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# Global Energy System Based on 100% Renewable Energy – Power Sector: Introduction to the study

Presentation · November 2017

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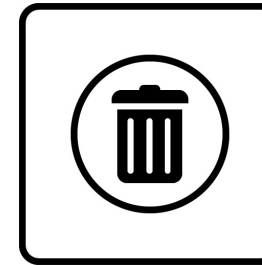
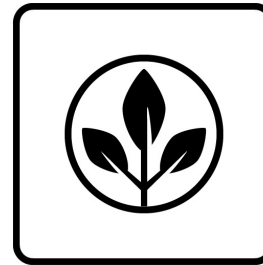
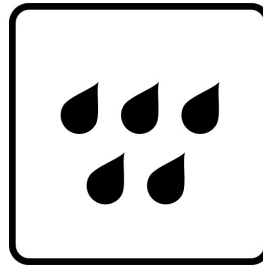
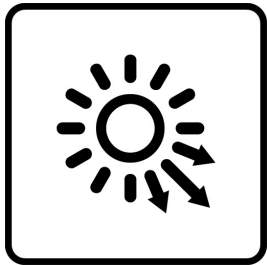
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# Global Energy System Based on 100% Renewable Energy - Power Sector: Global Overview



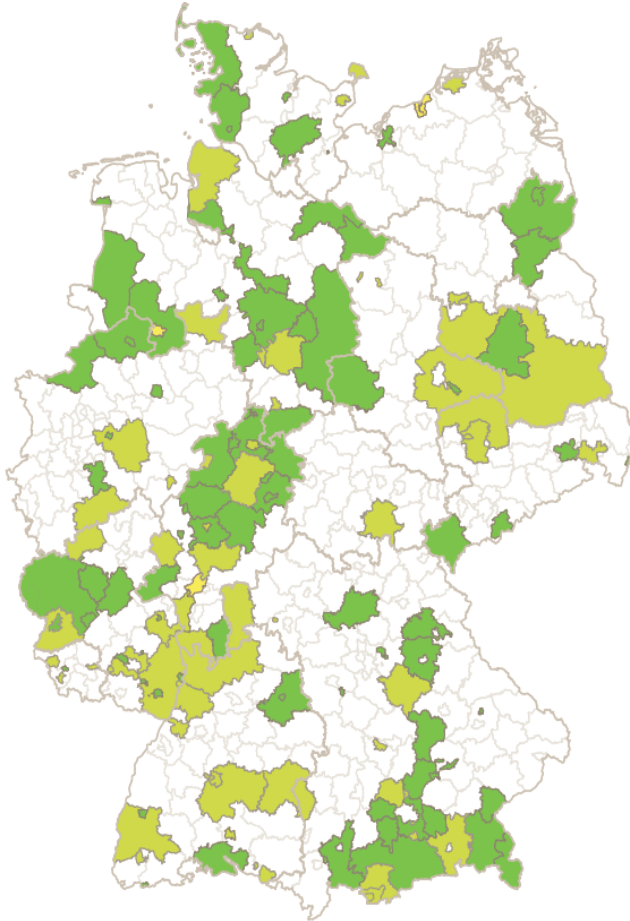
Study funded by the  
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Michael Child, Hans-Josef Fell, Christian Breyer



# 100% RENEWABLES

[www.go100re.net](http://www.go100re.net)



**Nov 2016, COP22, Marrakech:**  
**48 countries (Climate Vulnerable Forum) decided for a 100% RE target**

**More Countries set 100% targets, e.g.:**  
Denmark, Sweden, Costa Rica, Iceland, Cape Verde

**Cities with 100% RE targets, e.g.:**  
Barcelona, Masdar City, Munich, Masheireb, Downtown, Doha, Vancouver, San Francisco, Copenhagen, Sydney, ...

**Companies with 100% RE targets, e.g.:**  
Google, Coca-Cola, IKEA, Walmart, ...

[www.100-ee.de/](http://www.100-ee.de/)

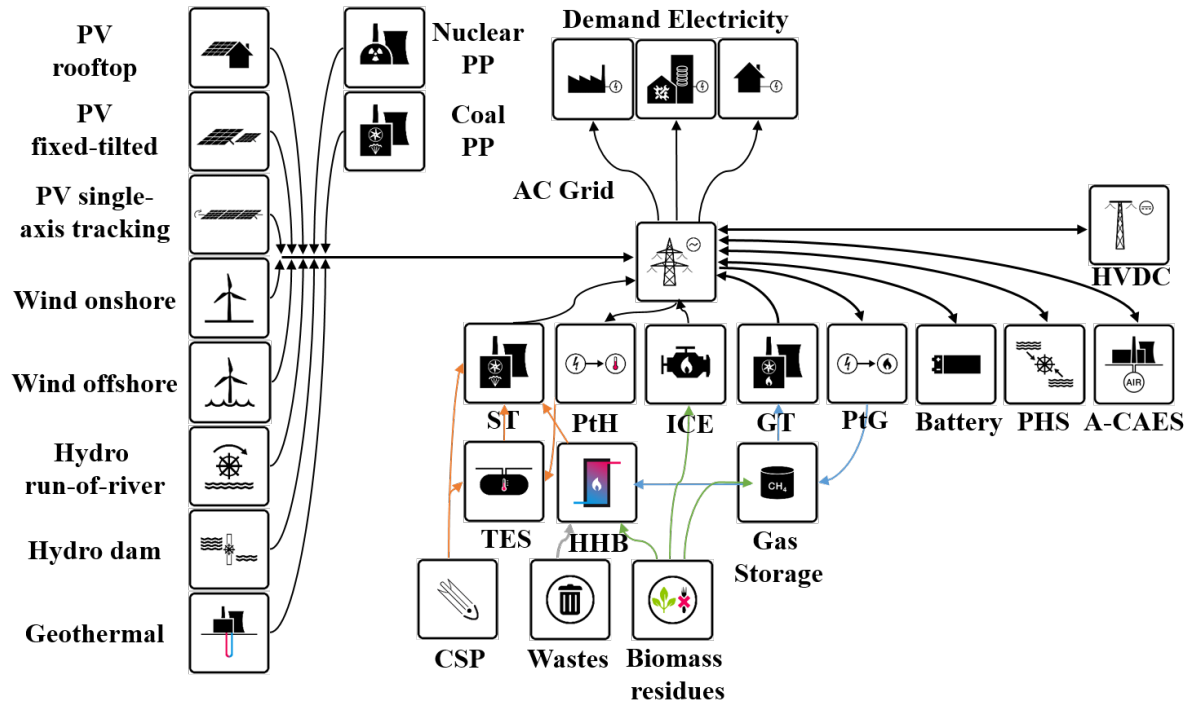
# 1<sup>st</sup> Modelling of 100% RE Global Power System



- The modelling by the Lappeenranta University of Technology as of 2017 is the only one to run at full hourly resolution on a global-local scale.
- Real weather data were used for assessing the solar, wind and hydro resources.
- By 2050, the world population is expected to grow from 7.3 to 9.7 billion.
- The global electricity demand for the power sector is set to increase from 24,310 TWh in 2015 to around 48,800 TWh by 2050.



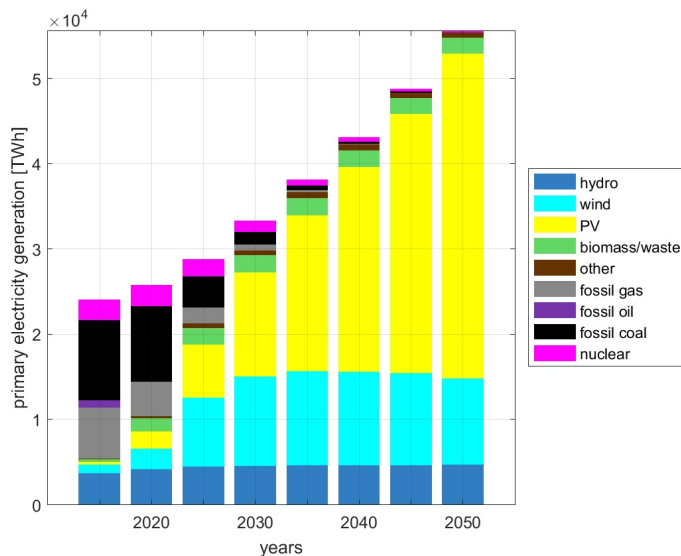
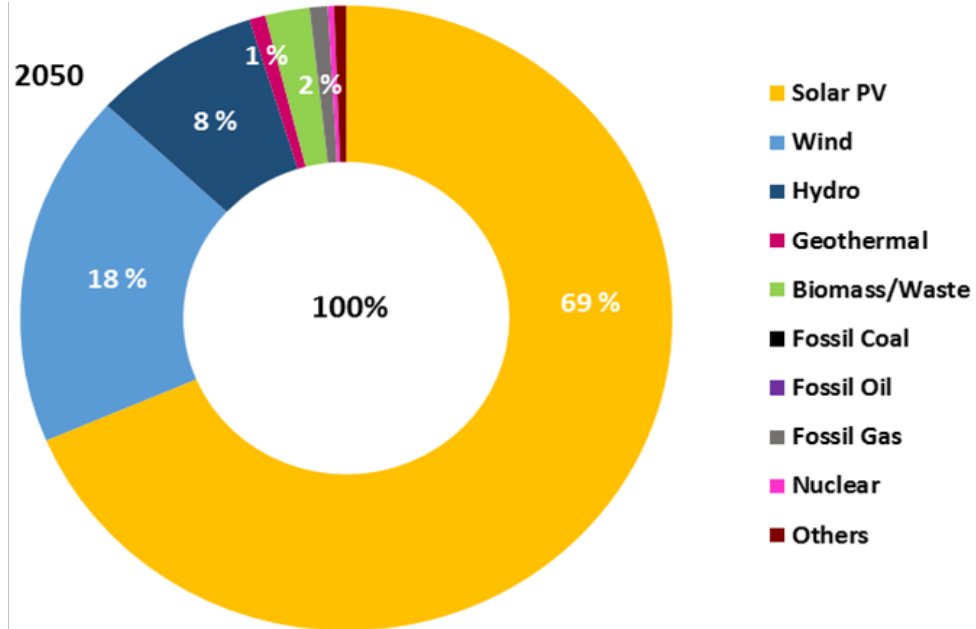
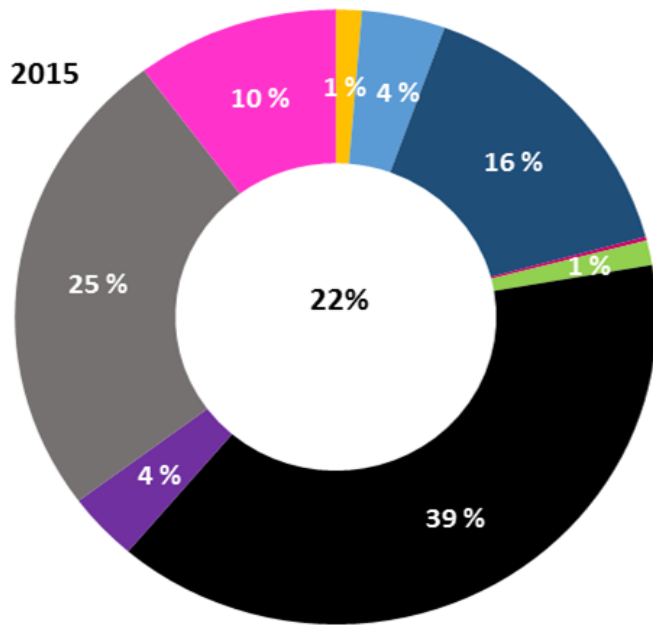
# LUT Energy System Model



- The technologies applied for the energy system optimisation include those for electricity generation, energy storage and electricity transmission
- The model is applied at full hourly resolution for an entire year
- The LUT model will be expanded to all energy sectors for a follow-up study



# Electricity Generation in 2015 and 2050

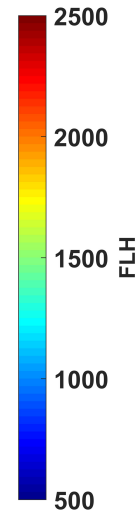
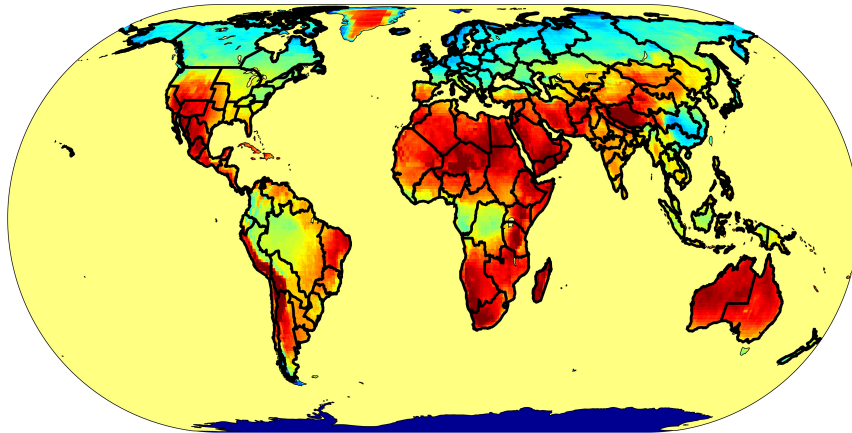


- In 2050, solar PV accounts for 69%, wind energy 18%, hydropower 8% and bioenergy 2% of the total electricity mix globally.
- Gas generation is only from renewable energy based gas (bio-methane and power-to-gas)
- Nuclear power still accounts for negligible 0.3% of the total electricity generation, due to the end of its assumed technical life, but could be phased out earlier.



# Global Full Load Hours

PV (single-axis tracking) full load hours



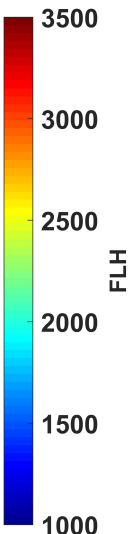
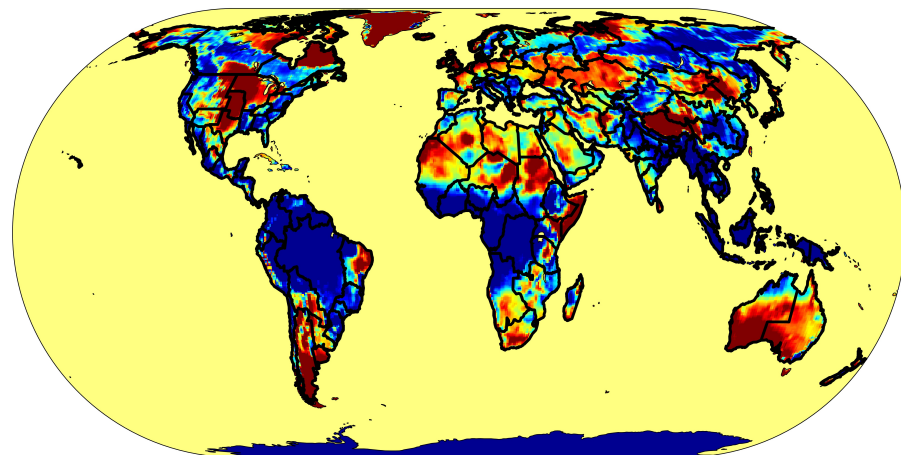
## Key insights for solar PV:

- most evenly distributed energy resource around the world
- diurnal variation
- seasonal stability in Sun Belt region
- stronger seasonality in northern hemisphere

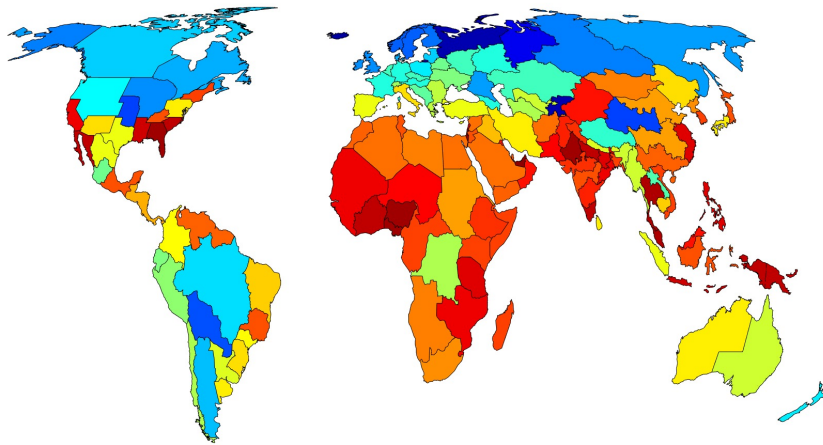
## Key insights for wind energy:

- uneven global distribution
- excellent conditions available in all major regions in the world
- seasonal variation of availability

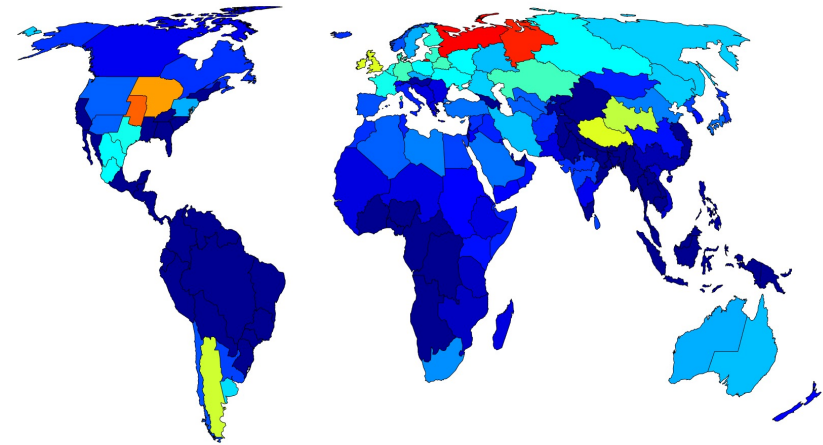
Wind onshore (E101 at 150m) full load hours



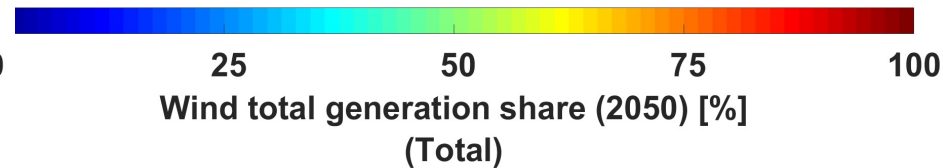
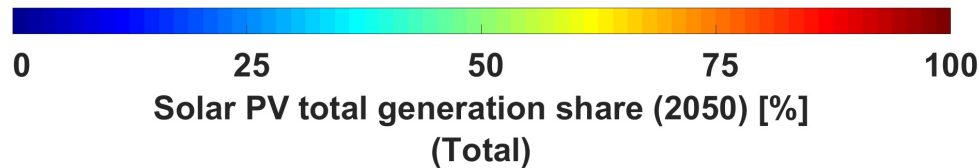
# Regional Variation – Solar PV and Wind



global weighted average: 68.6%



global weighted average: 18.3%

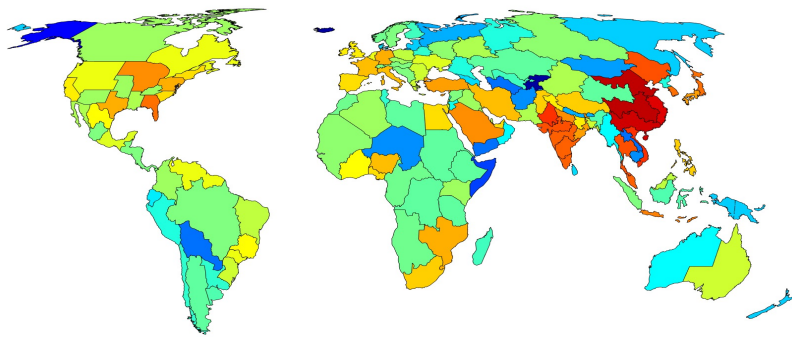


- Solar PV is the dominating source of electricity in the Sun Belt
- Wind energy is very important in the North
- In regions of less solar PV and wind energy the contribution of hydropower is excellent

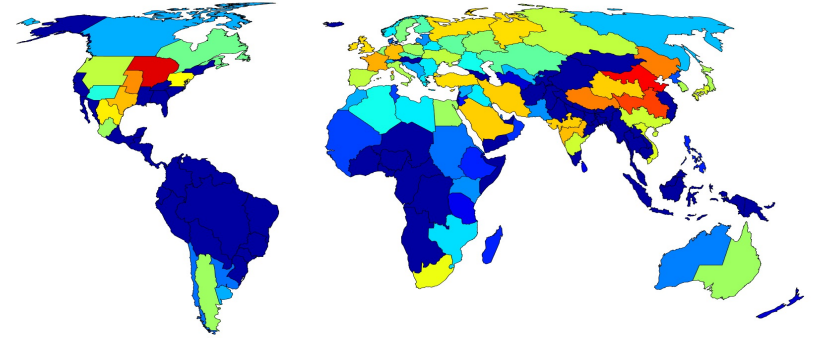




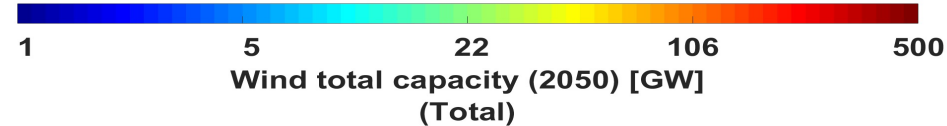
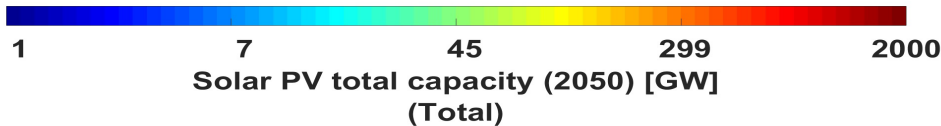
# Major RE Capacities in 2050



global total: 21959 GW



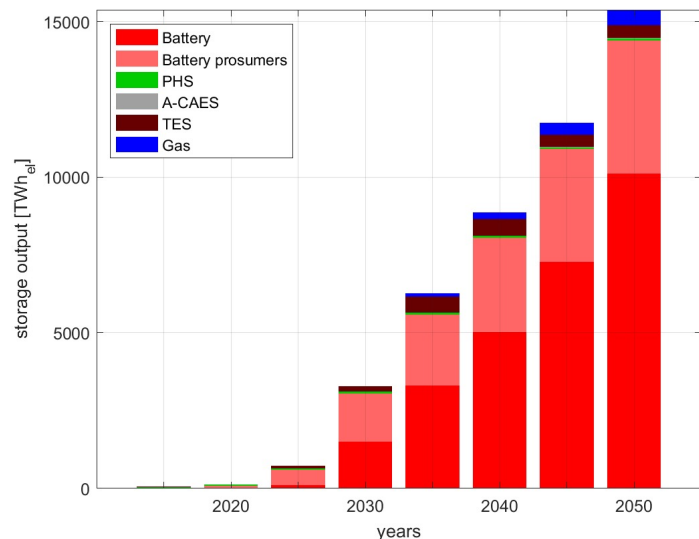
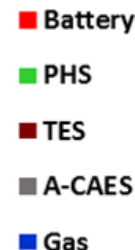
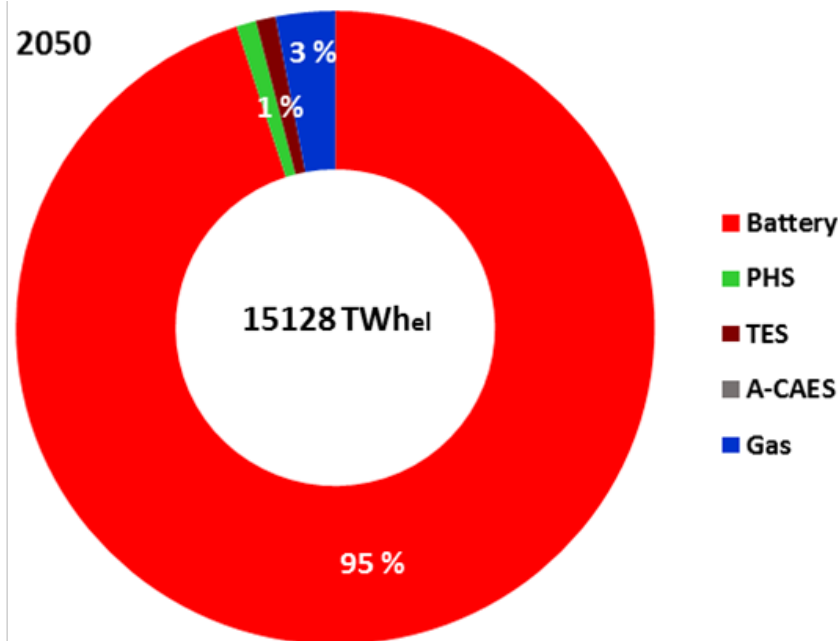
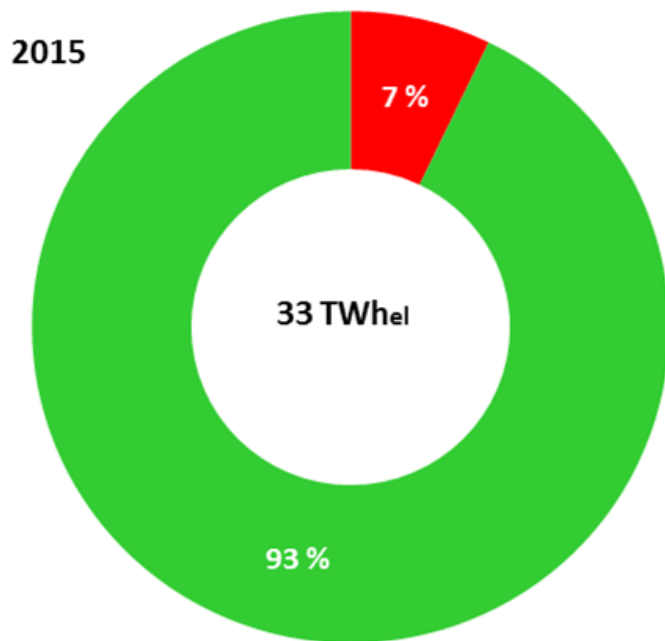
global total: 3154 GW



- Latitudes of 45° N and higher show a strong seasonality effect, i.e. parts of North America, Europe and Eurasia; this implies a strong wind demand
- The effect of excellent other RE resources can be observed for instance in Russia (excellent wind, and hydropower in Siberia and Far East), Brazil (excellent hydropower), Laos (excellent hydropower) or Sumatra in Indonesia (excellent geothermal energy)



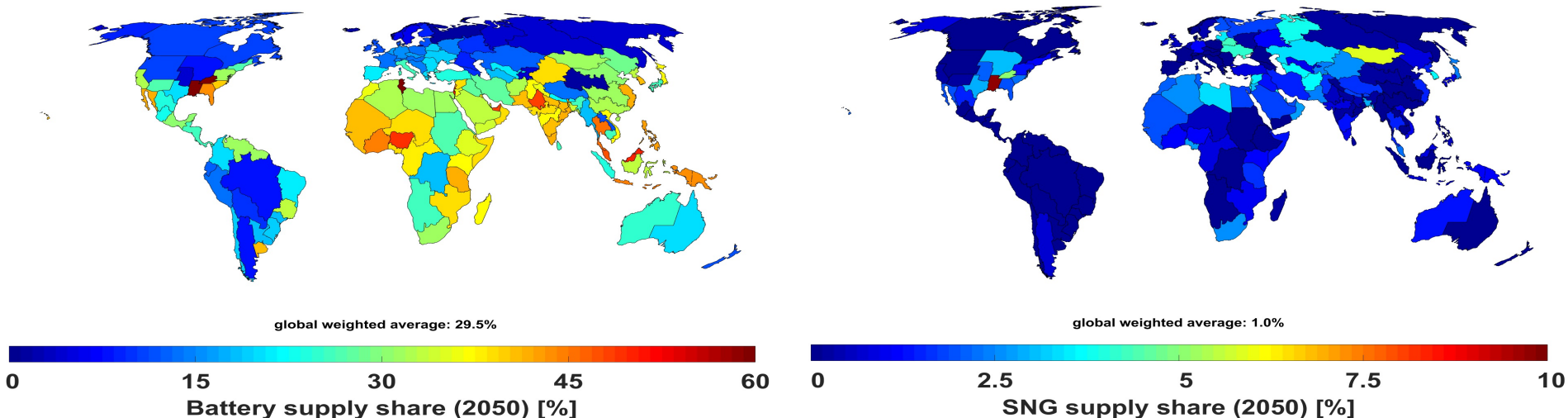
# Electricity Storage Output in 2015 and 2050



- Batteries are the key supporting technology for solar PV.
- Storage output covers 31% of the total demand in 2050, 95% of which is covered by batteries alone.
- Battery storage provides mainly diurnal storage, and renewable energy based gas provides seasonal storage.



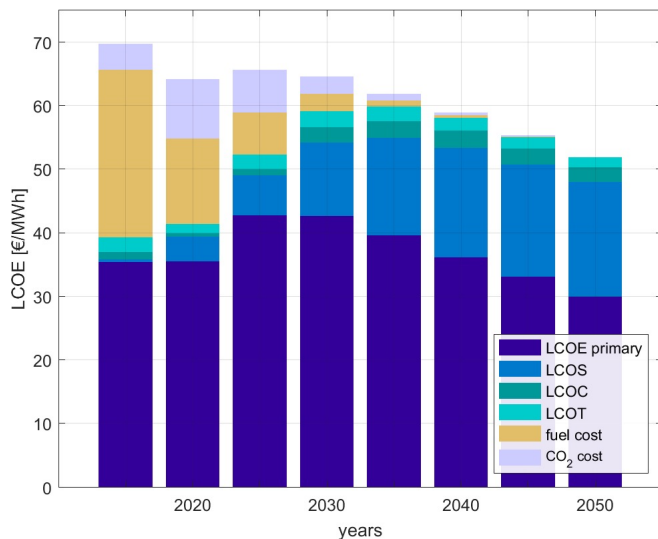
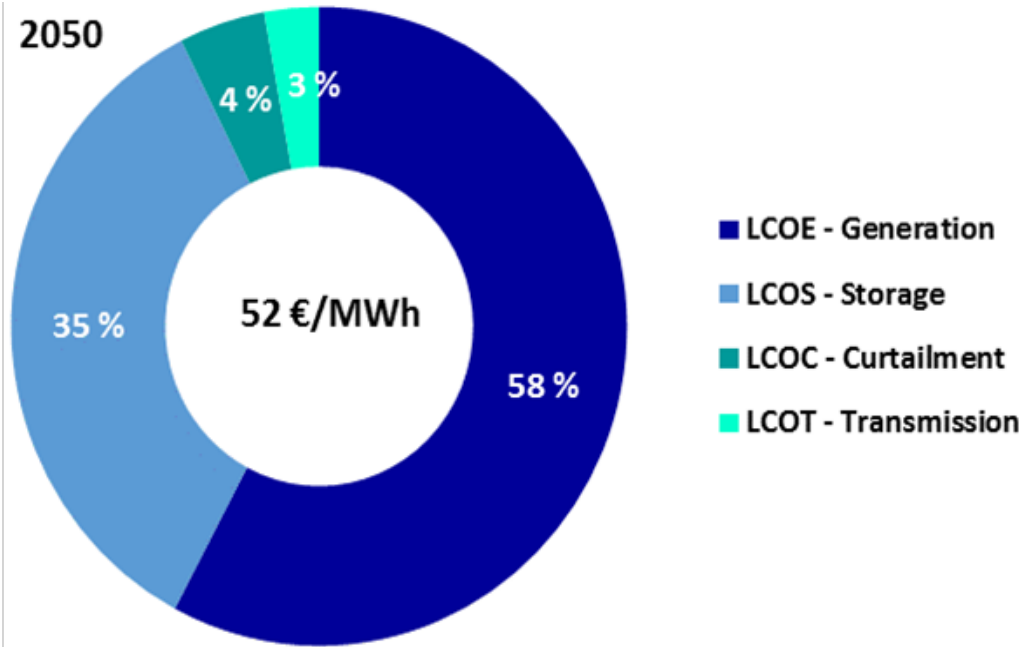
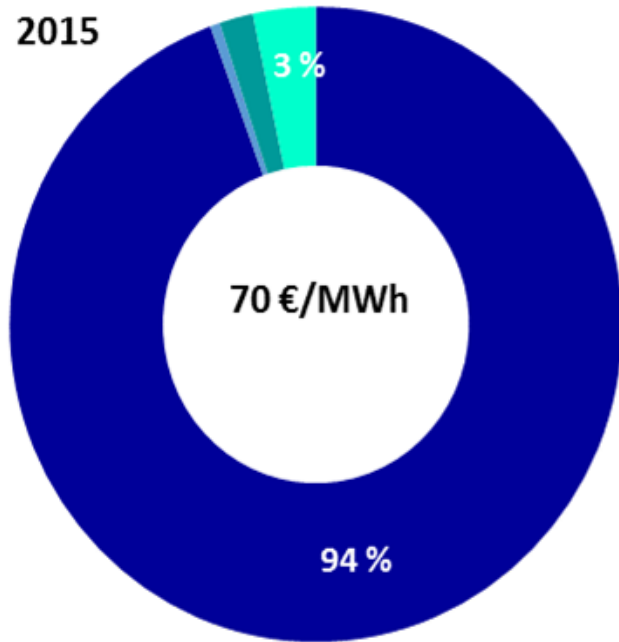
# Storage Supply Shares in 2050



- Battery storage mainly plays a role in providing diurnal storage with around 31% of the total supply
- Gas storage mainly plays a role in providing seasonal storage with just 2% of total supply (1% from synthetic natural gas and 1% from bio-methane – both RE-based)
- Prosumers play a significant role and hence a large portion of batteries can be observed in 2050, also with low costs of solar PV and batteries



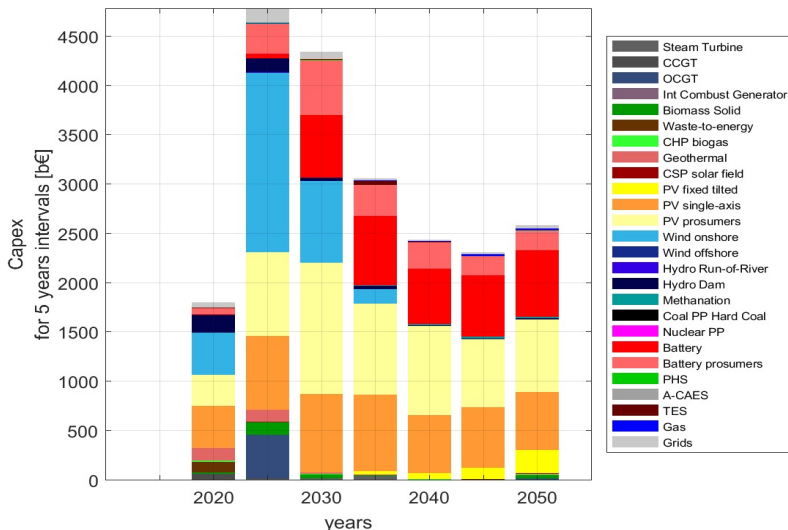
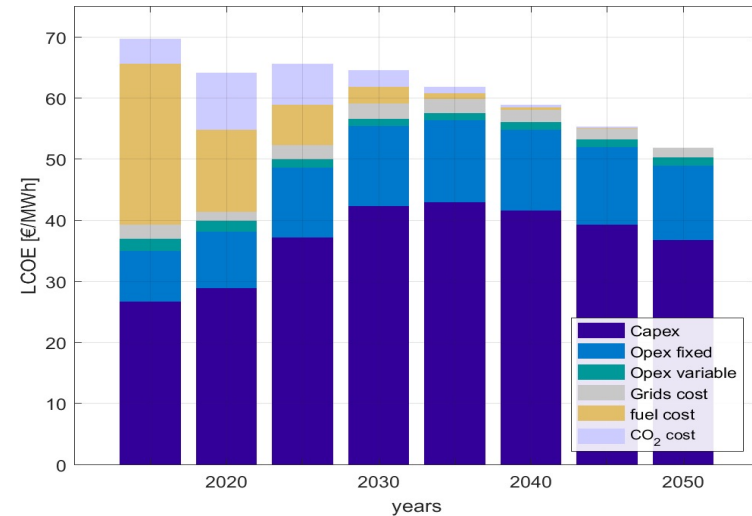
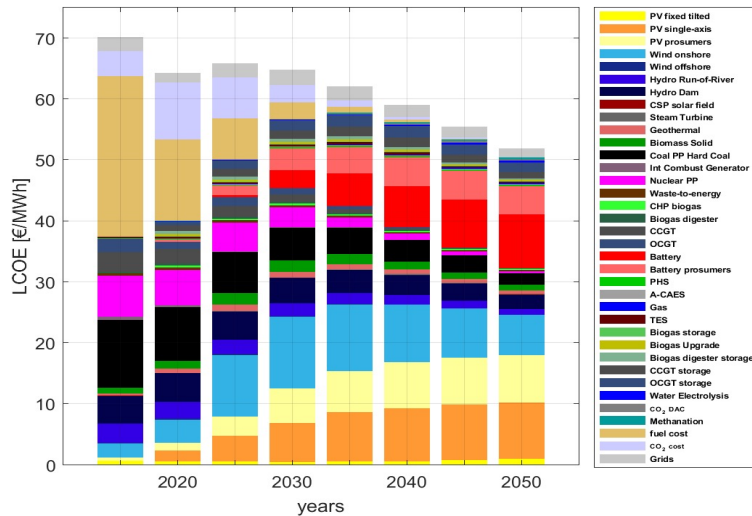
# Renewable Electricity is Cost-effective



- Total levelised cost of electricity (LCOE) on a global average for 100% renewable electricity in 2050 is 52 €/MWh compared to 70 €/MWh in 2015.
- These costs include generation, curtailment, storage and some grid costs.
- Stable and secure electricity supply for all hours of a year.



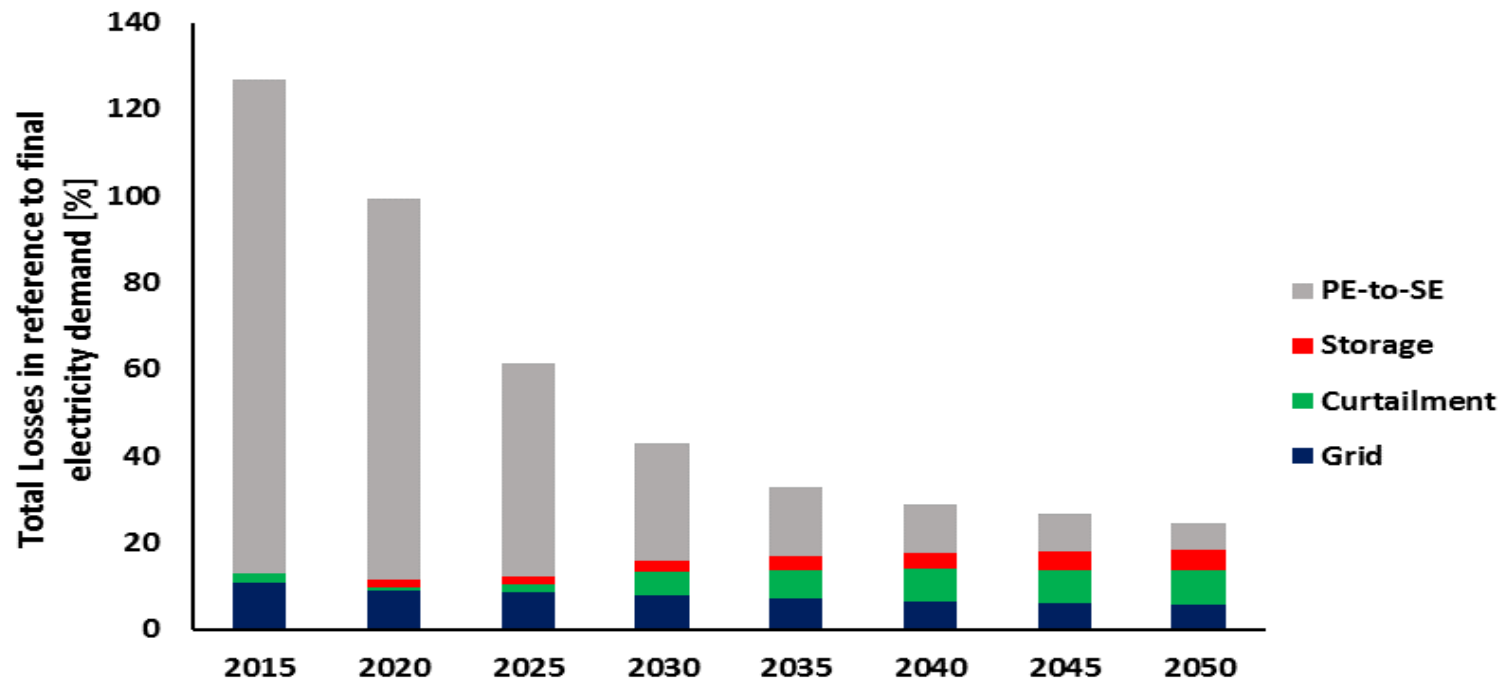
# Electricity System Cost during Transition



- The global power system LCOE remains stable for the first periods, showing a gradual decline from 70 €/MWh to 59 €/MWh from 2015 to 2040, including all generation, storage, curtailment and parts of the grid costs
- Beyond 2040 the LCOE further declines to 52 €/MWh by 2050, signifying that larger capacities of RE addition result in reduction of energy costs
- After an initial increase, the investment requirements decline after 2030 to stabilise between 2040 to 2050



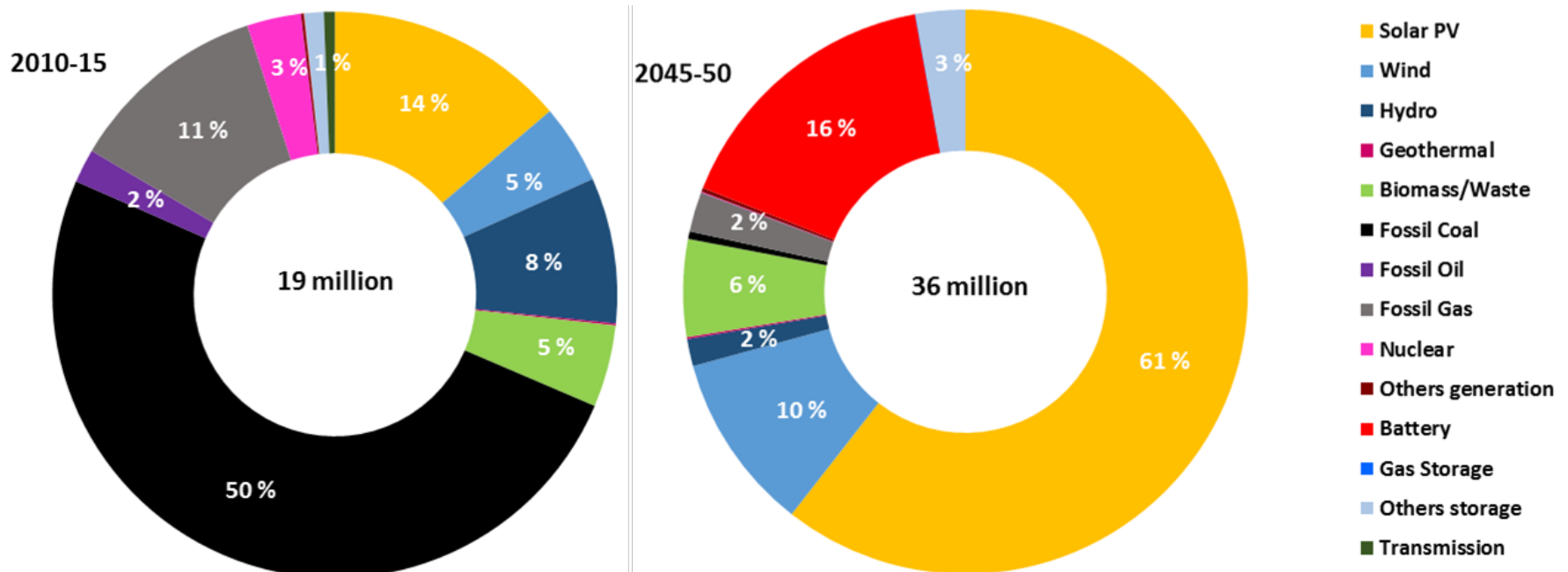
# 100% Renewables drastically reduces Losses



- The total losses in a 100% renewable electricity system are around 26% of the total electricity demand, compared to the current system in which about 58% of primary energy input is lost.
- Thermal power plants (coal, gas, oil, nuclear, biomass) lose much of the primary energy input.
- Curtailment is a low-cost flexibility option in future.



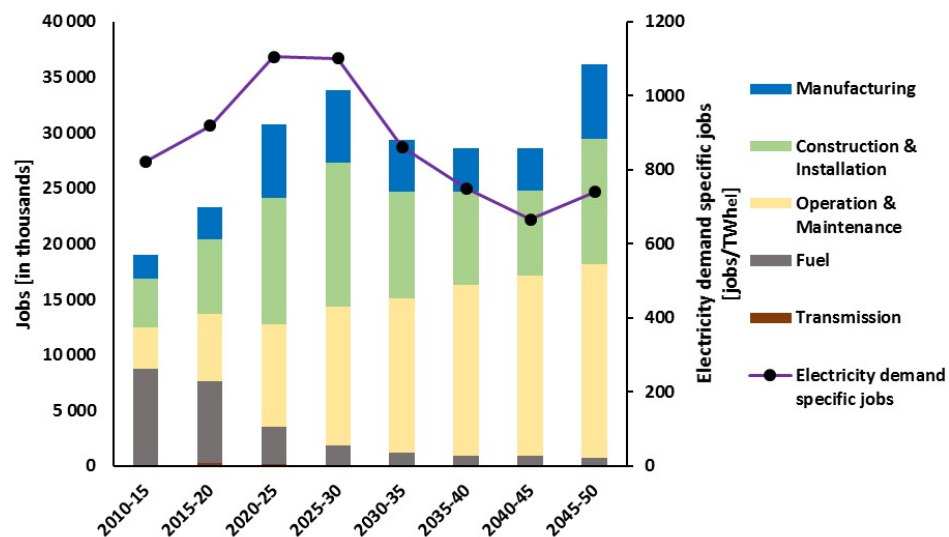
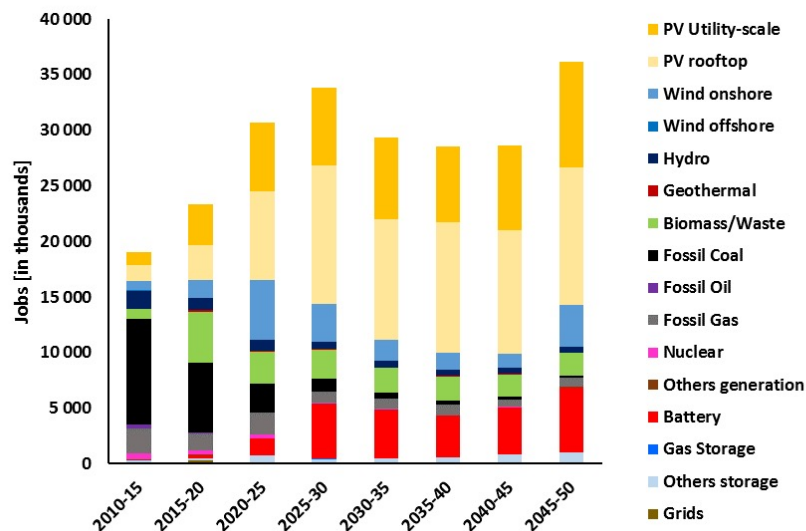
# Job Opportunities



- The global energy transition to a 100% renewable electricity system creates 36 million jobs by 2050 in comparison to 19 million jobs by 2015.
- Governments should start programmes to convert coal jobs to jobs for renewable energy.



# Job Opportunities

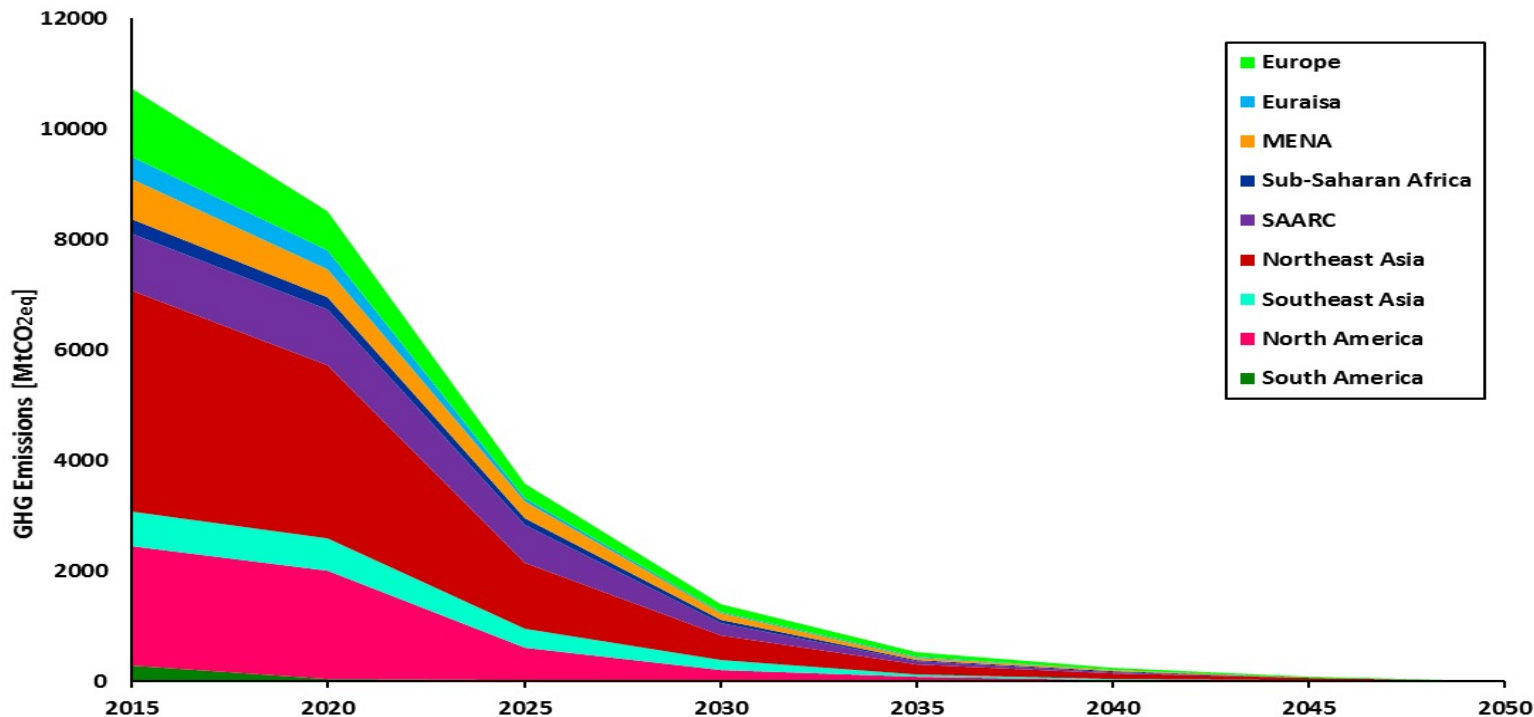


- Fossil and nuclear energy-related jobs can be easily substituted by RE-related ones
- Solar PV and battery storage will be prime job creators 2030 onwards
- More stable jobs will be available in operation and maintenance
- The total jobs per generated electricity will first increase due to strong investment needs and will stabilise towards 2050 comparable to the current level





# 100% Renewables reduce GHG Emissions to zero



- Global greenhouse gas emissions significantly reduce from about 11 GtCO<sub>2eq</sub> in 2015 to zero emissions by 2050 or earlier, as the total LCOE of the power system declines.



# Policy Recommendations

- Instruments, enabling direct private investments in renewable energy and other zero-emission technologies
  - Fixed feed-in-tariffs, such as the German Renewable Energy Sources Act (EEG)
  - Hybrid renewable power plant remuneration
  - Tenders only for capacities above 40 MW
- Phasing-out all state subsidies to fossil fuel and nuclear energy generation
- Tax exemptions for investments in renewable energy
- Replacement of emission trading systems with carbon & radioactivity taxes
- Research and education



# Key Findings

- Global electricity system based on 100% renewables is technically feasible and cost-effective
- Existing RE potential and technologies can generate sufficient and secure power to cover the entire global electricity demand by 2050
- Total LCOE on a global average for 100% RE is 52 €/MWh in 2050, vs. 70 €/MWh in 2015
- Electricity generation will be mainly based on solar PV, plus wind energy, hydropower and some bioenergy
- Substantial regional variations: solar PV dominance in the Sun Belt, more wind in the North
- Electricity storage mainly provided by battery storage plus RE gas for seasonal balancing
- The future electricity system is significantly more efficient than the present one
- Many new stable jobs will be created, which enables the substitution of lost coal jobs
- GHG emissions can be reduced to zero by 2050, even by 2040 is a possibility
- Political action that is pro renewables is the need of the hour

# Further Findings

Results for the world and all major regions are available (subsequent links to 92 countries/ regions are provided in the slides below):

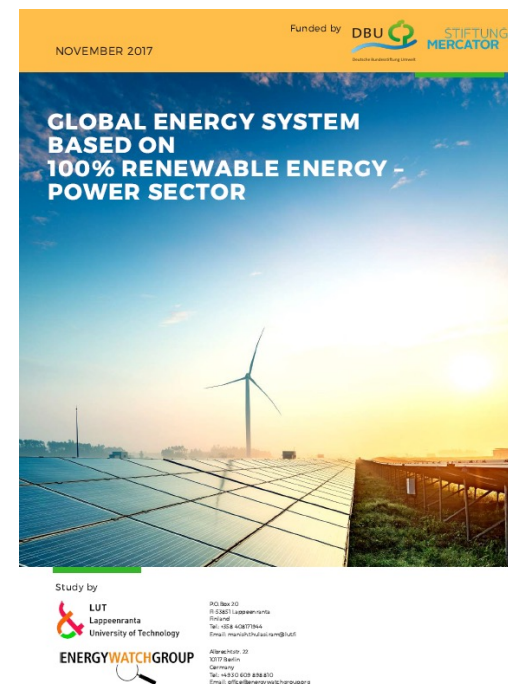
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