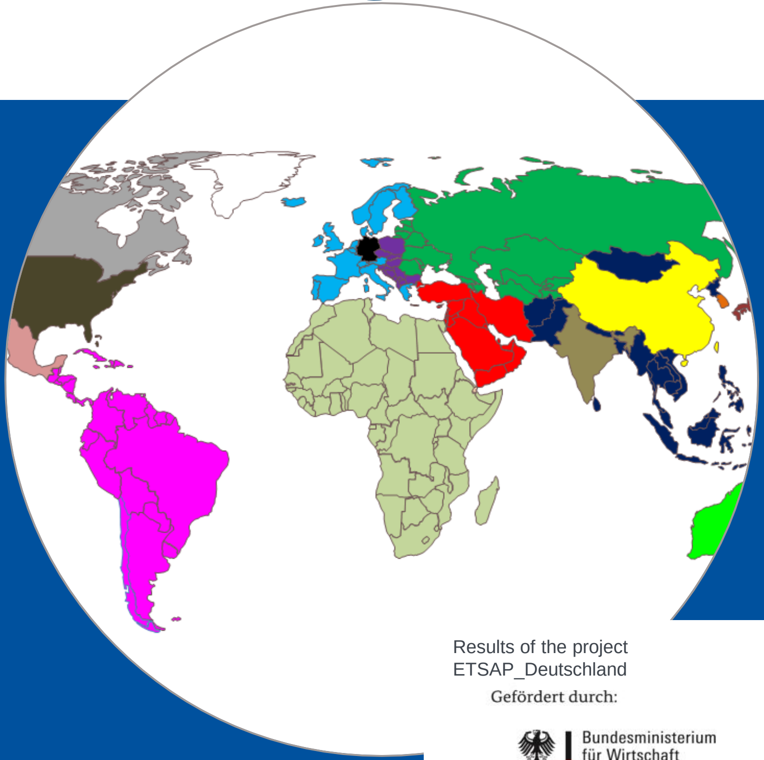
Universität Stuttgart
IER Institut für Energiewirtschaft und Rationelle Energieanwendungen

TUM

JÜLICH
Forschungszentrum

Renewable energy potential and the possibility to achieve the 1.5 °C target



Markus Blesl, Felix Lippkau, Patrik Buchenberg, Thushara Addanki, Philipp Kuhn, Thomas Hamacher, David Franzmann, Heidi U. Heinrichs

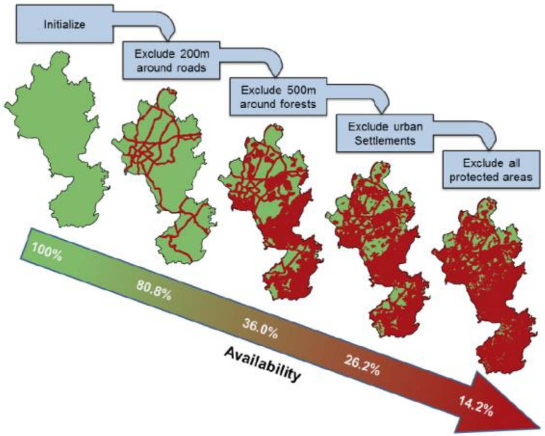
ETSAP WS Winter 2021, IFE Oslo and virtuell
29.11.2021

Results of the project ETSAP_Deutschland
Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

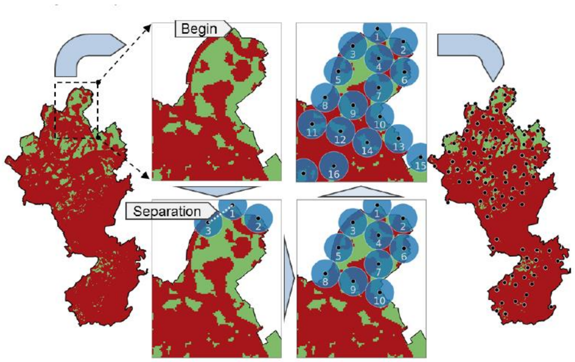
Motivation

- The Paris Agreement will determinate the GHG reduction target and budget in the long term.
- Decarbonization of the energy system will be one of the challenges and will only be realized if enough renewable energy can be integrated in the energy system and Biomass CCS will be available.
- The possibility to use renewable energy will depend on land use criteria and other criteria for example social criteria. In the literature and in the general discussion exist a broad range of estimations based on methodological different approaches.
- Therefore the influence of the criteria to use renewable energy and the long term impact on the structure of the energy system will be analyzed.

Method for Land Eligibilty & Placement for Volatile Renewable Energies (FZJ)



[1]



[1]

1) Determine eligible land area

2) Selection of specific locations for wind turbines and PV

- Land use criteria developed by FZJ:
  - ~40 criteria for various categories based on global unified datasets:
    - Sociopolitical (cities, land use, industry, etc.)
    - Physical (slope, dunes, etc.)
    - Conservation (Nature, Wildlife, etc.)
    - Resolution: FZJ 100x100m^2

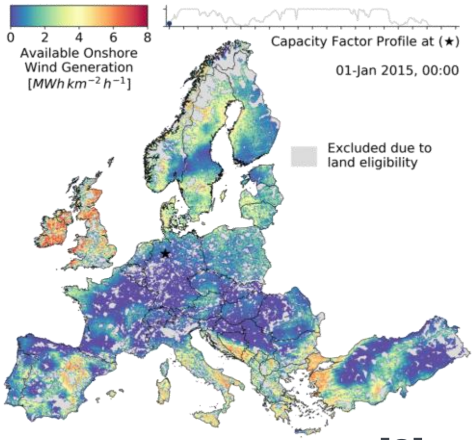
[1] Ryberg et al.: *Evaluating Land Eligibility Constraints of Renewable Energy Sources in Europe*. Energies. 2018

[2] Ryberg et al.: The future of European onshore wind energy potential: Detailed distribution and simulation of advanced turbine designs. Energy, 2019.

[3] Copernicus Climate Change Service (C3S) (2017): ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate . Copernicus Climate Change Service Climate Data Store (CDS), 2020. https://cds.climate.copernicus.eu/cdsapp#!/home

Method for Volatile Renewable Energy Potential Simulation (FZJ)

- ERA5 – weather dataset (resolution 30x30km^2)
- 10 weather year processing (robust system design across weather years)
- future and turbine design with synthetic power curves
- optimal wind turbine selection
- PV Module: ‘Winaico WSx-240P6’
- validated with real measured data globally
- Spatial refinement down to 250m with Global Wind Atlas (for wind), Global Solar Atlas (for PV)
  - GSA limited to -45° until +60° (beyond only ERA5, e.g. Russia, Canada)



[2]

3) Simulation of optimal (future) wind turbines for 10 years with ERA5 [3]

[1] Ryberg et al.: *Evaluating Land Eligibility Constraints of Renewable Energy Sources in Europe*. Energies. 2018
[2] Ryberg et al.: The future of European onshore wind energy potential: Detailed distribution and simulation of advanced turbine designs. Energy, 2019.
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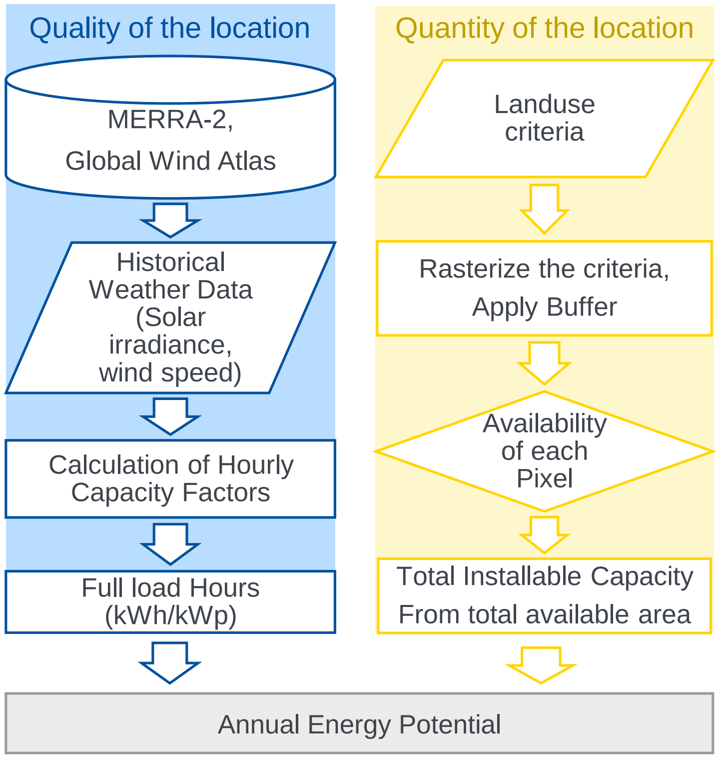
Methods to Estimate the Renewable Potentials (TUM)

pyGRETA

- **py**thon **G**enerator of **RE**newable **T**ime series and m**A**ps
- Technologies: PV, Wind, Biomass
- Scope: Worldwide
- Resolution
  - Temporal: 8760 hours /a
  - Spatial: 250 x 250m
- Redistribution of Wind speed Data from MERRA-2 to increase the spatial resolution

www.github.com/tum-ens/pyGRETA

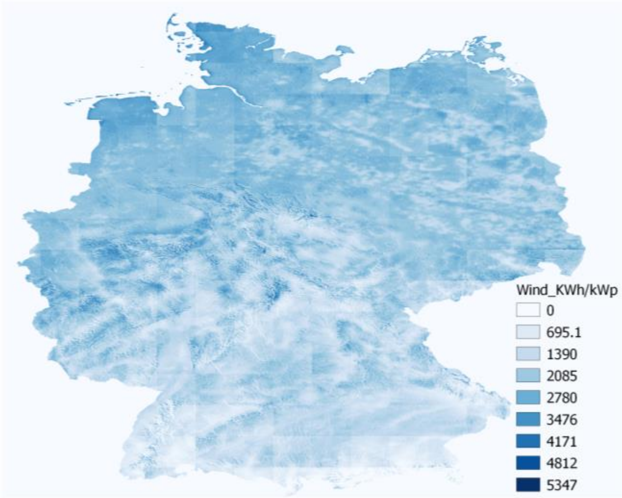
Methodology for PV and Onshore Wind



Methods to Estimate the Renewable Potentials (TUM)

Technology Assumptions

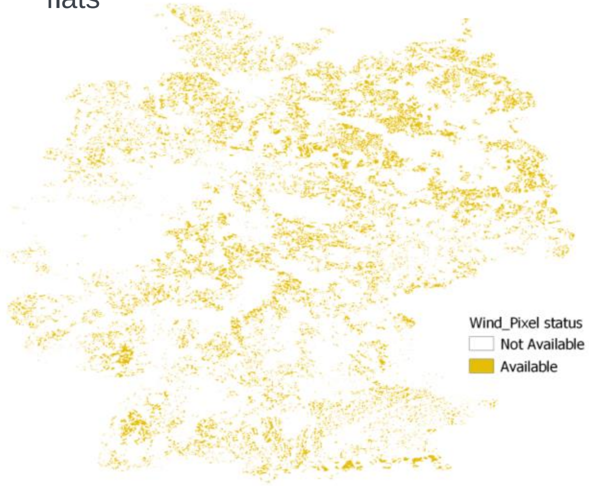
- Weather Data Year: 2019
- PV : Horizontal orientation & No tracking
  Land requirement: 160 Watt / sq.m
- Onshore Wind : Turbine type: 3MW, 80m hub height
  Land requirement: 8 Watt / sq.m



Landuse criteria: Primarily same as FZJ criteria

Differences to FZJ in order of importance

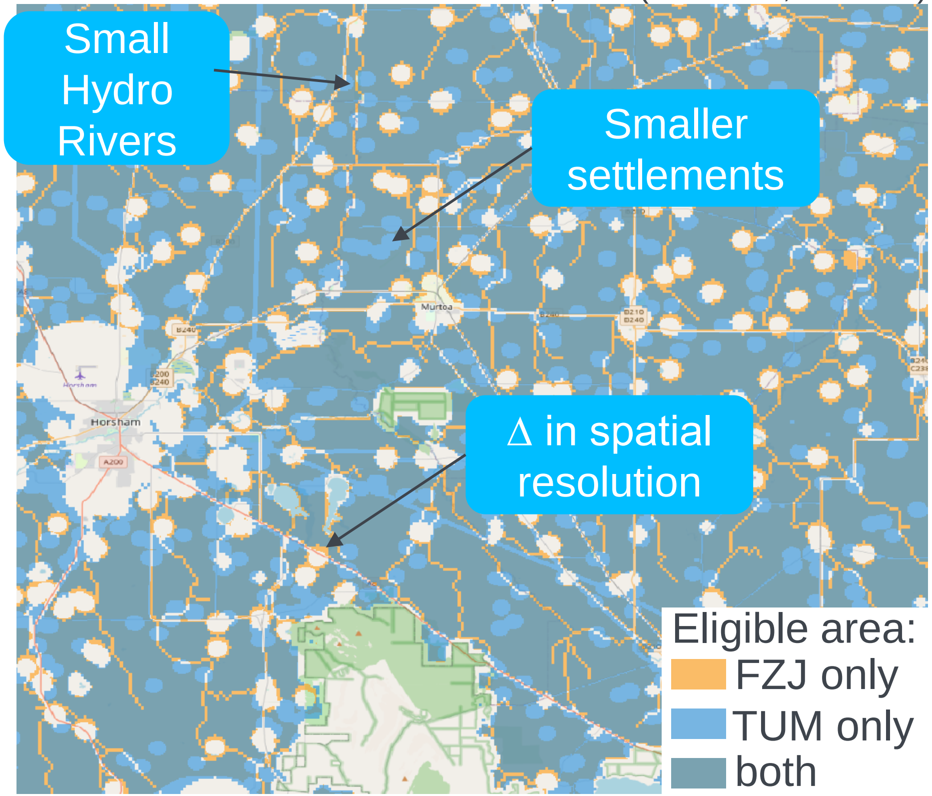
- Calculation of slope is different
- Buffer area is defined by number of pixels around
- Grasslands are also excluded for PV
- Some Differences in Airports & Settlements data
- Didn't exclude the flood risk areas, sand and salt flats



Deviations in Renewable Energy Potentials – Part A: Arising from Differences in Land Eligibility Approach (LEA)

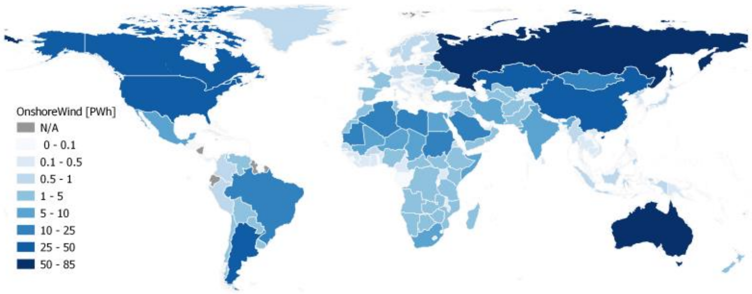
- Differences in LEA lead to deviations of eligible land from 2 to 30% absolute
- Exemplary differences (here: onshore wind):
  - TUM: exclusion of smaller hydro-rivers
  - FZJ: exclusion of smaller rural areas
- Further deviations due to differences in renewable energy simulation
- Paper planned with in-depth analysis

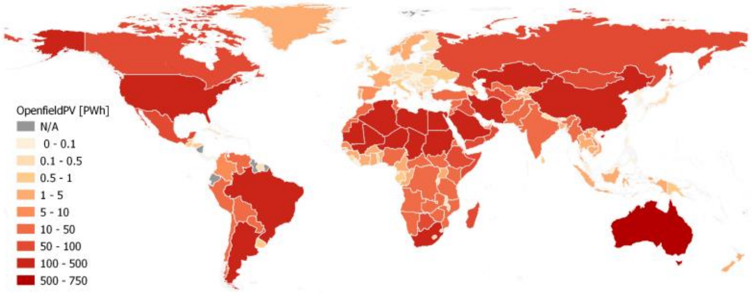
Australia, near (142.4575,-37.0233)



Preliminary Volatile Renewable Energy Potentials

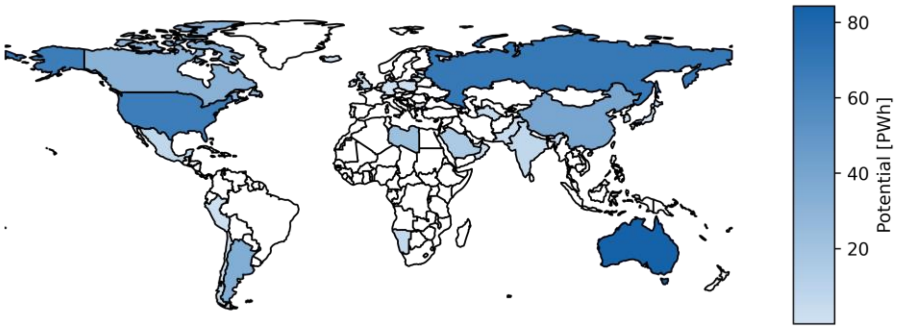
TUM Results



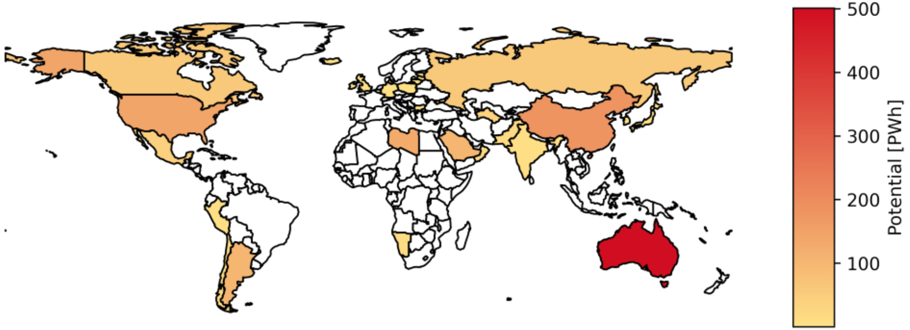


FZJ Results

Wind Onshore Potential



Open Field PV Potential



Scenario definition – Renewable Potentials [GW]

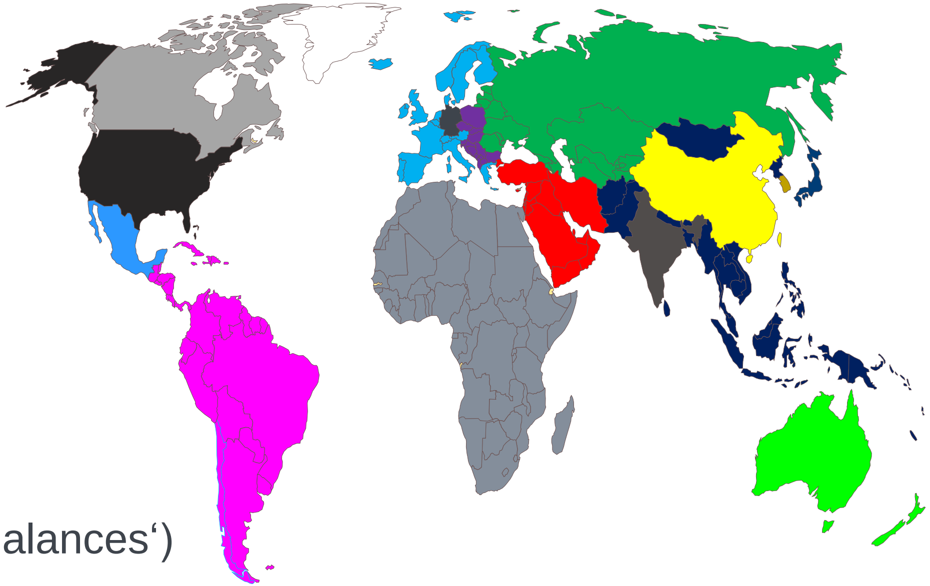
Solar PV

TIAM Regions	low	high
Africa	10.239.12	149.418.60
Australia	2.630.57	224.475.53
Canada	712.68	49.944.02
Central & South America	13.789.04	70.934.37
China	36.774.72	99.067.16
Eastern Europe	117.40	56.950.28
Former Soviet Union	1.510.87	107.716.71
Germany	193.49	2.032.62
India	4.496.45	19.787.95
Japan	3.22	3.295.99
Mexico	2.429.40	19.148.30
Middle East	6.374.86	56.824.63
Other Developing Asia	3.103.71	1.119.097.07
South Korea	1.95	252.23
United States of America	27.410.32	63.806.34
Western Europe	2.789.15	140.313.18
Global	236.807.28	2.764.815.74

Wind Onshore

TIAM Regions	low	high
Africa	601.50	149.418.60
Australia	776.28	41.831.80
Canada	3.672.12	27.800.00
Central & South America	2.792.80	86.787.10
China	19.810.00	36.774.72
Eastern Europe	537.00	19.100.00
Former Soviet Union	8.221.08	107.716.71
Germany	107.00	899.64
India	1.020.00	12.796.76
Japan	225.82	863.92
Mexico	1.007.24	8.743.43
Middle East	568.92	30.591.80
Other Developing Asia	2.873.36	63.638.68
South Korea	28.90	776.28
United States of America	5.171.68	34.543.66
Western Europe	460.00	8.920.76
Global	47.873.70	927.947.14

TIAM-IER



- Based on ETSAP TIAM
- structure:
  - 16 world regions
  - up to 42 energy service demands per region
  - Base year 2005 2015 (‚IEA World Energy Balances‘)
  - OPEC status 2019: →

Region	TIAM OPEC-member
AFR	Algeria; Angola; Libya; Nigeria; Gabon; Republic of the Congo; Gabon
CSA	Ecuador, Venezuela
ODA	-
MEA	Iran; Iraq; Kuwait, Saudi Arabia, UAE

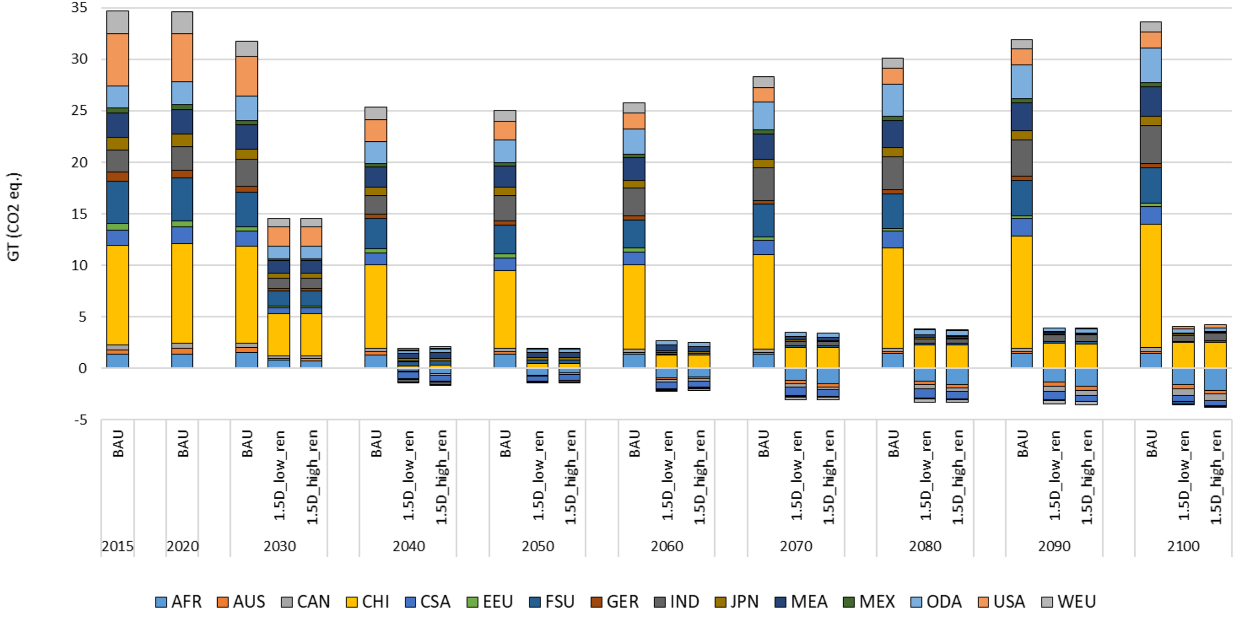
  - Temporal resolution: 12 timeslices per year

Scenario definition

- BAU (Business as usual):
  - No climate policies
- 1.5D_low_ren:
  - Carbon Budget starting 2020: 420 Gt [4] to achieve the 1.5° target
  - No CCS until 2040
  - Renewables potential according to low estimation availible in 2050
- 1.5D_high_ren:
  - Carbon Budget starting 2020: 420 Gt to achieve the 1.5° target
  - No CCS until 2040
  - Renewables potential according to high estimation availible in 2050

[4] IPCC, Mitigation Pathways Compatible with 1.5°C in the Context in the Context of Sustainable Development; 2018

Scenario comparison CO2 Emission World

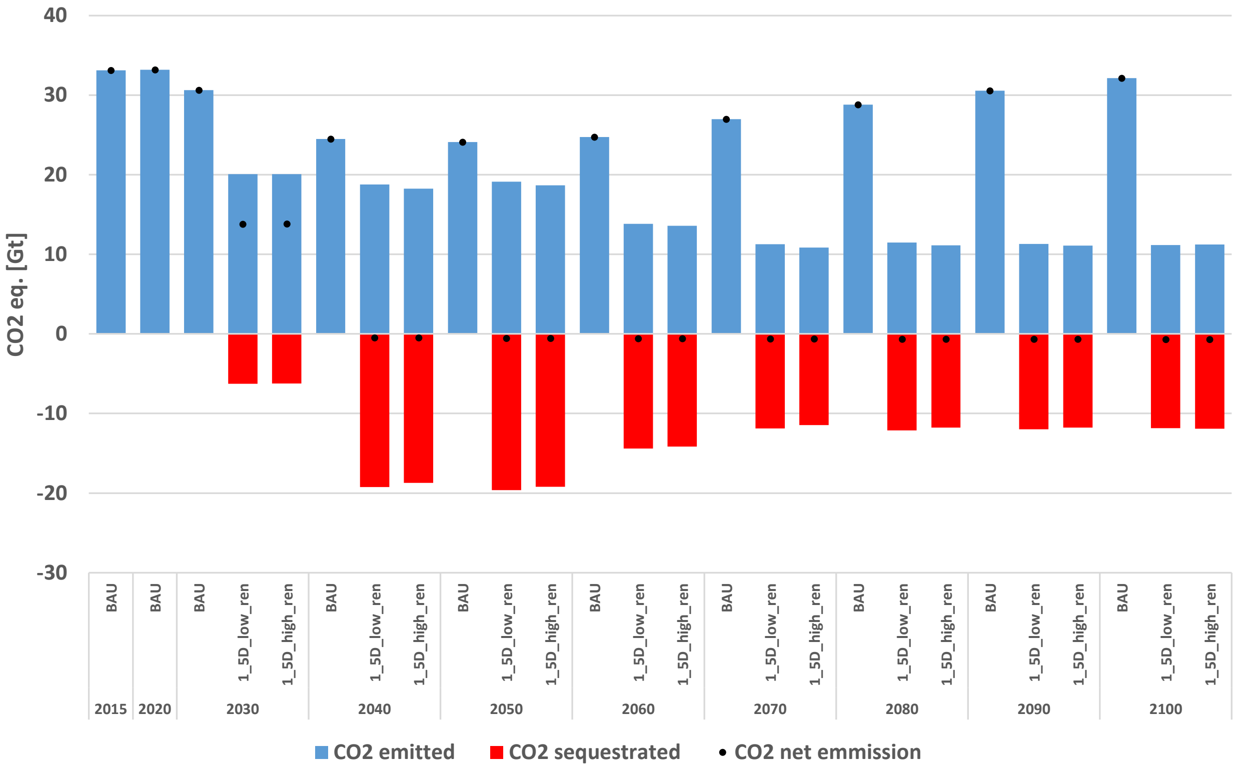


- Till 2100 there will be still CO2 emissions coming from the industry (process emissions).

  The different renewable potential haven’t any impact to the role of the regions related positive or negative CO2 Emissions.

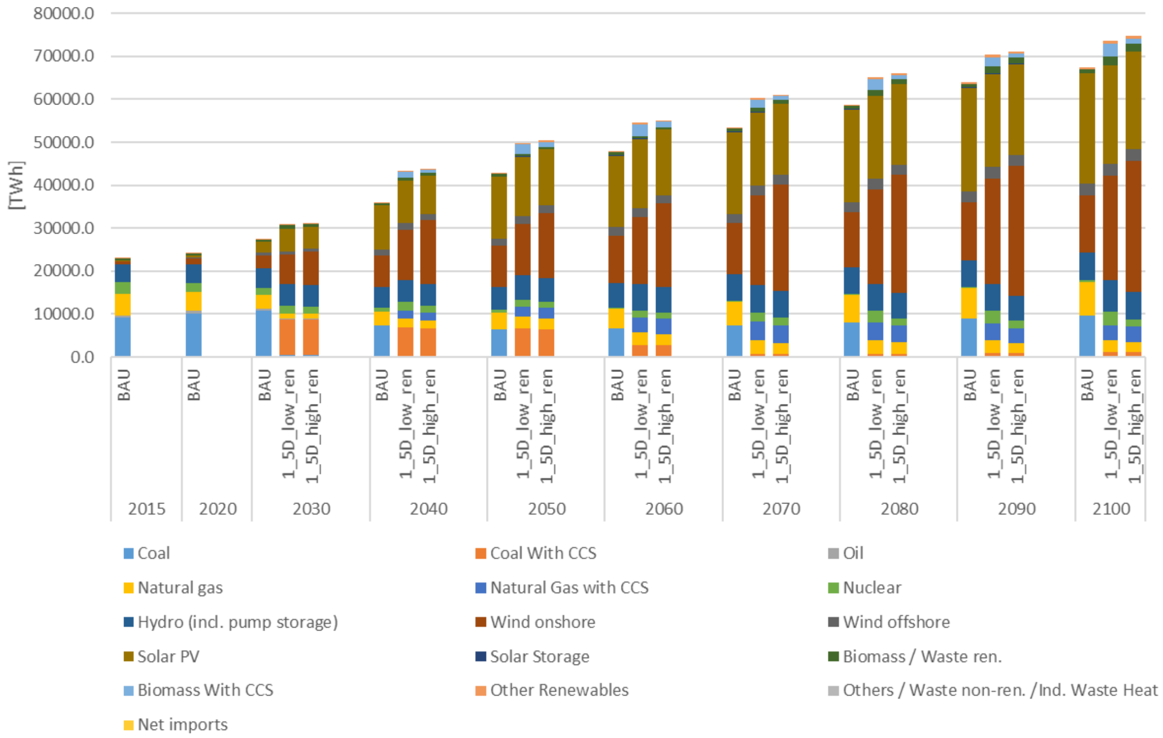
  The GDP growth and the production structure in the regions have an impact to the emission balance of the regions.

Scenario comparison net CO2 Emission balance World



- In the 1.5 °C scenario we already achieve net zero emissions in 2040.
- This is based on negative emissions from BECCS.
- In the long term there is no difference depending on the availability of renewables.

Scenario comparison Electricity generation world



- After 2040 the share of renewable electricity generation is higher then the conventional sources
- At the end of the century 50% based on VRE sources.
- The main differences will come from the wind onshore and offshore potentials in the high renewable scenario.

Conclusion and outlook

- Land use and social criteria have an impact on the available potentials of renewable energy source.
- The renewable potential has an impact on the quantity to use electricity to decarbonization the energy system.
- The use of emission free energy carriers like Synfules and Hydrogen depend on the optimal economical connection between renewable electricity generation, production system and transport to the end-users.
- The coupling of GIS based analysis systems and a world wide energy system helps to indicate the demand for the future and the optimal place allocation. The results will be presented an discussed in a series of workshops.

Thank you for your attention !!

Results of the project ETSAP Germany

Gefördert durch:

Bundesministerium
für Wirtschaft
und Energie

aufgrund eines Beschlusses
des Deutschen Bundestages

Renewable Potentials TIAM (TUM)

TIAM Regions	%Land available	Power Potential GW	Energy Potential TWh	%Land available	Power Potential GW	Energy Potential TWh
Africa	72,86	151559,41	170439,34	36,33	1162134,78	2424764,26
Australia	67,62	37444,38	69408,35	41,24	351577,54	736250,27
Canada	57,23	39656,41	45890,46	21,33	109452,89	96253,68
Central & South America	59,50	73596,12	54882,56	15,50	283965,77	543836,23
China	62,77	40990,24	45890,46	16,03	137741,57	240150,83
Eastern Europe	31,49	2036,65	2218,46	1,84	1419,35	2023,30
Former Soviet Union	71,37	110574,99	123896,76	15,35	222910,71	285630,26
Germany	11,44	284,84	558,76	1,24	341,63	431,62
India	50,69	11124,21	8690,60	5,15	17410,80	31611,93
Japan	30,68	795,42	833,98	0,76	268,29	404,74
Mexico	65,07	8840,03	6096,11	22,84	47235,76	93199,43
Middle East	77,10	31911,50	35390,04	54,62	340145,41	690978,85
Other Developing Asia	57,92	34443,26	23066,82	15,91	126524,86	224919,26
South Korea	26,37	183,99	192,92	0,53	50,93	81,68
United States of America	53,94	35491,82	49294,82	13,69	111868,72	188404,22
Western Europe	22,98	8799,52	10270,30	5,07	16974,63	20683,13