ILF Consulting Engineers (Asia) Ltd

Optimized Hybridization and Storage in Mini Grids using Renewable Energy Sources from Solar-PV and Wind

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ENGINEERING EXCELLENCE

8th Asian Solar Energy Forum, ADB – Manila, Philippines – 15 June 2015

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Agenda

Content of the Presentation

- ILF Group
- General Explanation of Hybridization
- Potential / Opportunities of Hybridization
- Arguments for Hybridization
- Challenges of Hybridization
- Introduction of ILF-Opti-Hybrid-Tool
- Selected References

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The ILF Group

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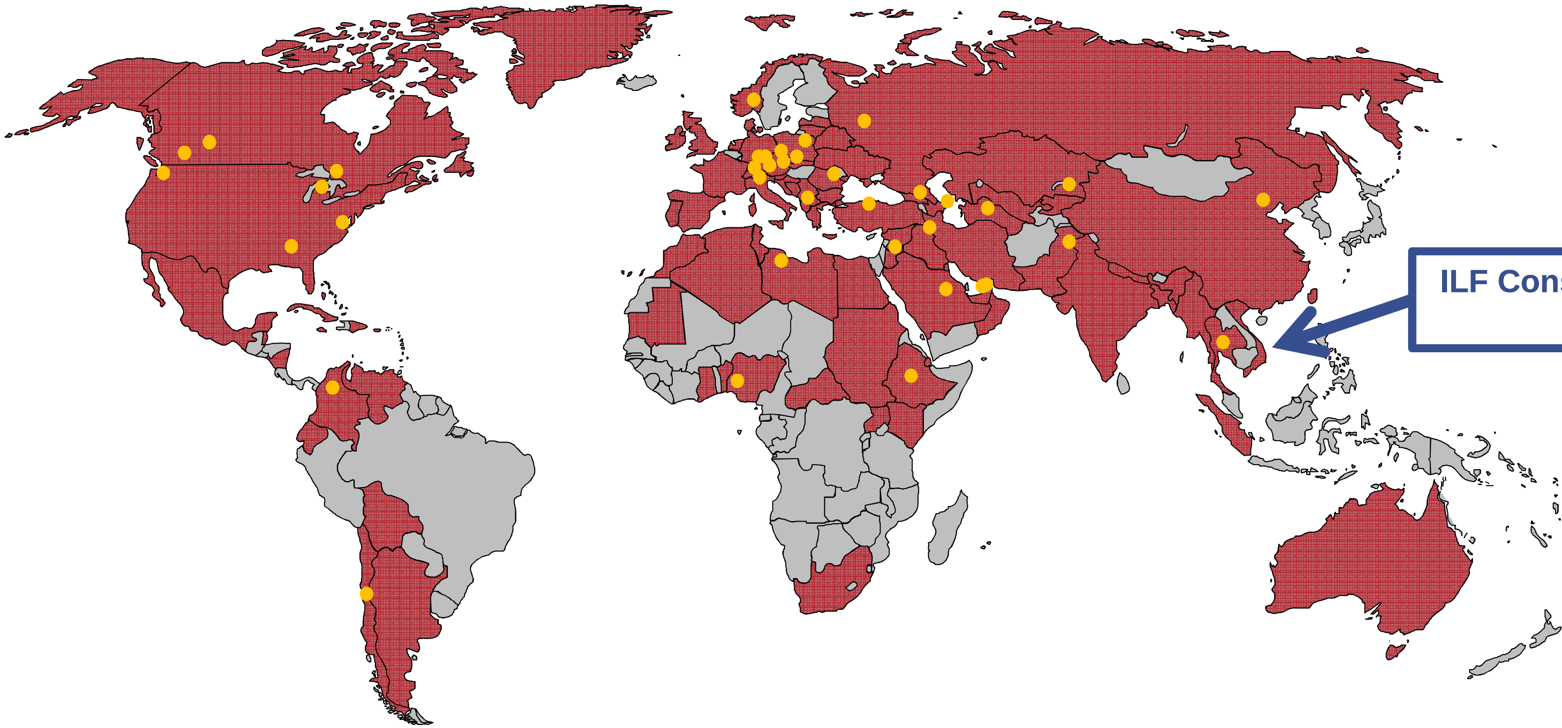
Offices and Projects

> 1,900	> 40	> 6,000	> 100	> 190 million €
employees	offices	projects	countries	revenue

100% privately owned



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What is Hybridization?

What to hybridize:

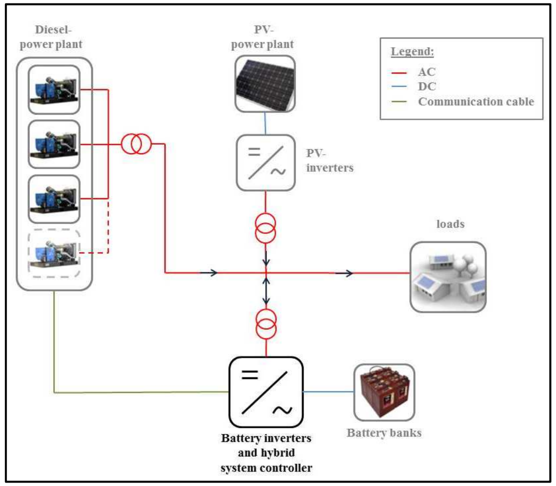
- Diesel
- Gas
- Heavy fuel oil

Hybrid system types:

- stand-alone
- mini-grid
- micro-grid
- isolated-grid

How to hybridize:

- PV
- Wind
- Hydro power
- Battery



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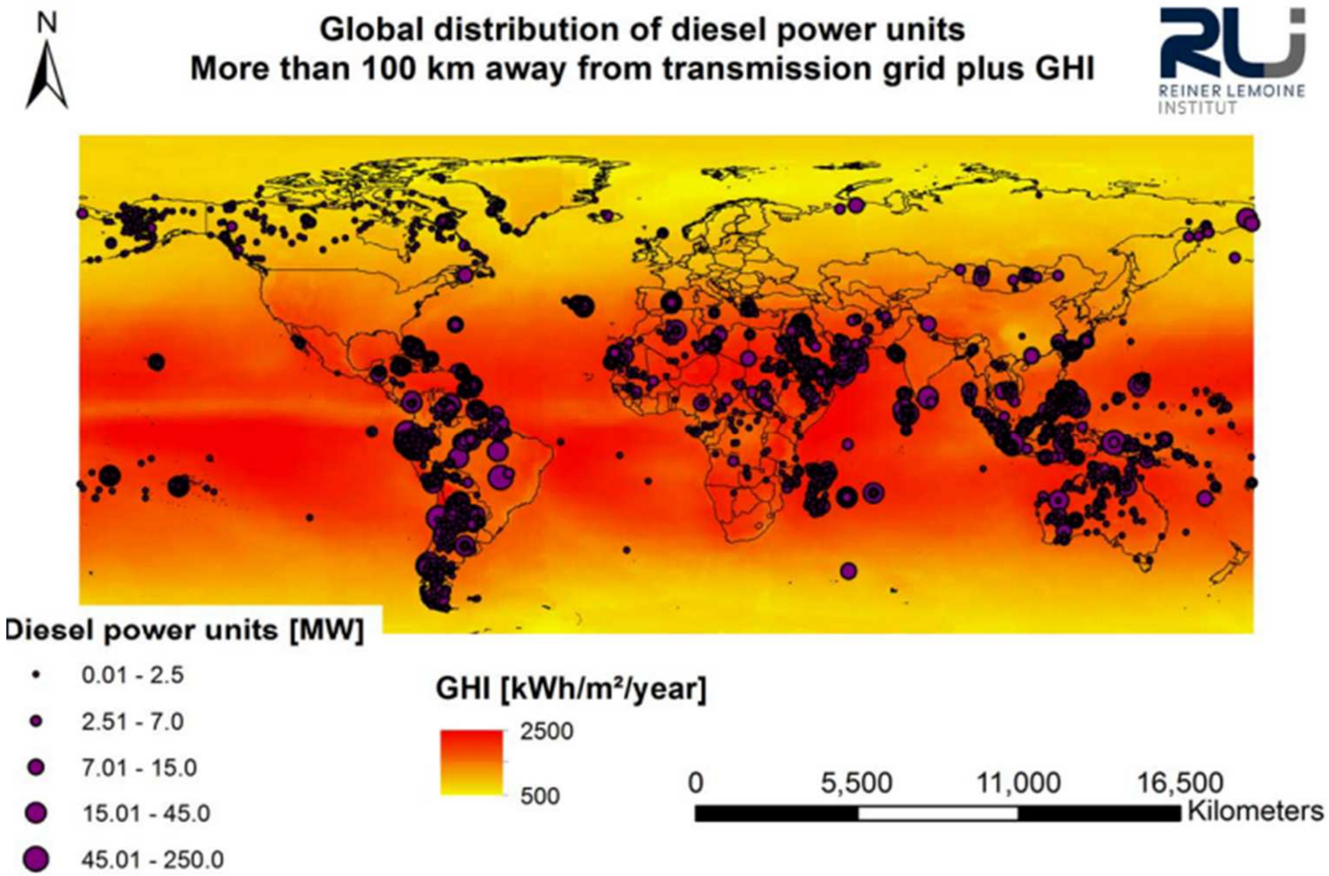
Potential / Opportunities for Hybridization



Source: Reiner Lemoine Institute, "Hybridisierungspotentiale von Dieselkraftwerken"

Most potential:

- On remote islands
- In big countries with poorly developed infrastructure

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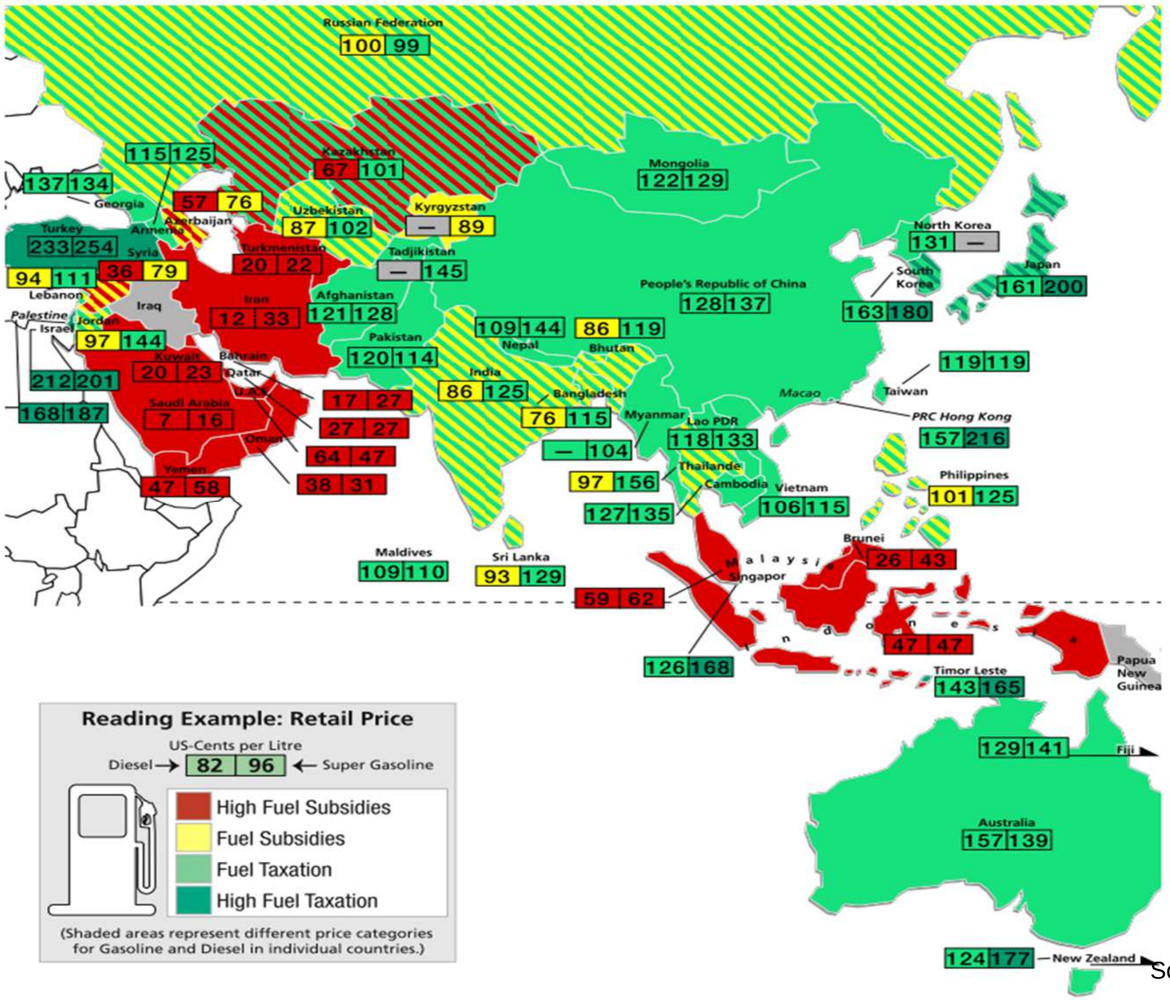
Opportunities

■ Potential / Opportunities for Hybridization



- High fuel subsidies, especially in Indonesia, Malaysia, Singapore
  Diesel price: **0.25-0.60 USD**

- Fuel subsidies in Thailand and Philippines
  Diesel price: **~1.0 USD**

- Fuel taxation in Cambodia, China, Myanmar and Vietnam
  Diesel price: **1.0-1.3 USD**

Source: GIZ, "International Fuel Prices 2012/2013", 8th Edition

Arguments for Hybridization

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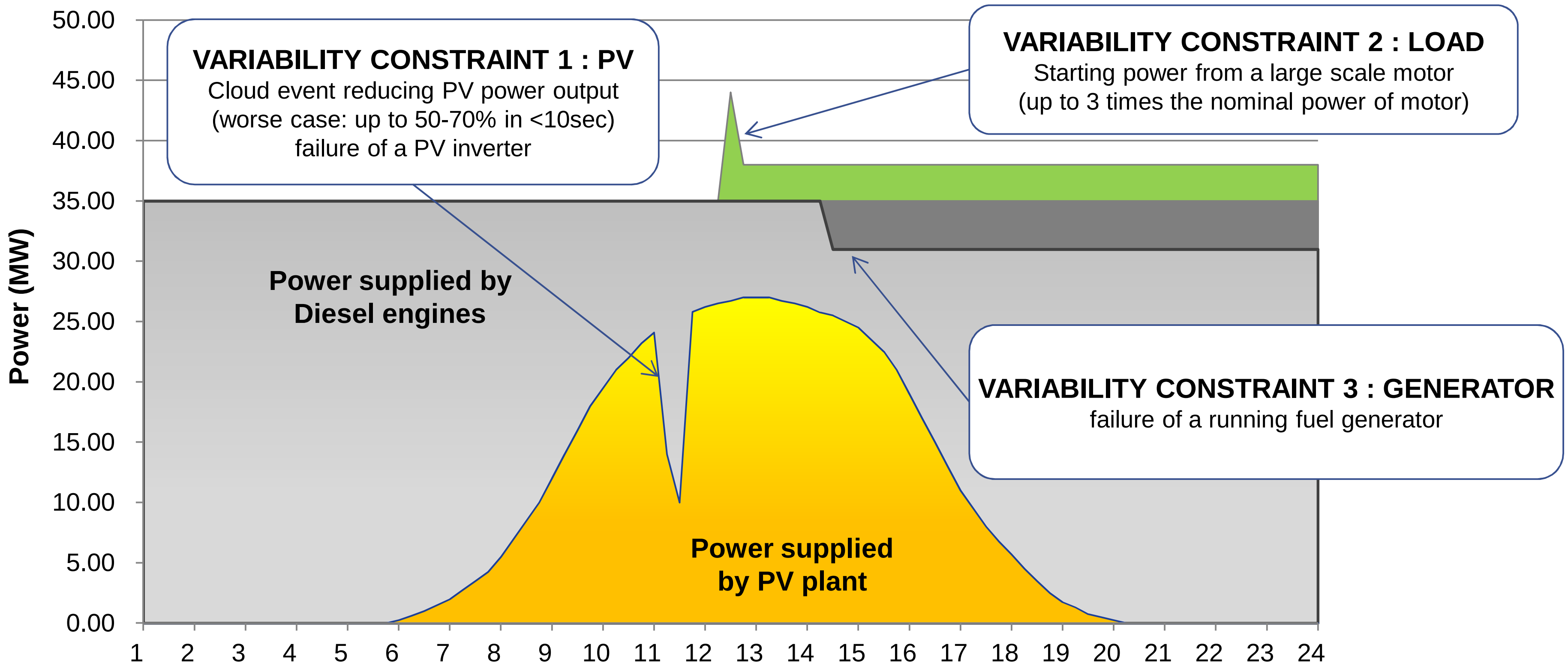
Arguments for hybrid systems

- Decreasing PV module & battery price -> lower system costs
- More independence from imports and price fluctuations of oil price
- Remote areas –> high transport and logistic costs
- Reducing operating hours of generators -> higher life expectancy
- Low maintenance
- Increasing grid stability
- Natural market
- Reducing CO_2-emissions, environmentally friendly -> “green image”

Challenges in Hybridization with PV

- Reliable Energy Management System to ensure grid stability is key
  - Sufficient Primary / Spinning reserve (from Fuel generators) required at any time



ILF Opti-Hybrid-Tool

- Developed by ILF
- Based on Microsoft Excel VBA
- Using hourly values of load profile over one year
- Using hourly values of PV, wind and battery over one year

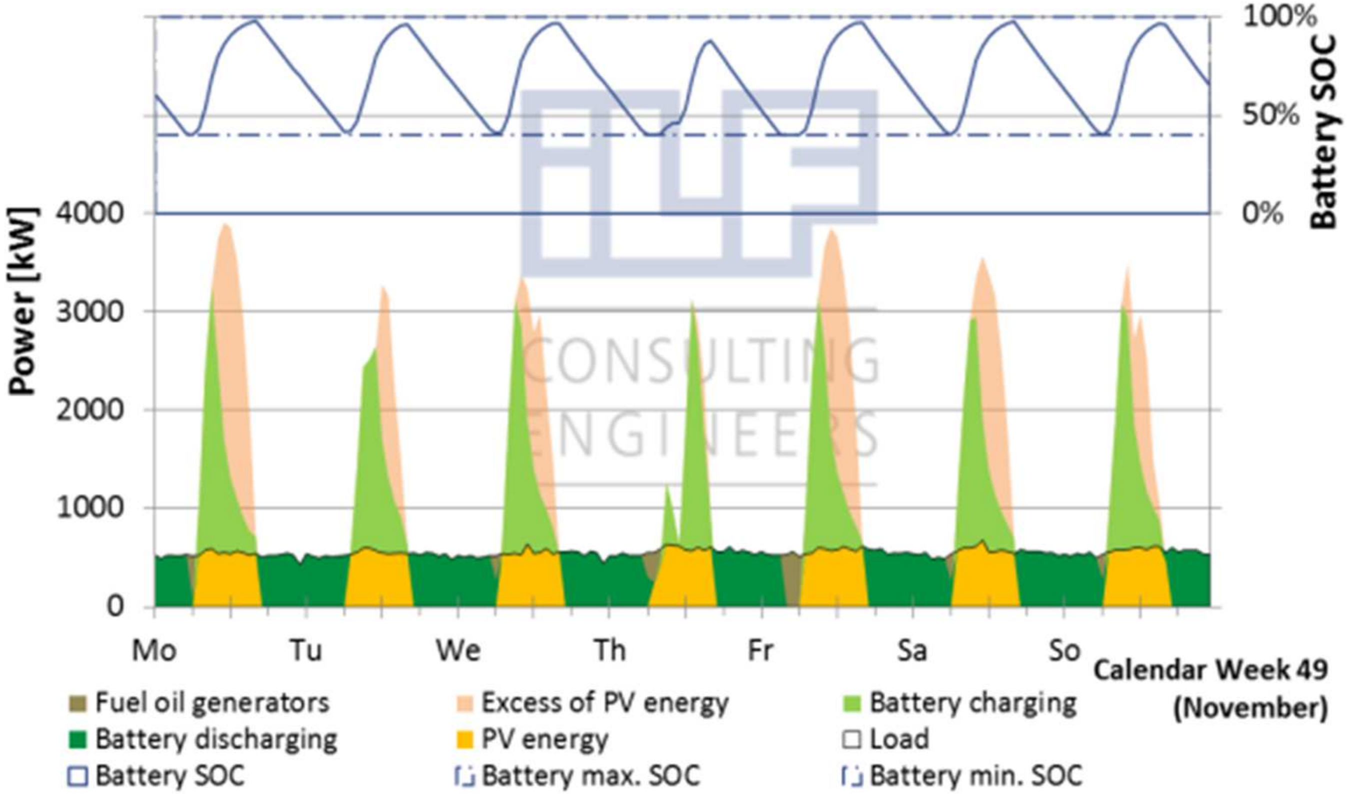
-> Very flexible tool for new or existing power plants!

- Input data
- Sensitivity analysis
- Output data: technical & financial

ILF Opit-Hybrid-Tool

➢ Input data:

- Load profiles
- Irradiation
- Economic parameters
- Grid stability parameters
- Diesel generator settings
- PV generator settings
- Battery system settings
- Sensitivity analysis



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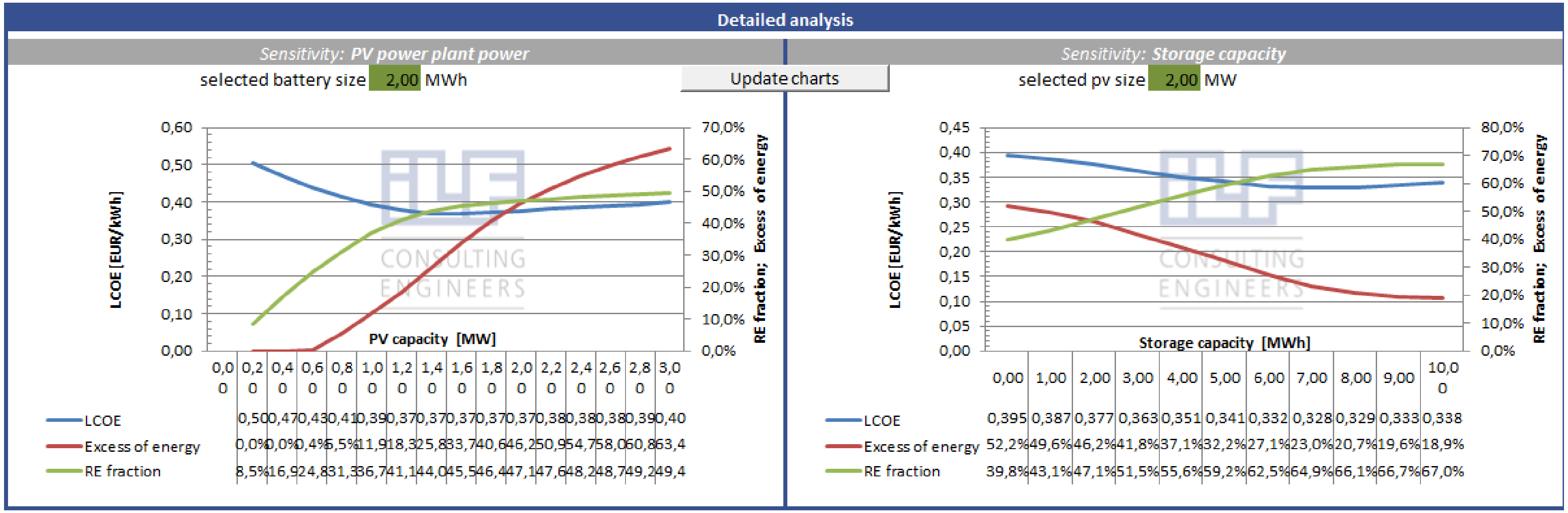
➢ Sensitivity analysis

- Variation of PV capacity
- Variation of wind capacity
- Variation of battery capacity

  -> Technical-economic design optimization



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ILF Opit-Hybrid-Tool

➢ Output data: technical

3 variability constraints are taken into account in the simulation to allow checking the robustness and reliability of the designed systems by calculating Grid stability indicators (probability analysis)

Inputs:

Grid stability		
Case 1: Fast RE dropdown		
Max short term PV power loss	60%	of current power
~~Max short term Wind power loss~~	~~75%~~	~~of current power~~
Annual probability of occurrence	4,17%	
Case 2: Startup of biggest load / engine		
Nominal power of biggest load / engine	50,00	kW
Inrush power	200%	of nominal power
Annual probability of occurrence	8,33%	
Case 3: Failure of largest Diesel generator		
Annual probability of occurrence	0,07%	

Results after simulation

Grid stability indicators (worst case scenarios)

		Ensured stability on the year		Annual probability of occurrence		Probability of network instability on the year	
		Base Case	Calculated scenario	Base Case	Calculated scenario	Base Case	Calculated scenario
Single event	Case 1 Fast RE dropdown		92%		4,2%		**0,34%**
	Case 2 Startup of biggest load	97%	95%	8,3%	8,3%	**0,27%**	**0,43%**
	Case 3 Failure of largest generator	59%	63%	0,1%	0,1%	**0,03%**	**0,03%**
	Total					***0,29%***	***0,79%***
Multiple events	Case 1+2		85%		0,3%		**0,05%**
	Case 1+3		0%		0,0%		**0,00%**
	Case 2+3	0%	0%	0,0%	0,0%	**0,01%**	**0,01%**

ILF Opit-Hybrid-Tool

Output data: financial

LCOE (Levelized cost of electricity) for every energy source and for the overall hybrid system

Financial factors of hybrid system

- NPV (net present value)
- IRR (internal rate of return)
- Benefit/cost ratio
- Payback period

Revenue from savings

- Fuel cost reduction
- Avoided diesel O&M and replacement

Levelized cost of electricity		Base case	100% equity	30% equity
LCOE of **Diesel generators**	[EUR/kWh]	0,536	0,587	0,595
LCOE of **PV power**	[EUR/kWh]	-	0,146	0,164
LCOE of **Wind power**	[EUR/kWh]	-	-	-
LCOE of **Renewable power**	[EUR/kWh]	-	0,164	0,182
LCOE of the hybrid system	[EUR/kWh]	-	0,358	0,371

Financial factors of the hybrid system (incl. financing costs)		100% equity	30% equity
NPV	[kEUR]	28.190,0	23.757,5
IRR	[%]	29,39%	24,57%
Benefit/cost ratio	[1]	2,99	2,73
Payback period	[a]	4,23	5,76

Revenue from savings		SUM	NPV
Fuel cost reduction	[kEUR]	104383,4	38516,6
Avoided diesel O&M and replacement	[kEUR]	9325,8	3804,3

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Selected References

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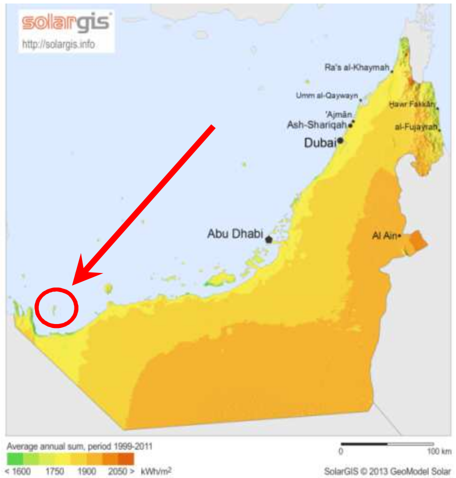
Photovoltaic / Diesel Hybrid Power Plant, UAE

1) PV

2) PV & Wind

3) PV, Wind & battery



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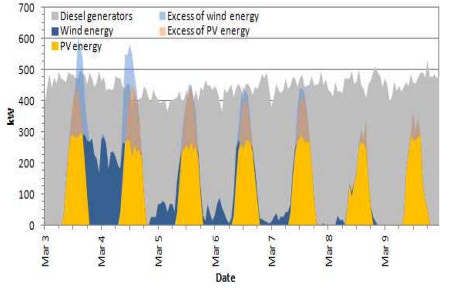
Photovoltaic / Diesel Hybrid Power Plant, UAE



Client: Dubai Electricity and Water Authority (DEWA)

Type of work: PV / Diesel hybrid power plant on an off-grid island

Time frame: 2013-2015

Data: Diesel power plant: 3.2 MW (4 x 0.8MW)
MV Grid: 11 kV,
PV power plant: 0.8 MW,

Services:

- Detailed technical & financial feasibility study (6 scenarios including PV, Wind and battery)
- Site investigations, Geotechnical surveys
- Conceptual design
- Financial analyses (CAPEX, OPEX, LCOE, RoI etc.)
- Owner´s engineer: EPC Tender Design, Tender evaluation, design vetting, site supervision, test procedures
- Commissioning in 01/2015

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Selected References

■ 8 PV interconnected and hybrid power plants, Senegal

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■ 8 PV interconnected and hybrid power plants, Senegal

Client: SENELEC / KfW

Type of work: PV and PV / Diesel / Battery power plants

Time frame: 2014

Data:
- 1 grid connected PV (15 MWp), 7 PV/Diesel/Battery hybrid syst.
- 7 Remote Cities from 5.000 to 50.000 inhabitants
- Total PV power: 17MWp ; Total battery capacity: 2.4MWh; Total Diesel generators: 3.6MW

Services: Feasibility studies:
- Detailed socio-economic site survey
- Energy demand analysis of the 7 cities (load profile and future evolution until 2026)
- Technical audits: 7 existing diesel power stations & 4 PV plants
- Site selection and evaluation for the new power plants
- Detailed Technical and economic Feasibility Study of each plant
- Optimized sizing of the power plants (based on the LCOE)
- Conceptual design of all 8 power plants
- EIA study for the 8 project locations

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Quick Assessment - Input Data

■ **Initial calculations to identify the feasibility of project – Input Data**

- Location, available area
- Load curve, ideal case: hourly values over one year, biggest load/motor
- Diesel price incl. transportation costs, diesel generator setting, number
- Discount rate / inflation rate / economic lifetime of the plant

Quick Assessment - Results

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Initial calculations to identify the feasibility of project - Results

Energetic Result

- share of diesel / PV / wind / battery [MWh]
- renewable energy fraction [%]
- consumption and reduction of fuel oil [%]

Grid Stability

- Annual probability of network instability on single / multiple events [%]

Financial Results

- LCOE for overall hybrid system [$$$/kWh]
- IRR [%]
- payback period [a]

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Thank you for your attention!

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