Hybrid Mini-Grids:
A Huge Market for Rural Electrification and Island Energy Supply

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Reiner Lemoine Institute

Research focuses:

- **Integrated energy systems**
  - Optimization of energy systems
  - Energy transition processes
  - Off-grid energy systems
- **Mobility with renewable energies**
  - Integration of renewable energies into e-mobility
- **Renewable energy technology**
  - Small wind power

Reiner Lemoine
Founder of the Reiner Lemoine-Foundation

Scientific research for an energy transition towards 100% renewable energies

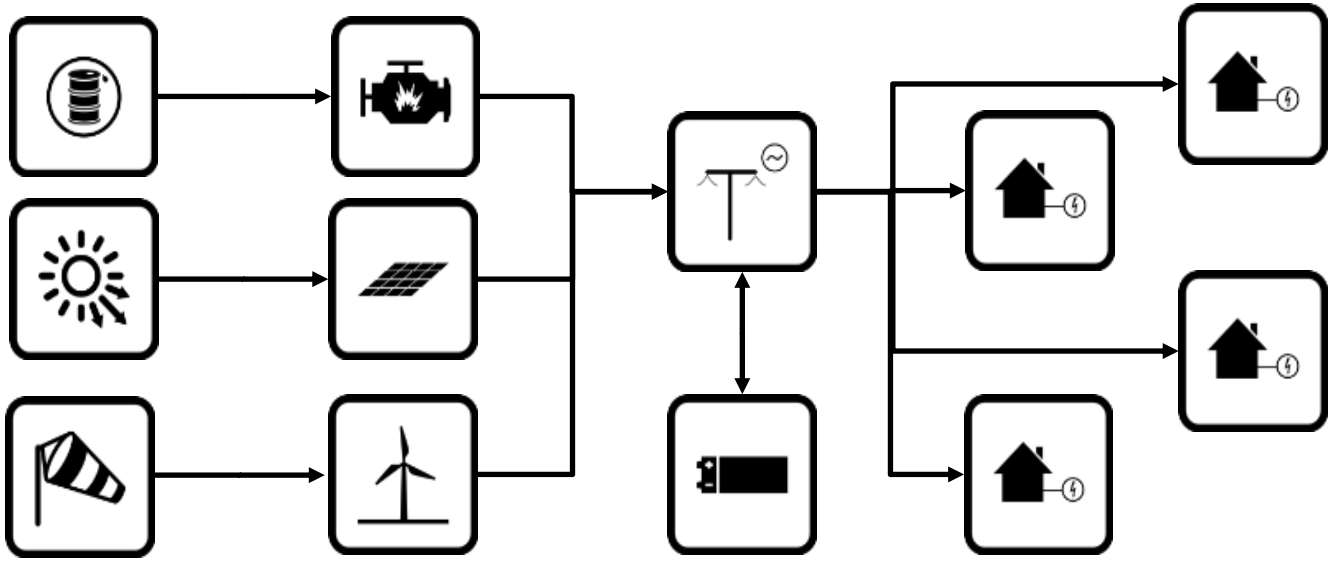
Outline

- Introduction: Mini-Grids
- Rural Electrification
- Island Energy Supply
- Summary + Discussion

Definition Hybrid Mini-Grid

A **hybrid Mini-Grid** combines at least two different kinds of technologies for power generation and distributes the electricity to several consumers through an independent grid.

Thus, the mini-grid is supplied by a mix of renewable energy sources and a genset, generally supplied with diesel, used as a back-up.



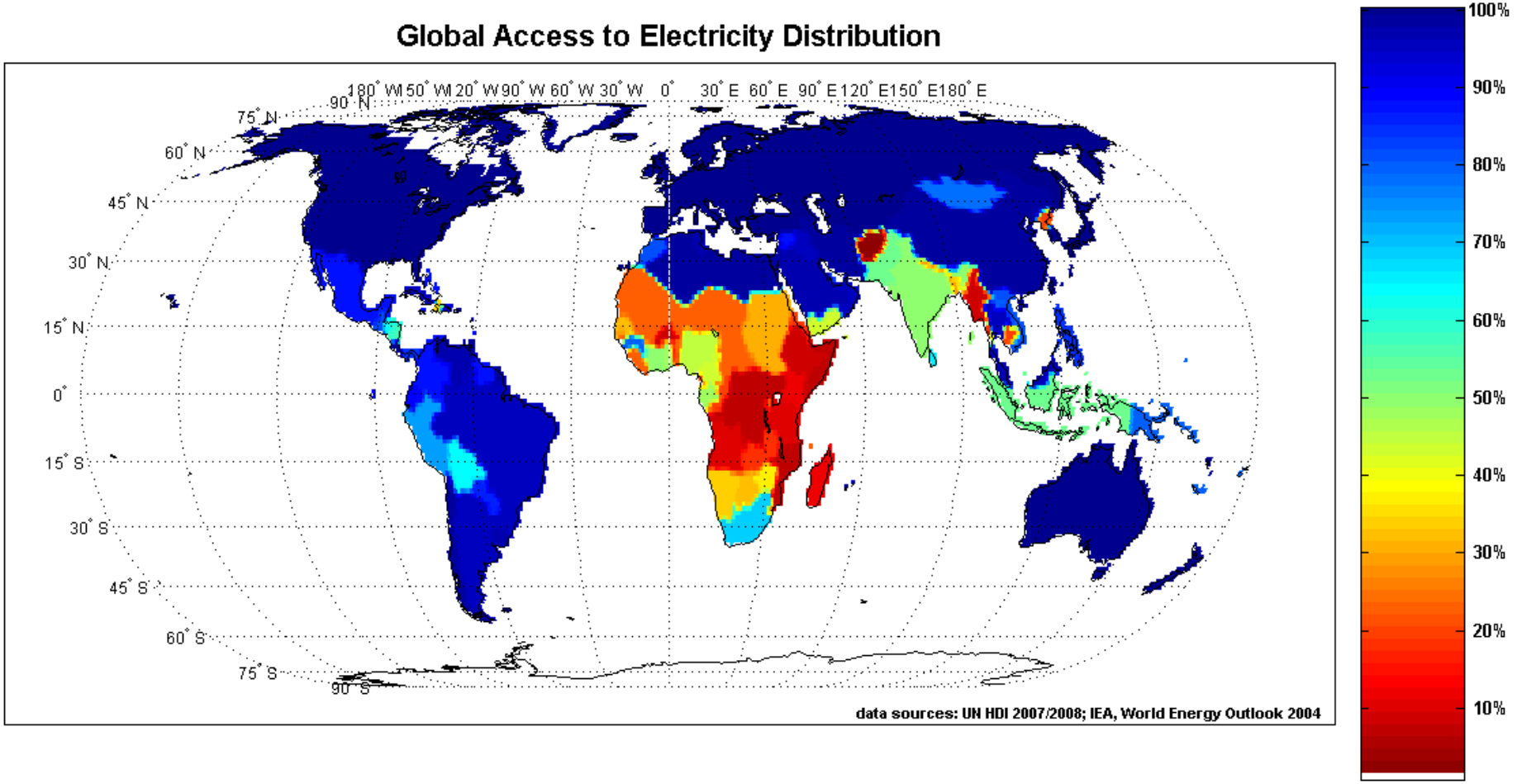
Specific Applications for Hybrid Mini-Grids

- Enabling power supply for non-electrified areas
- Support pico-electrified (solar home systems) areas
- Ensure quality of supply in on-grid areas
- Substitute diesel-only Mini-Grids

Rural electrification

Islands

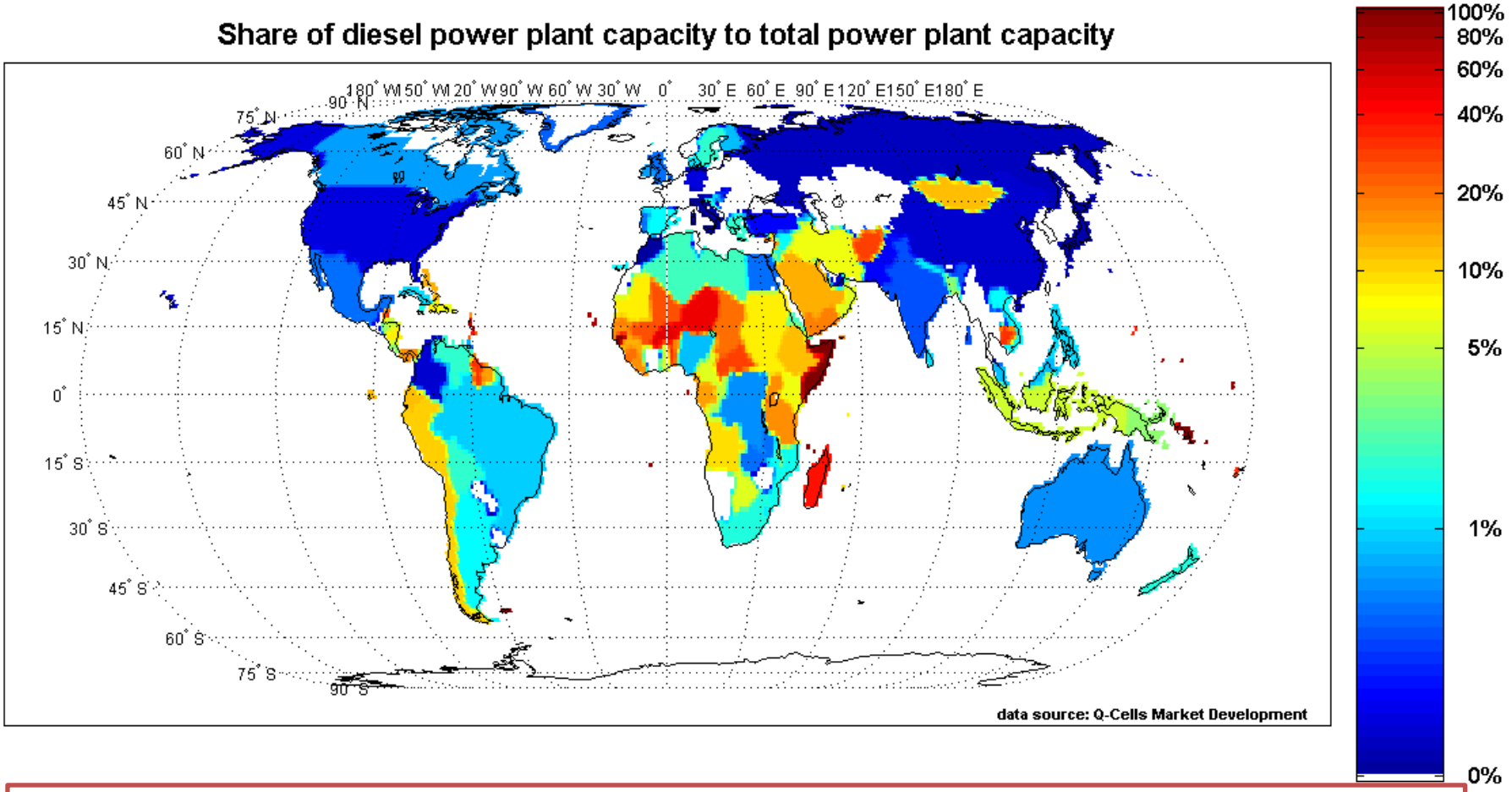
1.3 Billion People without Access to Electricity



Source:

Breyer Ch., Werner C., et al., 2011. Off-Grid Photovoltaic Applications in Regions of Low Electrification: High Demand, Fast Financial Amortization and Large Market Potential, 26th EU PVSEC, Poster 5BV.1.45

Diesel-Grids worldwide



The higher the diesel share the more local diesel-grids can be expected.

Source:

Breyer Ch., Werner C., et al., 2011. Off-Grid Photovoltaic Applications in Regions of Low Electrification: High Demand, Fast Financial Amortization and Large Market Potential, 26th EU PVSEC, Poster 5BV.1.45

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  - Un-Electrified and Pico-Electrified Regions
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PV-based Mini-Grids for Electrification in Developing Countries

(published at
http://www.sma-stiftungsverbund.de/de/downloads/elektrifizierung-netzferner-regionen.html)

Geodata-referenced Cost Analyses

national diesel price + **road network** + **renewable sources** =

cost-optimized hybrid mini-grid

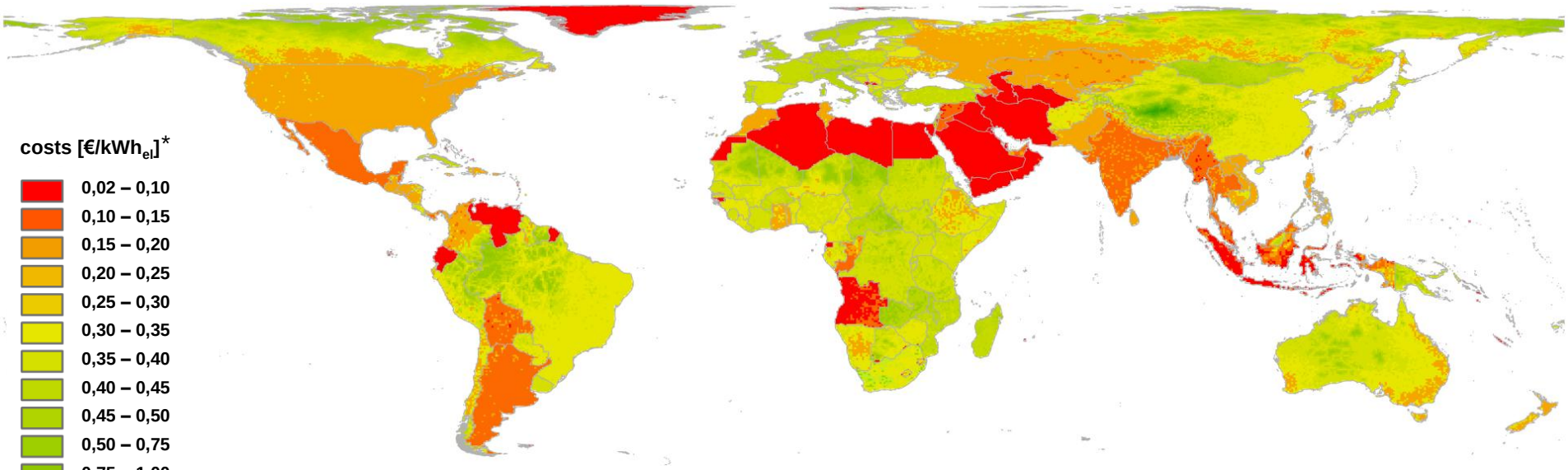
- Hybrid Mini-Grids compete with grid extension and pure diesel-grids.
- Increasing **distance to the national grid** makes grid extension improvident.
- High **national diesel prices** make pure diesel-grids improvident.
- Increasing **distance to large trade routes** leads to high transport costs for diesel.

With high local diesel prices and redundant renewable energy sources in rural areas hybrid Mini-Grids become competitive.

Source:
PV-based Mini-Grids for Electrification in Developing Countries, Ch. Breyer et al., 2012. study on behalf of SMA Stiftungsverbund

Local Diesel Price Worldwide

Electricity generation costs of pure diesel grids



costs [€/kWh$_{el}$]*

- 0,02 – 0,10
- 0,10 – 0,15
- 0,15 – 0,20
- 0,20 – 0,25
- 0,25 – 0,30
- 0,30 – 0,35
- 0,35 – 0,40
- 0,40 – 0,45
- 0,45 – 0,50
- 0,50 – 0,75
- 0,75 – 1,00
- 1,00 – 1,25
- 1,25 – 1,50
- 1,50 – 1,75
- 1,75 – 2,00
- 2,00 – 2,25

* 1 l diesel corresponds to approx. 3 kWh$_{el}$

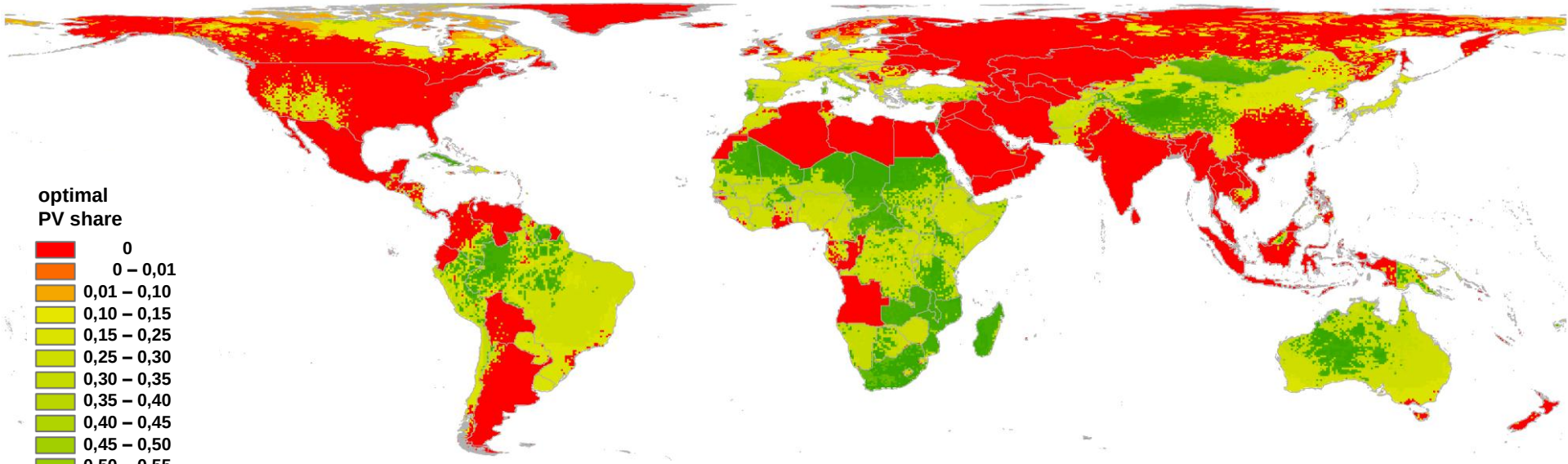
- Costs of local energy production depend highly on the diesel price.
- Subsidization and taxation of diesel have strong effects on costs.
- High diesel prices call for renewable energy sources for electrification.

model based on: *Energy solutions in rural Africa: mapping electrification costs of distributed solar and diesel generation versus grid extension*, Szabo S. et al., Environ. Res. Lett., 6, 034002 (2011).

Source:
PV-based Mini-Grids for Electrification in Developing Countries, Ch. Breyer et al., 2012. study on behalf of SMA Stiftungsverbund

Economically Optimal PV share

PV share in hybrid PV-battery-diesel systems

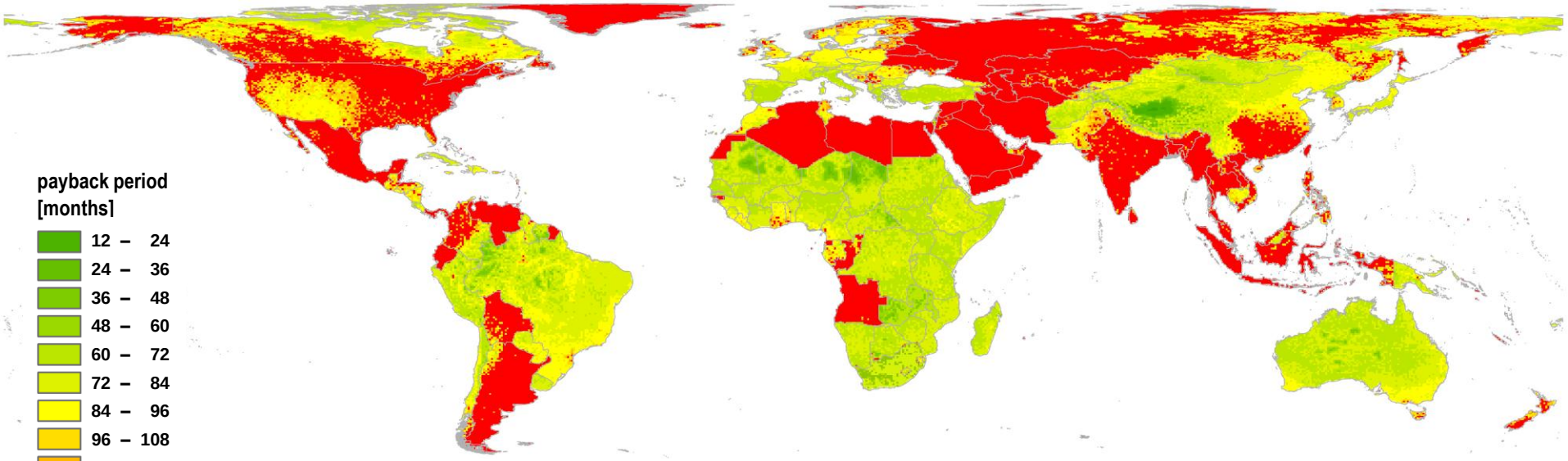


- 25% to 85% PV share of energy supply is economically optimal for current diesel prices.
- In areas where use of batteries is profitable, also evening- and night-hours can mostly be covered by PV, i.e. ca. 85 % PV share.
- PV becomes the backbone of rural electrification.

Source:
PV-based Mini-Grids for Electrification in Developing Countries, Ch. Breyer et al., 2012. study on behalf of SMA Stiftungsverbund

Global: PV Mini-Grids Payback Period

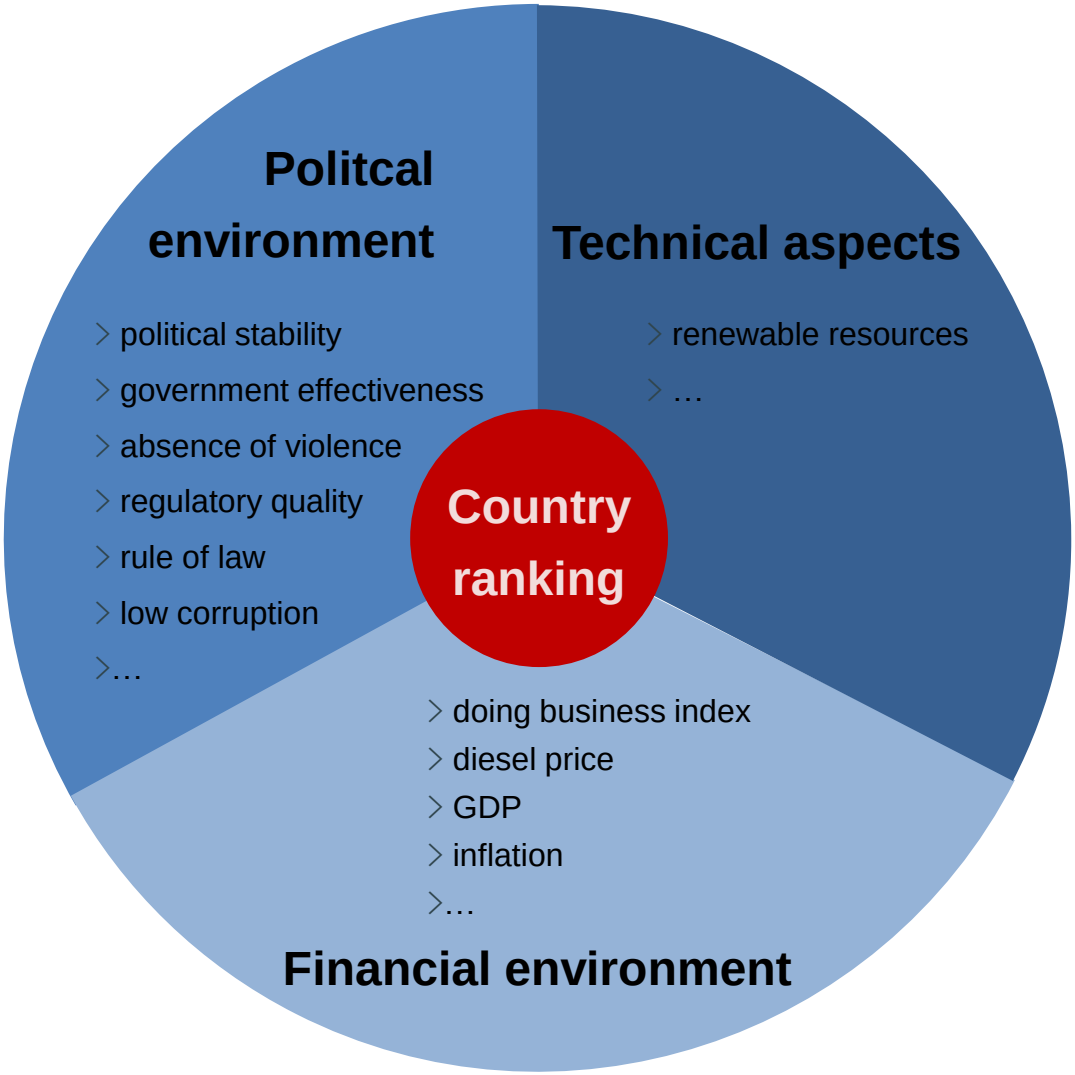
Amortization of hybrid PV-battery-diesel systems vs. diesel



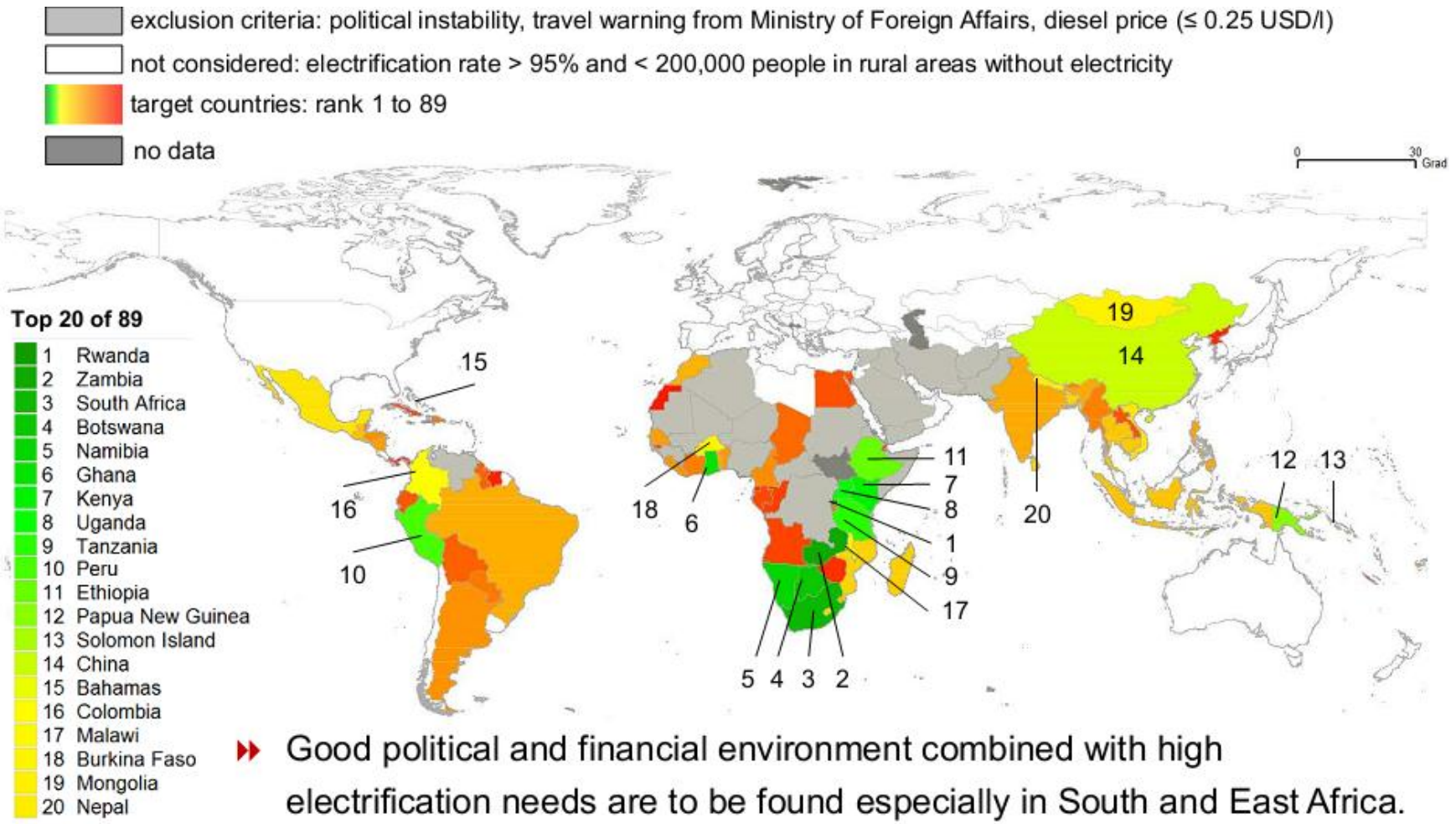
- The payback period of a PV Mini-Grid depends highly on the local diesel price.
- In many regions in Africa and South America very attractive payback periods of 5 – 7 years can be reached.
- In very remote areas very lucrative payback periods of less than 4 years arise for PV Mini-Grids.

Source:
PV-based Mini-Grids for Electrification in Developing Countries, Ch. Breyer et al., 2012. study on behalf of SMA Stiftungsverbund

Comparative Country Ranking



Comparative Country Ranking



- Good political and financial environment combined with high electrification needs are to be found especially in South and East Africa.

Source:
PV-based Mini-Grids for Electrification in Developing Countries, Ch. Breyer et al., 2012. study on behalf of SMA Stiftungsverbund

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  - Diesel Mini-Grids
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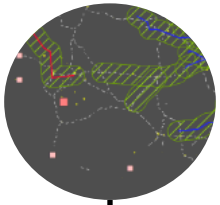
Methods: Localization of Diesel Mini-Grids

Global spatial information on country areas

Information on power plant inventory and locations from Platts database

Spatial extension of transmission grid

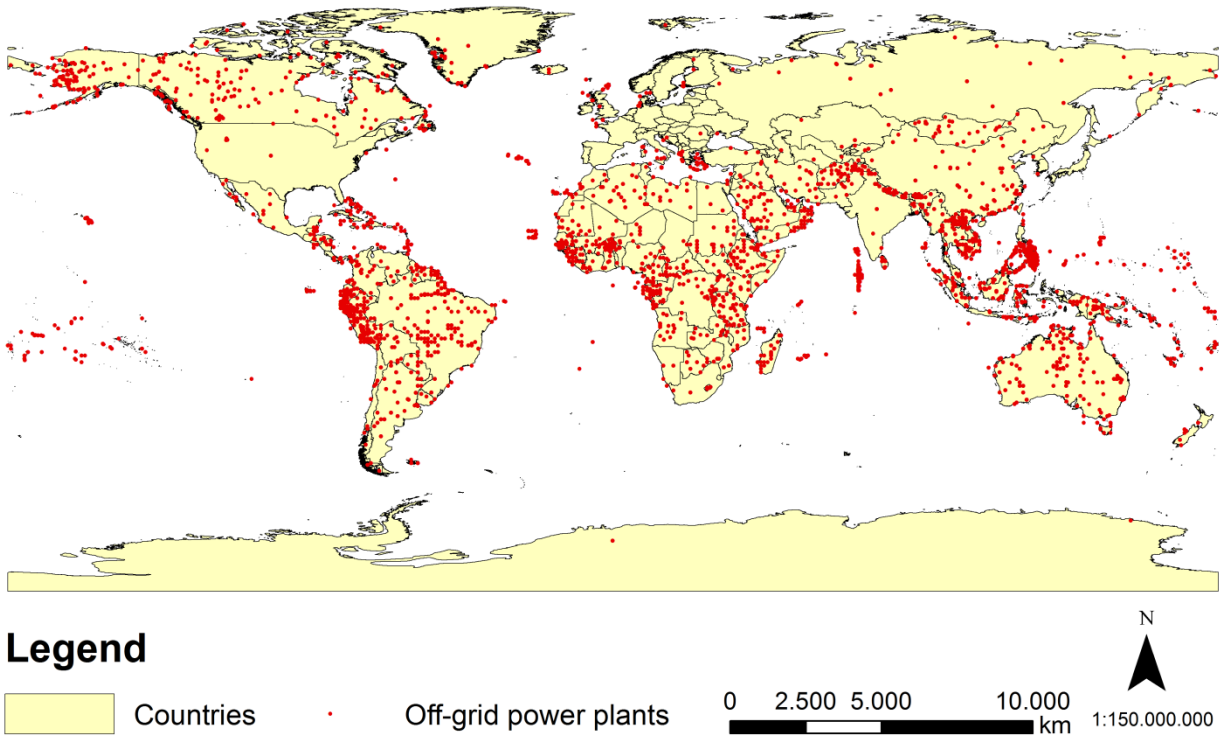


Extraction of 50 km buffer zone

Determination whether a power plant operates **on-grid** or **off-grid**

Source:
P. Bertheau: „Analysis of diesel-based mini-grids for enabling the implementation of renewable energies", Master's Thesis

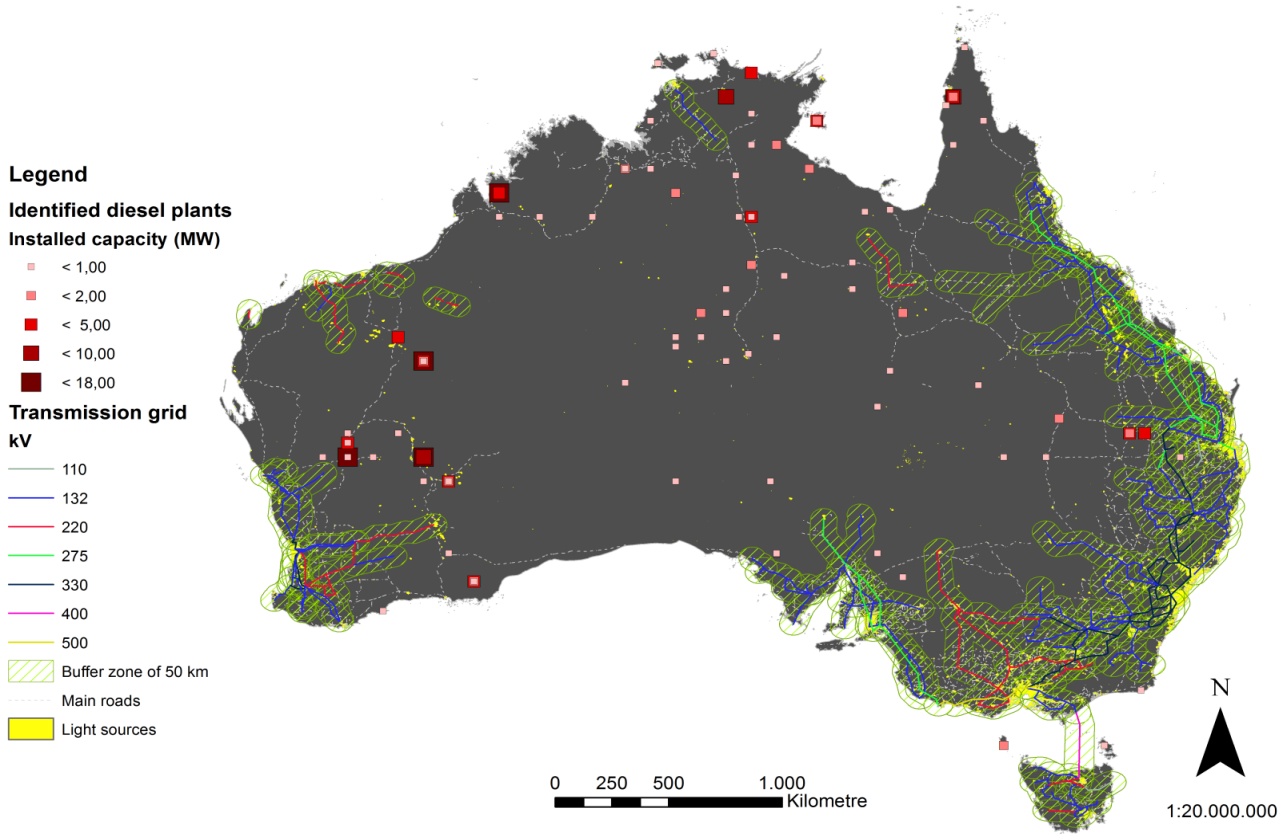
Deriving global Capacity



Global Diesel Mini-Grid capacity of minimum 20 GW

Source:
P. Bertheau: „Analysis of diesel-based mini-grids for enabling the implementation of renewable energies", Master's Thesis

Case Study Australia



Identified off-grid capacity: appr. 500 MW
Main purposes: Mining-supply and remote villages

Source:
P. Bertheau: „Analysis of diesel-based mini-grids for enabling the implementation of renewable energies", Master's Thesis

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Islands are very attractive Markets for RE

"An island is a naturally formed area of land, surrounded by water, which is above water at high tide"

Source: United Nations Convention on the Law of the Sea Part VIII, Article 121

Small islands are mainly powered by diesel power plants

Global Island Distribution

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Global Non-Continental Islands

Global distribution of islands.
Islands are defined as landmasses except the seven continents.

1:32.000.000
Coordinate system: World Robinson
Projection: Robinson
Datum: WGS 1984
Sources: www.gadm.org
December 2012

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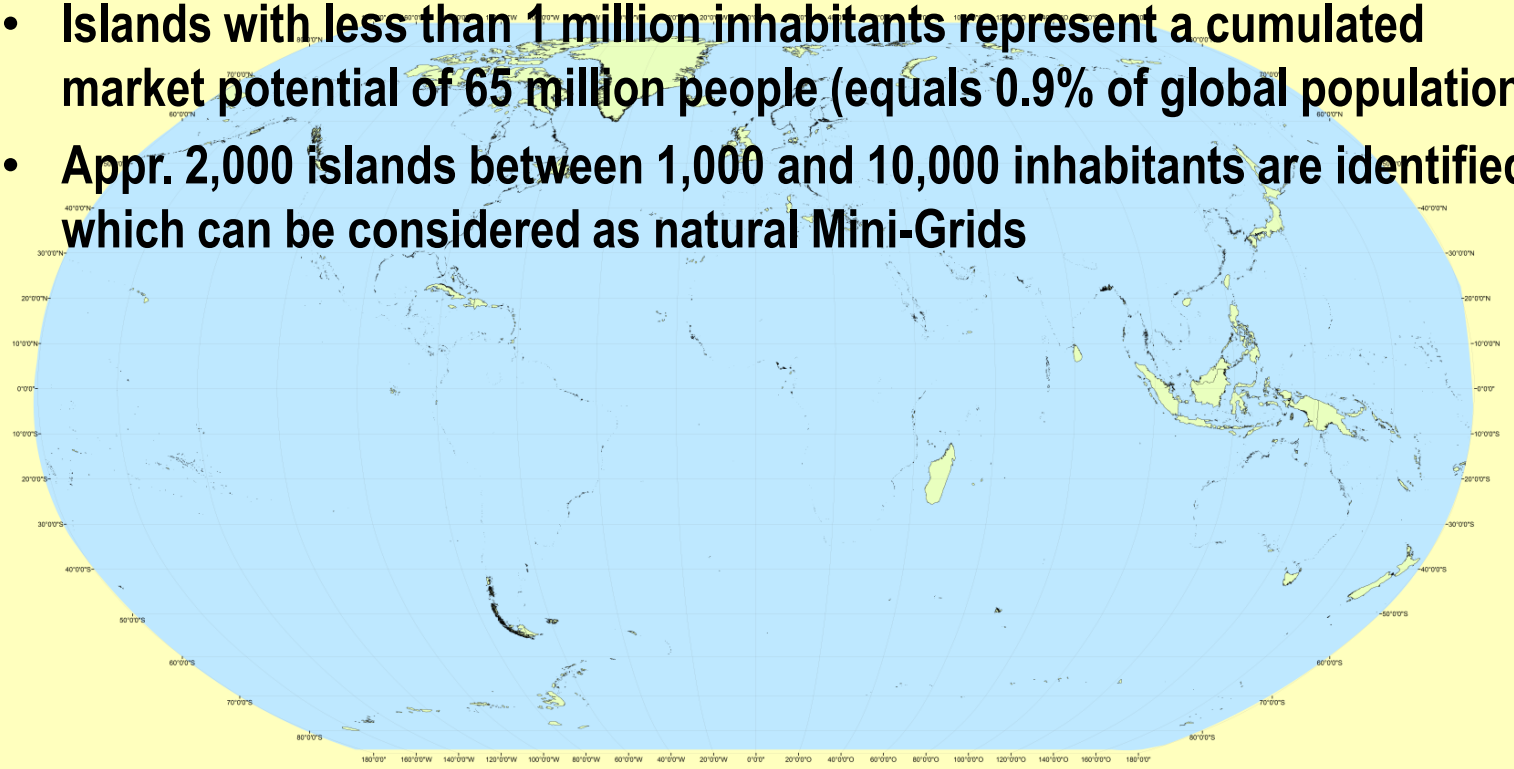
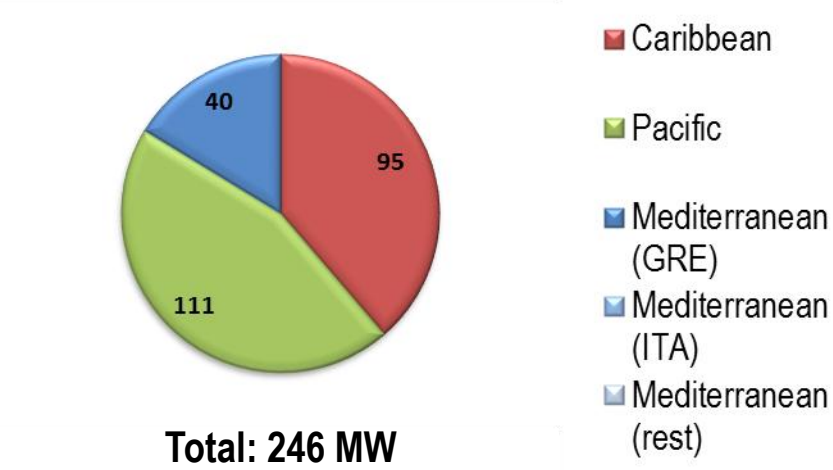
- **11% of the global population lives on islands.**
- **Islands with less than 1 million inhabitants represent a cumulated market potential of 65 million people (equals 0.9% of global population).**
- **Appr. 2,000 islands between 1,000 and 10,000 inhabitants are identified, which can be considered as natural Mini-Grids**



Market Potentials

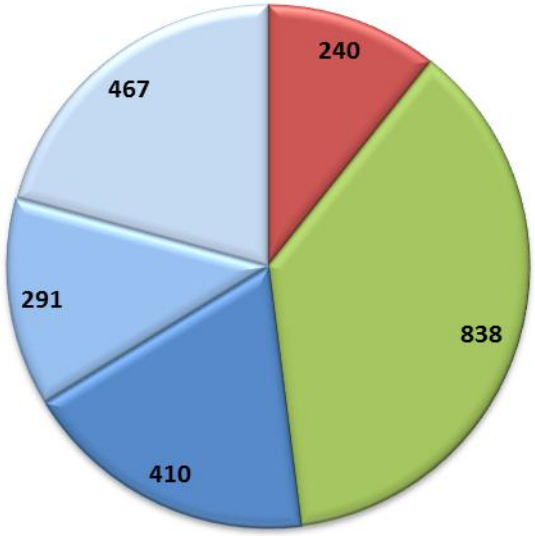
Market potentials of **renewable energy producers** (PV, Wind) on islands of **1,000 – 10,000 inhabitants** for different regions [MW].
Number of islands: CAR: 42, PAC: 367, MED: 61

conservative szenario
(low diesel price, high capital costs)



Total: 246 MW

aggressive szenario
(high diesel price, low capital costs)



Total: 2.246 MW

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Summary

Only few hybrid Mini-Grids are installed globally

- Even fewer operate sustainable and profitable

Huge potential in all four fields of application for hybrid Mini-Grids!

Challenges:

- Identification of market region
- Optimization of configuration
- Applying the best fitting operating / business model

Thank you!

And special thanks to the RLI off-grid team for providing the presented information

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