

2050

Energy Pathfinder

An integrated energy system simulator



Overview
paper

February 2018

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Executive summary

Overview

The 2050 Energy Pathfinder has been built to assess the feasibility of how different future energy mixes would work in practice. It enables any energy scenario, current or future, to be modelled for a town, city, county or country and the results show the costs, carbon impact and any shortfall / surplus in heat and power supply. The simulator can be used to find the feasibility of alternate solutions across all energy types in a more integrated way.

INPUTS

As demand, supply and appliance efficiency constantly vary, a high resolution model was required and runs hourly through a year. The simulator looks at:

Different supply sources of electricity and gas

- Limited variability – nuclear, geothermal
- Intermittent renewables – wind, solar, tidal
- Flexible – coal, gas, biomass
- Off grid sources – oil, biomass, bottled gas
- Storage

Demand for electricity (power and transport) and gas (heat and transport) on an hour by hour basis

- Including the efficiency of heating (e.g. boilers, heat pumps, etc)
- Transport (electric and gas powered vehicles) – cars, vans and HGVs
- Storage

Scalability

- Scale demands e.g. for smaller regions, for colder/warmer winters, for population change
- Scale supply e.g. for future renewables plans, new tidal, etc
- Energy efficiency

(New vectors) Flexibility services

- Micro generation (combined heat and power) hybrid heating
- Storage
- Demand side flexibility
- Peaking power generation

Costs

- Levelised generation
- Network (gas and power) reinforcement
- Energy storage
- Appliances

OUTPUTS

The simulator delivers

- Carbon emission implications for each scenario
- Cost to energy customers of each scenario
- Reliability impact (heat and power cuts) due to short-term energy imbalance
- Annual cumulative imbalance to understand seasonal storage requirements
- Interconnection requirements

Example of results

In one scenario for Cornwall:

- Scenario – Annual energy needs met by a mix of 50% wind, 25% solar and 25% geothermal plus battery storage
- Carbon emissions – Zero
- Reliability – 100%
- The seasonal storage requirement calculated as 500 gigawatt hours – 52 million Tesla Powerwalls
- Cost – £60,000 per household per year*

NEXT STEPS

The simulator has been independently peer reviewed by Delta EE, we are developing a user interface which we aim to be available on our website shortly to enable wider use of the 2050 Energy Pathfinder.

* At an assumed cost of £3,000 per Powerwall lasting 10 years based on 260,000 households (costs as at 2015)

Background and context

The energy sector is going through significant change as it adapts to the “trilemma” challenges of affordability, security of supply and carbon reduction. Against this background, much research is taking place around future energy options.

The cost and practicality of electrification are being extensively challenged and the UK needs to look at alternatives to achieve a low carbon, reliable and affordable energy future. Those being considered include Hydrogen, heat networks or a ‘patchwork’ of different solutions.

The whole energy system is already becoming more integrated and greener, with a shift change in the interaction between the electricity and gas networks, including powering transport.

The 2050 Energy Pathfinder enables solutions to be tested for feasibility in the real world.

ELECTRICITY

- Around 50% of generation currently comes from gas, increasing to more than 60% at peak times
- Increasing intermittent renewable electricity generation (eg wind, solar, tidal)
- New peaking power generation to respond to intermittency of renewables
- CHP and low carbon energy centres

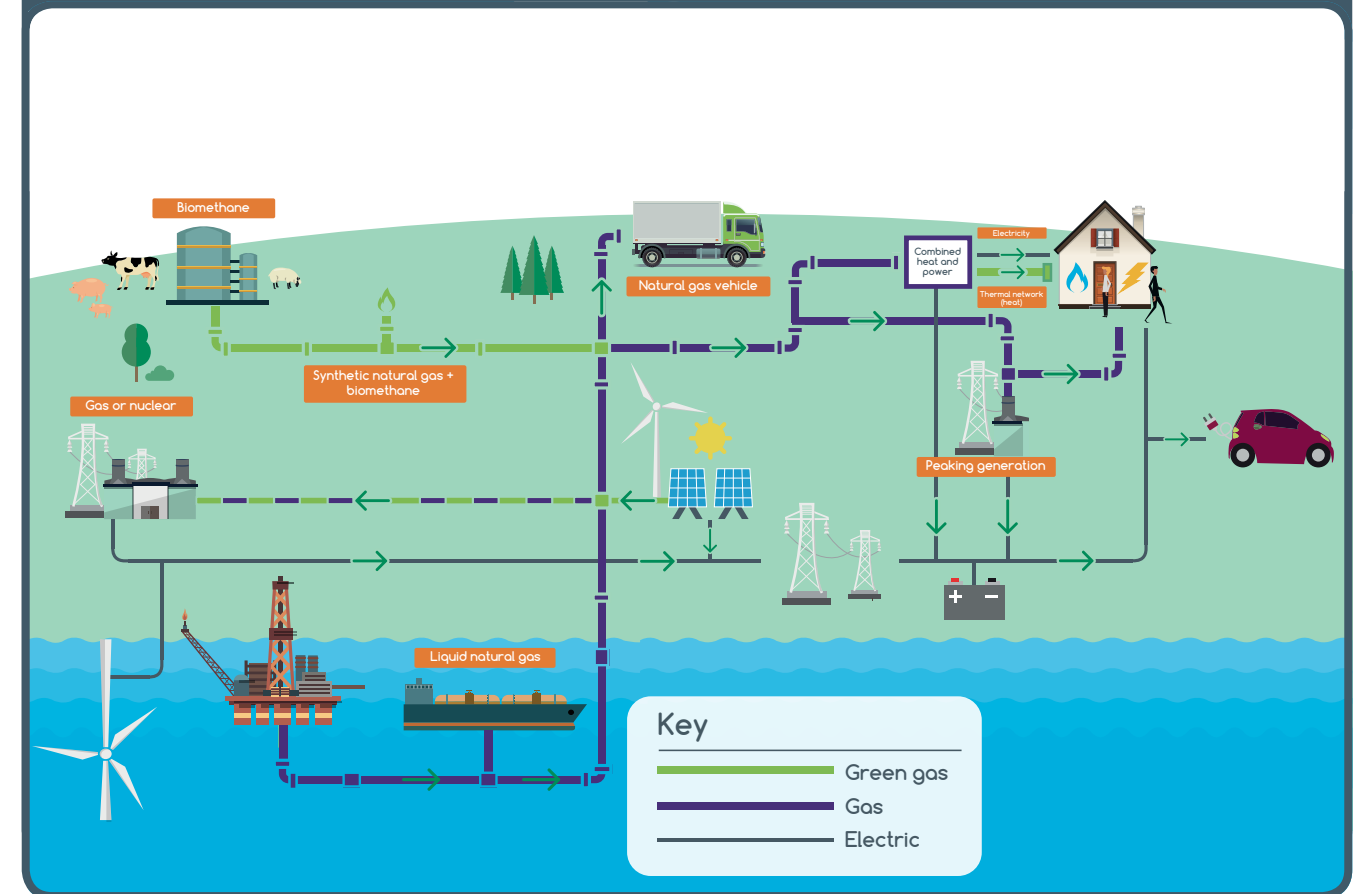
GAS

- Introduction of biogas into networks to green the gas
- Further green gas sources such as BioSNG and hydrogen blending are being trialled
- Hydrogen cities are being investigated

TRANSPORT

- Increasing targets for electric vehicles to deliver air quality objectives
- Gas powered transport including CNG vehicles and gas powered buses are in use

The energy network in 2018



As the networks continue to integrate, variation of demand and supply on the electricity network will have immediate impacts on the gas network. For example, where more electric vehicles are connected to intermittently generated renewables, this creates larger demand swings on the electricity network, affecting demand on the gas distribution system as gas peaking plants respond to maintain capacity on the electricity network.

It was evident a high-resolution, spatial and temporal dynamic model was needed to enable the industry to further understand and evaluate the changing interactions between gas and electricity networks and allow network companies to develop their future investment plans based on stakeholder needs.

Simulator inputs and outputs

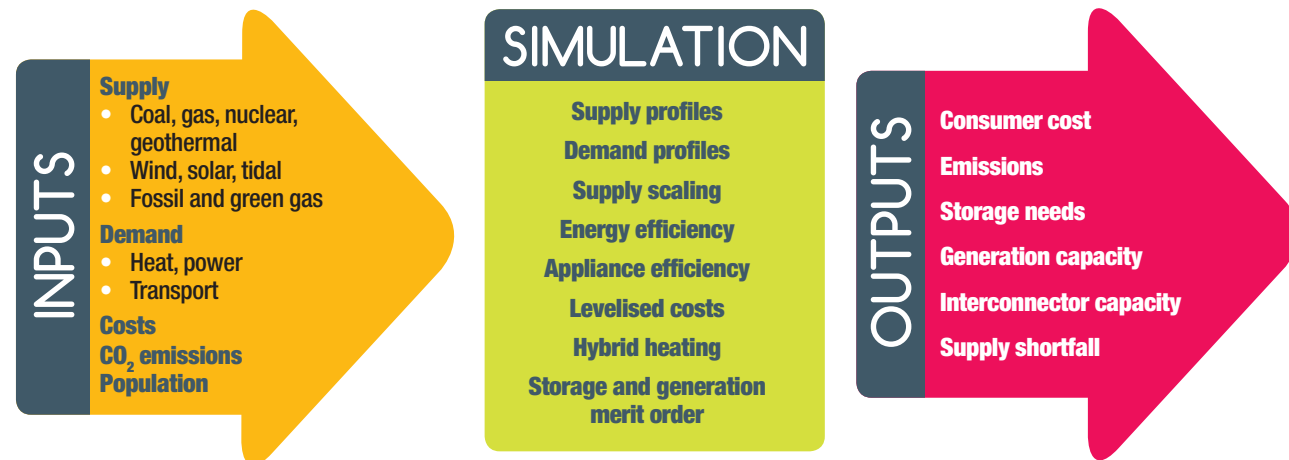
THE CHALLENGE WAS TO PRODUCE A SIMULATOR THAT:

- adds heat, power and transport demand together by hour/day/month
- balances against the full range of supply options e.g. wind, solar, nuclear and gas
- determines interconnection requirements, storage or demand side response/shift, to address imbalance
- is scalable i.e. can model a house, a town, a county, or a country
- provides indicative costs for the modelled scenario taking into account levelised costs of generation, costs of storage and costs of network reinforcement
- provides annual CO₂ emissions.

STORAGE AND INTERCONNECTOR REQUIREMENTS

The model calculates hourly imbalances as **hourly supplies - hourly demands = hourly imbalance**

Hourly imbalances can be resolved using storage, interconnection, or flexibility.



COST INFORMATION

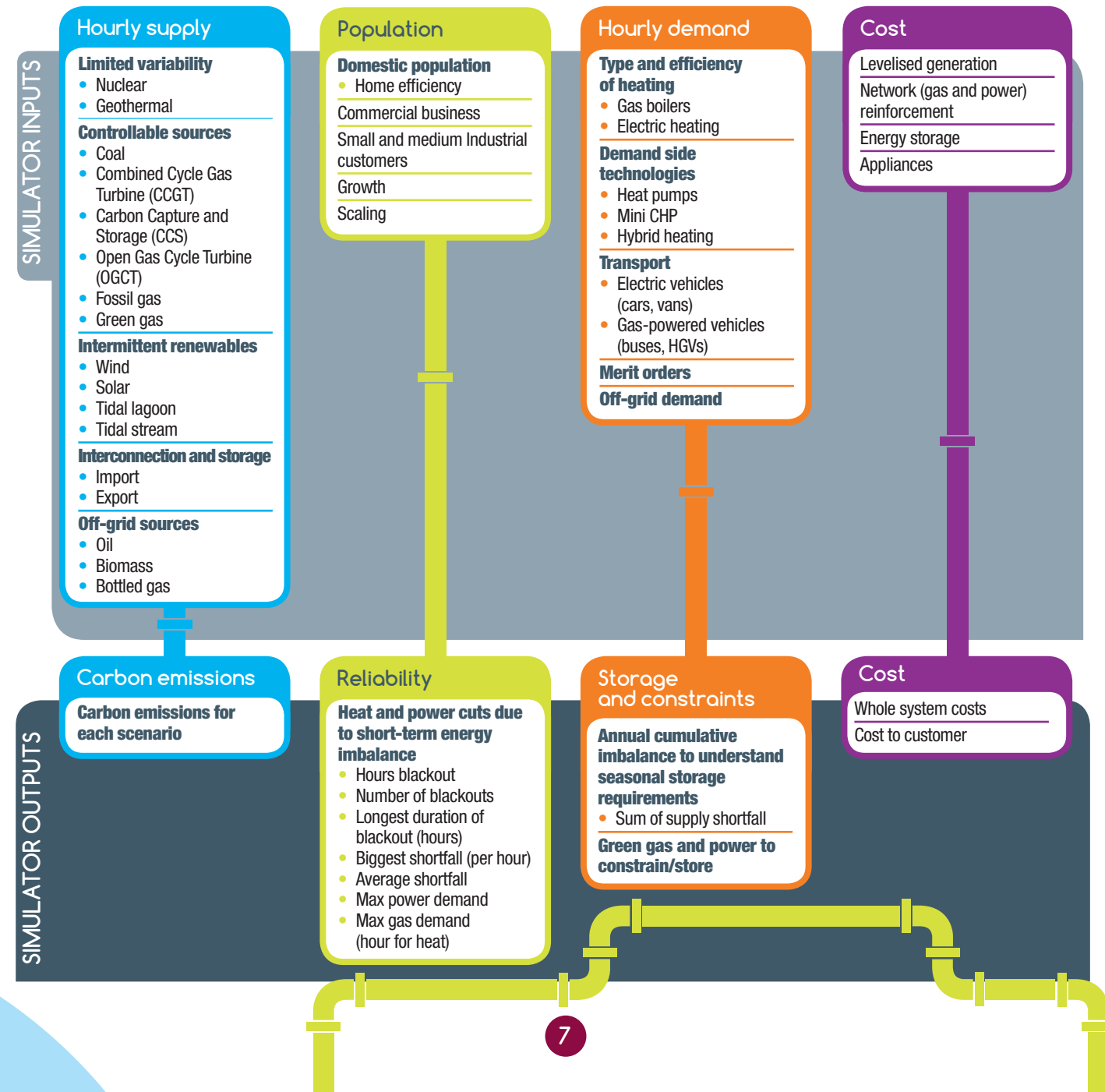
In order to determine the full cost impact, supply, demand and imbalance information is considered across the whole of the energy systems as represented below:



These can be represented as a whole system cost or as an indicative customer bill.

CARBON EMISSIONS

The simulator will provide carbon emissions for the configured scenario. In addition, information on heating sources for off-grid properties such as biomass, propane and oil can also be included in order to obtain a more robust estimate for the region.



Application

The 2050 Energy Pathfinder simulator has been built to assess how different future energy mixes would work in practice. It enables energy scenarios, current or future, to be modelled for a town, city, county or country and the results show the costs, carbon impact and any shortfall / surplus in heat and power supply. The simulator can be used to model alternate solutions across all energy types in a more integrated, joined-up way.

It is dynamic, enabling the modelling of opportunities, risks and trade-offs to evaluate multiple options at local, regional and national system levels. While the model includes commercial and small industrial loads, large industry is best modelled in a standalone way.

It can be used by local stakeholders, using a single data source, to model:

- multiple “what-if” scenarios
- optimal local energy solutions
- impact on wider energy system
- whole system costs
- impact on customer bills
- local contribution to UK emissions targets
- forecasts for any year based on the input data and beyond.

In the spirit of sharing, the aim is to make the model available online.



About your population:

Domestic Population to model	65,000,000
Average people per property	2.5
Potential Domestic Population Change (enter + for increase or – for decrease)	10%
Include Assumed Non-Domestic? (i.e. small commercial not industry)	yes
%age Commercial Heat met by CHP	10%

Case study: Cornwall

To illustrate its use, the 2050 Energy Pathfinder simulator was used to evaluate independent proposals to create a totally renewable Cornwall, and a 2015 project published as **The Cornwall Energy Island** as follows:

- Annual energy needs met by an approximate mix of 50% wind, 25% solar, 25% geothermal, with battery storage to balance supply and demand
- Aim to deliver zero carbon emissions
- Hourly heat, power demand profiles modelled
- The seasonal storage requirement calculated as 500 gigawatt hours equivalent to 52 million Tesla Powerwalls
- Cost – up to £60,000 per household per year*

In summary, the simulator highlighted that the use of renewable energy sources in providing heating in this way requires very large seasonal storage at a cost consumers are unable to afford.

This has enabled better value for money storage and supply options to be considered.

* At an assumed cost of £3,000 per Powerwall lasting 10 years based on 260,000 households (costs as at 2015)



Next steps...

The Energy Pathfinder is a simulator which supports modelling various energy supply and demand scenarios, with the outputs including indicative levels of network investment. However, it is currently not designed to indicate where the physical network investment is required, nor does it provide an impact assessment of local disruption.

Therefore, the next steps will include a physical network analysis tool. It is proposed that a joint gas and electricity network analysis tool is developed to supplement the 2050 Energy Pathfinder simulator.

In the short term, we will continue to work with local authorities and other interested parties to evaluate their scenarios using the 2050 Energy Pathfinder simulator.

Further reading

We're committed to continuing with our leadership on the future of energy. We're working hard to develop objective, robust information to support national and local decision makers and community representatives to make the right decisions for their stakeholders. For further information on our work on the future of energy go to www.utilities.co.uk/futureofenergy

Wales & West Utilities publications

- Lancaster, O., 2017. *On the road to a green energy UK: Freedom – hybrid heating*.
- Clarke, C., 2017. *On the road to a green energy UK: Integrated gas & electricity networks support the journey*.
- Clarke, C., 2016. *The Renewable Cornwall Project: The Heat, Light & Power Simulator*.
- Clarke, C., Harding, S., Leach, R., and Wych, J., 2017. *Future of Energy & Investment in Gas Networks*.

Other publications

- Howard, R., and Bengherbi, Z., 2016. *Too Hot to Handle? How to decarbonise domestic heating*. Policy Exchange.
- Mortimer, O., and Boyle, M., 2015. *Policy for Heat: Transforming the System*. Carbon Connect
- KPMG and Kiwa Gastec, 2015. *2050 Energy Scenarios: The UK Gas Networks role in a 2050 whole energy system*. KPMG.
- National Grid. *Future Energy Scenarios (FES)*

LEGAL

USING PATHFINDER

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QUALITY TESTED

Pathfinder is an open model, allowing transparency of modelling and user adjustable assumptions. It has been peer reviewed through its development to test the algorithm and results.

APPENDIX

Pathfinder methodology

OBJECTIVE

The 2050 Energy Pathfinder assesses how a future energy mix would meet the needs of the UK according to the energy trilemma:

- Security of supply – balancing hourly supply/demand
- Emissions reduction
- Cost to customer.

The simulator recognises the integrated nature of energy systems across electricity and gas, both of which can be flexibly used to meet customers' energy needs.

Users can input information about a region, including population size and growth, home efficiency improvements, proportion of different types of heating appliances and electric vehicle take-up. A proposed generation mix can then be specified, and the model will evaluate how the system is balanced on an hourly basis for both electricity and gas, whether customers will experience any blackouts, and the annual cost per customer and CO₂ reduction.

METHODOLOGY

Electricity demand

- **Domestic light and power:** Hourly demand profile scaled to relevant population size, and adjusted for population growth and energy efficiency assumptions
- **Domestic heat:** Hourly demand profile for domestic heat is split between gas and electricity according to assumed heating technology:
 - Air source heat pump: electric heat demand accounts for Coefficient of Performance (COP) varies depending on daily

temperature)

- Hybrid heating: prioritises low-carbon electricity as fuel source, unless there is a shortfall in electricity supply, in which case the required proportion switch to gas
- Boilers: accounts for domestic boiler efficiency
- If required, information for off-grid heating types can be included in order to return a more complete CO₂ estimate

- **Commercial:** Hourly profile scaled to relevant population size, and adjusted for population growth and energy efficiency assumptions

- **CHP:** Use of Combined Heat and Power and impact on electricity demand

- **Transport:** Electric vehicle demand based on penetration and charging profile. Separate inputs available for electric cars, gas buses and lorries.

Electricity supply

- Generation types available:
 - Intermittent renewables – wind, solar, tidal
 - Limited controllability – nuclear, geothermal
 - Controllable sources – coal, gas
 - Off-grid sources – oil, biomass, tankered gas
- Supply based on installed capacity and hourly profile of generation fleet
- Amount of battery storage can be specified – charge from excess renewables, and discharge when there is a shortfall in supply
- Balancing occurs in the following order:

- Renewables and sources with limited controllability (solar, wind, tidal, nuclear)
- Hybrid heaters switch to gas
- Battery storage (if capacity is available)
- Flexible/controllable generators
 - Coal/oil/gas – merit order can be specified in the model.

Gas demand

- **Domestic heating:** Includes heat demand of households using boilers, as well as demand in times when hybrid heaters switch to gas
- **Commercial:** option to include/exclude commercial gas load
- **Power station:** gas required for any gas-fired power plants
- **Heat networks:** those powered by or backed up by gas CHP.

Gas supply

- **Hydrogen:** potential for electrolysers to use excess electricity generation to produce and store hydrogen. Hydrogen blending is likely to be constrained to 20% by volume of gas supply at any given time.
- **Green gas:** Production and storage of biomethane, bio-synthesis gas
- **Natural gas:** Remaining shortfall in gas supply is met by natural gas.

Cost

- Levelised generation
- Network (gas and power) reinforcement
- Energy storage
- Appliances.



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