

Snapshot of - PROMETHEUS

Archive of PROMETHEUS, version: 1.0

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Reference card - PROMETHEUS

The reference card is a clearly defined description of model features. The numerous options have been organized into a limited amount of default and model specific (non default) options. In addition some features are described by a short clarifying text.

Legend:

not implemented

- implemented
- implemented (not default option)

About

Name and version	PROMETHEUS 1.0
Model link	https://e3modelling.com/modelling-tools/prometheus/
Institution	E3Modelling (E3M), Greece, https://e3modelling.com/modelling-tools .
Documentation	PROMETHEUS documentation consists of a referencecard and <u>detailed model documentation</u>
Process state	under review

Model scope and methods

Model documentation: [Model scope and methods - PROMETHEUS](#)

Model type	<input type="checkbox"/> Integrated assessment model <input checked="" type="checkbox"/> Energy system model	<input type="checkbox"/> CGE <input type="checkbox"/> CBA-integrated assessment model
Geographical scope	<input checked="" type="checkbox"/> Global	<input type="checkbox"/> Regional
Objective	<p>PROMETHEUS is a global energy system model covering in detail the complex interactions between energy demand, supply and energy prices at the regional and global level. Its main objectives are: 1) Assess climate change mitigation pathways and low-emission development strategies for the medium and long-term 2) Analyse the energy system, economic and emission implications of a wide spectrum of energy and climate policy measures, differentiated by region and sector) 3) Explore the economics of fossil fuel production and quantify the impacts of climate policies on the evolution of global energy prices</p>	
Solution concept	<input checked="" type="checkbox"/> Partial equilibrium (price elastic demand) <input type="checkbox"/> Partial equilibrium (fixed	demand) <input type="checkbox"/> General equilibrium (closed economy)
Solution horizon	<input checked="" type="checkbox"/> Recursive dynamic (myopic)	

Intertemporal optimization (foresight)

Solution method **Simulation** Optimization

Anticipation Energy system simulation. Foresight is included only in some sub-modules (i.e. electricity generation)

Temporal dimension Base year: 2000, time steps: 1, horizon: 2100

Spatial dimension Number of regions: 10

- | | |
|------------------|---------------------------------|
| 1. China | 6. Middle East and North Africa |
| 2. India | 7. CIS |
| 3. North America | 8. Emerging Economies |
| 4. OECD Pacific | 9. Rest of the world |
| 5. EU-28 | |

Time discounting type **Discount rate exogenous** Discount rate endogenous

Policies	<input checked="" type="checkbox"/> Emission tax	<input checked="" type="checkbox"/> Capacity targets
	<input checked="" type="checkbox"/> Emission pricing	<input checked="" type="checkbox"/> Emission standards
	<input checked="" type="checkbox"/> Cap and trade	<input checked="" type="checkbox"/> Energy efficiency standards
	<input checked="" type="checkbox"/> Fuel taxes	<input type="checkbox"/> Agricultural producer subsidies
	<input checked="" type="checkbox"/> Fuel subsidies	<input type="checkbox"/> Agricultural consumer subsidies
	<input checked="" type="checkbox"/> Feed-in-tariff	<input type="checkbox"/> Land protection
	<input checked="" type="checkbox"/> Portfolio standard	<input type="checkbox"/> Pricing carbon stocks

Socio-economic drivers

Model documentation: Socio-economic drivers - PROMETHEUS

Population **Yes (exogenous)** Yes (endogenous)

Population structure **age** **Yes (exogenous)** Yes (endogenous)

Education level Yes (exogenous) Yes (endogenous)

Urbanization rate	<input checked="" type="checkbox"/> Yes (exogenous)	<input type="checkbox"/> Yes (endogenous)
GDP	<input checked="" type="checkbox"/> Yes (exogenous)	<input type="checkbox"/> Yes (endogenous)
Income distribution	<input type="checkbox"/> Yes (exogenous)	<input type="checkbox"/> Yes (endogenous)
Employment rate	<input checked="" type="checkbox"/> Yes (exogenous)	<input type="checkbox"/> Yes (endogenous)
Labor productivity	<input type="checkbox"/> Yes (exogenous)	<input type="checkbox"/> Yes (endogenous)
Total factor productivity	<input type="checkbox"/> Yes (exogenous)	<input type="checkbox"/> Yes (endogenous)
Autonomous energy efficiency improvements	<input type="checkbox"/> Yes (exogenous)	<input checked="" type="checkbox"/> Yes (endogenous)

Macro-economy

Model documentation: Macro-economy - PROMETHEUS

Economic sector

Industry	<input type="checkbox"/> Yes (physical)	<input type="checkbox"/> Yes (physical & economic)
	<input checked="" type="checkbox"/> Yes (economic)	
Energy	<input type="checkbox"/> Yes (physical)	<input checked="" type="checkbox"/> Yes (physical & economic)
	<input type="checkbox"/> Yes (economic)	
Transportation	<input type="checkbox"/> Yes (physical)	<input checked="" type="checkbox"/> Yes (physical & economic)
	<input type="checkbox"/> Yes (economic)	
Residential and commercial	<input type="checkbox"/> Yes (physical)	<input checked="" type="checkbox"/> Yes (physical & economic)
	<input type="checkbox"/> Yes (economic)	
Agriculture	<input type="checkbox"/> Yes (physical)	<input type="checkbox"/> Yes (physical & economic)
	<input type="checkbox"/> Yes (economic)	
Forestry	<input type="checkbox"/> Yes (physical)	<input type="checkbox"/> Yes (physical & economic)
	<input type="checkbox"/> Yes (economic)	

Macro-economy

Trade

 Coal
 Oil
 Gas
 Uranium

 Electricity
 Bioenergy crops

 Food crops

 Capital

 Emissions permits
 Non-energy goods

Cost measures

 GDP loss

 Welfare loss

 Consumption loss

 Area under MAC

 Energy system cost mark-up

Categorization by group

 Income

 Urban - rural
 Technology adoption
 Age

 Gender

 Education level

 Household size

Institutional and political factors

 Early retirement of capital allowed
 Interest rates differentiated by country/region
 Regional risk factors included

 Technology costs
 differentiated by country/region
 Technological change differentiated by country/region

 Behavioural change differentiated by country/region
 Constraints on cross country financial transfers

Resource use

Coal

 Yes (fixed)

 Yes (supply curve)
 Yes (process model)

Conventional Oil

 Yes (fixed)

 Yes (supply curve)

 Yes (process model)

Unconventional Oil

 Yes (fixed)

 Yes (supply curve)
 Yes (process model)

Conventional Gas

 Yes (fixed)

 Yes (supply curve)

 Yes (process model)

Unconventional Gas

 Yes (fixed)

 Yes (supply curve)

 Yes (process model)

Uranium

 Yes (fixed)

 Yes (supply curve)

Yes (process model)

Bioenergy

Yes (fixed)

Yes (process model)

Yes (supply curve)

Water

Yes (fixed)

Yes (process model)

Yes (supply curve)

Raw Materials

Yes (fixed)

Yes (process model)

Yes (supply curve)

Land

Yes (fixed)

Yes (process model)

Yes (supply curve)

Technological change**Energy conversion technologies**

No technological change

change

Exogenous technological

Endogenous technological change

Energy End-use

No technological change

change

Exogenous technological

Endogenous technological change

Material Use

No technological change

change

Exogenous technological

Endogenous technological change

Agriculture (tc)

No technological change

change

Exogenous technological

Endogenous technological change

Energy

Model documentation: Energy - PROMETHEUS

Energy technology substitution**Energy technology choice**

No discrete technology choices

Production function

Logit choice model

Linear choice (lowest cost)

Lowest cost with adjustment penalties

Energy technology substitutability

- Mostly high substitutability
- Mostly low substitutability

Mixed high and low substitutability

Energy technology deployment

Expansion and decline constraints

System integration constraints

Energy

Electricity technologies

- Coal w/o CCS**
- Coal w/ CCS**
- Gas w/o CCS**
- Gas w/ CCS**
- Oil w/o CCS**
- Oil w/ CCS**
- Bioenergy w/o CCS**
- Bioenergy w/ CCS**
- Geothermal power**
- Nuclear power**

- Solar power**
- Solar power-central PV**
- Solar power-distributed PV
- Solar power-CSP**
- Wind power**
- Wind power-onshore**
- Wind power-offshore**
- Hydroelectric power**
- Ocean power

Hydrogen production

- Coal to hydrogen w/o CCS**
- Coal to hydrogen w/ CCS**
- Natural gas to hydrogen w/o CCS**
- Natural gas to hydrogen w/ CCS**
- Oil to hydrogen w/o CCS
- Oil to hydrogen w/ CCS

- Biomass to hydrogen w/o CCS
- Biomass to hydrogen w/ CCS**
- Nuclear thermochemical hydrogen**
- Solar thermochemical hydrogen**
- Electrolysis**

Refined liquids

- Coal to liquids w/o CCS**
- Coal to liquids w/ CCS**
- Gas to liquids w/o CCS**
- Gas to liquids w/ CCS**

- Bioliqids w/o CCS**
- Bioliqids w/ CCS**
- Oil refining**

Refined gases

- Coal to gas w/o CCS**
- Coal to gas w/ CCS**
- Oil to gas w/o CCS

- Oil to gas w/ CCS
- Biomass to gas w/o CCS**
- Biomass to gas w/ CCS**

Heat generation

- Coal heat
- Natural gas heat

- Oil heat
- Biomass heat

- Geothermal heat
 Solarthermal heat

CHP (coupled heat and power)

Grid Infra Structure

- | | | |
|-----------------------|--|---|
| Electricity | <input checked="" type="checkbox"/> Yes (aggregate) | <input type="checkbox"/> Yes (spatially explicit) |
| Gas | <input type="checkbox"/> Yes (aggregate) | <input type="checkbox"/> Yes (spatially explicit) |
| Heat | <input type="checkbox"/> Yes (aggregate) | <input type="checkbox"/> Yes (spatially explicit) |
| CO₂ | <input type="checkbox"/> Yes (aggregate) | <input type="checkbox"/> Yes (spatially explicit) |
| Hydrogen | <input checked="" type="checkbox"/> Yes (aggregate) | <input type="checkbox"/> Yes (spatially explicit) |

Energy end-use technologies

- | | | |
|-----------------------------------|---|--|
| Passenger transportation | <input type="checkbox"/> Passenger trains | <input checked="" type="checkbox"/> Hybrid LDVs |
| | <input type="checkbox"/> Buses | <input checked="" type="checkbox"/> Gasoline LDVs |
| | <input checked="" type="checkbox"/> Light Duty Vehicles (LDVs) | <input checked="" type="checkbox"/> Diesel LDVs |
| | <input checked="" type="checkbox"/> Electric LDVs | <input type="checkbox"/> Passenger aircrafts |
| | <input checked="" type="checkbox"/> Hydrogen LDVs | |
| Freight transportation | <input type="checkbox"/> Freight trains | <input type="checkbox"/> Freight aircrafts |
| | <input checked="" type="checkbox"/> Heavy duty vehicles | <input type="checkbox"/> Freight ships |
| Industry | <input checked="" type="checkbox"/> Steel production | <input type="checkbox"/> Paper production |
| | <input type="checkbox"/> Aluminium production | <input type="checkbox"/> Plastics production |
| | <input checked="" type="checkbox"/> Cement production | <input type="checkbox"/> Pulp production |
| | <input type="checkbox"/> Petrochemical production | |
| Residential and commercial | <input checked="" type="checkbox"/> Space heating | <input type="checkbox"/> Refrigeration |
| | <input checked="" type="checkbox"/> Space cooling | <input type="checkbox"/> Washing |
| | <input checked="" type="checkbox"/> Cooking | <input checked="" type="checkbox"/> Lighting |

Land-use

Model documentation: [Land-use - PROMETHEUS](#)

- | | | |
|-------------------|-----------------------------------|---|
| Land cover | <input type="checkbox"/> Cropland | <input type="checkbox"/> Cropland irrigated |
|-------------------|-----------------------------------|---|

- | | |
|--|---|
| <input type="checkbox"/> Cropland food crops | <input type="checkbox"/> Natural forest |
| <input type="checkbox"/> Cropland feed crops | <input type="checkbox"/> Pasture |
| <input type="checkbox"/> Cropland energy crops | <input type="checkbox"/> Shrubland |
| <input type="checkbox"/> Forest | <input type="checkbox"/> Built-up area |
| <input type="checkbox"/> Managed forest | |

Agriculture and forestry demands

- | | |
|---|---|
| <input type="checkbox"/> Agriculture food | <input type="checkbox"/> Agriculture non-food crops |
| <input type="checkbox"/> Agriculture food crops | <input type="checkbox"/> Agriculture non-food livestock |
| <input type="checkbox"/> Agriculture food livestock | <input type="checkbox"/> Agriculture bioenergy |
| <input type="checkbox"/> Agriculture feed | <input type="checkbox"/> Agriculture residues |
| <input type="checkbox"/> Agriculture feed crops | <input type="checkbox"/> Forest industrial roundwood |
| <input type="checkbox"/> Agriculture feed livestock | <input type="checkbox"/> Forest fuelwood |
| <input type="checkbox"/> Agriculture non-food | <input type="checkbox"/> Forest residues |

Agricultural commodities

- | | |
|--|---|
| <input type="checkbox"/> Wheat | <input type="checkbox"/> Sugar crops |
| <input type="checkbox"/> Rice | <input type="checkbox"/> Ruminant meat |
| <input type="checkbox"/> Other coarse grains | <input type="checkbox"/> Non-ruminant meat and eggs |
| <input type="checkbox"/> Oilseeds | <input type="checkbox"/> Dairy products |

Emission, climate and impacts

Model documentation: Emissions - PROMETHEUS, Climate - PROMETHEUS, Non-climate sustainability dimension - PROMETHEUS

Greenhouse gases

- | | |
|---|---------------------------------------|
| <input checked="" type="checkbox"/> CO2 fossil fuels | <input type="checkbox"/> N2O land use |
| <input checked="" type="checkbox"/> CO2 cement | <input type="checkbox"/> N2O other |
| <input type="checkbox"/> CO2 land use | <input type="checkbox"/> CFCs |
| <input checked="" type="checkbox"/> CH4 energy | <input type="checkbox"/> HFCs |
| <input type="checkbox"/> CH4 land use | <input type="checkbox"/> SF6 |
| <input type="checkbox"/> CH4 other | <input type="checkbox"/> PFCs |
| <input checked="" type="checkbox"/> N2O energy | |

Pollutants

- | | |
|---------------------------------------|---------------------------------------|
| <input type="checkbox"/> CO energy | <input type="checkbox"/> SO2 land use |
| <input type="checkbox"/> CO land use | <input type="checkbox"/> SO2 other |
| <input type="checkbox"/> CO other | <input type="checkbox"/> BC energy |
| <input type="checkbox"/> NOx energy | <input type="checkbox"/> BC land use |
| <input type="checkbox"/> NOx land use | <input type="checkbox"/> BC other |
| <input type="checkbox"/> NOx other | <input type="checkbox"/> OC energy |
| <input type="checkbox"/> VOC energy | <input type="checkbox"/> OC land use |
| <input type="checkbox"/> VOC land use | <input type="checkbox"/> OC other |
| <input type="checkbox"/> VOC other | <input type="checkbox"/> NH3 energy |
| <input type="checkbox"/> SO2 energy | <input type="checkbox"/> NH3 land use |

NH3 other

Climate indicators

- Concentration: CO2**
- Concentration: CH4**
- Concentration: N2O**
- Concentration: Kyoto gases**
- Radiative forcing: CO2
- Radiative forcing: CH4
- Radiative forcing: N2O
- Radiative forcing: F-gases

- Radiative forcing: Kyoto gases
- Radiative forcing: aerosols
- Radiative forcing: land albedo
- Radiative forcing: AN3A
- Radiative forcing: total
- Temperature change
- Sea level rise
- Ocean acidification

Carbon dioxide removal

- Bioenergy with CCS**
- Reforestation
- Afforestation

- Soil carbon enhancement
- Direct air capture**
- Enhanced weathering

Climate change impacts

- Agriculture
- Energy supply
- Energy demand

- Economic output
- Built capital
- Inequality

Co-Linkages

- Energy security: Fossil fuel imports & exports (region)**
- Energy access: Household energy consumption**
- Air pollution & health: Source-based aerosol emissions

- Air pollution & health: Health impacts of air Pollution
- Food access
- Water availability
- Biodiversity

Model Documentation - PROMETHEUS

Introduction

The PROMETHEUS model provides detailed projections of energy demand, supply, power generation mix, energy-related carbon emissions, energy prices and investment to the future covering the global energy system. PROMETHEUS is a fully fledged energy demand and supply simulation model aiming at addressing energy system analysis, energy price projections, power generation planning and climate change mitigation policies. PROMETHEUS contains relations and/or exogenous variables for all the main quantities, which are of interest in the context of general energy systems analysis. These include demographic and economic activity indicators, primary and final energy consumption by main fuel, fuel resources and prices, CO2 emissions, greenhouse gases concentrations and technology dynamics (for power generation, road transport, hydrogen production and industrial and residential end-use technologies).

PROMETHEUS quantifies CO₂ emissions and incorporates environmentally oriented emission abatement technologies (like RES, electric vehicles, CCS, energy efficiency) and policy instruments. The latter include both market based instruments such as cap and trade systems with differential application per region and sector specific policies and measures focusing on specific carbon emitting activities. Key characteristics of the model, that are particularly pertinent for performing the analysis of the implications of alternative climate abatement scenarios, include world supply/demand resolution for determining the prices of internationally traded fuels and technology dynamics mechanisms for simulating spill-over effects for technological improvements (increased uptake of a new technology in one part of the world leads to improvements through learning by experience which eventually benefits the energy systems in other parts of the World).

PROMETHEUS is designed to provide medium and long term energy system projections and system restructuring up to 2050, both in the demand and the supply sides. The model produces analytical quantitative results in the form of detailed energy balances in the period 2015 to 2050 annually. The model can support impact assessment of specific energy and environment policies and measures, applied at regional and global level, including price signals, such as taxation, subsidies, technology and energy efficiency promoting policies, RES supporting policies, environmental policies and technology standards.

PROMETHEUS is a self-contained large-scale world energy demand and supply model consisting of a large set of equations describing the time evolution of key variables, which are of interest in the context of a general analysis of the energy-environment-economic system. The model can be used either in its deterministic or in its stochastic mode. Equations in PROMETHEUS represent the model's endogenous variables as a function of other endogenous variables, exogenous variables, parameters and residual terms. PROMETHEUS incorporates a recursive dynamic (partial equilibrium energy system) model with annual resolution currently serviced to run up to the year 2050 (the process to extend model horizon to 2100 is ongoing). The PROMETHEUS model has a triangular structure in order to avoid contemporaneous simultaneity. On the other hand, simultaneity is modelled through lagged instances of endogenous variables. Most of the model equations are specified in difference terms in order to avoid excessive early variability and adequately represent accumulation of uncertainty in the longer term.

The model simulates both demand and supply of energy, interacting with each other to form market equilibrium at different regional scales: detailed regional balances are aggregated in order to simulate world energy markets. Apart from international fuel prices, regional energy systems influence each other particularly through trade, technical progress and network effects including changing patterns of consumption and spillover effects with regard to technology diffusion.

The geographical representation is based on the importance of countries in energy consumption and GHG emissions. PROMETHEUS describes full energy and emissions balances for 10 geographical units, in particular for: China, India, North America (USA and Canada), OECD Pacific (Japan, S. Korea, Australia, New Zealand), EU-28, CIS (Russian Federation and other Commonwealth of Independent States), MENA (Middle East and North Africa), EMRG (Emerging economies) and RESTW (Rest of the world).

The model runs with a 1 year time step, usually from 2018 to 2050, the 2015-2018 period being almost entirely set by data and used for calibration. The model horizon will be expanded to 2100.

PROMETHEUS model is organized in sub-models (modules), each one representing the behaviour of a representative agent, a demander and/or a supplier of energy. The figure below presents a simplified summary flow chart of the PROMETHEUS model. The main modules are:

- 1) The demographic and economic activity module, which projects population and activity growth for each region.
- 2) The fossil fuel supply module that includes oil and gas resources, while coal is assumed to have abundant supplies relative to production prospects at least for the projection time horizon
- 3) The biomass supply module, which contains technical and economic potential for biomass per region and their effects on biomass costs.
- 4) The cost-supply curves for renewable energy sources (RES) module.
- 5) The fuel prices module projecting both international and final consumer prices, with the latter being differentiated for each demand sector. Global fossil fuel prices are determined from the equilibrium of demand and supply of each fuel at the global level.
- 6) The final energy demand module, projecting energy demand and fuel mix in three main sectors; industry, transport and residential/services/agriculture sector. The following energy forms are considered as options in the final demand sectors: natural gas, oil, coal, biofuels, electricity, steam and hydrogen. The private passenger cars sector is modelled in detail, by distinguishing the following types of passenger cars: internal combustion engine cars (using gasoline, diesel, biofuels or hydrogen as a fuel), conventional and plug-in hybrids, electric cars and fuel-cell cars (using hydrogen or gasoline as a fuel).
- 7) The electricity generation module, identifying 26 power generation technologies and their competition to cover electricity demand for base, medium and peak load.
- 8) The hydrogen production sub-model, identifying 18 hydrogen production options
- 9) The hydrogen storage and delivery module, including 16 different technological options in order to represent in detail the development of hydrogen infrastructure.
- 10) The technology dynamics module, which endogenises technical progress through both learning by research and learning by experience (“learning by doing”) mechanisms.
- 12) The technology diffusion module incorporating network effects accelerating spillovers between regions in cases where technology uptake attains critical levels

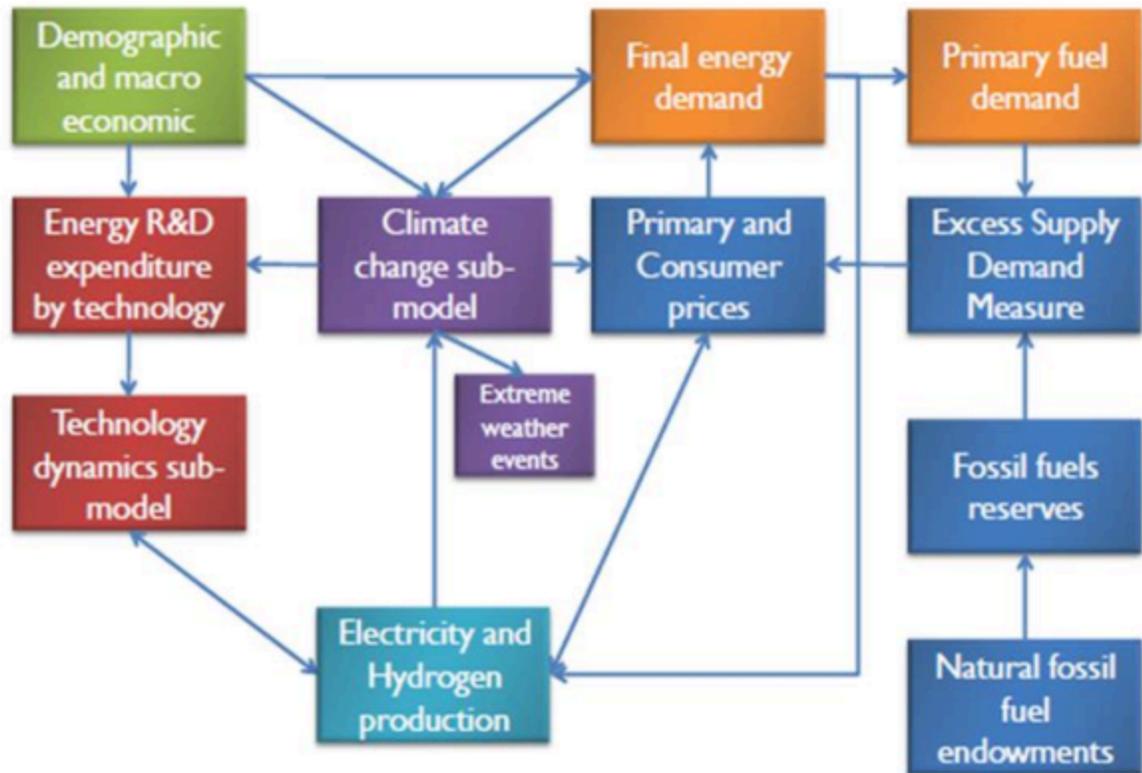
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Socio-economic drivers

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PROMETHEUS modules

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Macro-economy

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- **Technological change**

Energy

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Non-climate sustainability dimension

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Appendices

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- Data

References

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