Carbon neutral archipelago – 100% renewable energy supply for the Canary Islands

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Fachkonferenz der BMWi Exportinitiative: Energieeffizienz und erneuerbaren Energien für Nichtwohngebäude auf den Kanarischen Inseln

Tenerife, 7.6.2018

Overview

- ➢Objective of decarbonisation
- ➢Methodology
  - Scenario development
  - Modelling approach
- ➢Resulting concept for the energy system
  - Transformation pathways for the heat sector
  - Power system optimization
  - Emissions
- ➢Conclusions

Objective

Background: Global carbon budget → 70-90% GHG reduction by 2050 → complete decarbonisation of the energy system is necessary

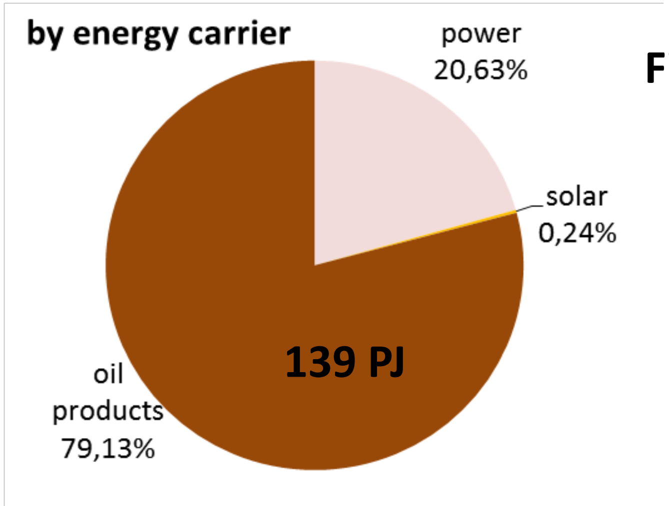
Main objective: Development of a consistent and robust transformation concept towards **100% renewable energy systems**

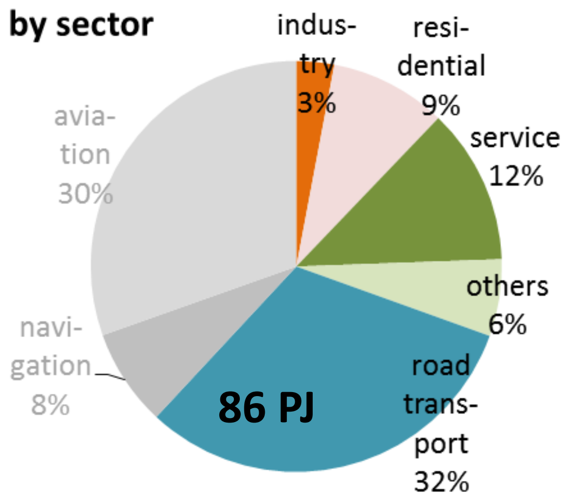
→ Assessing feasibility and viability

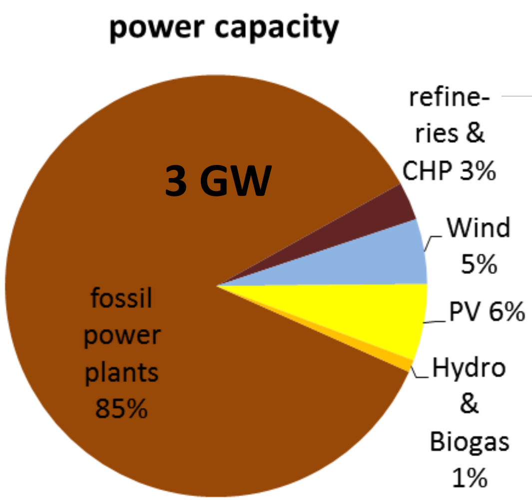
→ Targeting the **Canary Islands**: remote, today largely dependent on fossil fuels & mainly on imports

Current energy system on the Canary Islands

Final energy demand 2015

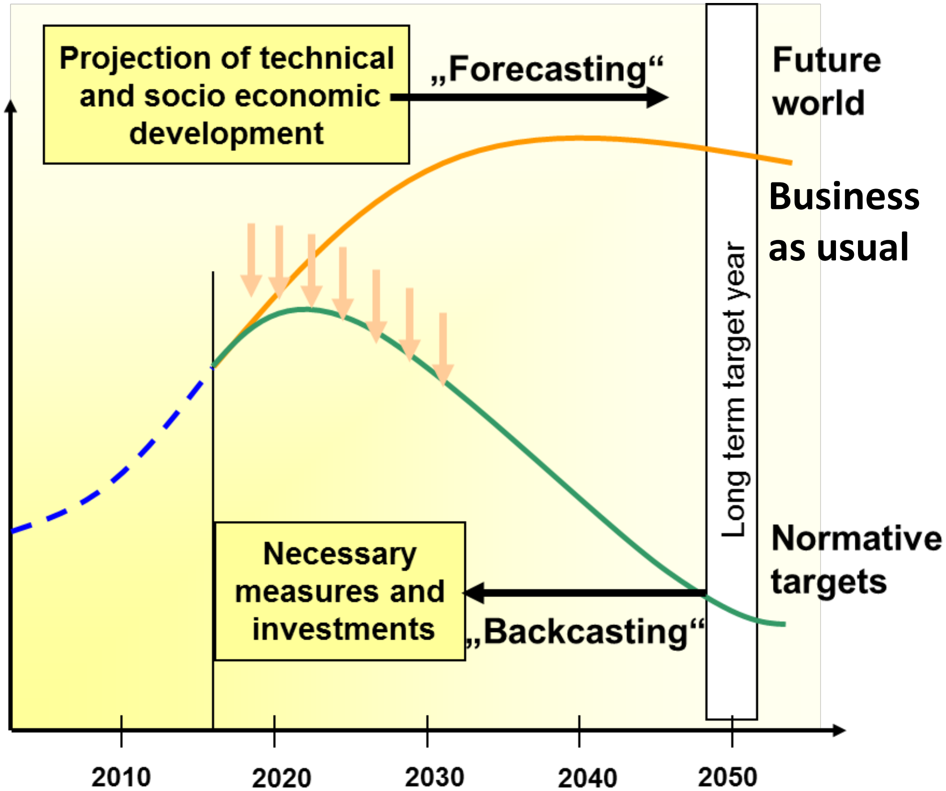






Scenario approach: target orientation and backcasting

- Target: **100%RE** in 2050
- Including **proven** technologies
- Exploiting **efficiency** potentials
- Assessing effects of **sector coupling**
- Optimizing demand and supply in 100% RE power system with high shares of **Variable Renewable Energy** (VRE) in 2050
- **Backcasting** of transformation pathways for the heat, transport and power sectors



Energy System Modelling

Joint model input and technology representation

Technologies: power, heat & transport technologies (RE & fossil)

REMix-EnDAT

RE potentials

MESAP-PlaNet

Simulation & Backcasting

Model coupling

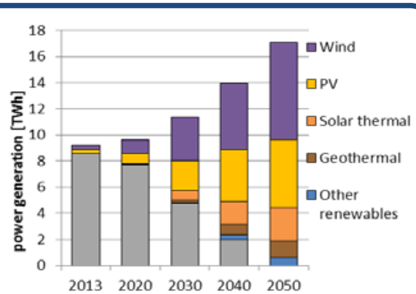
Energy demand development

System configuration at final stage

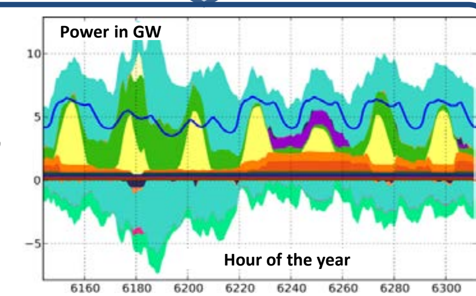
REMix-OptiMo

Least cost optimization of supply
Temporally and spatially resolved

System transformation pathways



Hourly generation, transmission and balancing



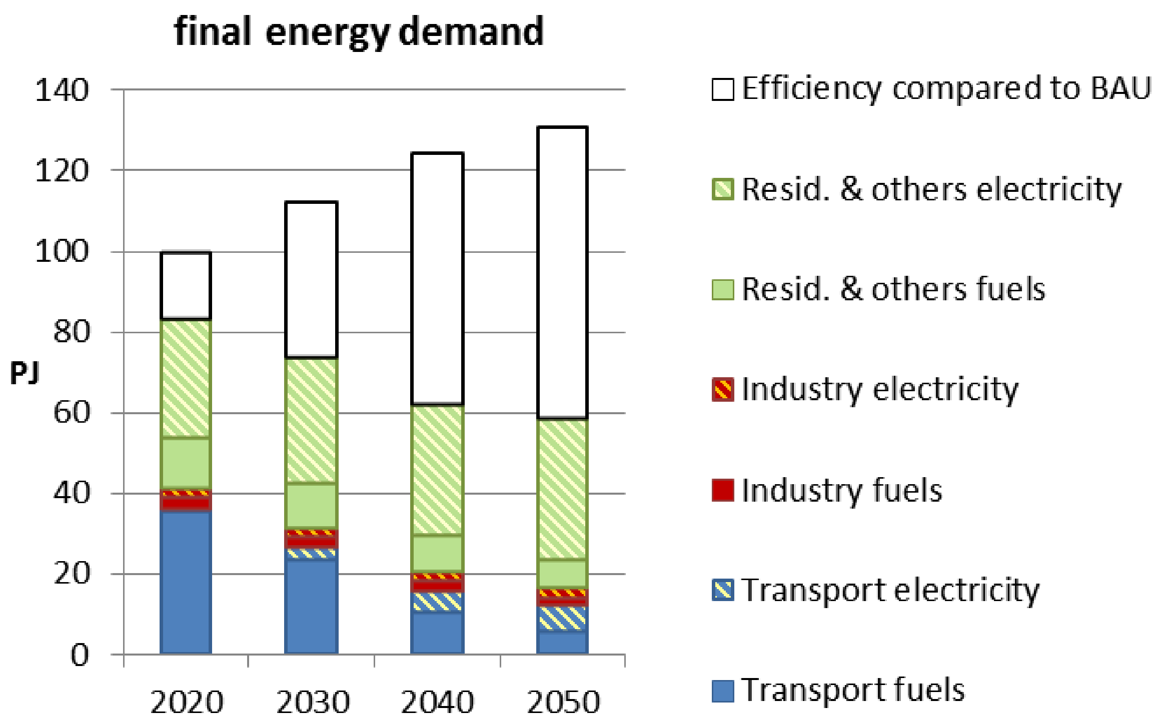
Renewable energy potentials by island

	Photovoltaics	Concentrating Solar Power (CSP)	Wind onshore	Wind offshore fix	Wind offshore floating
	MW	MW (th)	MW	MW	MW
El Hierro	39	0	58	107	342
Fuerte-ventura	477	8892	1824	846	2592
Gran Canaria	2205	1523	896	332	1510
La Gomera	67	0	106	139	696
La Palma	224	0	116	171	771
Lanzarote	581	2157	512	589	1660
Tenerife	2876	0	388	428	1414
Total	**6,468**	**12,572**	**3,900**	**2,612**	**8,985**

Limited potential for hydro, wave, geothermal and biomass (total 2.5 GW)

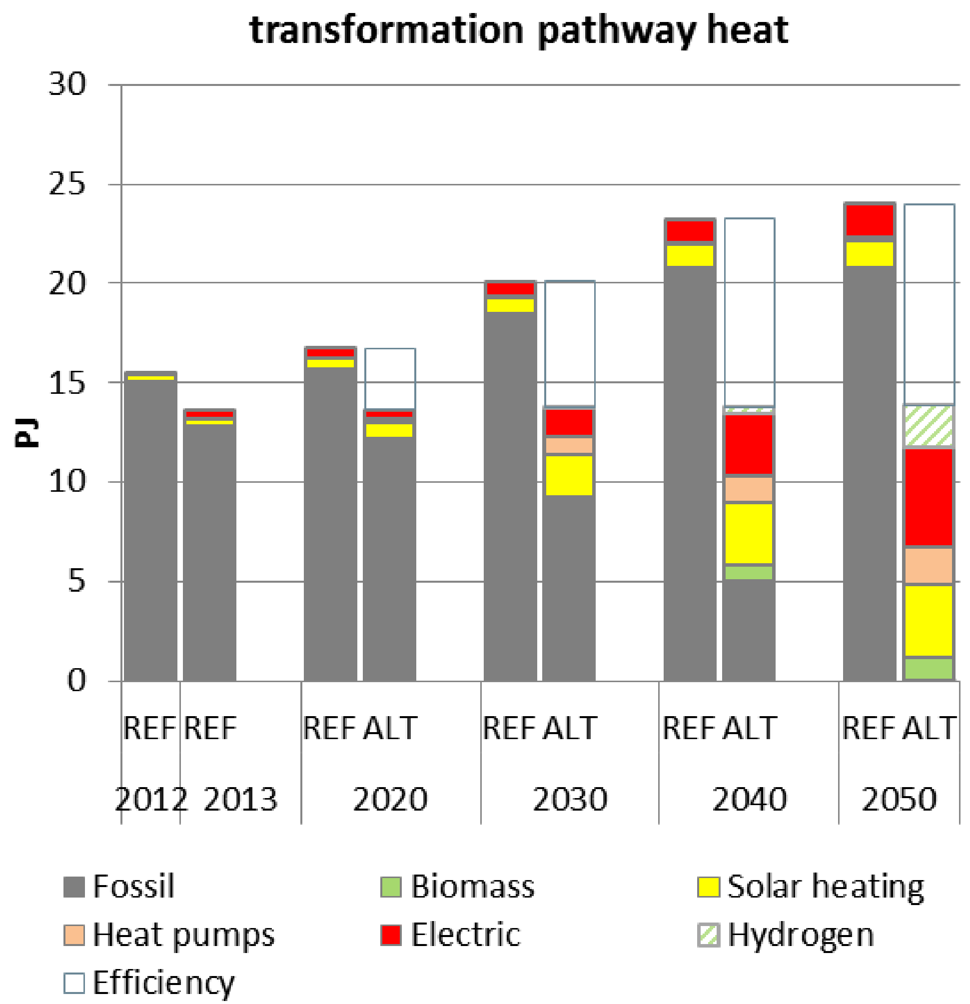
Demand assessment

- Reference scenario based on assumptions for Spanish demand developmen
- Efficiency potentials based on best available appliances
- Efficiency via electrification of heat and transport based on wind and solar
- Additional power demand for heat, transport & synthetic H_2

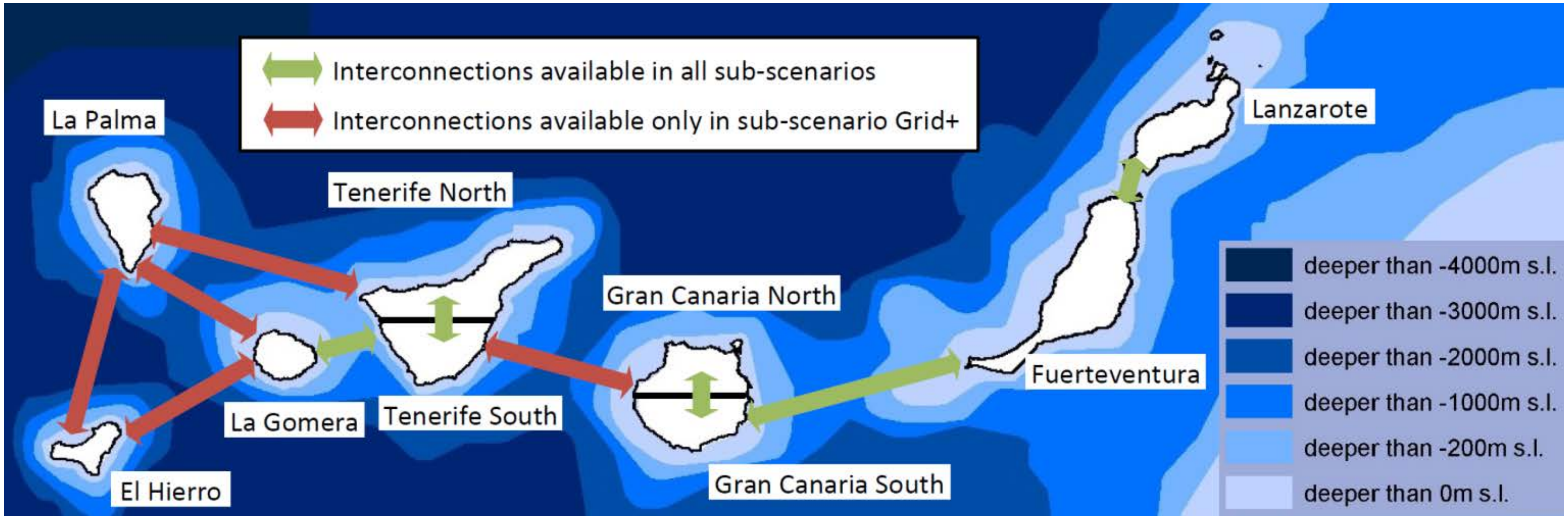


Transformation pathways for the heat sector

- ➢Electric heat supply necessary to transform the complete system
- ➢Hot water (& heating) for residential and service: heat pumps and solar
- ➢Efficient CHP from biomass
- ➢High temperature process heat→ hydrogen, if biomass is not available



Power Optimization for 100% renewables by Island



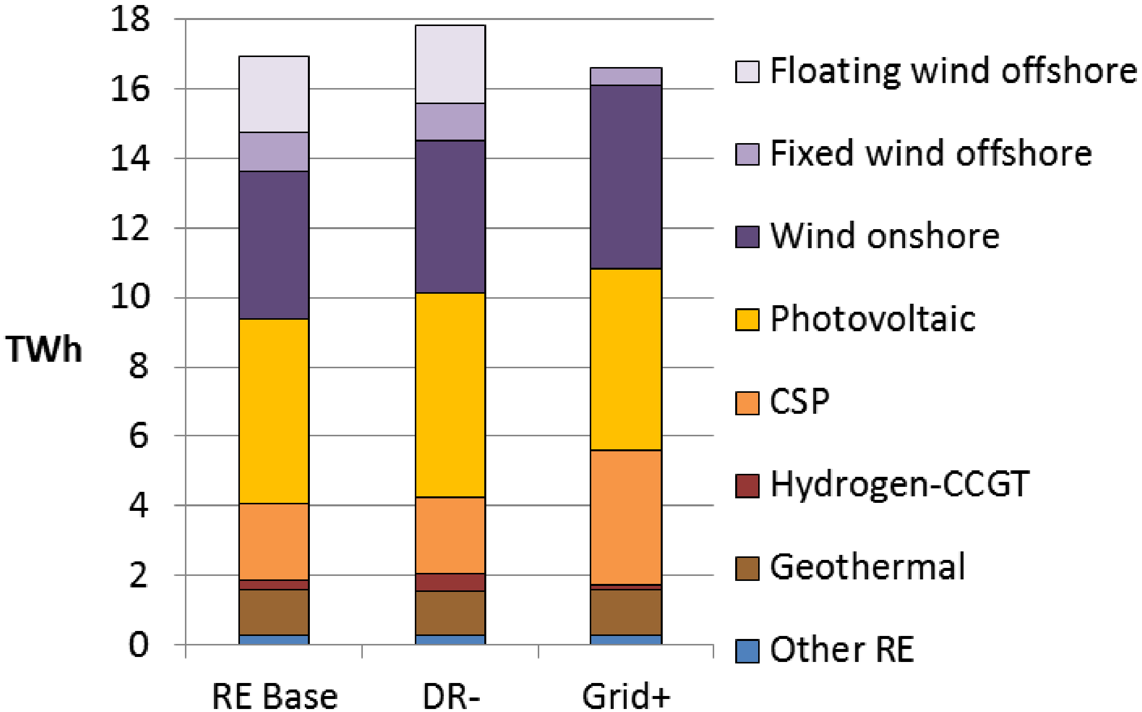
- Sub-Scenarios targeting effects of
  - existing and planned power grid (RE Base)*
  - demand response (DR-)
  - additional grid connections (Grid+)

*according to REE

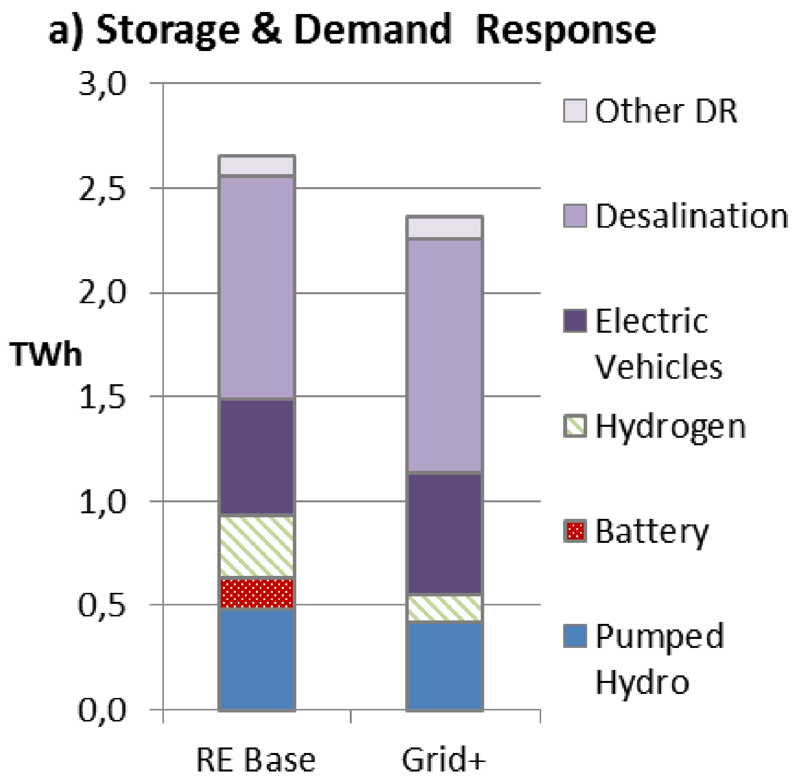
Optimization results power supply for 2050

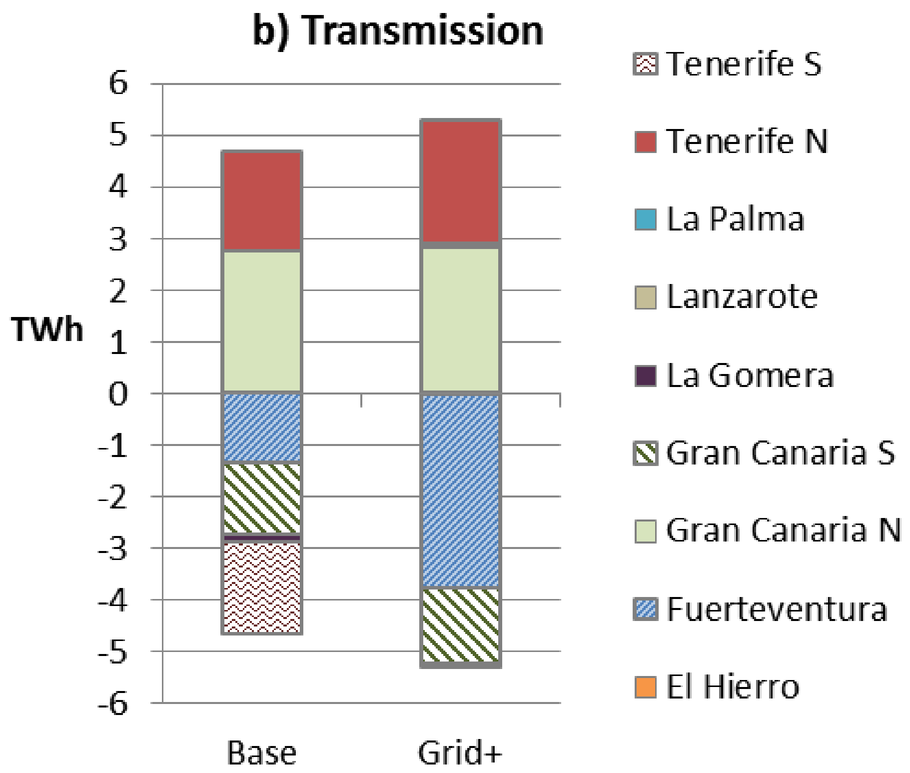
- ➢PV and Onshore Wind potentials are exploited to a large extent

- ➢Additional inter-island grid connections favour CSP & onshore wind and reduce (expensive) floating offshore wind installations



Optimization results power supply for 2050



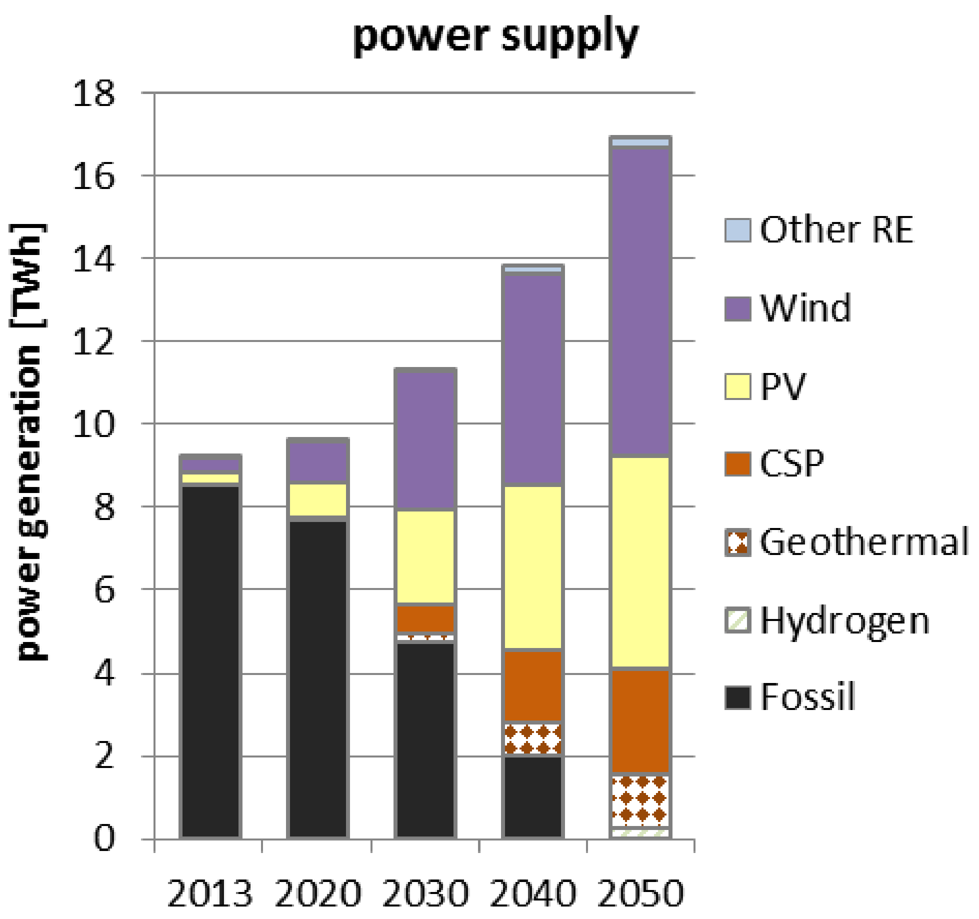


- 25 % of total power production is transmitted to other regions
- Grid expansion taps wind potential in Fuerteventura & provides a potential to reduce system costs by 15%

Transformation pathways for the power sector (RE Base)

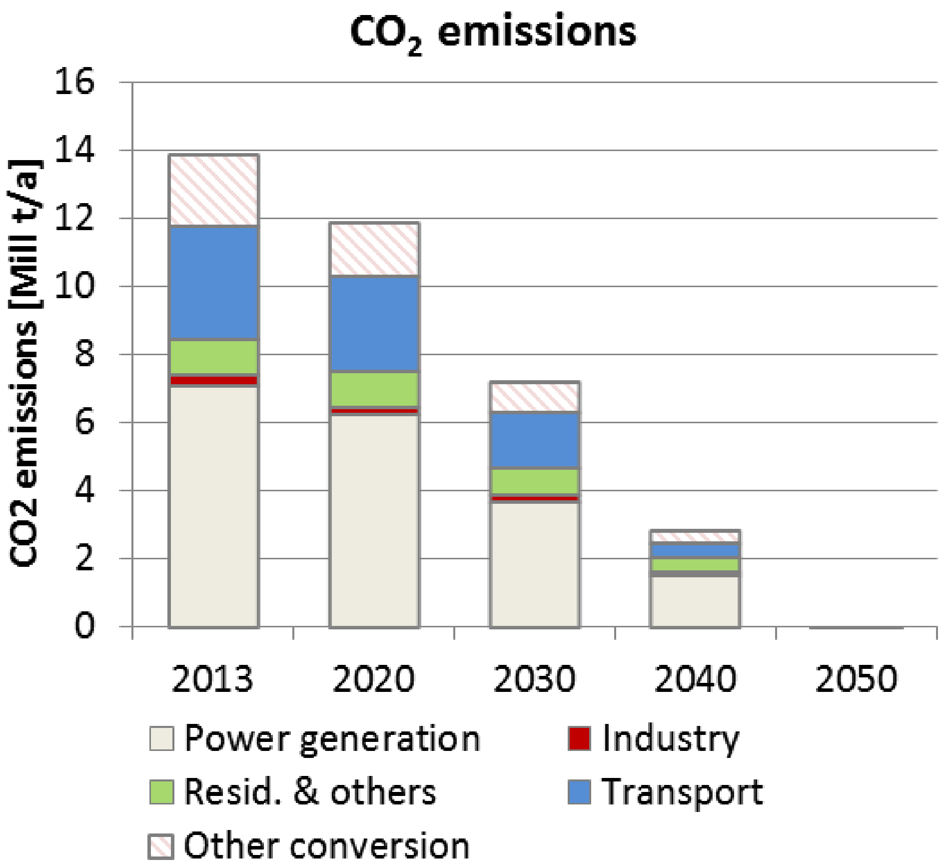
- Significant expansion of wind & PV necessary before 2030
- Relevant shares of dispatchable power generation necessary from 2030 on in order to phase out fossil power
  - Geothermal
  - CSP
  - RE Hydrogen

Early diversification is important!



Resulting CO_2 emissions and costs

- Phase out of direct CO_2 emissions by 2050
- In the power sector 70% of VRE are backed up by CSP and grid extension at costs of around 17-20 €ct/kWh
- Additional storage and grid infrastructures account for 1/3 of the costs



Main Insights and Challenges

Challenges in the heat and transport sector:

- Tapping efficiency potentials first → renewable electrification
- Exploiting low temperature solar heat as well as ambient & waste heat with heat pumps
- Heat storage can serve as a “sink” for variable power supply
- High cost and low efficiency of future fuels →direct electrification first
- High temperature applications: must be supplied by electricity as well

Main Insights and Challenges

Challenges for the power sector: Integration of Variable Renewables - Challenge of System stability

- ➢Grid extentions are essential for cost efficiency
- ➢Secured capacity at early stages from CSP & geothermal, later supplemented by H_2 or PtX
- ➢Adaptation to steep power ramps is necessary

→Sector coupling (heat storage, EV, hydrogen) is essential to tap the full VRE potential for all sectors

Summary

- Our scenarios provide insight, what is **necessary** to completely phase out CO_2 emissions in Island energy systems

- Efficiency and renewable energy potentials need to be exploited simultaneously and early on

- **Our results show, that the Canary Islands can completely provide their own heat and road transport supply as well as an increase power demand can be securely supplied by RE in 2050; but the challenges is to start now!**

Thank you for your attention!

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Publications

Gils, H.C. and Simon, S. (2017) Carbon neutral archipelago – 100% renewable energy supply for the Canary Islands, Applied Energy, 188: 342-355. http://dx.doi.org/10.1016/j.apenergy.2016.12.023

Gils, H. C.; Scholz, Y.; Pregger, T.; Luca de Tena, D.; Heide, D., Integrated modelling of variable renewable energy-based power supply in Europe. Energy 2017, 123, 173-188. http://dx.doi.org/10.1016/j.energy.2017.01.115.

Krewitt, W., Teske, S., Simon, S., Pregger, T., Graus, W., Blomen, E., et al. (2009) Energy [R]evolution 2008 - a sustainable world energy perspective. Energy Policy;37: 5764-75. http://dx.doi.org/10.1016/j.enpol.2009.08.042

Krewitt, W., Simon, S., Graus, W., Teske, S., Zervos, A., Schäfer, O. (2007) The 2°C scenario - A sustainable world energy perspective. Energy Policy;35: 4969-80. http://dx.doi.org/10.1016/j.enpol.2007.04.034