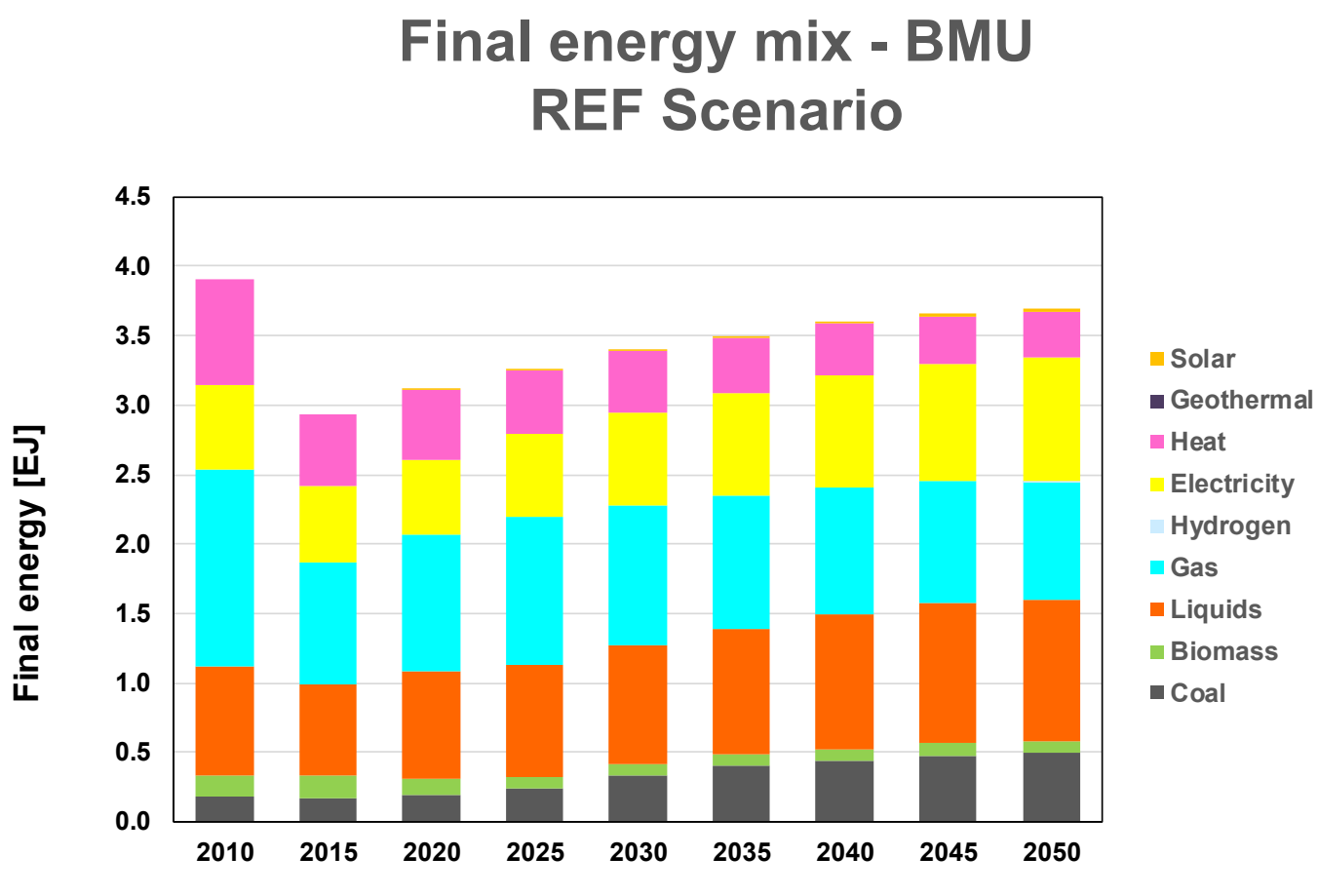
BMU

Modeling Results: BMU

Final Energy Mix

ENERGY

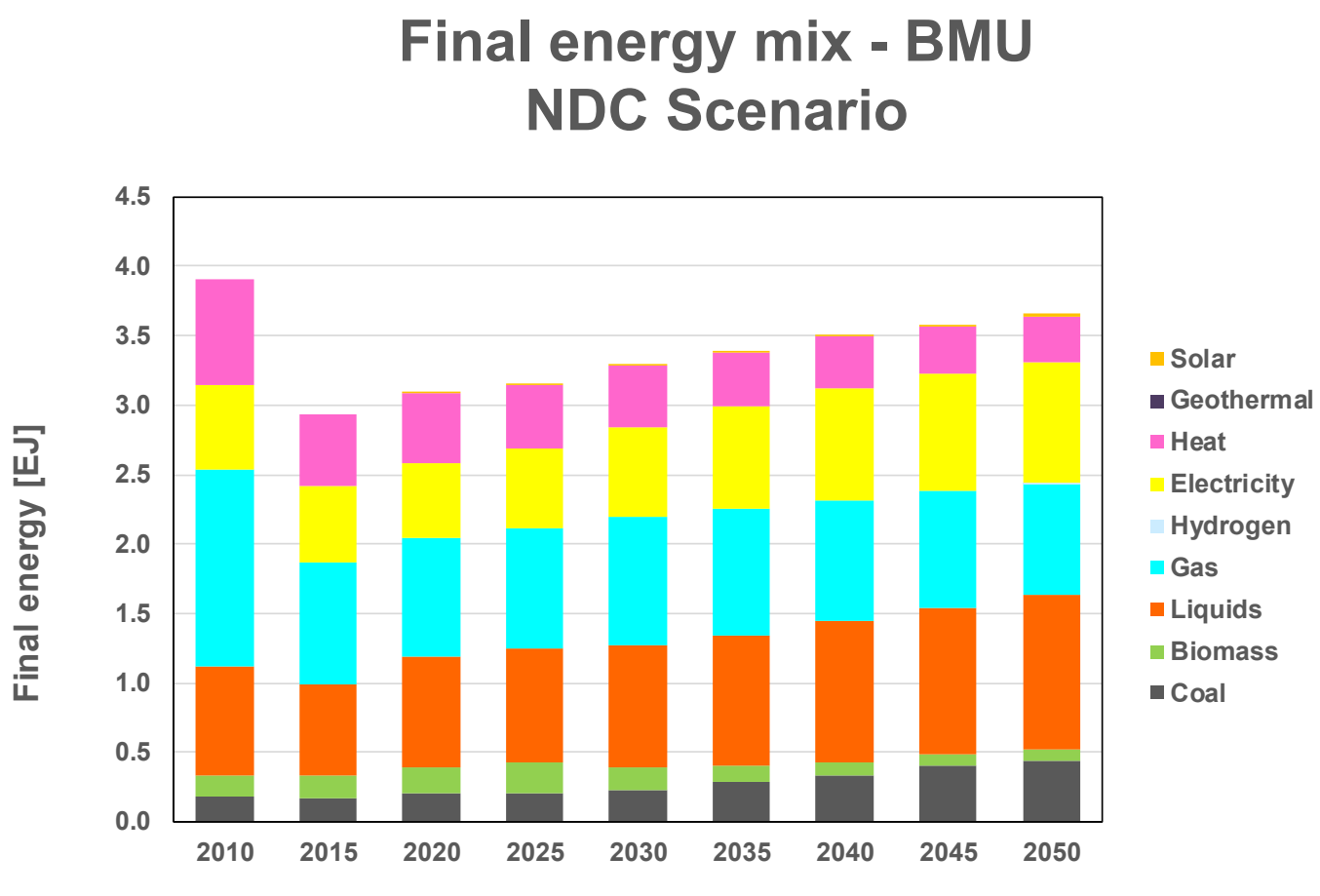


- *Modest growth of all final fuels except district heat and to a lesser extent natural gas*
- *Electricity and liquid fuels expand market shares*

Modeling Results: BMU

Final Energy Mix

ENERGY



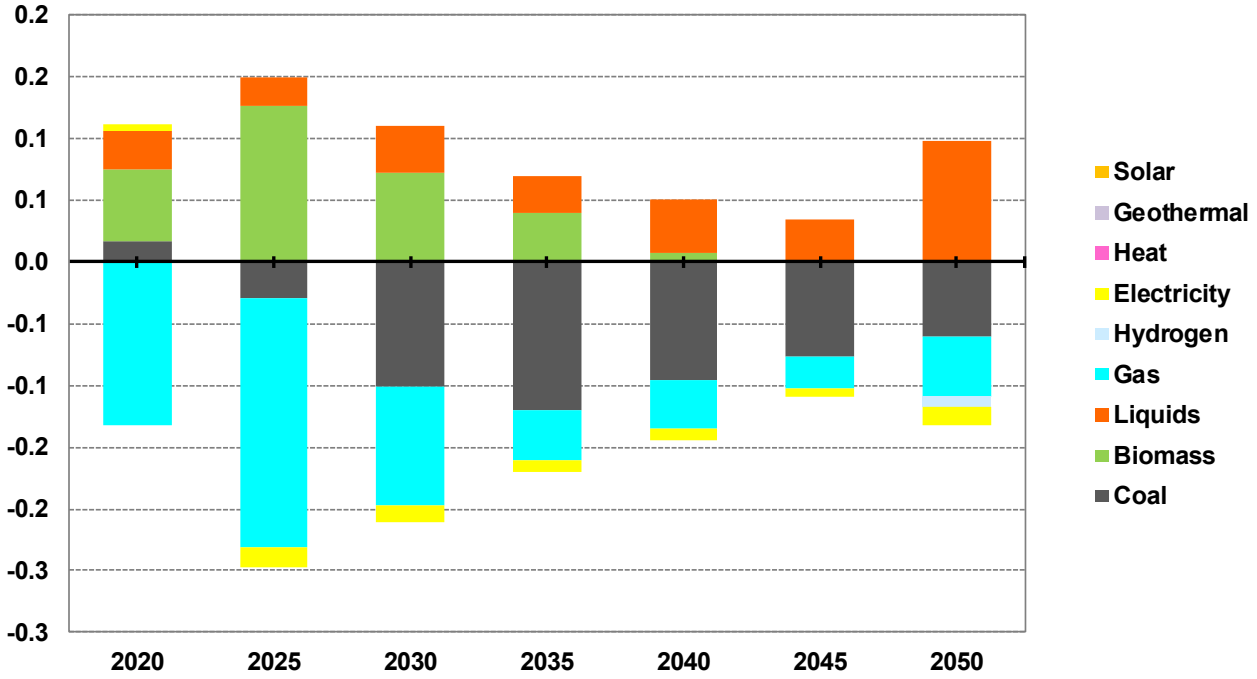
- *NDC marginally reduces final energy demand: Between 2020 and 2050 final demand grows for all fuels except:*
  - *Natural gas*
- *Liquids driven by demand for transportation services*

Modeling Results: BMU

Final Energy Mix: Scenario differences

ENERGY

Final energy mix - BMU
NDC versus REF Scenario

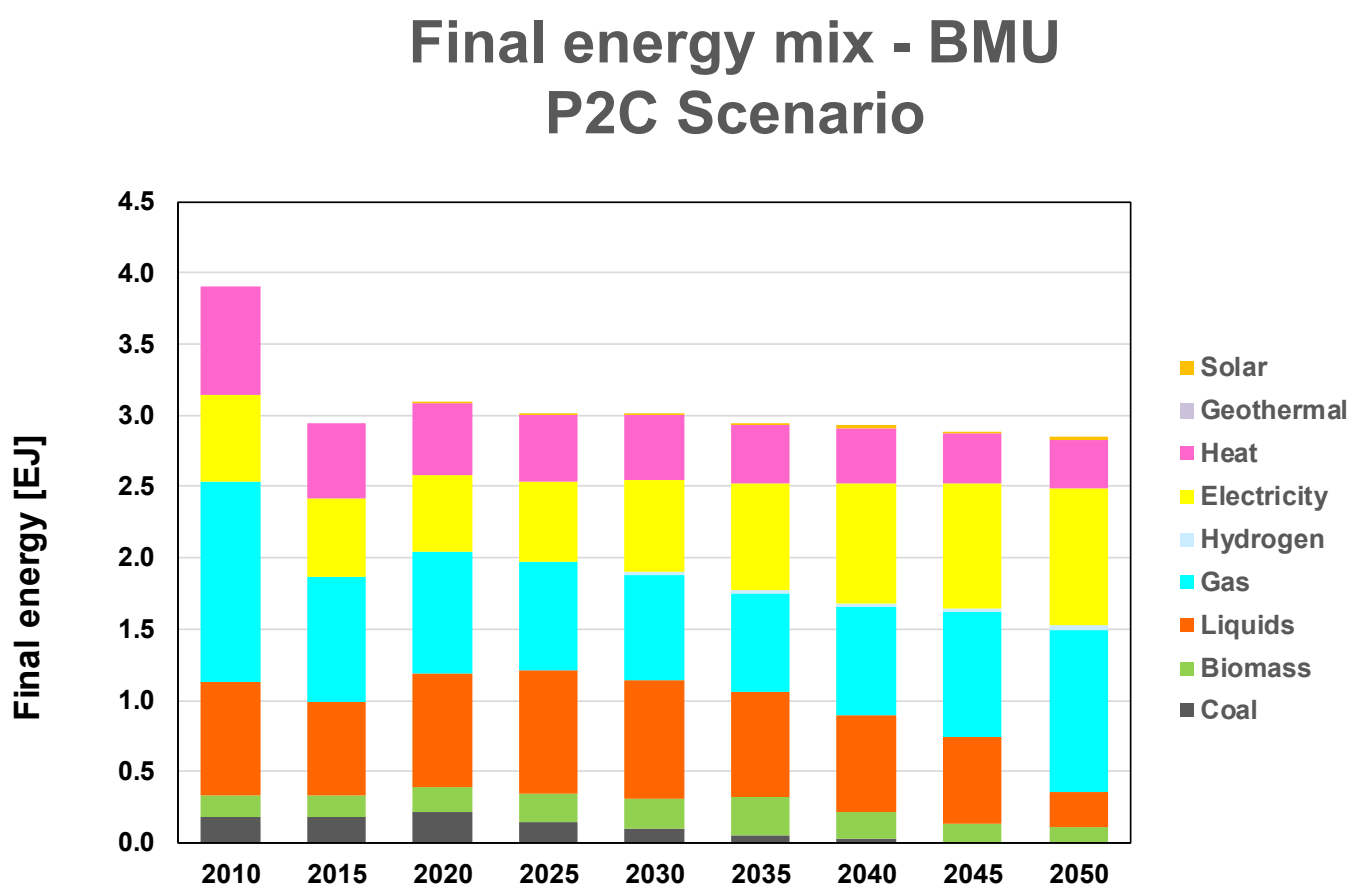


- *In the short run, liquids and biomass displace natural gas and coal but also electricity*
- *Reason: RUS' NDCs are higher than the region's CO2 emissions under REF condition (Note: NDC are regional constraints)*

Modeling Results: BMU

Final Energy Mix

ENERGY



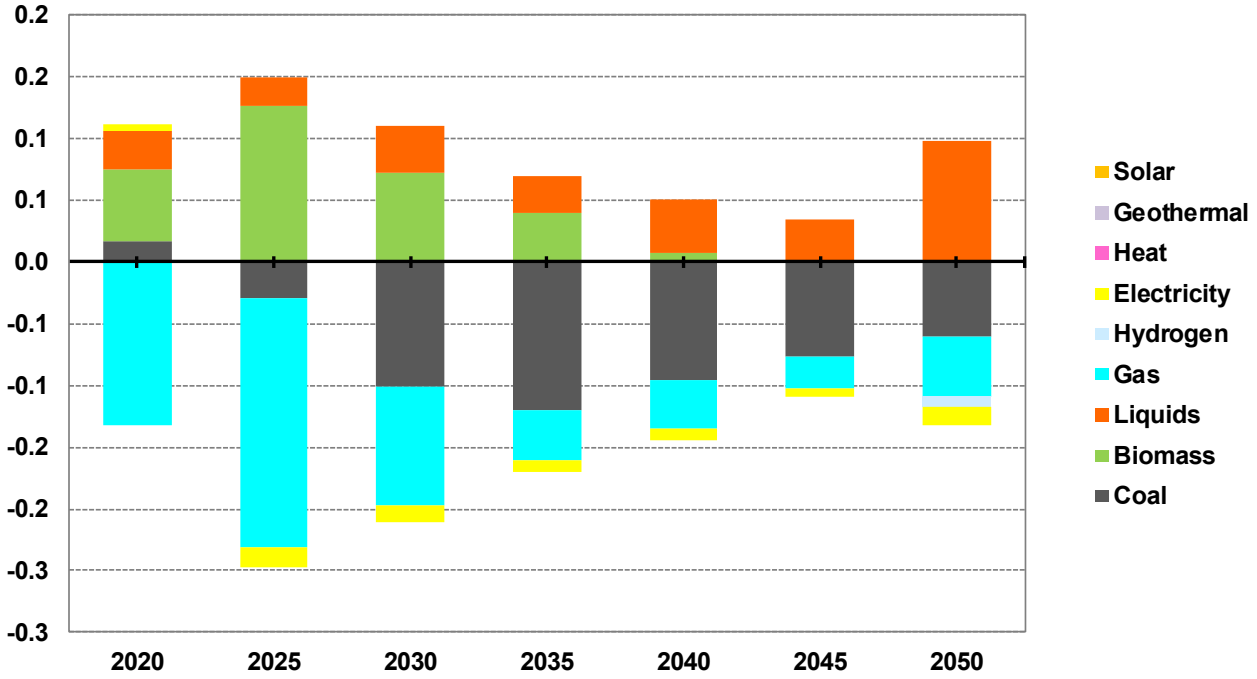
- *Climate mitigation policies affect overall final energy demand (at constant supply of energy services)*
  - *Efficiency improvements primarily in transportation and industry and, to a lesser extent households*
  - *Life style changes*
- *Natural gas largest component in FE mix by 2050*
- *Higher share of electricity displaces lower efficient fossil fuels (see next slide)*

Modeling Results: BMU

Final Energy Mix: Scenario differences

ENERGY

Final energy mix - BMU
P2C versus REF Scenario



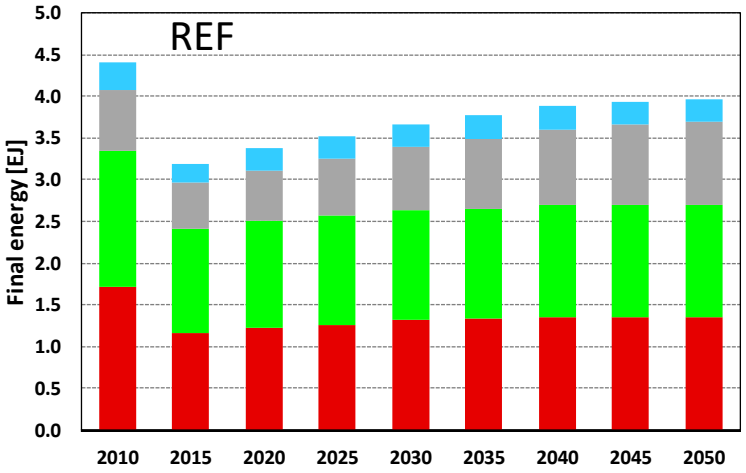
- *Until 2035 liquids and biomass increasingly displace natural gas and coal*
- *Shift to higher reliance on electricity, solar and natural gas after 2035*

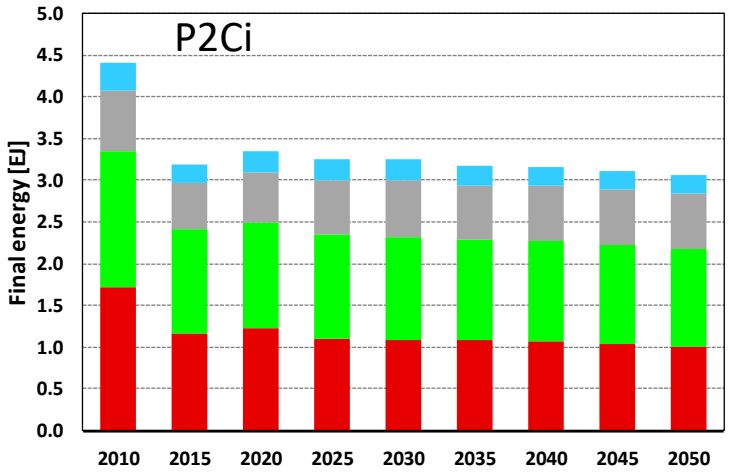
Modeling Results: BMU

Sector implications

ENERGY

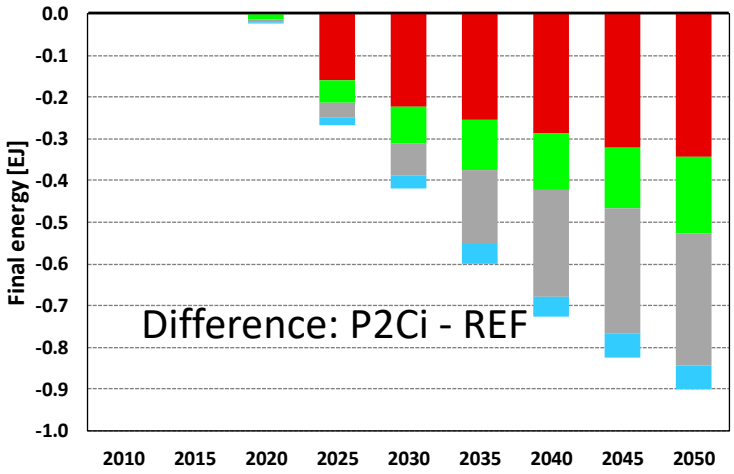
Final energy by sector - BMU





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

- *Main impact: Demand side management & energy intensity improvements as the capital stock is progressively renewed*
- *Focus is on the transportation and industry sectors (and non-energy uses, primarily feedstocks for petrochemicals)*

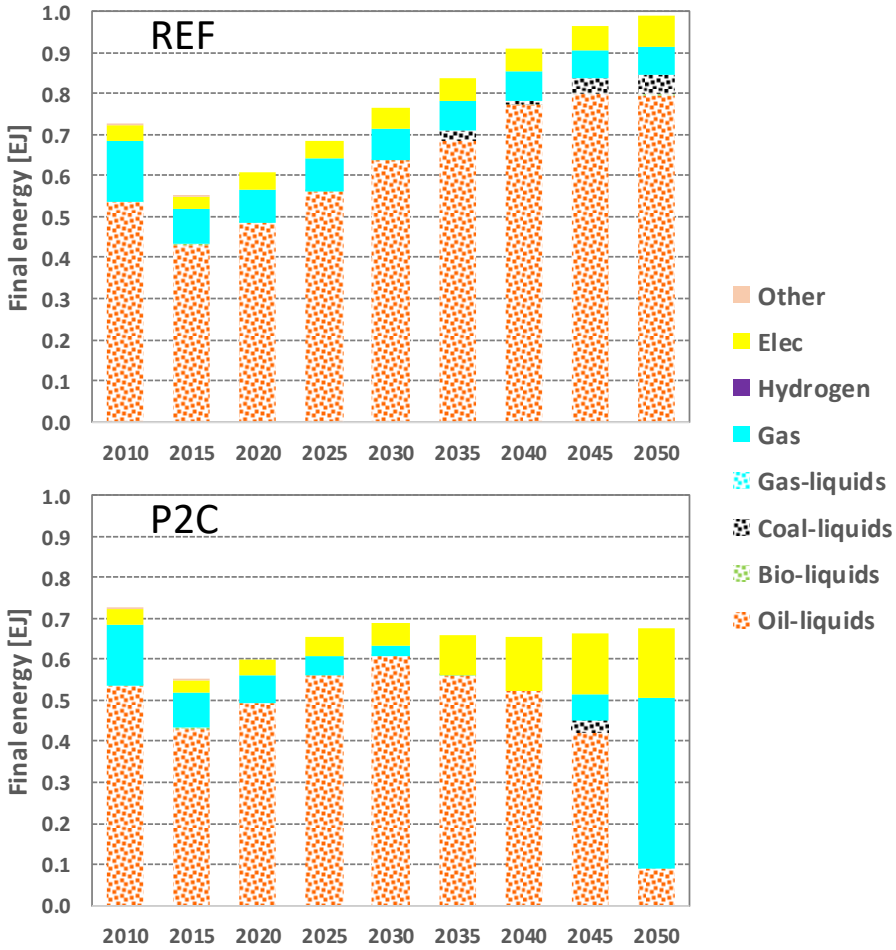


Modeling Results: BMU

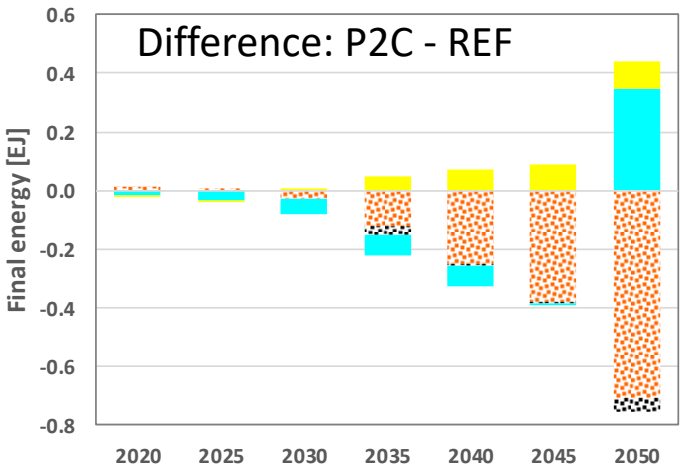
Sector implications: Transportation

ENERGY

Final transportation sector - BMU



- *REF: 50% increase in transport related FE demand (2015 to 2050)*
- *Liquids with rapidly expanding market share*
- *P2C: Substantial reduction in transportation related energy demand*
  - *Strong market penetration of electric mobility (higher efficiency)*
  - *Life style changes*
- *Natural gas takes on the role of a swing fuel*

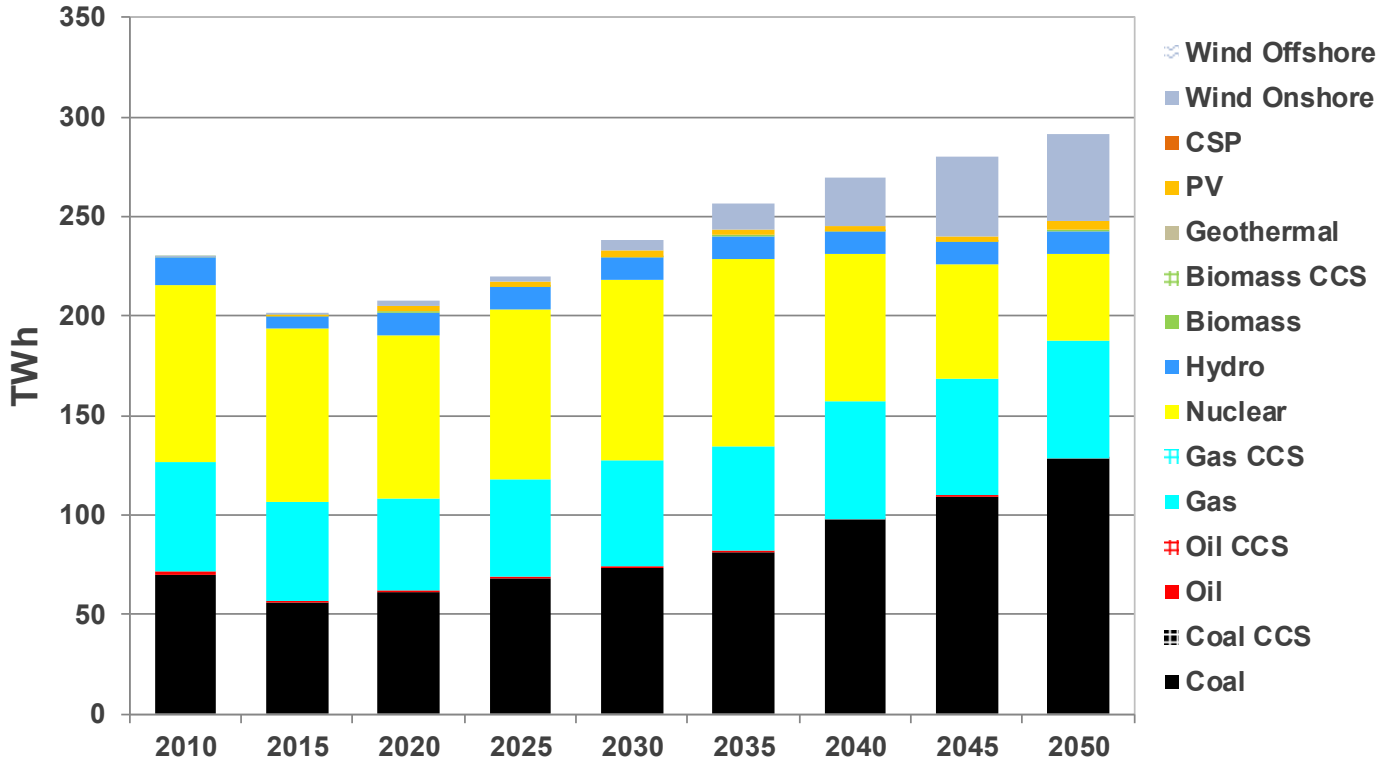


Modeling Results: BMU

Electricity Generation

ENERGY

Electricity generation by technology - BMU
REF Scenario



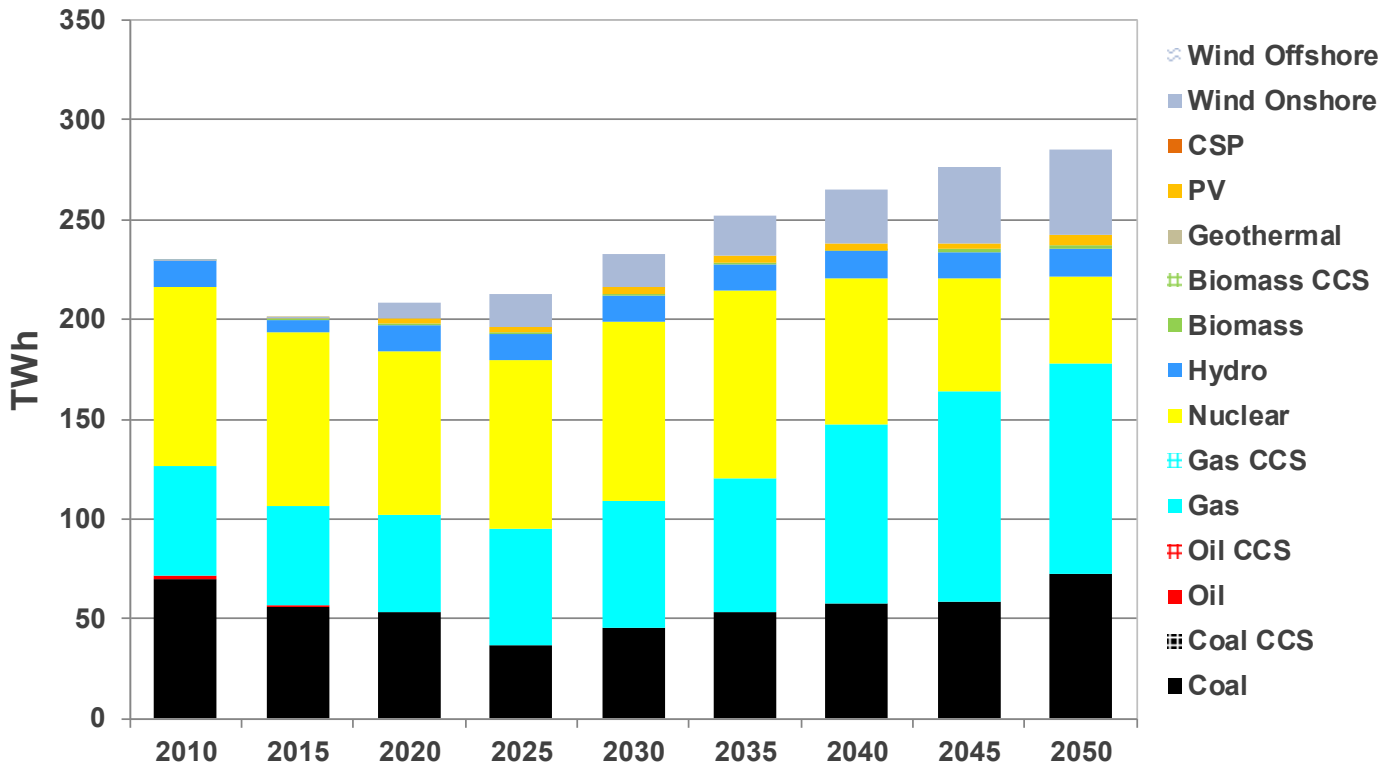
- *Declining nuclear electricity only partly offset by on-shore wind, PV and natural gas*
- *Coal use on the rise*

Modeling Results: BMU

Electricity Generation

ENERGY

Electricity generation by technology - BMU NDC



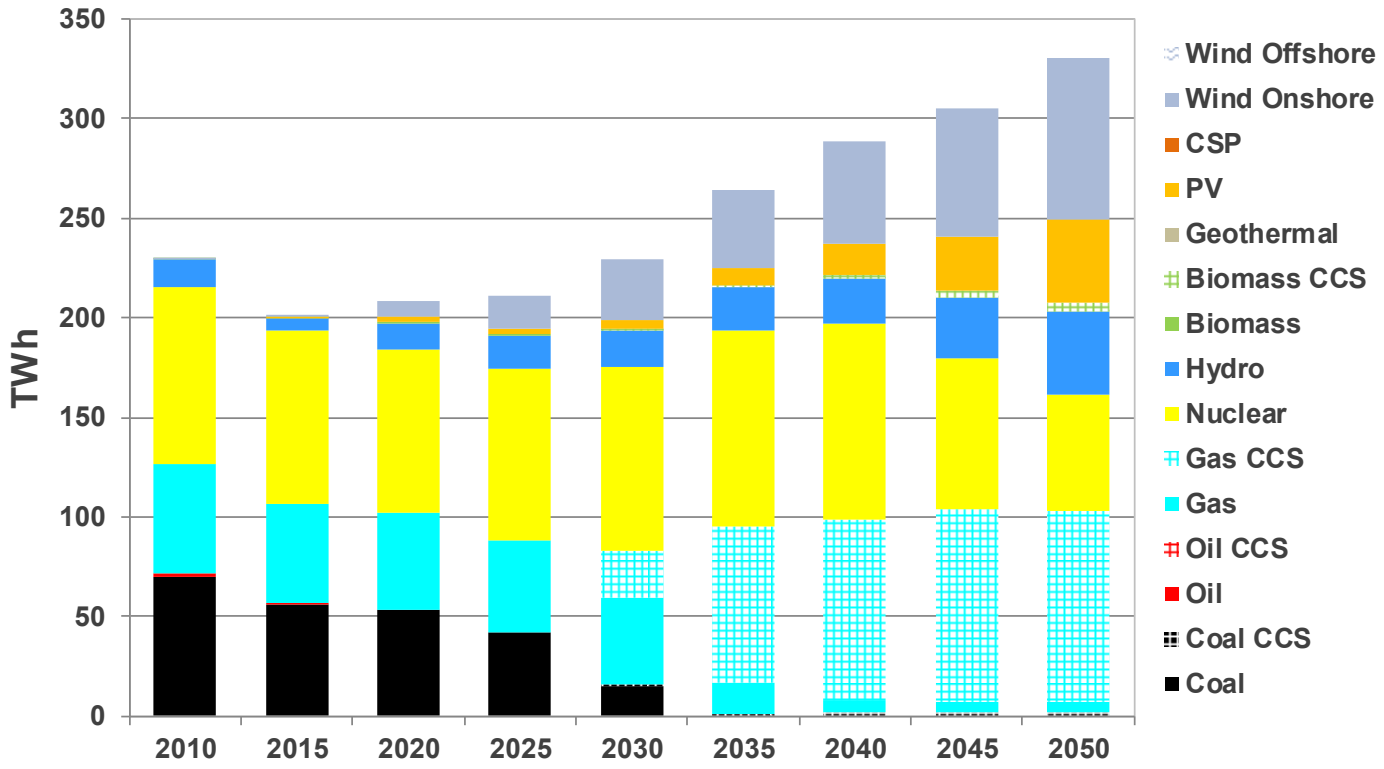
- *NDC is not so ambitious and the main trends prevail as REF except*
  - *A quick reduction in coal-fired electrify by natural gas in 2025*
- *After 2030 coal rebounds*
- *Strong market expansion of natural gas*
- *Growth in wind (on and off shore) and timid beginnings of PV introduction*

Modeling Results: BMU

Electricity Generation

ENERGY

Electricity generation by technology - BMU P2C



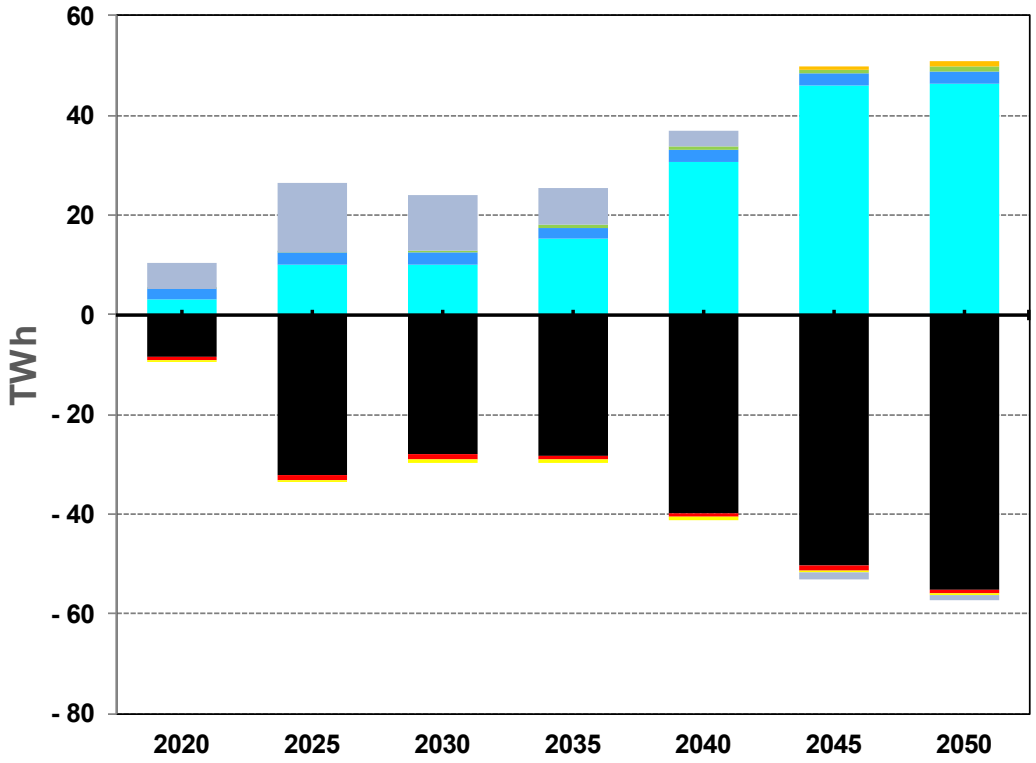
- *Electricity demand growth mainly met by wind and solar*
- *Fast expansion of on-shore wind and solar PV*
- *Unabated coal use is completely phased out by 2035 (some minor coal with CCS survives until 2050)*
- *Gas with CCS enables*
  - *the substitution of coal in base load generation*
  - *natural gas market expansion after 2025*

Modeling Results: BMU

Electricity Generation

ENERGY

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



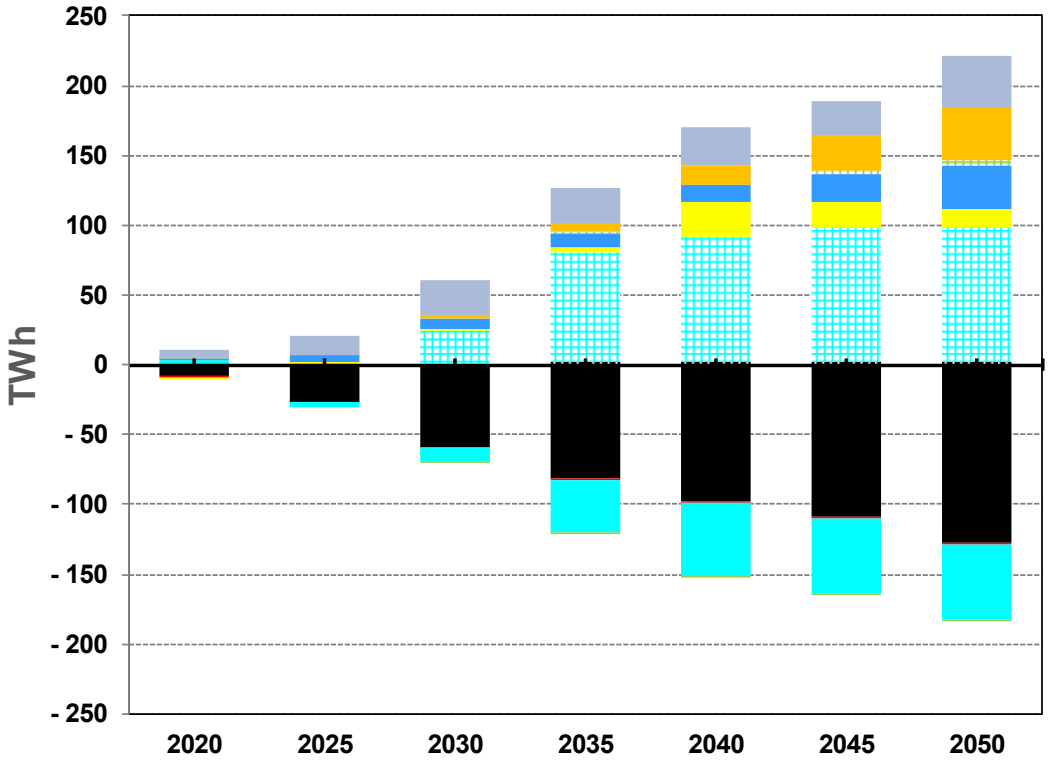
- *Until 2035 gas and onshore wind and, to a lesser extent, hydro power, displace coal and oil in the generation mix*
- *After 2035 solar PV tests its market compatibility*

Modeling Results: BMU

Electricity Generation

ENERGY

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



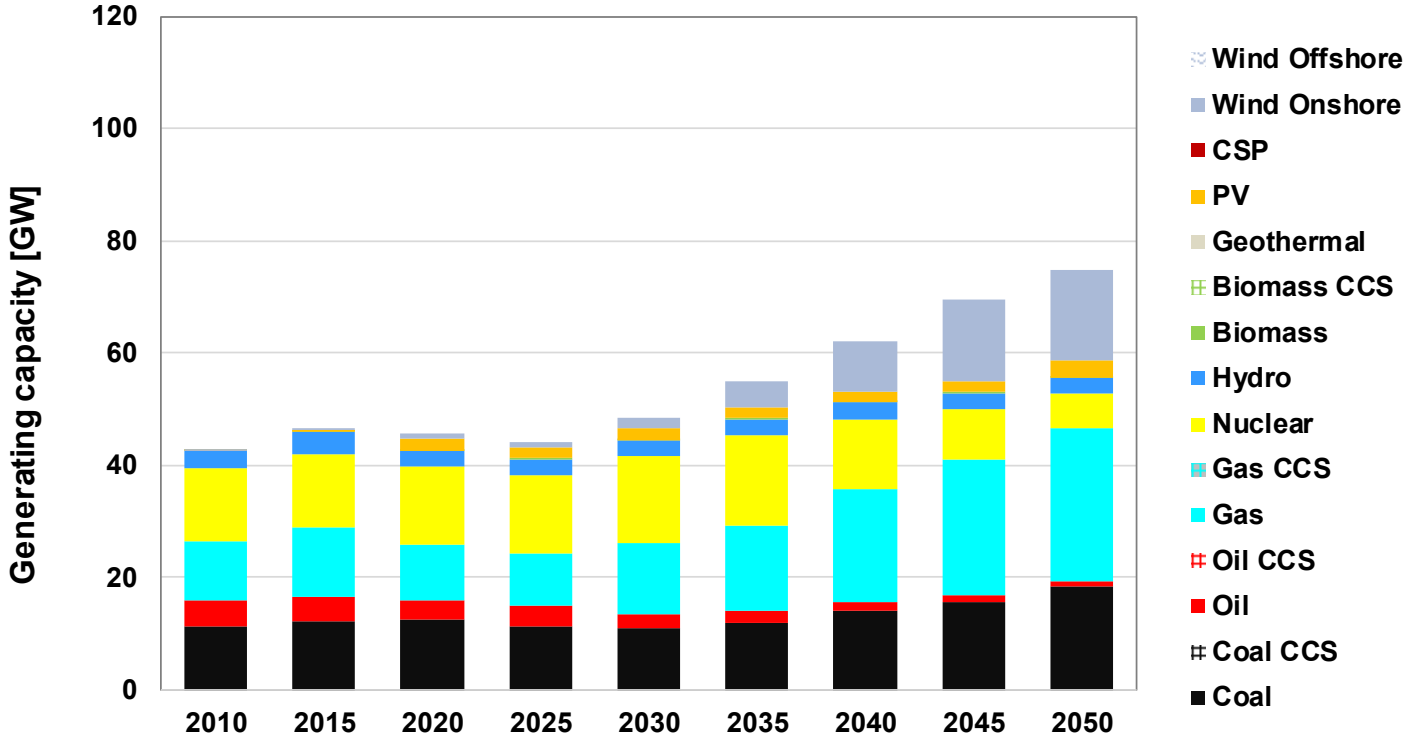
- *Low carbon generation displace coal and natural gas without CCS*
- *Gas with CCS allows natural gas to become the lead technology in generation by 2050*
- *Coal gets completely phased out (some minor coal with CCS survives until 2050)*
- *Fast expansion of off-shore wind and solar PV*
- *Modest expansion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

Modeling Results: BMU

Electricity generating capacity

ENERGY

Electricity generating capacity by technology - BMU REF Scenario



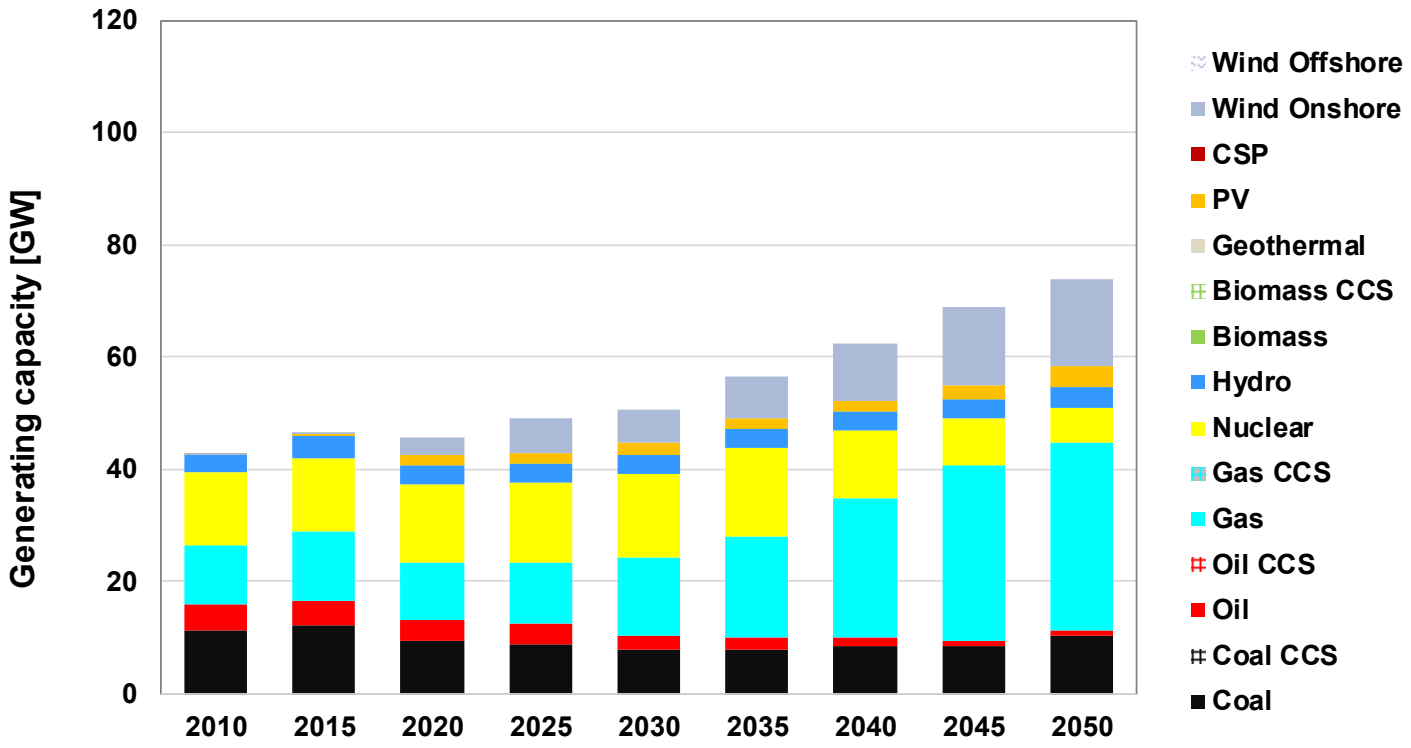
- *Capacity structure reflects REF generation mix*
- *Onshore wind (notable) and solar PV (modest) on the rise*
- *Natural gas continues its dominating role in capacity mix throughout 2050*
- *Coal capacities inch upwards in the long run as gas is providing balancing service to variable renewables*
- *Nuclear and oil capacities decline*

Modeling Results: BMU

Electricity generating capacity

ENERGY

Electricity generating capacity by technology - BMU NDC



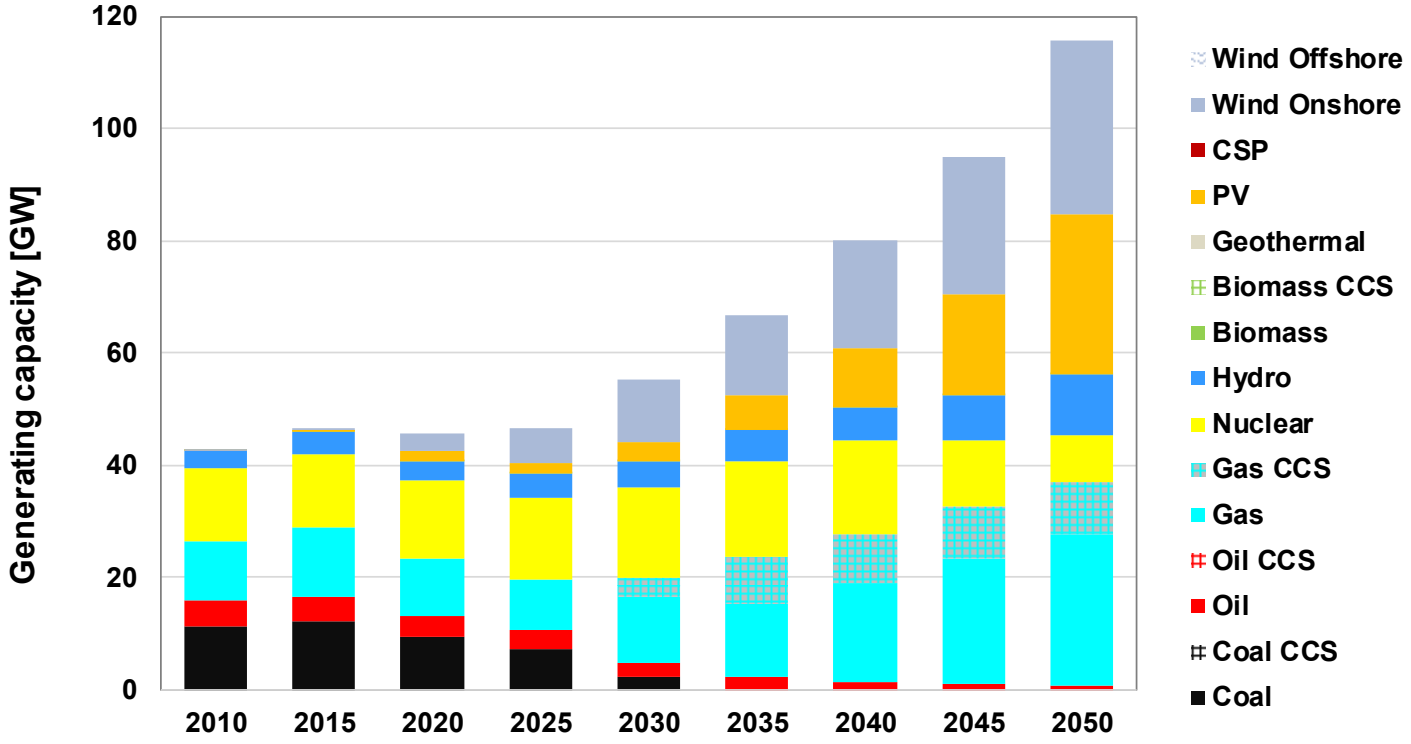
- *Despite a higher contribution of VRE marginally lower total capacity requirements due to the retirement and/or replacement of aged coal capacities by natural gas*
- *Natural gas capacities continue as the lead technology*
- *Nuclear power and oil capacities reflect the NDC generation structure and decline correspondingly*

Modeling Results: BMU

Electricity generating capacity

ENERGY

Electricity generating capacity by technology - BMU P2C



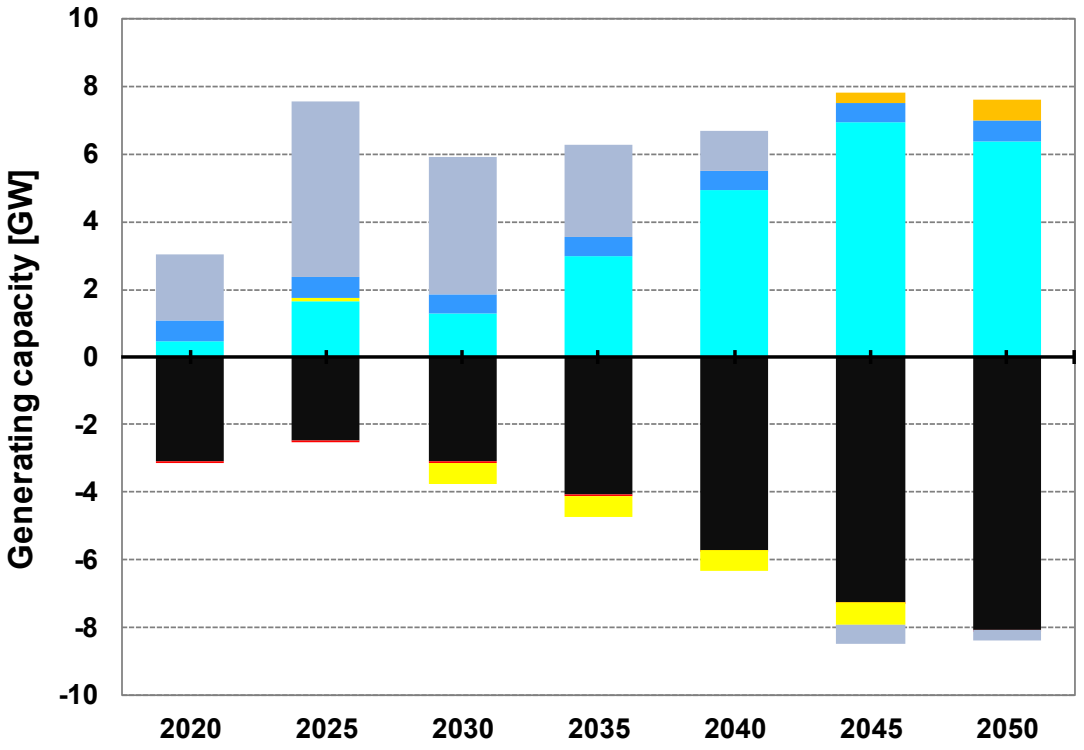
- *Substantially higher total capacity requirements due to larger VRE generation and electricity exports*
- *Offshore and onshore wind and PV account for almost 30% of generating capacity*
- *Natural gas capacities now increasingly relying on CCS*
- *Hydro and nuclear provide baseload capacity*
- *Coal and oil capacities practically phased-out by 2050*

Modeling Results: BMU

Electricity generating capacity

ENERGY

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



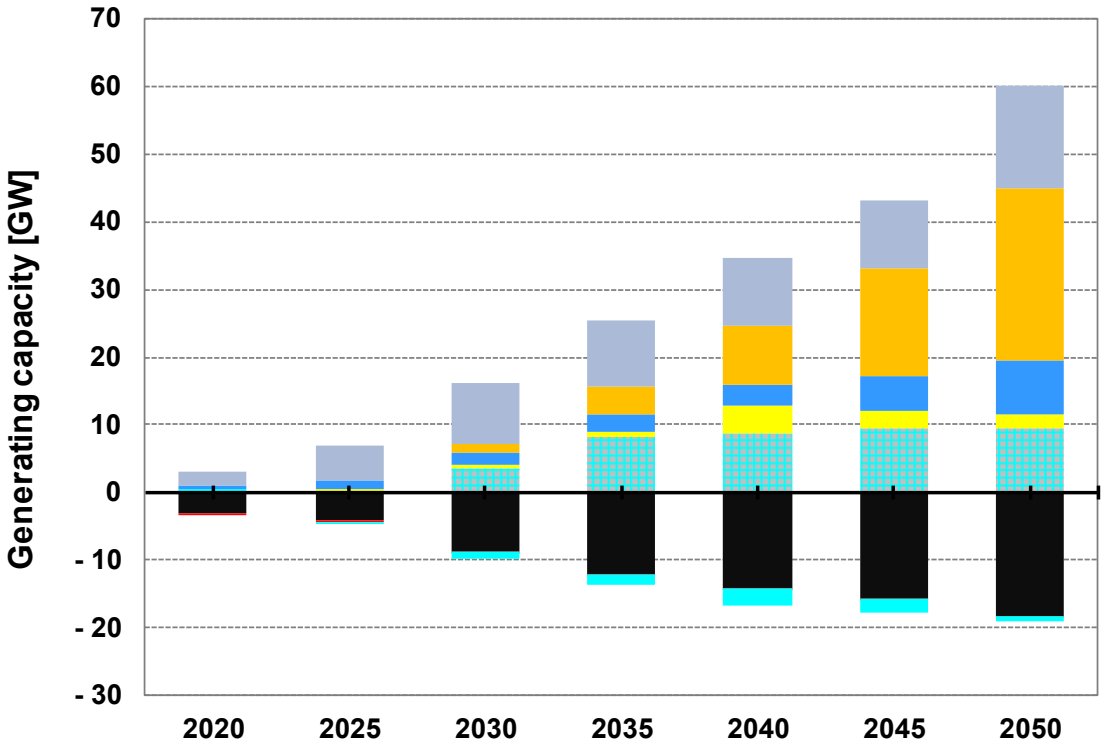
- *See comments on previous slides regarding generation structure*
- *Until 2020, wind, hydro and natural gas substitute for coal and, to a lesser extent, nuclear power*
- *Tas of 2045, the advent of solar competes with wind*

Modeling Results: BMU

Electricity generating capacity

ENERGY

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



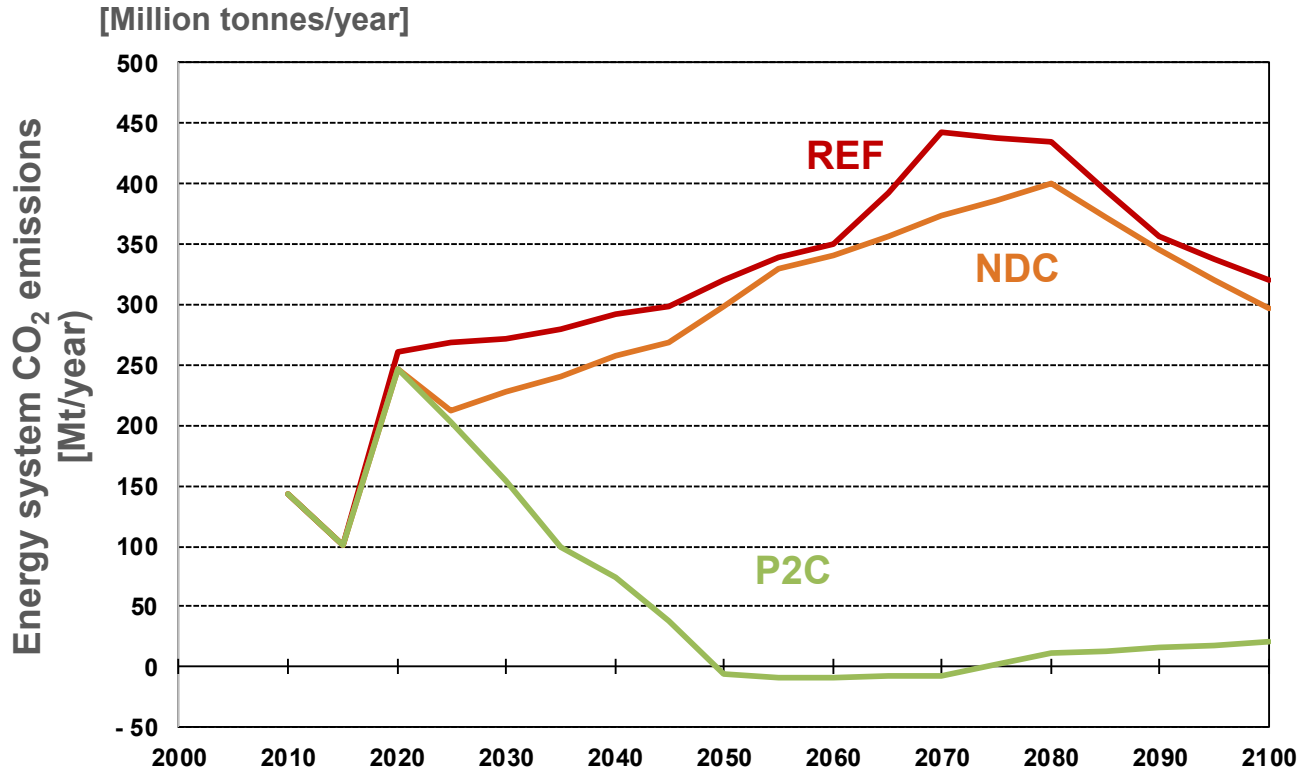
- *Capacity structure reflects the comments on P2C and REF generation mixes*
- *Major role of wind and solar*
- *Low carbon options including hydro , gas with CCS and nuclear power increasingly displace baseload coal capacities as well as gas without CCS*

Modeling Results: BMU

Carbon dioxide emissions

ENERGY

CO_2 emissions by scenario - BMU



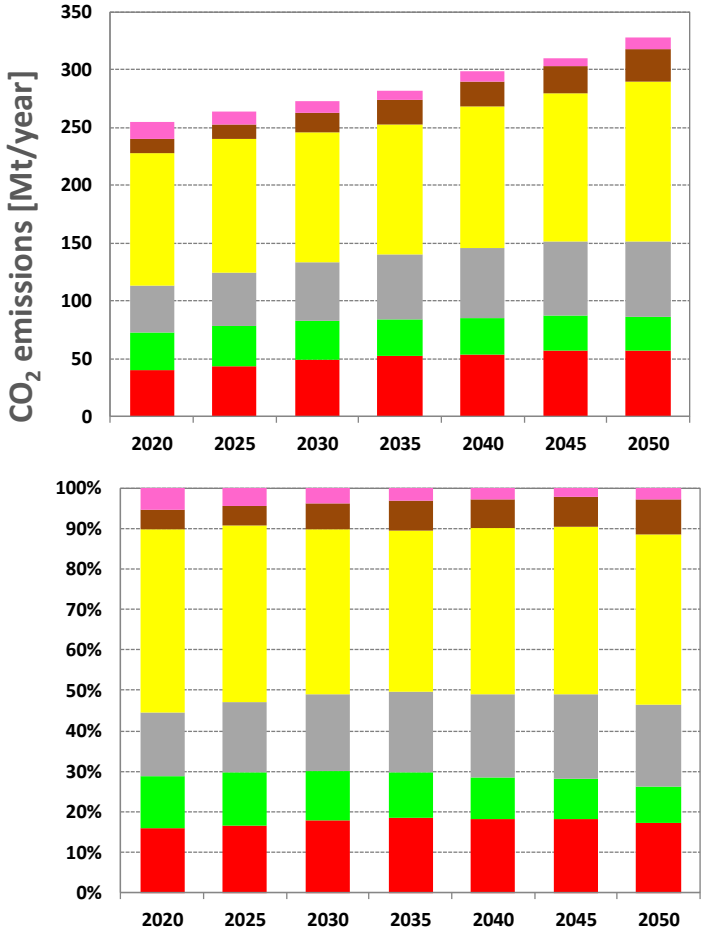
- ***REF: Even without climate policies in place, BMU emissions peak by 2070***
- ***P2C: Negative emissions between 2050 and 2075 – thereafter slightly positive***
- ***NDC leads to notable short-term emission reductions but without higher ambitions after 2030, emissions rise to almost REF levels***
- ***Cumulative emissions (2020-2100) are 9% (or 2.6 Gt CO_2) lower than in REF***

Modeling Results: BMU

Carbon dioxide emissions

ENERGY

CO_2 emissions by sector – BMU 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*

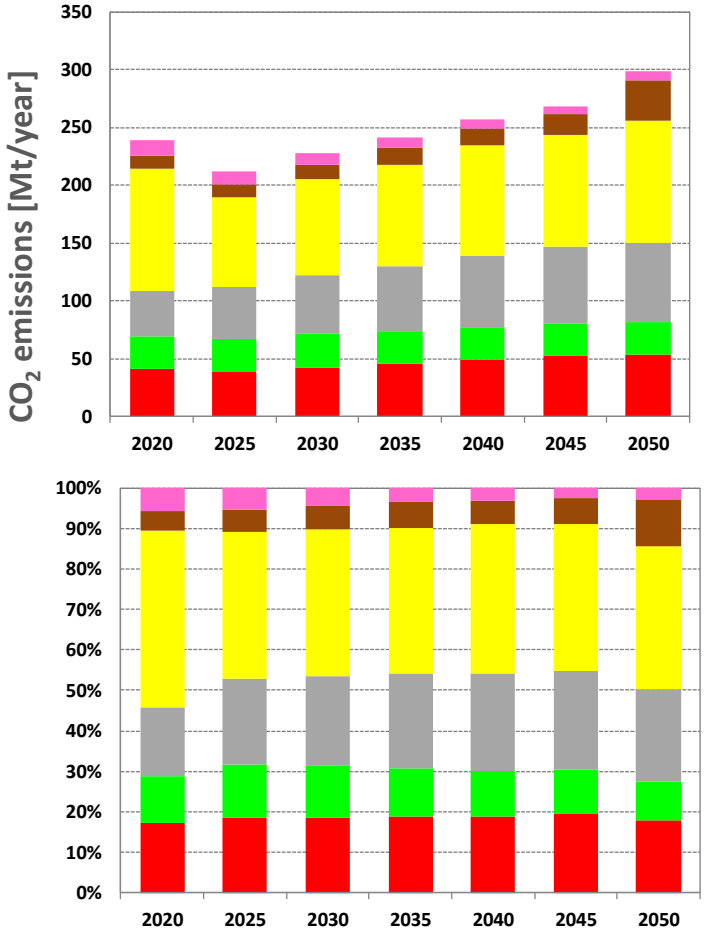
NOTE: **Fuel supply** includes emissions from extraction, refining, synfuel and biofuel manufacture

Modeling Results: BMU

Carbon dioxide emissions

ENERGY

CO_2 emissions by sector – BMU NDC Scenario



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

- *Lower NDC final energy demand and electricity generation responses:*
  - *Electricity generation related CO_2 reductions more pronounced than in REF but the slack is largely absorbed by fossil upstream operations, followed by transportation and industry*

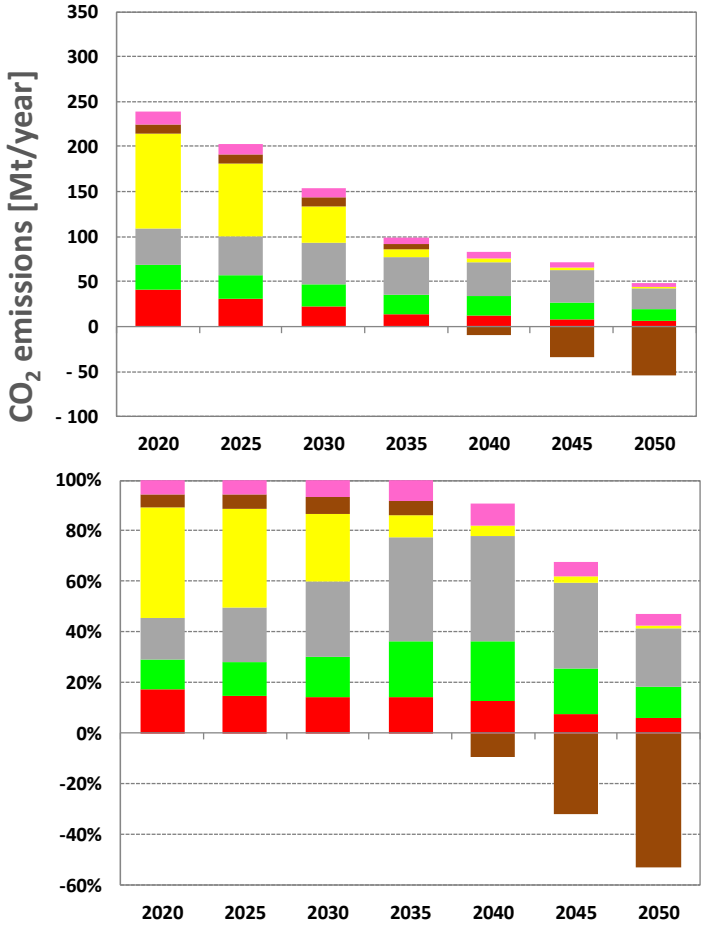
NOTE: **Fuel supply** includes emissions from extraction, refining, synfuel and biofuel manufacture

Modeling Results: BMU

Carbon dioxide emissions

ENERGY

CO_2 emissions by sector – BMU 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*

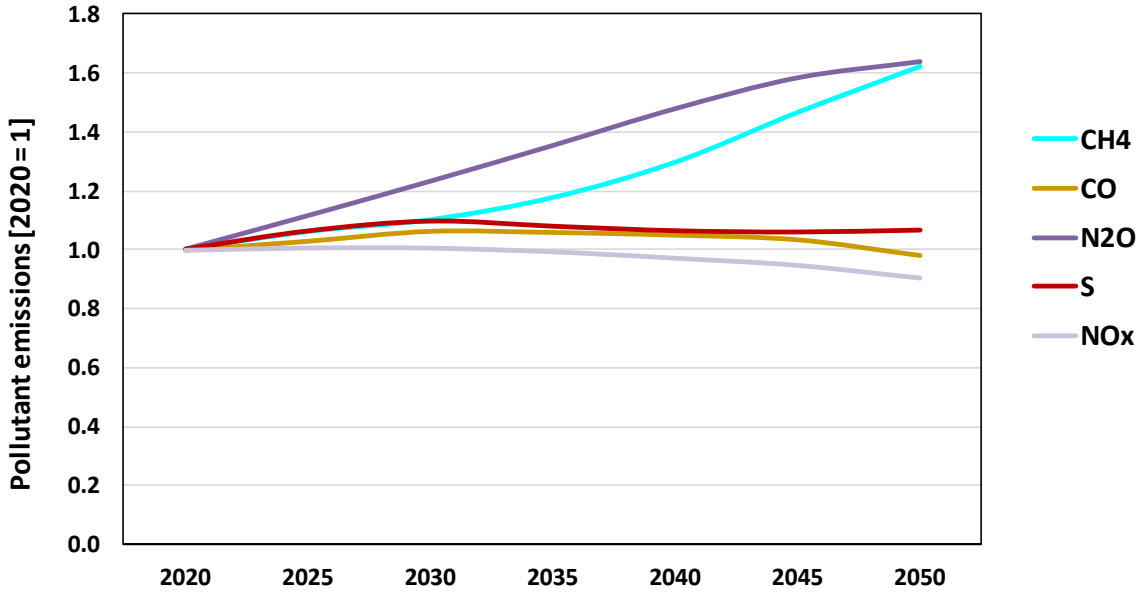
NOTE: **Fuel supply** includes emissions from extraction, refining, synfuel and biofuel manufacture

Modeling Results: BMU

Air quality

ENERGY

Non-CO_2 pollutant emissions – BMU REF



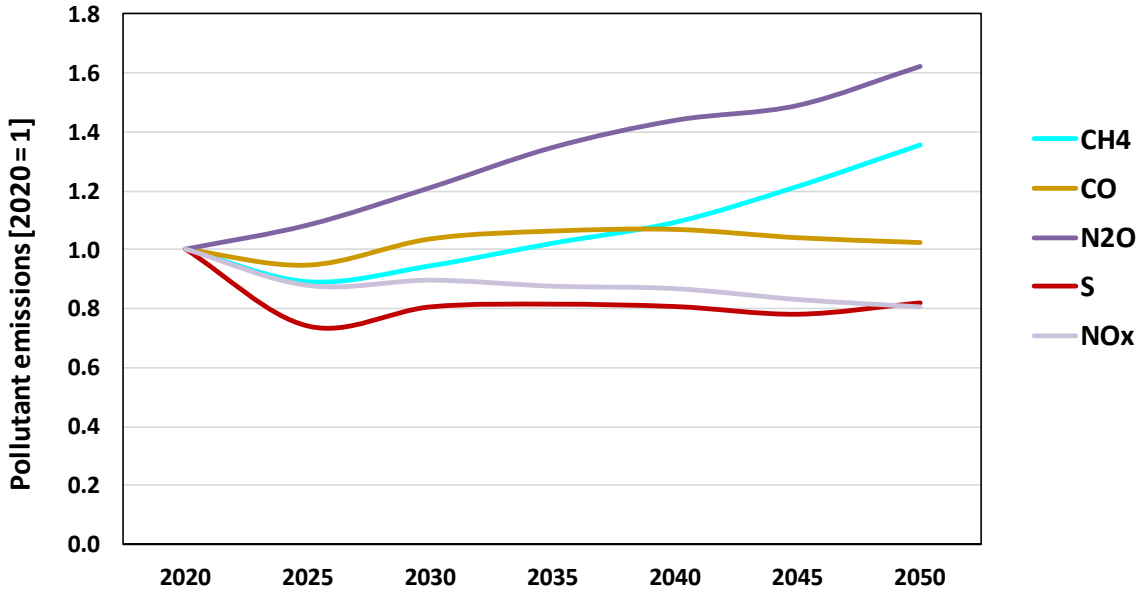
- *Energy related methane and N2O emissions grow considerably by 2050*
- *Sulfur emissions decrease after a temporary rise as*
  - *coal becomes less popular as end-use fuel*
  - *coal combustion technology for electricity generation increasingly equipped with desulfurization equipment*

Modeling Results: BMU

Air quality

ENERGY

Non-CO_2 pollutant emissions – BMU NDC



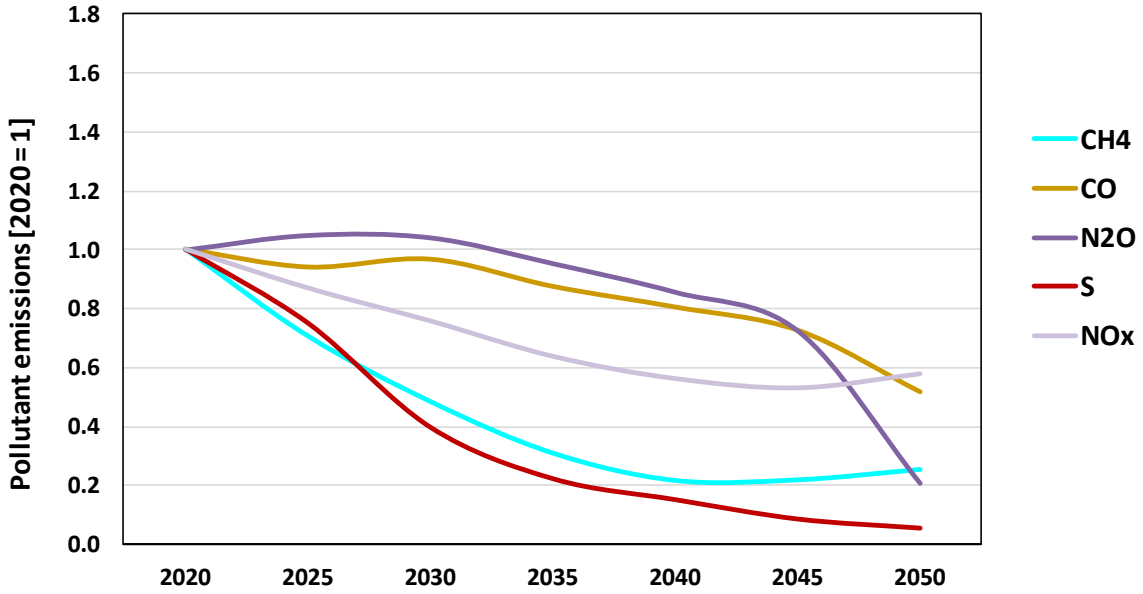
- *NDC driven changes in the energy sector further reduce sulfur releases as gas and nuclear substitute for coal and oil*
- *Lower CH4 emissions due to overall lower gas and coal consumption*

Modeling Results: BMU

Air quality

ENERGY

Non-CO_2 pollutant emissions – BMU P2C



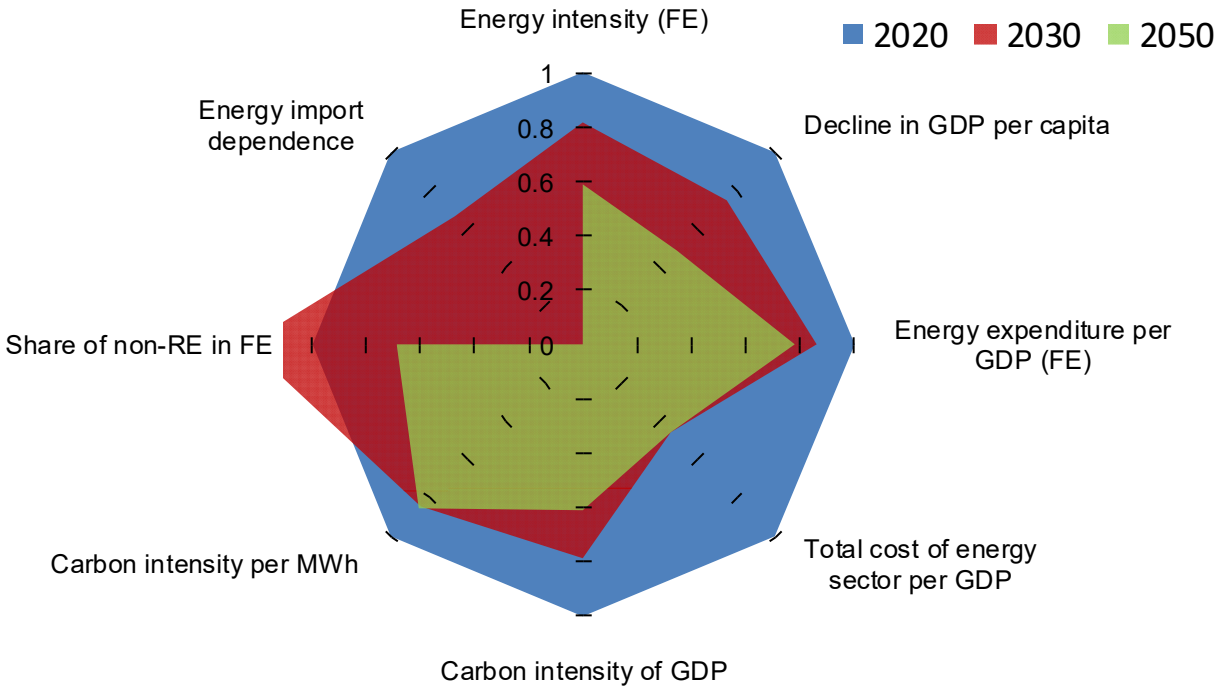
- *P2C leads to substantial reductions in all air born pollutant emissions – quasi a co-benefit of the energy system transformation to protect the global climate system*

Modeling Results: Indicators

Tradeoffs and synergies: BMU

ENERGY

Energy and environment indicators - BMU REF Scenario



- *Final energy intensity improves as aging infrastructure is being replaced (faster before 2030 then slowing down)*
- *Energy expenditures per GDP decline by 2030 but slow down thereafter*
- *Carbon intensity of GDP declines faster than CO_2/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*
- *BMU turns from a net importing region to an exporter by 2050*

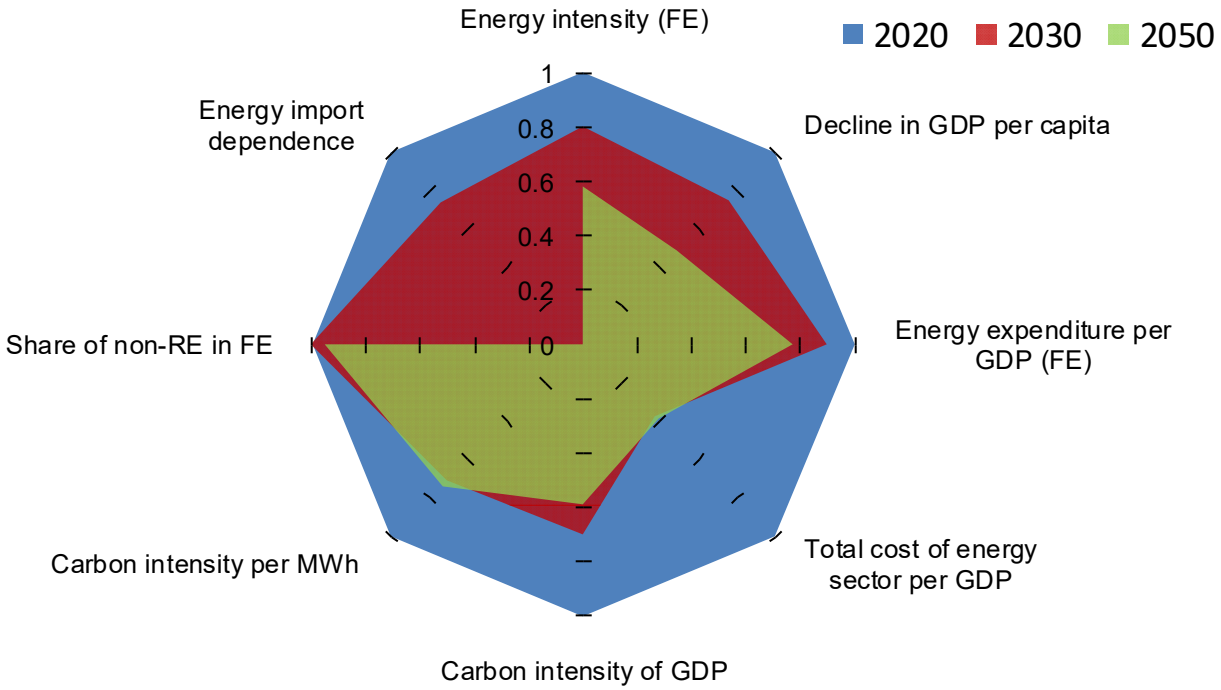
- Indicators are scaled relative to 2020 (2020=1), and any *improvement in an indicator will result in values lower than 1*
- If the shape of polygon becomes smaller compared to 2020, it shows improvement in the indicators

Modeling Results: Indicators

Tradeoffs and synergies: BMU

ENERGY

Energy and environment indicators - BMU NDC Scenario



- *In the absence of ambitious NDC targets only slight improvements in the share of RE*
- *Marked improvement of CO_2/MWh (more pronounced than carbon intensity of GDP), primarily due to lower coal and oil exports*
- *Declining domestic coal use as well as coal exports require lower upstream investments and thus result in an improvement of the Total cost of energy sector per GDP*
- *No notable change in GDP per capita compared to REF*

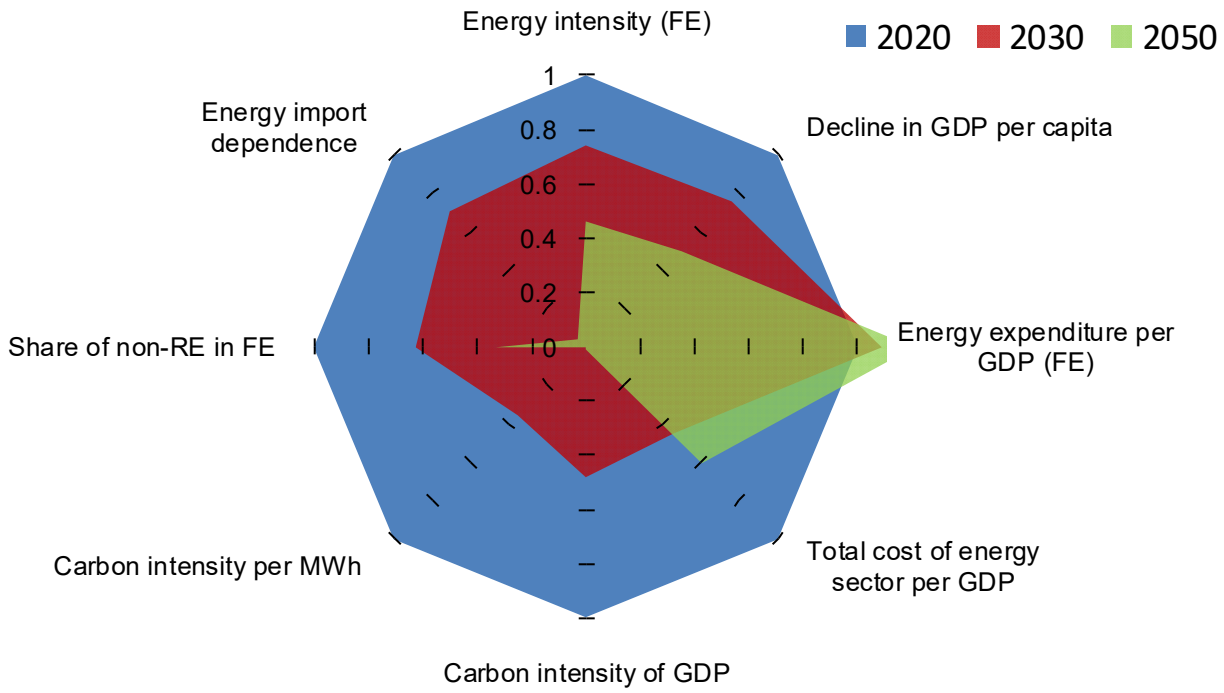
- Indicators are scaled relative to 2020 (2020=1), and any *improvement in an indicator will result in values lower than 1*
- If the shape of polygon becomes smaller compared to 2020, it shows improvement in the indicators

Modeling Results: Indicators

Tradeoffs and synergies: BMU

ENERGY

Energy and environment indicators - BMU 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 CO_2/MWh indicator (>95% compared to 2020) outpacing carbon intensity of GDP*
- *Energy intensities decline along with the unprecedented investments in efficiency measures*
- *Total energy sector costs reduced due to higher non-fossil domestic energy use and increased gas exports*

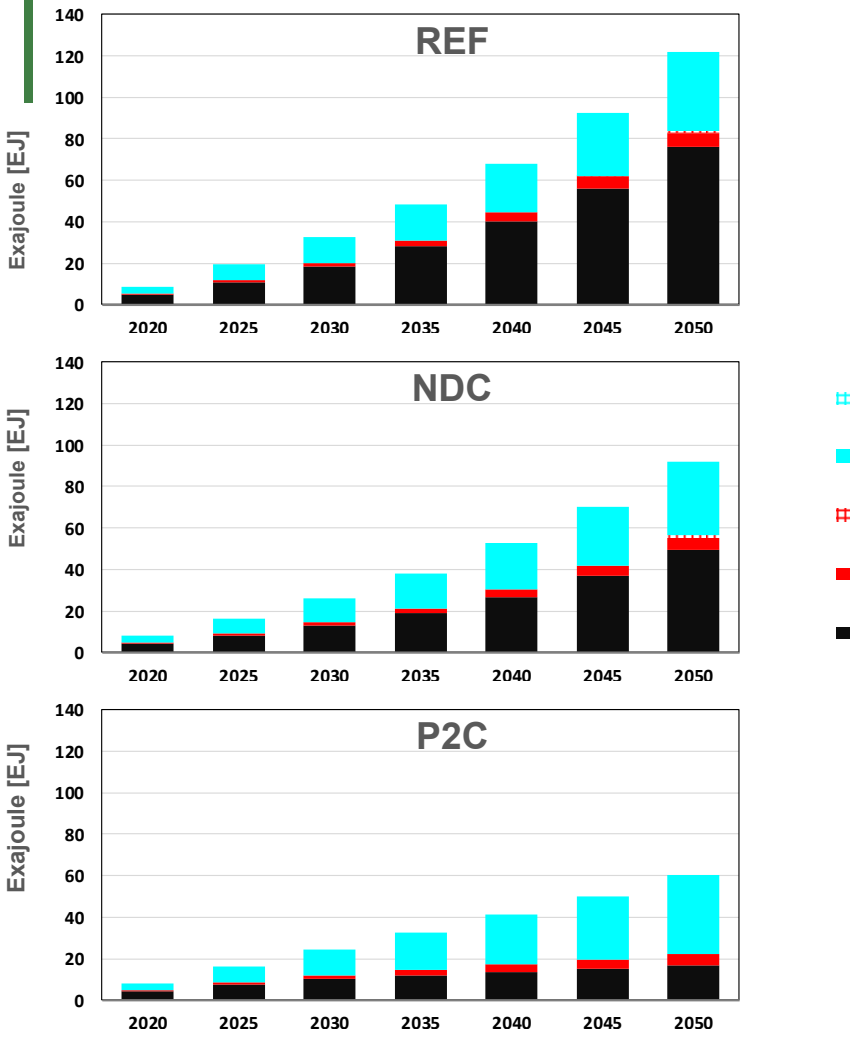
- Indicators are scaled relative to 2020 (2020=1), and any *improvement in an indicator will result in values lower than 1*
- If the shape of polygon becomes smaller compared to 2020, it shows improvement in the indicators

Modeling Results: Indicators

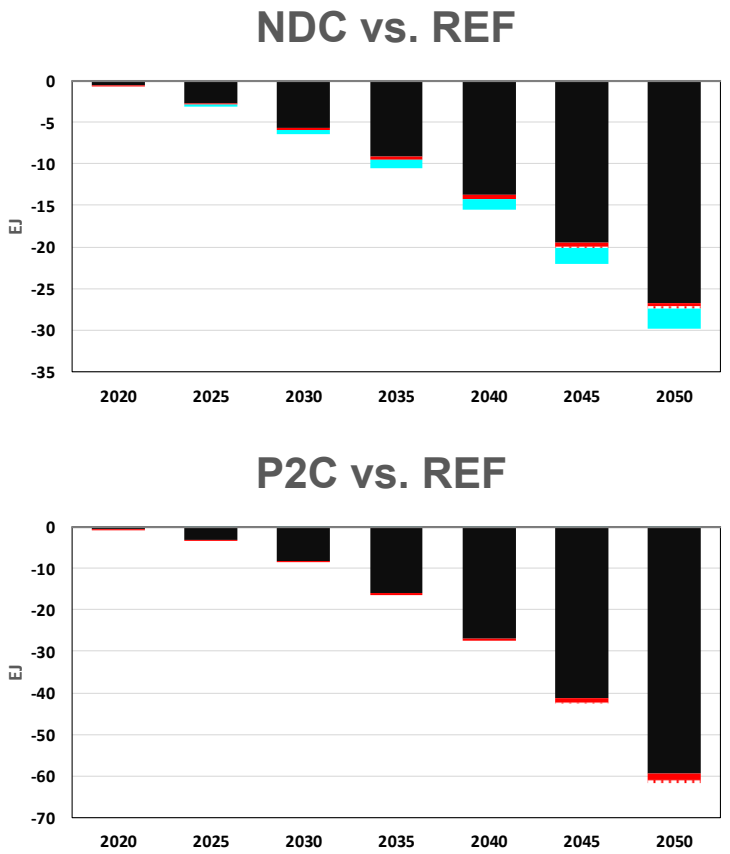
Resource extraction: BMU

ENERGY

Cumulative fossil fossil resource extraction



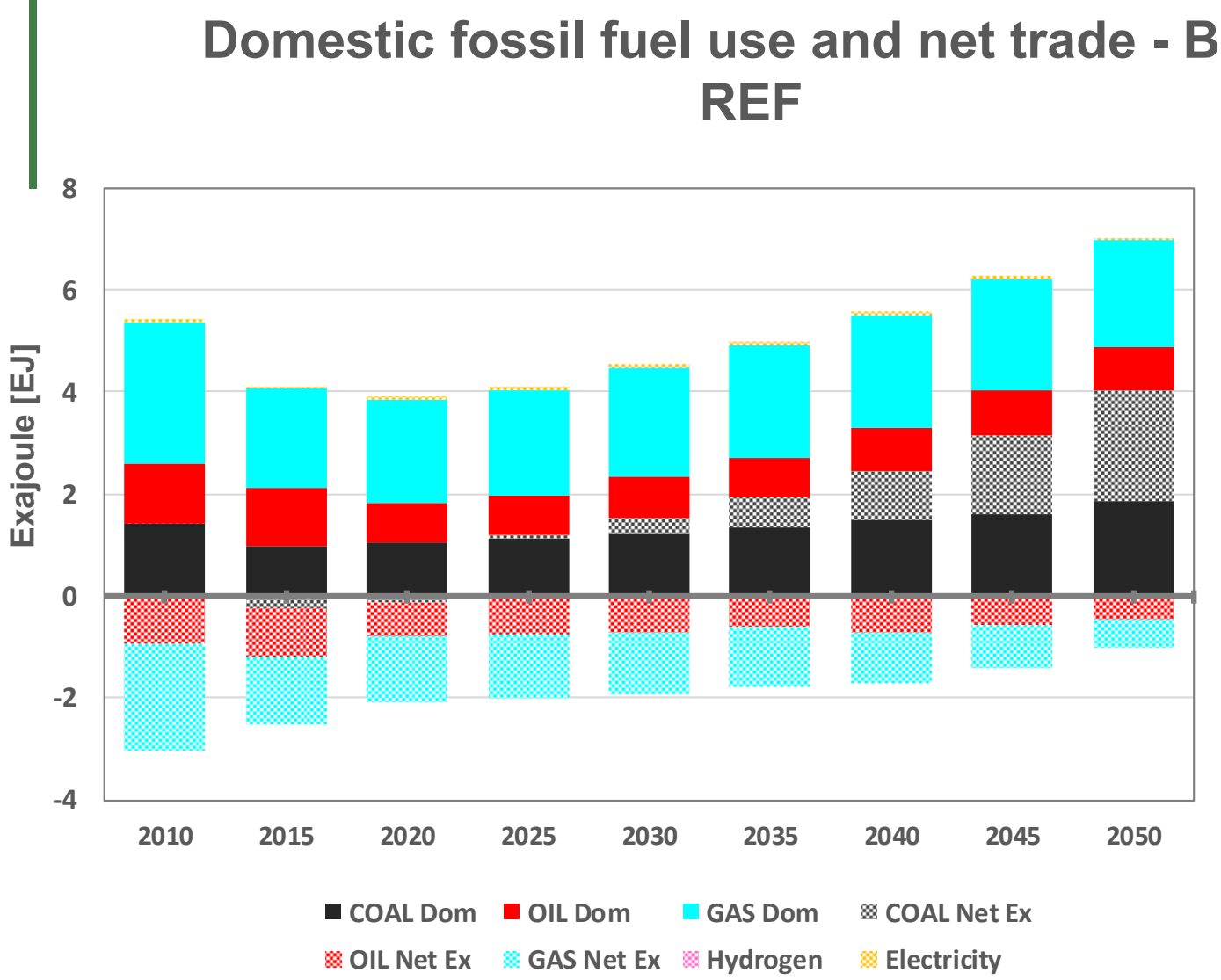
Difference in cumulative fossil resource extraction 2020 to 2050



Modeling Results: Indicators

Domestic use versus trade: BMU

ENERGY

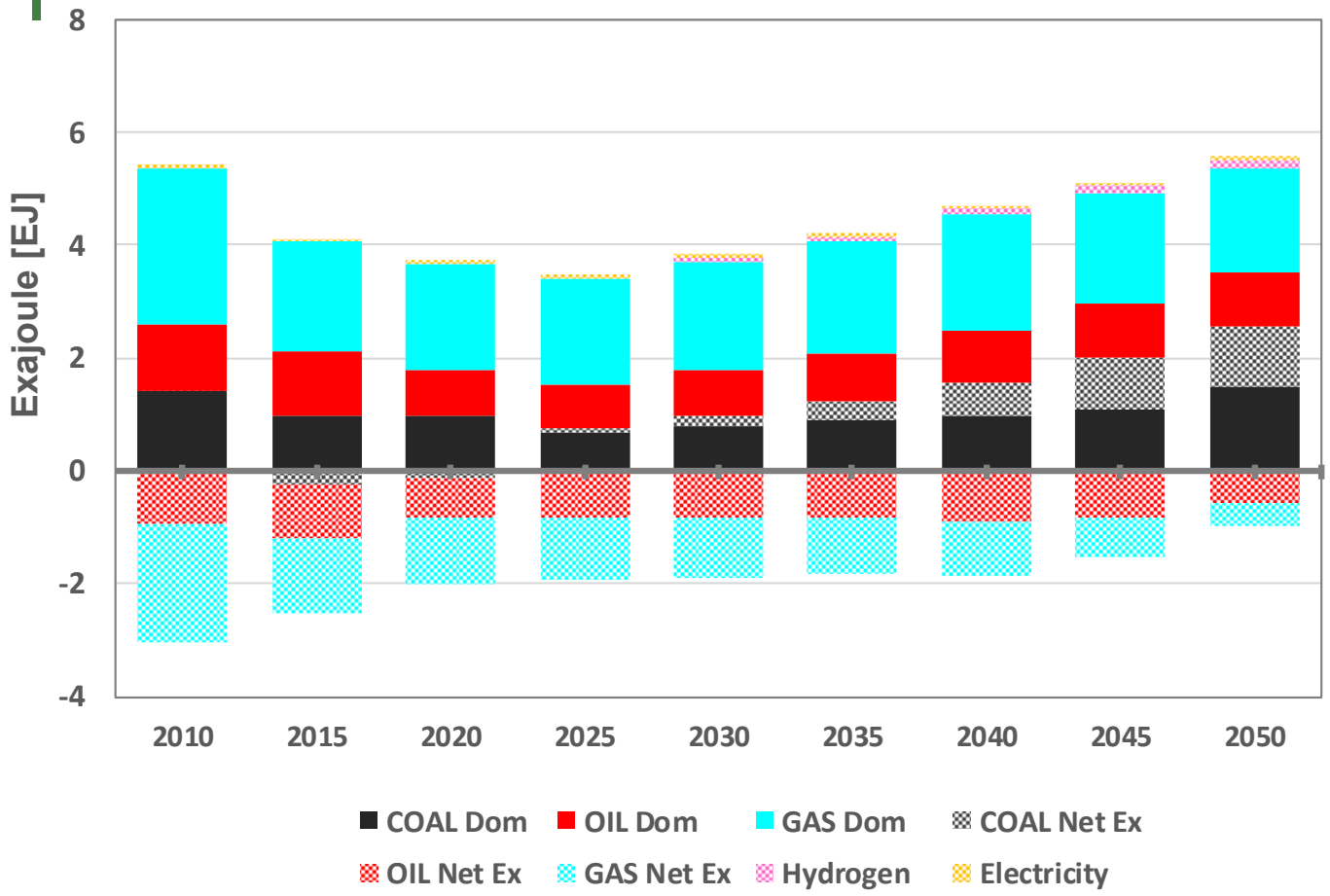


Modeling Results: Indicators

Domestic use versus trade: BMU

ENERGY

Domestic fossil fuel use versus net trade - BMU NDC

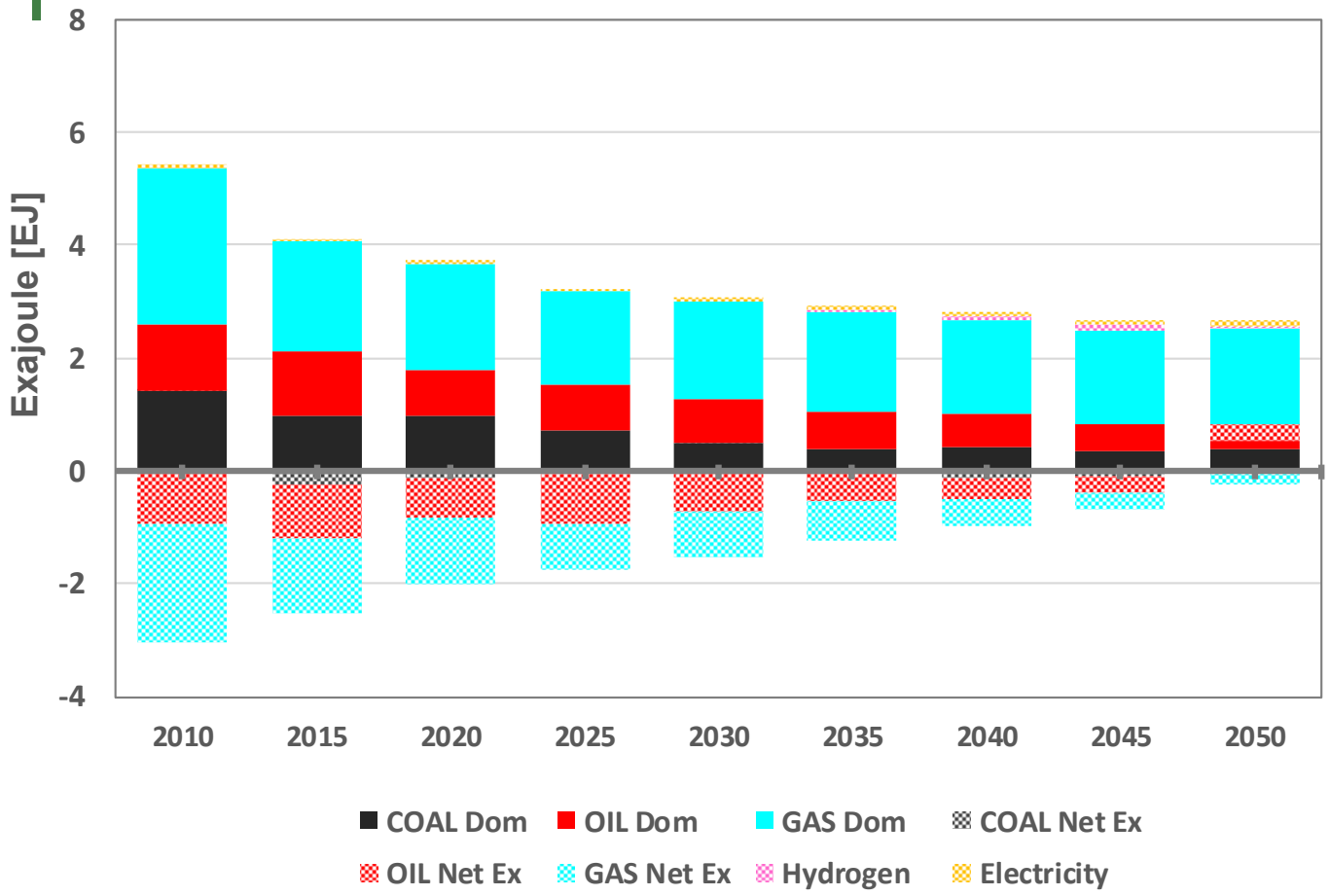


Modeling Results: Indicators

Domestic use versus trade: BMU

ENERGY

Domestic fossil fuel use versus net trade - BMU P2C

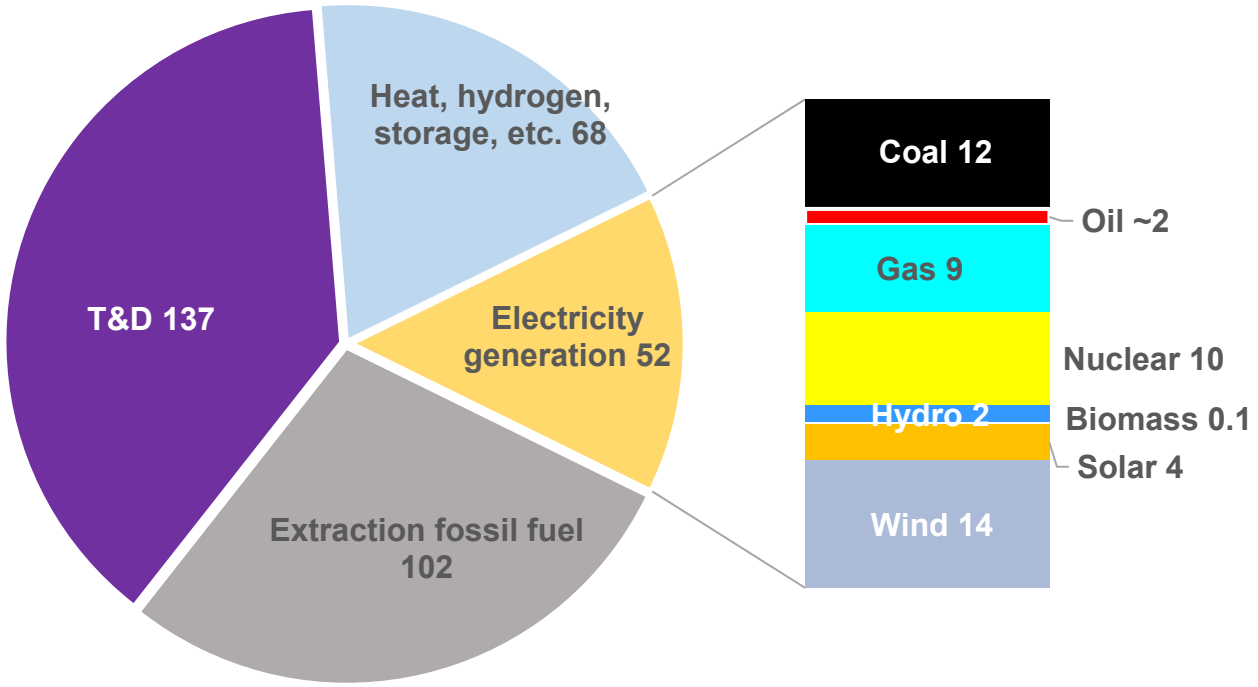


Modeling Results: Indicators

Investment needs: BMU

ENERGY

Cumulative investments 2020-2050: *358 billion US$*
REF - BMU



- *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*

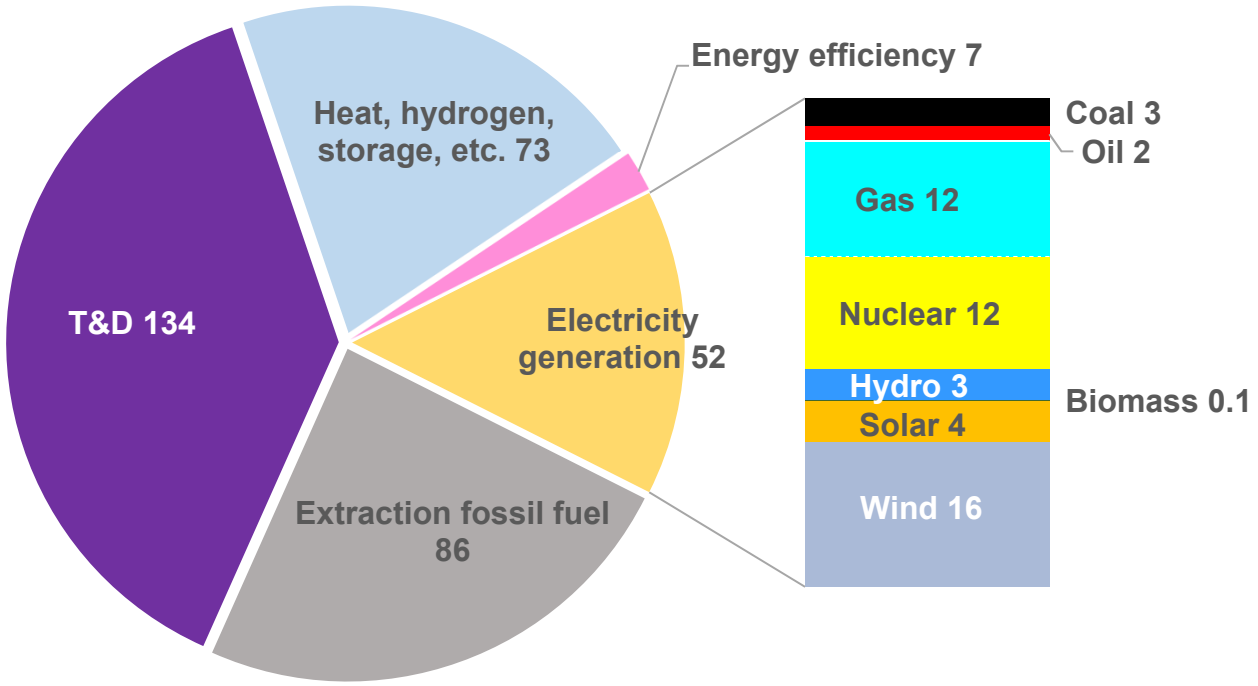
- T&D: transmission and distribution of electricity and district heat
- Investments in US$ at 2010 prices and exchange rates

Modeling Results: Indicators

Investment needs: BMU

ENERGY

Cumulative investments 2020-2050: *353 billion US$*
NDC - BMU



- *Lower upstream fossil fuel investments (than REF) due to reduced coal and oil exports*
- *Energy efficiency measures are gradually introduced – predominately after 2030*
- *Investments in gas and nuclear generation replace declining coal*
- *Solar and wind pick up momentum (though modestly by international standards)*

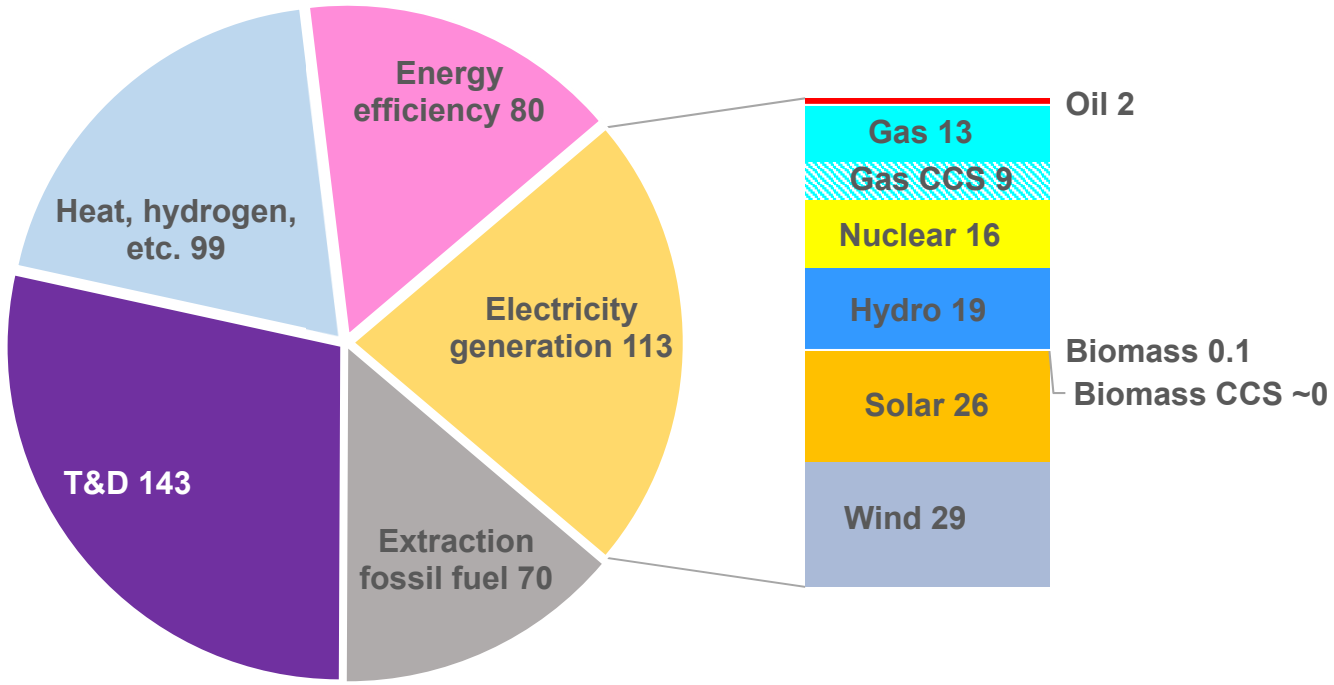
- T&D: transmission and distribution of electricity and district heat
- Investments in US$ at 2010 prices and exchange rates

Modeling Results: Indicators

Investment needs: BMU

ENERGY

Cumulative investments 2020-2050: *506 billion US$*
P2C - BMU



- *Significant change in overall investment structure*
- *Upstream investments considerably lower - in terms of $ expenditures, the decline in upstream investments is equivalent to the increase in efficiency investments*
- *Energy efficiency becomes the second largest investment category*
- *No other significant investments in fossil electricity generation but gas*
- *Gas generation with CCS exceeds gas without CCS*
- *Generation commands 50% higher capital investment (45% of the total for renewables)*
- *Nuclear power remains largest single generating investment category*

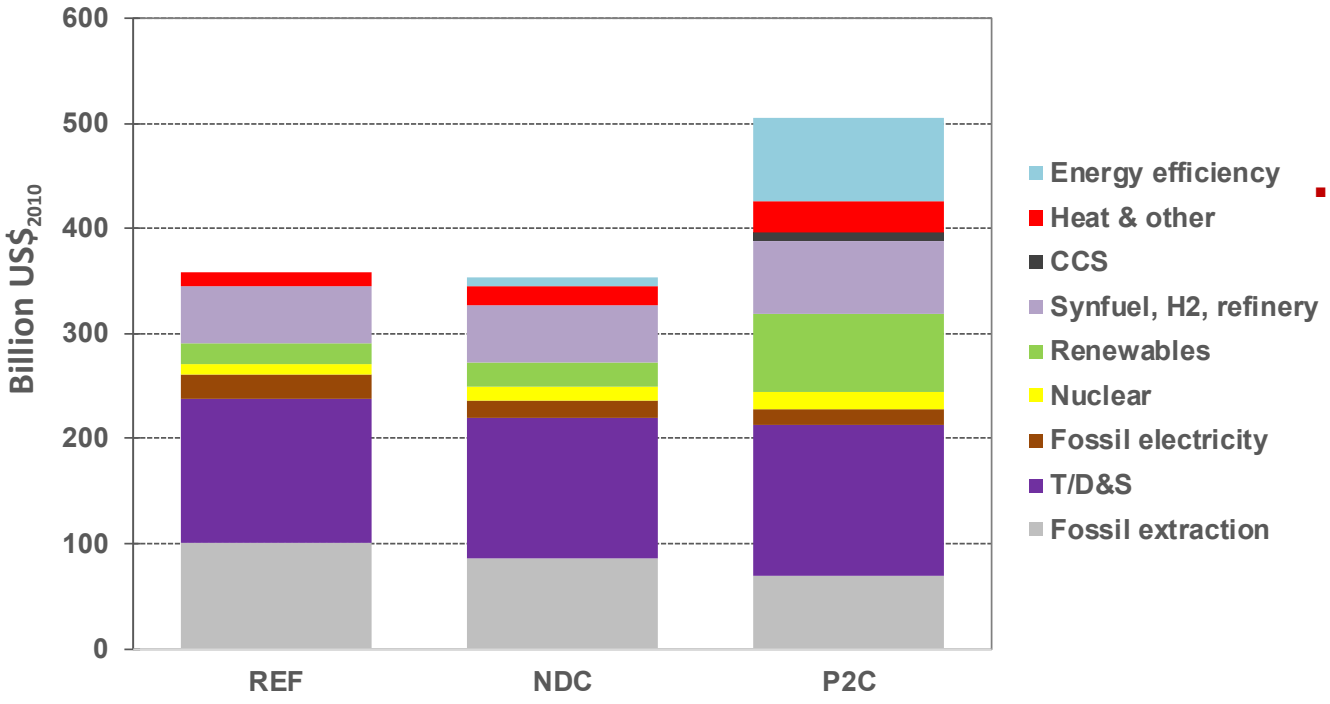
- T&D: transmission and distribution of electricity and district heat
- Investments in US$ at 2010 prices and exchange rates

Modeling Results: Indicators

Investment needs: BMU

ENERGY

Comparing investment requirements - BMU REF, NDC and P2C scenarios



- *NDC commitments only marginally affect the overall investment structure (exception: Fossil fuel extraction due lower export demand for oil and gas)*
- *Total capital demand in P2C just slightly higher than in REF (replacement of inefficient capacities with BAT)*
  - *upstream investments continue to dominate RUS energy sector investments*
  - *Energy efficiency measures absorb the investments not demanded by upstream activities*
  - *Strong market penetration of wind and solar generating capacities in P2C*

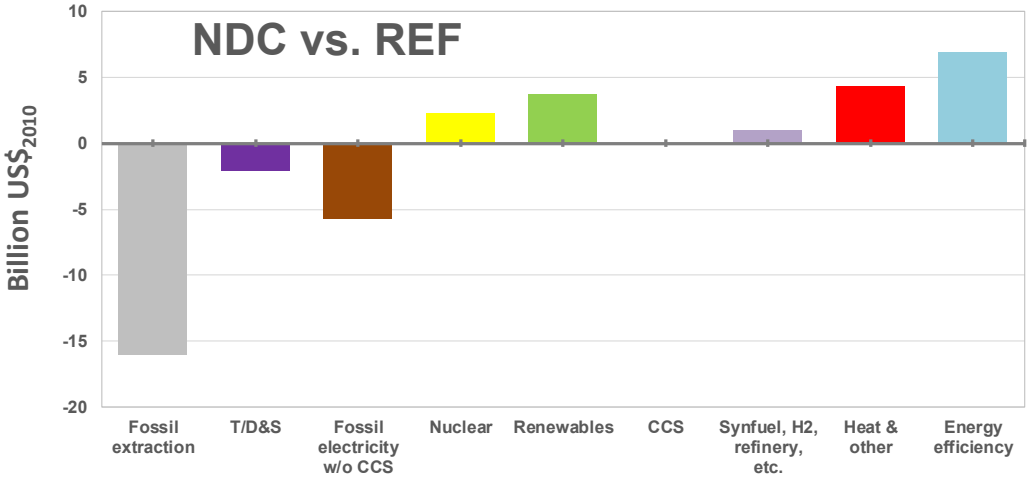
- T/D&S: transmission, distribution and storage of electricity and district heat
- CCS: carbon capture and storage
- H2: hydrogen
- BAT: Best available technology

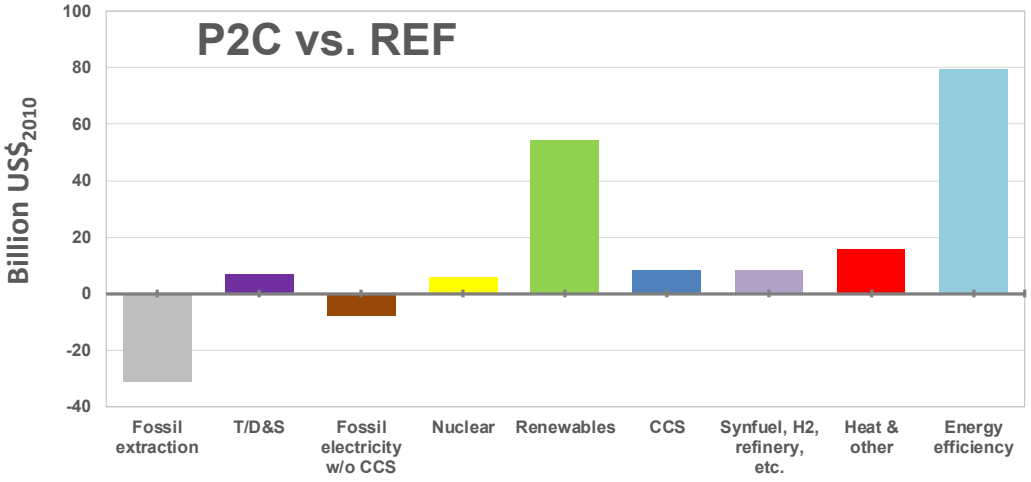
Modeling Results: Indicators

Investment needs: BMU

ENERGY

Distributional effects of investment requirements between scenarios - BMU





NDC vs. REF

- *See earlier comments*
- *Modest revision of the energy sector investment structure other than the fossil fuel export driven decline in upstream activities*

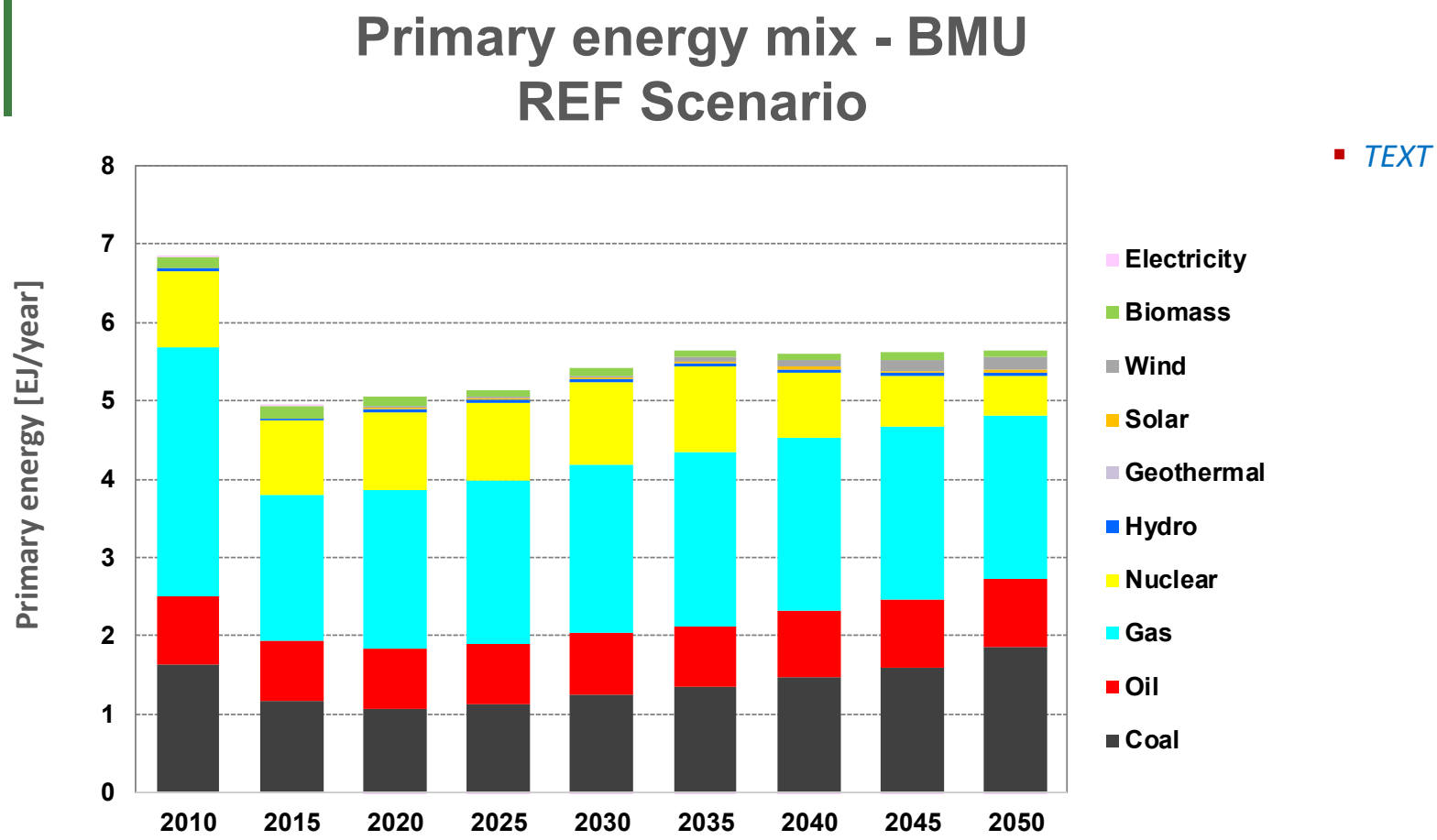
P2C vs. REF

- *See earlier comments*
- *Clearly visible shift from upstream investments to expenditures in energy efficiency*
- *Gas CCS and renewables are the winners in electricity generating*

Modeling Results: BMU

Primary Energy

ENERGY



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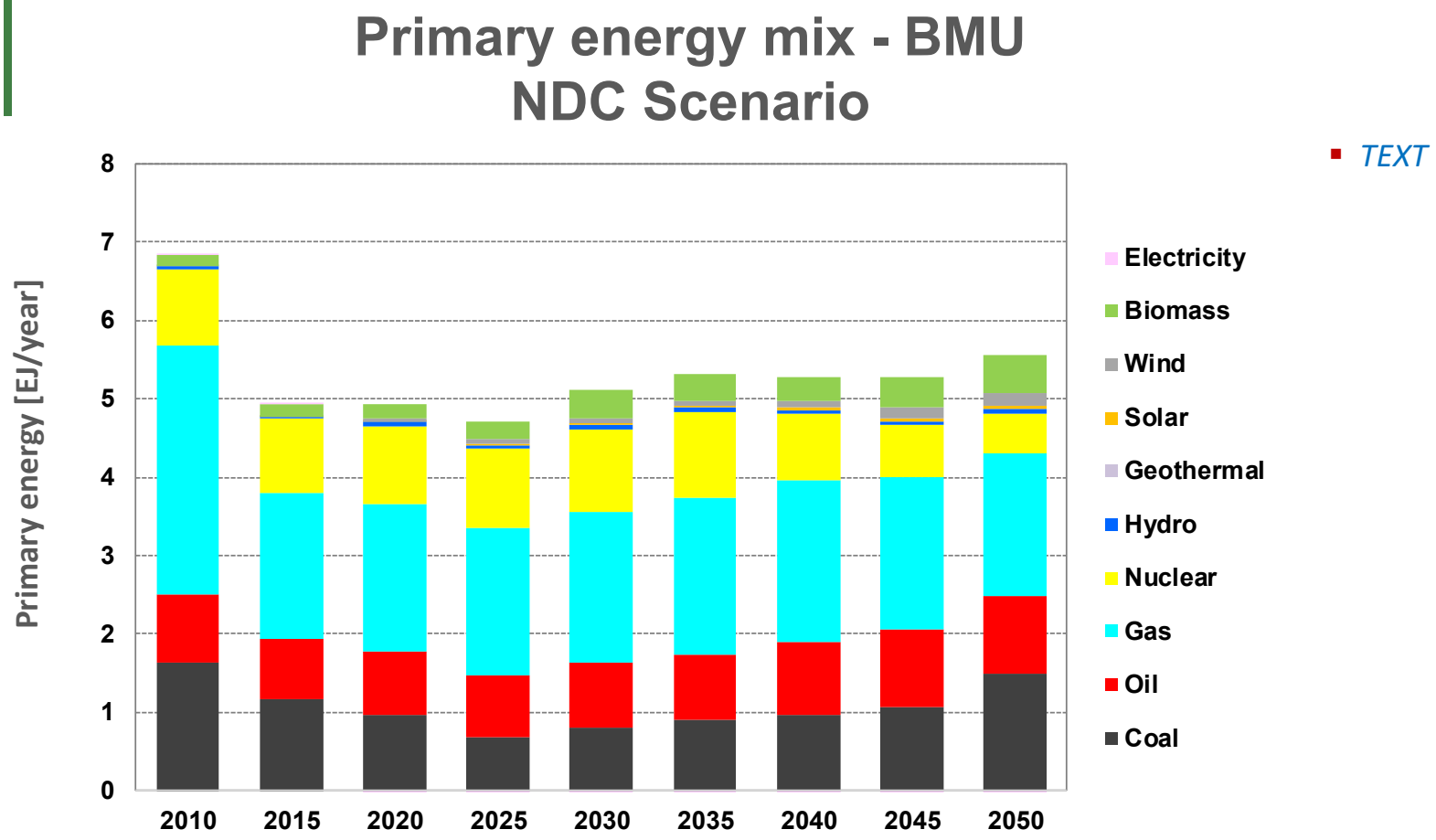
Modeling Results: BMU

Primary Energy

ENERGY

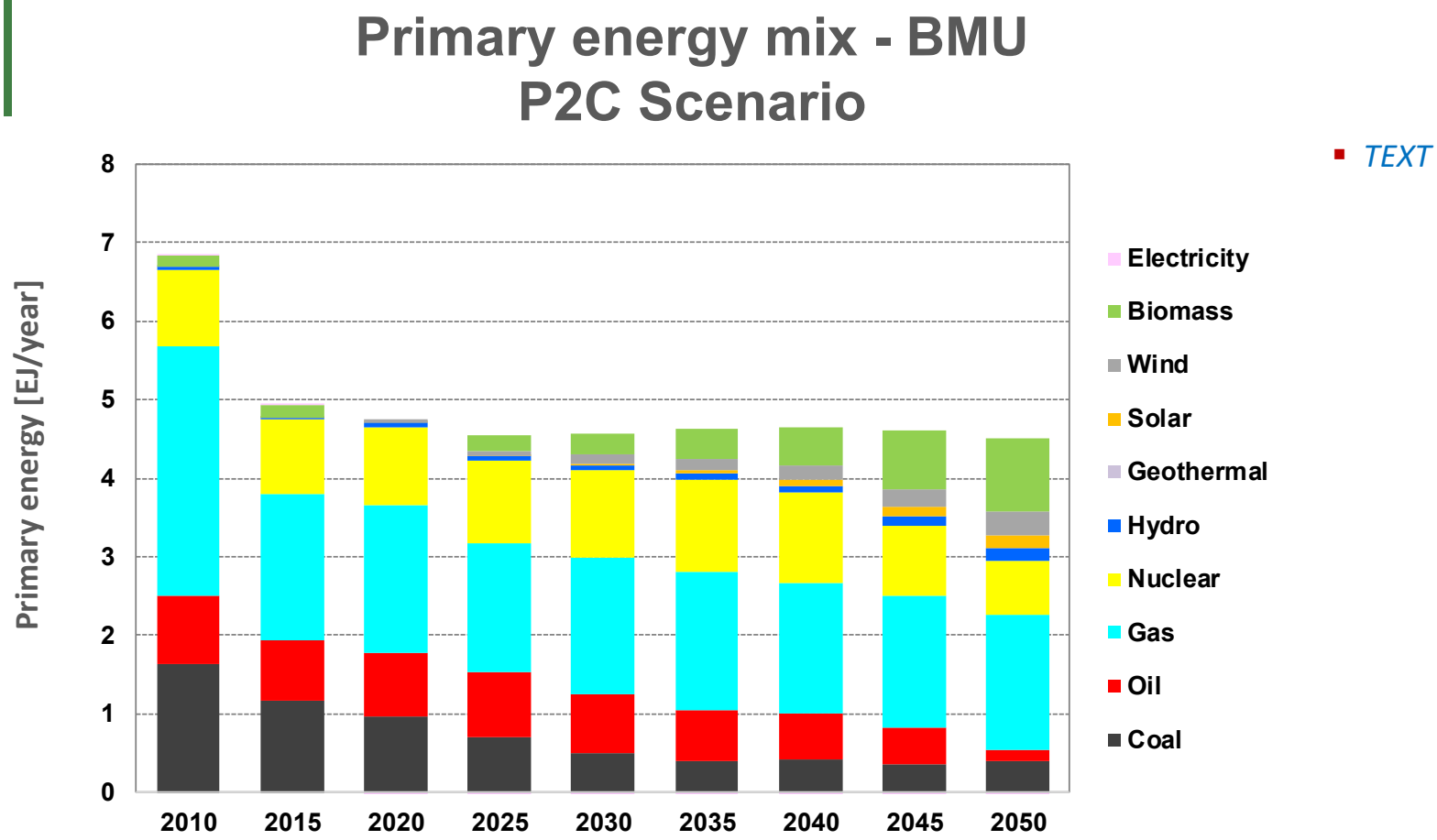


- *TEXT*

Modeling Results: BMU

Primary Energy

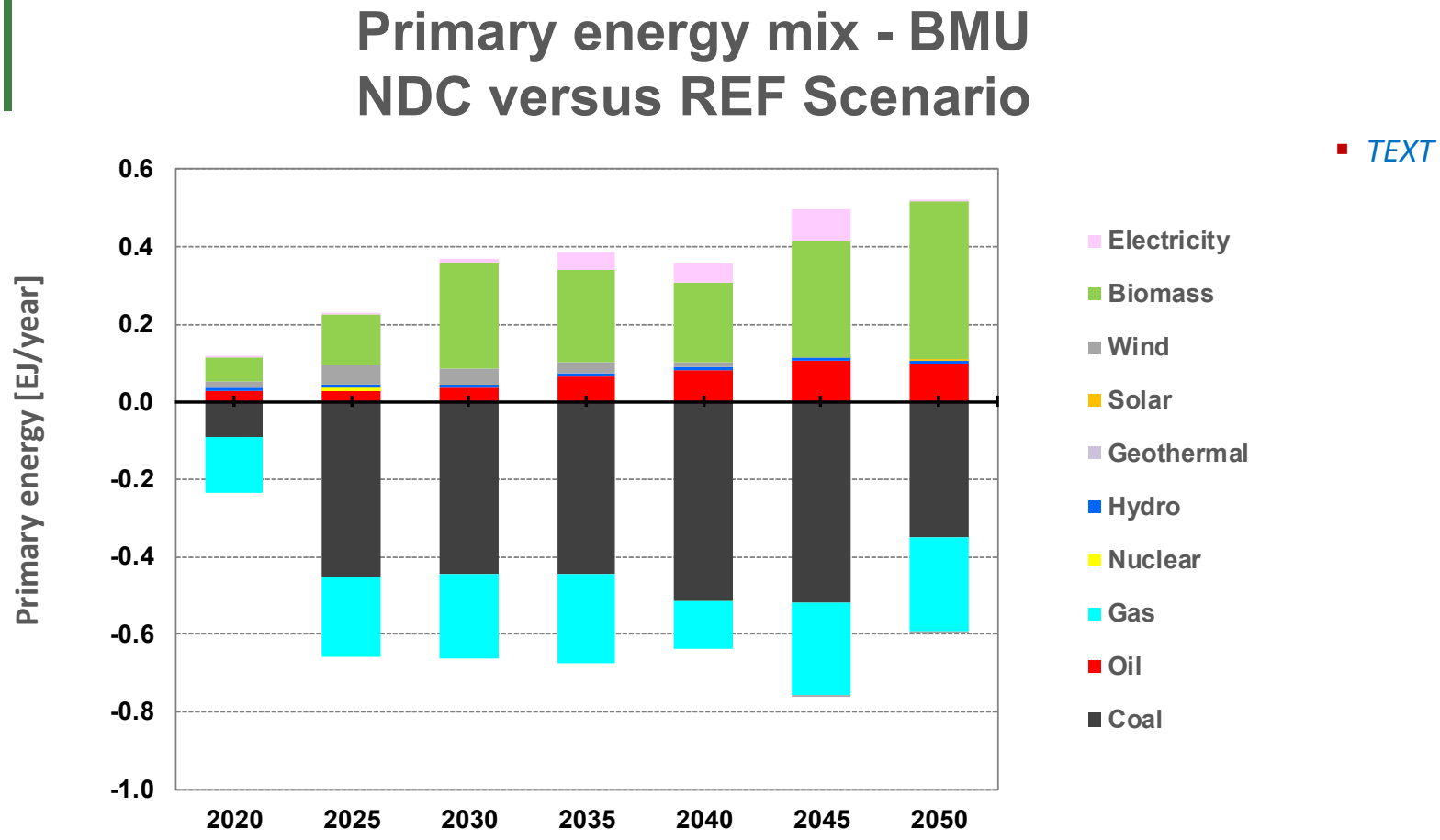
ENERGY



Modeling Results: BMU

Primary Energy: Scenario differences

ENERGY



Modeling Results: BMU

Primary Energy: Scenario differences

ENERGY