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ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

IET International Energy Transition

Planning for Energy Access – Assessing Electrification Options and Costs

Dr. David Jacobs,
IET – International Energy Transition, CEO

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Agenda

I. Important definitions and background
II. Step 1: Make use of maps and geographic information systems (GIS)
III. Step 2: Analysis of detailed decision parameters (off-grid vs. on-grid)
IV. Step 3: Planning for off-grid technology solutions (mini-grids, solar-home-systems and hybrid systems)
V. Summary and Conclusion

Source: IEA (2015)

Important Definitions and Background

Important definitions: Energy Access

- Modern energy access
  - NO universally-agreed and universally-adopted definition
  - UN Secretary General's Advisory Group on Energy and Climate (AGECC)
    - minimum threshold of modern energy services
    - reliable and affordable, sustainable and low-carbon

Source: IEA (2015)

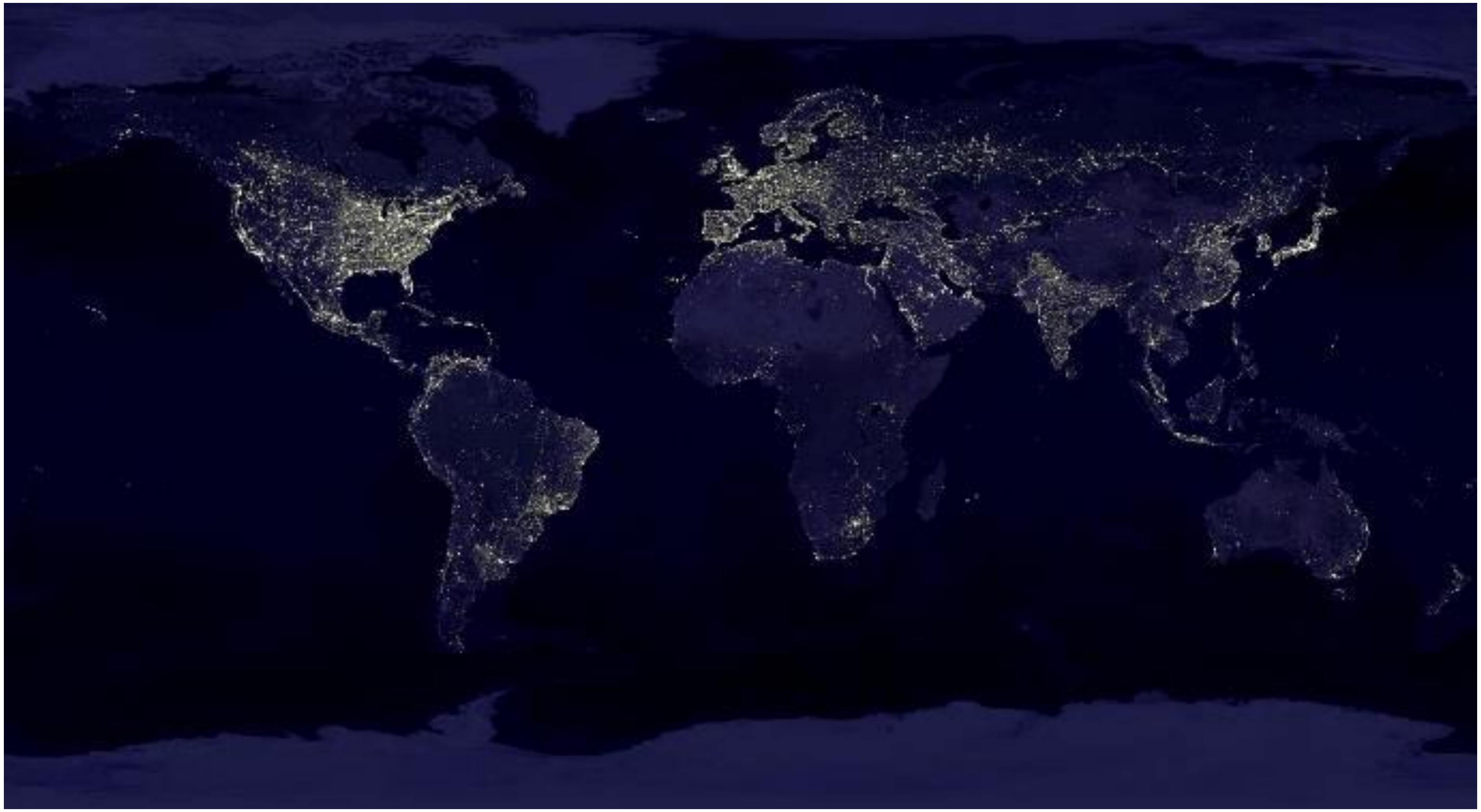
Important definitions: Electrification

- IEA (WEO methodology)
  - „A household having reliable and affordable access to a minimum level of electricity consumption which is increasing over time”
  - More than a first supply;
  - minimum level of electricity (rural = 250 kWh/y; urban = 500 kWh/y).

- Access/electrification rate (cover rate):
  - – Access to electricity is the percentage of population with access to electricity (World Bank).

Energy Access and Rural Electrification

• 1.2 billion people (17% of the global population) have no access to electricity



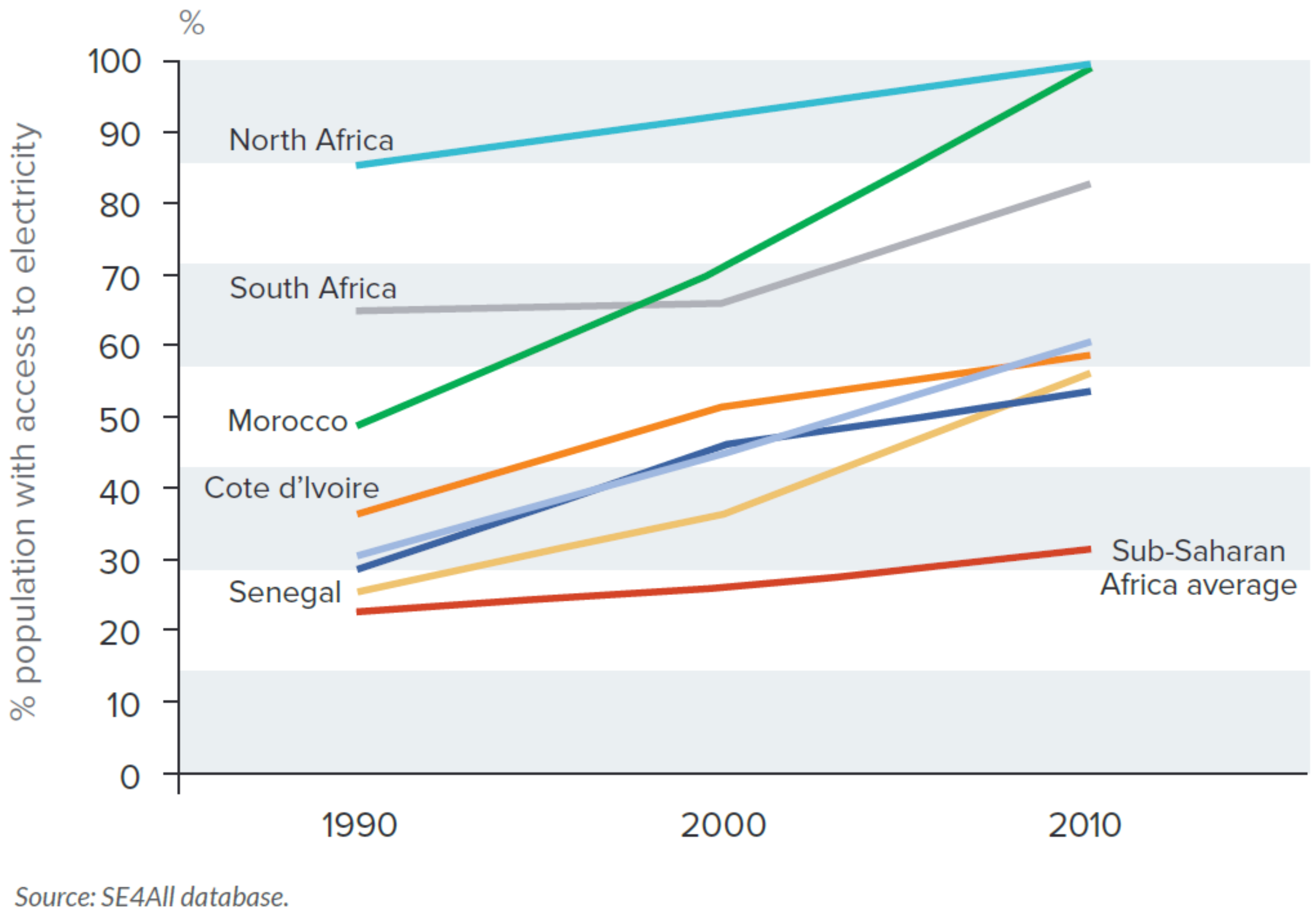
Energy Access and Rural Electrification

- World electricity demand is expected to double by 2030 (highest increase in developing countries)
- Most developing countries have very good natural conditions for renewable energy sources
- Important piece of the puzzle in combating global climate change

Electification rates in Africa

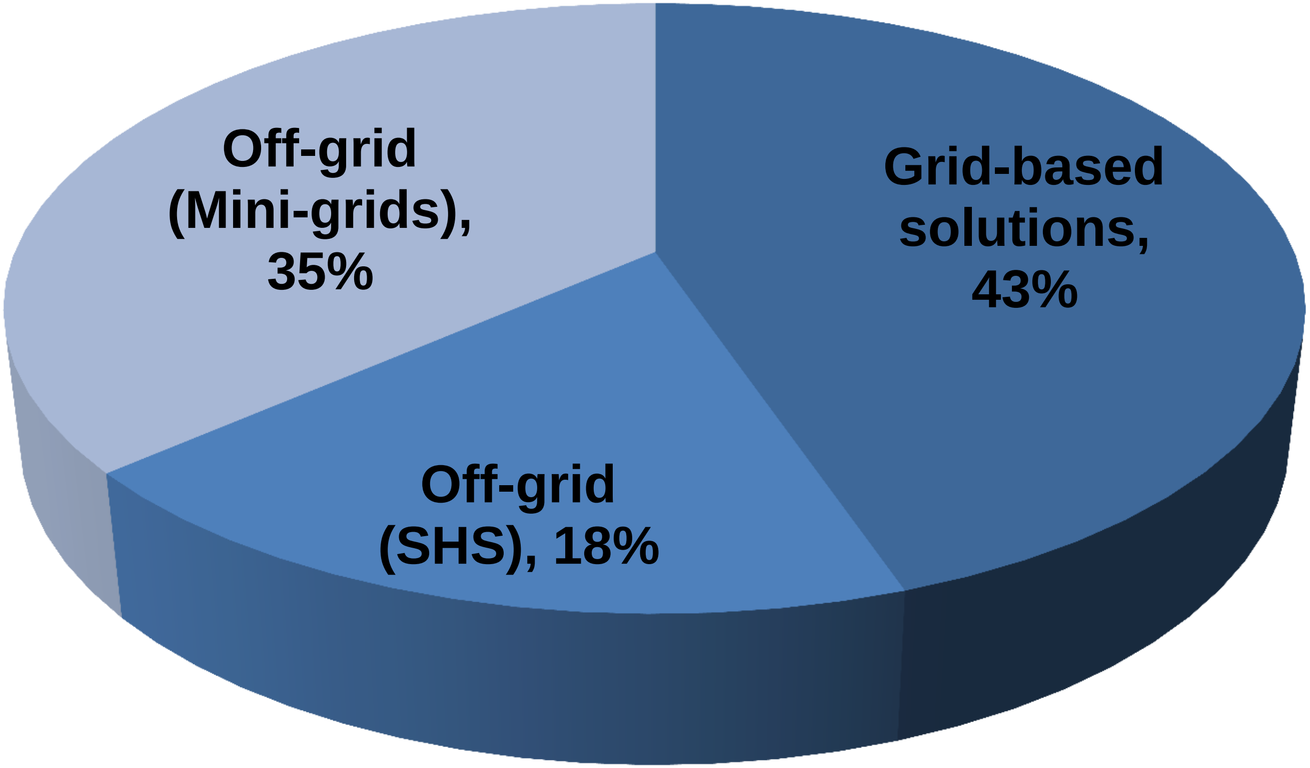
- Since 2000, 145 million people in sub-Saharan Africa have gained access to electricity
- The average electrification rate was 32% (up from 23% in 2000)
  - 85% in South Africa
  - Less than 10% in six countries
    - Chad, Central African Republic, DR Congo, Liberia, Malawi and South Sudan
- 59% of the urban population
- 16% rural population

Electrification rates in Africa



Source: Scott 2015

Universal electricity access by 2030: Technological solutions



Source: IEA 2014

Step 1:

Make use of maps and geographic information systems (GIS)

Use multiple layers of maps (GIS)

1. Resource quality (e.g. solar radiation in a given area, yearly global irradiation (kWh/m2))

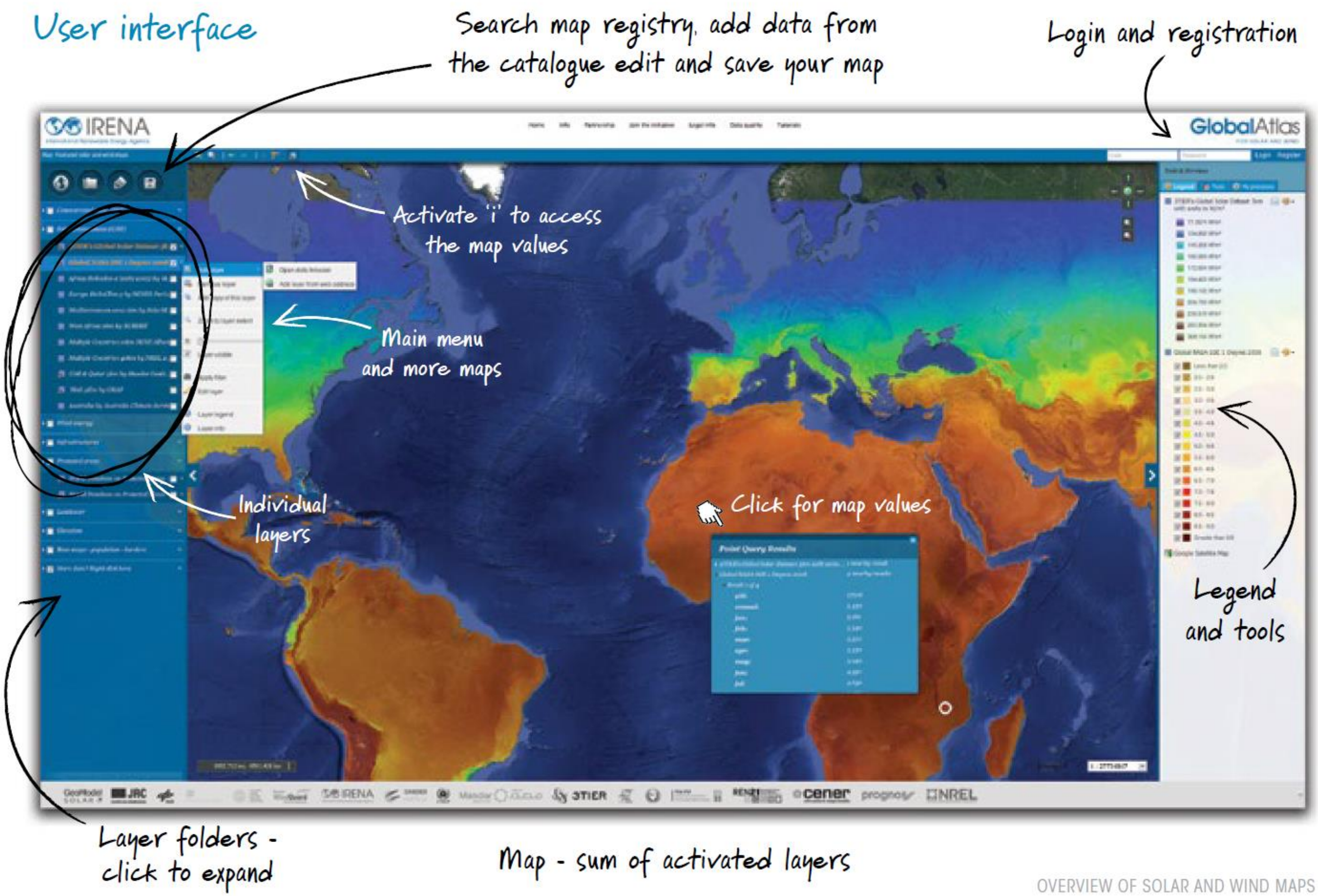
2. Electricity grid (distance to the grid)

3. Population density (persons/km2)

4. Road network (for deployment)

5. Terrain/slope (level of difficulty to construct transmission lines)

Ressource mapping (e.g. IRENA – Global Atlas



Source: IRENA http://irena.masdar.ac.ae/ , http://www.irena.org/documentdownloads/publications/ga_booklet_web.pdf

Opportunity areas for grid connected and off grid solar PV applications in ECOWAS

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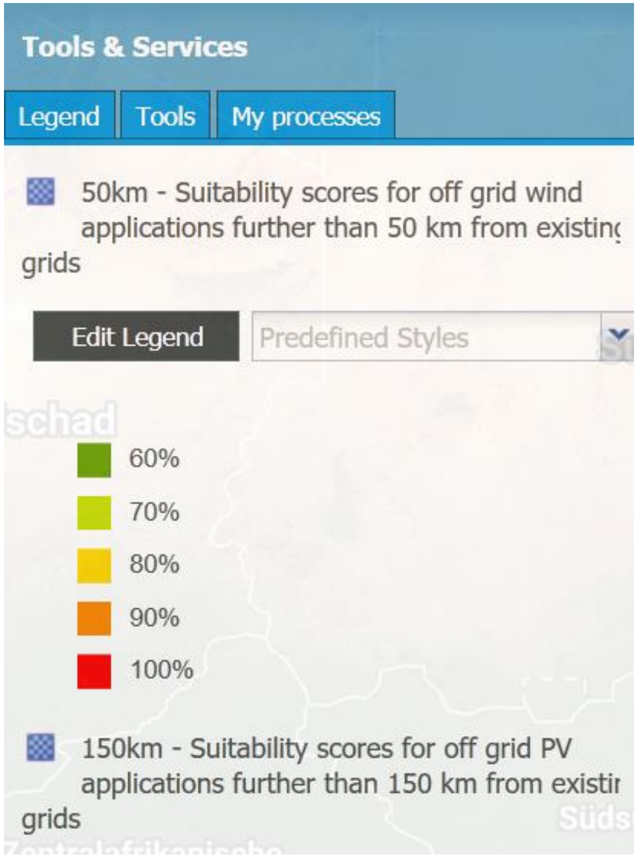
- Map shows opportunity areas for grid connected and offgrid PV in the ECOWAS region.
- The maps illustrate the capabilities of the Global Atlas for spatial planning purposes, in the case of the ECOWAS region.
- This demonstration shows a first range of possibilities for opportunity areas, based on a range of assumptions.
  - Yearly global irradiation (kWh/m2)
  - Grid distance (km)
  - Slope (%)
  - Population density (persons/km2)
  - Protected area



Source: http://www.irena.org/DocumentDownloads/Publications/GA_ECOWAS_Solar_Web.pdf

Opportunity areas for off-grid solar PV in ECOWAS – 20 km from grid

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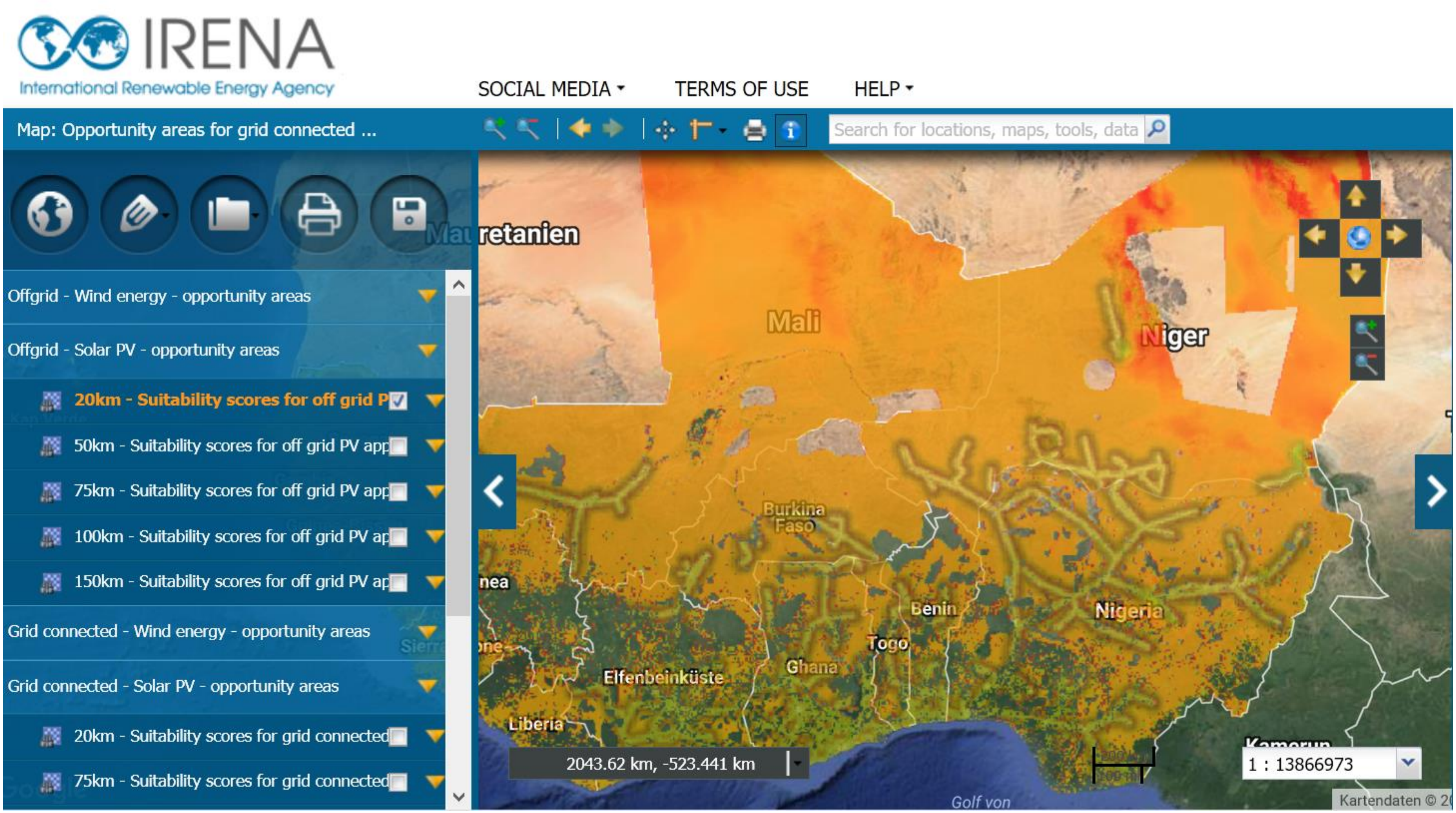
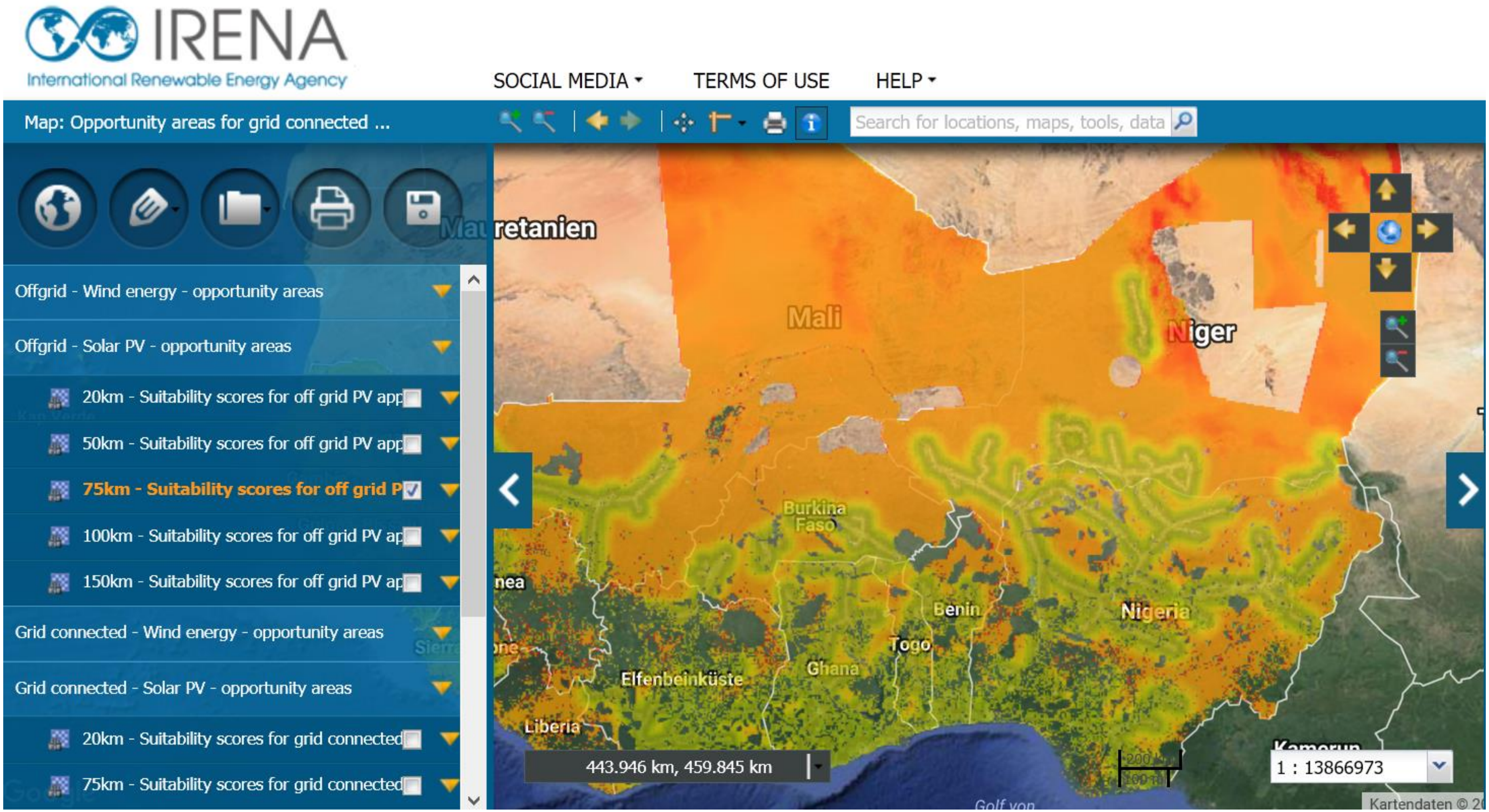


http://irena.masdar.ac.ae/?map=507

Opportunity areas for off-grid solar PV in ECOWAS – 75 km from grid



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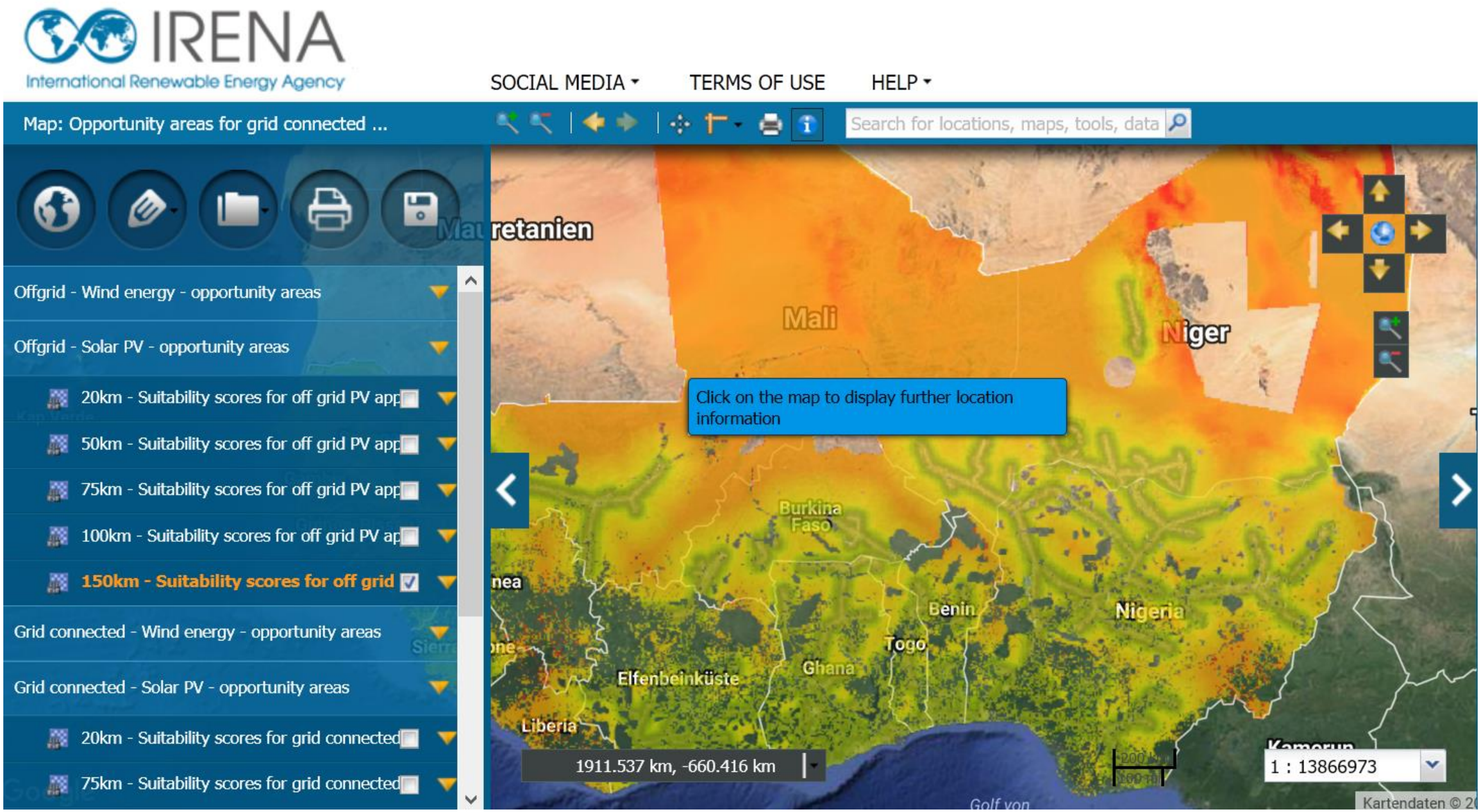
Opportunity areas for off-grid solar PV in ECOWAS – 150 km from grid



http://irena.masdar.ac.ae/?map=507

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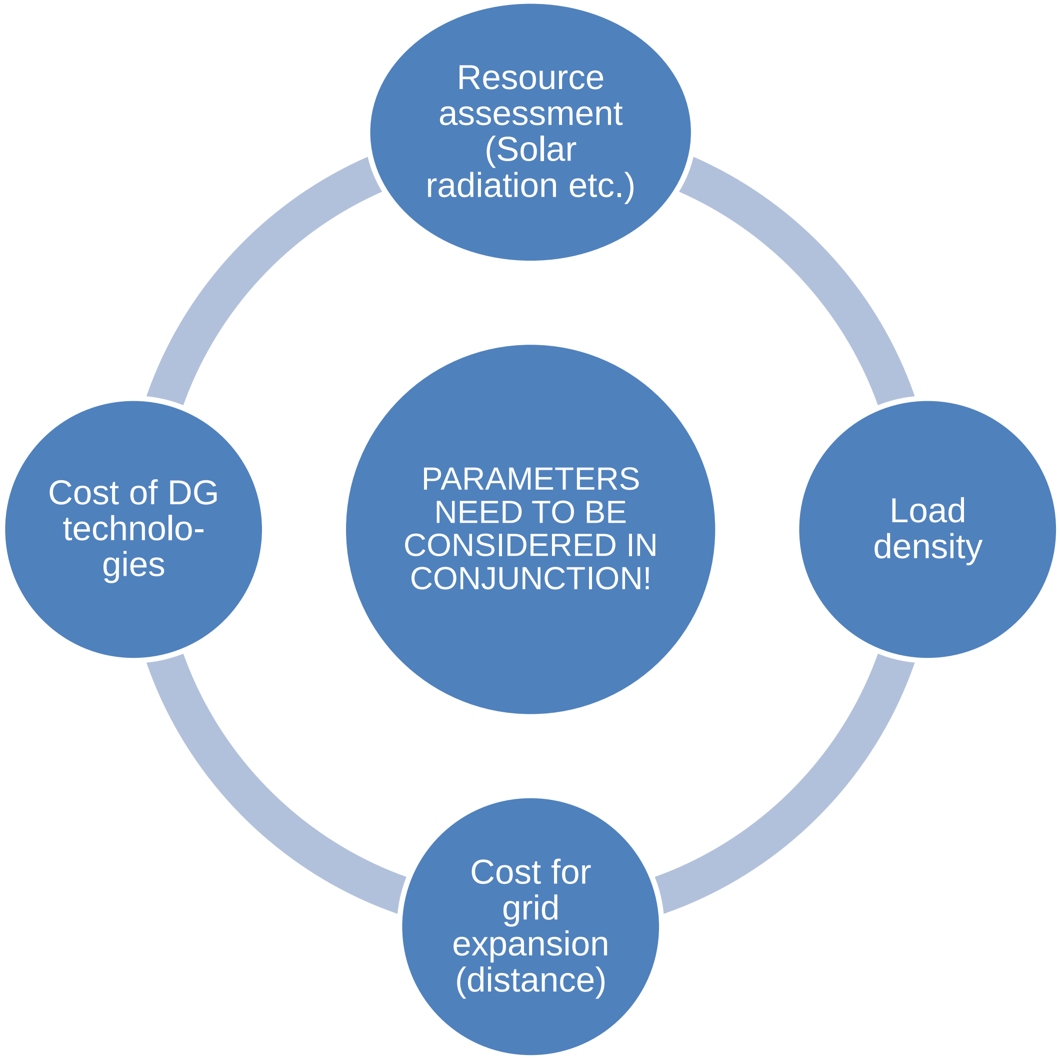
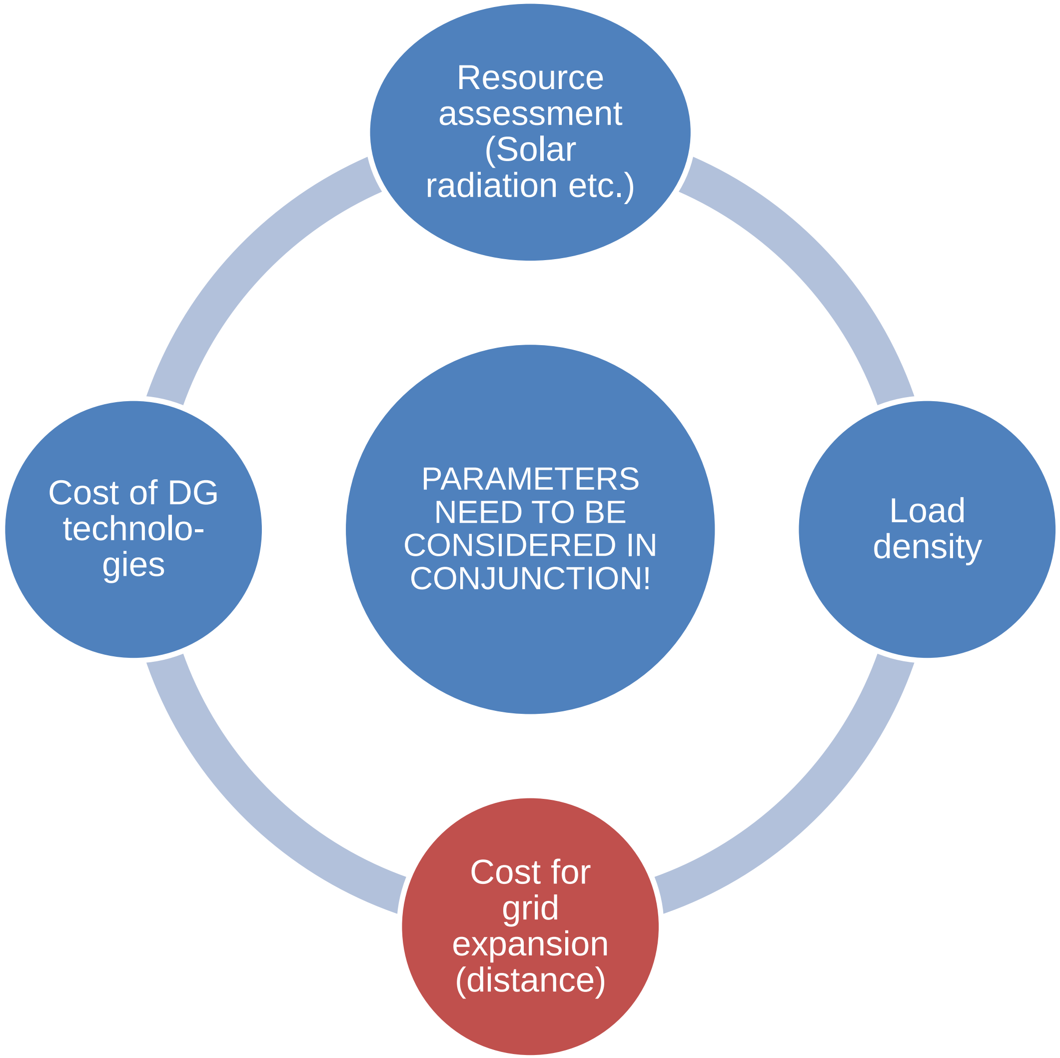
Step 2:

Analysis of detailed decision parameters (off-grid vs. on-grid)

Parameters for energy access planning decisions



Parameters for energy access planning decisions



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Grid expansion costs

- New connections in cities with existing grids: starting at 140 US$
- Cost estimates for grid expansion (World Bank): between US$8,000-US$10,000 per km,
- Cost can increase to as much as US$22,000 per km in difficult terrains
- Mini-grids can reduce transmission and distribution losses and theft

Source: WFC 2013, Kimani 2008, UNDP-ESMAP 2000, Alliance for Rural Electrification 2011

Least cost grid expansion plan in Rwanda

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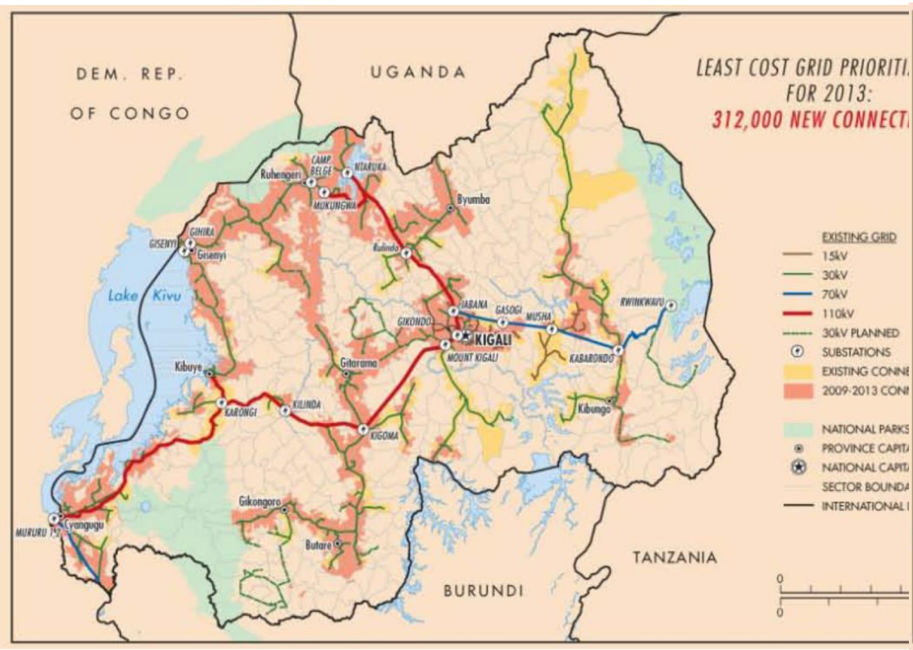
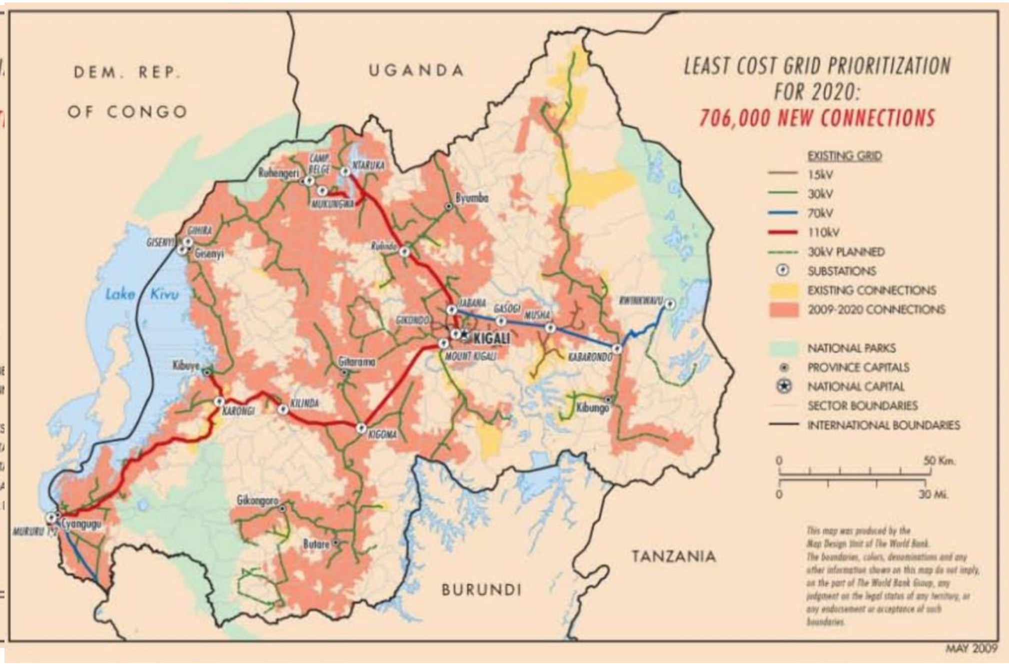
- Identify all areas that can be reached by the grid in the near term
- Keep in mind that the economics for off-grid solutions are likely to improve further in the future

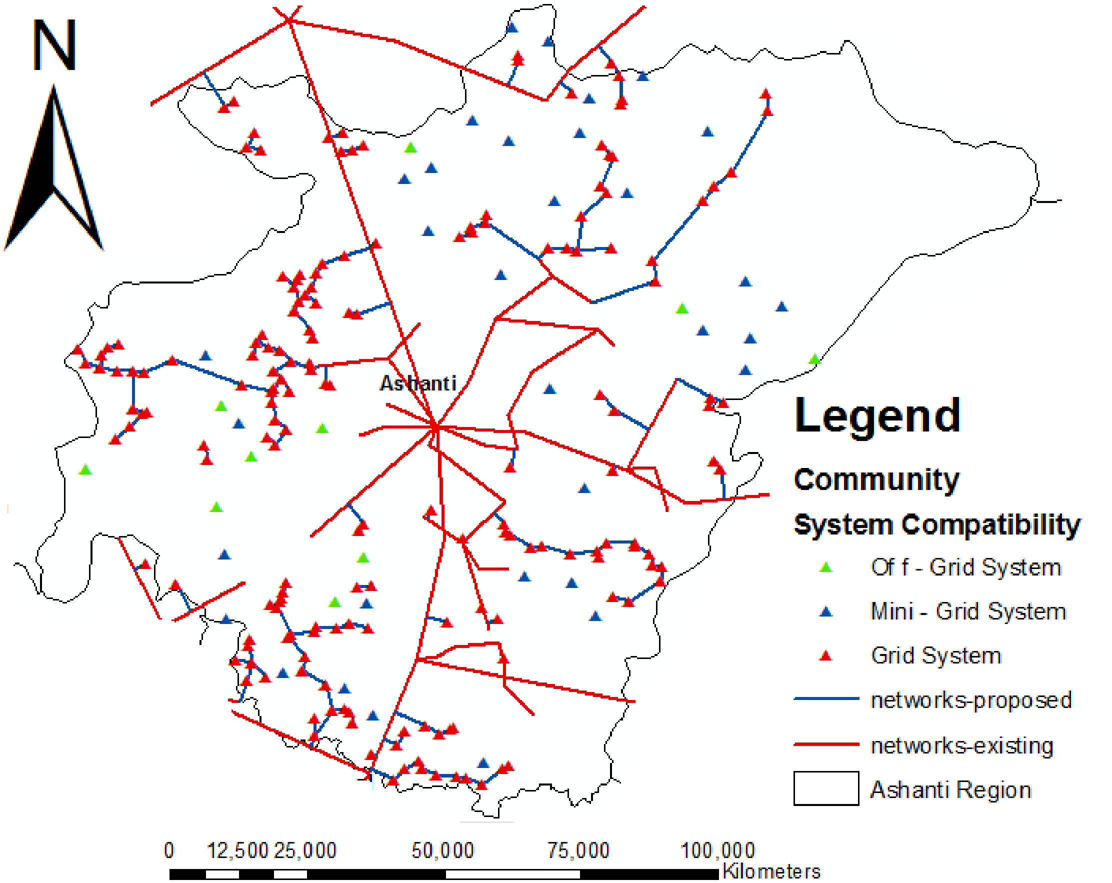




Source: World Bank http://siteresources.worldbank.org/EXTAFRREGTOPENERGY/Resources/717305-1327690230600/8397692-1327691237767/DAKARHVI_AEI_Practitioner_WorkshopNov14-15_2011_Nov7.pdf

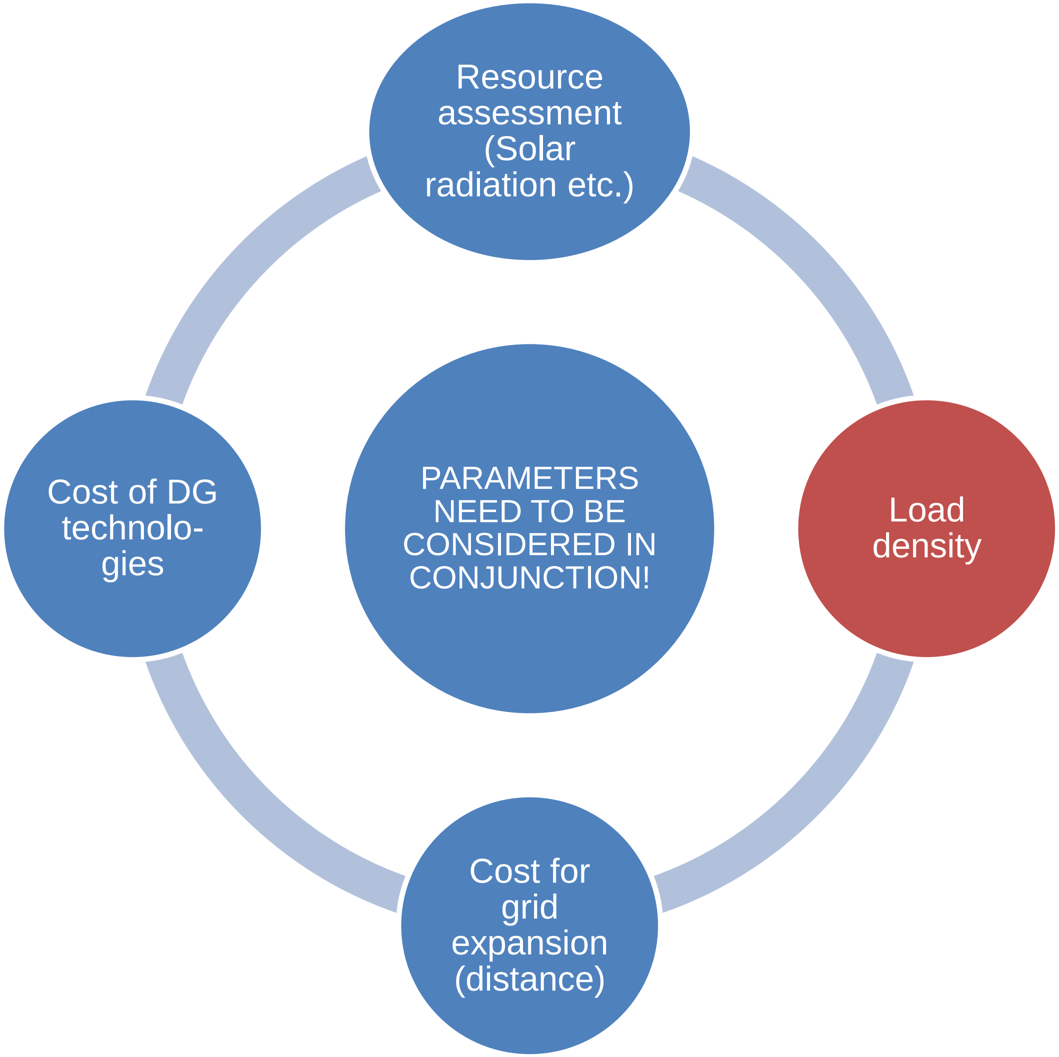
More Granular Grid Expansion and Off-grid Solutions

- regional map showing the proposed electrification technology options for the modelled un-electrified communities



Source: http://siteresources.worldbank.org/EXTAFRREGTOPENERGY/Resources/717305-1327690230600/8397692-1327697380446/Electrification_cost_estimation_Ghana_4Pager.pdf

Parameters for energy access planning decisions

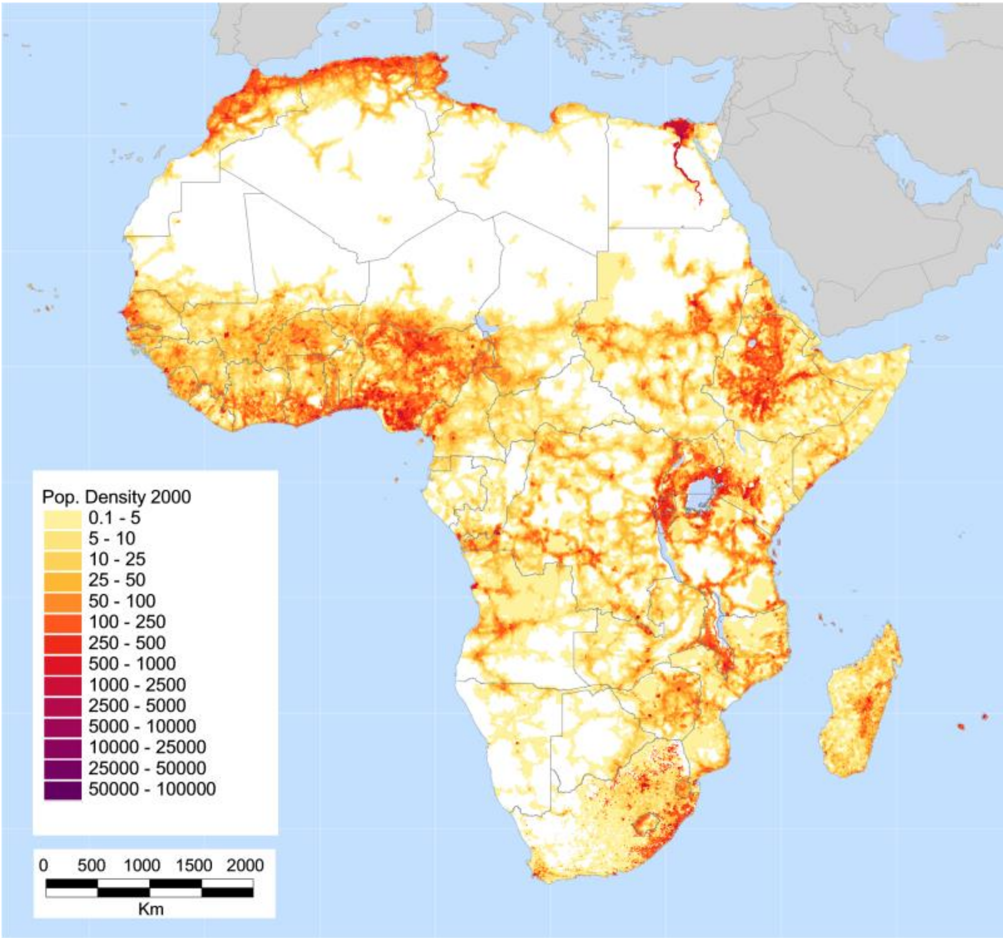


Load density

Electricity consumption + Population density = Load density

Population density

- Focus on grid expansions to areas with high population density
- Most Africans live in sparsely populated rural areas
  - About 60% today
  - About 45% in 2030



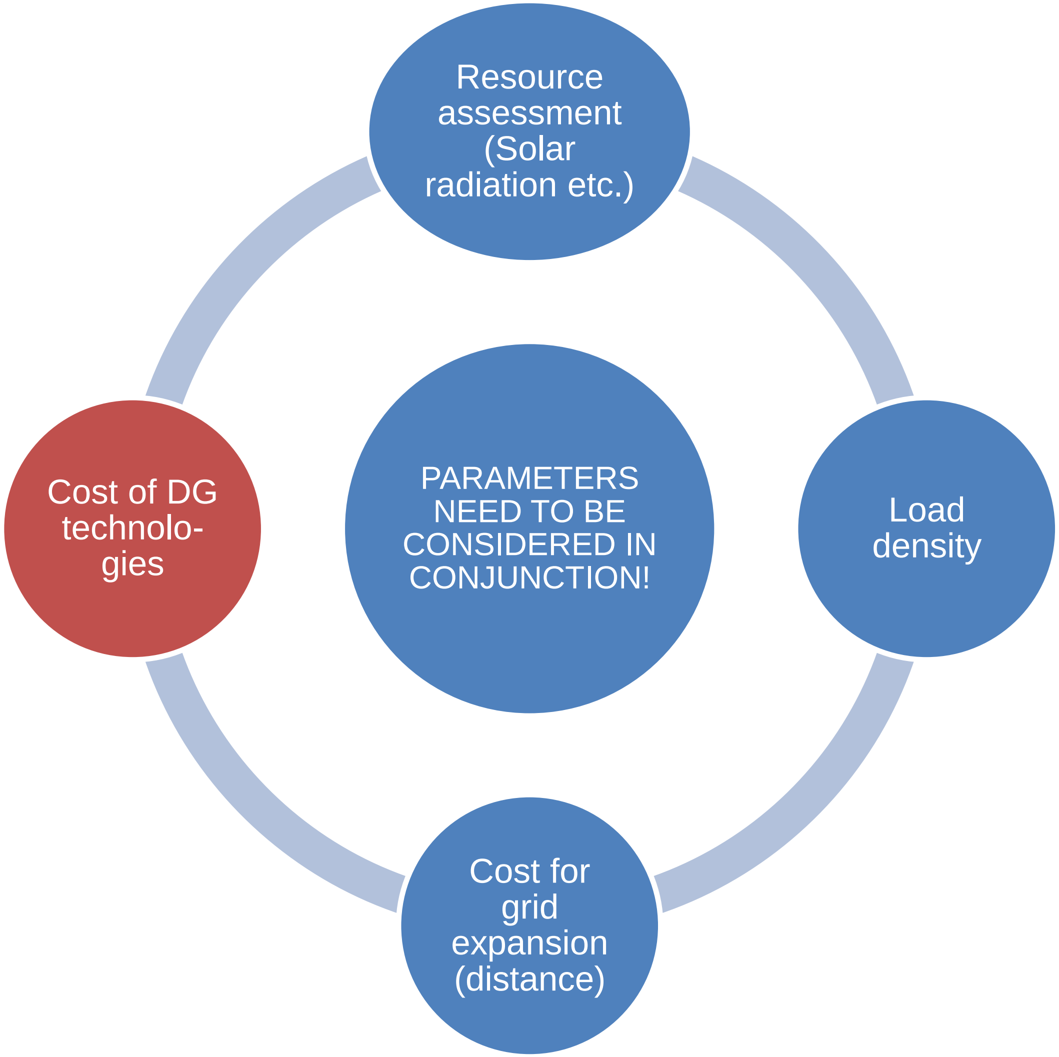
Source: http://imgur.com/9CLeRzR

Load density: Electricity consumption per household (kWh)

- Long-term developments unclear:
  - Rural electrification programs are implemented in order to spur economic development in rural areas
  - Once village is connected to the grid/supplied by electricity via off-grid solutions, electricity supply might increase considerably
  - provide estimates of expected consumption growth when planning energy access!
- REMARK(able):
  - Electricity from AA(A) batteries costs between 100-400 US$ per kWh!

Source: Mobisol

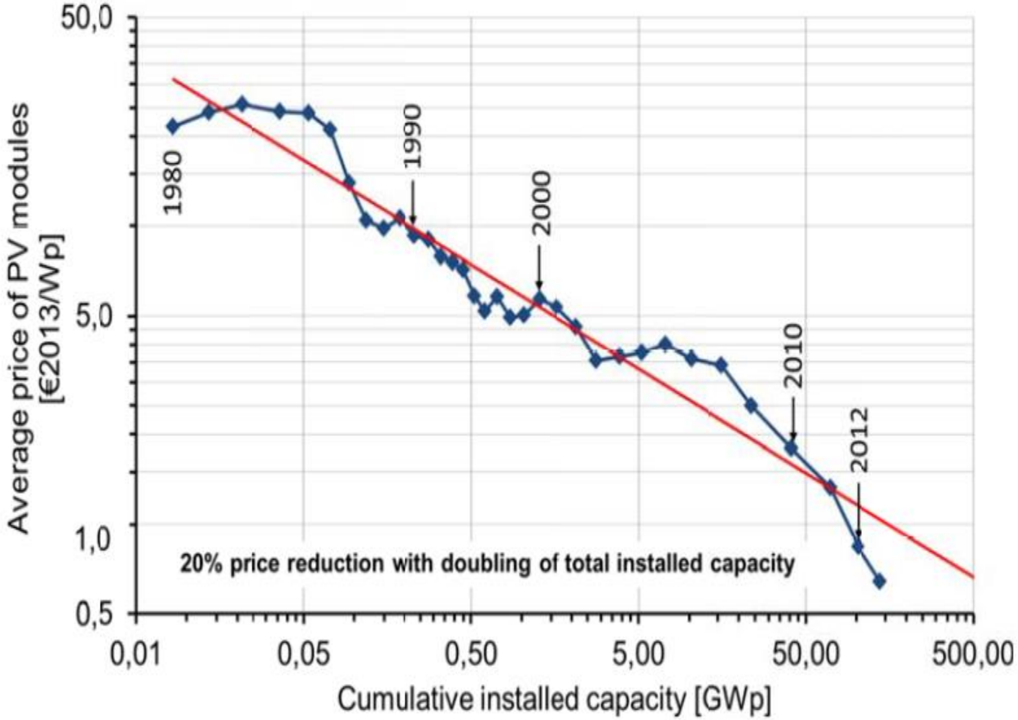
Parameters for energy access planning decisions



Cost of DG technologies - PV

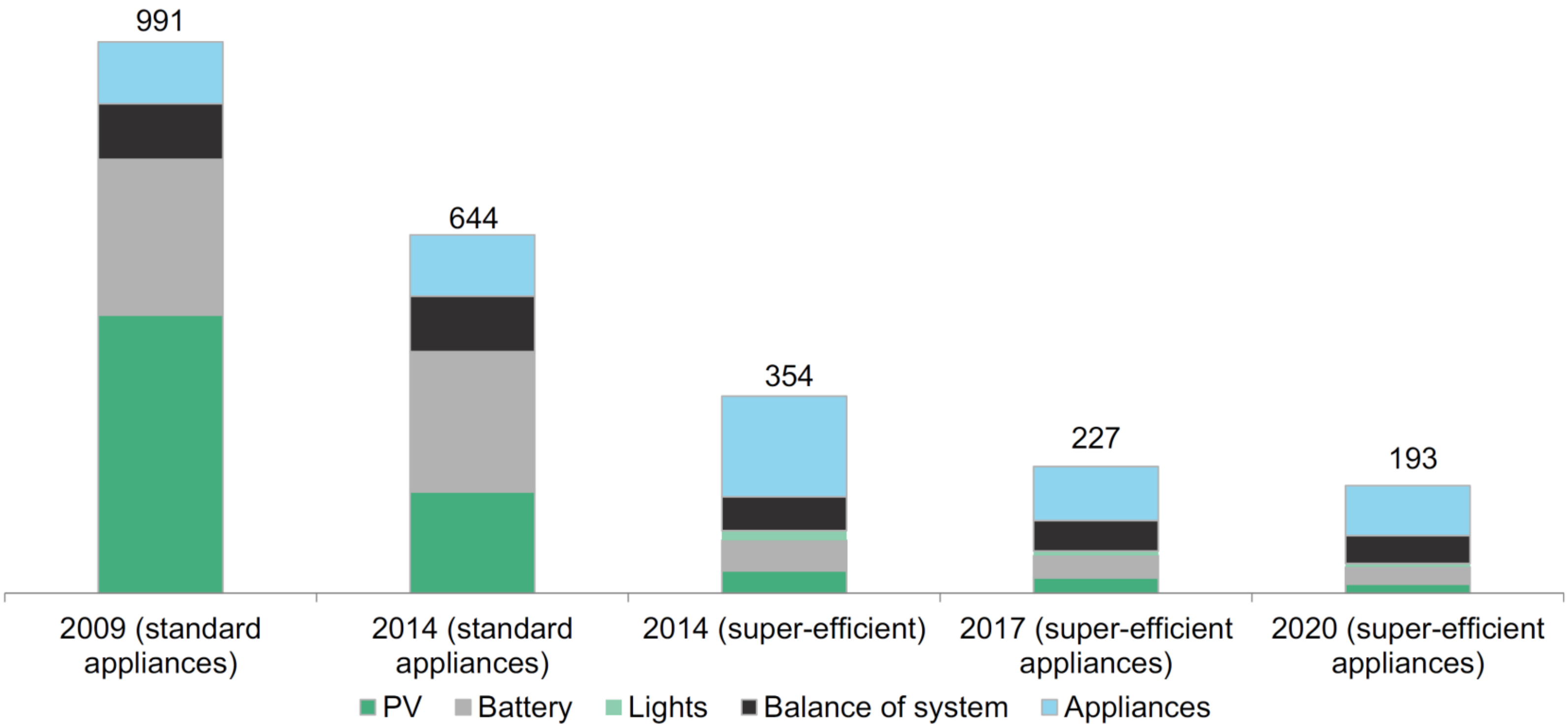
- Due to dramatic reductions in PV costs in the past years, PV mini-grids are a viable alternatives to grid extension and diesel mini-grids.

- Obstacles: the need for upfront financing, ensuring proper maintenance, intermittency, etc.



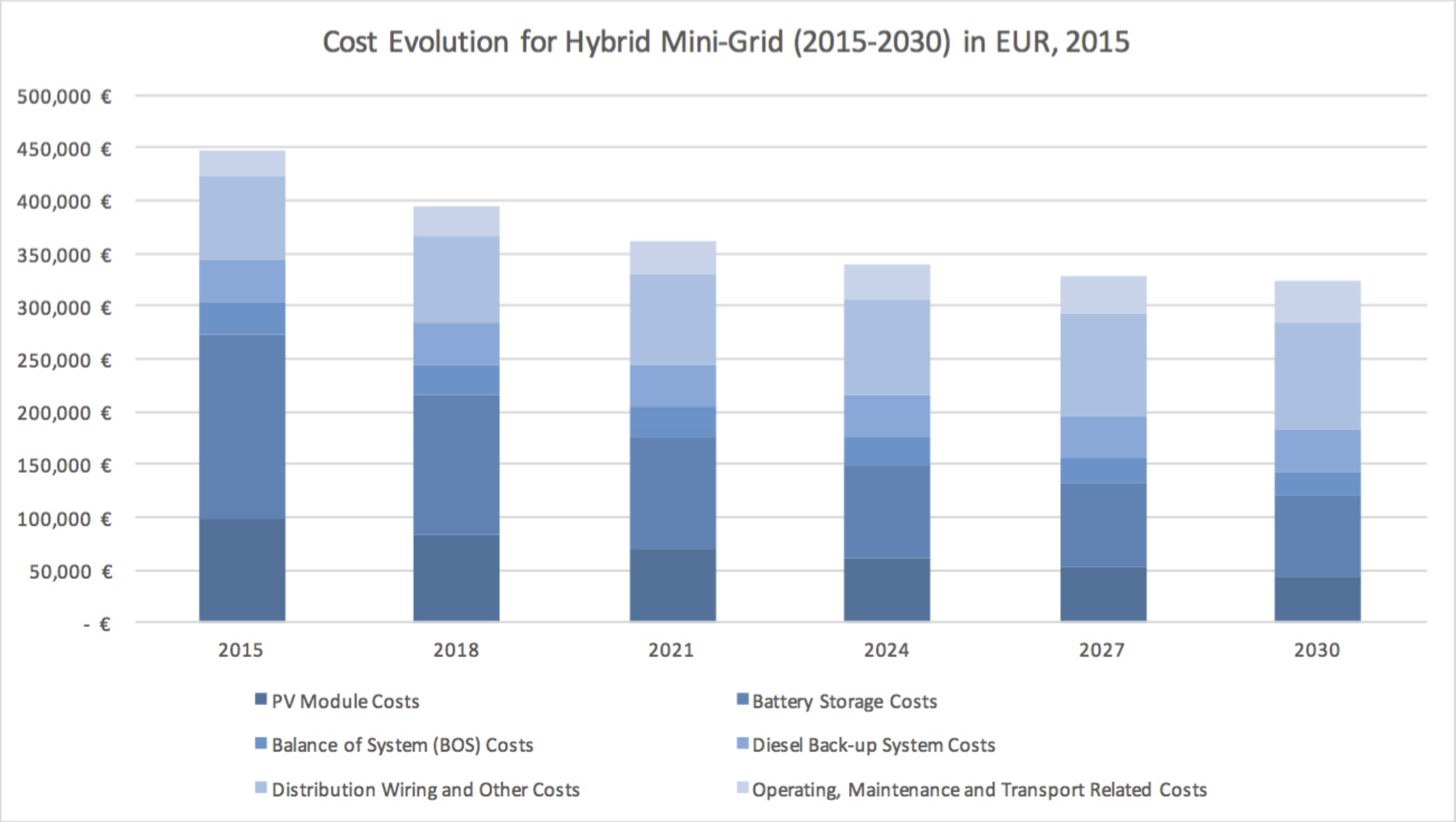
Source: Norplan 2012

Cost of DG technologies: SHS



Source: (Global LEAP, 2016)

Cost of DG technologies: Mini grids



System Parameters: 70kW PV Array; 500KWh Lithium Ion Battery System; 100kVA Diesel Generator

Source: Based on EUEI Mini-grid Policy Toolkit Financial Model, 2015, http://minigridpolicytoolkit.euei-pdf.org/support-tools

Cost of DG technologies: Batteries

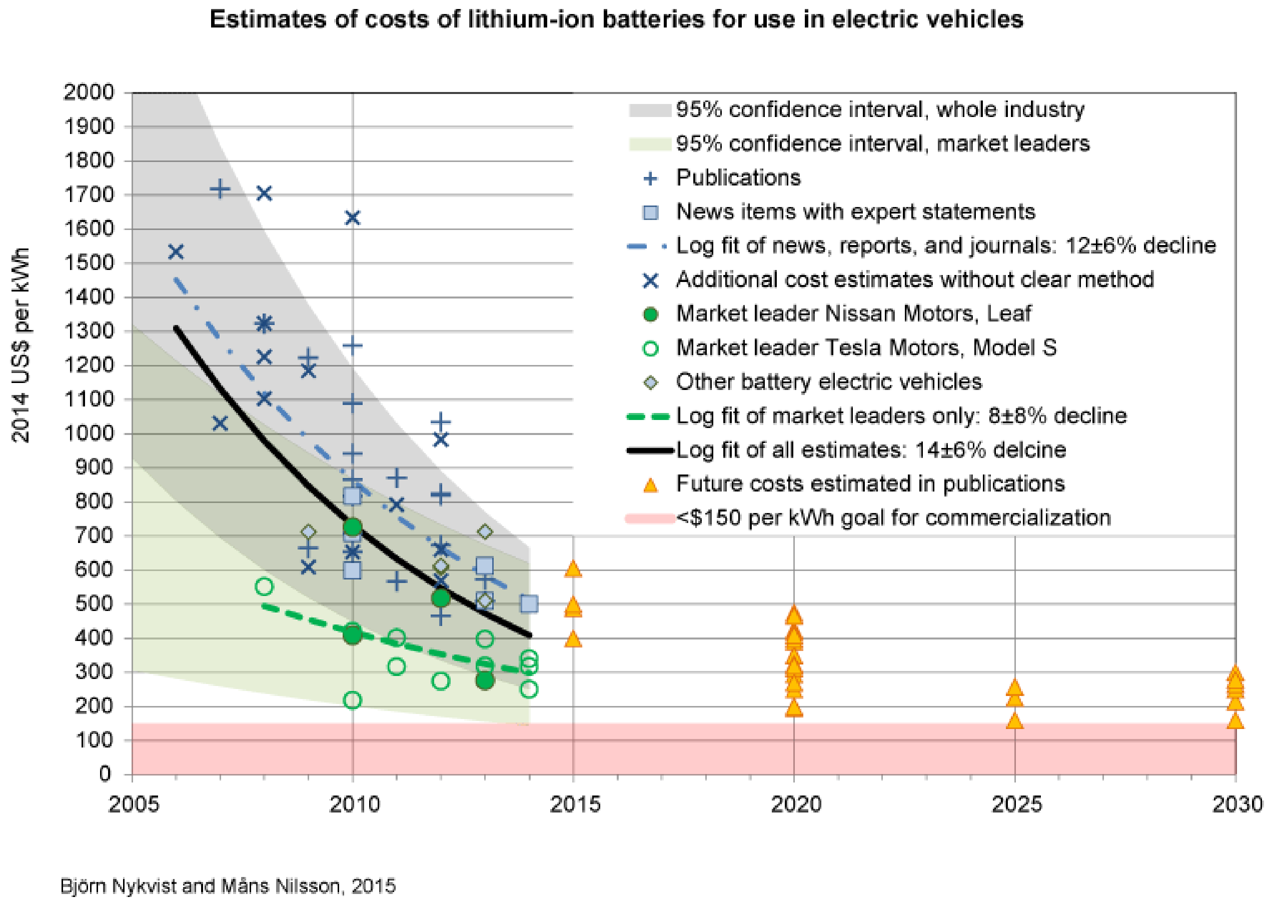


Figure XYZ: Historical and Forecasted Cost Evolution for Lithium-Ion Battery Systems (USD $/kWh)
Source: 2015

Step 3:

Planning for off-grid technology solutions (mini-grids, solar-home-systems and hybrid systems)

Willingness and ability to pay

- End-user perspective important!

Need for energy + Ability to pay + Willingness to pay = **Electrification strategy**

- What is the available income of a household/business?
- Is the income regular and foreseeable?
- What is the share already spent on energy today?
- Is (micro-)financing available and used?
- …

Some facts & figures

- Cost of energy from a small, cheap petrol or diesel genset?
  - 1.50…2.00 EUR/kWh
- Average household spending on energy in percent of household income?
  - 5…10% (3 to 15 USD)
- Household / small business spending on kerosene for lamps and candles?
  - around 17 billion USD
- Cost for energy of unelectrified customers?
  - Cell-phone charging: 20 to 80 EUR per kWh (0.10 to 0.40 EUR per charge)

Source: RENAC

Methods for data collection

„Willingness to pay is the maximum amount that an individual indicates that he or she is willing to pay for a good or service.“

- Ask potential customers which service they want and what they are willing to pay.
  - Result: Usually leads to overestimations.
- Ask questions about current energy consumption and expeditures for comparable services.
  - Result: Usually leads to underestimations.
- Ask to sign an *unbinding* „take or pay“ contract for a specific amount of energy at a specific price.
  - Result: Usually leads to quite accurate estimations.

BUT: „Willingness to pay is however not a fixed value but strongly depends on the quality of services provided and the available alternatives.“

Source: RENAC

Financing off-grid, rural electrification programs

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- **Cover cost-gap between willingness-to-pay and actual costs**
- Subsidies should be as high as necessary, yet as low as possible.

- project planning/pre-investment phase:
  - feasibility studies, business plan development, technical planning, capacity building and transaction costs)

- implementation/construction
  - e.g. as capital subsidies, connection subsidies

- during operation
  - operational subsides, tariff top-ups, cross-subsidies

Source: REN21 2014

Cost of technological solutions

- In-depth analysis of costs of different electrification options

- Several other factors influence the viability of off-grid solutions, e.g. the level of market penetration, transport cost for equipment, transport of fuels (e.g. diesel), etc.

Matrix for decision making (small hybrid system)

Small hybrid systems (3kWp to 30 kWp PV)

Remote village with very few activities **Peak load 30-60 kW** **150-300 kWh/day** **low growth rate**

Option	Key figures for economic / financial analysis				Level of service	Required operating skills
Grid extension	distance to grid	MV line cost 8-13 k€ / km	yearly sales 55 to 110 MWh / year	timeline for grid extension	full service	no
Diesel-based power plant	initial investment (incl. 1 genset) 40-70 k€	actual cost of diesel fuel kWh tariff	-if mandatory subsidy on diesel: for a total of 55 to 110 MWh / year (Ex: 8 to 16 k€/year)* -yearly O&M costs	genset lifespan	limited service schedule (no base load)	basic local skills (genset maintenance)
Hybrid-based power plant (Ex: 30 kWp PV)	initial investment 180-250 k€ + battery renewal (8 years) 35-50 k€	accessible penetration rate > 40% kWh tariff	-reduced mandatory subsidy on diesel: @40% PV penetration: 30-65 MWh / year (Ex: 3 to 7 k€/year)** -reduced O&M costs	-payback period -long lasting PV investment (25yrs) -battery lifespan -increased genset lifespan	24-hour service possible	training required for operator + distant support

Investment data shown for comparing options does not include cost of the local MV / LV grid or minigrid.
Initial investment and battery renewal cost for the PV / diesel hybrid option are based on a 30 kWp system as an example.
*Based on a 30% subsidy on 1.00 €/L fuel price and genset consumption 0.5 L/kWh
**Based on improved genset consumption: 0.35 L/kWh

Source: IEA PVPS 2014 https://www.iea.org/media/openbulletin/Rural_Electrification_with_PV_Hybrid_systems.pdf

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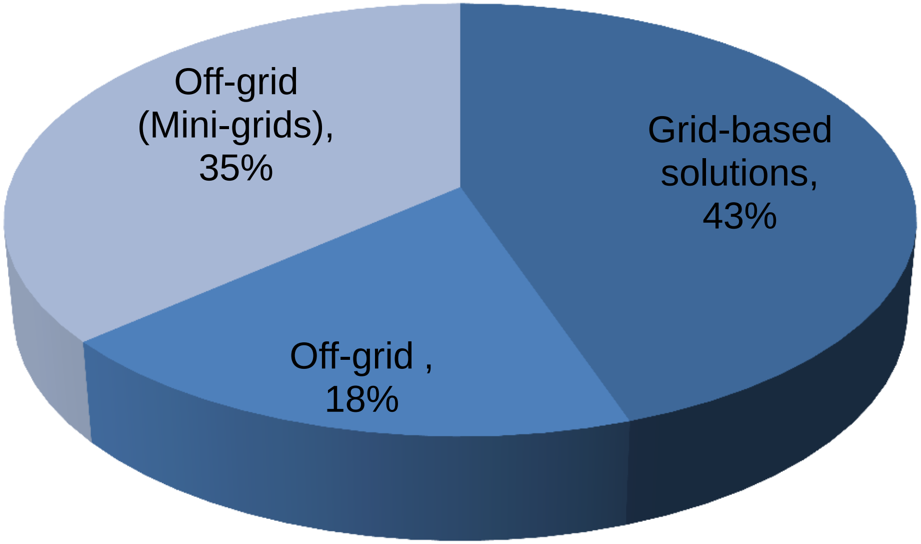
Summary and conclusion

Strategies for energy access planning

- To reach energy access for all by 2030 we need an **integrated strategy** for near-grid and off-grid solutions

- Coordination of responsibilities (several ministries?)



Source: IEA 2014

Strategies for energy access planning

- Strategy 1: Focus on the “low hanging fruits”
  - Electrification of near-grid households via grid expansion
  - lowest cost per new household connected to the grid (e.g. starting at 140 US$)
  - Highest cost efficiency to improve electrification rate

Strategies for energy access planning

- Strategy 2: Develop specific frameworks for remote, rural communities (off-grid and mini-grid solutions)

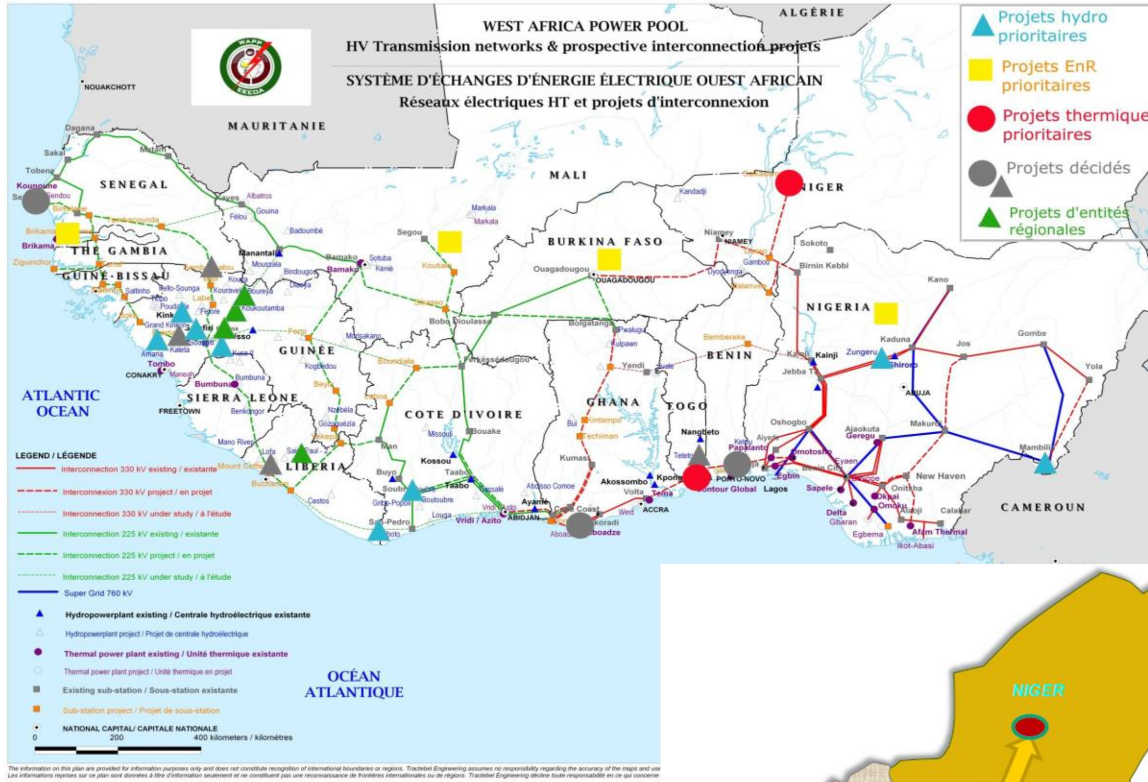
  - Low ability to pay (even to cover O&M costs of mini-grids)

  - Higher costs ($/kWh)

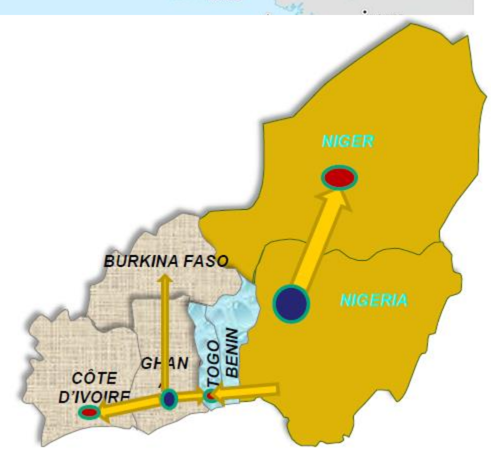
  - Specific finance mechanism needed (e.g. government fund)

Regional Solutions (e.g. West African Power Pool)

- Foster regional solutions
- Expand existing grid in neighboring countries if closer to rural communities
- Enable cross-border trade



Source: WAPP 2014



List of references and further reading

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List of references and further reading

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- Jacobs and Kiene 2009, renewable energy policies for sustainable African development, http://www.worldfuturecouncil.org/fileadmin/user_upload/PDF/World_Future_Council_Renewable_Energy_Policy_Africa_June09.pdf
- ECREE 2012, Ecree training manual on energy policy and incentive schemes, http://www.ecreee.org/sites/default/files/event-att/manual_re_incentive_scheme_ecowas_en.pdf
- More information from the World Bank on mini-grids: http://en.openei.org/wiki/World_Bank_Renewable_Energy_Toolkit#Mini_Grid_Renewable_Energy

Further reading

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- **Mini-Grid Policy Toolkit by EUEI-PDF**
  - http://minigridpolicytoolkit.euei-pdf.org/
- **„Scaling up successful micro-utilities for rural electrification“**
  - http://www.inensus.de/download/2013-SBI-INENSUS-Studie.pdf
- **„From the bottom up: How small power producers and mini-grids can deliver electrification and renewable energy in Africa“**
  - http://documents.worldbank.org/curated/en/2014/01/18812270/bottom-up-small-power-producers-mini-grids-can-deliver-electrification-renewable-energy-africa

Thanks for your attention!

Dr. David Jacobs
Founder and CEO

IET – International Energy Transition GmbH
Phone: +49 163 233 90 46
E-mail: jacobs@iet-consulting.com
Twitter: @InterEnerTrans

Additional slides

Technologies for universal electrification in Sub-Sahara Africa

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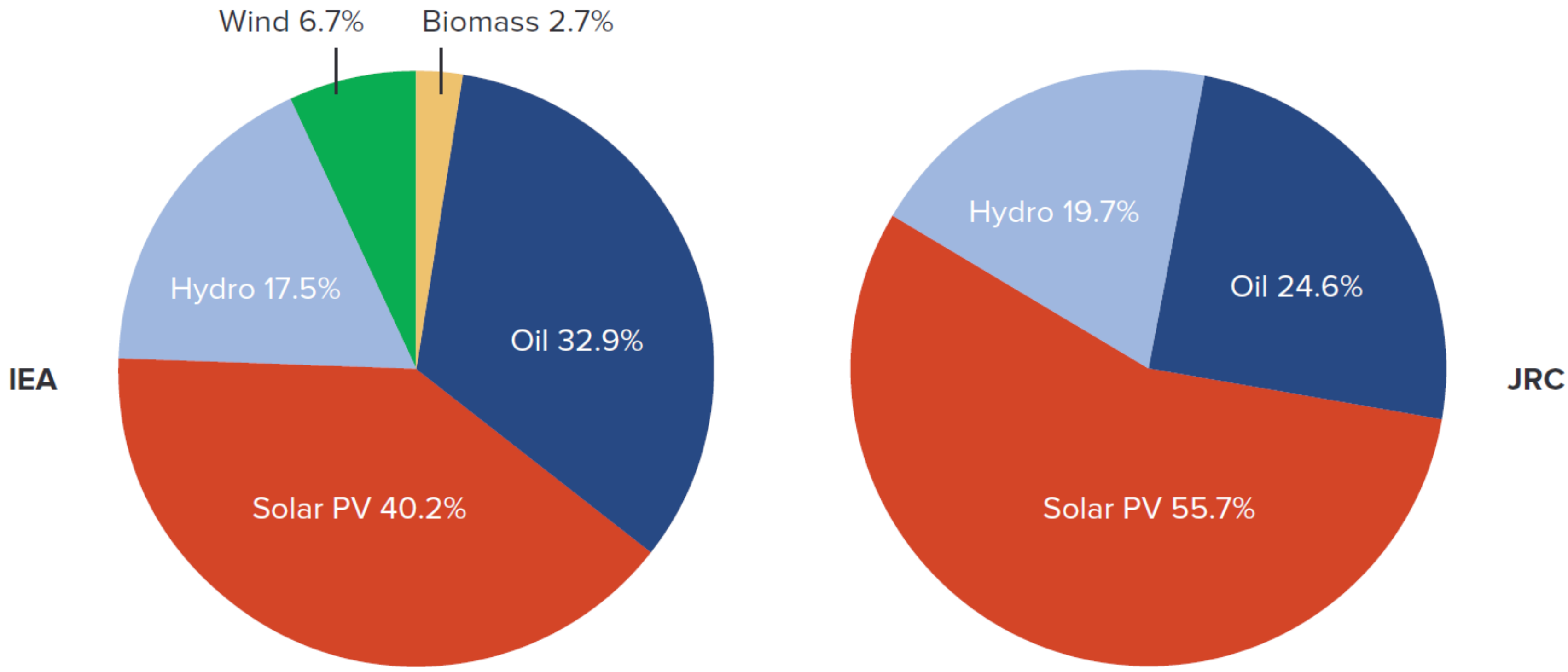
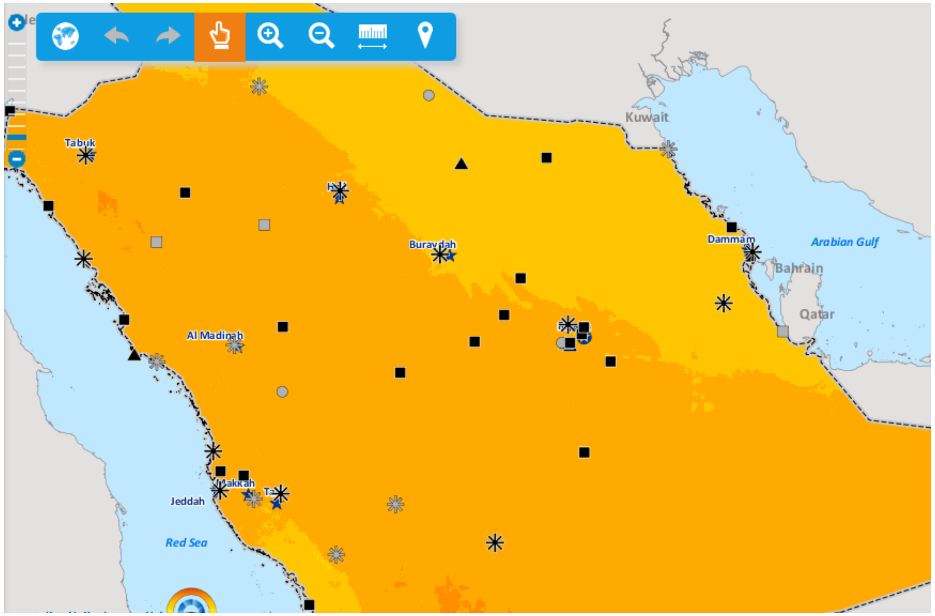


Source: Scott 2015 based on IEA 2014 and Szarca 2011

Assessing resource availability – KSA solar map

- Renewable energy atlas was launched in Dec 2013:
- Existing resource maps are important elements for Statement of Opportunities (SOO) for project developers
- Onsite measurement required for financing

- Available ONLINE: http://rratlas.kacare.gov.sa/RRMMPublicPortal/



Source: http://rratlas.kacare.gov.sa/RRMMPublicPortal/

Planning energy access: Parameters for cost calculation

Grid Extension
Transformer Capacities Available (kW)
Distribution loss
Installation cost per connection
Voltage Line cost per meter
Voltage Line lifetime
Voltage Lines O&M costs per year
Cost of transformers
Transformer lifetime
Transformer O&M costs

Source: Kemausuor et al 2011

Planning energy access: Parameters for cost calculation

Diesel Generator	Solar System
Available System Capacities (kW)	Available System Capacities (kW)
Diesel fuel (litres) consumed per kWh	PV balance (other accessories, excluding battery) cost as fraction of panel cost
Diesel generator cost per kWh of energy produced	PV panel lifetime
Diesel generator installation cost (as fraction of generator cost)	PV balance (other accessories, excluding battery) life time
Diesel generator lifetime	PV battery cost per kWh
Diesel generator O&M cost per year (as fraction of generator cost)	PV battery lifetime
Distribution Loss	PV battery kWh per PV component kW
	PV component effieiciency loss
	PV component O&M cost per year as fraction of component cost
	PV panel cost per PV component kilowatt

Source: Kemausuor et al 2011

Planning energy access: Parameters for cost calculation

Socio-economic
Economic Growth Rate
Population Growth Rates
Electricity Demand Growth
Elasticity of Electricity Demand
Interest Rate

Source: Kemausuor et al 2011

Planning energy access: Parameters for cost calculation

Costs for Grid and off-grid (solar, diesel) technologies
Materials for grid extension (poles, wire, transformers, etc.), and for off-grid (solar and diesel generation equipment)
Recurring costs (operations & maintenance), and "soft costs" such as system design and installation
Electricity connection fees for households, businesses (single-phase and three-phase)

Source: Kemausuor et al 2011

IRENA – Global Atlas (example ECOWAS)

- Geographic coverage: The Economic Community of West African States (ECOWAS)
- Source: ECOWAS Center for Renewable Energy and Energy Efficiency
- Website: www.ecreee.org
- Direct access: Search 'ECREEE' through the Global Atlas Data Browser.
- Detailed description and original website: www.ecowrex.org
- http://www.irena.org/documentdownloads/publications/ga_booklet_web.pdf