



# **Decentralized Renewable Off-Grid Solutions versus Grid Extension in Developing Regions – Necessary Criteria for a Spatial Analysis of Key Drivers**

Catherina Cader  
7th International Conference on PV-Hybrids  
and Mini-Grids  
April 10th, 2014

## Research Groups

- Off-grid energy systems
- Integrated energy systems
  - Optimization of energy systems
  - Analysis of energy transition scenarios
- Mobility with renewable energies
  - Integration of renewable energies into e-mobility concepts
- Renewable energy technology
  - Small wind power

Managing Director: Prof. Dr. Jochen Twele



**Reiner Lemoine**  
Founder of the Reiner Lemoine  
Foundation

**Scientific research for an energy transition towards  
100 % renewable energies.**

- 
- Introduction
  - Key criteria for on- and off-grid solutions
  - Conclusion
-

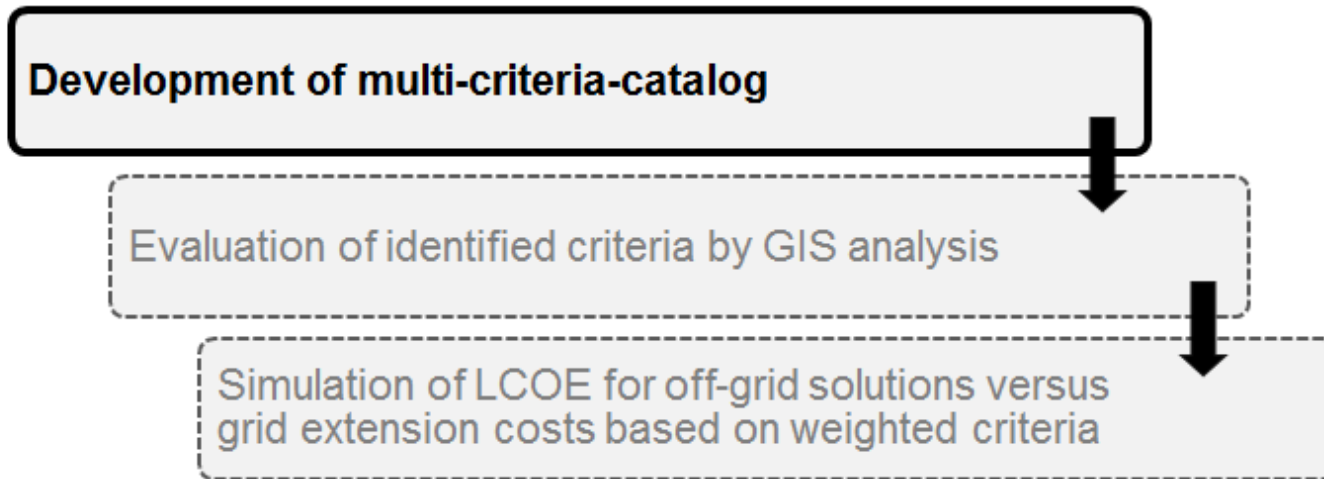
## Number of people without access to electricity by region (million).

	Rural	Urban	Total	Share of population
Developing countries	1,081	184	1,265	24%
Africa	475	114	590	57%
Developing Asia	556	62	628	18%
Latin America	23	6	29	6%
Middle East	16	2	18	9%
<b>World</b>	<b>1,083</b>	<b>184</b>	<b>1,267</b>	<b>19%</b>

Source: World Energy Outlook 2012, International Energy Agency, 2012.

Global need for electrification exists especially for rural areas. Comparison between off-grid electrification and grid extension is crucial to find technological and economic viable solutions.

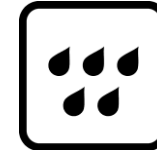
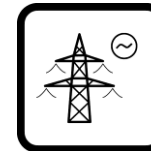
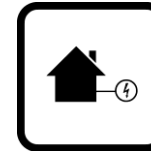
# Introduction: Research Approach



Multi-criteria catalog is developed to distinguish advantages and disadvantages of on- and off-grid electricity supply.

# Key Criteria

- Remoteness
- Electricity Demand
- Existing Electricity Generation and Transmission Schemes
- Natural Resource Assessment
- Non-Spatial Parameters



⇒ Examples of the most important spatial criteria are mapped along the example of Cameroon.

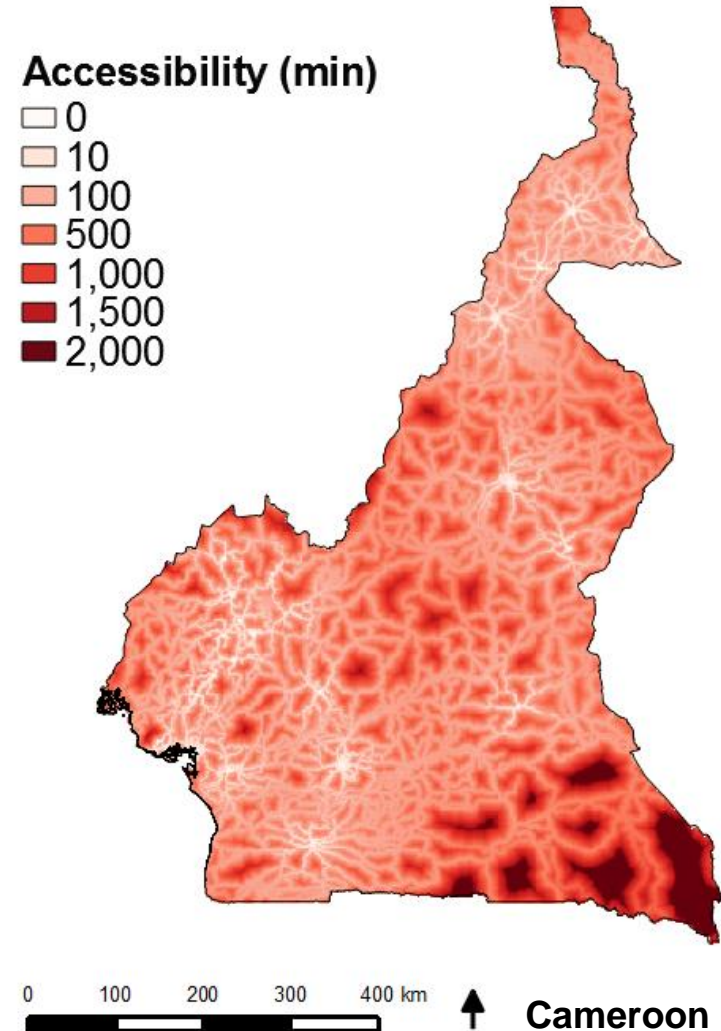
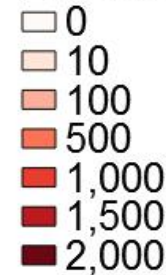


- Travel time to the next city with more than 50,000 inhabitants
- Distribution of towns and villages
- Urban / rural area distinction

#### Sources:

- Nelson , A., Estimated travel time to the nearest city of 50,000 or more people in year 2000, Global Environment Monitoring Unit - Joint Research Centre of the European Commission, Ispra, Italy, 2008.
- Center for International Earth Science Information Network - CIESIN - Columbia University, International Food Policy Research Institute - IFPRI, The World Bank, and Centro Internacional de Agricultura Tropical - CIAT. 2011. Global Rural-Urban Mapping Project, Version 1 (GRUMPv1): Settlement Points.

#### Accessibility (min)



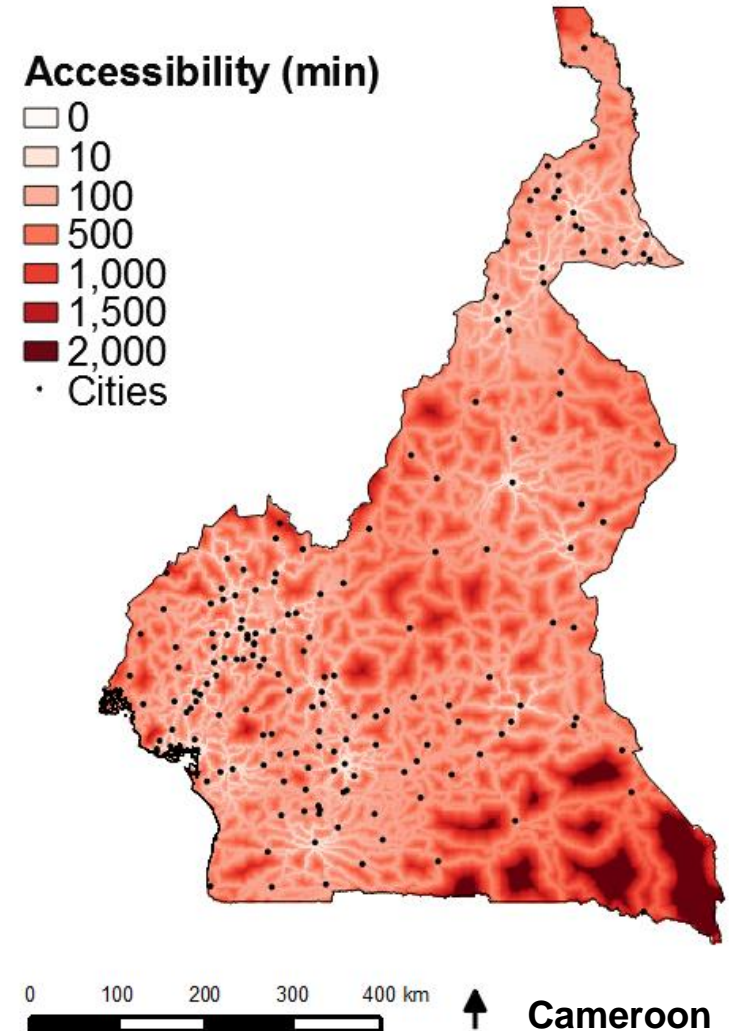
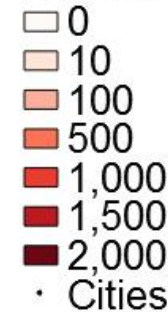


- Travel time to the next city with more than 50,000 inhabitants
- Distribution of towns and villages
- Urban / rural area distinction

### Sources:

- Nelson , A., Estimated travel time to the nearest city of 50,000 or more people in year 2000, Global Environment Monitoring Unit - Joint Research Centre of the European Commission, Ispra, Italy, 2008.
- Center for International Earth Science Information Network - CIESIN - Columbia University, International Food Policy Research Institute - IFPRI, The World Bank, and Centro Internacional de Agricultura Tropical - CIAT. 2011. Global Rural-Urban Mapping Project, Version 1 (GRUMPv1): Settlement Points.

### Accessibility (min)





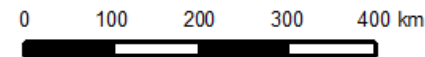
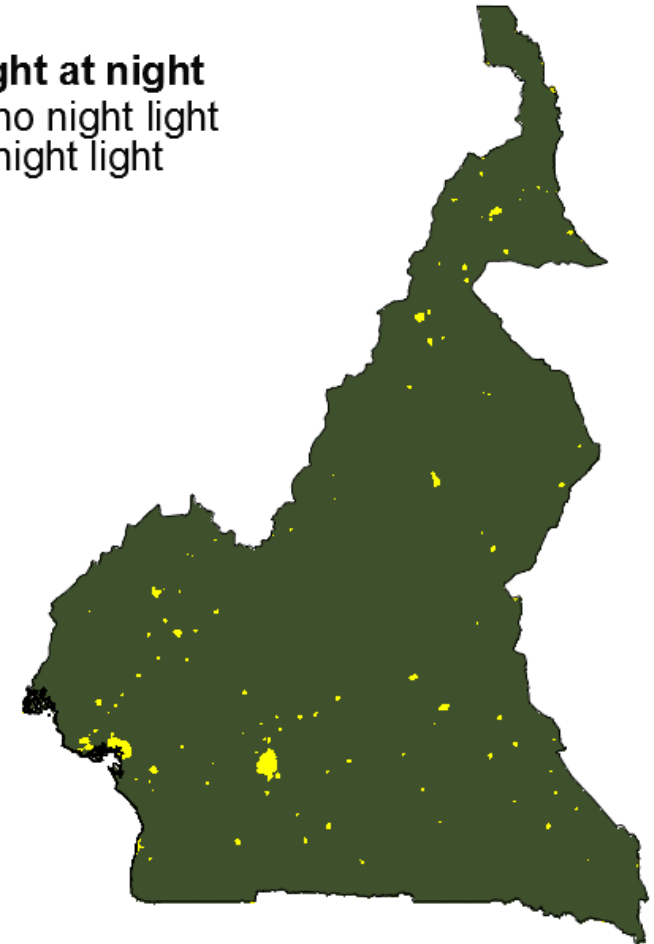


- Electricity access
- Population density
- GDP
- Tourism/industry

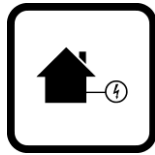
**Sources:**

- *Night Light Imagery*, version 4 DMSP-OLS Night Lights Time Series, NOAA National Geophysical Data Center, US Air Force Weather Agency, Boulder, Colorado. LandScan 2011™ *High Resolution global Population Data Set*, copyright UT-Battelle, LLC, operator of Oak Ridge National Laboratory under Contract No. DE-AC05-00OR22725 with the United States Department of Energy.
- Nelson, A., *Estimated travel time to the nearest city of 50,000 or more people in year 2000*, Global Environment Monitoring Unit - Joint Research Centre of the European Commission, Ispra, Italy, 2008.
- Ghosh, T., Powell, R. L., Elvidge, C. D., Baugh, K. E., Sutton, P. C., Anderson, S., *Shedding Light on the Global Distribution of Economic Activity*. The Open Geography Journal, 3, 148 – 161, 2010.

**Light at night**  
 no night light  
 night light



**Cameroon**

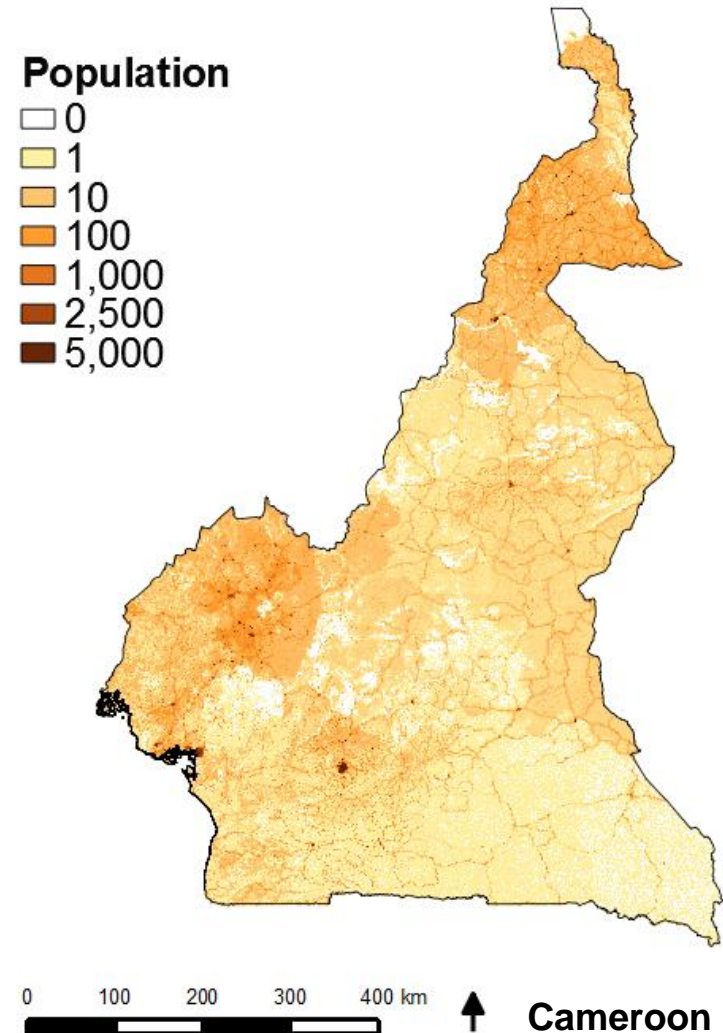
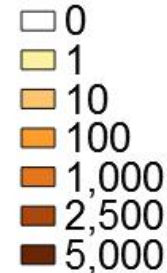


- Electricity access
- Population density
- GDP
- Tourism/industry

#### Sources:

- *Night Light Imagery*, version 4 DMSP-OLS Night Lights Time Series, NOAA National Geophysical Data Center, US Air Force Weather Agency, Boulder, Colorado. LandScan 2011™ *High Resolution global Population Data Set*, copyright UT-Battelle, LLC, operator of Oak Ridge National Laboratory under Contract No. DE-AC05-00OR22725 with the United States Department of Energy.
- Nelson, A., *Estimated travel time to the nearest city of 50,000 or more people in year 2000*, Global Environment Monitoring Unit - Joint Research Centre of the European Commission, Ispra, Italy, 2008.
- Ghosh, T., Powell, R. L., Elvidge, C. D., Baugh, K. E., Sutton, P. C., Anderson, S., *Shedding Light on the Global Distribution of Economic Activity*. The Open Geography Journal, 3, 148 – 161, 2010.

#### Population



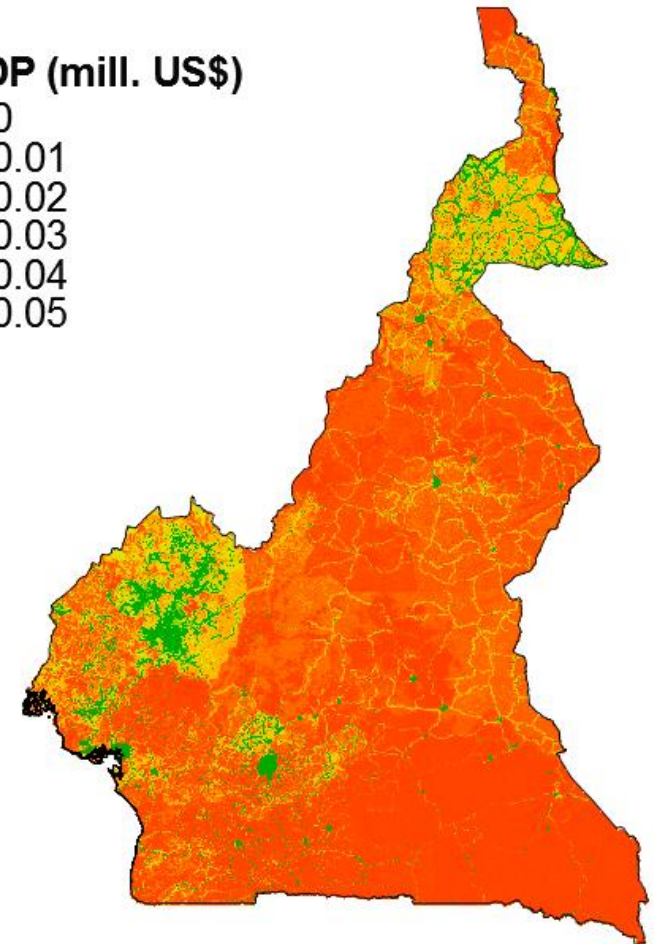


- Electricity access
- Population density
- GDP
- Tourism/industry

**Sources:**

- *Night Light Imagery*, version 4 DMSP-OLS Night Lights Time Series, NOAA National Geophysical Data Center, US Air Force Weather Agency, Boulder, Colorado. LandScan 2011™ *High Resolution global Population Data Set* , copyright UT-Battelle, LLC, operator of Oak Ridge National Laboratory under Contract No. DE-AC05-00OR22725 with the United States Department of Energy.
- Nelson , A., *Estimated travel time to the nearest city of 50,000 or more people in year 2000*, Global Environment Monitoring Unit - Joint Research Centre of the European Commission, Ispra, Italy, 2008.
- Ghosh, T., Powell, R. L., Elvidge, C. D., Baugh, K. E., Sutton, P. C., Anderson, S., *Shedding Light on the Global Distribution of Economic Activity*. The Open Geography Journal, 3, 148 – 161 , 2010.

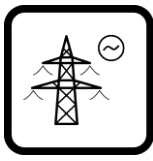
**GDP (mill. US\$)**



0 100 200 300 400 km



**Cameroon**



- Transmission line course
- Quality of service (load shedding, limited supply)
- Transport losses
- Central electricity generation plants (capacity, type)

## Electricity Transmission

- Existing
- - - Planned



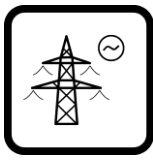
0 100 200 300 400 km



**Cameroon**

### Sources:

- *UDI World Electric Power Plants Data Base (WEPP)*, Platts 2012.
- Africa Infrastructure Knowledge Program, <http://www.infrastructureafrica.org> (accessed 30.03.14)



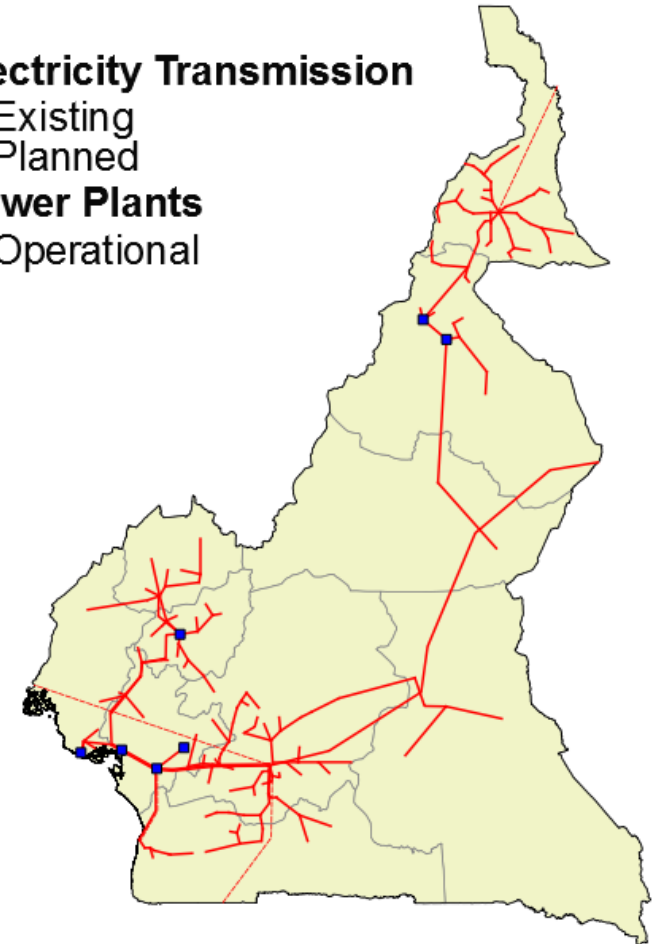
- Transmission line course
- Quality of service (load shedding, limited supply)
- Transport losses
- Central electricity generation plants (capacity, type)

## Electricity Transmission

- Existing
- - - Planned

## Power Plants

- Operational



0 100 200 300 400 km



**Cameroon**

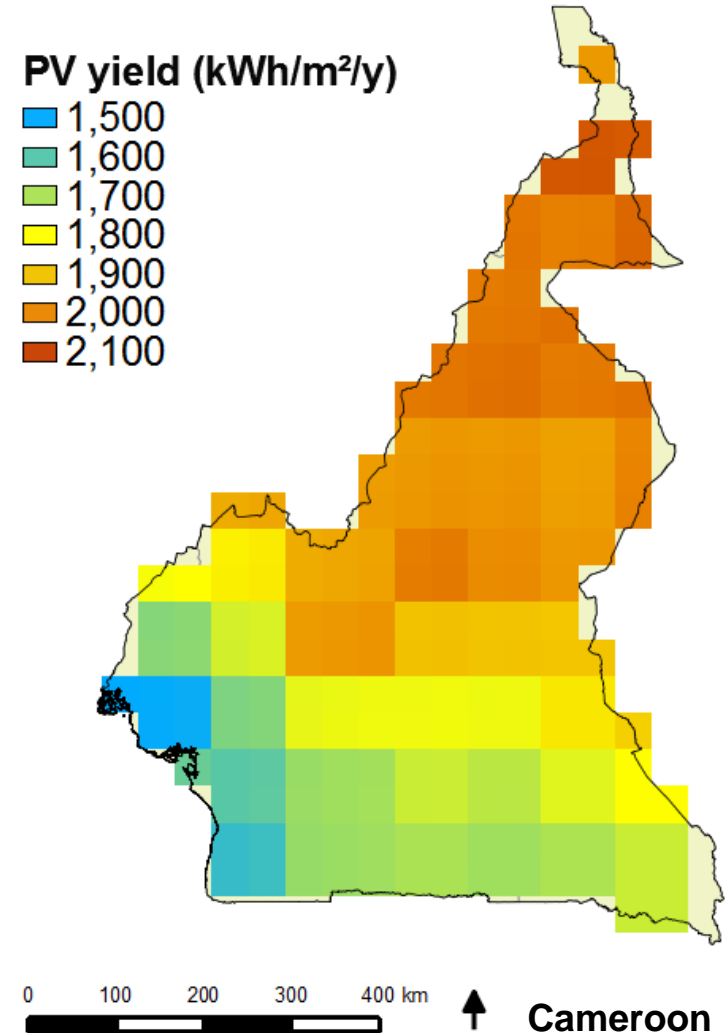
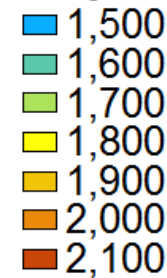
## Sources:

- *UDI World Electric Power Plants Data Base (WEPP)*, Platts 2012.
- Africa Infrastructure Knowledge Program, <http://www.infrastructureafrica.org> (accessed 30.03.14)



- Solar irradiation
- Wind speed
- Hydro power potential (Digital elevation model (DEM) + rivers)
- Land cover

**PV yield (kWh/m<sup>2</sup>/y)**



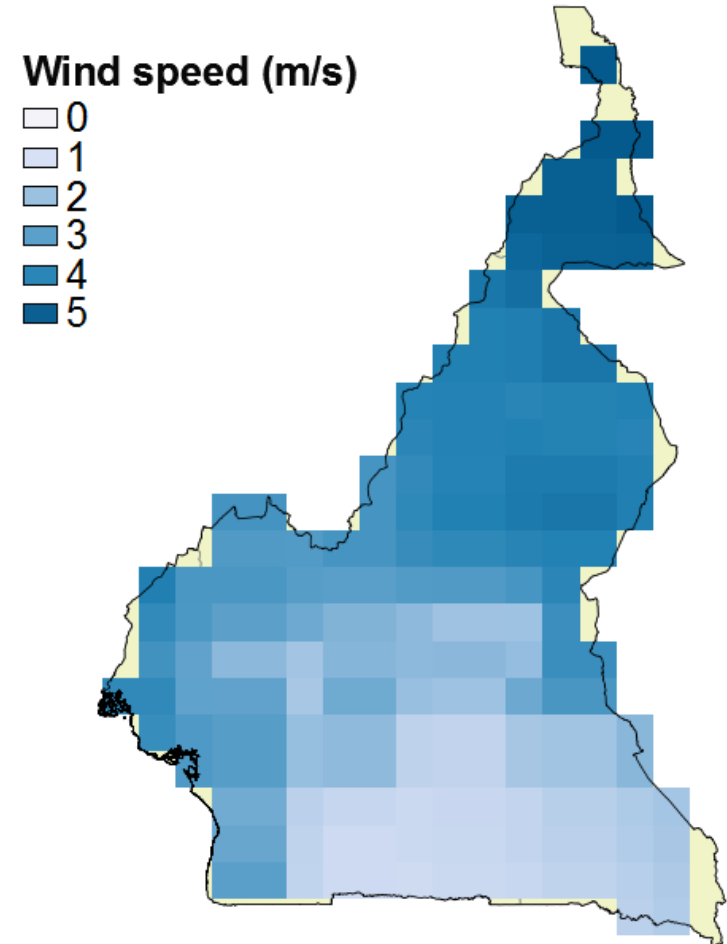
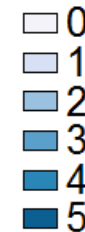
**Sources:**

- NASA & Deutsches Zentrum für Luft- und Raumfahrt (DLR)
- Jarvis, A., H.I. Reuter, A. Nelson, E. Guevara, 2008, Hole-filled SRTM for the globe Version 4, available from the CGIAR-CSI SRTM 90m Database: <http://srtm.csi.cgiar.org>.
- GlobCover 2009 ESA



- Solar irradiation
- Wind speed
- Hydro power potential (Digital elevation model (DEM) + rivers)
- Land cover

## Wind speed (m/s)



0 100 200 300 400 km



Cameroon

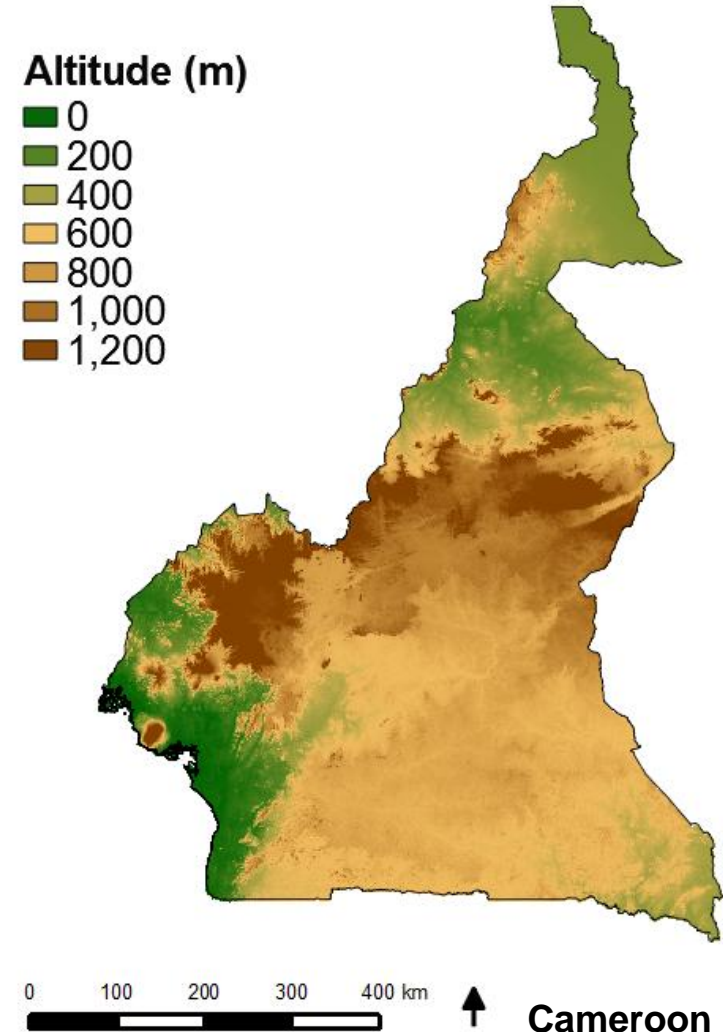
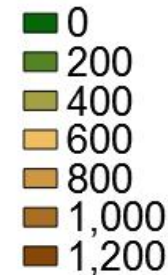
### Sources:

- NASA & Deutsches Zentrum für Luft- und Raumfahrt (DLR)
- Jarvis, A., H.I. Reuter, A. Nelson, E. Guevara, 2008, Hole-filled SRTM for the globe Version 4, available from the CGIAR-CSI SRTM 90m Database: <http://srtm.csi.cgiar.org>.
- GlobCover 2009 ESA



- Solar irradiation
- Wind speed
- Hydro power potential (Digital elevation model (DEM) + rivers)
- Land cover

## Altitude (m)



### Sources:

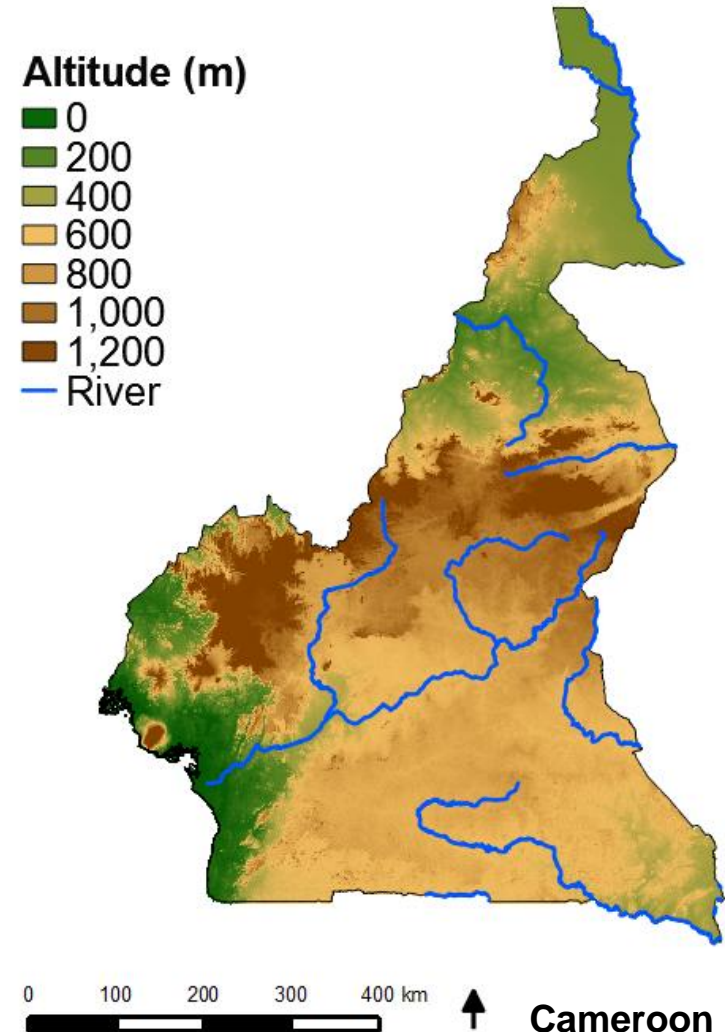
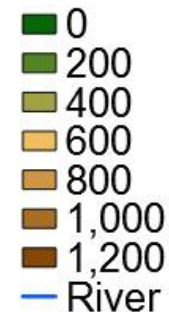
- NASA & Deutsches Zentrum für Luft- und Raumfahrt (DLR)
- Jarvis, A., H.I. Reuter, A. Nelson, E. Guevara, 2008, Hole-filled SRTM for the globe Version 4, available from the CGIAR-CSI SRTM 90m Database: <http://srtm.csi.cgiar.org>.
- GlobCover 2009 ESA





- Solar irradiation
- Wind speed
- Hydro power potential (Digital elevation model (DEM) + rivers)
- Land cover

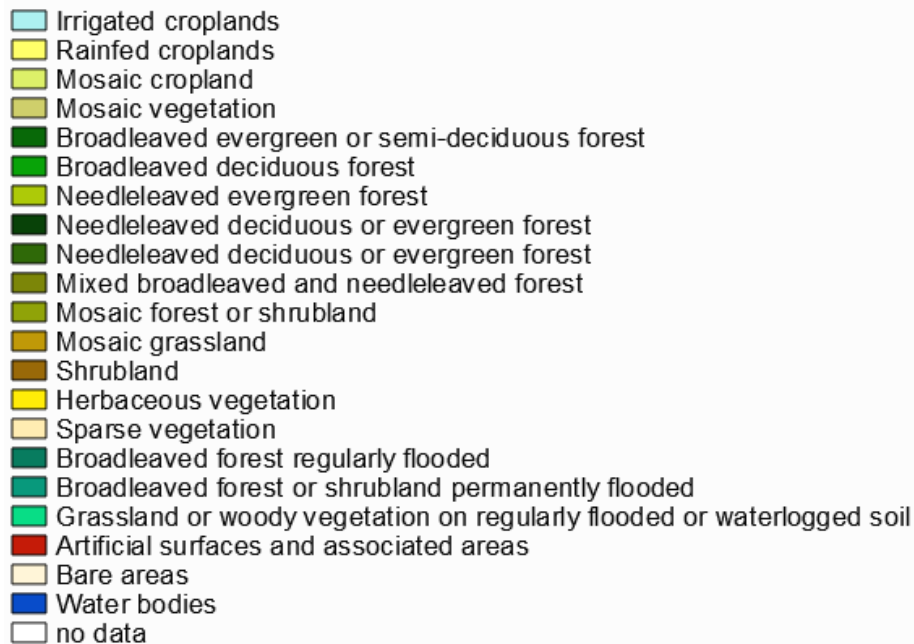
## Altitude (m)



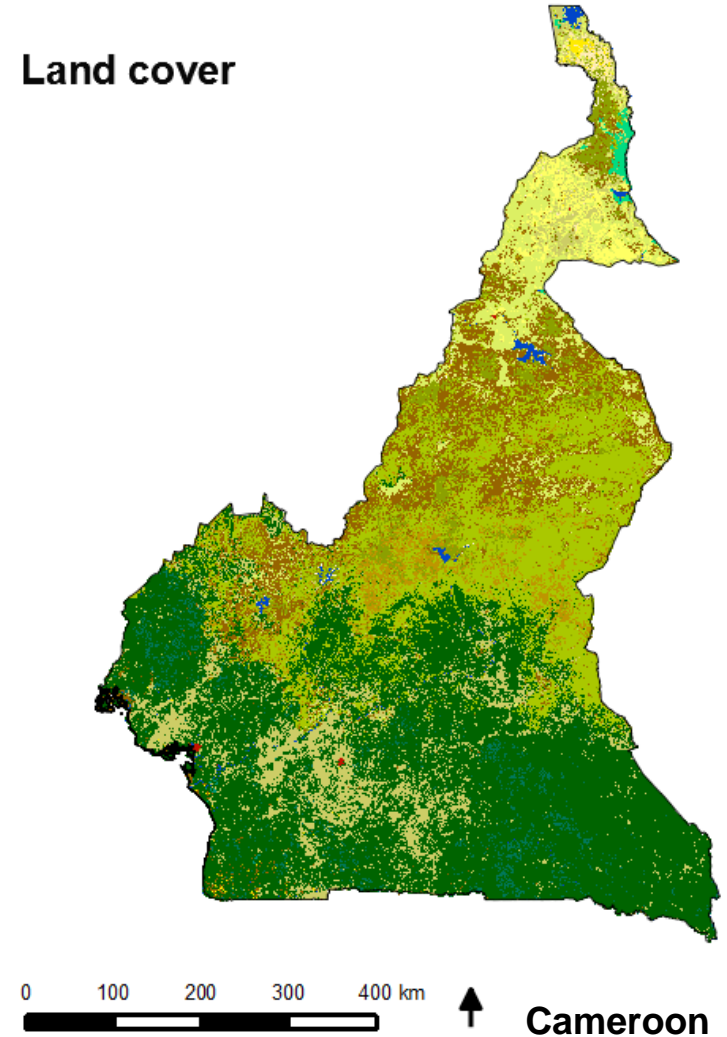
### Sources:

- NASA & Deutsches Zentrum für Luft- und Raumfahrt (DLR)
- Jarvis, A., H.I. Reuter, A. Nelson, E. Guevara, 2008, Hole-filled SRTM for the globe Version 4, available from the CGIAR-CSI SRTM 90m Database: <http://srtm.csi.cgiar.org>.
- GlobCover 2009 ESA

- Solar irradiation
- Wind speed
- Hydro power potential (Digital elevation model (DEM) + rivers)
- Land cover



Land cover



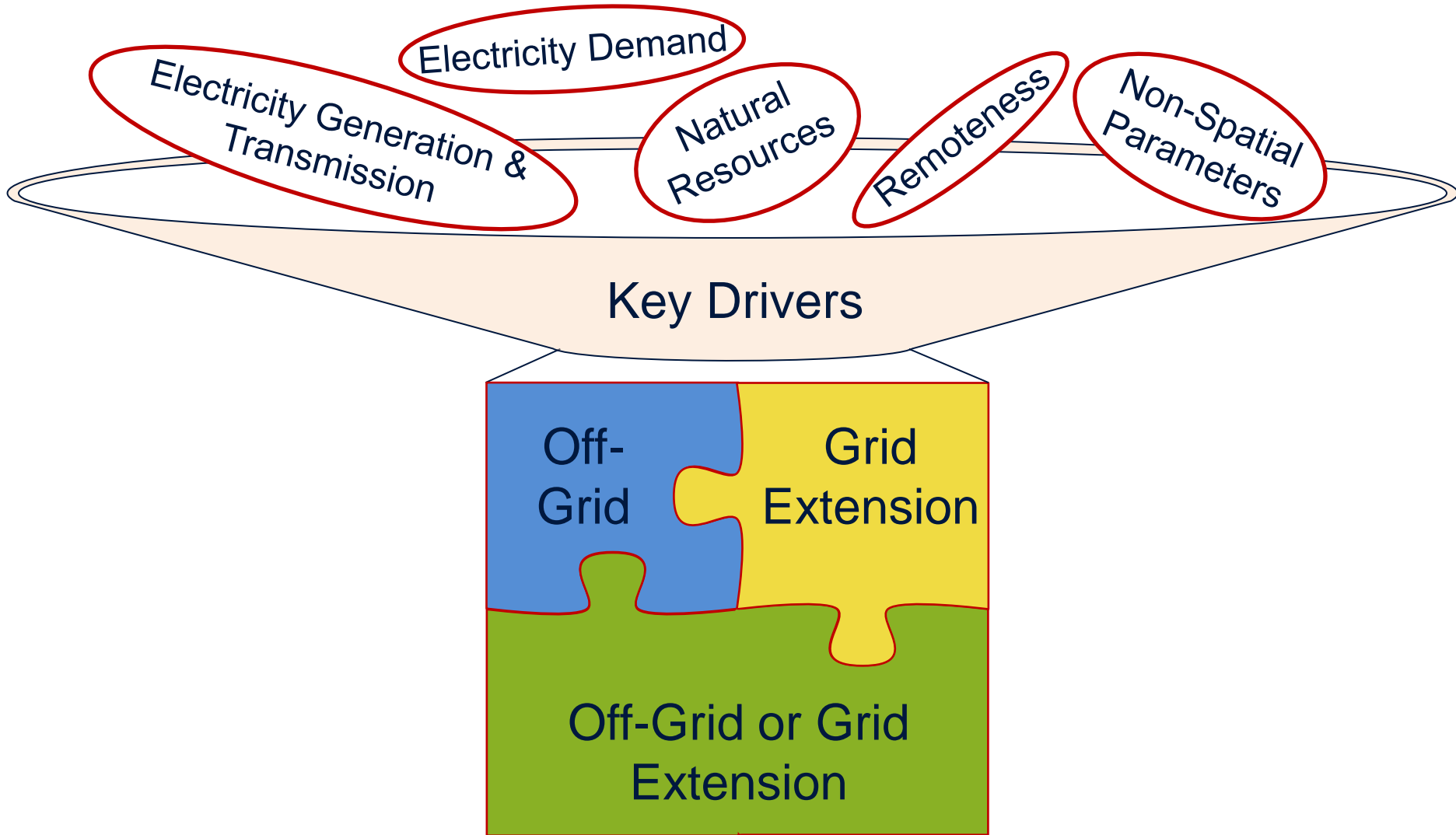


- Policy structures (e.g. electrification objectives, renewable energy targets)
- Investment incentives
- Ownership structure of power plants and transmission line infrastructure, utilities, and regulation authorities
- Attractiveness for investors (e.g. ease of doing business index, corruption index)

- A spatial approach is necessary to understand the dynamics between energy demand clusters, resources, distances to overcome etc.
- Only with this knowledge it is possible to assess the most economic strategy to provide electricity to rural non-supplied areas.

**The spatially distributed nature of renewable energy resources calls for their local usage, especially for remote, small clusters of electricity demand.**

# Next Steps





# Thank you!



Special thanks to the RLI off-grid team  
and the Reiner Lemoine-Foundation for financing this research work.

For further questions please contact us:

**[catherina.cader@rl-institut.de](mailto:catherina.cader@rl-institut.de)**

**[www.reiner-lemoine-institut.de](http://www.reiner-lemoine-institut.de)**