SIMULATION OF DIESEL SAVINGS OF PV HYBRIDIZED MINI-GRIDS, BRAZIL

Field examples in Brazil and Canada – Simulations in Egypt, Greece and Nepal

Alexander Schies

Fraunhofer Institute for Solar Energy Systems ISE

OFF-Grid Power Forum

Intersolar Europe 2014, June 6th, 2014

www.ise.fraunhofer.de

Fraunhofer ISE

AGENDA

- Fuel saving potentials of field systems
- Case studies for fuel saving potential of
  - PV integration without batteries
  - Load Management System
- Conclusions

Integration of PV into Diesel systems

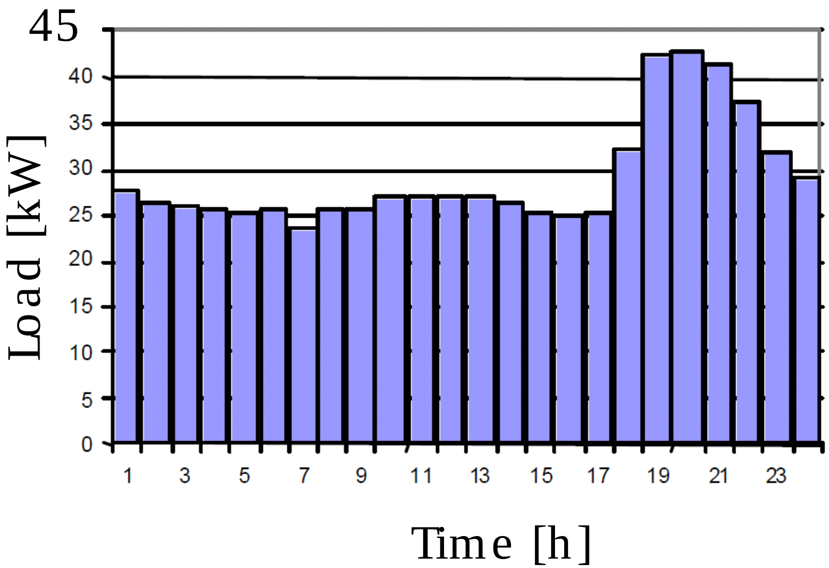
- Low penetration systems
  - PV penetration < 50%
- Medium penetration systems (control action needed)
  - PV penetration 50% – 100%
- High penetration systems (storage systems)
  - PV penetration > 100%

Fraunhofer ISE

Diesel Dominated Mini Grids – Low Penetration RES

Araras, Amazonas, Brazil

- 224 MWh consumption
- Diesel: 3* 54 kW
- PV: 12.5 kW
- PV yield: 1488 kWh/kWp
- PV used: 100%
- PR: ~0,84



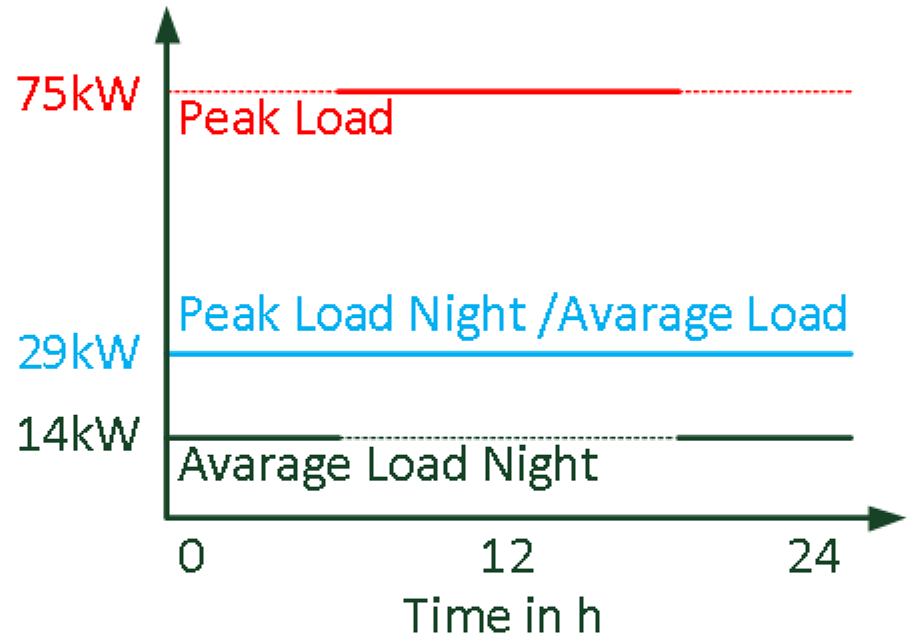
Diesel savings from PV	5,5% / (4600 l)
PV energy share per year	8,3%

Source: H.G. Beyer, R. Rüther, S.H.F. Oliveira, Adding PV-Generator without storage to medium size stand allone diesel generator sets to support rural electrification in Brazil, 2003

Diesel Dominated Mini Grids – Medium Penetration RES

Nemiah Valley, Canada

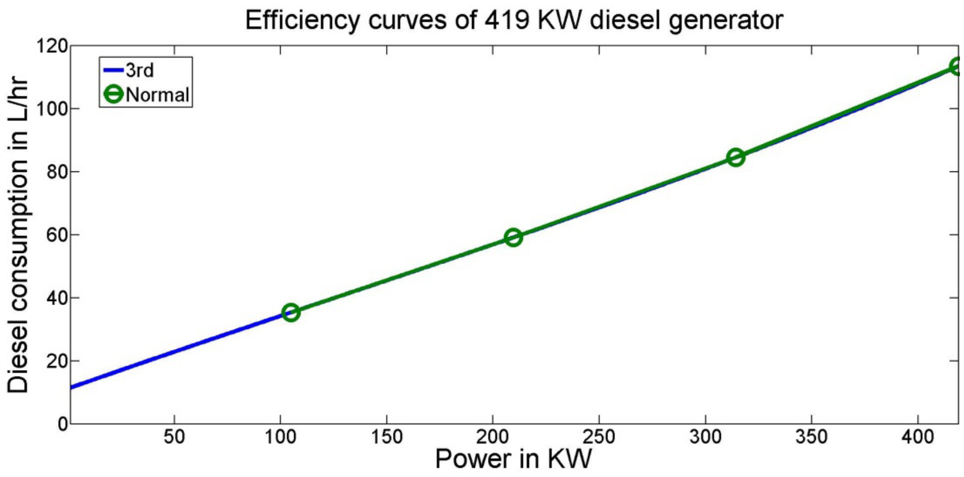
- Consumption 270 MWh/year
- Diesel: 95kW / 30kW
- PV: 28 kW
- PV yield : 1043 kWh/kWp
- PV used: ~90%
- PR: 0,67



Diesel savings from PV	(5,7%) / 5900 l
Diesel savings from system optimization	25% / 26000 l
PV energy share per year	11,4%

Source: S. Pelland at. all, Nemiah Valley Photovoltaic-Diesel Mini-Grid

Models for case study



Hourly simulation

- PV
- Inverter Model
- Diesel Model

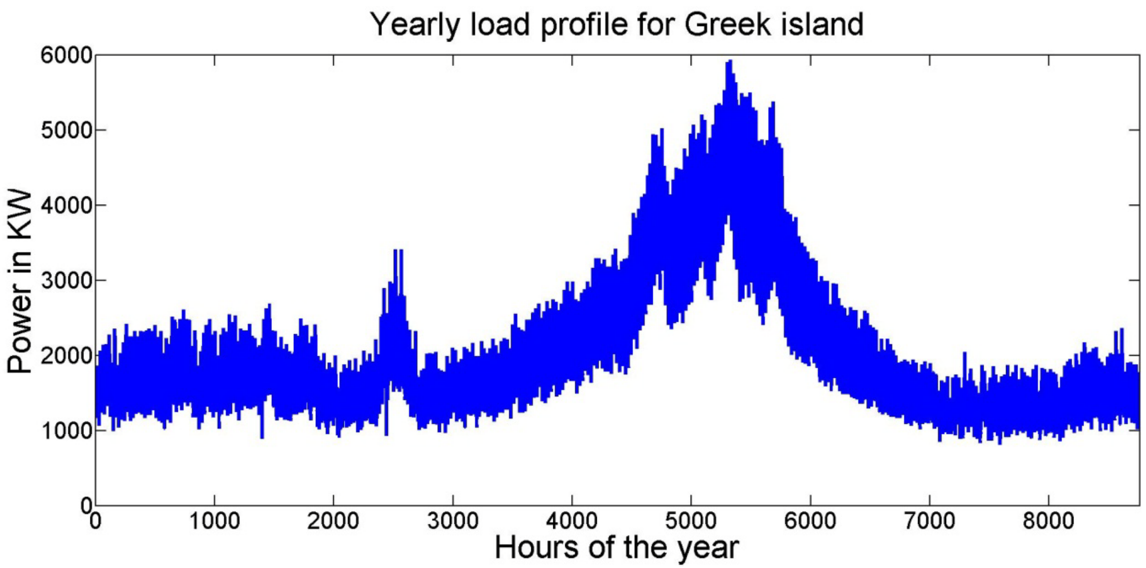
- Power controller / fuel saver model rules:
  - reduce PV power that diesel never runs beneath 30% of nominal power
  - Keep always enough running diesel reserve to cover 100% load in the case of sudden clouds covering PV generator
- Optimal generator management

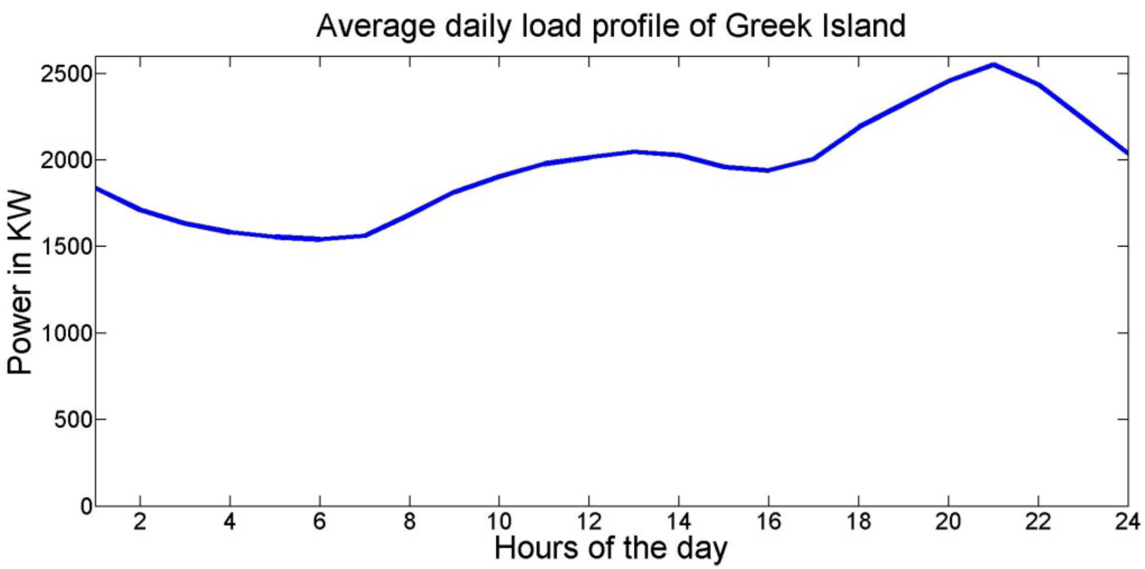
Greek island

- Load: 17 GWh/a
- Peak load: 6MW

- Diesel:

1) 3* 1520 kW
2) 2* 419 kW
3) 1* 1257 kW

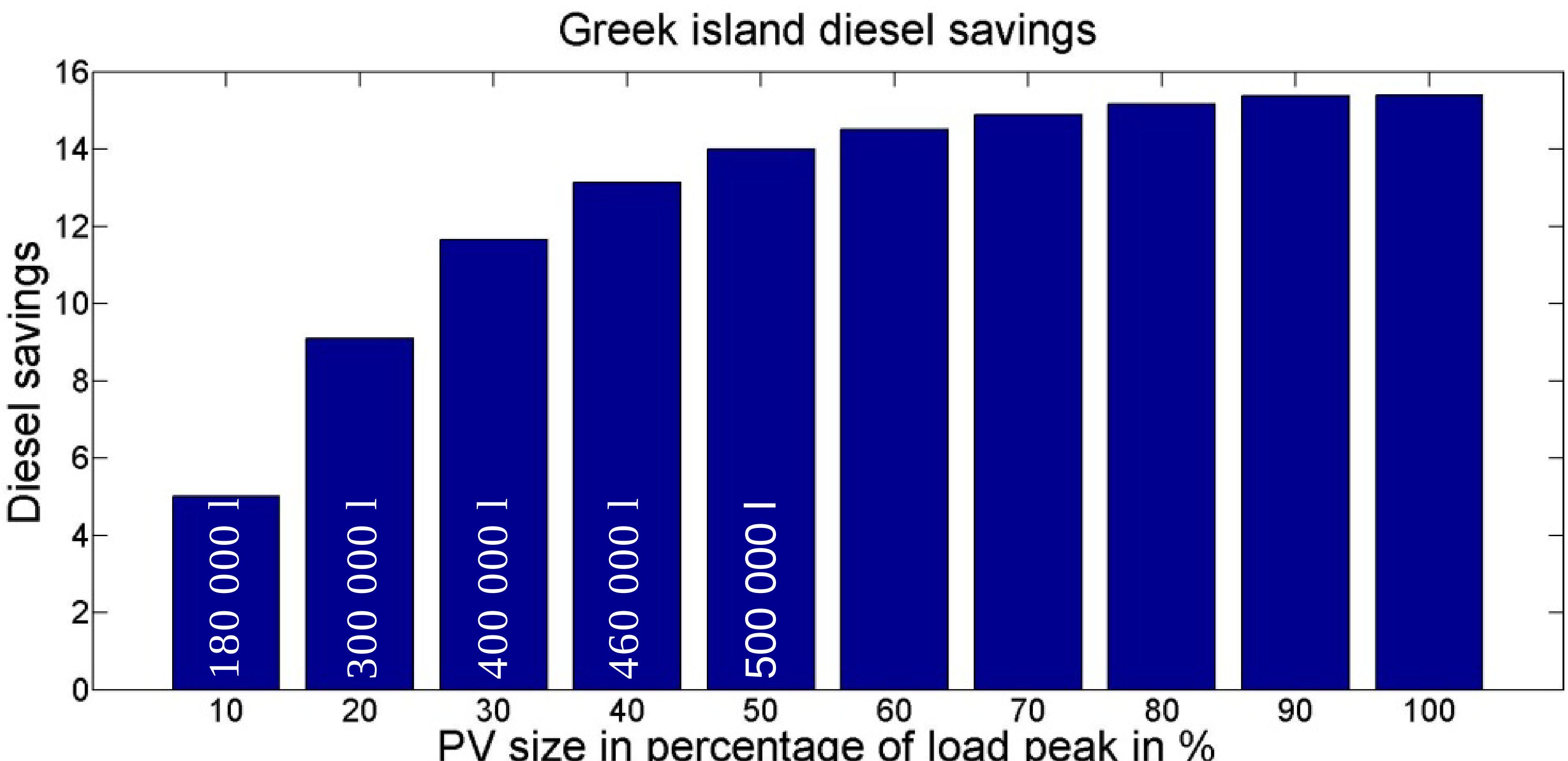




Fraunhofer ISE

Greek island

- Peak load: 6MW
- Diesel consumption: 3500 million liter



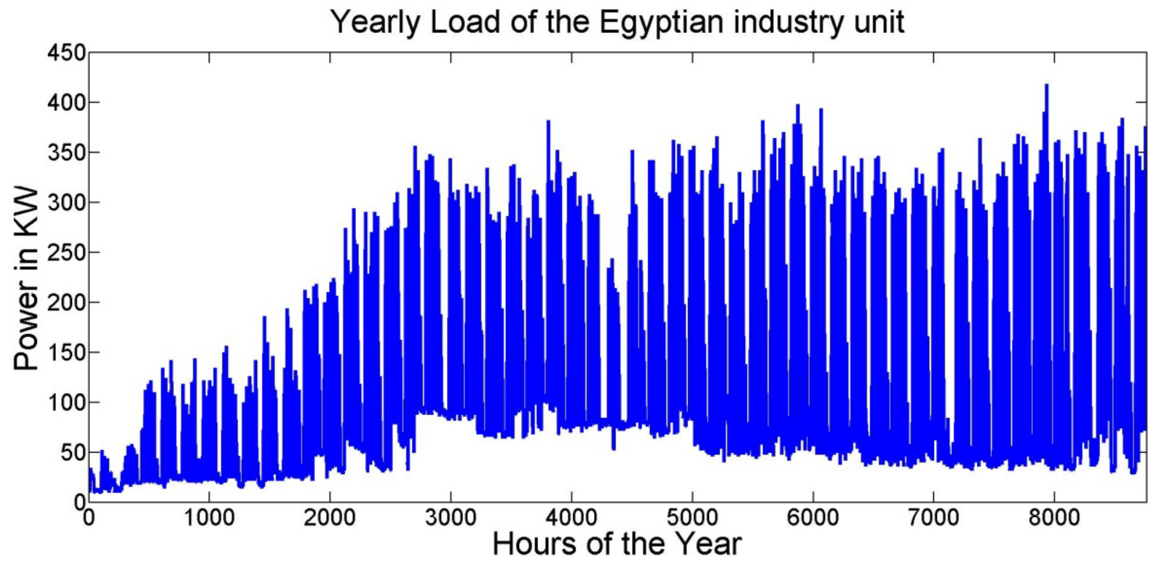
Fraunhofer ISE

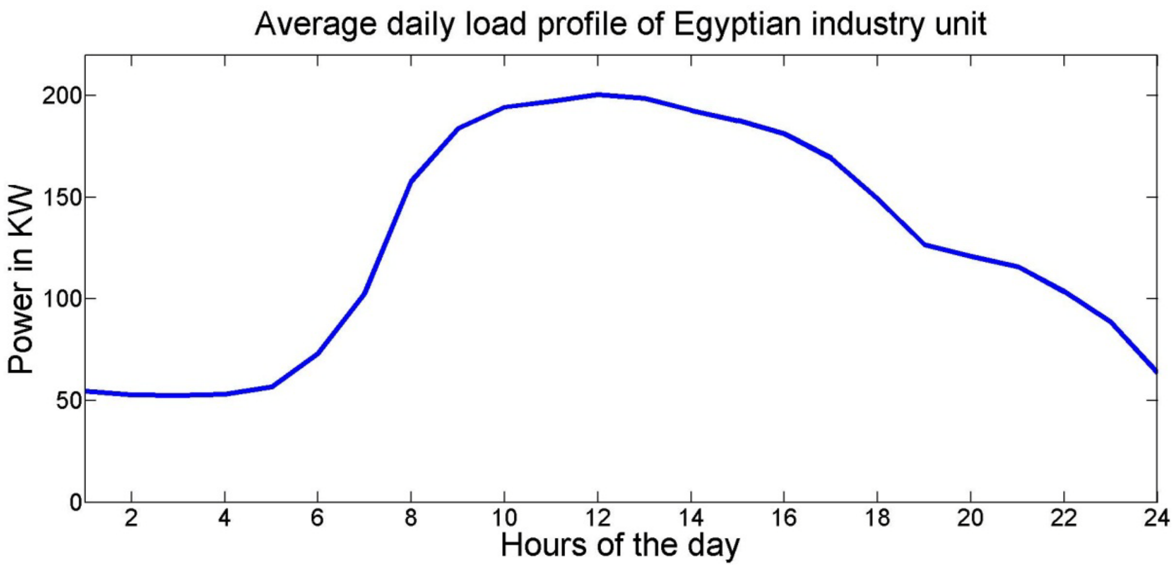
Egypt industry

- Load: 1120 MWH
- Peak load: 420 kW

- Diesel:

1) 350 kW
2) 120 kW

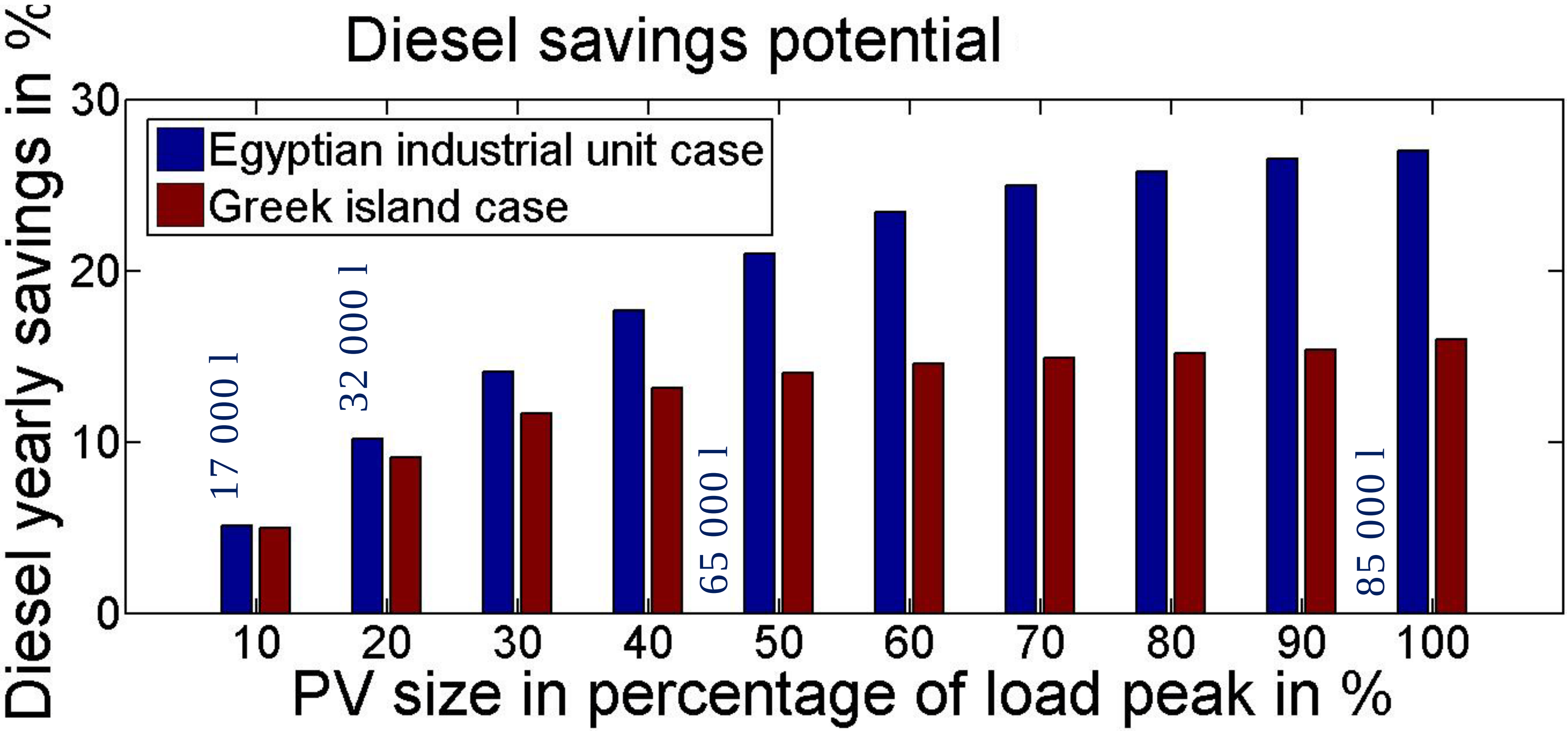




Fraunhofer ISE

Egypt industry

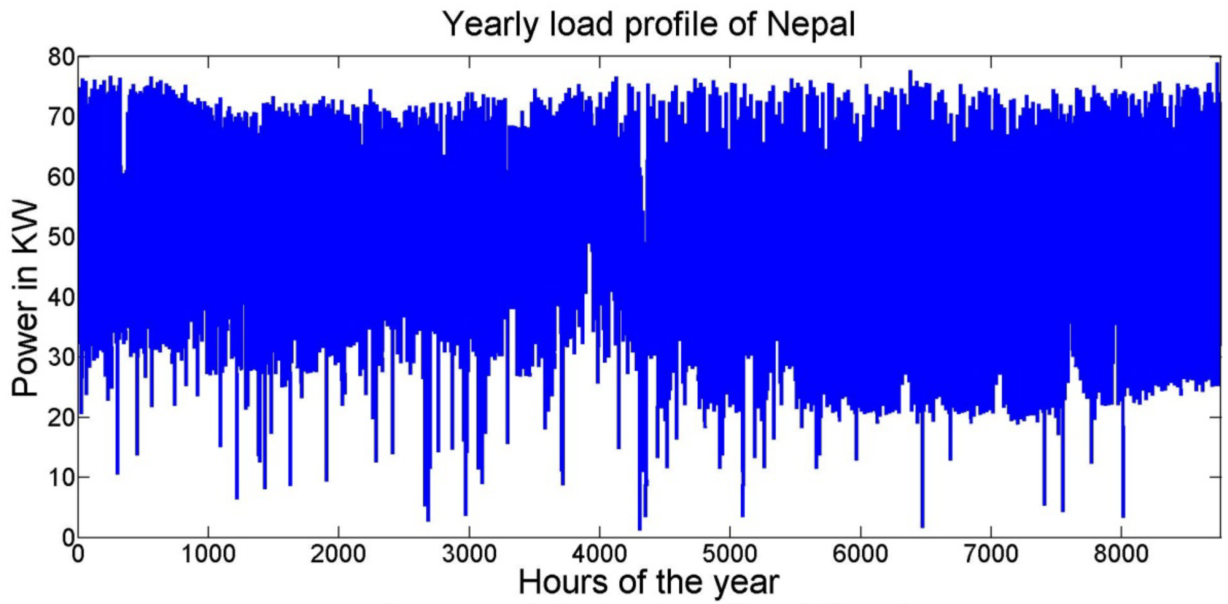
- Peak load: 420 kW
- Diesel consumption: 300 000 liter

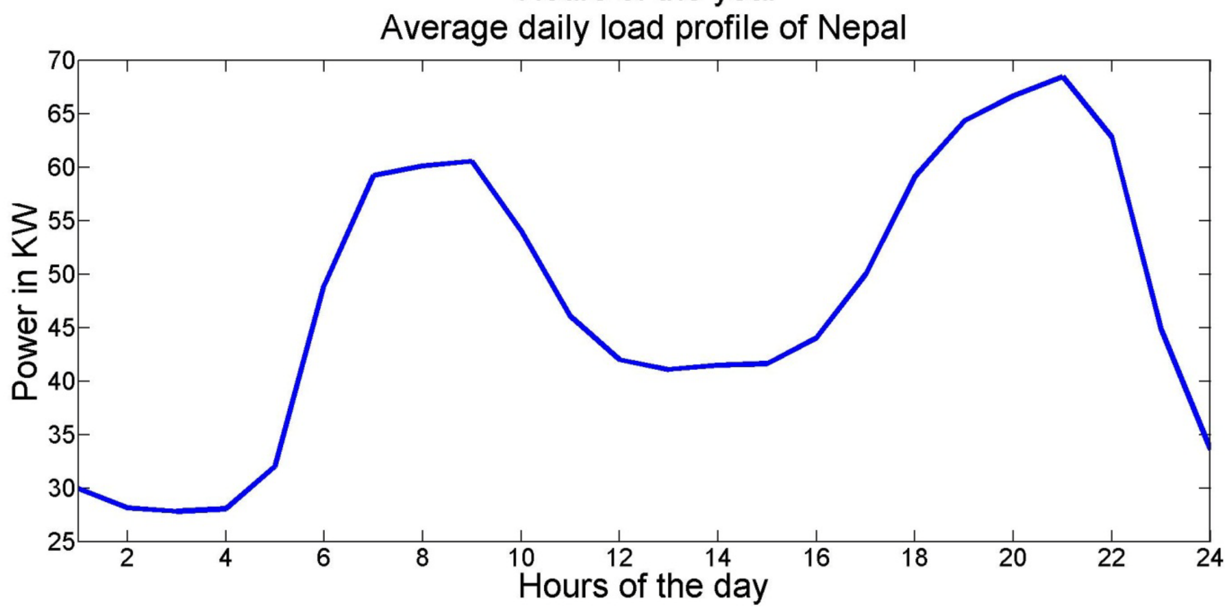


Fraunhofer ISE

Nepal village

- Load: 410 MWh
- Diesel: 80 kW

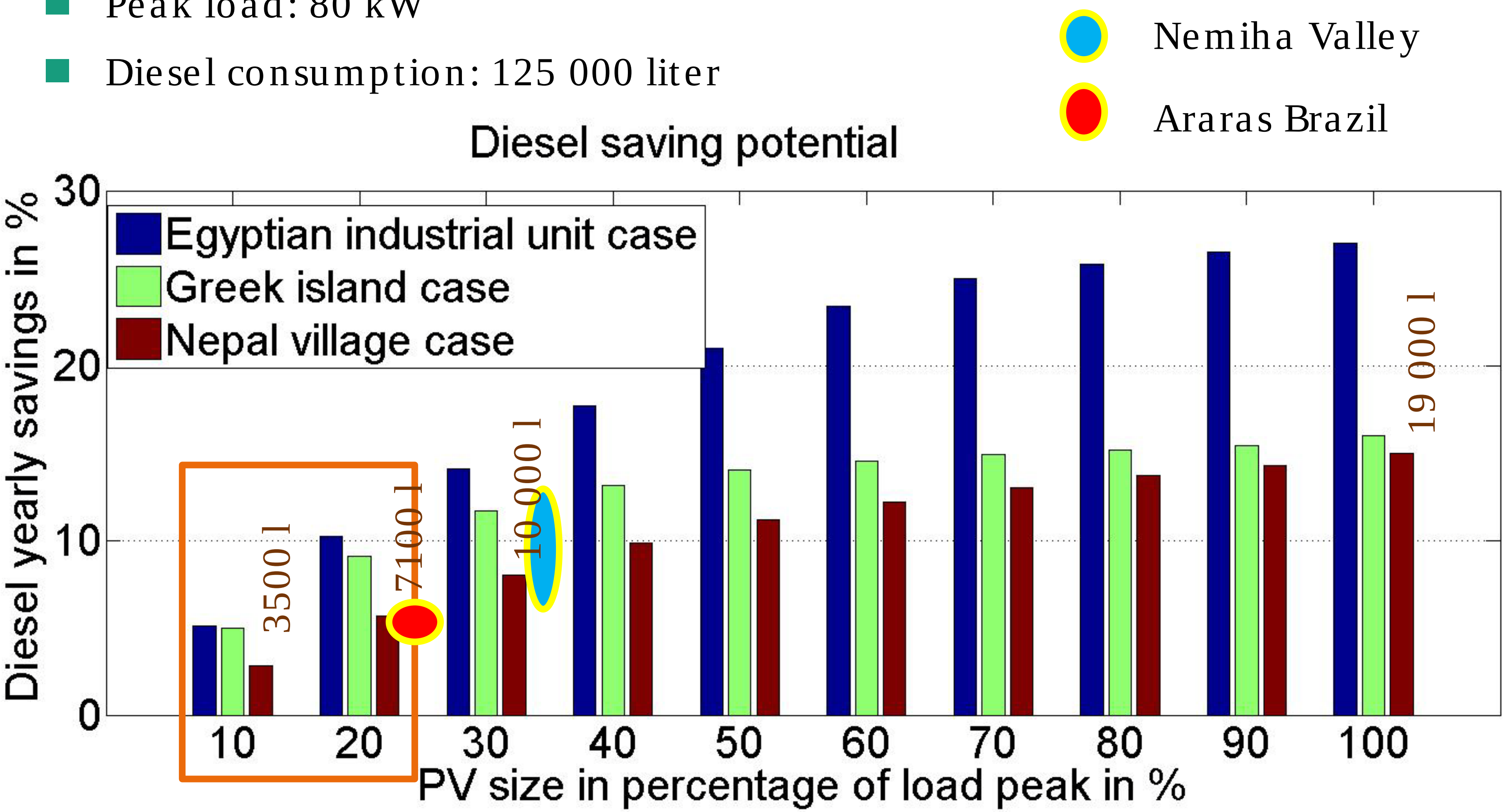




Fraunhofer ISE

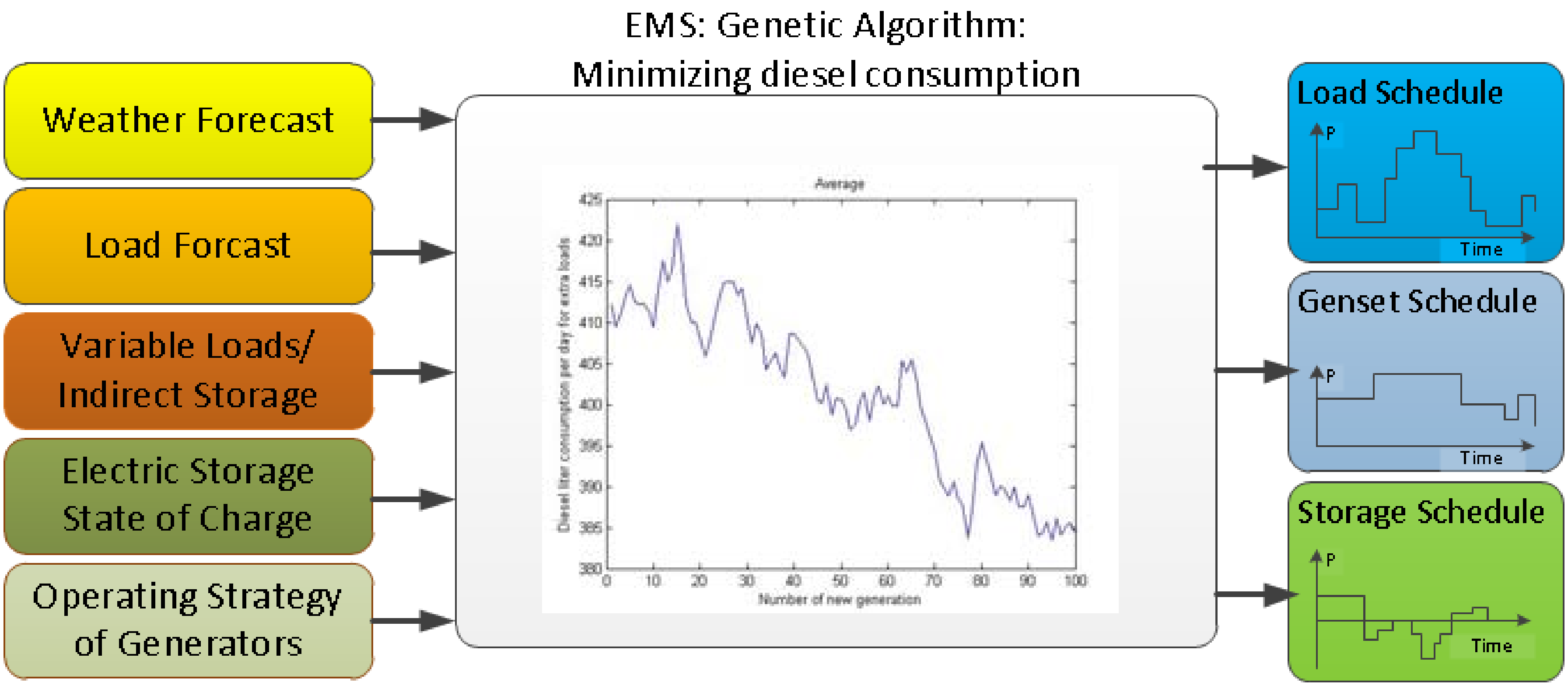
Nepal village

- Peak load: 80 kW
- Diesel consumption: 125 000 liter

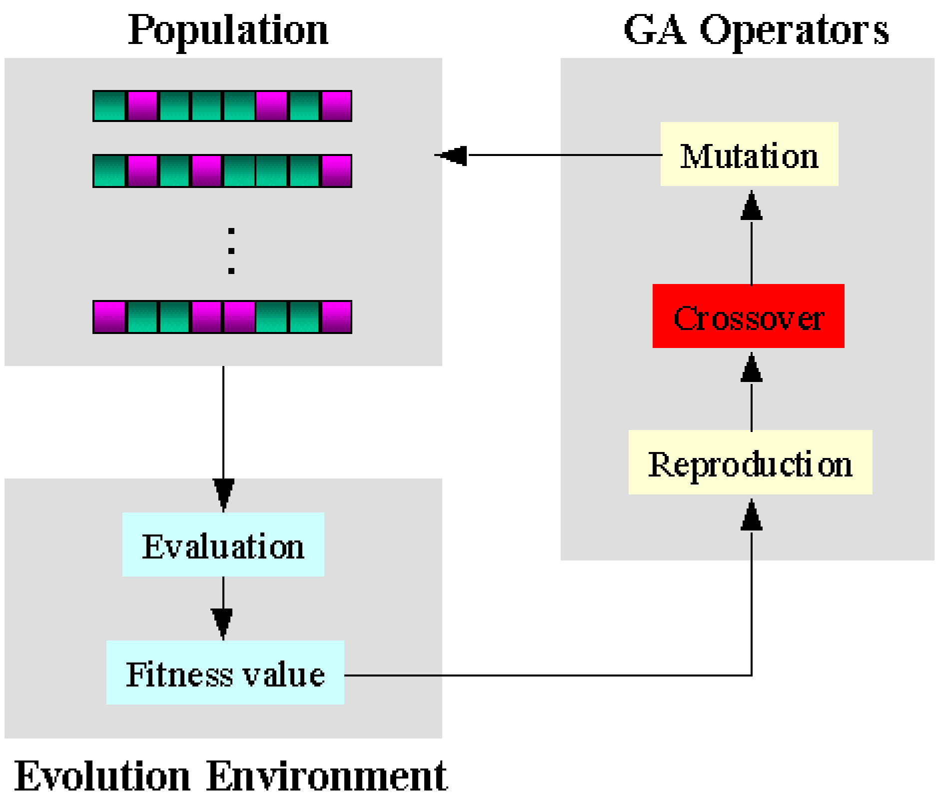


Energy Management System

- Goal: Fuel saving through load management to icrease usage of PV and rise diesel generator efficiency



Genetic algorithm to minimize diesel consumption



Genetic Algorithm Evolution Flow

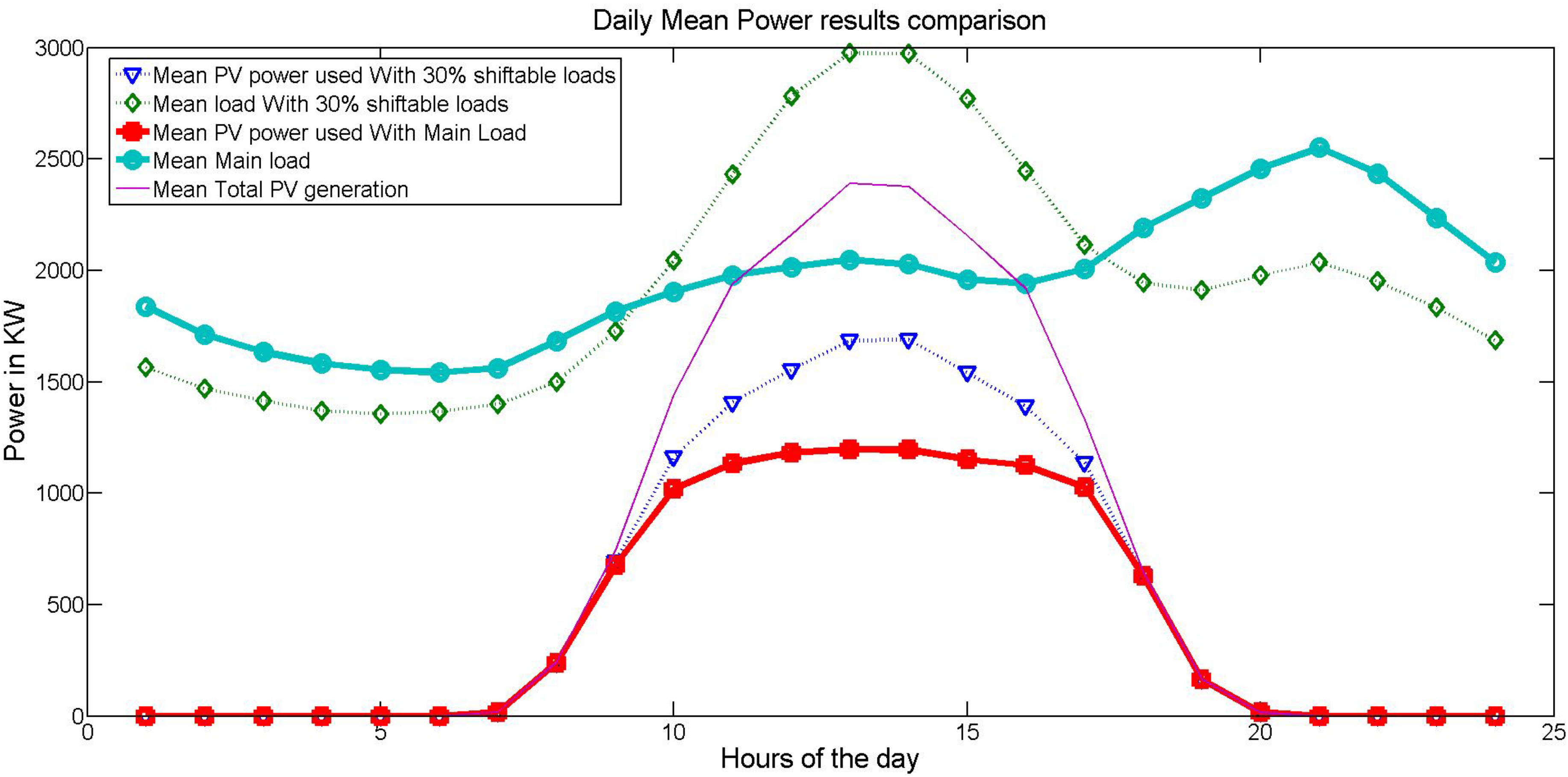
Potential analysis load management system

- Defined certain percentage of every dayload as shiftable load
- Divide this energy through certain defined loads with defined parameters

	Start time	End time	Operation time	Continously	Season	Loads power
Desalination	7	7	8	1	2	200 kW
Pumping 1	1	24	4	0	1	40 kW
Cooling 1	1	24	6	0	1	30 kW
…						

Fraunhofer ISE

Daily mean power



Fraunhofer ISE

Fuel saving potential of load management system

Percentage of shiftable load of load profile		10	20	30
Greek island	Fuel saving in [%] with 55% PV share of peak load (perfect prognosis)	9,8	11,9	13,3
	Fuel saving in [%] with 55% PV share of peak load (simple prognosis)	5,8	7,9	9,8

Conclusions

In the presented specific cases we find fuel saving potentials with

- system optimizing, optimal generator management 20%
- low penetration PV 10%
- PV curtailment controllers 30%
- With Load Management 15% additional saving is possible

Savings strongly depend on

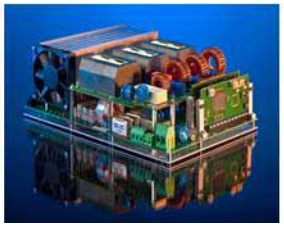
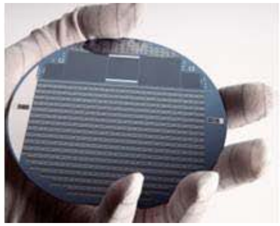
→ Load profile

→ Availability of shiftable loads

→ Forecast quality

Thank you for your attention!




Fraunhofer Institute for Solar Energy Systems ISE

Alexander Schies

www.ise.fraunhofer.de

alexander.schies@ise.fraunhofer.de

Fraunhofer
ISE

References

- **[1]** A. Schies, J. Wachtel, B.P. Koirala, L. Yang, M. Vetter, J. Wüllner, A. Gombert, F. Abulfotuh, The NACIR project: CPV island system for water pumping and irrigation in Egypt – energy management strategy and field results, 6th European Conference on PV-Hybrids and Mini-Grids, Chambery, France 2012.
- **[2]** L. Arribas, I. Cruz, W. Meike, High-power PV-Hybrid systems: Is their time now?, 6th European Conference on PV-Hybrids and Mini-Grids, Chambery, France 2012.
- **[3]** H.G. Beyer, R. Rüther, S.H.F. Oliveira, Adding PV-Generator without storage to medium size stand allone diesel generator sets to support rural electrification in Brazil, 2003
- **[4]** S. Pelland, D. Turcotte, Member, IEEE, G. Colgate, and A. Swingler, Nemiha Valley Photovoltaic-Diesel Mini-Grid: System Performance and Fuel Saving Based on One Year of Monitored Data, IEEE Transactions on Sustainable Energy, VOL. 3, NO. 1, January 2012
- **[5]** Wolfgang Heydenreich, Björn Müller, Christian Reise, Describing the World with three Parameters: a new Approach to PV Module Power Modelling, 23rd European Photovoltaic Solar Energy Conference, Valencia, Spain September 2008
- **[6]** Alexander Schies, Georg Bopp, Evandro Augusto Dresch,Tamer Hanna, Panagiotis Raptis, Matthias Vetter, Yasser Hegazy, Mohamed ElSobky, Fuel saving potential in PV diesel systems with different strategies, 7th European Conference on PV-Hybrids and Mini-Grids, Bad Hersfeld, Germany 2014.