

CAS

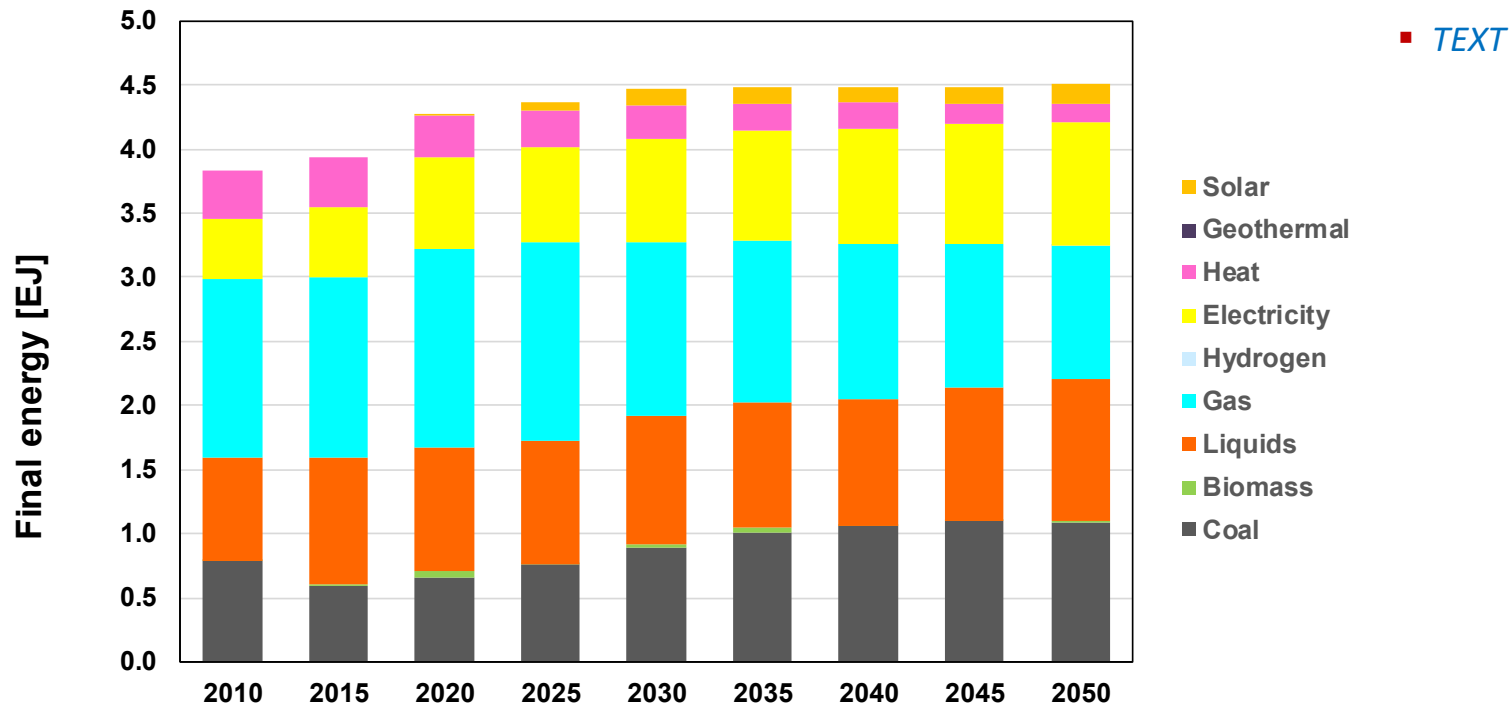
Modeling Results: CAS

Final Energy Mix

ENERGY



Final energy mix - CAS REF Scenario



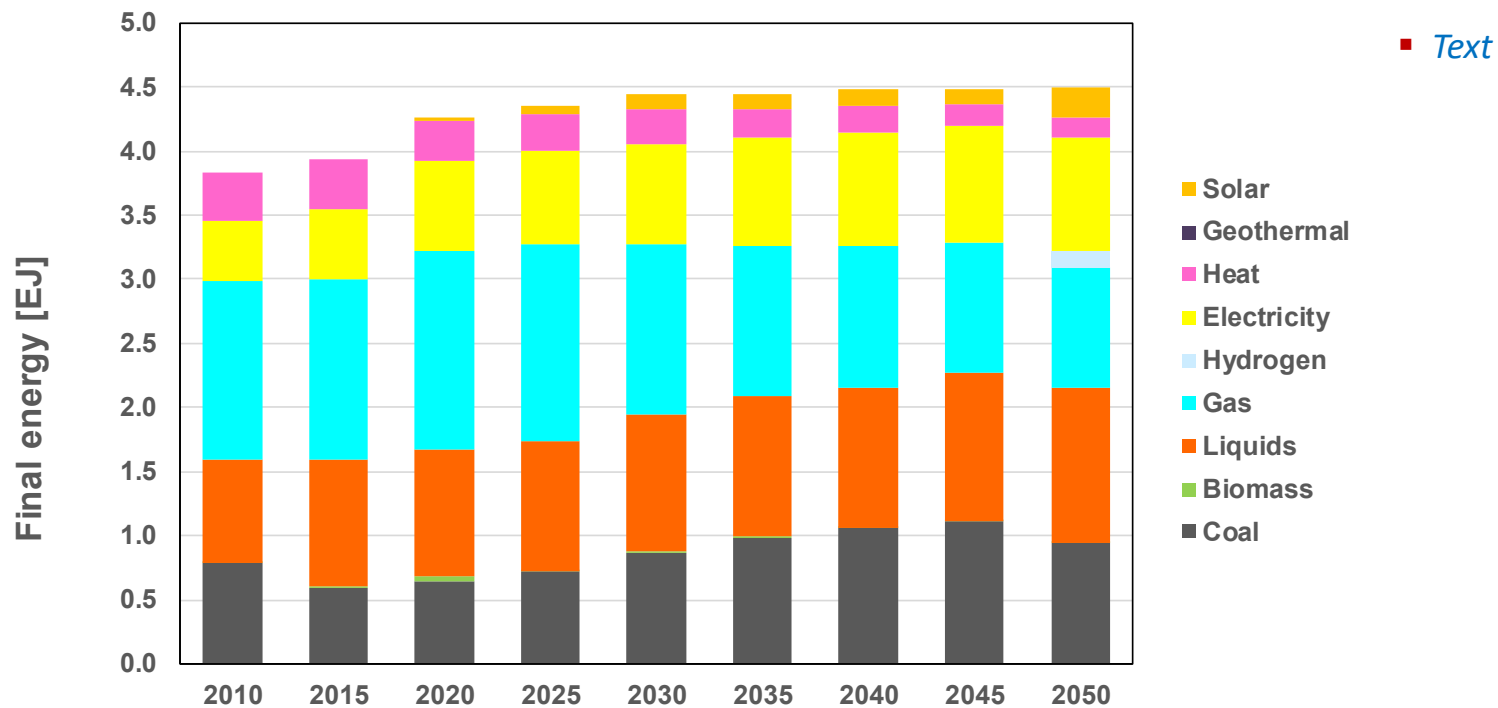
Modeling Results: CAS

Final Energy Mix

ENERGY



Final energy mix - CAS NDC Scenario



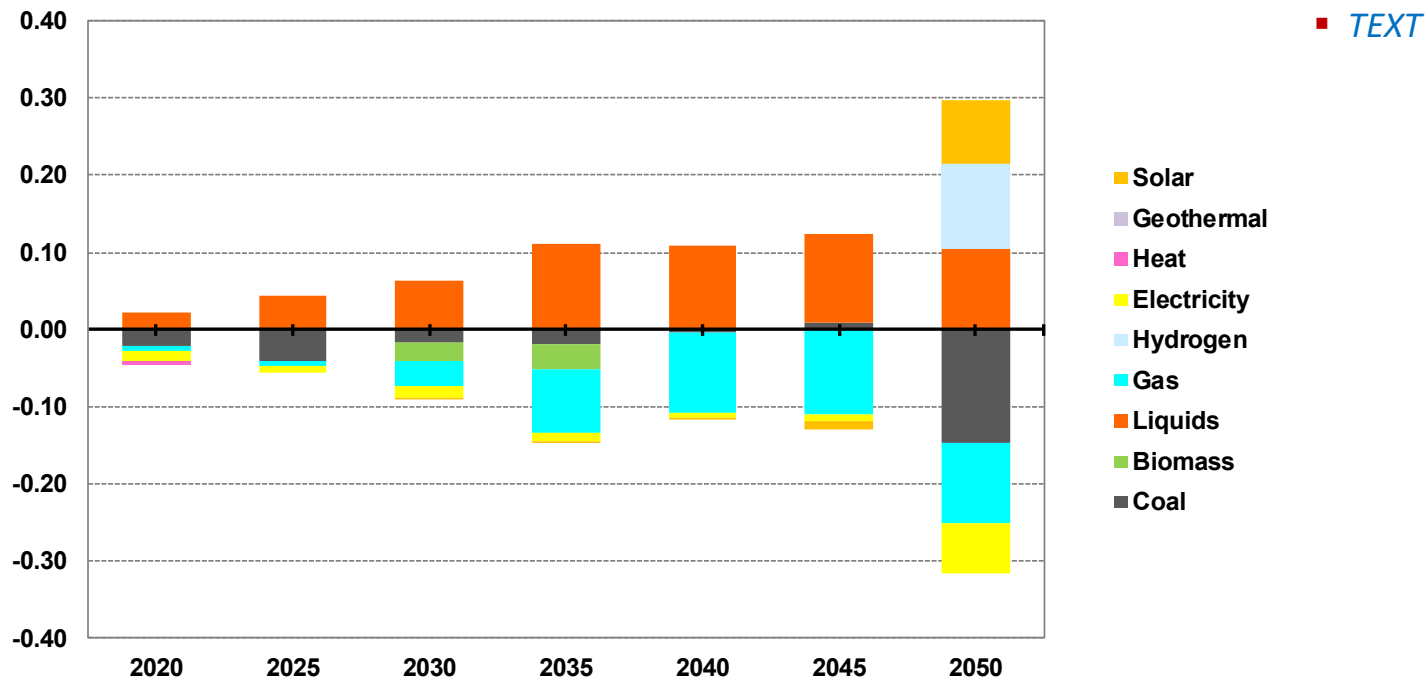
Modeling Results: CAS

Final Energy Mix: Scenario differences

ENERGY



Final energy mix - CAS NDC versus REF Scenario



Modeling Results: CAS

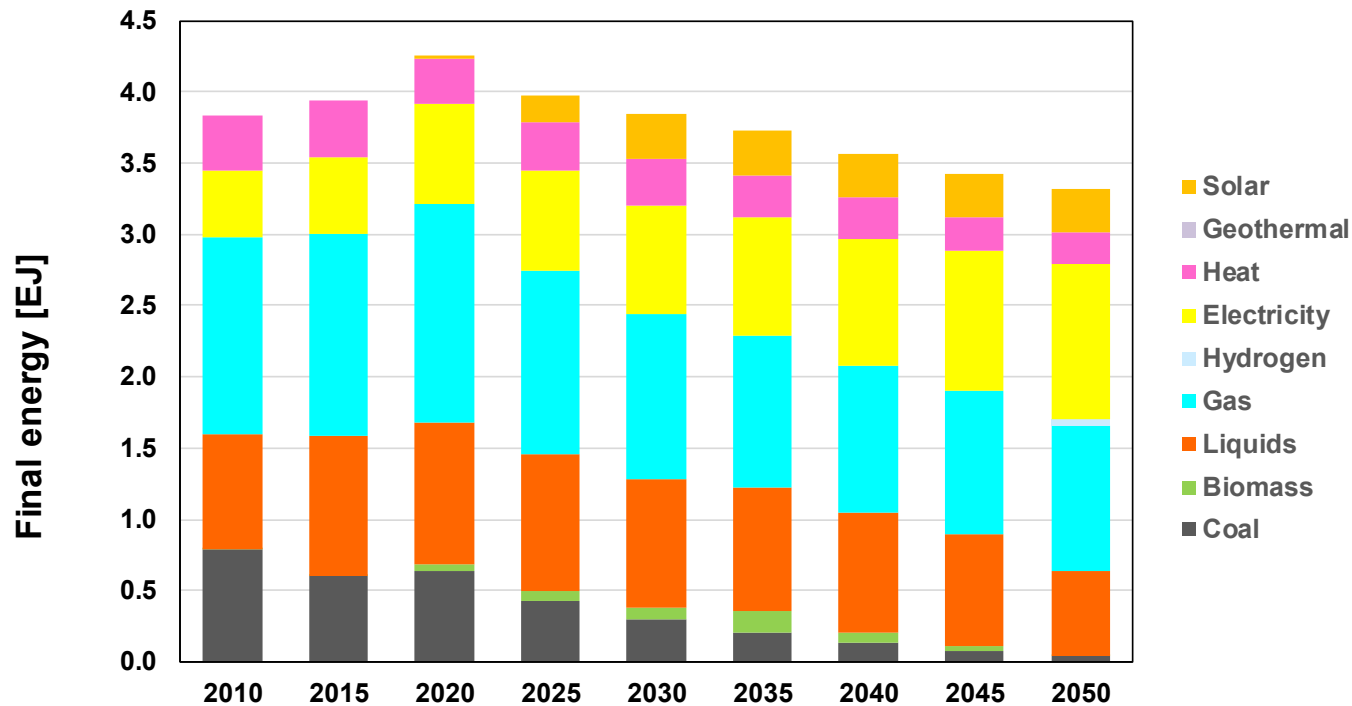
Final Energy Mix

ENERGY



Final energy mix - CAS P2C Scenario

■ *TEXT*



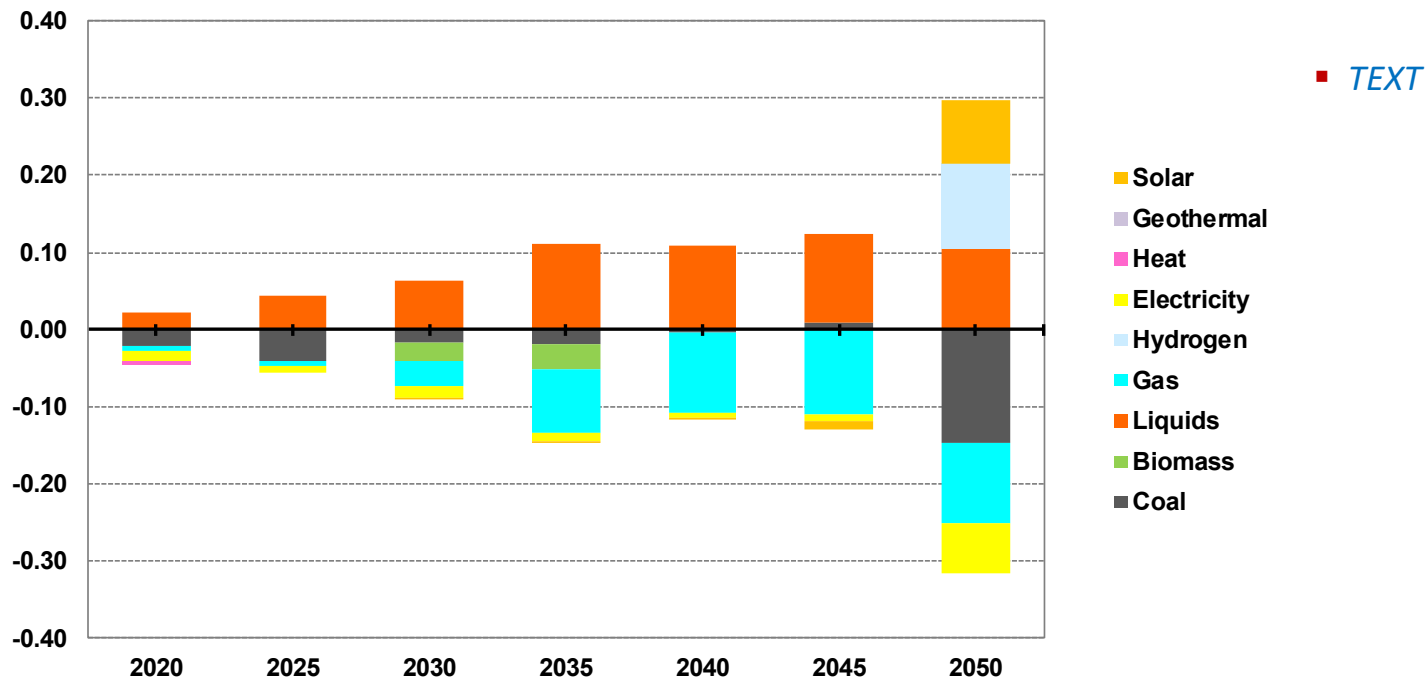
Modeling Results: CAS

Final Energy Mix: Scenario differences

ENERGY



Final energy mix - CAS P2C versus REF Scenario



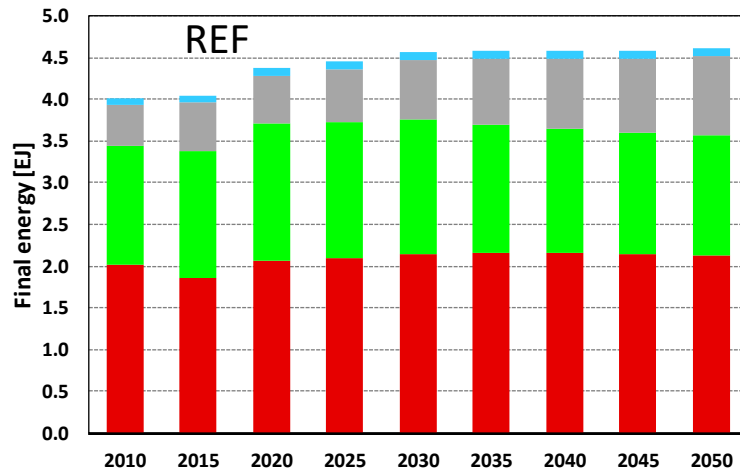
Modeling Results: CAS

Sector implications

ENERGY

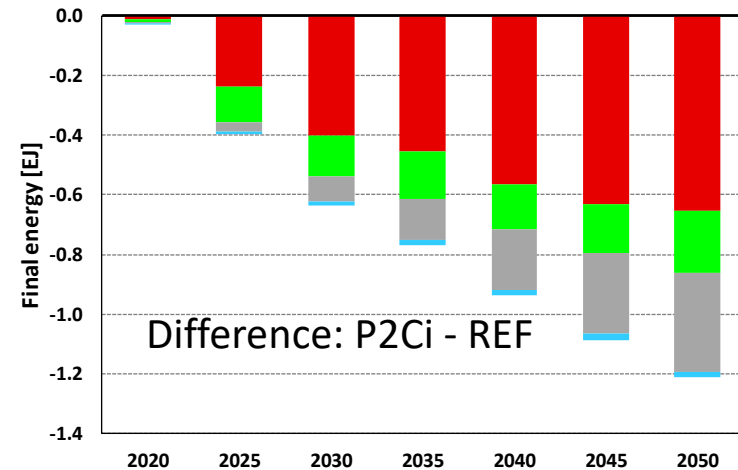
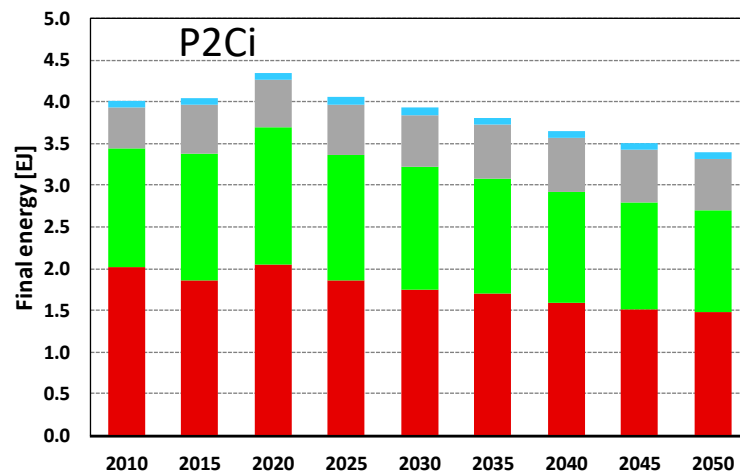


Final energy by sector - CAS



- Non-energy use
- Transportation
- Residential & commercial
- Industry

■ TEXT



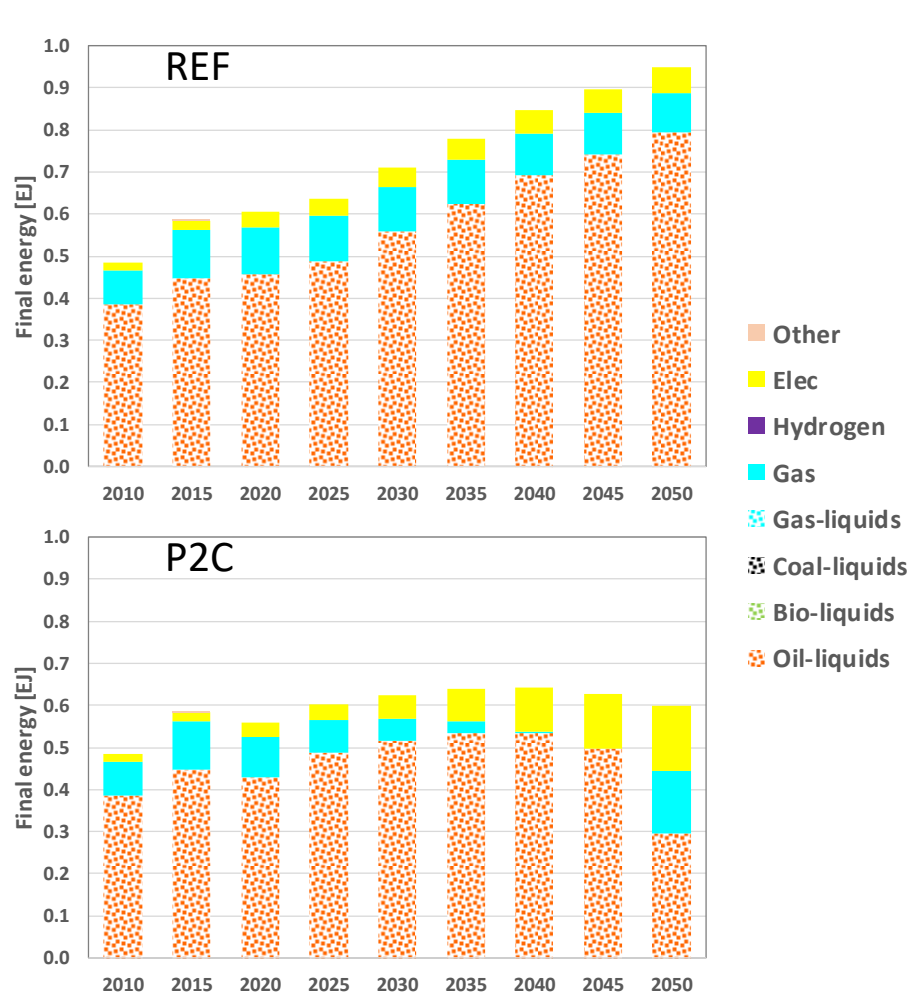
Modeling Results: CAS

Sector implications: Transportation

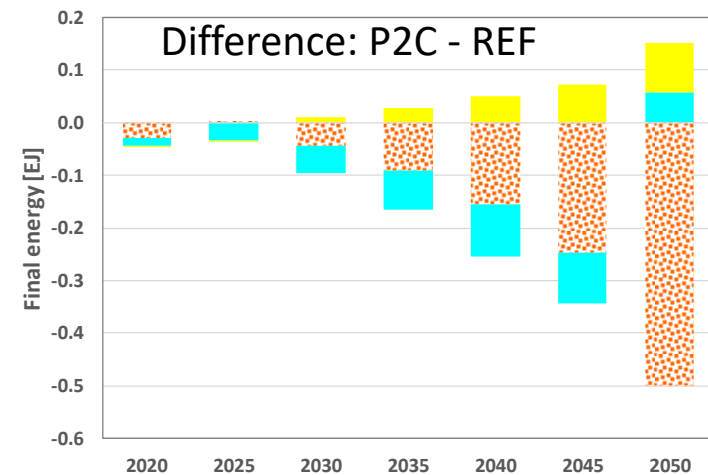
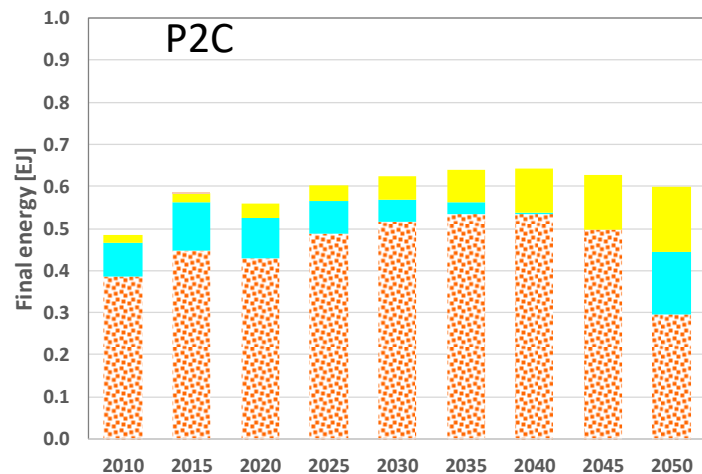
ENERGY



Final transportation sector - CAS



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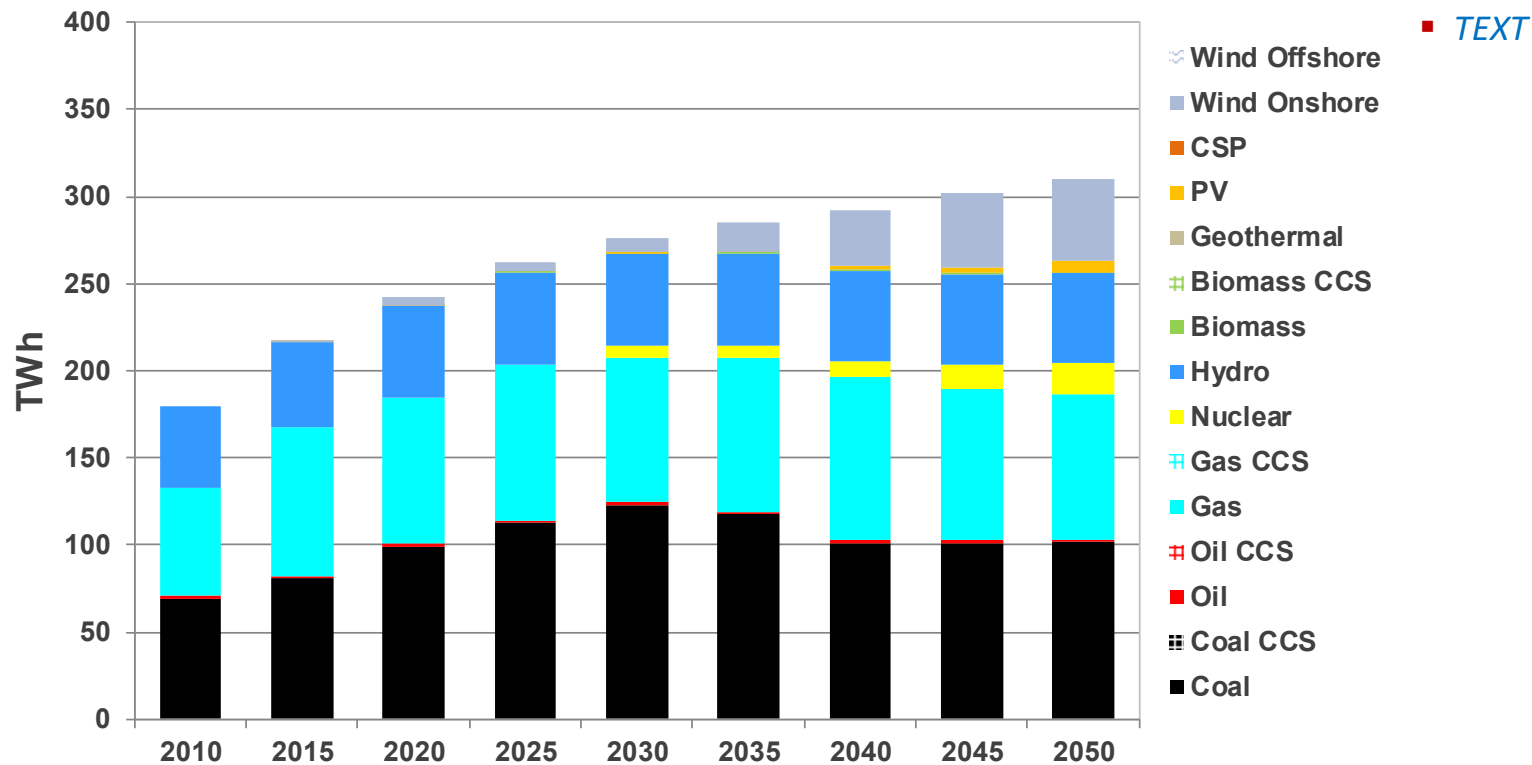
Modeling Results: CAS

Electricity Generation

ENERGY



Electricity generation by technology - CAS REF Scenario



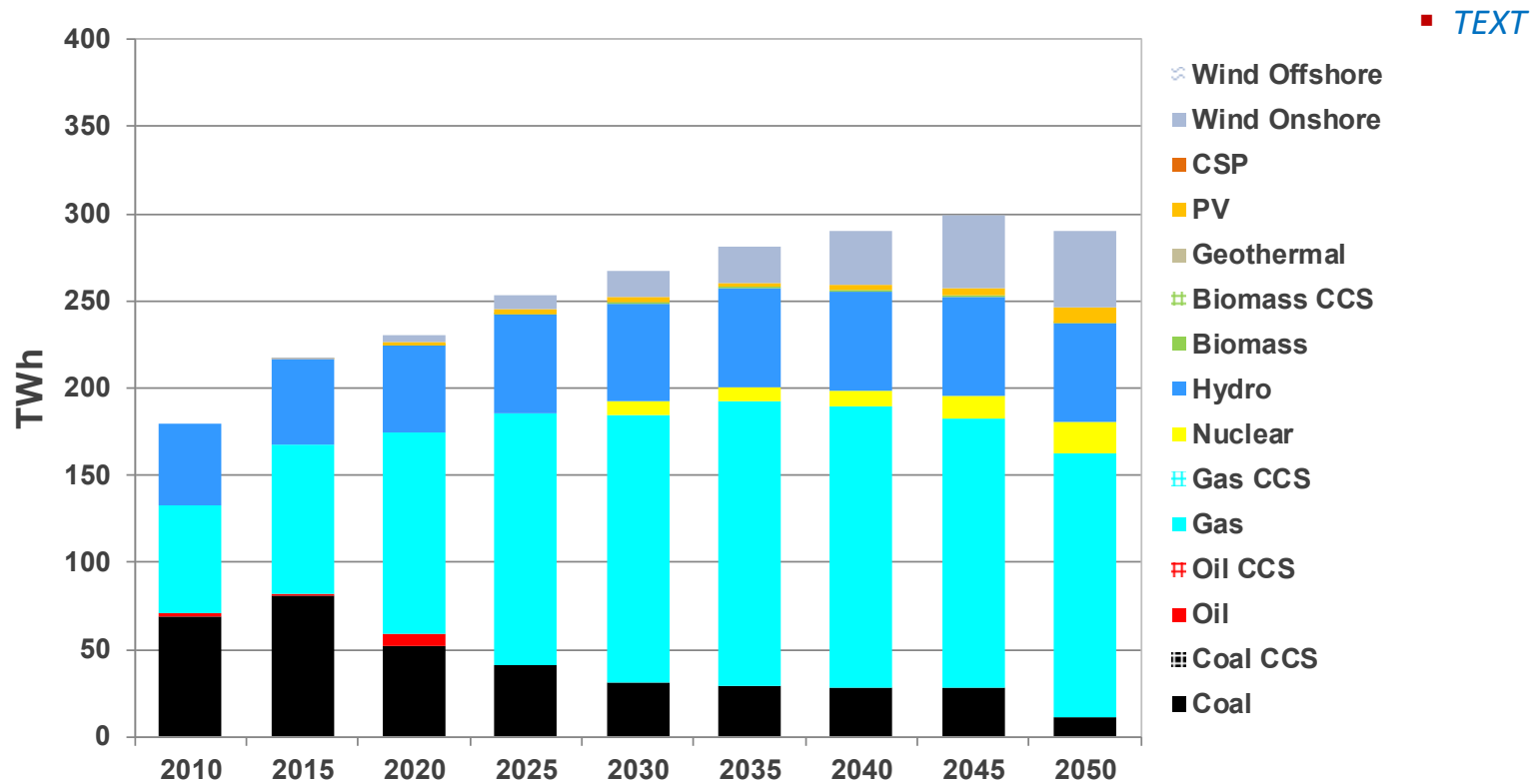
Modeling Results: CAS

Electricity Generation

ENERGY



Electricity generation by technology - CAS NDC



Modeling Results: CAS

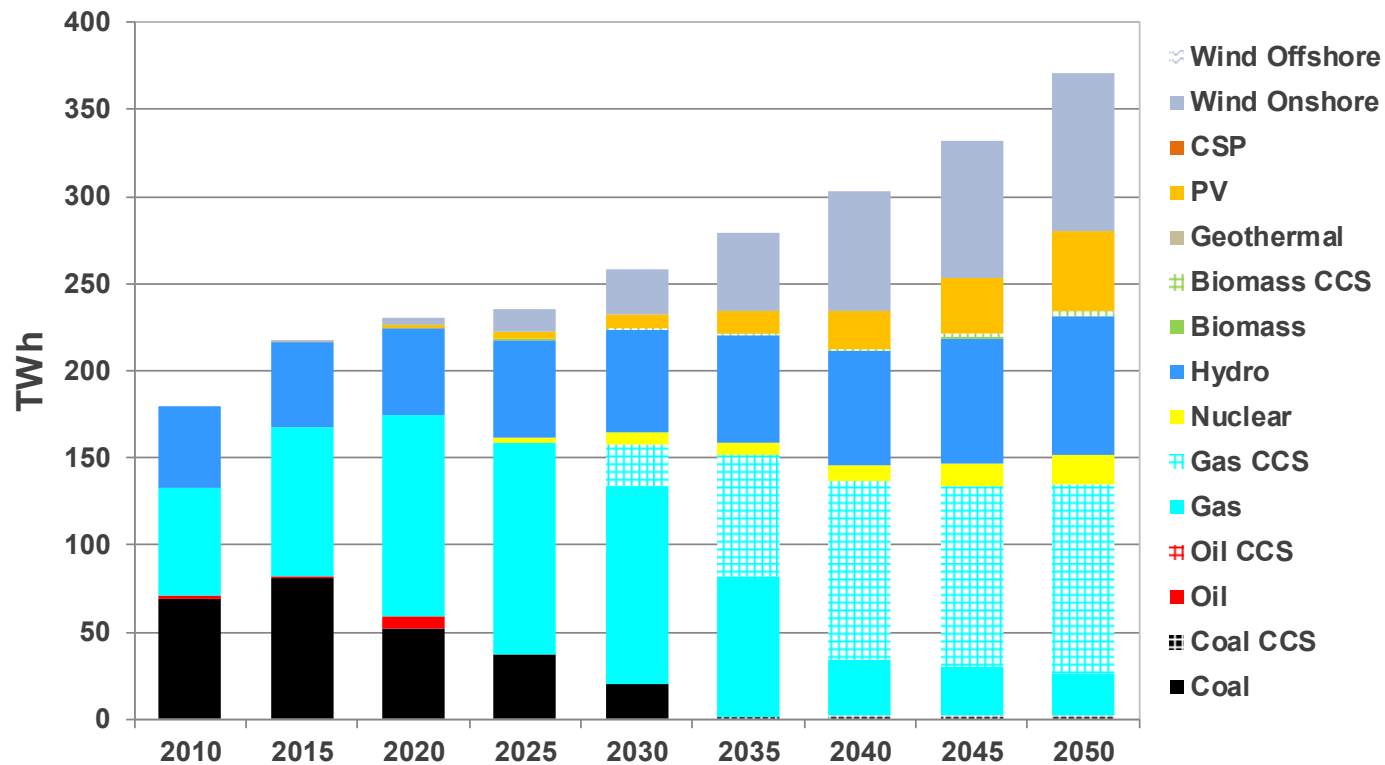
Electricity Generation

ENERGY



Electricity generation by technology - CAS P2C

■ TEXT



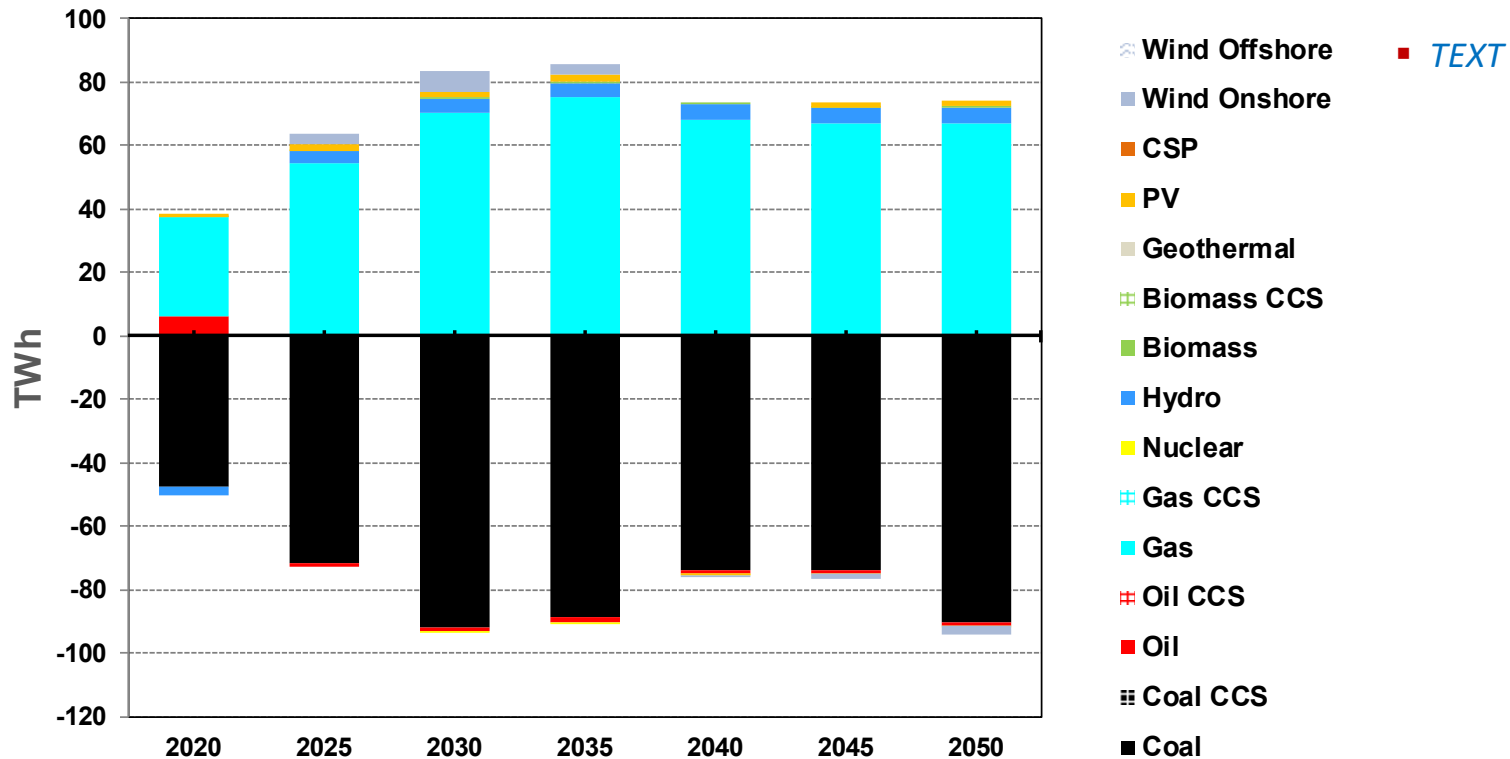
Modeling Results: CAS

Electricity Generation

ENERGY



Electricity generation by technology & fuel - CAS Difference: NDC - REF



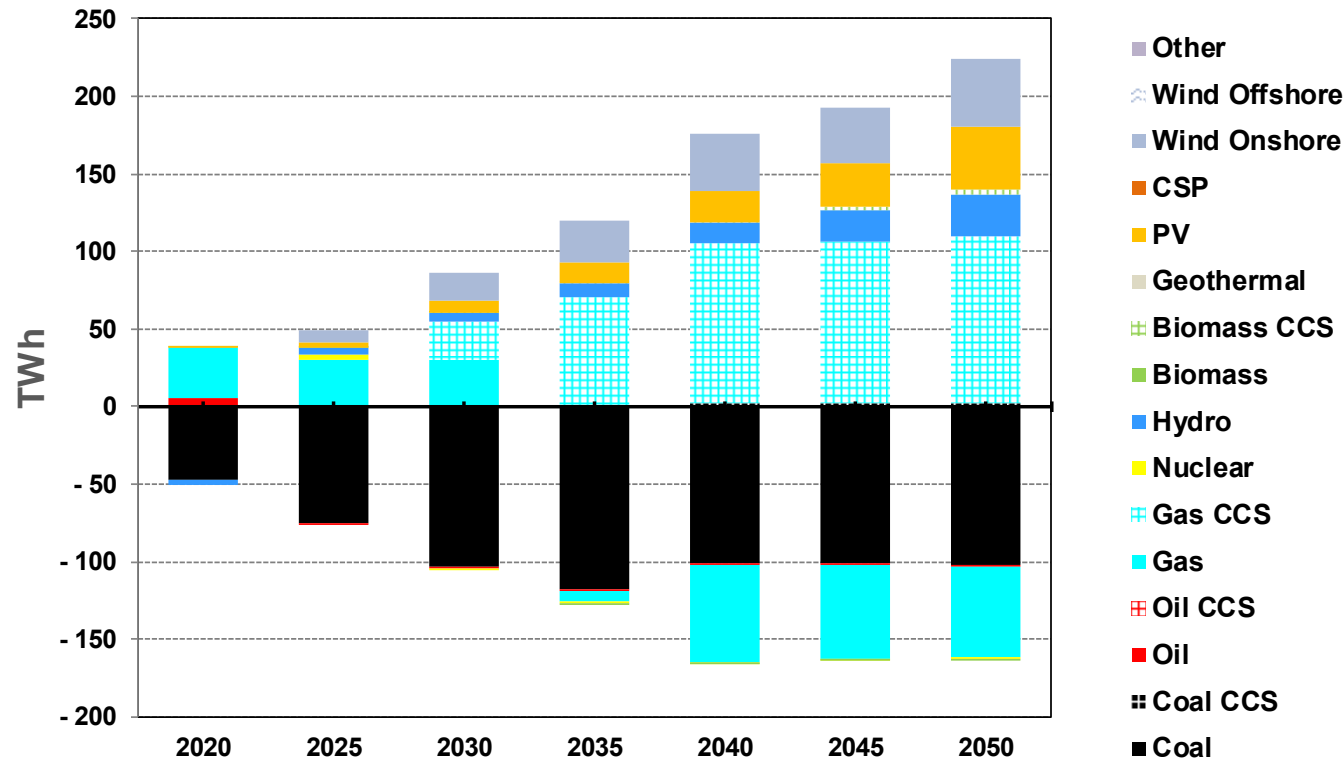
Modeling Results: CAS

Electricity Generation

ENERGY



Electricity generation by technology & fuel - CAS Difference: P2C - REF



- Low carbon generation displace coal and natural gas without CCS
- Gas with CCS allows natural gas to become the lead technology in generation by 2050
- Coal gets completely phased out (some minor coal with CCS survives until 2050)
- Fast expansion of off-shore wind and solar PV
- Modest expansion of nuclear power in the longer run

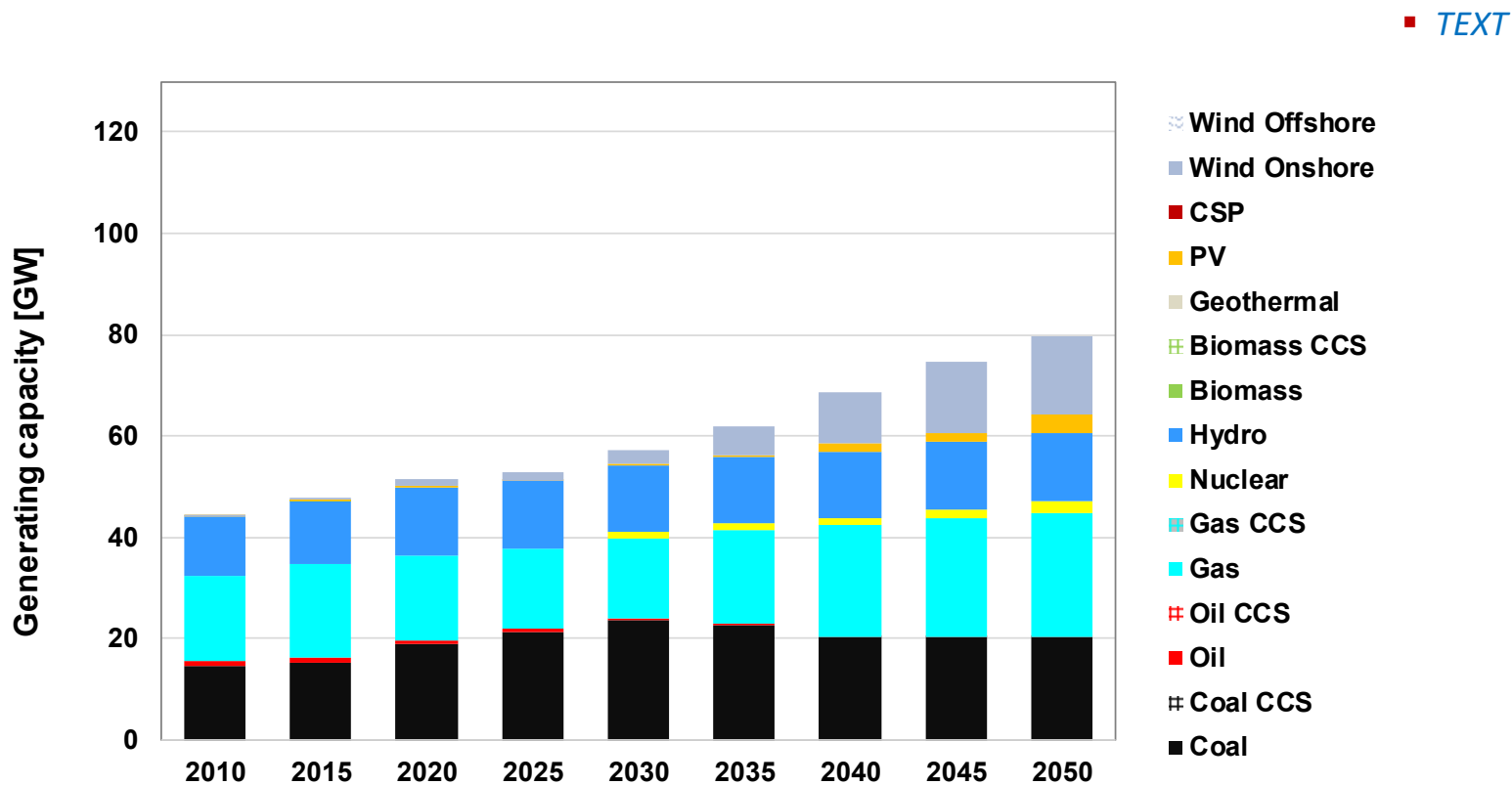
Modeling Results: CAS

Electricity generating capacity

ENERGY



Electricity generating capacity by technology - CAS REF Scenario



Modeling Results: CAS

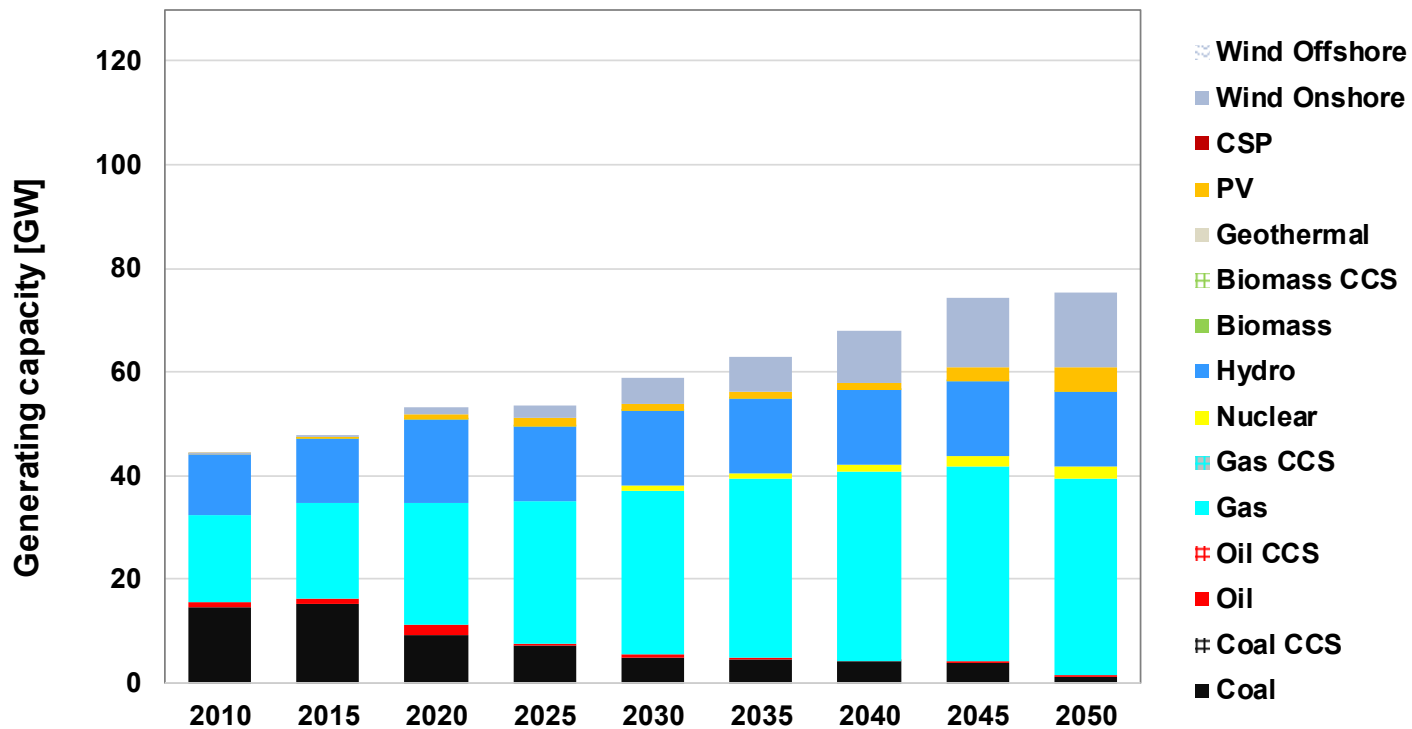
Electricity generating capacity

ENERGY



Electricity generating capacity by technology - CAS NDC

■ TEXT



Modeling Results: CAS

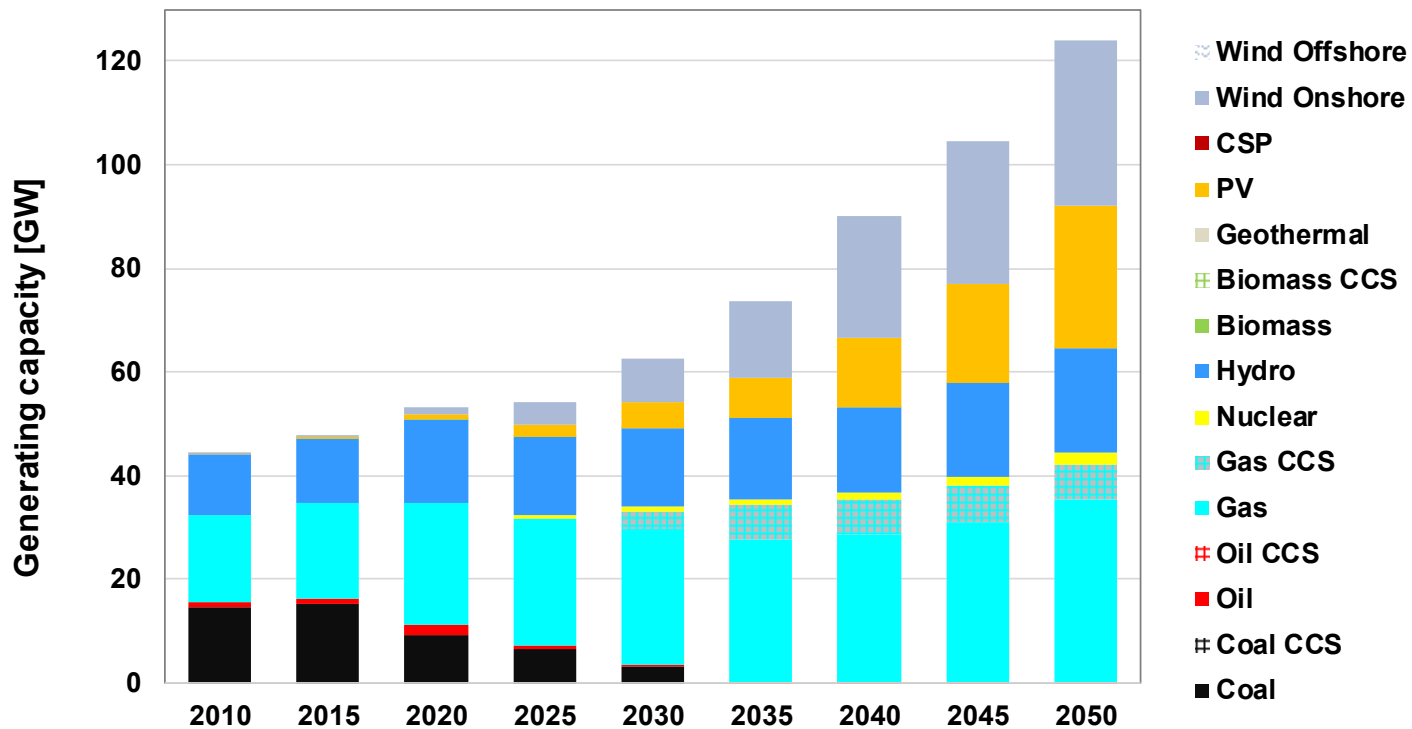
Electricity generating capacity

ENERGY



Electricity generating capacity by technology - CAS P2C

■ TEXT



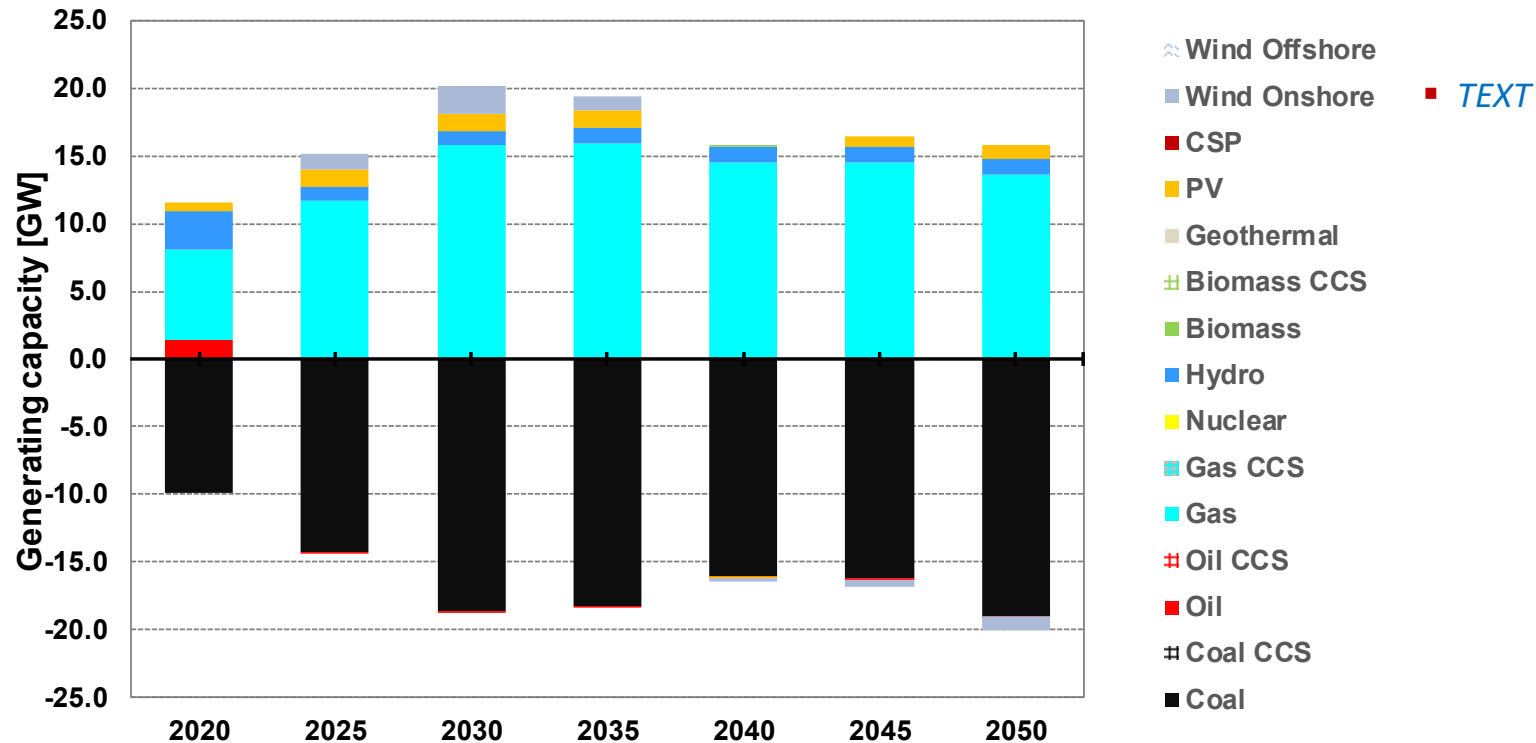
Modeling Results: CAS

Electricity generating capacity

ENERGY



Electricity generating capacity by technology & fuel - CAS Difference: NDC - REF



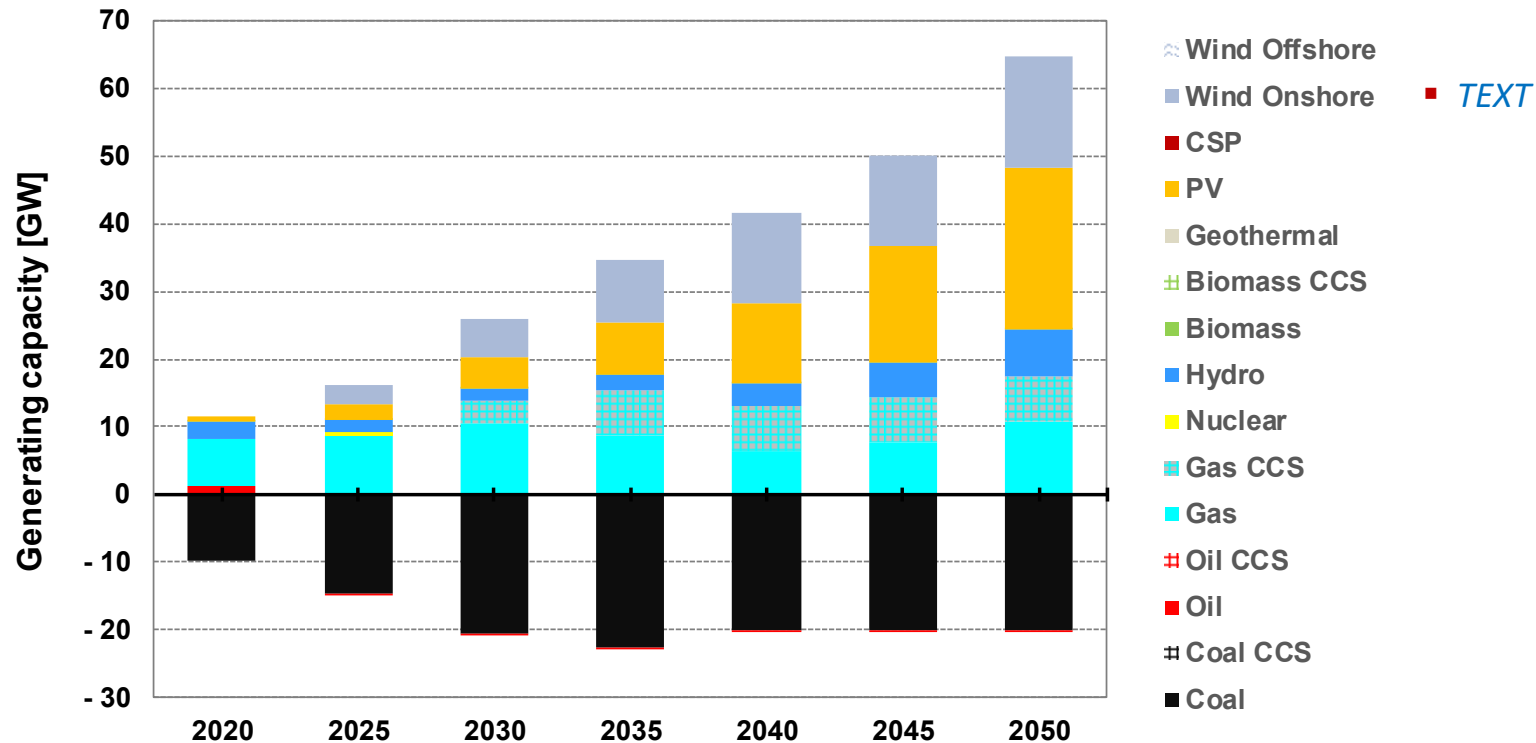
Modeling Results: CAS

Electricity generating capacity

ENERGY



Electricity generating capacity by technology & fuel - CAS Difference: P2C - REF



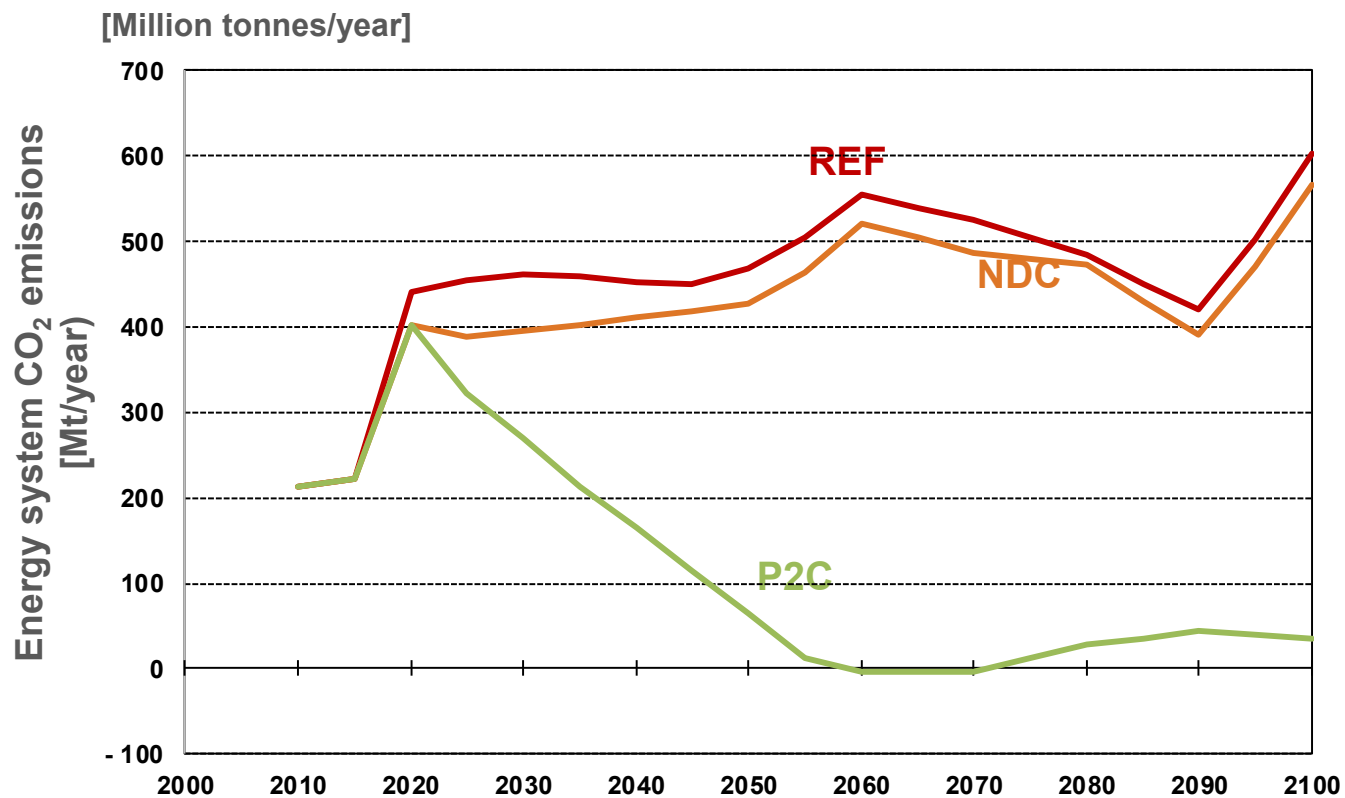
Modeling Results: CAS

Carbon dioxide emissions

ENERGY



CO₂ emissions by scenario - CAS



- **REF: Emission growth stopped by 2060 and emissions decline thereafter**
- **Strong rebound after 2090 due added gas use for electricity generation and growth of fossil fuels in meeting final energy demand**
- **NDC: Follow the trend of REF after 2030 given the 'ambition' assumptions**
- **Cumulative (2020-2100) NDC emissions are only 7.4% or 13.9 Gt CO₂ lower than in REF and annual emissions are almost identical by 2100)**
- **P2C: Emissions peak by 2020**
- **Slightly negative emissions between 2060 and 2070**
- **Emissions positive again after 2070 with a second peak of 40 Mt in 2090 (or 10% of the absolute peak in 2020)**

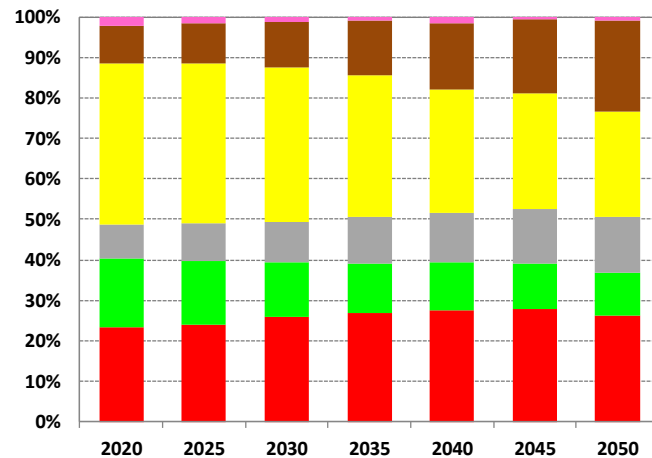
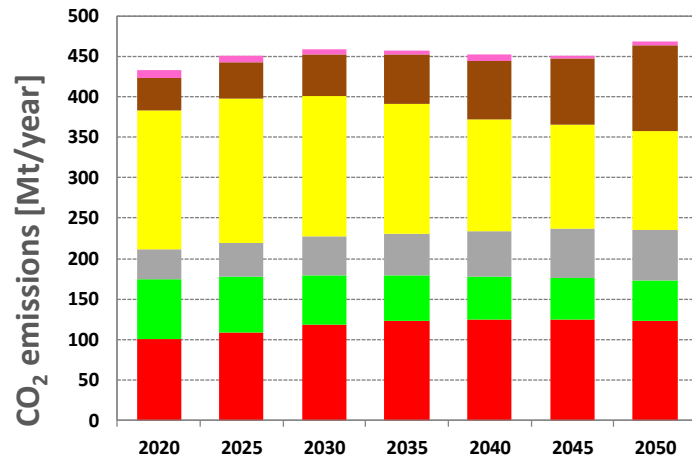
Modeling Results: CAS

Carbon dioxide emissions

ENERGY



CO₂ emissions by sector – CAS REF Scenario



- Heat
- Fuel supply
- Electricity generation
- Transportation
- Residential/commercial
- Industry

- *Marginal emission increases from electricity generation and fossil upstream operations including synfuel and hydrogen manufacture*
- *Largest emission growth from transportation*
- *Industry CO₂ emissions expand slightly*
- *Residential/commercial sector emissions are stable after a short-term expansion*

NOTE: **Fuel supply** includes emissions from extraction, refining, synfuel and biofuel manufacture

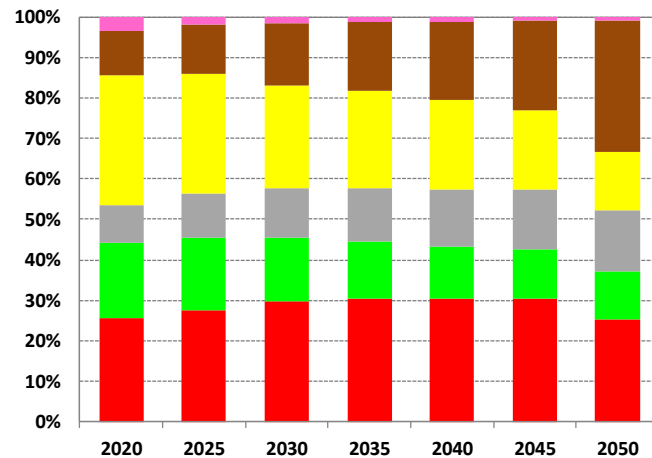
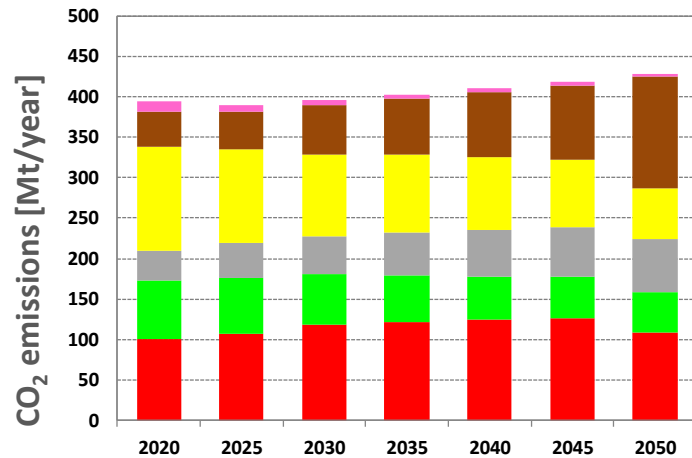
Modeling Results: CAS

Carbon dioxide emissions

ENERGY



CO₂ emissions by sector – CAS NDC Scenario



- Heat
- Fuel supply
- Electricity generation
- Transportation
- Residential/commercial
- Industry

- Lower NDC final energy demand and electricity generation responses:
 - Electricity generation related CO₂ reductions more pronounced than in REF but the slack is largely absorbed by fossil upstream operations, followed by transportation and industry

NOTE: Fuel supply includes emissions from extraction, refining, synfuel and biofuel manufacture

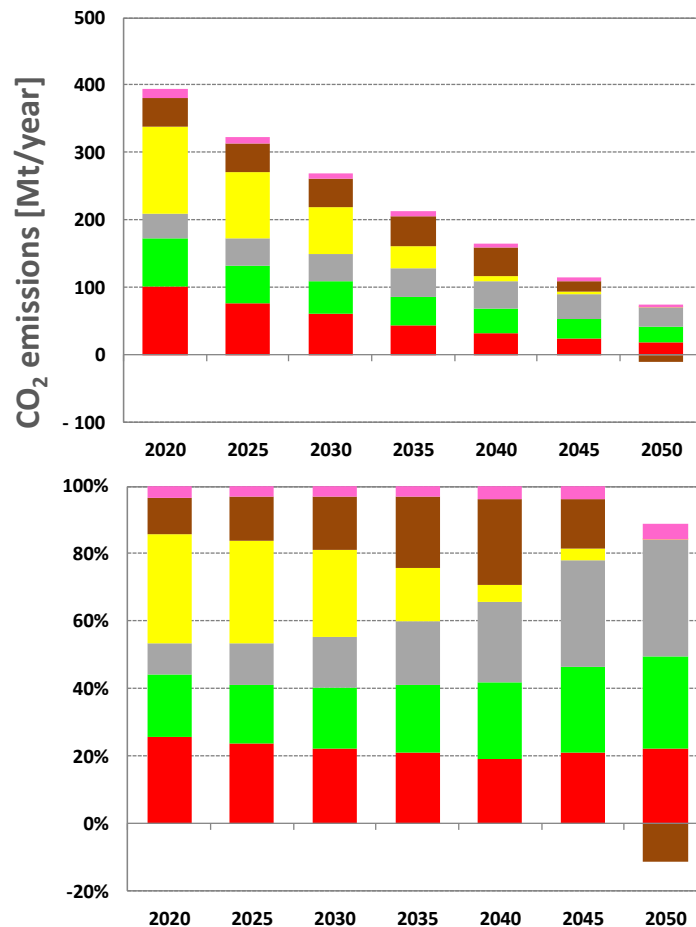
Modeling Results: CAS

Carbon dioxide emissions

ENERGY



CO₂ emissions by sector – CAS P2C Scenario



- *Drastic emission reductions after 2030 in all sectors*
- *VRE, nuclear and CCS combine to facilitate to achieve net negative emissions*
- *CCS in fuel supply* and electricity generation*
- *Electricity generation related CO₂ reductions almost entirely eliminated by 2050*
- *Transportation becomes largest CO₂ emitting sector by 2050*

NOTE: **Fuel supply** includes emissions from extraction, refining, synfuel and biofuel manufacture

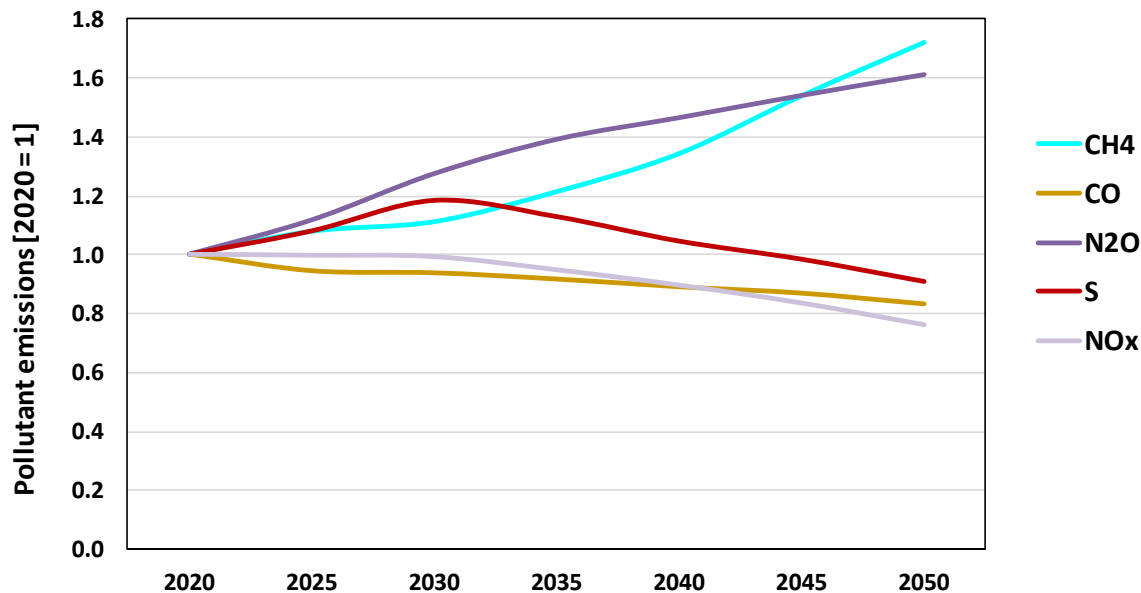
Modeling Results: CAS

Air quality

ENERGY



Non-CO₂ pollutant emissions – CAS REF



- Energy related methane and N₂O emissions grow considerably by 2050
- Sulfur emissions decrease after a temporary rise as
 - coal becomes less popular as end-use fuel
 - coal combustion technology for electricity generation increasingly equipped with desulfurization equipment

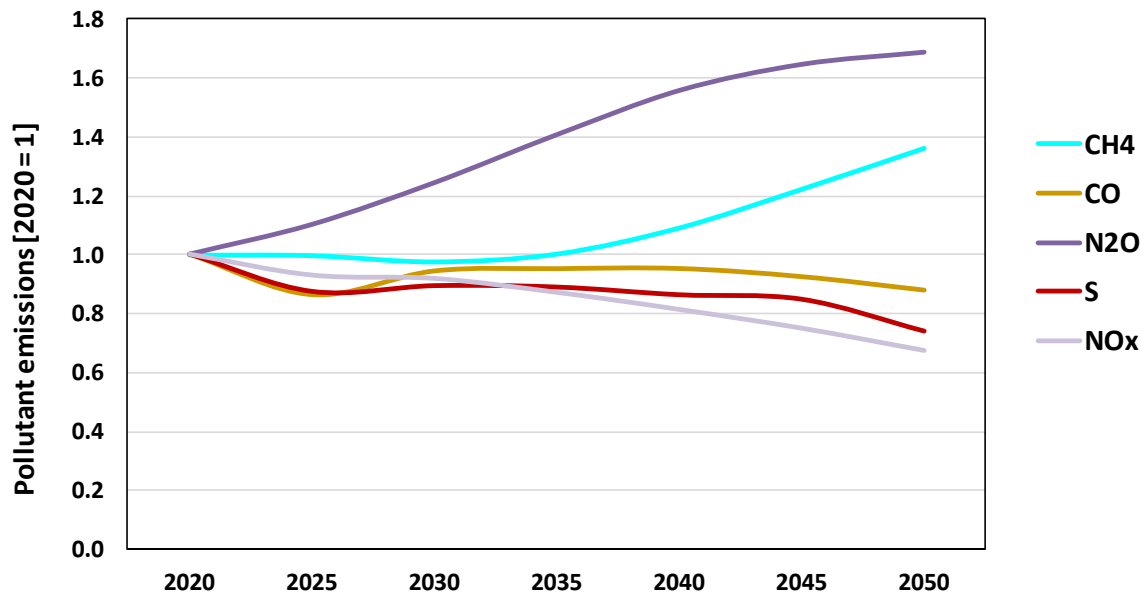
Modeling Results: CAS

Air quality

ENERGY



Non-CO₂ pollutant emissions – CAS NDC



- *NDC driven changes in the energy sector further reduce sulfur releases as gas and nuclear substitute for coal and oil*
- *Lower CH4 emissions due to overall lower gas and coal consumption*

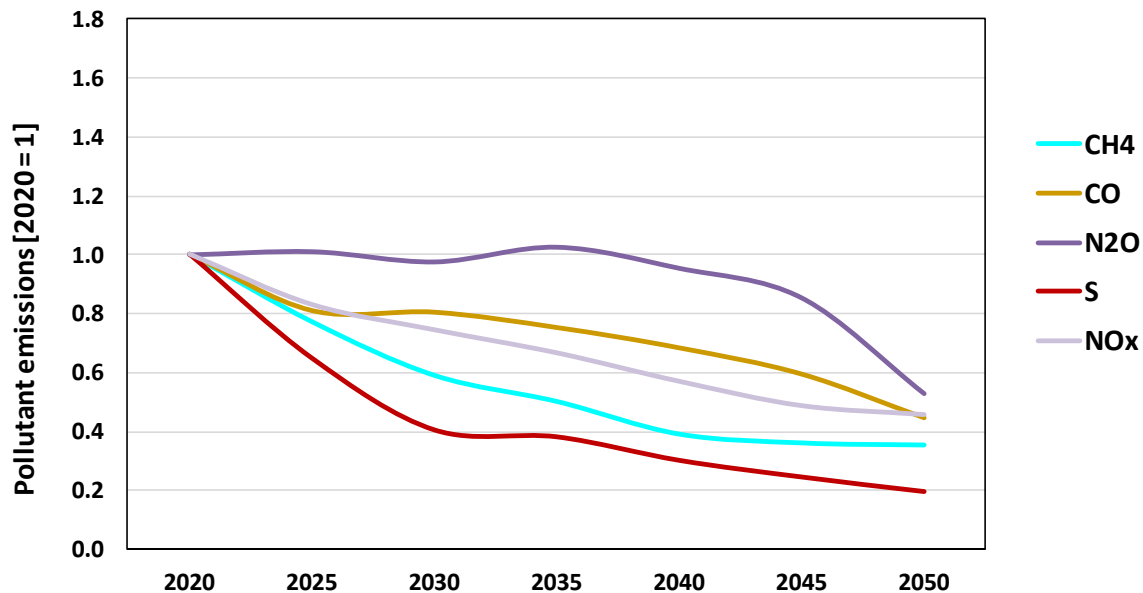
Modeling Results: CAS

Air quality

ENERGY



Non-CO₂ pollutant emissions – CAS P2C



- *P2C leads to substantial reductions in all air born pollutant emissions – quasi a co-benefit of the energy system transformation to protect the global climate system*

Modeling Results: Indicators

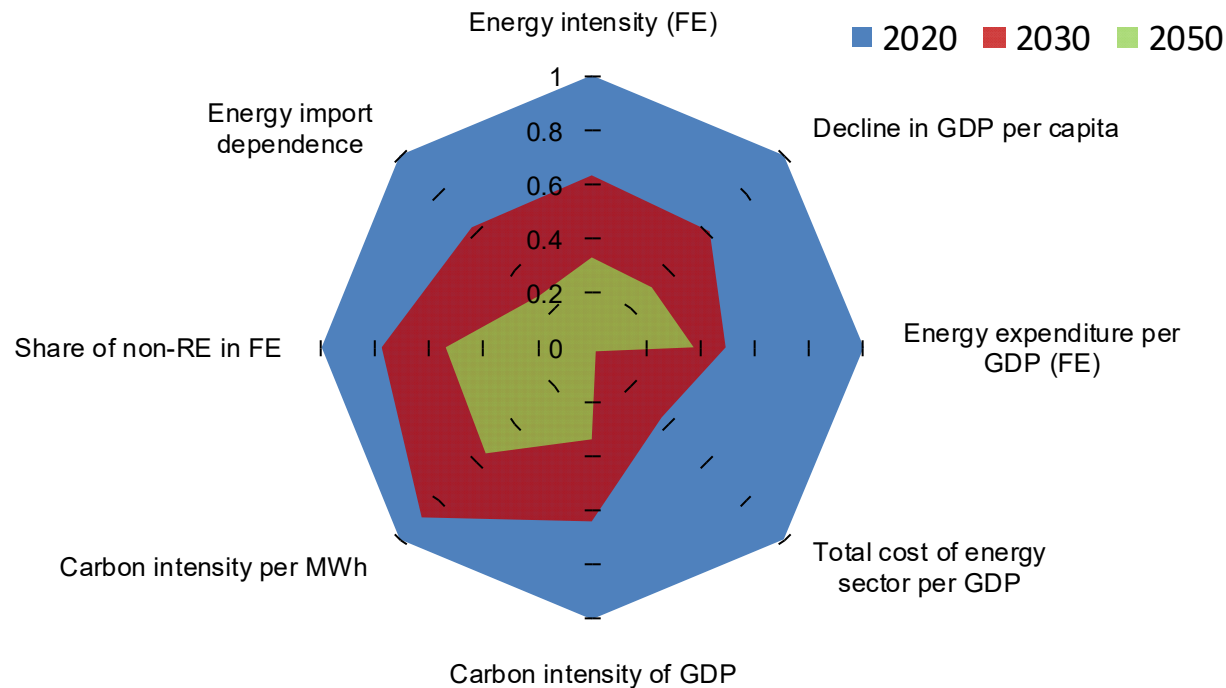
Tradeoffs and synergies: CAS

ENERGY



Energy and environment indicators - CAS REF Scenario

■ TEXT



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

Modeling Results: Indicators

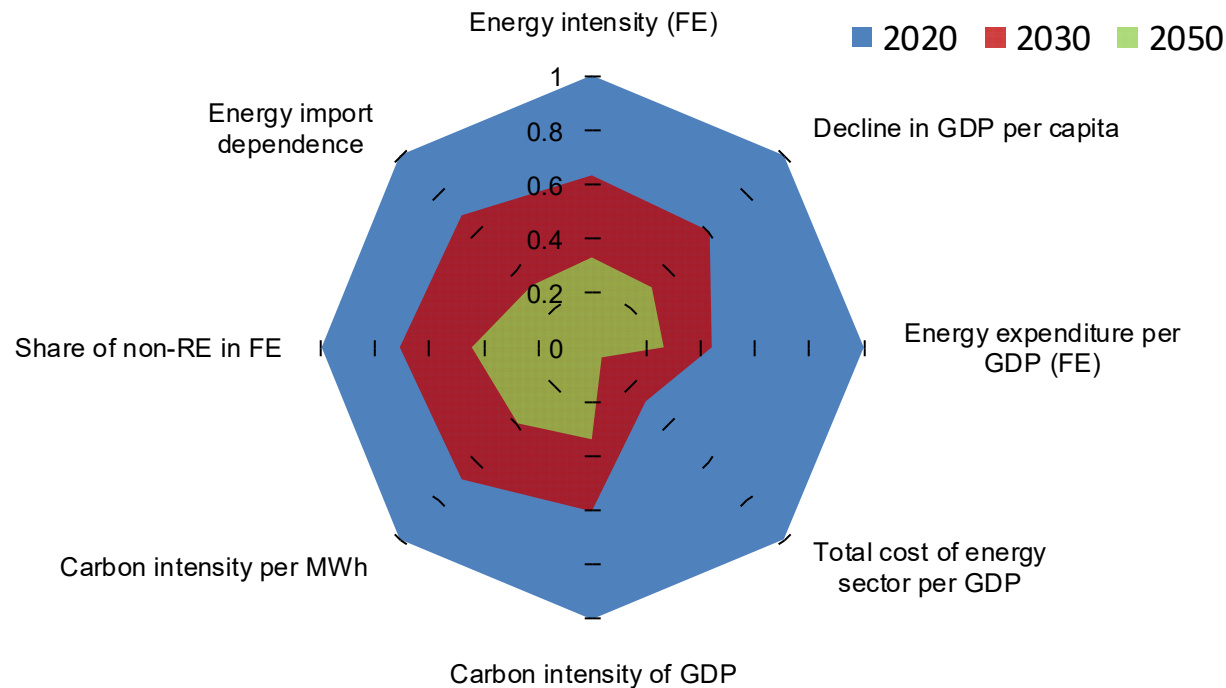
Tradeoffs and synergies: CAS

ENERGY



Energy and environment indicators - CAS NDC Scenario

■ TEXT



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Modeling Results: Indicators

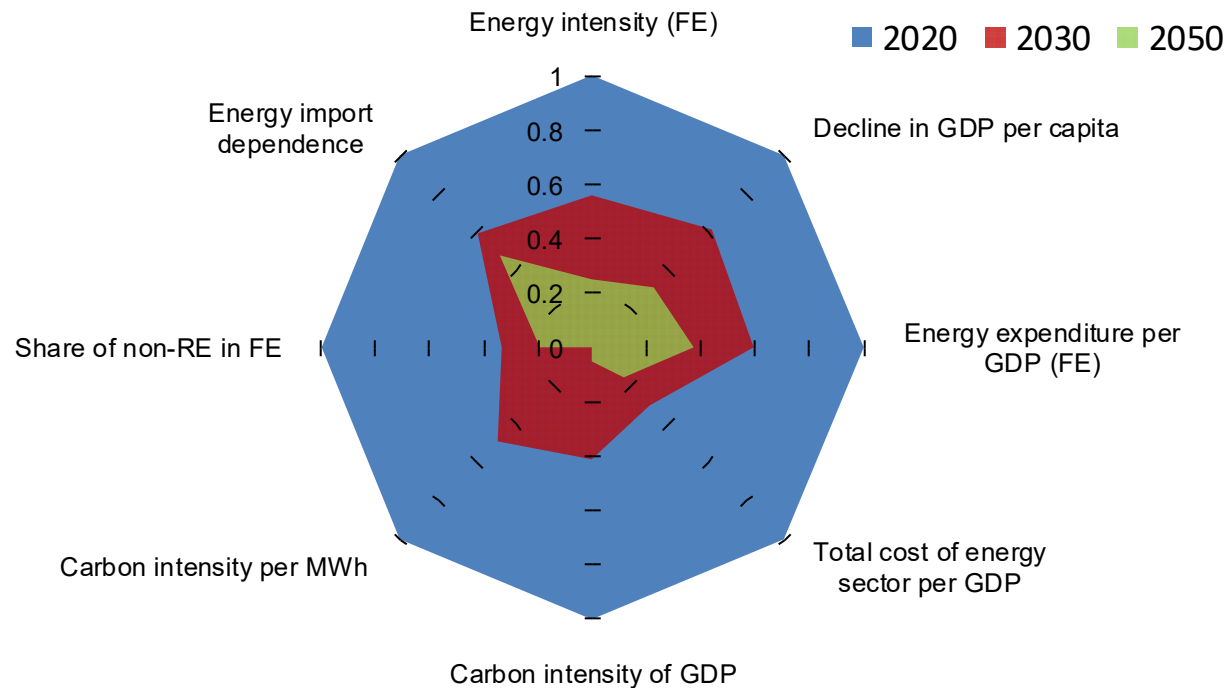
Tradeoffs and synergies: CAS

ENERGY



Energy and environment indicators - CAS P2C Scenario

■ TEXT



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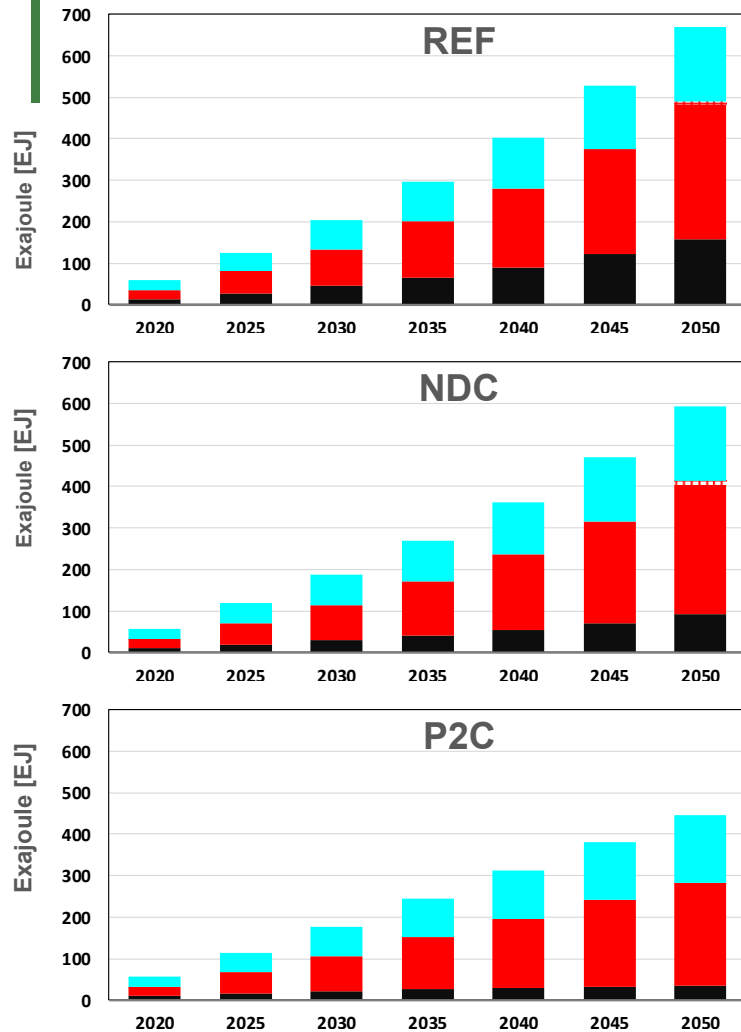
Modeling Results: Indicators

Resource extraction: CAS

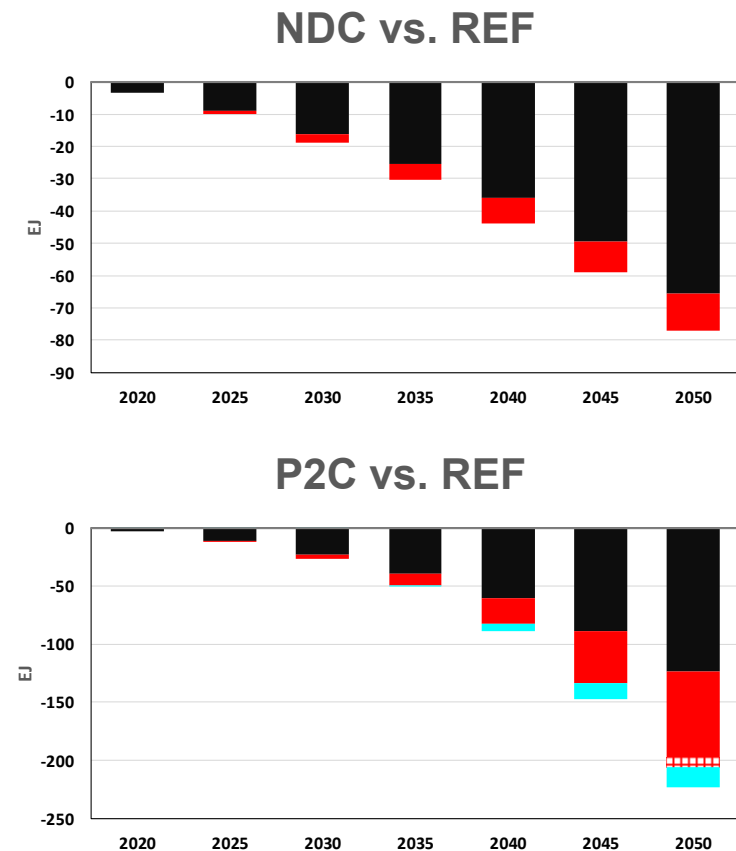
ENERGY



Cumulative fossil resource extraction



Difference in cumulative fossil resource extraction 2020 to 2050



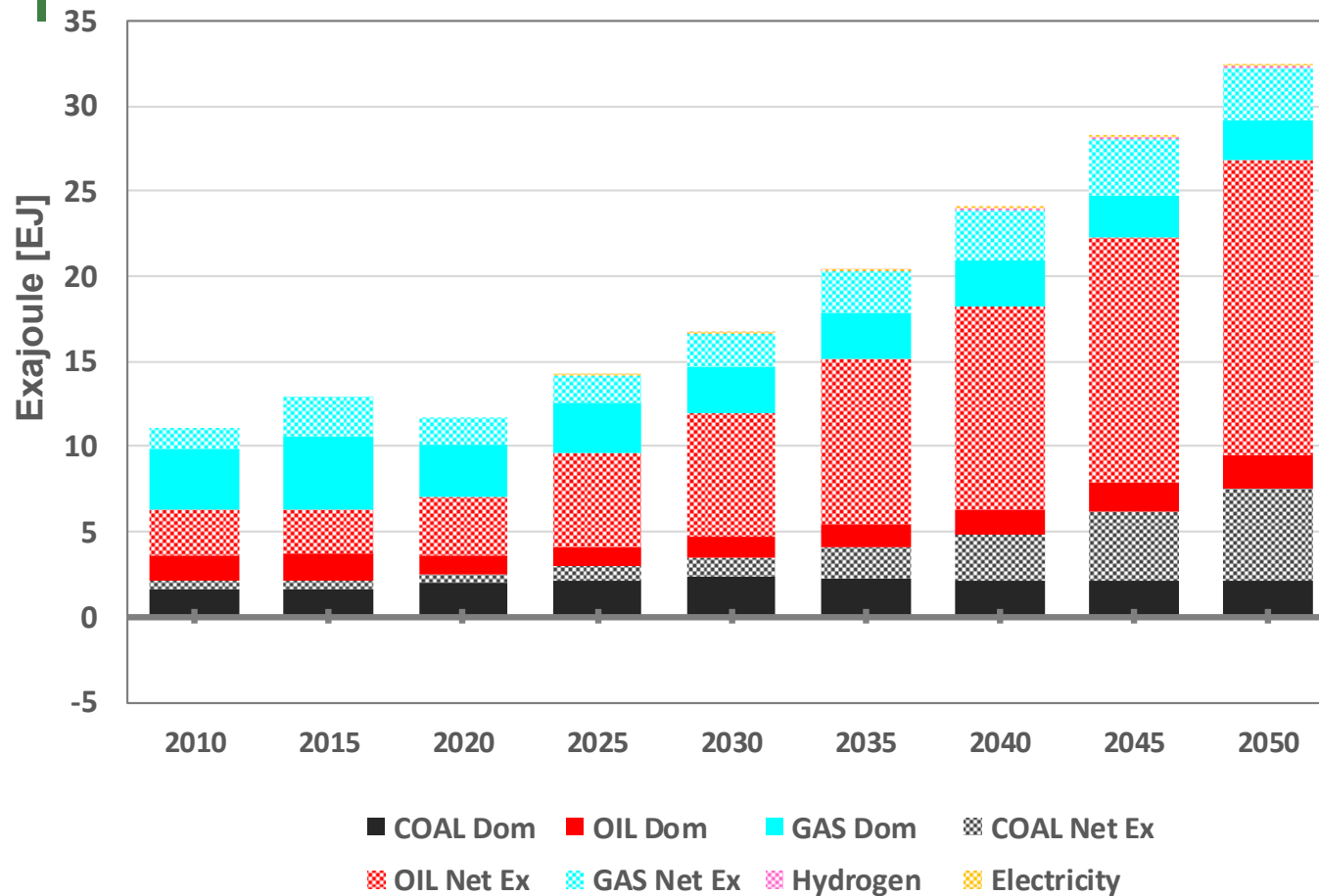
Modeling Results: Indicators

Domestic use versus trade: CAS

ENERGY



Domestic fossil fuel use and net trade - CAS REF



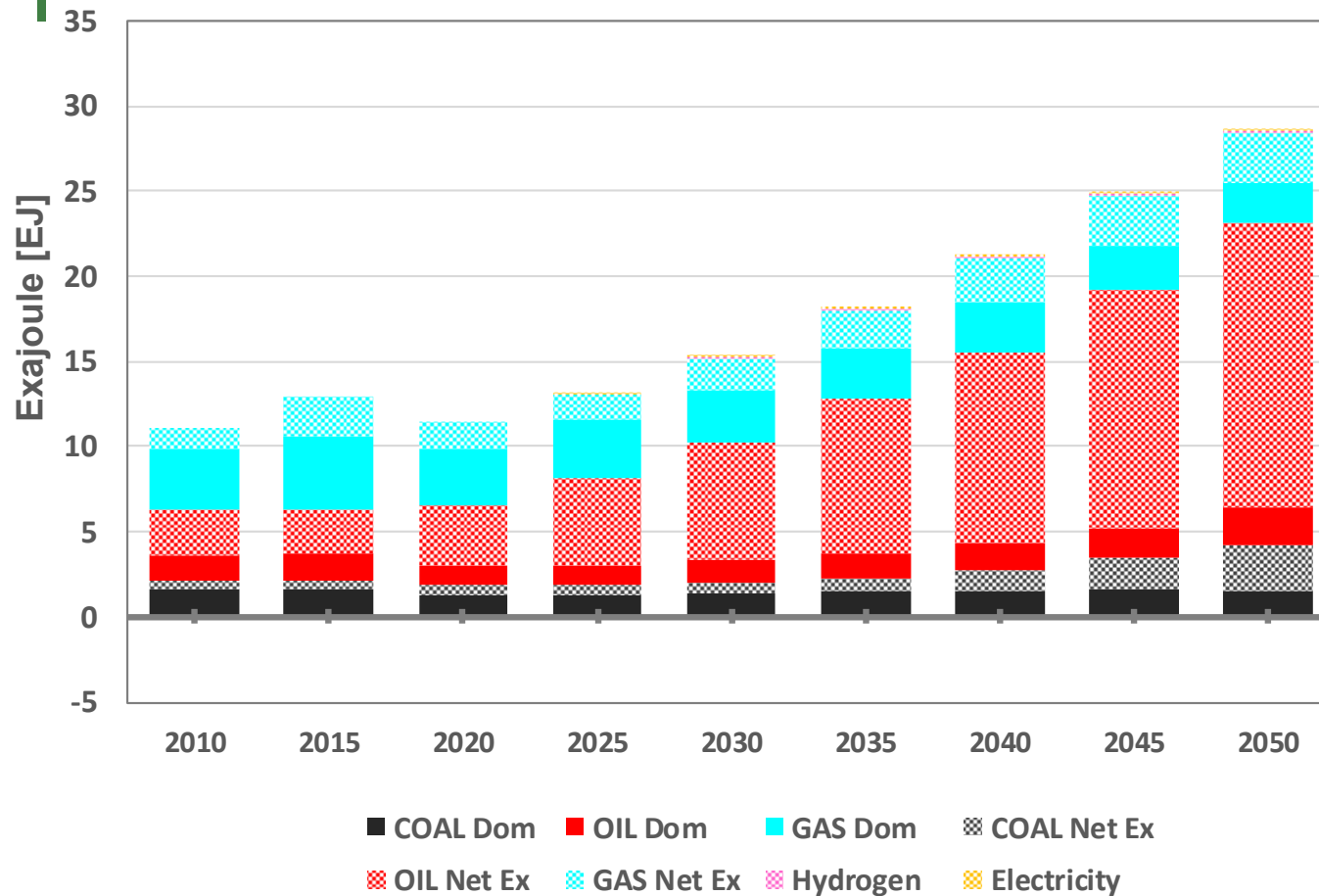
Modeling Results: Indicators

Domestic use versus trade: CAS

ENERGY



Domestic fossil fuel use versus net trade - CAS NDC



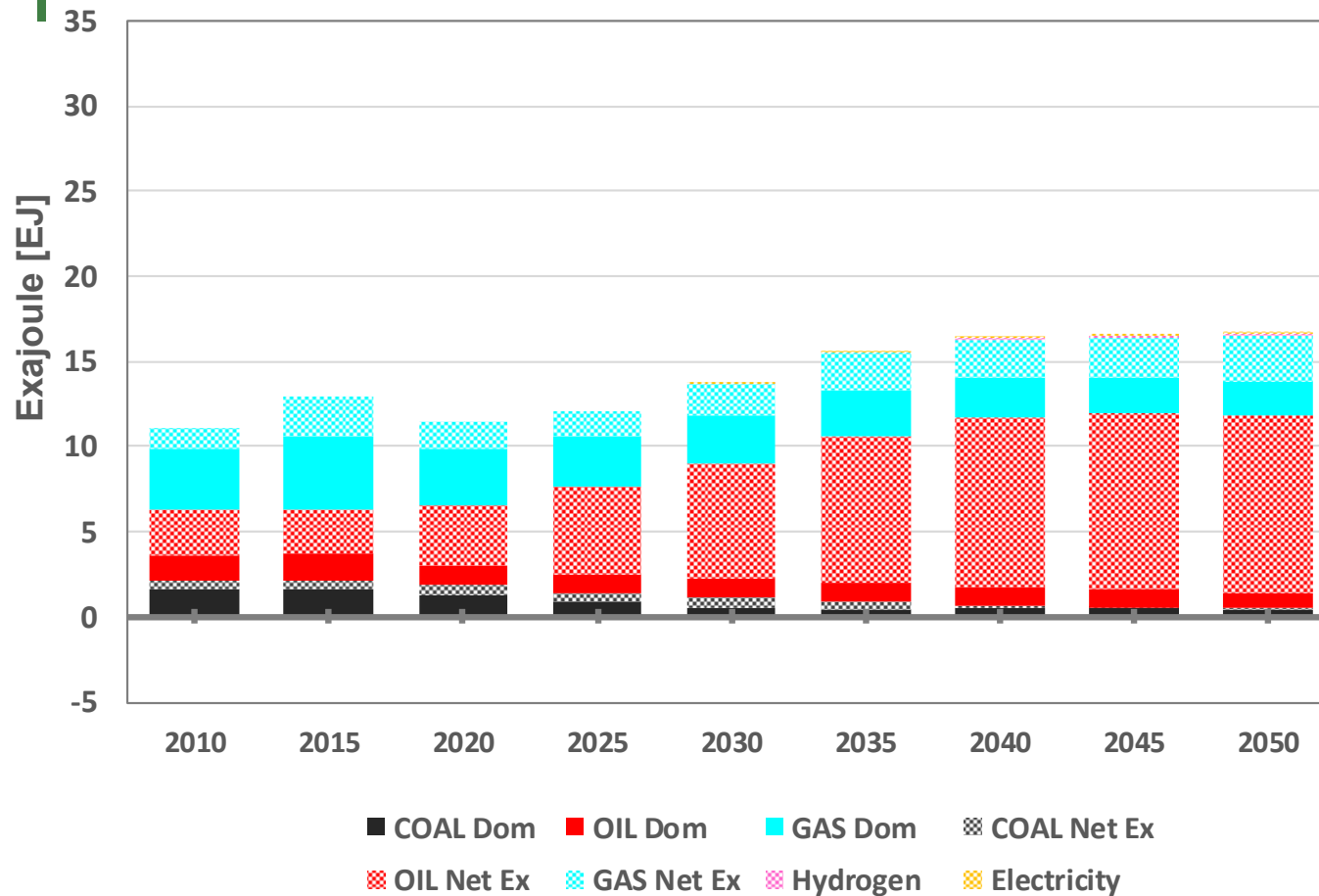
Modeling Results: Indicators

Domestic use versus trade: CAS

ENERGY



Domestic fossil fuel use versus net trade - CAS P2C



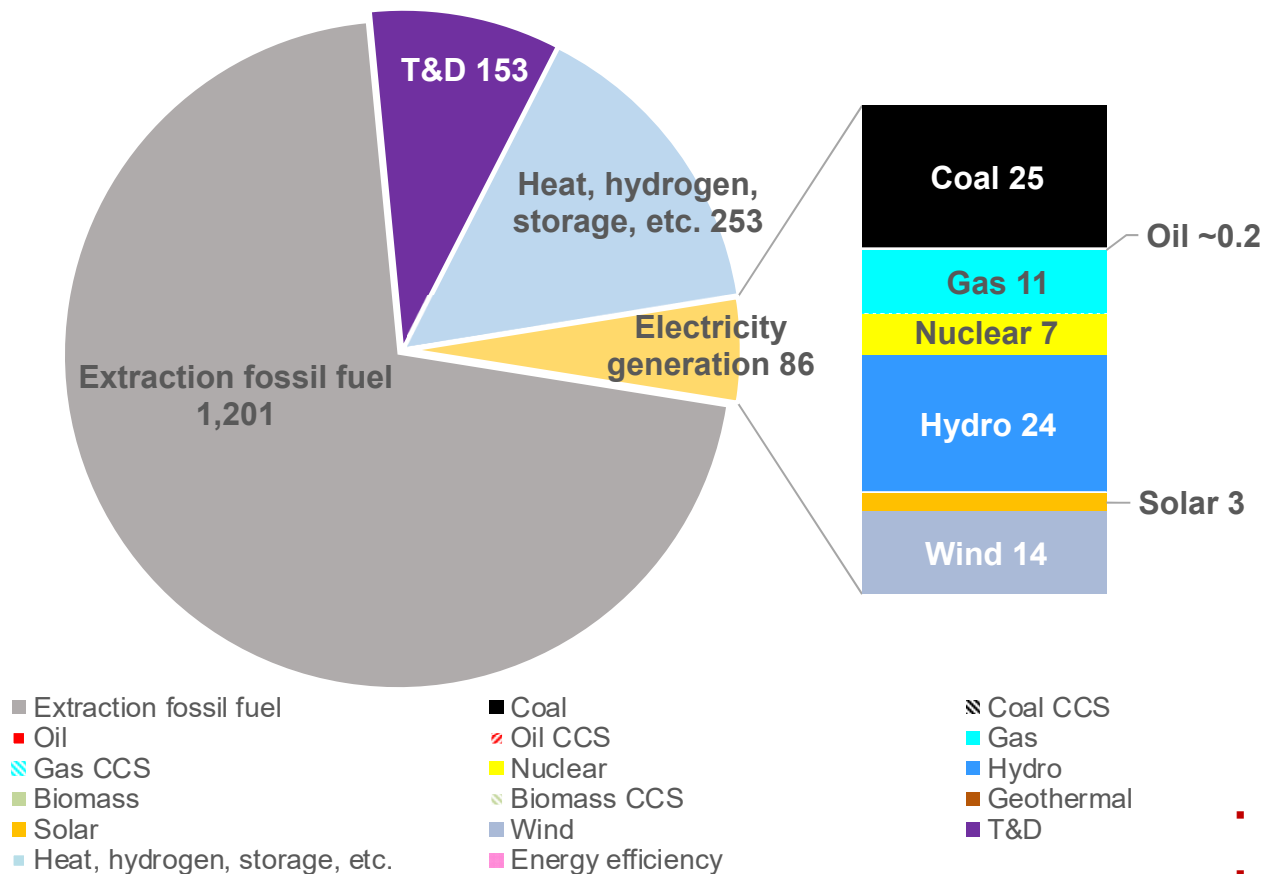
Modeling Results: Indicators

Investment needs: CAS

ENERGY



Cumulative investments 2020-2050: 1,693 billion US\$
REF - CAS



- Fossil fuel extraction absorb 80% of total energy sector investments – in large part export driven (more than doubling over the period)
- T&D commands twice as much capital than investments in electricity generating equipment
- Generation investments are dominated by lowest carbon emitting nuclear and hydro plants (more than twice the investments in coal and natural gas)
- Hydro power (traditional) and onshore wind (new) dominate investments in renewables

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

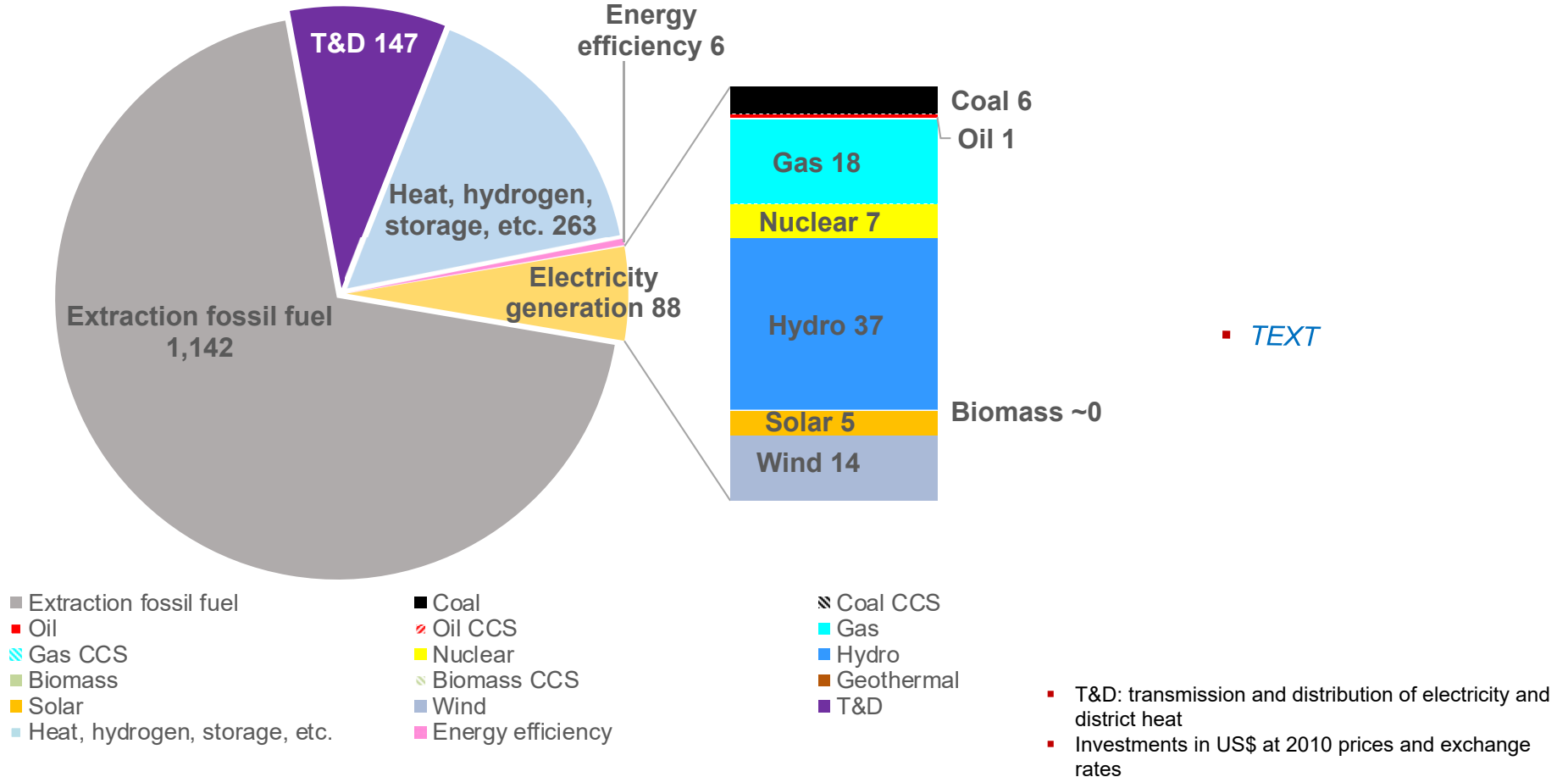
Modeling Results: Indicators

Investment needs: CAS

ENERGY



Cumulative investments 2020-2050: *1,646 billion US\$*
NDC - CAS



Modeling Results: Indicators

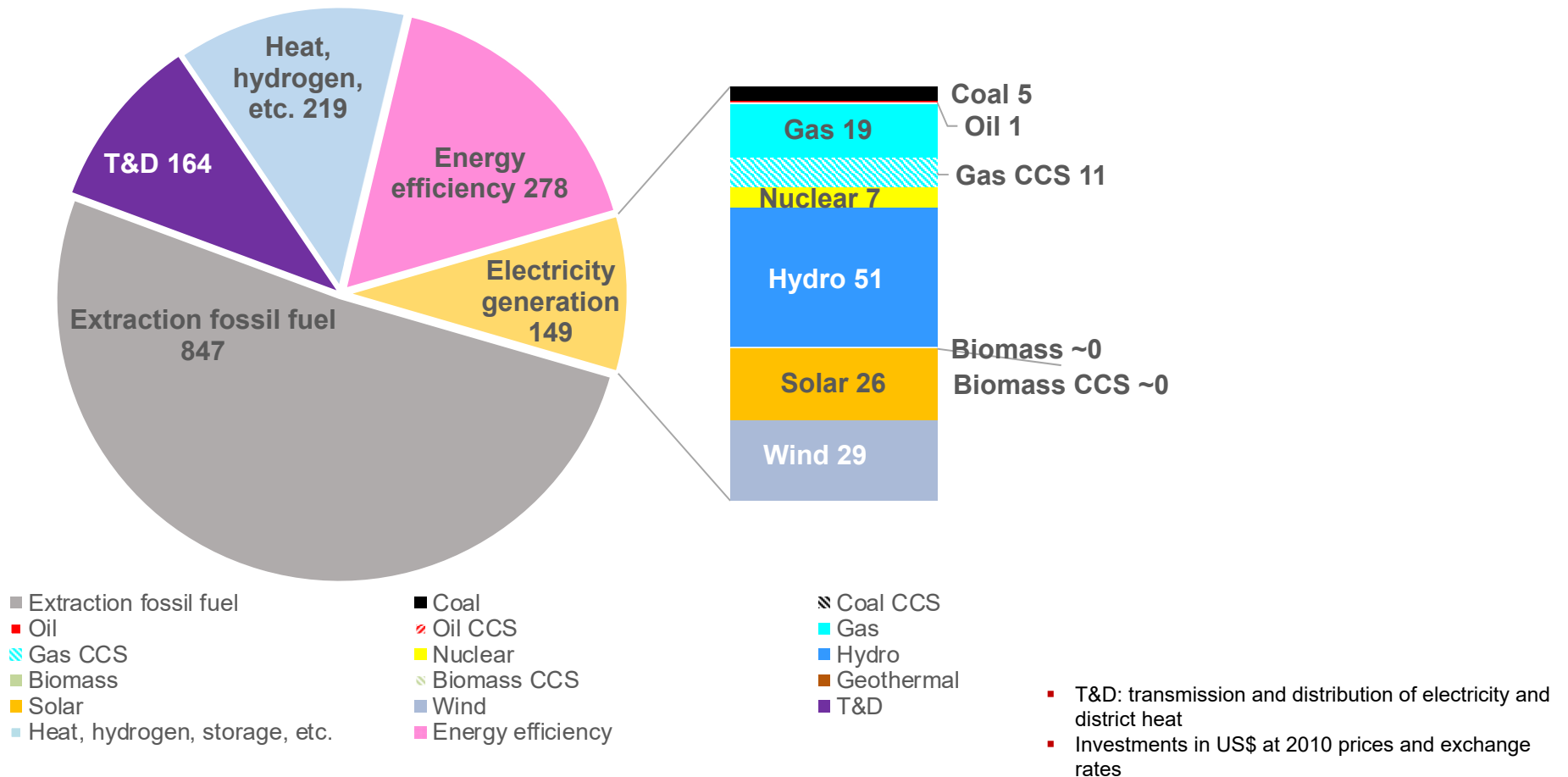
Investment needs: CAS

ENERGY



Cumulative investments 2020-2050: 1,657 billion US\$
P2C - CAS

■ TEXT



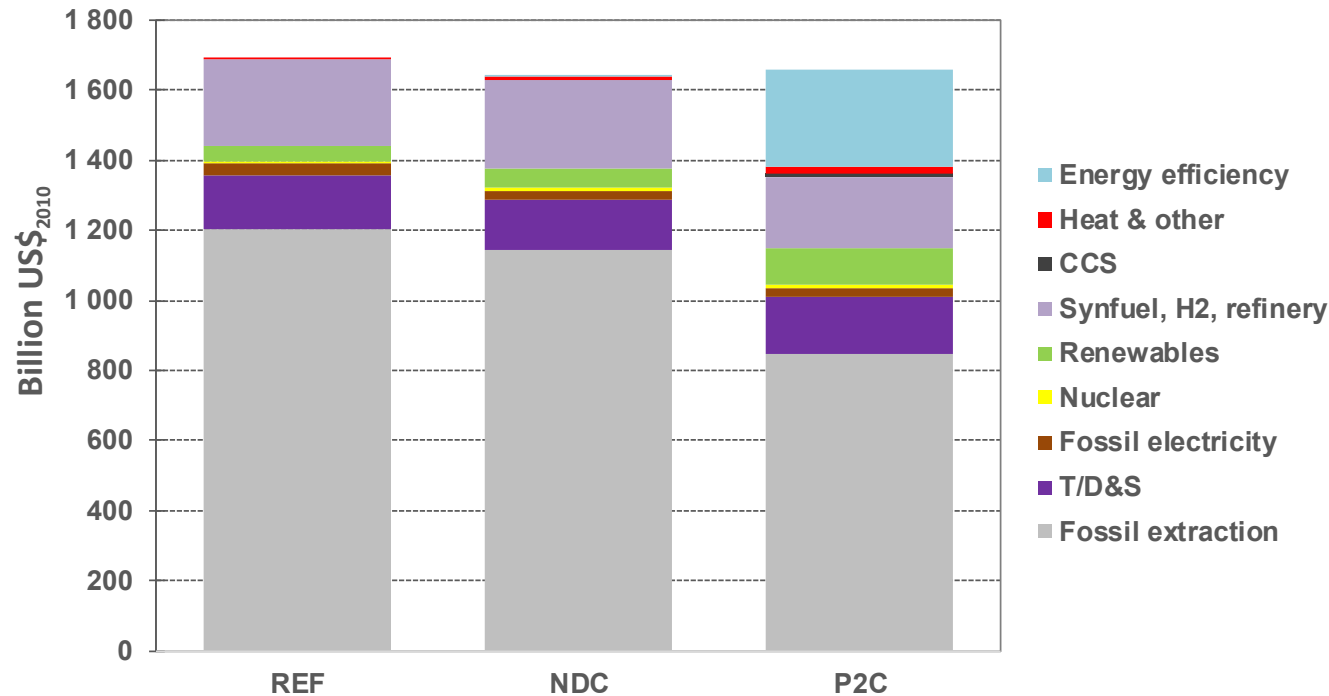
Modeling Results: Indicators

Investment needs: CAS

ENERGY



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

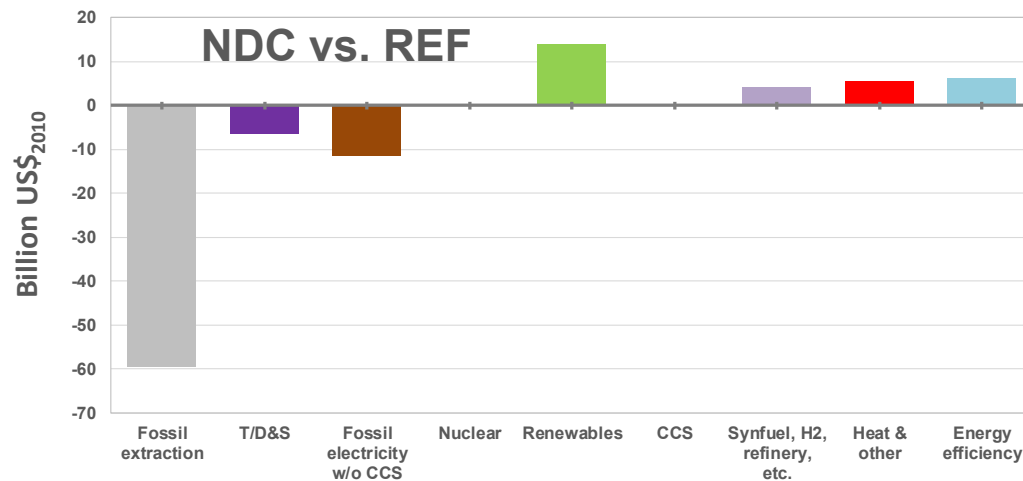
Modeling Results: Indicators

Investment needs: CAS

ENERGY



Distributional effects of investment requirements between scenarios - CAS

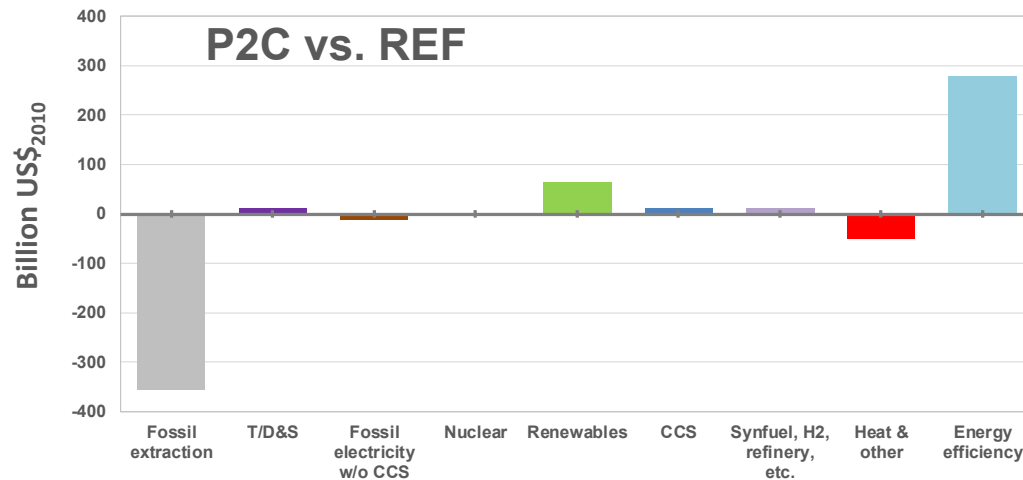


NDC vs. REF

▪ *See earlier comments*

P2C vs. REF

▪ *See earlier comments*



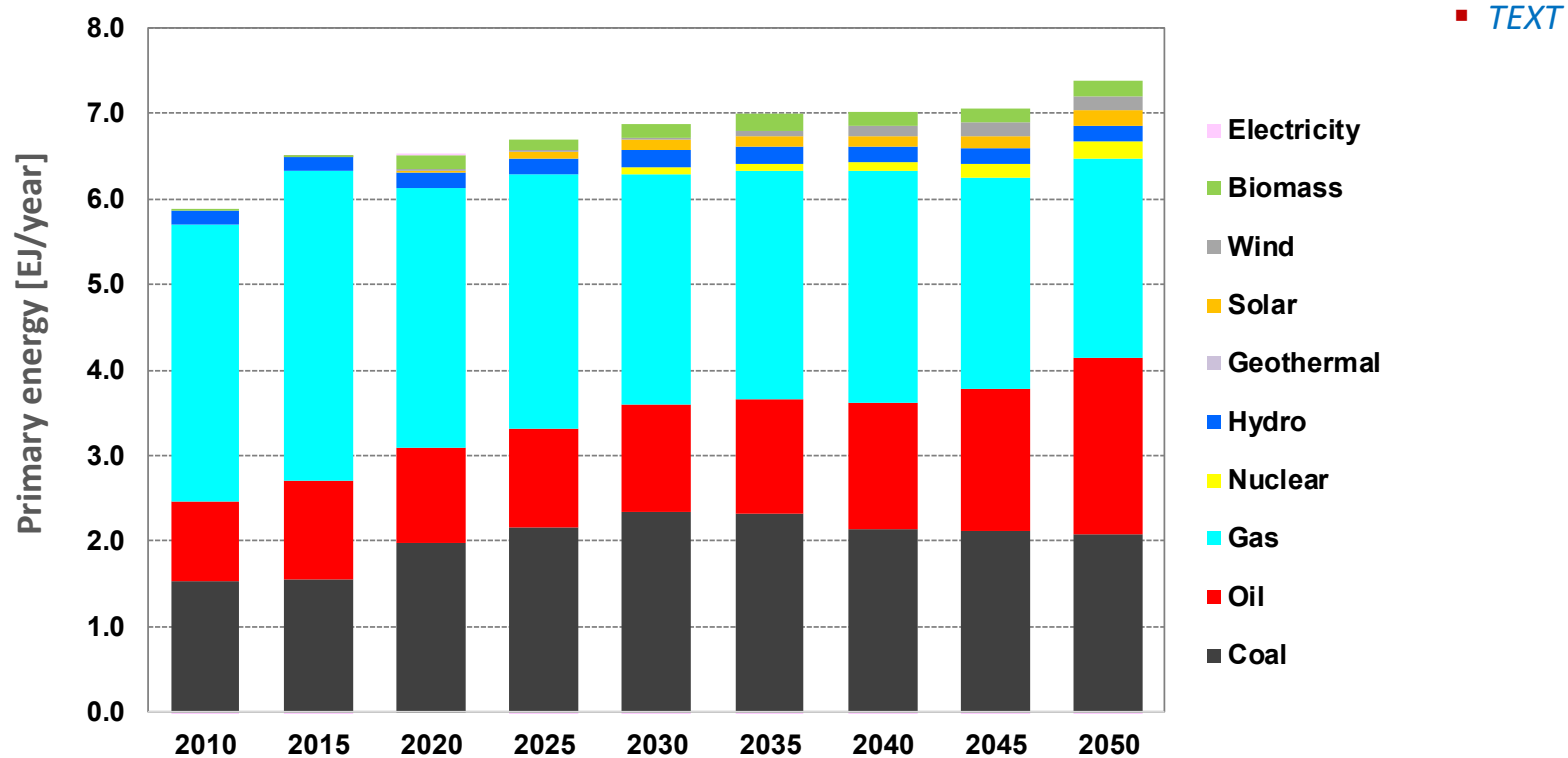
Modeling Results: CAS

Primary Energy

ENERGY



Primary energy mix - CAS REF Scenario



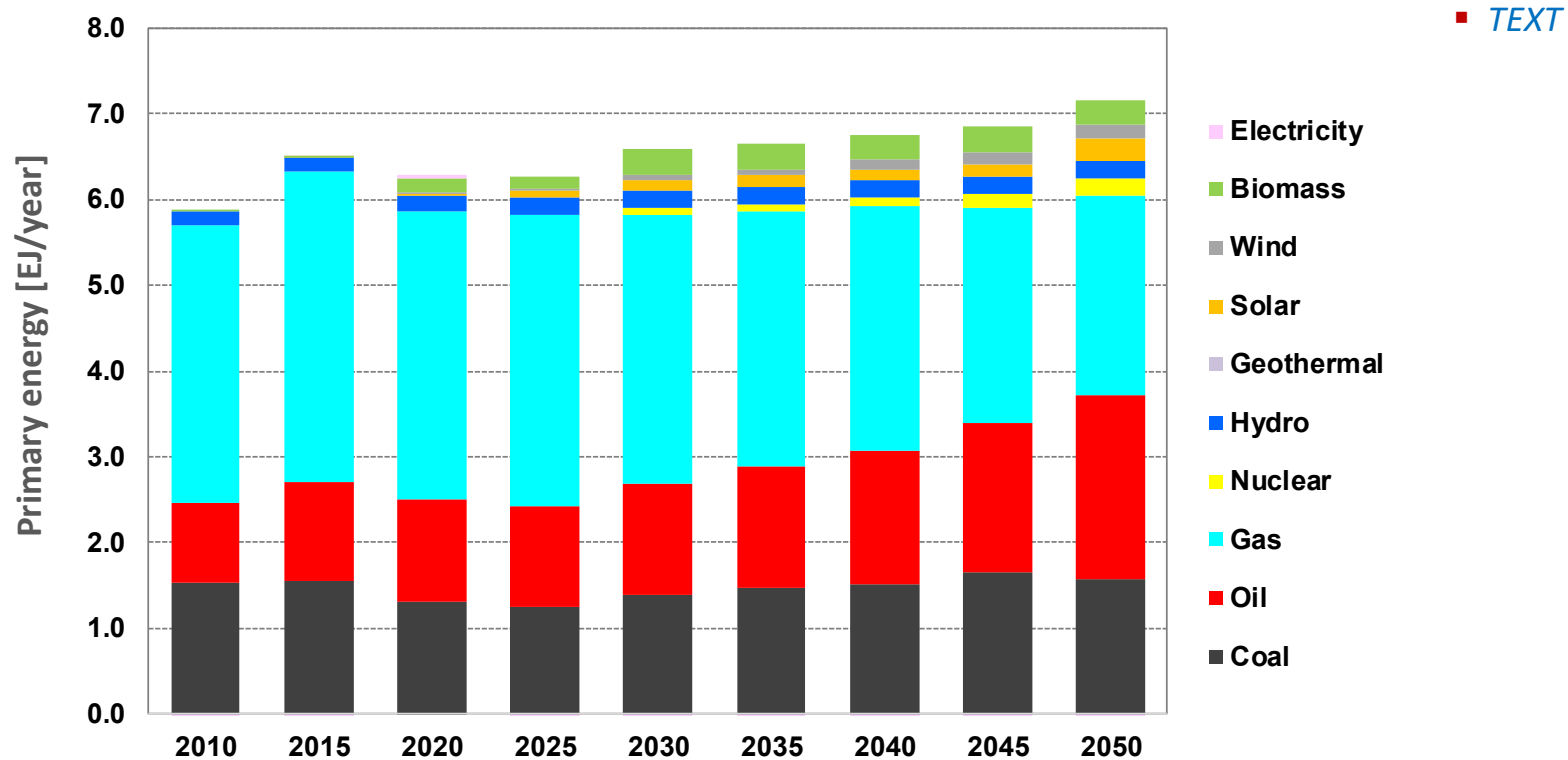
Modeling Results: CAS

Primary Energy

ENERGY



Primary energy mix - CAS NDC Scenario



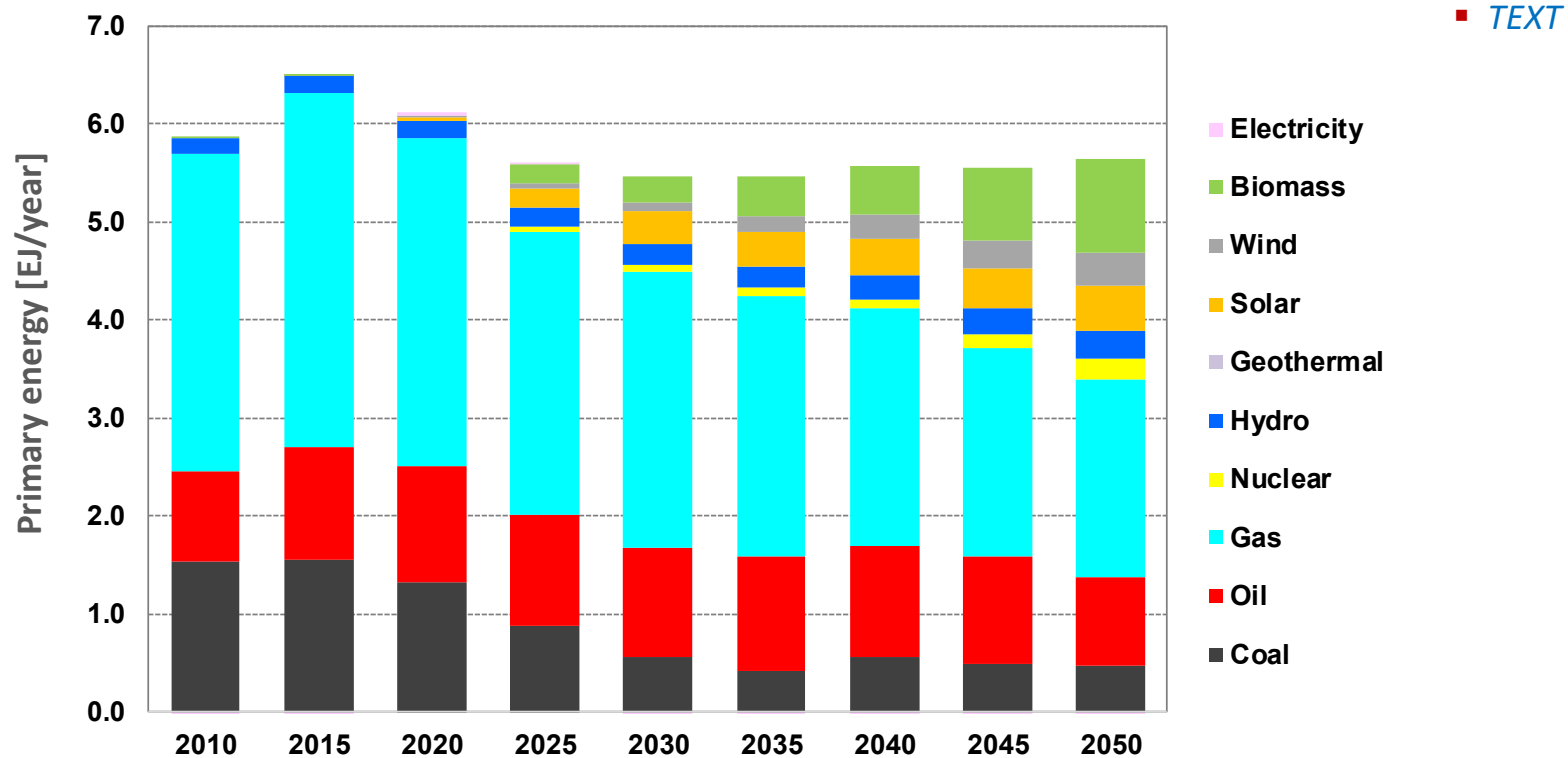
Modeling Results: CAS

Primary Energy

ENERGY



Primary energy mix - CAS P2C Scenario



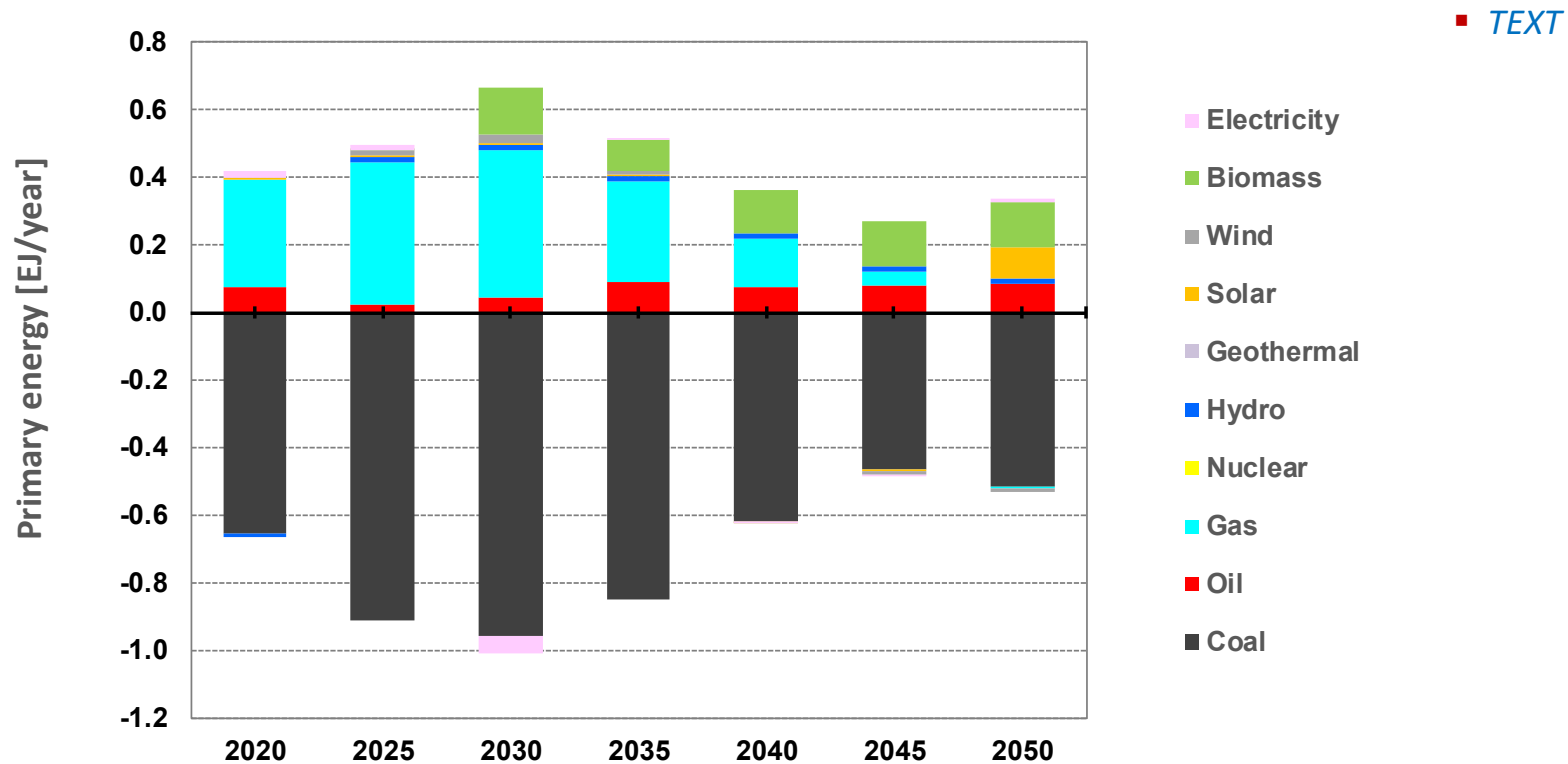
Modeling Results: CAS

Primary Energy: Scenario differences

ENERGY



Primary energy mix - CAS NDC versus REF Scenario



Modeling Results: CAS

Primary Energy: Scenario differences

ENERGY



Primary energy mix - CAS P2C versus REF Scenario

