Alliance for Rural Electrification

Shining a Light for Progress

Potential of Off-Grid PV Technologies for Rural Electrification in Developing Countries

Reiner Lemoine Institut

- **Renewable Energy Mobility**
  - Mobility concepts based on RE
- **Renewable Energy Technology**
  - Small wind power applications
  - Technical integration of RE
- **Renewable Energy Systems**
  - Optimization of energy systems
  - Energy transition processes
  - Off-grid systems

Reiner Lemoine
Initiator of the Reiner Lemoine-Foundation and Institute

Scientific research and support for a transition towards 100 % renewable energies

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Off-Grid Systems

- Simulation and optimization of renewable energy systems
- Analyses with geo-information systems (GIS)
- Resource assessment (solar, wind, hydro)
- Market potential analyses & feasibility studies

Decentralized energy systems with high shares of renewable energies

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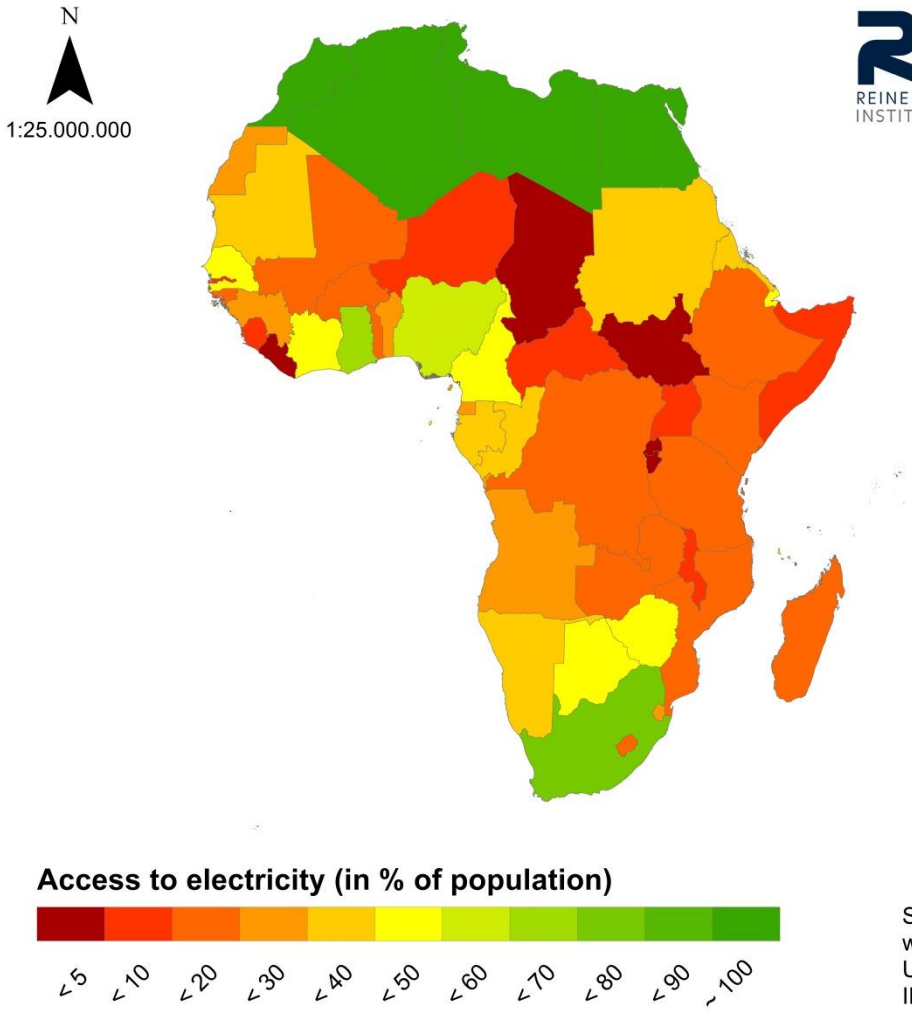
Motivation: Lack of Electrification in Africa



- 590 mn people without access to electricity
- Electricity access shares remain low although much effort is undertaken
- African energy sector faces very high power generation costs
- Significant parts of GDP are spent on subsidizing electricity prices

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Background:
Status Quo and Electrification Strategies

- **Access to electricity is a basic need and prerequisite for**
  - → Education
  - →Health care
  - →Economic development
- **Different electrification approaches:**
  - → Centralized approach:
    - Grid extension
  - → Decentralized approach
    - Solar home systems
    - **Diesel generator**
    - **Hybrid systems (e.g. PV-battery-diesel)**

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Background: Fuel Price Trend/Solar Price Trend

- Prices for crude oil have increased over the last years and are expected to do so in the future
- Costs for PV have been plummeting in the last years improving the economic feasibility additionally to its obvious ecological advantages

High economic pressure on existing electrification schemes based on oil / diesel

Renewable energies become an interesting option for remote locations

➢ **Upgrade of diesel grids with RE technology to reduce the dependency on fossil fuels and provide environmentally sound power supply**

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Study: The potential for decentralized PV power on the African continent

Aim of the study:

Quantify the potential for decentralized PV power by comparing the power generation costs of diesel only systems to RE based hybrid systems and work out the influence of diesel fuel subsidies.

Research question:

Where are PV- diesel or PV-battery-diesel systems more cost effective than diesel only sytems?

Geoinformation systems + **Energy system modelling**

Link:
http://www.reiner-lemoine-institut.de/literatur/veroeffentlichungen/influence-fuel-subsidies-and-taxes-potential-decentralised-pv-power-af

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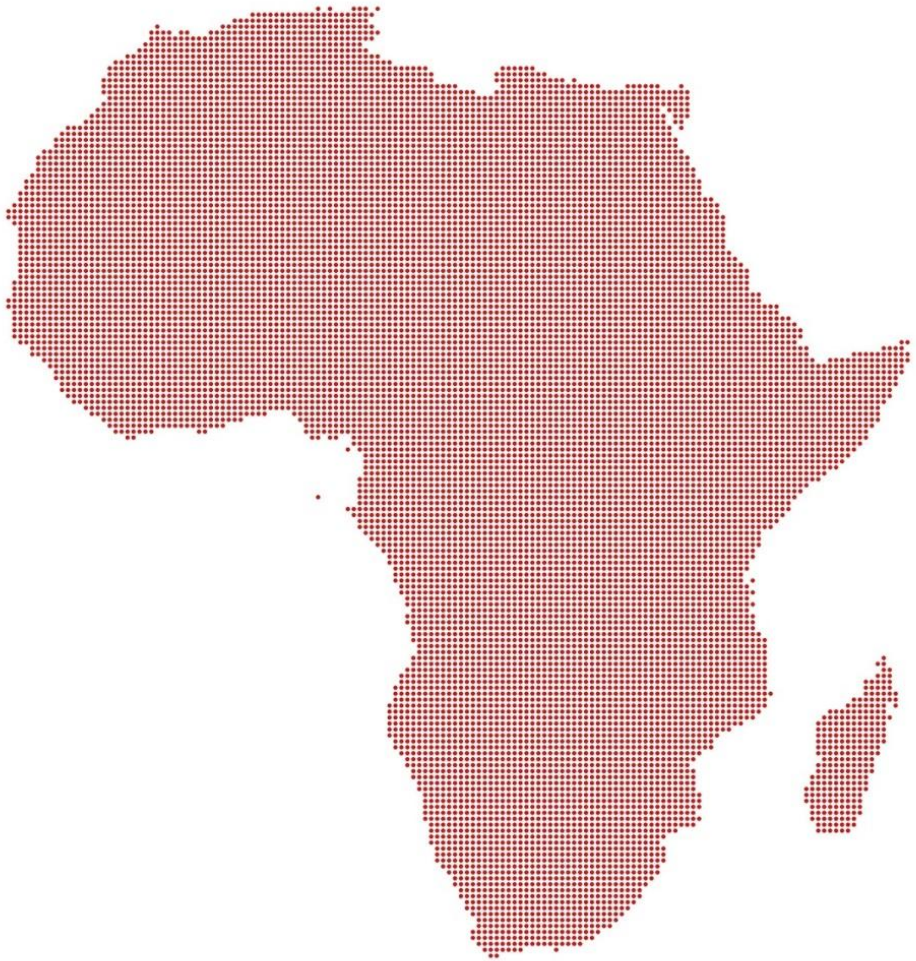
Method: Geoinformation Systems

- Raster grid composed of 12,605 pixels covering the entire African continent
- Reference points are derived for each pixel
- Pixel's centroids are applied for deriving resource data (solar irradiation and local diesel price), necessary as input parameter in the simulation model



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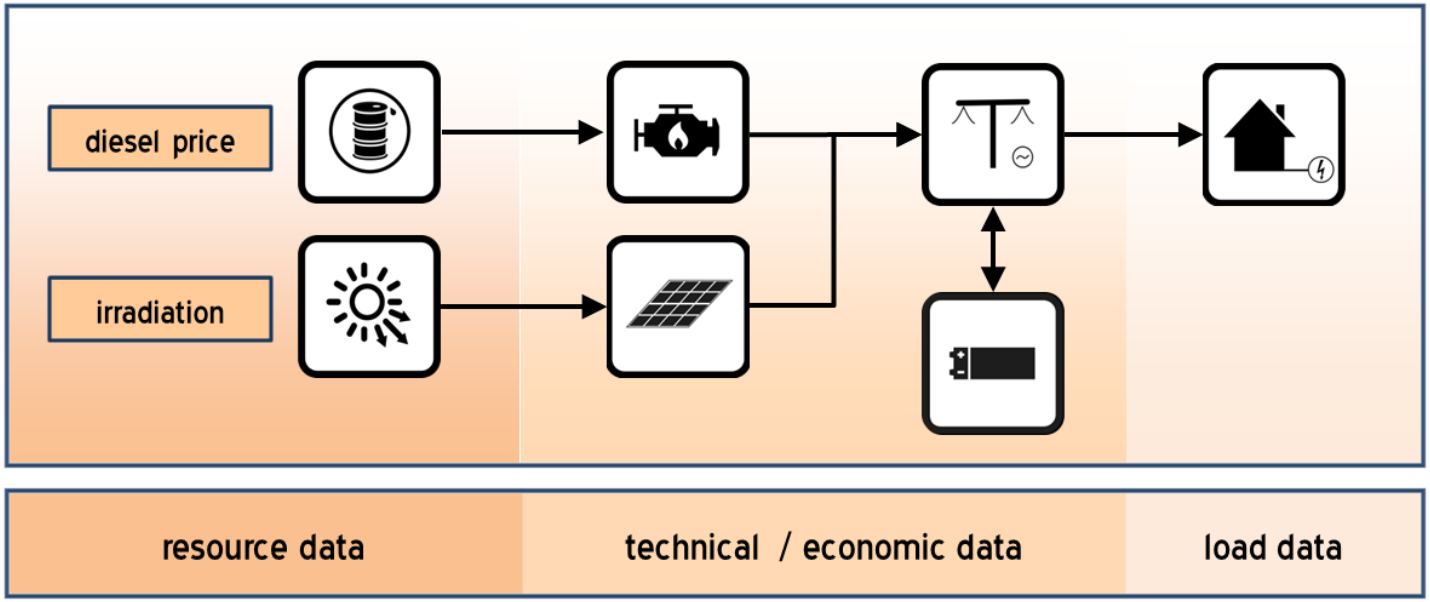
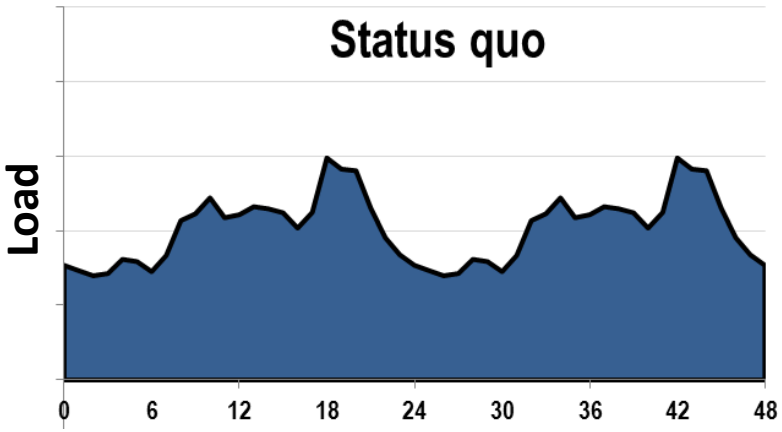
Method: Energy System Modelling

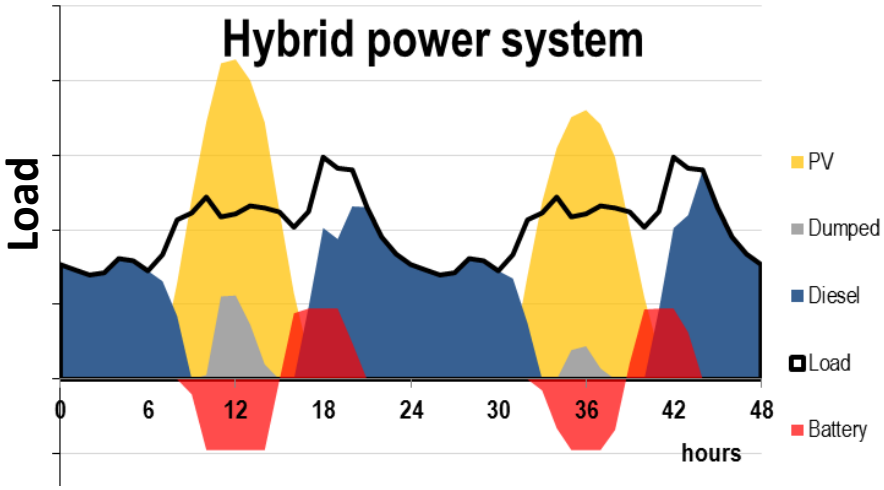
- For given input parameters a cost optimized energy system configuration (out of diesel generator, PV module & battery) is computed in hourly time steps over one reference year
- Energy flows of components and resulting costs form the baseline for calculating power generation costs



Method: Energy System Modelling

- Typical power demand of rural village/town applied
- Sizes of components are optimized in order to minimize the LCOE
- Load has to be covered in every time step, i.e. every hour
- PV power supplies the load primarily, battery stores surpluses or discharges energy, diesel generators fill the gap in case of insufficient supply





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Input: Economic Parameter & Scenarios

- Two scenarios are defined in order to study the influence of fuel subsidies and taxes

	Scenario I	Scenario II
Diesel base price	0.58 €/l (average 2013)	national prices
Diesel price increase	3 % annual increase	
Diesel local price	comprised of base price, transportation costs and price increase	

- Cost parameters

	CAPEX	OPEX
Diesel generator (eff.: 30%)	0 €/kW	0.01 kWh/a
PV module (incl. inverter etc.)	1,600 €/kWp	2 % of Capex/a
Battery (incl. inverter)	350 €/kWh	10 €/kWh/a

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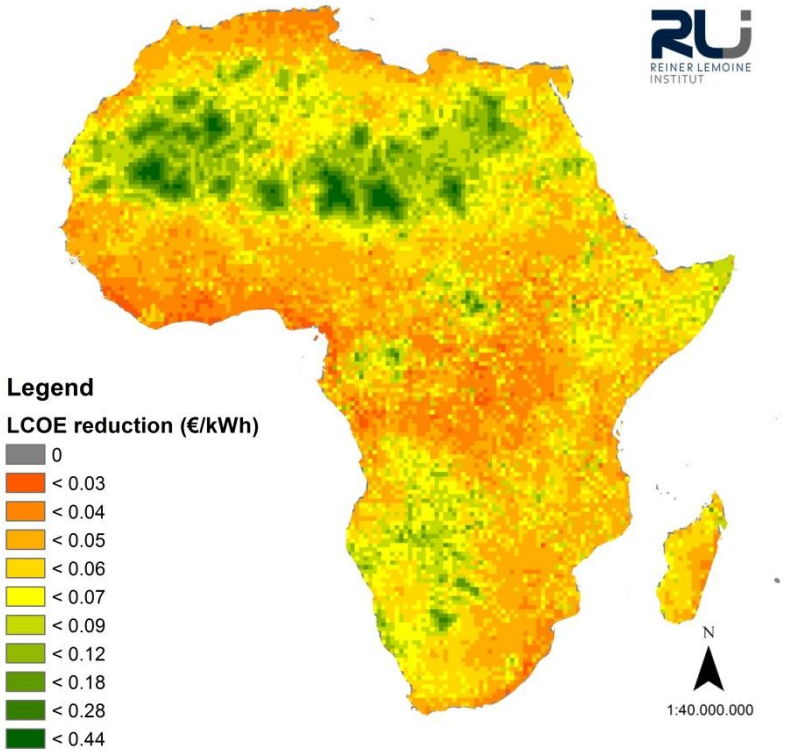
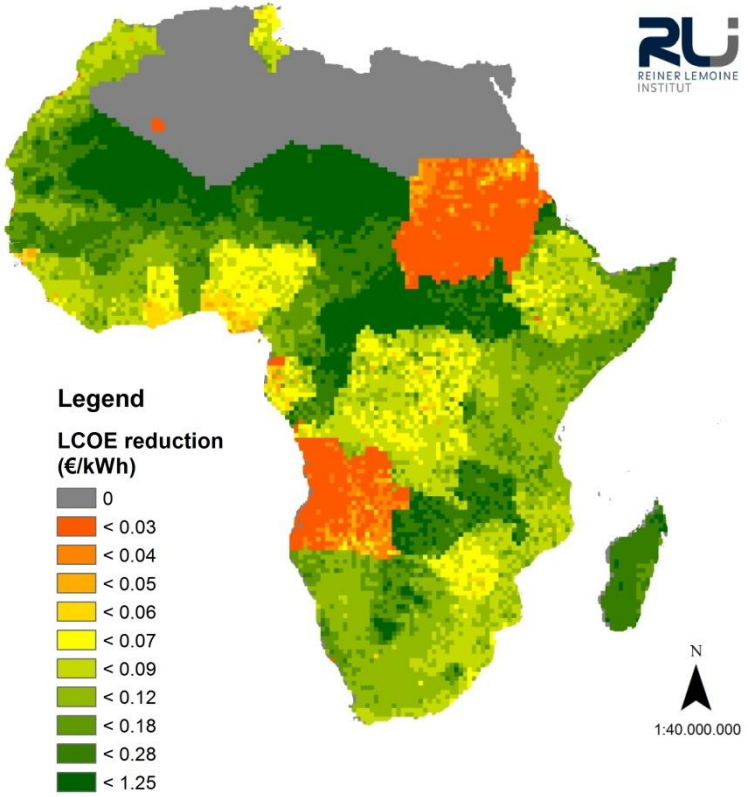
Results: LCOE reduction

Scenario I (Global diesel price)



- Hybrid system outperforms diesel only system all over Africa

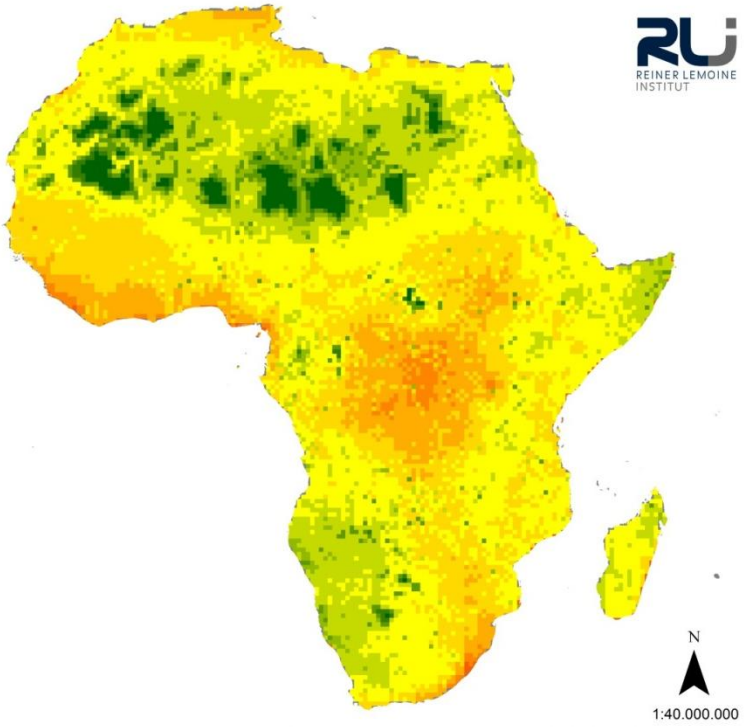
Scenario II (National diesel price)

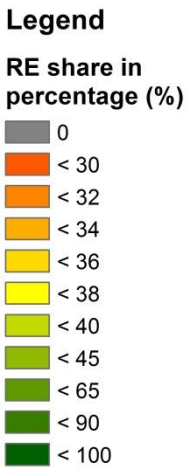


- Subsidies prevent hybrid system despite of high solar resources

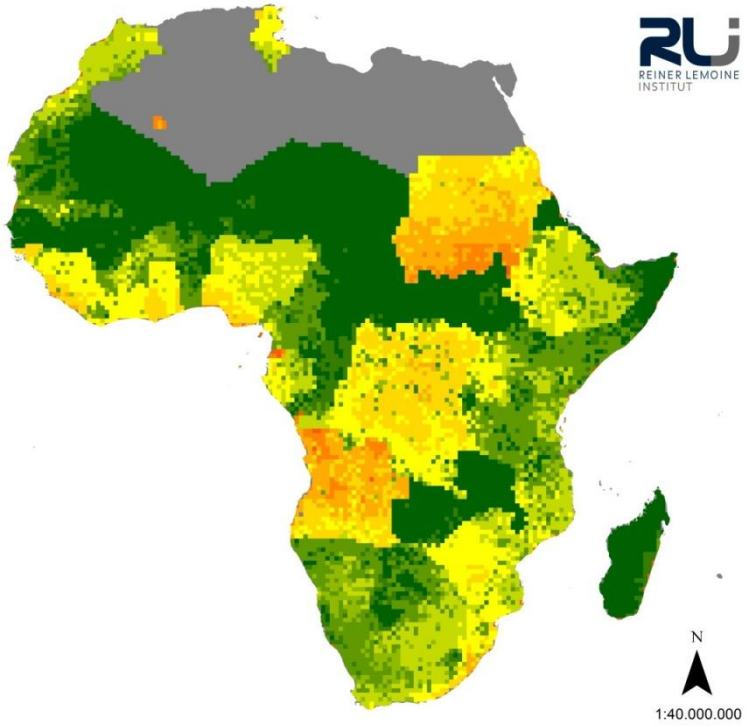
Results: RE share

Scenario I (Global diesel price)





Scenario II (National diesel price)



- Hybrid systems with RE shares of 30 - 45 % are prevailing

- Three types of energy system observed
(0%; 30 - 45%; > 90% RE)

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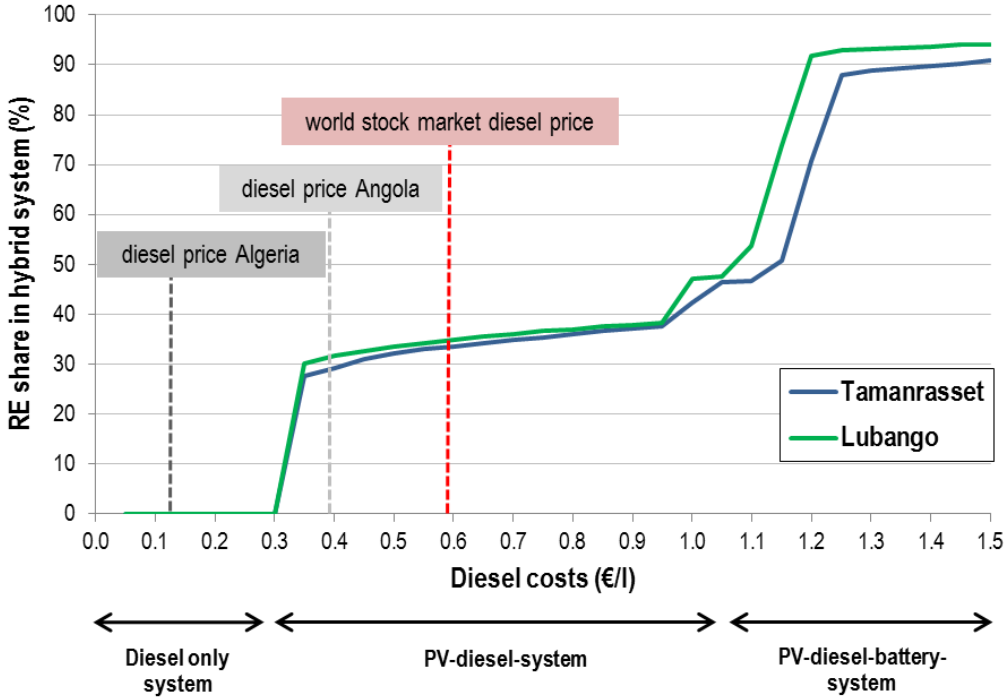
Results: Sensitivity Analysis – RE Share

- Sensitivity analysis of diesel prices with regard to RE share and LCOE reduction
- Diesel fuel prices are increased in 5 ct€/l steps from 0.05 €/l to 1.50 €/l in
- **Three diesel costs thresholds are identified:**



< 0.3 €/l; 0.3 – 1.15 €/l; > 1.15 €/l

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Conclusion of Study

- Results show that **hybridization** of diesel-based off-grid systems with PV and storage systems can lead to a significant **electricity cost reduction**
- Under assumptions of this study diesel fuel costs must surpass a threshold **of 0.3 €/l** to enable PV-diesel systems (with RE share of 30-45 %) and of **1.15 €/l** to enable hybrid systems including battery storage and high RE shares (> 90 %)
- With decreasing **PV Capex** and **battery Capex** the diesel fuel price **threshold** may further decrease
- **Fossil fuel subsidies hamper** the proliferation of renewables and thus prevent **alleviating economic pressure** on national energy budgets in the long run
- Shift towards **PV power** instead of diesel power can enhance **rural electrification** and deliver **revenues** to fuel subsidizing countries

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Next Steps:
Project Proposal for Global Electrification

„Which specific electrification scheme is best for a given location?“

Planned joint research project of RLI and ARE:

„Off-Grid Solutions for Global Electrification“

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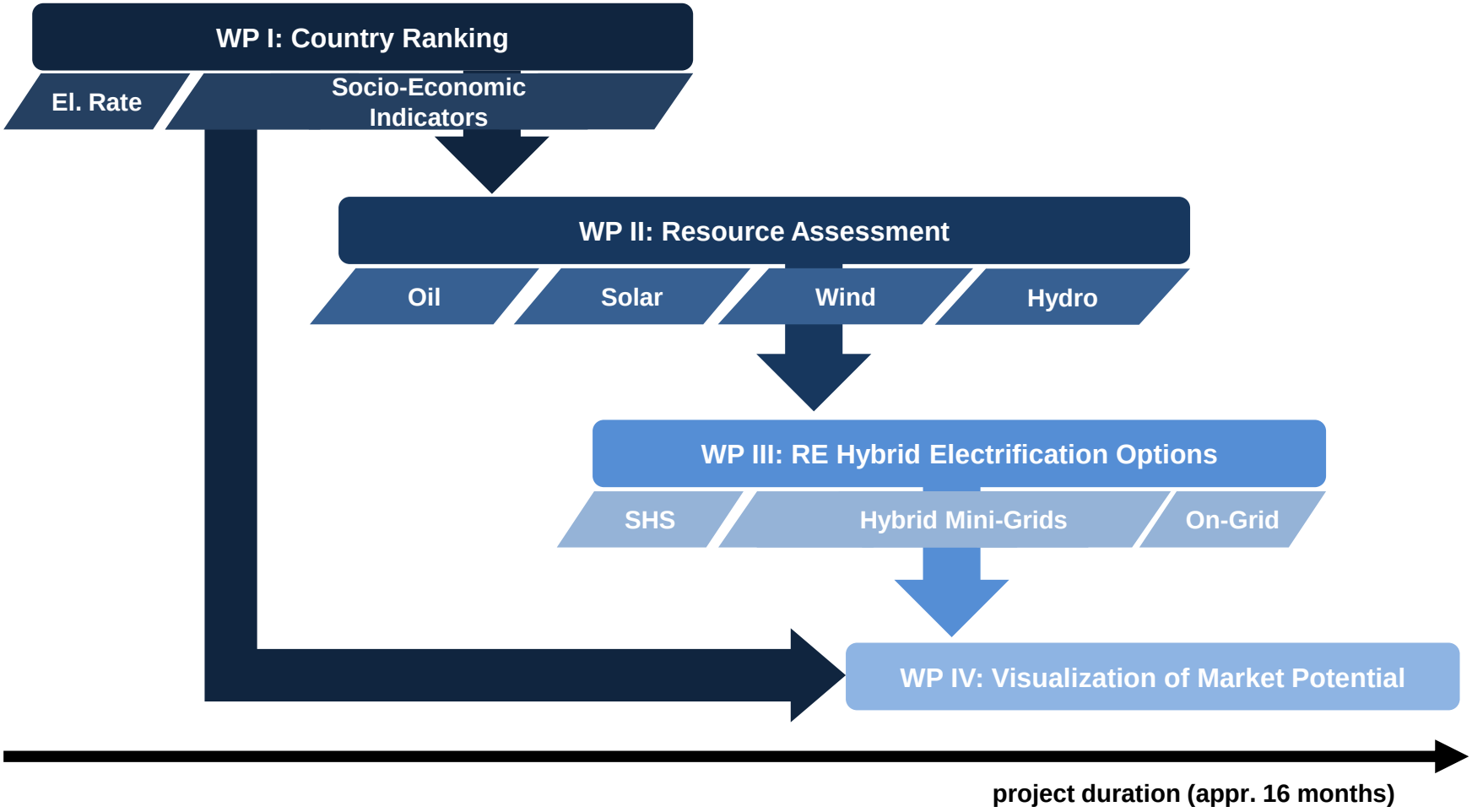
Project Proposal: Research Design - Approach



Thank you!

And special thanks to the RLI off-grid team

For further questions please contact us:

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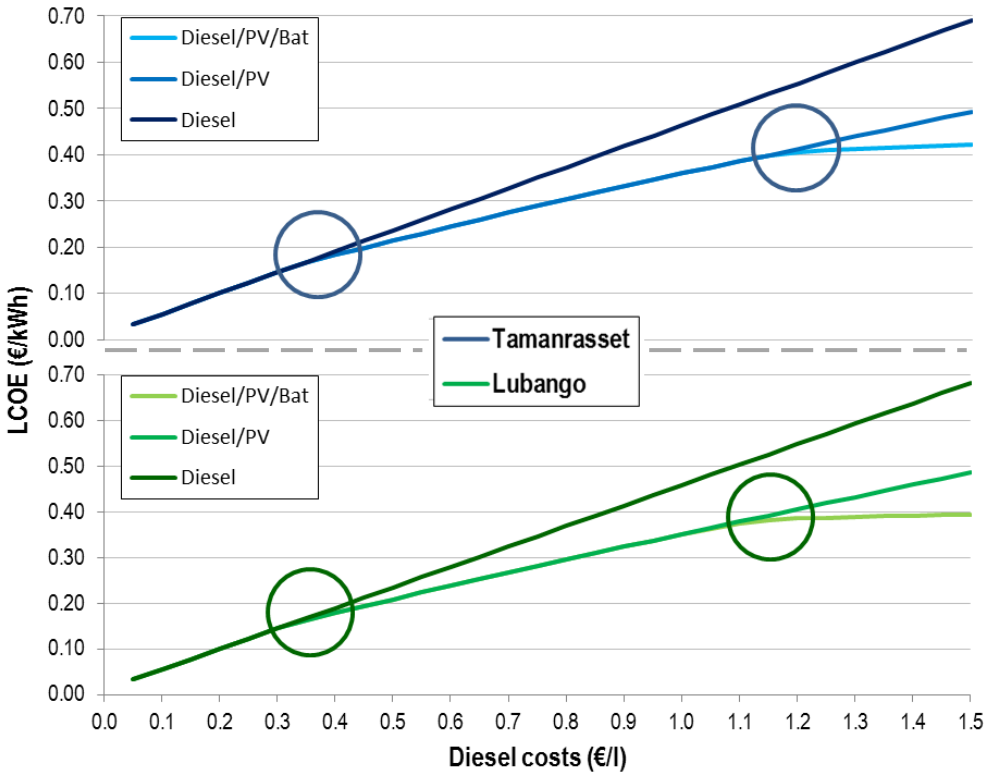
Results: Sensitivity Analysis – LCOE



- Hybrid system configurations change only slightly in a diesel price range of 0.3 – 1.15 €/l although LCOE reductions increase faster

- Cost optimized energy system configurations change stepwise whereas LCOE reductions increase continuously

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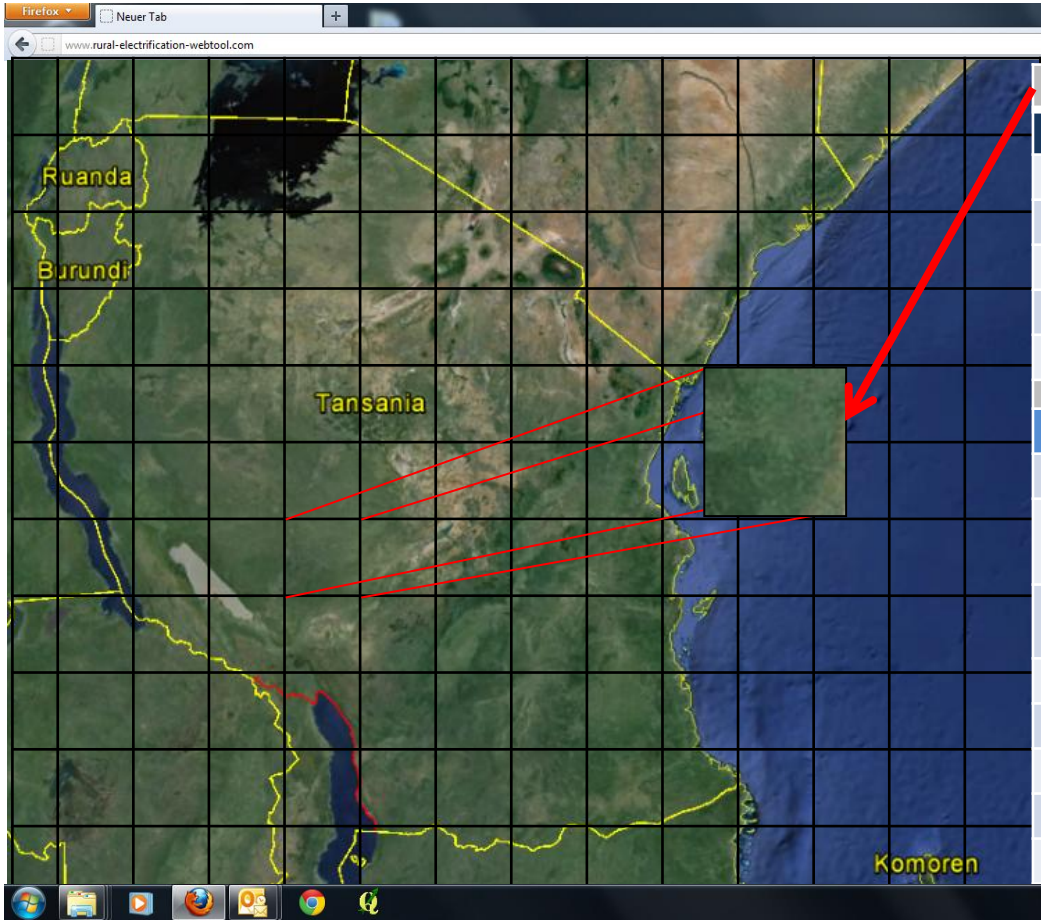
Project Proposal:
Visualization of Output Parameters



Information per pixel	
Resource Assessment	
Local diesel price	EUR/liter
Solar, wind, hydro	kWh, m/s, m³
Population	#
GDP	EUR
etc	
RE Hybrid Electrification options	
Diesel only	EUR/kWh
Hybrid micro grids (LCOE) (solar, wind, battery, diesel,…)	EUR/kWh
Optimized solution: capacities, RE share, diesel consumption	kW, %, liter
Solar-Home-Systems (LCOE)	EUR/kWh
Electricity demand	kWh/year
Distance to grid	km
Nightlights (access to electricity)	yes/no
etc.	

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