Energy Modelling and Scenario Analysis to Inform Policy Decisions for the 2030 Energy Transition

Regional Scenario Results

Exploring and facilitating the transition to sustainable energy systems
Models? Not crystal balls!
Processing data and assumptions

• Models are mathematical representations of real-world relationships, calibrated with historical data

• Assumptions required to parameterize models
  ▪ Future rates of technological development
  ▪ Socioeconomics
  ▪ Policy changes

• The model solves the mathematical relationships, given the input assumptions

• Scenarios explore different assumptions about inputs

• Policies can be defined through changes to model assumptions or specific policy goals

Using models

Models can inform policy makers on the implications of proposed domestic or international policies

Models cannot determine the “best” technology or policy options
## Scenario development

**Illustration of scenario design**

### INPUT

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Population by region</th>
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<tbody>
<tr>
<td>Productivity</td>
<td>GDP per capita by region</td>
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<tr>
<td>Technology</td>
<td>Power plant conversion efficiency, Transport fuel economy, etc., Crop yields, etc.</td>
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<tr>
<td>Resources</td>
<td>Fossil fuel, uranium, solar, wind, geothermal, land, water and other</td>
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<td>Policies</td>
<td>Pollution control, NDCs, Water use</td>
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### MODEL

**Integrated Model**
- Resource extraction, exports-imports, energy transformation and use
- Markets
- Capital
- Labor
- Agriculture
- Land use
- Carbon cycle
- Atmosphere
- Hydrology
- Oceans

### OUTPUT

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<thead>
<tr>
<th>Energy Security</th>
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<tr>
<td>Price of energy</td>
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<td>Energy imports/exports</td>
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<td>Electricity access</td>
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<td>Energy/GDP</td>
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<th>Quality of Life</th>
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<td>GDP per capita</td>
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<td>Energy services per capita</td>
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<td>Share calories from non-staples</td>
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<td>Water stress</td>
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<tr>
<th>Environmental Sustainability</th>
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<td>SO₂, NOₓ, O₃ concentrations</td>
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<td>Deforestation/afforestation</td>
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<td>Avg. Earth surface temp</td>
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<td>Water withdrawals/recharge</td>
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### Targets/Goals

LPG/KPI
I. Reference Scenario

Based on SSP 2* as point of departure, i.e., without dedicated sustainable energy or climate policies.

II. NDC scenario

A scenario that implements by 2030 the NDCs under the Paris Agreement but maintains the NDCs beyond 2030 – kind of NDCs forever. It also includes other current policies towards sustainable energy.

III. Designing pathways towards sustainable energy - Paris to 2°C -

One key component of SE is the 2°C target of the Paris Agreement by 2100 (Environment pillar). The other two pillars “energy security” and “quality of life” to follow – but models require quantified targets (similar to Paris to 2°C)

SSP: Shared Socio-economic pathway to 2100. Pathway 2 is a middle of the road future

Note: Metrics and KPIs will inform and quantify trade-offs between the three pillars
Central Asia (CAS) - REF Scenario

Final energy demand by sector

Final energy supply mix by fuel

Modeling Results: Demand & supply
Final energy: CAS
Central Asia (CAS) - P2C Scenario

Final energy demand by sector

Final energy supply mix by fuel
Modeling Results: Energy system transformation

Natural gas markets: CAS

Uses of natural gas in the CAS Region

Reference

P2C

Difference P2C minus REF

- Text
Uses of coal in the CAS Region

**Reference**

**P2C**

**Difference P2C minus REF**

- **Exports**
- **Electricity**
- **Electricity CCS**
- **District heat**
- **Synfuels**
- **Synfuels CCS**
- **T/D losses**
- **Feedstock**
- **Transportation**
- **Industry**
- **Resident/Commercial**
Modeling Results: Sectors
Final energy use: CAS

Industry: CAS Region

- Reference
- P2C
- Difference P2C minus REF

- Text
Modeling Results: Sectors
Final energy: CAS

Residential/Commercial sector: CAS Region

Reference

P2C

Difference P2C minus REF

- **Coal**
- **Biomass**
- **Oil-liquids**
- **Bio-liquids**
- **Coal-liquids**
- **Gas-liquids**
- **Gas**
- **Hydrogen**
- **Elec**
- **Heat**
- **Sol (el)**
- **Other**

- **Text**
Modeling Results: CAS

Electricity Generation

Electricity generation by technology and fuel - CAS

REF Scenario

- Wind Offshore
- Wind Onshore
- CSP
- PV
- Geothermal
- Biomass CCS
- Biomass
- Hydro
- Nuclear
- Gas CCS
- Gas
- Oil CCS
- Oil
- Coal CCS
- Coal
Modeling Results: CAS
Electricity Generation

Electricity generation by technology and fuel - CAS
P2C Scenario

- Wind Offshore
- Wind Onshore
- CSP
- PV
- CSP Onshore
- PV
- Geothermal
- Geothermal
- Biomass CCS
- Biomass
- Hydro
- Hydro
- Nuclear
- Nuclear
- Gas CCS
- Gas
- Gas CCS
- Gas
- Oil CCS
- Oil
- Oil CCS
- Oil
- Coal CCS
- Coal
- Coal CCS
Modeling Results: CAS
Electricity Generation

Difference in electricity generation – CAS: P2C versus REF Scenario

- Wind Offshore
- Wind Onshore
- CSP
- PV
- Geothermal
- Biomass CCS
- Biomass
- Hydro
- Nuclear
- Gas CCS
- Gas
- Oil CCS
- Oil
- Coal CCS
- Coal
Modeling Results: CAS

Electricity Generation

Generating capacities by technology - CAS

REF Scenario
Generating capacities by technology - CAS

P2C Scenario

- Wind Offshore
- Wind Onshore
- CSP
- PV
- Geothermal
- Biomass CCS
- Biomass
- Hydro
- Nuclear
- Gas CCS
- Gas
- Oil CCS
- Oil
- Coal CCS
- Coal
Difference in electricity generating capacities – CAS: P2C versus REF Scenario

- Wind Offshore
- Wind Onshore
- CSP
- PV
- Geothermal
- Biomass CCS
- Biomass
- Hydro
- Nuclear
- Gas CCS
- Gas
- Oil CCS
- Oil
- Coal CCS
- Coal
Modeling Results: Indicators
Investment needs: CAS

Cumulative investments 2020-2050: 1,700 billion US$
REF – CAS Region

- Upstream fossil sources: 1,211
  - Coal: 26
  - Oil: 0.2
  - Gas: 13
  - Nuclear: 7
  - Hydro: 24
  - Solar: 1
  - Wind: 11

- T&D: transmission and distribution of electricity and district heat
- Investments in US$ at 2010 prices and exchange rates
Cumulative investments 2020-2050: 1,686 billion US$

P2C – CAS Region

- **T&D**: transmission and distribution of electricity and district heat
- Investments in US$ at 2010 prices and exchange rates

### Upstream fossil sources
- **Coal**: 17
- **Coal CCS**: 2.2
- **Oil**: 0.2
- **Gas**: 21
- **Gas CCS**: 13
- **Nuclear**: 7
- **Hydro**: 39
- **Biomass**: 0.5
- **Biomass CCS**: 0.2
- **Solar**: 29
- **Wind**: 31

- **Heat, hydrogen, etc.**: 206
- **Energy efficiency**: 274
- **Electricity generation**: 160
- **T&D**: 175
- **Upstream fossil sources**: 871
Comparing investment requirements - CAS
REF, NDC and P2C scenarios

- T/D&S: transmission, distribution and storage of electricity and district heat
- CCS: carbon capture and storage
- H2: hydrogen
- BAT: Best available technology
Final energy intensity improves as aging infrastructure is being replaced and economies undergo structural change.

Energy expenditures per GDP decline by 2030 but slow down thereafter.

Carbon intensity of GDP declines faster than CO₂/MWh as the economy undergoes modernization and shifts to the production of higher value added goods and services.

Share of RE declines until 2030; thereafter expands slower compared to most other regions.

CAS turns from a net importing region to an exporter by 2050.

Indicators are scaled relative to 2020 (2020=1); an improvement in any indicator will result in values lower than 1.

If the shape of polygon becomes smaller compared to 2020, it shows improvements in the indicators.
Modeling Results: Indicators

Tradeoffs and synergies: CAS

Indicators: Energy security, environment, quality of life
CAS – P2C Scenario

- Energy system transformation clearly discernible by 2050
- Significant change in energy expenditures by 2030 (> 1) and remain thereafter at substantially higher level than in REF and NDC
- Drastic improvement of the $\text{CO}_2$/MWh indicator (>95% compared to 2020) outpacing carbon intensity of GDP
- Energy intensities decline along with the unprecedented investments in unprecedented measures
- Total energy sector costs reduced due to higher non-fossil domestic energy use and increased gas exports

Indicators are scaled relative to 2020 (2020=1); an improvement in any indicator will result in values lower than 1.
If the shape of polygon becomes smaller compared to 2020, it shows improvements in the indicators.
Modeling Results: Demand & supply

Final energy: SCS

South Caucasus (SCS) - REF Scenario

Final energy demand by sector

Final energy supply mix by fuel
Modeling Results: Demand & supply

South Caucasus (SCS) - P2C Scenario

Final energy demand by sector

Final energy supply mix by fuel
Modeling Results: Fuel markets

Natural gas markets: SCS

Uses of natural gas in the SCS Region

Reference

P2C

Difference P2C minus REF

- Exports
- Electricity
- Electricity CCS
- District heat
- Synfuels
- Synfuels CCS
- T/D losses
- Feedstock
- Transportation
- Industry
- Resident/Commercial
Modeling Results: Fuel markets

Coal markets: SCS

Uses of coal in the SCS Region

Reference

P2C

Difference P2C minus REF

Exports  Electricity  Electricity CCS  District heat  Synfuels  Synfuels CCS  T/D losses  Feedstock  Transportation  Industry  Resident/Commercial
Modeling Results: Sectors
Final energy use: SCS

Industry: SCS Region

Reference

P2C

Difference P2C minus REF

- Coal
- Biomass
- Oil-liquids
- Bio-liquids
- Gas-liquids
- Gas
- Hydrogen
- Elec
- Heat
- Sol (el)
- Other

Final energy [EJ]
Modeling Results: Sectors
Final energy use: SCS

Residential/Commercial sector: SCS Region

- Text
Modeling Results: SCS

Electricity Generation

Electricity generation by technology and fuel - SCS

REF Scenario

- Wind Offshore
- Wind Onshore
- CSP
- PV
- Geothermal
- Biomass CCS
- Biomass
- Hydro
- Nuclear
- Gas CCS
- Gas
- Oil CCS
- Oil
- Coal CCS
- Coal
Modeling Results: SCS
Electricity Generation

Electricity generation by technology and fuel - SCS
P2C Scenario
Modeling Results: SCS
Electricity Generation

Difference in electricity generation – SCS:
P2C versus REF Scenario

- Wind Offshore
- Wind Onshore
- CSP
- PV
- Geothermal
- Biomass CCS
- Biomass
- Hydro
- Nuclear
- Gas CCS
- Gas
- Oil CCS
- Oil
- Coal CCS
- Coal
Modeling Results: SCS
Electricity Generation

Generating capacities by technology - SCS
REF Scenario

- Wind Offshore
- Wind Onshore
- CSP
- PV
- Geothermal
- Biomass CCS
- Biomass
- Hydro
- Nuclear
- Gas CCS
- Gas
- Oil CCS
- Oil
- Coal CCS
- Coal
Modeling Results: SCS
Electricity Generation

Generating capacities by technology - SCS
P2C Scenario

- Wind Offshore
- Wind Onshore
- CSP
- PV
- Geothermal
- Biomass CCS
- Biomass
- Hydro
- Nuclear
- Gas CCS
- Gas
- Oil CCS
- Oil
- Coal CCS
- Coal

GW

35
30
25
20
15
10
5
0

2010 2015 2020 2025 2030 2035 2040 2045
Difference in electricity generation – SCS: P2C versus REF Scenario

GW
-10 -5 0 5 10 15 20 25
2010 2015 2020 2025 2030 2035 2040 2045 2050

- Wind Offshore
- Wind Onshore
- CSP
- PV
- Geothermal
- Biomass CCS
- Biomass
- Hydro
- Nuclear
- Gas CCS
- Gas
- Oil CCS
- Oil
- Coal CCS
- Coal
Cumulative investments 2020-2050: 371 billion US$
REF – SCS Region

- Upstream fossil sources 279
- T&D 35
- Heat, hydrogen, etc. 44
- Electricity generation 14

- Oil 1
- Gas 4
- Hydro 6
- Wind 2
- Biomass 0.07
- Solar 0.01

- T&D: transmission and distribution of electricity and district heat
- Investments in US$ at 2010 prices and exchange rates
Cumulative investments 2020-2050: 375 billion US$

P2C – SCS Region

- **Upstream fossil sources**: 193
- **Energy efficiency**: 60
- **Electricity generation**: 37
- **Heat, hydrogen, etc.**: 43
- **T&D**: 42

**Investment needs: SCS**

- **Cumulative investments 2020-2050**: 375 billion US$

**T&D**: transmission and distribution of electricity and district heat

**Investments in US$ at 2010 prices and exchange rates**
Comparing investment requirements - SCS REF, NDC and P2C scenarios

- T/D&S: transmission, distribution and storage of electricity and district heat
- CCS: carbon capture and storage
- H2: hydrogen
- BAT: Best available technology
Indicators: Energy security, environment, quality of life

SCS - REF Scenario

- Indicators are scaled relative to 2020 (2020=1); an *improvement in any indicator will result in values lower than 1*
- If the shape of polygon becomes smaller compared to 2020, it shows improvements in the indicators
Indicators: Energy security, environment, quality of life

SCS – P2C Scenario

- Indicators are scaled relative to 2020 (2020=1); an *improvement in any indicator will result in values lower than 1*.
- If the shape of polygon becomes smaller compared to 2020, it shows improvements in the indicators.
Modeling Results: Demand & supply
Final energy: BMU

Belarus, Moldova and Ukraine (BMU) - REF Scenario

Final energy demand by sector

Final energy supply mix by fuel

- Coal
- Biomass
- Oil-liquids
- Gas
- Coal-liquids
- Gas-liquids
- Hydrogen
- Electricity
- Heat
- Sol (el)
- Other
Modeling Results: Demand & supply

Final energy: BMU

Belarus, Moldova and Ukraine (BMU) - P2C Scenario

Final energy demand by sector

Final energy supply mix by fuel
Modeling Results: Fuel markets
Natural gas markets: BMU

Uses of natural gas in the BMU Region

Reference

P2C

Difference P2C minus REF

- Exports
- Electricity
- Electricity CCS
- District heat
- Synfuels
- Synfuels CCS
- T/D losses
- Feedstock
- Transportation
- Industry
- Resident/Commercial
Modeling Results: Fuel markets

Coal markets: BMU

Uses of coal in the BMU Region

**Reference**

**P2C**

**Difference P2C minus REF**

- **Exports**
- **Electricity**
- **Electricity CCS**
- **District heat**
- **Synfuels**
- **Synfuels CCS**
- **T/D losses**
- **Feedstock**
- **Transportation**
- **Industry**
- **Resident/Commercial**

- **Text**
Modeling Results: Sectors
Final energy use: BMU

Industry: BMU Region

- Text
Modeling Results: Sectors
Final energy use: BMU

Residential/Commercial sector: BMU Region

- Text
Modeling Results: BMU
Electricity Generation

Electricity generation by technology and fuel - BMU
REF Scenario
Modeling Results: BMU
Electricity Generation

Electricity generation by technology and fuel - BMU
P2C Scenario

- Wind Offshore
- Wind Onshore
- CSP
- PV
- Geothermal
- Biomass CCS
- Biomass
- Hydro
- Nuclear
- Gas CCS
- Gas
- Oil CCS
- Oil
- Coal CCS
- Coal
Modeling Results: BMU
Electricity Generation

Difference in electricity generation – BMU: P2C versus REF Scenario

- Wind Offshore
- Wind Onshore
- CSP
- PV
- Geothermal
- Biomass CCS
- Biomass
- Hydro
- Nuclear
- Gas CCS
- Gas
- Oil CCS
- Oil
- Coal CCS
- Coal

TWh

2010 2015 2020 2025 2030 2035 2040 2045 2050

Modeling Results: BMU

Electricity Generation

Generating capacities by technology - BMU

REF Scenario

GW

<table>
<thead>
<tr>
<th>Year</th>
<th>Wind Offshore</th>
<th>Wind Onshore</th>
<th>CSP</th>
<th>PV</th>
<th>Geothermal</th>
<th>Biomass CCS</th>
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</table>
Modeling Results: BMU

Generating capacities by technology - BMU

P2C Scenario
Modeling Results: BMU

Electricity Generation

Difference in electricity generating capacities – BMU: P2C versus REF Scenario

- Wind Offshore
- Wind Onshore
- CSP
- PV
- Geothermal
- Biomass CCS
- Biomass
- Hydro
- Nuclear
- Gas CCS
- Gas
- Oil CCS
- Oil
- Coal CCS
- Coal
Modeling Results: Indicators
Investment needs: BMU

Cumulative investments 2020-2050: 372 billion US$
REF – BMU Region

- T&D: transmission and distribution of electricity and district heat
- Investments in US$ at 2010 prices and exchange rates

- Upstream fossil sources
  - Coal: 101 billion US$
  - Oil: 14 billion US$
  - Gas: 9 billion US$
  - Nuclear: 10 billion US$
  - Hydro: 2 billion US$
- Electricity generation
  - Wind: 15 billion US$
  - Solar: 3.3 billion US$
  - Gas: 9 billion US$
  - Nuclear: 10 billion US$
  - Hydro: 2 billion US$
- Heat, hydrogen, etc.
  - 79 billion US$
- T&D: 137 billion US$
Cumulative investments 2020-2050: 520 billion US$
P2C – BMU Region

- T&D: transmission and distribution of electricity and district heat
- Investments in US$ at 2010 prices and exchange rates
Comparing investment requirements - BMU
REF, NDC and P2C scenarios

- T/D&S: transmission, distribution and storage of electricity and district heat
- CCS: carbon capture and storage
- H2: hydrogen
- BAT: Best available technology

Billion US$2010

Energy efficiency
T&D and storage
Nuclear
Renewables
Fossil CCS and hydrogen
Fossil fuel (extraction and conversion)
Indicators: Energy security, environment, quality of life

**BMU - REF Scenario**

- Indicators are scaled relative to 2020 (2020=1); an improvement in any indicator will result in values lower than 1.
- If the shape of polygon becomes smaller compared to 2020, it shows improvements in the indicators.
Indicators: Energy security, environment, quality of life
BMU - REF Scenario

Comparing different indicators relative to 2020 REF scenario, BMU

- Indicators are scaled relative to 2020 (2020=1); an improvement in any indicator will result in values lower than 1.
- If the shape of polygon becomes smaller compared to 2020, it shows improvements in the indicators.