BALMOREL
Energy system model

Renewable Energy Scenarios for Viet Nam

- DRAFT Technical Report

Hanoi, Viet Nam
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Ea Energy Analyses

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DRAFT Technical Report

- These are the DRAFT results of the Technical Report detailing the Balmorel model scenario analysis
  - Comments and feedback received during this Technical Workshop will be taken into account when completing the Final Technical Report
- The results are based on the best currently available information. However:
  - Future projections are associated with inherent uncertainty
  - Further data refinements (e.g. solar PV potential update, inclusion of storage and demand response etc.) would affect the modelling results
  - Simplifications have been made in the modelling process
- The scenarios are neither forecasts, nor recommendations towards the development of the Vietnamese power system
  - The results illustrate the alternative futures subject to realisation of the underlying assumptions and projections

Scenarios: Overview

- PDP 7 generation and expansion plan represented until 2020
- Model given ‘freedom to optimize’ thereafter

- PDP 7 generation and transmission expansion plan represented in its entirety
- Dispatch model run only

Core scenario descriptions

Stated policies

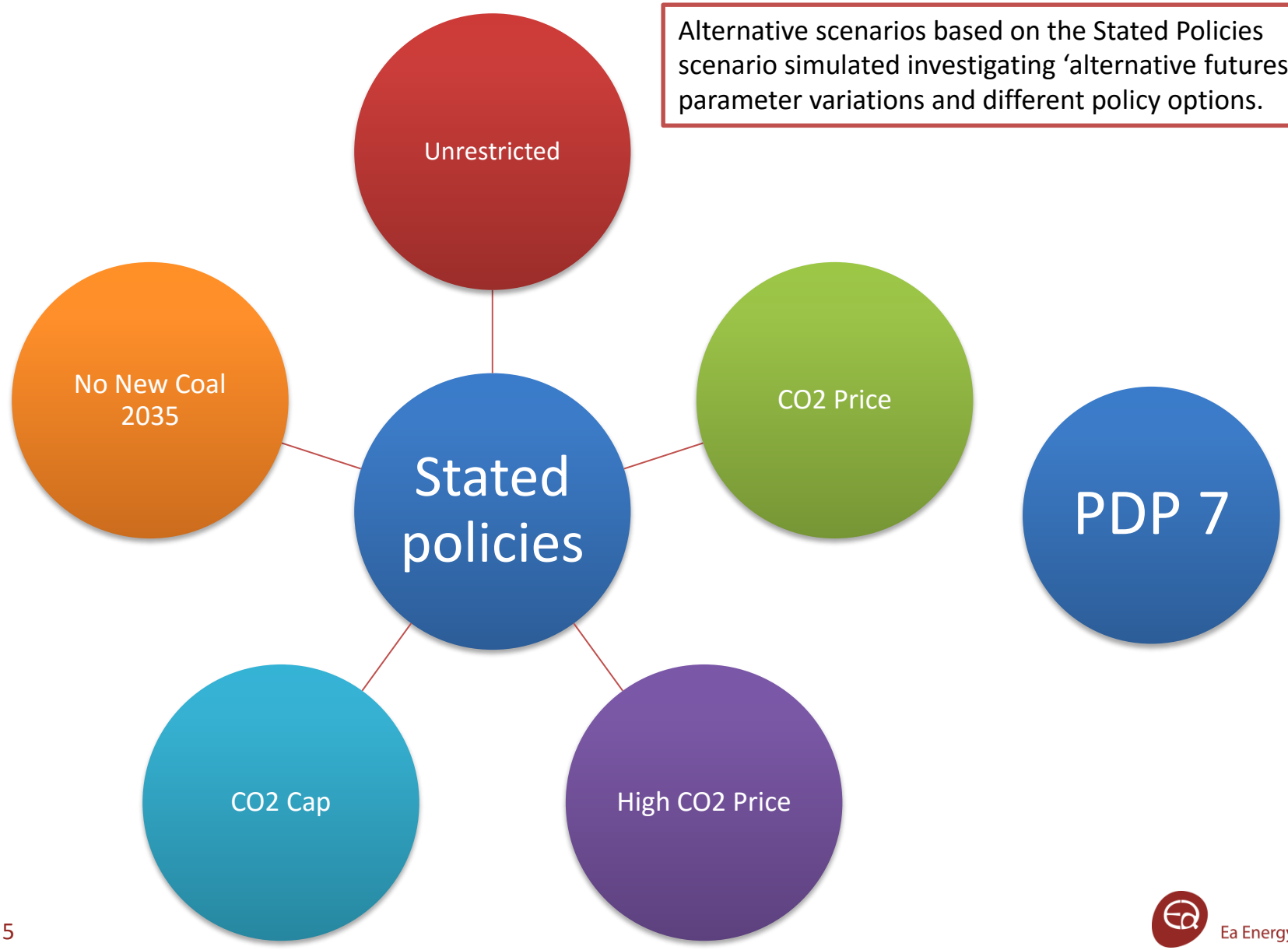
- PDP 7 capacity exogenous until 2020
- Investments allowed
  - Generation from 2020
  - Transmission from 2030
- Runs in 5-year periods until 2050
- RE goals in line with RE Strategy

PDP 7

- PDP 7 capacity exogenous until 2030
- No investments
- Runs in 5-year periods until 2030
- No RE goals
  - RE goals met by the projected expansion in PDP 7 revised

Scenarios: Overview

Alternative scenarios based on the Stated Policies scenario simulated investigating 'alternative futures', parameter variations and different policy options.



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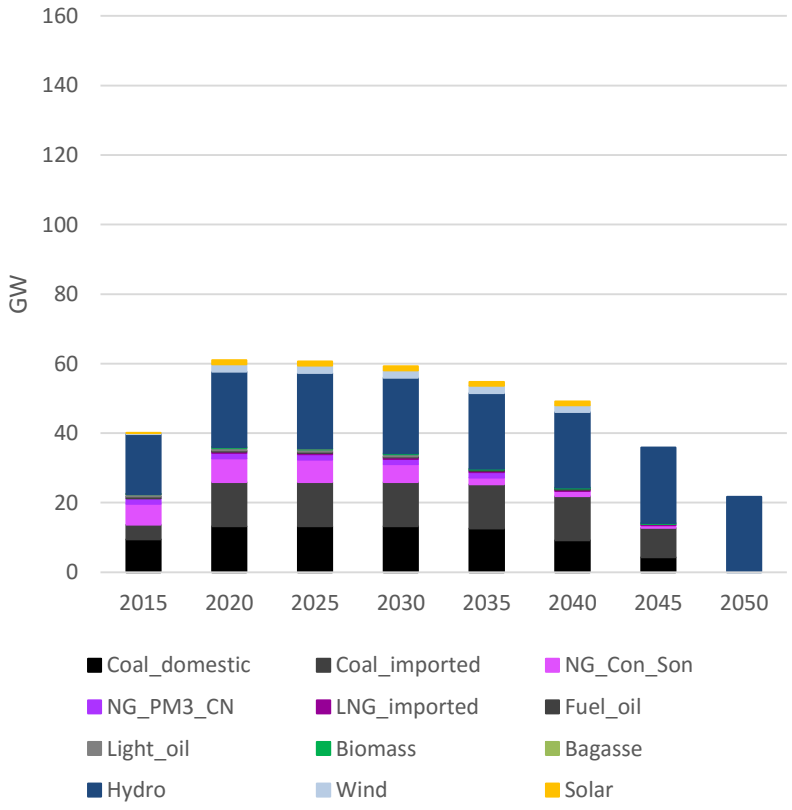
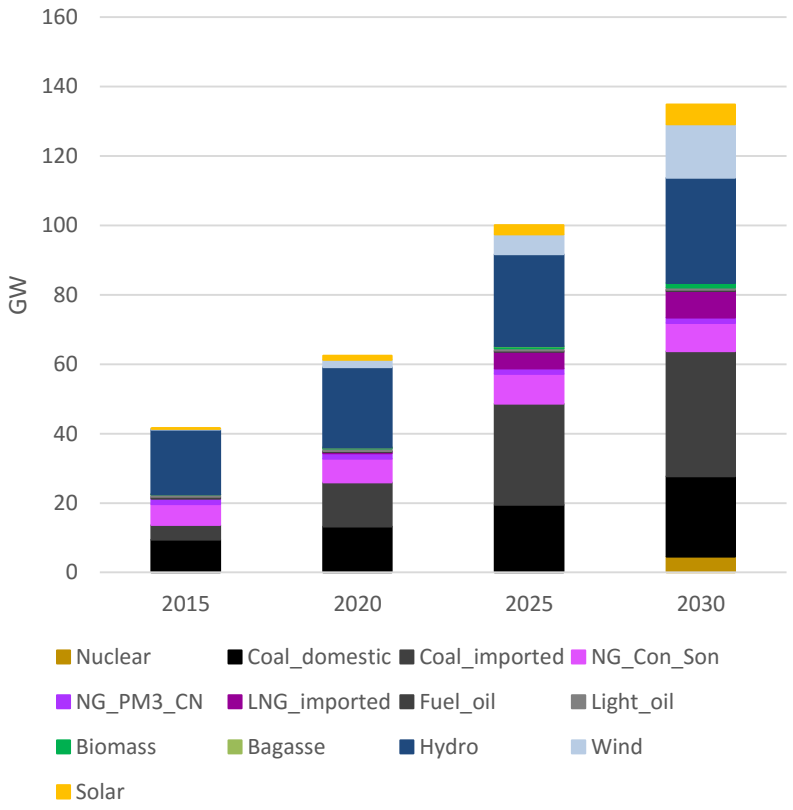
Exogenous generation capacity

Stated Policies and alternative scenarios are based on PDP7 until 2020, and on model-based investments thereafter. PDP7 scenario is fully based on PDP7 generation expansion plan, the model only does dispatch. Exogenous = existing and committed generation capacity (i.e. excluding model-based investments).

Stated Policies



PDP7 scenario



WORK-IN-PROGRESS RESULTS

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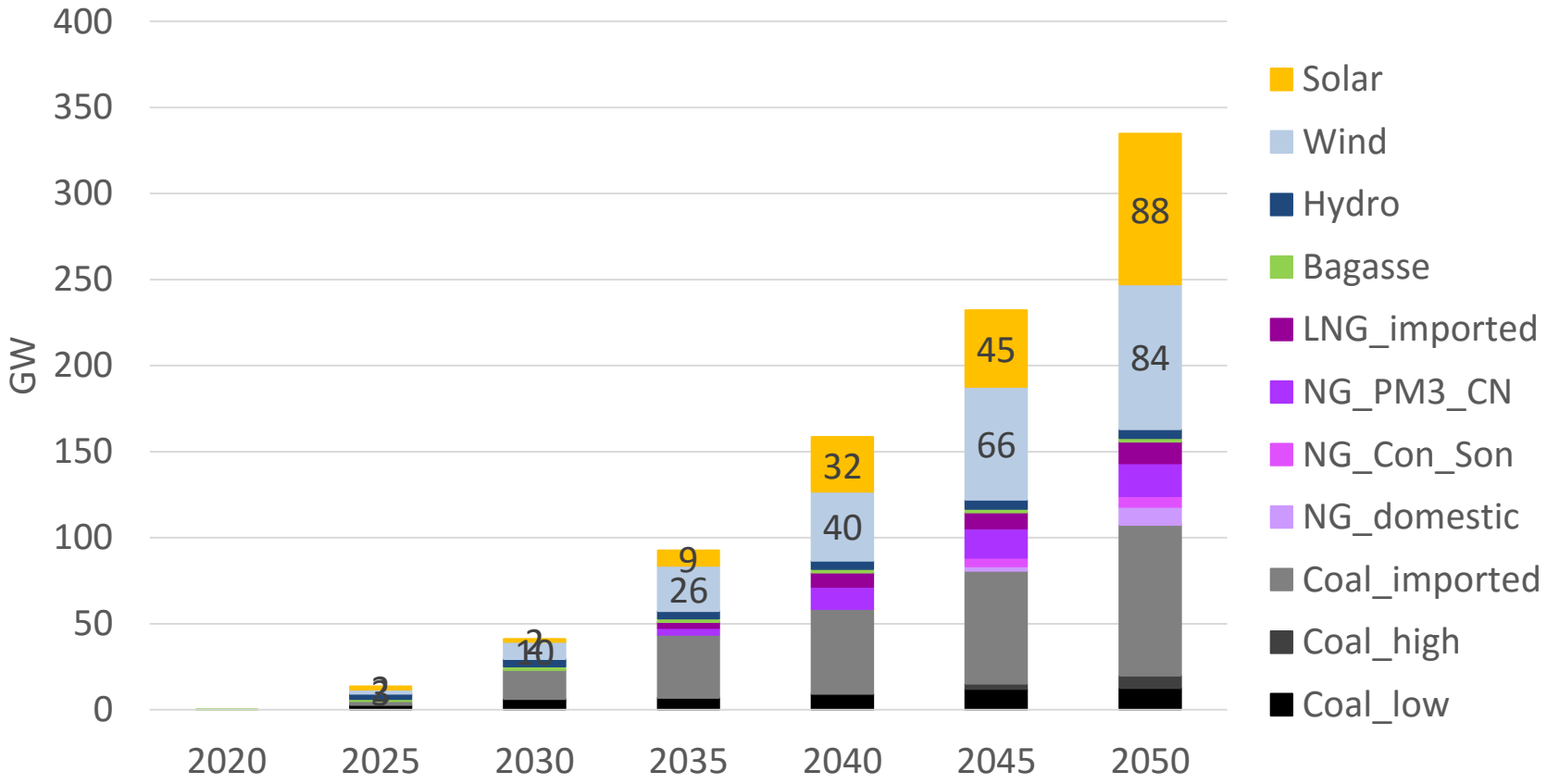
Endogenous (model-invested) generation capacity: Stated Policies scenario

The model invests in generation capacity in the Stated Policies scenario (in addition to the existing and PDP7 fleet until 2020) to satisfy the growing power demand and meet the constraints and requirements imposed (RE goals, resource limits etc.) at the lowest possible total system cost.



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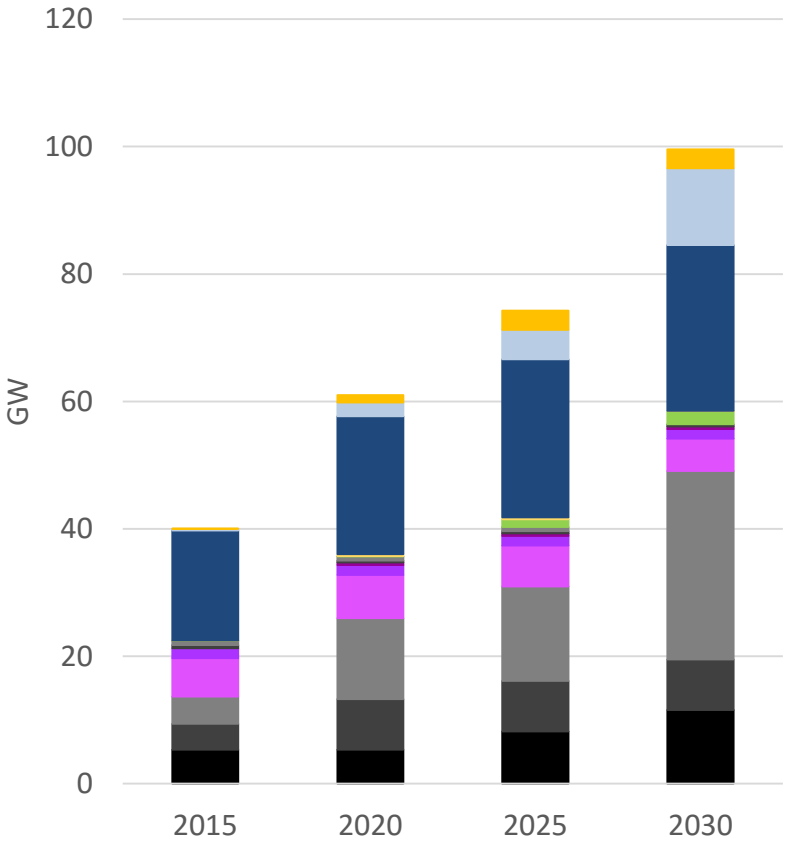
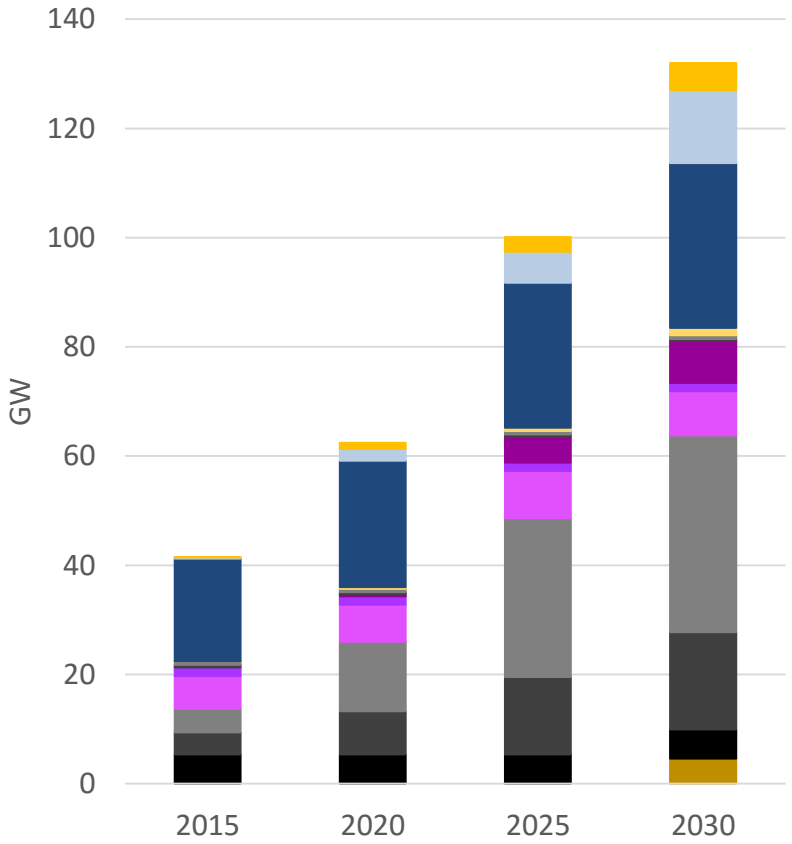
Total capacity: Stated Policies vs PDP7

Total generation capacity for Stated Policies = Exogenous capacity + Model-based investments.
The results of the Stated Policies scenario indicate that the model does not choose to invest in nuclear power.
Stated Policies scenario: no reserve margin required, and both investment and dispatch under perfect foresight.

Stated Policies



PDP7 scenario



Nuclear | Coal_low | Coal_high | Coal_imported | NG_Con_Son | NG_PM3_CN | LNG_imported
Fuel_oil | Light_oil | Bagasse | Rice_husk | Hydro | Wind | Solar

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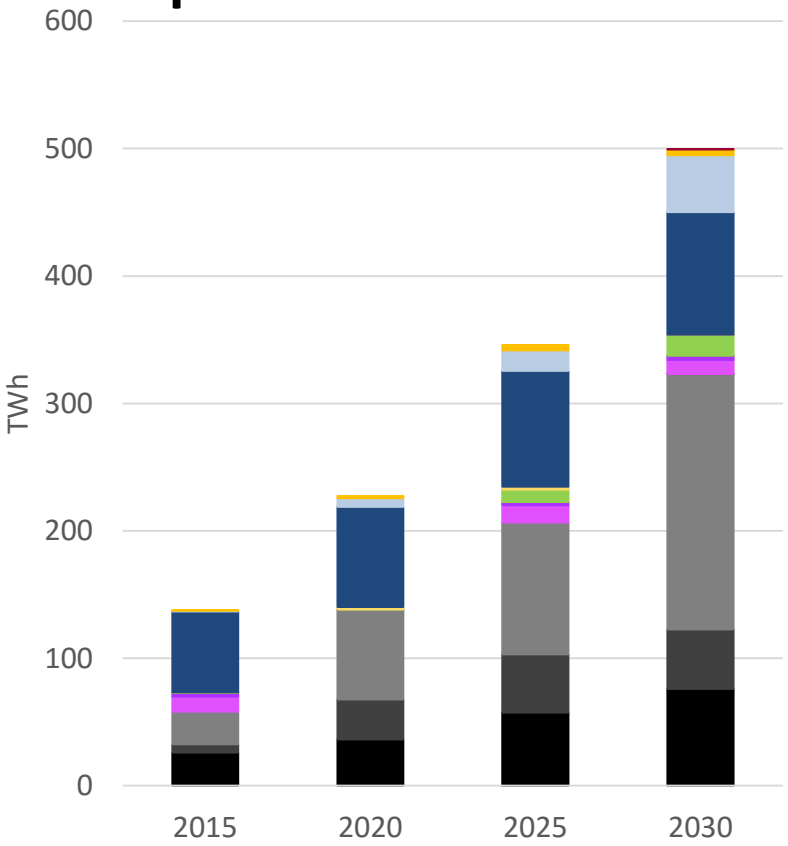
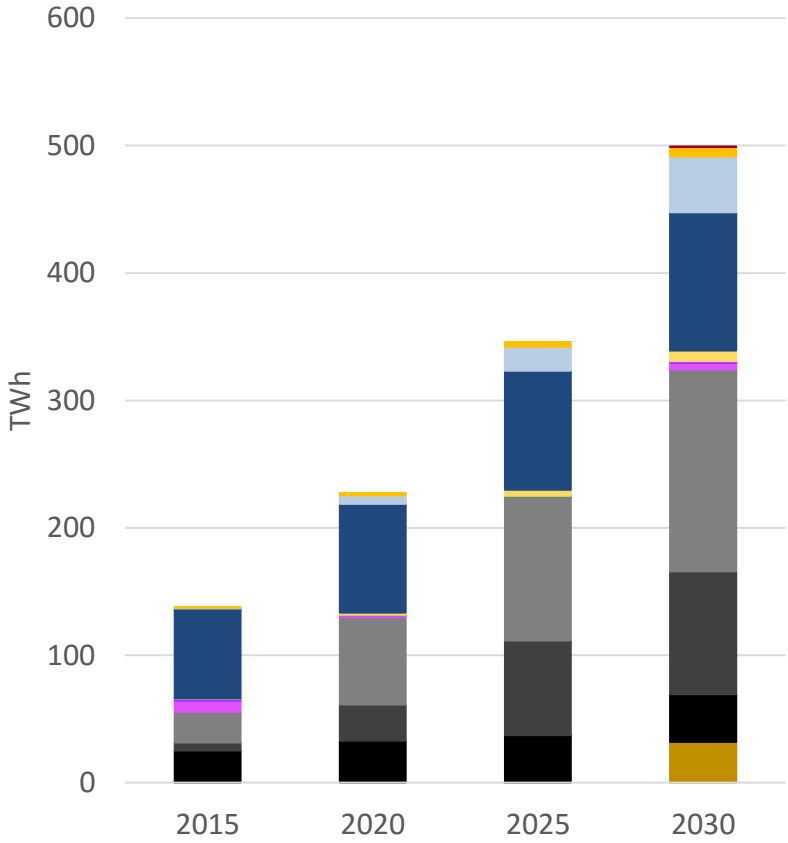
Generation: Stated Policies vs PDP7 (until 2030)

Model-based optimal (least-cost) dispatch for both scenarios based on merit order.
Both scenarios satisfy the projected power demand.
Highly coal-dominated power system development pathways.

Stated policies



PDP7



Nuclear Coal_low Coal_high Coal_imported Fuel_oil NG_Con_Son NG_PM3_CN
LNG_imported Bagasse Rice_husk Hydro Wind Solar Unserved

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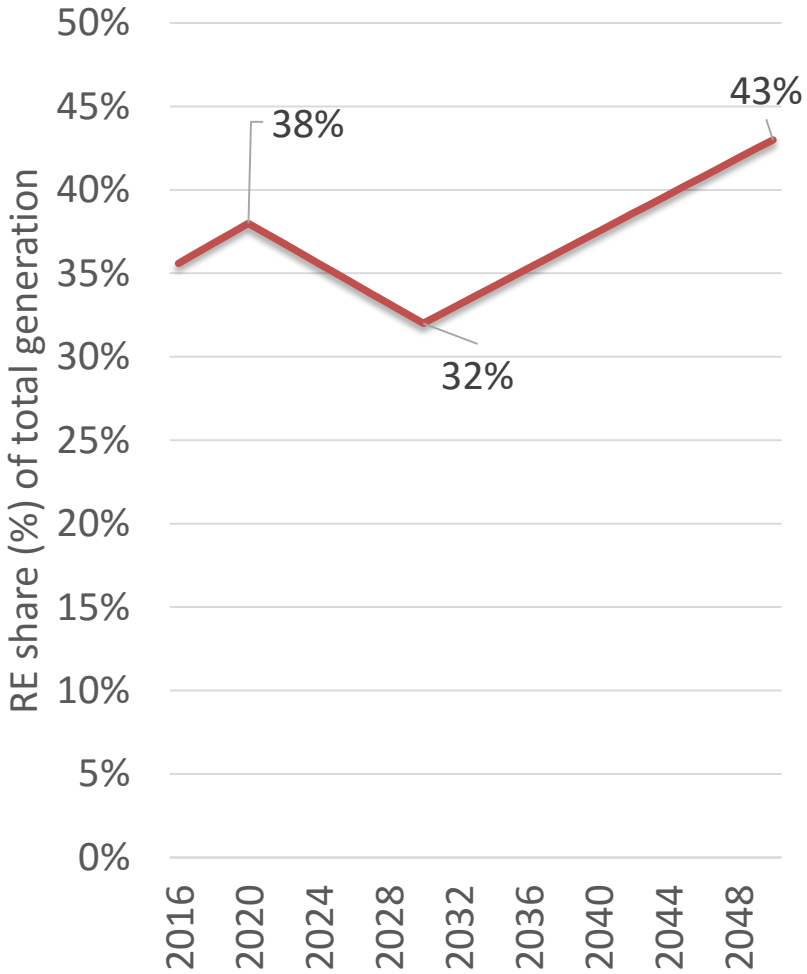
DESCRIPTION OF THE SCENARIOS

RE goals in the scenarios

- Stated Policies
  - RE goals in line with the RE Strategy
- No Coal
  - RE goals in line with the RE Strategy
  - No new investment in coal-fired capacity as of 2035
- Unrestricted
  - No RE goals
  - The BAU scenario



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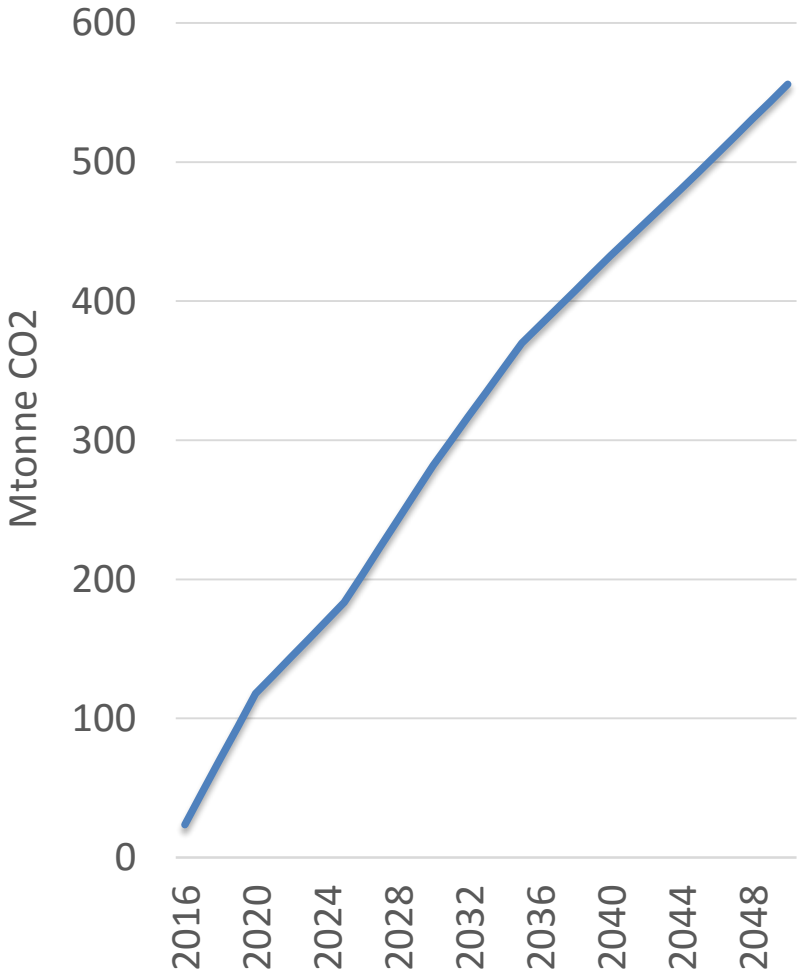
CO2 Cap scenario

- CO2 Cap
  - CO2 Cap implemented in line with the resulting CO2 emissions of the Stated Policies scenario
  - No RE goals as CO2 cap is a policy alternative



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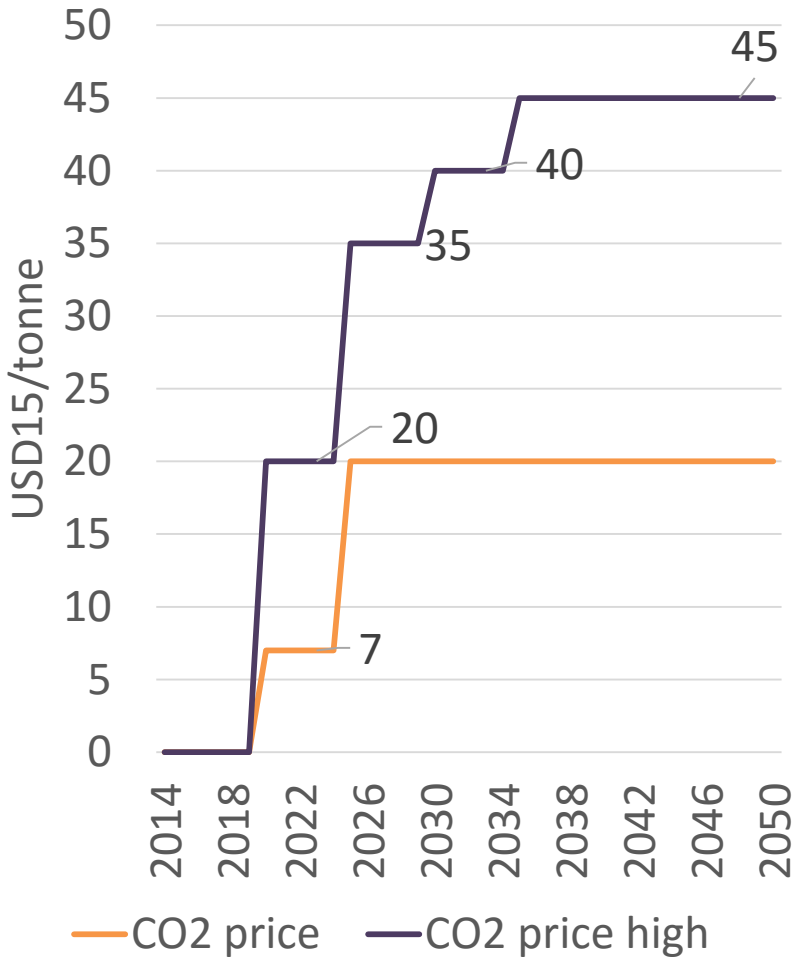
CO2 Price and CO2 Price High scenarios

- CO2 Price
  - 7 USD/tonne in 2020, 20 USD/tonne thereafter
  - No RE goals as CO2 price is a policy alternative
- CO2 Price High
  - Higher CO2 price (increasing from 20 to 45 USD/tonne in the 2020-2035 period)
  - No RE goals as CO2 price is a policy alternative



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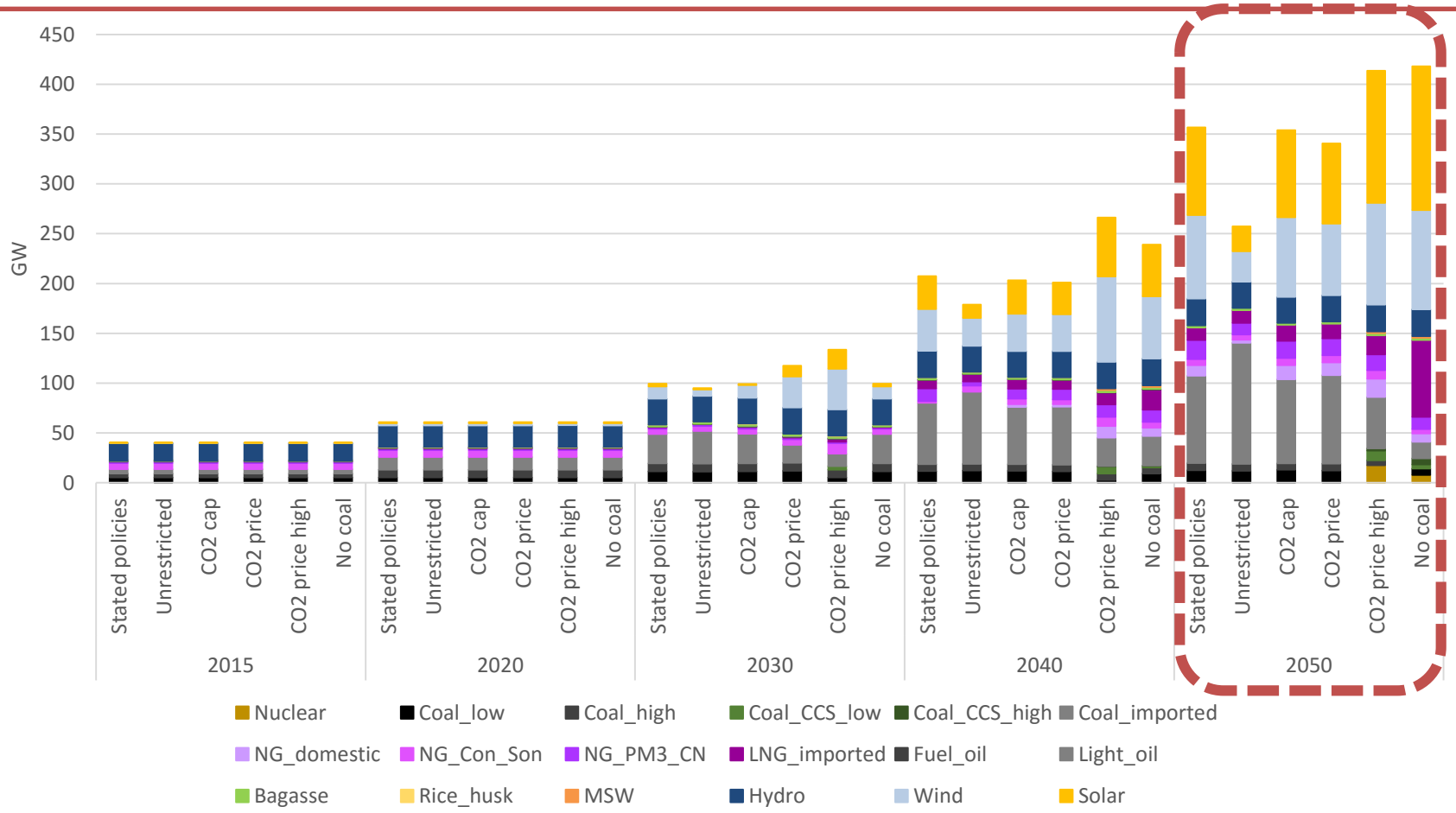
SCENARIO RESULTS

Total capacity

Total generation capacity for Stated Policies and alternative scenarios = Exogenous capacity + Model-based investments. Highest RE generation investments in No Coal scenario. Lowest – in Unrestricted (the Business-as-usual scenario without RE goals).



WORK-IN-PROGRESS RESULTS

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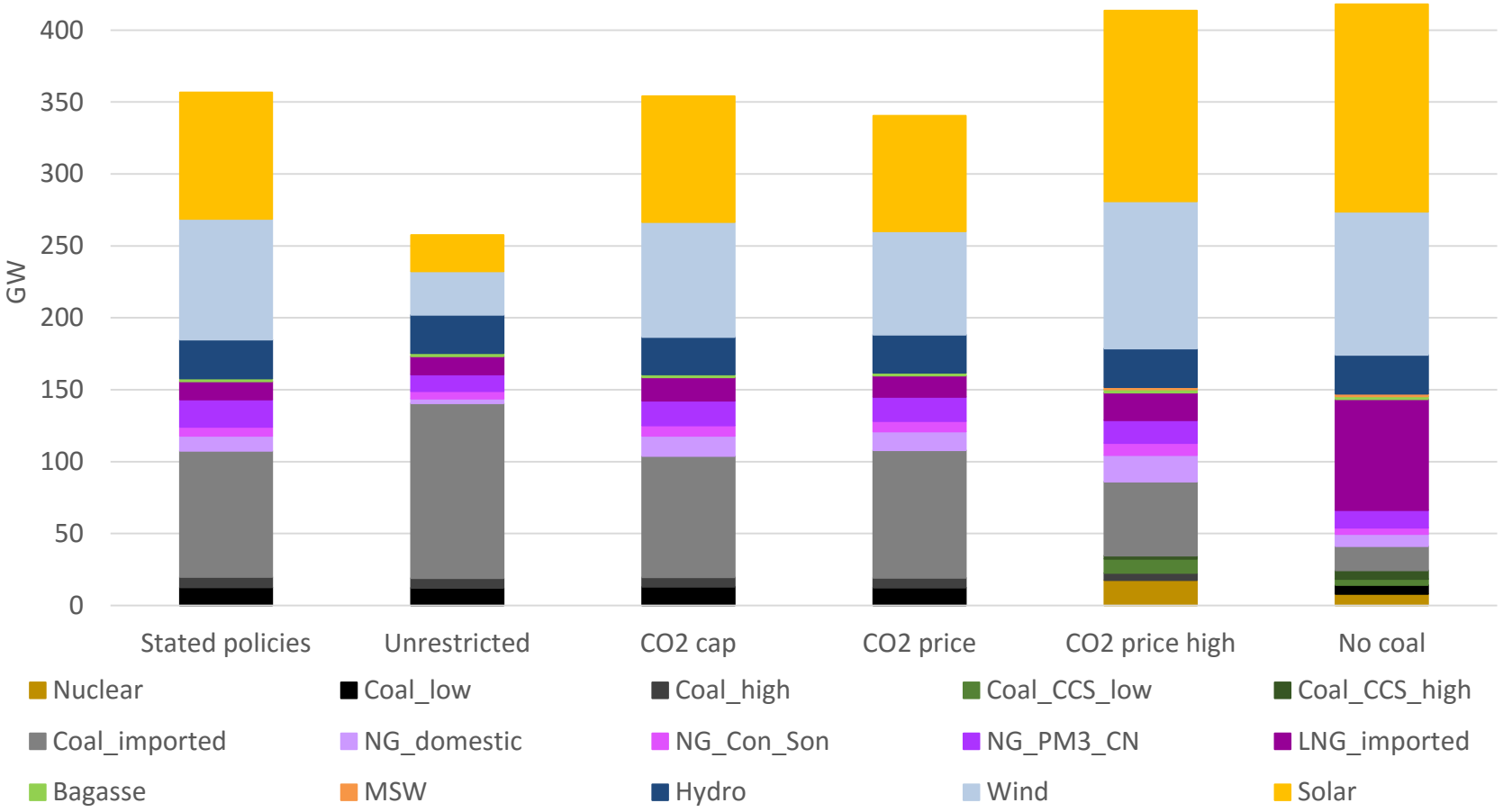
Total capacity - 2050

CO2 Cap and CO2 Price scenarios achieve very similar outcomes to Stated Policies. CO2 Price High and No Coal scenarios feature the highest RE capacities. No Coal also features significant additional natural gas-fired capacity



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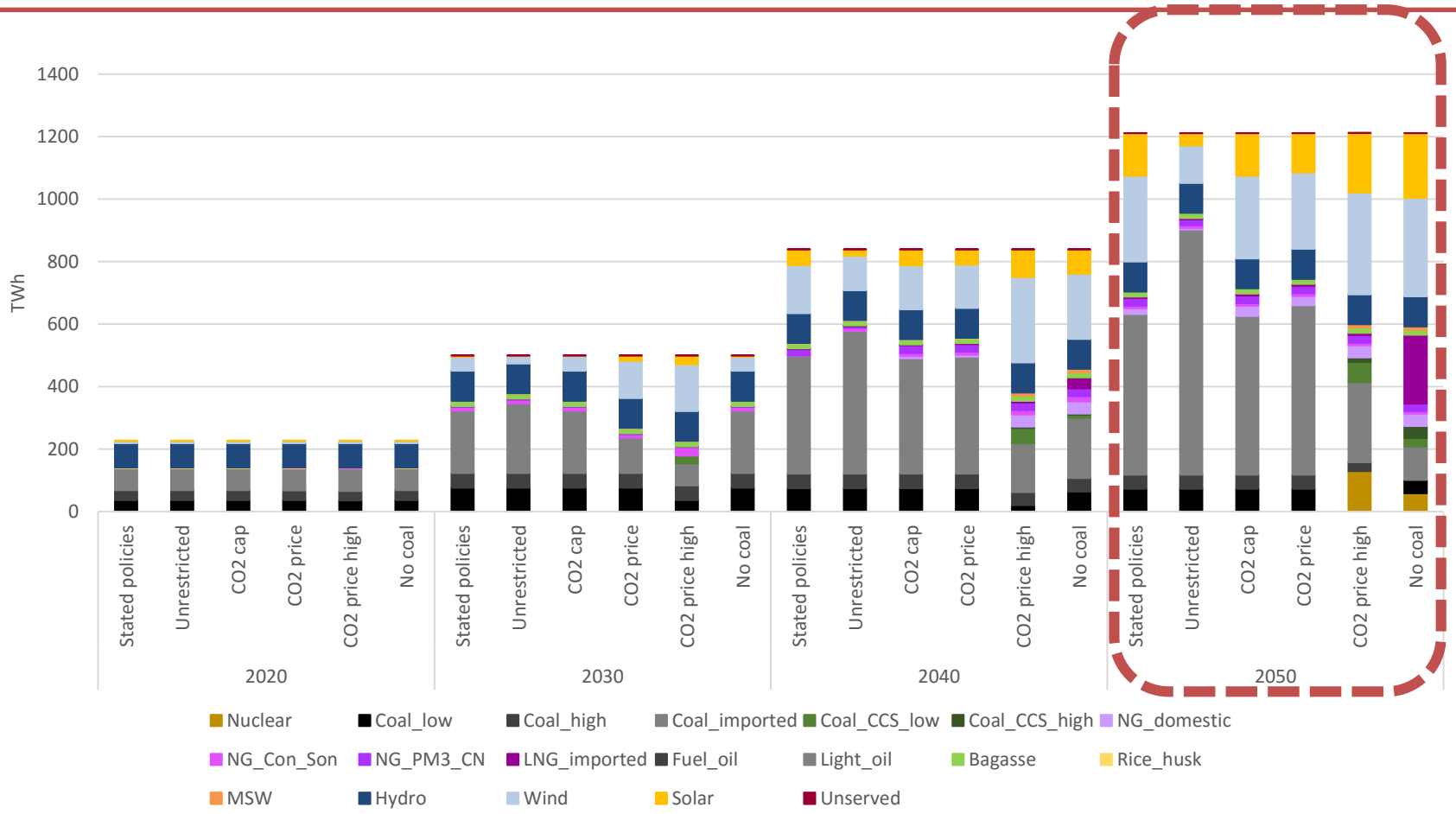
Total capacity - 2050

	Stated policies	Unrestricted	CO2 cap	CO2 price	CO2 price high	No coal
Nuclear					17,544	7,988
Coal	107,502	140,658	103,901	108,004	56,791	23,099
Coal CCS					11,853	10,184
Natural gas	48,292	32,619	54,608	51,737	61,884	102,031
Biomass and MSW	2,100	2,100	2,100	2,100	3,807	3,807
Hydro	26,913	26,603	26,019	26,416	26,835	27,070
Wind	84,036	30,400	79,902	71,902	102,258	99,590
Solar	87,750	25,057	87,467	80,320	132,476	144,170
Grand Total	**356,593**	**257,437**	**353,996**	**340,480**	**413,448**	**417,938**

Generation

Model-based optimal (least-cost) dispatch for all scenarios based on merit order.
Unrestricted scenario dominated by coal-fired generation. Stated Policies and CO2-focused policy scenarios feature significant shares of RE generation



WORK-IN-PROGRESS RESULTS

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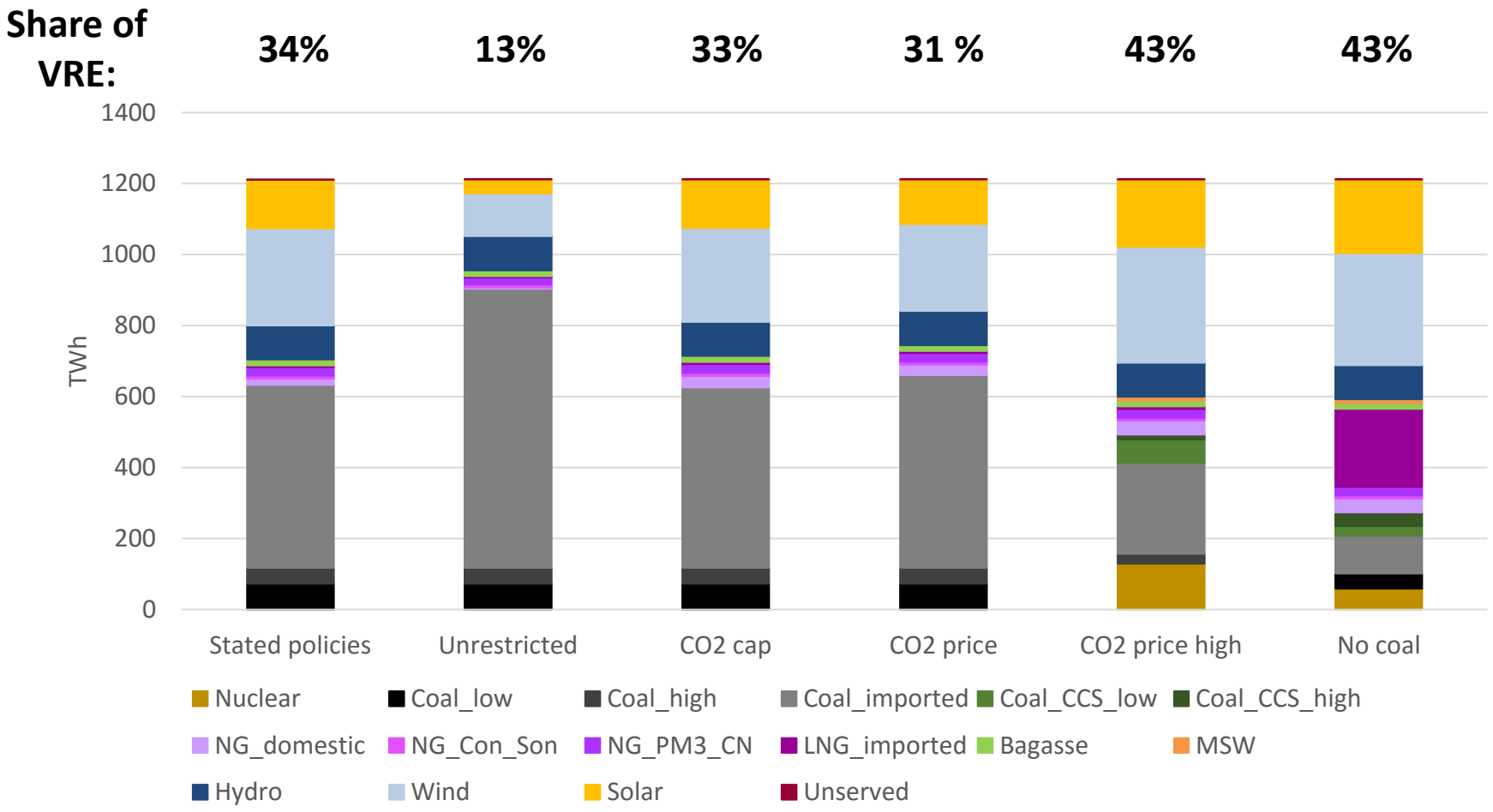
Generation 2050

Additional zero-carbon capacity needed in the CO2 Price High and No Coal scenarios. Limited investment in Coal CCS and nuclear takes place towards 2050.



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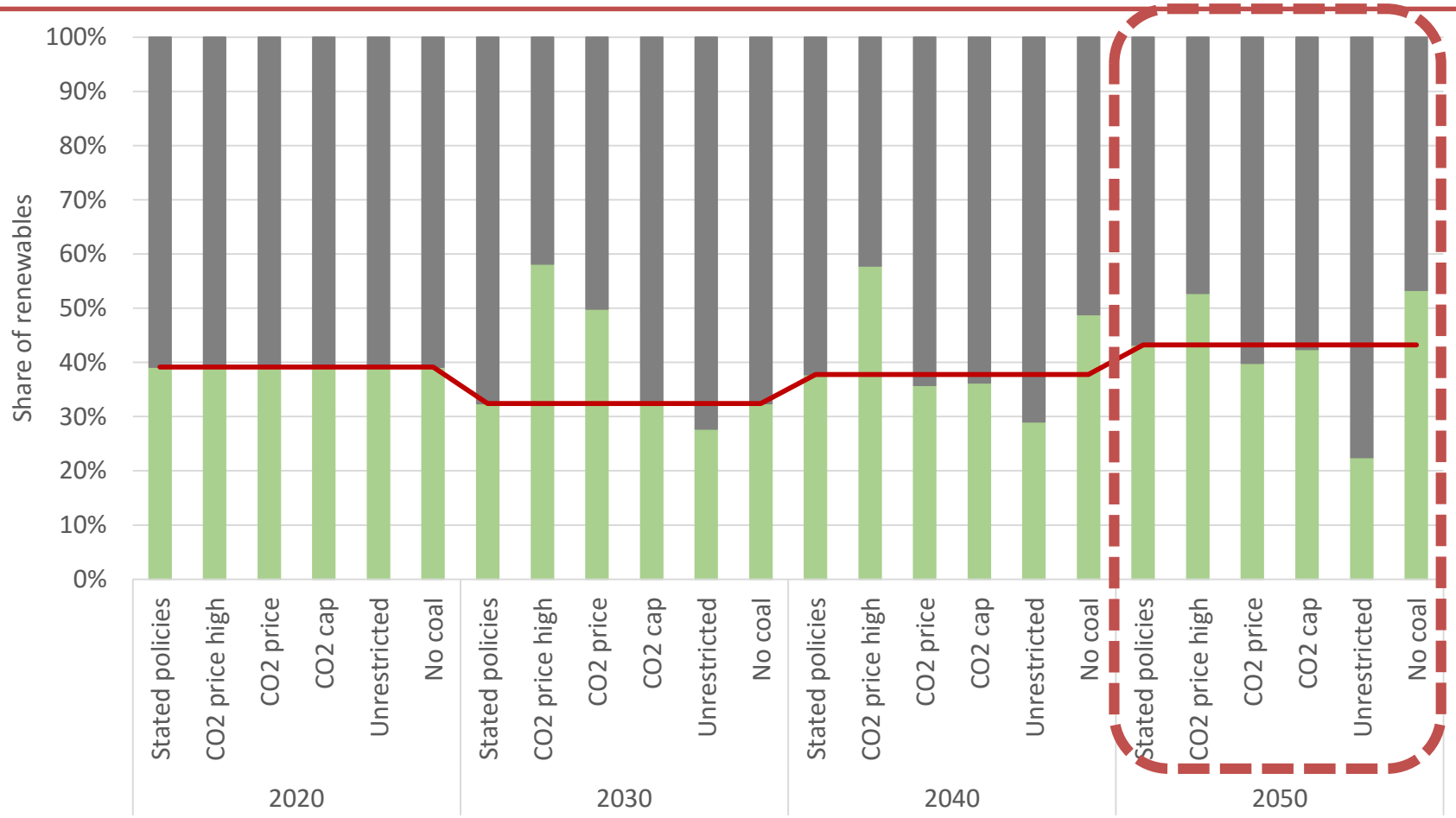
RE goals (including large hydro)

Unrestricted (BAU) scenario increasingly off the mark in the long term. CO2 price levels (based on externality value) in the CO2 Price scenario are very close to attain the RE investment levels mandated by the RE targets. No Coal and Co2 Price High scenarios exceed the RE generation targets set.



WORK-IN-PROGRESS RESULTS

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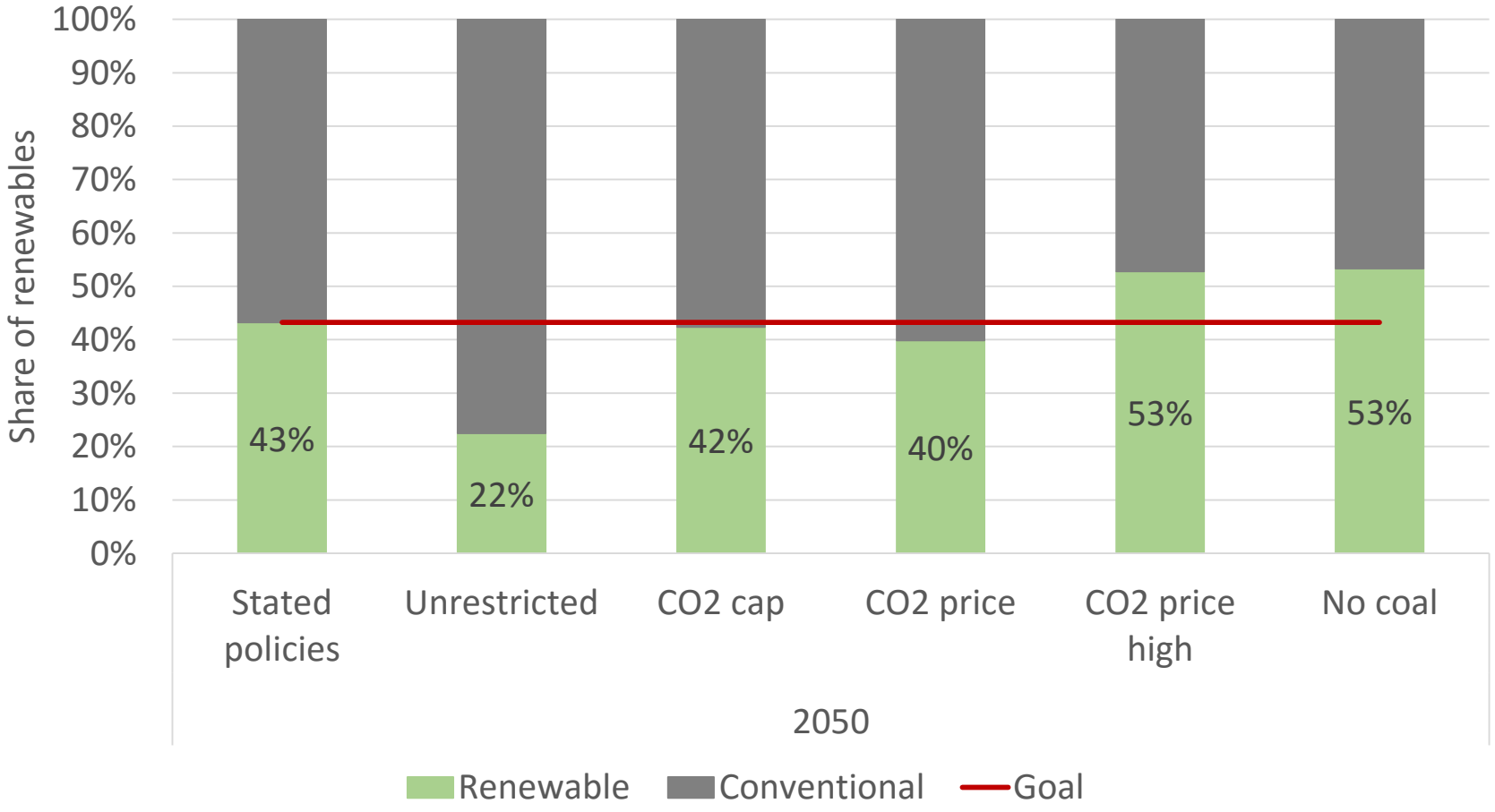
RE goals - 2050

Unrestricted (BAU) only meets half of the RE target for 2050. CO2 price level (based on externality value) in the CO2 Price scenario is very close to attaining the RE target for 2050, as is CO2 Cap scenario. CO2 Price High and No Coal scenarios exceed the RE generation targets set.



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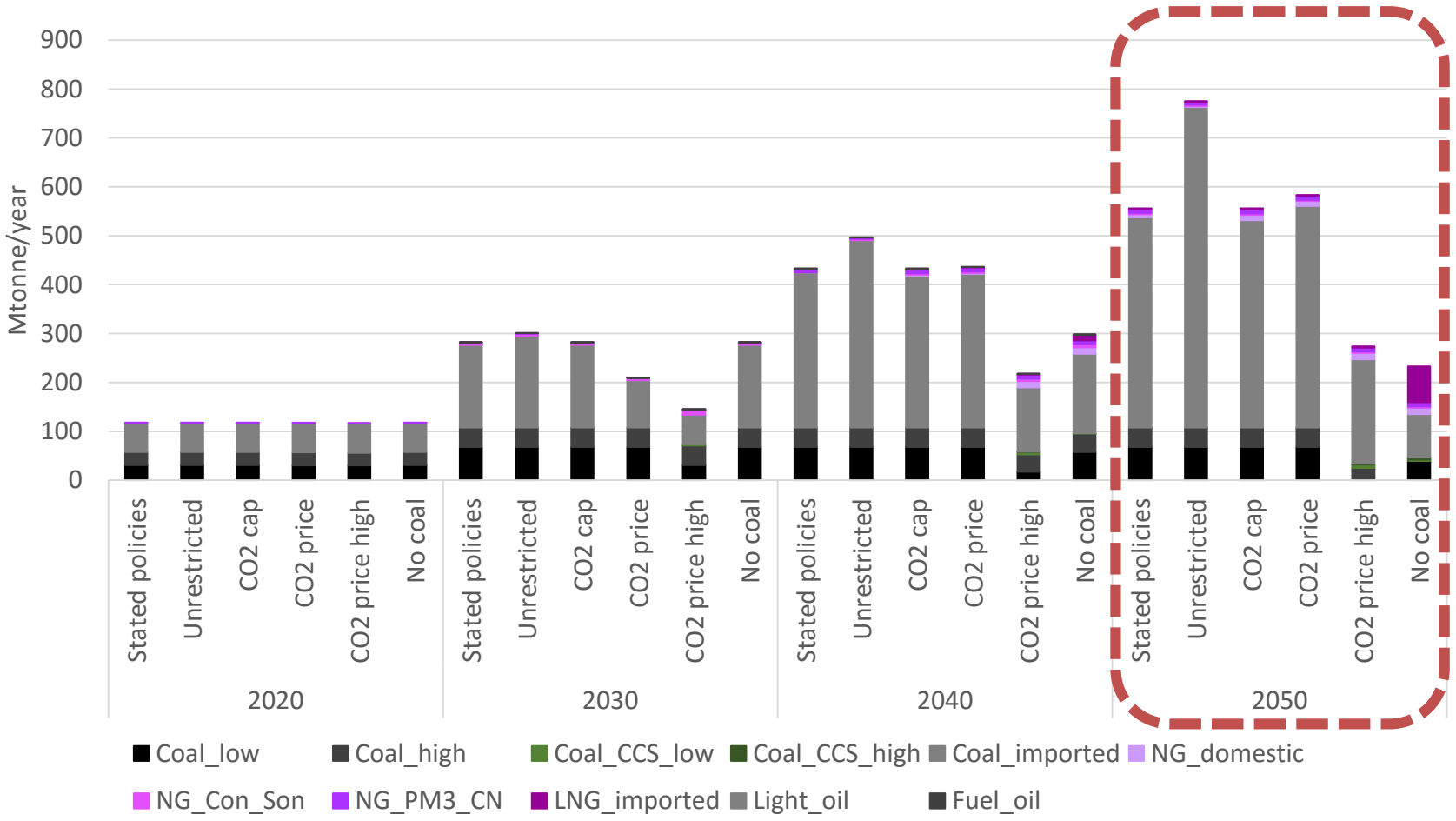
CO2 emissions

Significantly different outcomes in terms of the resulting CO2 emissions across scenarios. Unrestricted results in the highest emission levels, whilst No Coal – the lowest, respectively.



WORK-IN-PROGRESS RESULTS

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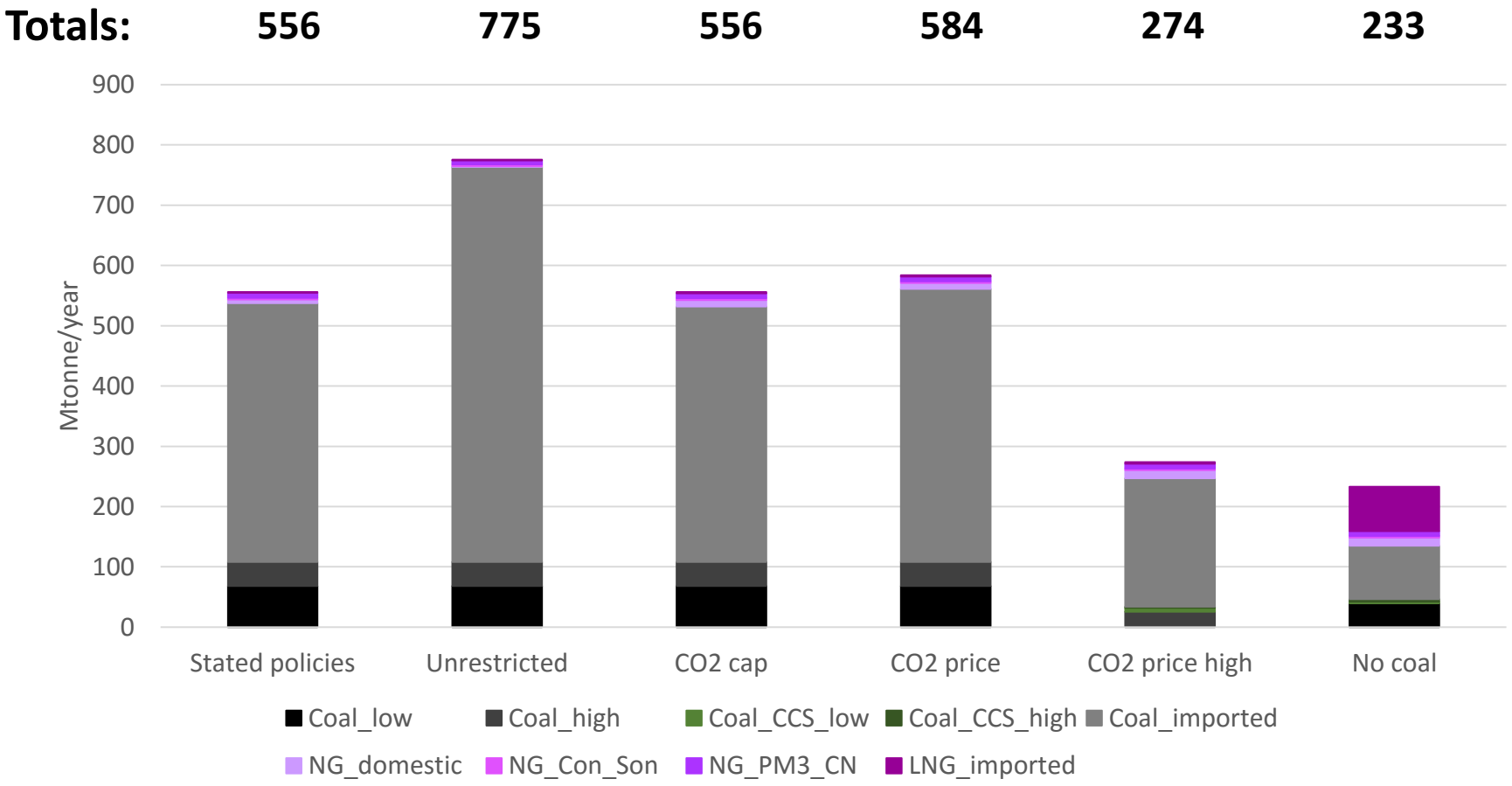
CO2 emissions - 2050

Stated Policies exhibits significant CO2 emission reductions compared to Unrestricted. CO2 price is an effective environmental policy alternative, and CO2 Price High scenario demonstrates the impact of a different CO2 price level. No Coal, in turn, pinpoints the key CO2 emission driver – coal-fired generation.



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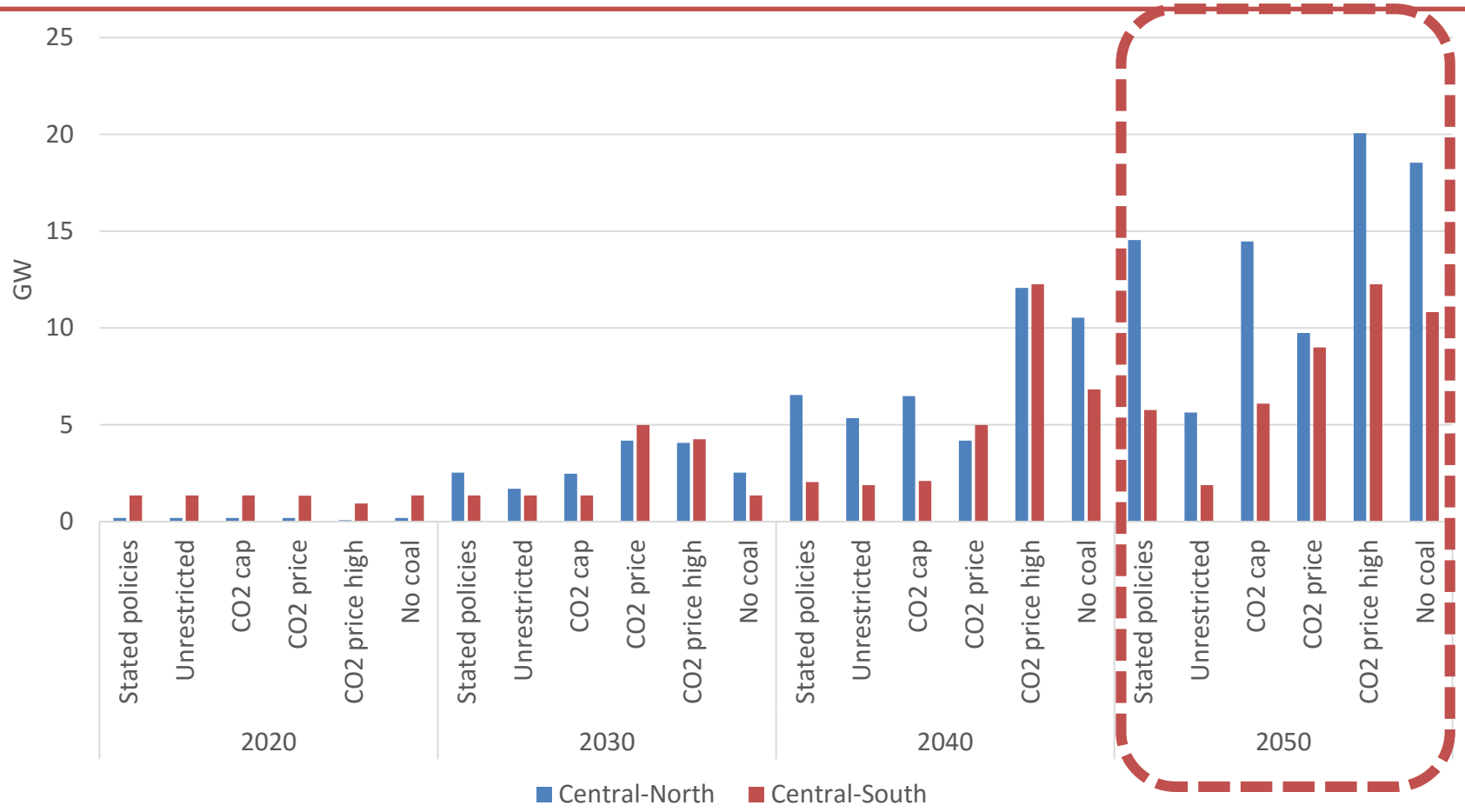
Endogenous transmission

The results illustrate the importance of transmission capabilities in the integration of RE generation. The scenarios featuring the highest RES build-out also feature the highest additional transmission expansion (CO2 Price High and No Coal).



WORK-IN-PROGRESS RESULTS

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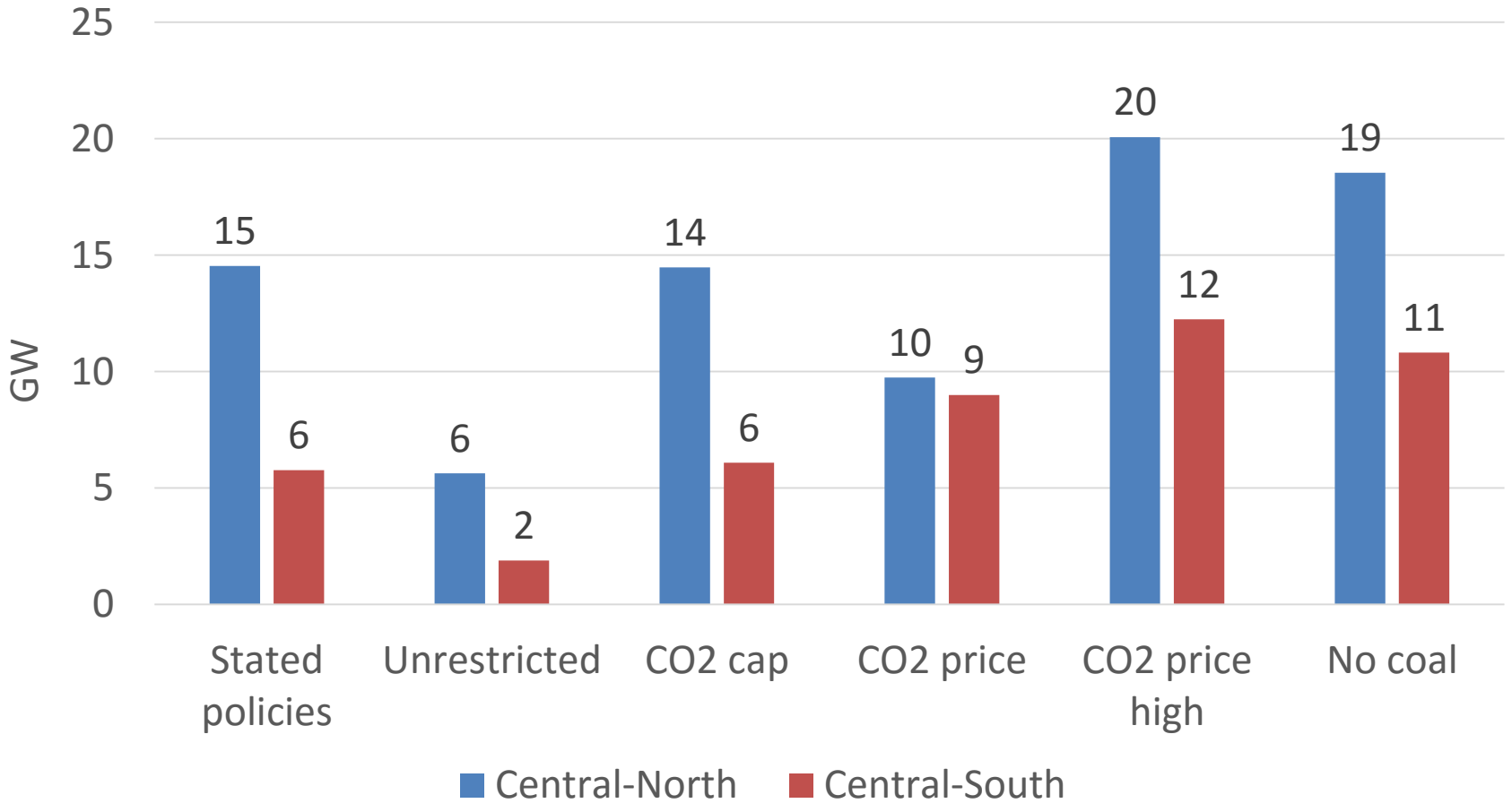
Endogenous transmission - 2050

Significant additional regional transmission investment required across all scenarios to satisfy the rapidly increasing demand and to ensure least-cost system operation, balancing and RE integration by 2050.



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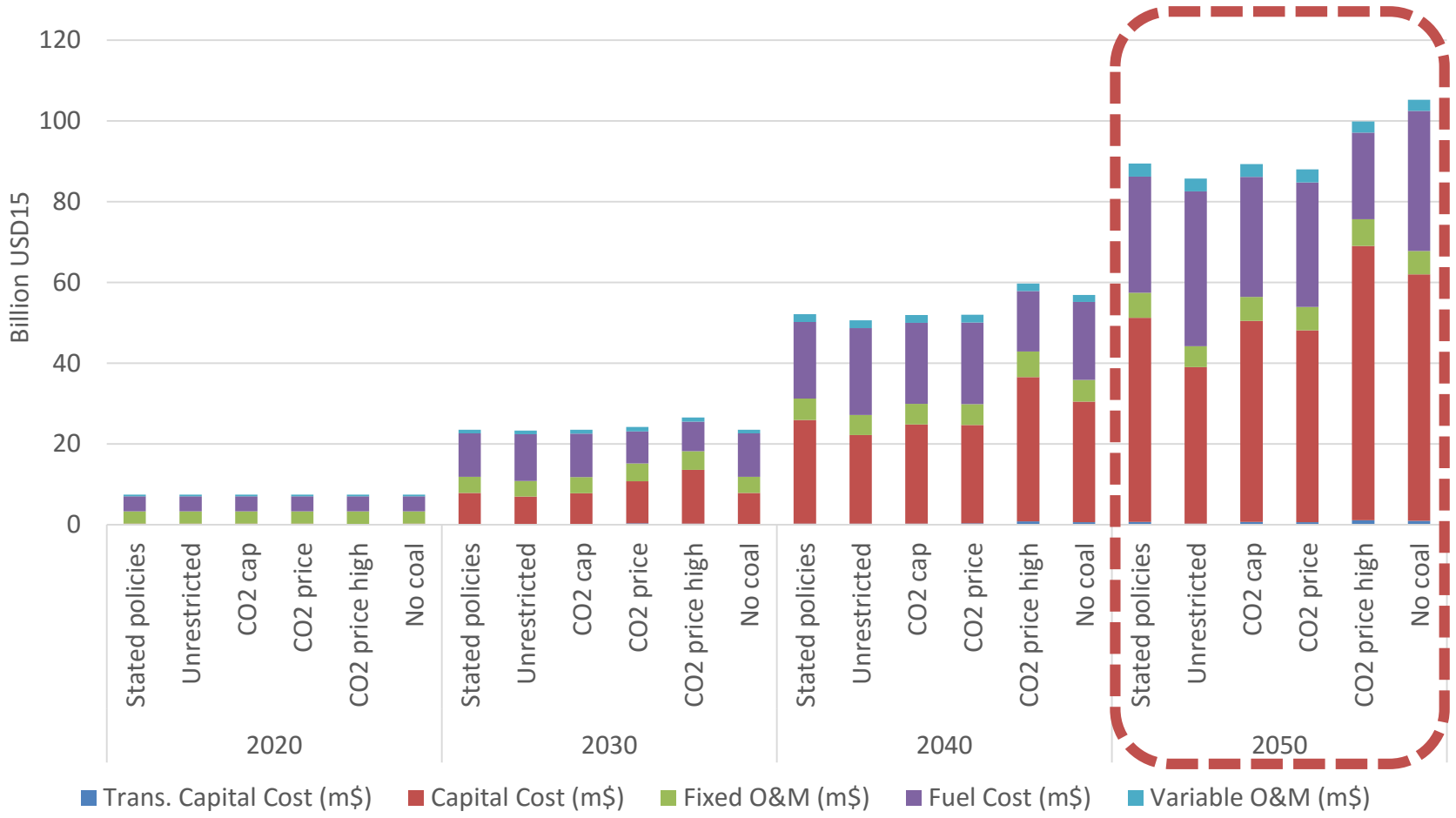
Economy

Total annualized system costs are calculated based on the (annualized) investments in generation and transmission and system dispatch in each scenario in each year modelled



WORK-IN-PROGRESS RESULTS

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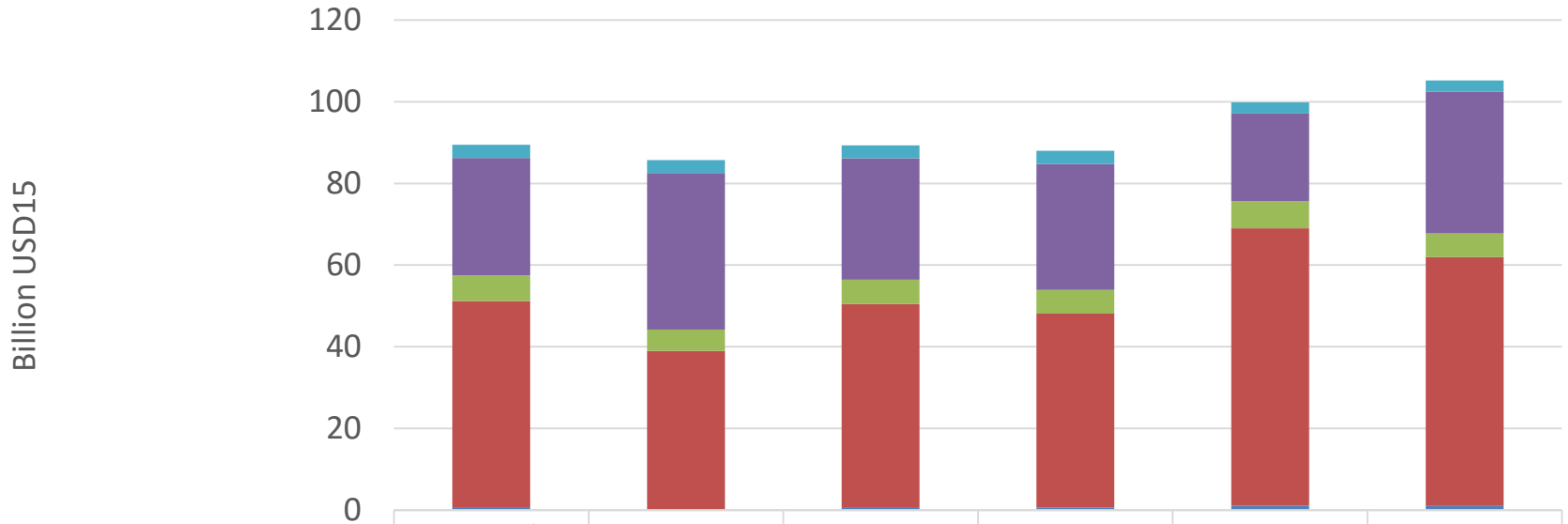
Economy - 2050

Meeting the RE goals (Stated Policies vs Unrestricted) come at only 4% additional annualized system cost as higher CapEx is compensated by lower fuel costs. Stricter environmental policy frameworks (CO2 Price High No Coal) increase the total system costs further.



	Stated policies	Unrestricted	CO2 cap	CO2 price	CO2 price high	No coal
Variable O&M (m$)	3,278	3,149	3,124	3,217	2,751	2,755
Fuel Cost (m$)	28,776	38,394	29,750	30,847	21,462	34,712
Fixed O&M (m$)	6,202	5,179	5,954	5,824	6,650	5,813
Capital Cost (m$)	50,536	38,746	49,767	47,468	67,928	60,982
Trans. Capital Cost (m$)	677	250	686	625	1,078	980
Total (m$)	**89,470**	**85,718**	**89,281**	**87,981**	**99,869**	**105,241**

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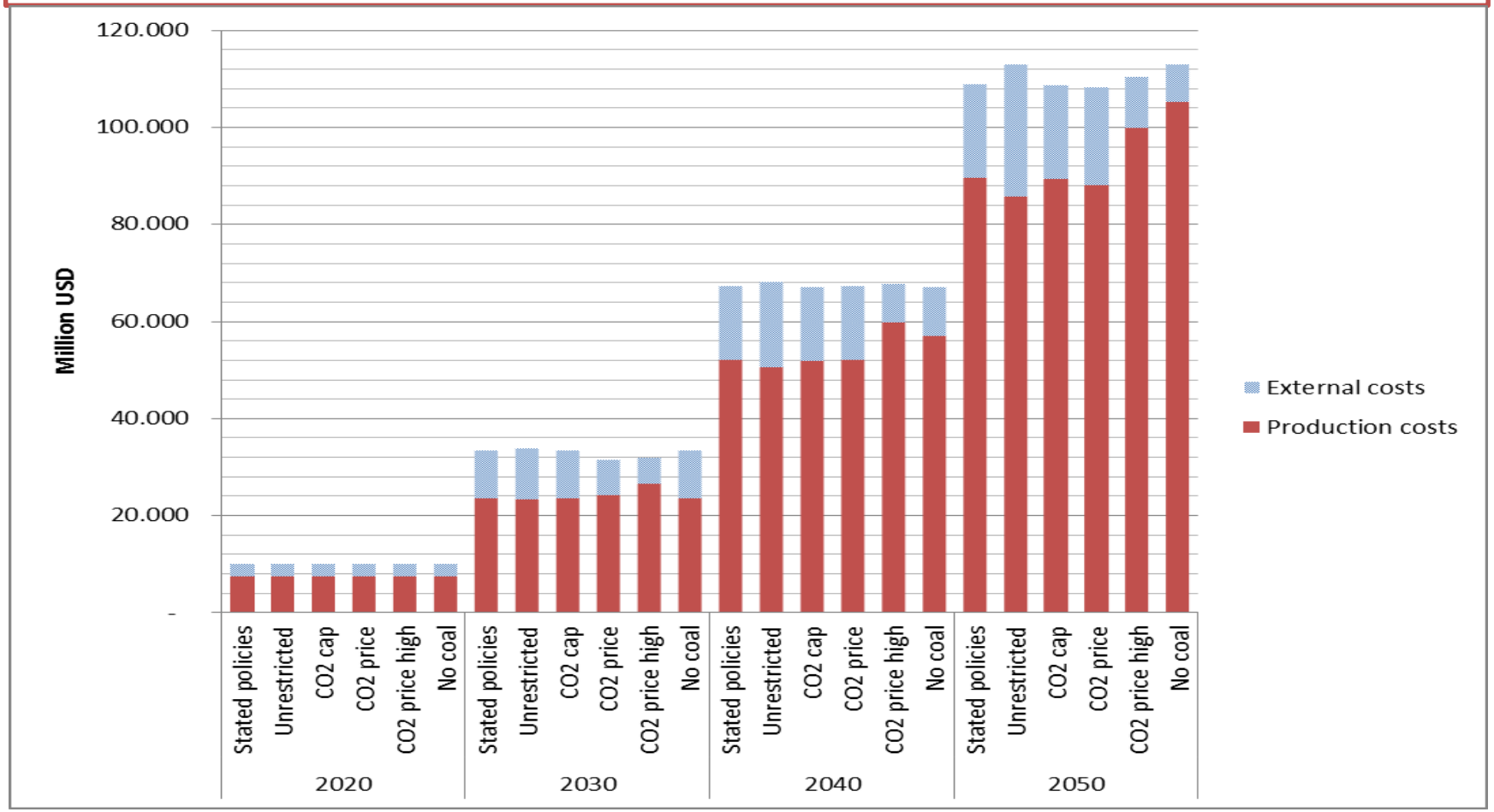
Economy – including externality value

When externality value of CO2 and SO2* is accounted for, Unrestricted becomes the most expensive scenario. In 2050, CO2 Price High and No Coal are only marginally more expensive than Stated Policies (1% and 4% respectively).



* Based on study of external costs of electricity generation in Vietnam:
H.A Nguyen-Trinh and M. Ha-Duong / GMSARN International Journal 9 (2015)

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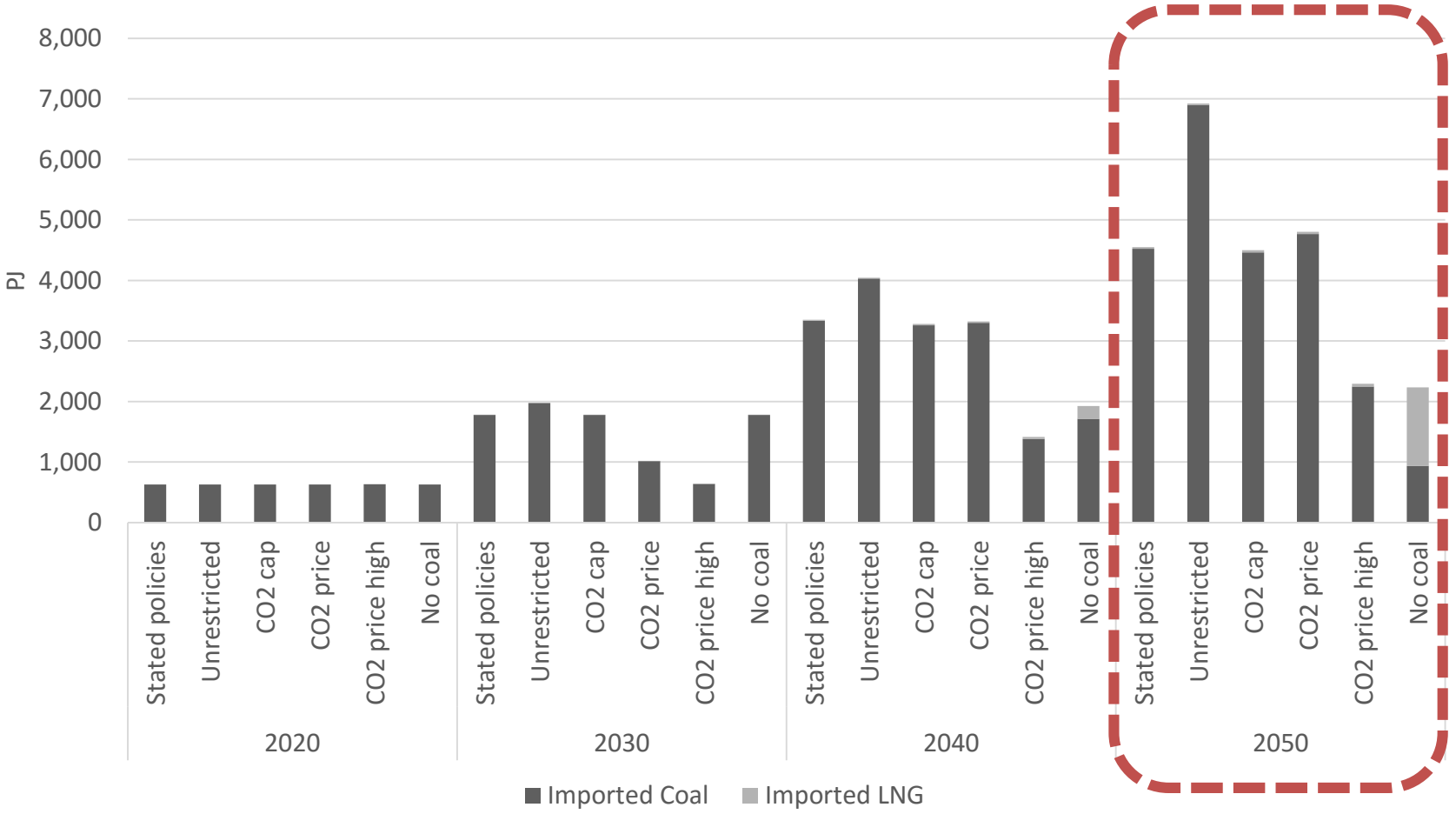
Imported coal and natural gas

Significant volumes of imported coal are required to keep up with the increasing power demand. The import requirements are susceptible to the prevailing environmental and RE policies, however



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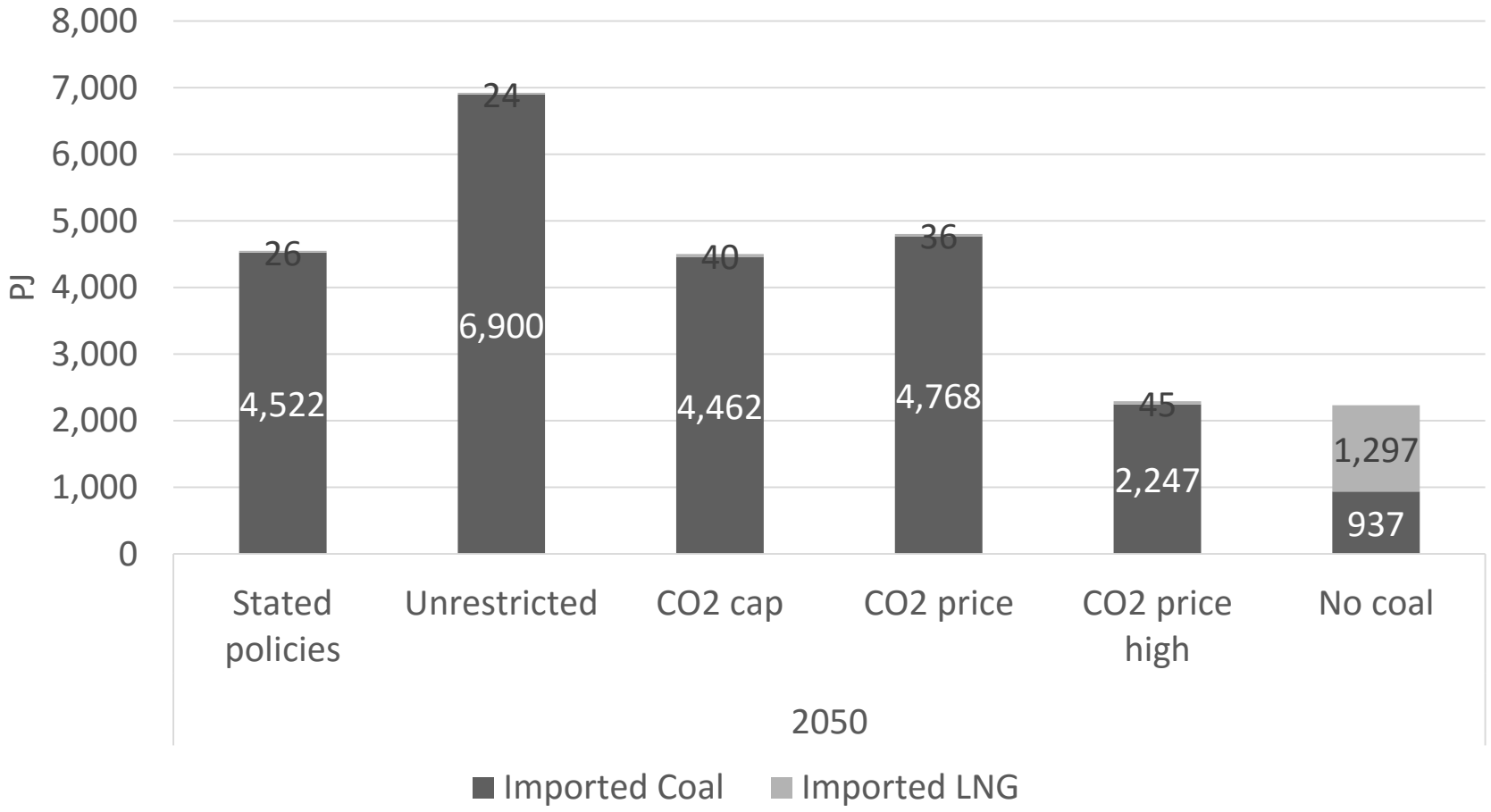
Imported coal and natural gas - 2050

Absence of environmental policies (Unrestricted) significantly increases the reliance on imported fuels. The most restrictive policy alternative (CO2 Price High and No Coal) result in the lowest volumes of imported fossil fuels required, due to largest shares of the power demand being covered by domestic renewable resources.



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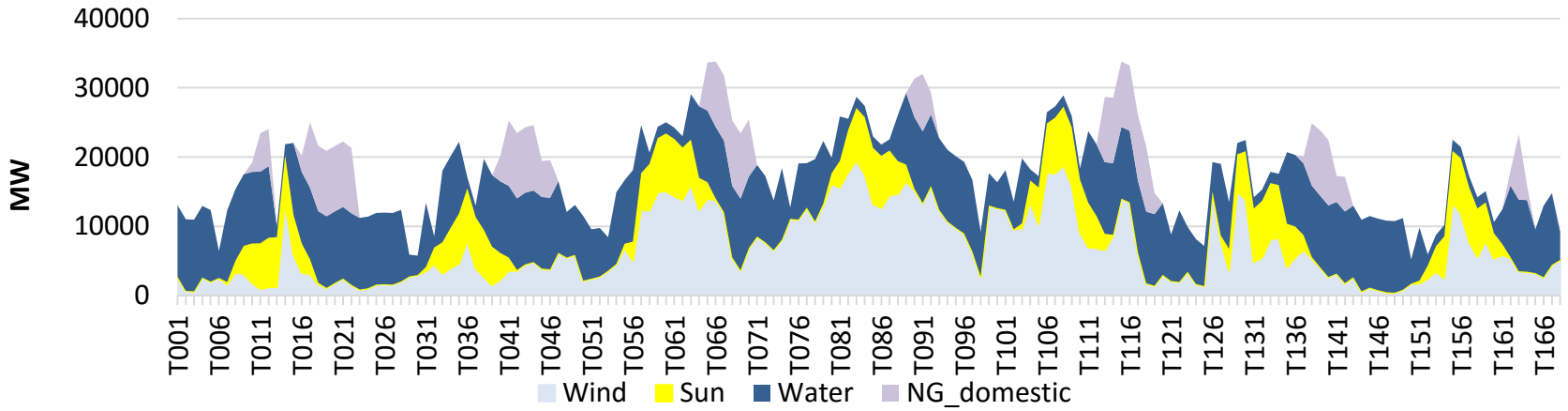
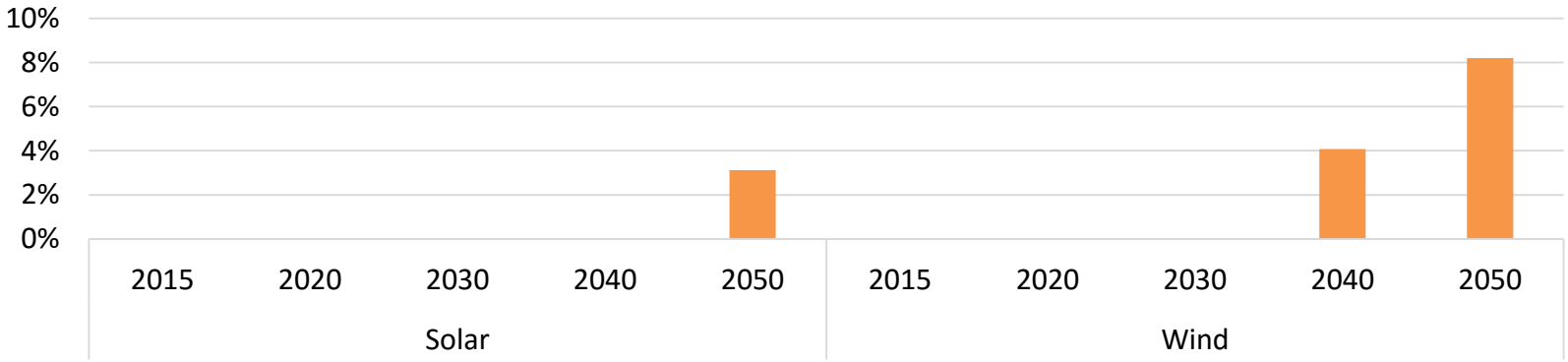
Integration of RE

Negligible curtailment rates until 2030 (and 2040 for solar PV) at very substantial RE penetration rates



Example of hourly dispatch. Stated Policies scenario in Central region, week 40, year 2050



Wind and solar PV curtailment rates in the hourly dispatch simulation of the Stated Policies scenario

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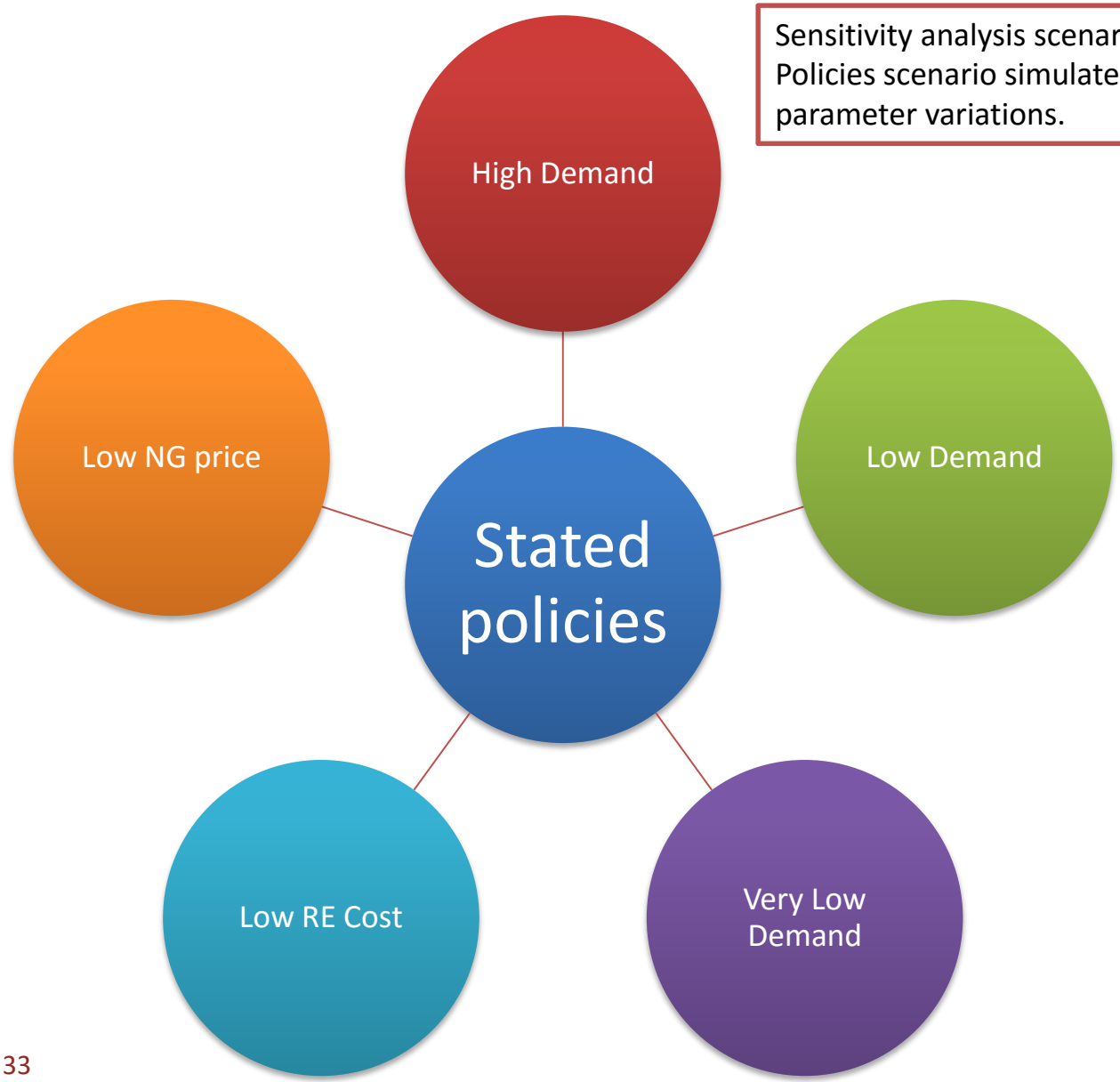
SENSITIVITY ANALYSIS

Sensitivity analysis scenarios: Overview

Sensitivity analysis scenarios based on the Stated Policies scenario simulated investigating key parameter variations.



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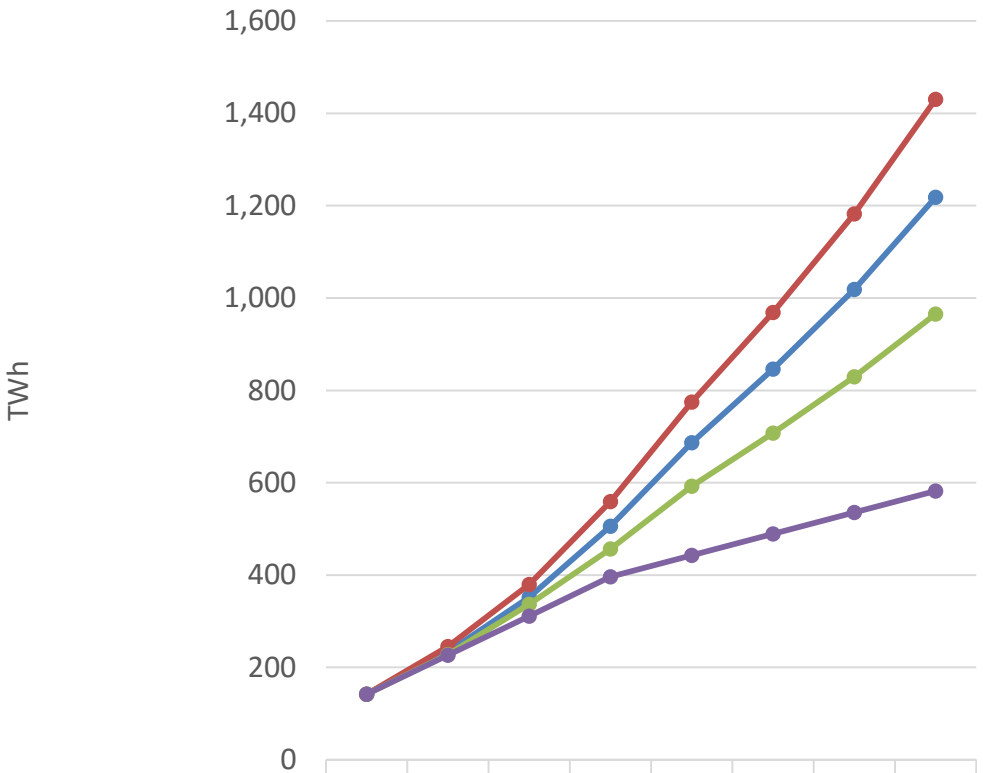
Demand projection sensitivity analysis

- Stated policies
  - PDP 7 revised until 2030
  - Continued growth towards 2050
- High Demand
  - As per PDP 7 revised
  - Continued growth towards 2050
- Low demand
  - As per PDP 7 revised
  - Continued growth towards 2050
- Very low demand
  - WWF demand projections – sustainable energy scenario



	2015	2020	2025	2030	2035	2040	2045	2050
Stated Policies	142	234	352	506	687	846	1,019	1,218
High demand	142	245	379	559	775	969	1,182	1,430
Low demand	142	228	337	456	592	708	829	965
Very low demand	142	227	312	396	443	489	536	582

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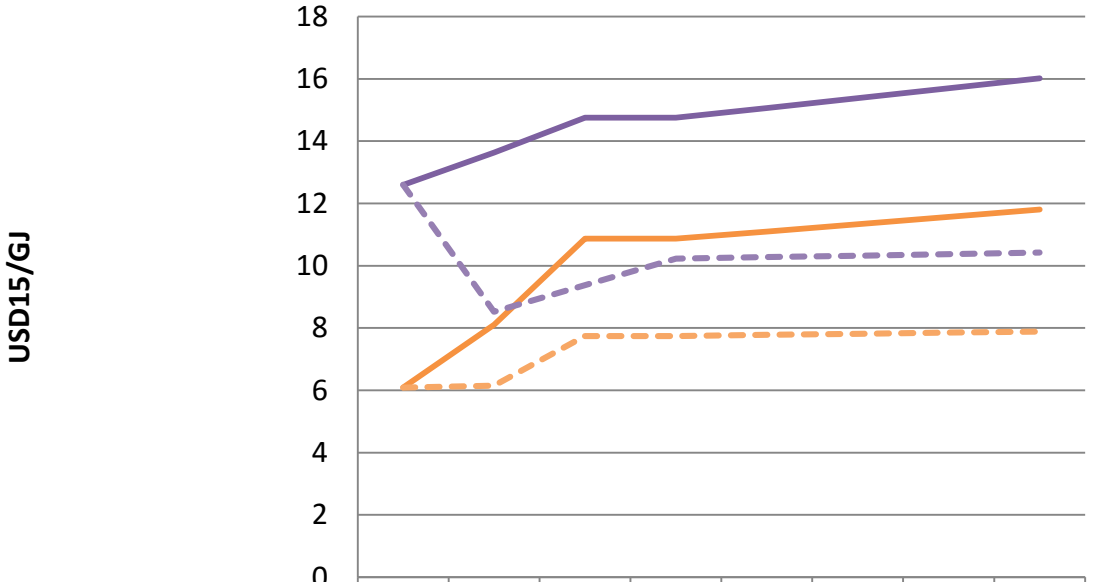
Fuel price sensitivity scenario

- Low NG Price
  - Natural gas price
    - LNG imports: follow the IEA WEO 2016 450 PPM scenario
    - Domestic: average between low and high estimate



	2015	2020	2025	2030	2035	2040	2045	2050
Stated policies - Domestic NG	6.09	8.10	10.87	10.87	11.10	11.33	11.57	11.80
Stated policies - Imported LNG	12.60	13.64	14.76	14.76	15.07	15.38	15.70	16.02
Low NG - Domestic NG	6.09	6.15	7.74	7.74	7.79	7.81	7.85	7.89
Low NG - Imported LNG	12.60	8.52	9.38	10.23	10.28	10.32	10.37	10.42

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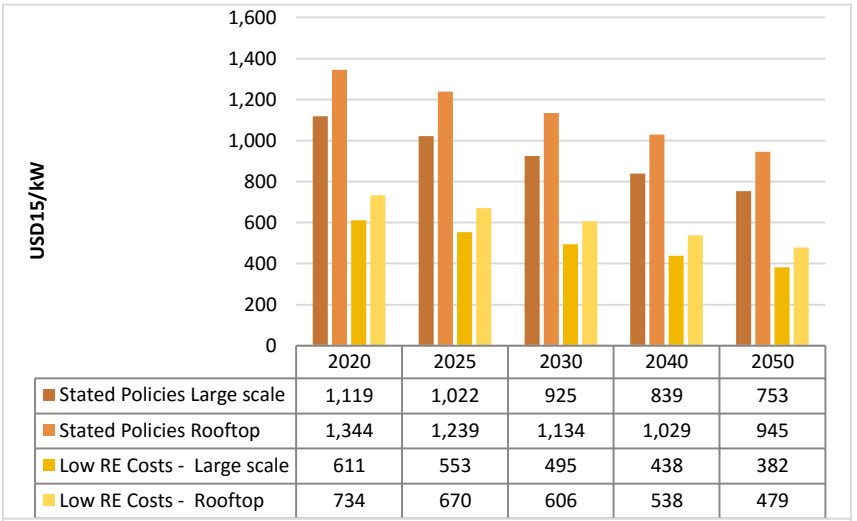
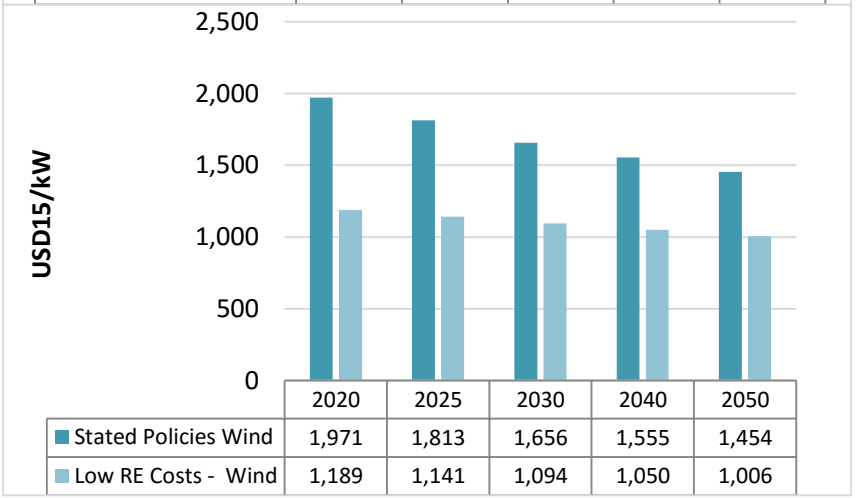
Renewable energy technology cost scenario

- Low RE Cost
  - Representing the continuation of the cost reduction trend observed in the recent years
    - Solar PV: based on the competitive auction winning bids globally, and a learning curve assumption (same as in Stated Policies)
    - Wind: based on Danish Energy Agency's Technology Catalogues





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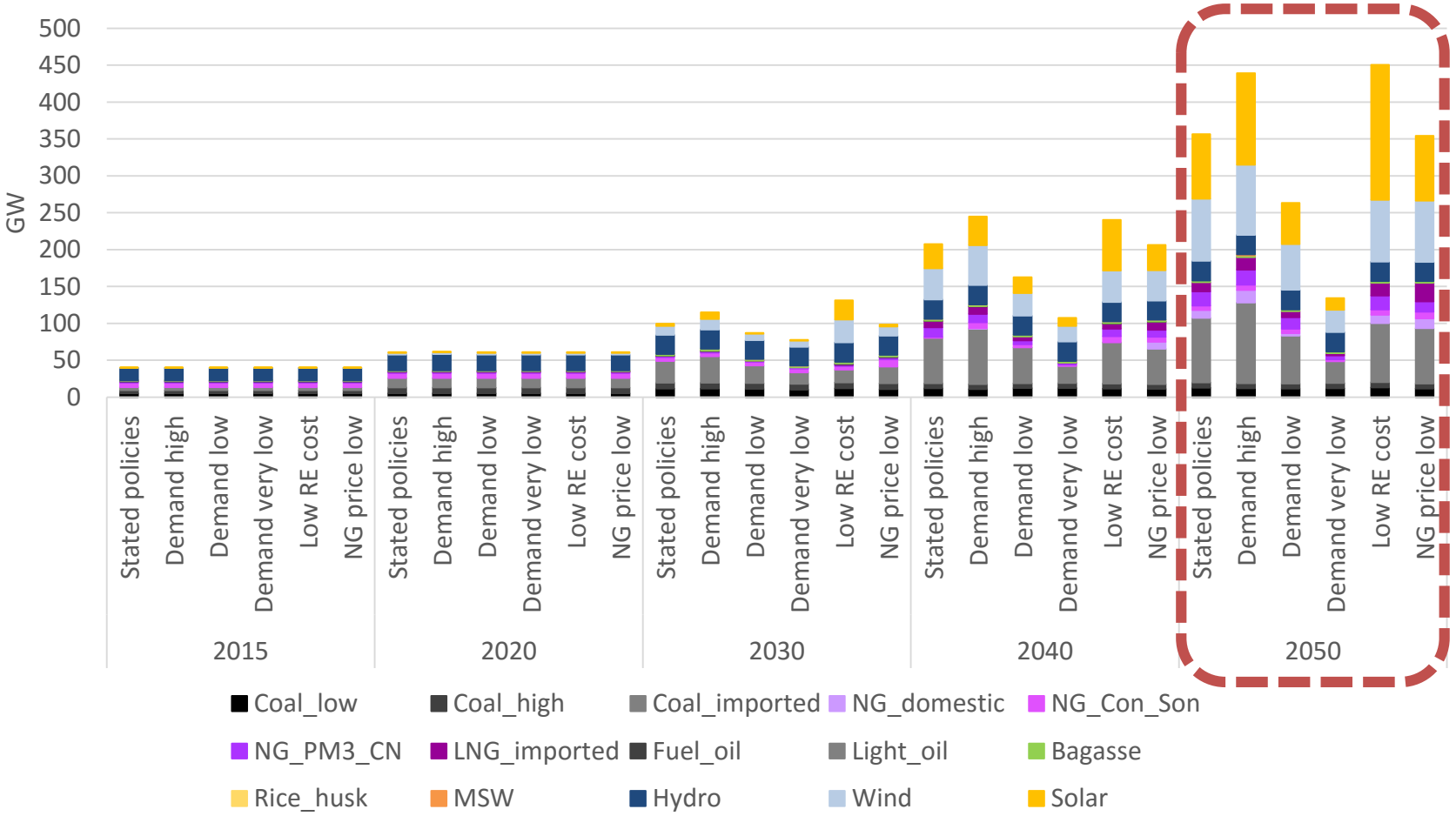
Total capacity

Total generation capacity for Stated Policies and alternative scenarios = Exogenous capacity + Model-based investments.



WORK-IN-PROGRESS RESULTS

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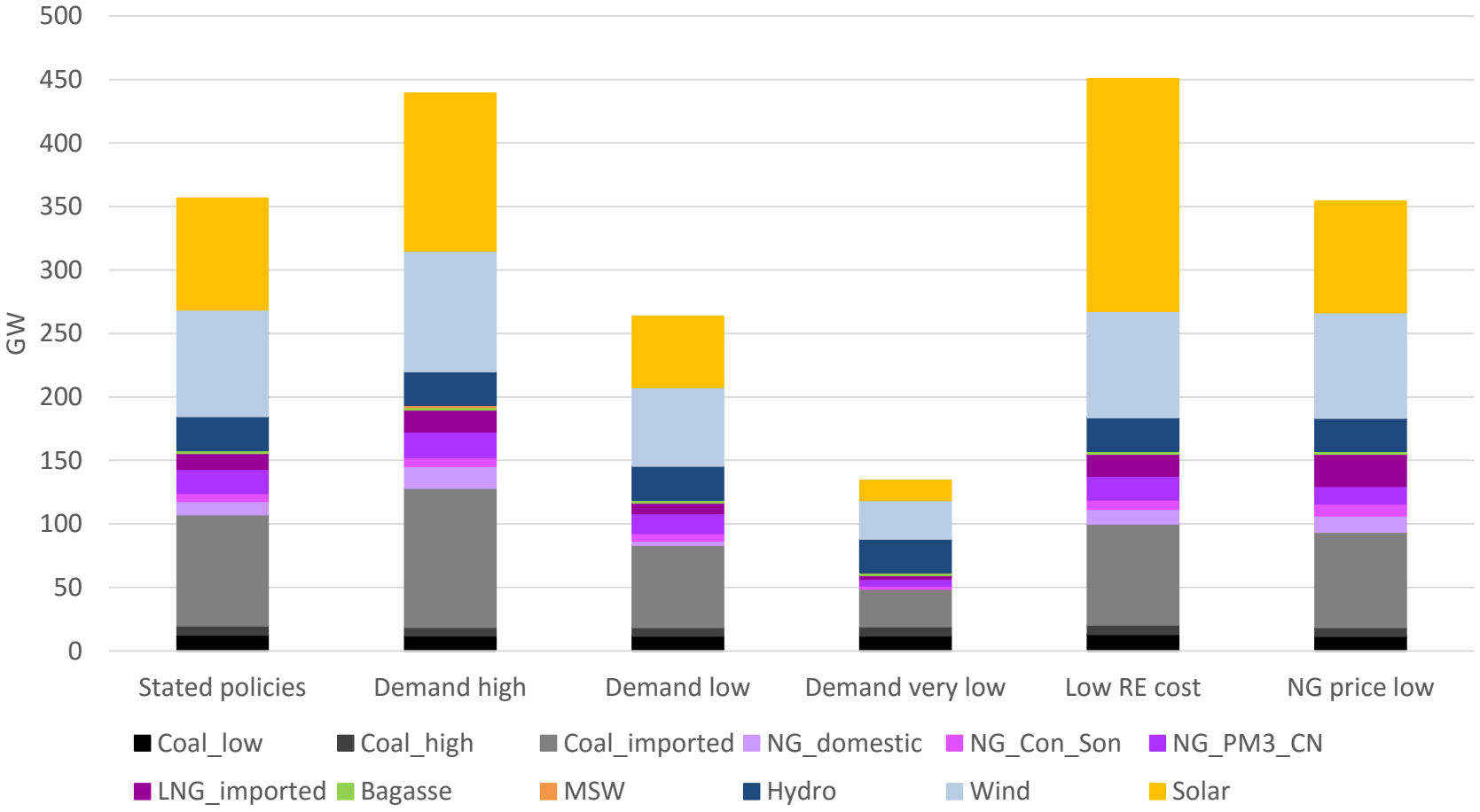
Total capacity - 2050

Demand projections are a critical determinant of the prospective system size and setup, also affecting the absolute levels of RE resources utilized. Low RE costs result in significantly higher RE shares in a least-cost optimal system. Lower natural gas prices lead to substitution of imported coal-fired with gas-fired capacity



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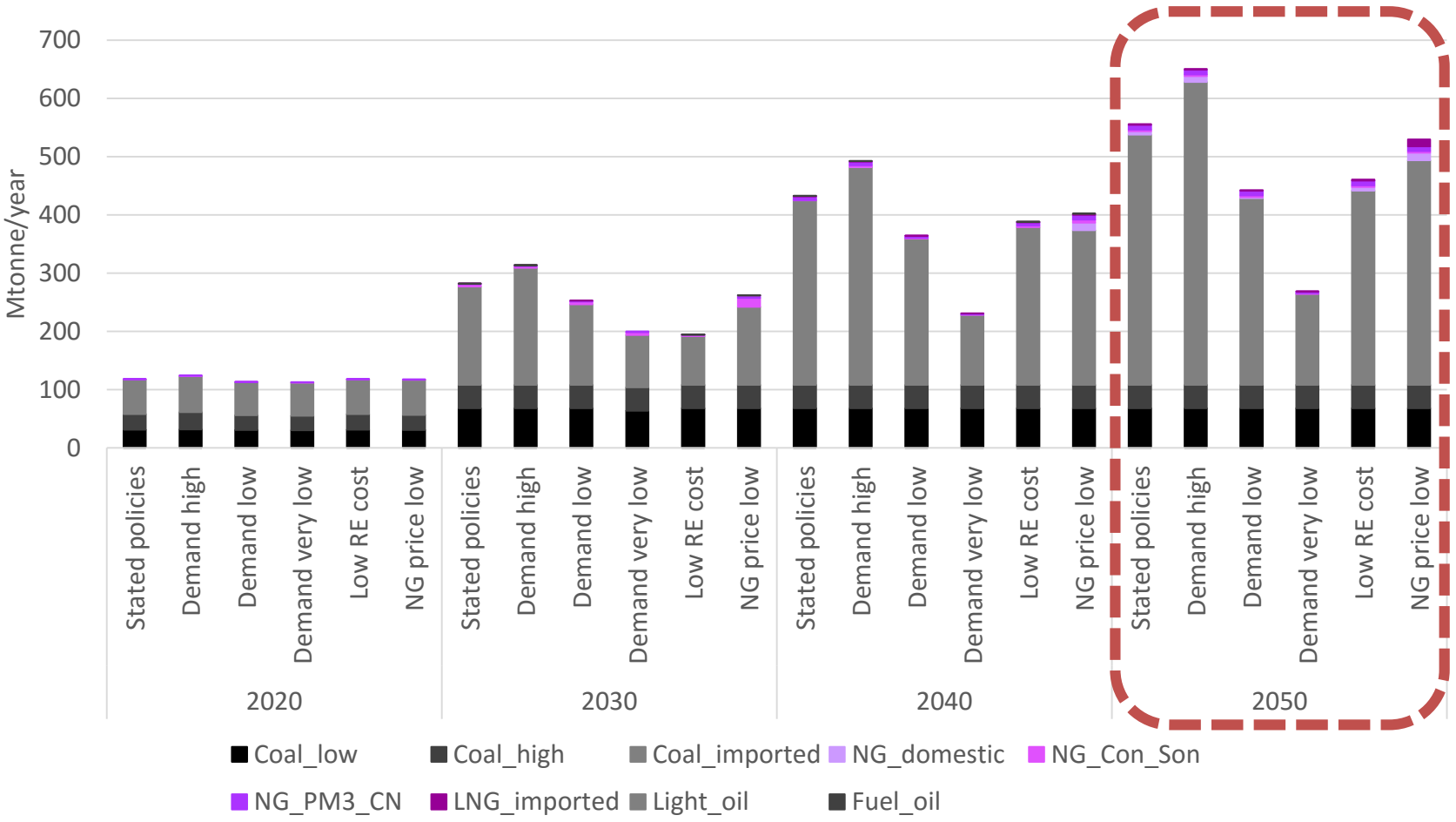
Total capacity - 2050

	Stated policies	Demand high	Demand low	Demand very low	Low RE cost	NG price low
Coal	107,502	128,213	83,277	48,668	100,161	93,665
Natural gas	48,292	61,583	33,408	10,932	54,958	61,429
Biomass and MSW	2,100	3,654	2,100	2,100	2,100	2,100
Hydro	26,913	26,545	26,815	26,430	26,596	26,286
Wind	84,036	95,109	61,926	30,400	83,764	82,918
Solar	87,750	124,171	55,779	15,651	182,973	87,719
Grand Total	**356,593**	**439,274**	**263,306**	**134,182**	**450,552**	**354,117**

CO2 emissions

Significant variation in CO2 emission levels across scenarios

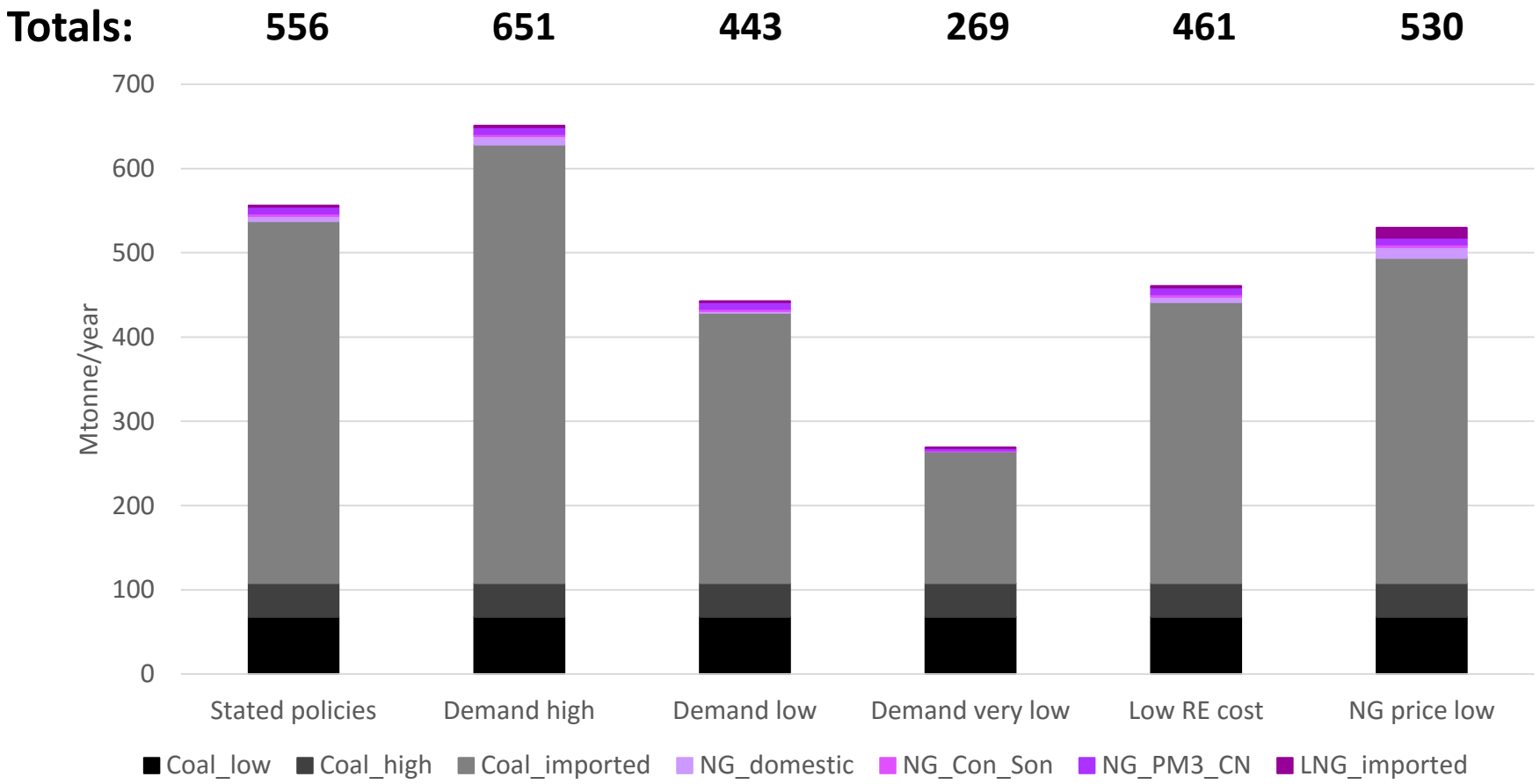


WORK-IN-PROGRESS RESULTS

Ea Energy Analyses

CO2 emissions - 2050

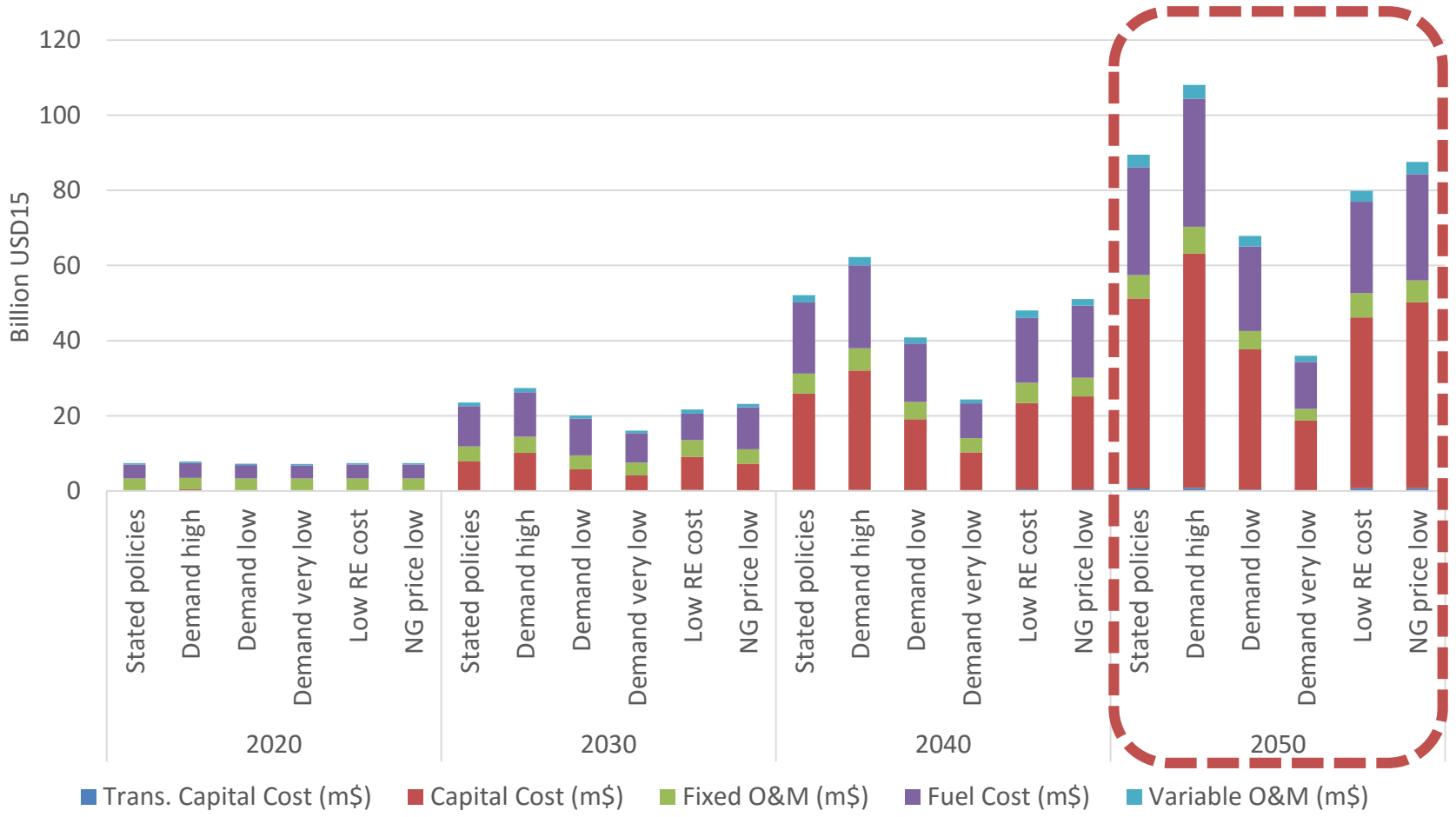
Highly significant impact of demand projections on the CO2 emission levels, thereby exemplifying the potential environmental benefits of e.g. Improved energy efficiency measures. Lower RE costs also contribute to lower CO2 emissions, as does lower natural gas price



Ea Energy Analyses

Economy

High impact of demand projections on the prospective system costs. Lower RE investment costs and lower natural gas costs result in system cost savings

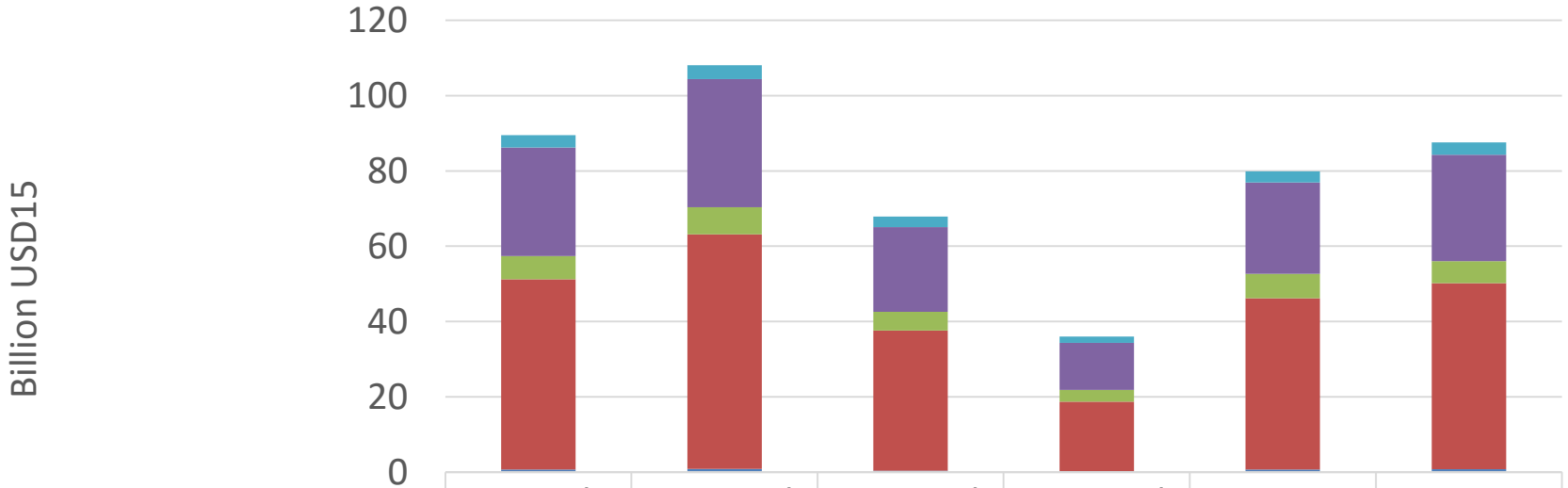


WORK-IN-PROGRESS RESULTS

Ea Energy Analyses

Economy - 2050

The major annualized system cost differences across the power demand scenarios emphasize the importance of both the planning assumption selection, as well as the benefit of limiting the electricity demand growth through e.f. improved energy efficiency practices



	Stated policies	Demand high	Demand low	Demand very low	Low RE cost	NG price low
Variable O&M (m$)	3,278	3,663	2,799	1,613	2,956	3,290
Fuel Cost (m$)	28,776	34,056	22,521	12,527	24,287	28,246
Fixed O&M (m$)	6,202	7,211	4,925	3,099	6,475	5,845
Capital Cost (m$)	50,536	62,310	37,283	18,495	45,478	49,476
Trans. Capital Cost (m$)	677	815	365	235	712	745
Total (m$)	**89,470**	**108,056**	**67,893**	**35,969**	**79,908**	**87,602**

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KEY TAKE-AWAYS

RE integration

- The results indicate that the Vietnamese power system could successfully integrate very significant shares of RES generation
  - Transmission capabilities play an important role in successful RES integration – the results include significant investments in additional transmission capacity
  - Further RE integration measures could be considered that are not currently implemented in the scenario analyses, e.g. demand response and regional interconnections

Environmental policy alternatives

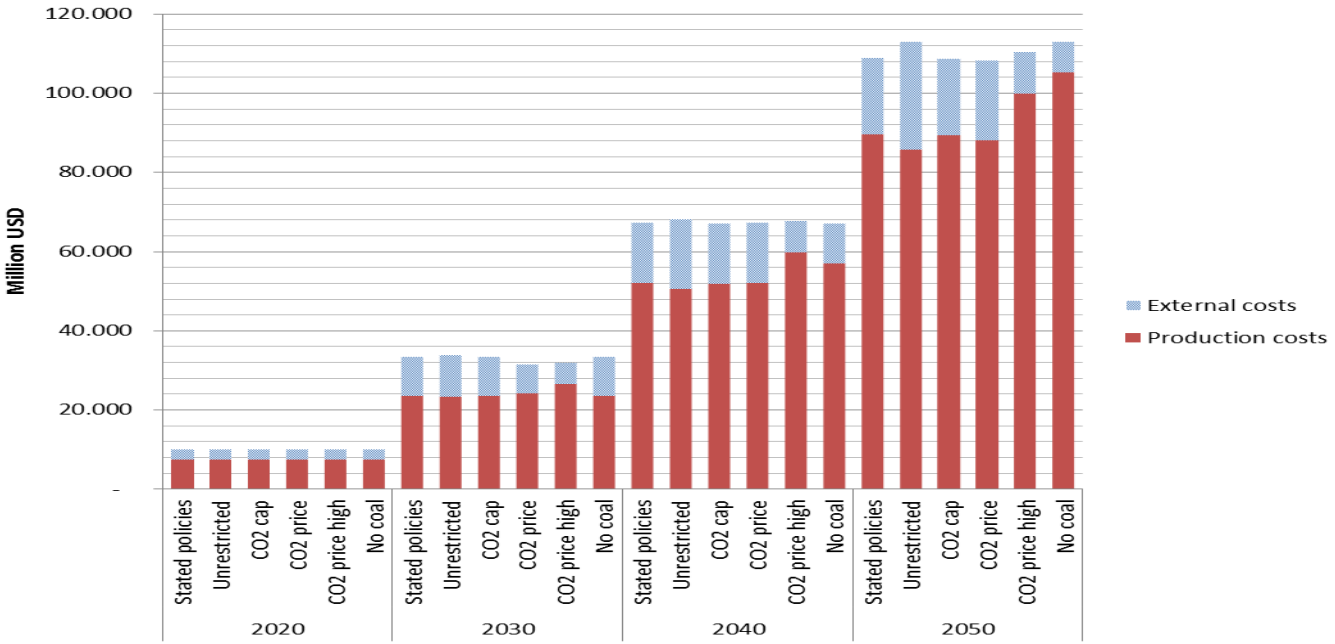
- In the absence of environmental policies (Unrestricted scenario), Vietnamese power system highly reliant on (imported) coal-fired generation in the long term
- RE Strategy goals could be achieved at a relatively modest additional cost compared to the business-as-usual scenario (Unrestricted)
  - 3% additional cost in 2040 and 4% in 2050
  - Higher capital expenditure of the RE capacity is partially outweighed by lower fossil fuel expenditure

Environmental policy alternatives (2)

- CO2-focused policies provide a viable alternative to RE targets
  - RE targets do not directly affect the rest of the system thereby potentially delivering more limited impact on CO2 emissions
  - Policies addressing CO2 emissions / costs directly could more efficiently achieve CO2 emission reduction ambitions (e.g. CO2 cap or CO2 price)
- No Coal (no new coal-fired capacity after 2035) outlines a more ambitious policy alternative
  - Results suggest the Vietnamese power system could successfully operate without additional coal-fired generation beyond 2035, but there will be additional costs

Environmental policy alternatives (3)

- Stricter environmental policies are more costly from system cost perspective
- However, if externality value of emissions is considered, the business-as-usual (Unrestricted) scenario results in the highest annualized costs in the long term
  - CO2 Price High and No Coal only 1% and 4% more costly than Stated Policies, respectively



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Reliance on imported fuels

- Reliance on imported fuels is higher in scenarios with less ambitious environmental and RE policies
  - Utilisation of the domestic RE resources reduces the need for imported fossil fuels
  - The domestic coal and natural gas resources are not sufficient to fully cover the growing electricity demand

RE resource potential

- Based on preliminary results*, significant feasible wind power potential is available in Vietnam
  - 27 GW capacity potential nationally (respecting technical, regulatory and 10km infrastructure proximity criteria)
- Further large potential is unlocked if siting on croplands is not restricted
  - Reaching 144 GW cumulative capacity potential nationally (respecting technical, regulatory and 20km infrastructure proximity criteria)

* Interim results of the wind resource mapping project supported by the GIZ in collaboration with the Danish Energy Agency 'Macroeconomic Cost-Benefit Analysis for Renewable Energy Integration' (Ea Energy Analyses and DHI GRAS, 2017)

Importance of planning assumptions

- Electricity demand growth is a very important planning assumption (affecting system size, setup, costs and CO2 emissions) that should be critically evaluated
  - Considering international experience and prospective developments in e.g. structural shifts and advancements in energy efficiency
- Lower natural gas price projections would favour gas-fired generation over coal, and deliver CO2 emission reductions
- RE technology cost developments would lead to more competitive wind and solar PV in Vietnam, affecting the optimal setup of the surrounding conventional system

BALMOREL
Energy system model

Thank you!

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EXTRA SLIDES

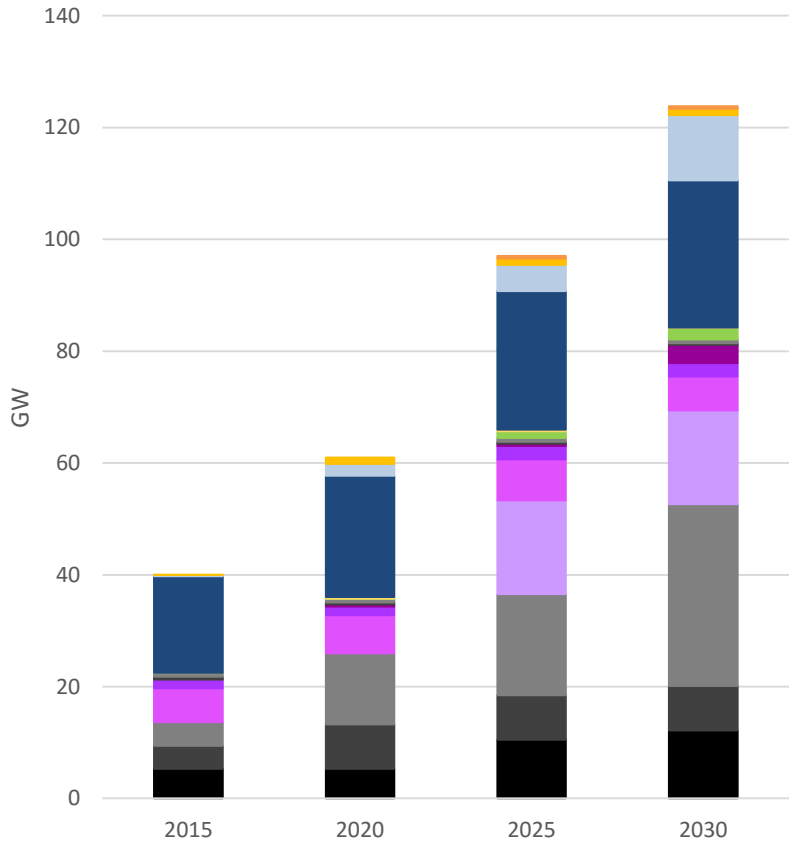
RESERVE MARGIN IMPLICATIONS

Reserve margin implications

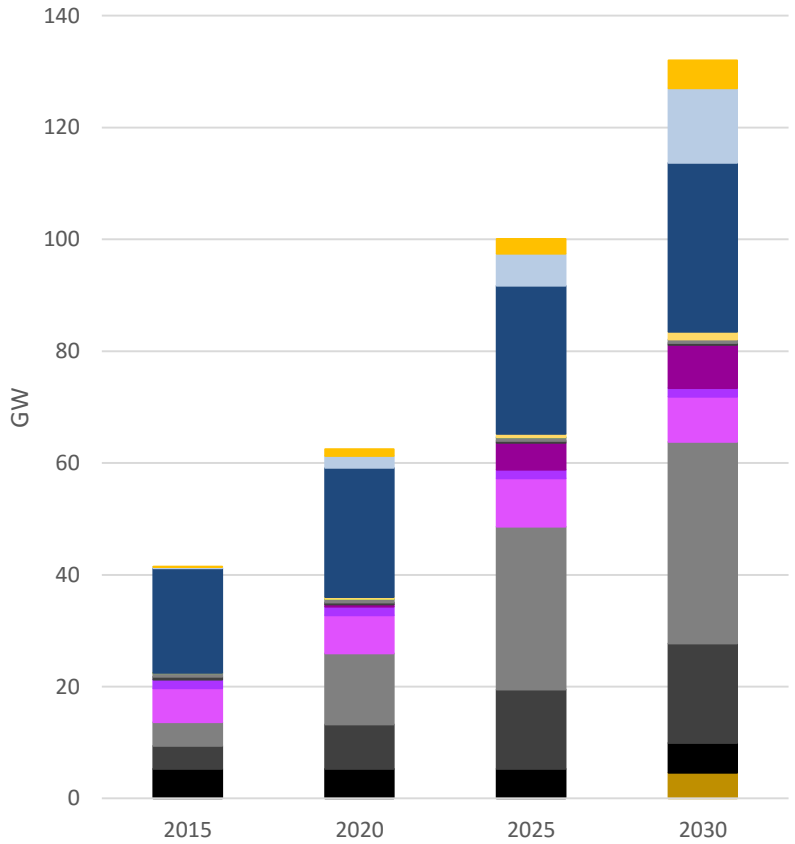
- Stated Policies scenario does not consider (or set any requirements for) reserve margin
  - One of the reasons for PDP 7 featuring significantly higher total installed generation capacity
- The impact of reserve margin considerations is tested in the Reserve Margin scenario, based on the Stated Policies scenario
  - Reserve Margin scenario sets a requirement for the same total 'firm' (i.e. dispatchable, including large hydro) capacity as in PDP 7 for every year modelled

Total capacity: Reserve margin vs PDP7

Reserve margin



PDP7



Nuclear | Coal_low | Coal_high | Coal_imported | NG_Con_Son | NG_PM3_CN
Bagasse | Rice_husk | Hydro | Wind | Solar | Unserved

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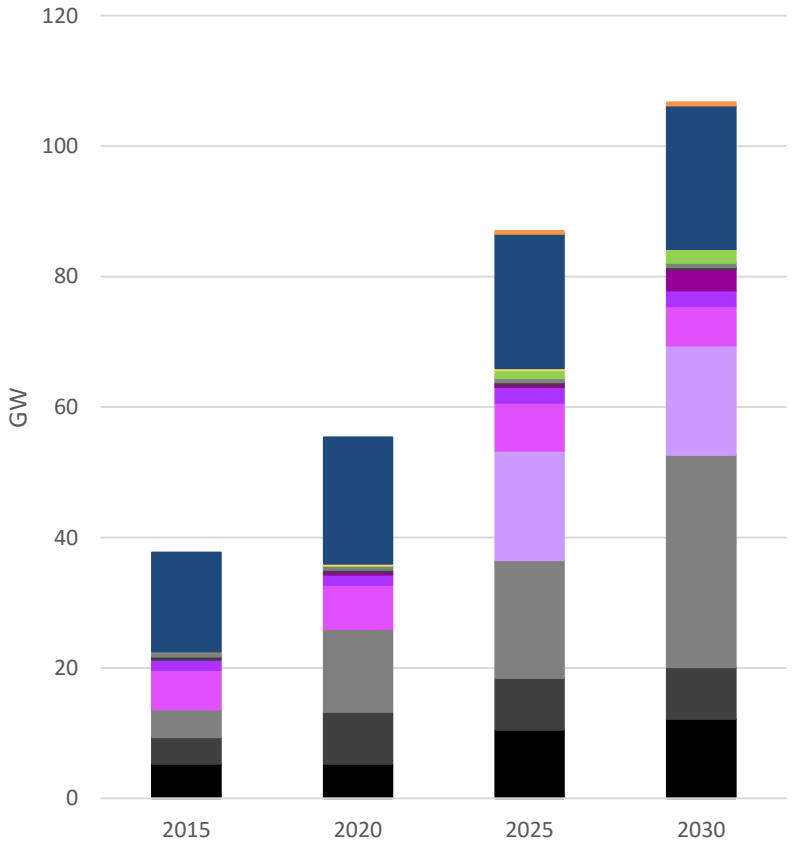
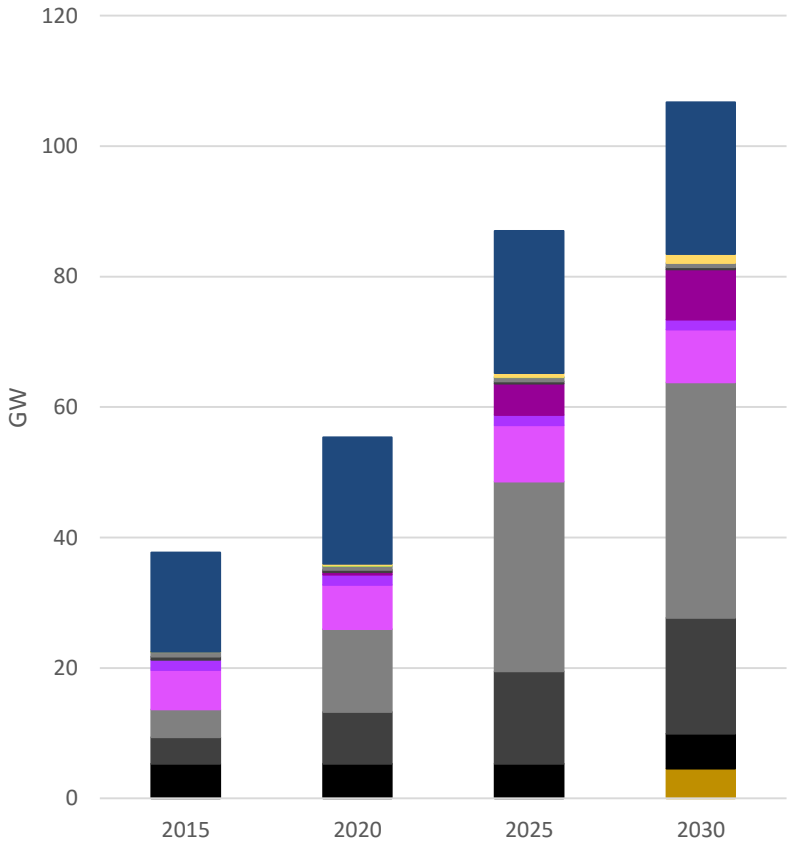
Total firm capacity: Reserve margin vs PDP7

Reserve margin



PDP7



Nuclear Coal_low Coal_high Coal_imported NG_Con_Son NG_PM3_CN
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