Renewables & Energy Storage

Technical, Financial and Risk analysis of grid connected renewable energy plant with storage

Annual Symposium HAEE, 4th Edition 2019

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company presentation - Fields of Activity

- **POWER SUPPLY**
  - OFF - GRID SYSTEMS
    - Solar Photovoltaics Systems
    - Wind Power Systems
    - Energy Storage Systems
    - EV charging Systems
  - GRID CONNECTED SYSTEMS
    - Solar Photovoltaics
    - Wind Power Systems
    - Small and Large hydroelectric systems
    - Solid and liquid biomass energy systems
    - Biogas energy systems
    - Co-generation systems
    - Diesel, Petrol and Gas Generators systems
    - Energy Storage Systems
    - EV charging System
- **LIGHTING PV SYSTEMS**
- **SOLAR STRUCTURES**
  - CAR PORT (ENERPORT)
  - WAREHOUSE AND SOLARHOUSES
- **SERVICES SUPPLIER**
  - SERVICES
    - Engineering Services
    - Financing Services
    - Due Diligence Services

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main components of microgrid systems

- System components
  - **Classification**

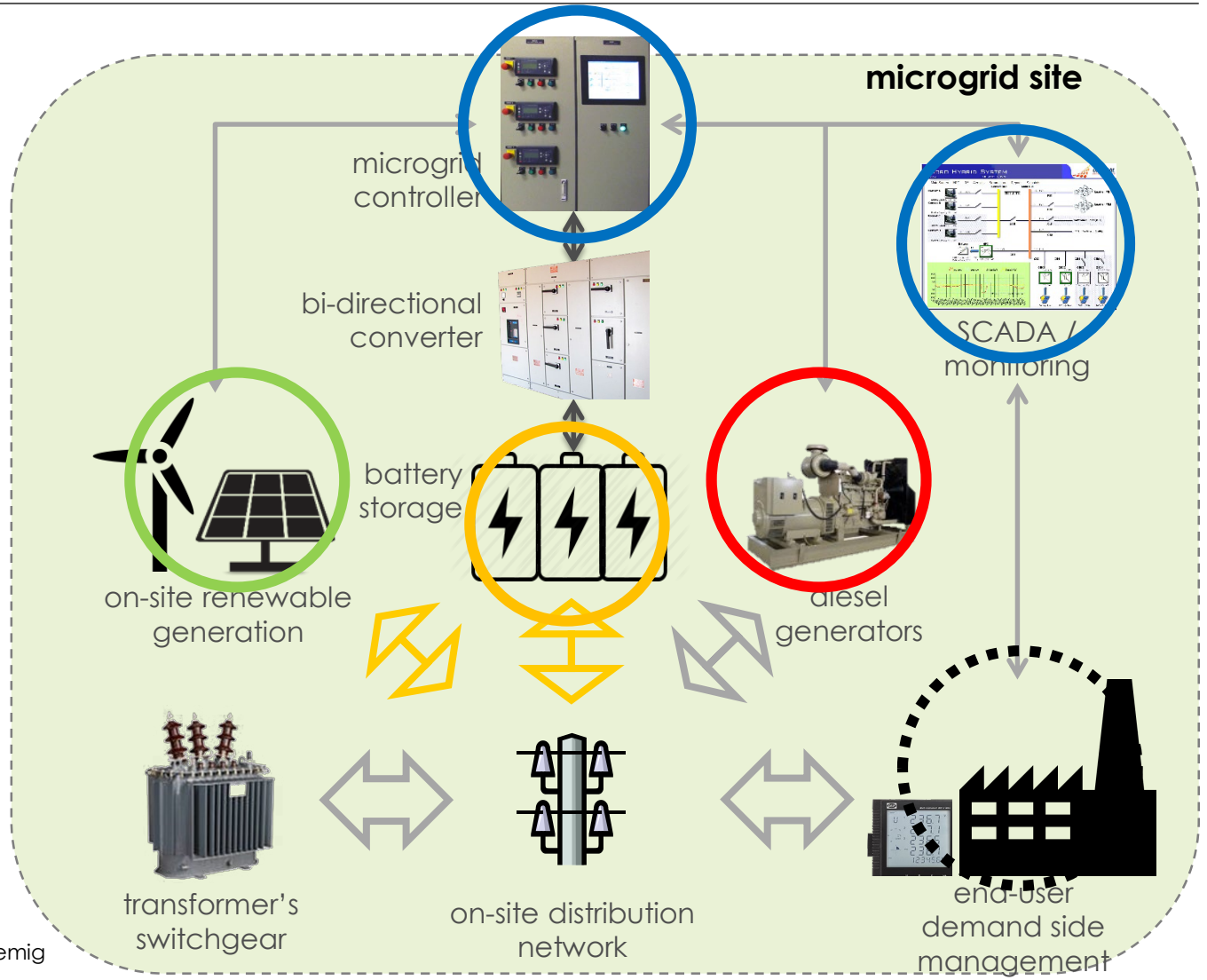
Microgrid controller

Conventional Generation

Renewable Generation

Battery Energy Storage System

Demand



Source: Renemig

generation categories

- Generation: conventional vs renewables
  - **Categories of electricity generation technologies**
    - **Conventional**
      - Gas ,Diesel, HFO, Kerosene, large hydro
    - **Controllable**
      - Fuel based generator, biomass [1], hydro dam, Rankine cycle [2]
    - **Storable**
      - Hydro dam, fuel based generator [3]
    - **Location dependent**
      - Hydro, solar, wind, biomass [4], tidal, Rankine cycle
    - **With by-product**
      - Fuel based generator, biomass, biogas, solar [6]
    - **Renewable**
      - Solar, wind, biomass, biogas, tidal, small hydro, Rankine cycle
    - **Uncontrollable**
      - RoR hydro, solar, wind, tidal
    - **Non-storable**
      - All others
    - **Location independent**
      - Fuel based generator [5],
    - **Without by-product**
      - Wind, Rankine cycle, tidal,

1: depending on the technology

2: low variation

3: Natural gas requires special installation

4: if biomass can be transported (chips vs pellet, waste, etc.)

5: Gas requires storage

6: special modules are required

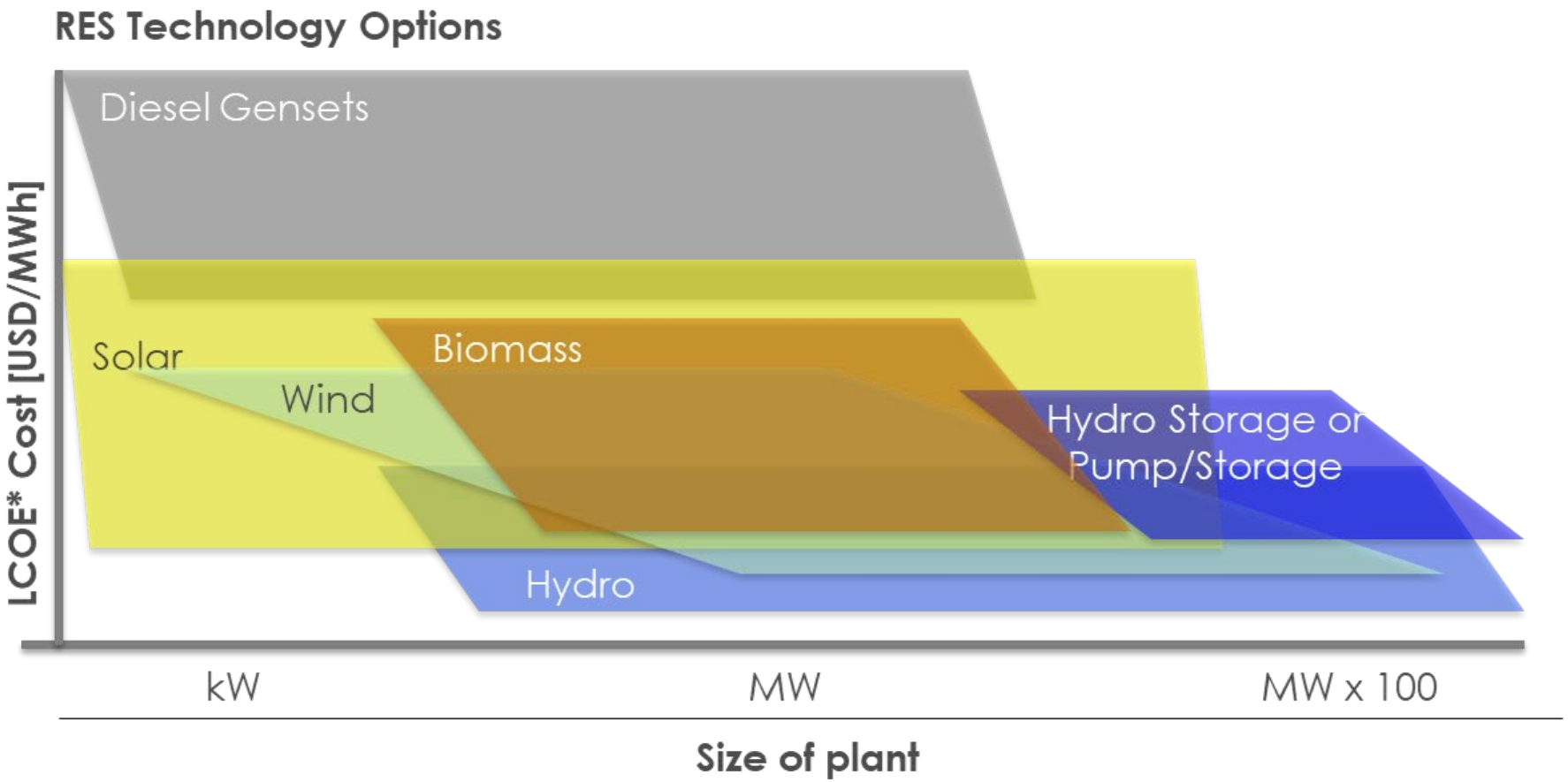
generation technologies sizes vs LCOE

- Generation: conventional vs renewables
  - **Generation sizes**

High
(> 500
[USD/MWh])

Medium
(250
[USD/MWh]

Low
(< 100
[USD/MWh]



renewable penetration, excess energy, diesel consumption / grid power use

- Excess energy: loss and use

  – **Definition of excess energy**
    - The energy that cannot be used from the system in a period of specific time

  – **Definition of excess power**
    - The power that cannot be absorbed instantaneously from the system

A system that can absorb the excess energy does not mean that it can absorb the excess power

  – **Managing excess energy**
    - Additional ESS energy capacity is required
    - ESS with important depth of discharge are used
    - ESS with low cost of capacity

  – **Managing excess power**
    - Additional ESS power capacity is required
    - ESS with high C rates are used
    - ESS with low cost of C rates

  – **Use of excess energy**
    - Deferrable loads
    - Battery charging

  – **Use of excess power**
    - Dump loads

main components of microgrid systems

- Controls
  - **Classification**

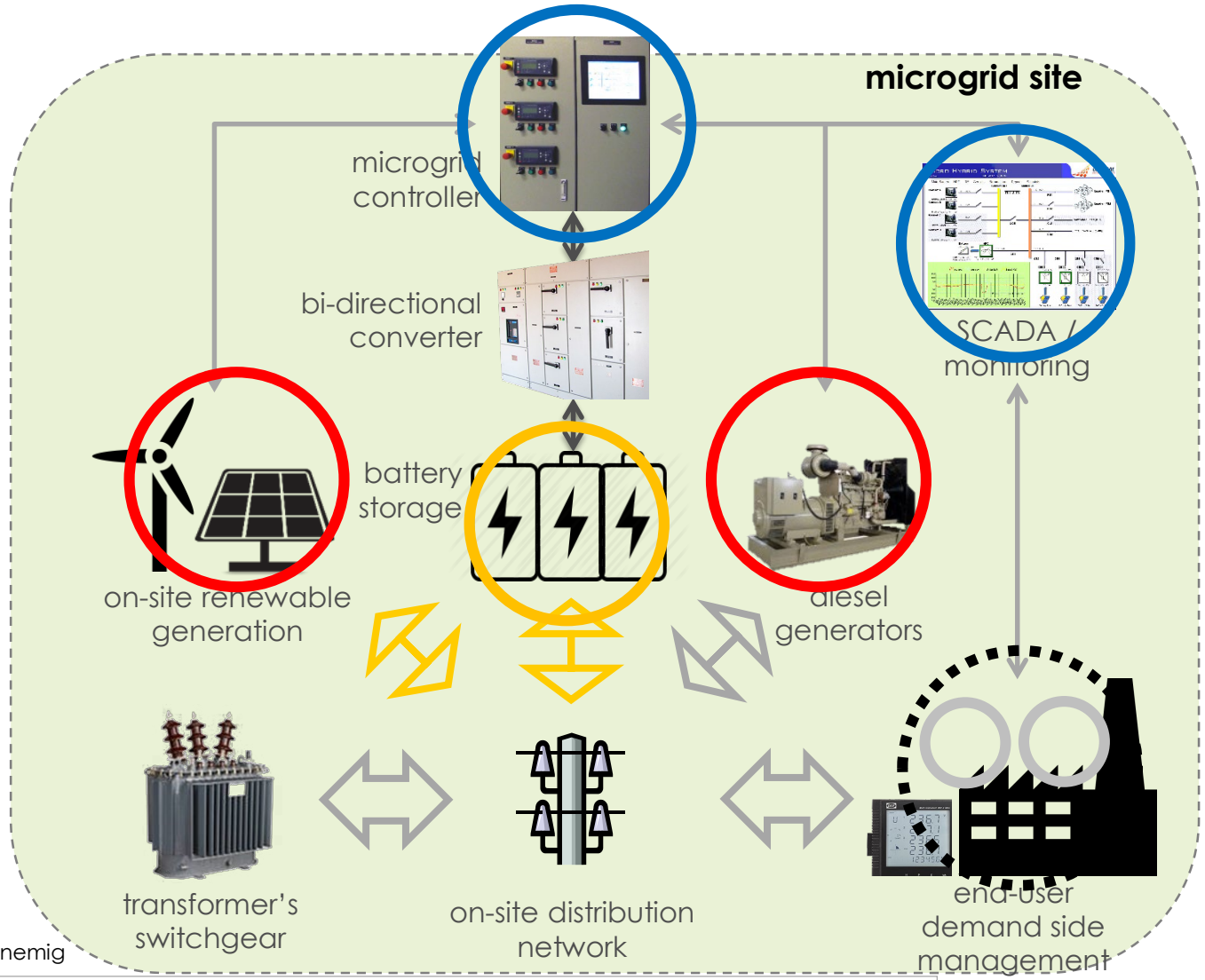
Energy management system (microgrid controller)

Generation controls

Battery Management System

Load controls

External units controls



Source: Renemig

system revenues, operating costs and cashflow

- Forms of revenue
  - **FIT**
    - Fixed (uniform, reverse auction)
    - Indexed on the electricity market exchange price
  - **PPA**
    - Fixed price
    - Indexed on the electricity market
    - Indexed on a fuel price
    - Performance based (RES fraction, power quality, number of outages)
  - **Savings**
    - Grid cost savings
    - Fuel consumption savings
    - Operation savings (power quality improvement, outages elimination)
    - Maintenance savings
    - Emissions savings

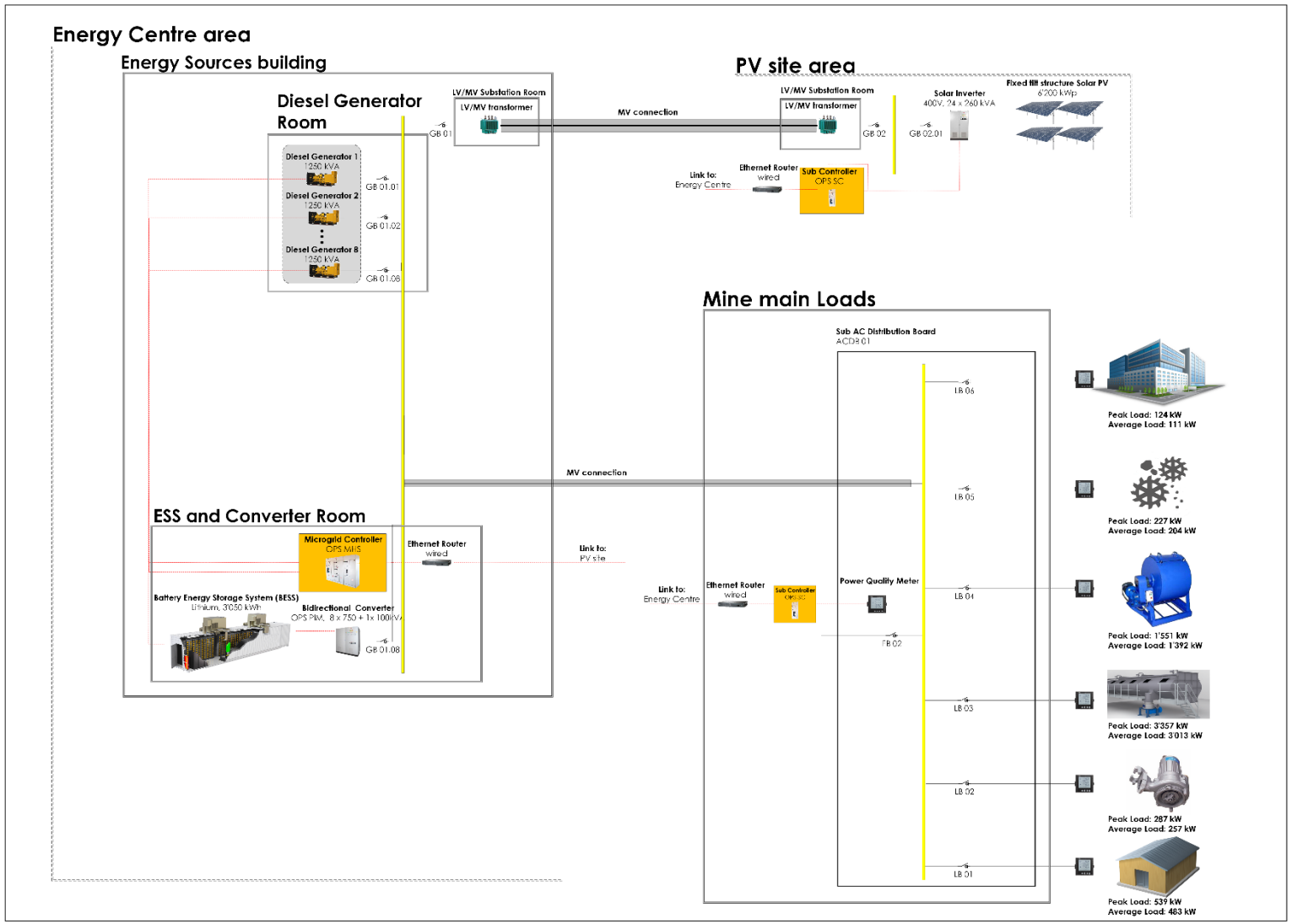
diesel based industrial microgrid

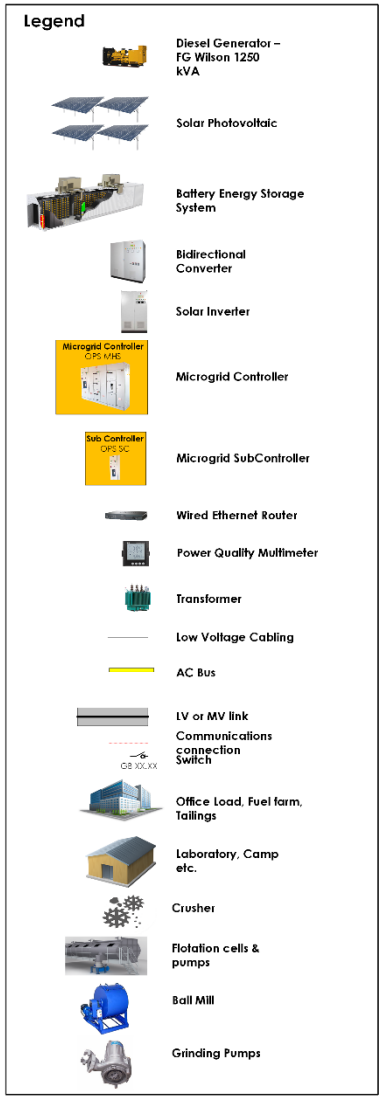
- Mine
  - **Location**: East Africa
  - **Load**: 48.2 GWh/y | 5.5 MWa | 6.1 MW peak
  - **Initial configuration**
    - Generation: 10 MVA diesel generators
    - Power cost: 0.38 – 0.44 USD/kWh (1.2 USD/l) (calculated – on the field)
  - **Approach**: specific budget, redeployable
  - **PPA Duration**: 10 years

  - **Solution A**
    - 30% of PV penetration => 1.65 MWp
    - No ESS
    - CapEx: 2.6 M USD
    - Comments:
      - Pros: low cost, lower maintenance
      - Cons: irregular generator usage, lower fuel efficiency, lower power quality

  - **Solution B**
    - 110% of PV penetration => 6.1 MWp
    - ESS = 3 MWh (stability purposes mainly) Lithium
    - CapEx: 10.7 M USD
    - Comments:
      - Pros: low cost, lower maintenance, better generator usage
      - Cons: higher CapEx,

diesel based industrial microgrid





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financial calculation

- Project economics
  - **CapEx**: 10.7 M USD
  - **LCOE**: 0.28 USD/kWh
  - **Fuel savings**: 623 k USD / year

  - **Sensitivity analysis of LCOE [USD/kWh]:**
    - lifetime [y] vs cost of capital [%]

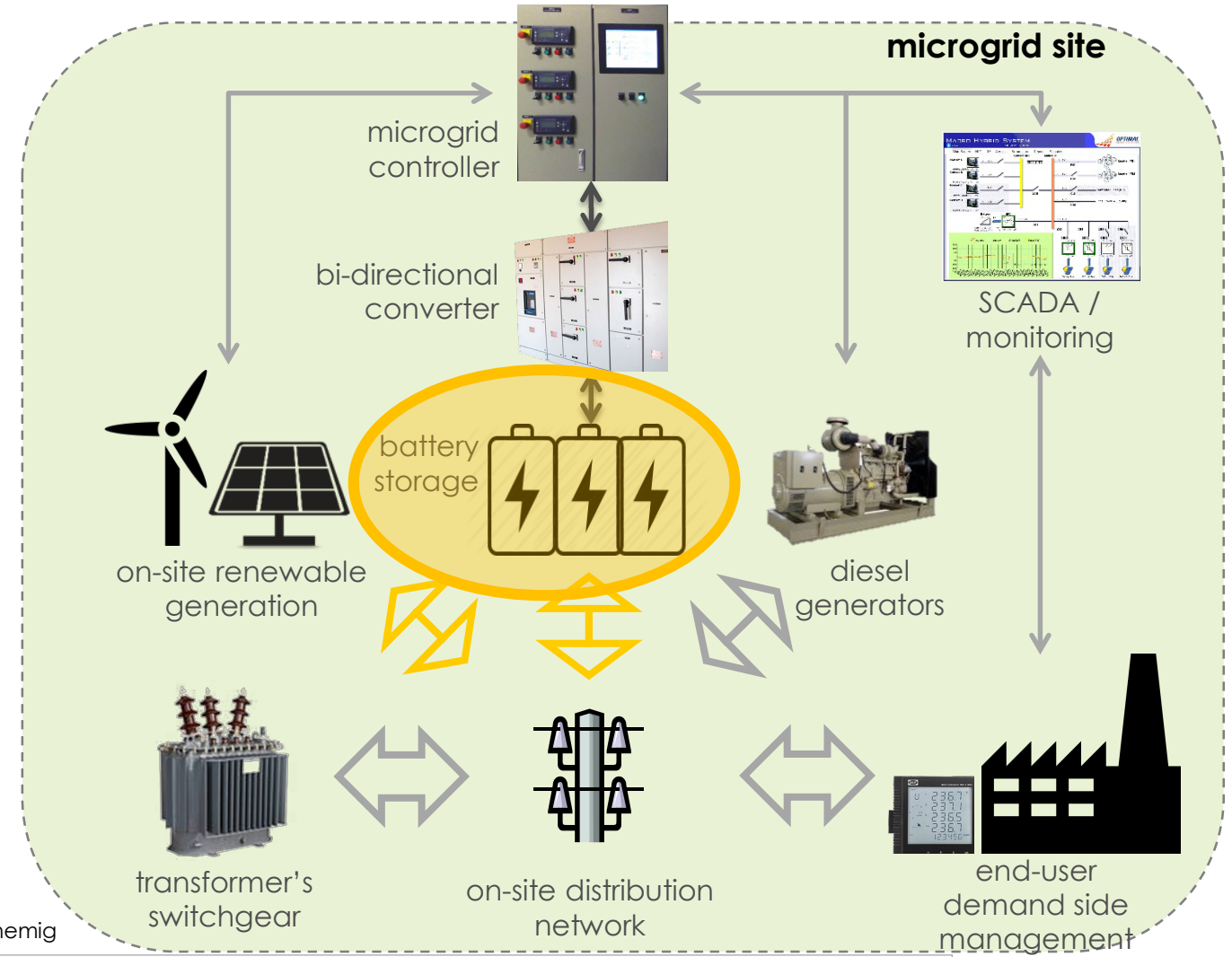
Levelised cost of power (USD / kWh)						
		10.0%	12.5%	15.0%	17.5%	20.0%
	6	0.312	0.333	0.354	0.376	0.398
Lifetime	8	0.262	0.283	0.305	0.328	0.351
	10	0.233	0.255	**0.278**	0.302	0.326
	12	0.215	0.237	0.261	0.286	0.311

  - **Sensitivity analysis of fuel and O&M savings:**
    - Fuel cost [USD/l] vs cost of capital [%]

Annual fuel savings + diesel maintenance savings						
		Cost of capital				
		10.0%	12.5%	15.0%	17.5%	20.0%
	0.30	845'021	648'431	443'551	231'075	11'685
	0.32	1'024'586	827'996	**623'116**	410'640	191'250
Diesel fuel	0.34	1'204'151	1'007'561	802'681	590'205	370'815
cost	0.36	1'383'716	1'187'127	982'247	769'771	550'381
(USD / kWh)	0.38	1'563'281	1'366'692	1'161'812	949'336	729'946
	0.40	1'742'846	1'546'257	1'341'377	1'128'901	909'511

public microgrid with PV, RES and diesel

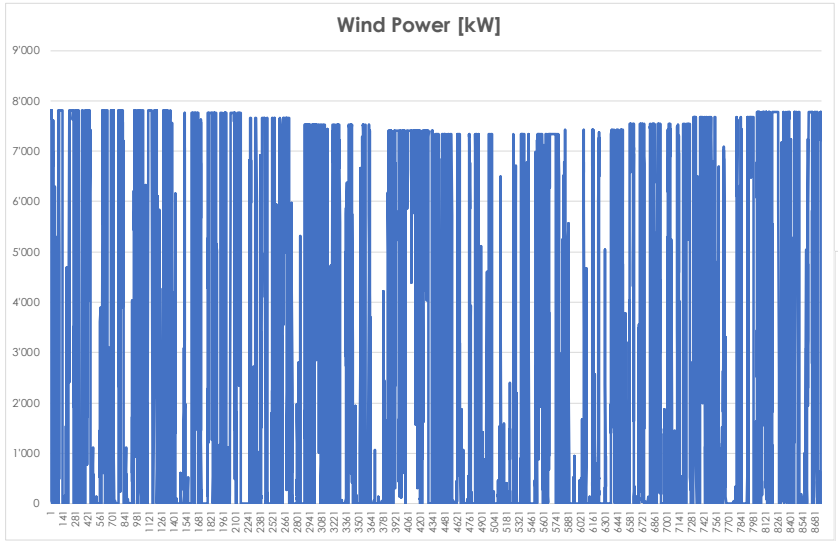
- Island
  - **Location**: North Aegean sea
  - **Load**: 148 GWh | 16.9 MWa | 43.6 MW peak
  - **Initial configuration**
    - Generation
      - HFO generators: 56.3 MW
      - Wind power: 8 MW
      - PV power: 4.4 MWp
  - **Approach**: RES penetration increase
  - **PPA Duration**: 25 years



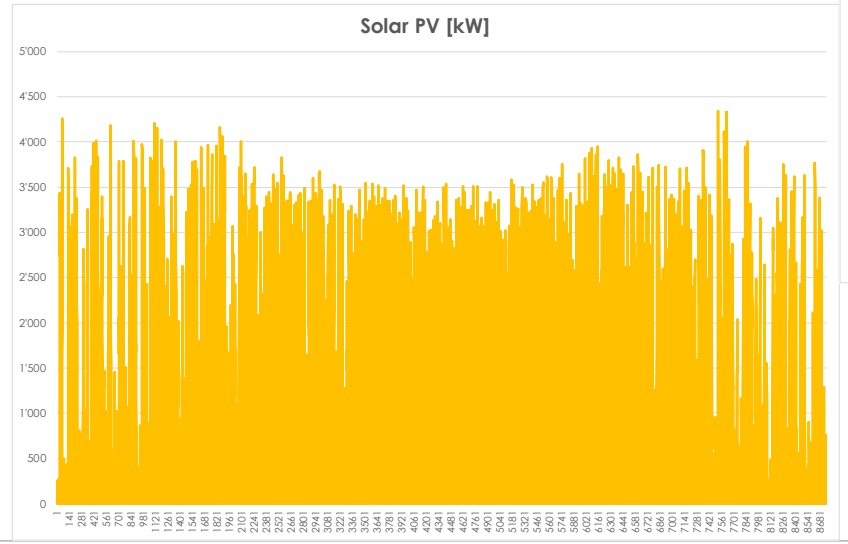
Source: Renemig

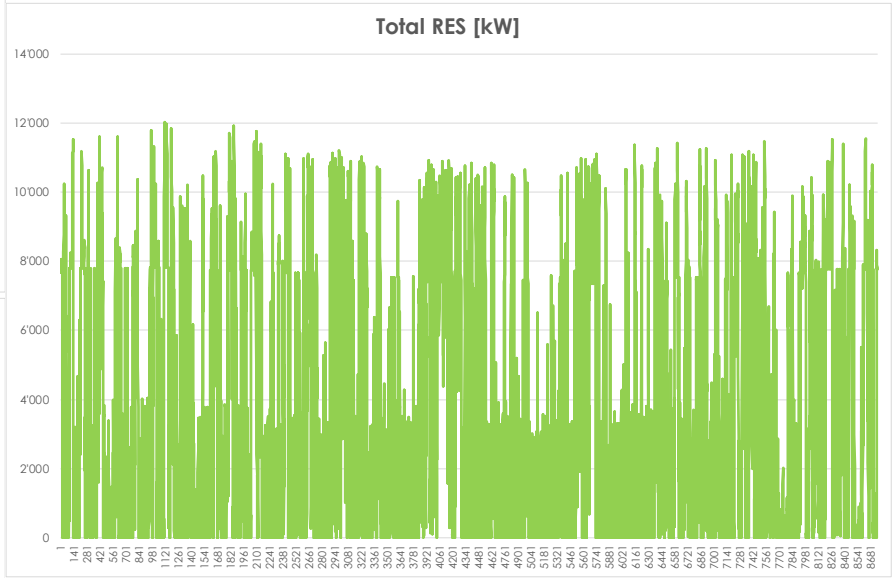
wind, solar and total RES

- Wind power
  - **Energy**: 23.4 GWh
  - **Standard Deviation**: 3'344 MW
  - **Coefficient of Variation**: 1.25



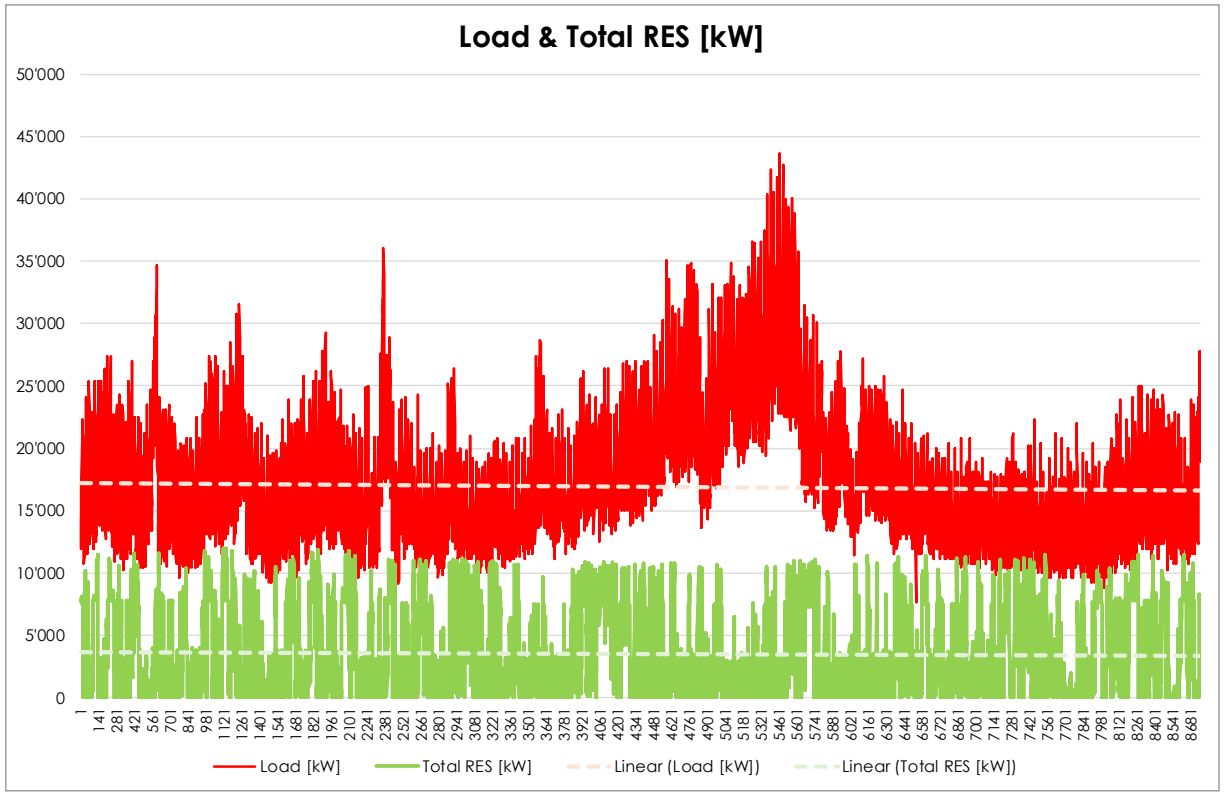
- PV power
  - **Energy**: 7.4 GWh
  - **Standard Deviation**: 1'147 MW
  - **Coefficient of Variation**: 0.68

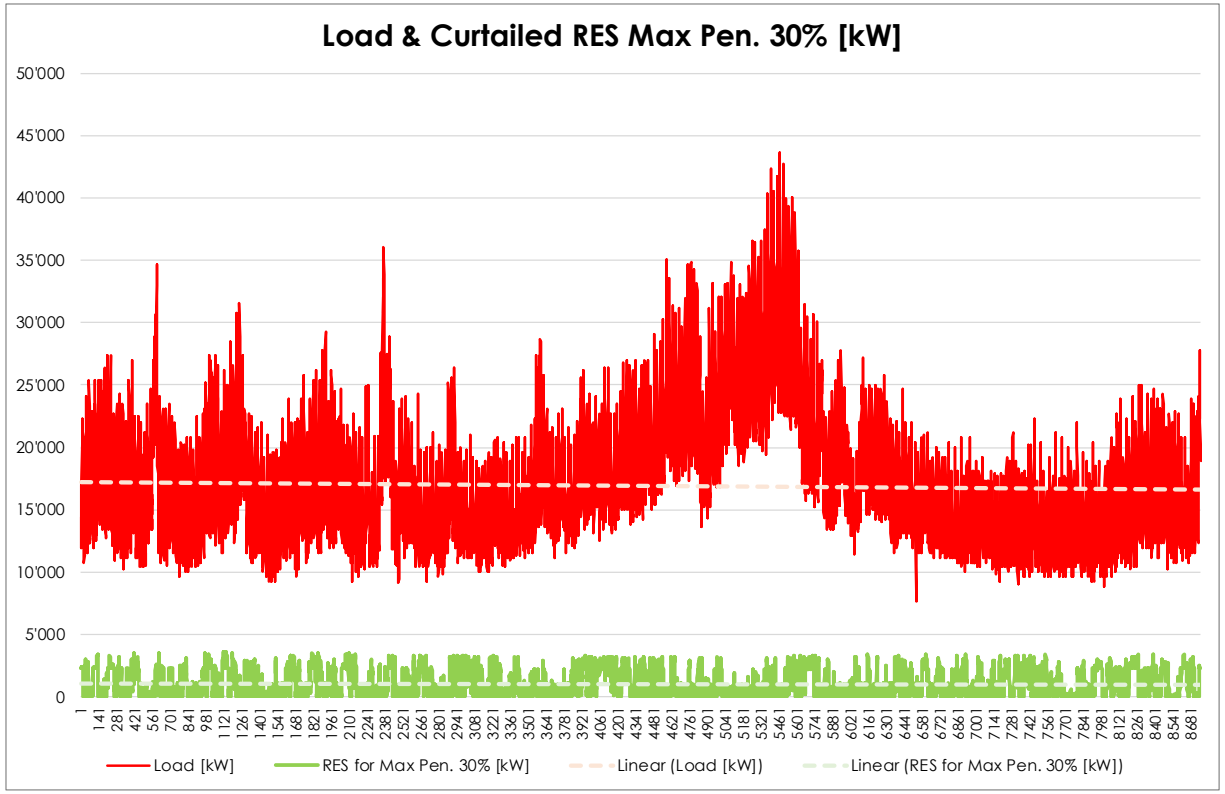




load and total RES

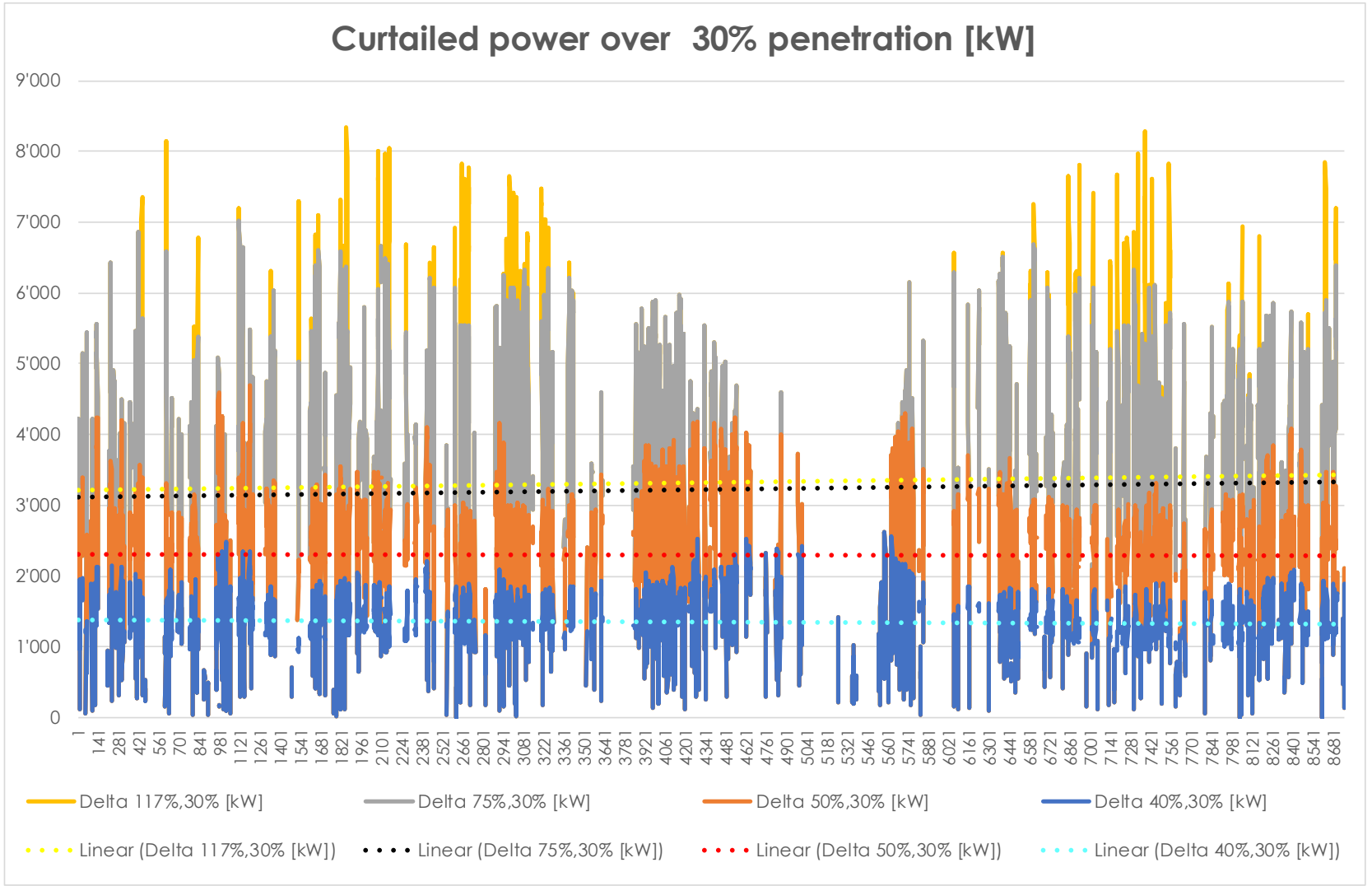
- Total RES without any curtailment reaches 117% penetration
- For grid stability purposes, the Max RES penetration is limited at 30% curtailing 9.6 GWh per year which represents 28% of RES energy produced





curtailed power for Max penetration 40%, 50%, 75% and unrestricted (117%)

- Penetration increase pros
  - Energy saved
  - CO2 decrease
- Penetration increase cons
  - Grid outages
  - Power quality decrease
  - Fuel increase
  - Maintenance increase

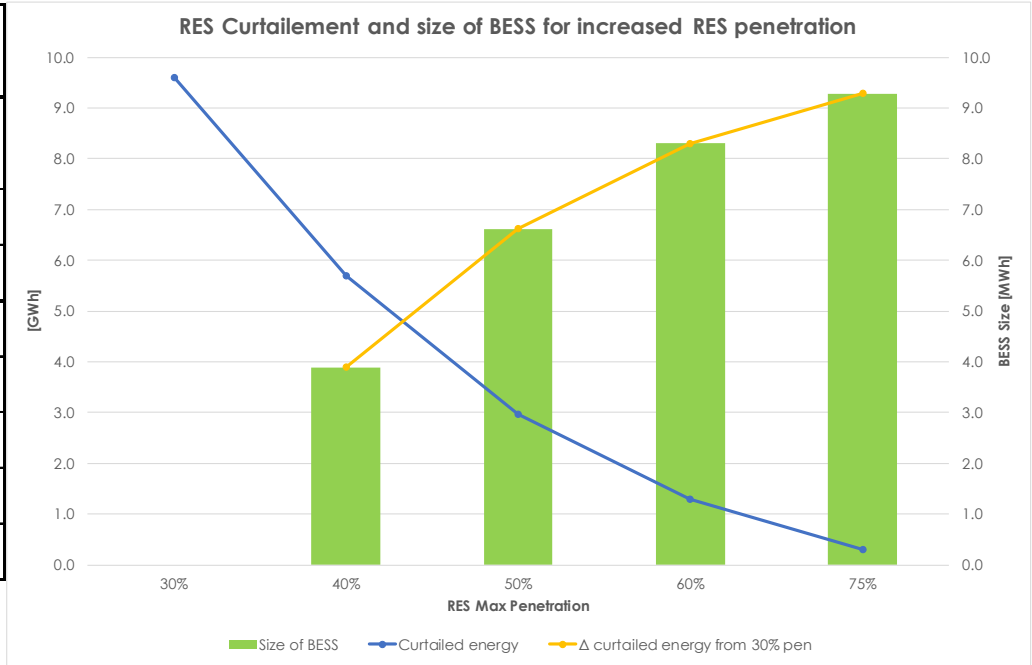


RES curtailment and BESS size

- Currently RES systems can reach penetrations over 100% using the appropriate technology (BESS, generation & load mgt.)
- The size of BESS is calculated based on the variation of power of the RES that should be absorbed to keep the penetration at 30%
- The BESS will be sized optimally because of the steep price decrease and thus will make multiple cycles per day
- The relation between the penetration increase and the curtailed energy is not linear
- The relation between penetration increase and BESS size is not linear, making the large systems more difficult to payback

RES curtailement

RES Max Pen.	Curtailed energy	Average curtailed power	Maximum curtailed power	Curtailement occurrence	Curtailed fraction of RES	Δ curtailed energy from 30% pen		Cost of Curtailement	Saved cost	Size of BESS
[%]	[GWh]	[MW]	[MW]	[%]	[%]	[GWh]	[MW]	[M EUR]	[M EUR]	[MWh]
30%	9.6	3.3	8.3	33	28			1.48		
40%	5.7	2.6	7.3	25	21	3.9	1.4		0.60	3.3
50%	3.0	1.9	6.4	18	15	6.6	2.3		1.02	6.3
60%	1.3	1.4	5.4	11	12	8.3	2.9		1.28	8.5
75%	0.3	1.2	4.0	3	10	9.3	3.2		1.44	10.2



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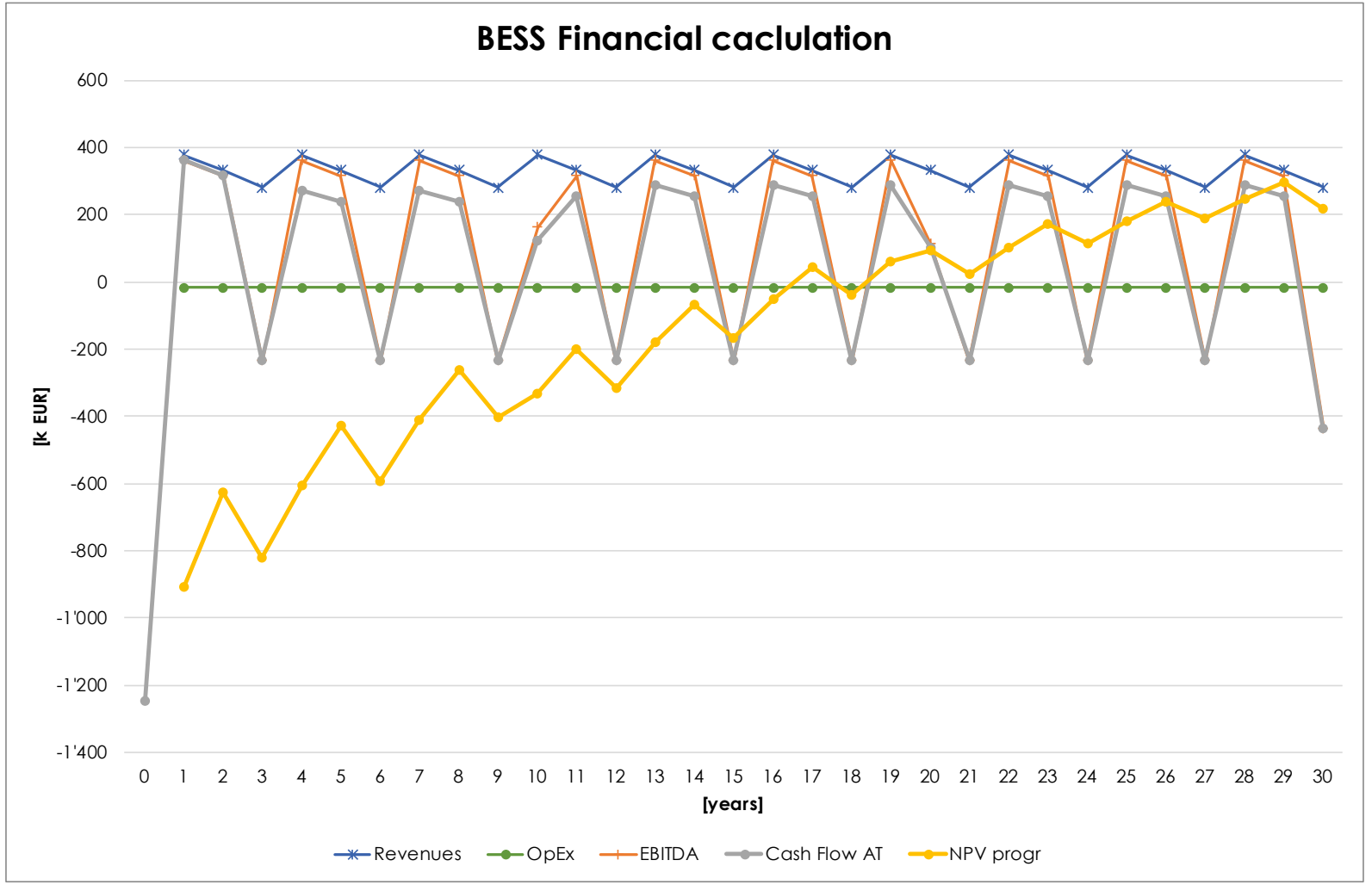
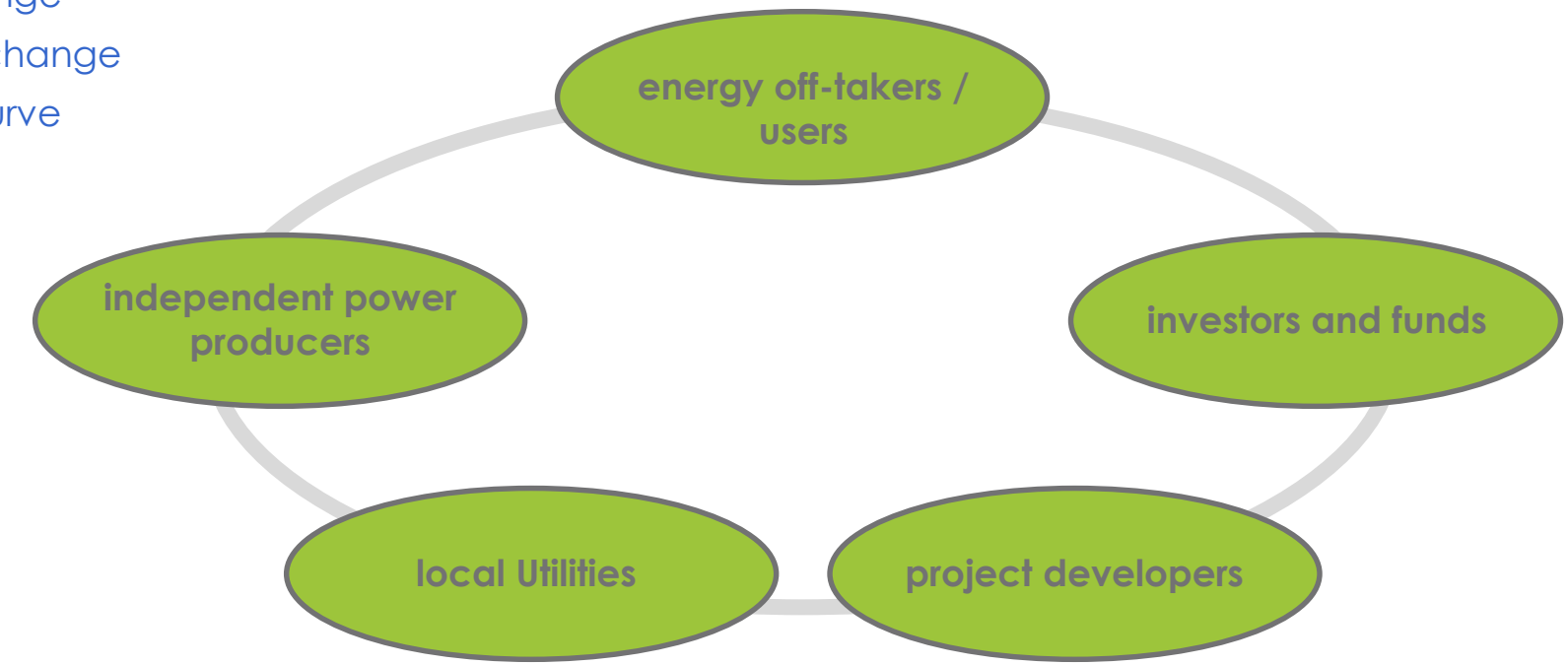
financial calculation

- financial model assumptions
  - Targeted RES penetration: 40%
  - BESS size: 3.3 MWh
  - Converter size: 2.6 MW
  - BESS CapEx: 1.25 M EUR
  - BESS OpEx: 16.6 k EUR/year
  - Total cycles before replacement: 5'000
  - Cost of equity: 8%
  - PPA duration: 25 years
  - PPA storage use price: 0.105 EUR/kWh
  - Project IRR: 9.5%
  - LCOES: 0.09 EUR/kWh



project risk analysis

- Country risk
  - Credit rating
  - Debt provision
  - Strategic stability
- Regulatory risk
  - PPA price change
  - PPA duration change
  - Dispatching curve
- Counterparty risk
  - Shareholders
  - Insurance capability
- Technology risk
  - Technology maturity

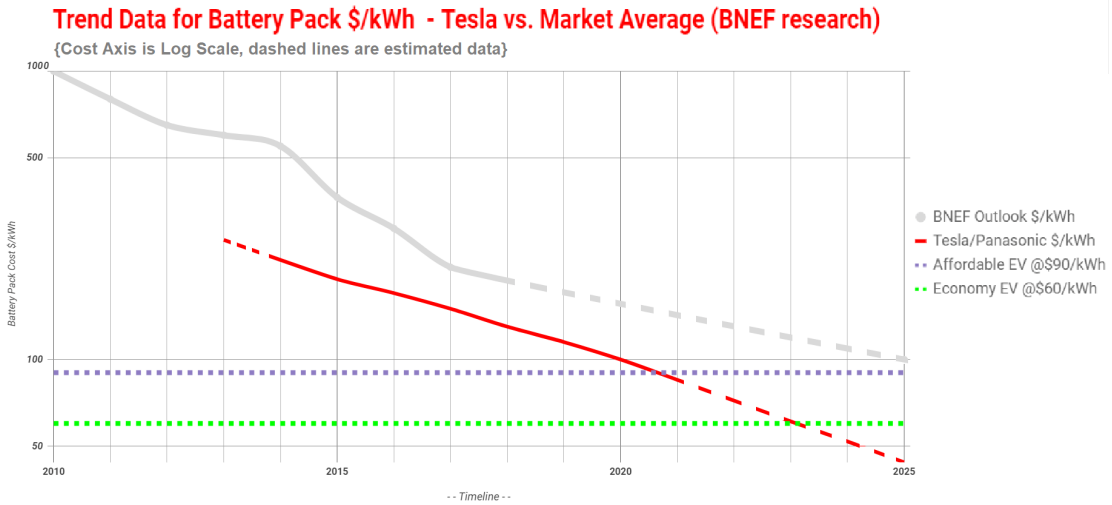


the next step

- Introduction of storage systems

- Structural change of the PPA to include:
  - emissions remuneration
  - improvement of power quality
  - ancillary services provision
  - impact on O&M of the system

- Creation of the appropriate markets
  - frequency regulation
  - voltage support
  - primary reserve
  - black start



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