# How Subsidies Impact on Temporal Diffusion of PV-Based Minigrids

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# How Subsidies Impact on Temporal Diffusion of PV-Based Minigrids

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## Introduction:

The International Energy Agency (IEA) estimates that only 30% of the people currently without access to electricity in sub-Saharan Africa can be cost-effectively served through national grid extensions due to the sparseness of the rural populations, rough terrains, low economic activities, and low load densities. The remaining 70% would be most cost-effectively served through decentralized systems, i.e. communal grids (52.5%) or stand-alone systems (17.5%) [1].

Fig. 1: A House with PV in Kendu Bay Area of Kenya

In this work, An agent-based model (ABM) is developed in NetLogo and used to simulate how socio-economic factors affect diffusion of PV microgeneration systems in a rural developing community. Survey data from Kendu Bay area of Kenya is used to inform the model [2].

## Methodology:

A household without a PV system must first develop the idea to install one given the costs and socio-economic factors such as subsidies. PV is only installed if a household can afford it and if:

$$LUCE_{PV} < C_{A/kWh}$$

where $C_{A/kWh}$ is avoided cost per kWh, i.e., the prevailing national grid electricity cost per kWh and equals $0.20/kWh as per current Kenyan rates, while $LUCE_{PV}$ is the levelized unit cost of delivered electricity and is given by

$$LUCE_{PV} = \frac{ALCC_{PV}}{W_p \times EHFS \times 365 \times CUF}$$

where $ALCC_{PV}$ is the annualized life cycle cost and is given by

$$ALCC_{PV} = (C_{0PV} \times CRF_{PV}) + (C_{0batt} \times CRF_{batt}) + (C_{0cc} \times CRF_{cc}) + \left(C_{0appl} \times CRF_{appl}\right) + C_{O\&M}$$

where $CRF$ is the capital recovery factor and is given by

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1}$$

Subsidies per kWh ($S_{kWh}$) is given by [3]

$$S_{kWh} = C_{PV/kWh} - C_{A/kWh}$$

$$C_{PV/kWh} = \frac{C_{PV-Total}}{(E_{PV-Total} \times L_{PV})}$$

$$C_{PV-Total} = (C_{0PV} - S_{m^2}) \times \varepsilon_{PV} \times A \times AF$$

Where $S_{m^2}$ is subsidies per m$^2$.

## Results and Discussion:

Currently there are 347 households with PV, 229 households connected to the national grid, and zero households connected to communal grids in Kendu Bay. After 25 years, and without subsidies, 4,325 households would have installed PV, 2,410 households would have joined communal grids, and 1,323 would have joined the national grid, as shown below.

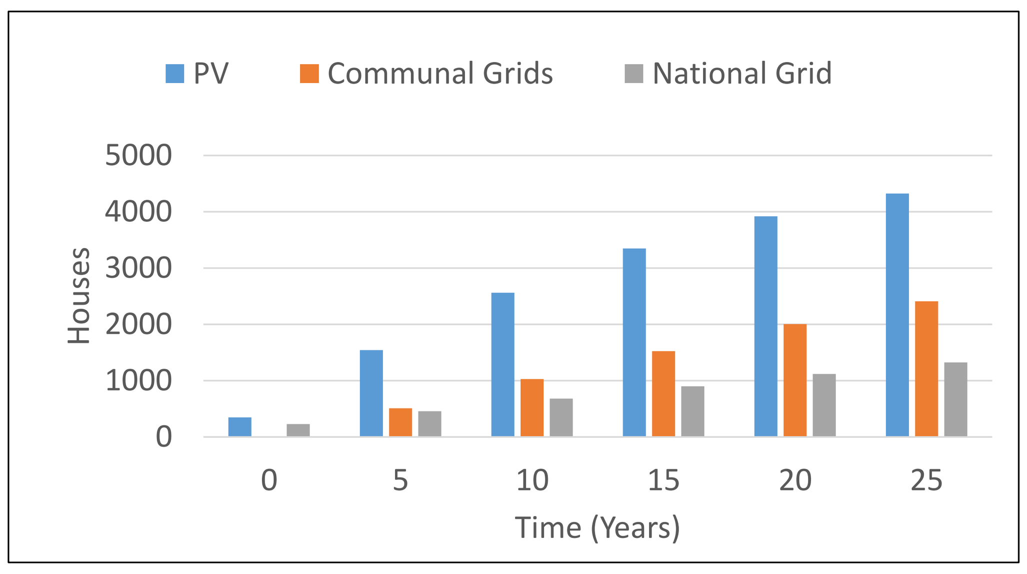


Fig. 2: Kendu Bay Electrification Topologies After 25 Years

With introduction of subidies, the numer of PV installations and communal grid connections increase as shown in the table and figure below:

Table 1: Impact of Subsidies on Electrification Topologies after 25 Years

| **Houses after 25 years** | **Subsidies/kWh ($)** | | |
|---|---|---|---|
| | **0** | **0.15** | **0.30** |
| Houses with PV | 4325 | 5374 | 5827 |
| Houses Connected to Communal Grids | 2410 | 2994 | 3685 |
| Houses Connected to National Grid | 1323 | 937 | 499 |
| **Houses after 25 years** | **Subsidies/m² ($)** | | |
| | **0** | **75** | **150** |
| Houses with PV | 4325 | 5321 | 6012 |
| Houses Connected to Communal Grids | 2410 | 3046 | 3689 |
| Houses Connected to National Grid | 1323 | 1027 | 701 |

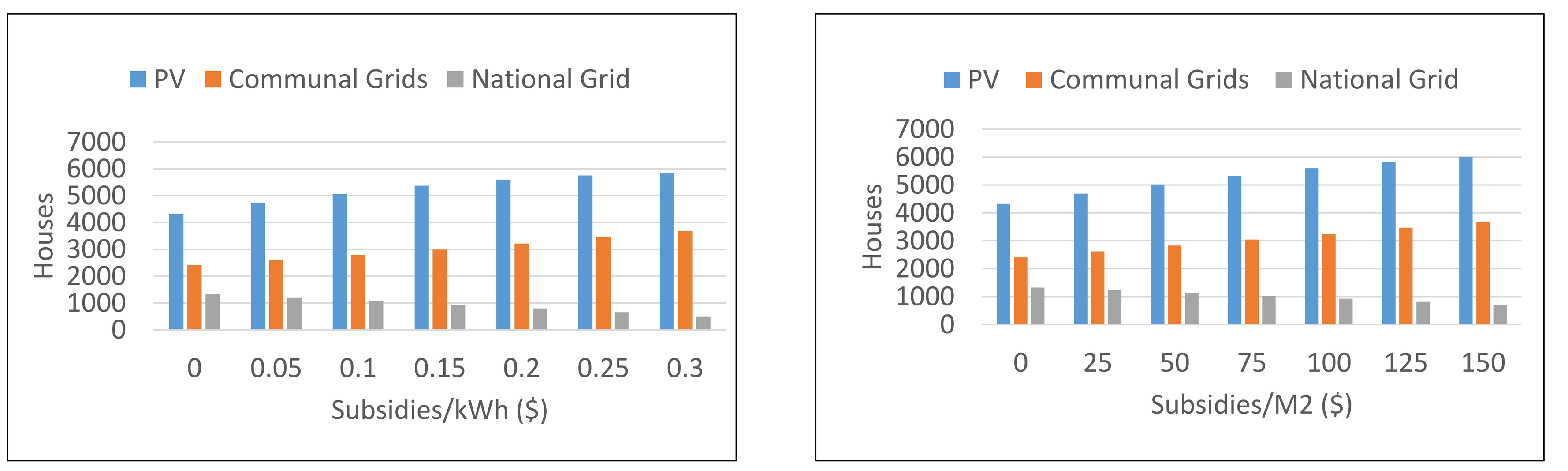


Fig. 3: Impacts of Subsidies on Electrification Topologies after 25 Years

## Conclusion:

The above findings demonstrate that a developing community could increase its rural electrification rate by introducing favourable subsidies to entice more households to install PV. The merits and demerits of both types of subsidies could be debated, but energy based subsidies enable the government to avoid direct capital investments in a household's own PV system. It could therefore be more affordable for developing countries with less financial capital. It is important to note that subsidies commit future governments to financial burdens and there may be concern over lack of commitment to promises made by previous governments.

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2. Opiyo, N. N., 2016. A Survey Informed PV-Based Cost-Effective Electrification Options for Rural Sub-Saharan Africa, *Energy Policy* **91**: 1-11
3. Green, M. A., 1992. Solar Cells: Operating Principles, Technology and System Applications, *University of New South Wales*