Hybrid PV-Wind-Renewable Methane Power Plants: A Potential Cornerstone of Global Energy Supply

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Motivation & Purpose of Work

A 100% renewable power supply on a low cost basis is prerequisite for a sustainable global development. Solar and wind resources are abundantly available on earth enabling the use of photovoltaic (PV) and wind energy technologies on a large scale in most regions in the world.[1,2] Renewable power methane (RPM) enables the storage of renewable excess power and the flexible balancing of power supply by combined cycle gas turbines (CCGT) re-converting RPM to power.[3]

This paper aims at investigating a global energy supply scenario based on hybrid PV-Wind-RPM-CCGT power plants interconnecting the power and gas infrastructure.

Full Load Hours of PV-Wind Plants

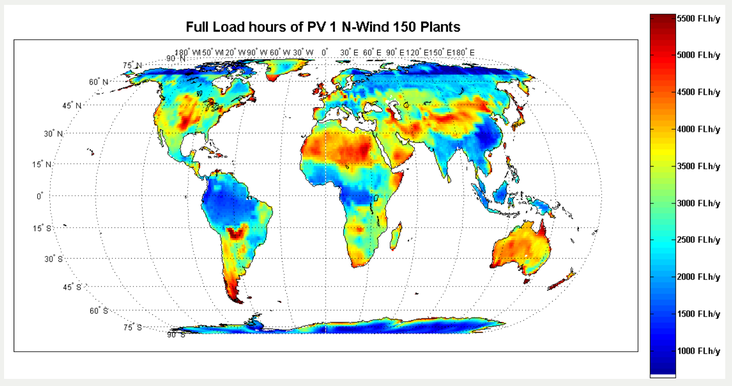


Fig. 1: Hybrid PV-Wind power plants characterized by their full load hours (FLh) projected for the year 2020. Assumed hybrid PV-Wind sub plants are 1-axis horizontal north-south continuous tracking PV power plants and wind power plants with a hub height of 150 m. The underlying resource data are provided by NASA SSE 6.0 [4] but further reprocessed [1].

LCOE of Hybrid PV-Wind Plants

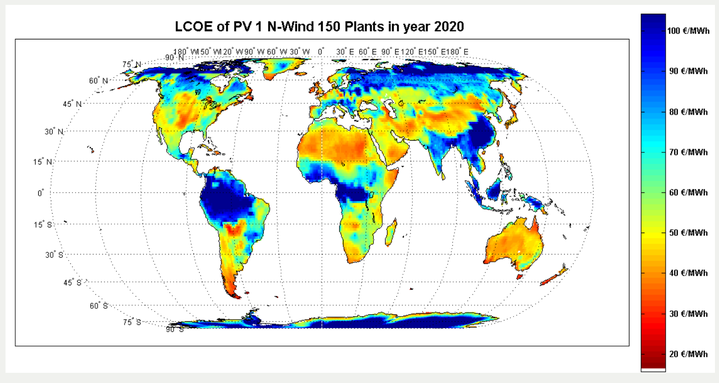


Fig. 2: Hybrid PV-Wind power plants characterized by their LCOE projected for the year 2020. Hybrid PV and wind power sub plants are according to Fig. 1. Key financial assumptions are: Capex of 1130 €/kW (PV) and 800 €/kW (wind), plant lifetime of 30 years (PV) and 25 years (wind) and weighted average cost of capital of 6%.

Renewable Power Methane Cost

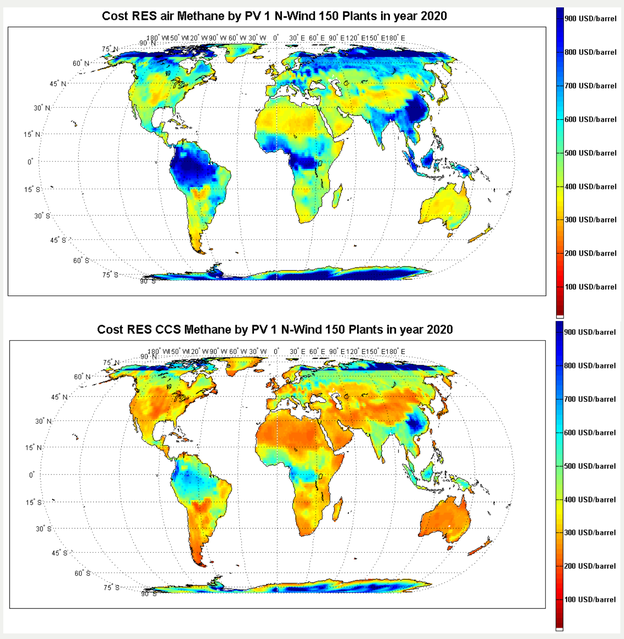
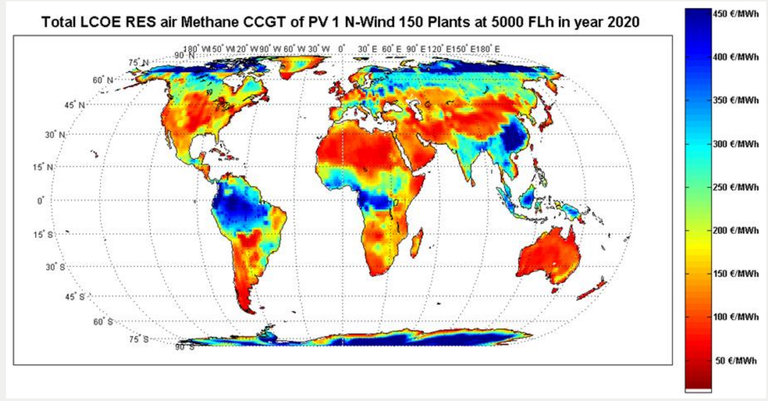


Fig. 3: Cost of Renewable Power Methane (RPM) production for CO_2 from the air (top) and supplied by carbon capture and storage (CCS) facilities (bottom) projected for the year 2020. Power supply by hybrid PV-Wind power plants (Fig. 2) is assumed. Cost of RPM production might be at about 300 USD/barrel$_{eq}$ for CO_2 from air and about 200 USD/barrel$_{eq}$ for CO_2 from CCS route (excluding CCS cost) at sites of excellent solar and wind resources.

Renewable Power Methane: total LCOE, Storage and System Integration



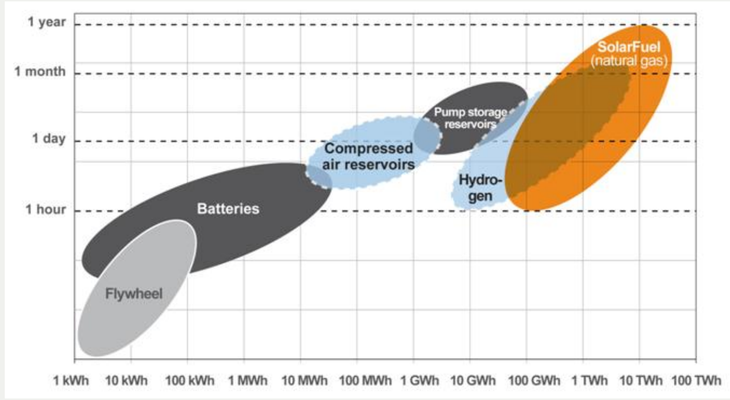
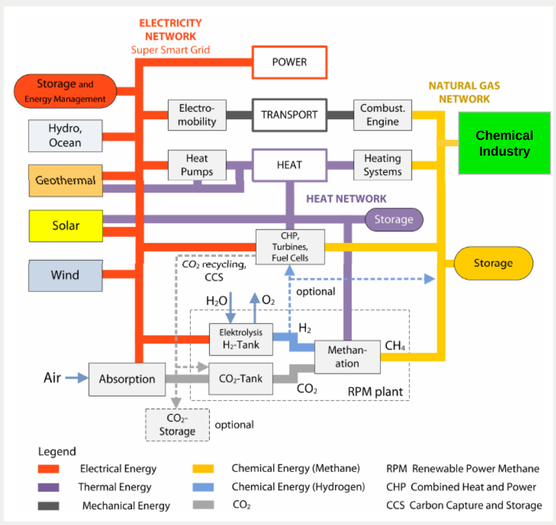


Fig. 4: Global LCOE of hybrid PV-Wind-RPM power plants for CO_2 from air (top/ left) projected for the year 2020. Power supply by hybrid PV-Wind power plants (Fig. 2) is assumed and 5,000 FLh in total for the hybrid power plant. LCOE of hybrid PV-Wind-RPM power plants might be about 80 €/MWh at sites of excellent solar and wind resources, whereas the CO_2 from air route could be slightly lower in LCOE mainly driven by challenging economics of CCS facilities.

Fig. 5: Overview on major electricity storage technologies in dependence on energetic storage capacity and charge cycling (top/ right). RPM (denoted as Solar Fuel) is one of only few seasonal storage options for large scale energy storage.

Fig. 6: Hybrid PV-Wind-RPM plant (bottom) as the integral centrepiece of a future sustainable energy supply system.[3] The four main energy systems are integrated and positively influenced by renewable power methane, i.e. power network, natural gas network, heat network and transportation network.



China: Exemplary Potential Market

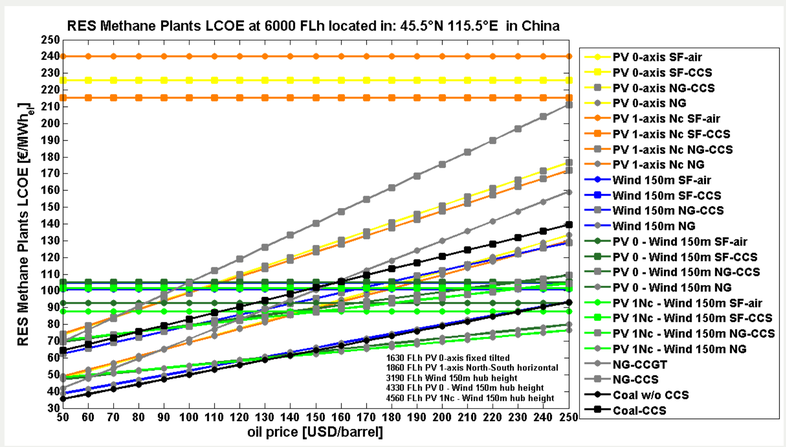


Fig. 7: Hybrid PV-Wind-RPM-CCGT and fossil fuel fired power plant LCOE dynamics for a site in China close to Mongolia (about 45.5°N/ 115.5°E) for 6,000 FLh and a fossil fuel price range of 50 – 250 USD/barrel$_{eq}$ in the year 2020. Abbreviations stand for: combined cycle gas turbine (CCGT), natural gas (NG), renewable power methane (SF) and tracking PV (1Nc).
The key results are:

- hybrid PV-Wind-RPM plant is cost competitive due to LCOE lower than 90 €/MWh$_{el}$
- coal with CCS and w/o CCS is higher in cost for oil prices of about 110 $/barrel and 230 $/barrel

Global Power Supply Potential

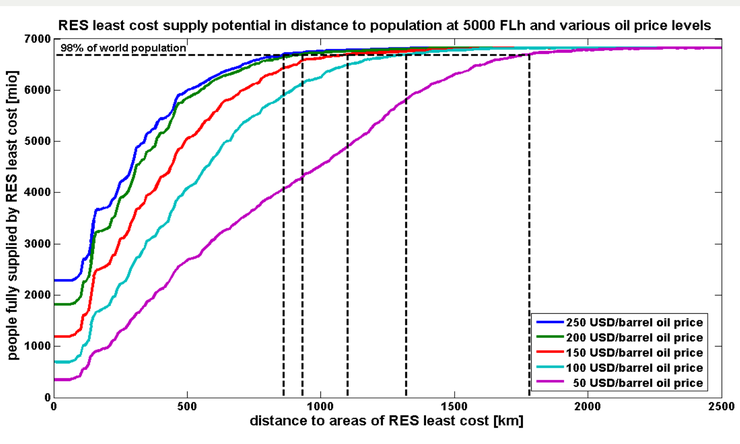


Fig. 8: Aggregated people living in regions of least cost 100% renewable power supply and respective distance to these regions in dependence of fossil fuel prices in the range of 50 – 250 USD/barrel$_{eq}$ in the year 2020. The evaluation is based on least cost hybrid PV-Wind-RPM-CCGT power plants and the distribution of global population density [5].
The major part of mankind is in reach of least LCOE power supply in less than 1000 km.

Conclusion

- **RPM might become a very attractive seasonal storage option also applicable for daily storage**
- **PV and Wind emerge to the backbone of global energy supply due to cost and complementarity**
- **Hybrid PV-Wind-RPM-CCGT plants: bidirectional interconnection of globally established large scale energy infrastructure**
- **RPM using CO_2 via CCS lower in cost than CO_2 by air, BUT**
- **Hybrid PV-Wind-RPM-CCGT power plant LCOE are for the air route slightly lower than for CCS**
- **>95% of mankind live closer than 1,000 km to sites of least cost RPM based power generation**

References

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