

Why Go Solar: Economics of Utility Scale Solar-Hybrid Solutions



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CEBC workshop, Dubai 3/16/16



Making the Case for Fuel Replacement

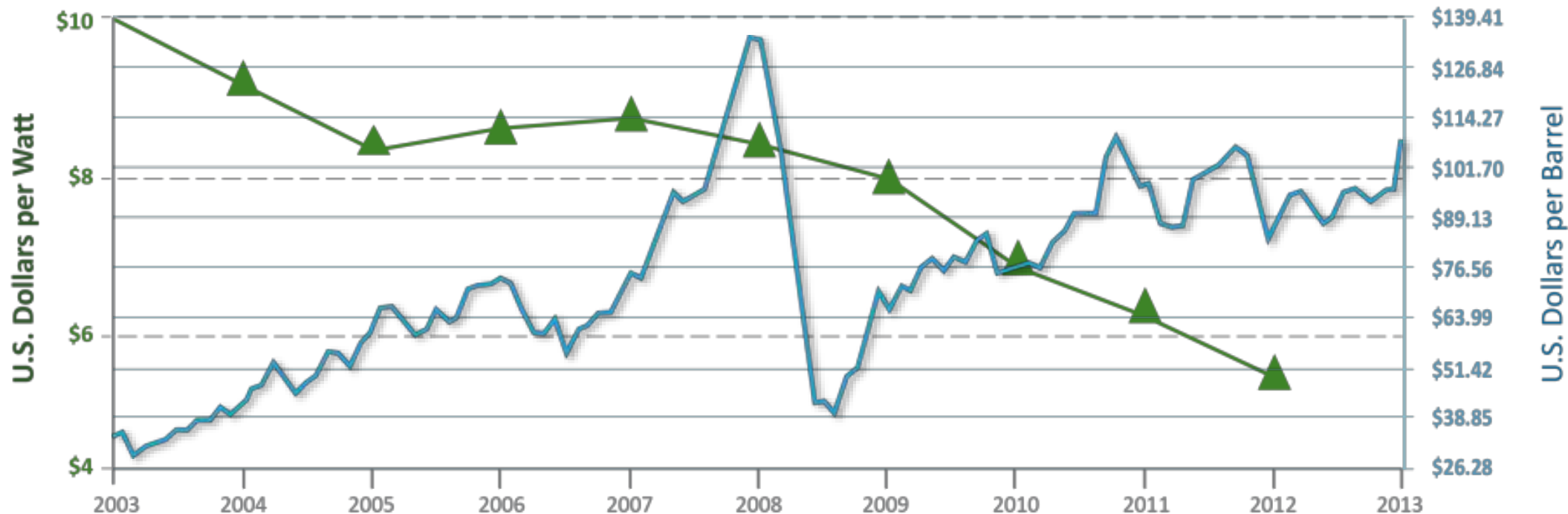
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Solar is Less Expensive than Diesel

- PV electricity prices have reduced over 50%
- Diesel prices remain highly volatile and have steadily increased

Small PV System Median Installed Price 2003–2012

WTI Crude Oil Prices 2003–2013

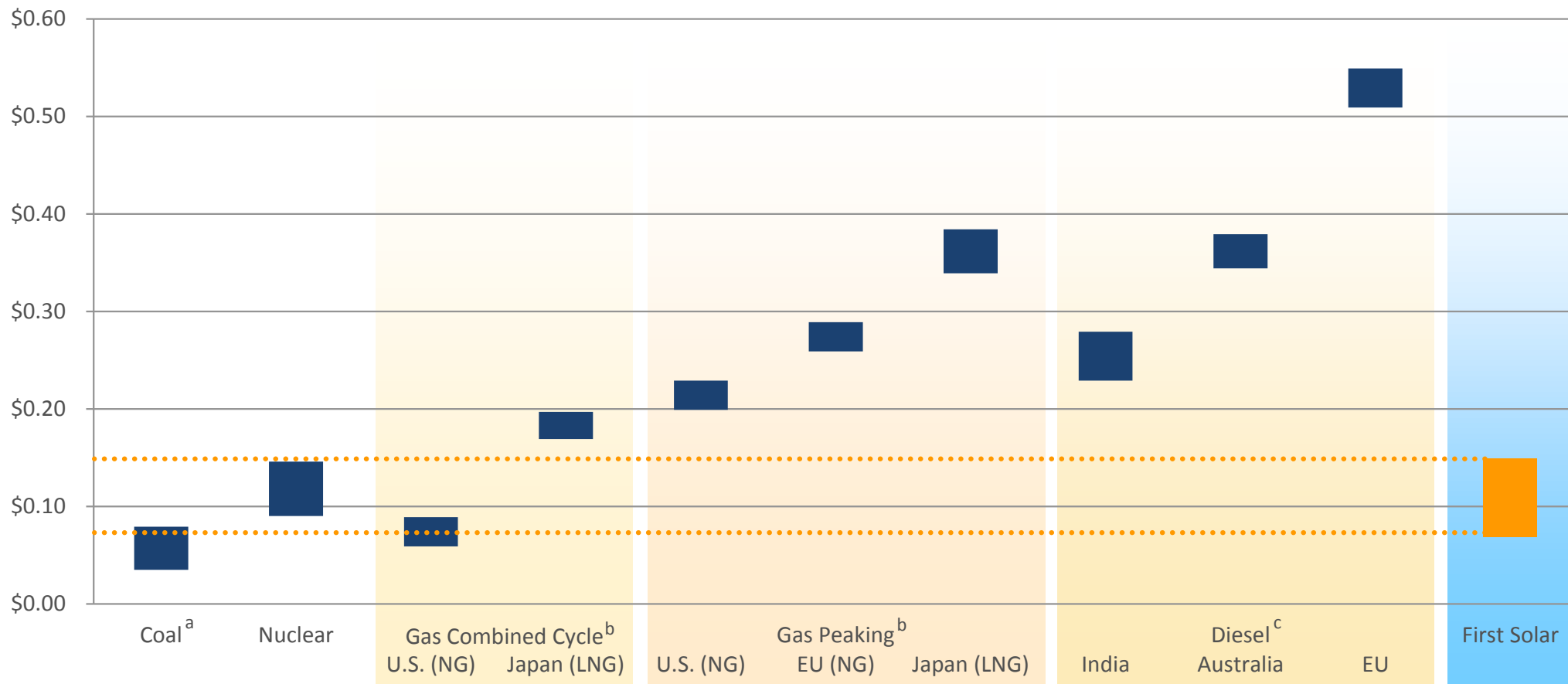


Sources: Diesel Pricing US Energy Information Administration; Solar Pricing: DOE, Lawrence Berkley National Laboratory

Solar is Less Expensive than Diesel



Solar is Cost Competitive with Conventional Energy Sources Today



Sources: Coal and Nuclear: Bloomberg New Energy Finance LCOE Update: Q2 2013; Gas Combined Cycle, Gas Peaking, and Diesel: Lazard LCOE Sensitivity Analysis June 2013; First Solar: Internal data.

(a) Does not include cost of carbon capture. (b) NG = natural gas. LNG = liquefied natural gas. Data assumes natural gas prices of \$10 in Northern Europe and \$18 in Japan (all in US\$ per MMBTU). (c) Assumes diesel prices of \$3.00 for India, \$4.30 for Australia, and \$7.00 for Northern Europe (all in US\$ per gallon). Diesel assumes a high end capacity factor of 30% representing intermittent utilization and low end capacity factor of 95% representing base load utilization, O&M cost of \$15 per KW/year, heat rate of 10,000 BTU/KWh and total capital costs of \$500-\$800 per KW of capacity.

Solution: The PV Hybrid

PV Hybrid Systems combine PV solar generation with a fossil fuel engine generator to **reduce fuel consumption and save costs.**



Low Speed Engine



Mid Speed Engine



Combustion Turbine



High Speed Engine



Compatible with any thermal engine technology

First Solar Hybrid Systems

- Operate as a **secondary power source**
- Will **not replace existing thermal** infrastructure/fleet
- Are **commercially viable** due to operational **fuel savings** alone



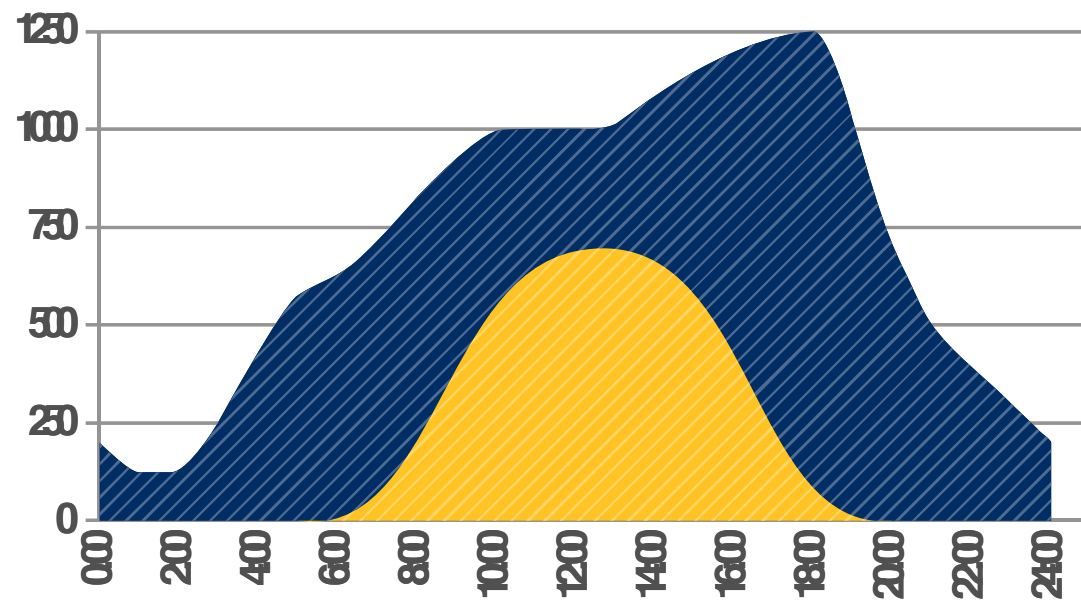
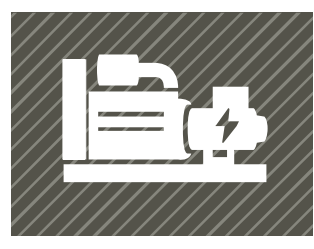
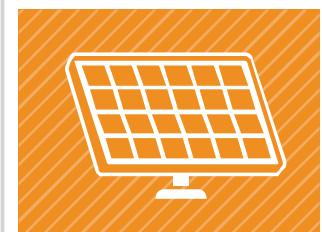
Think of solar as a source of fuel,
not just additional capacity.

How It Works

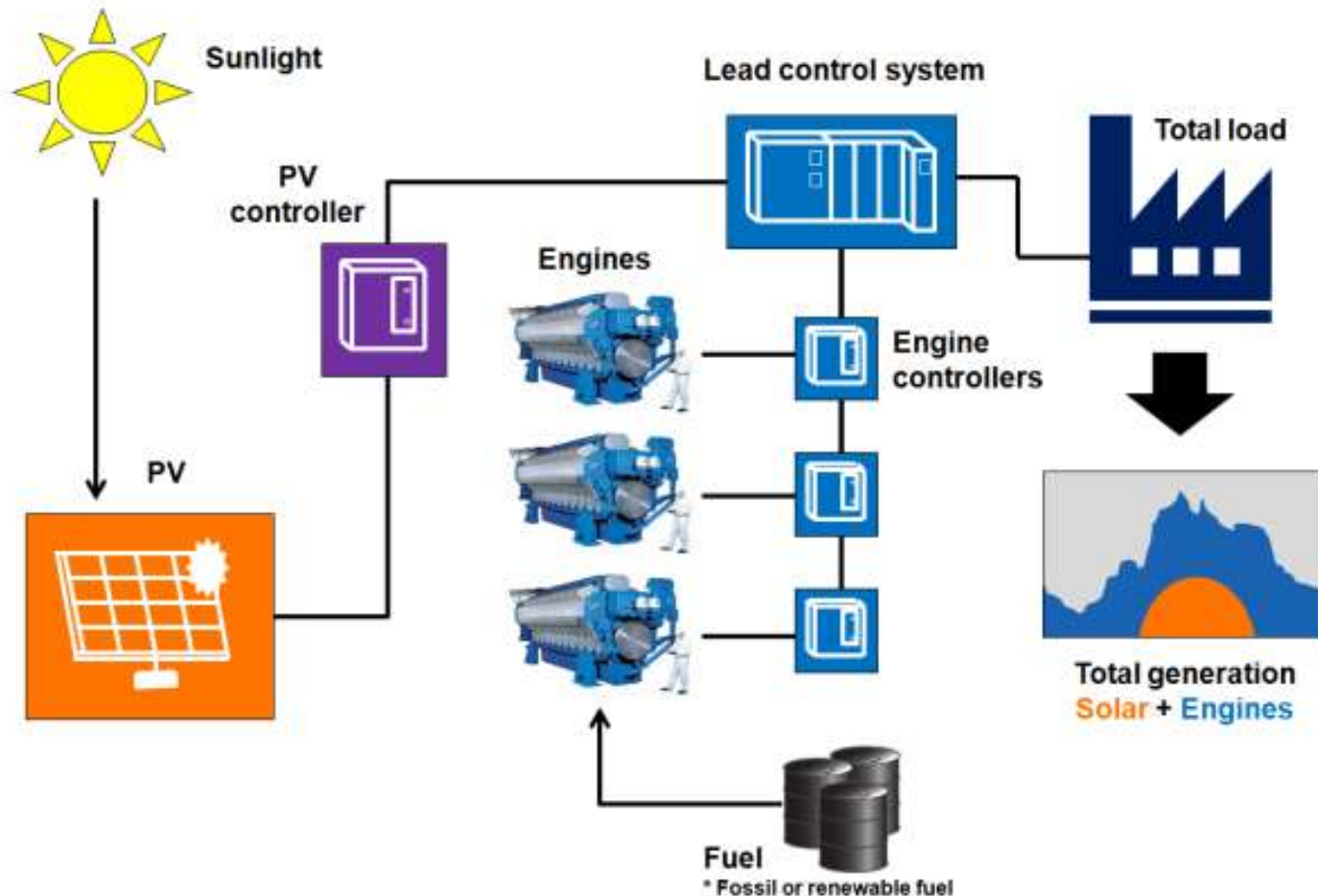
PV POWER PLANT

THERMAL FUEL SOURCE

LOAD



How an Engine – Solar PV Hybrid power plant works



CONTROL SYSTEM INTEGRATION

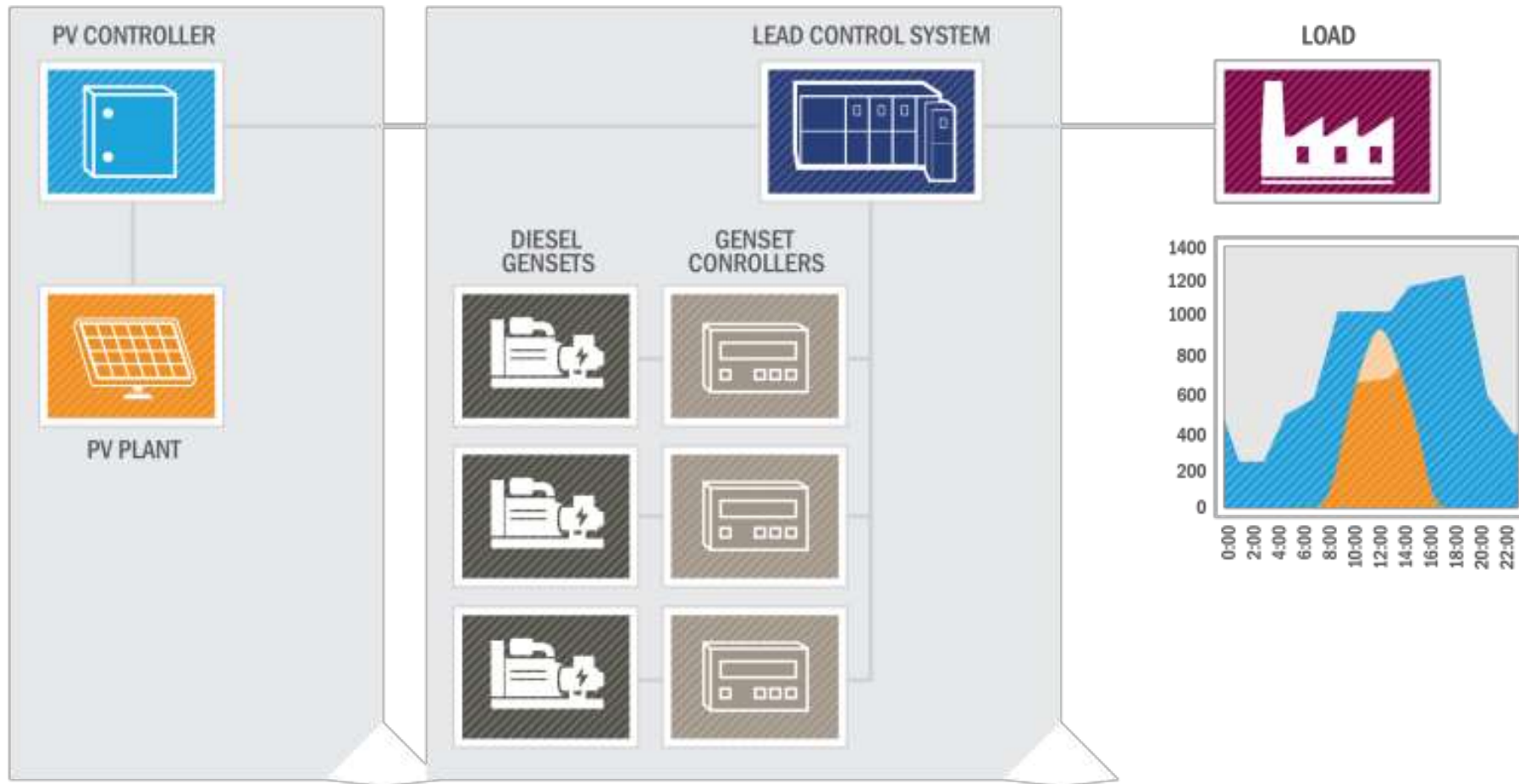
IC Engine Genset

- Primary Power for 24x7 Load
- Manage Load Variations
- Voltage/Frequency Regulation
- VAR Support
- Spinning Reserve

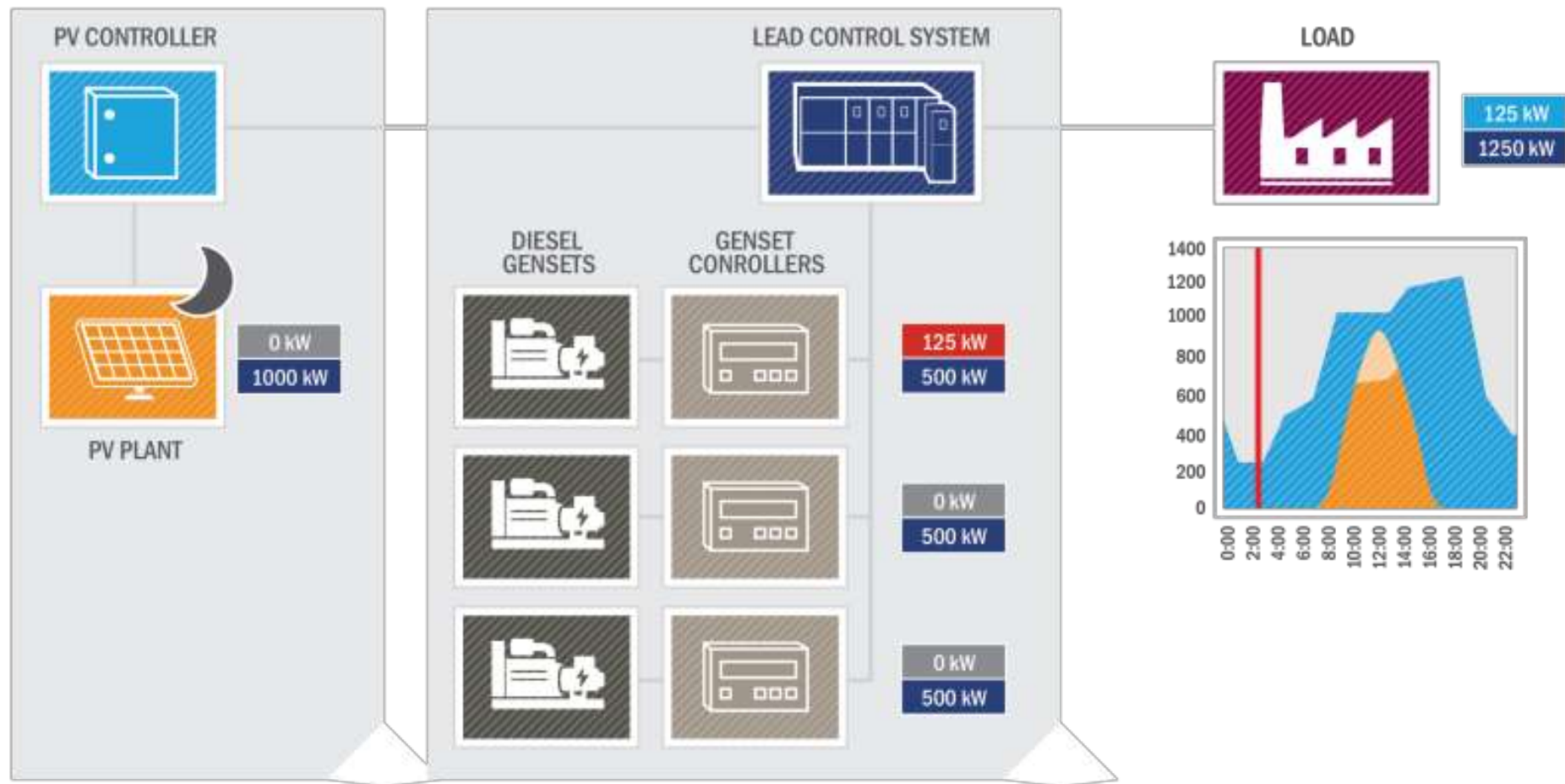
PV Power Plant

- Secondary Energy Source
- Voltage/PF or VAR Regulation
- High Power Quality Output
- Maximizes overall system efficiency
- Enables liquid fuel savings

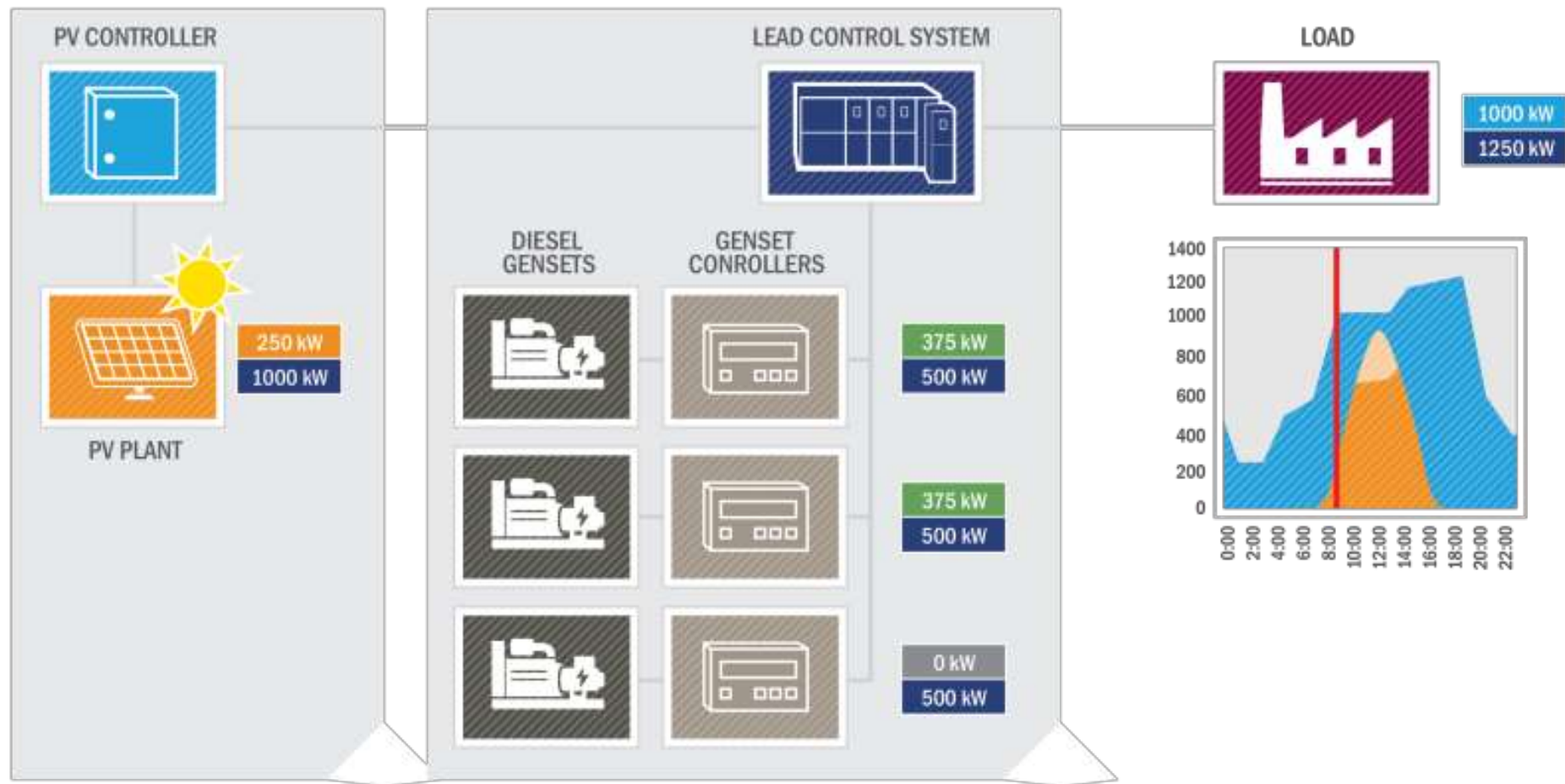
How It Works – Typical Day



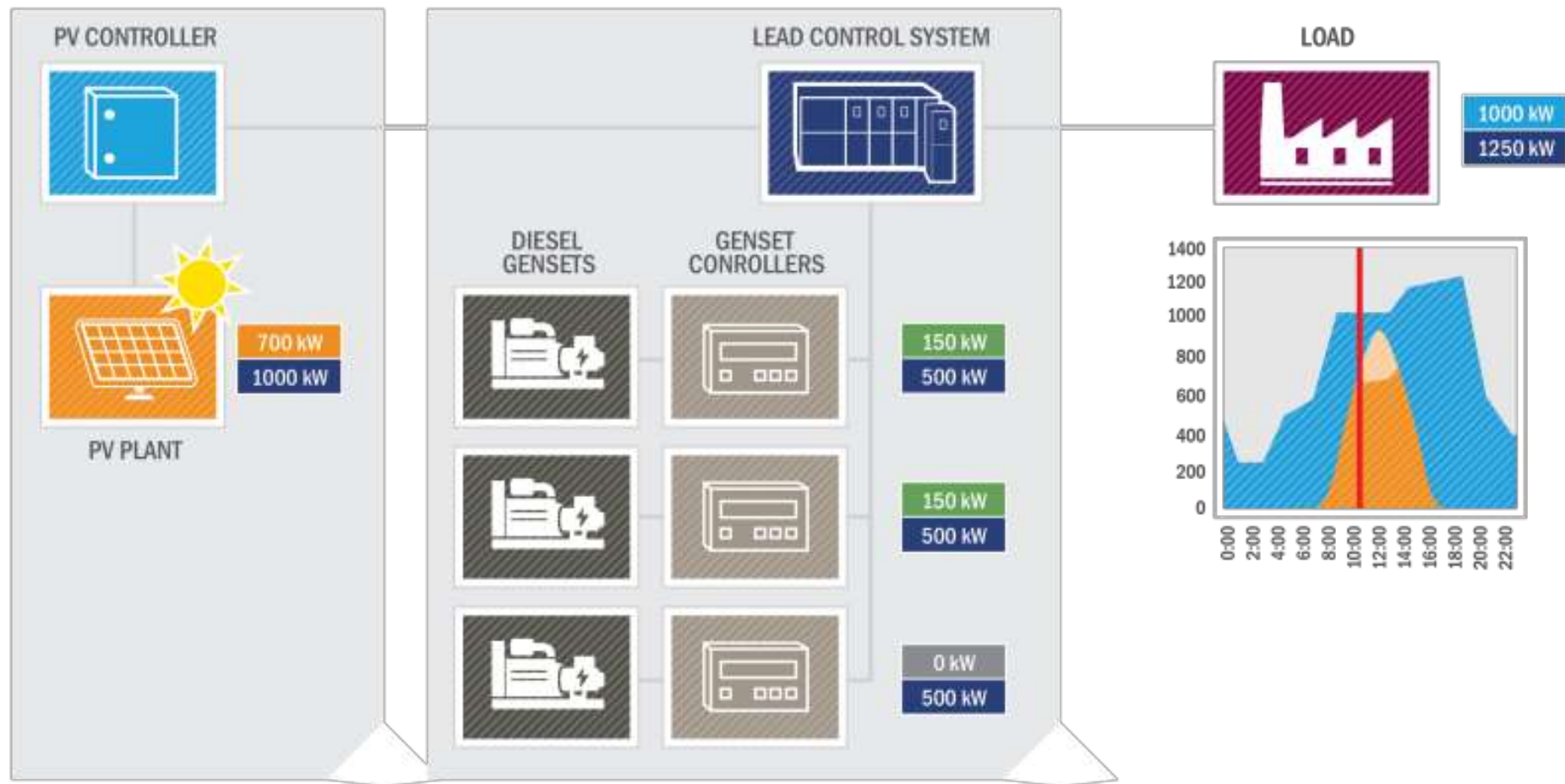
How It Works – Typical Day



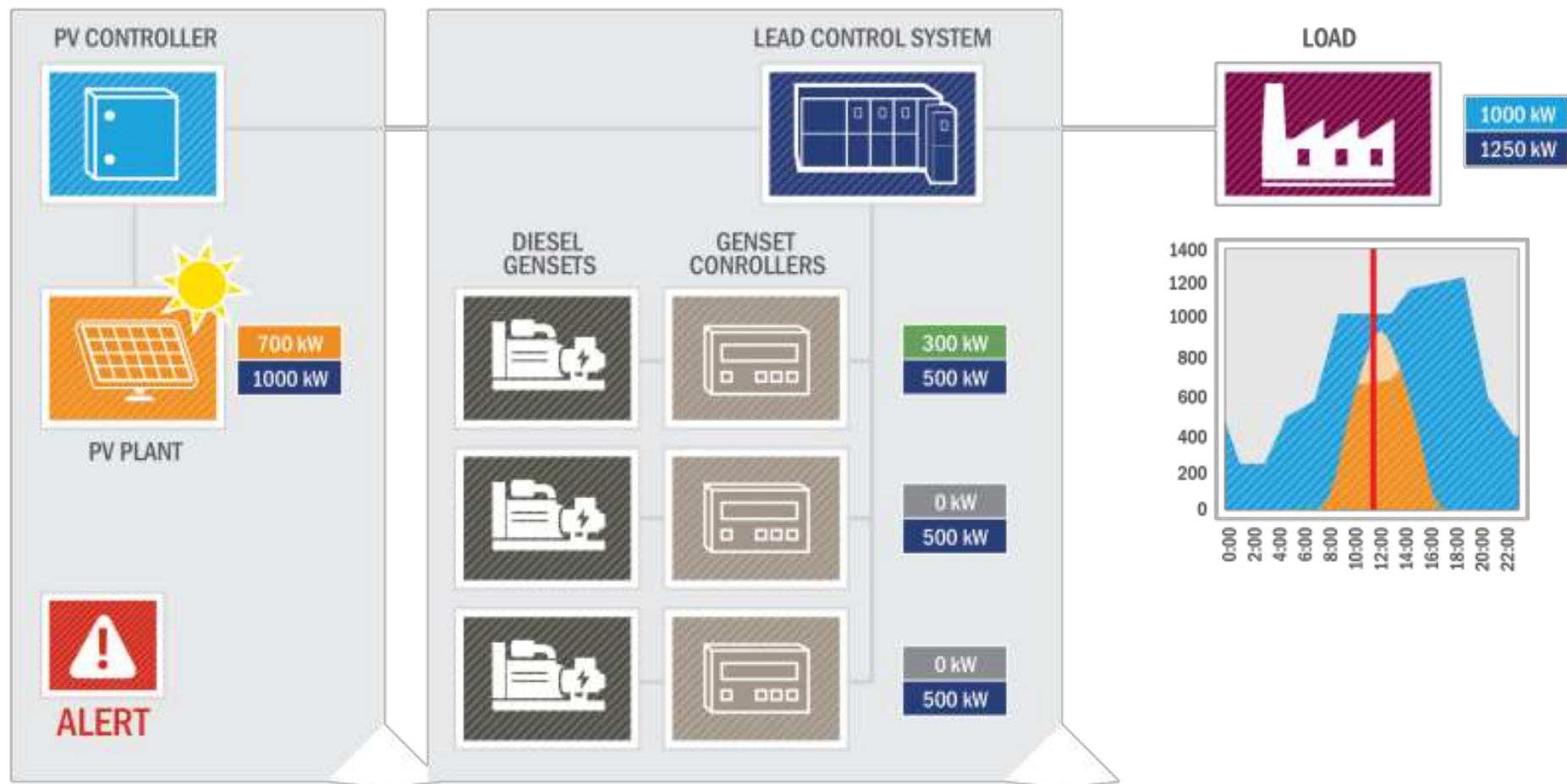
How It Works – Typical Day



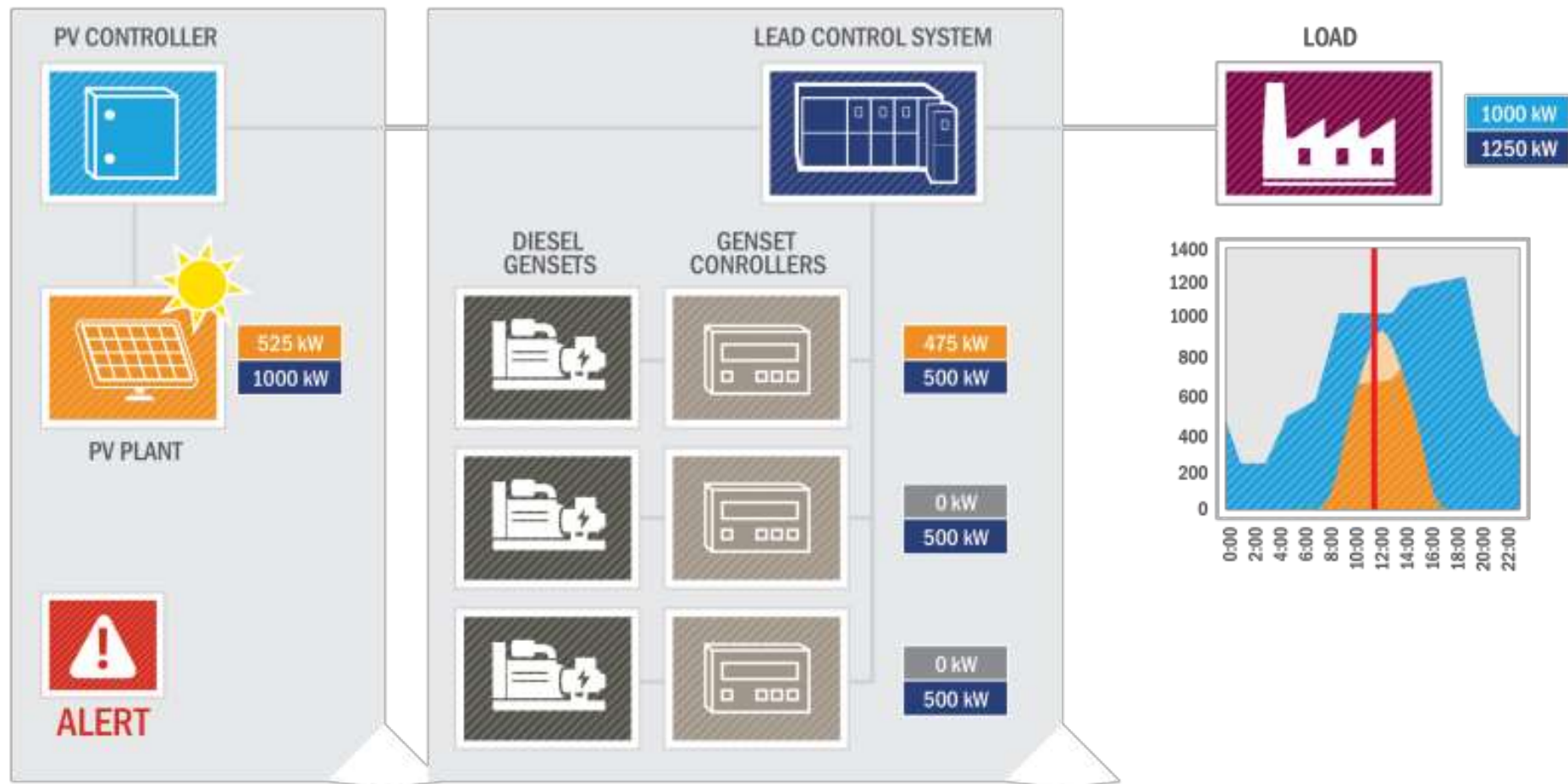
How It Works – Typical Day



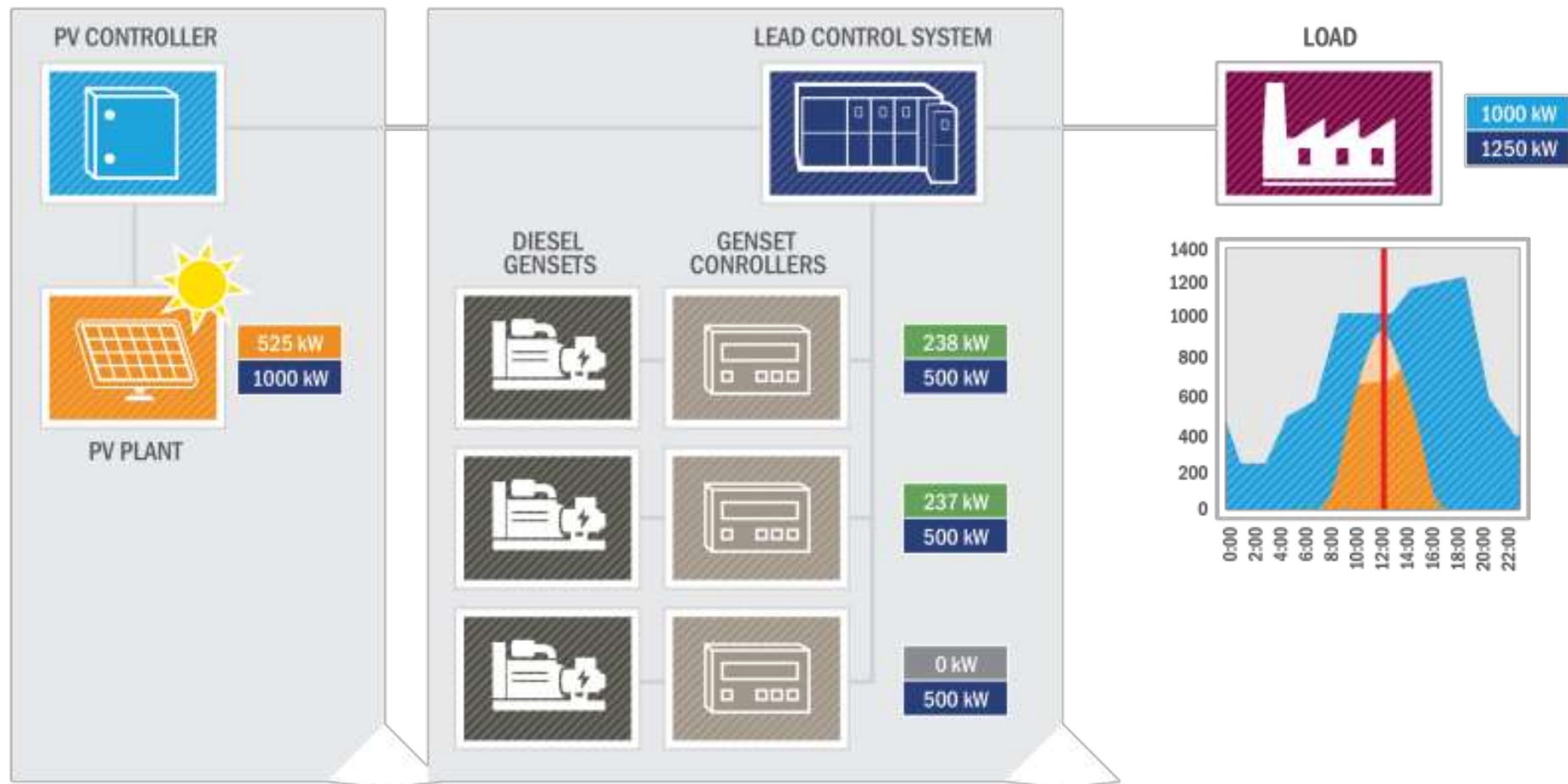
How It Works – Typical Day



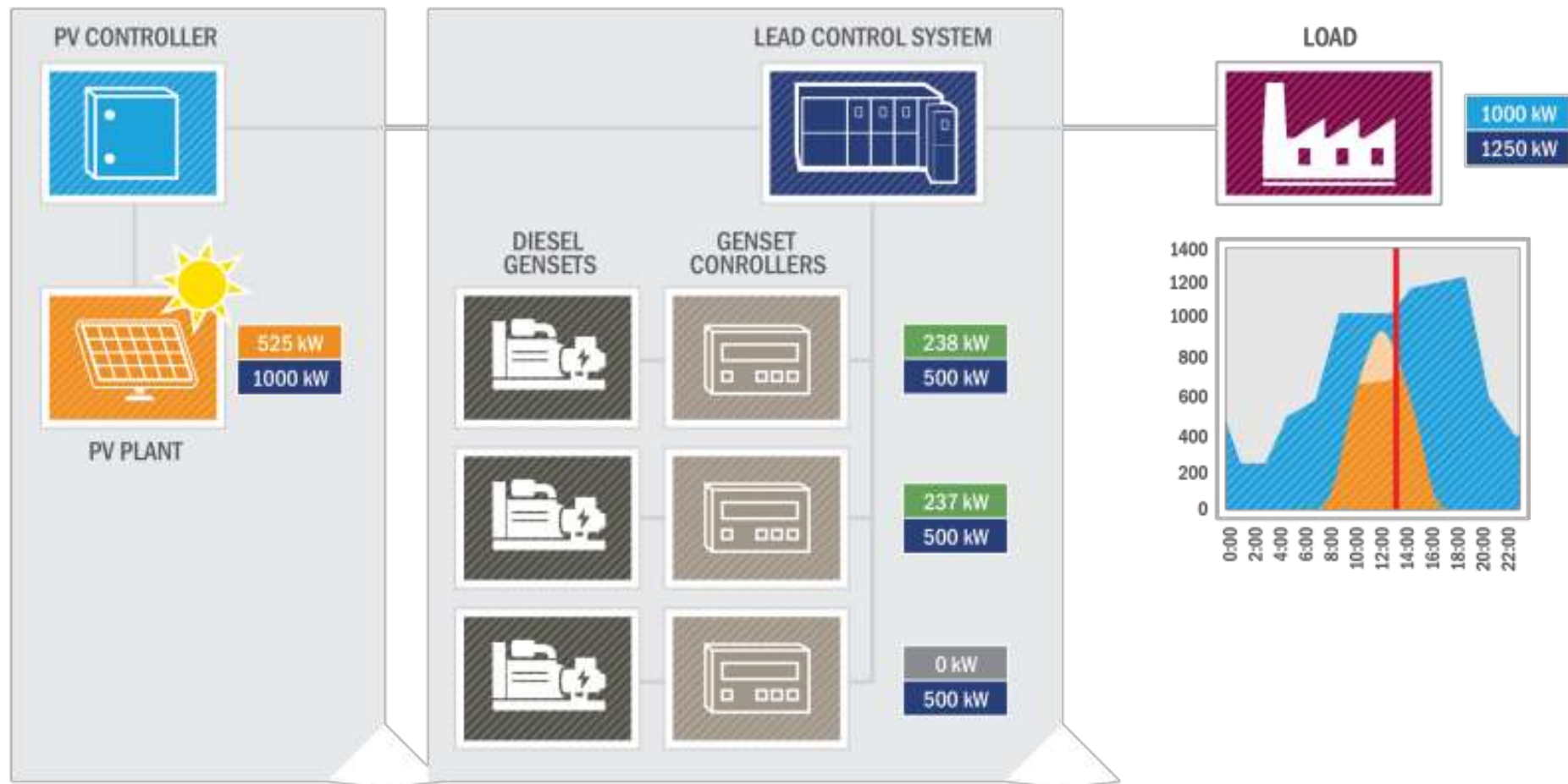
How It Works – Typical Day



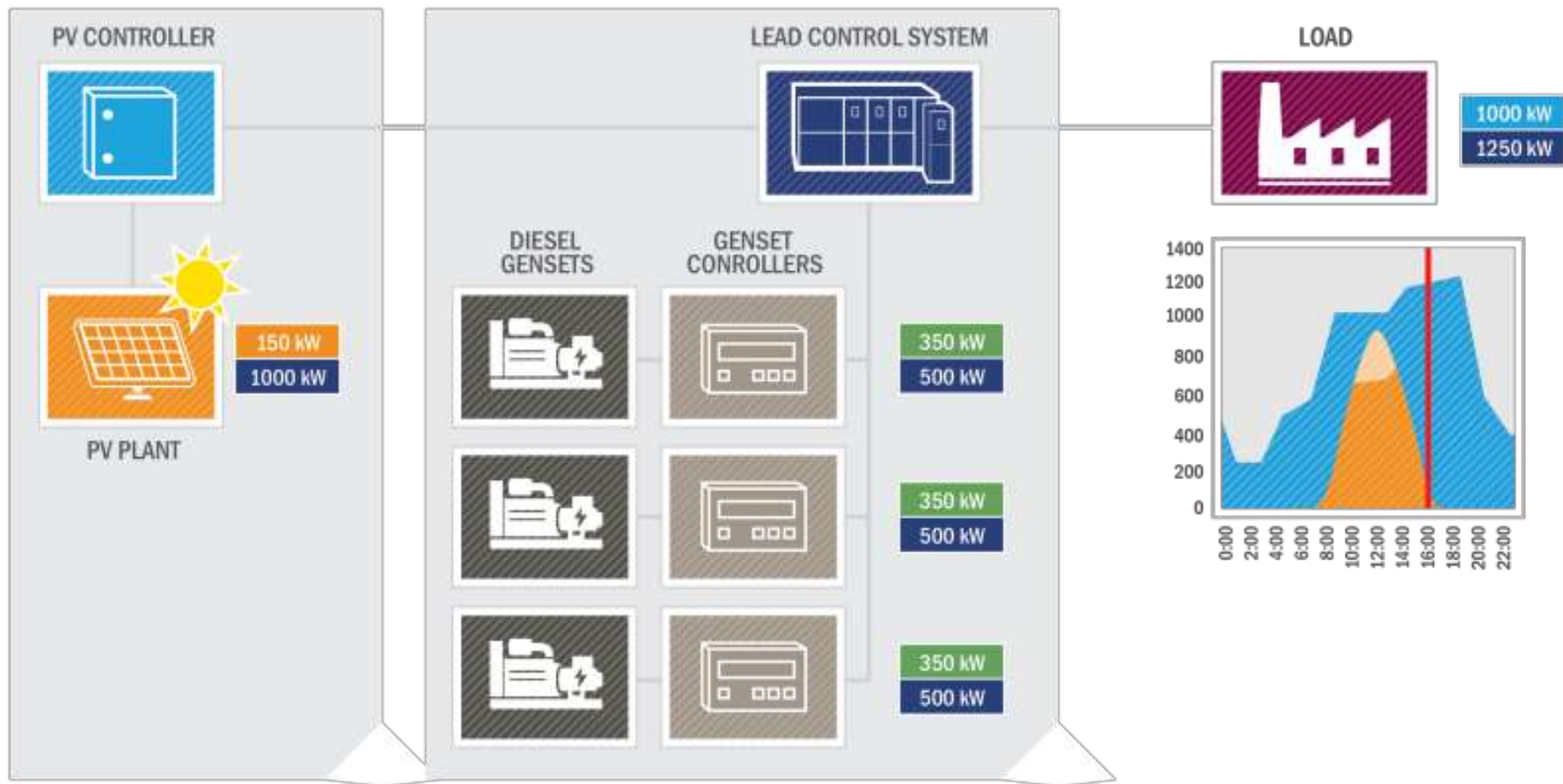
How It Works – Typical Day



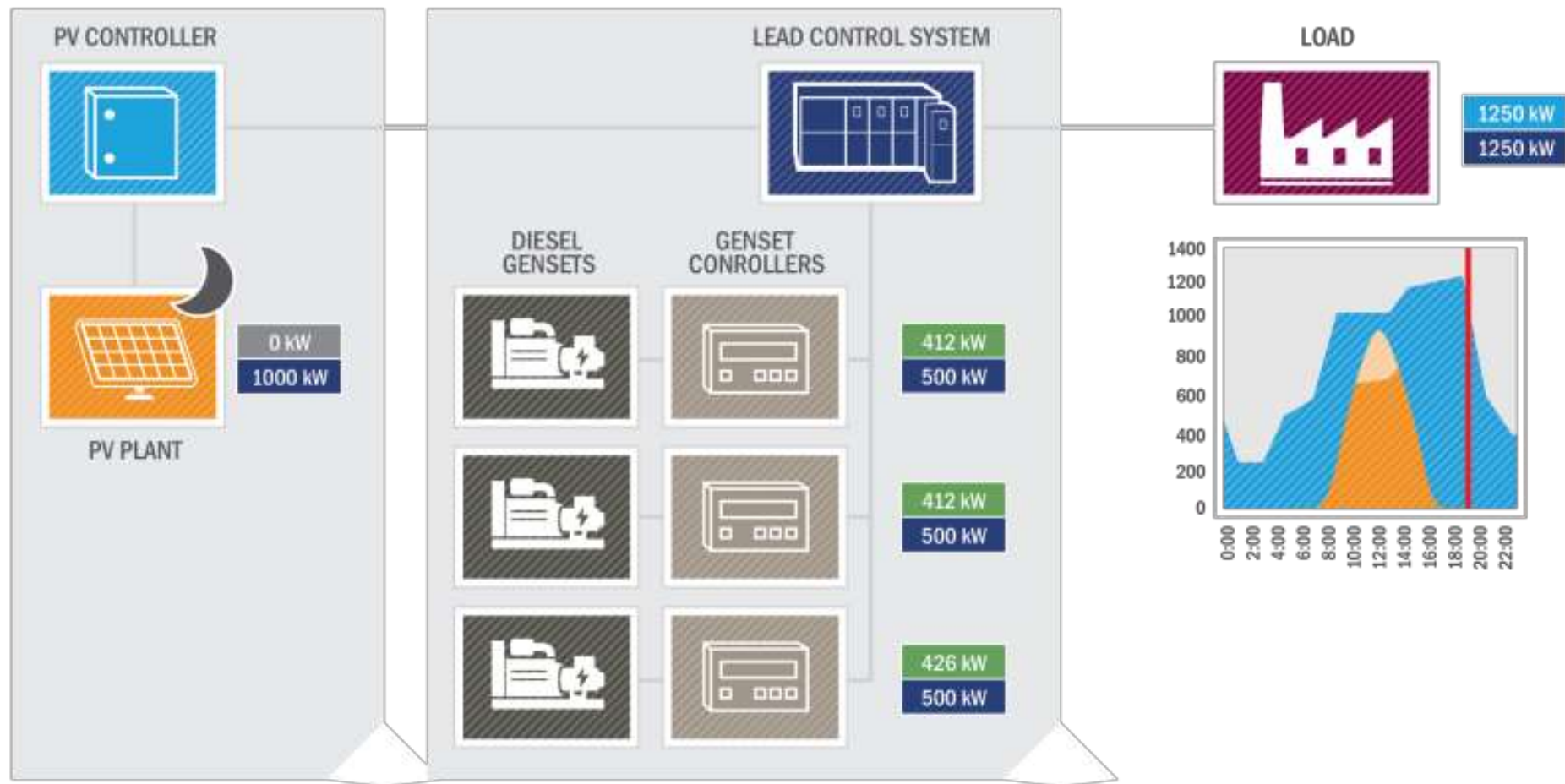
How It Works – Typical Day



How It Works – Typical Day

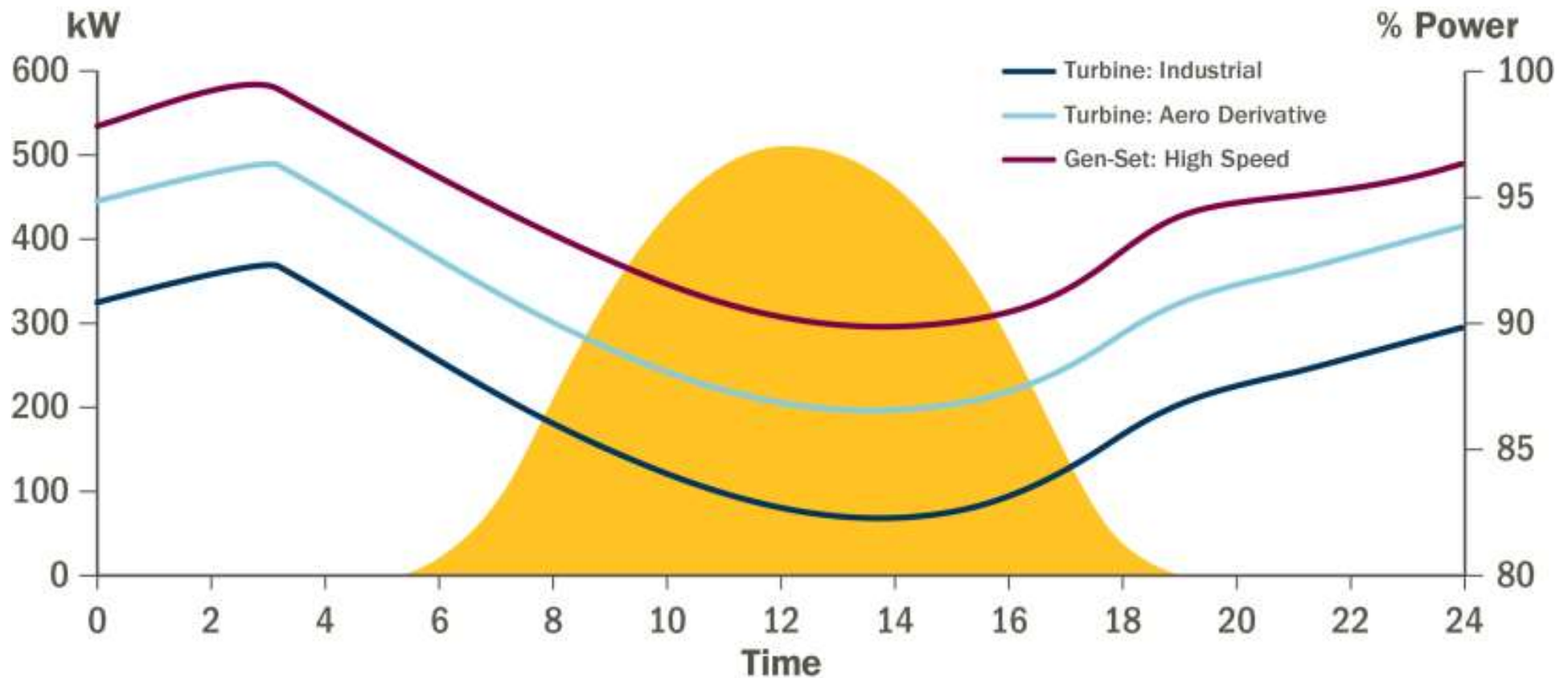


How It Works – Typical Day



PV is Highly Compatible with High Ambient Temperatures

- Thermal energy output decreases when PV energy output increases



Overall Benefits of Hybrid Power Plants

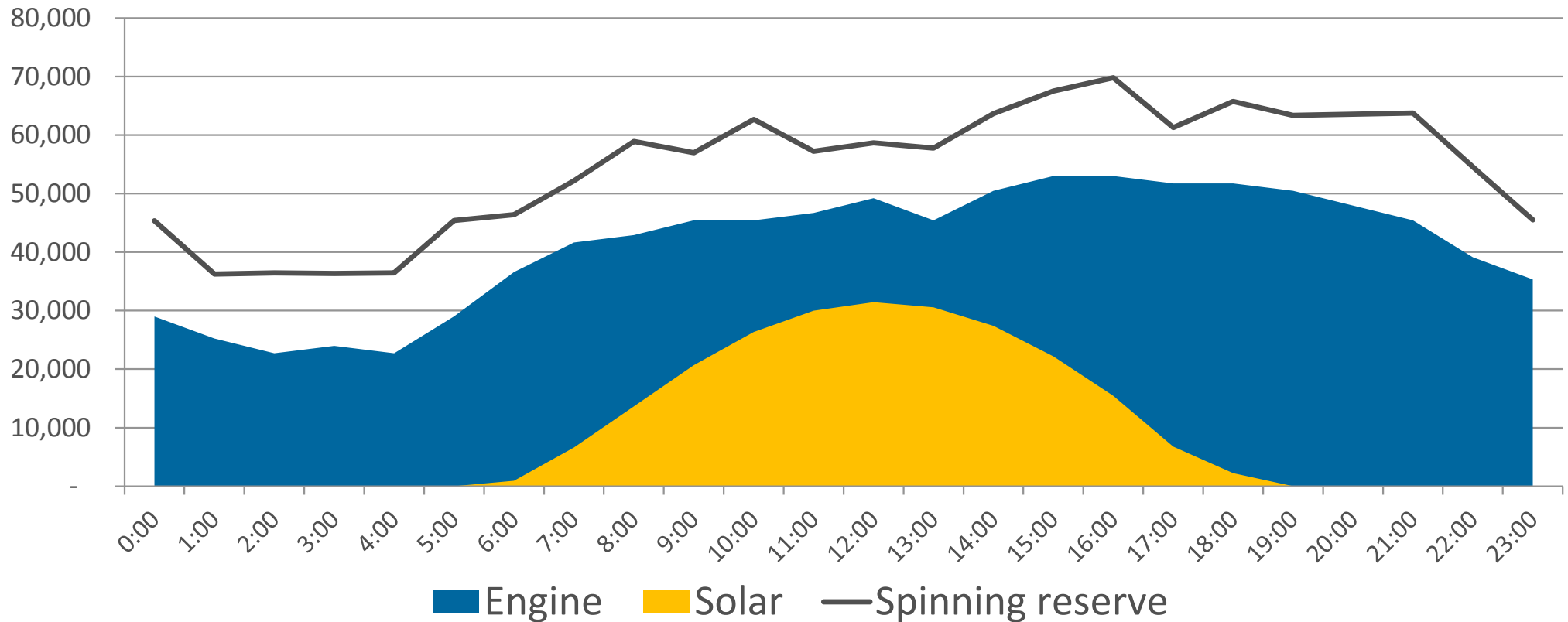
- **Economic**
- **Operational**
- **Environmental**



Generation split for Hybrid – Variable Load profile

N/ N+1 Engines + 39 MWac Solar + Battery storage

kW generated



Spinning Reserve using battery energy storage



+

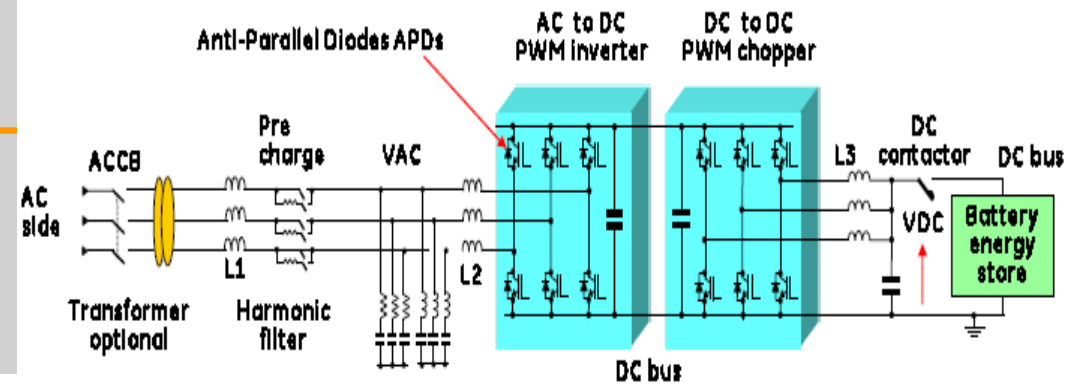
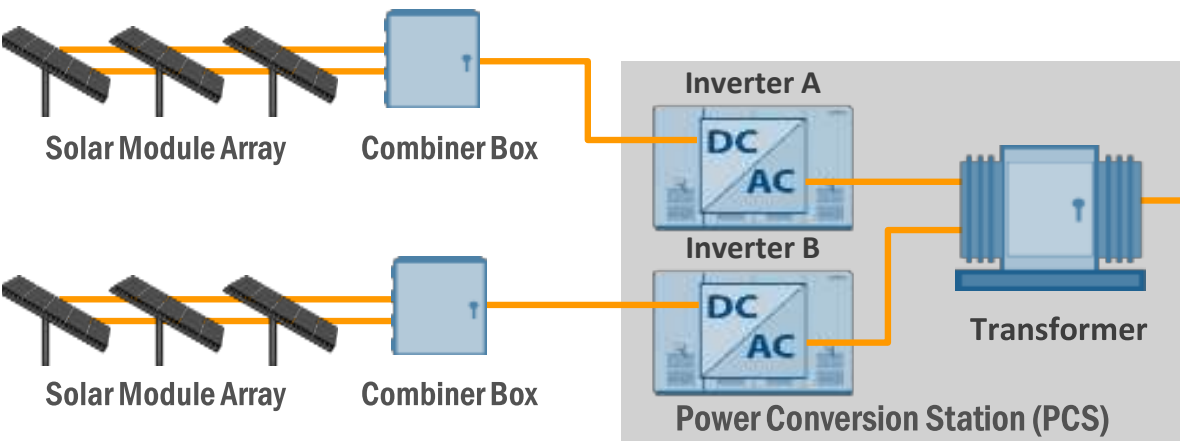


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Cold engine

Hot Spinning Reserve



Synergies for hybrid power plants

Land Utilization:

- Solar PV plant can be built on areas that are deemed unutilized such as HV transmission lines right of way, conventional plant associated zoning area, etc.



Operation and Maintenance:

- The O&M cost for hybrid PV power plants can be up to 50% lower than stand alone solar PV power plants
- Solar PV plant scheduled and [preventative maintenance can be coordinated with main conventional power plant

Electrical Grid Connection:

- Overall name plate can stay the same
- Typically 10 to 15% available capacity on MV/HV switch yard



Financial Overview

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Scenario for IPP Hybrid Power Plant

- **IPP business model used**
- **Flat load assumption**
- **No land lease incorporated**
- **No upfront financial fees and development costs included**
- **The fuel is considered as a pass-through to the IPP company**
- **Gensets are HFO-based engines**
- **Discount rate for calculation of levelized electricity price and NPV of fuel savings: 8%**
- **Total Power Capacity of 54.4MW**

Hybrid Model – Assumptions Overview

Case Study: Hybrid project including a 54.4MW_{AC} Genset facility and a 37.8MW_{ac} PV plant

SOLAR PV – KEY TECHNICAL ASSUMPTIONS

Energy

- Capacity Ratio(MW_{ac}/MW_{dc}): 37.8 / 47.9
- DC:AC ratio: 1.267
- 1st year generation (MWh): 85,726
- Degradation loss: 0.5%
- Availability loss: 1.0%

Costs

- Stand-alone EPC Price: US\$ 1.580/W_{DC}
- Stand-alone O&M Price: US\$ 32/KW_{DC}/Year

GENSET – KEY TECHNICAL ASSUMPTIONS

Energy

- Net Capacity (MW): 54.4
- Net heat rate, LHV (kJ/kWh): 8,544
- Plant life cycle efficiency: 40.9%
- Aging factor: 1.0%
- Sludge/spillage/Fugitive losses factor: 2.0%
- Lube oil consumption rate (g/kWh): 0.4

Costs

- Standalone EPC Price: US\$ 1.009/kW
- Standalone O&M Price: US\$ 18.67/MWh

Hybrid Model – Assumptions Overview (*cont'd*)

COMBINED CAPEX/OPEX ASSUMPTIONS

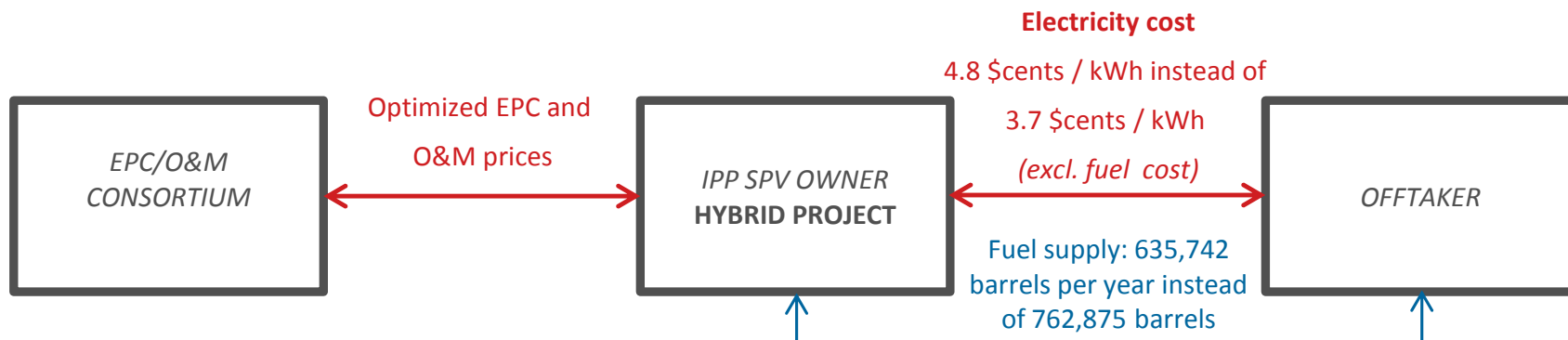
- **Total Capex (incl. IDC):** US\$ 115M
- **Total First Year Opex (excl. fuel cost):** US\$ 7.5M
- **Optimization of the EPC cost during the construction period through the combination of construction capabilities**
- **Optimization of the O&M cost through remote control of the PV portion and combination of the labor force on-site**

OTHER KEY ASSUMPTIONS

Schedule

- Construction period: 15 months
- Project lifetime: 20 years

POTENTIAL HYBRID BUSINESS MODEL WITH SAUDI ARAMCO AS FUEL PROVIDER & ELECTRICITY OFFTAKER



First Year Comparison

Case Study: Hybrid project including a 54.4MW_{ac} Genset facility and a 37.8MW_{ac} PV plant

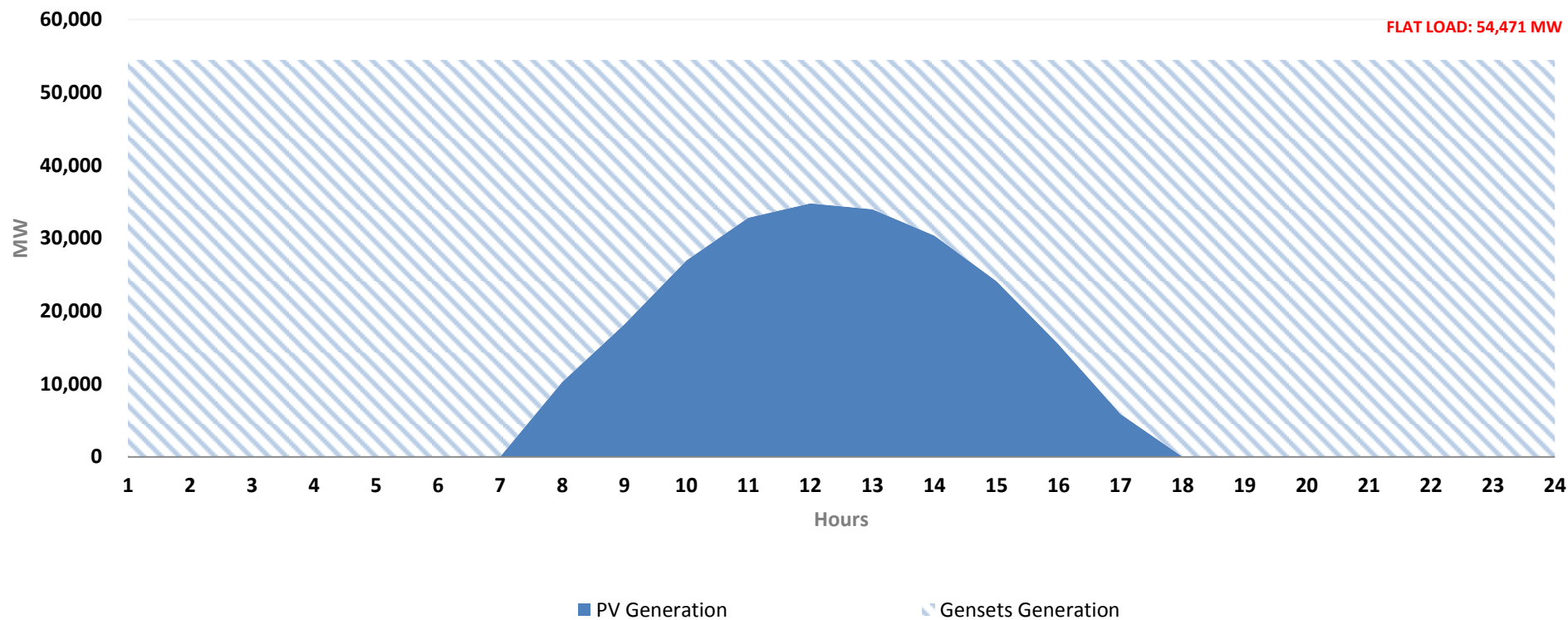
	Conventional		Hybrid		Delta
	Unit	Total \$ (M)	Unit	Total \$(M)	Total \$(M)
Fixed Cost/Kwh	\$0.037	\$17.5	\$0.048	\$22.7	\$5.2
Fuel	762,875	\$21.4	635,742	\$17.8	(\$3.6)
		\$38.9		\$40.5	\$1.6

127,133 B/Yr

Assume 28\$US bbl

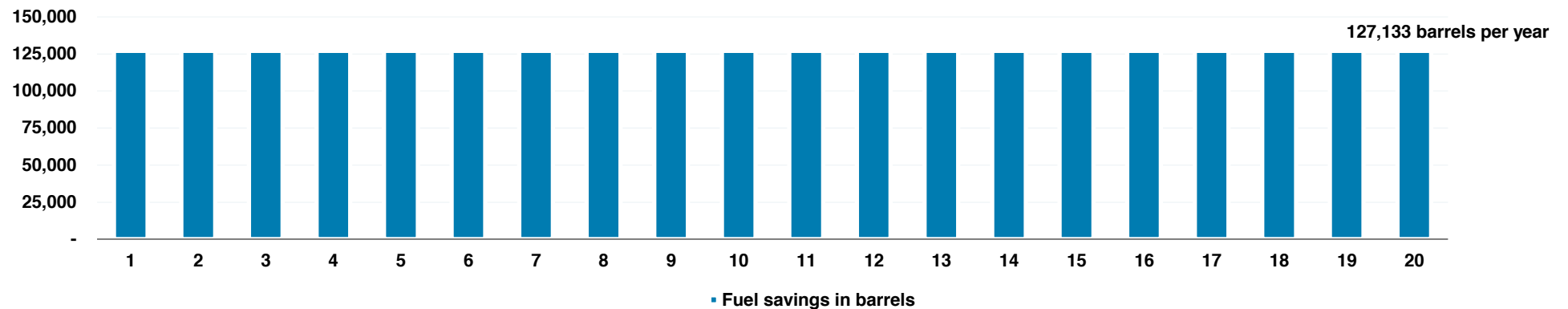
Hybrid Model – Daily Energy Generation

ENERGY GENERATION SPLIT BY TECHNOLOGY

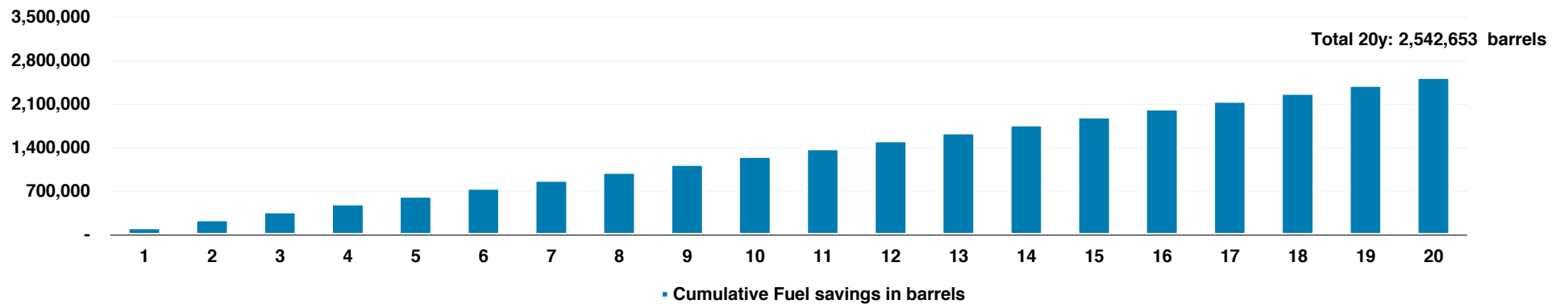


Hybrid Model – Fuel Savings Overview

FUEL SAVINGS PER YEAR (in barrels)

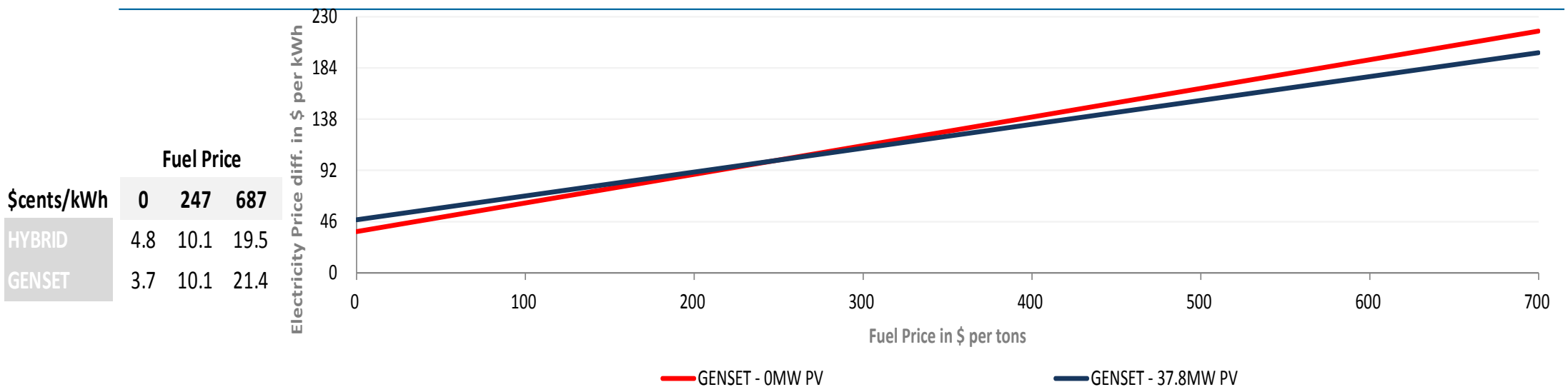


CUMULATED FUEL SAVINGS (in barrels)



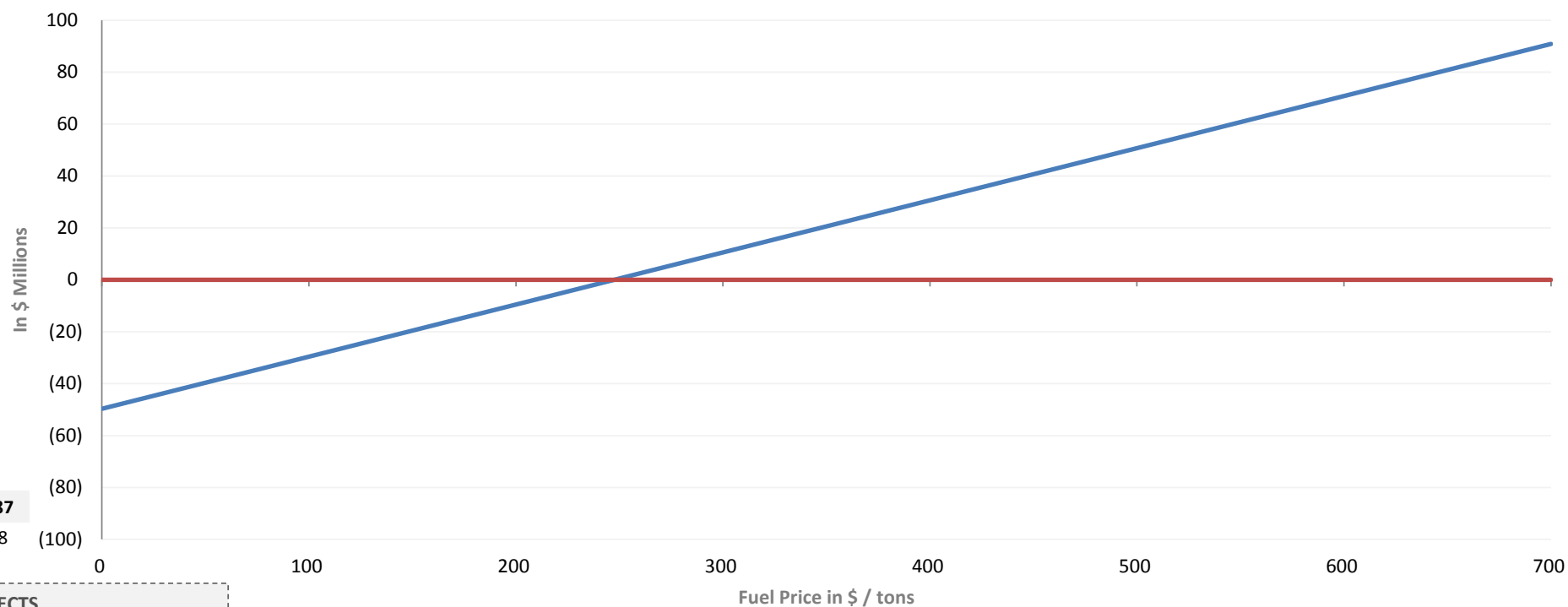
Hybrid model – Cost of Electricity Evolution

TOTAL LCOE (In US\$ / kWh) / HFO PRICE ANALYSIS (In US\$ per tons)



Hybrid Model – Net Savings Evolution

NET PRESENT VALUE OF NET SAVINGS (In US\$ M) / HFO PRICE ANALYSIS (In US\$ per tons)



BENEFIT IN HYBRID PROJECTS

- + **1** NPV(Fuel saved in tons * Fuel price)
- **2** NPV(Δ Tariff * Total energy generated)
- = **>0 WHEN HFO PRICE > \$247/Tons**
- @ Discount rate of 8%

— GENSET - 37.8MW PV — GENSET - 0MW PV

Benefits of Solar PV Hybrid Power Plants

Liquid Fuel Savings

Drop in Levelized Cost of Energy (LCOE incl. Fuel)

Higher system efficiency – Optimized operations of overall fleet

Hybrid power plants can offer a higher degree of flexibility / dispatchability

Optimization of CAPEX and OPEX for the Power Plant

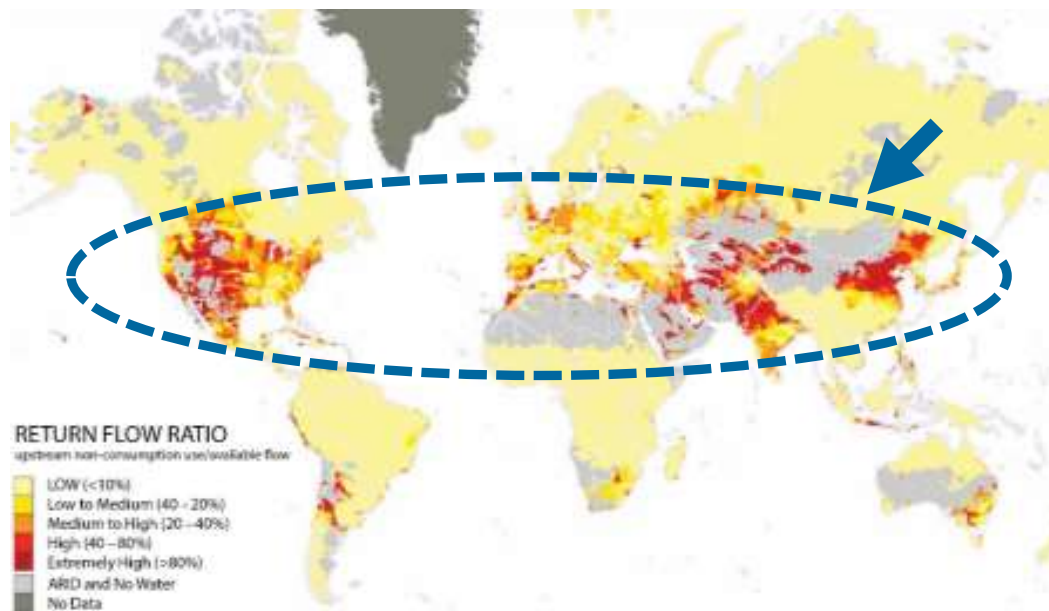
Environmental benefits – Greener Conventional Power Plants



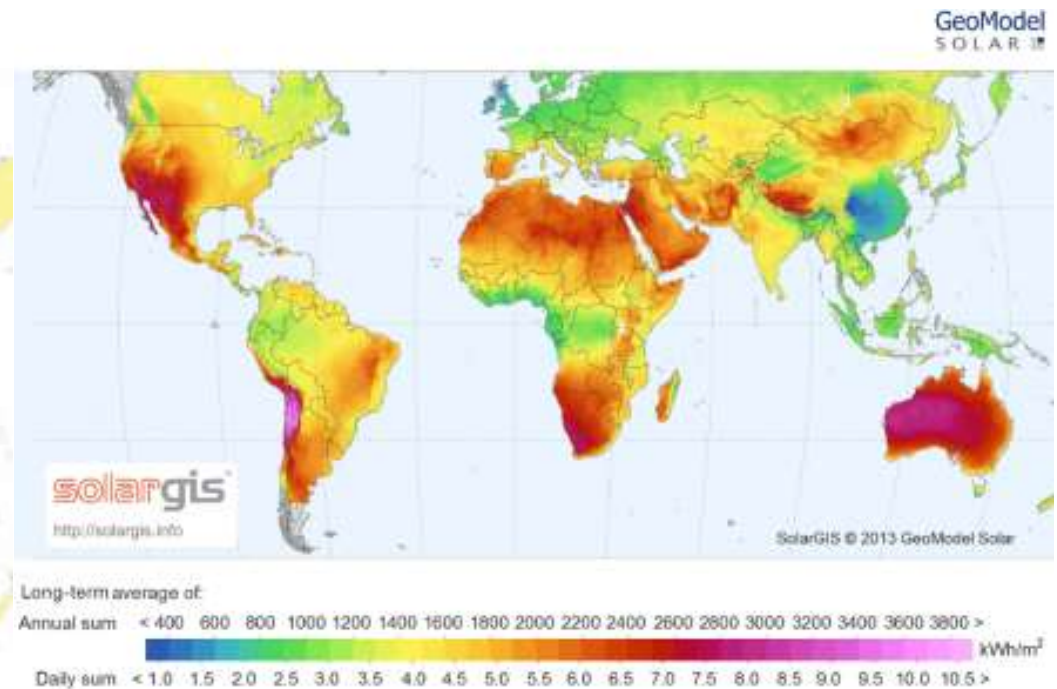
Sustainable Water Desalination using Solar PV

Regions of Water Stress are the Ones Rich in Solar Irradiance

Return Flow Ratio



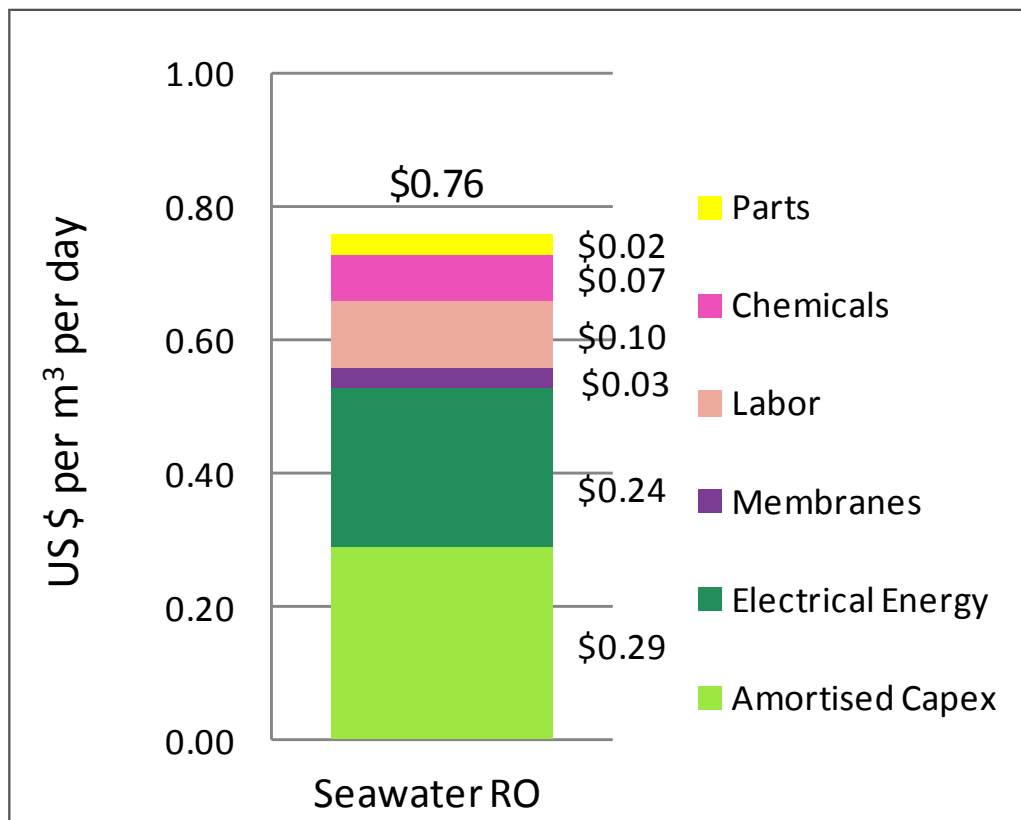
Global Horizontal Irradiation



Sustainable seawater desalination relying on solar energy is the right approach

Source: Gassert, Francis, et. al. (January 2013). *Aqueduct Metadata Document*

Water Desalination Cost Analysis



COST ANALYSIS

Assume 30% electricity cost/m³ of water

6.5¢/kWh = grid electricity cost

+ 10% Solar PV penetration
@LCOE 13¢/kWh

Blended cost:

$$0.9 \times 6.5 + 0.1 \times 13 = 7.15 \text{ \$/kWh}$$

(10% increase)

**ONLY 3% increase
in water costs**

Value of Clean Solar Energy

Solar
Electricity



Diesel
Power Plants



Avoid
Fuel Subsidy



1 kWh

DISPLACES

0.08
Gallons

SAVES

10¢
kWh

DISPLACES

0.8 kg CO₂

PV CdTe can Displace Electricity from Diesel Power Plants

Key Takeaways



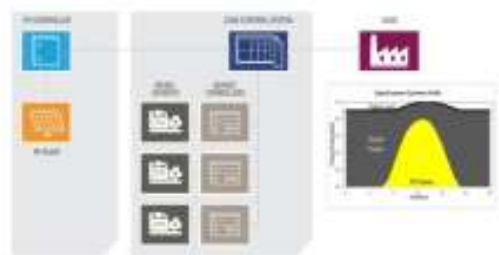
Integration of Solar PV with hydrocarbon based power generation is possible with significant improvement in overall net efficiency, fuel consumption and carbon foot print

Need for new regulation that sets minimum heat rates / efficiencies for conventional power plants or large scale loads such as Seawater RO



Economics of hybrid power plants are gaining momentum:

- Continued volatility in hydrocarbon pricing
- Reduction in Solar PV LCOE
- Development of cost effective storage solutions



Lower LCOEs are achieved for hybrid utility scale power plants as opposed to stand alone utility scale solar PV Power Plants

