Optimal investments into rooftop solar and batteries for a distribution grid company and prosumers: A case study in India

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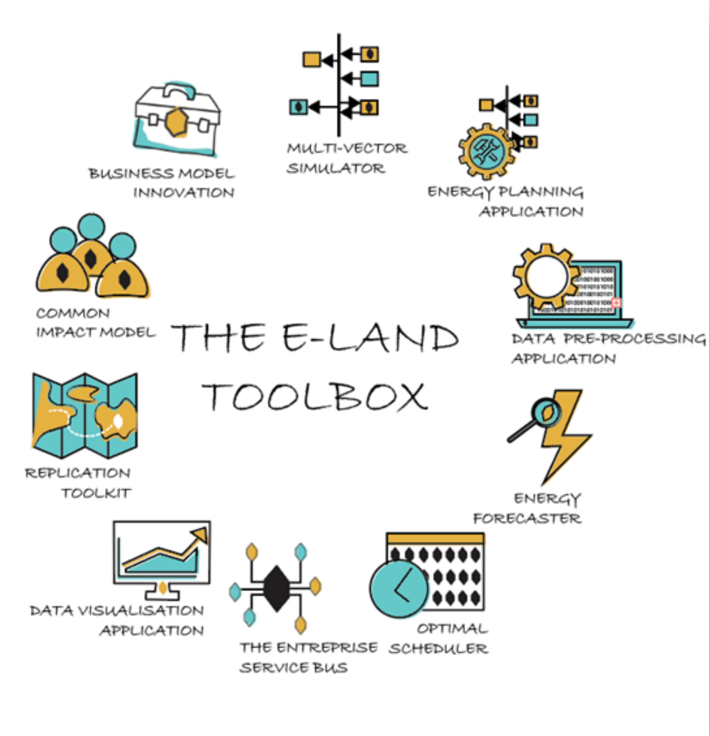
H2020 E-LAND project

Goal: To provide a synergistic solution between technological, societal and business challenges that the local energy sector faces

The E-LAND toolbox approach – a modular set of methodologies and ICT tools to optimally manage Multi-vector Local Energy Systems and isolated communities



Multi vector simulator

- oemof -based open source Python package which aims at facilitating the modelling of multi-energy systems in island or grid-connected mode
  - ✓ Long-term investment planning
  - ✓ Long-term dispatch optimization
  - ✓ Performance evaluation
- Uses linear programming and mixed-integer programming approach for optimization
- Pre-built energy system components

$$minZ = \sum_i a_i \cdot CAP_i + \sum_i \sum_t c_{var,i} \cdot E_i(t)$$

$CAP_i \geq 0$

$E_i(t) \geq 0 \quad \forall t$

i: asset

a_i: asset annuity [currency/kWp/year, currency/kW/year, currency/kWh/year]

CAP_i: asset capacity [kWp, kW, kWh]

$c_{var,i}$: variable operational or dispatch cost [currency/kWh, currency/L]

$E_i(t)$: asset dispatch [kWh]

Source: Hoffmann, Martha M., Duc, Pierre-Francois, & Haas, Sabine. (2021, March 4). Multi-Vector Simulator (Version v0.5.5, beta release). DOI: 10.5281/zenodo.4610237 Available online: https://multi-vector-simulator.readthedocs.io/en/stable/index.html

Background – Policy context

- Delhi govt. has set an aggressive target to generate 2 GW (33% of peak demand & 7 % of yearly demand) from rooftop solar by 2025
- Subsidy provided by the Indian government which covers 40% of investment cost up to 3 kW system size and 20% thereafter until 10 kW
- Feed-in tariff that the Delhi distribution company (DISCOM) is obligated to provide, and this is the same as the average purchase cost of electricity for DISCOM
- DISCOMs can benefit from selling renewable energy certificates (RECs).
- Renewable purchase obligation (RPO) obliges DISCOMs in Delhi to purchase a defined percentage of their demand from renewable sources

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Background – Policy context

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- Delhi govt. has set an aggressive target to generate 2 GW (33% of peak demand & 7 % of yearly demand) from rooftop solar by 2025
- Subsi… … to 3 kW sy…
- Feed-… … and this is the…
- DISC…

➢ The goal of this paper is to investigate optimal investment into rooftop solar and battery for both, the prosumers (who are currently consumers) and the electricity distribution companies (DISCOMs).
   - A sub-goal of the paper is to assess the effect of growing prosumerism on the business of DISCOMs.

- Renewable purchase obligation (RPO) obliges DISCOMs in Delhi to purchase a defined percentage of their demand from renewable sources

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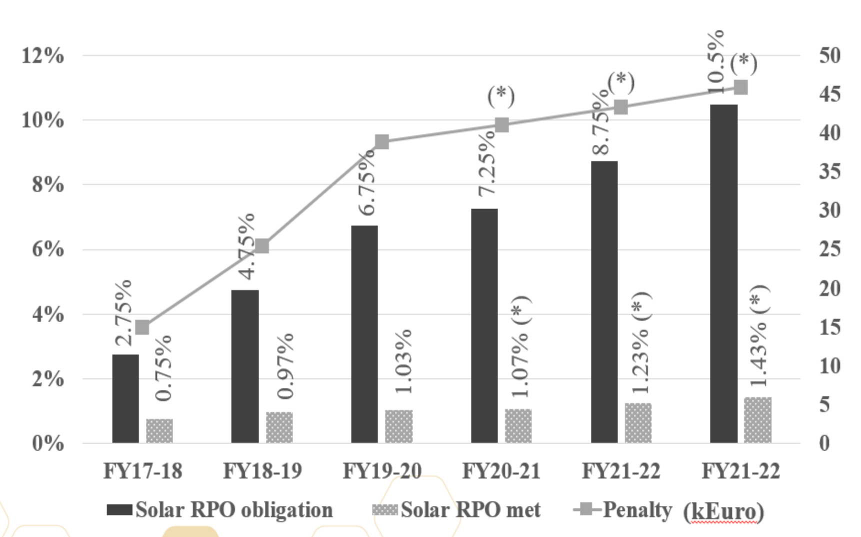
Case study

- BSES Yamuna Power Ltd. is a power distribution and retail company (DISCOM). It has 1.73 million consumers, a peak load of 1.7 GW and an annual electricity requirement of 7,183 GWh
- The case study considered in the paper is a section of the BYPL operation area called Saini enclave.
  - 3.5MW peak power; 11.9 GWh/yr
  - 1858 consumers; 82% residential, rest commercial buildings



Solar RPO set by Delhi government compared to actual RPO met by DISCOM. FY = financial year. (*) = estimated value based upon linear historic projection. Source: own depiction.

Method

- 7 scenarios created with different investment criterias
- Techno-economic assessment of rooftop solar and Li-ion battery is performed for all scenarios using the Multi-Vector Simulator (MVS)
- The MVS determines the optimal asset capacities and their dispatch, to minimize annual energy supply costs using a linear programming approach.
- The post-processing evaluates the performance of the energy system in different scenarios by calculating a few predefined key performance indicators.

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Scenarios

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S1	S2	S3	S4	S5	S6	S7
• Consumer depend upon grid energy • Long term power purchase • No peak power charges to residential consumer	• Same as S1 but: • Optimal invst. in PV & battery • Long term power purchase • Sale of REC • Consumer roof-top is available	• Same as S2 but: • Power market puschase • Arbitrage opportunity	• Same as S2 but: • Max PV limit of 500 kW • Only DISCOM building's rooftop is available	• Optimal invst. in PV & battery • Feed-in tariff • Max PV 80% of traf. Cap.	• Same as S5 • Max PV cap: 33% of peak demand	• DISCOM invests in response to S6

BAU (S1) · DISCOM invests (S2–S4) · Consumers invests (S5–S6) · both invests (S7)

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Modelling assumptions

Parameter	Value	Unit
Battery storage		
Battery storage, 11 kV (quotation received by BYPL) -Investment cost (incl. installation) -O&M cost (@10% of investment cost)	403.59 40.36	Euro/kWh Euro/kWh/year
Battery storage, 415 V and domestic level (quotation received by BYPL) -Investment cost (includes installation costs) -O&M cost, 415 V (@5% of investment cost) -O&M cost, residential	691.87 34.59 0	Euro/kWh Euro/kWh/year Euro/kWh/year
Battery lifetime	10	Years
C rate for battery storage	1	NA
Throughput efficiency	95	Percent

PV		
Commercial PV plant, BYPL [17] -Panel investment cost (incl. installation costs) -Panel O&M costs (@1.5% of installation costs) -Inverter investment cost (@11% of PV investment cost) [18]	410.17 6.76 49.9	Euro/kW Euro/kW/year Euro/kW
Domestic PV plant [17] -Subsidy on investment costs -Panel investment cost (incl. installation costs) -Panel O&M costs (@1.5% of installation costs) -Inverter investment cost (@11% of PV investment cost) [18]	20 341.87 5.20 61.55	Percent Euro/kW Euro/kW/year Euro/kW
PV lifetime	35	years
Inverter lifetime	15	years
Rooftop area needed per kW [5]	12	Sq..m
Other		
Discount factor (Provided by BYPL)	12	Percent
Project lifetime	35	Years
Approx. Area of Saini enclave	1	M Sq.m

Tariffs	Value	Unit
DISCOM (BYPL)		
Electricity purchase cost, average (Provided by BYPL)	0.0492	Euro/kWh
Electricity export tariff to the national grid	0	Euro/kWh
REC selling price for DISCOM	0.0115	Euro/kWh
Domestic consumers/prosumers		
Average sales price to consumers (revenue for BYPL)	0.0807	Euro/kWh
Feed-in tariff for consumers (expenditures for BYPL)	0.0492	Euro/kWh

Results (1)

Table 1

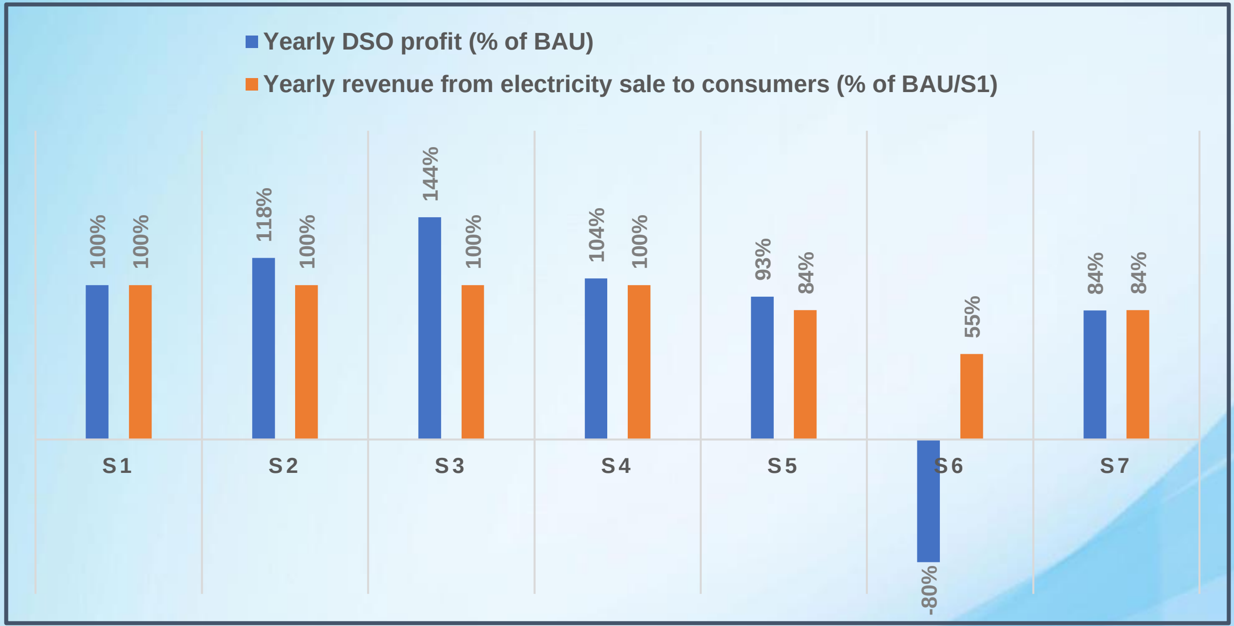
Parameters	Scenarios - DISCOM perspective				
Optimal capacities	*BAU (S1)*	*S2*	*S3*	*S4*	*S7*
Optimal PV capacity (MW)	0	3.05	2.12	0.5	1.8 (+1.2 Prosumers)
Optimal battery capacity (MWh)	NA	0	0	0	0
Indicators					
NPV (MEuro)	2.98	3.5	4.28	3.1	2.76
RES	Negligible	32%	28%	7%	25%
Rooftop PV feed-in (GWh)	Negligible	0.58	0.14	0	0.6
DISCOM gains from selling RECs (kEuro/yr)	Negligible	43.9	38.7	9.2	33.7
Area as % of Saini enclave	NA	4%	3%	1%	2%

Table 2

Parameters	Scenarios – Prosumerism		
Optimal capacities	*BAU*	*S5*	*S6*
Optimal PV capacity (MW)	0	12.9	1.2
Optimal battery capacity (MWh)	0	0	0
Indicators			
Collective NPC for all prosumers (MEuro)	7.87	4.6	7.23
RES	0%	172%	16%
Rooftop PV feed-in (GWh)	0	12.97	0.01
Govt. subsidy used for residential rooftop PV investments (MEuros)	0	1.18	0.11
Rooftop area as % of Saini enclave	0%	15%	1%

Note: Yearly demand = approx. 12 GWh

Results (2)



- DISCOM always increases its profit if it invests in rooftop PV
- In prosumerism scenario Rooftop PV results in savings for prosumers and reduces revenues of DISCOM
- S6 is an ideal scenario for prosumer

Conclusion

- Battery is not an economically viable option in any scenario.
- LCOE of PV less the power purchase cost for DISCOM and el. tariff. for consumers.
- In all scenarios except 1&4, the optimal PV capacity is more than 33% of peak demand and 7% of yearly demand (exceeding the targets of the Delhi solar policy locally).
- Buying electricity from power market is more profitable – should be investigated further
- Prosumerism scenario 5 highly unlikely - Is sufficient rooftop area available?
- Consumers lack initial investment – DISCOM can support here and come up with new business model to reduce the negative effect of prosumerism in their revenues.

Thank You!

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Status of Development and Release

Application of the tool:

- Discussed in a number of stakeholder workshops
- In the process to be applied to the 5 project locations of E-LAND
- Previous consulting experience with the tool: Hydrogen storage potential study for mini-grids in Chile

MVS v1.0.0 release
Github: https://github.com/rl-institut/multi-vector-simulator/releases/tag/v1.0.0
Zenodo: https://zenodo.org/record/4610237
Release of package Multi-Vector-Simulator on PyPI
https://pypi.org/project/multi-vector-simulator/
Documentation available on readthedocs:
https://multi-vector-simulator.readthedocs.io/en/latest/

Deliverable D4.4

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