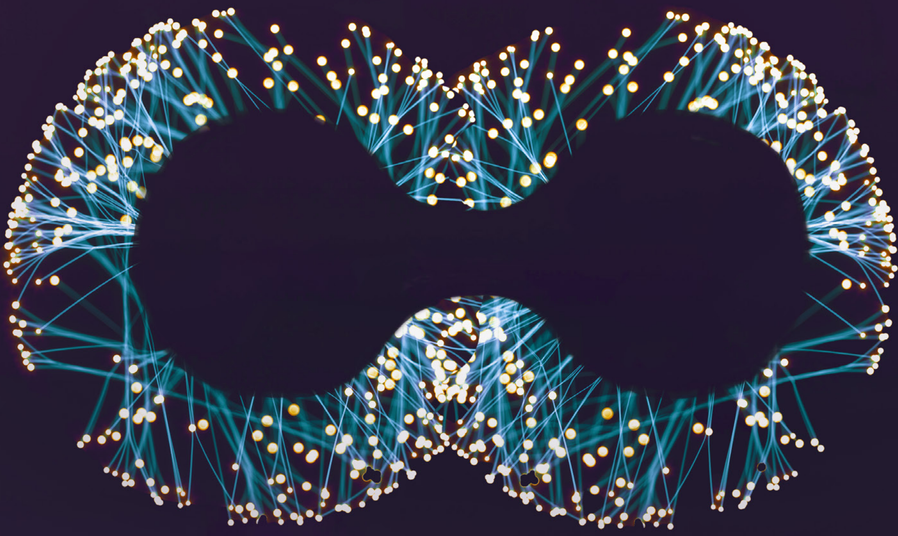


Unlocking the synergies of coupled energy networks to achieve decarbonisation

encoord

The traditional concept of an energy network is evolving. Where once, energy networks would operate independently of each other, increasingly there are opportunities to couple networks and leverage synergies between them to help solve some of our biggest decarbonisation challenges. Coupled energy networks can create new sources of flexibility, provide short and long-term energy storage, and incorporate increased amounts of carbon-neutral fuels, all while positively impacting security of supply and reliability.

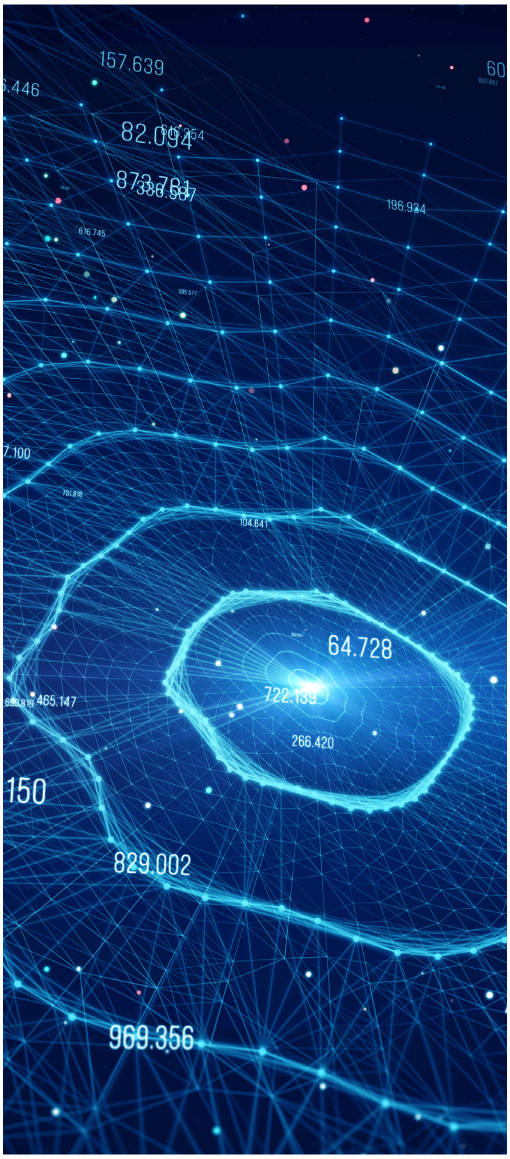
The most prolific example of coupled energy networks is that of electricity and gas. In 2019, 20% of Europe's electricity was produced by gas-fired power plants. Recognising the co-dependency of the networks, the European Parliament regulated that the European Network of Transmission System Operators for Gas and the European Network of Transmission System Operators for Electricity coordinate their network development plans and scenarios for Europe. The output covers some 90 transmission system operators in 35 countries.

> "Integration of the electricity and gas sector can optimise the assessment and usage of both grids, whilst continuing to meet the European energy policy objectives of sustainability, security of supply and competitiveness."
>
> - TYNDP 2020 Scenario Report

The interdependencies between gas and electricity networks are just one part of a much bigger picture. As our energy system diversifies to accommodate a low carbon future, we increasingly need to consider how all energy networks and renewable energy sources integrate, including hydrogen, LNG, and other networks, such as heat and liquid. The climate crisis is creating the need to plan new types of networks – particularly for water and for cooling – which will both require substantial amounts of electricity to operate. As a result, new interdependencies are rapidly being created and networks are becoming more interconnected than ever before.

What are coupled energy networks?

In the simplest sense, a network connects supply with demand. Energy network coupling is where these networks have become interconnected in some way, for example through the introduction of technology. Examples of energy network coupling include:



- Hydrogen produced using an electrolyser and injected into a gas network
- Hydrogen used for power generation
- Electric driven compressor stations used to transport gas
- Electric driven LNG regasification terminals
- Electric heat pumps
- Heat networks supplied by natural gas, electricity or in the future, hydrogen
- Gas to produce combined heat and power
- Hydro networks (rivers, lakes and dams) used to generate electricity
- Hydro networks (rivers, lakes and dams) used for thermal power plant cooling
- Electric driven water pumps
- Electric driven water desalination plants

Why do we need to consider the interdependencies between networks more proactively?

Some types of coupled energy networks have been in existence for decades. However, with the exception of the production of electricity using hydrological resources such as rivers and lakes, most networks were rarely planned with energy network interdependencies in mind. To achieve decarbonisation of our energy system, there is an increasing need to better quantify and leverage the synergies between them. The synergies leveraged by coupling energy networks fall broadly into three categories: security and reliability of supply, facilitating renewable integration with flexibility, and introducing carbon-neutral fuels to decarbonise hard-to-electrify industries.

01 Security and realibility of supply

Very few gas power plants store gas, meaning their ability to generate electricity relies on the gas pipelines to deliver gas at a given pressure. Most pipelines will supply more than one gas plant at a time. However, to date, most electricity networks have only been planned to be able to absorb the loss of its largest contingency, usually a single power plant or transmission line. The risk created by the potential loss of gas supplied by one pipeline to several sites is potentially more severe than the loss of the network's single largest generation asset, but this is often not considered by the electricity network operator.

In September 2021, an attack on a gas pipeline southeast of Damascus in Syria saw the loss of electricity generation from nearly 50% of the country's power plants. While earlier in the year, power was cut to millions of Texans for several days as plummeting temperatures created cascading impacts on the electricity, gas, and water networks. Frozen gas wells and supply lines, coupled with power plant equipment malfunctions caused by weather, and scheduled maintenance, rendered an estimated 45 GW of electricity generation offline.

As gas demand for both heating and electricity generation rose, many power plants experienced supply curtailments due to the nature of their contractual arrangements. While most power plants opt for interruptible gas supply contracts, gas distribution utilities typically have uninterruptible contracts, meaning gas for electricity generation was curtailed ahead of home heating. The outage was further compounded by similar issues for those gas producers with interruptible power contracts meaning that electricity to gas production and processing facilities was “unwittingly” shut-off, further impeding the delivery of gas to power stations.

02 Facilitating renewable integration with flexibility

Given the variability in renewable output, alongside seasonal changes in demand, different types of flexibility will be required across timescales – from seconds and minutes to days and seasons. Gas-fired powered plants, with their ability to ramp up and down quickly, will be key.

According to a 2021 study conducted by Wärtsilä4, G20 countries will require 933 GW of flexible gas power capacity (including hydrogen) and 2,964 GW of energy storage to facilitate a 100% renewable energy future. This approach is just one of many ways that flexibility can be achieved by coupling networks together.

Others include using large heat stores connected to heat networks which could take advantage of cheap gas or plentiful solar to provide short-term storage. Or battery storage to facilitate the use of renewable generation for the operation of water desalination pumps. Alternatively, green hydrogen could be used as a form of long-term (seasonal) storage. Produced over summer during times of excess renewable generation and then compressed and stored underground (in salt caverns or depleted gas fields, for example), green hydrogen could then be re-electrified over winter, helping to reshape seasonal fluctuations in renewable generation.

The use of dual-fuel energy consumption concepts, where consumers can switch fuel depending on availability, may also rise in popularity; hybrid vehicles are a good example of this in action.

03 Carbon-neutral fuels

While widespread electrification will be suitable to decarbonise much of the economy, energy-dense industrial processes such as steel and cement manufacturing, and long-haul transport, require a different approach. Hydrogen and ammonia are promising options that can take advantage of excess renewable electricity generation to offer a long-term storage solution. In addition, the existing gas pipeline infrastructure, which can store several days' worth of energy at a time, could be retrofitted for use with hydrogen.

While it is clear that many synergies could be unlocked between energy networks, there exists little in the way of a roadmap to help energy network planners and operators to do so. Modelling and simulation tools are the next step in allowing planners and operators to explore different outcomes to support the coupling of energy networks, however, given the numerous stakeholders and millions of assets involved, it is a complex challenge.

The challenges of planning coupled energy networks

01

Lack of coordinated planning between stakeholders

In many cases, planners and operators of different energy networks have never needed to work together or coordinate their work before, nor needed to share data that is either commercially sensitive or a matter of national security. This is particularly acute at the transmission level, where most operators only have data for one specific energy network.

02

Massive amounts of data

There is also the challenge of the volume and different types of data that require analysis. The computational ability must keep pace with the millions of new data points that are being made available on each energy network.

03

Difficulty of mathematical modelling

Typically, to model different networks in a coupled way requires iterating between two different mathematical models in two different environments. Sharing information between the two models is often challenging, fraught with the complexity of navigating between two different database structures, often without sufficient open APIs. This often results in an infinite loop of manual iterations in which a convergent solution cannot be reached, particularly when the couplings are bi-directional. To overcome this, the models need to be brought together in one environment to allow the networks to be modelled simultaneously.

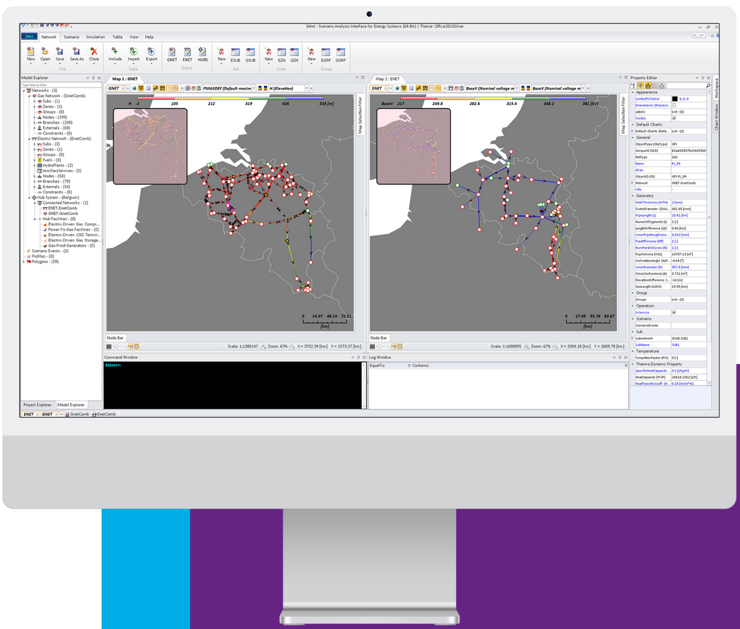
How can SAInt help address these challenges?

In 2013, as part of his Ph.D. research, Kwabena Pambour set out to create a solution that could model coupled energy networks in one environment with one mathematical model without the need for manual iteration. Today, SAInt, short for Scenario Analysis Interface for Energy Systems, is a comprehensive energy network planning tool that models the integration and coordination of coupled energy networks to optimise and accelerate the path to a fully decarbonised energy system, all in one platform.

With SAInt, modellers no longer need to iterate between modelling tools to consider the interdependencies between different energy networks. In a single platform, SAInt can model electricity and gas networks to quantify their synergies and interdependencies, enabling increased integration of renewable energy sources and hydrogen. It also comes with integrated wind and solar meteorological datasets to support robust modelling of variable renewable energy generation, making it easier to model increased amounts of renewable energy and its effect on different energy networks.

Intuitive and flexible to use, with a modern user interface, SAInt is highly customisable and offers a flexible API to support its users in seamlessly integrating the tool with existing software and databases, streamlining the ability to interrogate the outputs from their models using custom tables, charts, visualisations, and animations. The outcome of this customisable software is detailed insights that give planners the confidence to make better energy network investment decisions that will benefit the lives of millions of Europeans.

By providing a cost-effective and time-efficient solution, SAInt supports planners and operators to transition from independently planning and operating their electricity and gas networks to a future where energy networks are integrated and coordinated together. In doing so, new synergies including cost and risk reductions are achieved, and improvements to flexibility and reliability unlocked, supporting Europe's path to decarbonisation.



Addressing real-world challenges with SAInt

"As a society we rely tremendously on having reliable energy networks not solely to underpin the economy but to sustain life itself. The devastating impact of events such as the Texas outage in February 2021 show just how imperative reliable energy networks are.

The way that almost all power systems are planned today treats failures as independent events, however, there are often correlations between them. Until we can model how energy networks are coupled together, and put effective mitigation plans in place, we will continue to experience network events with outsized impacts.

Part of the challenge is having the right tools to model the coupling between different networks – attempting to stitch together existing network models doesn't always work out how you'd think. That's what makes SAInt so unique. Coupled energy network modelling needs are met by one software solution where you work in one system time and with a common data structure that facilitates seamless data sharing. The connections and correlations made between the various networks are modelled with no requirement for time-consuming iterations.

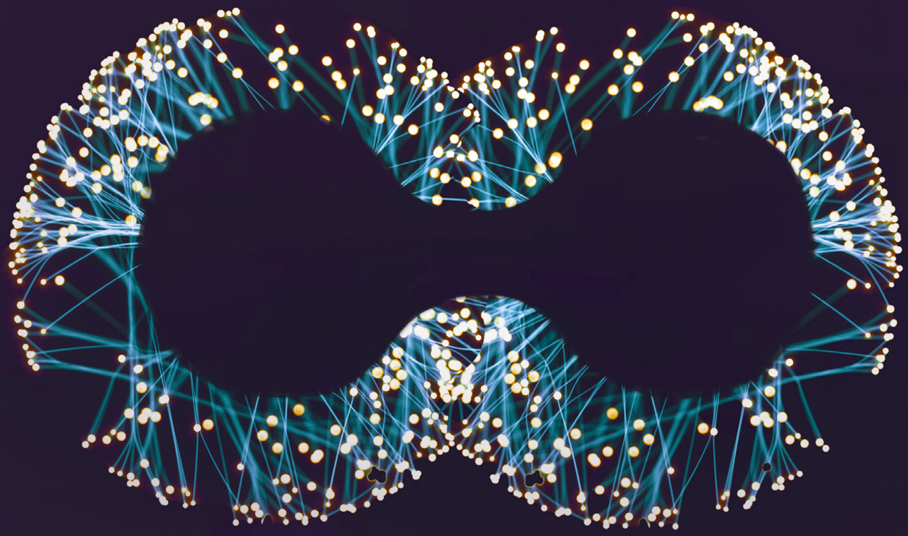
One of the most compelling benefits of being able to model coupled energy networks is the ability to take a system-level perspective. This is especially valuable as we model routes for decarbonisation – where some decisions may be locally better but not globally better. There are situations where reducing electricity emissions increases natural gas emissions – or vice versa. Being able to model energy network coupling proficiently will bring us closer to net-zero much more quickly, efficiently, and cost-effectively."

Dr. Bri-Mathias Hodge

is an Associate Professor for the Department of Electrical, Computer and Energy Engineering at the University of Colorado Boulder and a Chief Scientist at the National Renewable Energy Laboratory (NREL).

As part of his work with NREL, Dr. Hodge used SAInt to understand whether there are cost and reliability advantages of considering the natural gas network when optimising the unit commitment and economic dispatch of gas-fired power plants.

In a further project, Dr. Hodge used SAInt to study the operational limits of hydrogen injection into the natural gas grid including considerations such as the impact on compressor stations, downstream gas quality and the requirements of different end users. SAInt provided a unique level of detail for the simulation allowing NREL to consider the impacts on pressure and the need for additional compression power.



To find out more about how SAInt could enhance your energy network modelling and planning capabilities, contact encoord today, at

info@encoord.com

encoord