

Successfully Incorporating Renewable Energy with Traditional Generator Set Power Systems

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Caterpillar Inc**

Asia Clean Energy Forum

June 16, 2015

Agenda

- 1. Caterpillar Presence in Power Generation Industry**
- 2. Experience with Integration of Renewable Power and other Emerging Energy Technologies**
- 3. Critical Success Factors for Successful Projects**

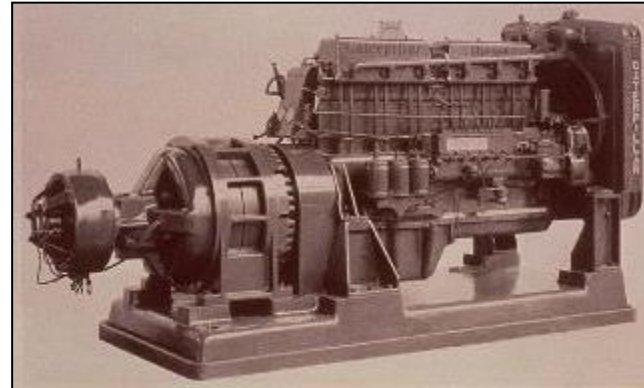
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Background: Caterpillar Electric Power Division

- In 1939 Caterpillar introduced the first engine manufacturer complete generator set solution
- 75+ years experience in Electric Power
- 135,000 MW Electric Power generation installed worldwide
- \$4 billion yearly sales in Electric Power Division

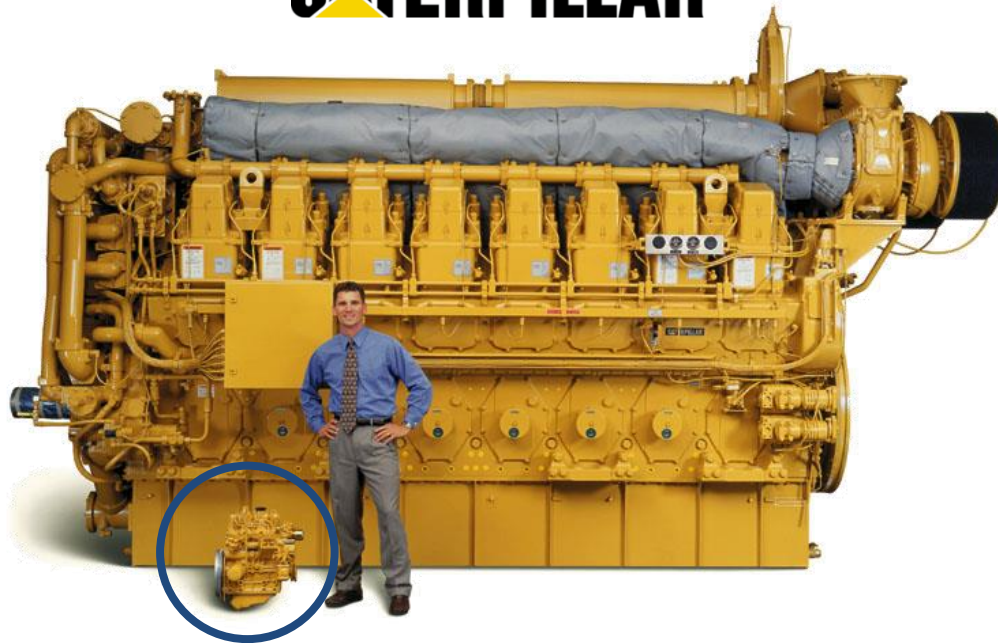
Cat® D13000 | 60 kW Generator Set



Caterpillar Electric Power: World Leader

Manufacturing and Distribution of Reciprocating Engine Generators, Gas Turbines, and Power Systems

CATERPILLAR®



Solar Turbines
A Caterpillar Company



Distributed Generation from 5 kW to 29 MW

Diesel, Natural Gas, & Bio-Gas

Caterpillar: Electric Power Customer Base

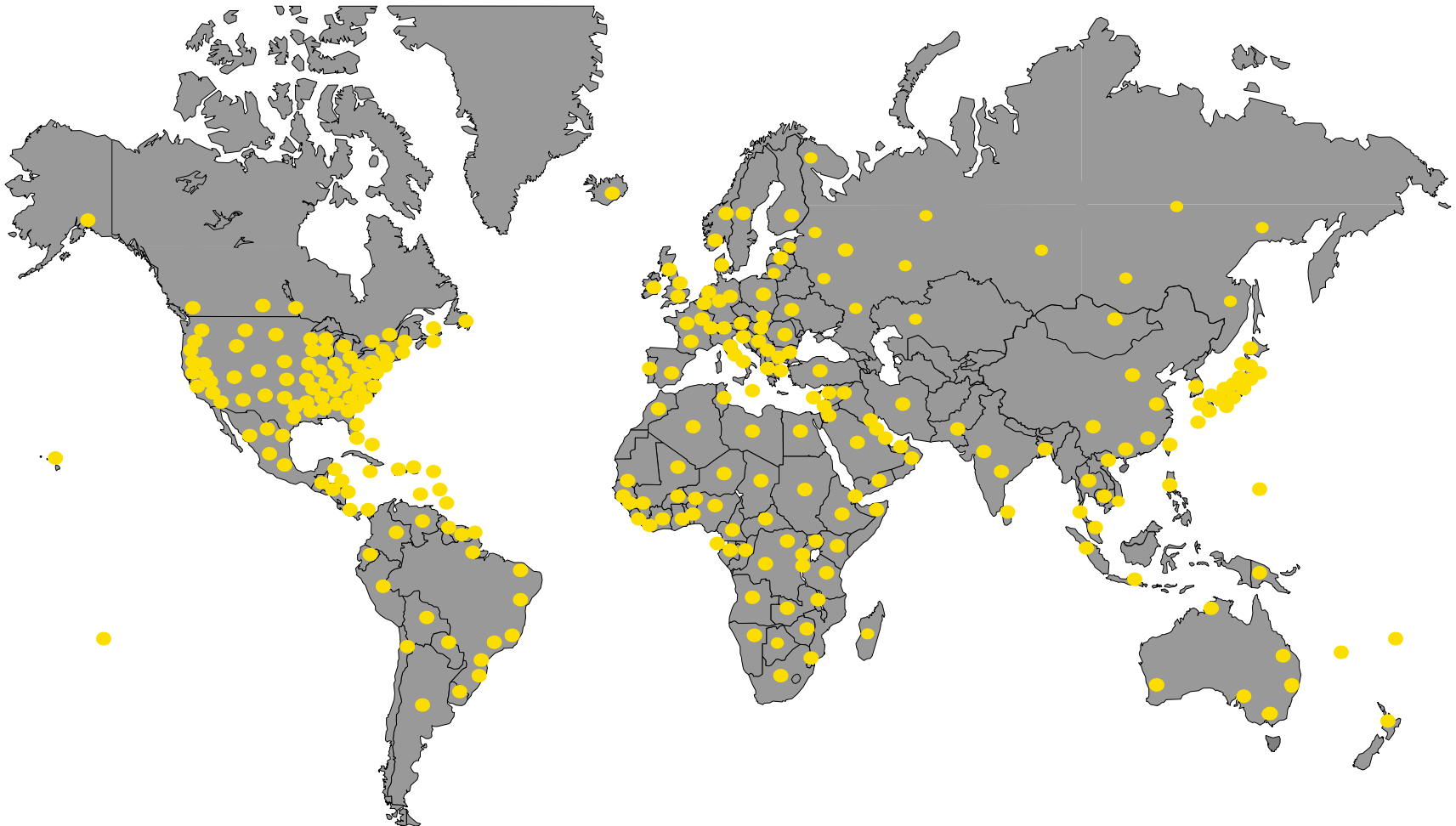
Hundreds of Thousands of Installations World-Wide

- **Commercial / Industrial / Governmental Facilities & Data Centers**
- **Architects / Engineers / Contractors / Developers**
- **Utilities & Municipals**
- **Landfills and Waste Water Treatment Plants (Bio-Gases)**
- **Military**
- **Remote Off-Grid Applications**



Caterpillar: Market Coverage

Global Dealer Networks Covering 180 Countries



Agenda

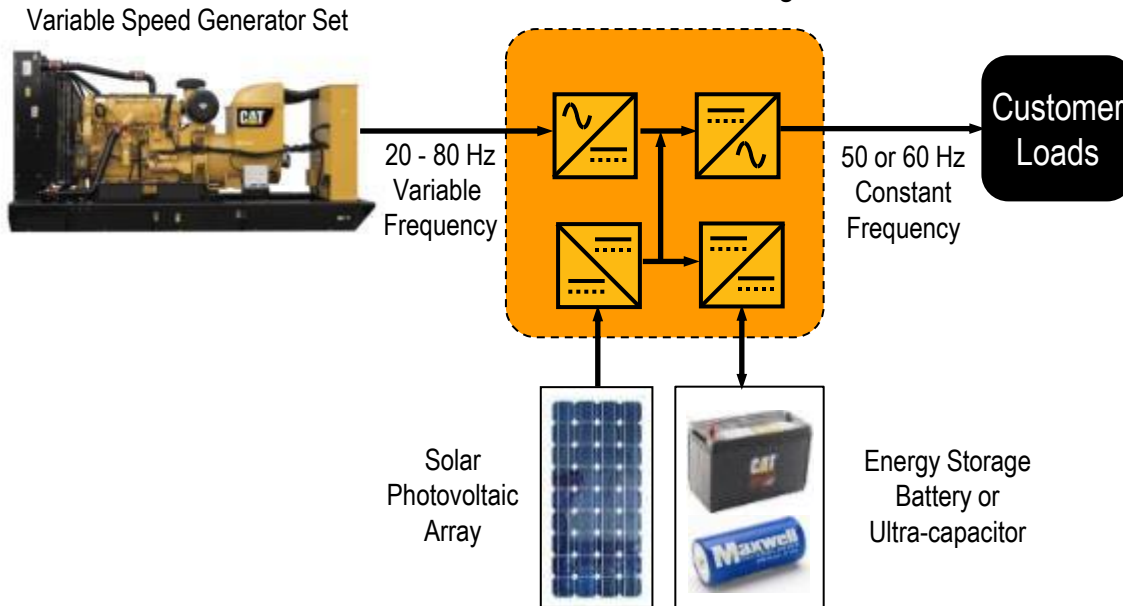
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First Generation Cat Projects

Cat Hybrid Power solution 20 kW with Variable Speed Genset for Military (2008)



Cat Power Electronics
Variable Speed Power Conversion
and Renewable PV Integration



First Commercial Hybrid Power Project - 2011

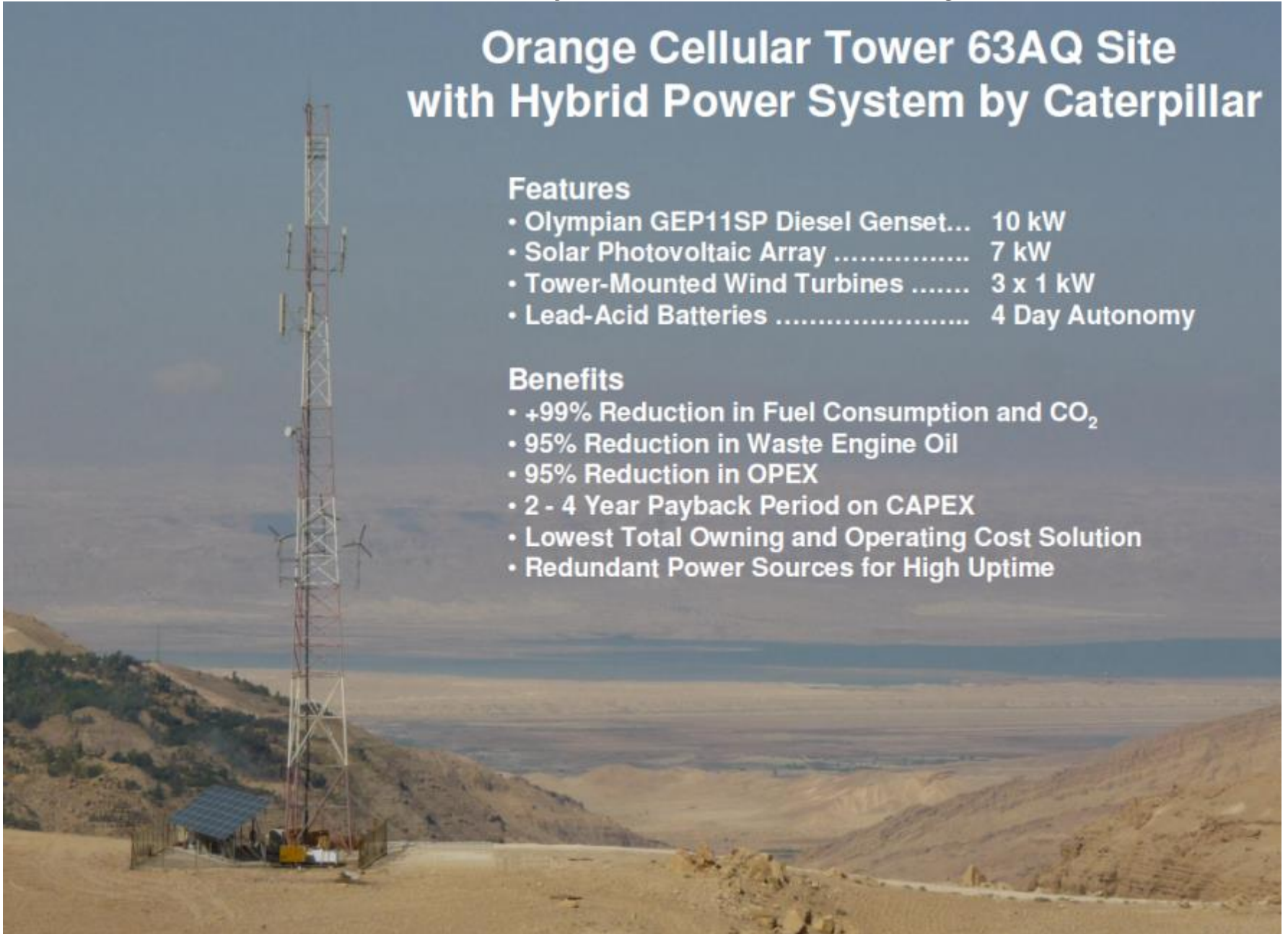
Orange Cellular Tower 63AQ Site with Hybrid Power System by Caterpillar

Features

- Olympian GEP11SP Diesel Genset... 10 kW
- Solar Photovoltaic Array 7 kW
- Tower-Mounted Wind Turbines 3 x 1 kW
- Lead-Acid Batteries 4 Day Autonomy

Benefits

- +99% Reduction in Fuel Consumption and CO₂
- 95% Reduction in Waste Engine Oil
- 95% Reduction in OPEX
- 2 - 4 Year Payback Period on CAPEX
- Lowest Total Owning and Operating Cost Solution
- Redundant Power Sources for High Uptime



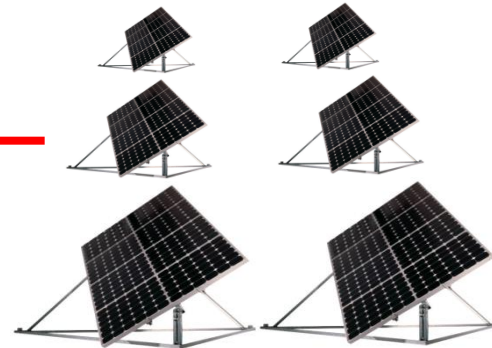
Caterpillar 250 kW Microgrid Project



XQ100 Commercial Gensets



**Energy Storage
for Micro-Grid
Stabilization and
Energy Time-Shifting**



Communications:

Power: _____

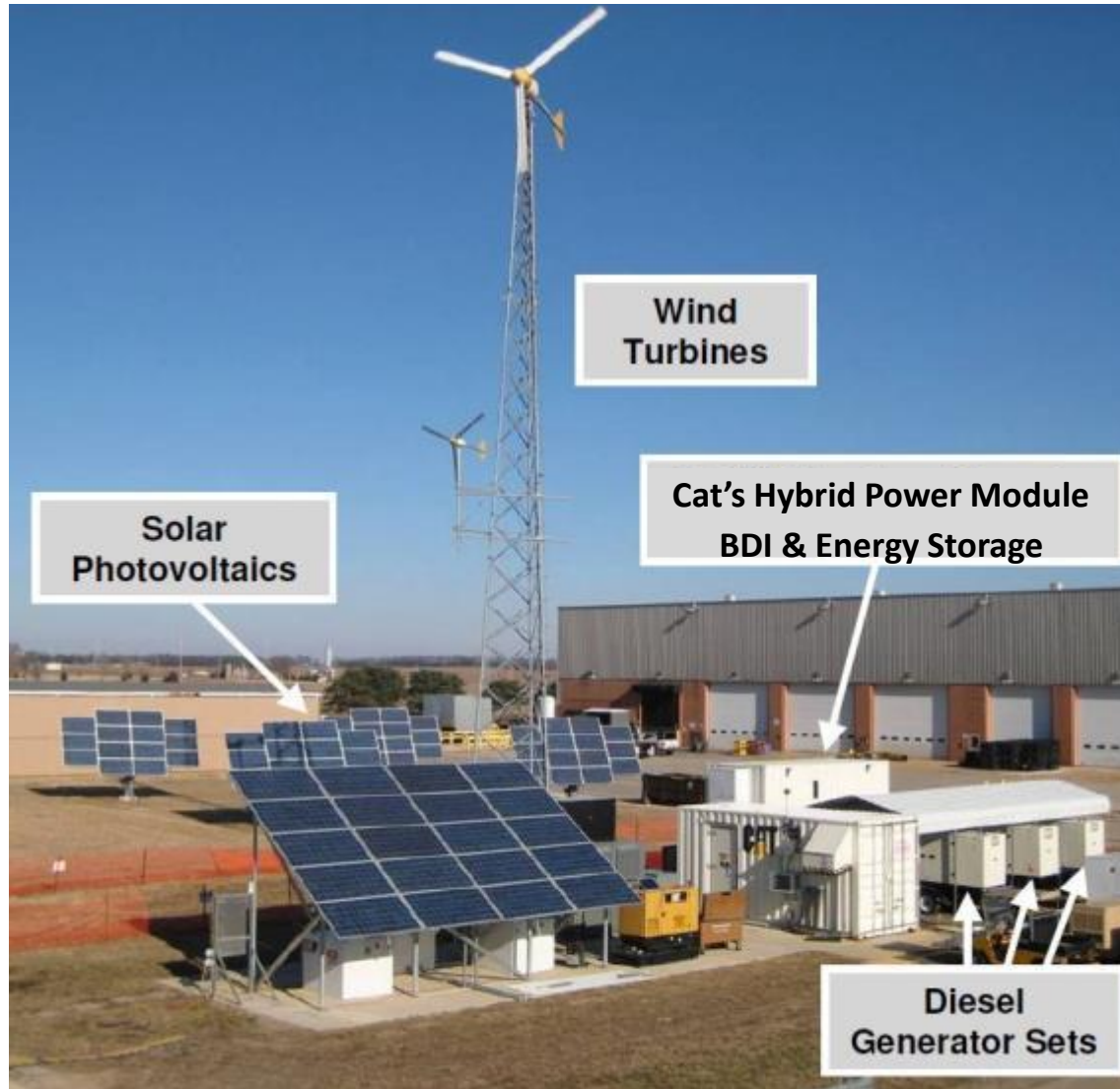
Cat Hybrid Projects

Cat Hybrid Power solution with Solar PV: US Army SAGE project (since 2012)

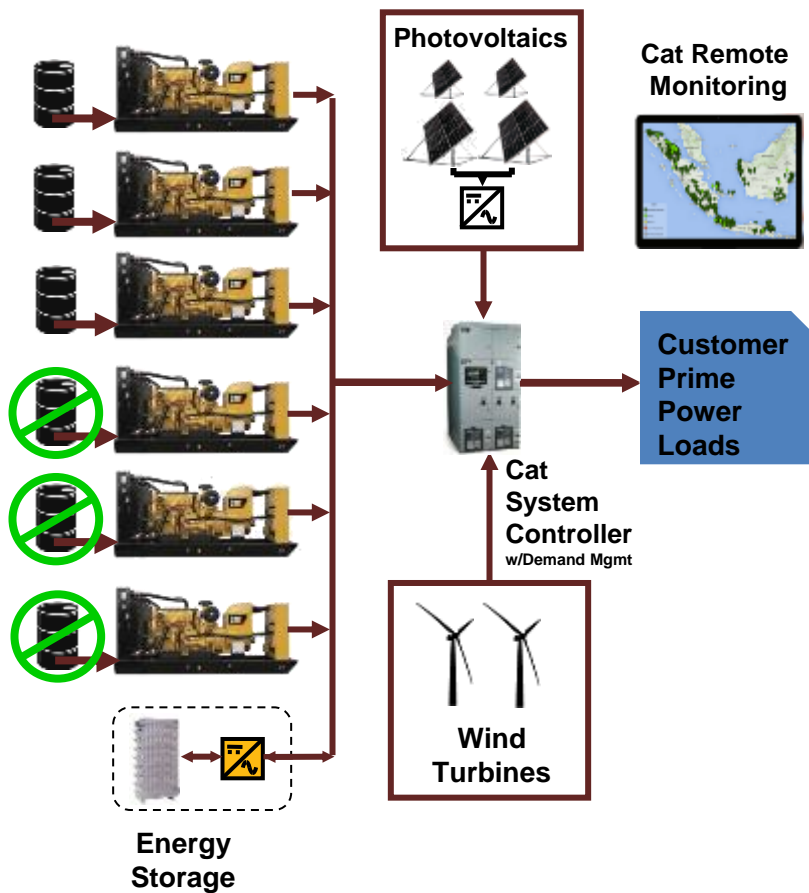


BCIL's South and North camps were each configured to support 150 soldiers. The 3 SAGE shelters in the North camp provided additional space for up to 66 soldiers (22 soldiers per shelter).

Caterpillar Hybrid Power Design and Development Centre



CAT[®] Microgrid hybrid power solution



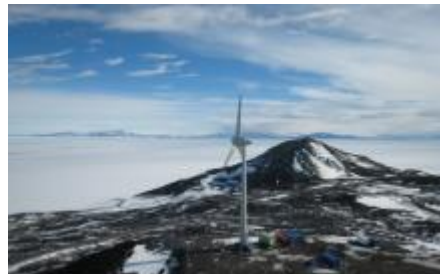
Integrate and Stabilise Renewables

Features

- **Shut Down all Generator sets** if Renewable Energy is adequate
- Stabilise Voltage & Frequency to provide **Grid Stability**
- Provide system with **Virtual Spinning Reserve (VSR)**
- Utilise Energy Storage to **'Time Shift' Renewable Energy**
- Enables **High-Penetration of Renewable Power** to achieve the **lowest Levelised Cost of Energy (LCOE)** or life-cycle costs

Benefits

- Retains full capability of the **reliable base load** (generator sets)
- Substitute Gas/Diesel fuel with "free" Solar and/or Wind Energy to **reduce Fuel & Maintenance** by 5 to 75% PLUS
- **Optimise System Sizing** to meet customer objectives
- Reducing fuel usage also **reduces emissions**
- **Full product support from the same company**



Market Drivers

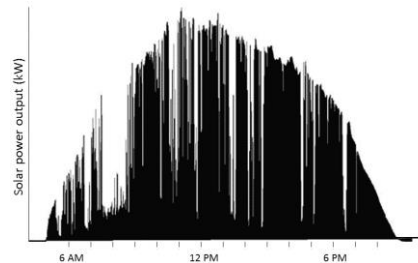
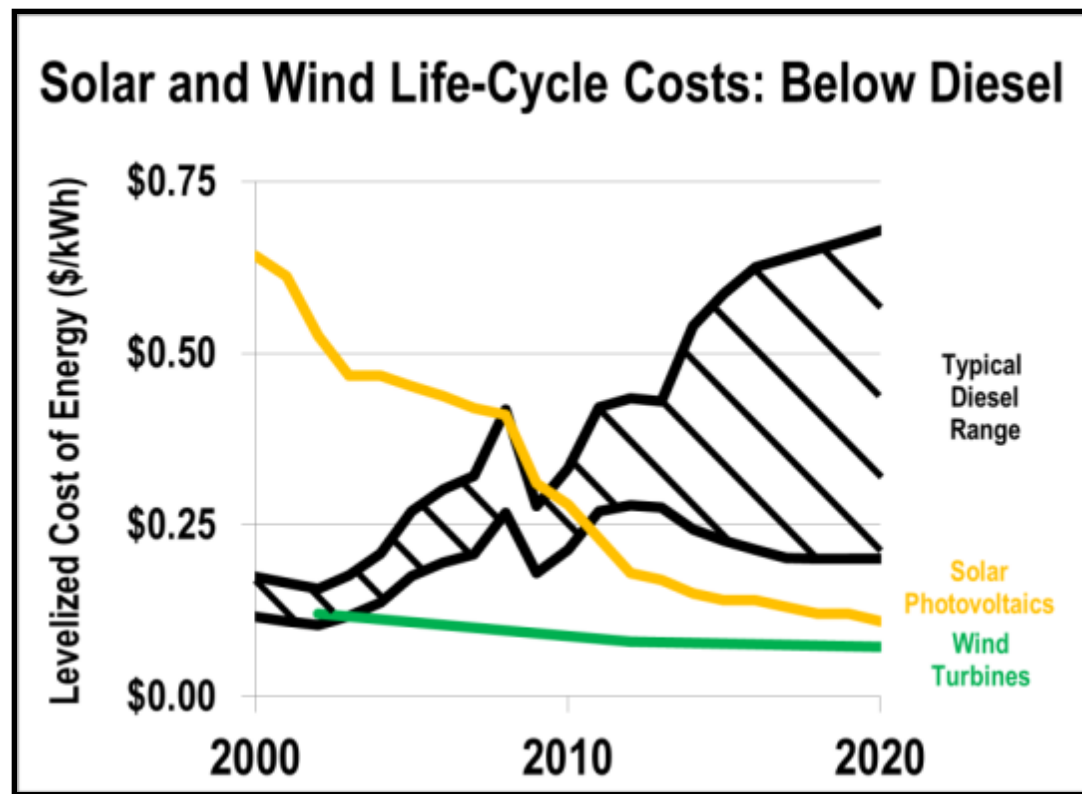
Solar PV (and Wind) levelised cost of energy lower than typical diesel only system.

However, Solar and Wind are **intermittent power sources**.

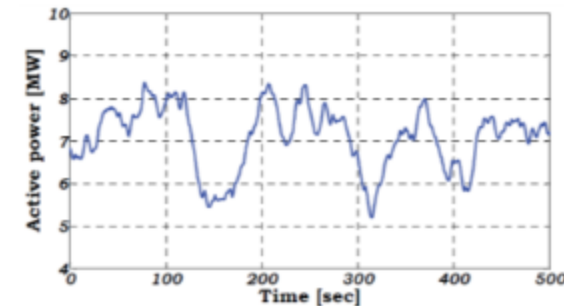
Reliable **base load power** generation and / or **energy storage** required.

Hybrid Power microgrid requires a **combination** of:

- Base load power
- Renewable power source

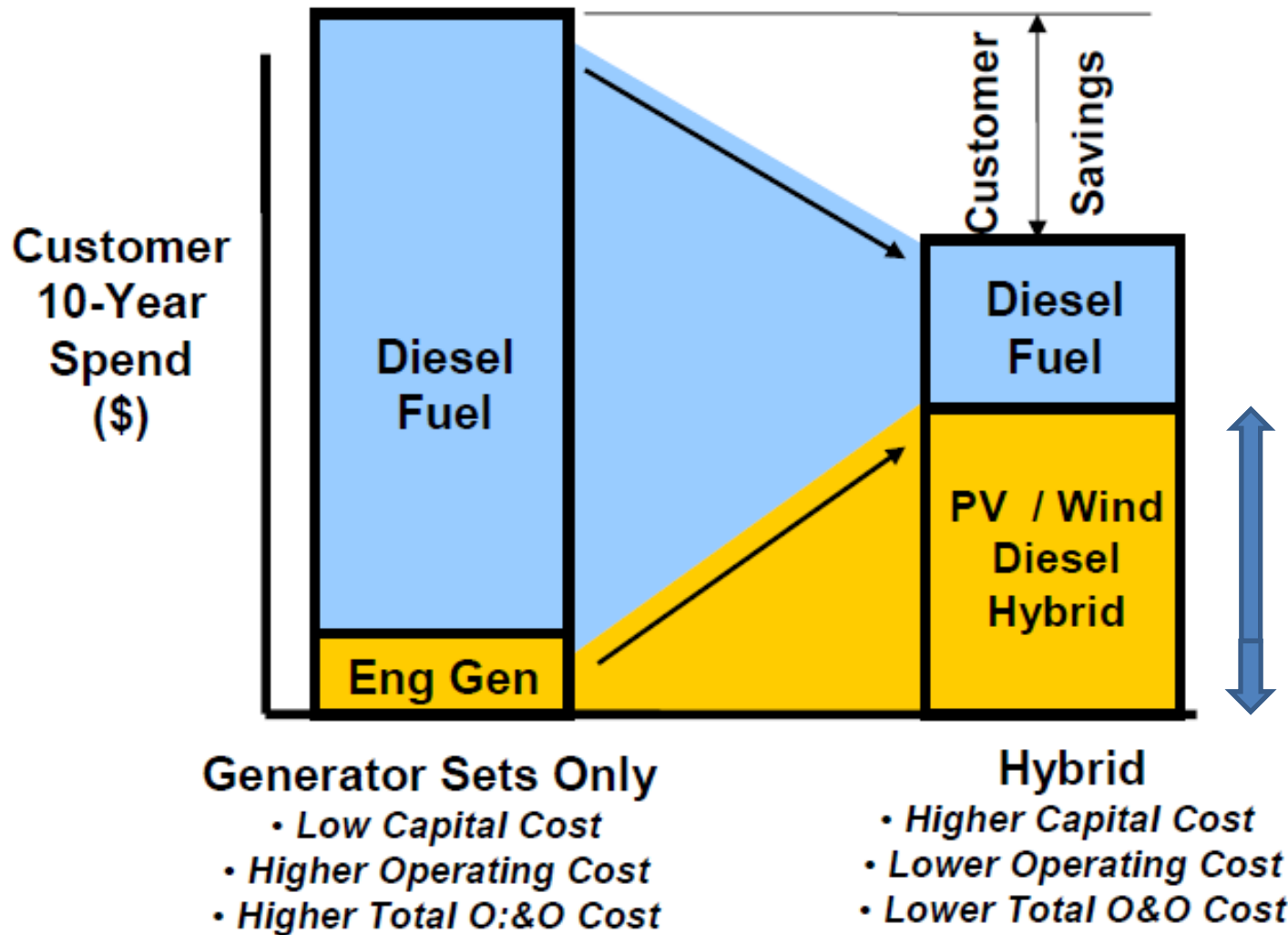


Solar Resource



Wind Resource

Objectives – Economic Justification



Agenda

1. Caterpillar Presence in Power Generation Industry
2. Experience with Integration of Renewable Power and other Emerging Energy Technologies
3. **Critical Success Factors for Successful Projects**

Successful Renewable Integration Projects

Three Critical Success Factors

1. Essential Pre-Work

2. Optimal System Design & Project Execution

3. Long-Term Field Support

Successful Renewable Integration Projects

Three Critical Success Factors

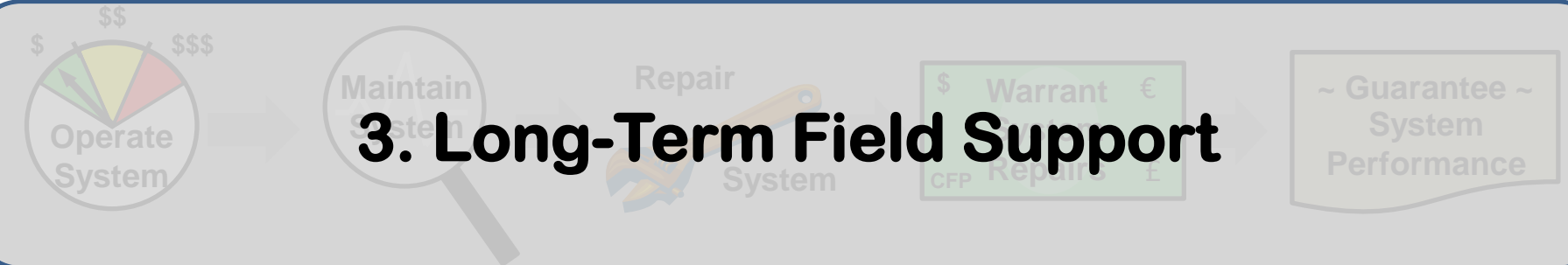
1. Essential Pre-Work



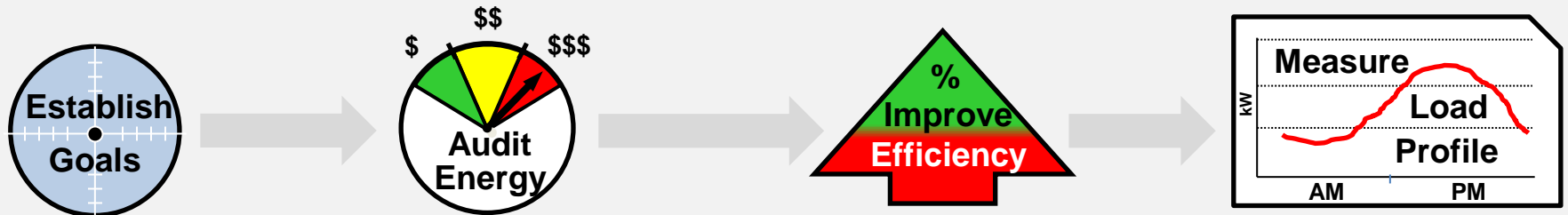
2. Optimal System Design & Project Execution



3. Long-Term Field Support



1. Essential Pre-Work



1. Essential Pre-Work



Key Tasks

- What are you really trying to accomplish?
- What problems can be solved simultaneously with integration of renewables?
- Establish financial criteria for project success
- Establish a high-level timeline and budget

Lessons Learned

- Customers on a steep learning curve
- High-penetration renewables is politically desirable, but economic optimum uses mix of traditional generation, renewables, and storage
- Customers who shift from payback period to levelized cost of electricity see true value
- Access to capital is absolutely essential....
Shift from OpEx-intensive to CapEx-intensive

1. Essential Pre-Work



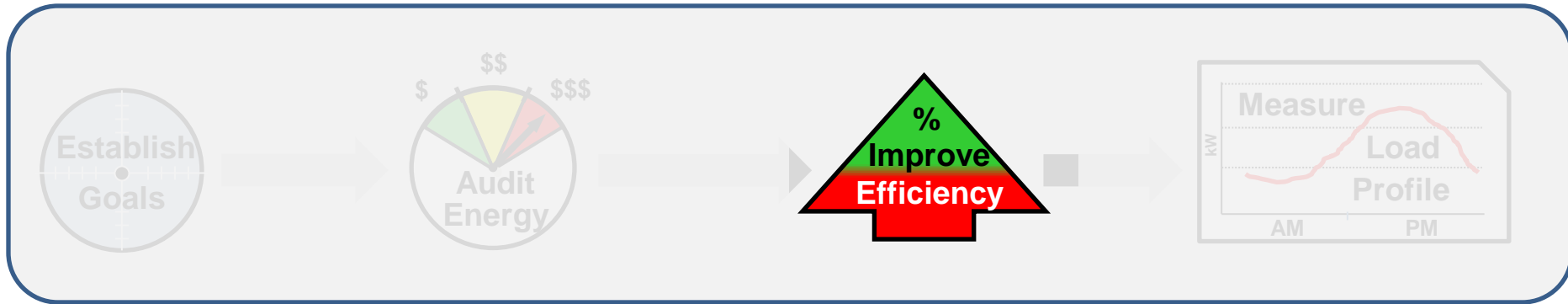
Key Tasks

- Measure energy usage patterns
- Measure generation patterns
- Document equipment efficiency
- Document waste

Lessons Learned

- Energy availability is taken for granted
- Many users are unaware of waste
- Smaller generation systems operate frequently at low load factors giving low fuel efficiency

1. Essential Pre-Work



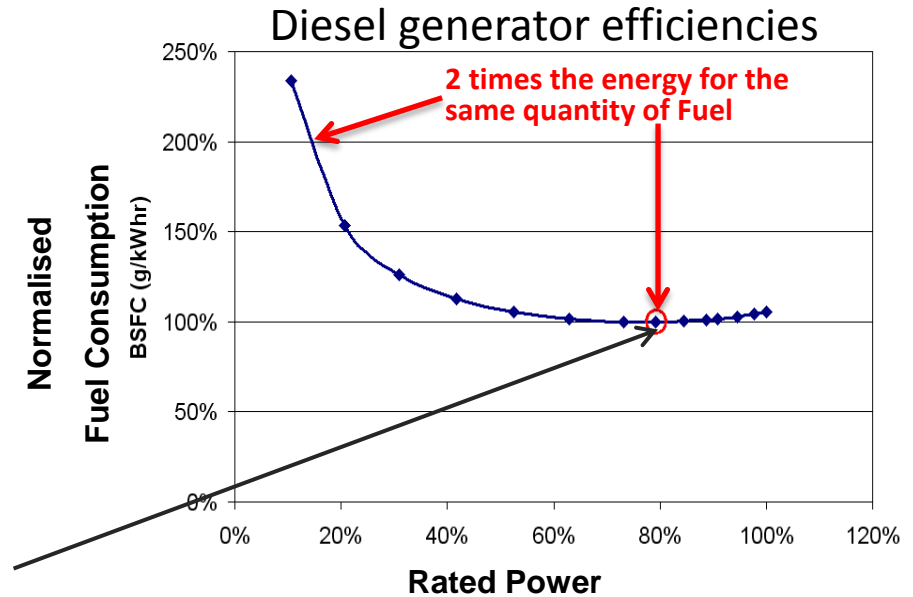
Key Tasks

- Reduce wasted energy usage (unnecessary loads, leaks, redundancy)
- Install equipment with higher usage efficiency
- Install generators with higher fuel efficiency

Lessons Learned

- Improving usage efficiency is often a cost-effective dollar spent (6 mo to 5 yr payback)
- High efficiency HVAC, lighting, telecom transmission equipment, and insulation are typically the most cost-effective usage improvements
- Replacing large generator sets with several smaller generator sets can allow higher load factors higher generation efficiencies
- Smaller generator sets operating at low-load factors can benefit from variable speed operation

Optimising and Maintaining Reliable Baseload Power



- Peak efficiency at 70-90% of maximum rating
- Low loading can cause carbon build-up from poor combustion.
- Large Generators typically more efficient than smaller generators
- Applications with Single Generator Set
 - Variable Speed Generators
 - Cycle-Charging Generator/Battery Systems (Charge-Discharge)
- Applications with Multiple Generator Sets
 - Break load into smaller segments, run generator sets at higher load factor
 - Good candidates for Energy Storage as “virtual spinning reserve”

1. Essential Pre-Work



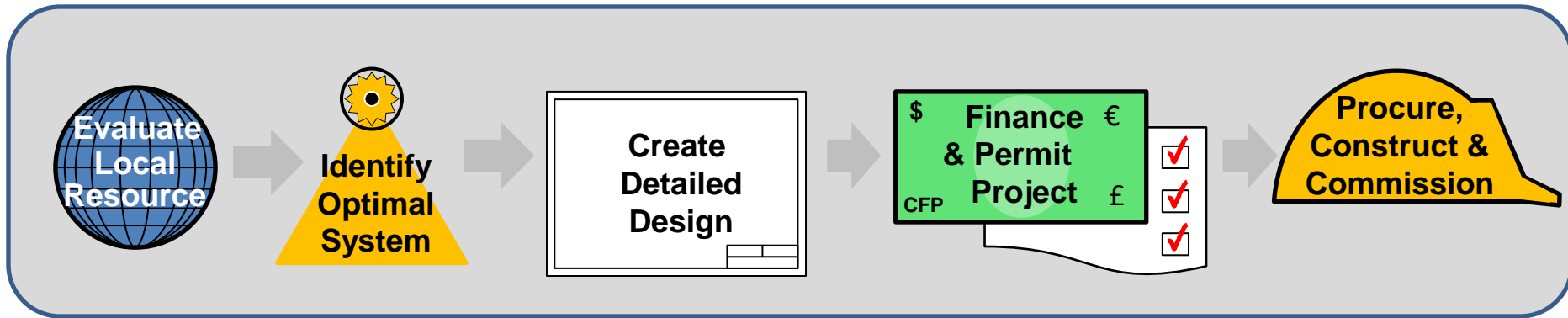
Key Tasks

- Measure actual load profiles (hourly, minute)
- Identify load surges (motor starts, current inrush)
- Forecast loads from new equipment
- Characterize loads by time of day, week, year
- Account for efficiency improvements

Lessons Learned

- Accurate load profile data is critical for optimal sizing of renewable systems
- Many commercial / industrial users are far less aware of load profile than utilities
- Look for opportunities to match loads to times of low-cost generation or renewable availability
- Identify soft-start or walk-in strategies to reduce load surges and enable less spinning reserve

2. Optimal System Design & Project Execution

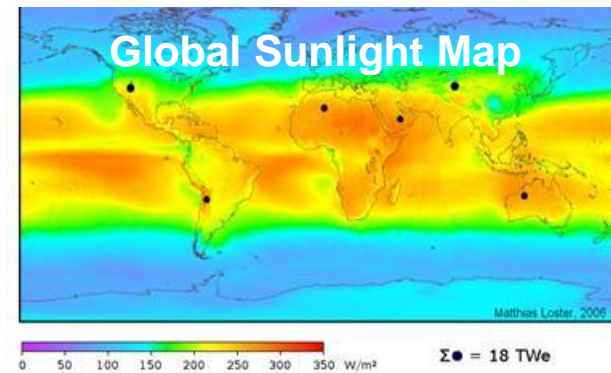


2. Optimal System Design & Project Execution

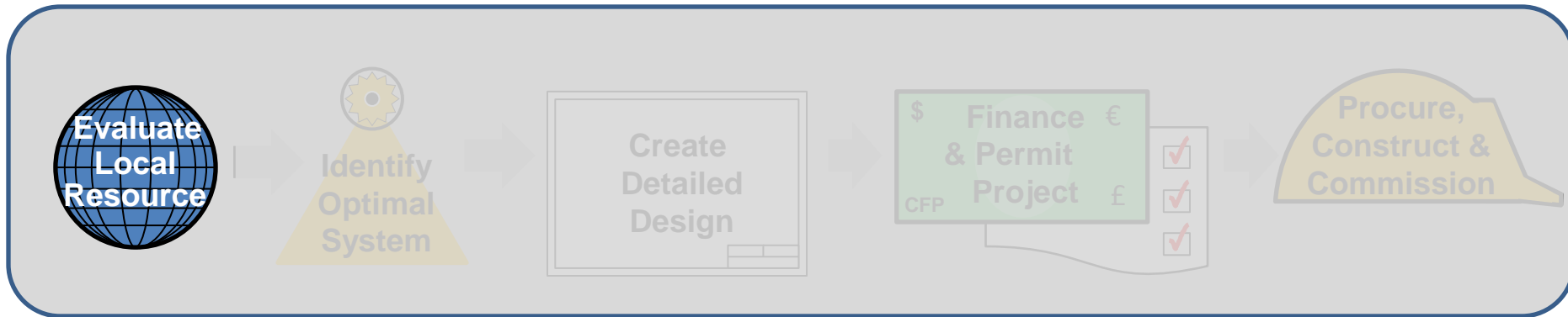


Key Tasks

- Obtain site-specific solar radiation from global databases
- Obtain wind speed from global databases or local weather stations
- Obtain fuel cost including delivery to site and government fuel subsidies
- Evaluate site transportation logistics
- Perform geotechnical survey for construction conditions



2. Optimal System Design & Project Execution



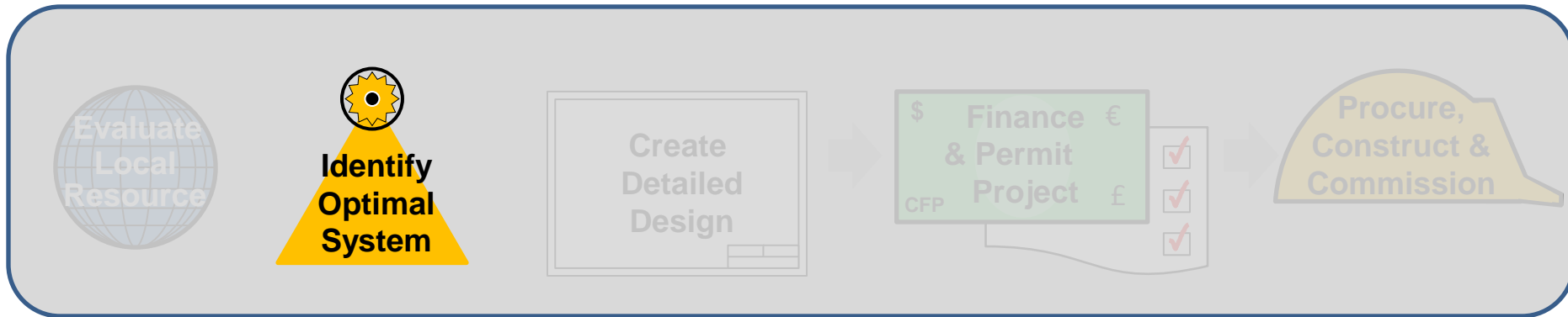
Key Tasks

- Obtain site-specific solar radiation from global databases
- Obtain wind speed from global databases or local weather stations
- Obtain fuel cost including delivery to site and government fuel subsidies
- Evaluate site transportation & construction logistics
- Evaluate site conditions (cursory)

Lessons Learned

- Solar is a widely distributed resource
- Wind is a highly site-specific resource, typically best on coastlines and mountains
- Large items are difficult to transport to very remote sites

2. Optimal System Design & Project Execution







Key Tasks

- Make site-specific cost estimates for PV, wind
- Model site-specific and load-specific performance using computer simulation
- Evaluate all combinations of PV / wind / storage / gensets
- Evaluate sensitivity to fuel price, installed cost, renewable resource availability
- Select 2-3 solutions that offer optimal customer value proposition

Lessons Learned

- Renewable penetration level drives need for energy storage in various amounts
- Low-penetration systems have fastest payback, but lowest fuel savings and can lead to genset light-load issues
- Medium-penetration systems are attractive at current energy storage prices. Enable engine shut-down
- High-penetration systems more attractive at high fuel prices or lower energy storage cost points

Typical Renewable Penetration Levels

System Configurations				
Fuel Savings Objective	Solar PV	Storage	Wind	
				
	Above 30% Fuel Savings	PV Size Greater than Generator Set Capacity	Energy Storage for Power Stability & Energy Time-Shifting	Wind Turbine Size Greater than Generator Set Capacity
	10-40% Fuel Savings	PV Size Equal to Generator Set Capacity	Energy Storage for stability	Wind Turbine Size Equal to Generator Set Capacity
	5-10% Fuel Savings	PV Size Under 15-20% of Generator Capacity	No Energy Storage required	Wind Turbine Size 15-20% of Generator Set Capacity
	2-5% Fuel Savings	No PV	Energy Storage for Reducing Generator Spinning Reserve	No Wind Turbines
Baseline	Prime Power Generator Sets			
				



2. Optimal System Design & Project Execution



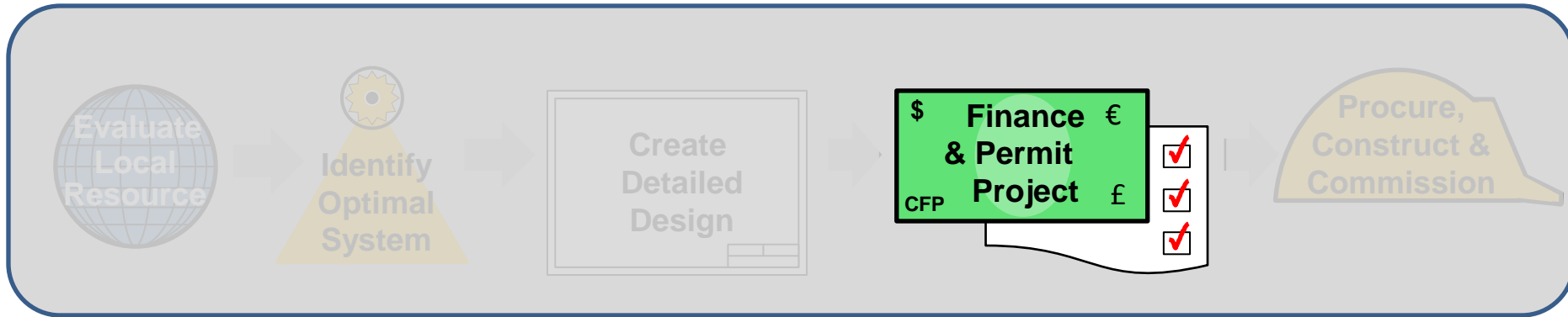
Key Tasks

- Model transient behavior for power quality
- Model distribution network behavior
- Perform geotechnical survey for construction conditions – site prep, foundations, cable runs
- Create detailed construction drawings
- Refine project costs

Lessons Learned

- Renewable transient behavior and customer power quality requirement may modify needs for energy storage
- Connection of renewables to distribution network may cause voltage problems
- Energy storage system and PV / wind inverters can be used to correct poor power factors and improve system efficiency
- Fault performance, low voltage ride through, and protection schemes must be adjusted to ensure proper system behavior under all contingencies

2. Optimal System Design & Project Execution



Key Tasks

- Identify potential sources of grants, loans, leases, or power purchase agreements
- Create financing structure most appropriate for the project
- Secure access to site, obtain appropriate permits

Lessons Learned

- Access to capital is greatest challenge for renewable energy adoption
- Availability of sites can be second greatest challenge
- Governments and local tribes / indigenous peoples often control site availability
- Wind turbines can be more difficult to permit than PV

2. Optimal System Design & Project Execution



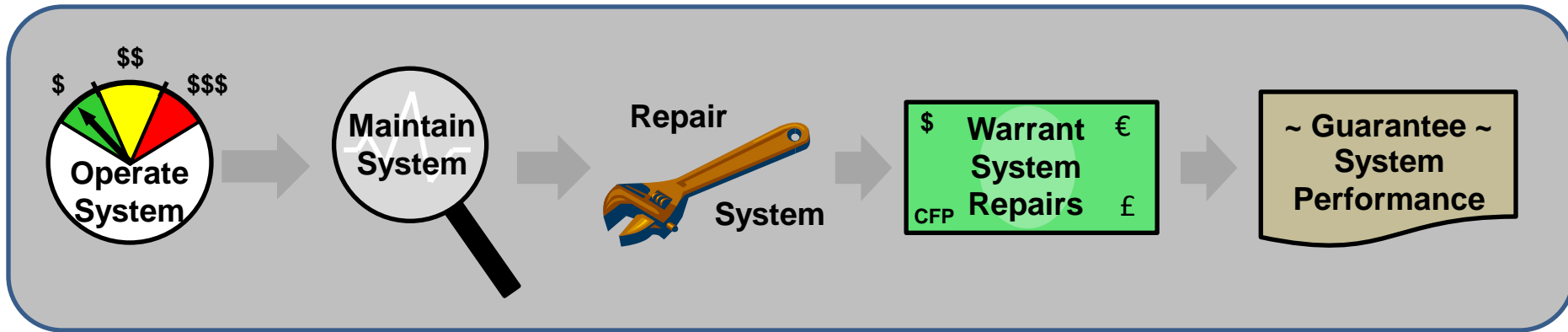
Key Tasks

- Coordinate supply and shipment of all components to site
- Coordinate site build
- Startup individual systems, overall controls, and demonstrate performance meeting specs
- Train local operators

Lessons Learned

- Factory integration and test of components
- Complexity of construction jobs varies widely
- Low availability of tools and supplies in remote areas can be time-consuming and costly

3. Long-Term Field Support



Key Tasks

- Perform all tasks to enable system to operate as intended for project life

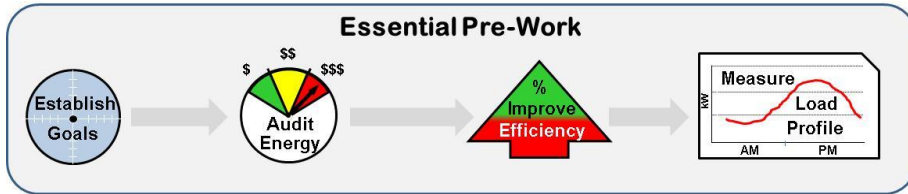
Lessons Learned

- Many early remote hybrid systems failed due to lack of proper operation and maintenance
- Operating condition may change over system life
- Few parties are adequately staffed to service hybrid systems in remote areas
- Many EPC companies do not offer post-commissioning support
- System owners can be left to fend for themselves

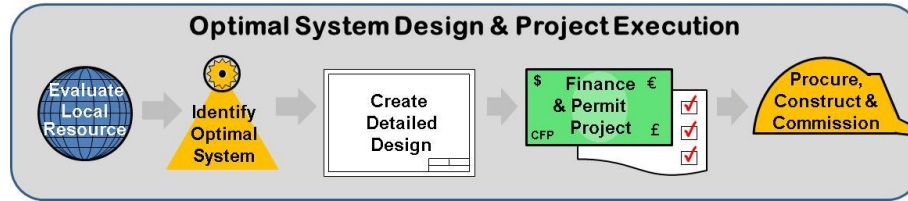
Our Success Depends Heavily upon Field Support

Up to 2 Years

Essential Pre-Work

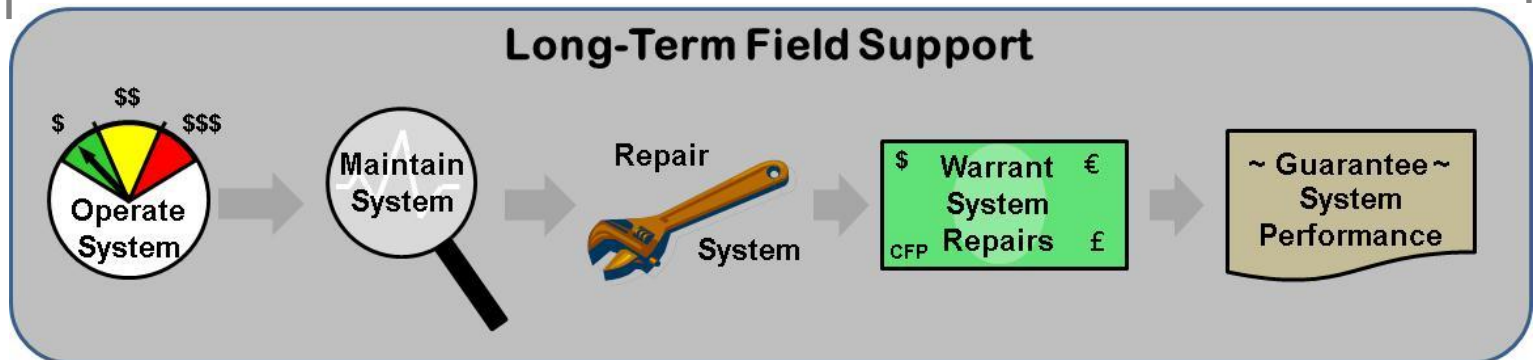


Optimal System Design & Project Execution



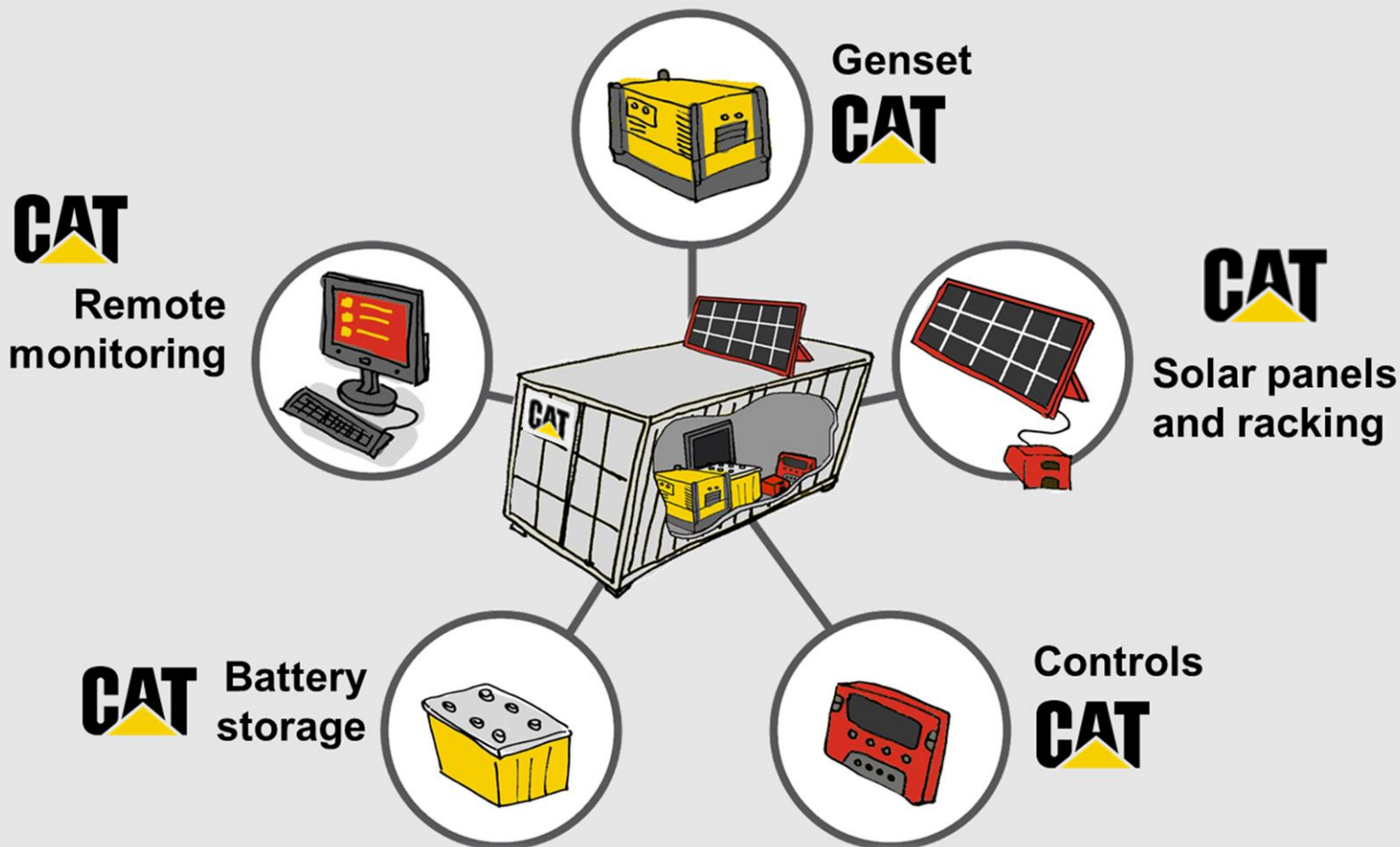
10-40 Years in Field Operation

Long-Term Field Support



Single source your Microgrid power solution

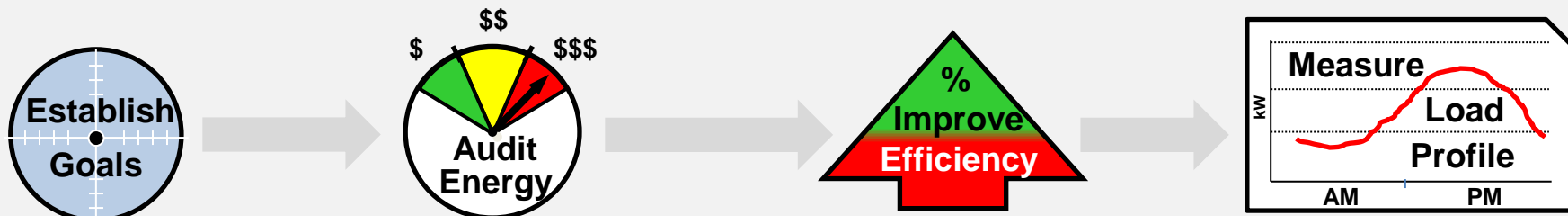
One way to reduce risk and ensure integrating of renewable energy is a success



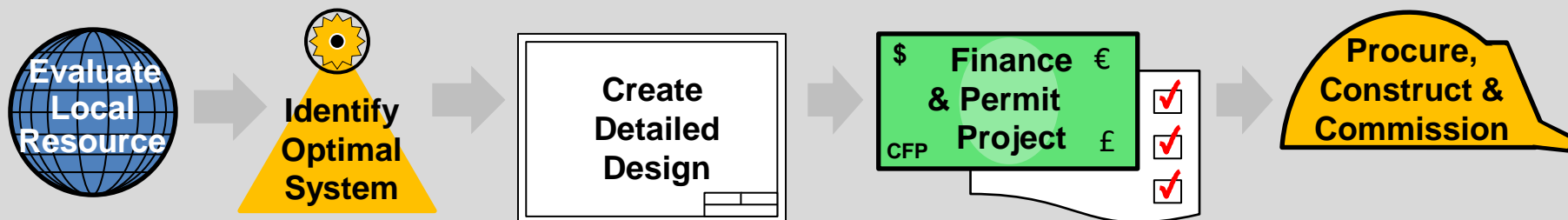
Including lifetime support from the same company

Recap: Critical Success Factors

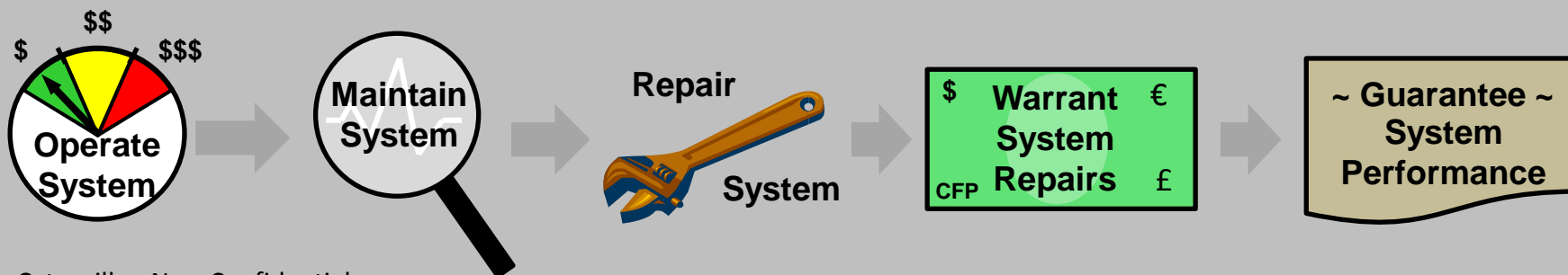
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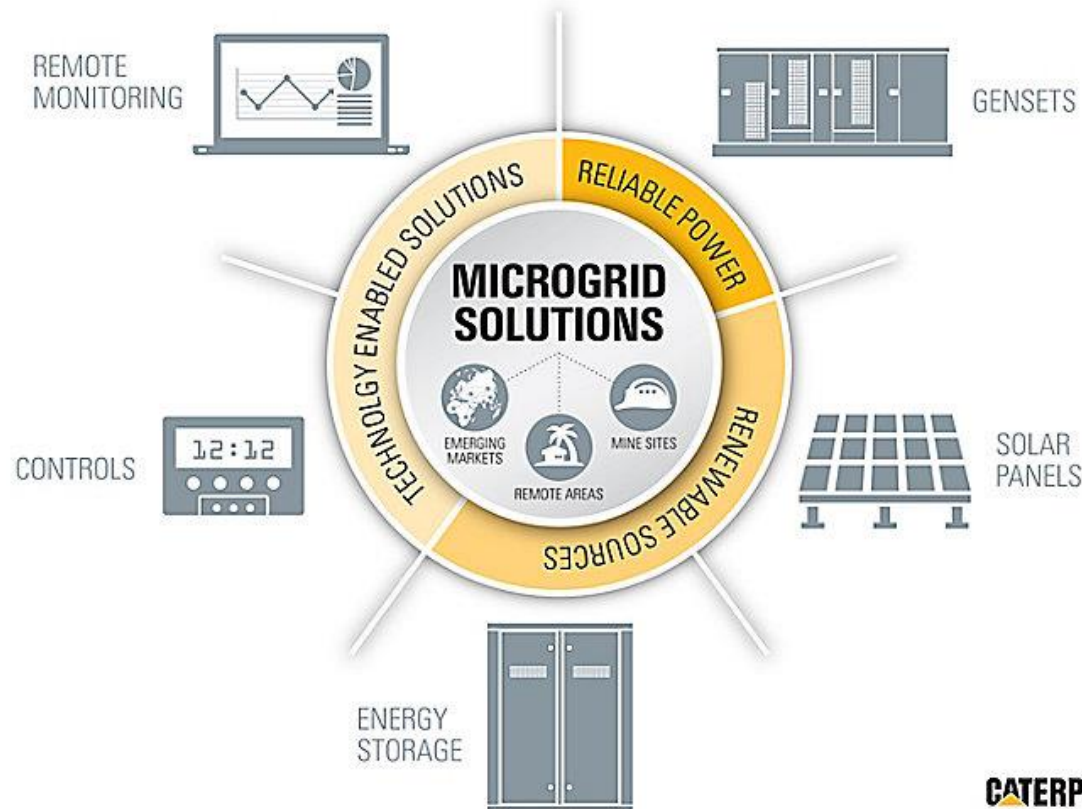
2. Optimal System Design & Project Execution



3. Long-Term Field Support



Powering Sustainable Progress. Everywhere. All the time.



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Thank you