Promoting rural Electrification in Sub-Saharan Africa:
Least-Cost Modeling of decentralized Energy-Water-Food Systems

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Why?

600 Mio. capita
* 300 kWh/year/capita
* 0.4 USD/kWh
* 20 years

= 1,4 * $10^{12}$ USD
Case Study: St. Rupert Mayer, Zimbabwe
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- Village in rural Zimbabwe
- 250 inhabitants
- Model input data by literature, local measurements and questionnaires
- No (reliable) power grid connection
- Electrical load profile based on questionnaire (Monte Carlo)
- No water grid connection
- Sufficient groundwater
- Good soils (max 10 ha)
- **750 USD annual salary for farmers** (= variable costs field)
- Weighted average costs of capital (**WACC**): **15% per year**
Scenario 1: Diesel
Scenario 1: Diesel - Electricity Supply [kW]

- LCOE: 44,5 c/kWh
- Annual Costs per Capita: 153,3 USD/year
Scenario 2: + PV
Scenario 3: + Batteries
Scenario 3: + Batteries - Electricity Supply [kW]

• LCOE: 37,9 c/kWh (before: 44,5 c/kWh)
• Annual Costs per Capita: 130,8 USD/year (before: 153,3 USD/year)
Scenario 4: + Water Demand
Scenario 5: + Water Pump
Scenario 5: + Water Pump - Electricity Supply [kW]

- **LCOE:** 37,7 c/kWh (before: 37,9 c/kWh)
- **Annual Costs per Capita:** 132,0 USD/year (before: 130,8 USD/year)
Scenario 6: + Food Demand
Scenario 7: + Fields
Scenario 7: + Fields - Electricity Supply [kW]

- **LCOE:** 34,4 c/kWh (before: 37,7 c/kWh)
- **Annual Costs per Capita:** 189,8 USD/year (before: 132,0 USD/year)
- **Field Size:** 2,9 ha
- **Jobs created:** 17

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Scenario 8: + Food Selling
Scenario 8: + Food Selling - Electricity Supply [kW]

- **LCOE:** 30,5 c/kWh (before: 34,4 c/kWh)
- **Annual Costs per Capita:** 105,0 USD/year (before: 189,8 USD/year)
- **Field Size:** 10 ha (= max) (before: 2,9 ha)
- **Jobs created:** 60 (before: 17)
Scenario 9: + Biogas
Scenario 9: + Biogas - Electricity Supply [kW]

- LCOE: 16.4 c/kWh (before: 30.5 c/kWh)
- Annual Costs per Capita: 28.6 USD/year (before: 105.0 USD/year)
- Field Size: 10 ha (= max) (before: 10 ha)
- Jobs created: 60 (before: 60)
Summary
Summary – Annual Energy Generation [kWh]

- Diesel
- +PV
- +Battery
- +Water Demand
- +Water Pump
- +Food Demand
- +Fields
- +Food Selling
- +Biogas

- Diesel Generator
- PV
- Biogas Generator
- Dump Load

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Summary – LCOE & Annual Costs per Capita

- LCOE [c/kWh]
- Annual Costs per Capita [USD/year]

Demand + Water Pump + Food Selling + Biogas

Diesel + PV + Battery + Water Demand + Food Demand + Fields
Summary – System Costs [USD/year]

- Biogas
- Food Selling
- Fields
- Food Demand
- Water Pumping
- Water Demand
- Battery
- PV
- Diesel

Categories:
- Revenue
- Invest
- Fuel
- Fixed
- Variable
- Purchase

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Decentralized Energy-Water-Food Solutions for Sustainable Development
Thanks for your attention!!!
Next Steps

- Rainfall timeseries
- Ground water as storage
- Enhanced soil analysis
- Fertilizer demand
- Fertilizer: Commercial vs. biogas digester residue
- Life-Cycle-Analysis for soil nutrients
- Different crops
- Variation crop prices
- Livestock farming
- Food processing
- Other commercial and social power loads
- Cooking: Biogas vs. firewood
- Labor as commodity
- Intertemporal modelling
Legend (2)

Bat  Battery  PV  Photovoltaic
BD  Biogas Digester  Sol  Solar Radiation
BG  Biogas Generator  M  Maize
BS  Biogas Storage  MF  Maize Field
D  Diesel  W  Water
DG  Diesel Generator  WP  Water Pump
E  Electricity  WT  Water Tank