Business Models for Renewable Energy Based Mini-Grids in Non-Electrified Regions

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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 RE**
  - Integration of renewable energies into mobility
- **Renewable energy technology**
  - Small wind power

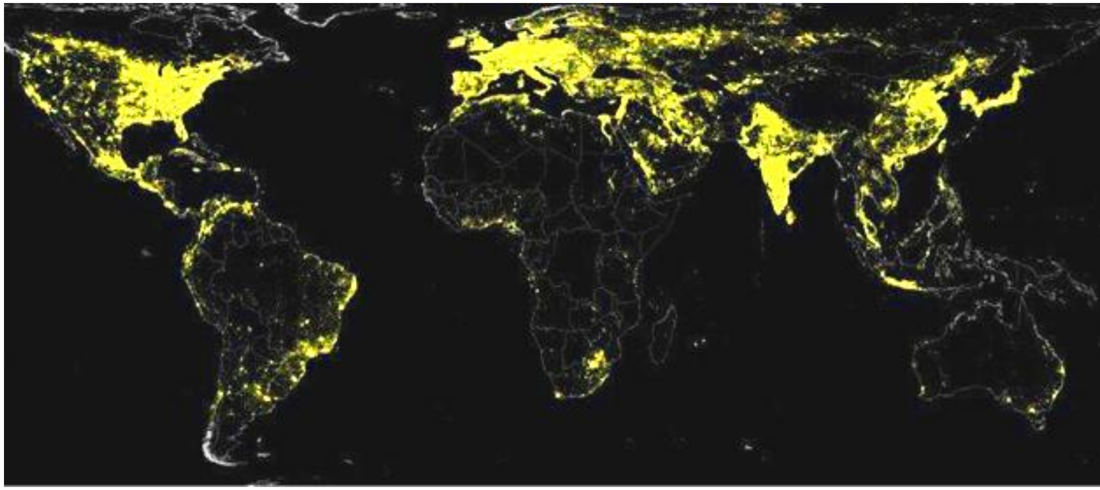
Reiner Lemoine
Founder of the Reiner Lemoine-Foundation

Scientific research for an energy transition towards 100% renewable energies

Agenda

Status Quo Electrification

- Worldwide 1.3 billion people live without access to electricity
- Especially rural regions without grid connection are affected by this
- Grid extension is there often improvident.



earth by night

Image and data processing by NOAA's National Geophysical Data Center. DMSP data collected by US Air Force Weather Agency.

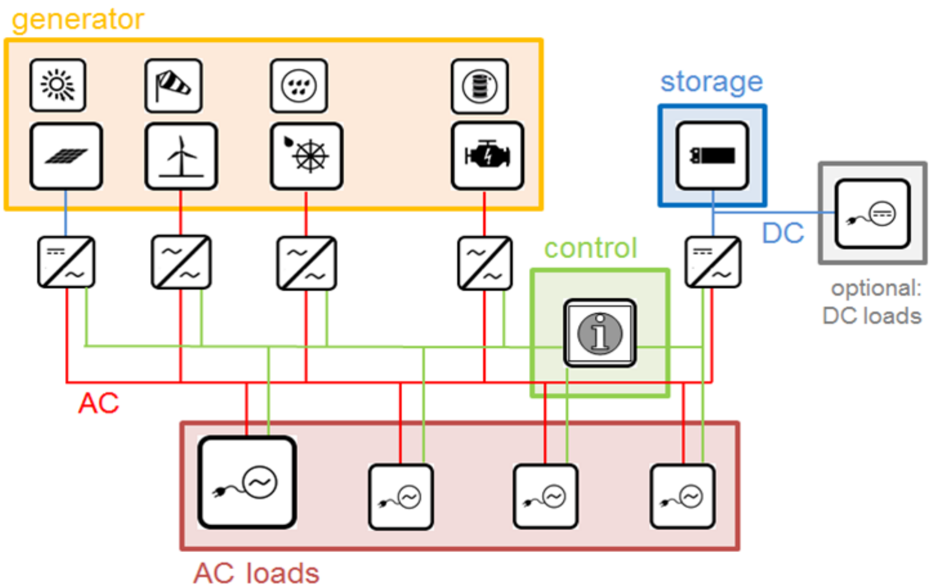
- Electricity is a fundamental requirement for economic development and basis for improving elementary needs like education, health, security and communication.
- Autarkic island grids are often the only possibility to enable flexible access to electric energy for people in rural areas and to enhance local creation of value.

Photovoltaics: Basis for decentralised energy supply

Advantages of PV for decentralised sites

- cost-effective
- modular expandable
- wear-free technology
- solar energy everywhere available
- easy installation

picture: Sunlabob Renewable Energy Ltd.



Possible systems:

solar home systems (5 – 250 Wp)

- are suitable for very small energy needs
- are linked with small capital costs

mini-grids (kW – MW)

- are flexible expandable
- higher power enables supply of commercial usage, hospitals, villages etc.

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Cost analyses on a global scale

analysis of national diesel price + **analysis of existing road network** + **recording of solar irradiation** = **most convenient local energy source (PV vs. diesel)**

- **PV mini-grids compete with grid extension and pure diesel-grids.**
- **Increasing distance to the national grid and low density of consumers make grid extension improvident.**
- **High national diesel prices make pure diesel-grids improvedent.**
- **Increasing distance to large trade routes leads to high transport costs for diesel.**

With high local diesel prices and good solar irradiation in rural areas solar energy becomes the most convenient energy source.

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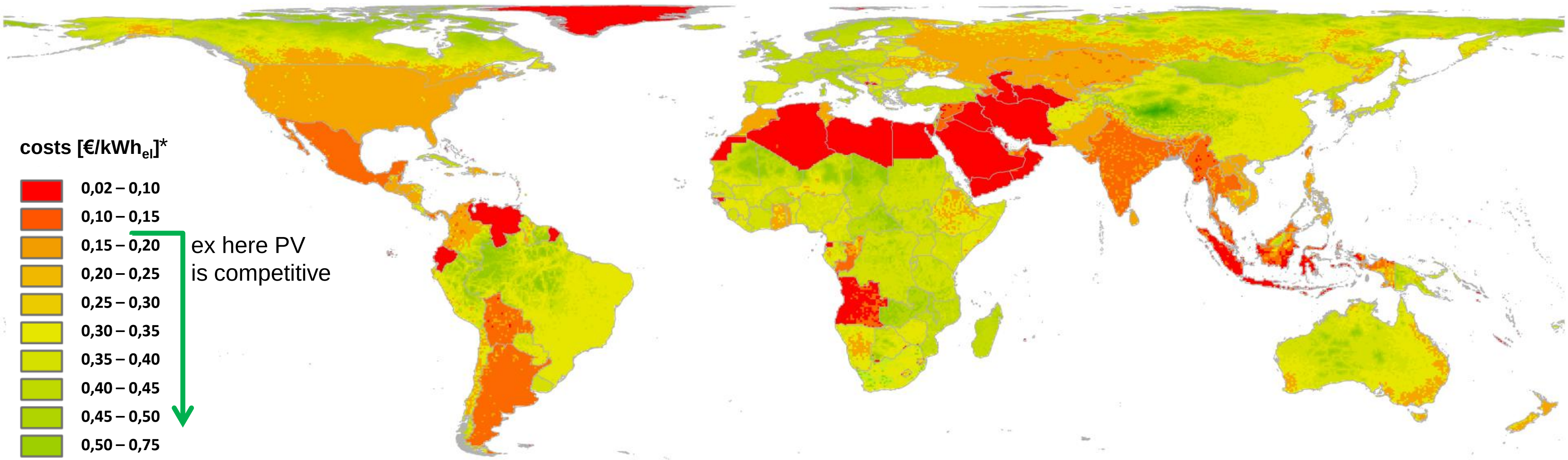
Electricity generation costs of pure diesel grids



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

ex here PV is competitive

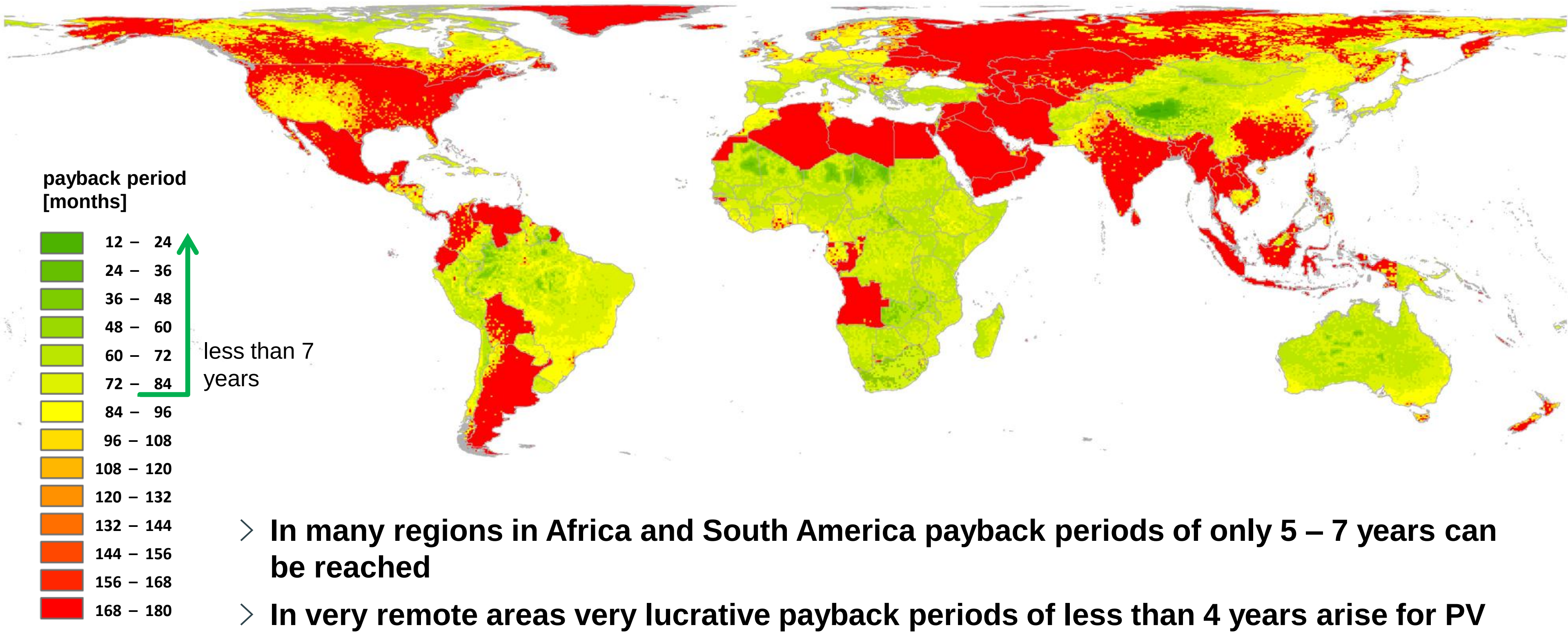
* 1 l diesel corresponds to ca. 3 kWh$_{el}$

- **Costs of local energy production depend highly on the diesel price**
- **Subsidization and taxation of diesel have strong effects on costs**

Diesel price is essential for competitiveness of PV-based mini-grids

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

Amortization of hybrid PV-battery-diesel systems



- **In many regions in Africa and South America payback periods of only 5 – 7 years can be reached**
- **In very remote areas very lucrative payback periods of less than 4 years arise for PV mini-grids**

» In many regions are already reached very attractive payback periods for PV-based mini-grids

source: Cader C., Hlusiak M., Breyer Ch., 2013. High-resolution global cost advantages of stand-alone small-scale hybrid PV-Battery-Diesel Systems, 2nd MES, Berlin, February 27 – March 1

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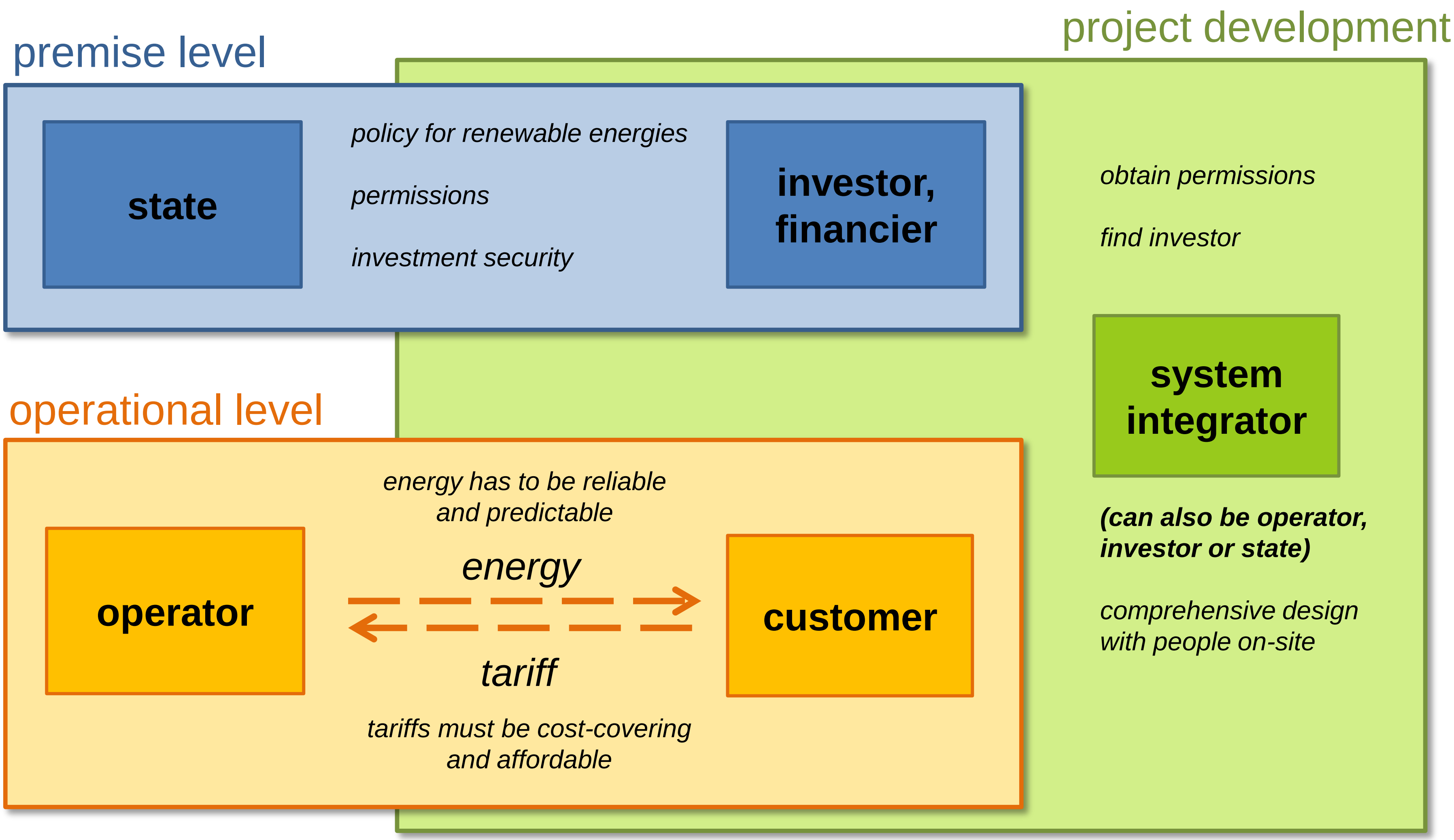
Levels and Participants of Electrification Projects



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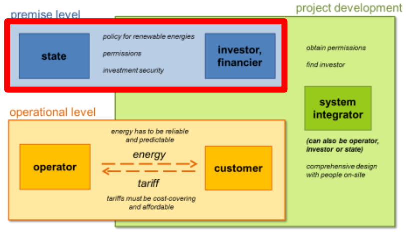
Political and Economic Premises



state

investor, financier

requirements

- has to agree to permit tariffs for mini-grids which are mostly higher than in the remaining country
- has to create legal framework

frequent problems/experiences

- legal framework lacks
- complex licensing procedures
- scepticism about renewable energies
- high import duties
- monopoly on energy supply
- financial sector is underdeveloped

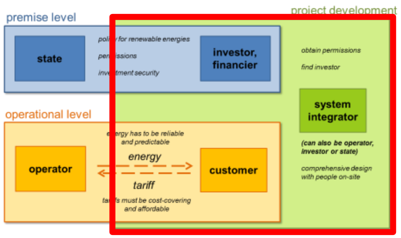
requirements

- investor has to take risks
- financier has to be willing, to provide enough capital (for investor)

frequent problems/experiences

- high investment costs at the beginning
- foreign exchange risk
- lack of credit availability
- high transaction costs
- insufficient trust in project development
- lacking security during project period
- local expectations on capex and return times

Project Development



system integrator

requirements

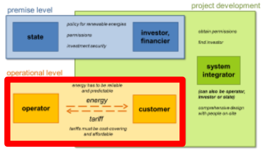
- has to obtain permissions
- has to find investor and financier
- currently has often firstly to create requirements

operation

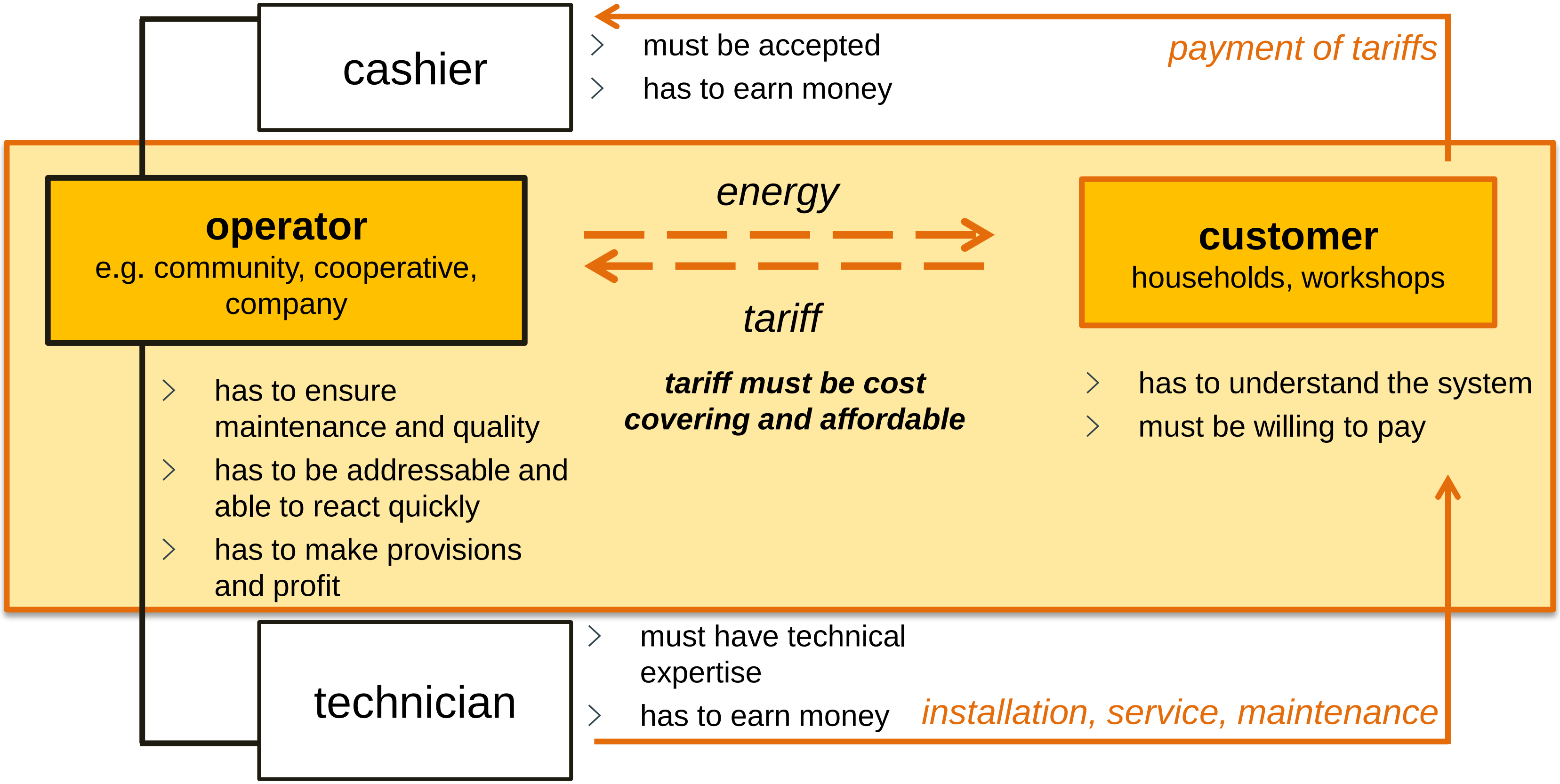
- has to meet cultural needs
- has to plan for long-term operation
- has to integrate and train local participants
- has to create a sustainable tariff structure
- has to ensure that responsibilities are clear defined

frequent problems/experiences

- knowledge lack of local conditions
- projects not adapted to local conditions
- scarce communication with community and integration of local players



Operational Level



frequent problems/ experiences

- **maintenance and responsibility for operation is neglected**
- **continuous adaption with demand not considered**
- **poor payment practices of consumers**

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Best Practice: Approaches of Existing Business Models

- **financing**
  - capital costs are subsidised and running costs are covered by tariffs
  - tariffs are subsidised in order to ensure equal electricity prices nationwide
  - social funds or family offices as investor
- **operator**
  - national utility
  - single operator model – operator has much power
  - community model – villagers need access to technical expertise
- **tariffs**
  - no prepaid – more non-payer, risk of high debts
  - prepaid without time limit – less planning security
  - intelligent tariffs – technically useful, but complex; facilitates awareness for the system

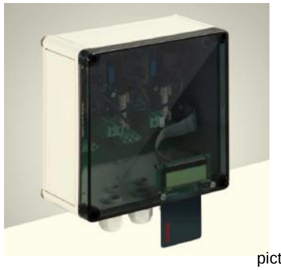
pictures: top: Namibia, 200 kWp solar power plant; below: Rwanda, training of technicians
[© Juwi Solar GmbH]

▸▸ There are already good approaches for business models but only few successful implementations

Best Practice: INENSUS Micro Power Economy

- public private partnership (ppp)
  - private investor owns production units (power station operator)
  - community owns fixed assets (mini-grid operator)
  - micro finance inst. allows capital expenditures in commercial activities
- six months contract duration
  - continous adapting to needs
  - sufficient planning security
  - satisfaction and good service through periodical negotiations
- electricity blocks
  - units of fixed energy amount and specific capacity
  - only valid in determined period
  - additional energy is available at higher prices
- Load Management and Accounting Unit (LAU)
  - load shedding based on determined priorities
  - prepayment meter and house connection
  - electricity block trading

- subsidies for grid possible
- prospective subsidies will not be necessary through proven model and growing trust



pictures: top: technician; below: LAU [INENSUS]

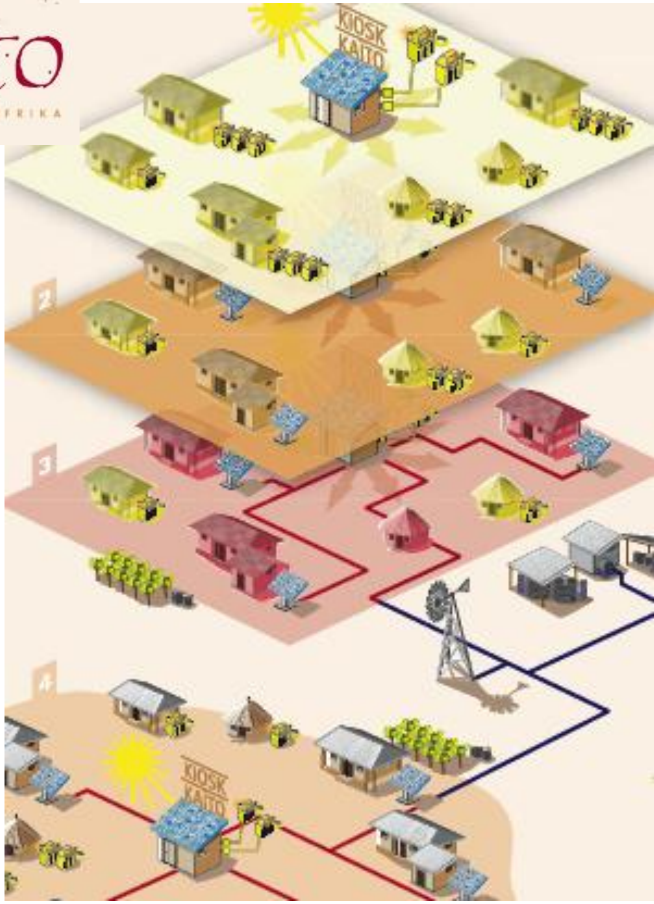
▶▶ Separation of property enables mutual quality check and flexible ending of business relationship at breaking contracts

Best Practice: KAÏTO Concept of Phases

- phase 1: charging station (franchise)
  - renting of battery-operated lamps and energy-cases
  - charging cellphones, torches, etc.
  - lamps, spare parts, installation material
- phase 2: additional PV systems
  - for public institutions and workshops on lease
  - maintenance by Kaïto staff

if demand for energy increase:

- phase 3: interconnection to an AC grid
  - additional energy production with plant oil, biogas or wind power minimum purchase needed for connection
  - cross-linking of all installed generators
- phase 4: interconnection of village grids to regional energy clusters
  - option for the future



Concept of 4 phases [© KAITO Energie AG, München]

▶▶ Single phases build upon each other and will be realized depending on the energy demand and commitment of population

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Summary

- massive need for rural electrification
- PV-based mini-grids are an (economic) optimal solution
- considering of local macro-economic conditions essential for success of business models
- financing is an enormous obstacle and has to be addressed early
- several preconditions still often have to be created
  - clarifying the benefits and chances of renewable energies
  - reduction of political and economic barriers
  - training/ support of local banks, project developers and companies
  - linking of all parties
  - implementation and presentation of sustainable projects
- for success on a long-term interests of consumers, operators, financiers and governmental organizations should complement each other positively

[© KAITO Energie AG, München]

With successfull pilot projects business models can become reproduceable and the electrification of rural regions can be pushed

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picture: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)

further presentations and study available:
www.cdw-stiftungsverbund.de → Downloads

PV-based Mini-Grids for Electrification in Developing Countries

Thank you for your attention.

Backup

Parameter	Szabó et al.	RLI
Availability PV/Battery-System	95 % according to text but does not match results	PV/Battery/**Diesel-**Hybrid
Diesel transport cost	0.08 • travel time in h • nat. diesel price	**0.02** • travel time in h • nat. diesel price
PV cost	3,500 €/kW$_p$ (70 % modules, 30 % BOS)	**2,000 €/kW$_p$**
Battery cost	125 €/kVAh$_{nom}$	**120 €/kWh**
Interest rate	5 % p.a.	**8 % p.a.**
Irradiation	Daily GHI, PVGIS (HelioClim) 15'-pixel size	Hourly GHI, DLR (NASA) 27'-pixel size
Load curve	1/3 PV direct (daytime), 2/3 via Battery (nighttime), no seasonal changes	
Performance Ratio	70 % (includes battery cycle efficiency)	
Max DoD	70 %	
Life times	PV 20 a, Battery 5 a	
Genset efficiency	36 % or 0.286 l/kWh$_{el}$	**30 %** or **0.333 l/kWh$_{el}$**
Opex PV/Battery	2.5 % of Invest p.a.	
Opex Diesel	0,01 €/kWh$_{el}$ (includes genset write-off)	**0.02 €/kWh$_{el}$**
National diesel prices	2009 data	