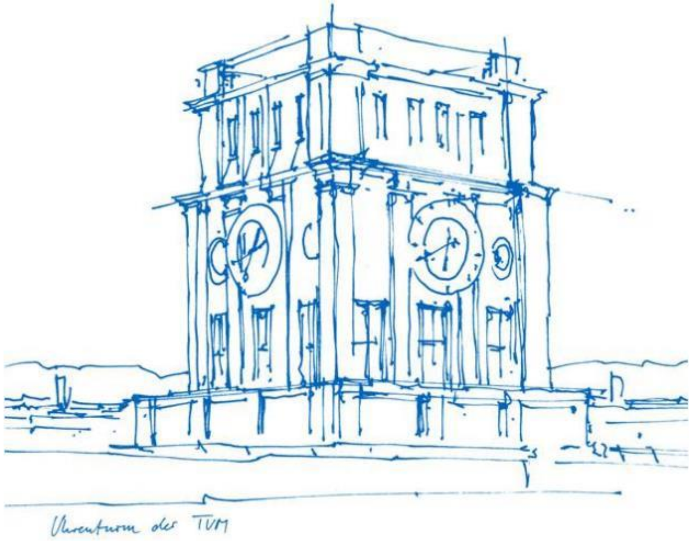
Cost-optimal regional deployment of renewable energy in the Mexican electric power system

Anahi Molar Cruz, Beatriz Guillén, Thomas Hamacher

Technical University of Munich

Faculty of Electrical and Computer Engineering

Chair of Renewable and Sustainable Energy Systems



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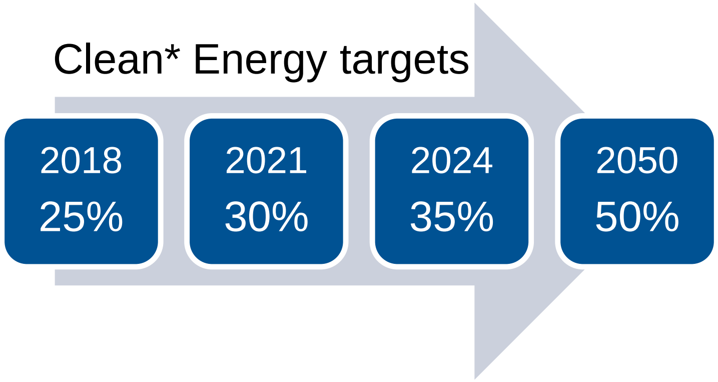
Context

1. Transformation of the Mexican power sector to a low-carbon system
2. Clean energy policy (2015)



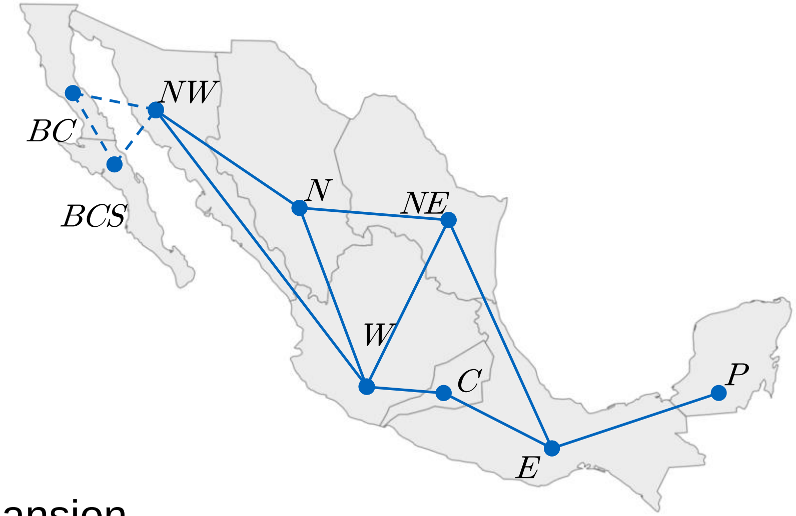
3. Long-term auction prices of RE projects in 2017 (with financial incentives):
   - Solar: 21 USD/MWh (avg 27 USD/MWh)
   - Wind: 19 USD/MWh (avg 32 USD/MWh)
4. Massive national RE potential
5. High dependency on imported natural gas
6. Very few literature on the gradual transformation of the power system until 2050

*RE, nuclear, efficient cogeneration, waste-based generation

Methodology

Regional model in *urbs*

- Nine regions + interconnections
- 2016-2050 in four years: 2016, 2020, 2030, 2050
- Input data:
  - Hourly time series of electricity demand
  - Hourly time series of RES
  - Power plant list
  - Storage capacities
  - Transmission capacities
  - Restrictions for grid and generation capacity expansion
- Scenarios: `BASE`, `CLEAN-ENERGY`, `COST-OPTIMAL`

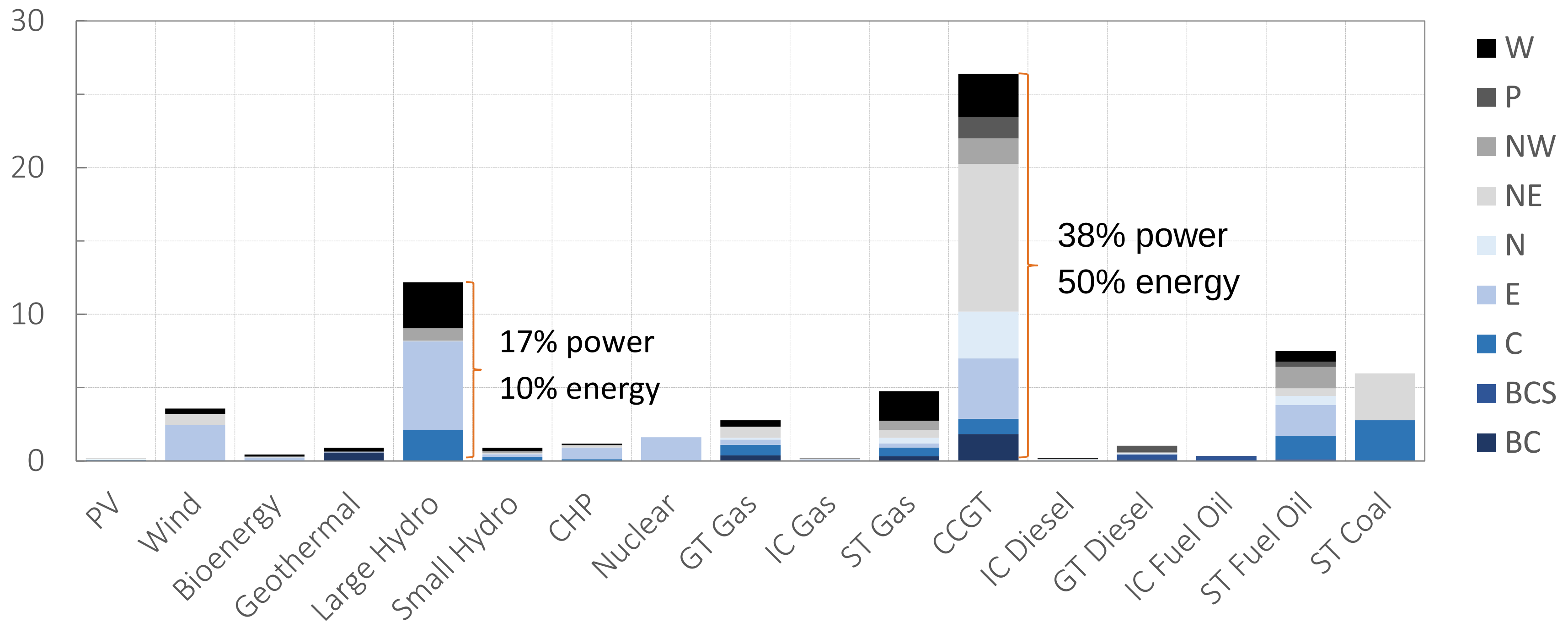


Control regions and demand

	Annual average growth rate	Annual electricity consumption [TWh]			
		*2016**	*2020*	*2030*	*2050*
BC	2.2%	13	15	20	27
BCS	3.0%	3	3	5	7
C	1.6%	59	64	78	100
E	2.1%	48	53	69	94
N	2.3%	25	28	37	51
NE	2.5%	52	59	80	117
NW	2.5%	23	27	36	52
P	3.0%	12	14	20	32
W	2.5%	63	72	99	142
Mexico	2.4%	299	334	445	623

The Mexican power system in 2016

Installed capacity by technology and region in GW - **TOTAL: 70 GW**

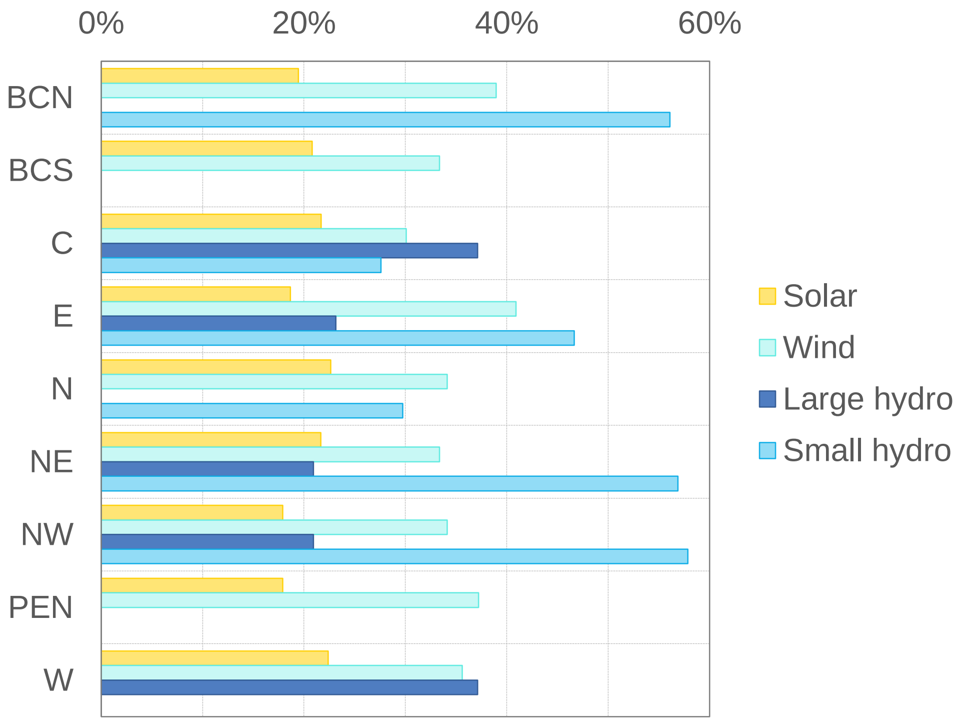


Untapped renewable potential

	Bio	CHP	Geo	Large Hydro	Small Hydro	Wind	PV	PSHP
BC	0	0.1	0.8	0	0.2	0.8	2.9	0.3
BCS	0.1	0	0	0	0	0.1	6.4	0
C	0.3	0.9	0.4	0.2	0.7	1.3	7.0	2.8
E	0.4	3.2	0.1	1.0	1.8	8.0	13.0	0
N	0.5	0.2	0	0	0.1	10.6	47.4	0
NE	0.2	2.1	0	0	0.2	8.4	21.8	0.2
NW	0.2	0.1	0.4	0	0.6	0.8	35.7	0
P	0.1	0	0	0	0	0.8	19.1	0
W	0.5	0.5	1.9	0	0.2	3.0	29.5	0
MEX	2.3	7.0	3.6	1.2	3.8	33.7	183	3.3

- Cogeneration in the industrial sector
- Hydro has been exploited already
- Geothermal potential with temperatures above 130°C
- Share of available considered:
  - Wind: 2.5%
  - PV: 1%

Average load factors for RE



National averages

Solar: 21%

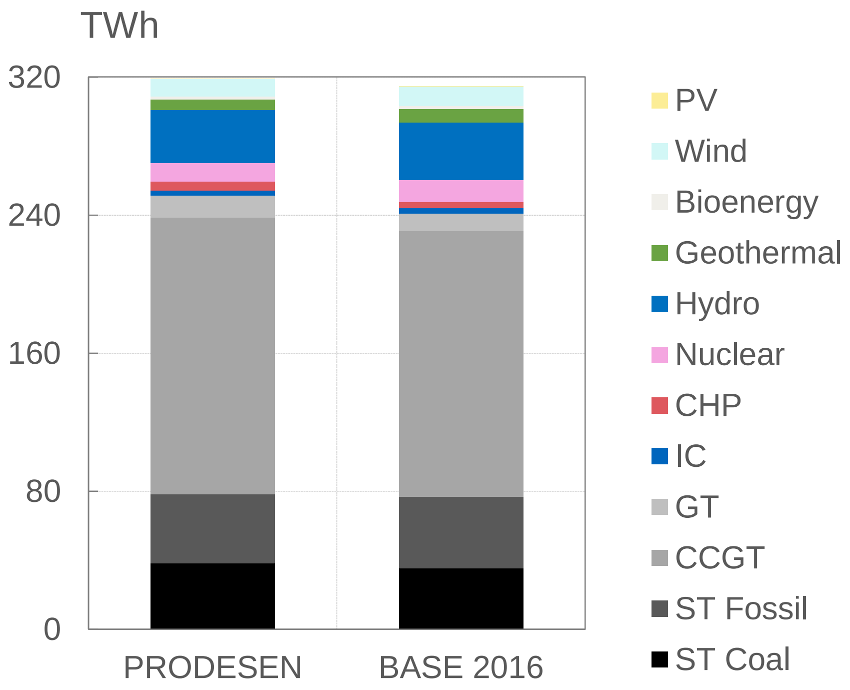
Wind: 35%

Large hydro: 27%

Small hydro: 44%

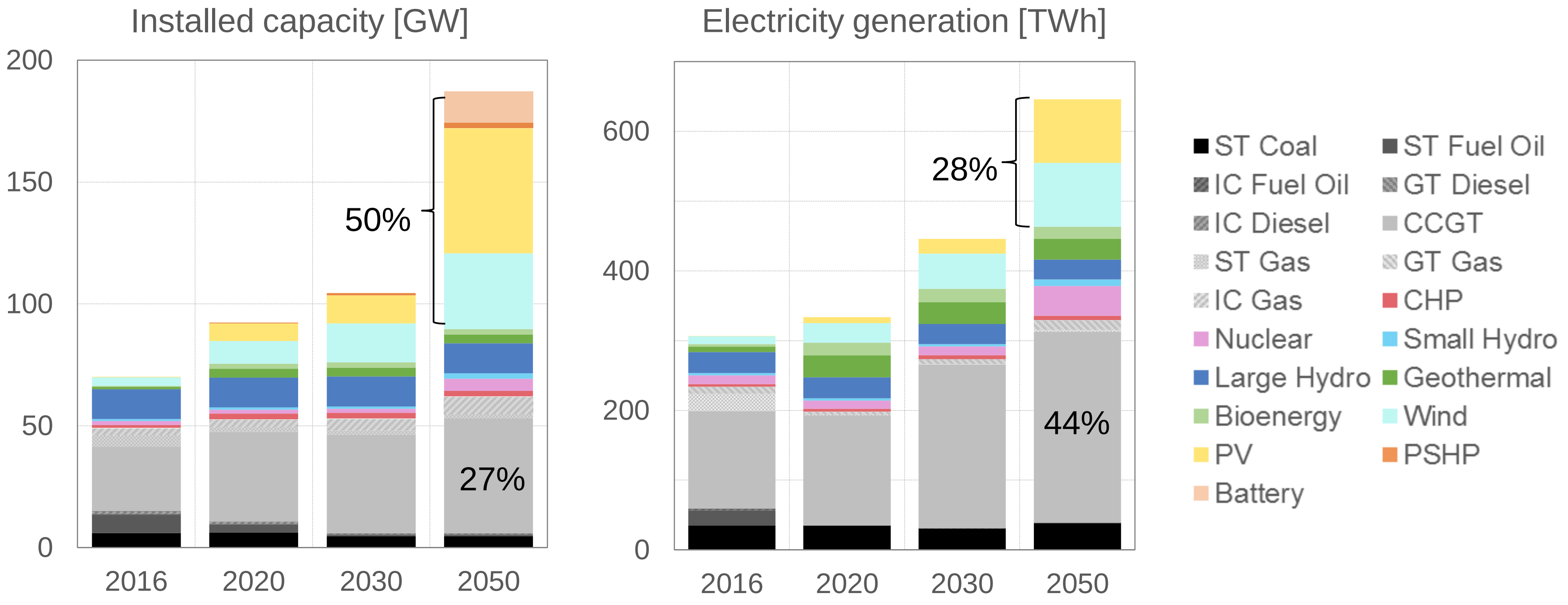
Validation – Electricity generation mix

Real generation mix from PRODESEN 2017 vs `BASE 2016`



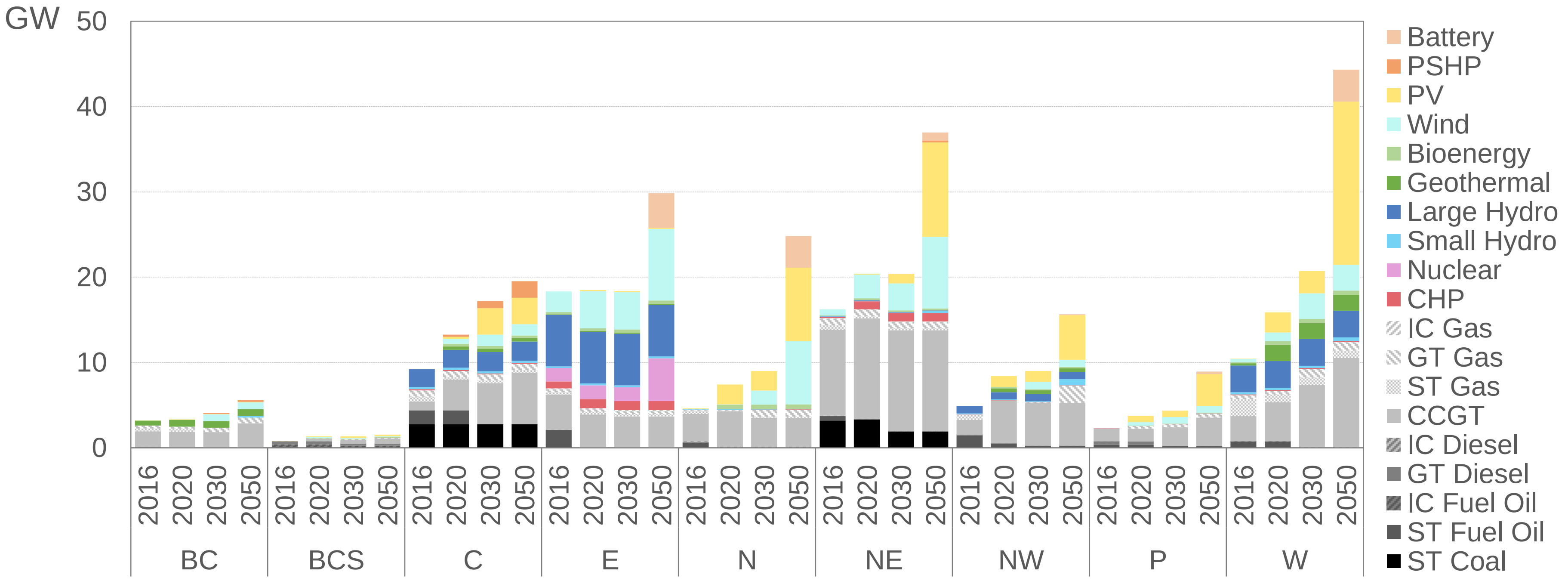
Evolution of installed capacity at the country level

2016-2050 (CLEAN-ENERGY)



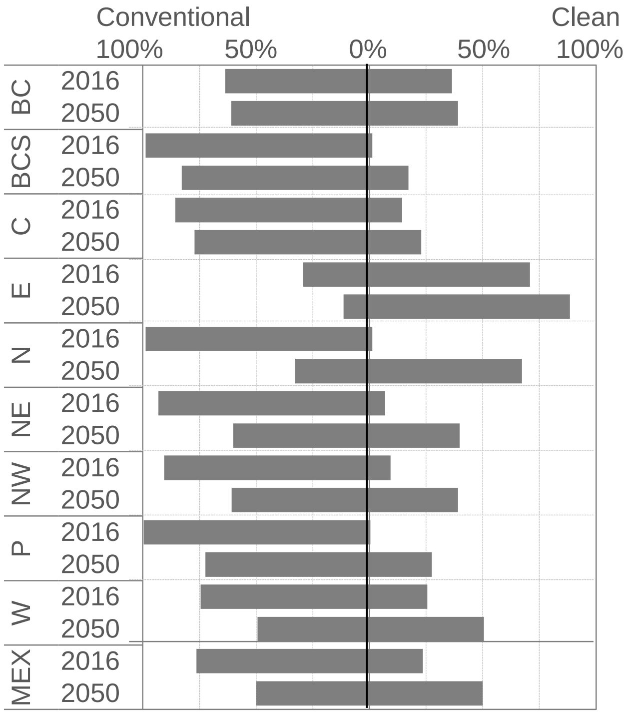
Evolution of installed capacity at the regional level

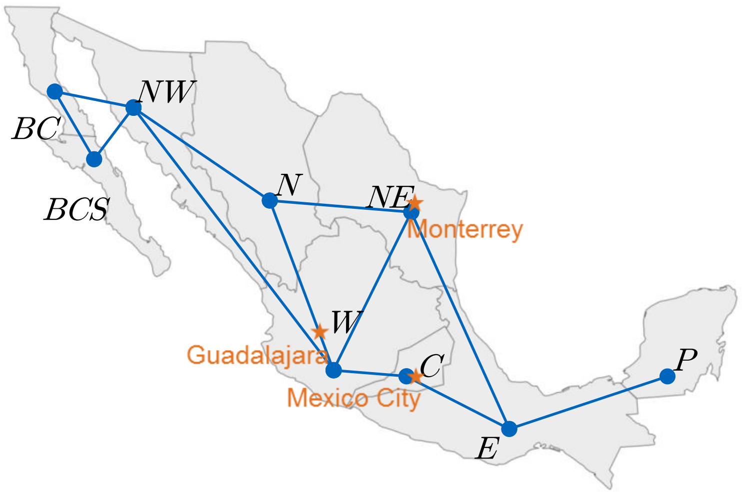
2016-2050 (CLEAN-ENERGY)



Regional clean energy share

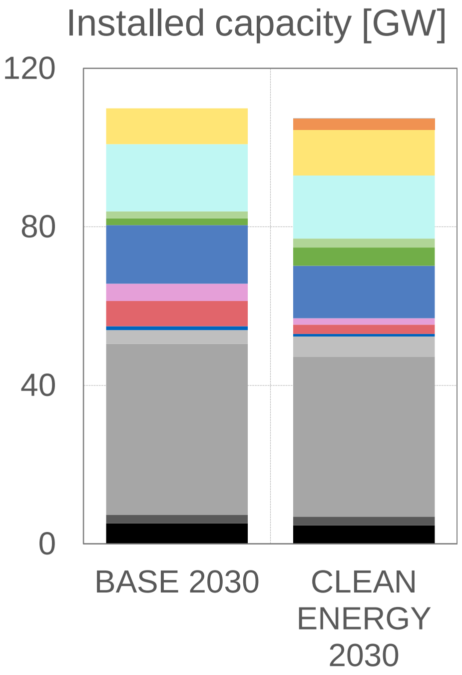
2016-2050 (CLEAN-ENERGY)

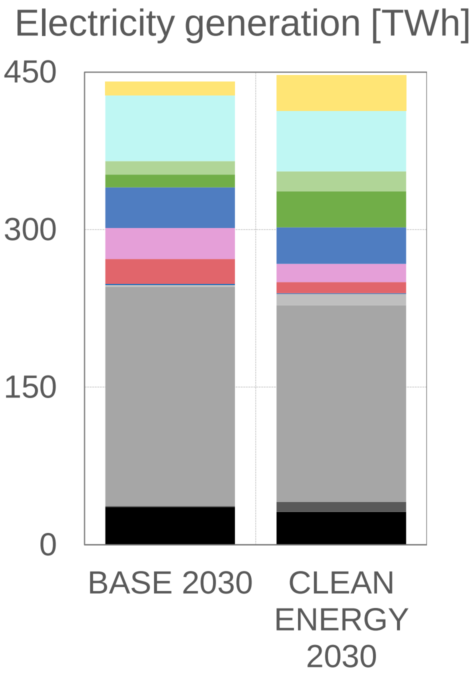




Comparison with the national sector plan (PRODESEN)

2030 (`CLEAN-ENERGY vs BASE`)

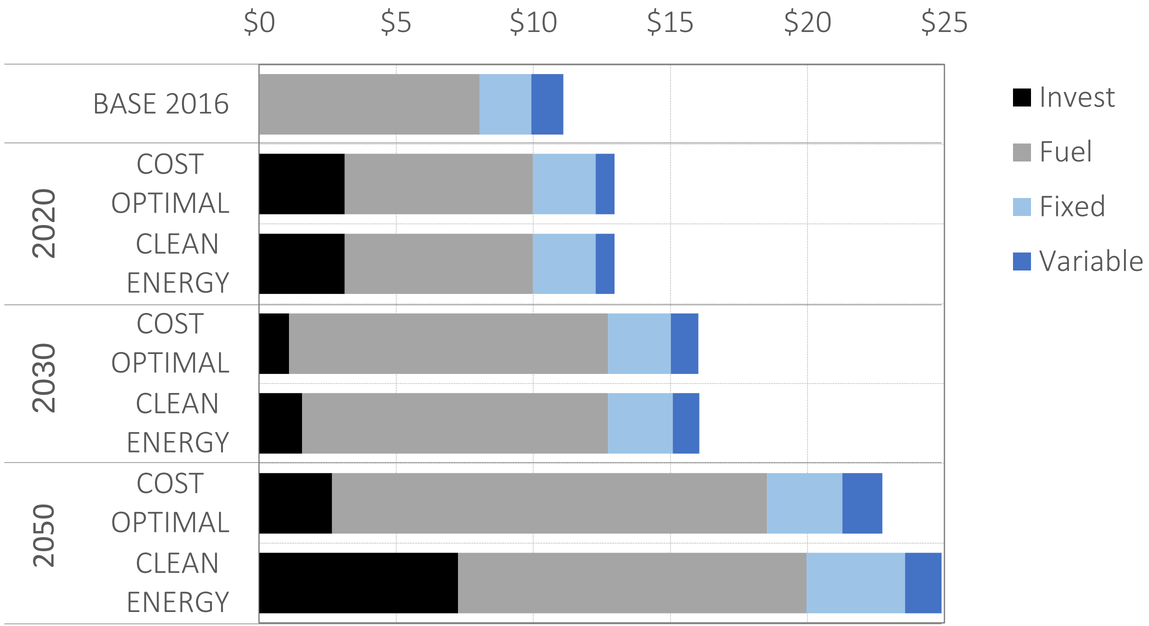




- Geothermal energy could play a major role
- CHP fraction is overestimated
- Storage allows the integration of PV

The cost of the clean energy targets

CLEAN-ENERGY vs COST-OPTIMAL



Additional
$2.4 USD billions per year
or 0.38 ¢/kWh
to reach the targets

Conclusions

- 50% share of clean energy by 2050 is an attainable goal

- In the scenarios analyzed:
    - Short term: geothermal
    - Medium term: wind + PHSP
    - Long term: solar + nuclear + battery + small hydro
    - The interconnection of regions is strengthened
    - Even with low costs of RES-based generation, an additional 0.38 c/kWh is required

- Results are highly sensible to the future demand and the costs of the technologies

Anahi Molar-Cruz
Technical University of Munich
Chair of Renewable and Sustainable Energy Systems
anahi.molar-cruz@tum.de