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NEO CARBON ENERGY

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Zero emission energy supply for South and Central America

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Motivation & Purpose of Work

South and Central America are economically emerging regions that have had sustained economic growth and social development during the last decade. The regions' 3% GDP growth rate [1] followed by an estimated fast-paced electricity demand growth over the coming decades requires the development of the power sector to guarantee efficiency and security of supply.
Nowadays, the regions' electrical energy mix is the least carbon-intensive in the world due to the highest share of renewable energy, mainly based on hydropower installed capacities [2]. However, the need to reduce the vulnerability of the power system to a changing hydrological regime is evident. Furthermore, regarding non-hydro renewable energy (RE), the regions have vast solar, wind and biomass potentials, which could allow the region to maintain its high share of renewables, even under a low hydropower future scenario.
Therefore, this study aims at designing an optimal and cost competitive 100% RE power system for South and Central America for achieving a 'net zero' emission system by 2030 [3] .

Main Objectives

- To design a least cost energy system for the given constraints
- To have an optimal mix of capacities for all technologies
- To define an optimal set of technologies which can be best adapted to the availability of the region's resources.
- Optimal operation modes for every element of the energy system.

Methodology

- The energy model is based on linear optimization of energy system parameters under applied constraints. The model details can be found in Bogdanov and Breyer [4]..

Input data used

- historical weather data for: solar irradiation, wind speed and precipitation
- available sustainable resources for biomass and geothermal energy
- potential of areas with geologies favorable to A-CAES
- gas and water desalination demand
- synthetic load data for South and Central America region
- efficiency/yield characteristics of RE plants and seawater desalination
- efficiency of energy conversion processes
- capex, opex, lifetime for all energy resources
- min and max capacity limits for all RE resources
- nodes and interconnection configuration

Energy Model

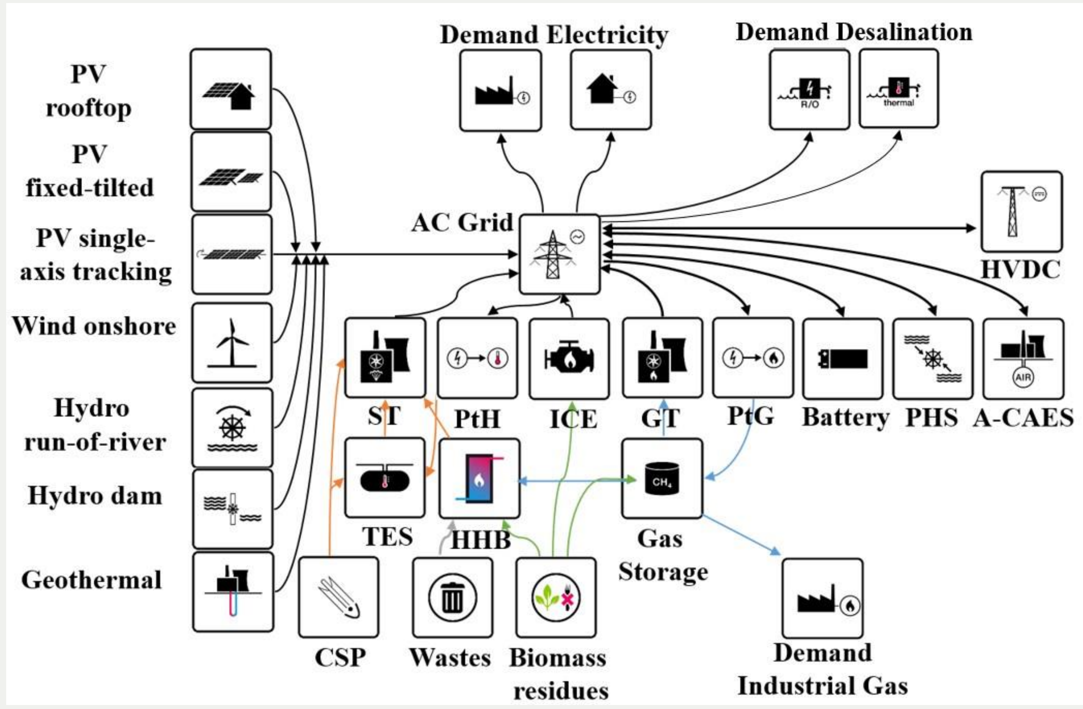

Fig. 1: Schematic composition of the LUT energy model including energy resources, conversion technologies, storage options, major end-use categories and all energy sectors [4]. The model determines the optimal combination of the components that meets the electricity demand of every hour for the year 2030.

South and Central America Subdivision

Fig. 2: Region's division into 15 sub-regions:
- Central America
- Colombia
- Venezuela (Venezuela, Guyana, French Guiana, Suriname)
- Ecuador,
- Peru
- Central South America (Bolivia and Paraguay)
- Brazil South,
- Brazil São Paulo
- Brazil Southeast
- Brazil North,
- Brazil Northeast
- Argentina Northeast (includes Uruguay),
- Argentina East
-- Argentina West
-- Chile.

Scenario Assumptions

Scenarios based on grid configurations
- Regional-wide open trade (no interconnections between regions)
- Area-wide open trade (country-wide HVDC grids are interconnected)
- Integrated area-wide open trade with water desalination and industrial gas additional demand sectors

Table 1. Summary of the considered scenarios

Assumption	Scenarios			
	Regional-wide open trade	Country-wide open trade	Area-wide open trade	Integrated
PV self-consumption	X	X	X	X
Water Desalination				X
Industrial gas demand				X

Results (Key Numbers)

Table 2. Key results for the studied scenarios

2030 Scenario	Total LCOE [€/kWh]	LCOE primary [€/kWh]	LCOC [€/kWh]	LCOS [€/kWh]	LCOT [€/kWh]	RE capacities [GW]	Electricity [TWh]
Region-wide	0.062	0.042	0.003	0.017	0	798	2080
Country-wide	0.059	0.040	0.002	0.016	0.001	744	1978
Area-wide	0.056	0.041	0.001	0.011	0.003	690	1905
Integrated	0.047	0.036	0.001	0.008	0.002	1173	2970

Key insights

- HVDC transmission lines lead to a significant reduction in RE installed capacities, electricity cost for the system and storage costs.
- Grid utilization decreases the primary energy installed conversion capacities.
- .Cost of transmission is relatively small in comparison to the decrease in primary generation and storage costs.
- Industrial gas and desalination sectors decrease the need for long-term storage utilization, giving additional flexibility to the system through demand management

Results

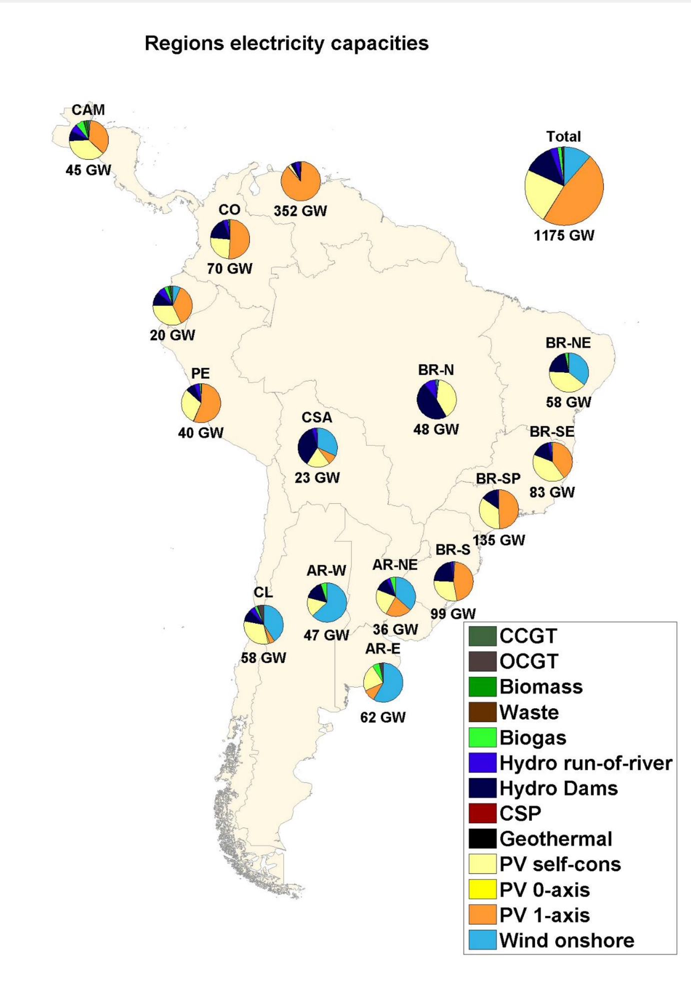

Fig. 3: Installed capacities of RE generation for the integrated scenario.

Key insights

- For region-wide and area-wide scenarios, solar PV dominates in almost all sub-regions considered;
- For the integrated scenario, the sub-regions that have excellent wind conditions and low cost wind energy, have high shares of wind installed capacities. For all other sub-regions, the increase in electricity demand system flexibility is followed by an increase in solar PV single-axis installed capacities,

Comparison with a BAU scenario

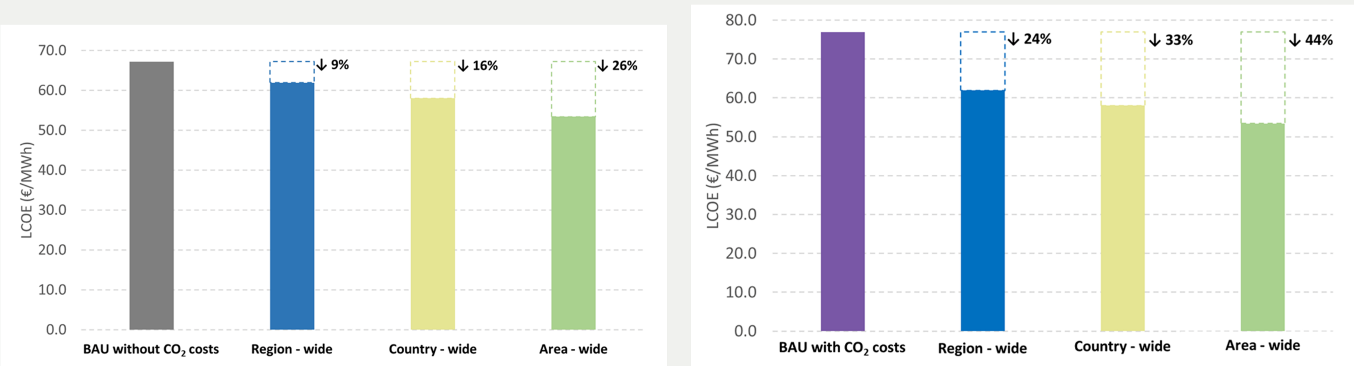

Fig. 4 a) Comparison of $LCOE_{BAU}$, to country-wide, region-wide and area-wide scenarios. b) Comparison of $LCOE_{BAU-CO2}$ (59.8 €/tCO_2) emission cost to country-wide, region-wide and area-wide scenarios.

Key insights

- The calculated $LCOE_{BAU}$ and $LCOE_{BAU-CO2}$ values are 67.2 €/MWh_{el} and 77.0 €/MWh_{el}, respectively.
- Comparing $LCOE_{BAU}$ to LCOE for 100% RE scenarios, the values are at least 9% and at most 16% lower: a 100% RE power system is the least cost solution for the increase in the region's electricity demand by 2030.
- If CO_2 emission costs are considered, these percentages are even higher ranging from 24% to 44% as shown on Fig. 4b.

Conclusion

- RE technologies can cover all electricity demand in South and Central America for the year 2030 on a price level of 47 - 62 €/MWh_{el}.
- The electricity for PtG technology and SWRO desalination demand can also be produced by RE sources.
- The vulnerability of the existing power system is solved by a high share of complementary renewable sources.
- Compared to a BAU scenario, this research indicates that a 100% RE system is a real economic, environmental and health option.

Acknowledgments

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References

[1] IEA, 2014. World Energy Outlook 2014. IEA Publishing, Paris.
[2] Farfan J. and Breyer Ch., 2017. Structural changes of global power generation capacity towards sustainability and the risk of stranded investments supported by a sustainability indicator, Journal of Cleaner Production, 141, 370-384.
[3] Barbosa LSNS, Bogdanov D, Vainikka P, Breyer C.,2017. Hydro, wind and solar power as a base for a 100% renewable energy supply for South and Central America. PLoS ONE 12(3): e0173820.
[4] Bogdanov D. and Breyer Ch., 2016. North-East Asian Super Grid for 100% RE supply: Optimal mix of energy technologies for electricity, gas and heat supply options, Energy Conv Mgm, 112, 176-190.