ILF Consulting Engineers (Asia) Ltd

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

Thai-German Technology Conference on Photovoltaics and Grid-Integration
Bangkok, 23 May 2016

AHK Thailand Business Trip on Photovoltaic and Grid-Integration

Frank Zimmermann - Biography

- **Dipl.-Ing. MBA Frank Zimmermann**

Education	UNIVERSITÄT KARLSRUHE (TH); SCHILLER INTERNATIONAL UNIVERSITY; UNSW THE UNIVERSITY OF NEW SOUTH WALES
1997 – 2002	**Sales: Wholesale and Consumer** **Sales- and Projectengineer** **Export Manager, Fürth, de**
2002 – 2005	**Export Manager, Wuxi, cn**
2005 – 2009	**Managing Director, Singapore, sg**
2009 - 2014	**Managing, Haslach i.K., de**
since 2014	**Business Development Manager South East Asia for Renewable Energies,** **Senior Project Manager Photovoltaics of ILF Asia** **based in Bangkok, th**

Certified Qualification
Valid until: 2018-03-30
www.tuv.com
ID 0000051357

Sachverständiger für Photovoltaik (TÜV)
Certified Expert for Photovoltaic Equipment (TUV)

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The ILF Group

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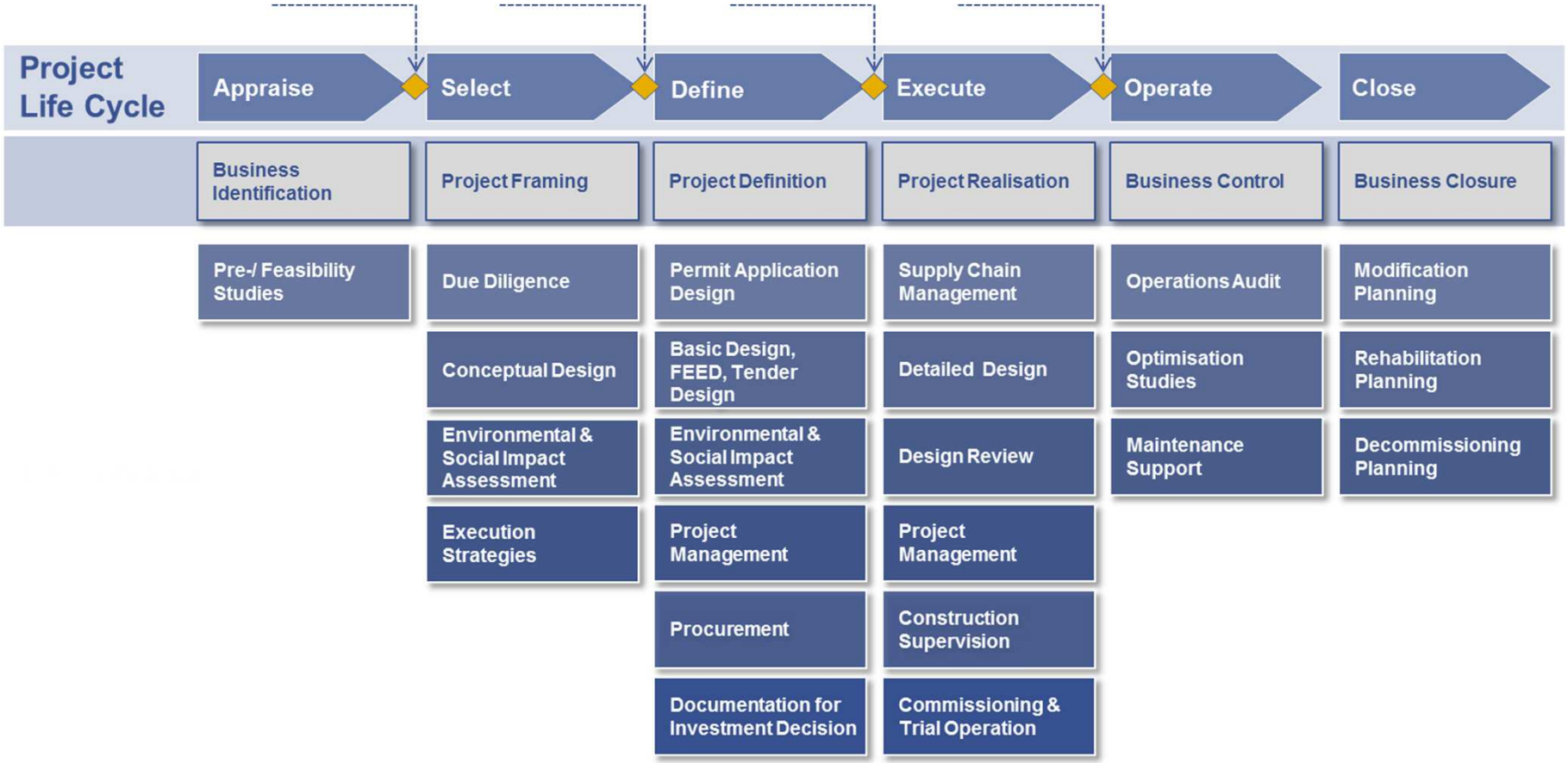
ILF at a glance

- **1967** Year of establishment and development in a leading enterprise for engineering, consulting, and project management
- **100%** Private ownership and independent
- **2,000+** Employees worldwide
- **40+** Office locations
- **6,000+** Projects
- **100+** Countries
- **200+** Mio. € revenue

ILF Asia

- Regional presence for ASEAN in Bangkok, Thailand
- Core competencies on site: renewable energies, focus on photovoltaic and hydropower

ILF Service Portfolio



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General Explanation

What is Hybridization?

What to hybridize:

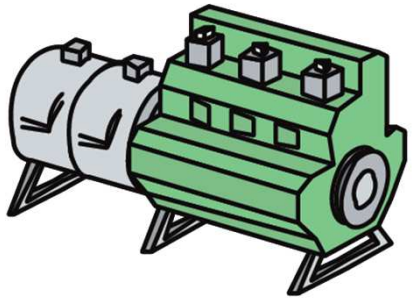
- Diesel
- Gas
- Heavy fuel oil
- Waste-to-energy
- Biomass-to-energy

Hybrid system types:

- Stand-alone (islands)
- Mini-grid
- Micro-grid
- Remote grid

How to hybridize:

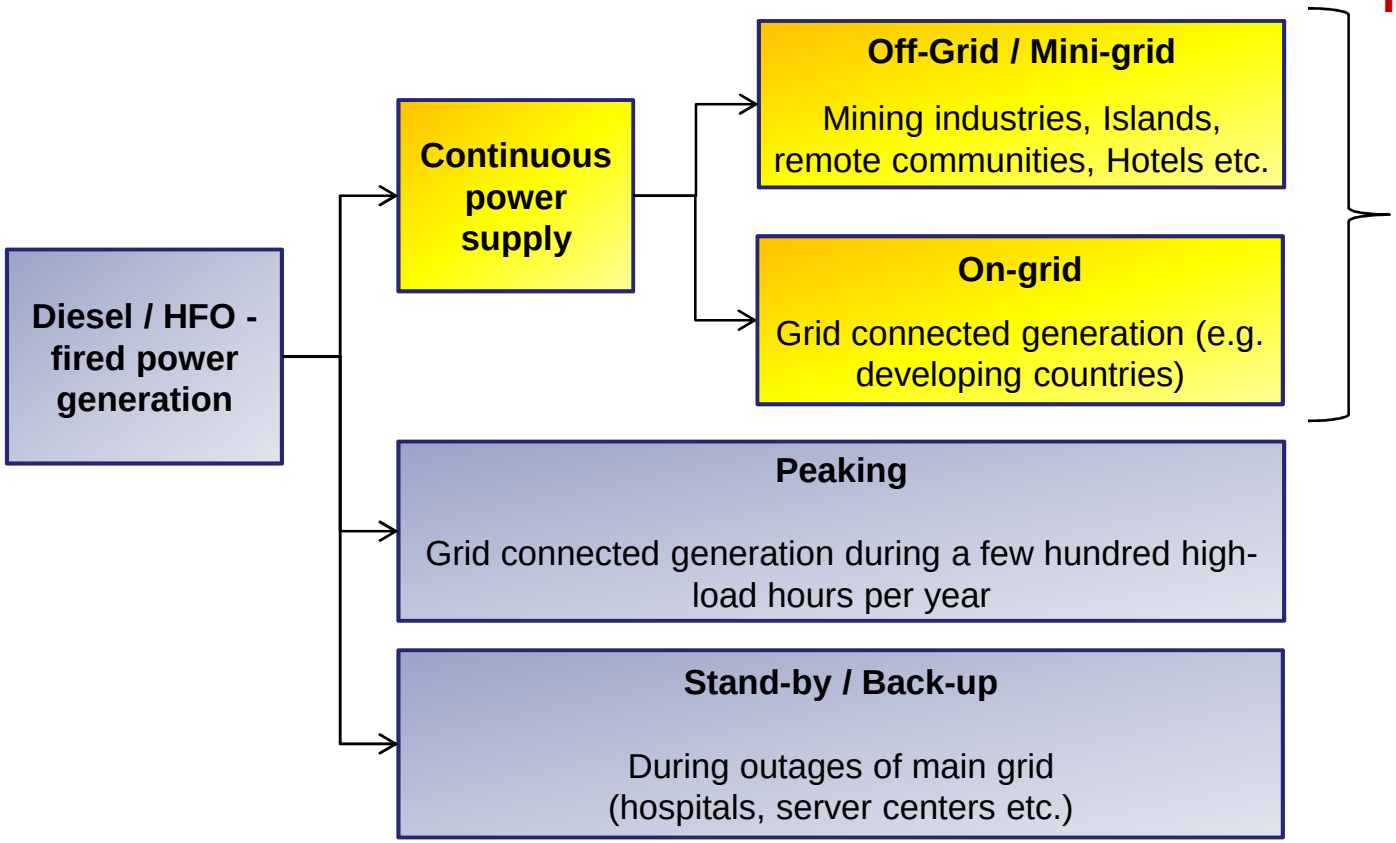
- Photovoltaic (PV)
- Wind
- Hydro power
- Battery



Diesel power generation market

Facts: 30-35GW of <u>new</u> large scale Diesel generators (>0.5MW) are sold in the world every year!

Segmentation



Size of the market

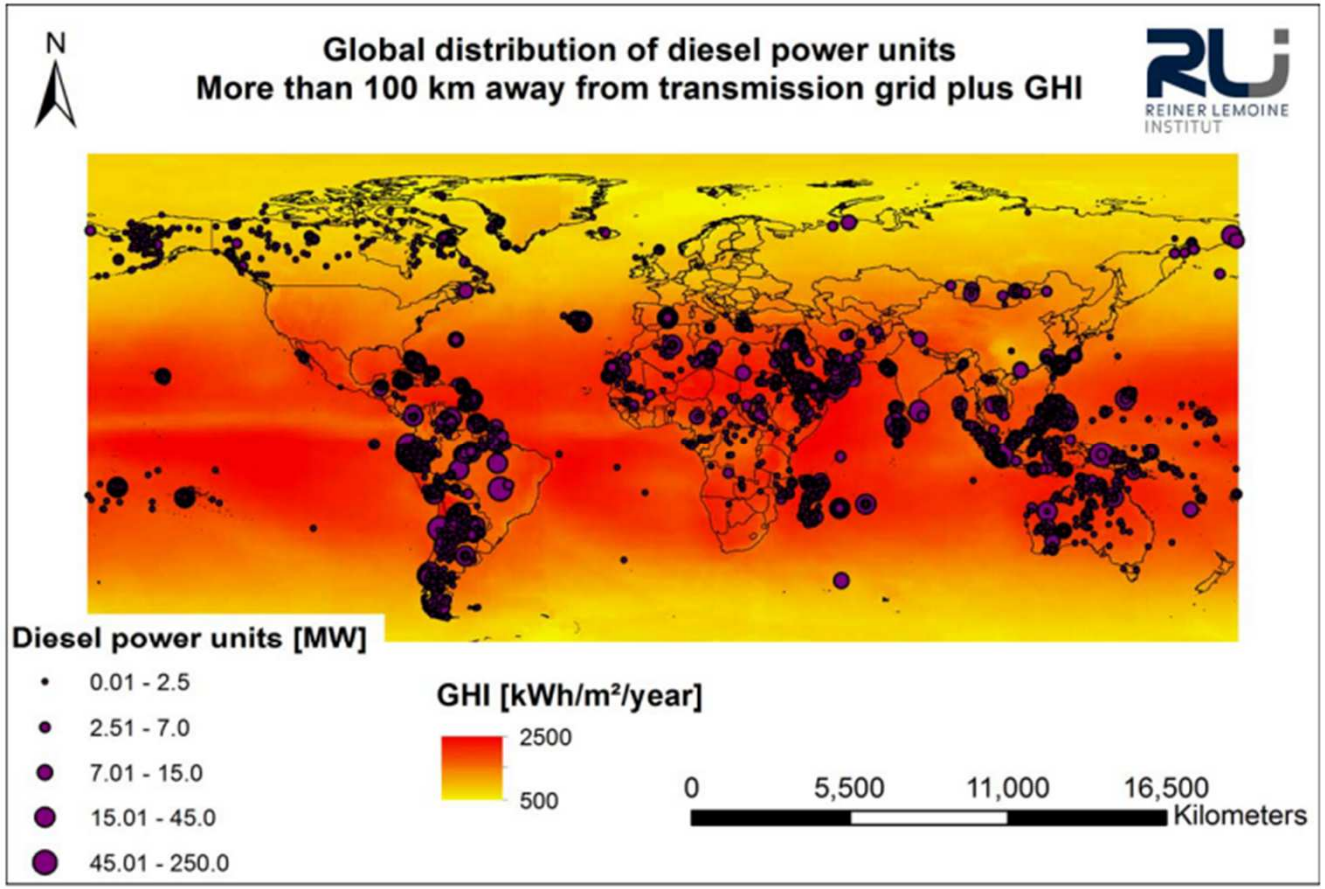
Total 30-35 GW/year

40 - 50 % — **Business case for hybridization with Photovoltaic power plant**

1 - 3 %

40 – 50 %

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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Market Potential and Opportunities

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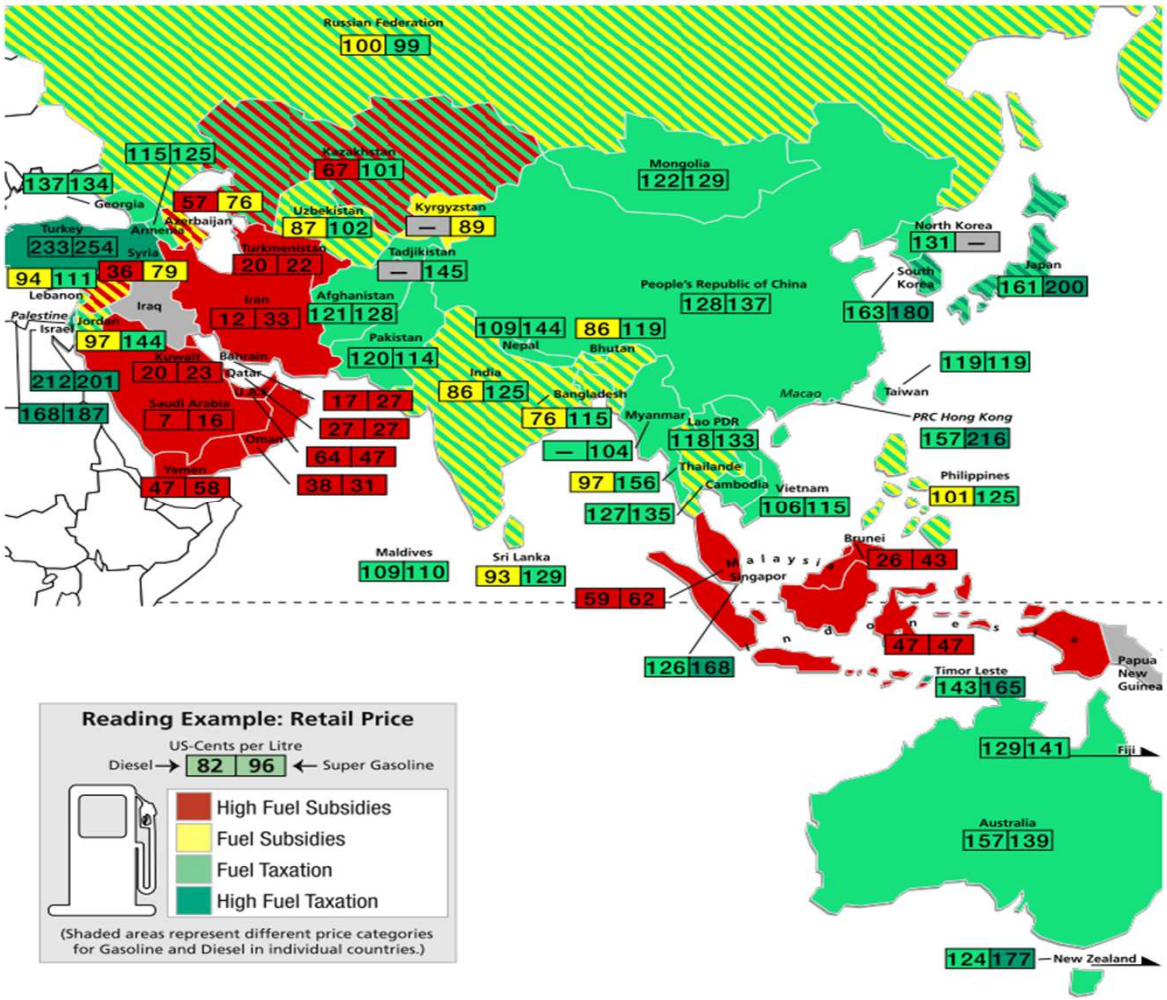
■ Potential / Opportunities for Hybridization



- High fuel subsidies:
  Indonesia*, Malaysia,
  Diesel price: **0.25-0.50 USD / l**
  * = as of 2012/2013

- Fuel subsidies
  Philippines and Thailand
  Diesel price: **~0.75 USD / l**

- Fuel taxation:
  Cambodia, China, Myanmar, Singapore and Vietnam
  Diesel price: **1.00 - 1.20 USD / l**

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

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Arguments Hybridization

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Why hybrid systems?

- ✓ Decreasing PV module & battery price
- ✓ Obtain less fuel imports
- ✓ No price fluctuations (like oil)
- ✓ After installation: less transport or logistic costs of fuels
- ✓ Reducing operating hours of generators
- ✓ Lower maintenance
- ✓ Increasing grid stability
- ✓ Reducing CO_2-emissions, environmentally friendly
- ✓ No subsidies
- ✓ No subsidies
- ✓ Less fuel consumption

- ➢ Lower system costs
- ➢ More independence
- ➢ Investment security
- ➢ … and less diminution
- ➢ Higher life expectation
- ➢ Less costs, less chances of failure
- ➢ Higher acceptance of mini-grids
- ➢ “Green”
- ➢ Less governmental expenses
- ➢ ”Natural market” for PV
- ➢ **Save OPEX**

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!

Introduction of ILF Opti-Hybrid-Tool

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

ILF Opti-Hybrid-Tool

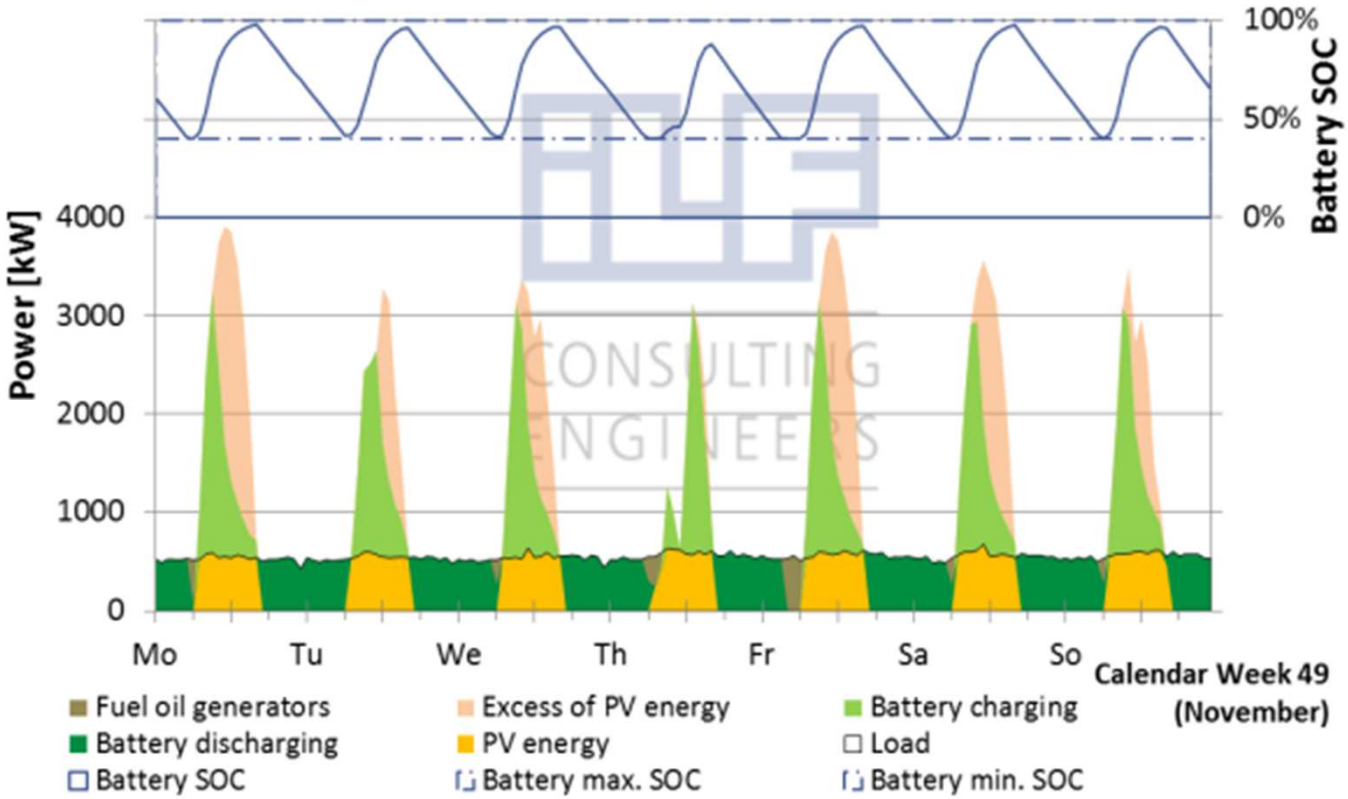
ILF Opti-Hybrid-Tool

Input data

- Irradiation (location)
- Diesel generator settings
- Load profiles

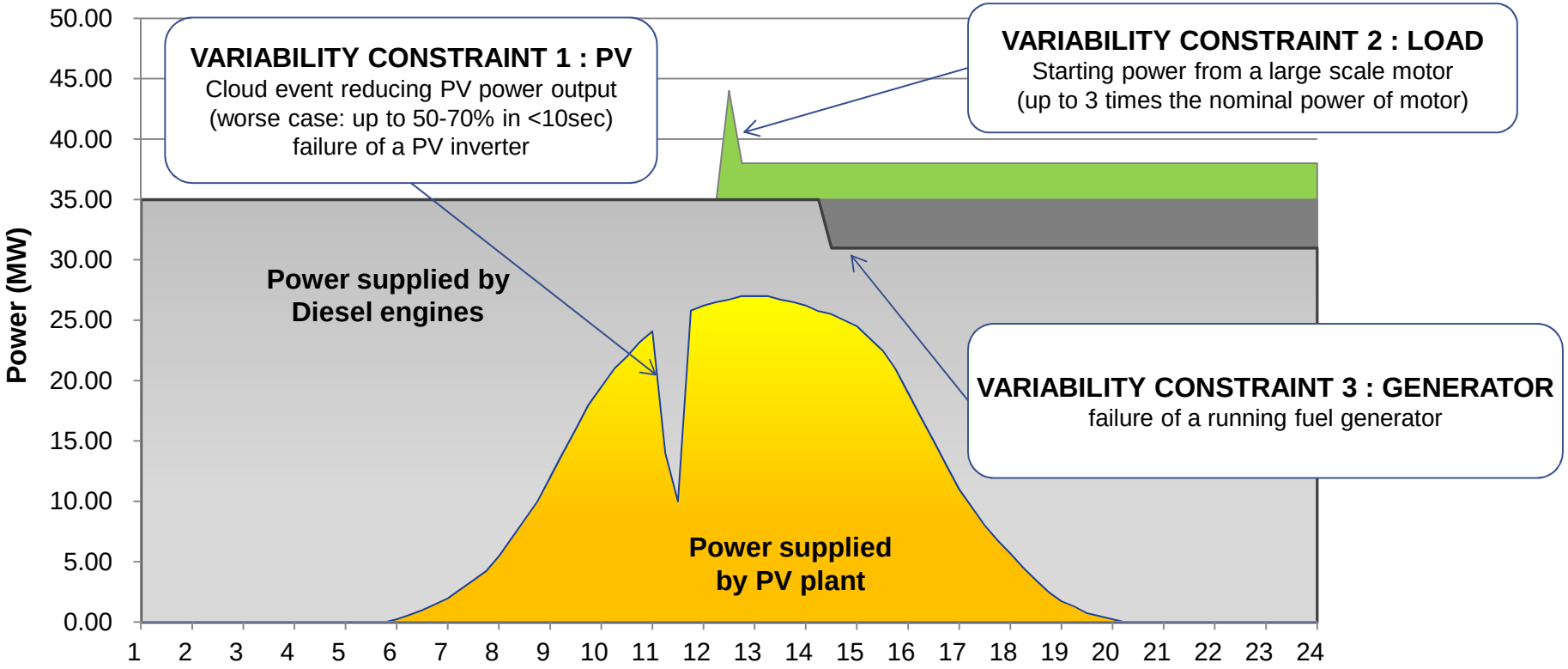
For verification

- PV generator settings
- Battery system settings
- Economic parameters
- Grid stability parameters
- Sensitivity analysis



ENERGETIC RESULTS - Grid stability considerations (without battery)

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



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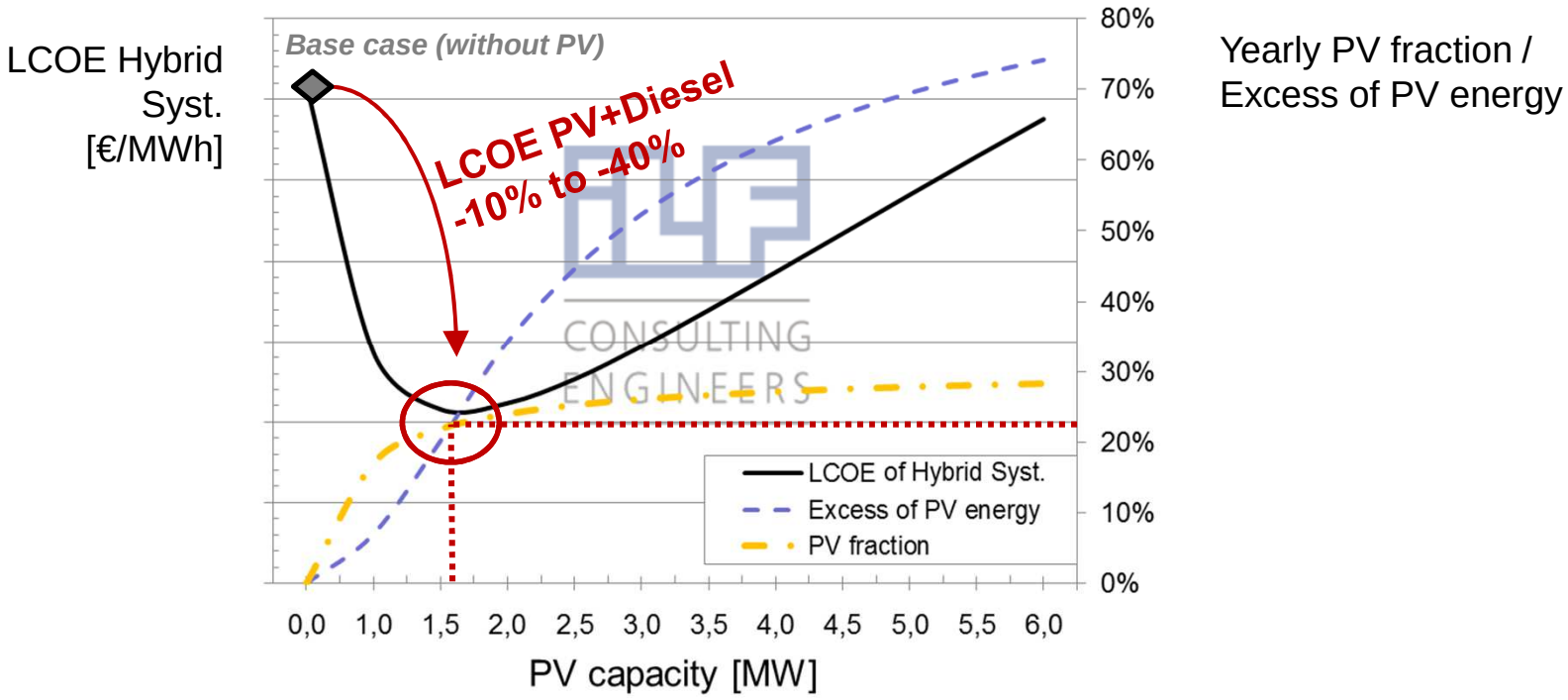
ILF Opti-Hybrid-Tool

Sizing of the PV power plant

Proper sizing of the PV power plants allows reaching an economic optimum of the overall PV/Diesel hybrid system

Technical Output



ILF Opti-Hybrid-Tool

Financial output

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

Revenue from savings

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

Financial factors of hybrid system

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

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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ILF Opti-Hybrid-Tool

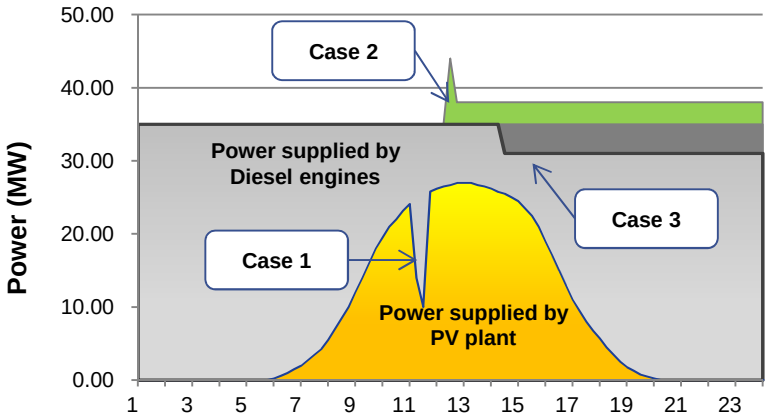
■ ILF Opti-Hybrid-Tool

❑ Robust-Check

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%	



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%

Results after simulation

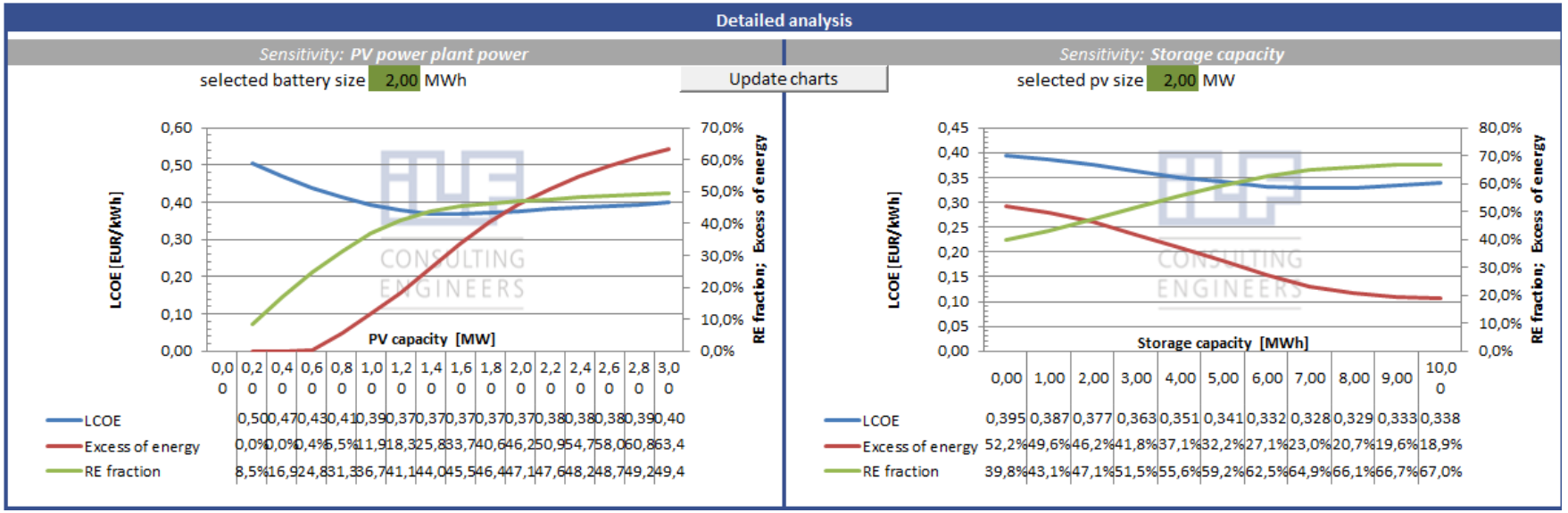
ILF Opti-Hybrid-Tool

■ ILF Opti-Hybrid-Tool

❑ Sensitivity analysis

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

  -> Technical-economic design optimization



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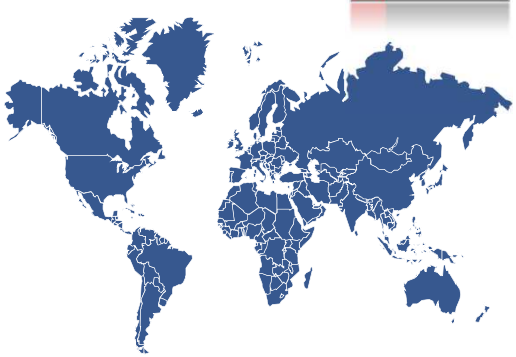
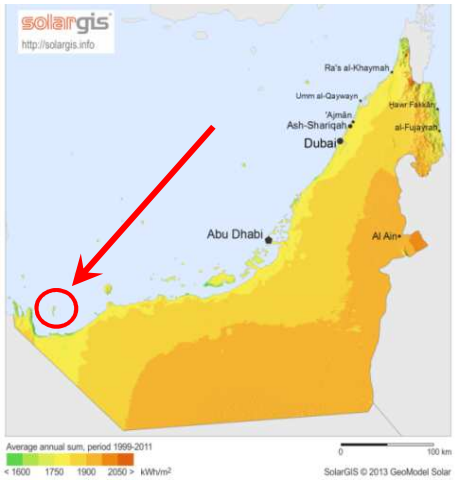
Selected References

■ Photovoltaic / Diesel Hybrid Power Plant, UAE





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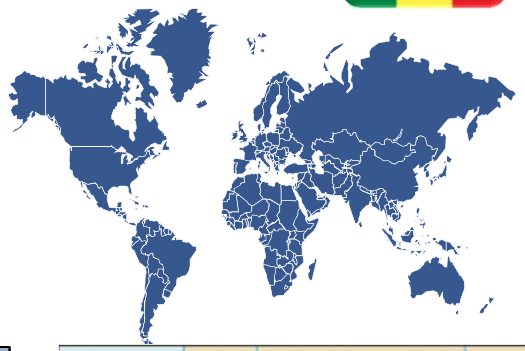
Selected References

- **8 PV interconnected and hybrid power plants, Senegal (1)**



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Selected References

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■ 8 PV interconnected and hybrid power plants, Senegal (2)

Client: **SENELEC / KfW**

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

Time frame: 2014 - ongoing

Data:

- ❑ 1 grid connected PV (15 MWp)
- ❑ 7 PV/Diesel/Battery hybrid systems for
  7 Remote Cities from 5.000 to 50.000 inhabitants
- ❑ PV power: 26 MWp
  Battery capacity: 2.4 MWh
  Diesel generators: 3.6 MW

Services: **Feasibility studies:**

- ❑ Detailed socio-economic site survey
- ❑ **Energy demand analysis** of the 7 cities
  (load profile and future evolution until 2026)
- ❑ **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, incl. EIA study

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Selected References

166 PV hybrid power plants, Maldives (1)

Client: **STELCO , FENAKA, financed by ADB**

Setup: JV of ILF Consulting Engineers GmbH, Munich with GOPA International GmbH

Time frame: 2016 – 2020, status: fixed order

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Selected References

166 PV hybrid power plants, Maldives (2)

Data:

- Implement hybrid systems and mini-grids on 166 islands
- Technology: PV, battery storage, diesel generators

Services:

- Feasibility study
- Conceptual design
- Tender design
- Site and construction supervision
- Commissioning
- Project Management

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Quick Assessment – Input Data

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Application for:

- IPPs / Utilities
- Hotels / Resorts
- Villages / Communities / Islands / Remote Places
- Telecommunication
- NGOs / International Aids

Typical sizes:

- Generator / Grid size of 1…50 MW

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

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Quick Assessment – Results

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Initial calculations to identify the general 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]

Thank you for your attention!

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