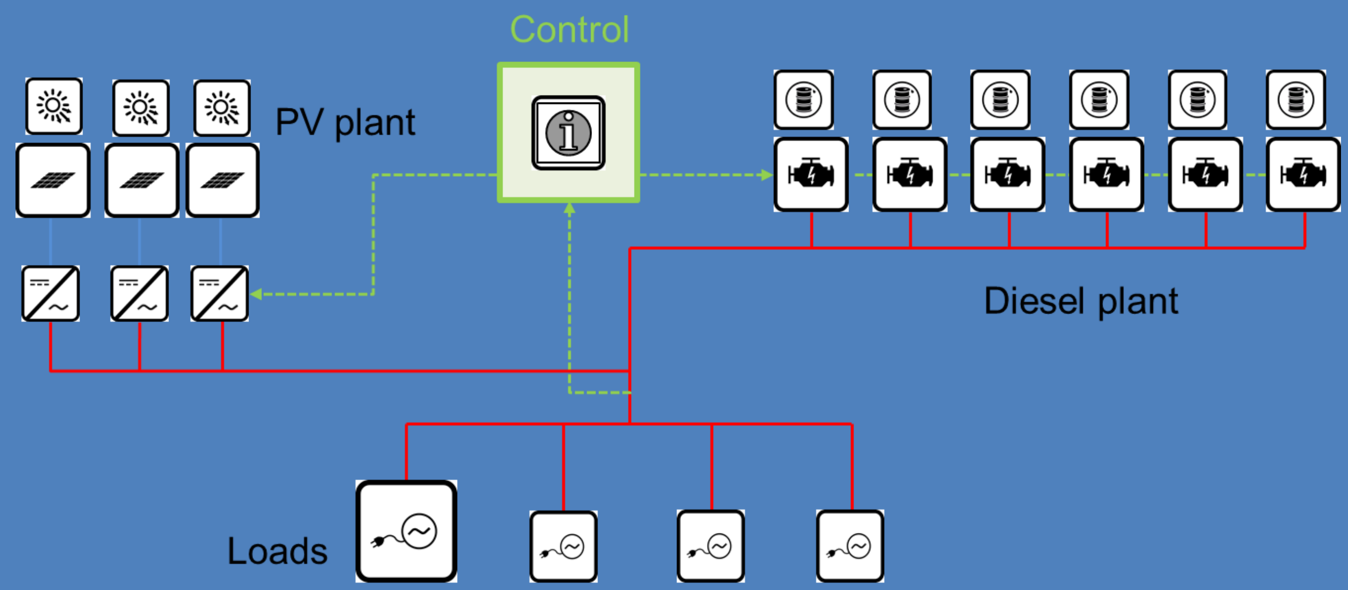

Planning of PV-hybrid power plants

Paul Bertheau – Reiner Lemoine Institut

http://www.export-erneuerbare.de

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Agenda

- Reiner Lemoine Institute
- PV in Germany
- Planning of PV-hybrid power plants

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Reiner Lemoine Institut

Overview

- Not-for-profit research institute
- 100% owned by Reiner Lemoine Stiftung
- Based in Berlin, established in 2010
- 25 research assistants + students
- Member of e.g. ARE, eurosolar, BNE

Alliance for Rural Electrification

EUROSOLAR Europäische Vereinigung für Erneuerbare Energien e.V.

BERLIN BRANDENBURG ENERGY NETWORK e.V.

Mission

Scientific research for an energy transition towards 100 % renewable energies

Reiner Lemoine
Founder of the Reiner Lemoine Foundation

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Reiner Lemoine Institut

Optim. Energy Systems and Transition

- Simulation of integrated energy systems
- Modelling of energy supply including storage options (e.g. batteries, PtG)
- Feasibility studies for energy supply by GIS
- Energy transition and social acceptance

Mobility with Renewable Energies

- Mobility concepts with renewable energies
- Research on electrolyses and PtG
- Implementation of hybrid mini-grids and small wind turbines
- Hardware in the loop testing and measurements

Off-Grid Systems

- Rural electrification planning
- Simulation of hybrid mini-grids
- Combination of GIS analyses and energy system simulations
- Market research and business strategies

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PV in Germany – Recent developments

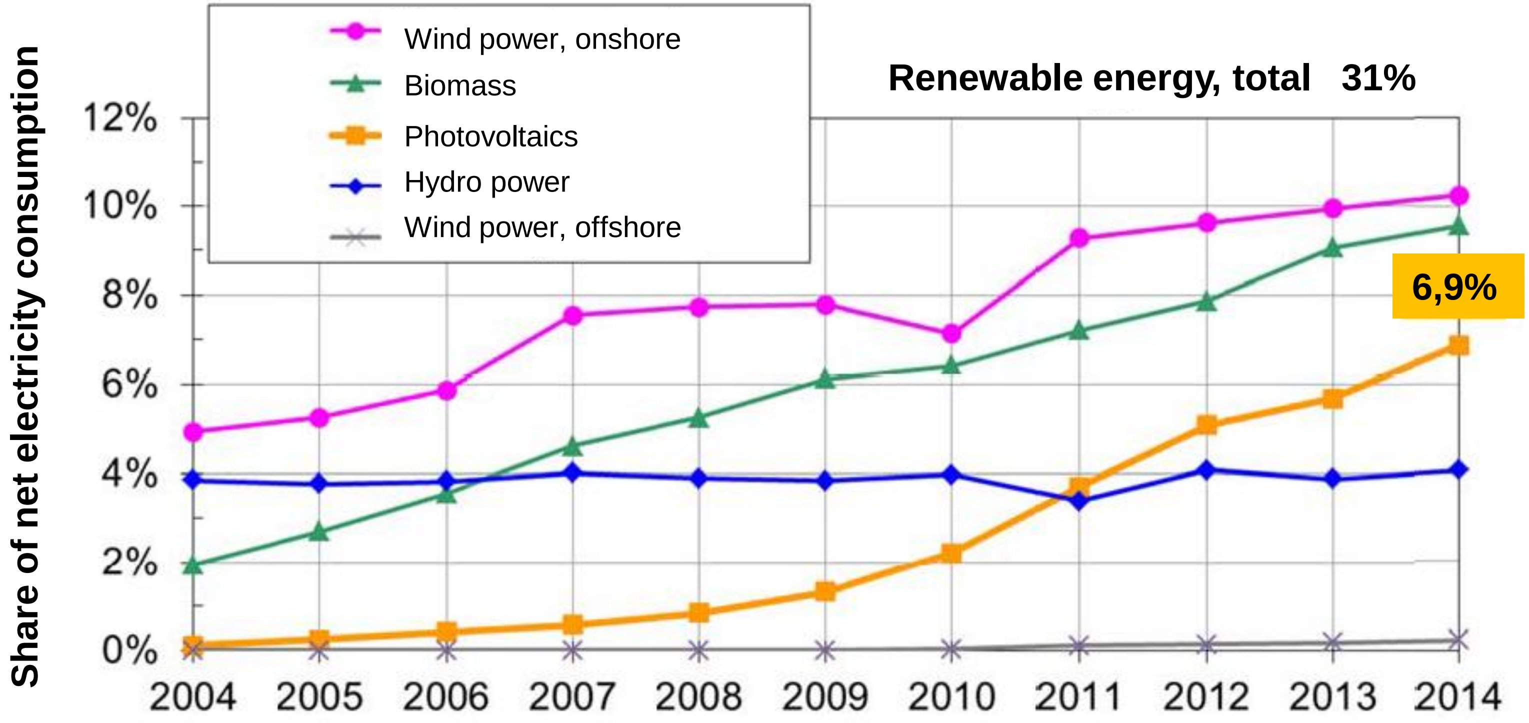

Fig: 1: Renewable share of net electricity consumption.
Source: Fraunhofer ISE. Aktuelle Fakten zur Photovoltaik in Deutschland (2015)

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PV in Germany – Facts for 2014

- **38.5** GW of PV installed (approx. 19 % of global capacity)
- **1.5 million** PV installations
- PV power covers up to **35** % of demand on workdays and up to **50** % of demand on weekends in summer
- PV power remains one of the main technologies for achieving Germanys RE targets and the “Energiewende” (**35** % by **2020** and **80** % by **2050**)

Fig: 2: PV plant and roof-top PV in Bavaria.
Source: Matthias Resch

Source: Fraunhofer ISE. Aktuelle Fakten zur Photovoltaik in Deutschland (2015)

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PV in Germany – Cost explosion?

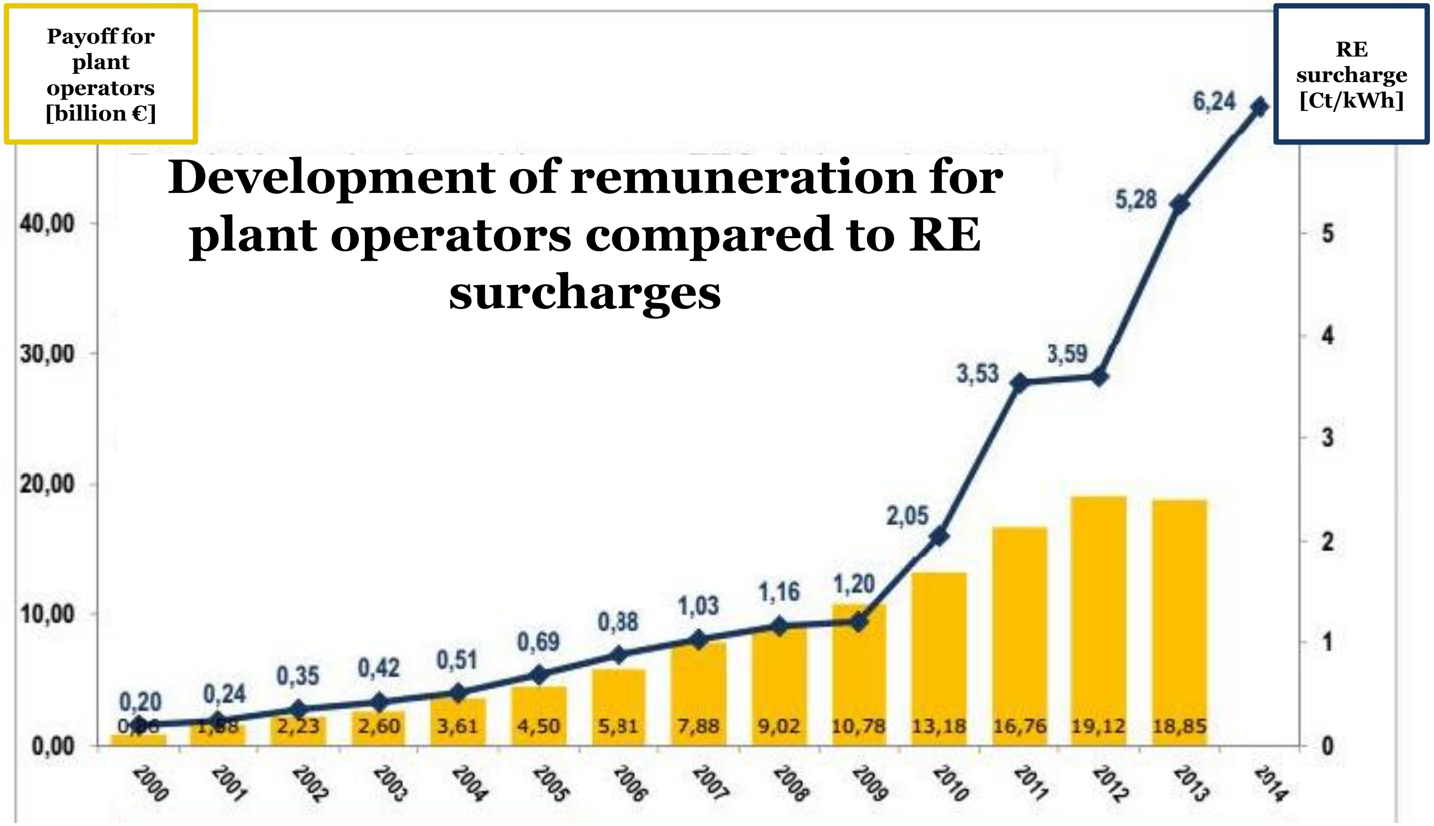

Fig: 3: Development of remuneration for plant operators compared to RE surcharges
Source: Fraunhofer ISE. Aktuelle Fakten zur Photovoltaik in Deutschland (2015)

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PV in Germany – Cost explosion?

- Electricity is traded at Energy Exchange (EEX), Gap between feed-in-tariff and demand driven price is reimbursed
- Expenditures are covered by RE surcharge of 6.17 €ct/kWh (PV=1.4 €ct)
- Reasons:
  - Energy intensive industry is not obliged to pay RE surcharge
  - PV feed-in reduces power costs at exchange which in turn increases gap between feed-in tariff and EEX price
- RE surcharge makes up 21 % of total costs per kWh electricity (tariff for residential customers)

RE surcharge

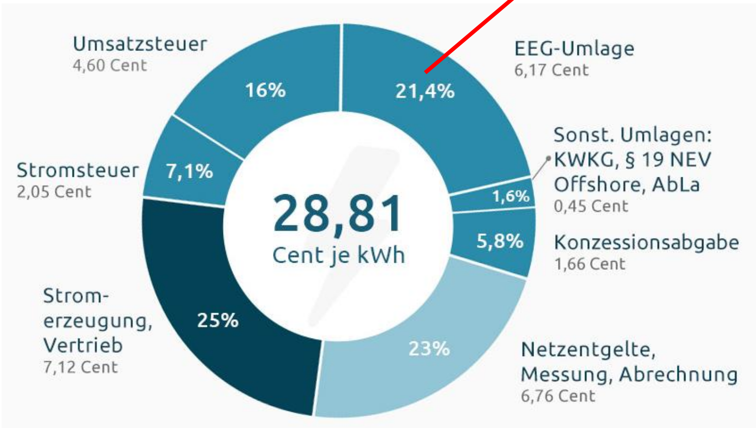

Fig: 5: Compilation of the electricity tariff for residential customers in 2015
Source: Stromreport.de based on BDEW 2015

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PV in Germany – "Energiewende" next steps

Decarbonization of electricity, heat and transport sector

Till 2020 (Focus: Flexibilisation)

- 52 GW PV power capacity
- Increased energy efficiency and smart demand management
- Integration of battery storage solutions
- Reinforcement of grid connection to neighbouring countries

Beyond 2050 (Focus: Storage)

- 200 GW PV power capacity
- Integrated renewable energy storage system, power-to-gas
- Heat supply 100% covered by RE
- Transport sector mainly relies on electric mobility or RE gas driven vehicles

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PV-Hybrid Power Plants - Why Philippines?

- Power supply in separate central grids for main regions Luzon, Visayas region and Mindanao
- Power supply through isolated diesel mini-grids in a large number of remaining islands (areas in red)
- PV-hybrid power plants competitive to pure diesel power plants without subsidies

Let's save money by saving diesel fuel and save the environment at the same time!

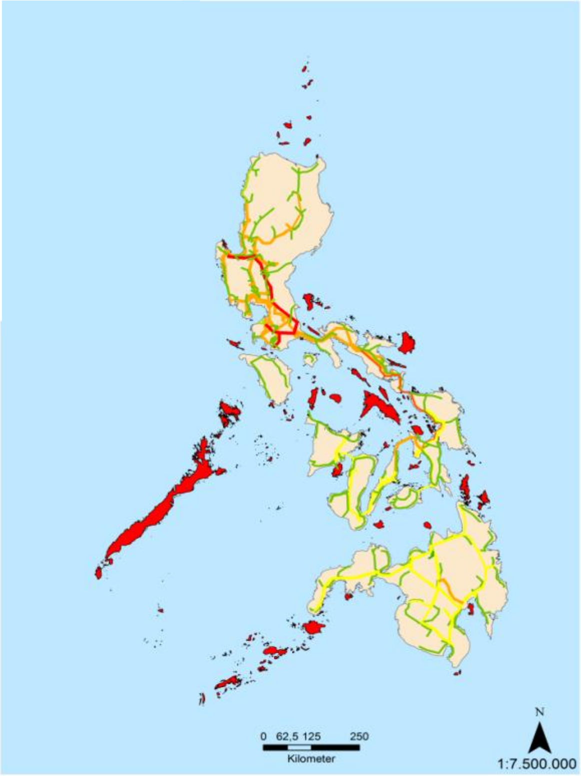

Fig 6: Philippines – On-grid and off-grid islands
Source: (GADM, 2012; NGCP, 2012).

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PV-Hybrid Mini-Grids - Motivation

Diesel power plants:

- high power generation costs:
  - diesel fuel price, transport costs, outdated infrastructure
- CO_2 emissions, air pollutants

Upgrade of diesel mini-grids with Renewable Energies

✓ lower power generation costs

✓ lower fuel dependency

✓ fewer CO_2 emissions, fewer detrimental environmental effects

Fig 7: Destroyed diesel power barge, Lazi, Siquijor. May 2013.
Source: Paul Bertheau

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PV-Hybrid Mini-Grids – What is a mini-grid?

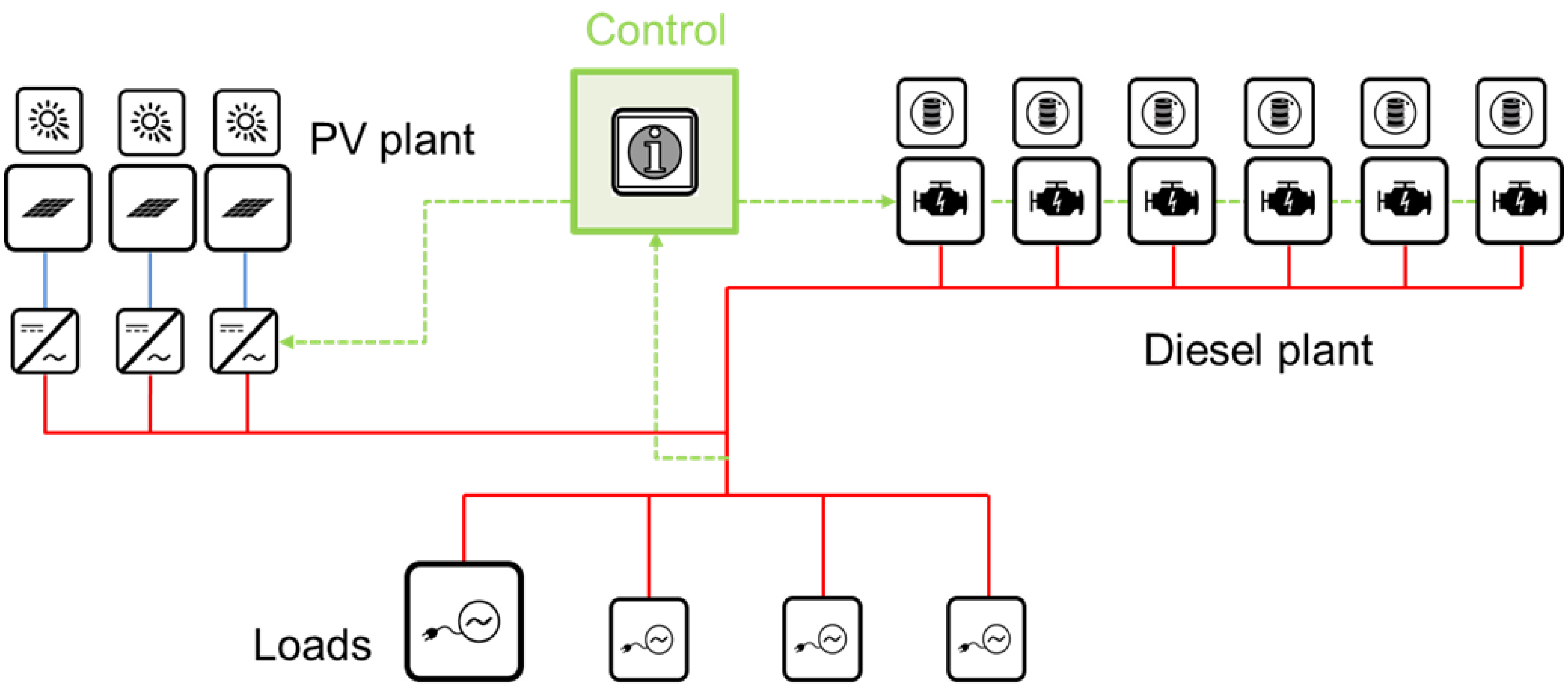

Fig 8: Sketch of hybrid mini-grid

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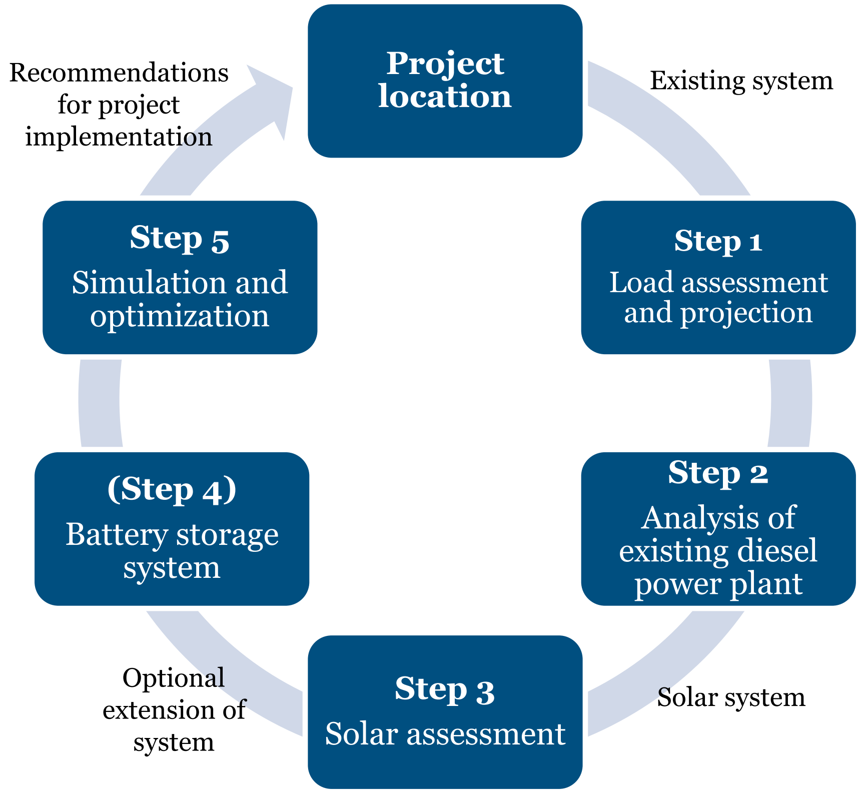
PV-hybrid power plants – Feasibility assessment

Feasibility process



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PV-hybrid power plants – Load assessment

- Load profile depends upon location and customers
- Load assessment essential for appropriately sizing of hybrid power plants and assessing financial and technical viability
- Load (kW & Hz) should be measured for at least one month in at least 15 min time steps
- Addition of growth projections to measured load profiles for assessing feasibility of a project on the long term

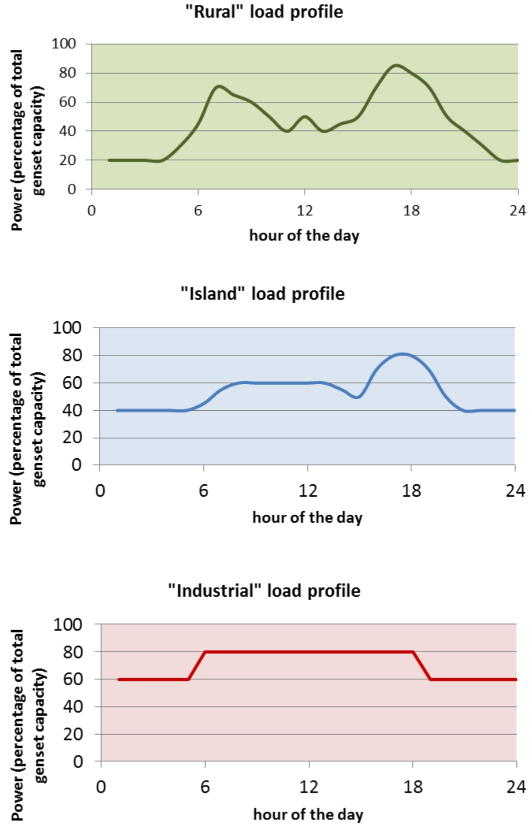

Fig 9: Sketch of typical load profiles

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PV-hybrid power plants – Existing diesel generators

- Characteristics of generators dependent on capacity and type
- Assessment of quantity and technical characteristics of generators crucial
- A combination of larger and smaller gensets necessary for coping with different PV inputs
- Minimal operating time, minimal loading and maximal loading need to be considered

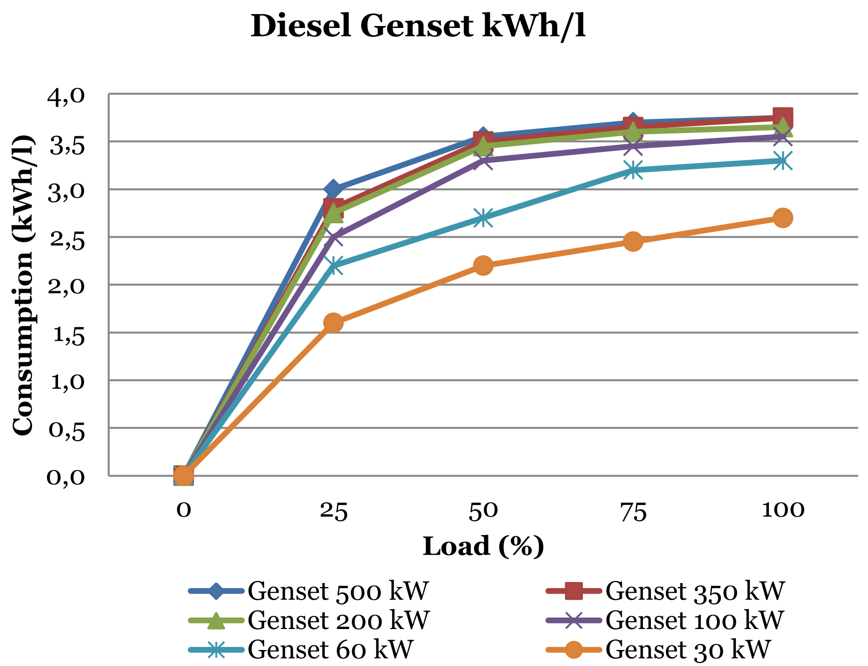

Fig 10: Sketch of typical efficiency curves

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PV-Hybrid Mini-Grids – Solar assessment

- PV yield characterized by PR (performance ratio) according to location and module type

1 kWh/kWp → 0.85 kWh/kWp → 0.82 kWh/kWp

Losses by
- Shading (1.5%)
- Dust (1.5%)
- Temperature (10%)
- DC cabling (2%)

Losses by
- Inverter (2%)
- AC cabling (1.5%)

- Software tools available (e.g. PVsyst) for e.g. optimizing tilt angle

Fig 11: PV solar tracking system
Source: Paul Bertheau

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PV-Hybrid Mini-Grids – Battery storage systems

- Integration of battery storage dependent on specific target, e.g. high energy share/independence
- Batteries can be applied for system stability or shifting generated power to night hours
- Lead-acid batteries and Lithium-ion batteries are commonly applied
- Li-batteries advantageous in terms of energy density, deep-cycle discharging and lifetime, however still more expensive

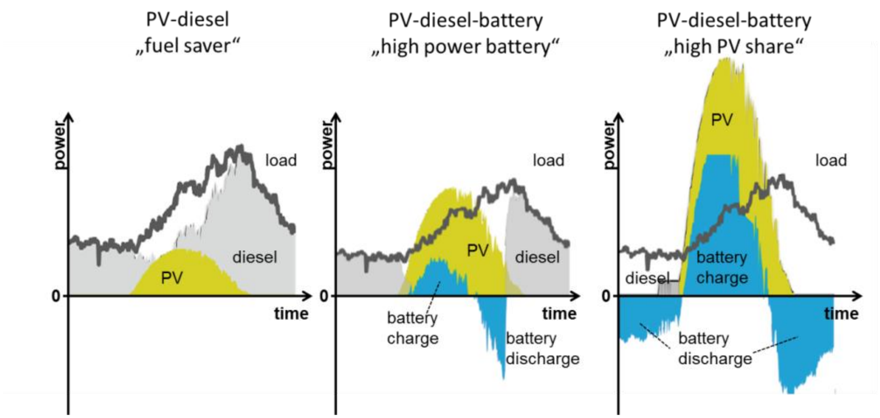

Fig 12: Different types of PV-hybrid systems
Source: Qinous

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PV-Hybrid Mini-Grids – Simulation and Optimization

- Modelling tools are applied for identifying the techno-economic optimal solution - taking into account local resource data and constraints defined by operator (e.g. load supplied at each time step)

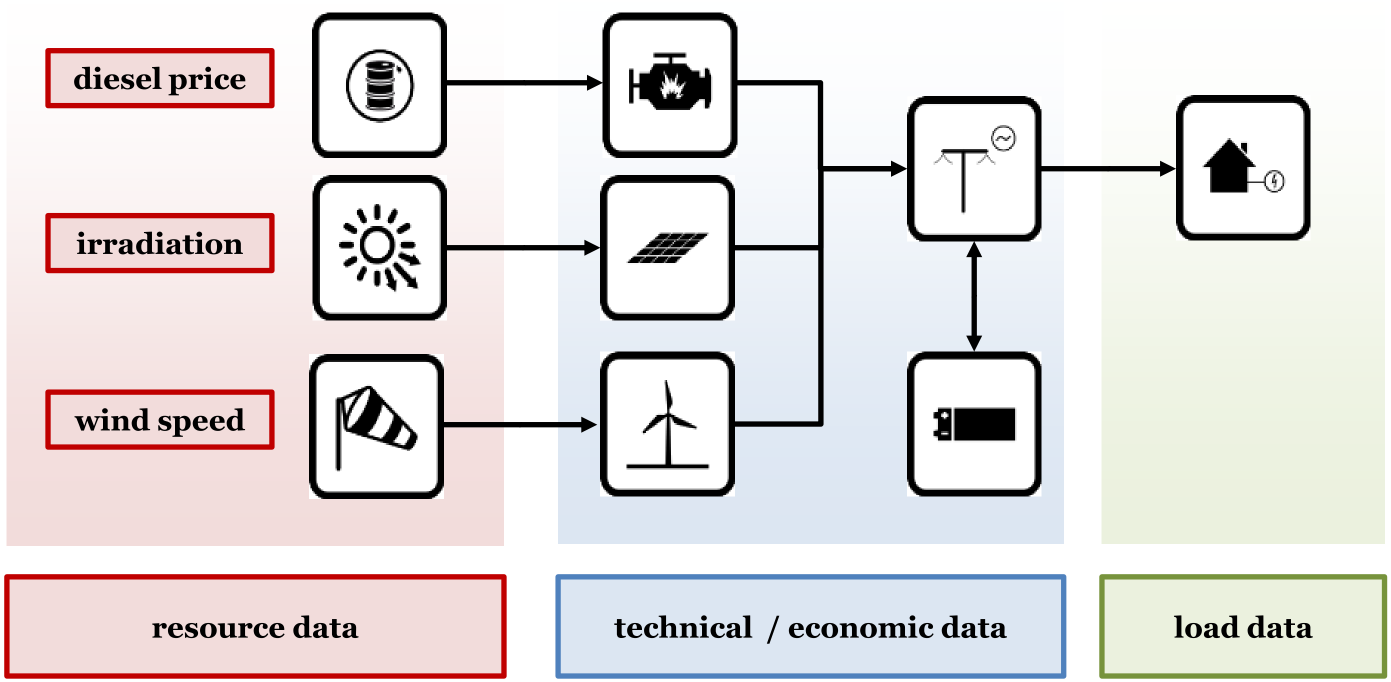

Fig 13: Sketch of simulation model

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PV-Hybrid Mini-Grids – Economics of PV-hybrid power plants

- Possible hybrid power plant configurations are compared in terms of Levelized Costs of Electricity (LCOE)
- Final system design is developed taking into account system stability requirements and operation constraints
- Subsequently, a team of engineers proceeds with the planning of "on-the-ground" implementation

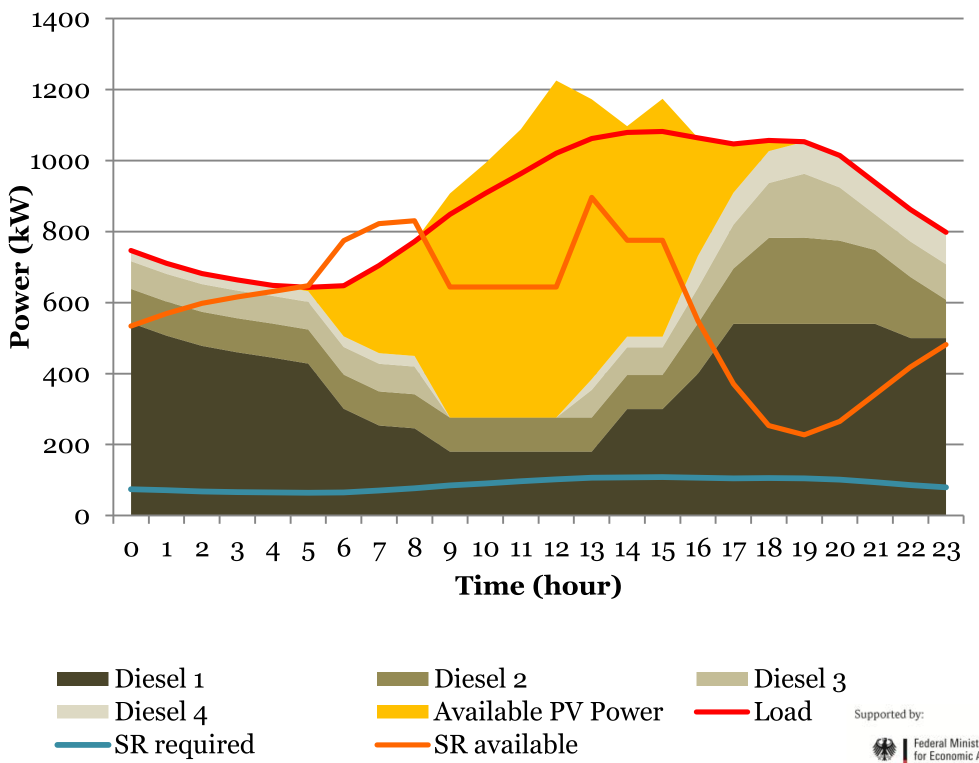

Fig 14: Flow diagram of techno-economic system for one day

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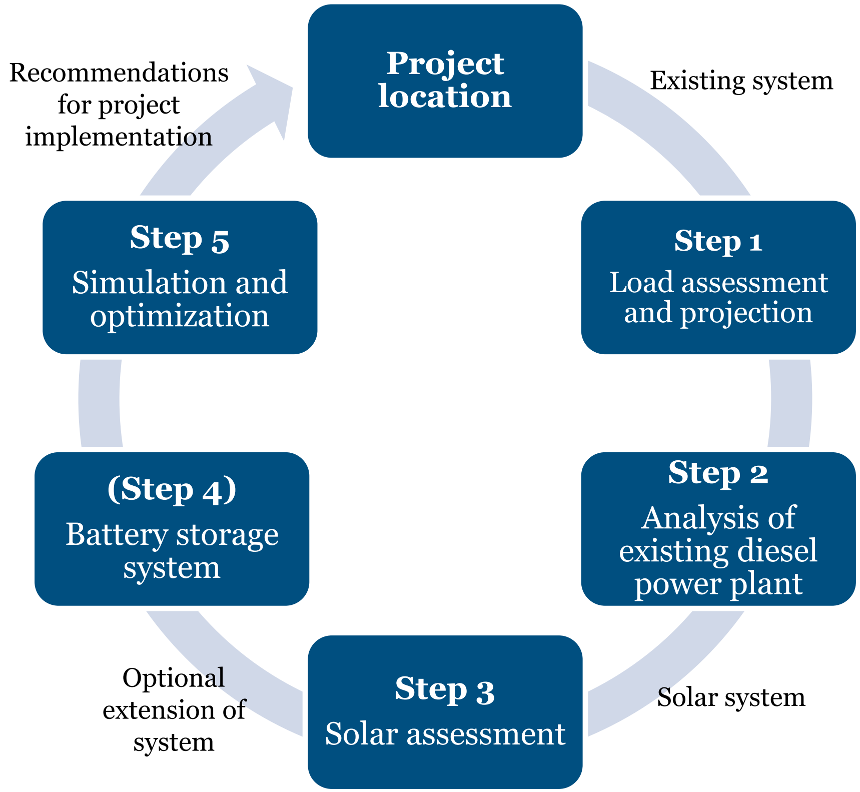
Feasibility cycle: German companies eager to bring in expertise!

Feasibility process



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