Modelling clean energy transitions for PICTs

developing tools and planning frameworks to facilitate energy transitions and bolster resilience in the Pacific

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ENERGY TRANSITION PLANNING

- Specific challenges relating to energy security in PICTs

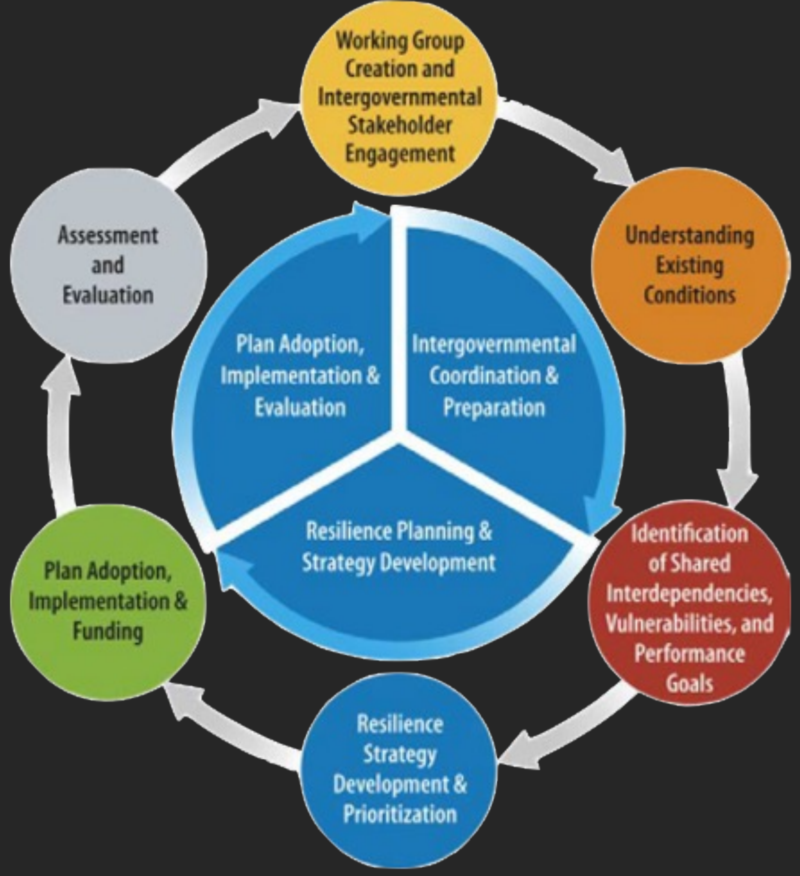
supply chain limitations (remoteness, fragmentation), fuel dependence, low energy access, vulnerability to climate change, limited technoeconomic capacity, lack of data, unfavourable financing arrangements, dependence on donor aid, ageing infrastructure, institutional limitations

- Plentiful opportunities to develop *resilience*

sectoral electrification & decarbonisation, disaster response preparedness, diversification & decentralisation of energy resources, community resilience and engagement, specialised planning tools

Planning frameworks should support the fulfillment of these opportunities and help address these challenges

- Determination of energy transition goals
- Identify and address current technical and institutional limitations
- Use of specialised modelling tools to explore future scenarios and adjust goals
- Development of policies, integration programs, and funding proposals



From 'Resilience roadmap: a collaborative approach to multi-jurisdictional resilience planning' (NREL, 2019)

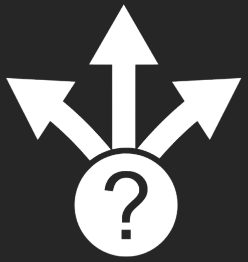
ENERGY MODELLING PRINCIPLES

Energy Supply Chain **RESOURCES** → **CONVERSION** → **DELIVERY** → **CONSUMPTION**

MODELLING: <u>simplified</u> & <u>organised</u> model structures to represent every step of the supply chain

Accurately represent future scenarios

Provide flexible options to forecast demand and the uptake of specific technologies

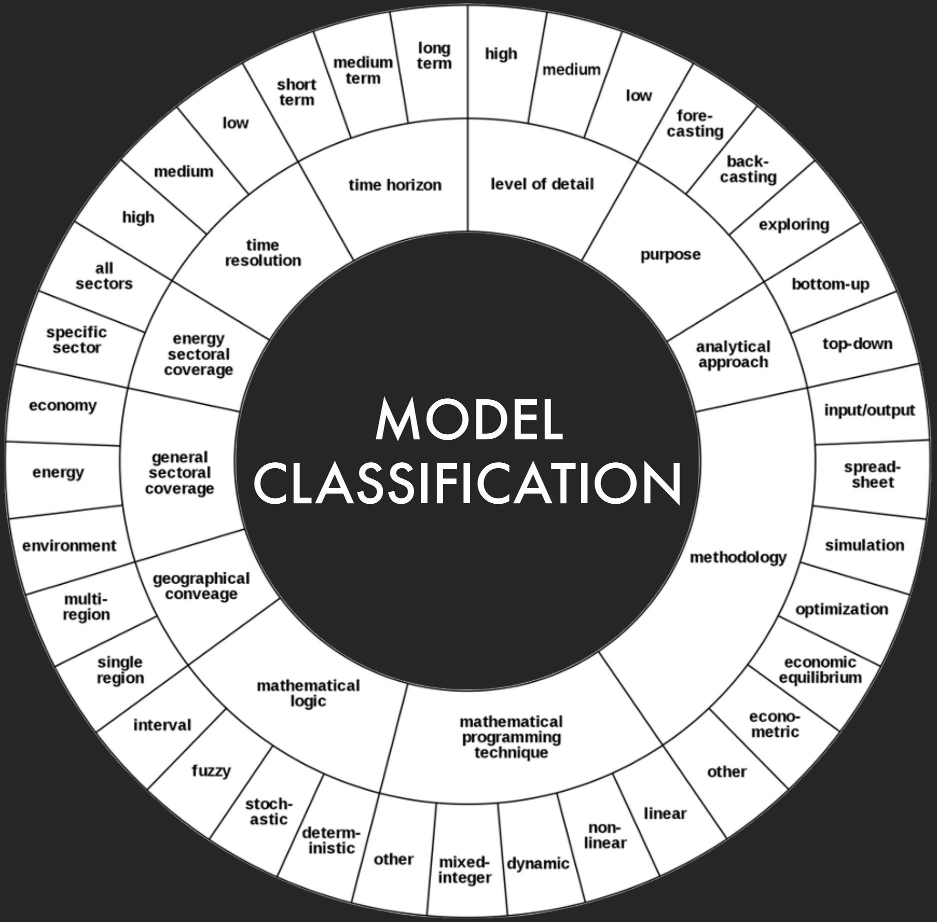


Assist with energy planning & policy making

Assess the outcomes of specific technologies and trends to make better decisions regarding capacity and policy mechanisms

Track progress against strategic targets

Determine how likely an energy system is to meet current targets relating to specific technologies and emissions



REVIEW

of available modelling tools to investigate energy transitions

Challenges encountered

- Lack of energy data for the Pacific
- Modelling options do not reflect Pacific energy challenges
- Complex user input requirements
- Limited case study applications to test practicality for planning
- Restricted system compatibility
- Barriers to accessibility
- Developed without stakeholder consultation
- Lack of adaptable dashboards
- Requirement of extensive specialised training
- Selective outputs

Some examples...

IRENA FlexTool

openCEM

WASP — Wien Automatic System Planning Package

HOMER Energy by UL

OSeMOSYS — Open Source Energy Modelling System

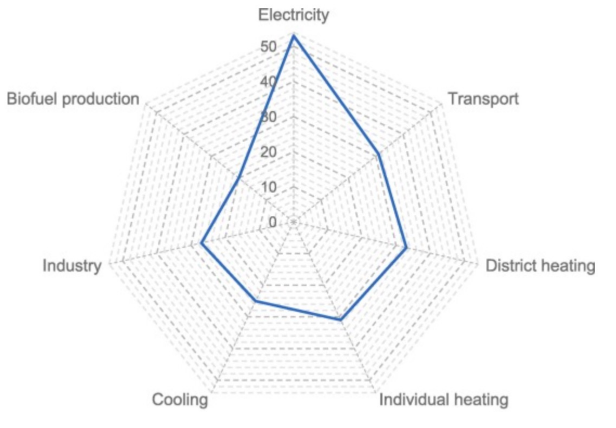
ENERGY TRANSITION MODEL — Independent, Comprehensive and Fact-based

Global Energy and Climate Model

PLEXOS BY ENERGY EXEMPLAR

LEAP

PRIMES Energy System Model



Model family	Examples	Primary focus
Energy system optimization models	MARKAL, TIMES, MESSAGE, OSeMOSYS	Normative scenarios
Energy system simulation models	LEAP, NEMS, PRIMES	Forecasts, predictions
Power systems and electricity market models	WASP, PLEXOS, ELMOD, EMCAS	Operational decisions, business planning
Qualitative and mixed-methods scenarios	DECC 2050 pathways, Stabilization wedges	Narrative scenarios

From 'Energy systems modelling for twenty-first century energy challenges' (Pfenninger et al., 2014)

Are you using any particular tools to assist with energy transition planning? Are they achieving your desired outcomes?

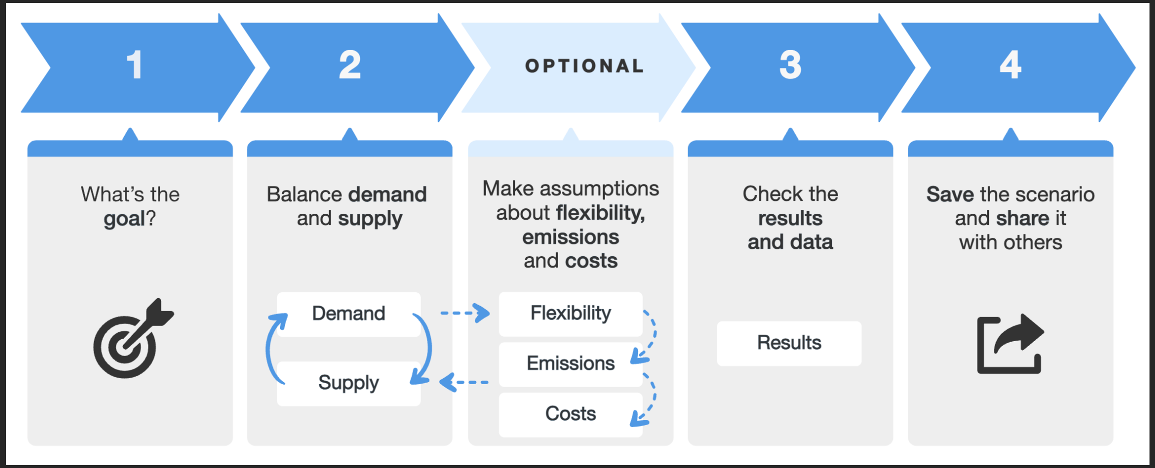
Energy Transition Model (ETM)

ENERGY TRANSITION MODEL
Independent, Comprehensive and Fact-based

Quintel

Open-source multi-sectoral simulation model with interactive dashboard to produce future energy scenarios and transition plans

Workflow



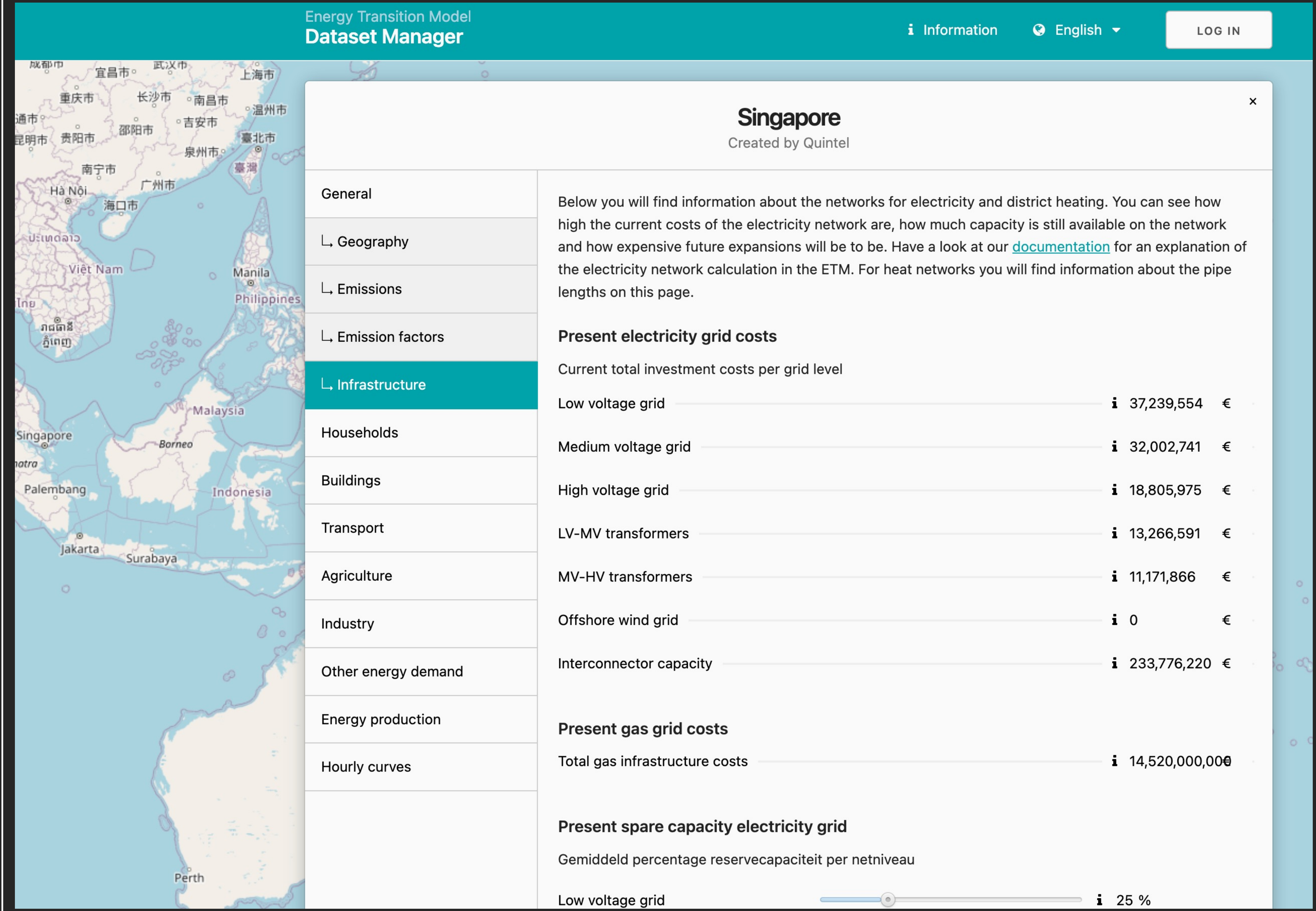
Available for 28 countries (EU + Singapore)

www.energytransitionmodel.com

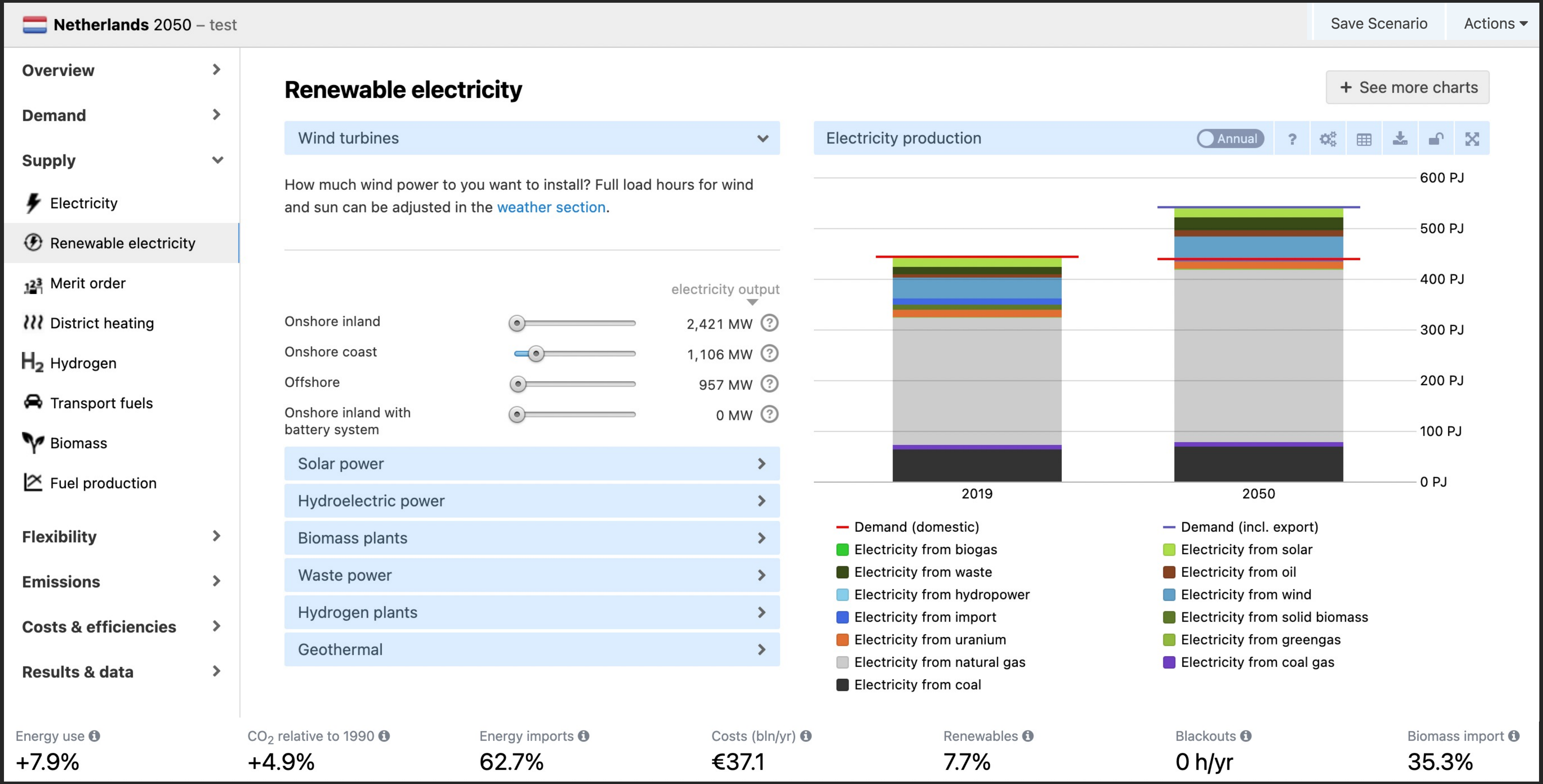
Key characteristics

- Copper-plate model (the "island assumption")
- Includes an open-source dataset manager to blend tools with databases
- Considers aspects of the energy supply chain that are crucial to the Pacific (e.g. imports, security of supply)
- Extensive documentation available
- Widely used in EU for policy making and strategic plan development with success
- Interactive and adaptable interface
- Minimal training required and highly adept to being used for technical/planning capacity development
- Supports detailed analyses regarding capacity expansion, grid stability, technology deployment, infrastructure requirements, and decarbonisation
- Integration with variety of Python and Excel tools
- Ease of maintenance via data collection framework
- Multiple output formats (charts, reports, raw data, infographics)

DATASET MANAGER



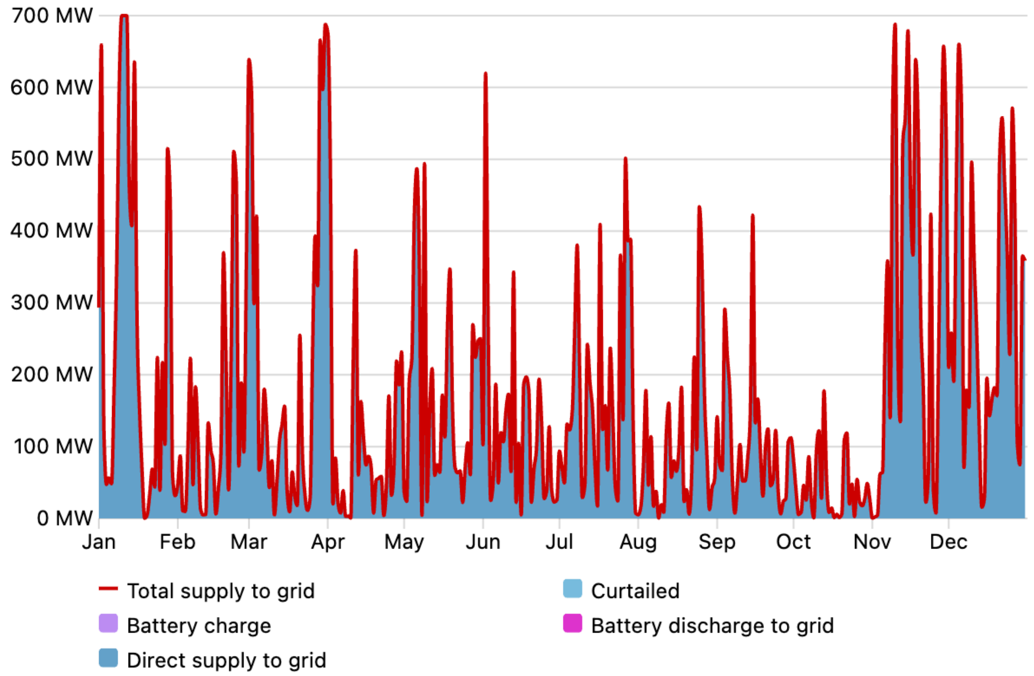
A look at the dashboard...



AVAILABLE OUTPUTS

Charts & tables

Hourly production of wind inland with battery

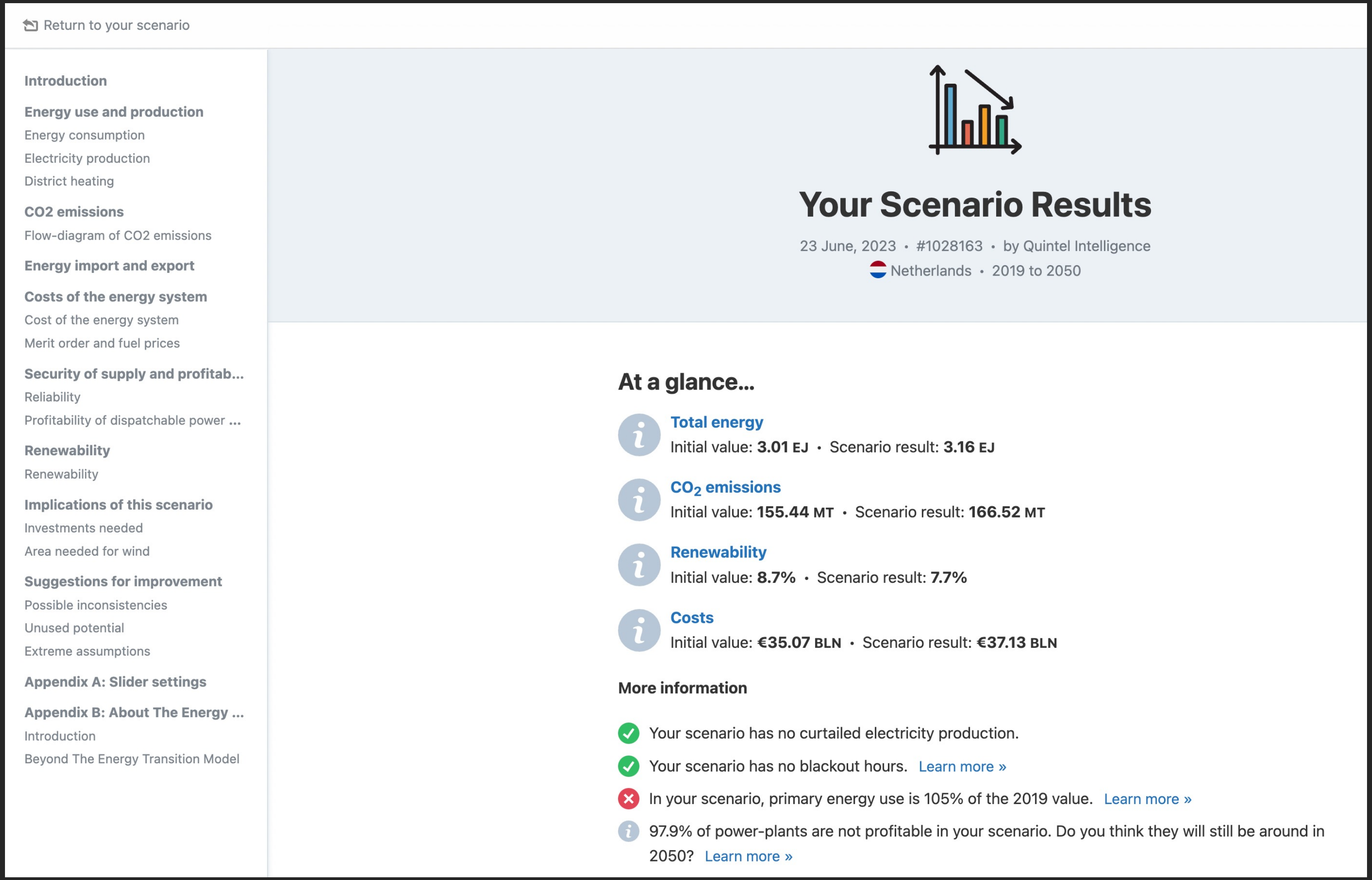


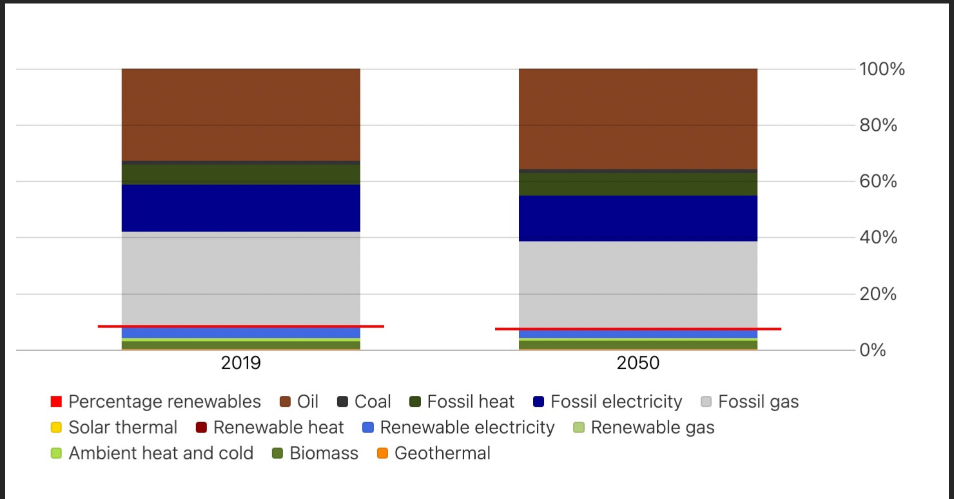
Electricity network capacity and peaks

	Peak load, present (MW)	Usable capacity, present (MW)	Peak load, future (MW)	Usable capacity, future (MW)	Required additional network (MW)
LV net	7,455.19	9,940.25	8,425.02	9,940.25	0
LV MV transformer	7,455.19	9,940.25	8,425.02	9,940.25	0
MV net	7,902.66	10,536.88	10,350.26	10,536.88	0
MV HV transformer	7,902.66	10,536.88	10,350.26	10,536.88	0
HV net	10,437.07	13,916.09	12,286.85	13,916.09	0
Interconnection net	-	0	0	0	0
Offshore net	-	0	0.85	1	1

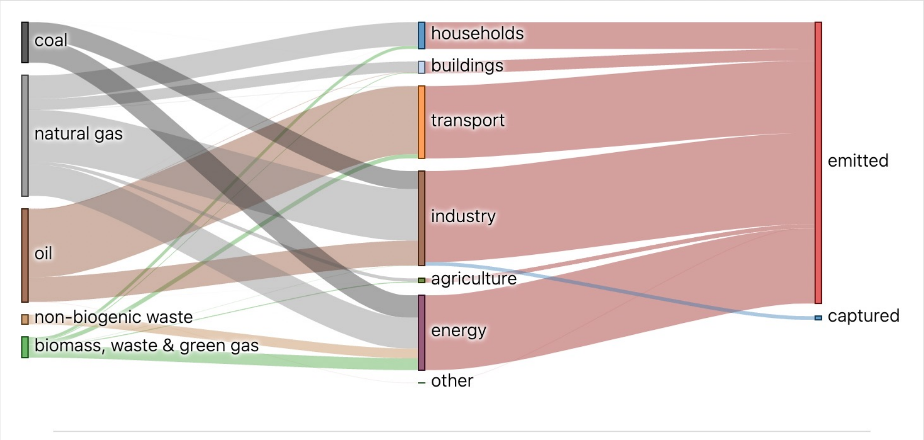
AVAILABLE OUTPUTS

Scenario report





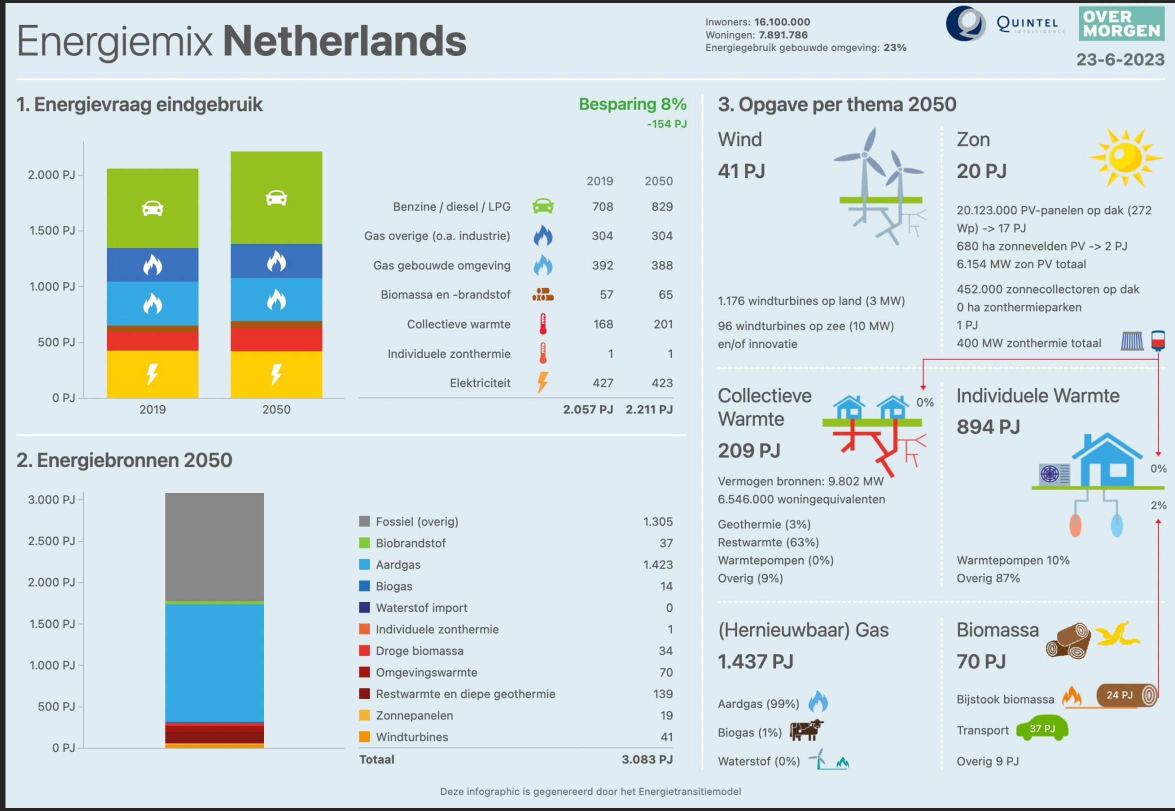
Renewability percentage of final energy demand.



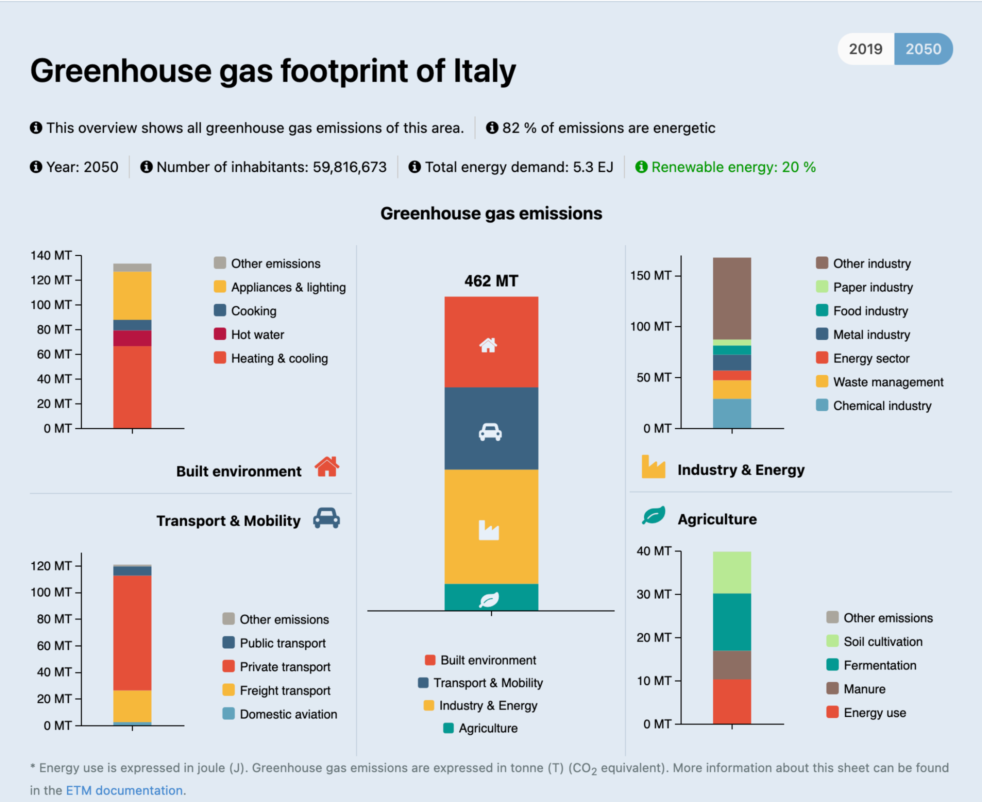
Sankey diagram showing which carriers and sectors are primarily responsible for CO_2 emissions.

AVAILABLE OUTPUTS

Energy mix infographic

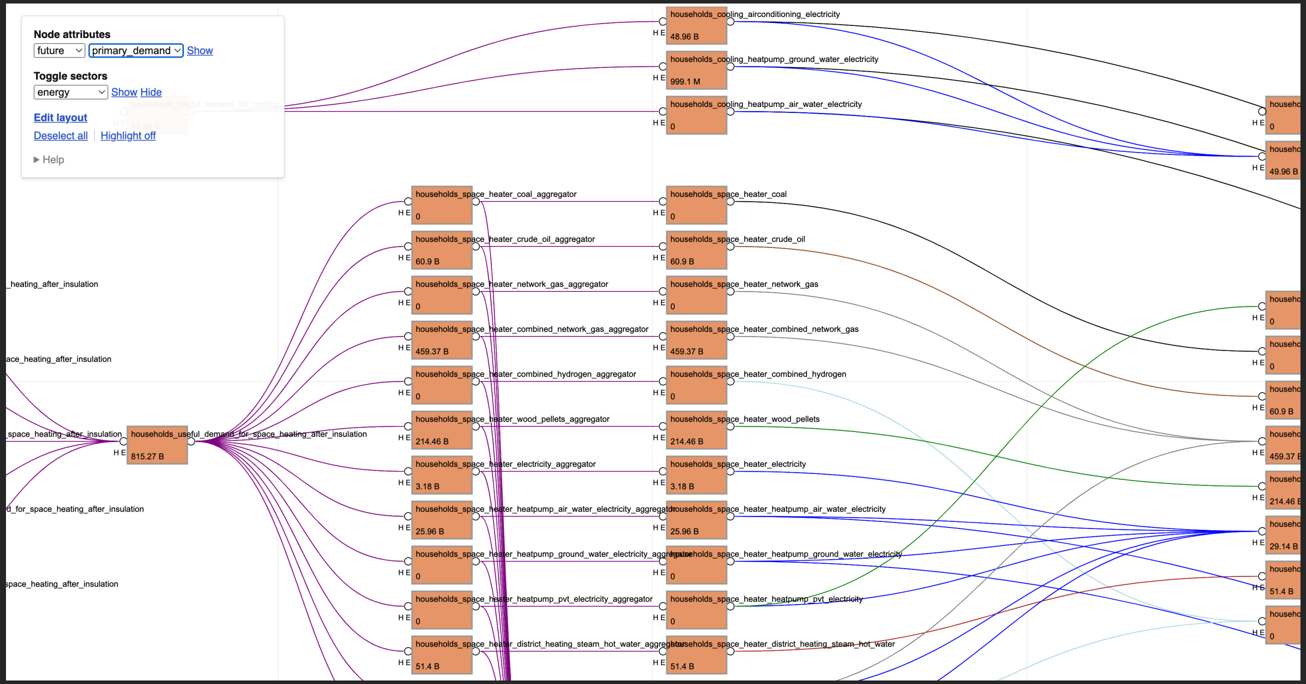


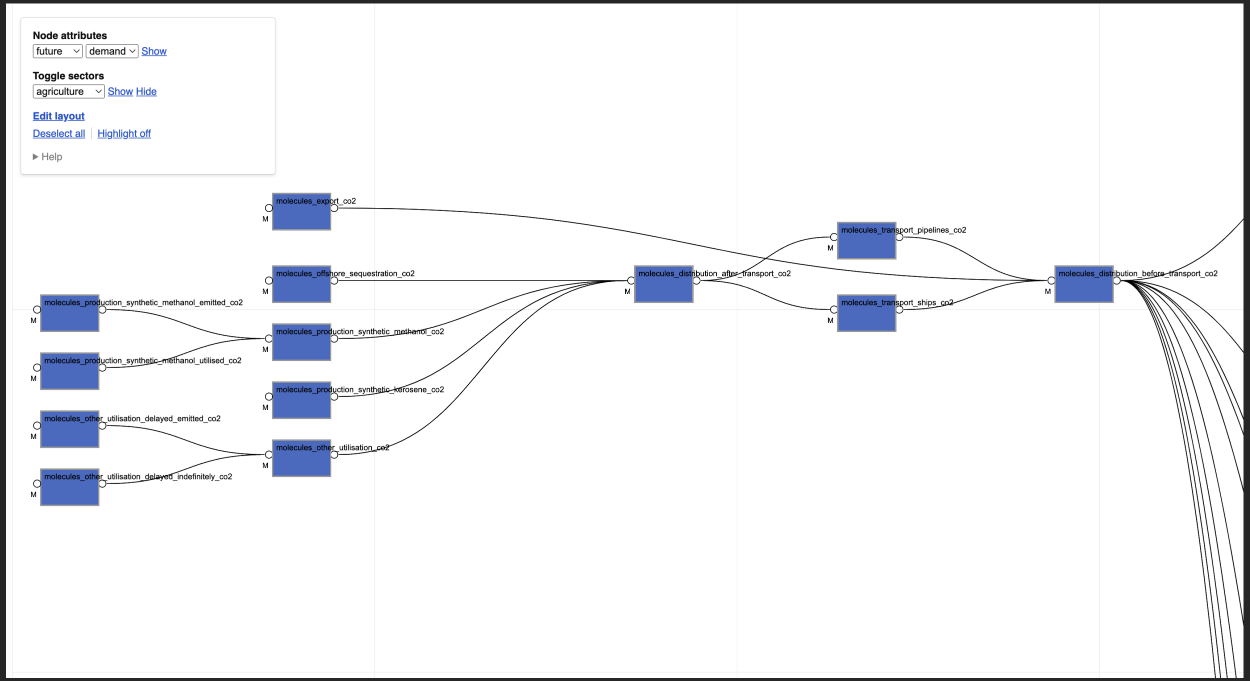
Greenhouse gas footprint



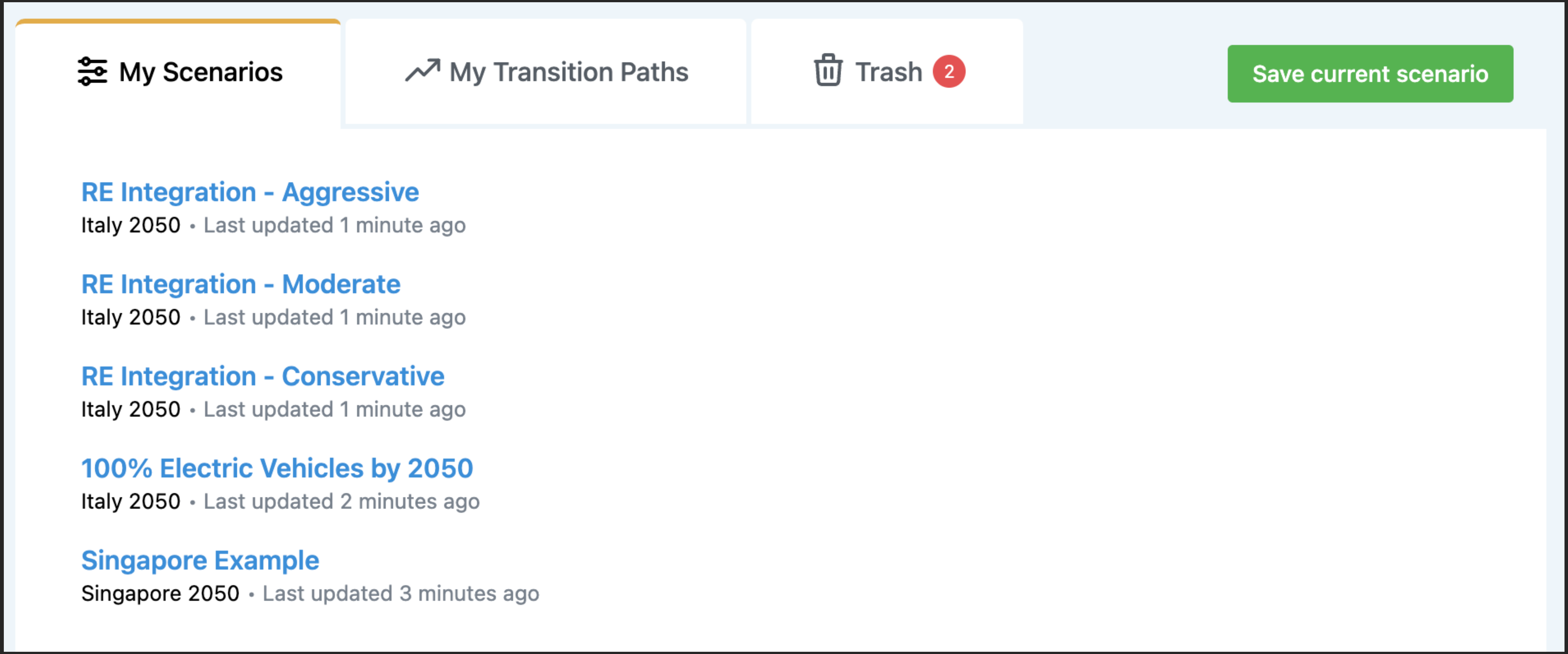
AVAILABLE OUTPUTS

Detailed energy & emissions flows





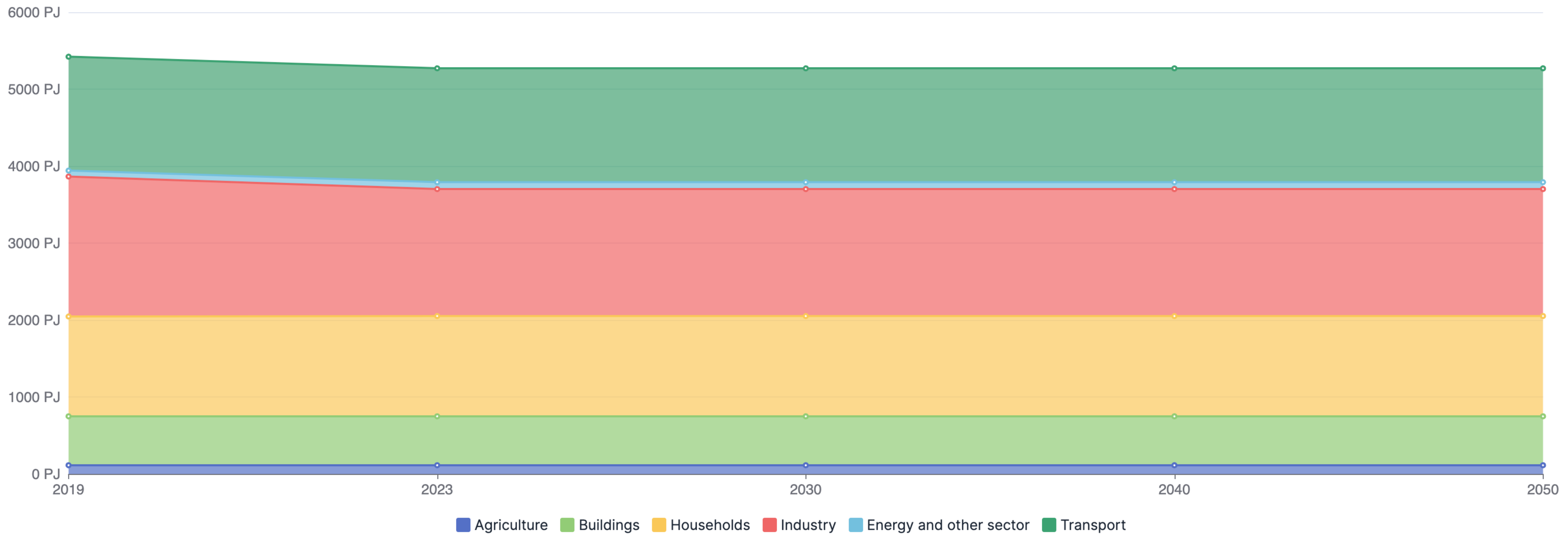
TRANSITION PATHWAYS



TRANSITION PATHWAYS

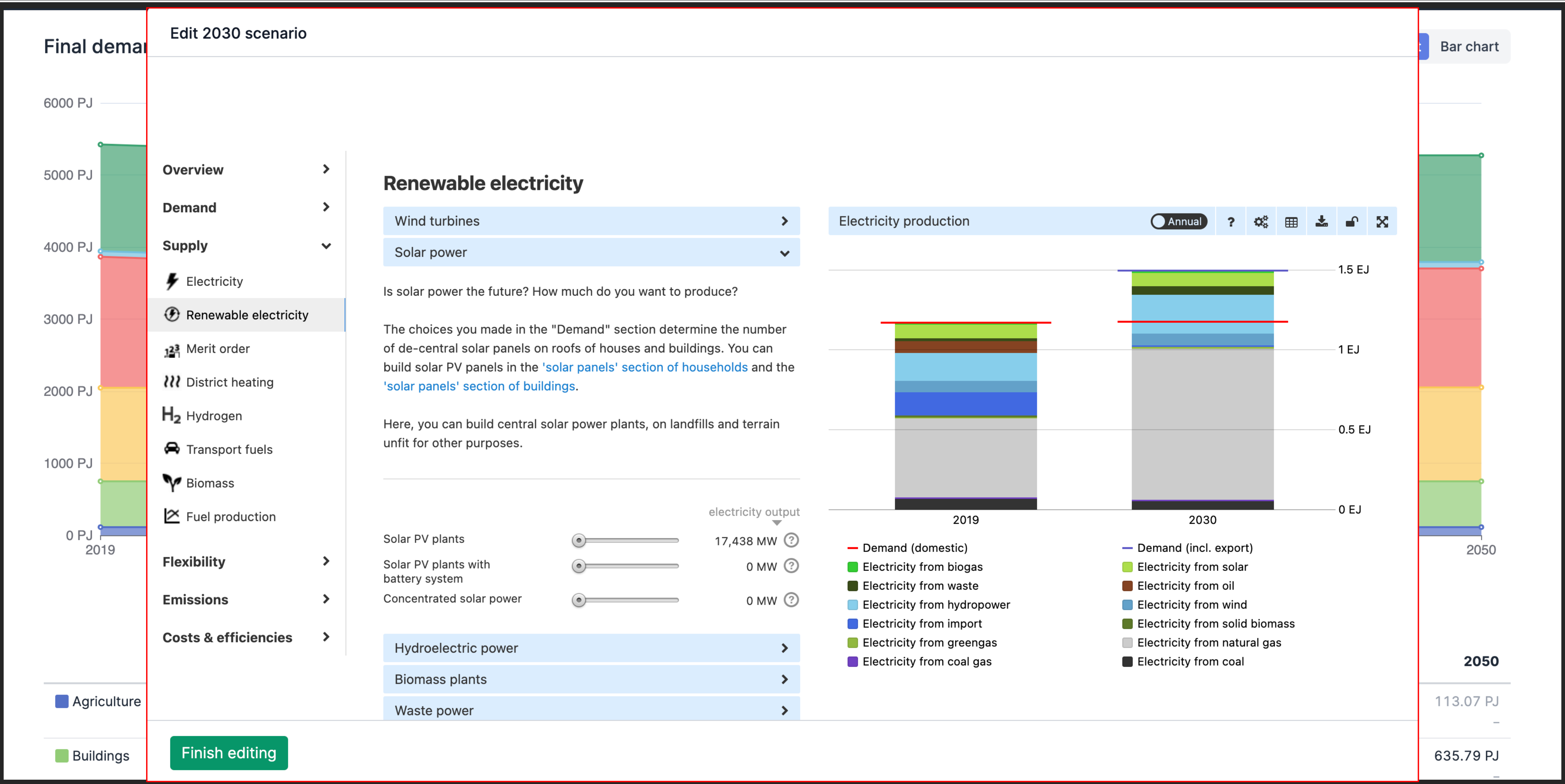
Final demand (energetic & non-energetic) › By sector

CSV | Area chart | Bar chart

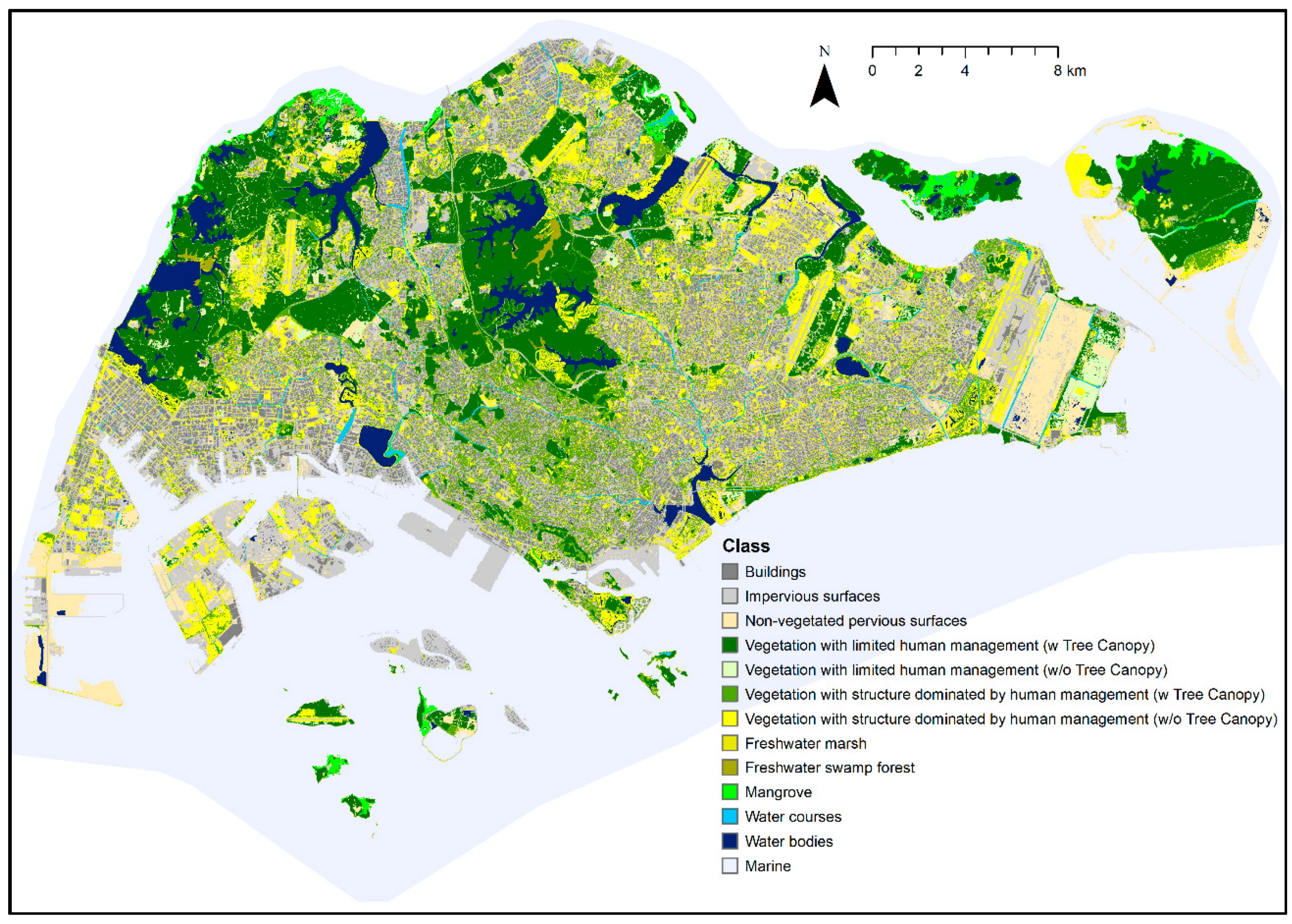


	2019	2023	2030	2040	2050
Agriculture	113.07 PJ	113.07 PJ –	113.07 PJ –	113.07 PJ –	113.07 PJ –
Buildings	635.77 PJ	635.79 PJ +0.02 PJ	635.79 PJ –	635.79 PJ –	635.79 PJ –

TRANSITION PATHWAYS



APPLIED EXAMPLE: Singapore



ISLAND NATION

Population 5.5m
Housing stock 1.37m

Total land area 733.2 km2
of which arable 7 km2
Offshore wind 0 km2
Coastline 193 km

CAPACITY: 14.3 GW

Pulverised coal with co-firing 400MW
Gas CCGT 6205MW
Large scale gas plant district heating CHP 3701MW
Oil fired 2539MW
Diesel generator 857MW
Solar 374MW
Waste 257 MW

Energy sector emissions 1.13 MtCO2-e

APPLIED EXAMPLE: Singapore

Scenario strategy

- Increased RE penetration + waste to power,
- Development of a hydrogen network for energy production, industry (in particular for steel), and other demand uses
- Full e-mobility transition as well as shift to public transport and use of bikes
- Moderate consumer-level energy efficiency technologies and behaviour
- Elimination of cooking via gas
- Large-scale battery deployment only in conjunction with RE
- Consideration of one trading network (import-only)

At a glance...

Total energy
Initial value: **720.73 PJ** • Scenario result: **1.32 EJ**

CO_2 emissions
Initial value: **50.4 MT** • Scenario result: **80.68 MT**

Renewability
Initial value: **1.6%** • Scenario result: **10.4%**

Costs
Initial value: **€24.22 BLN** • Scenario result: **€40.83 BLN**

More information

- Your scenario has no curtailed electricity production.
- Your scenario has no blackout hours. Learn more »
- In your scenario, primary energy use is 182.7% of the 2019 value. Learn more »
- 89.5% of power-plants are not profitable in your scenario. Do you think they will still be around in 2050? Learn more »

Key outcomes

- Renewability 10.4% (39.4% for electricity sector)
- No blackout hours – secure supply
- Primary energy consumption greatly increased
- Mostly unprofitable generators due to large dependence on hydrogen CHP turbines to partially decarbonise industrial processes

Suggestions for improvement...

Extreme assumptions

Depending on your choices, this section highlights some assumptions which imply big changes in the energy system. This might help you to focus on which aspects of your scenario could use some extra argumentation or research.

In your scenario, 89.5% of power plants is not profitable. This means that they are not earning back their investment costs and sometimes not even their running costs. Such plants will not stay open very long. Having them around in your future year might not be realistic. You can either

- **Increase electricity demand**: making the unprofitable plants run more hours could improve their situation.
- **Reduce competing production**: typically, wind and solar electricity generation has marginal costs close to zero, 'pushing' conventional plants out of the merit order.
- **Close the plants**: closing unprofitable plants might increase the realism of your scenario as such plants are not expected to exist very long.

ALL ASSUMPTIONS

GENERAL

Population 6m
Housing stock 1.52m, still 94.2% apartments

HOUSEHOLD

Air heat pumps 50% air heat pumps, 50% condensing combi boiler
25% of PV potential used
Cooking 80% induction, 20% electric
All appliance efficiencies at least A in 2050
Lighting fully switch to LED for households
All demand types grow 2% per year (except heating demand)
10% people turn off light and appliance and wash at low temperatures

BUILDINGS

2% per year appliance efficiency LED full with 20% exploited daylight control and motion detection
PV 5% solar thermal 5%
2% growth in cooling and electricity demand per year

TRANSPORT

Passenger transport growth 2% per year
Cars electric 64% and hydrogen 36%, all other vehicles fully electric (including freight)
Freight transport growth 2% per year
Shipping 80% hydrogen, 5% LNG, 15% ammonia (same for international)
2% growth per year aviation and navigation
Consider only 10% of energy demand from international services

INDUSTRY

Steel 100% DRI hydrogenDirect reduction of iron DRI using hydrogen 100% for steel
Aluminium 100% electrolysis
0.5% per year efficiency improvements for electricity and heat for all sectors
Refineries 100% hydrogen fired heaters + 50MW power to heat boiler gas
Ammonia 100% hydrogen network
Size same for all industry
Chemicals 10% heat pump, 40% hydrogen fired, 50% electric boiler
Hydrogen fully replaces feedstocks needed for chemicals
No change in telecommunications
Food & paper 100% hydrogen fired
Other sectors 75% hydrogen, 25% electricity
15000 MW hydrogen heater and 15000 MW hydrogen CHP turbine
No agriculture sector considered
300 MW ammonia import

CAPACITY

Wind 50 MW onshore, 1 MW offshore, 1000 MW inland with battery
Solar 500 MW, 8000 MW with battery
CSP 1000 MW
Waste incinerator 2000 MW
Hydrogen turbine 8000 MW
Geothermal 500 MW
No fossil fuel in electricity generation

Demand Modelling

Households
Population, residences, insulation, heating & cooling, lighting, appliances, efficiency improvements, demand changes, PV & solar thermal systems, behaviours

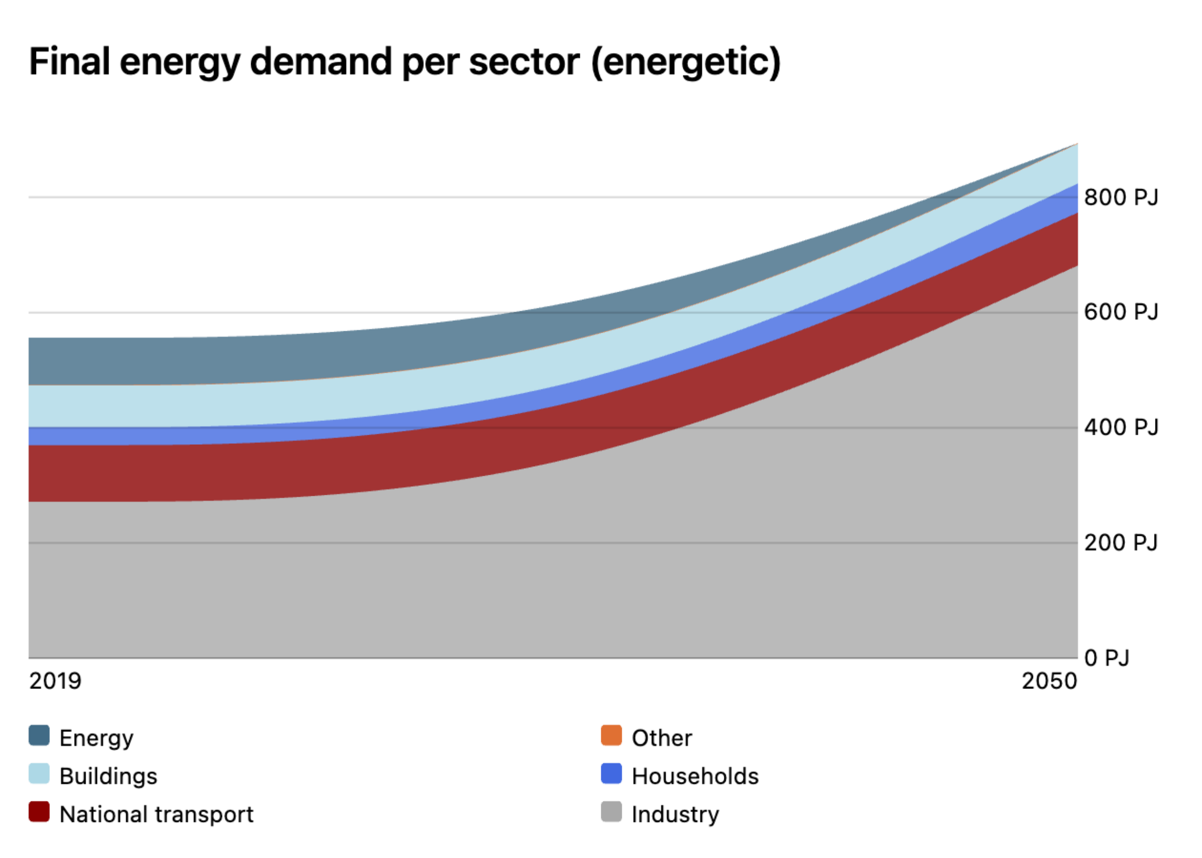
Buildings
Number of buildings, insulation, heating & cooling, lighting, efficiency improvements, demand changes, smart controls, PV & solar thermal systems

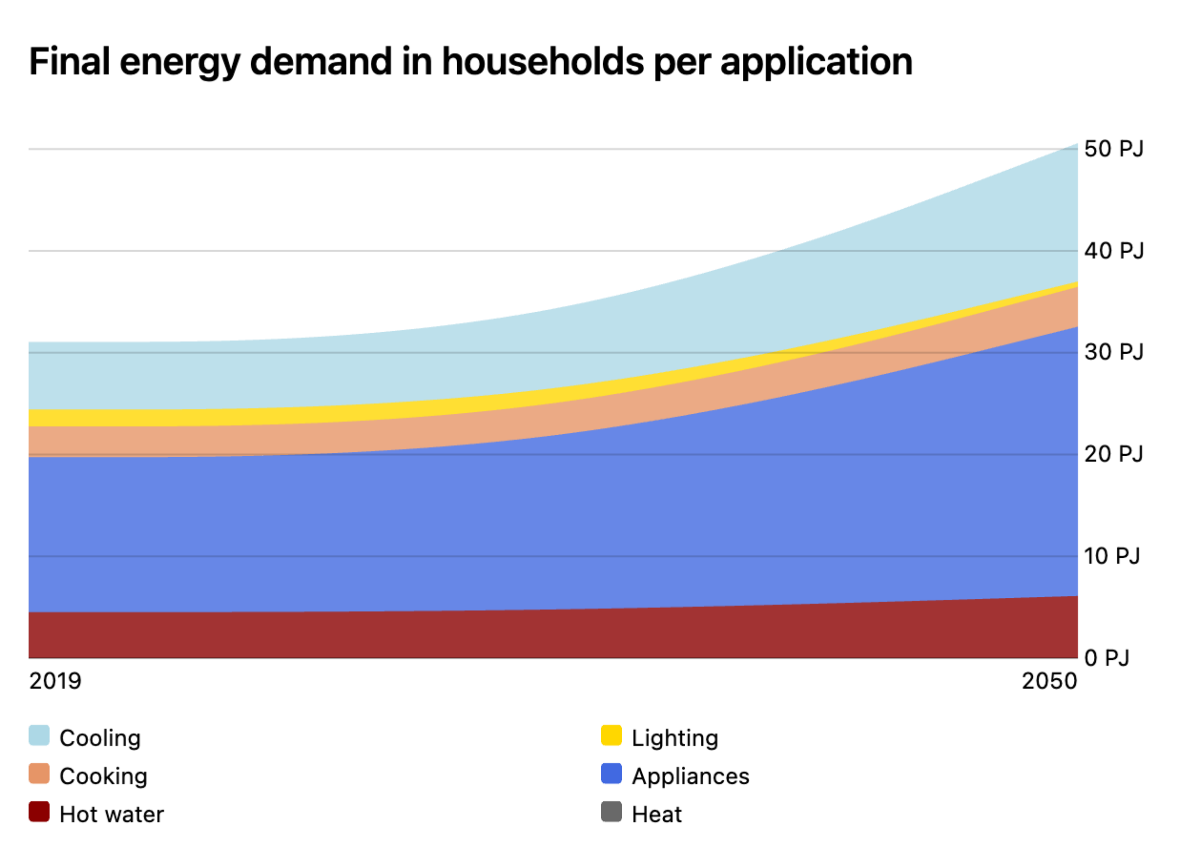
Transport
Passenger transport, applications, mobility growth, vehicle types, technologies & fuel types, freight transport (land & navigation), international transport (aviation & navigation)

Industry
Number of buildings, insulation, heating & cooling, lighting, efficiency improvements, demand changes, smart controls, PV & solar thermal systems

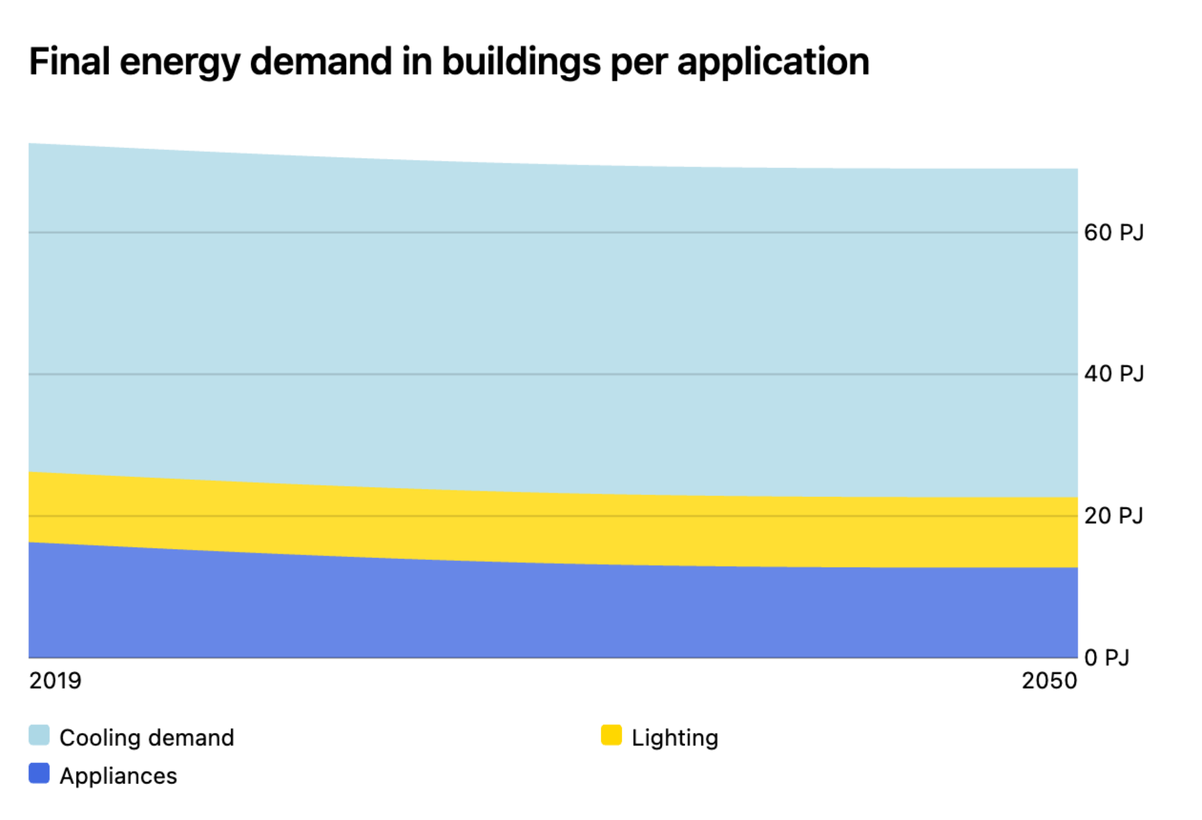
Agriculture
Number of buildings, insulation, heating & cooling, lighting, efficiency improvements, demand changes, smart controls, PV & solar thermal systems

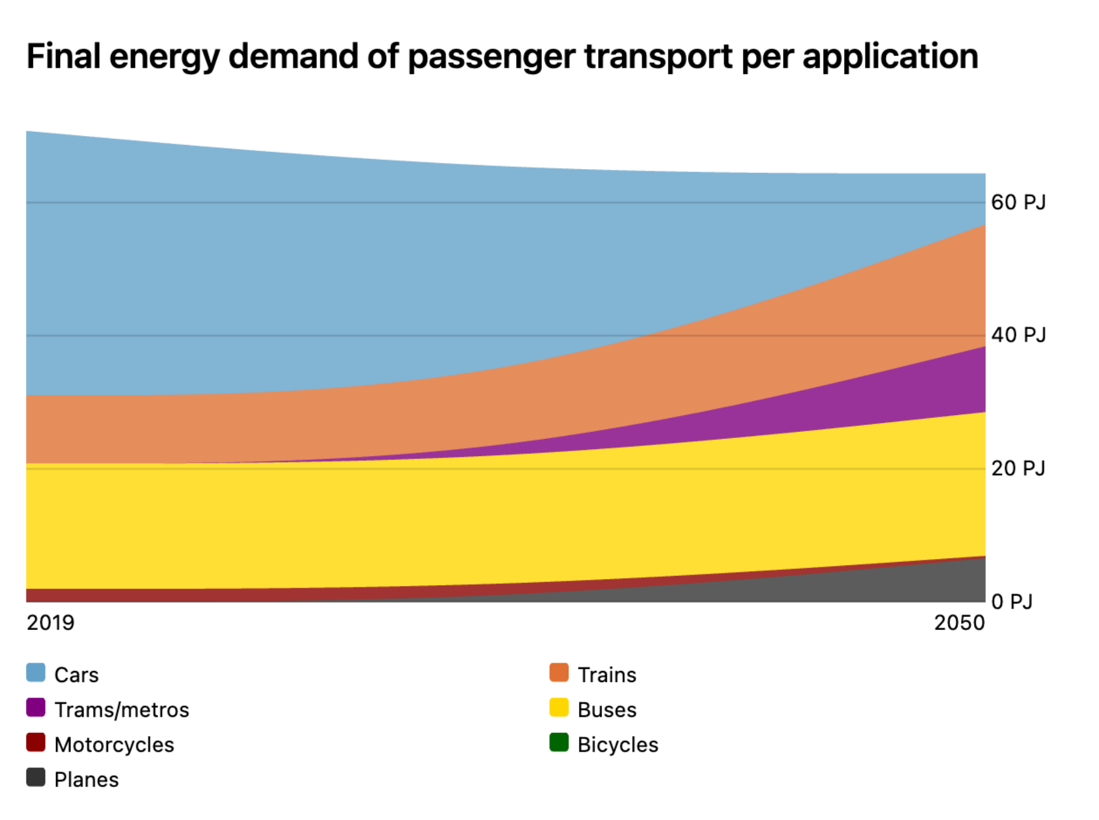
Demand Modelling



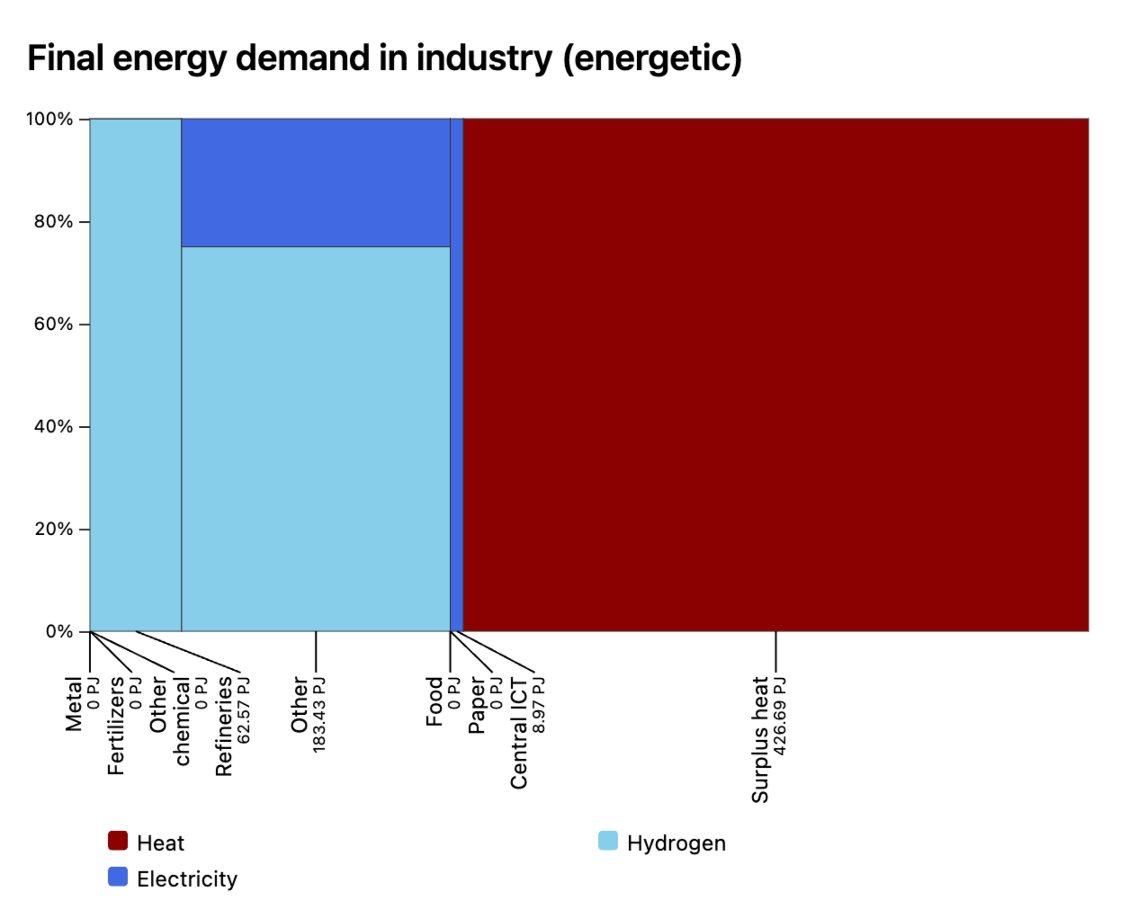


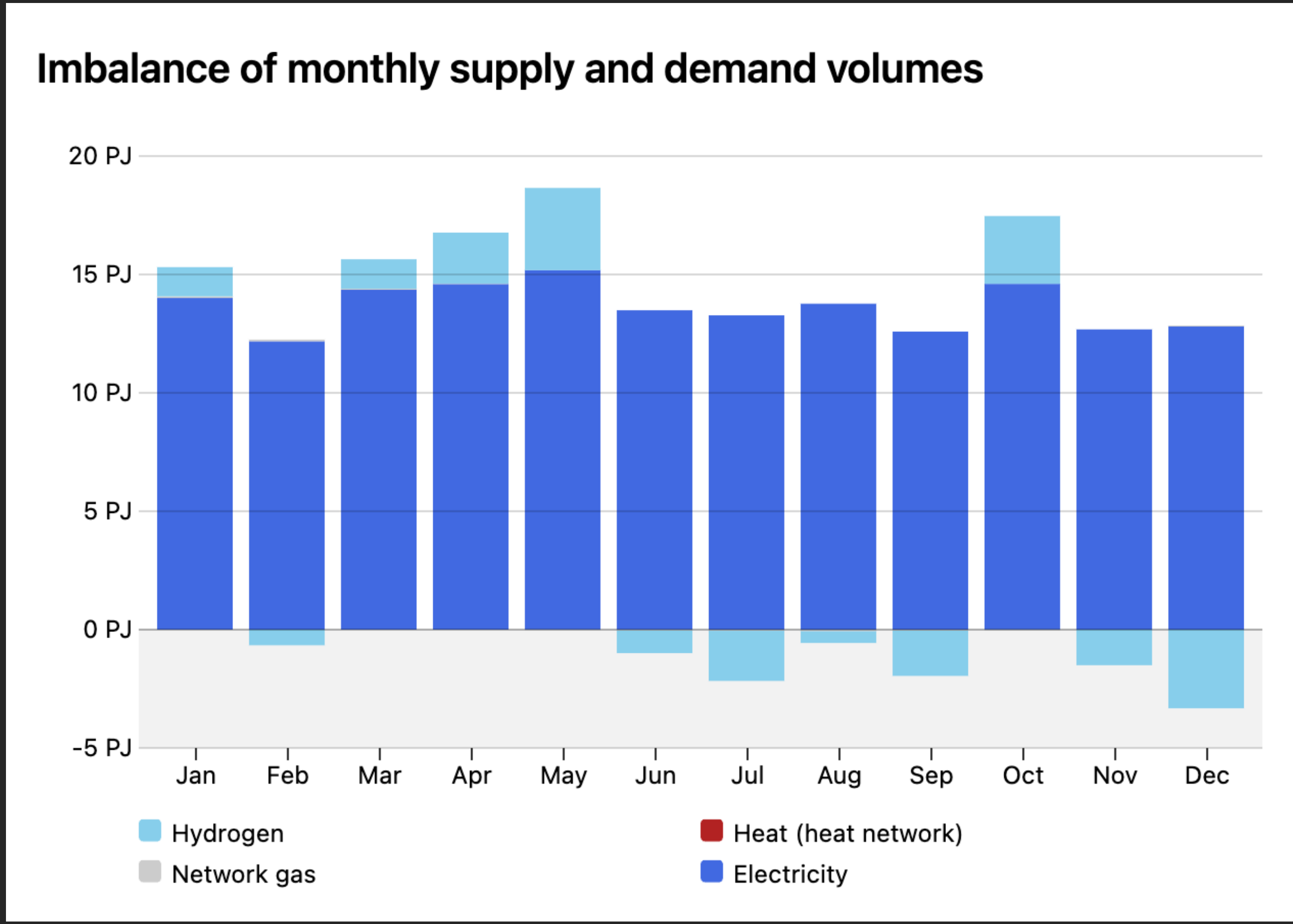
Demand Modelling





Demand Modelling





Supply Modelling

Electricity
Coal, gas, and oil plant technologies & capacity, small modular nuclear reactors, coal gases from steel making (chemical feedstock or energy production)

Renewable Electricity
Wind, solar, solar thermal, hydro, biomass, waste, hydrogen and geothermal technologies and capacity

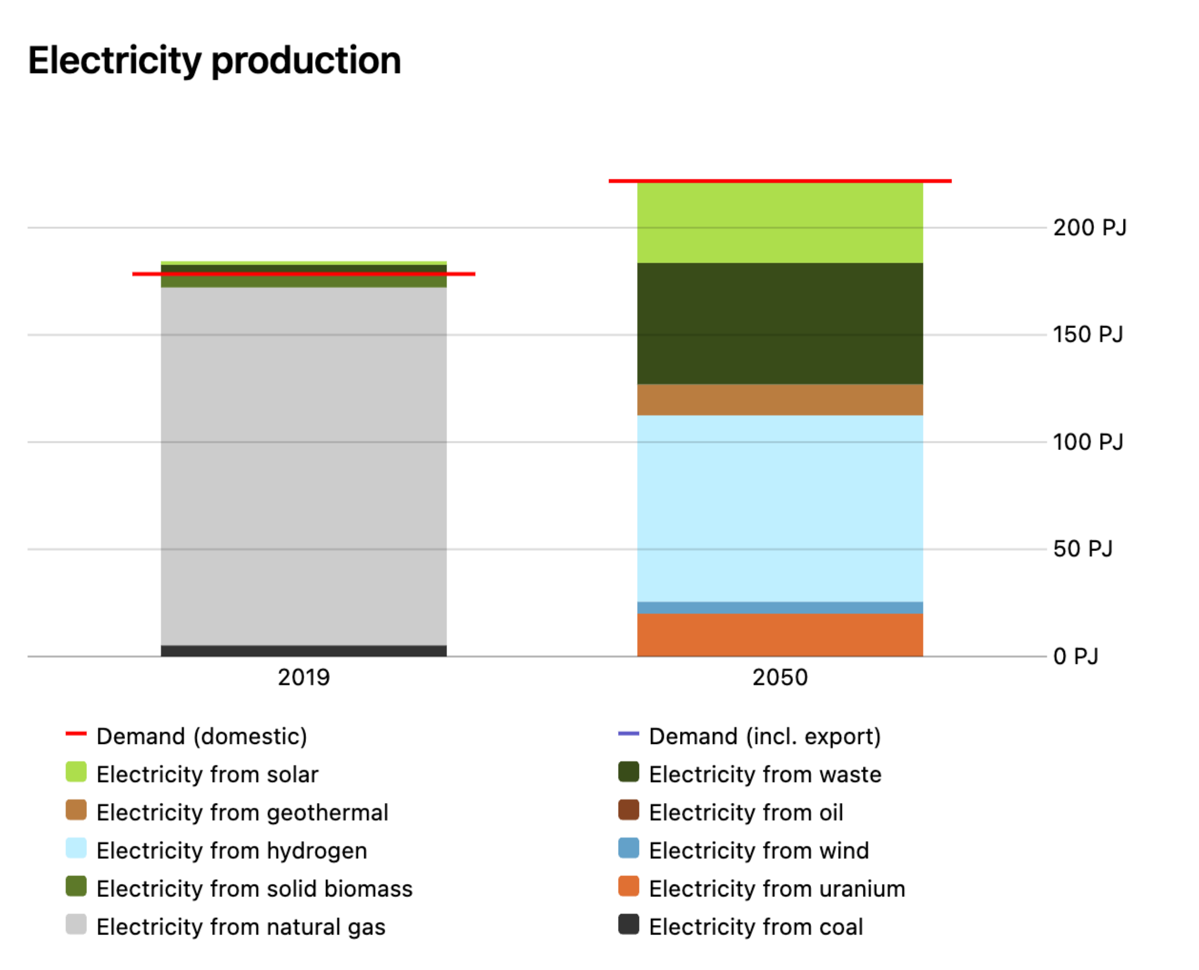
Merit Order
ON/OFF switch. Works for types of plants, not individual plants. When OFF, all plants have the same full load hours and do not respond to cost and fuel assumptions. Load & price curves download.

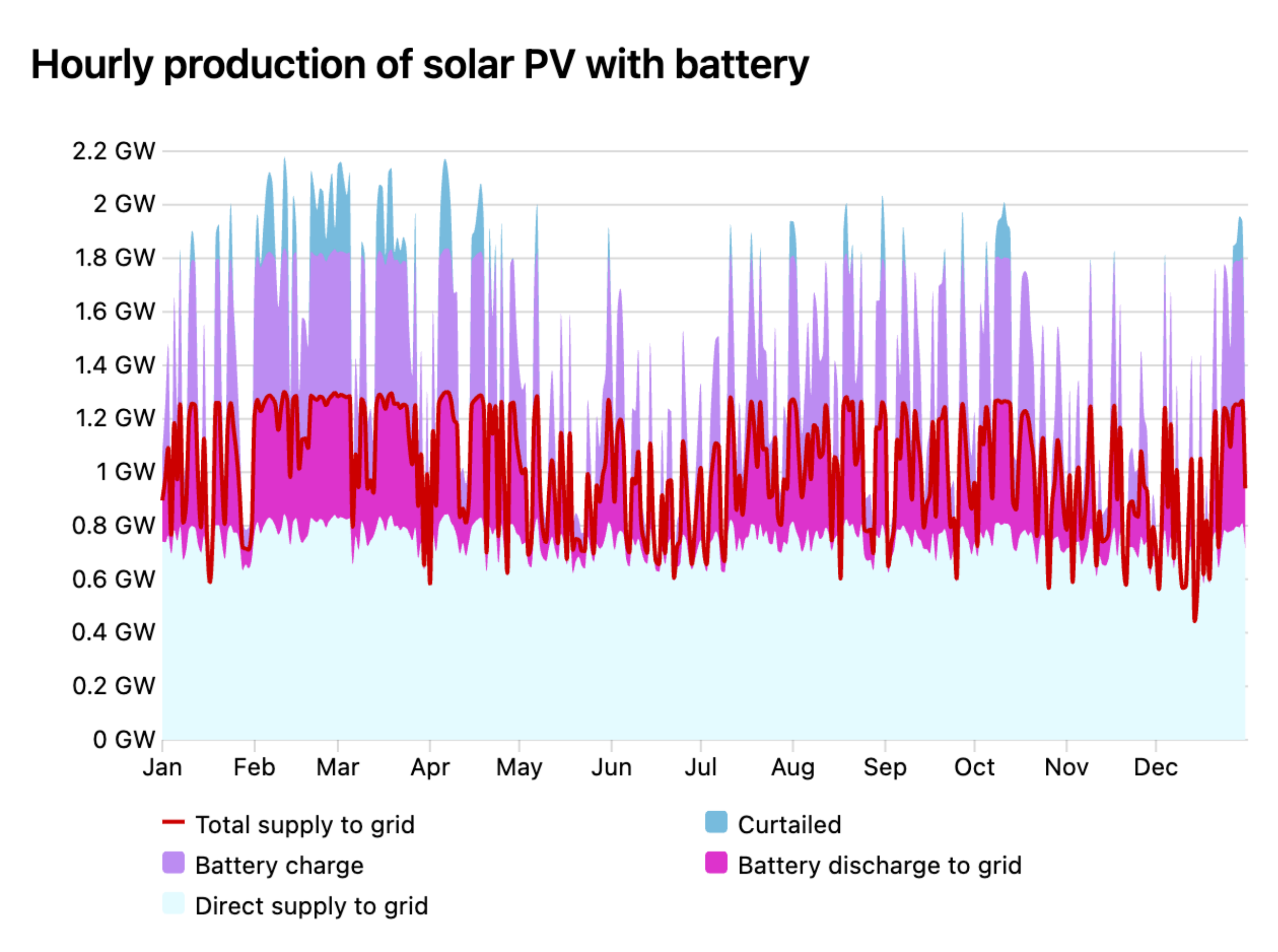
Hydrogen
Production technologies & capacity, demand (summary), transport (pipelines, trucks), storage, ammonia production, emissions of imported hydrogen and ammonia

Clean fuels
Biodiesel, bioethanol, bioLNG, and biokerosene for various types of transport

Biomass
Typology and potential, gaseous mixtures, gas production, wood pellets for steel production, biocoal and bio-oil in power plants (e.g. coconut oil), emissions, oil mix in demand sectors

Supply Modelling





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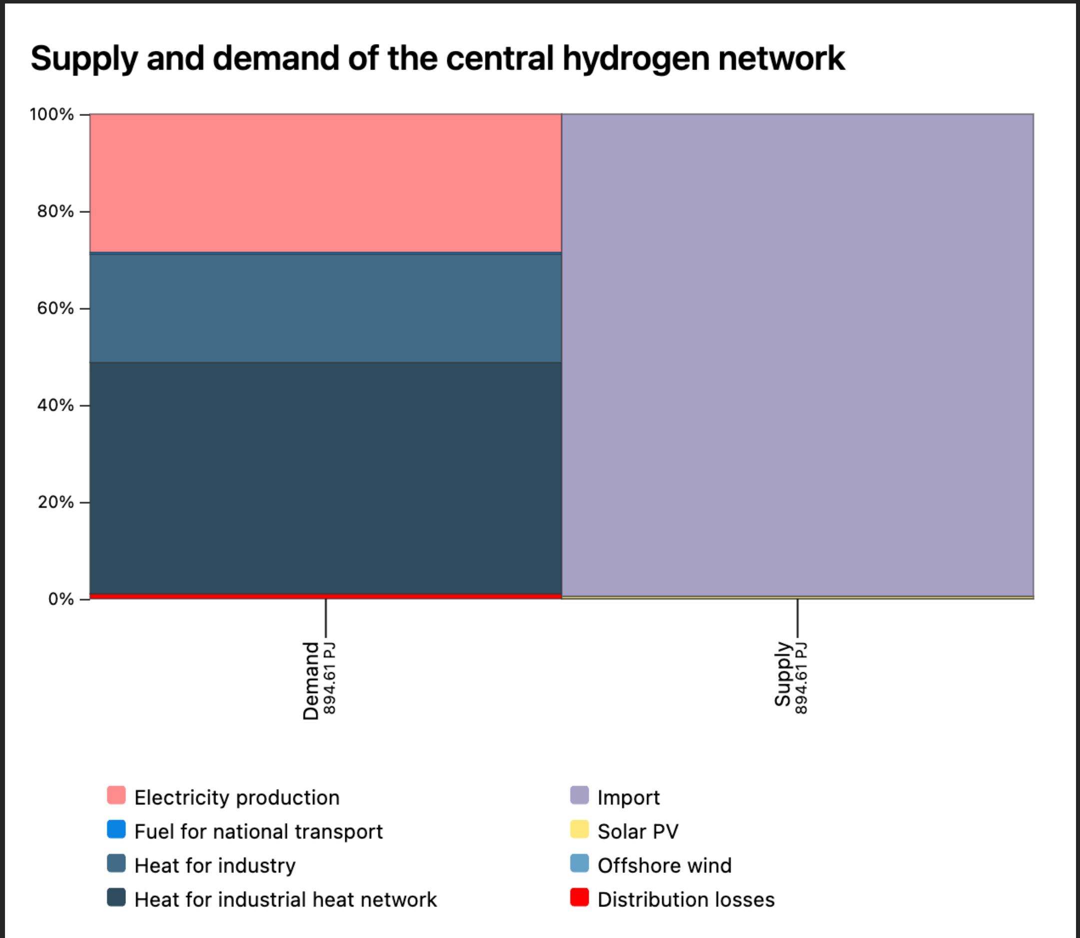
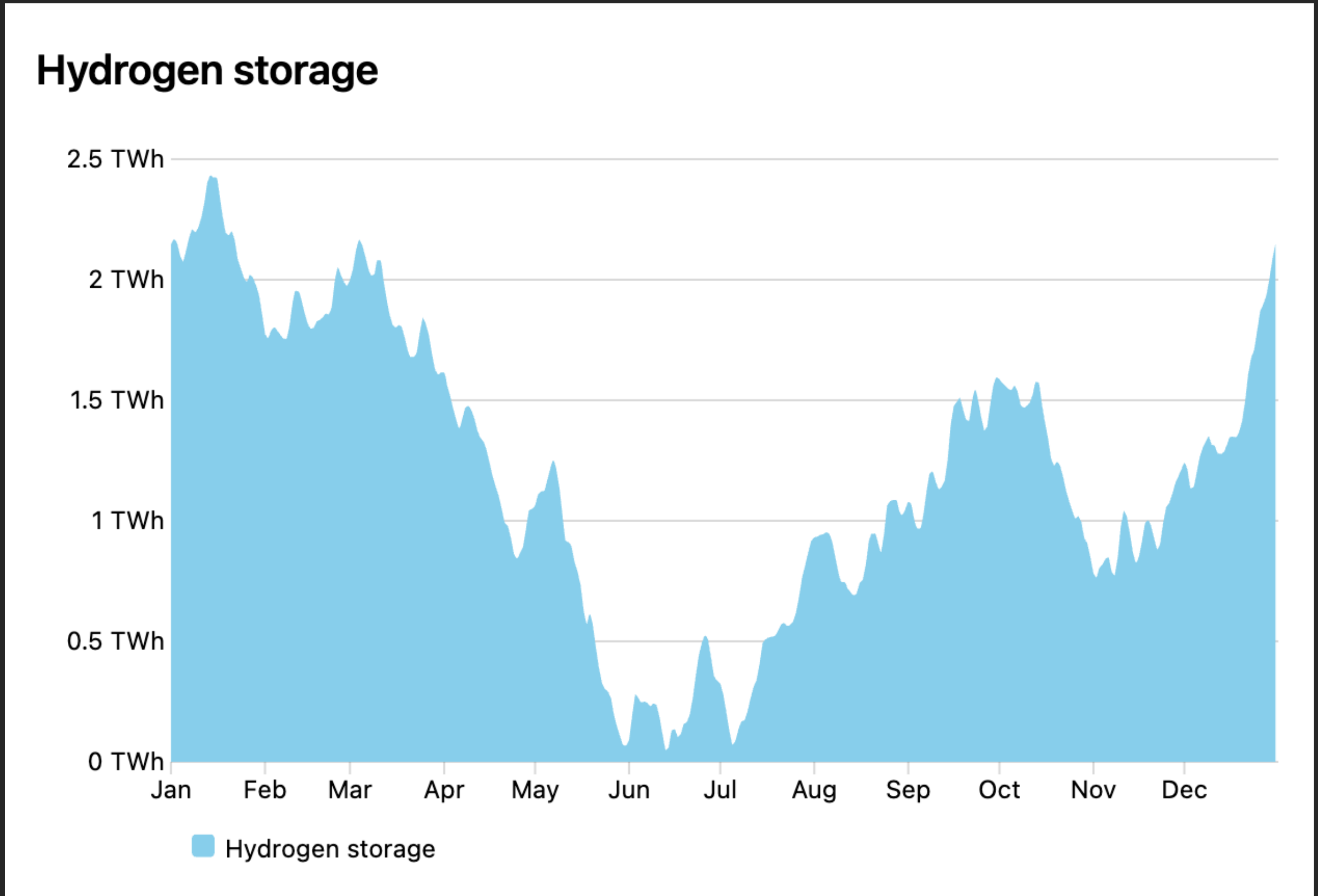




Flexibility Modelling

Electricity storage

ON/OFF residual load forecast, household batteries, EV batteries (deployable capacity, relative storage volume), utility batteries (technical & economic specifications), reservoirs, pumped hydro, flow batteries, wind turbines with storage, solar plants with storage

Electricity conversions

Electricity to hydrogen and heat (households, industry, agriculture)

Net load

Solar curtailment (households, buildings, utility), demand response (load shifting, EVs, hybrid heat pumps)

Import/export

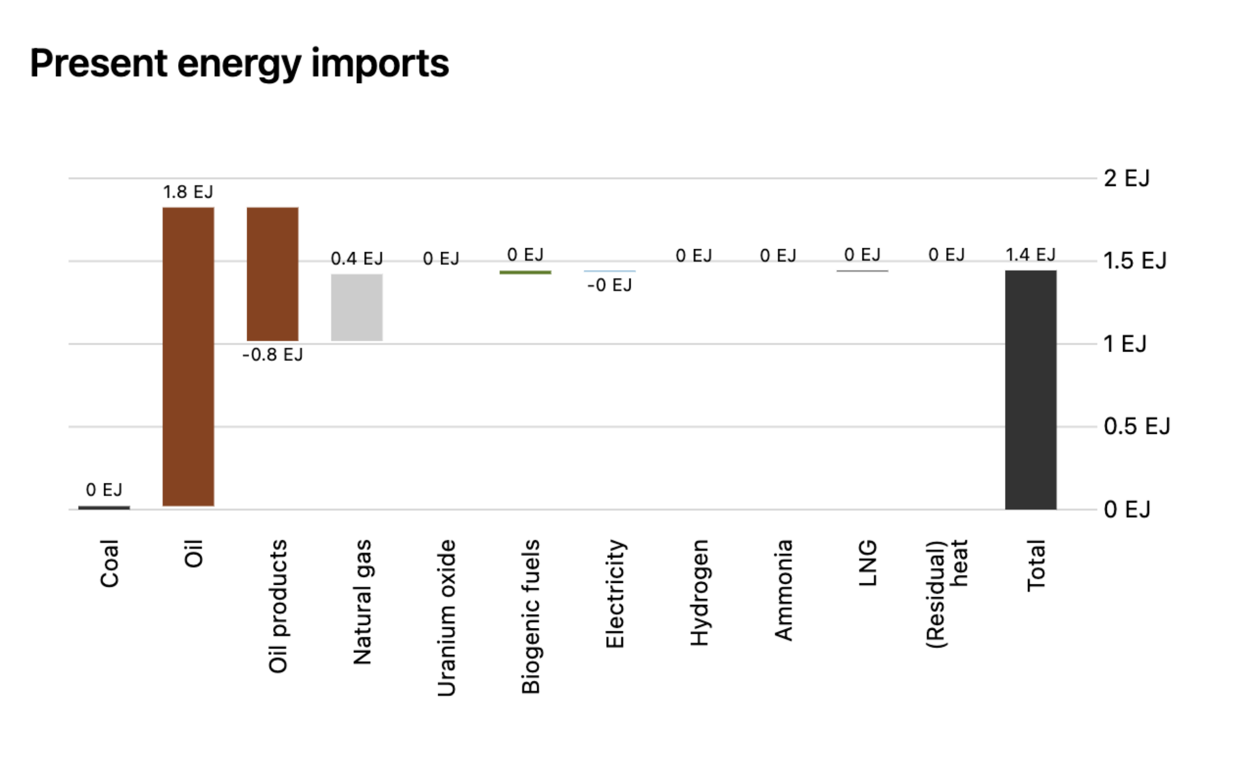
Connection to external markets modelled with interconnectors (capacity, availability, costs)

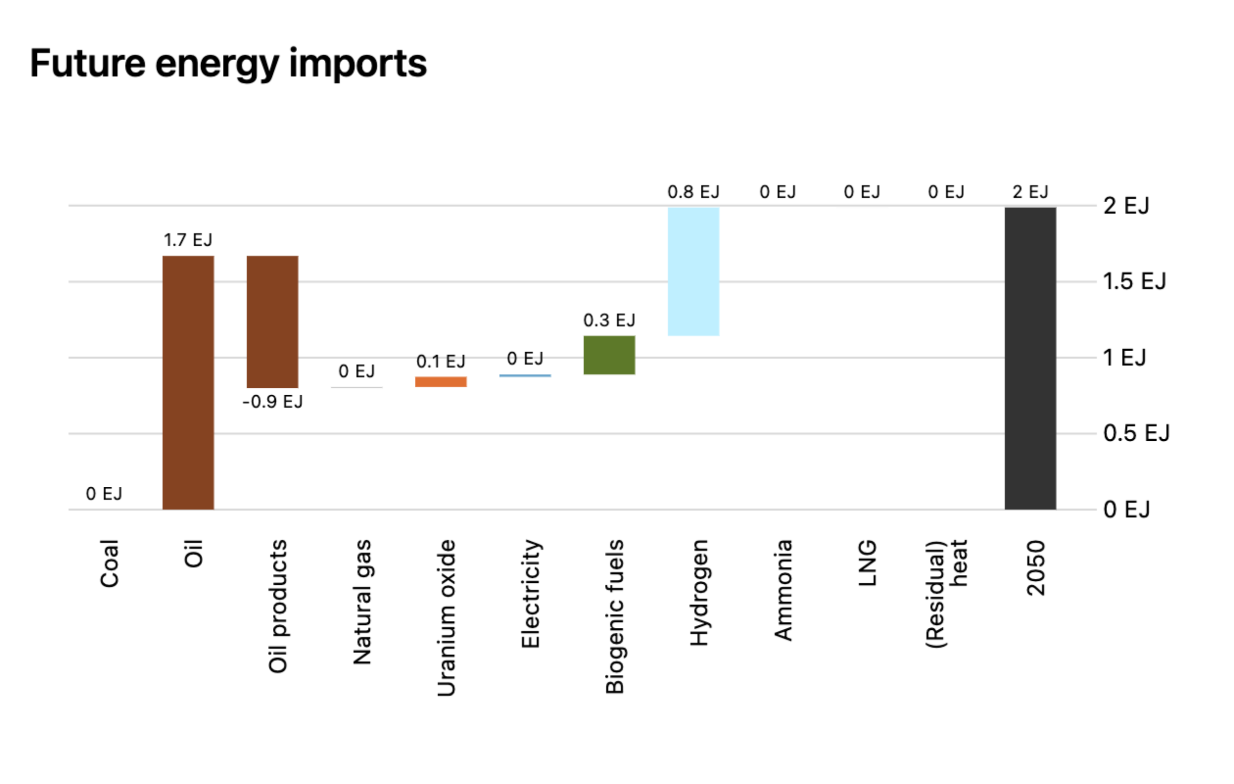
Weather conditions

Full load hours of solar & wind, outdoor temperature

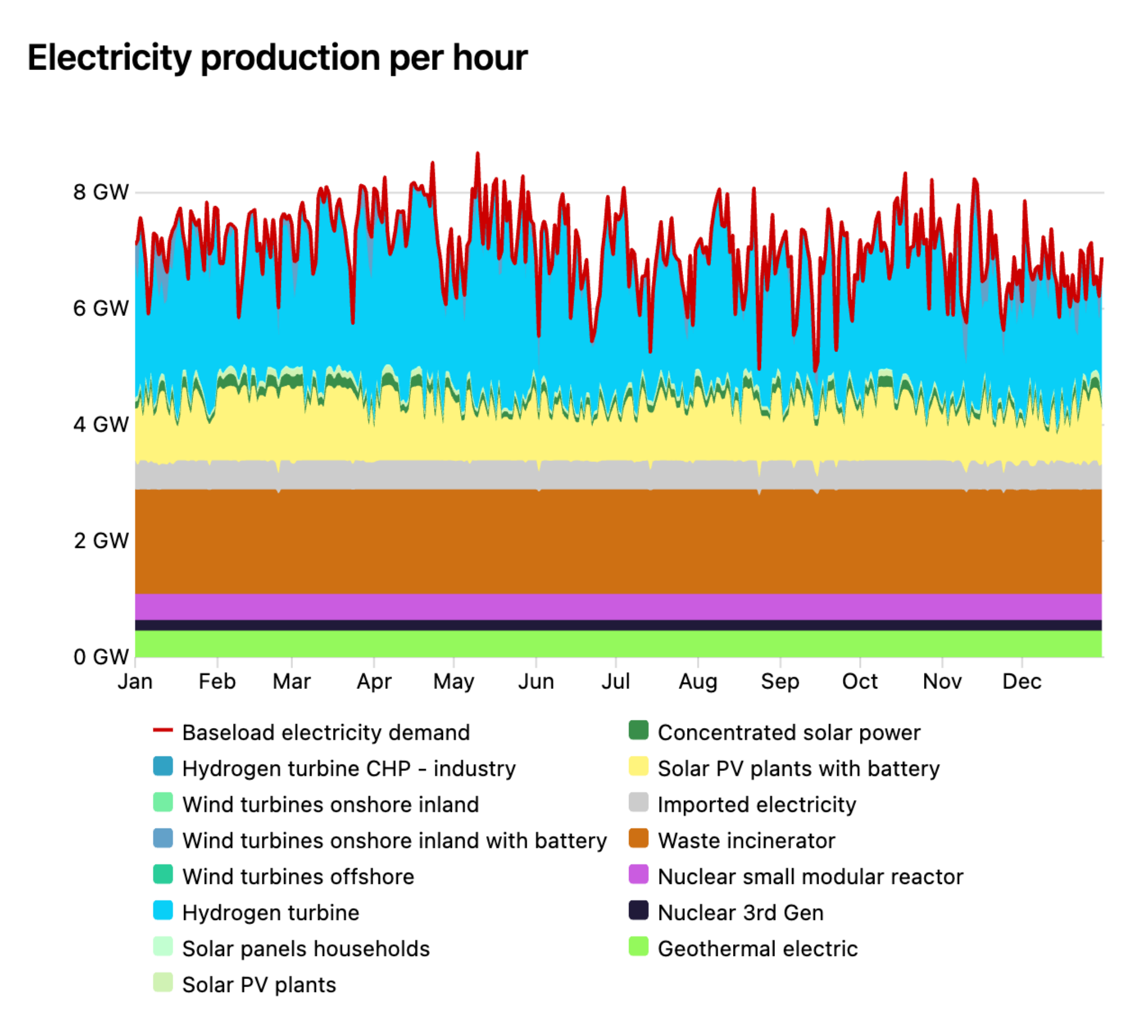
+ Input customised hourly profiles for supply, demand, import/export, and weather

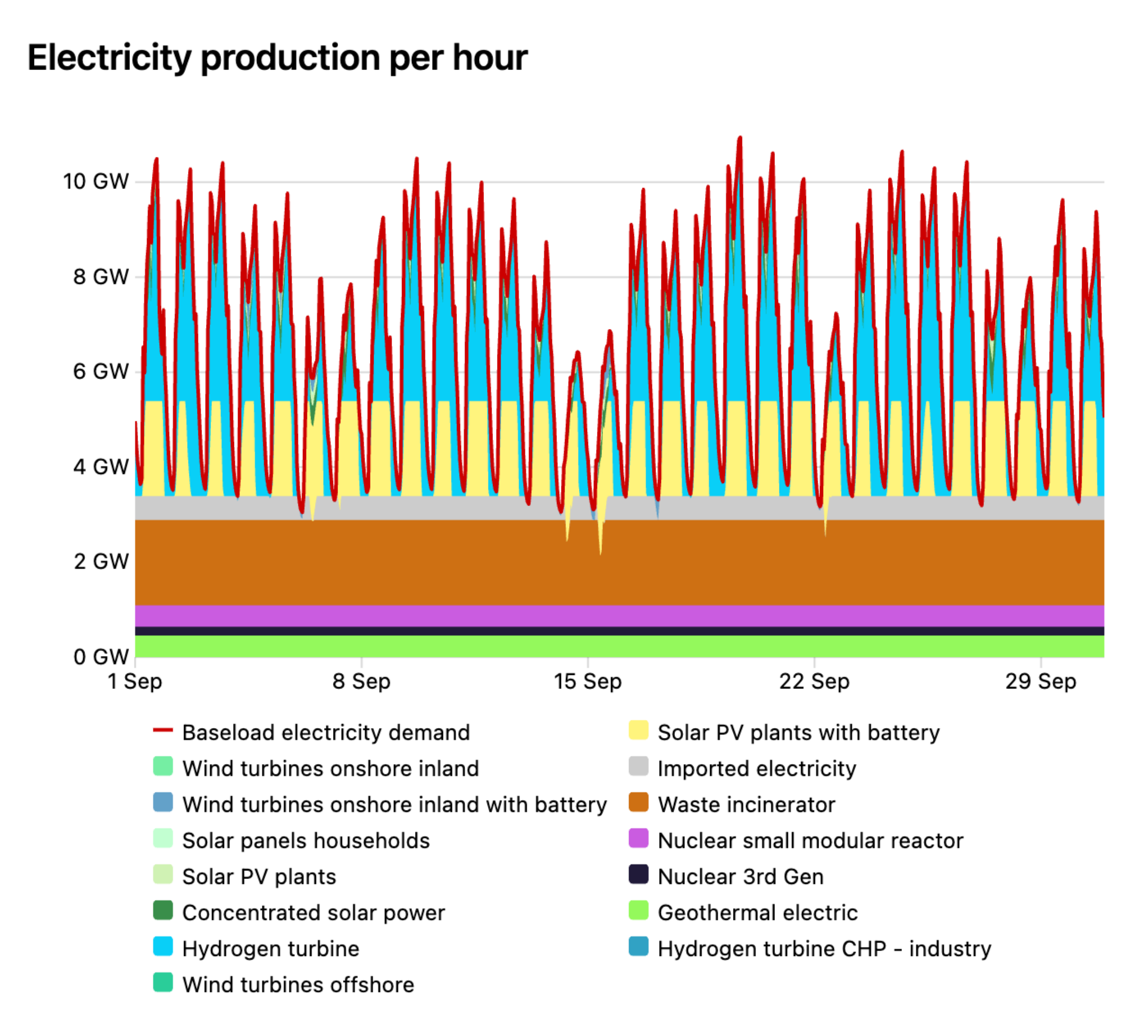
Flexibility Modelling





Flexibility Modelling





Emissions Modelling

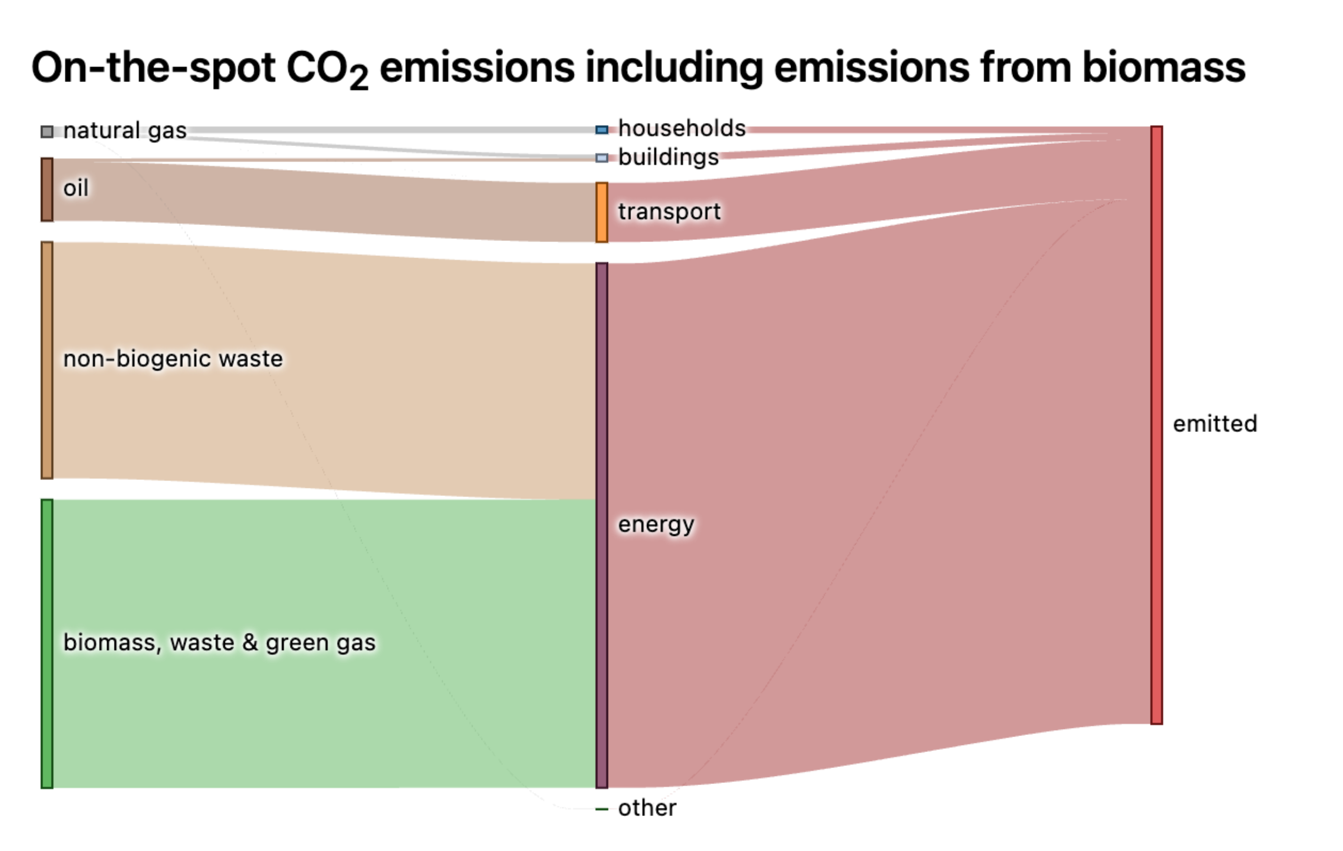
Greenhouse gases

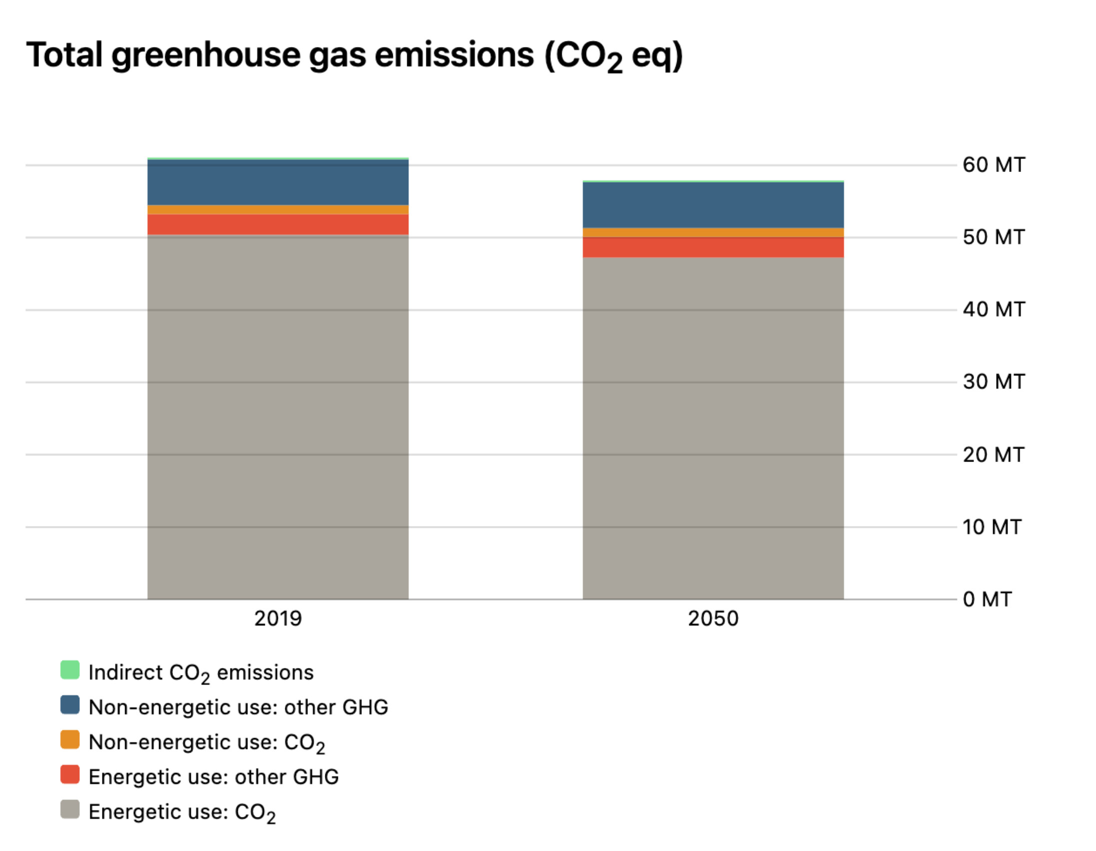
Built environment (households, buildings), transport, industry (non-energetic, energetic; for various industry sectors), agriculture (including manure, soil cultivation, fermentation), indirect emissions, delayed emissions (fertilisers, plastics production)

CCUS

Industrial, power plants, hydrogen plants, direct air capture, offshore storage, utilisation (synthetic kerosene, methanol, and other), transport (pipelines, liquefied in ships)

Emissions Modelling





Cost & Efficiency Modelling

Electricity & Renewable Electricity & Hydrogen
Investment costs and O&M costs per technology type, efficiency changes per technology type

Infrastructure
Electricity infrastructure costs (interconnectors, low, medium, high voltage connectors), calculation of required network expansion (non-nodal)

Heat
Appliance efficiencies for heating/cooling and hot water, geothermal and solar thermal investment costs and O&M costs

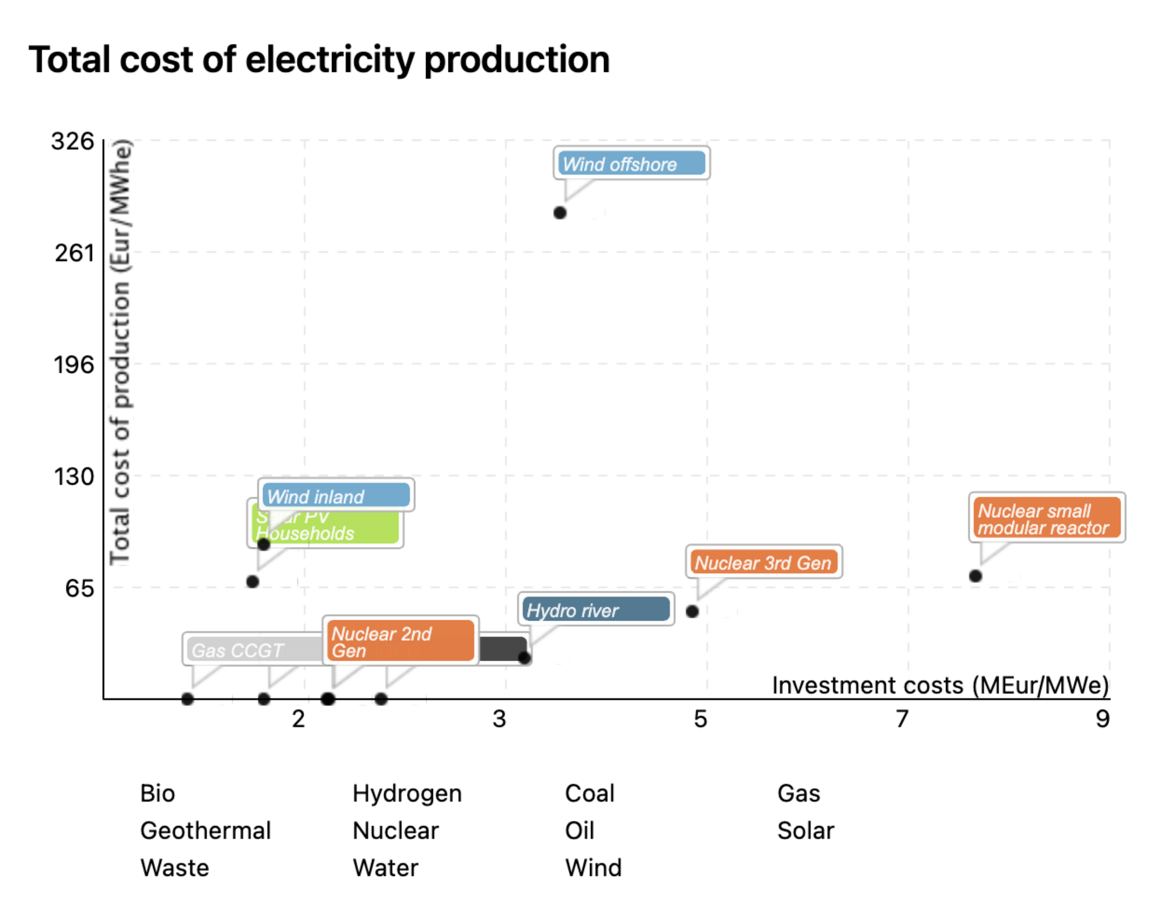
Transport & Fuel Prices
Efficiency improvements for vehicle types, changes in fuel price per fuel type

Flexibility
Value of lost load, investment costs for storage type, conversions

CCUS
Carbon prices & free allocations, investment & O&M costs in capture and storage technologies

WACC
Set different rates for households, public infrastructure, commercial technologies, immature technologies

Cost & Efficiency Modelling



APPLICATIONS FOR PICTS

Policy Development
Assist in developing effective energy policies and goals to support energy transitions

Geographic Fragmentation
Reflect multi-island context of Vanuatu and develop strategies for independent islands to form a national strategy

Energy Independence
Identify opportunities reduce need for imports and expand local energy resource utilisation

Resilience & Security
Understand implications and opportunities associated with carrying out key energy transitions and experiencing disastrous weather

Data Centralisation
Opportunity to adopt a proven data collection framework to track national/state energy production, conversion, and consumption

Economic Development
Identify opportunities to expand economy/infrastructure in conjunction with energy sector and create a regional trade network in the Pacific

PILOT STUDY: VANUATU

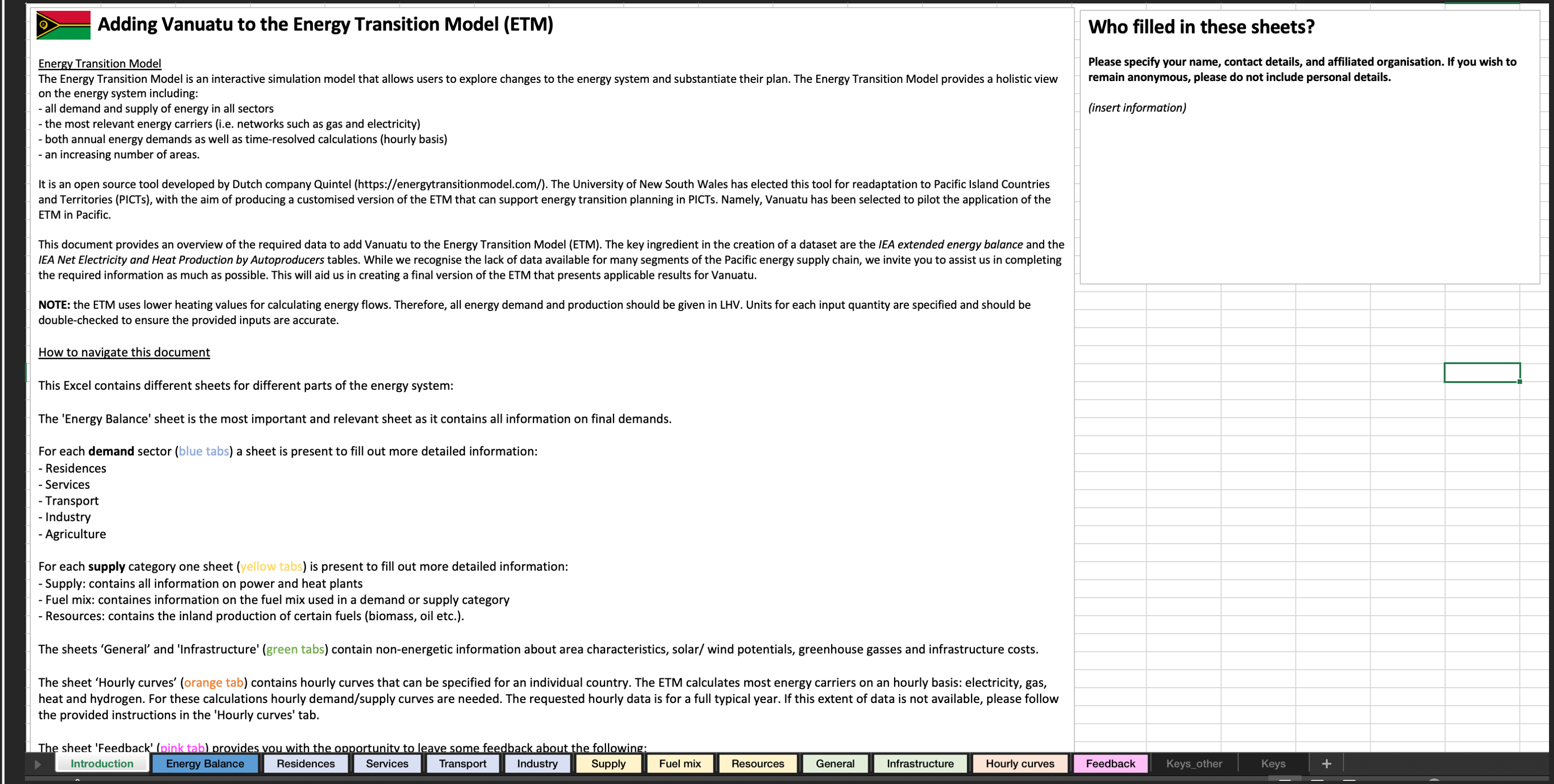
EFATE
UNELCO

ESPIRITU SANTO
VUI

MALEKULA
VANPOWER

TANNA
VANPOWER

Data collection process



Adding Vanuatu to the Energy Transition Model (ETM)

Energy Transition Model
The Energy Transition Model is an interactive simulation model that allows users to explore changes to the energy system and substantiate their plan. The Energy Transition Model provides a holistic view on the energy system including:
- all demand and supply of energy in all sectors
- the most relevant energy carriers (i.e. networks such as gas and electricity)
- both annual energy demands as well as time-resolved calculations (hourly basis)
- an increasing number of areas.

It is an open source tool developed by Dutch company Quintel (https://energytransitionmodel.com/). The University of New South Wales has elected this tool for readaptation to Pacific Island Countries and Territories (PICTs), with the aim of producing a customised version of the ETM that can support energy transition planning in PICTs. Namely, Vanuatu has been selected to pilot the application of the ETM in Pacific.

This document provides an overview of the required data to add Vanuatu to the Energy Transition Model (ETM). The key ingredient in the creation of a dataset are the *IEA extended energy balance* and the *IEA Net Electricity and Heat Production by Autoproducers* tables. While we recognise the lack of data available for many segments of the Pacific energy supply chain, we invite you to assist us in completing the required information as much as possible. This will aid us in creating a final version of the ETM that presents applicable results for Vanuatu.

NOTE: the ETM uses lower heating values for calculating energy flows. Therefore, all energy demand and production should be given in LHV. Units for each input quantity are specified and should be double-checked to ensure the provided inputs are accurate.

How to navigate this document

This Excel contains different sheets for different parts of the energy system:

The 'Energy Balance' sheet is the most important and relevant sheet as it contains all information on final demands.

For each **demand** sector (blue tabs) a sheet is present to fill out more detailed information:
- Residences
- Services
- Transport
- Industry
- Agriculture

For each **supply** category one sheet (yellow tabs) is present to fill out more detailed information:
- Supply: contains all information on power and heat plants
- Fuel mix: containes information on the fuel mix used in a demand or supply category
- Resources: contains the inland production of certain fuels (biomass, oil etc.).

The sheets 'General' and 'Infrastructure' (green tabs) contain non-energetic information about area characteristics, solar/ wind potentials, greenhouse gasses and infrastructure costs.

The sheet 'Hourly curves' (orange tab) contains hourly curves that can be specified for an individual country. The ETM calculates most energy carriers on an hourly basis: electricity, gas, heat and hydrogen. For these calculations hourly demand/supply curves are needed. The requested hourly data is for a full typical year. If this extent of data is not available, please follow the provided instructions in the 'Hourly curves' tab.

The sheet 'Feedback' (pink tab) provides you with the opportunity to leave some feedback about the following:

Who filled in these sheets?

Please specify your name, contact details, and affiliated organisation. If you wish to remain anonymous, please do not include personal details.

(insert information)

Introduction | Energy Balance | Residences | Services | Transport | Industry | Supply | Fuel mix | Resources | General | Infrastructure | Hourly curves | Feedback | Keys_other | Keys

Workbook distribution to key stakeholders
(utilities, ministries & departments, authorities)

Contribution to PPA annual benchmarking?

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Thank you!

Tankyu! Merci! Faafetai! Tubwa! Vinaka! Malo! Koṃṃool! Whakawhetai ki ́a koe! Fakafetai fāfetai! Si Yu'os Ma'åse'!

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