Green Hydrogen Production in Uruguay:

Integrating Life Cycle Assessment and Energy System Optimisation using Impuls-urbs Framework

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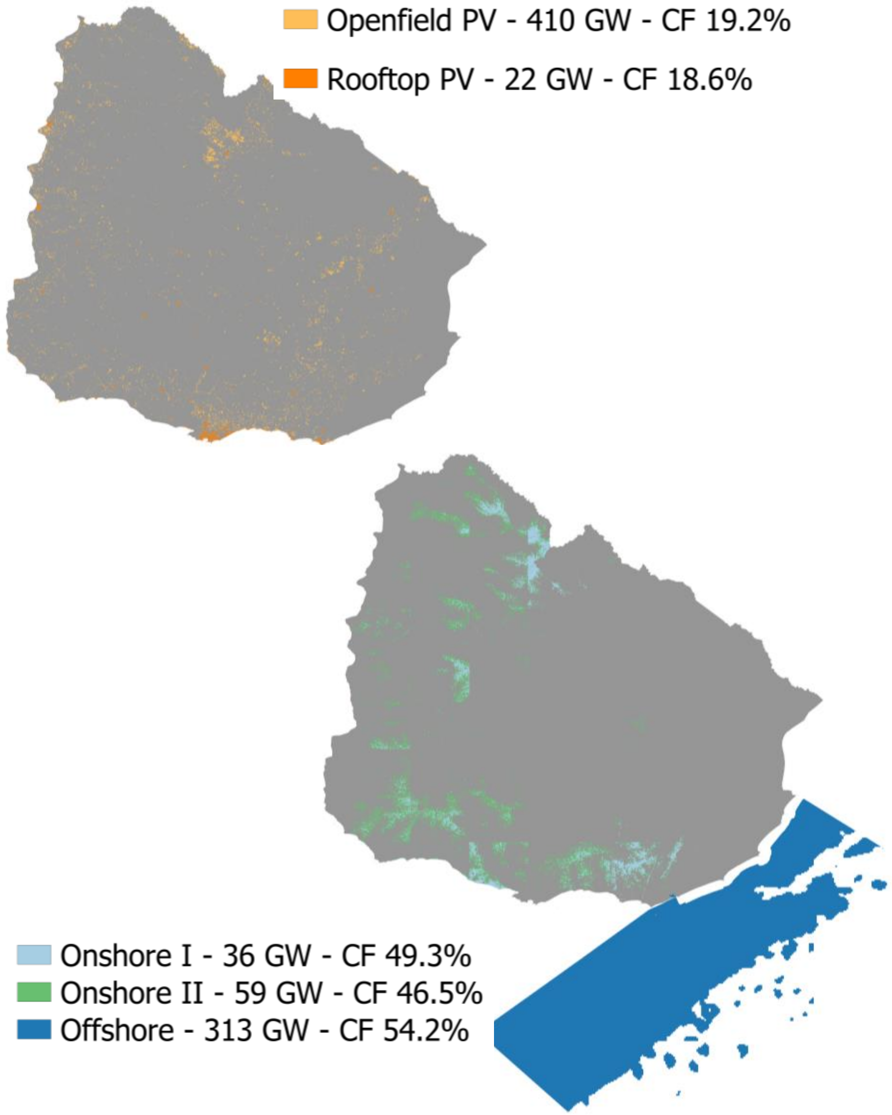
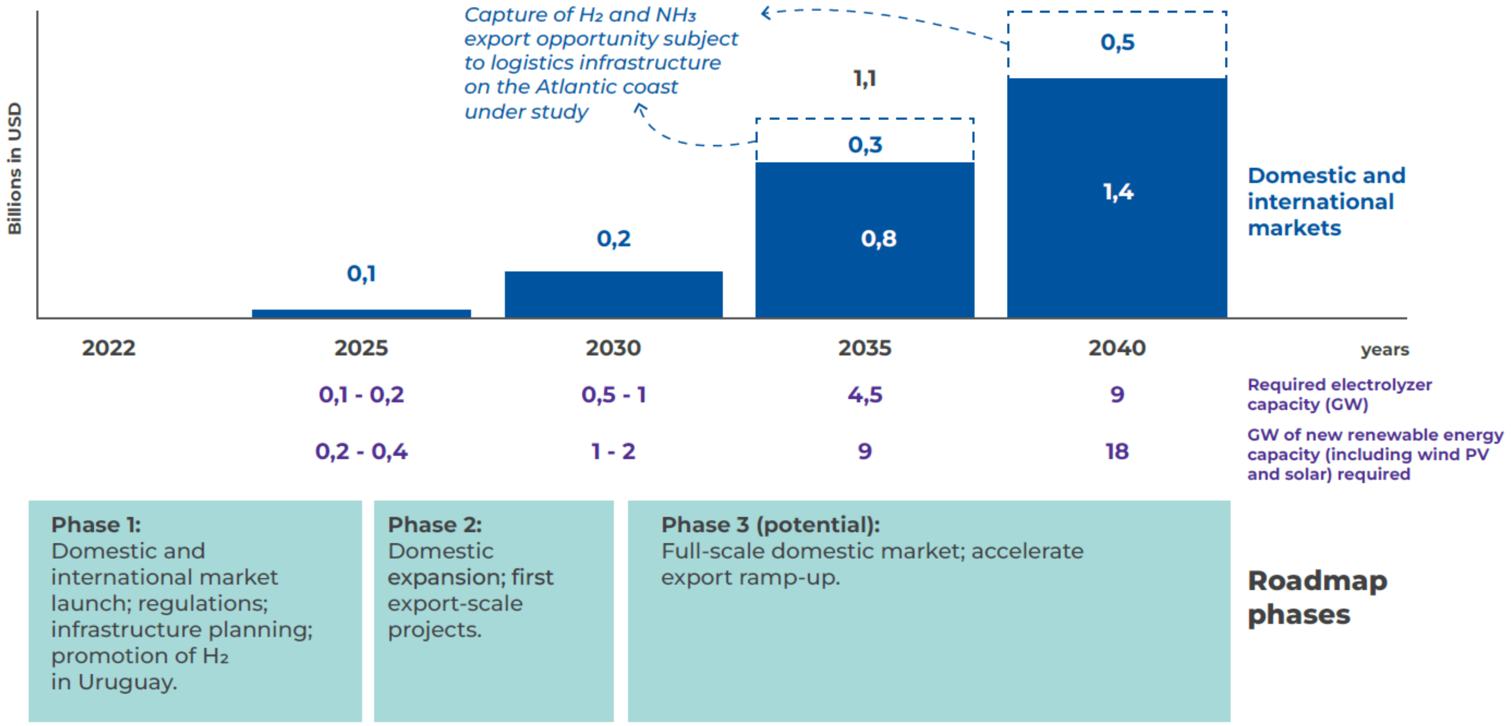
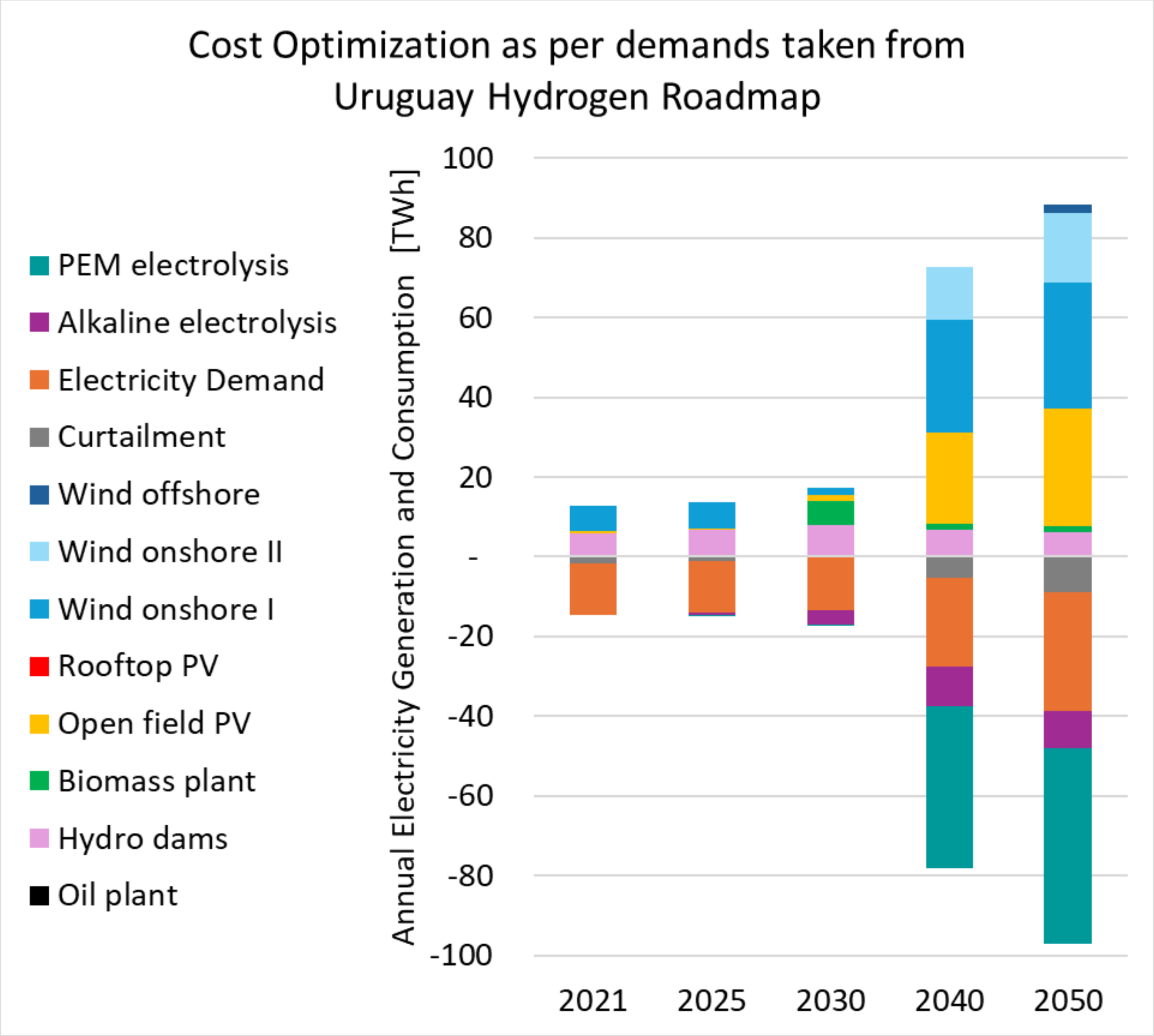
Uruguay as Green Hydrogen Exporter



Uruguay’s Roadmap for Green Hydrogen and Derivatives, MIEM 2023



Research Question



What we know from LCA?
Production of technologies is energy and emission intensive.

Problem:
Energy system models doesn't necessarily capture the emissions from manufacturing of the technologies.

Goal:
What are the economic, environmental, and technical impacts of integrating Life Cycle Assessment (LCA) into the optimization of Uruguay's energy system for green hydrogen production?

Previous Work

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Impuls-urbs: Integration of life cycle assessment into energy system models

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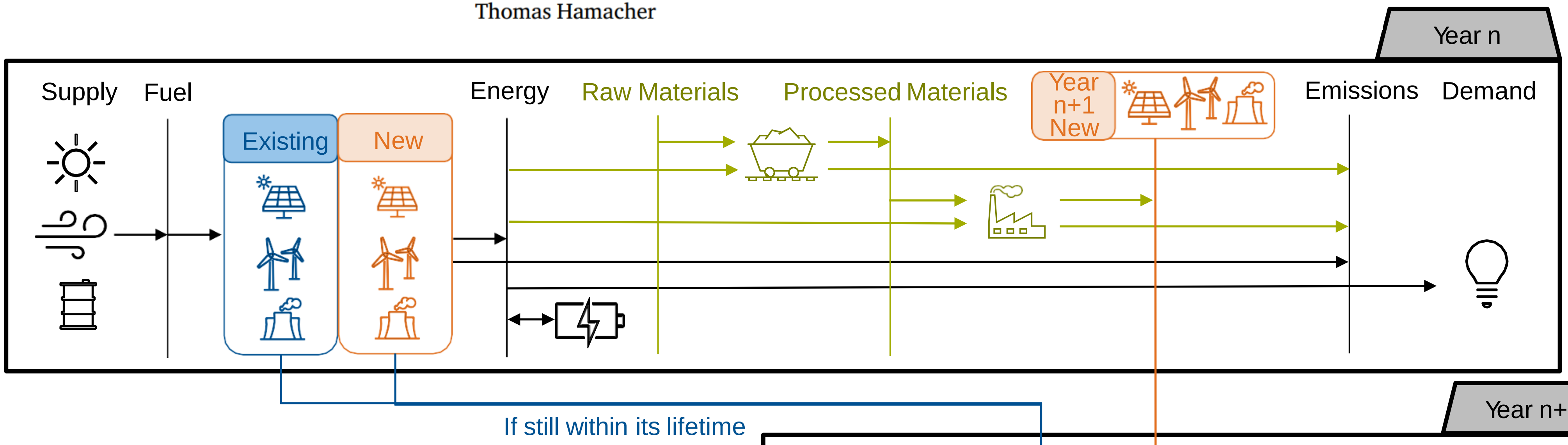
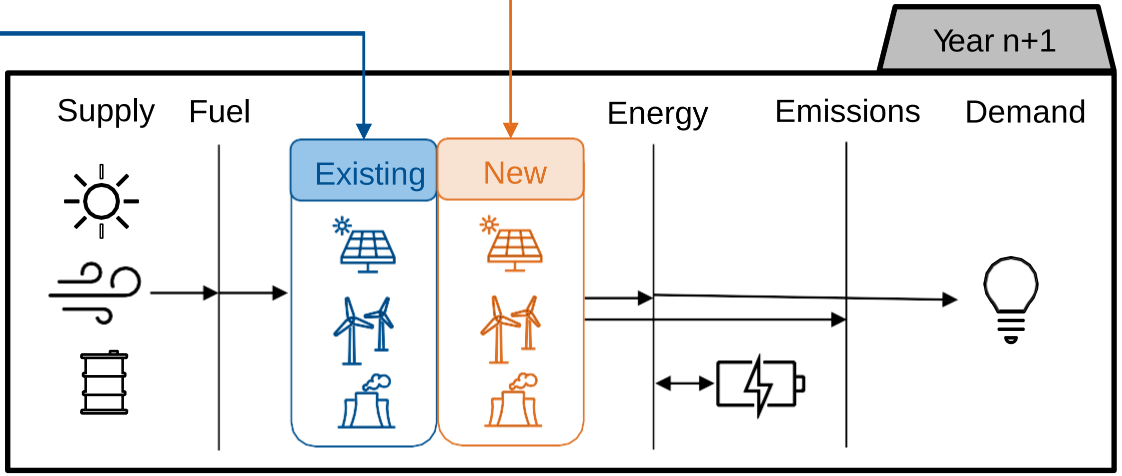
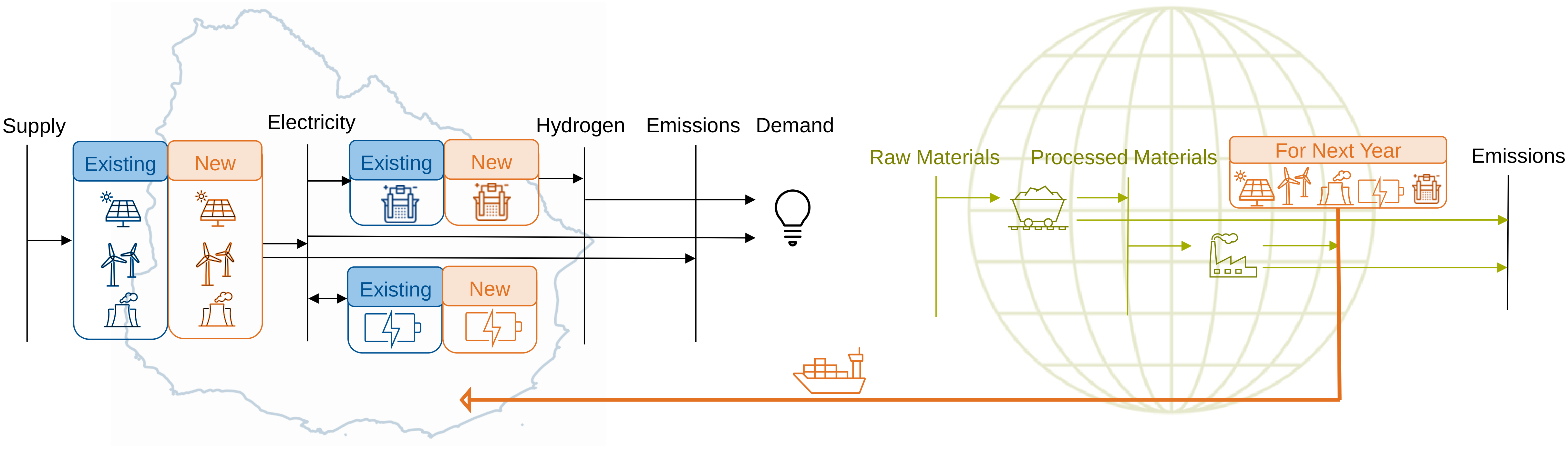




Basis for Impuls-urbs framework

- Existing modeling framework – urbs
- Intertemporal mode with multiple years
- Single optimization problem for all years
- Cost or CO_2 minimization

Uruguay Optimization Model



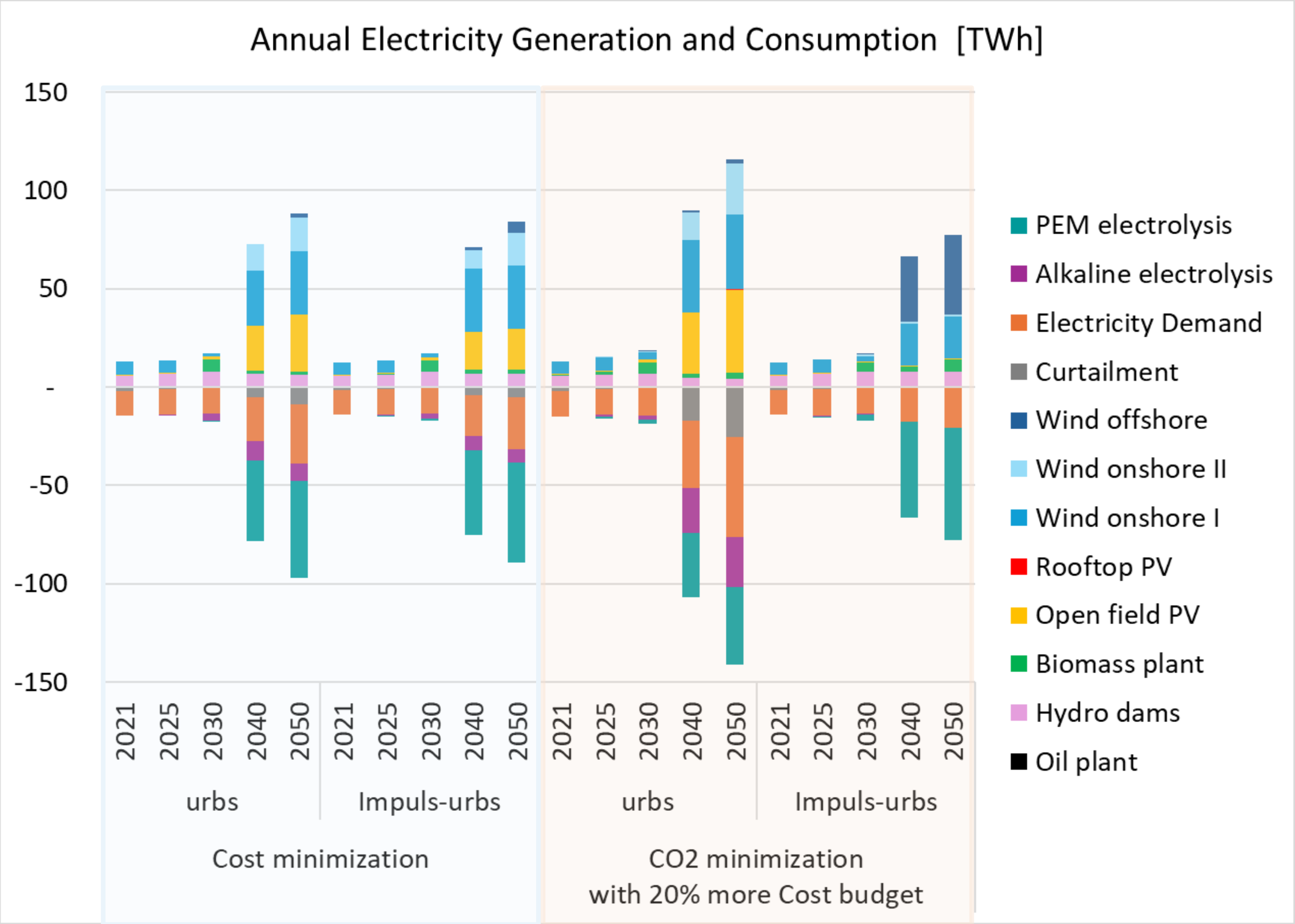
- One node of Uruguay
- Electricity and Hydrogen demands from Roadmap
- Years: 2021, 2025, 2030, 2040, 2050
- Import of technologies from outside (Global market)
- Material production related emissions calculated prospectively until 2050 with the scenario remind - SSP1-RCP1.9.

Scenarios

Models: urbs (without material production)
Impuls-urbs (with material production)

Cases: Cost minimization
CO_2 minimization with 20% more cost budget

Results



Key observations

Cost minimization:

- No big changes between the models because it is highly decarbonized system.
- Offshore wind is favored over PV due to less embedded emissions.
- Curtailment decreases.
- More inclination towards PEM over alkaline.

CO_2 minimization:

- All those effects are stronger as costs are relaxed.
- Offshore wind is favored also over onshore wind II.
- Better utilization of existing resources.

Outlook

Summary

- Optimal energy mix can be affected by the introduction of embedded emissions into the model.
- Relative merit among the renewable technologies must be considered not just from technological and economic perspective, but also from environmental perspective.
- With the learning curves, offshore wind could become a more attractive renewable option, especially for countries like Uruguay with good potential.
- Impuls-urbs proves to be more impactful with CO_2 minimization.

Scope for future work

- Energy mixes within the export regions can also be optimized together for a better representation of energy transition within the manufacturing industries and global supply chain.

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Backup

LCA Data

Technology	Premise / Ecoinvent dataset	Location	Ton CO2 per MW			
			2020	2025	2030	2040
Wind Onshore I and II	Market for wind turbine, 4.5MW, onshore + Market for wind turbine network connection, 4.5MW, onshore	GLO	998	918	695	527
Wind Offshore	Market for wind power plant, 2MW, offshore, fixed parts + Market for wind power plant, 2MW, offshore, moving parts	GLO	829	774	612	500
PV Open-field	Market for photovoltaic plant, 570kWp, multi-Si, on open ground	GLO	1684	1328	783	509
PV Rooftop	Market for photovoltaic slanted-roof installation, 3kWp, multi-Si, panel, mounted, on roof	GLO	1647	1296	751	481
Biomass plant	Heat and power co-generation unit construction, organic Rankine cycle, 1000kW electrical	GLO	171	160	115	94
PEM Electrolyzer	Electrolyzer production, 1MWe, PEM, Stack + Electrolyzer production, 1MWe, PEM, Balance of Plant	RER	373	299	189	124
Alkaline Electrolyzer	Electrolyzer production, 1MWe, AEC, Stack + Electrolyzer production, 1MWe, AEC, Balance of Plant	RER	303	261	191	155
Battery (Capacity)	Market for battery capacity, stationary (CONT scenario)	GLO	118	89	57	29

Techno-economic Data

Technologies	Capital costs (USD/kW)					Annual O&M Costs					Efficiency (gross, LHV)			
Name	Units	2021	2030	2040	2050	Units	2021	2030	2040	2050	2021	2030	2040	2050
Oil plant	USD/kW	412	408	404	400	USD/kW/a	21	20	20	20	38%	39%	40%	41%
Open field PV	USD/kW	820	450	385	320	USD/kW/a	12	10	10	10				
Rooftop PV	USD/kW	640	350	300	250	USD/kW/a	10	8	8	8				
Wind onshore	USD/kW	1150	1060	1030	1000	USD/kW/a	28	28	27	26				
Wind offshore	USD/kW	4440	2600	2140	1680	USD/kW/a	110	75	65	55				
Hydro dam	USD/kW	4839	3926	3013	2100	USD/kW/a	127	93	72	50				
Biomass plant	USD/kW	2500	2400	2325	2250	USD/kW/a	85	85	83	80	35%	35%	35%	35%
Alkaline Electrolysis system (Stack+BOP)	USD/kW	700	402	381	370	USD/kW/a	14.00	8.04	7.62	7.40	60,6%	60,9%	61,1%	61,4%
PEM Electrolysis sys tem (Stack+BOP)	USD/kW	700	402	381	370	USD/kW/a	14.00	8.04	7.62	7.40	63,7%	66,9%	70,1%	73,2%