Renewable Energy generation
Cost of generation

Non-renewable energy generation
Diesel fuel

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Statement about challenges of using diesel fuels

Cheapest capital costs but most expensive operational costs

Back up use

Integration with PV

Non-renewable energy generation
Diesel fuel

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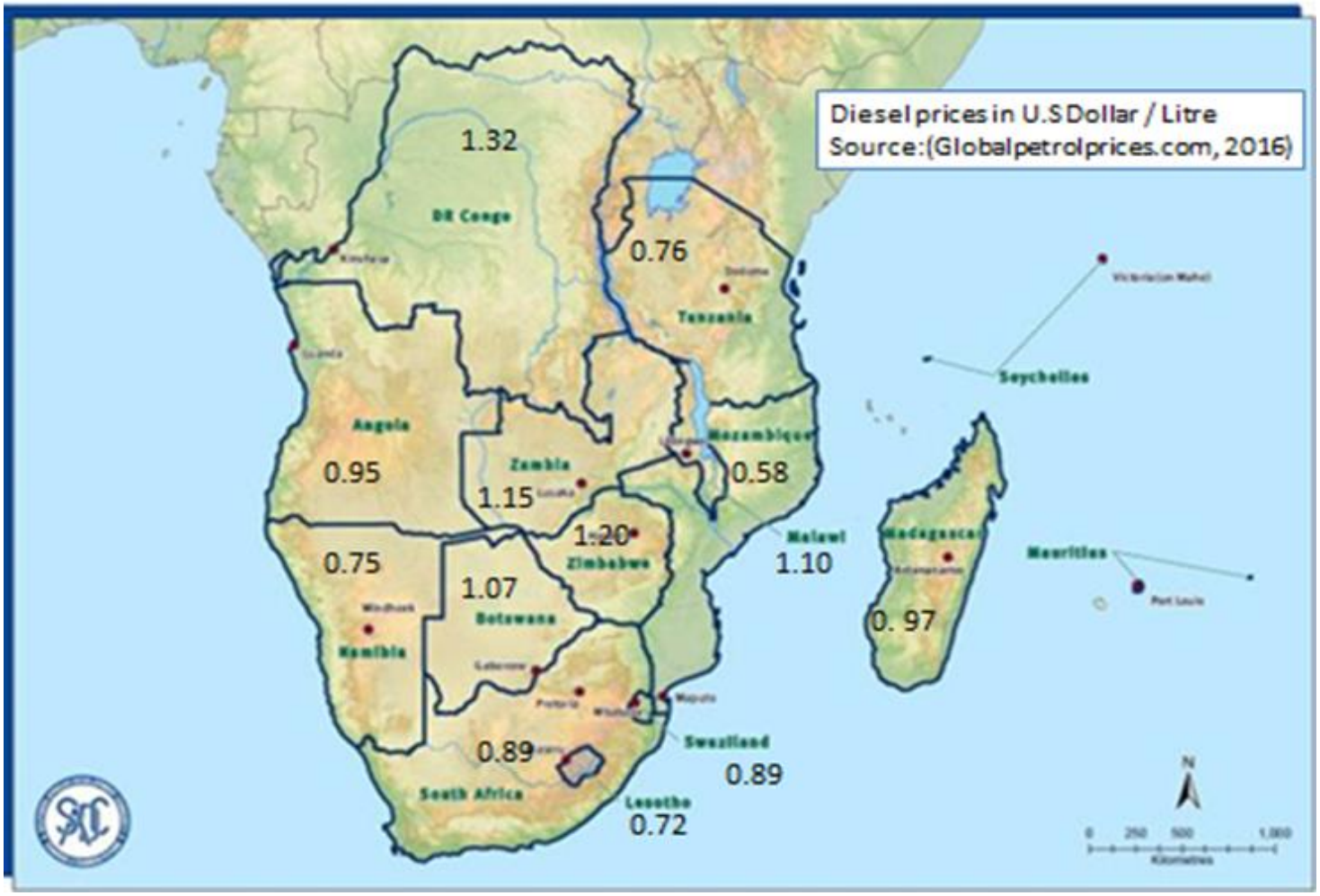
Diesel prices (US$/L) in the region of South Africa (SADC.int, 2016)



Non-renewable energy generation
Diesel fuels

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Country:	Diesel cost ($ per L)	(2014 data)					(persons/ square km)
		National Electrification rates (%)	HDI Value	HDI ranking /188	Type of human development	MPI value	Population density
Namibia	0.75	32	0.628	126	Medium	0.205	3
Botswana	1.07	53	0.698	106	Medium	N/A	4
Lesotho	*0.72*	*17*	*0.497*	*161*	*Low*	*0.227*	*70.3*
Swaziland	*0.89*	*65*	*0.531*	*150*	*Low*	*0.113*	*74.8*
Mozambique	0.58	40	0.416	180	Low	0.390	35.6
Madagascar	0.97	13	0.510	154	Low	0.420	41.7
Zambia	1.15	28	0.586	139	Medium	0.264	21.8
Malawi	1.10	12	0.445	173	Low	0.332	182.6
Tanzania	0.76	30	0.521	151	Low	0.335	60.4
Dem. Rep of the Congo	1.32	18	0.433	176	Low	0.369	34.1

Non-renewable energy generation
Diesel fuels

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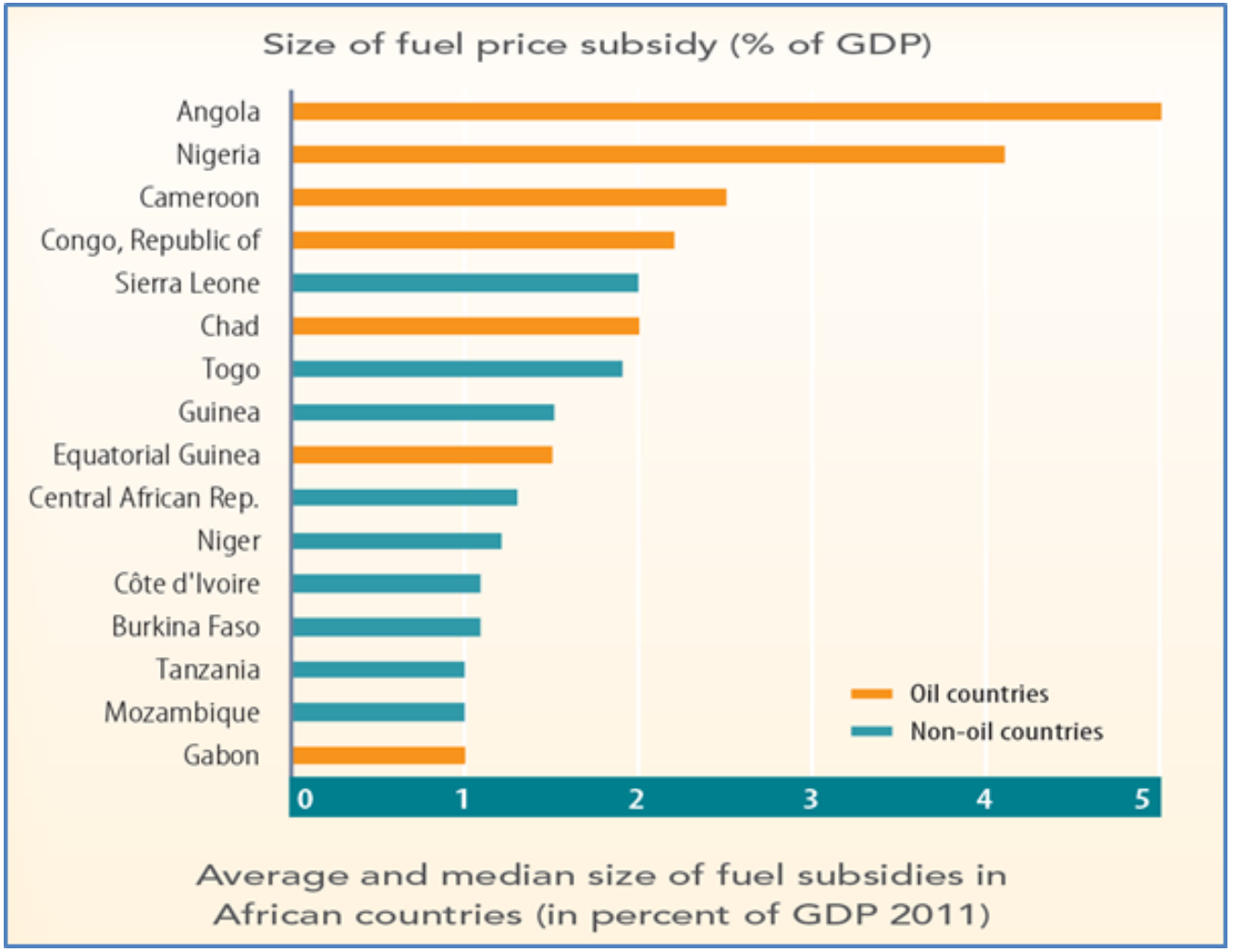
*the variation in fuel subsidies in African countries. (*Devarajan et al., 2012)



Non-renewable energy generation
Diesel fuel

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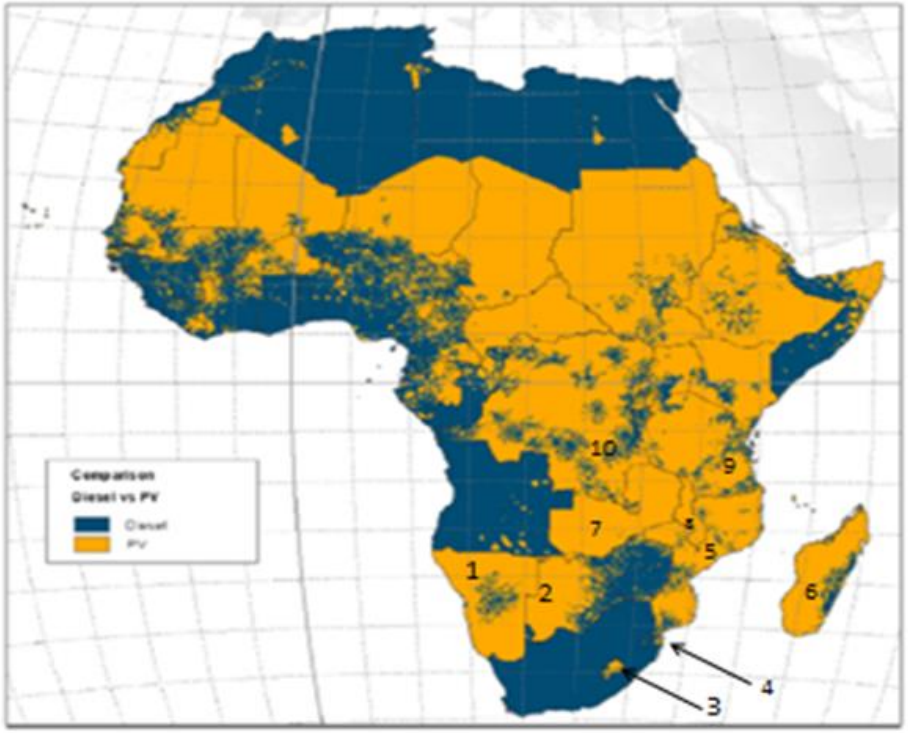
Economic comparison of preference of diesel v PV:



Countries in the sub-region of South-Africa that have high diesel prices:

1. Namibia
2. Botswana
3. Lesotho
4. Swaziland
5. Mozambique
6. Madagascar
7. Zambia
8. Malawi
9. Tanzania
10. Dem. Rep of the Congo

The countries in the yellow were of particular interest because this mapping exercise demonstrates the high cost of diesel in this area. An alternative to diesel in such a country would make a huge impact in providing electricity. These ten countries identified were then crosslinked to current diesel prices.

Approx. Cost for microgrid generation

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Consider:

- Operational costs
- Ease of repair
- Distance of load from supply
- Resilience

	Cost ($/kW)
Solar PV	995
Wind	4,000
Gasification	1,300
Anaerobic Digestion	3,000
Micro-hydro	820
Diesel Generator	280

Approx. Cost for microgrid generation

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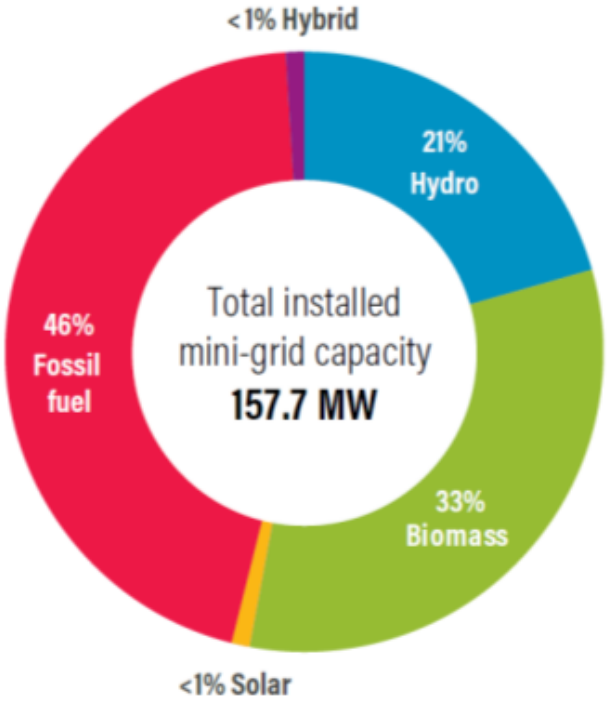
Around 7,507 mini grids are planned for global development, **mostly solar or solar hybrid.** More than 4,000 are planned for Africa.

In Tanzania there are about 109 mini grids but only 3 hybrid systems :

- ✓ 24 kW diesel/60 kWp PV solar that connects 250 customers
- ✓ 8.8 kW diesel/(SVO) /20 kW gasifier
- ✓ 25 kWp solar /32 kW biomass

Distribution of installed Mini-grid Capacity in Tanzania, by Energy Source, 2016.



Summary of generation methods

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	Diesel generator	Gasification + engine generator	Anaerobic digestion + engine generator	Solar	Wind	Hydro
Installed cost/kW	Very low	Medium	High	Medium	High	Low
Operation and maintenance cost	Very high (fuel)	High (labour)	Medium (Labour)	Low	Low	Low
Start-up time	Fast	Slow	Fast	N/A	N/A	Medium
Ramp rate	Fast	Medium-fast	Fast	Control system dependent	Slow	Medium
Microgrid role	Backup, peak load and when no renewables/ battery available	Peak loads (3-5hrs)	Backup, peak load and when no renewables/ battery available	Baseload	Baseload	Baseload

Summary of generation methods cont.

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	Diesel generator	Gasification + engine generator	Anaerobic digestion + engine generator	Solar	Wind	Hydro
Other considerations	Fuel price is volatile	Turndown ratio. Must run at ~25% of maximum power	The amount of biogas that can be sensibly stored is limited	Peak microgrid load usually occurs when sun is setting	Can be too windy or not windy enough to use	Silt run-off into rivers during rainy season can block turbines
	Poor efficiency for small loads	Produce huge amounts of power when it is needed	Competing clean cook fuel use		Hard to control voltage and frequency	
	Easily stored fuel	Could run out of suitable supply of biomass				
		Poor efficiency for small loads				

- Hybrid systems maximise advantages and mitigate disadvantages of each
- Batteries provide energy storage and are a flexible load

High Load optimisation

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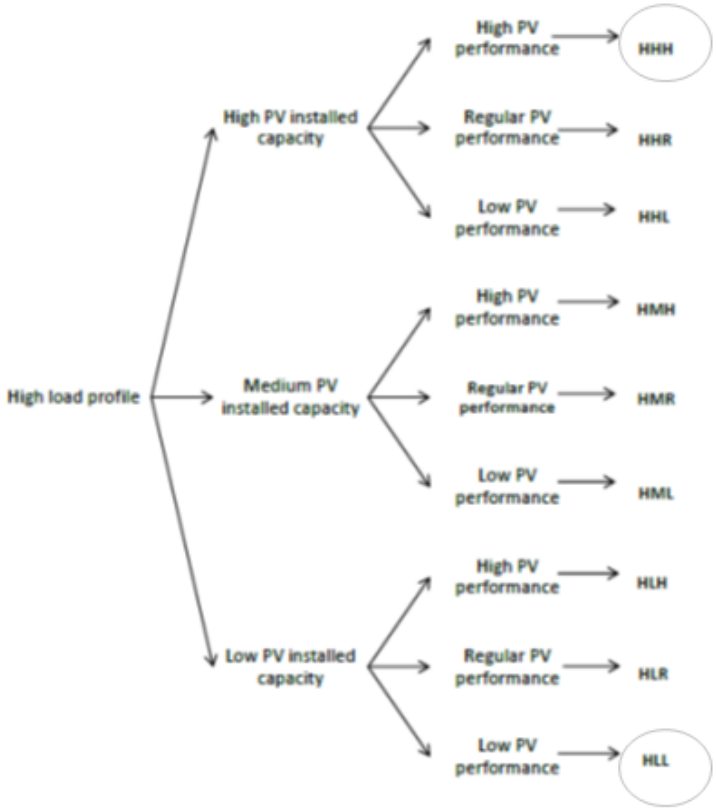
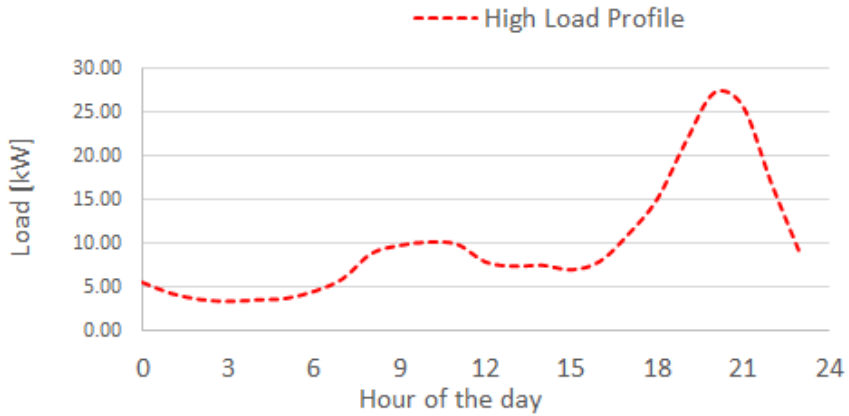


Load Profile	PV Installed Capacity	PV Operating Performance	Scenario ID	Genset Selected*	Genset Power (kWh/day)	Genset fuel operating cost (£/year)	Genset emission cost (£/year)	Scenario total cost in year 1 (£/year)
High	High (9 kW)	High	HHH	Gen. 2	151.4	11594.6	289.1	30818.70
				Gen. 4	106.8	6914.7	172.7	
	Low (4 kW)	Low	HLL	Gen. 3	212.7	14994.2	374.4	34036.26
				Gen. 4	92.3	5965.8	149	

* Gen. 2: 10.37 kW, Gen. 4: 23.94 kW



Low Load optimisation

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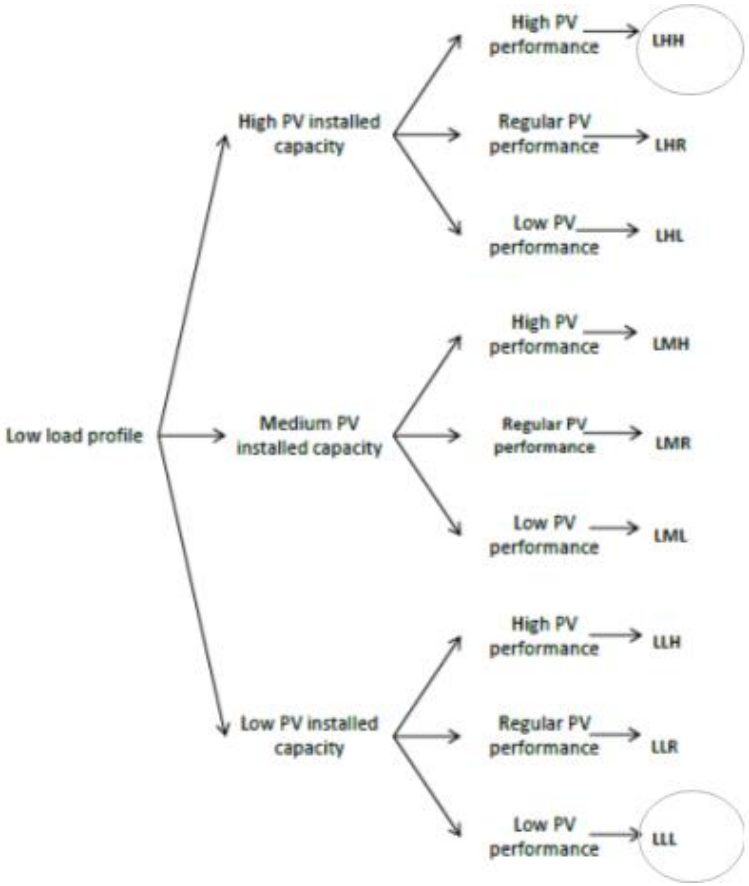
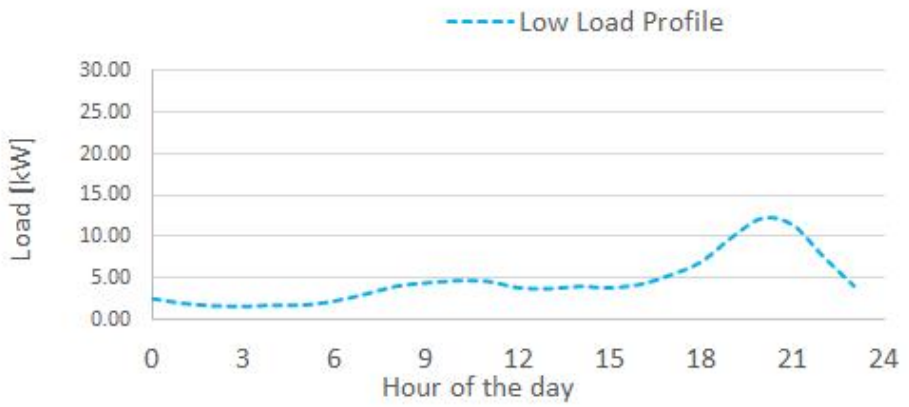


Load Profile	PV Installed Capacity	PV Operating Performance	Scenario ID	Genset Selected*	Genset Power (kWh/day)	Genset fuel operating cost (£/year)	Genset emission cost (£/year)	Scenario total cost in year 1 (£/year)
Low	High (4 kW)	High	LHH	Gen. 1	97.8	8599.1	214.7	21330.48
				Gen. 2	40.9	3141.9	78.3	
	Low (2 kW)	Low	LLL	Gen. 1	100.1	8732	218	21332.98
				Gen. 2	38.5	3011.5	75	

* Gen. 1: 7.31 kW, Gen. 2: 10.37 kW



Optimisation Results

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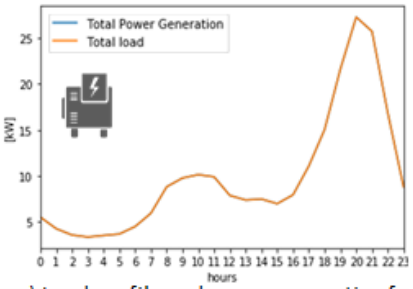
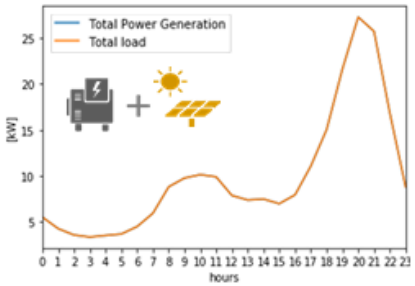
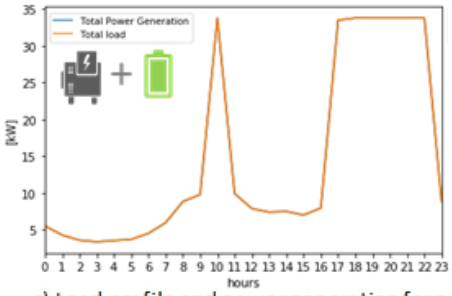


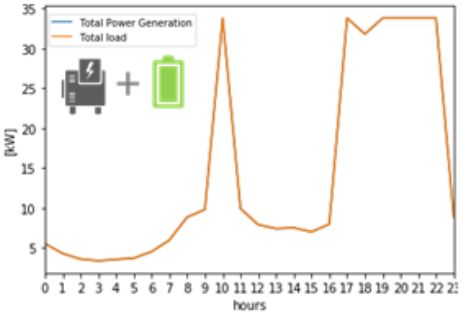
a) Load profile and power generation for a diesel generator system.



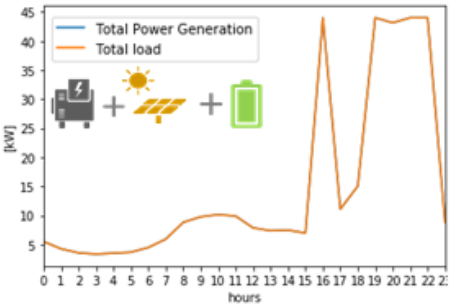
b) Load profile and power generation for a genset/PV system.



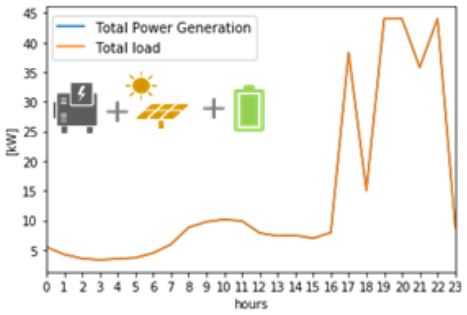
c) Load profile and power generation for a genset/Lead-acid battery system.



d) Load profile and power generation for a genset/Li-ion battery system.



e) Load profile and power generation for a genset/PV/Lead-acid battery system.



f) Load profile and power generation for a genset/PV/Li-ion battery system.

Table. Fuel Cost, Life Cycle Cost (LCC), and Levelized Cost of Energy (LCOE) from the optimisation scenarios.

System Configuration	Yearly Fuel Cost (£)	LCC-25 years (£)	LCOE-25 years (£/kWh)
Genset	17,623.18	1,046,452.27	1.39
Genset and PV	15,776.37	972,033.45	1.29
Genset and Battery (Lead-acid)	14,741.83	733,969.10	0.68
Genset and Battery (Li-ion)	13,962.50	696,798.82	0.65
Genset, PV, and Battery (Li-ion)	12,111.40	673,927.31	0.63
Genset, PV, and Battery (Lead-acid)	12,831.90	678,149.09	0.61