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Energy system pathways of a decarbonization of the Norwegian oil-dependent economy

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Outline



Transition pathways

01 Norwegian energy system

02 TIMES energy system pathways

Part I – Norwegian energy system

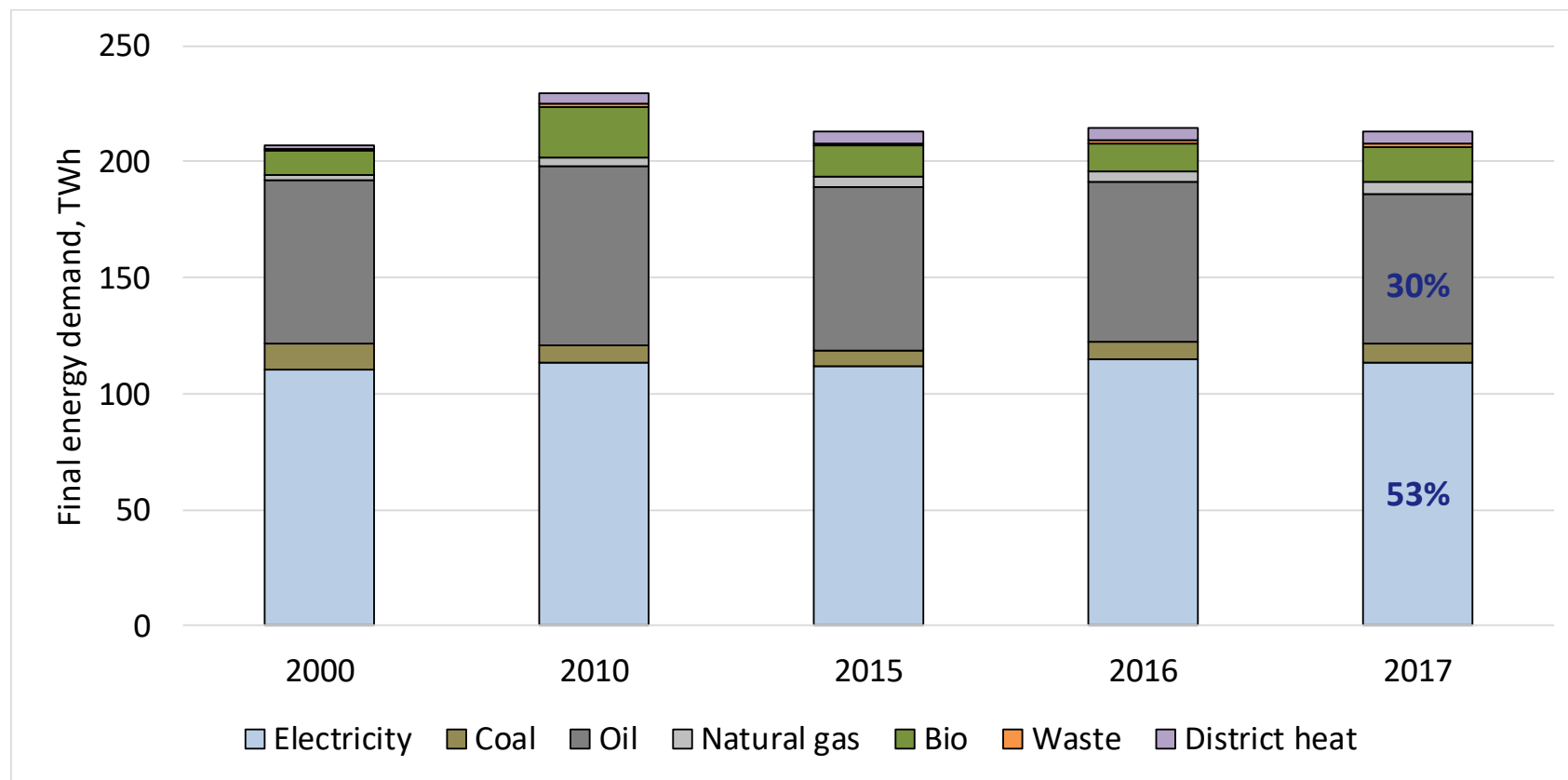
The Norwegian energy system



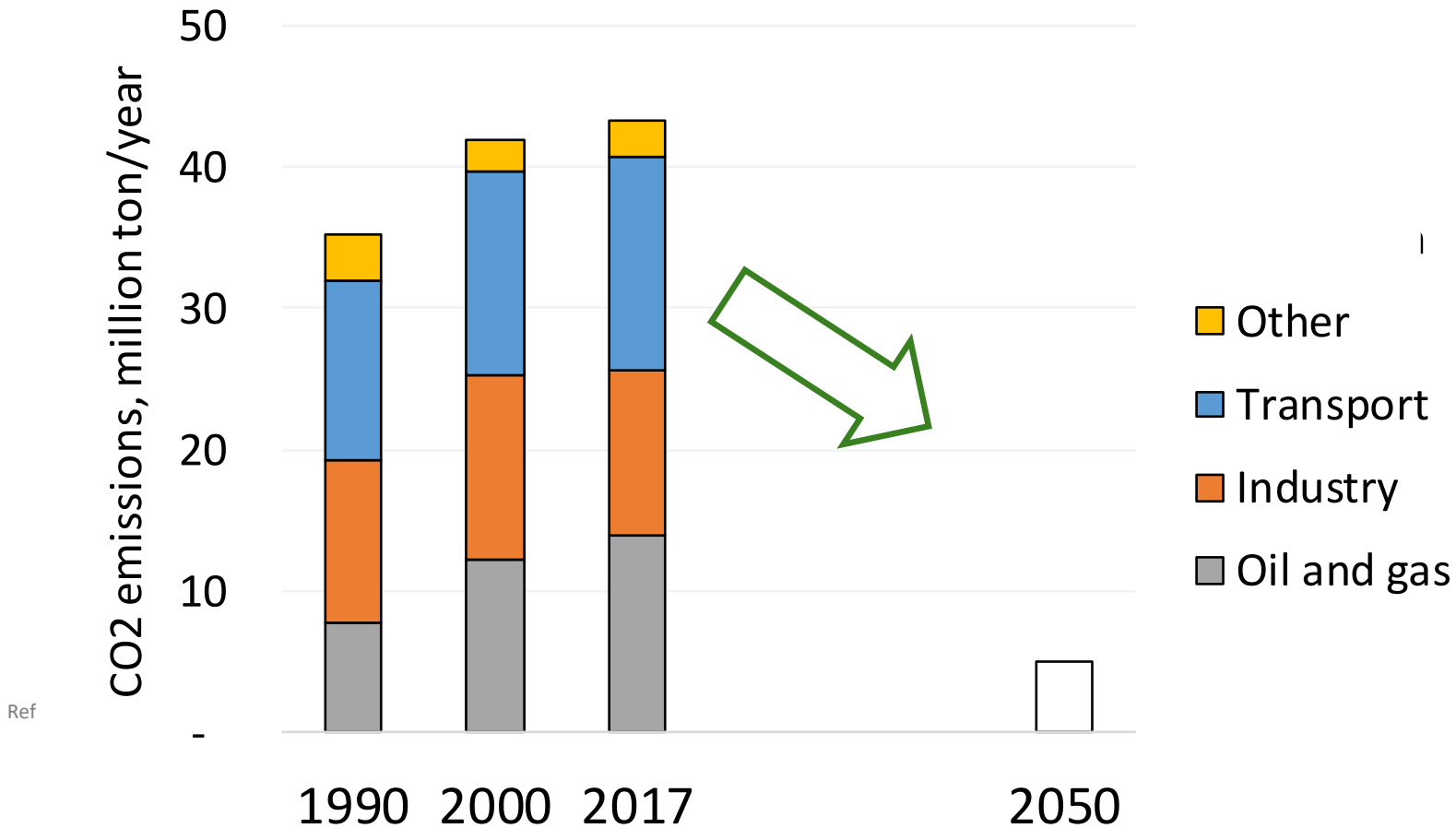
- Electricity generation mainly based on hydropower
 - 2017: 96%
 - Large water reservoirs - 50% of European capacity
- Cold climate → High demand for space heating
- Historically electricity has been relatively inexpensive
 - Energy-intensive industry
 - Electricity based heating system
- Large potential for onshore and offshore wind power
- EVs dominate new car sale
- Petroleum sector- oil & gas export
 - 25% of EUs gas demand in 2017
 - 2 % of global oil demand



Final energy consumption in Norway

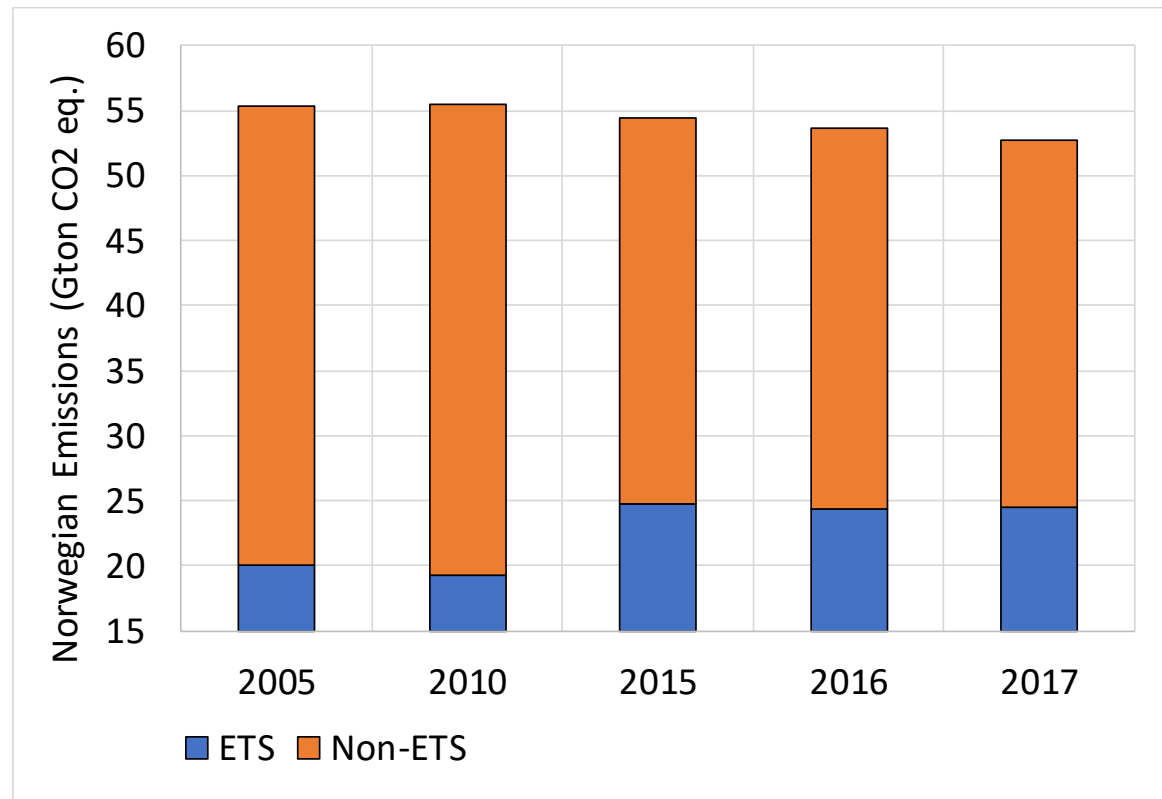


A transition requires CO₂ cuts in transport, industry, and oil and gas



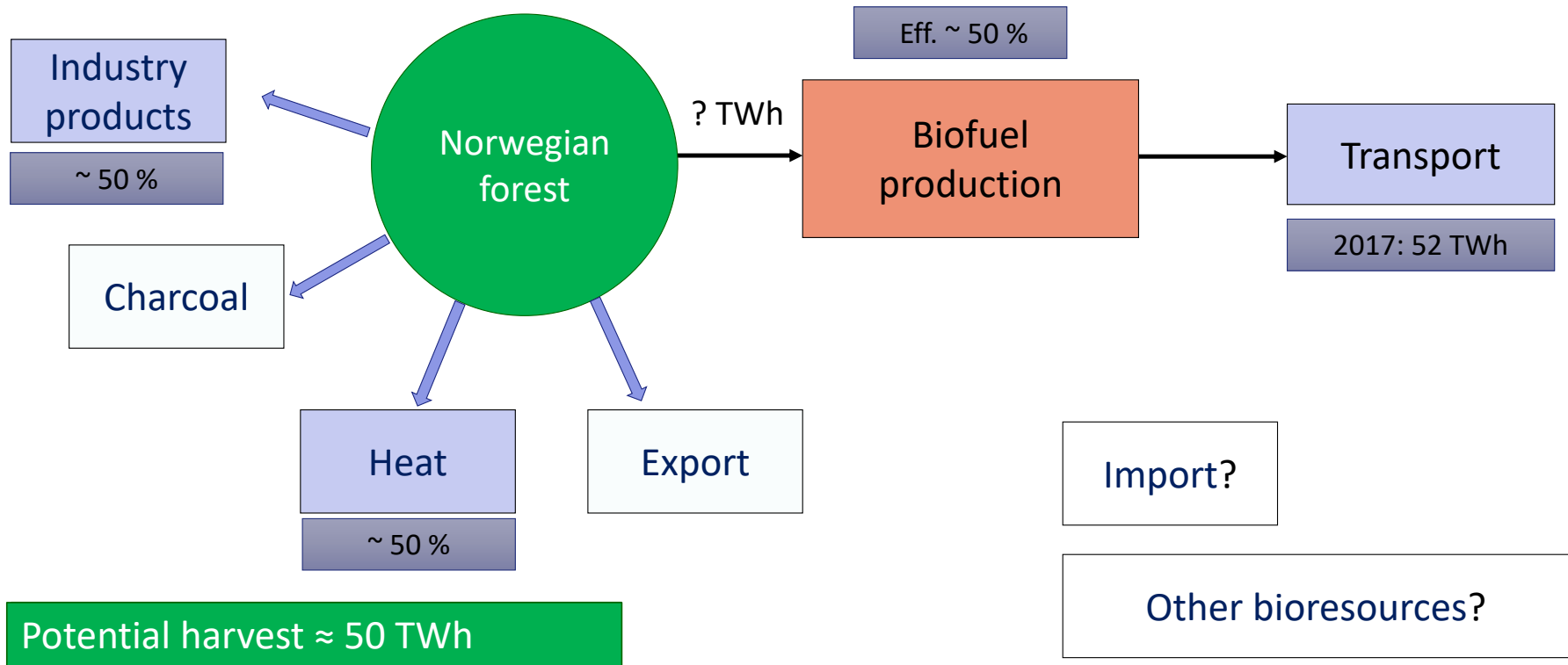
Norwegian GHG emission targets

- **2030: non-ETS target**
 - Minimum 45% reduction in 2030 compared to 2005
 - Minimum 31 % reduction in 2030 compared to 2017
- **2050: Climate neutrality**
 - 80-95% reduction compared to 1990
 - 1990: 51.2 Gton CO₂ eq.
 - 2017: 52.9 Gton CO₂ eq.



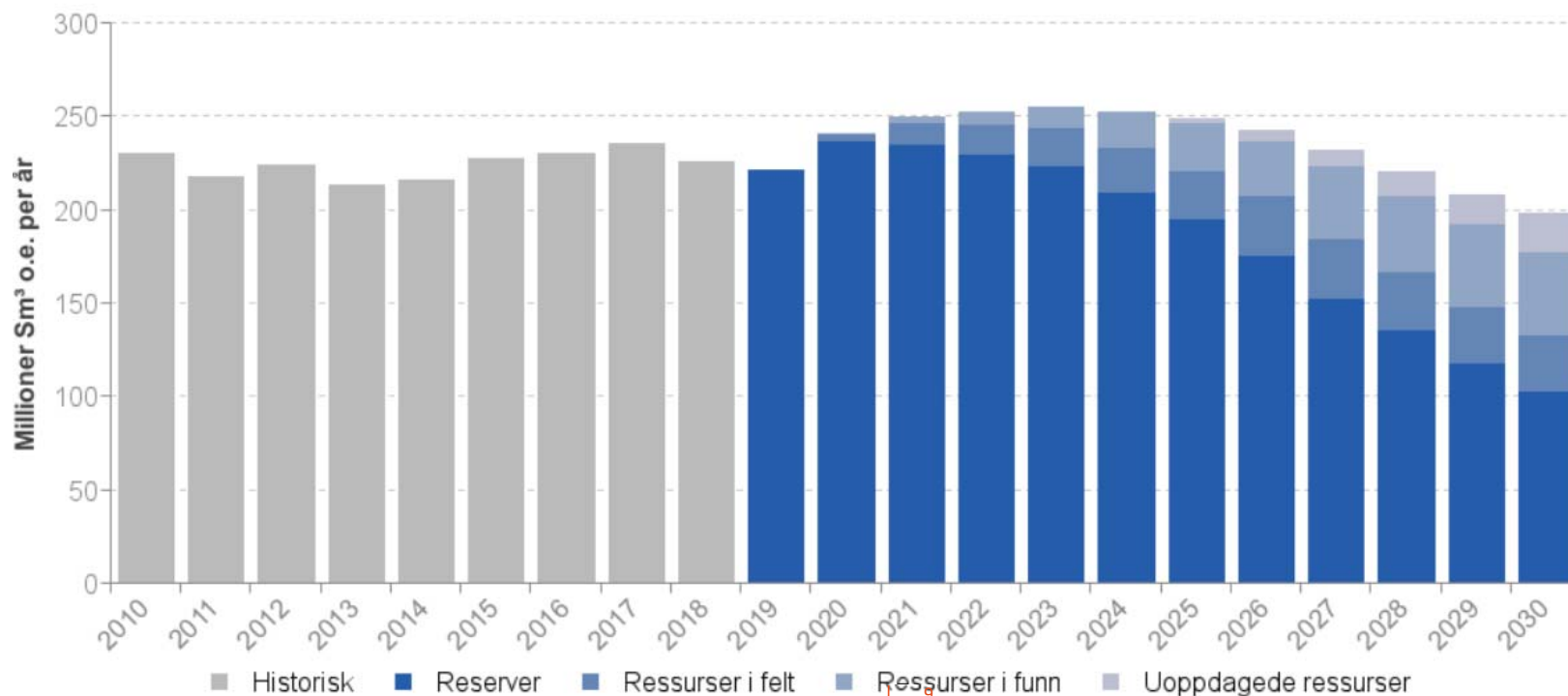
Energy system

- Biomass resources are limited and have multiple applications

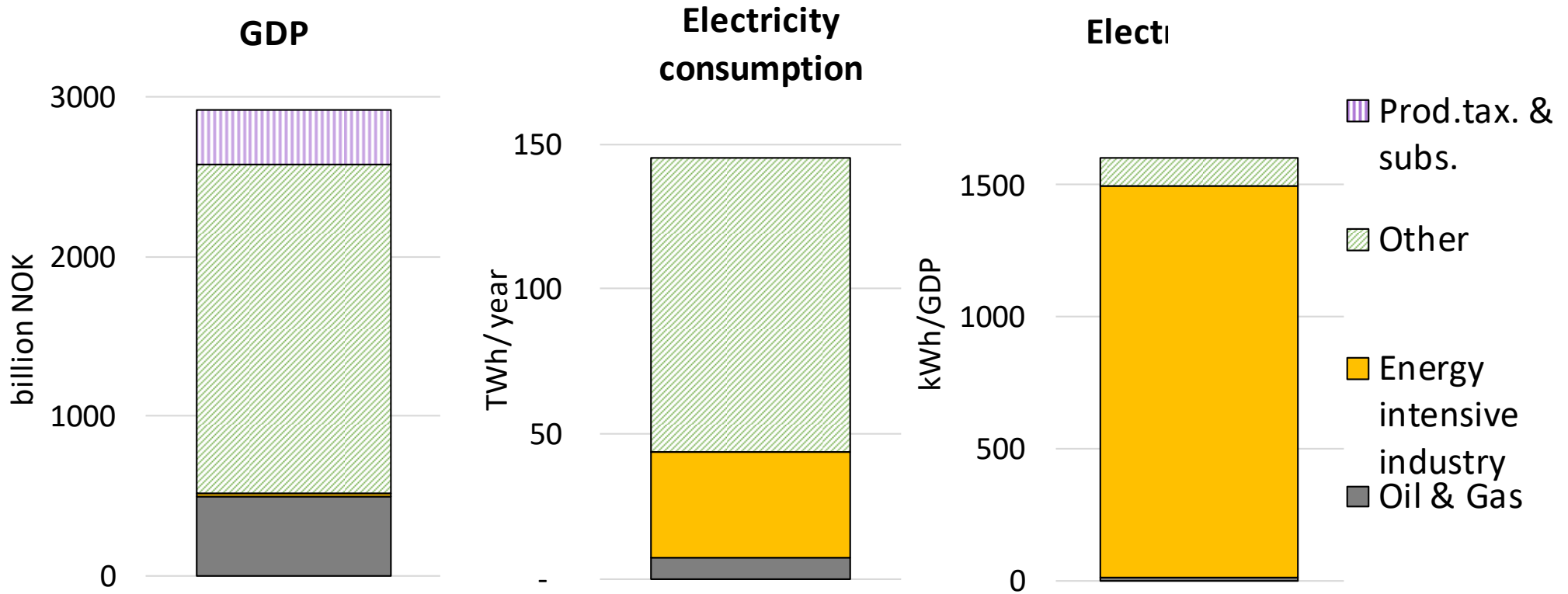


Norwegian petroleum sector

- Official production prognosis from Norwegian Petroleum: <https://www.norskpetroleum.no/>
- Erna Solberg, November 2018: «The person shutting down the Norwegian petroleum sector is not yet born»



Relationship between electricity use and GDP



Power intensive industry cannot replace all welfare from oil & gas

- PM17**
 Official Prognosis: 0.8 % GDP growth per year and capita
- Constant**
 0 % GDP growth per year and capita
- BNP-2015**
 Replace GDP from oil and gas

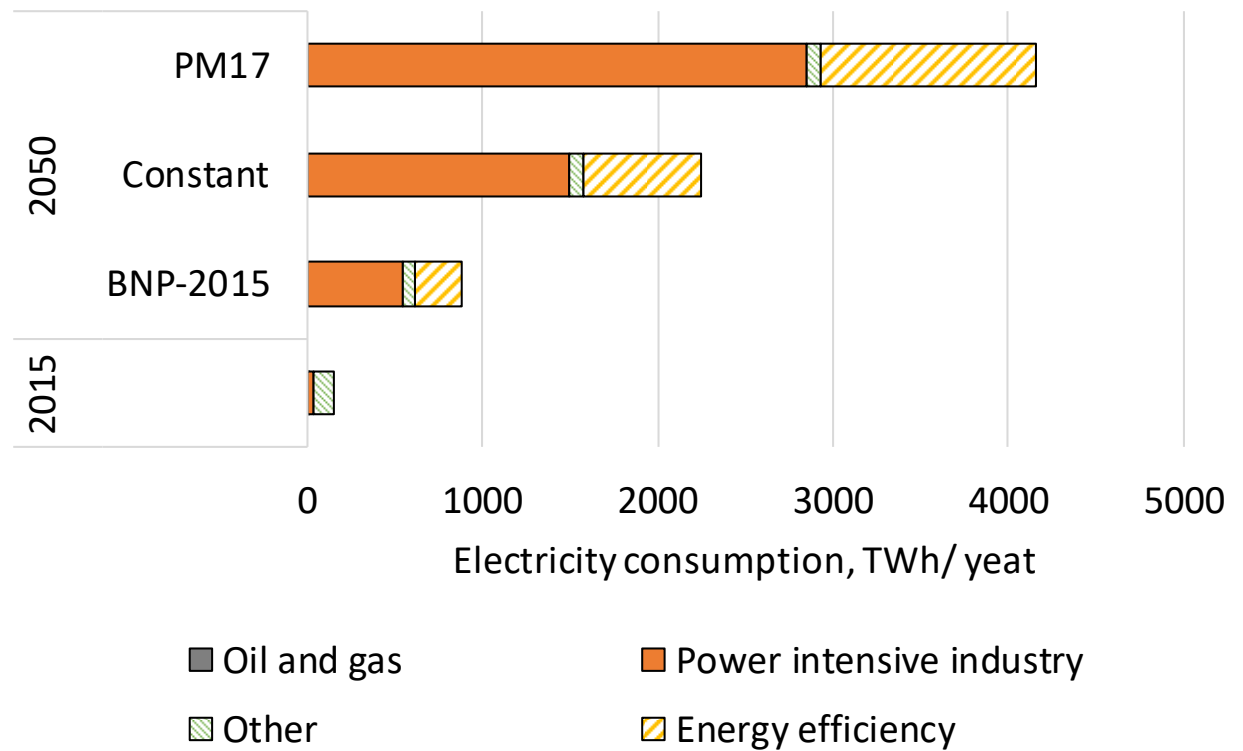
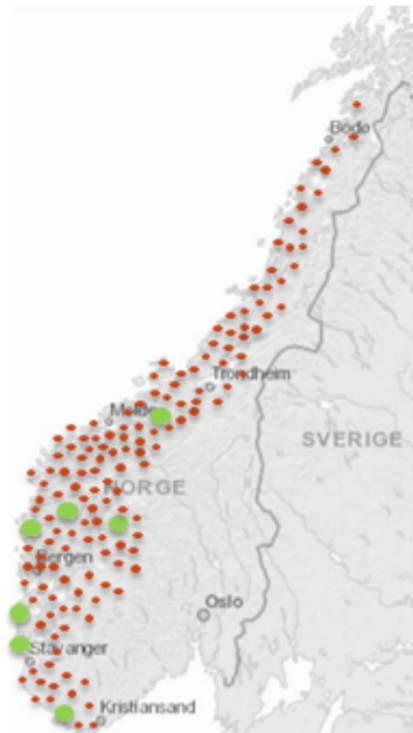


Illustration of 500 TWh

Aluminium smelters



- Current
- New

Wind farms



- Current
- New

Part II – TIMES energy system pathways

Norwegian Energy Road Map 2050

Norwegian Energy Roadmap 2050

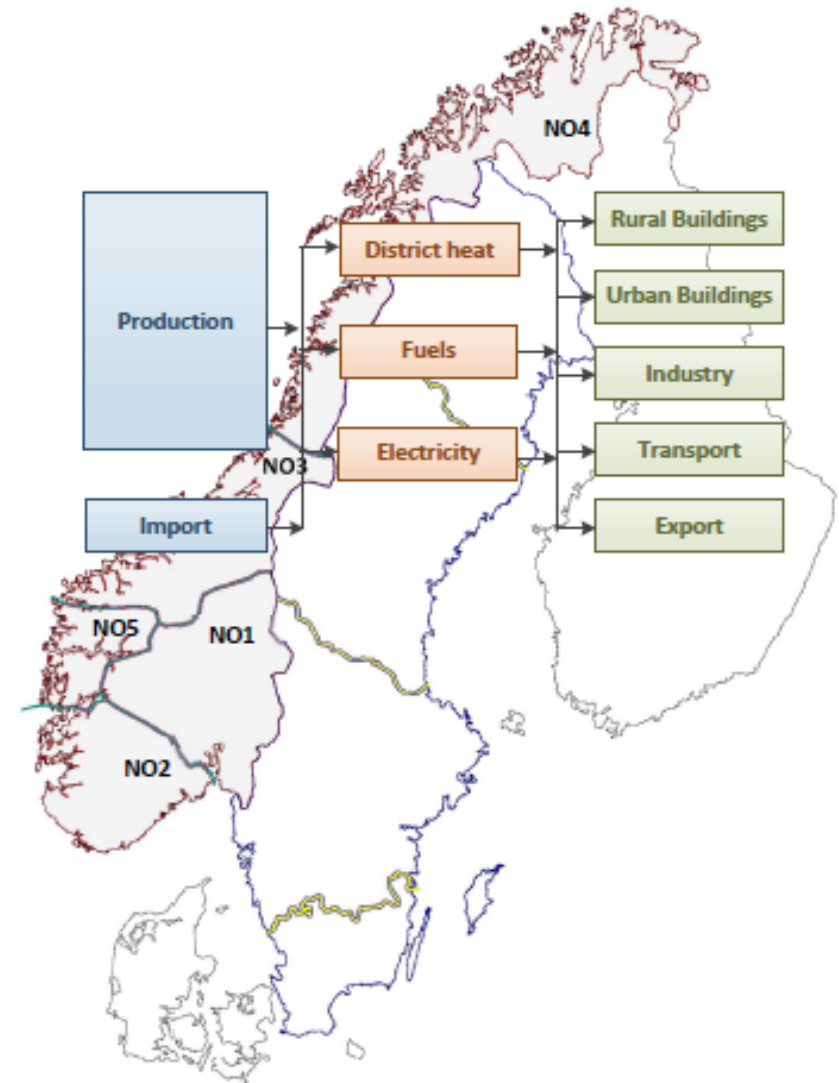
- **Norwegian pathways to a low-carbon energy system in 2050**
 - Presumption: Norwegian welfare is remained with a phase-out of petroleum sector
 - New revenue from service and industry sector
- **Impact of low carbon future on the energy system, power sector and the overall economy**
 - Energy system model: TIMES-Norway
 - Power market model: EMPS
 - CGE model: REMES



Figure: Adobe Stock

TIMES-Norway 2015-2050

- Developed together with the Norwegian Water and Resources Directorate
- Norwegian Spot price regions
- Detailed end-use and power sector
- 260 time-slices
- Currently converted to VEDA_FE from Answer
- Flexible temporal resolution
- High detailed demand sectors
- Ongoing research focus:
 - Flexibility
 - Transport and Buildings



Norwegian Energy Roadmap 2050

- **Norwegian pathways to a low-carbon energy system in 2050**

- Norwegian welfare level is remained
- Constant GDP per population
- Sensitivity
 - 0.8 % increase in GDP per pop and year

- **Scenarios**

- **REFerence**
 - Petroleum activity according to official prognosis
 - No CO₂-limitation

- **INDustry**

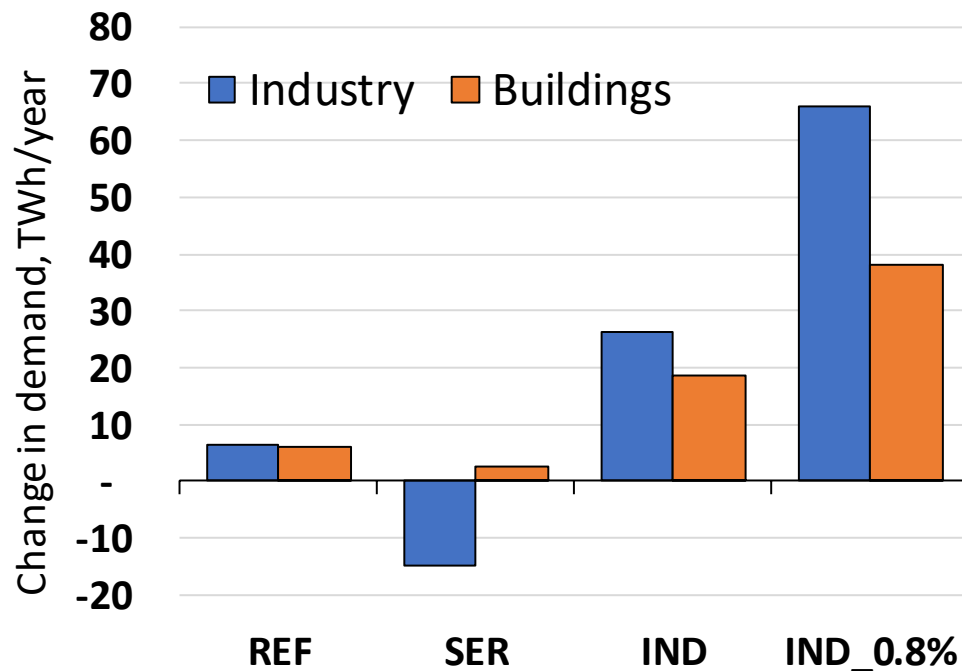
- Petroleum activity = 50% of current activity
- Income loss covered by
 - New industry
 - Hydrogen production NG with CCS
 - Biofuels limited and high costs

- **SERvice**

- No petroleum activity
- Welfare loss covered by
 - Highly increase in service sector
 - High energy efficiency implementation
 - Biofuels at current cost and unlimited

Demand projections varies between scenarios - Change from 2015 to 2050

- **REF**
 - Industry and buildings **+7%**
 - Road transport **+51%**
- **SER**
 - Industry and buildings **-7%**
 - Road transport: **0%**
- **IND**
 - Industry and buildings **+26%**
 - Road transport **+51 %**
- **IND-0.8%**
 - Industry og buildings **+60%**



Change from 2015 to 2050

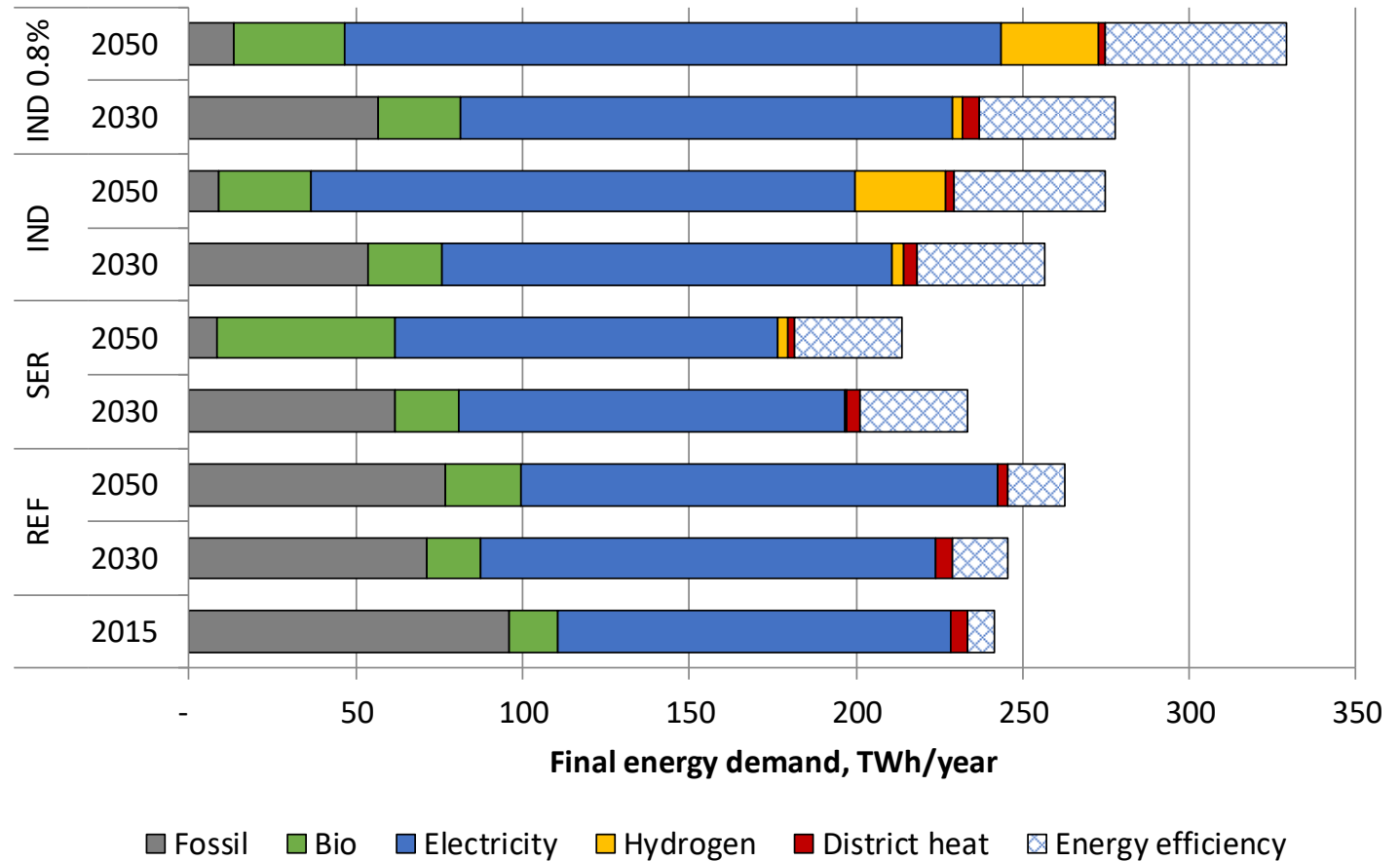
Results- Final energy demand 2030 & 2050 depends on end-use demand and technologies

- **Final energy demand 2050, relative 2015**

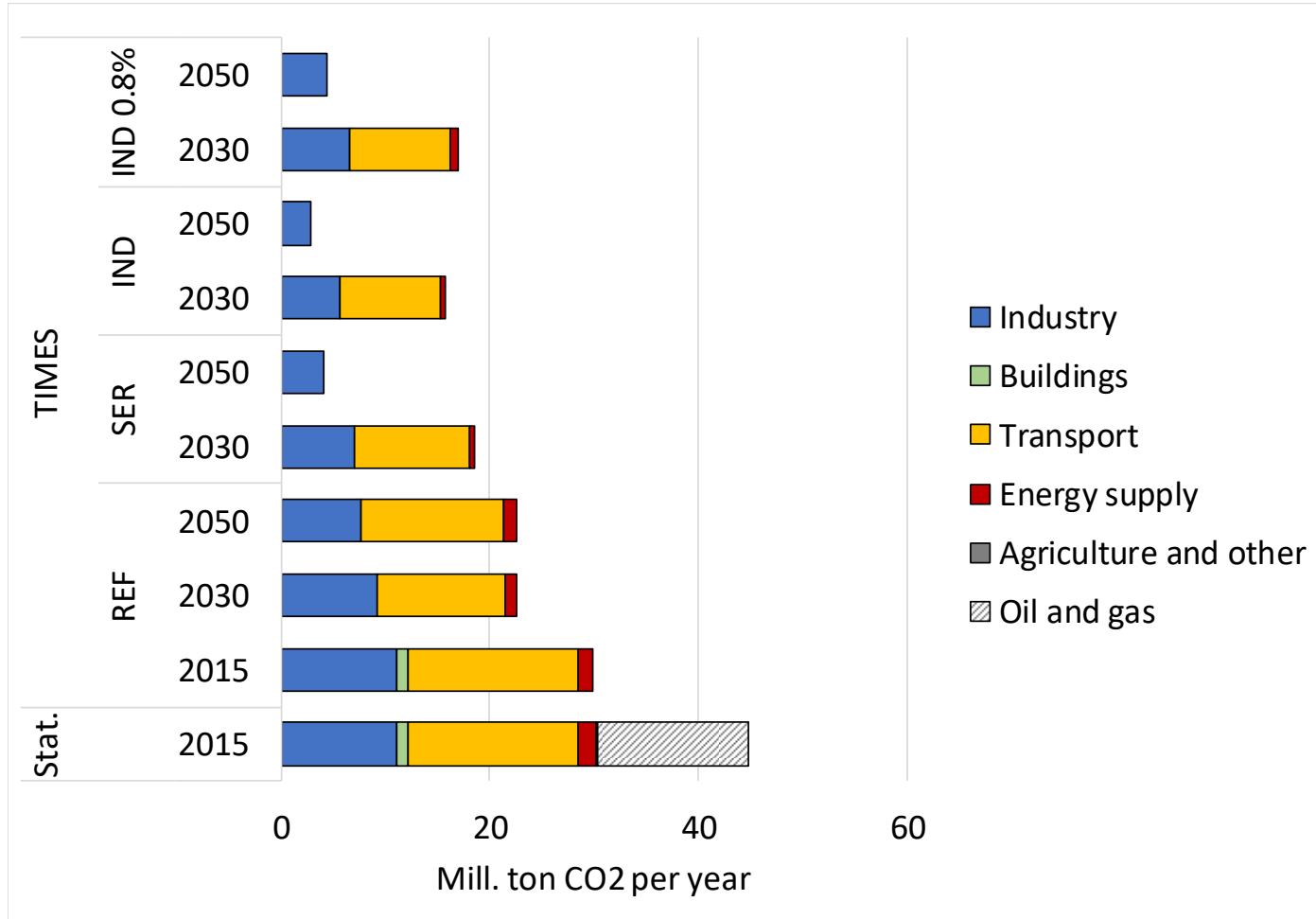
- REF 5%
- SER -22%
- IND -2%
- IND-0.8% 18%

- **Electricity share 2050**

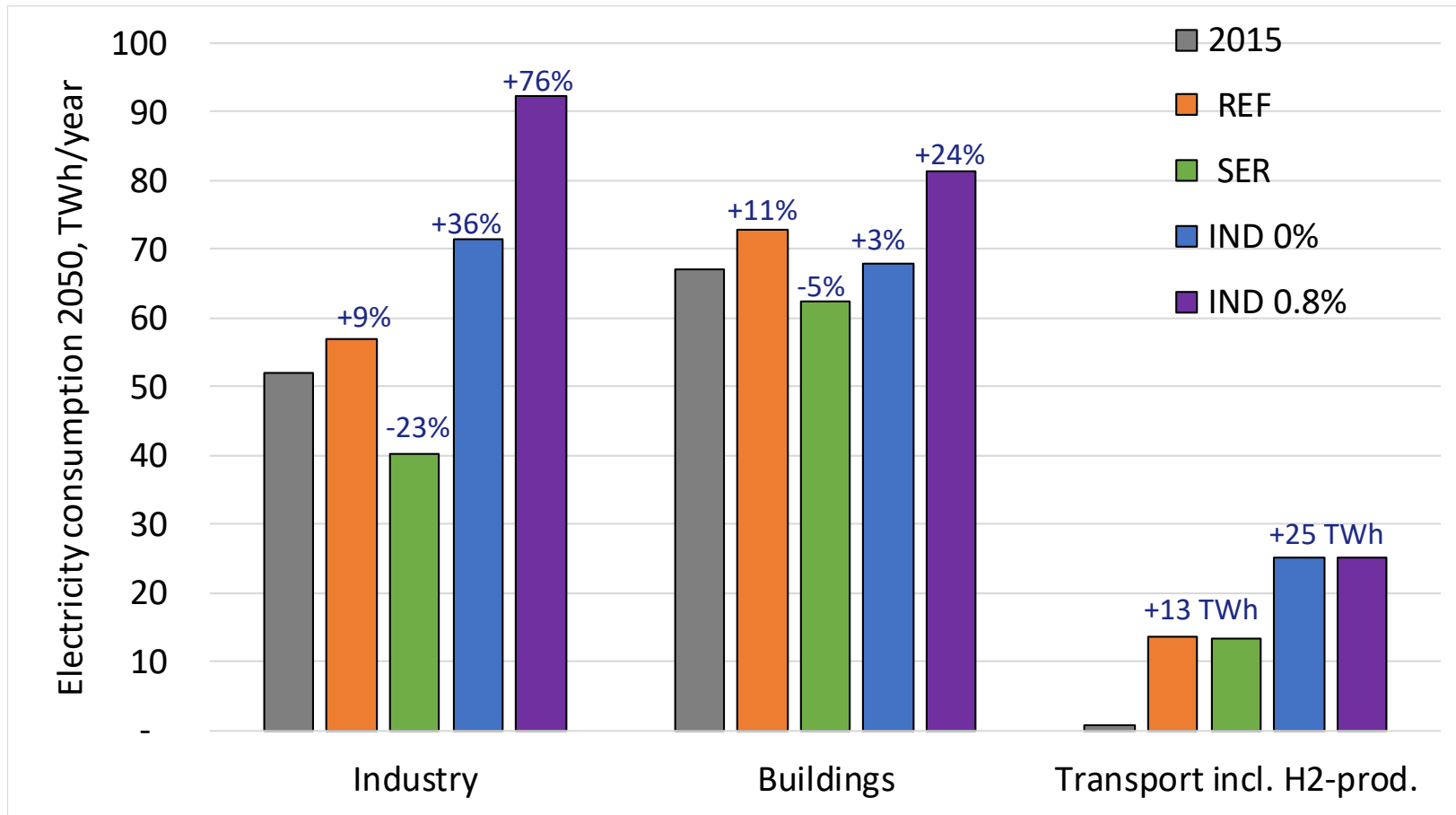
- REF 56%
- SER 63%
- IND 72%
- IND-0.8% 71%
- (2015: 51%)



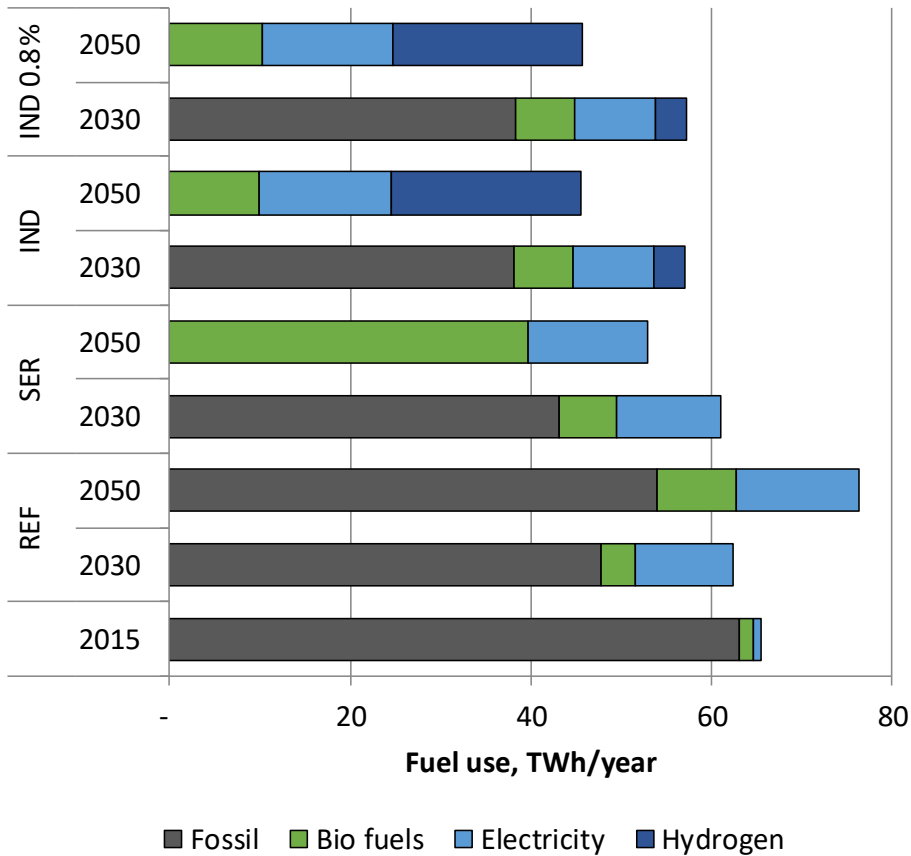
Results- Emission cuts is most challenging in Industry



Results- Electricity consumption increases in all scenarios except SERvice



Results- Fuel use in transport sector is scenario dependent

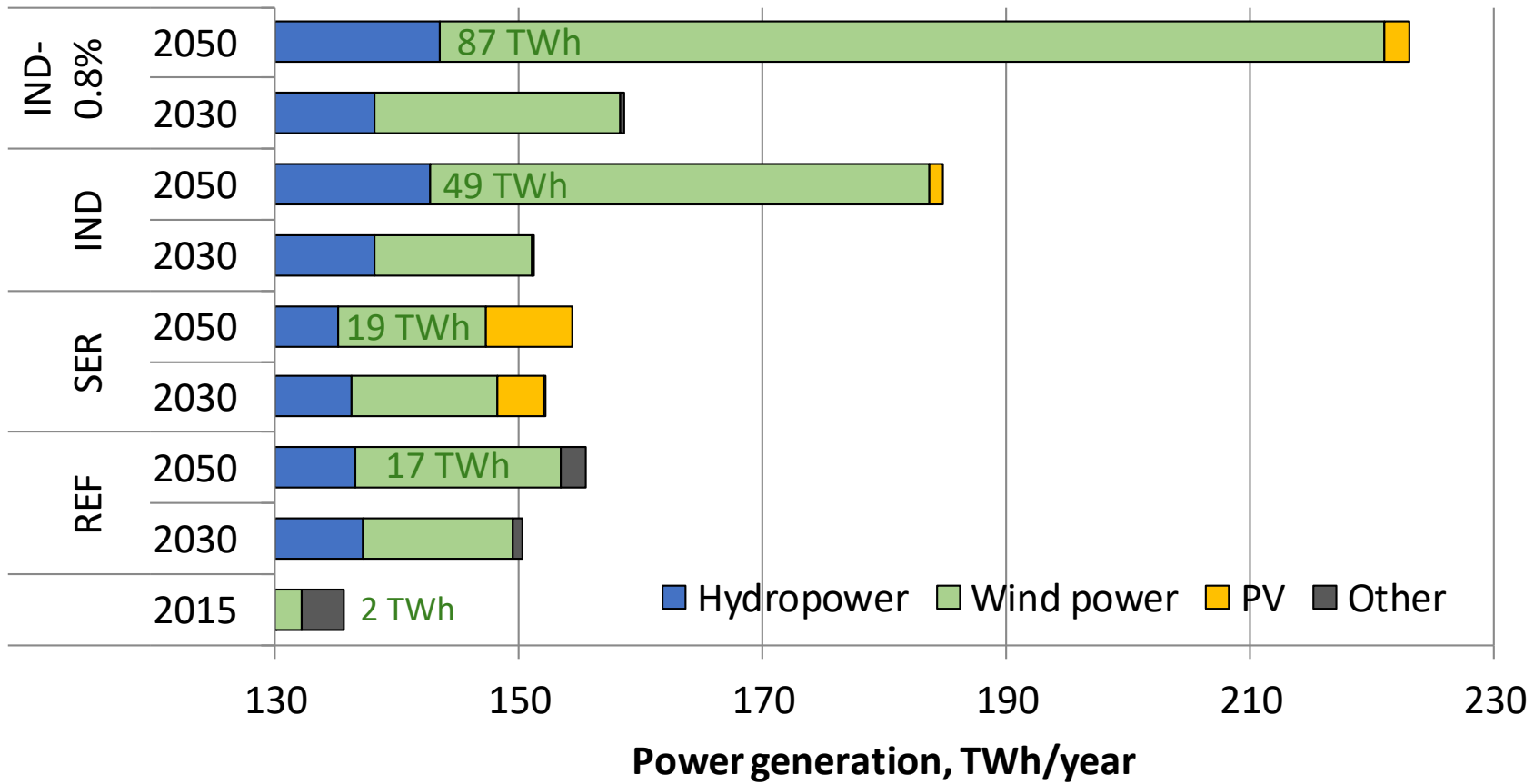


- **Bio fuel share 2050**
 - REF 11%
 - **SER 75%**
 - IND 22%

- **Electricity share 2050**
 - REF 18%
 - **SER 25%**
 - IND 32 %

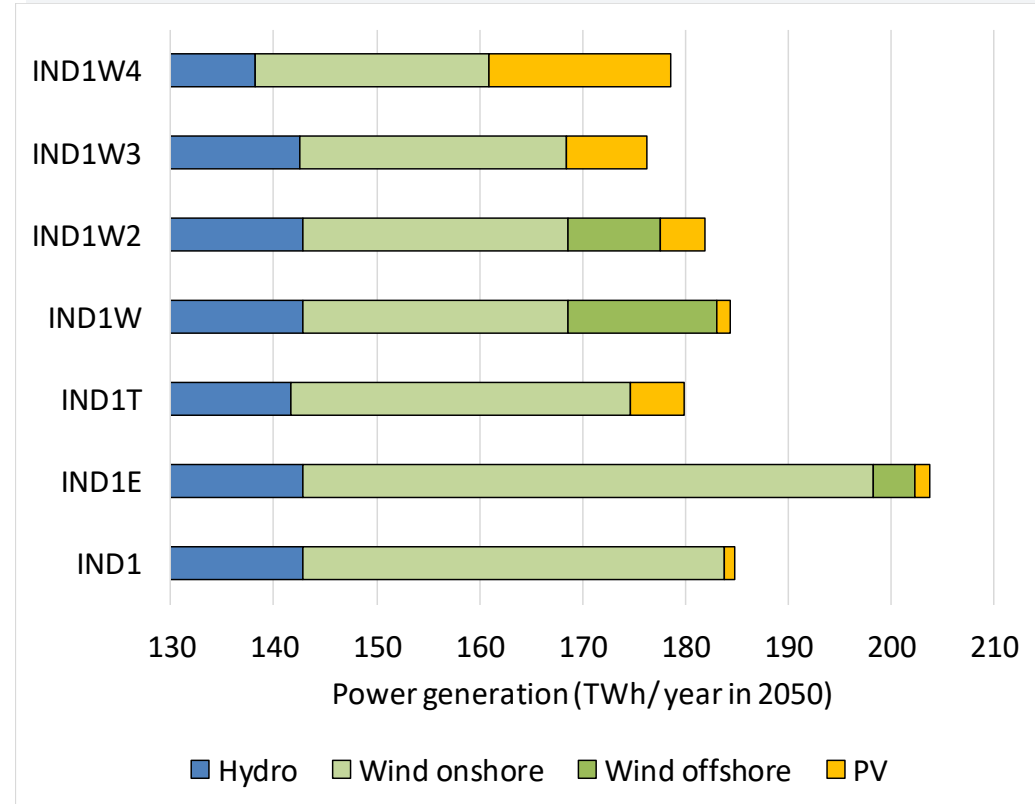
- **Hydrogen share 2050**
 - REF 0%
 - SER 0%
 - **IND 46%**

Results- Significant new wind power investments in all scenarios



Power generation INDustry scenario depends on policy and technology development

- IND1: Basis
- IND1E: No energy efficiency
- IND1T: 2017-taxation
- IND1W: Onshore wind power <26 TWh
- IND1W2:W + increased grid fee 10 øre/kWh
- IND1W3: W + double grid fee
- IND1W4: W3 + cheaper PV



Conclusions- Norwegian energy system pathways

- **There are several transition pathways to a low-carbon Norwegian energy system**
 - Dependent on future revenue streams
 - Technology development; e.g. hydrogen & sustainable biofuels
- **A low-carbon future requires considerably changes to the Norwegian energy system**
 - More electrification/ H2 and use of biomass
 - New power generation
- **Actions are required today to facilitate a Norwegian transition to a low-carbon energy system**
 - Alternative revenue streams than oil and gas
 - Infrastructure



Thank you

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