Long Term Profitability Scenarios For A CHP-Based Microgrid

Carlos Gamarra, CEM, P.E.

June 27th, 2017

Definitions – Microgrid

CERTS (2002) *White Paper on integration of Distributed Energy Resources. The CERTS MicroGrid Concept*

IEEE 1547.4 -2011 *Guide for Design, Operation, and Integration of DR Island Systems with EPSs*

A local power system (a power system on its own)

- ✓ Locally/Regionally limited energy system (no actual size limitations).
- ✓ It is an intentionally planned entity, focused on electrical demand covering.
- ✓ Includes energy generation, energy consumption systems, and (sometimes) energy storage devices.
- ✓ A multi-site microgrid may require developing a power distribution network.
- ✓ It may also produce thermal energy (cold and/or, heat).

Can operate in interconnected or/and isolated states.

- ✓ Has its own control and management systems
- ✓ Control relies on power electronic devices and ICTs.
- ✓ Could work in coordination with other grids, even be operated as a unit of a larger grid.
- ✓ Can operate different distributed energy resources at a time.

Can take part of a Smart grid or not, but it can be smart too. Scalability.

- ✓ Can develop DR and/or DSM strategies.

The role of microgrids in the future power grid

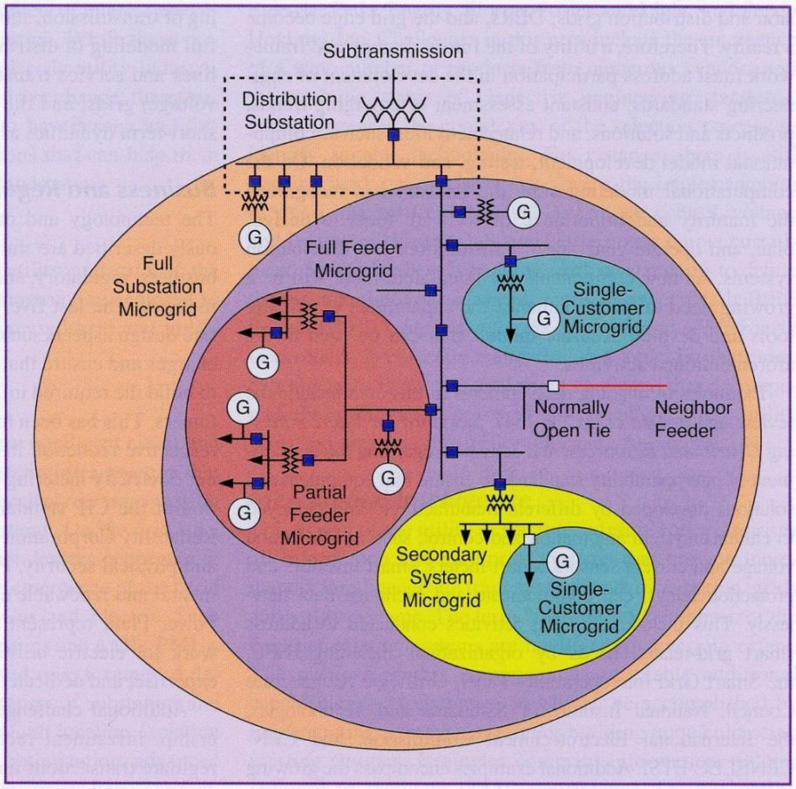


figure 3. This hierarchical microgrid is an example of the grid architectures being explored to enable the highly distributed grid concept and maximize reliability and resiliency under a wide variety of contingency conditions and locations as well as DER and load-balance scenarios. (Source: Sandia National Laboratory.)

SOURCE: *IEEE POWER & ENERGY. Vol.*14, Number 5, September/October 2016

- Provide power and/or ancillary services.
- Act as individual power systems, take part of other microgrids or act a as part of the distribution grid.
- No massive establishment: only those based on competitive advantages or added value proposals.
- Regarding the other power systems they can:
  - Coexist: as individual power systems
  - Cooperate: take part of other microgrids or work as part of the distribution grid
  - Compete: as individual power systems

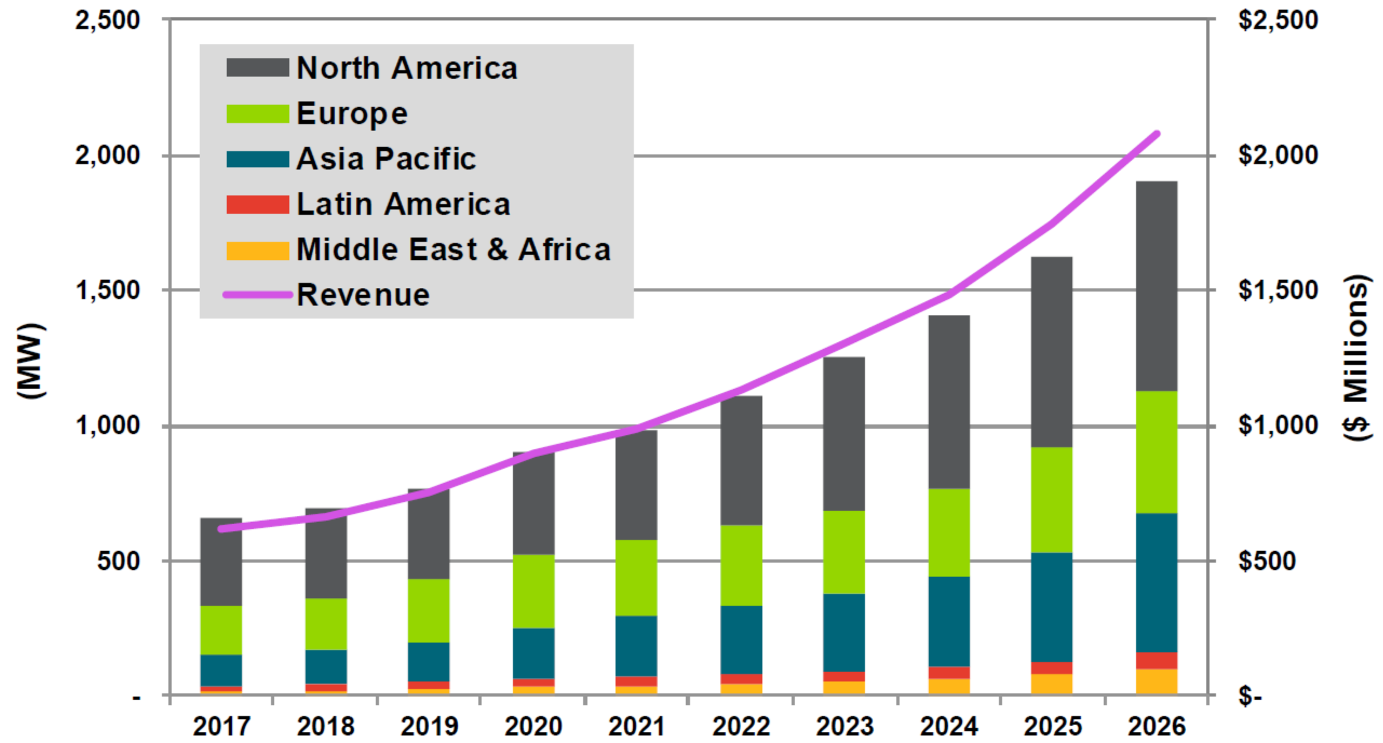
CHP, District Energy & Microgrids: Combined Benefits

CHP technologies provide competitive advantages to microgrids

- CHP provides reliable dispatchable power
- CHP provides thermal energy during grid outage
- CHP results in daily operating cost savings that can significantly help offset costs of resilient microgrids
- CHP can offset some capital costs associated with investments in traditional backup power

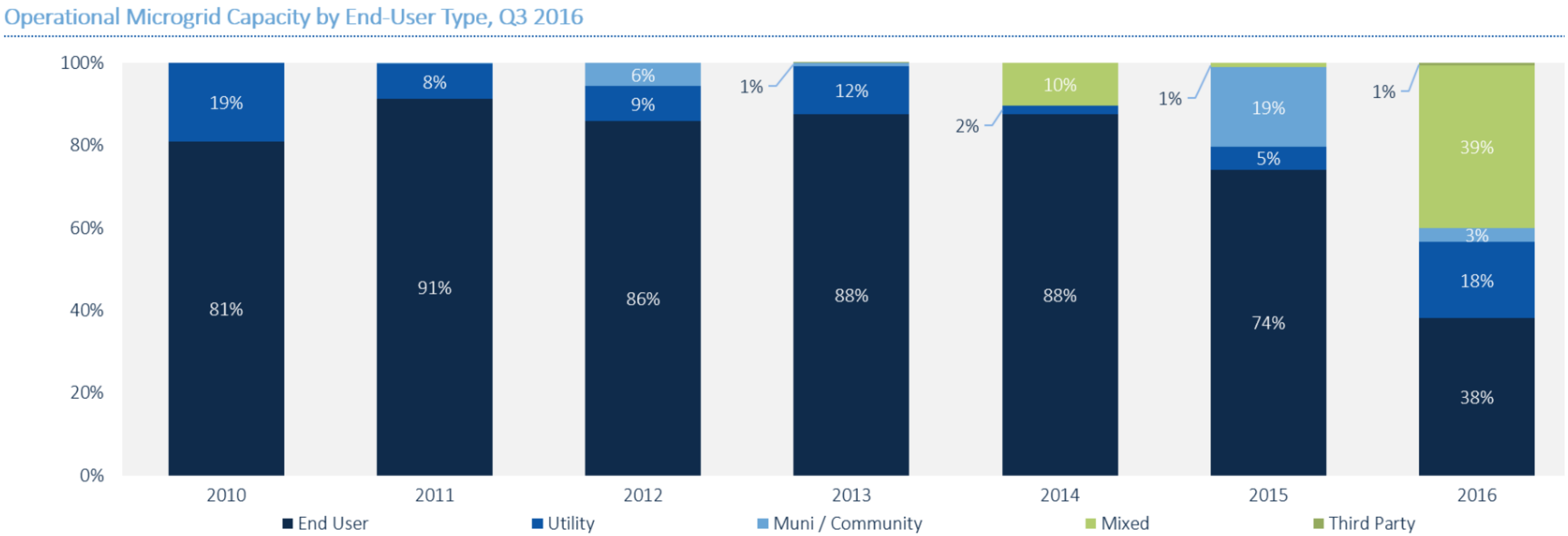
CHP Market Evolution Forecast

Chart 1.1 Annual CHP Equipment Capacity and Revenue by Region, World Markets: 2017-2026



(Source: Navigant Research)

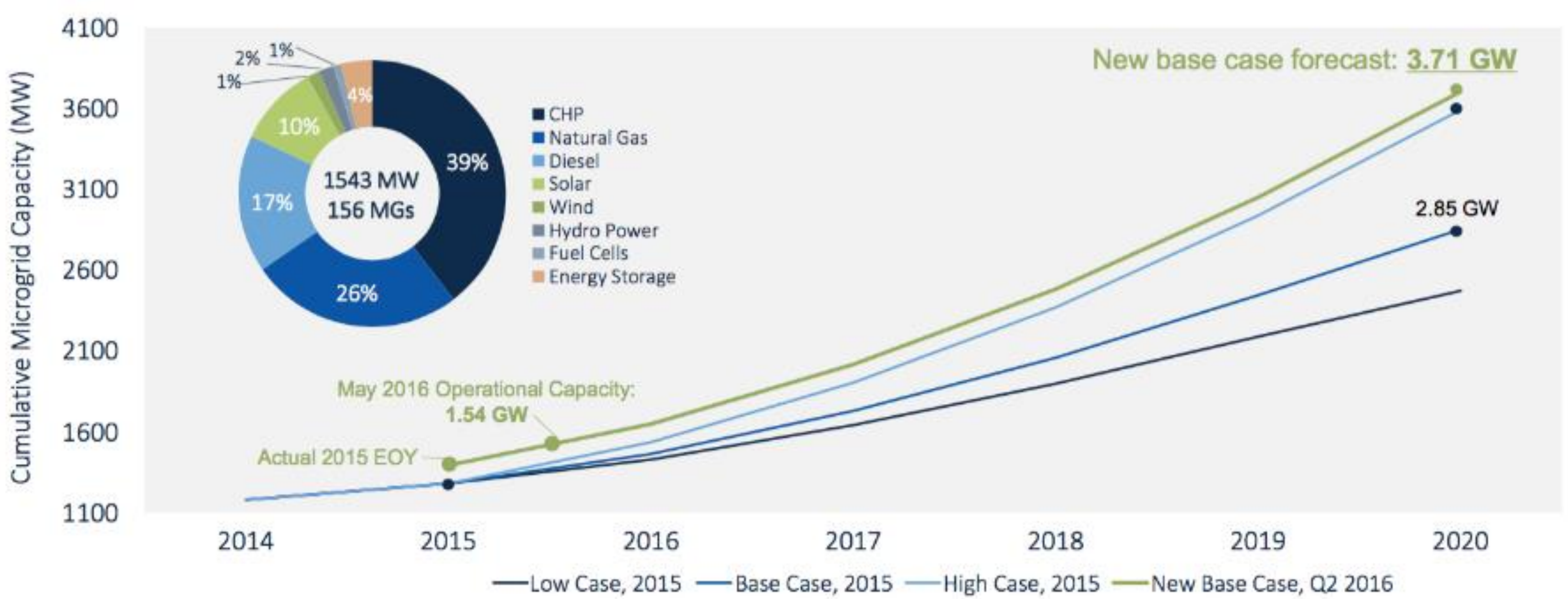
MG Market Evolution



SOURCES: www.greentechmedia.com/articles/read/US-Installed-Microgrid-Capacity-to-Grow-115-And-Reach-4.3-GW-Over-Next-Fiv

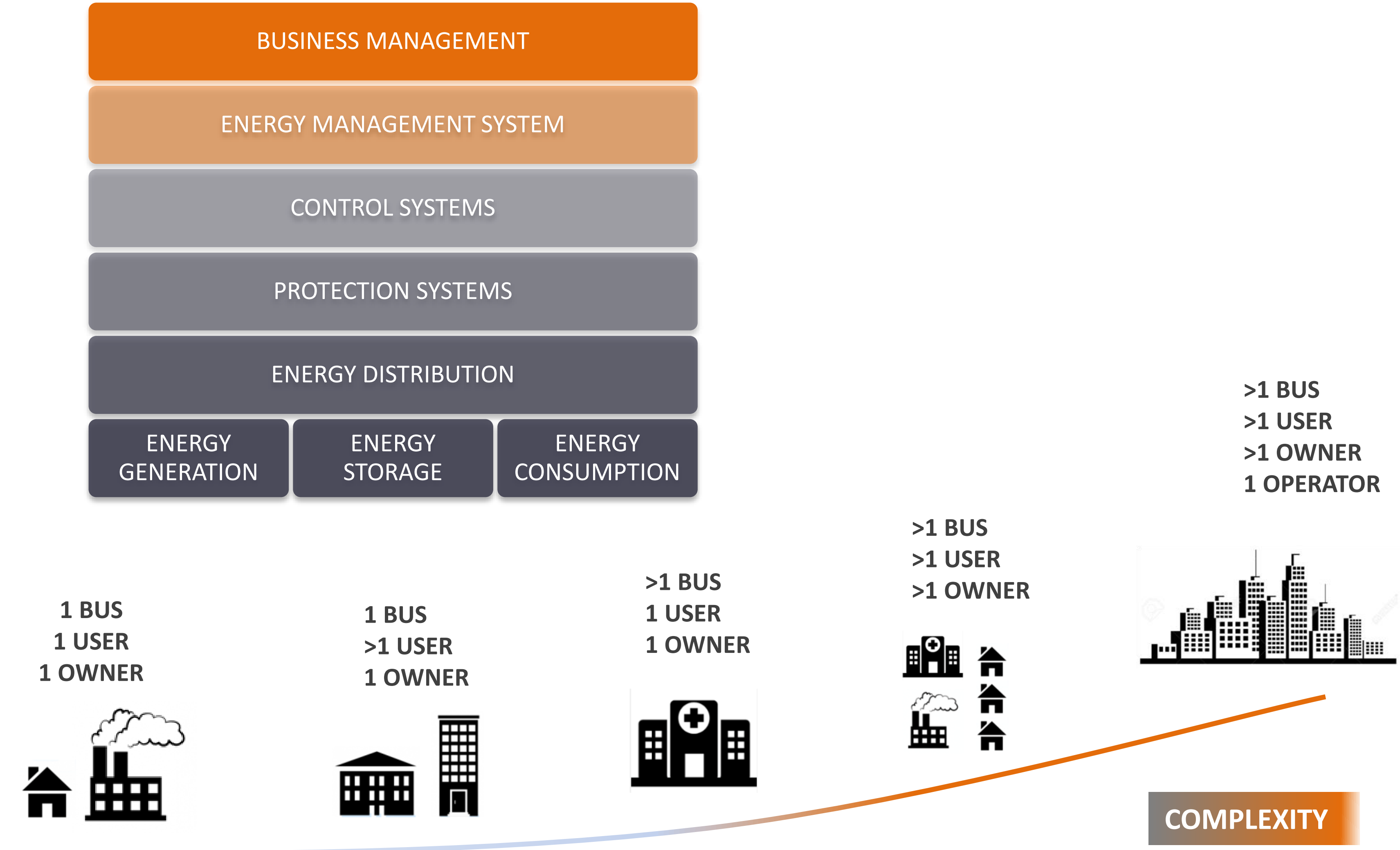
MG Market Evolution

- Market research companies are updating their forecasts.
- The MG market is expected to reach 3.71 GW of operational capacity in 2020.
- **A 39% of the existing microgrids are based on CHP systems.**



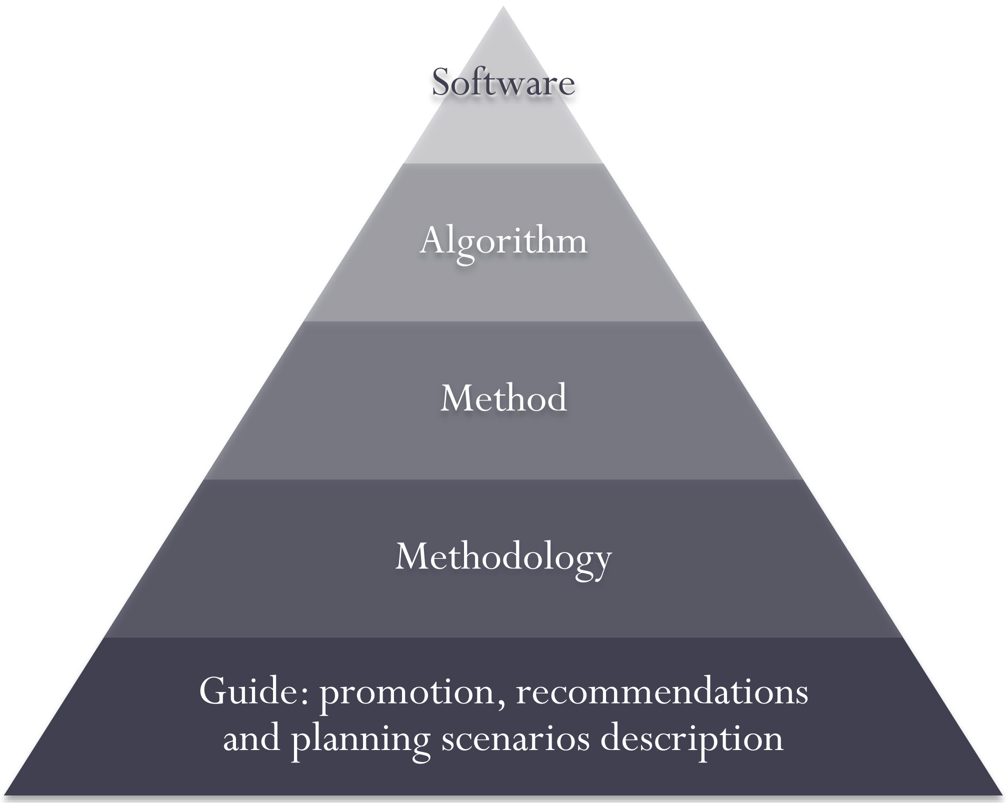
SOURCES: www.greentechmedia.com/articles/read/u.s.-microgrid-growth-beats-analyst-estimates-revised-2020-capacity-project

MG Market Evolution



Trends In Microgrid Planning

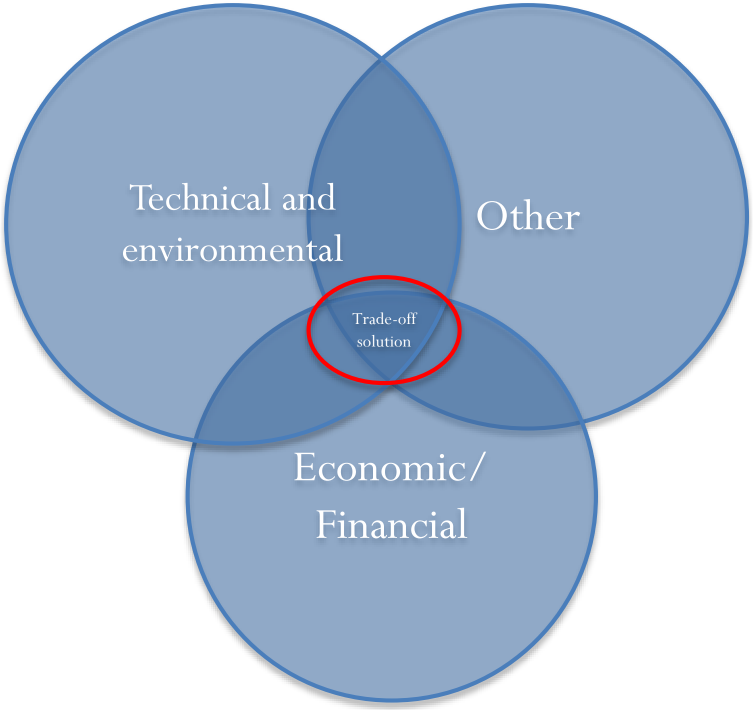
- Planning tools can be classified into different categories

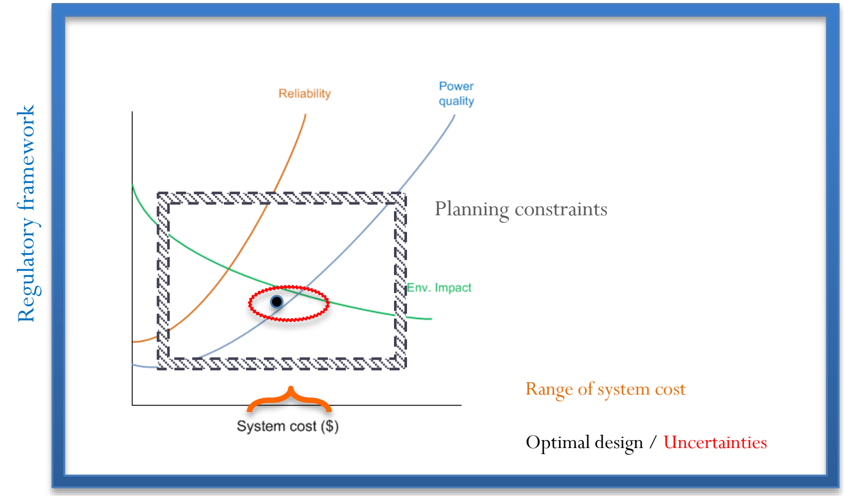


Trends In Microgrid Planning

- A microgrid planning process is a study of present and future profitability scenarios.
- Design and planning stages must be strongly focused around specific goals, e.g. save money, save energy, and save environmental emissions.
- Specific competitive advantages must be the basis of the planning process.
- Incentives will support the system only in the short-term. The system must be profitable.
- Tailored solutions vs modular MG.
- Data mining and machine learning based design and management strategies

Trends In Microgrid Planning





Case Study

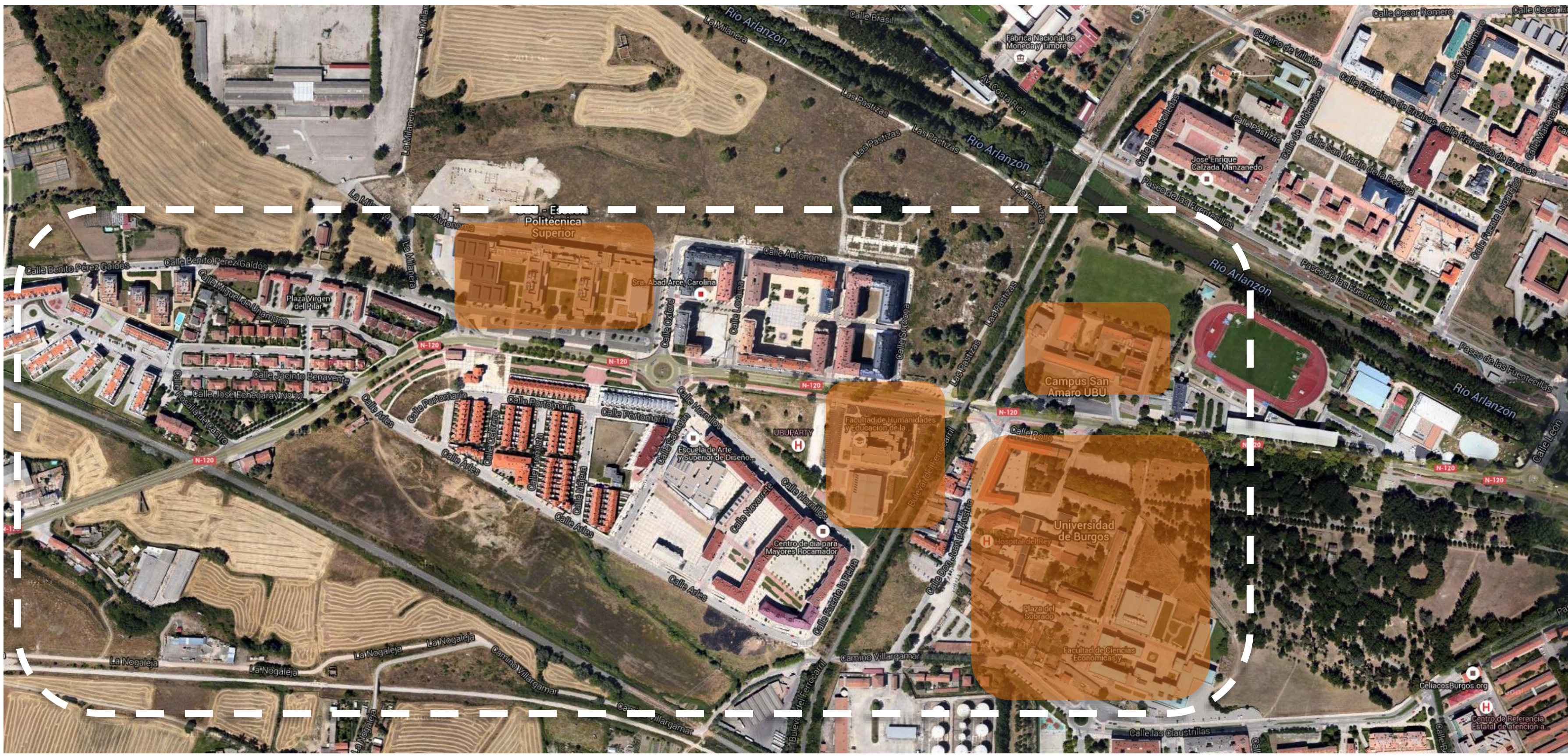
STAGE 0. PROJECT GOALS DEFINITION

• To take advantage of local fuels or sources of energy	Cost efficiency , Reliability and Sustainability
• **To improve the energy efficiency of your facilities**	Cost efficiency , Reliability and Sustainability
• **To generate economic returns**	Cost efficiency , Reliability and Sustainability
• **To minimize the impact of tariffs or electricity price oscillations**	Resiliency
• **To protect/guarantee the supply against external contingencies**	Security, Resiliency, Reliability
• To include distributed generation based on clean technologies	Sustainability
• **To minimize transmission and distribution losses**	Sustainability
• To built and upgraded the microgrid in different stages	Scalability, and Cost efficiency
• To supply energy where there is no power supply	Technology and community development
• To provide high-quality energy both connected or isolated from the main grid	Reliability, Cost efficiency
• To promote investments and create jobs	Technology and community development

Case Study

STAGE 1. INFLUENCE AREA DEFINITION

Case study: Campus Microgrid Assessment at University of Burgos (Spain)



Case Study

STAGE 2. INFLUENCE AREA STUDY.

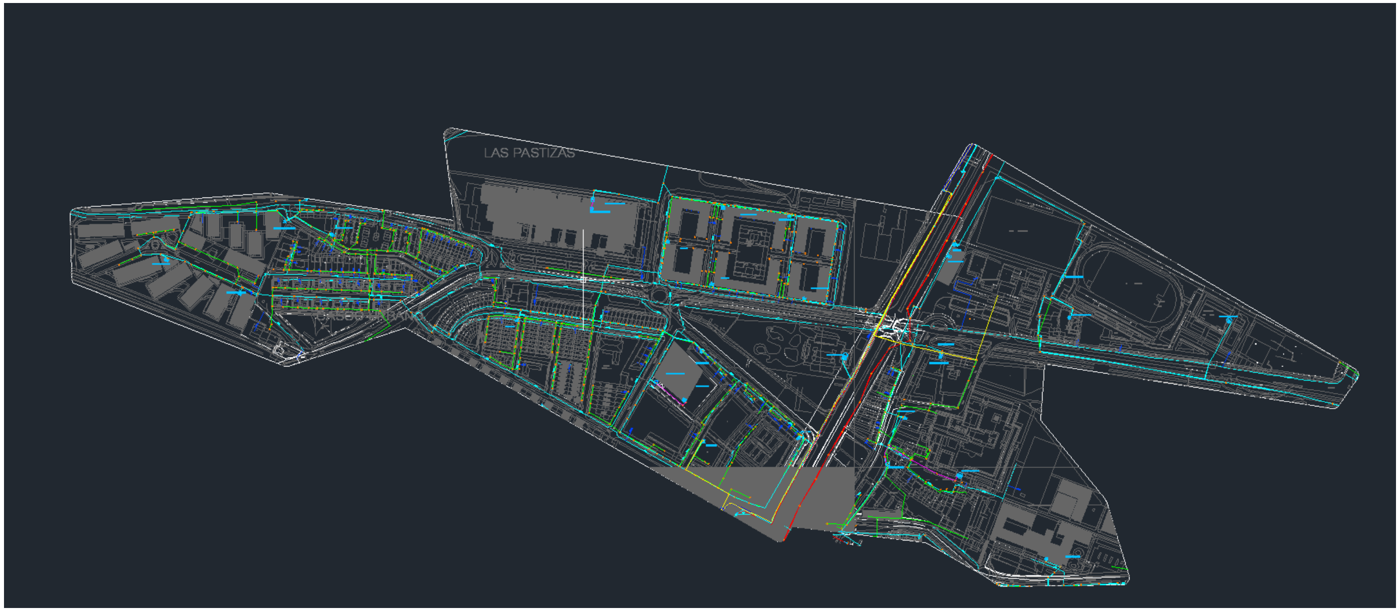
Study of existing facilities, local constraints and potential solutions

- Power demand curve and other consumption-base data
- Thermal energy demand curve and other consumption-base data
- Existing energy infrastructures, including predominant power and thermal energy systems.
- Availability and characterization of space.
- Demand points locations and gathering of power consumption data.
- Renewable power sources availability (solar and wind resource, biomass, etc..)
- Fuel availability and costs

Case Study

STAGE 2. INFLUENCE AREA STUDY

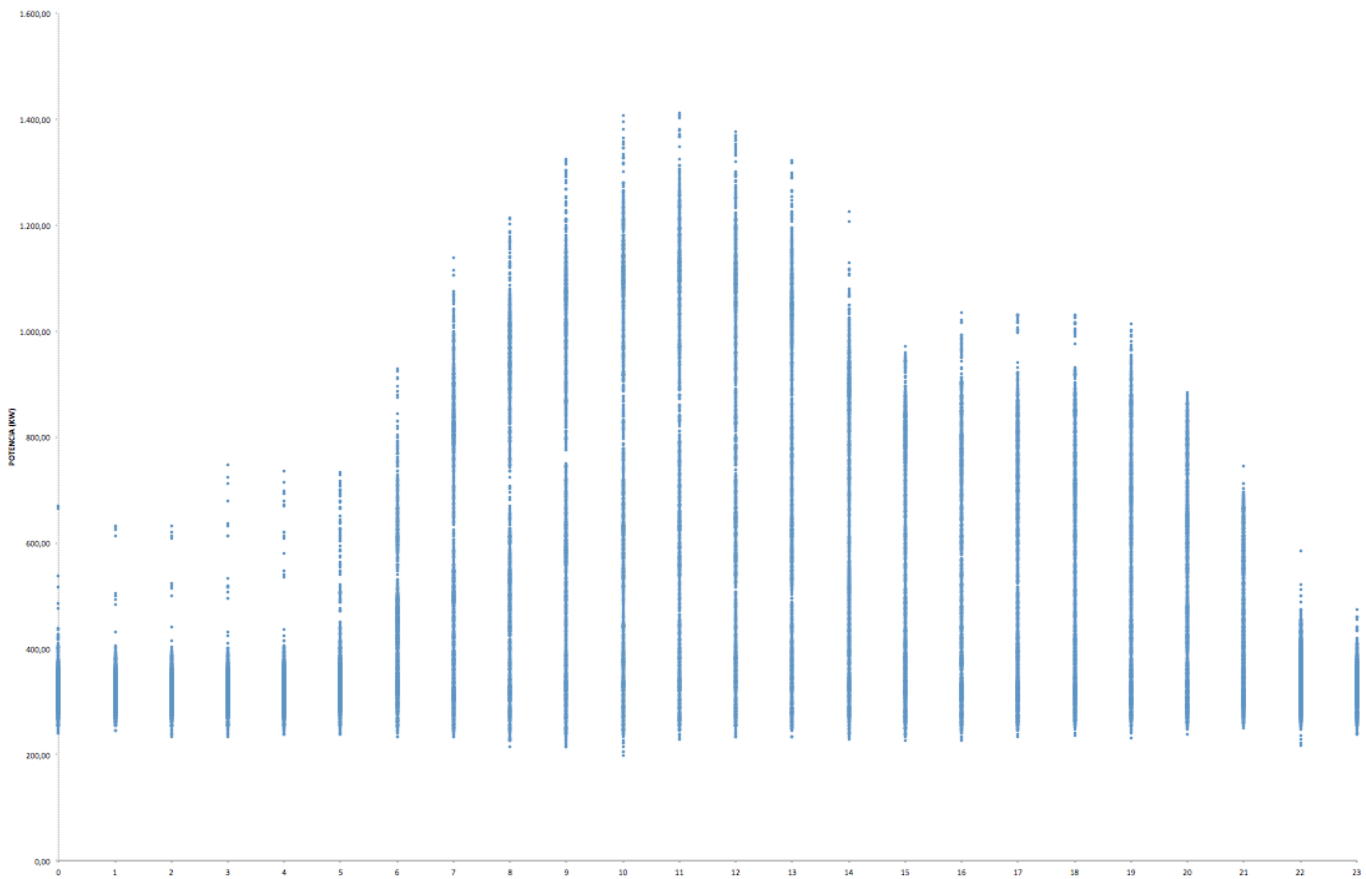
- Electricity costs for final customers (tariffs of energy companies in the area).
- Environmental indicators (air pollution levels , etc..)
- Energy technologies available in the area (technical and social constraints in the area).



Case Study

STAGE 2. INFLUENCE AREA STUDY

Hourly power demand points per hour in a year



Case Study

STAGE 3. OPTIMAL DESIGN OF MULTI-NODE GRID

Problem approach

- **Design of a CHP-based microgrid interconnected to the traditional power grid**
- Resilience is based on equipment and fuel redundancy: Max Gen Capacity = 2 x Peak demand
- 14 generators of different technologies and sizes modelled (CHP, PV, Diesel and Gas gensets)
- 7 existing transformer centers
- 1 additional node has been purposed as the PCC
- 28 potential power lines drafted
- 5 cable sizes considered for each power lines
- Mix of different optimization techniques applied to power gen technology selection, sizing and scheduling
- Optimization techniques applied to power flow analysis and constraints verifications
- Simulation techniques applied to future scenarios analysis

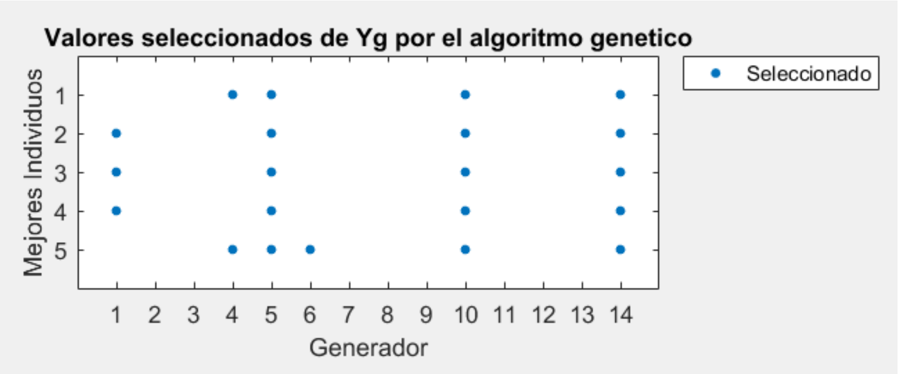
Case Study

STAGE 3. OPTIMAL DESIGN OF MULTI-NODE GRID

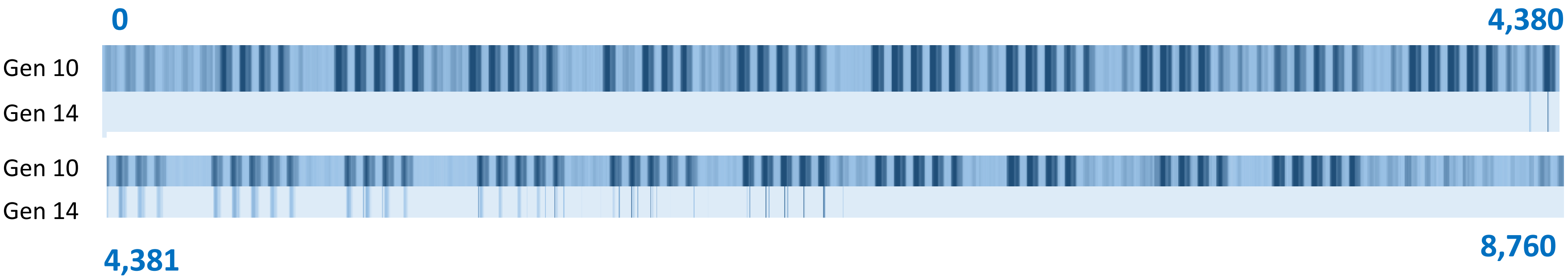
Sizing solutions

LEYEND

1. PV 50 KVA
2. PV 150 KVA
3. PV 300 KVA
4. DIESEL GENSET 250 KVA
5. DIESEL GENSET 400 KVA
6. DIESEL GENSET 630 KVA
7. NG GENSET 250 KVA
8. NG GENSET 400 KVA
9. NG GENSET 630 KVA
10. CHP RECIP ENG 299 KVA
11. CHP RECIP ENG 636 KVA
12. CHP RECIP ENG 847 KVA
13. CHP RECIP ENG 1063 KVA
14. POWER GRID 1000 KVA



Scheduling



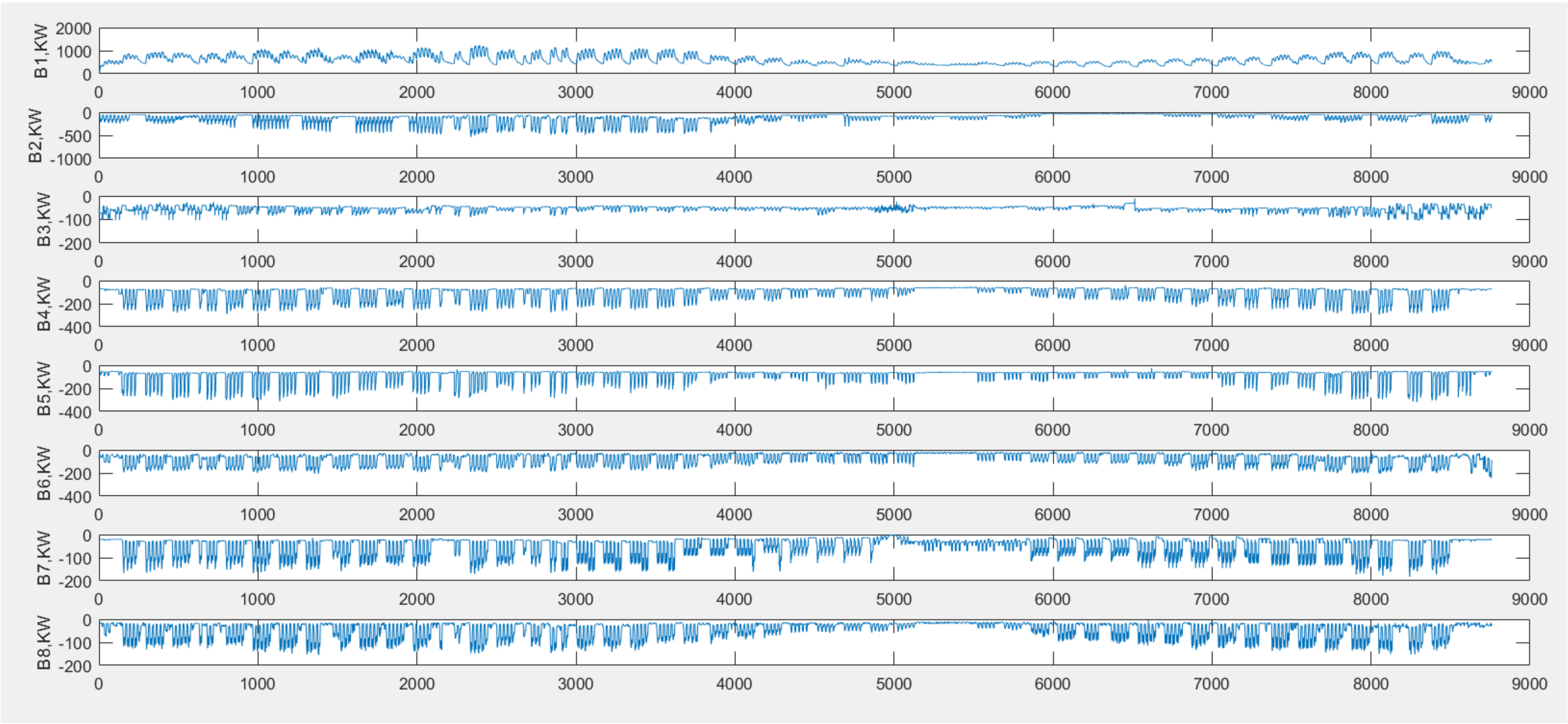
Case Study

STAGE 3. OPTIMAL DESIGN OF MULTI-NODE MICROGRID

Case Study

STAGE 3. OPTIMAL DESIGN OF MULTI-NODE GRID

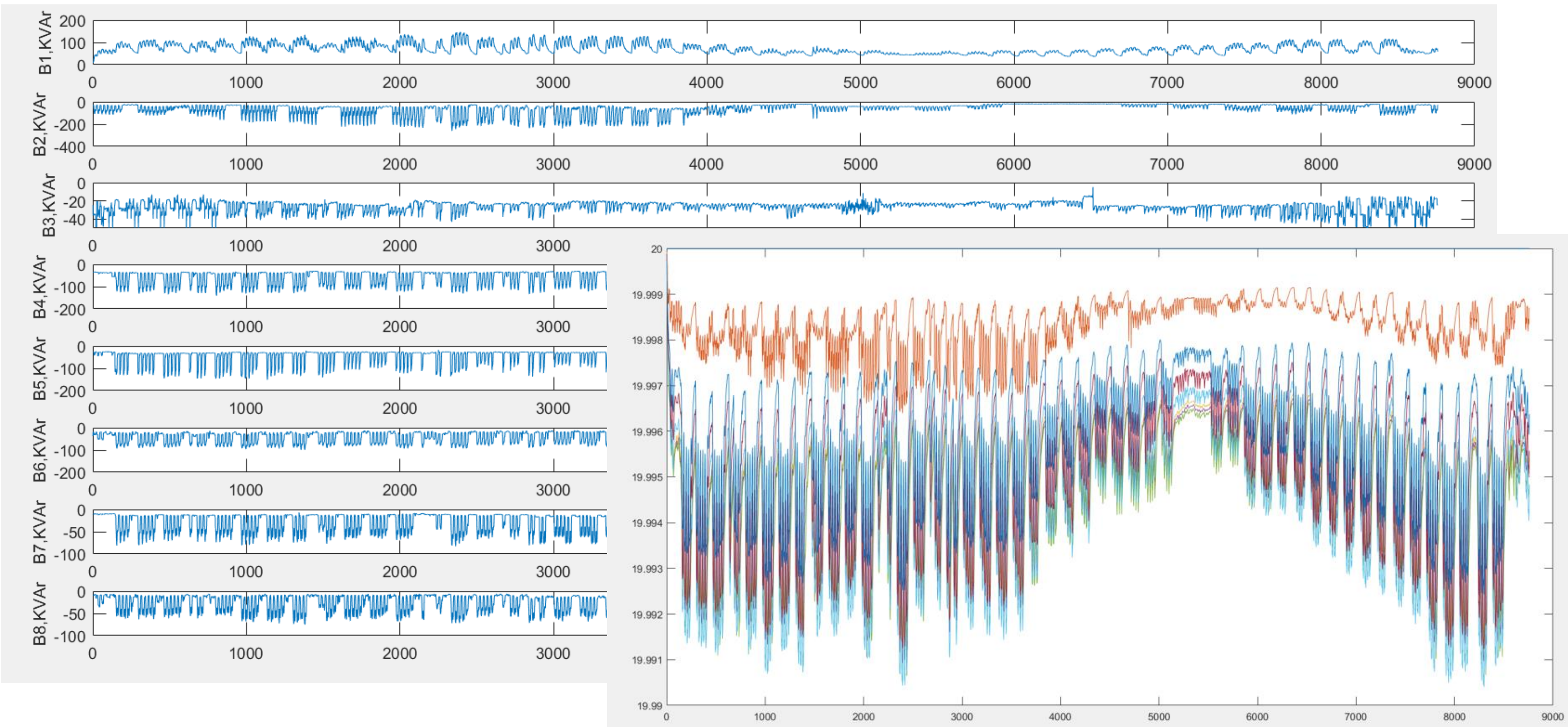
Power Flow Analysis, Power Lines Siting and Sizing



Case Study

STAGE 3. OPTIMAL DESIGN OF MULTI-NODE GRID

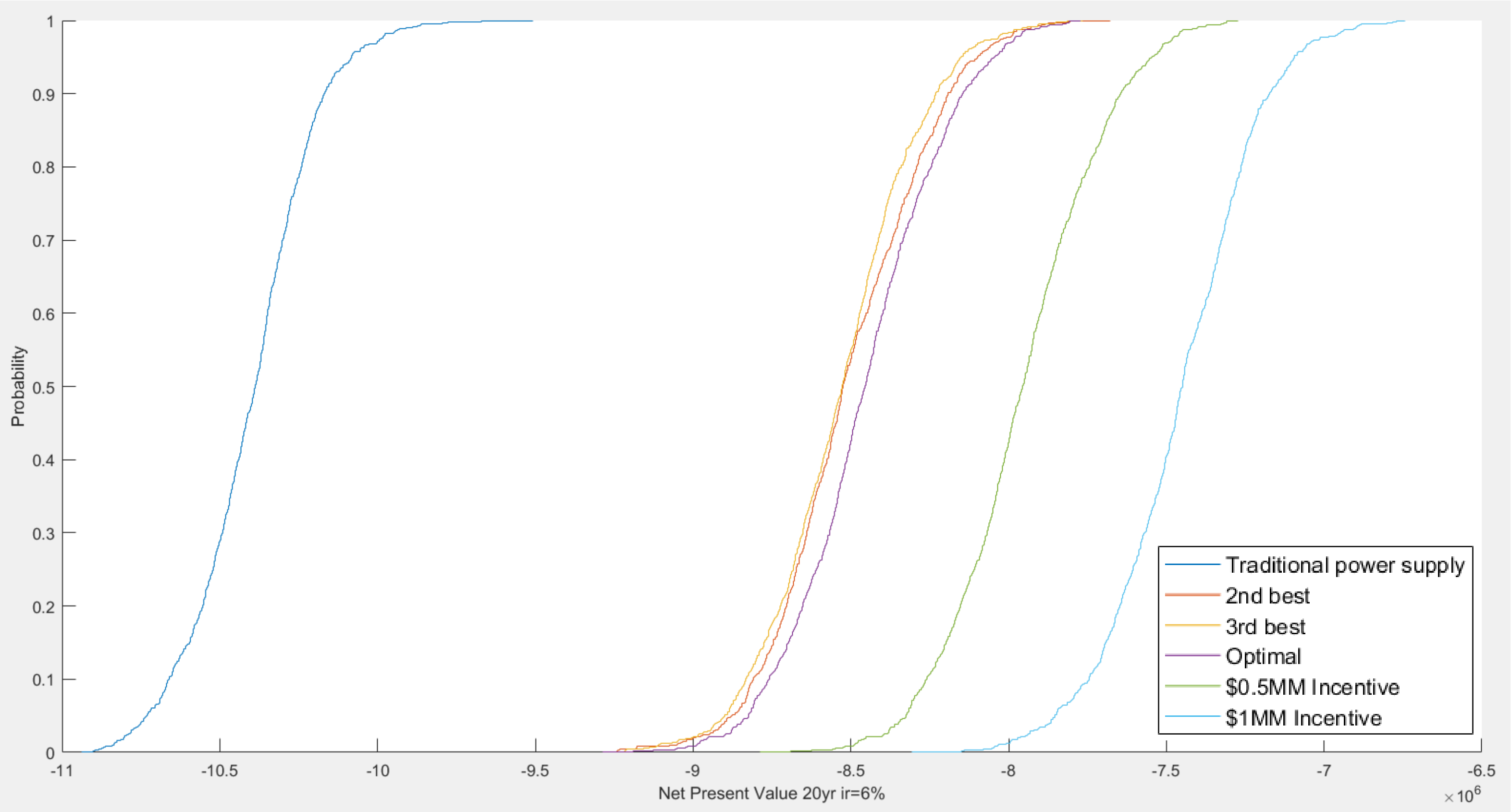
Power Lines Siting and Sizing



Case Study

STAGE 4. FUTURE PROFITABILITY SCENARIOS

Probability Distribution of NPV



Conclusions

	IRR	DPP	Initial Investment	Annual Balance
DIRECT PAYMENT	2.04	-	-$1,683,175.82	$107,464.22
LOAN$1MM 10yr 1%	3.36	-	-$683,175.82	$1,882.22 (*)
INCNTV $.5MM	6.13	20.35	-$1,183,175.82	$107,464.22
INCNTV $1MM	14.41	9.75	-$683,175.82	$107,464.22

- Although the designed microgrid could fulfill most of the objectives, the investment doesn't look promising.
- An incentive between 0.5 and $1MM will be required to make it profitable, depending on the promoter group.
- **Other alternatives must be considered: smaller microgrids per building or group of buildings.**

Next Steps

- Continue performing feasibility studies for our clients, including microgrids with commercial purposes.
- Define profitability boundaries for microgrids:
    - For different areas: urban, rural, industrial, military and college campus, ancillary services for other grids.
    - For different business models: Direct ownership, TPO, etc..
    - For different funding and financial models: Incentives, Loans, Grants
- Analyze market conditions and identify potential opportunities for the promotion of CHP and MG.

Thank You!

Carlos Gamarra, P.E., CEM
US DOE Southwest CHP TAP
(281) 364-6032
cgamarra@harcresearch.org