the impact of disruptions or extreme events on interconnected electricity and gas networks.
- Perform security of supply analyses by considering electric and gas network contingencies.



Example of a coupled electricity and gas network simulation application

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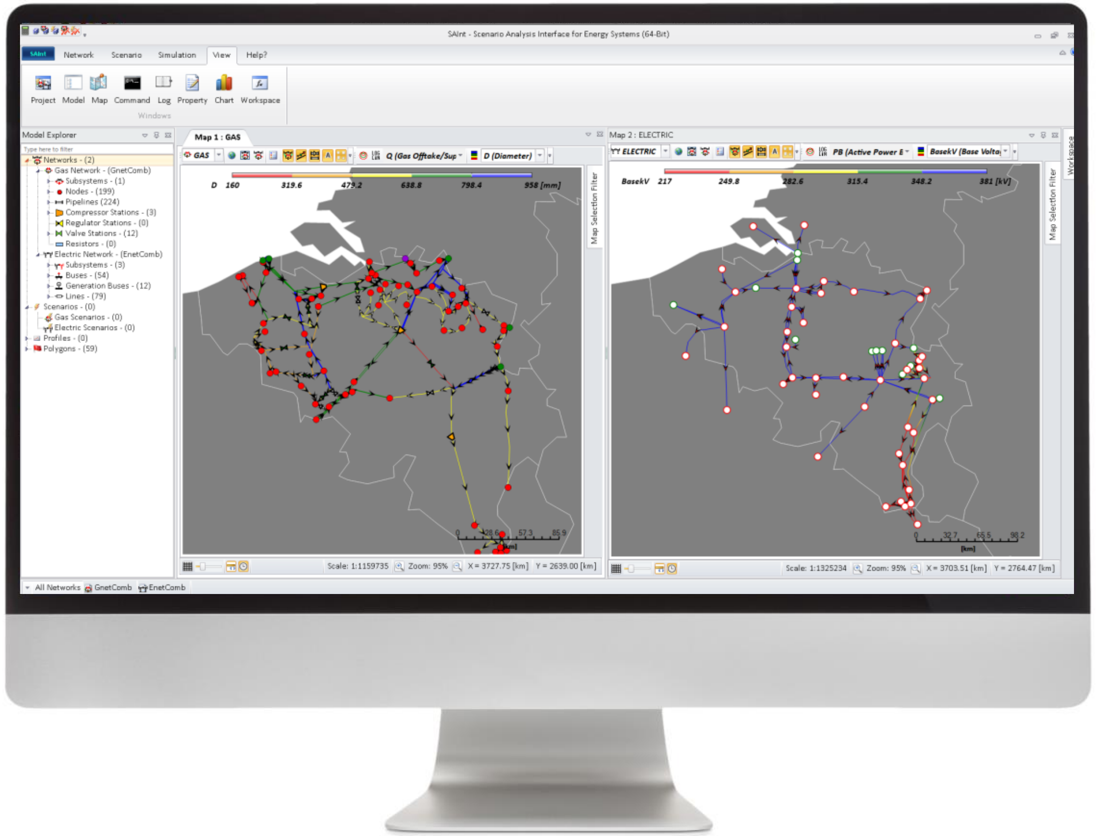

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Thank you for your attention!

Do you have any questions?

Please contact us if you are interested in a specific application of SAInt

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