“GOING HYBRID“

THE SUSTAINABLE ELECTRIFICATION OF A MONASTIC COMMUNITY

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CONTENTS

THE TASK

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- RES power supply to a remote Monastic Community
  - Monastic Community (not Monastery) because of multiple dispersed installations
- Customer
  - Wants to have complete RES power coverage
  - Serious investigation started years ago (when Hydro was still competitive to PV !)
  - Much more engineering-aware than average
  - Very competent in technical skills & support activities
  - Very resourceful (this attribute is both Good and Bad)

  BUT ALSO
  - Has reservations about technical effectiveness of solution
  - Has reservations about cost-effectiveness of solution
  - Would rather see live-proof of success before fully committing
  - Has real "*needed-yesterday*" requirements that cannot be "orderly" satisfied
- Result:
  - Need for <u>Phased project implementation</u>
  - Need for Modular & Scalable system that can satisfy "needed-yesterday" requirements and allow introduction of equipment in subsequent phases
- *"**TASK:** Phased transition from Full Diesel to "Full" RES"*

THE SITE

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- Location: Mount Athos, Greece

OUR METHODOLOGY

- **STANDARD APPROACH**
- Step 1: Pre-plan based on EUROSOL Expertise
- Step 2: Customer & Site Audits
- **Step 3: Simulate for Cost Optimization (dynamic simulation)**
- **Step 4: Optimize for Effectiveness (*"de-optimize"* Step 3)**
- Step 5: Design Solution (introduce actual equipment to Step 4)
- Step 6: Verify with Technology Providers (boundary conditions)
- Step 7: Verify Final Design – Dynamic Simulation

- **PROJECT APPROACH**
- Step 1: Pre-plan based on EUROSOL Expertise
- Step 2: Customer & Site Audits
- Step 3-Step 4: Repeat for all possible systems for phased implementation
- Step 5: Design Phase 1 Solution
- Step 6: Verify Phase 1 Solution with Technology Providers
- Step 7: Verify Phase 1 Final Design – Dynamic Simulation

ON-SITE AUDITING

PROJECT RESTRICTIONS

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LOADS 1

4 building clusters with 4 different load types (time & intensity):

- Monastery
  - 24/7 operation, critical & non-critical loads, rigid schedule
- Woodshop
  - 8/5 operation, critical & non-critical loads, rigid schedule
- Garage & Metal Works
  - 12/7 operation, critical & non-critical loads, flexible schedule
- Workers Compound
  - 24/7 operation, non-critical loads, flexible schedule
- VERY Detailed Recording & Analysis
  - Iteration 1 Monastery Battery Loads: **68 kWh per day**
  - Iteration 5 Monastery Battery Loads: **197 kWh per day**

That is A BIG DIFFERENCE !!!

LOADS 2

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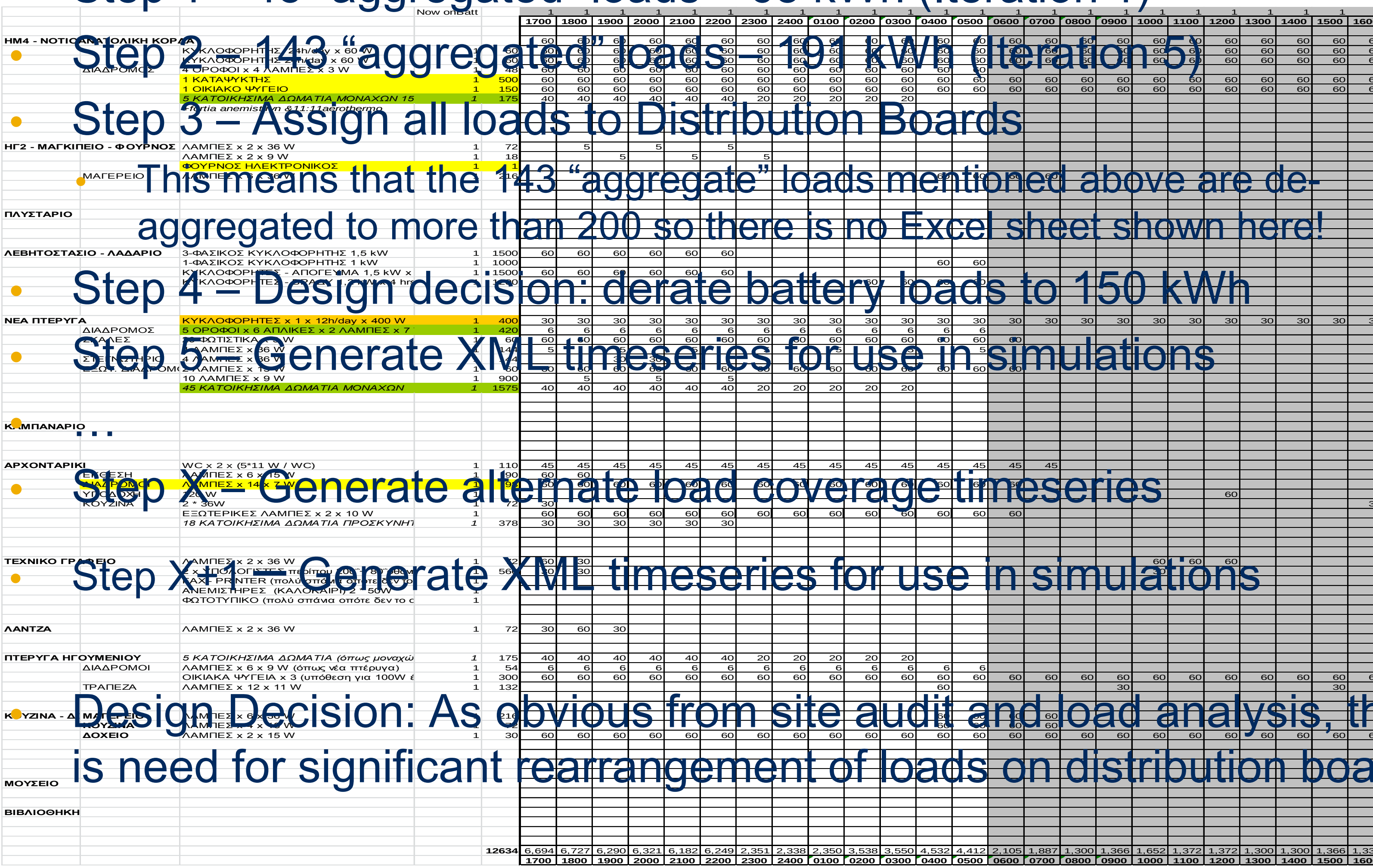
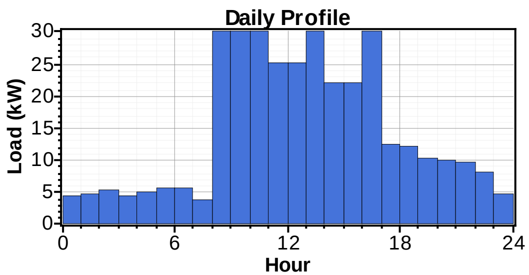
- Load Cataloguing and Analysis – Monastery
  - Step 1 – 45 “aggregated” loads – 68 kWh (Iteration 1)
  - Step 2 – 143 “aggregated” loads – 191 kWh (Iteration 5)
  - Step 3 – Assign all loads to Distribution Boards
    - This means that the 143 “aggregate” loads mentioned above are de-aggregated to more than 200 so there is no Excel sheet shown here!
  - Step 4 – Design decision: derate battery loads to 150 kWh
  - Step 5 – Generate XML timeseries for use in simulations
  - …
  - Step X – Generate alternate load coverage timeseries
  - Step X+1 – Generate XML timeseries for use in simulations
  - Design Decision: As obvious from site audit and load analysis, there is need for significant rearrangement of loads on distribution boards

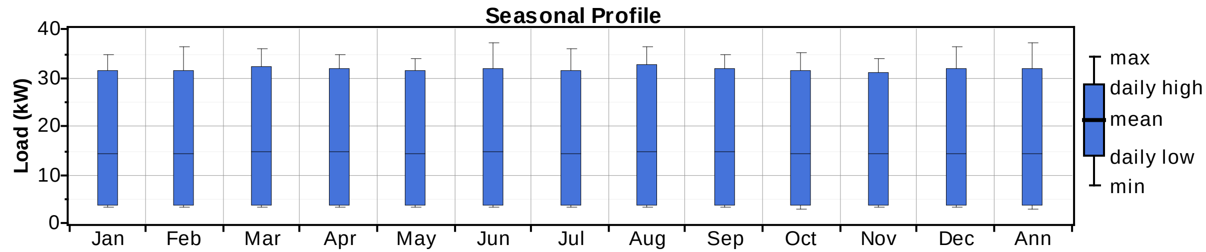


LOADS 3

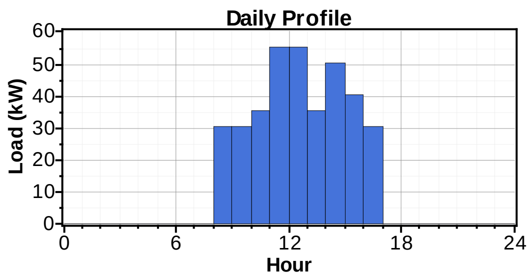
For our simulations we used 3 different load segmentations:

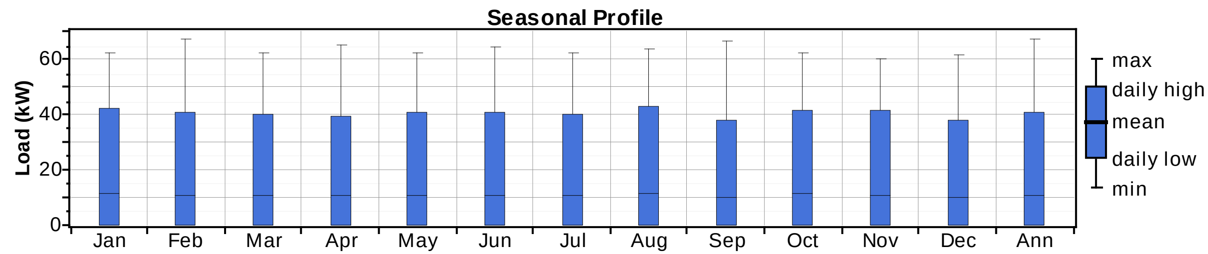
1. Full Loads – Monastery



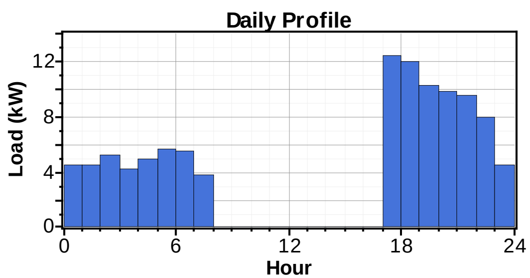


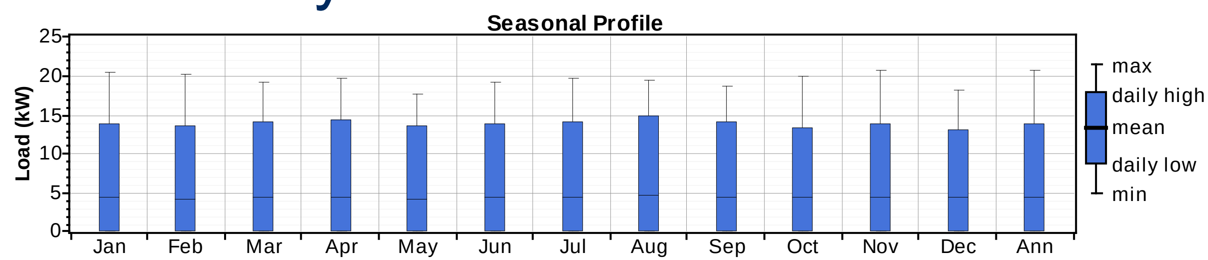
2. On-Gen Loads – Woodshop (this is Full as well)





3. Off-Gen Loads - Monastery





PROJECT PLANNING - PHASES

Due to budget scheduling and *"needed yesterday"* issues we planned for a minimum of 3 phases:

- **Phase 1:** Energy Storage, Distribution Grid, Load Management

- **Phase 2a:** Extension of Energy Storage & Delivery
- **Phase 2b:** PV, Wind and Energy Management

- **Phase 3a:** Extension of Energy Storage & Delivery
- **Phase 3b:** Small Hydro (old plan, may not be possible due to costs)

SYSTEM SIZING & SIMULATION

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As stated, we sized & simulated distinct systems for all potential implementation phases, starting from the AS-IS in order to verify our assumptions & analysis.

- **AS-IS:** Assumed Loads, Existing Batteries, Generators Only
- **Phase 1:** Selected Loads, New batteries, Generators Only
- **Phase 2:** Phase 1 + PV + Wind + Additional Loads + Battery Extension
- **Phase 3:** Phase 2 + Small Hydro + Additional Loads + Battery Extension

- *HOMER Energy* used for running all scenarios
- Loads repeatedly re-generated for each specific scenario
- AS-IS simulation verified Load calculations, generator diesel consumptions and our assumptions

PHASE 1 - TECHNICAL SOLUTION 1

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- After countless simulation rounds and all scalability consideration accounted for (steps 3 to 6 in our methodology), we ended up with the following solution for phase 1:

1. Discrete power feed to Woodshop, not supported by our energy storage system
2. 525 kWh nominal battery capacity, 30% DoD allowed, 160 kWh usable capacity
3. Need for battery inverters to supply at least 30 kW continuous power and 55 kW for 1-3’
4. Using SMA power electronics, the following system configuration was chosen:

	Description	QTY
SMA Components	Sunny Island 8.0 H Master	2
	Sunny Island 8.0 H Slave	4
	MC Box 36.3	1
	Sunny Webbox	1
	Batfuse-B.03	2
Batteries	Enersys PowerSafe TYS 11 (2V)	144
	Airlift (48 V) Electrolyte System Circulation	6
	Rack SGS 2-14 HH	8
	Rack SGS 2-27 HH	2
Electrical Boards	Boards	5
Site Material	Plantron - 3G RUT	1
	Minor - Not Invoiced	5

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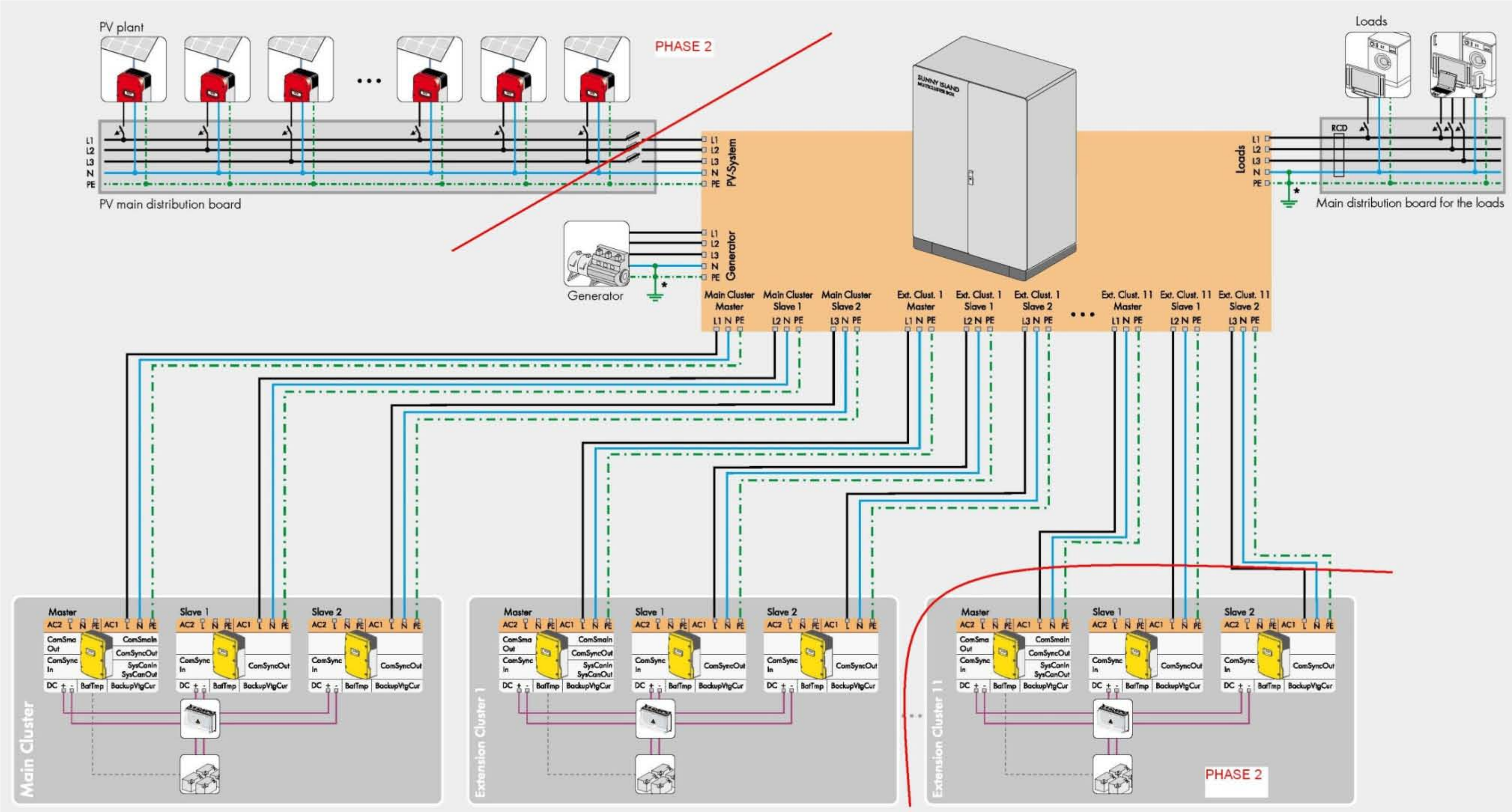
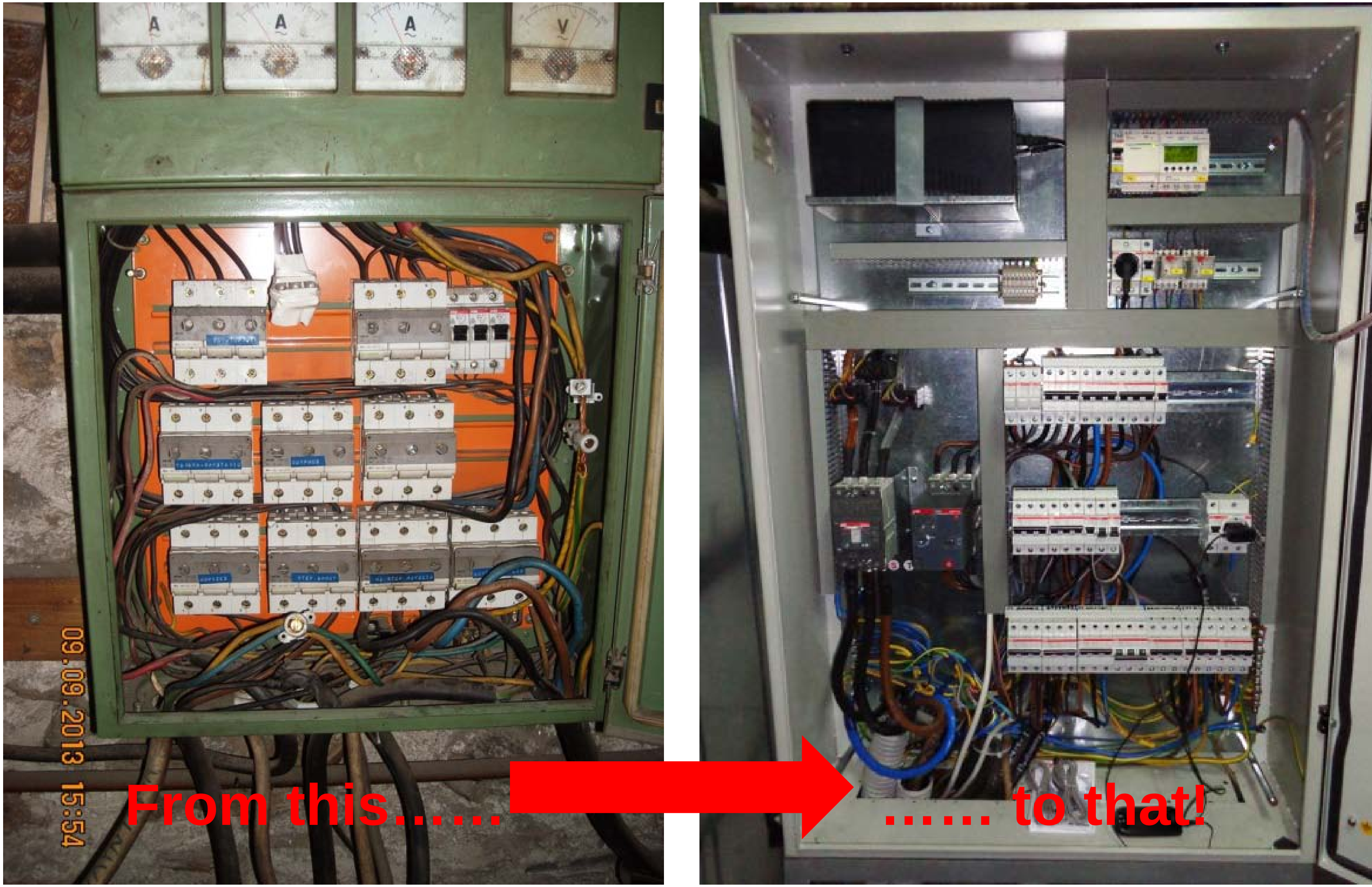
Typical off-grid architecture based on the SMA Sunny Island and Multi Cluster Box solutions.



PHASE 1 - TECHNICAL SOLUTION 3



Energy Storage Centre Housing

PHASE 1 – INSTALLATION 2

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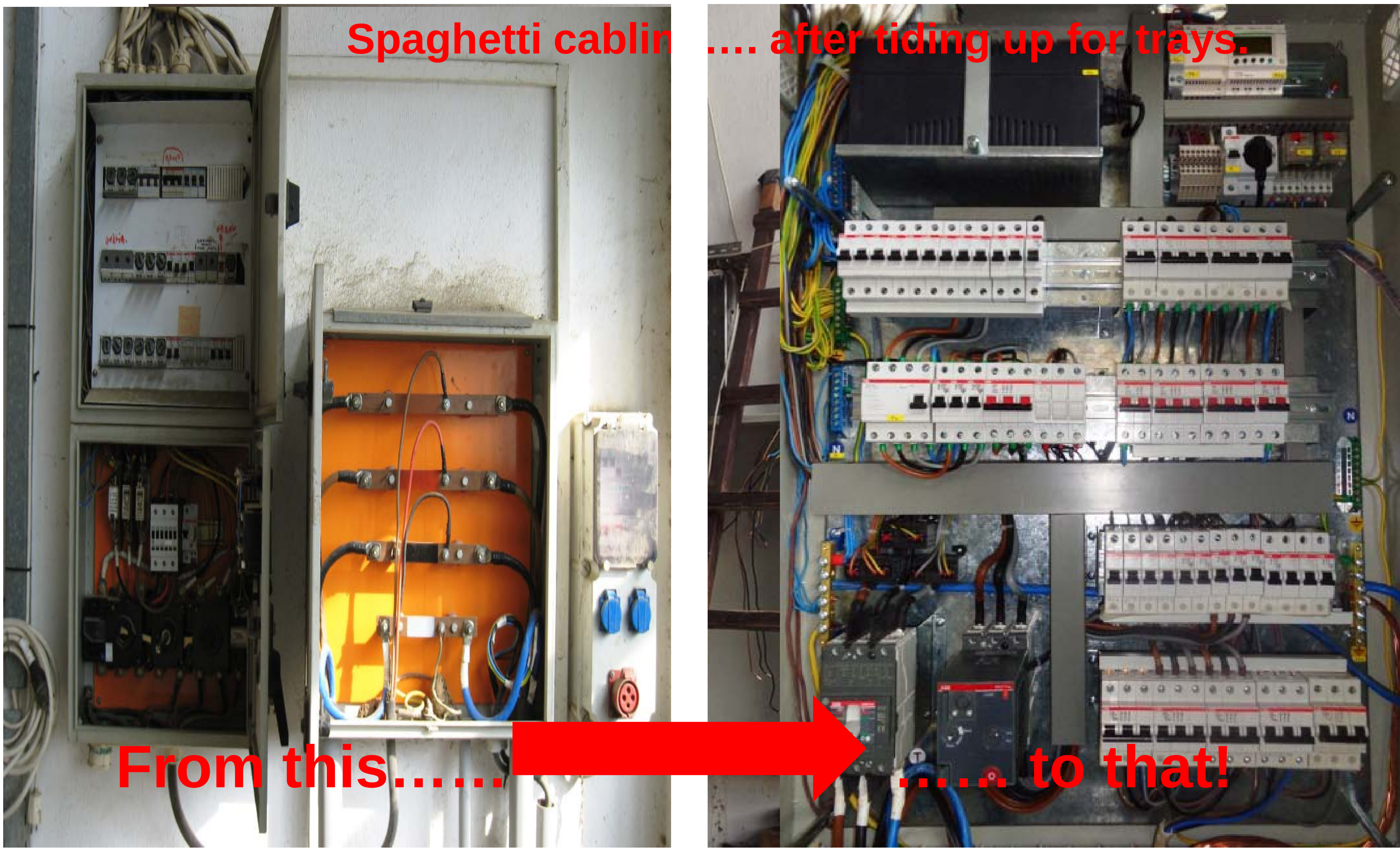
Or, How a planned 5-day job becomes a 10-day job!



PHASE 1 - OPERATION

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System operates as expected…Well… almost!

- Diesel consumption down from 90,000 lt/year to 52000 lt/year
- Some “hiccups” …
  - Unexpected system shutdown during Power-Up
  - Unexpected system shutdown during Power-Down
    - Both solved by judicious PLC programming
  - Uneven phase loading
    - Planned for resolution next month
  - Unidentified & undocumented large loads on power up
    - User behaviour – resolved
- Some strange behaviour…
  - Uneven battery bank discharging/recharging (under investigation)
  - Probably measurement error due to different initial charge state of the two banks and manual gen-set operation (not controlled by our system yet)

PHASE 2

Phase 2 has already started:

- PV Plant Status
  - Position identified
  - Cable routing options identified
  - LV/MV/LV transmission solution due to distance (over 750m)
  - Customer is deciding between 100, 150, 200, 250 kWp
- Wind Generator Status
  - Wind potential in 2 specific locations has been measured for the past 4 months with very good results
    - Overall average wind speed 5.9 m/s
    - Night average wind speed 6.3 m/s
  - Wind generator selection is down to 2 manufacturers
  - One horizontal axis and one vertical axis units evaluated
- Battery Upgrade Planned (depending on PV size): 30-100% of current, 12 additional Sunny Island inverters

SCALABILITY OF SOLUTION

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Scalability restricted by technology up to 300 kW total power through our SMA Multi-Cluster Box 36.3

- Planned total of 18 Sunny Island Inverters
- Planned total of up to 1500 kWh of energy storage (based on PV size)

- In case the PV is ≥ 150 kWp we will be reaching the limits of the MC 36.3 almost immediately
- Customers have already agreed on Woodshop machinery utilization planning and control so thatit can always be powered through the SMA Multicluster Box 36.3)
- Monastery loads will be increased by 60 kW of installed power after phase 2 due to new wing being built right now
- Concurrent loads will not increase by same amount

LESSONS LEARNED

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For projects of any scale

- Even sophisticated customers underestimate effort & costs
- Energy storage technology and its scalability restrictions are still grossly misunderstood
- Monitoring & reporting are critical for system success

For retrofit projects of this scale & complexity

- Scalability is the 2nd *"top selling point"*, after Cost
- Distribution grid interventions 200-300% of 1st estimate
- In-house expertise on electrical installations is a must
- Final system operation will need at least 2 readjustments, refinements, etc., after monitoring.

CRITICAL SUCCESS FACTORS

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For projects of any scale

- Educate customers on (hidden) costs upfront
- Educate customers on rough system sizing
- Involve customers from the very beginning of analysis
- Have great customers like we did in this project!

For projects of this scale & complexity

- Audit before, during, after design… and be prepared to change design decisions at every step
- Design for expandability… aim for modular and scalable
- Give extra attention to consumption side
- Include energy-saving interventions in your solution
- Get tech support from your vendors at all stages

EUROSOL GmbH

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EUROSOL GmbH, with head offices in Ludwigshafen Germany, is a leading international project development, engineering and EPC company in the power generation field from renewable and alternative energy sources.

From its 1994 origins with pioneering projects and small off-grid PV solutions, it has successfully delivered over 2.500 solar systems of all types (open-space, rooftop) and scale (commercial, industrial, utility) across Europe and MENA region.

The company has built its presence in Europe, North Africa and Middle East, through a well-developed network of subsidiaries and associated companies, and focuses on markets and market segments where energy rationalization policies and incentives promote the utilization of renewables.

Capitalizing on its international experience, engineering competencies and proven track record, EUROSOL can design and deploy energy supply solutions to serve diverse application requirements. Its comprehensive pre- and after-sales services cover the entire project implementation chain from design, procurement and construction to training and O&M.

Currently, EUROSOL invests significant resources in training, R&D and technology acquisition in order to make inroads in the Energy Management, Power Saving and E-Mobility sectors.

References

Hybrid Power Generation System (RRS)

Where:	Kingdom of Saudi Arabia, Classified Locations
What:	Hybrid power system design, construction and commissioning • Solar 68 kWp • Wind 19,5 kW • Energy Storage 231,84 kWh/C10 • Intelligent Energy Management System
Suppliers:	SMA, Schletter, Solar World, Braun, ABB, Schneider, Hoppecke

References

Hybrid Power Generation System

Where:	Kingdom of Saudi Arabia, Classified Locations
What:	Hybrid power system design, construction and commissioning • Solar 15,6 kWp • Wind 6,5 kW • Energy Storage 77,28 kWh/C10 • Intelligent Energy Management System
Suppliers:	SMA, Schletter, CNPV, Braun, ABB, Schneider, Hoppecke

References

RES Powered Electric Vehicle Charging Station

Where:	Mercedes Benz Hellas HQ, Greece
What:	Charging station design, construction and commissioning • Solar 4,4kWp • Indoor Cabinet BYD DESS (Inverter, Charger, Batteries, Battery Management System) • Energy Storage 8kWh
Suppliers:	BYD, REM, ABB, KEBA

THANK YOU