

Methodology for Architecting Energy Systems in Ultra Low Energy Communities

Energy System Architecting Tool (ESAT)

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for

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SYMPOSIUM & EXHIBITION E2S2**

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Why Distributed Power Systems / Energy Microgrids?

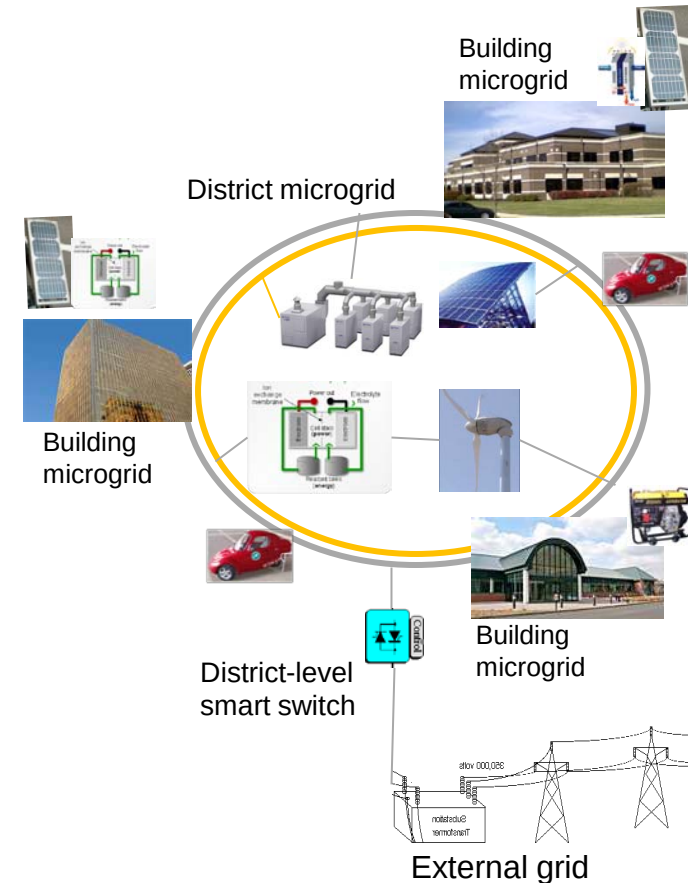
Security of supply, reduced energy, and minimized environmental impact

Security of energy supply

- **Vulnerable loads** served under all operating conditions.
- 'Customizable' **power quality and reliability**
- **Seamless transition** between islanding and off-grid operation

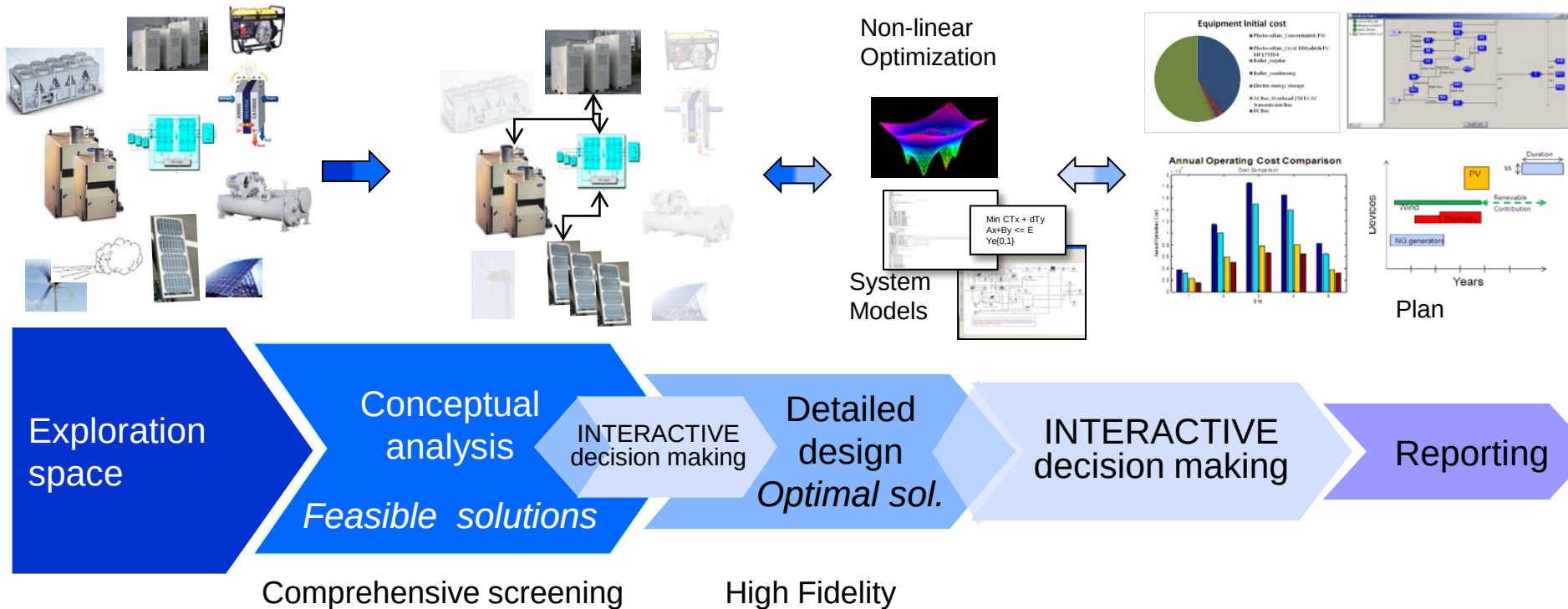
Reduced energy costs and environmental impact

- Improved power systems architectures
 - **Waste heat utilization**
 - 85-90% fuel utilization vs. 40-50% for central power
 - **Renewable sources with energy storage**
 - **Maximize ROI**
 - Integrated demand/supply management:
 - **Reduced energy consumption/cost,**
 - **Peak shaving**
 - **Decrease in T&D losses and required infrastructure**
-
- **Energy microgrids are distributed power systems with the capability to work seamless in islanding and grid-connected modes.**
 - **They include thermal and electrical systems**



Energy Microgrids Architectural Synthesis Tool: Overview

The objective is to develop methodology and prototype tools to identify best distributed power system architectures;



- Extensible to energy demand technologies for NET Zero Architectures
- Provides 'if-then' scenario and sensitivity analysis capability
- Economics, performance and environmental metrics are some of the metrics

Energy Microgrids Architectural Synthesis Tool: **Process**

Requirements

(default & editable)

Exploration
space

Conceptual analysis

Feasible solutions

INTERACTIVE
decision making

Detailed
design
Optimal sol.

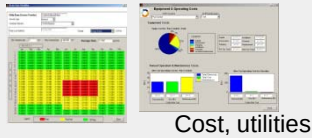
INTERACTIVE
decision making

Reporting

Component Model Library

Sources
Storage
Loads
Converters

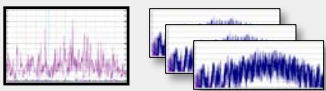
Economic models



Location and weather

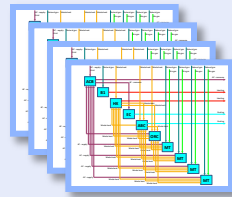


Loads

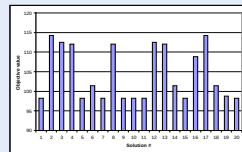


Objectives and Constraints

Super-structure generation

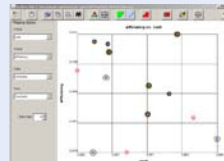


Linear Optimization



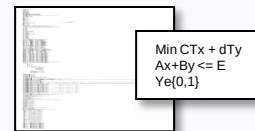
N 'best' solutions

First comparison Metric 1

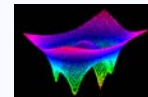


Metric 2

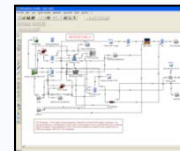
Automatic model generation



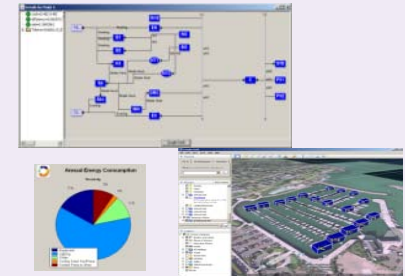
Non-linear Optimization



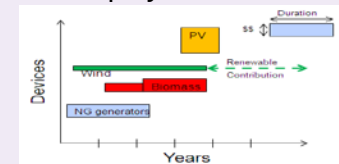
Best architecture and energy management



Visualization and reporting



Deployment Plan



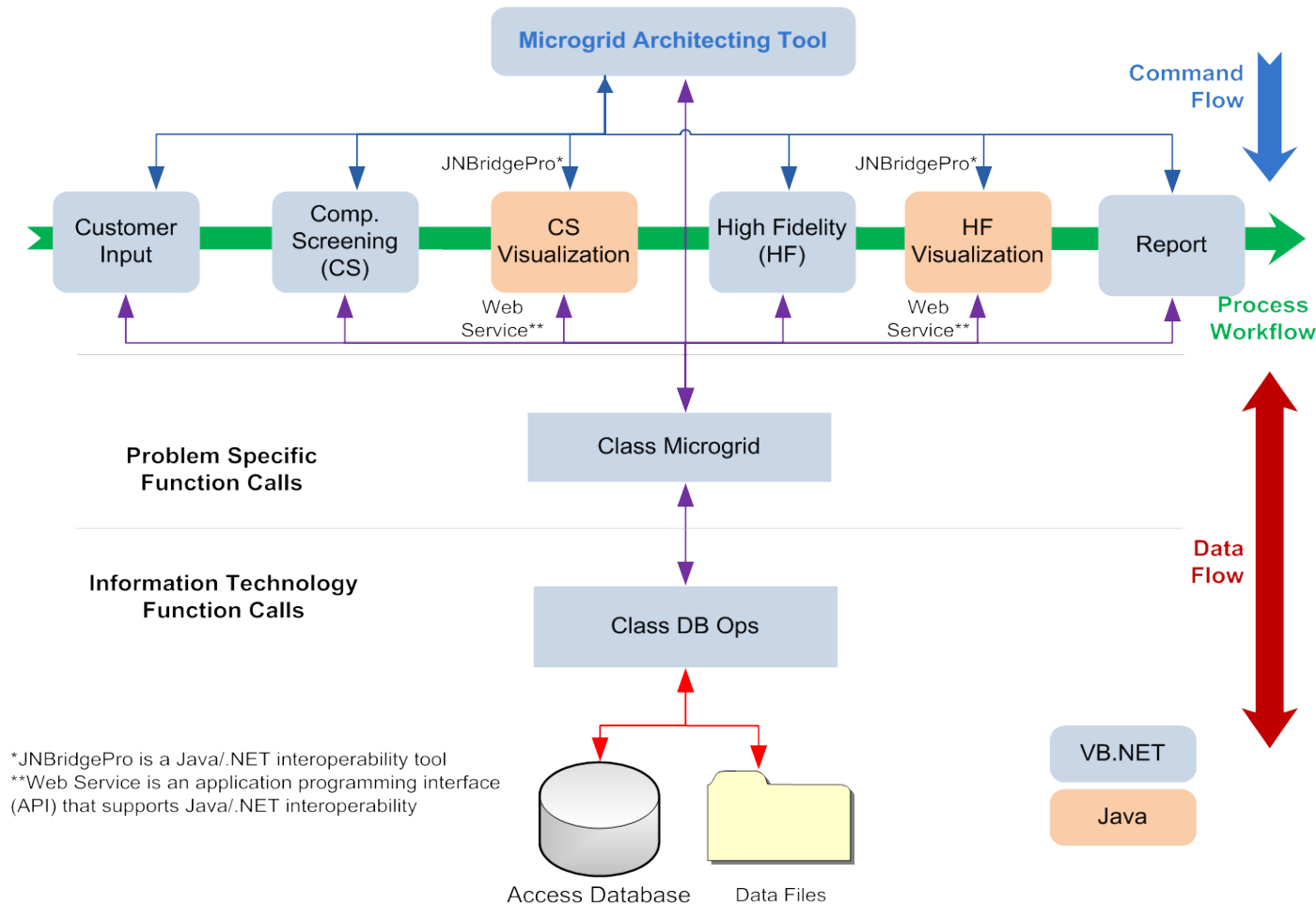
Interactive process



Energy Microgrids Architectural Synthesis Tool: [Architecture](#)

- Front end and coordination engines (or classes) are based on .Net
- Java to VB libraries support synchronous message passing between modules
- Extensible architecture to include demand and supply problems

Army Microgrid Analysis – Process and Data Flow



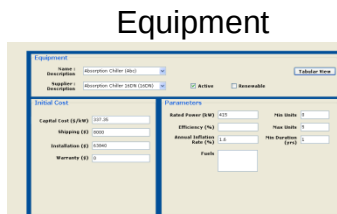
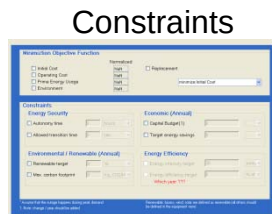
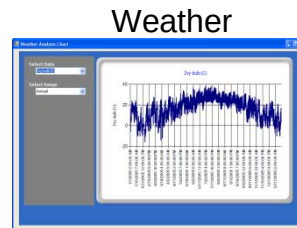
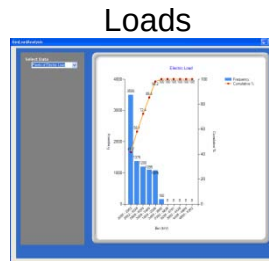
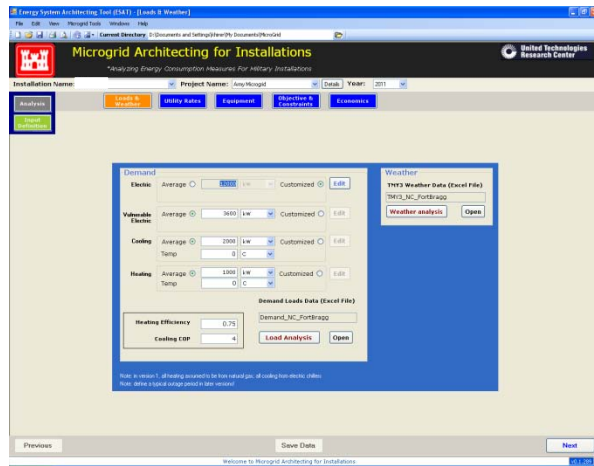
*JNBridgePro is a Java/.NET interoperability tool

**Web Service is an application programming interface (API) that supports Java/.NET interoperability

Energy Microgrids Arch. Synthesis Tool: User Interfaces: Inputs

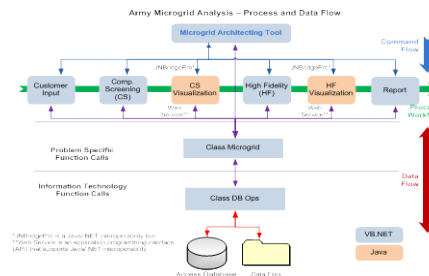
Front end and coordination engines (or classes) are based on .Net

Graphics User Inputs (pre-populated by default values)



Databases

Equipment models, economics, loads, outputs, requirements, constraints, etc.



User-selected objectives

- Minimize lifecycle cost
- Minimize environmental impact
- Minimize operational cost

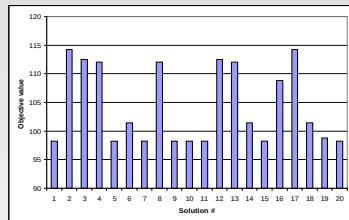
Inputs Constraints

- Budget
- Renewable usage

Energy Microgrids Architectural Synthesis Tool: **Output Metrics**

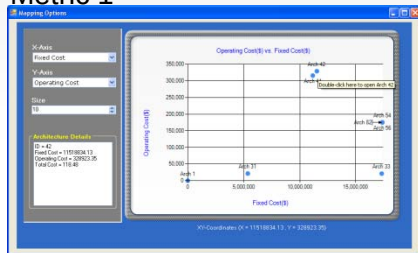
Performance metrics will be visualized and exported in the form of a report

Architectures comparison



N 'best' solutions

Metric 1

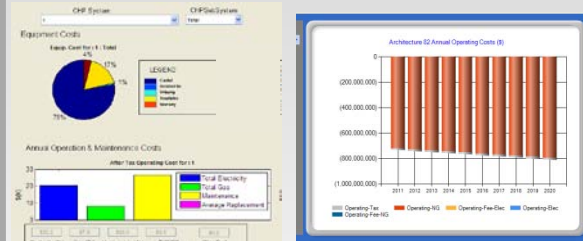


Metric 2

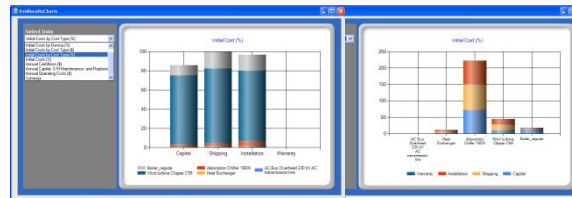
Architectural diagrams



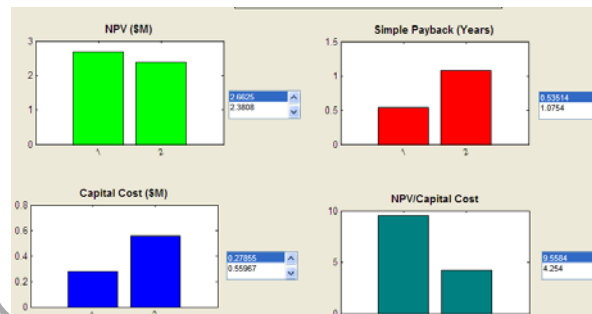
Capital cost & cashflows



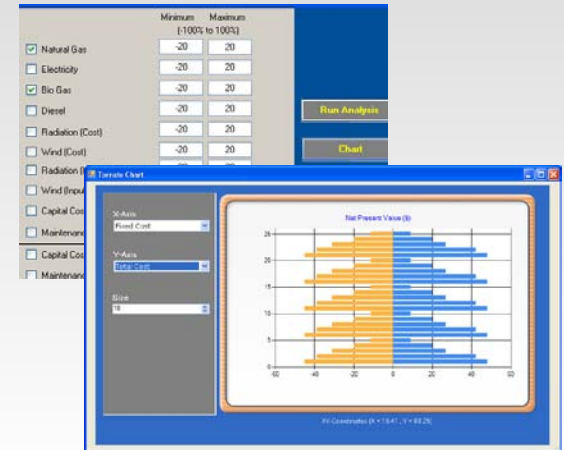
O&M cost, detailed utility costs



Economic metrics: NPI, simple and compound payback, ROI



Simple and compound sensitivity analysis



Report Generation



Energy Microgrids Architectural Synthesis Tool: Sample Problem

Objective: Lifecycle cost Minimization

Objective

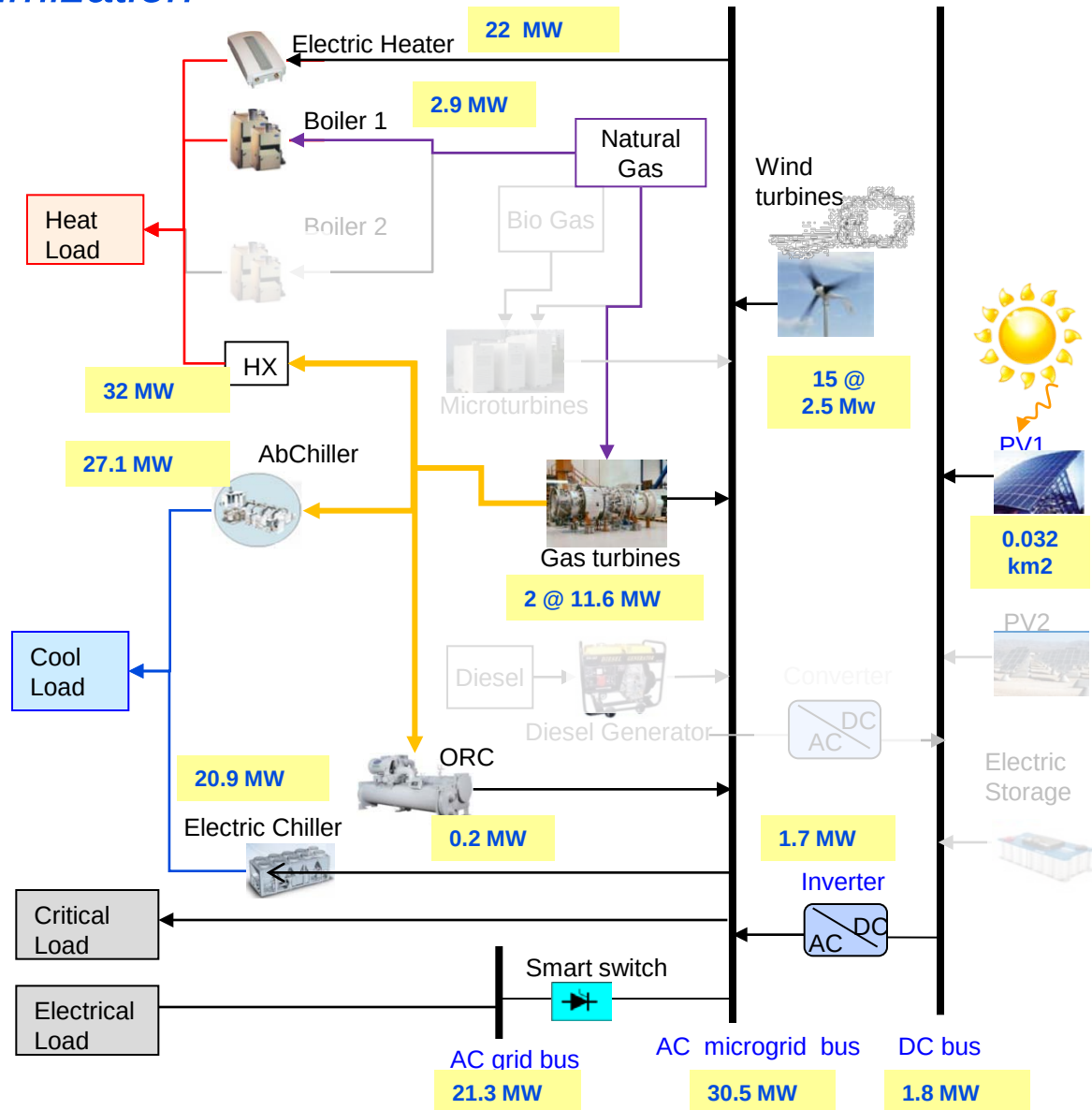
- Minimize total 20-yr. discounted cost
 - Fixed cost
 - Operating cost
 - Discounted
 - Inflation accounted for
 - Replacement cost

Constraints

- Meet load at all times
- Meet critical load during islanding
- Min renewable = 7.5%
- Max renewable
 - Area 4km²

Assumptions

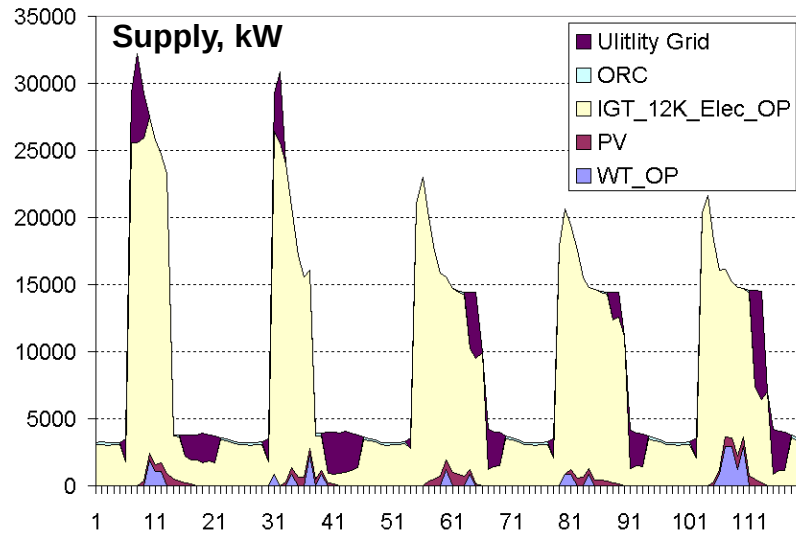
- Demand and energy charges for utility included
- Load profiles derived using DOE2
- Life = 20 years



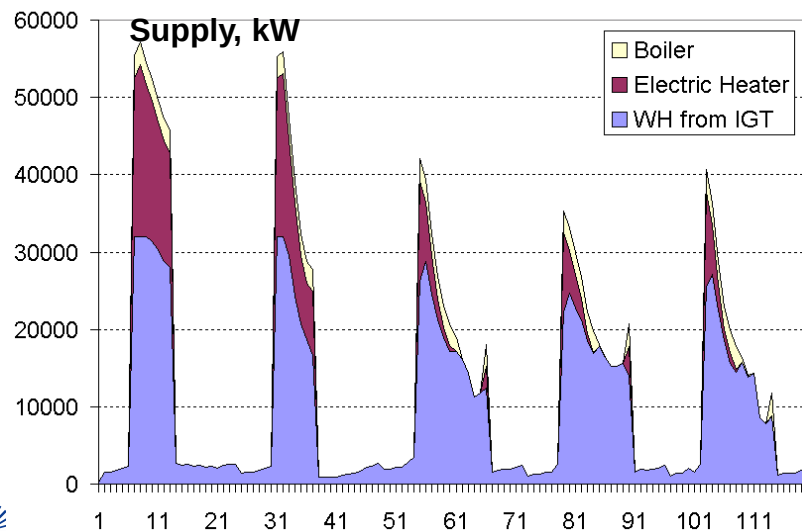
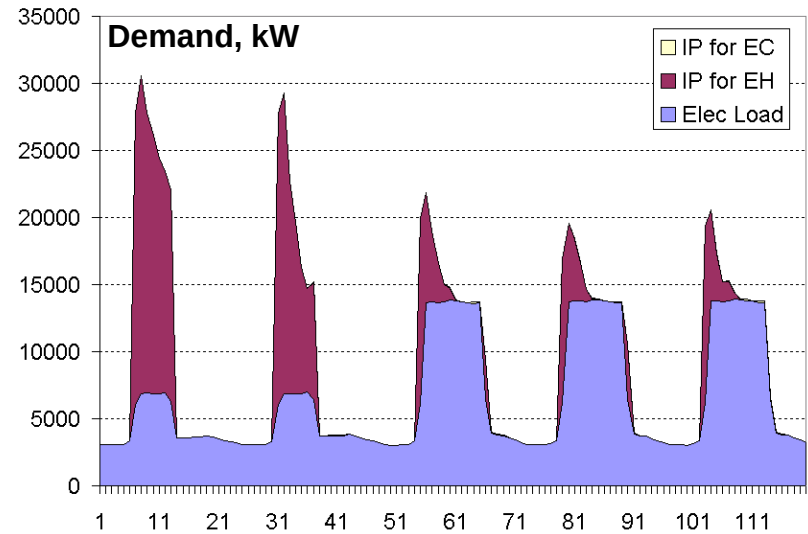
Verification of Results

Supply always more than to demand → Ensures Energy Balance

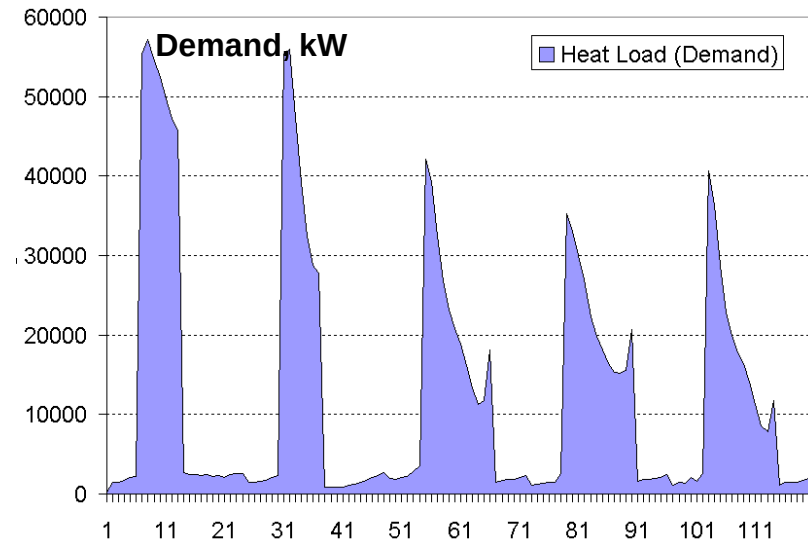
No Excess Supply → Consistent with Cost Minimization



Electricity



Heat

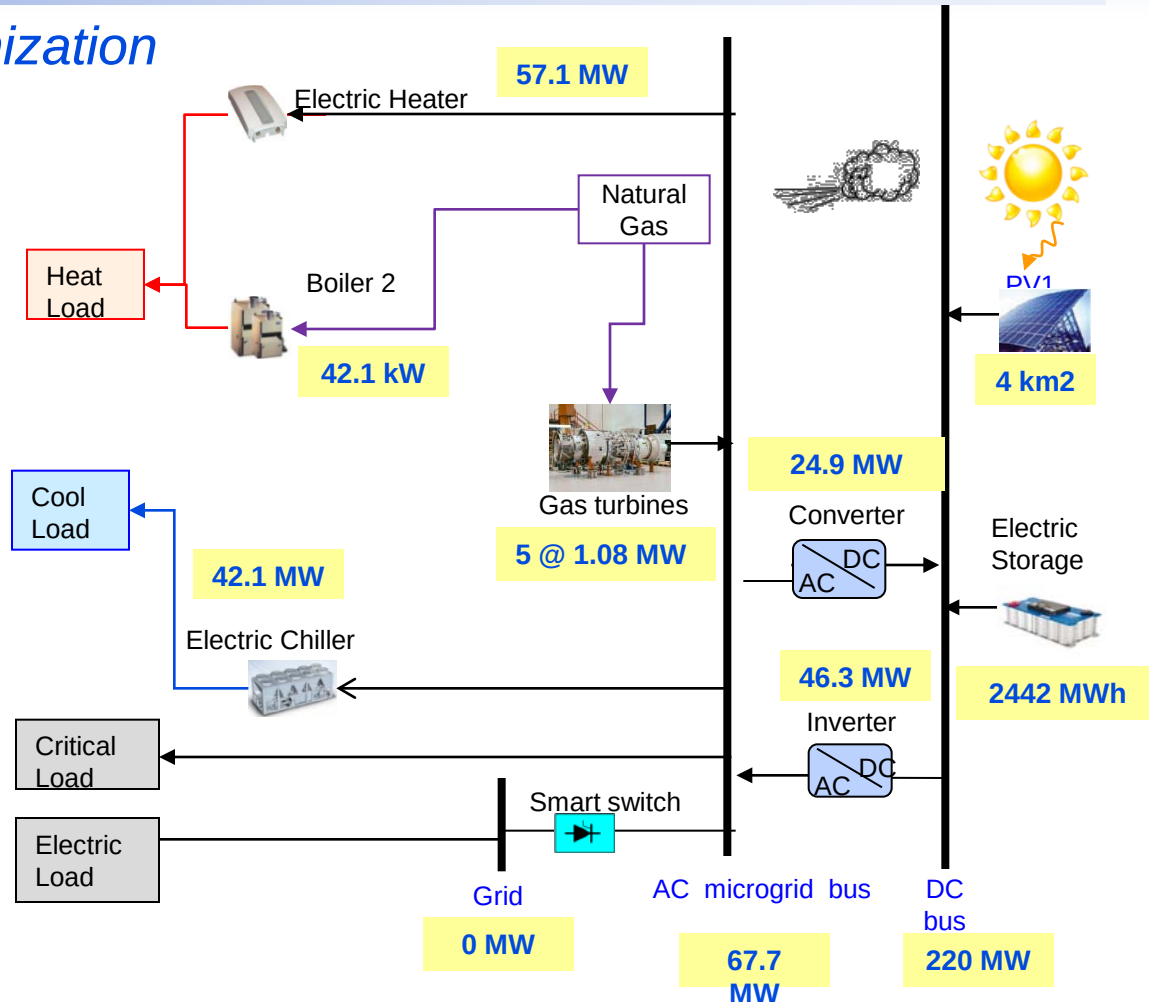


Sensitivity to Objective Function Selection, Sample Problem

Objective: CO₂ release minimization

Observations

- Max possible PV selected
- PV preferred over WT, due to high solar in selected site
- Significant reduction in operating cost achieved (with significant initial cost increase)
- Utility Grid independent System



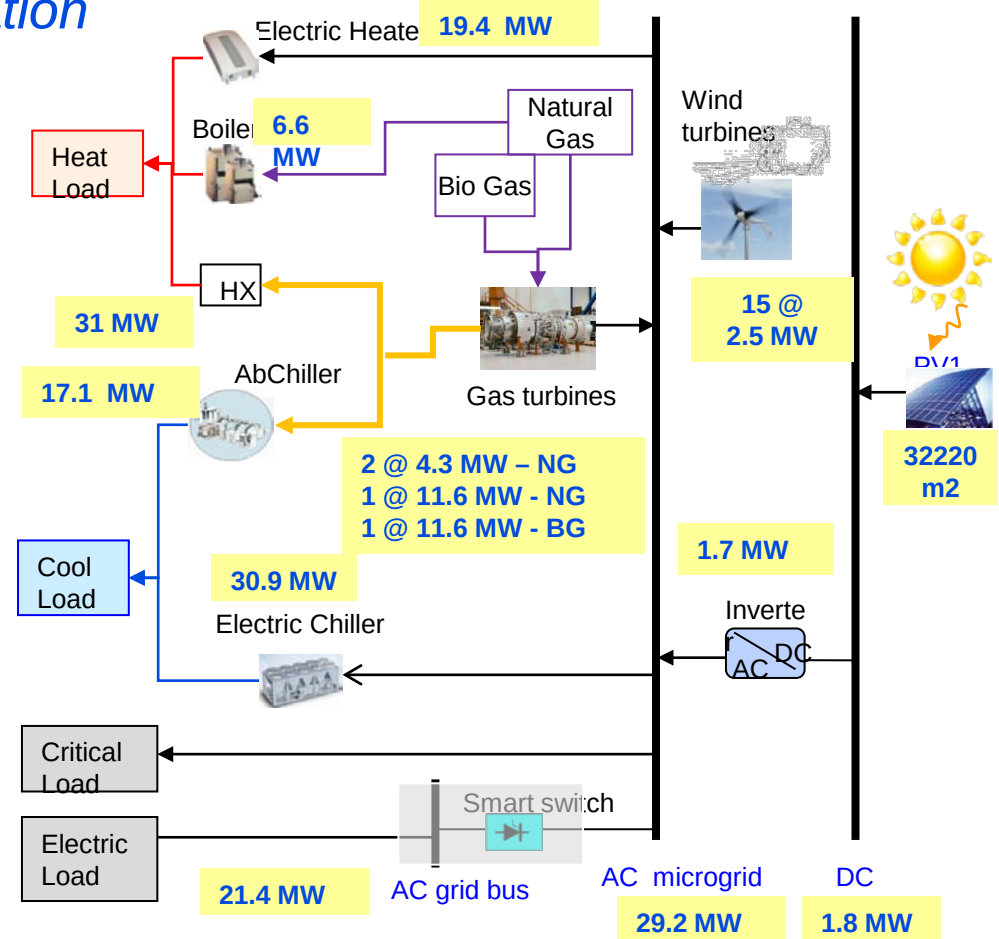
	Initial Cost	Operating Cost (Discounted over 20 yrs)	Primary energy (kWh/year)	CO ₂ (kg/year)
Reference	\$ 202 M	\$137.3 M	27.26 x10 ⁶	4.94 x10 ⁶
CO2 Minimization	\$ 23,227 M	\$0.78 M	0.175 x10 ⁶	0.007x10 ⁶

Sensitivity to Objective Function Selection, Sample Problem

Objective: Lifecycle cost Minimization
Sensitivity to NG price

Observations

- No architecture change for 20% increase in NG Cost
- For 50% increase: Some IGT load is transferred from NG to BG
- Increase in primary energy due to lower efficiencies for BG
- Higher CO₂ due to BG
- 27% reduction in annual NG consumption



	NG Consumption (kW/Year)	Initial Cost	Operating Cost (Discounted over 20 yrs)	Primary energy (kWh/year)	CO ₂ (kg/year)
Reference	17.5x10 ⁶	\$202.0 M	\$137.3 M	27.26 x10 ⁶	4.94 x10 ⁶
150% NG	12.7x10 ⁶	\$203.9 M	\$178.4 M	30.40 x10 ⁶	6.40 x10 ⁶



Project Plan : Sample Results

Project Planning Parameters

Project duration = 9 years

Renewable targets

1st year = 1%

Annual increment = 1%

Annual Budget = \$ 9 M

Inflation rate = 1.5 %

Discount rate = 0 %

Minimize Budget overruns → Strict renewable

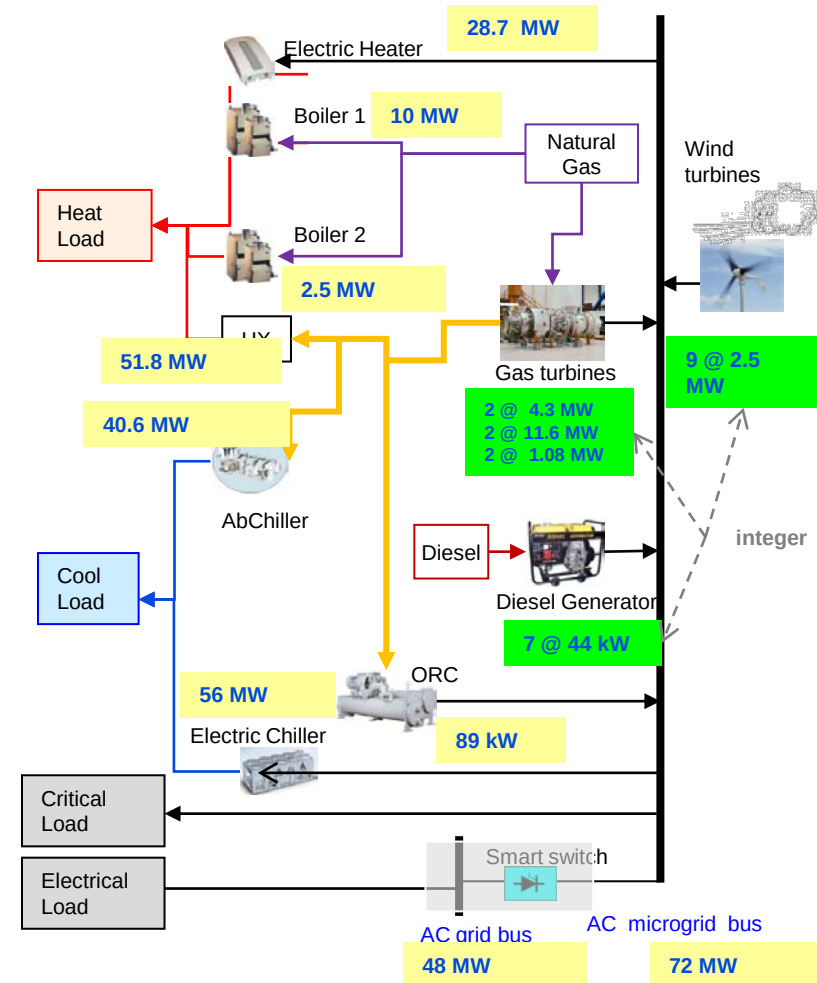
Annual installed capacity

		Year								
		1	2	3	4	5	6	7	8	9
Electric Heater	MW				28.7					
Heat Exchanger	MW		51.8							
Absorption Chiller	MW	16.9			1	1.2	0.1	5.4	5.1	
Electric Vhiller	MW		55.9							
ORC	MW		0.1							
Boiler 1	MW							10		
Boiler 2	MW	1	1.5							
Wind Turbine	#	1	1	2		2	1	1		1
Disel Generator	#			7						
Gas Turbine 1	#						2			
Gas Turbine 2	#				1				1	
Gas Turbine 3	#			2						

Annual budget plan (\$M)

Year									
1	2	3	4	5	6	7	8	9	
10.2	9	10.2	9	9	9	9	9	9	9

Optimized final architecture



Energy Microgrids Architectural Synthesis Tool: Strengths

- The selected architecture does not have to be assumed a-priori.
- The entire framework is interactive.
- Considers non-linear behavior of various technologies/devices.
- The framework is extensible to include energy supply, demand and storage as a holistic approach to obtain Net-Zero solutions.
- The selected framework is scalable to consider buildings, campus or district.
- The optimal energy system architecture could satisfy vulnerable loads in islanding mode.
- ESAT developed an staged plan (development plan) that satisfies budget constraints and renewable mandates during installation.
- Includes special consideration of energy solutions that consider thermal and electrical losses as well as cost of pipes and transmission lines (work in progress).

Future Developments

- Energy demand /supply: ESAT is *currently* focused on the architecting of energy supply side. An extension to include demand systems is planned.
- Reliability: Currently, ESAT is a purely deterministic methodology (MTBF and maintenance cost *are* included, but still not the potential cost of an stochastic power outage).
- Uncertainty: The current ESAT version, does not include uncertainties in weather or building loads forecasts. Sensitivity analysis is provided.
- Include GIS (Graphical Information System): Interfacing commercially available GIS software with ESAT will significantly enhance its capability, in terms of simplifying data gathering for users and visualizing results in geographical environment.



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