Impact of Decentralized Electrification Projects on Sustainable Development: A Meta-Analysis

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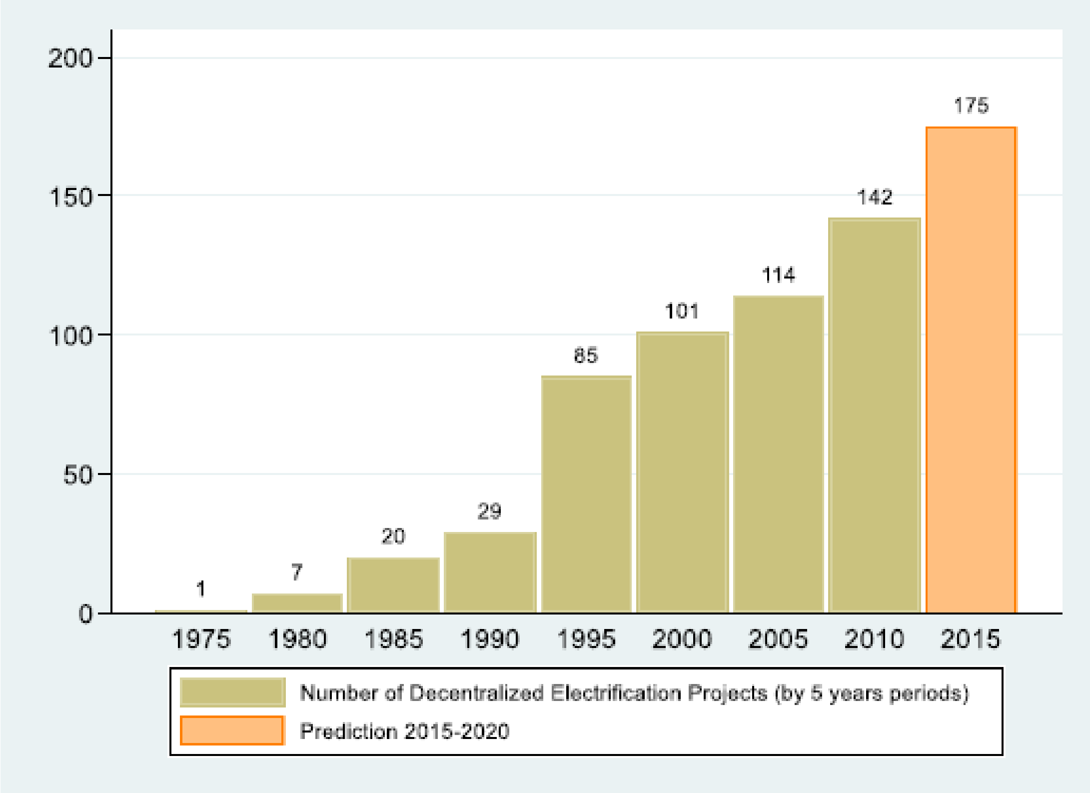
Stylized Facts

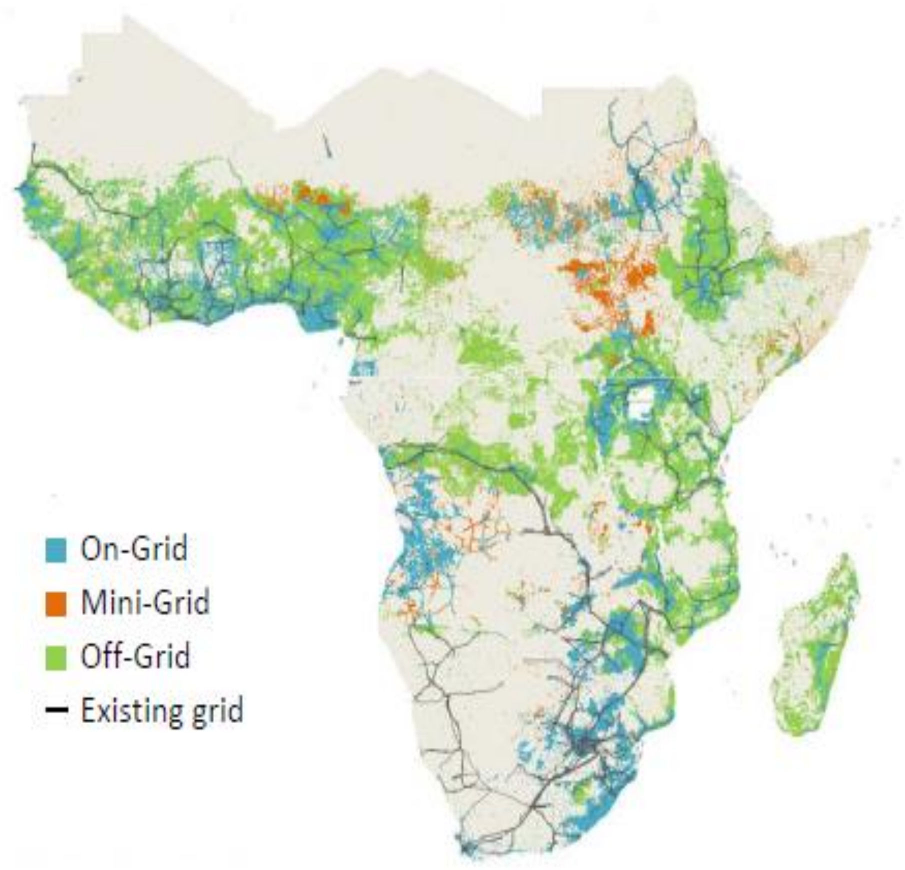
Energy transition : new technologies, new projects design

- **Sharp decrease of production costs**
  - Solar electricity now at first place in merit-order curve in 2018 (BloombergNEF, 2018)
- **Decreasing cost of batteries**
- **Growing energy efficiency** (ESMAP, 2018)
  - Since 2010, end of decoupling
  - Now : more growth for the same kWh (>+1)
- **Ramp up of electricity access**
  - 600 millions people still have no access in SubSaharan Africa
  - **But, for the first time un 2018, this number decreased** (ESMAP, 2018)
- **30 million people are now using a Solar Home System in developing countries** (ESMAP, 2018)

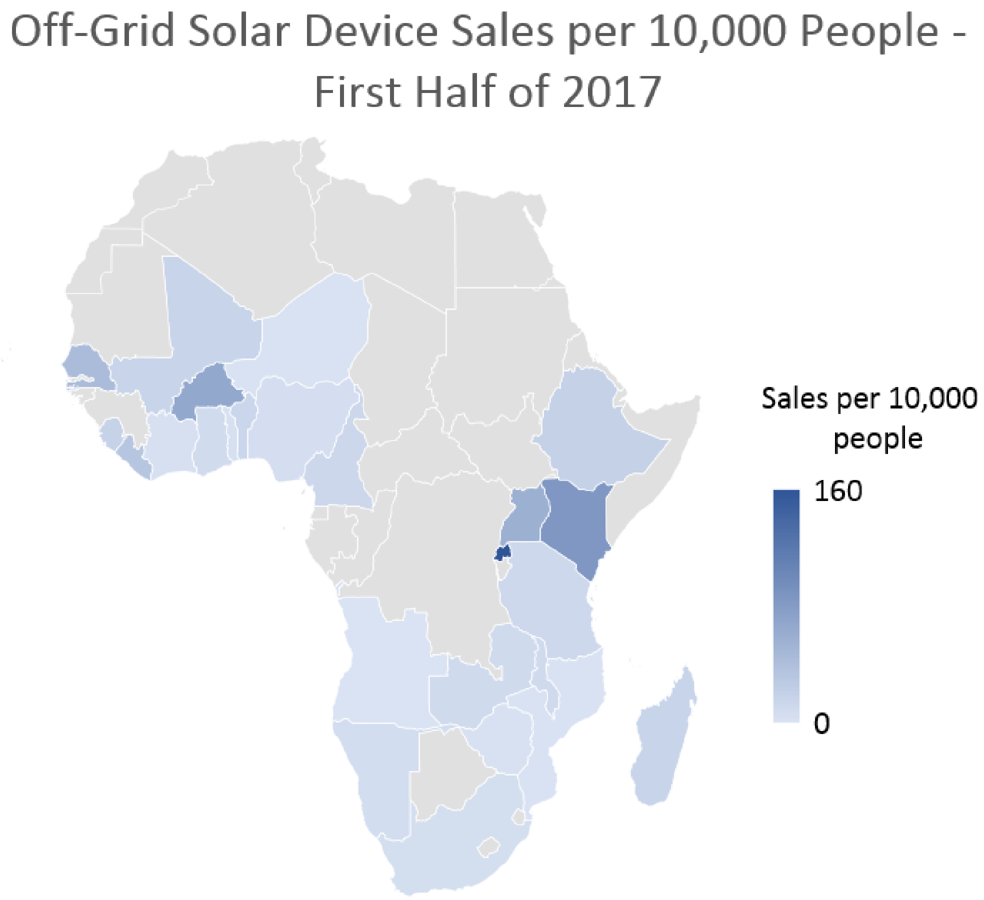
A growing trend of Decentralized Electricity Projects (DEPs : < 100 MW)



Off-grids, mini-grids and Solar Systems Sales in Sub-Saharan Africa



Crédit : OECD/IEA 2018



Source: GOGLA/Lighting Global

Motivation and Research Question

Energy transition and sustainable development

- **Distributed Electricity : an answer to local off-grid demand**
  - High rate of rural occupation
  - Issues of large centralized grids :
    - Marginal cost in rural area, Access to funding, Maintenance and training, Outages and corruption, Preference for electricity export
  - An emerging regulatory framework for mini-grids : Uttar Pradesh (2016), Nigeria (2016)

- 7th SDG, example : 3 billion people do not have access to clean cooking, with high detrimental impacts on lunge diseases

- Does distributed electricity solve indoor air pollution ? (example)

Research Question and Method

- **Economic issue :**
- **Do Decentralized Electricity Projects yield favorable impacts for sustainable development ?**
  - Positive socio-economic impacts might be key for the scalability of electricity projects.

- **Our research strategy :**
- **Do scientific evaluations bring evidences of DEPs' impacts on sustainable development ?**
  - A Meta-analysis : using data from peer-reviewed evaluations of DEPs, we relate key components of projects' design with the probability to observe a favorable impact

Data & Descriptive Statistics :

Collaborative Smart Mapping of Minigrids Actions (CoSMMA) : a meta-base of effects of Decentralized Electricity Projects in developing countries

With FERDI (Fondation pour les Etudes et la Recherche sur le Développement International)

CoSMMA, 1st observatory on socio-economic effects of decentralized electricity

- Data in brief

123	articles
421	**projects**
2605	**observed effects**
132	**variables (excl. Id keys)**
765	indicators
157	dimensions
15	thems
8	domains

68	developing countries
91%	renewables
81%	no carbon tech.

- 2605 observed or reported effects
- 1486 have been measured with scientific approach (statistical samples with N>1)
- 225 proven positive impacts (ie. significant below 5%)
- 2299 effects remain unproven (88%)

Methodology

Specification

$$P(outcome_{ip} = k) = constant + c.EvalCond_{ip} + s.ProjectSpec_{p} + error\text{-}term_{ip}$$

Where:

- *p* is a project
- *i* is an observed or reported effect
- *outcome* = k is one of 5 possible outcomes
- $EvalCond_{ip}$ is a vector of control variables : N, delay of evaluation, Statistical Method
- $ProjectSpec_{p}$ is a vector of a project's specifications : technology, power, decision level, continental area

5 outcomes:

	Economic directions of effects (5)		Economic directions of effects (5)	
	Freq	Pct	Freq	Pct
Unconclusive direction	134	5.1	27	1.8
Proven - Favorable	225	8.6	225	15.1
Proven - Unfavorable	81	3.1	81	5.5
Unproven - Favorable	1659	63.7	797	53.6
Unproven - Unfavorable	506	19.4	356	24.0
Total	2605	100.0	1486	100.0

Main Results

Coping with local needs, bringing global support

	Positive	Unproven favorable	Proven unfavorable	Unproven unfavorable	Inconclu sive
No. of Observations (N)	-0.000	0.000**	-0.000***	0.000*	-0.000***
Delay of evaluation	-0.010***	-0.013	0.021***	0.001	0.002*
Method (ref. = Econometrics without inference)					
Identification	0.335***	-0.242*	-0.012	-0.040	-0.041
Econometrics without inference	0.000	0.000	0.000	0.000	0.000
No inference	-0.158***	0.307	-0.128***	0.039	-0.060
Technology: (ref. = Hydroelectric)					
Hydroelectric power source	0.000	0.000	0.000	0.000	0.000
Solar	0.123***	-0.107*	0.027	0.027	-0.070***
Hybrid with Fossil fuel	0.320***	-0.176*	0.017	-0.119***	-0.042
Hybrid renewables	0.418***	-0.177*	-0.015	-0.157***	-0.069***
Biomass (and related tech.)	0.212***	0.035*	-0.029	-0.133***	-0.086***
Fossil Fuels	0.238***	-0.352	-0.040	0.241	-0.086***
Power : (ref. = Nano)					
Nano: <1 kW	0.000	0.000	0.000	0.000	0.000
Micro: 1 to 100 kW	0.365***	-0.188**	-0.051***	-0.102	-0.025***
Mini: 100 kW to 100 MW	0.319***	-0.162***	-0.059***	-0.086	-0.012***
Programme Decision Level (ref. = Local)					
Country	0.086***	-0.099***	-0.008**	0.058*	-0.037**
Province	-0.173***	0.034**	0.014	0.155***	-0.031
County	-0.089***	-0.237***	0.109***	0.251***	-0.034**
District	-0.011**	0.050*	-0.029***	0.030	-0.041**
Local	0.000	0.000	0.000	0.000	0.000
Total number of obs. in Mprobit	1,486	1,486	1,486	1,486	1,486
Obs. number of outcomes	225	797	81	356	27

Model with fixed effect at continental area

- Larger off-grid projects have higher chance to bring favorable impacts
- Hybrid solutions are the most effective ones
  - They combine several local renewable resources : insolation, radiation, biomass, wind, hydraulic flow or geothermic gradient

Coping with local needs, bringing global support

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Model with fixed effect at continental area

- Governance shows a U-shaped curve
  - Projects designed at global or at local levels are the most effective ones
  - At local scale : a Common Pool of Resource
    - lower risk of hidden passengers
    - Inclusive choices
  - At global scale :
    - Expertise and supervision gains
    - Imbrication gains : effective support for local projects

Beyond the probability of impact : a variety of effects

	Type of effects No.	%
Energy (type, costs & faults)	322	21.7
Education (O4)	251	16.9
Health (O3)	210	14.1
Basic Access (O7)	152	10.2
Economic transformation (O8)	112	7.5
Environment (O13)	70	4.7
Usable time & leisure	61	4.1
Information & communication	60	4.0
Income & living conditions (O1)	56	3.8
Housework	50	3.4
Security (O16)	49	3.3
Gender (O5)	39	2.6
Financial transformation	28	1.9
Community (O11)	21	1.4
Migration	5	0.3
Total	1486	100.0

- 30% of evaluated effects occur from immediate benefits of electricity : basic access to electricity (10,2%), substitution and cost change of energy (21,7%)
- 31% of measured effects concern health and education
- 11% concern economic transformation (7,5%), income & living conditions (3,8%)
- Important impacts remain poorly evaluated *expost* : environment, migration, security, gender

Concluding Remarks

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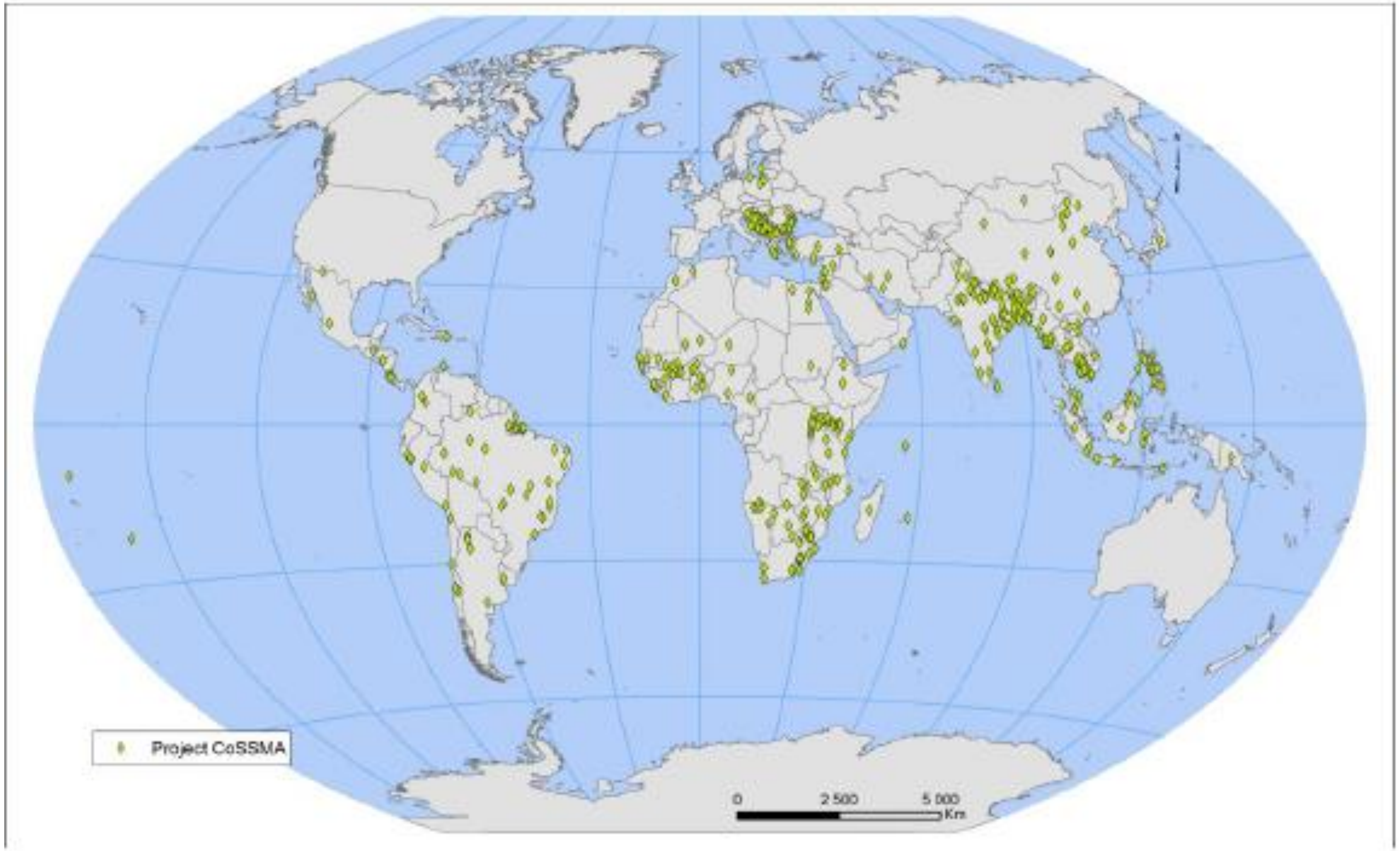
- Combining technology, capacity and governance is key in order to achieve development goals
- Proven impacts are scarce but they do exist
- Relating projects’ design with the types of effects would require more scientific evaluations of DEPs’ effects

Concluding discussion

- Which projects for which types of effects ? =>
  - The electron is a homogenous component, but decentralized projects are heterogenous
  - We have taken into account the variety of electricity services
- Model limits :
  - The location constraint must be explored more in depth :
    - There is a trade-off between no (short) transportation and intermittence
    - => Does this trade-off change the channel of impacts for off-grid electricity ?
  - A more accurate measurement of projects' governance :
    - national program,
    - legal framework for mini-grids,
    - cost-reflective tariffs,
    - financial incentives,
    - standards and quality

Thank you for your attention

Figure 2 Map of DEPs registered in CoSMMA



Bibliographie

(In this presentation. See the Working Paper for complete bibliography).

- Bell, S., Judson, E., Bulkeley, H., Powells, G., Capova, K.A., Lynch, D., 2015. Sociality and electricity in the United Kingdom: The influence of household dynamics on everyday consumption. Energy Res. Soc. Sci. 9, 98–106. https://doi.org/10.1016/j.erss.2015.08.027
- BloombergNEF, 2018. Climatescope - Emerging Markets Outlook 2018.
- Bonan, J., Pareglio, S., Tavoni, M., 2014. Access to modern energy: a review of impact evaluations.
- Brenneman, A., Kerf, M., 2002. Infrastructure & Poverty Linkages. Lit. Rev. World Bank Wash. DC.
- Carré, E., Couppey-Soubeyran, J., Dehmej, S., 2015. La coordination entre politique monétaire et politique macroprudentielle. Que disent les modèles dsge ? Rev. Économique 66, 541–572. https://doi.org/10.3917/reco.663.0541
- ESMAP, 2018. TRACKING SDG7: THE ENERGY PROGRESS REPORT Highlights 2018.
- Goodman, S., BenYishay, A., Lv, Z., Runfola, D., 2019. GeoQuery: Integrating HPC systems and public web-based geospatial data tools. Comput. Geosci. 122, 103–112. https://doi.org/10.1016/j.cageo.2018.10.009
- Hayn, M., Bertsch, V., Fichtner, W., 2014. Electricity load profiles in Europe: The importance of household segmentation. Energy Res. Soc. Sci. 3, 30–45. https://doi.org/10.1016/j.erss.2014.07.002
- Holtorf, H., Urmee, T., Calais, M., Pryor, T., 2015. A model to evaluate the success of Solar Home Systems. Renew. Sustain. Energy Rev. 50, 245–255. https://doi.org/10.1016/j.rser.2015.05.015
- Jamasb, T., Nepal, R., Timilsina, G.R., 2017. A Quarter Century Effort Yet to Come of Age: A Survey of Electricity Sector Reform in Developing Countries. Energy J. 38. https://doi.org/10.5547/01956574.38.3.tjam
- Kanagawa, M., Nakata, T., 2008. Assessment of access to electricity and the socio-economic impacts in rural areas of developing countries. Energy Policy 36, 2016–2029. https://doi.org/10.1016/j.enpol.2008.01.041
- Katre, A., Tozzi, A., 2018. Assessing the Sustainability of Decentralized Renewable Energy Systems: A Comprehensive Framework with Analytical Methods. Sustainability 10, 1058. https://doi.org/10.3390/su10041058
- Katre, A., Tozzi, A., Bhattacharyya, S., 2019. Sustainability of community-owned mini-grids: evidence from India. Energy Sustain. Soc. 9. https://doi.org/10.1186/s13705-018-0185-9
- LARC POWER, N., 2018. POWER Data. NASA Langley Research Center (LaRC) POWER Project, Hampton, VA (USA).
- Marszal-Pomianowska, A., Heiselberg, P., Kalyanova Larsen, O., 2016. Household electricity demand profiles – A high-resolution load model to facilitate modelling of energy flexible buildings. Energy 103, 487–501. https://doi.org/10.1016/j.energy.2016.02.159
- Occhiali, G., Falchetta, G., 2018. The Changing Role of Natural Gas in Nigeria. SSRN Electron. J. https://doi.org/10.2139/ssrn.3149339
- Peters, J., Sievert, M., 2015. Impacts of Rural Electrification Revisited: The African Context.
- Praktiknjo, A.J., Hähnel, A., Erdmann, G., 2011. Assessing energy supply security: Outage costs in private households. Energy Policy 39, 7825–7833. https://doi.org/10.1016/j.enpol.2011.09.028
- RISE, SE4All, 2017. RISE - Regulatory Indicators for Sustainable Energy. The WorldBank Group.
- SE4ALL, 2017. Why wait ? Seizing the energy access dividend. SE4ALL.
- Stackhouse Jr, P.W., Zhang, T., Westberg, D., Barnett, A.J., Bristow, T., Macpherson, B., Hoell, J.M., Hamilton, B.A., 2018. POWER Release 8.0. 1 (with GIS Applications) Methodology (Data Parameters, Sources, & Validation).
- Stanley, T.D., 2001. Wheat from Chaff: Meta-Analysis as Quantitative Literature Review. J. Econ. Perspect. 15, 131–150.
- Thopil, G.A., Pouris, A., 2015. Aggregation and internalisation of electricity externalities in South Africa. Energy 82, 501–511. https://doi.org/10.1016/j.energy.2015.01.059
- van Gevelt, T., 2014. Off-grid energy provision in rural areas: a review of the academic literature.
- WFPGeoNode, 2017. Global Ports.