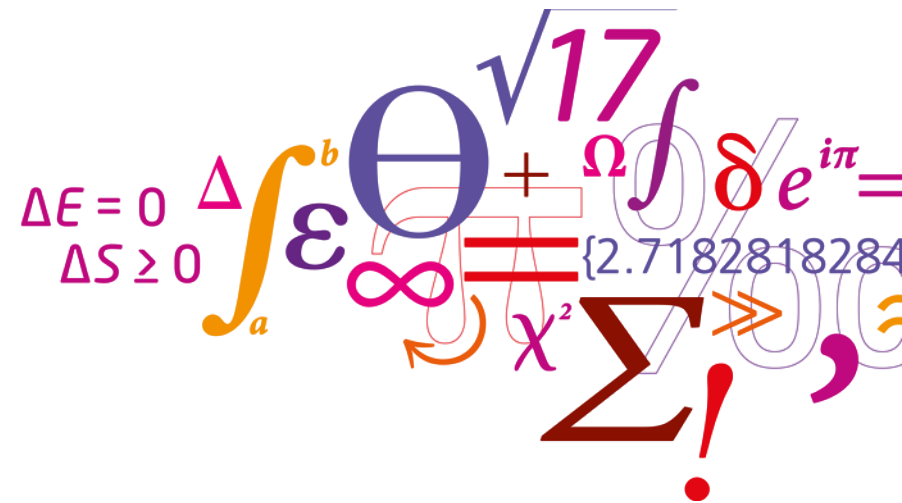


# Integrated Energy Planning with a High Share of Variable Renewable Energy Sources for a Caribbean Island

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# Outline

- Methods and limitations
- Caribbean island-state: Aruba
- Results: fossil fuels vs. Renewables based energy system
- Sensitivity analyses
- Conclusions and the outlook

# Methods

- PLEXOS
  - A unit commitment and economic dispatch tool
- 5-minutes and 1-hour time resolutions
- Power, cooling, transport and water desalination
- Curtailed energy

# Limitations

- 5-minutes resolution: no frequency and voltage control
- No grid congestion
- Industry consumption: no data
- Socio-economic costs
- Air pollution

# Case study: Island state Aruba

- Population: 104,000
- Area: 179 km<sup>2</sup>
- GDP: 28,900 USD/capita
- $\frac{3}{4}$  of GNP earned through tourism

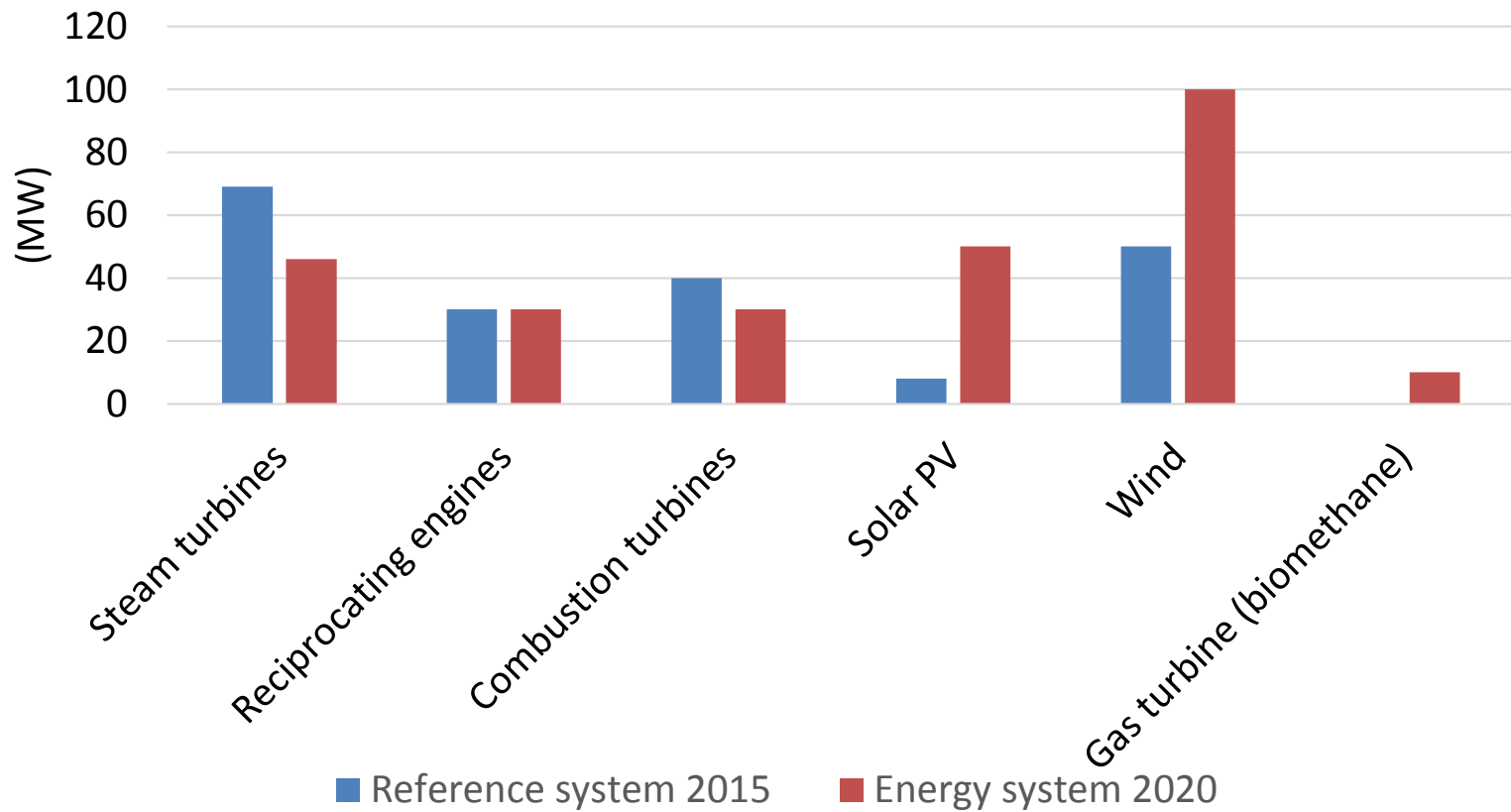


<b>Oil Consumption</b>	<b>GWh/Year</b>	<b>Share</b>
Electricity generation	3141	75%
Transport	743	18%
Industry	304	7%
<b>Total</b>	<b>4188</b>	

# Storage capacities

- Buses, tour buses and taxis: 11.9%
  - 21.3 MWh buses; 4.1 MWh cars
- Reverse Osmosis: 38% of overcapacity
  - 3 days of storage for desalinated water
- Thermal storage capacity: 0.8 GWh
  - 3 days of average cooling demand

# Installed capacities of different technologies

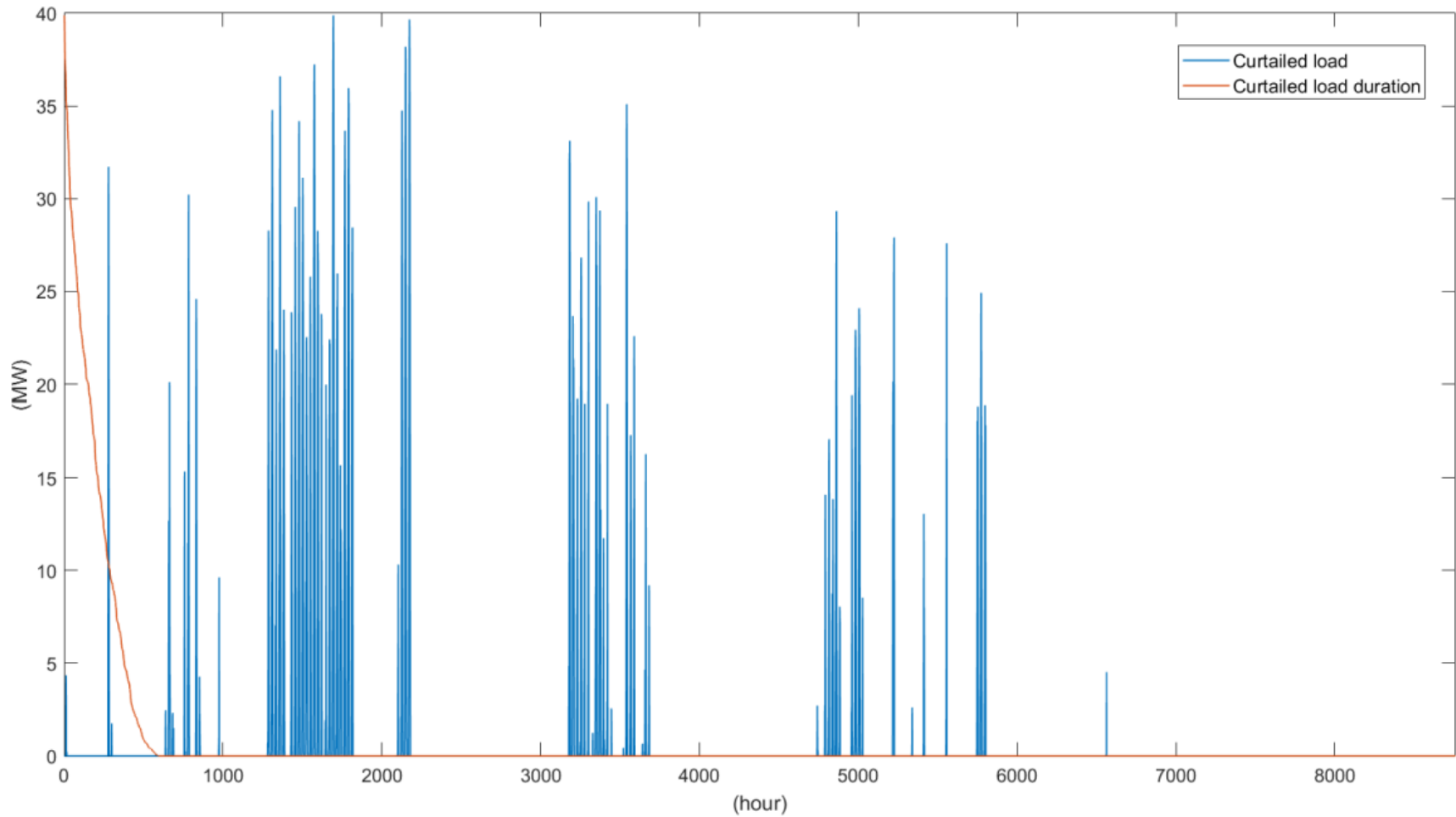


# Results

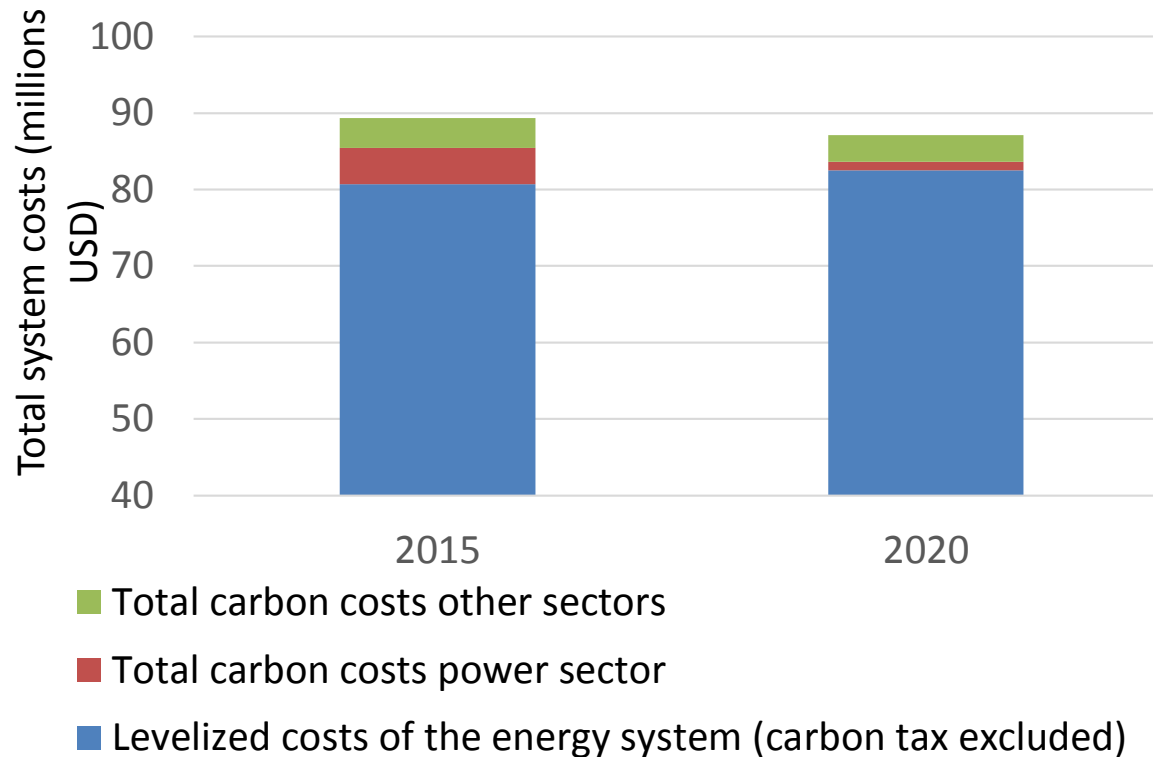
	2015	2020
Peak demand (MW) 1h	93.6	109.4
Peak demand (MW) 5min	99.5	110.6
Total generation (GWh)	657.5	699.0
Curtailed energy 1-h (GWh)	0	0.5
Curtailed energy 5-min (GWh)	0	7.1
Wind (GWh)	237.9	461.5
PV (GWh)	17.81	98.4
Oil* for power sector (GWh)	1273.2	<u>305.8</u> -76%
Oil* for transport and industry (GWh)	1047	939
Primary energy supply (GWh)	2575.8	<u>1805.1</u> -30%



# Curtailed energy



# Results (continued)



	2015	2020	Unit
Carbon emissions power sector	317,000	<u>76,000</u>	tonCO <sub>2</sub> <b>-76%</b>
Total carbon emissions (including industry and transport)	578,000	<u>311,000</u>	tonCO <sub>2</sub> <b>-46%</b>

# Sensitivity analyses

- 1) smart charging vs. Vehicle-to-grid
- 2) fossil fuel prices
  - » 7.3% increase to reach the break-even point

# Outlook

- 11,000 inhabited islands globally
- 740 million people
- Tropics: district cooling vs. renewable electricity + cold storage (?)

# Conclusions

- 78% of final el. demand met by variable renewables
- Vehicle-to-grid only marginally better than smart charging
- Similar socio-economic costs
- Oil imports reduced by 46%

Thank you!