Sustainable Cities and Military Installations
NATO Workshop

Dr. Michael Case
Program Manager, Installations
U.S. Army Corps of Engineers
Engineer Research and Development Center
Construction Engineering Research Lab
P.O. Box 9005, Champaign IL 61826
Phone 217-373-7259
michael.p.case@us.army.mil

US Army Corps of Engineers
BUILDING STRONG®

Net Zero Hierarchy

"The primary goal is a focus toward net zero and when we talk about net zero, it's not only net zero energy, but it's net zero energy, water, and waste. When you look at the term "net zero" or a hierarchy of net zero you must start with reduction, then progress through repurposing, recycling, energy recovery, disposal being the last."

— HON Katherine Hammack, DoD Bloggers Roundtable, 10 October 2010

- **A Net Zero ENERGY Installation** is an installation that produces as much energy on site as it uses, over the course of a year.
- **A Net Zero WATER Installation** limits the consumption of freshwater resources and returns water back to the same watershed so not to deplete the groundwater and surface water resources of that region in quantity or quality.
- **A Net Zero WASTE Installation** is an installation that reduces, reuses, and recovers waste streams, converting them to resource values with zero solid waste to landfill.
- **A Net ZERO INSTALLATION** applies an integrated approach to management of energy, water, and waste to capture and commercialize the resource value and/or enhance the ecological productivity of land, water, and air.

Net Zero Pilot Installations

Net Zero Energy

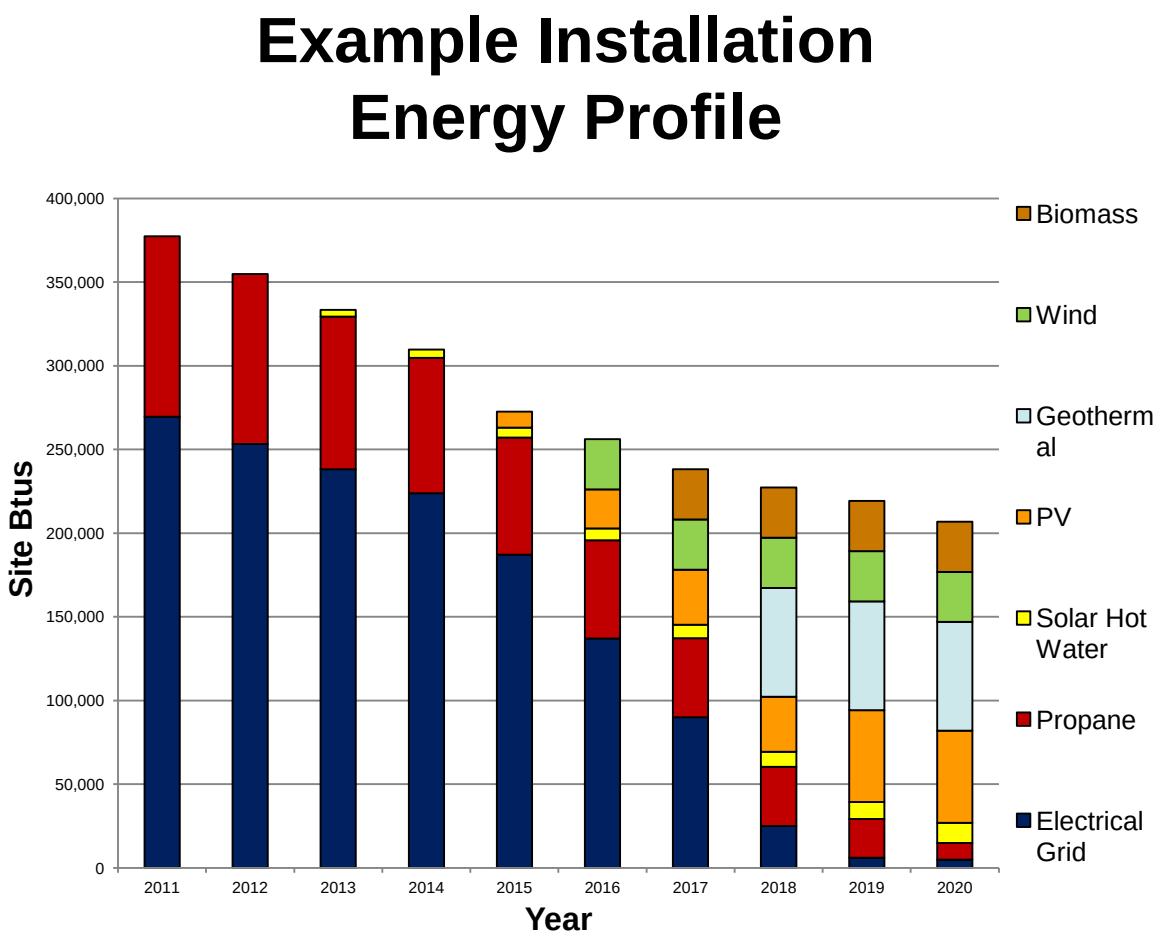
A Net Zero ENERGY Installation is an installation that produces as much energy on site as it uses, over the course of a year.

Goals:

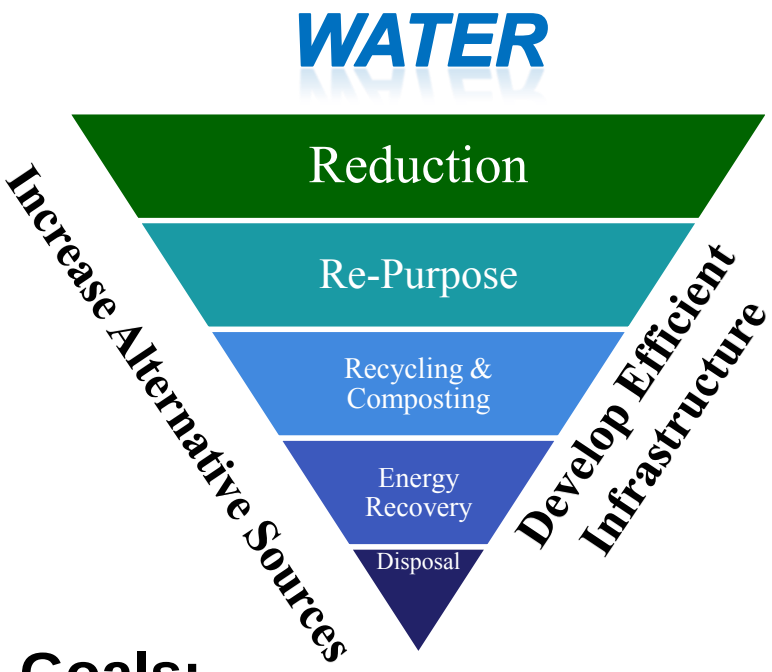
- Contribute to the Army Campaign Plan's objective of energy security for the Army
- Address energy efficiency and conservation first
- Preference for use of renewable energy for on-site power; enables operation if grid goes down
- Must address redundant energy supply sources
  - Can the installation function for long periods of time during supply disruptions affecting the electric grid, natural gas pipeline, propane & fuel oil deliveries, etc.
- Applies to both electrical and thermal energy
- Behavioral change are necessary to change culture
- Must be fiscally responsible

Energy Roadmaps

- Energy Baseline
- Energy Efficiency Assessments
- Renewable Energy Assessments
- Energy Security Assessments
- Energy Project List and Implementation Recommendations



Net Zero Water Strategy

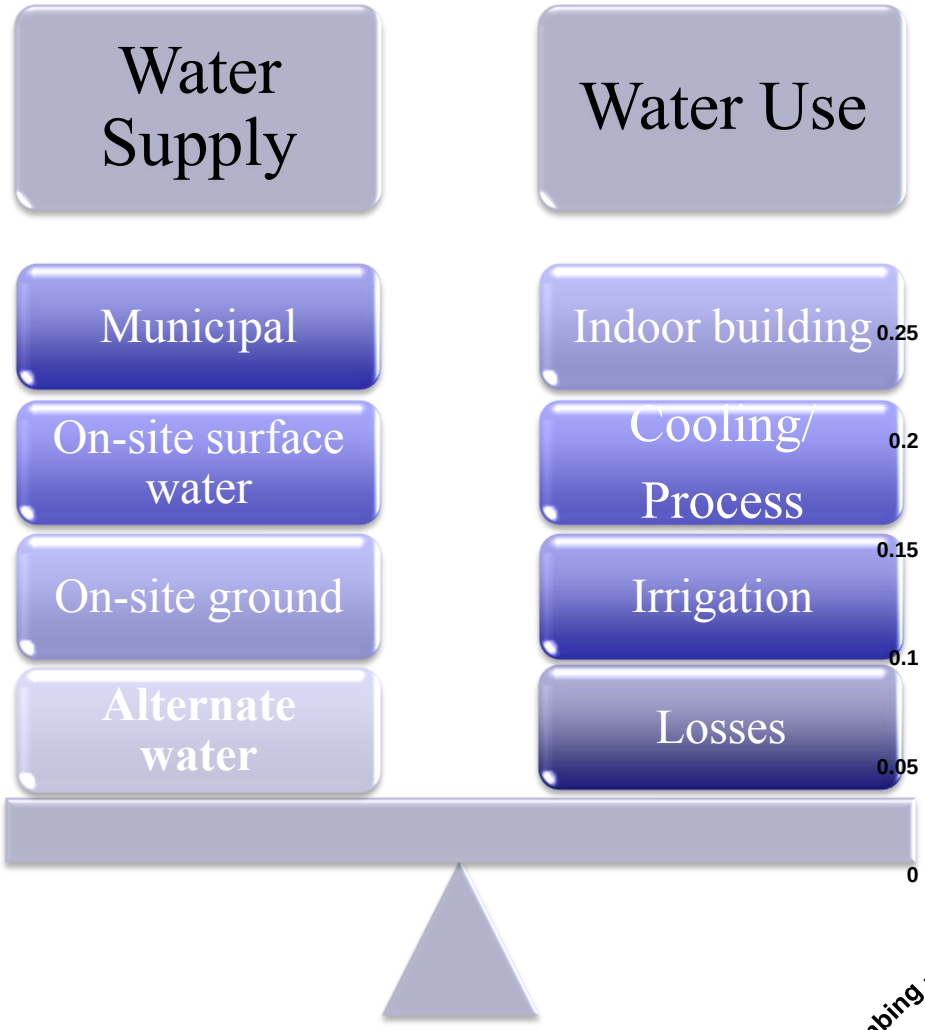


A Net Zero WATER Installation limits the consumption of freshwater resources & returns water back to the same watershed so not to deplete the groundwater and surface water resources of that region in quantity and quality over the course of a year

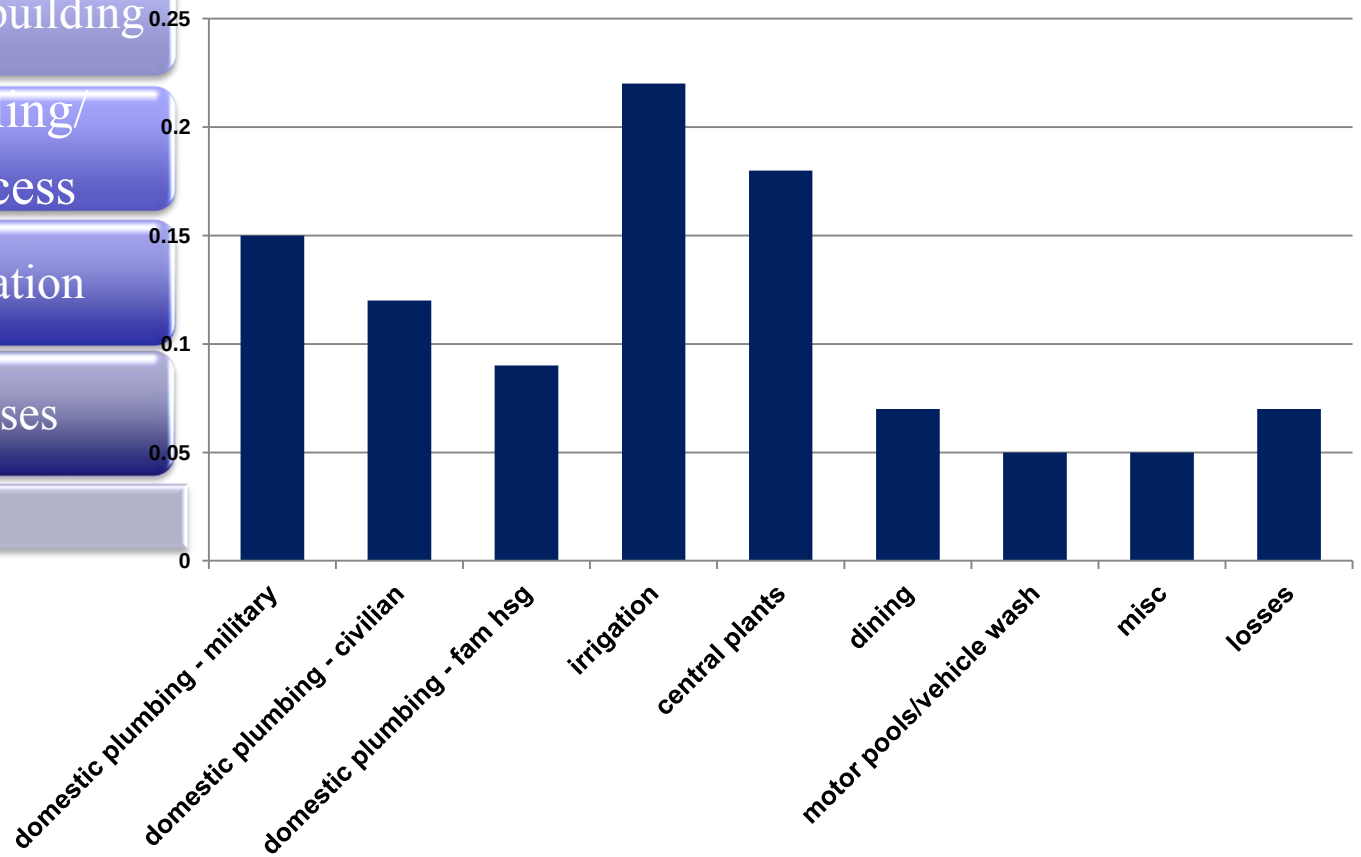
Goals:

- Contribute to the Army Campaign Plan's water security Major Objective
- Reduce freshwater demand through water efficiency and conservation
- Access/develop alternate water sources to offset freshwater demand
- Develop water-efficient green infrastructure
- Implement low-impact development to manage storm water

Net Zero – Water Balance



Water Balance = comparison of water supplied to water used



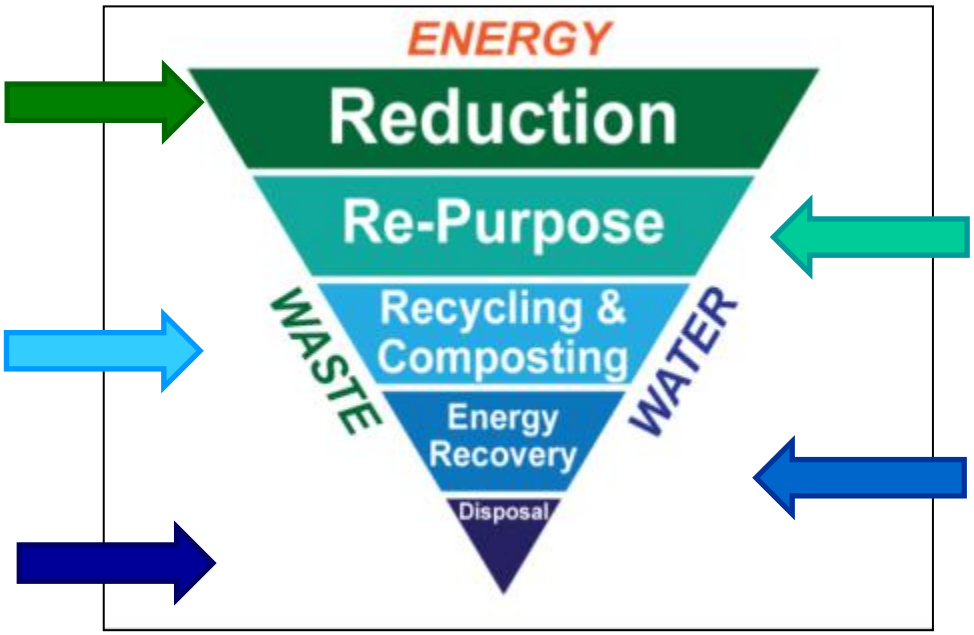
Net Zero Waste Strategy

Pilot Installations should have a comprehensive program that starts at the top of the hierarchy

Waste avoidance via procurement practices & other pollution prevention (P2) efforts

All recyclable or compostable waste collected & diverted (to on- or off-post facilities)

Waste-to-Energy ash (if not further diverted) & any limited special wastes

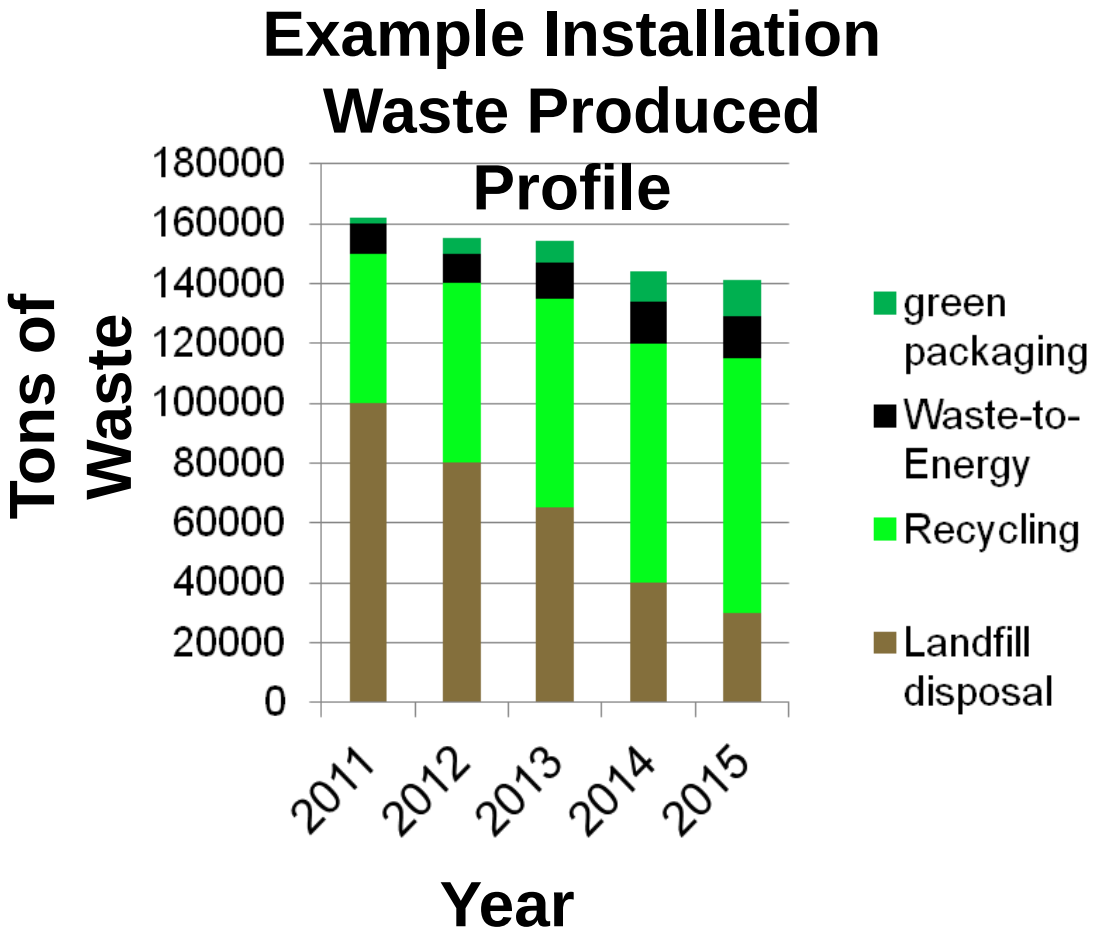


Installation re-use centers & efforts to match waste stream 'products' with potential users (e.g., crushed drywall used for soil amendment; construction & demolition (C&D) debris reuse)

Waste that can't be re-used, recycled, or composted is sent to a WTE plant (on- or off-post)

Waste Roadmaps

- Material flow analysis
- Improved procurement practices
- Re-purpose / re-use strategy
- Recycling & composting strategy
- Potentially viable waste-to-energy technologies



Leveraging Private Investments

Potential Financing Mechanisms

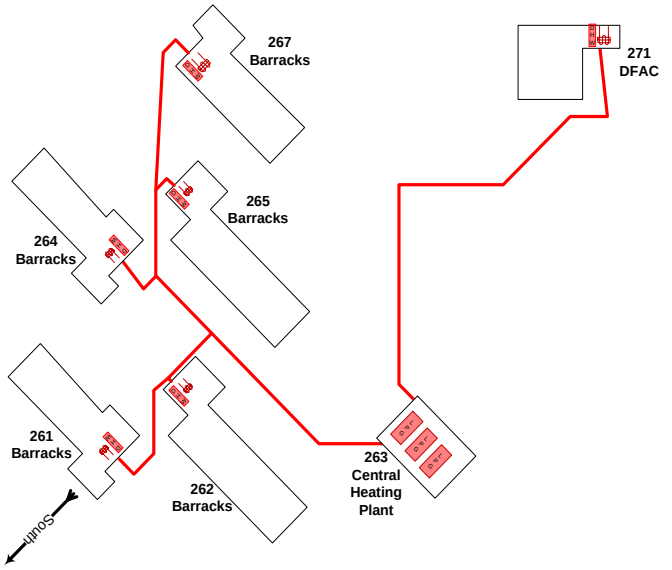
- **Energy Savings Performance Contracts (ESPC)**
  - Utilize private capital to make infrastructure improvements on military installations
  - Payment is derived from the savings generated by the improvements – Savings are verified through Measurement & Verification (M&V)
- **Utility Energy Service Contracts (UESC)**
  - Procurement method using utility expertise & capital to meet Federal conservation mandates
  - Utility's costs repaid directly from installation's avoided costs resulting from project implementation
- **Enhanced Use Lease (EUL)**
  - Funding method for construction on installations by allowing a private developer to lease underutilized property
  - Payment usually in the form of power back to the installation
- **Power Purchase Agreement (PPA)**
  - Allow federal agencies to fund on-site renewable energy projects with no upfront capital costs incurred

NZI-E Planning Tool Objectives

- **Provide Installation Planners and contractors a capability for integrated analysis and optimization so that they achieve Net Zero Energy status.**
- **Provide support for Installation Master Plans, Energy Plans, and prioritization for energy upgrades**
- **Support public/private partnerships by identifying sound projects appropriate for private financing.**
- **Establish framework for follow-on Water, Waste, and Greenhouse Gas modeling**

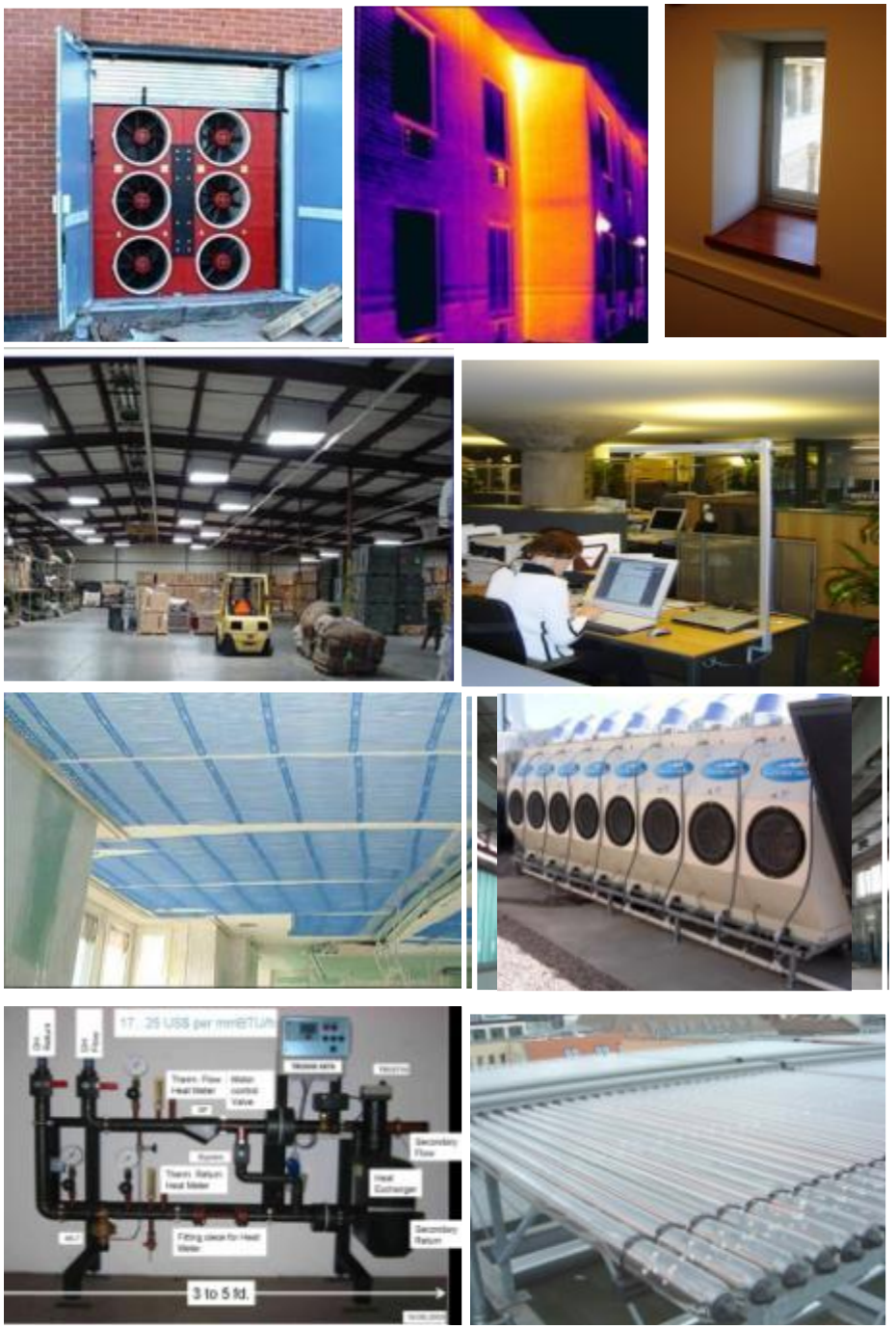
Typical Current Approach

- Expert Team
  - Optimize Buildings
  - Examine District Heating/Cooling/CHP options
  - Renewable Projects
- Recent/Ongoing Projects
  - EISA 2007 study
  - Fort Irwin
  - Fort Carson
  - Fort Bliss
  - Fort Bragg
- Pros/Cons
  - Pro – Draw on valuable experience
  - Pro – Access to specialized knowledge
  - Con – expensive
  - Con – takes time
  - Con – limited resources
  - Con – repetitive



NZI Approach

- Best practices process
- Automated facility load estimation
- Library of energy models
- Region/Facility type Energy Efficiency Measure (EEM) package optimization
- District/Cluster equipment package optimization
- Recommended phasing of NZI projects



NZI Planning Cycle

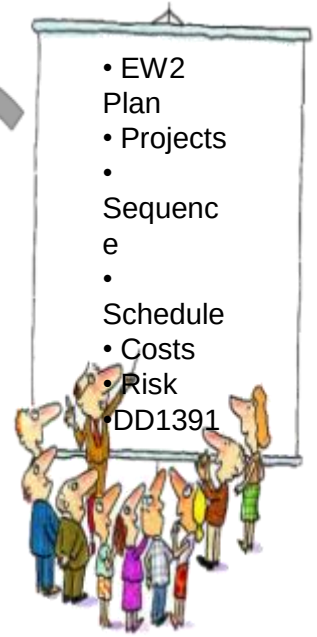
1
Setup Site Data

- Building
- Geography
- Utilities
- Cost Data
- Water
- Waste
- Greenhouse Gas

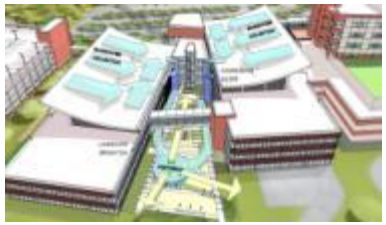
Execute, Track, Measure

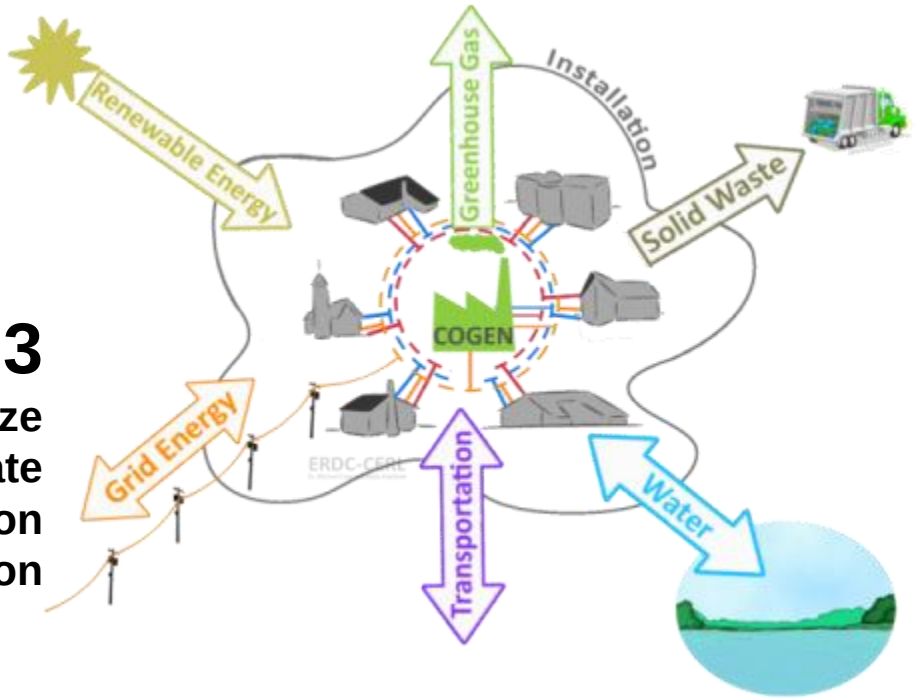
4
Update plans with Justification & Documentation

- EW2 Plan
- Projects
- Sequence
- Schedule
- Costs
- Risk
- DD1391



2
Minimize loads





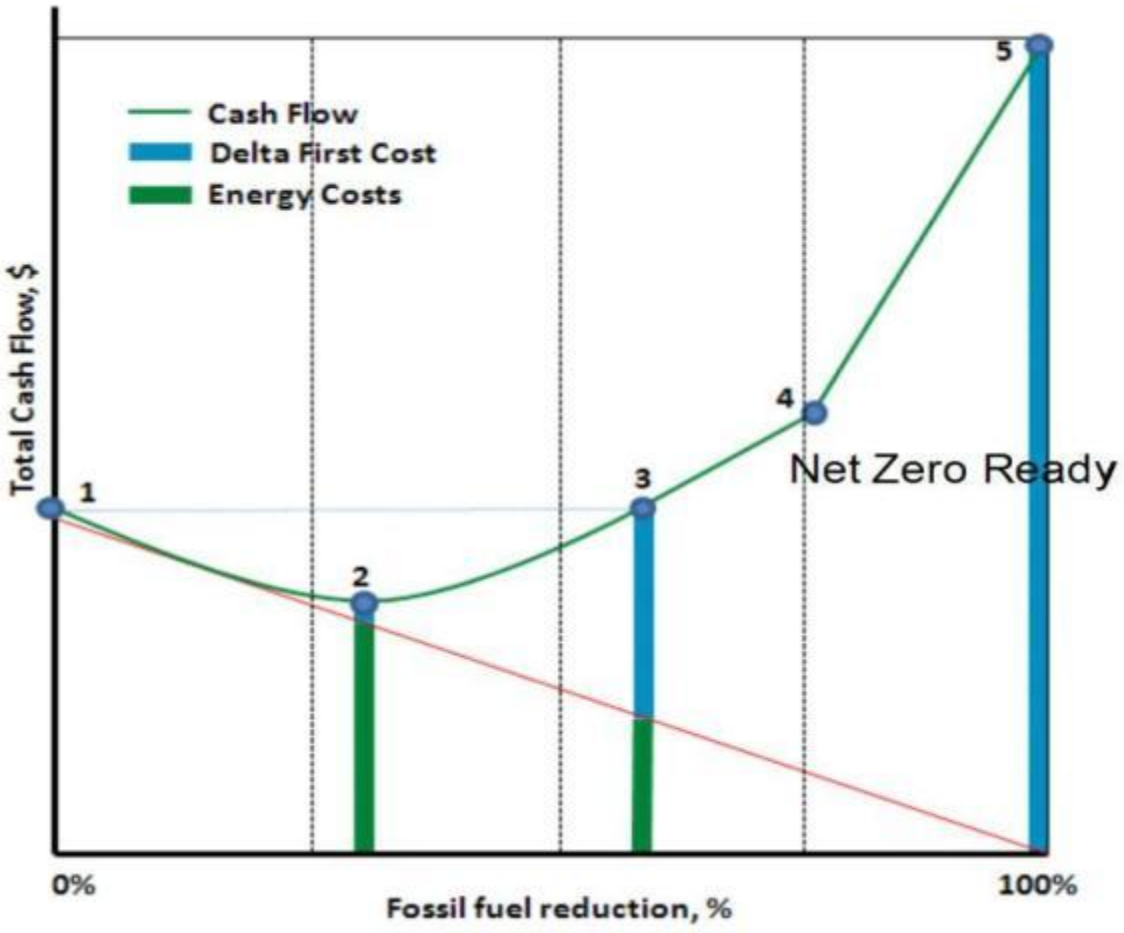
3
Optimize and integrate across Installation and region

Supports

Cost-Optimizing Zero Energy Systems

Integrating EEM's that are Net Zero Ready

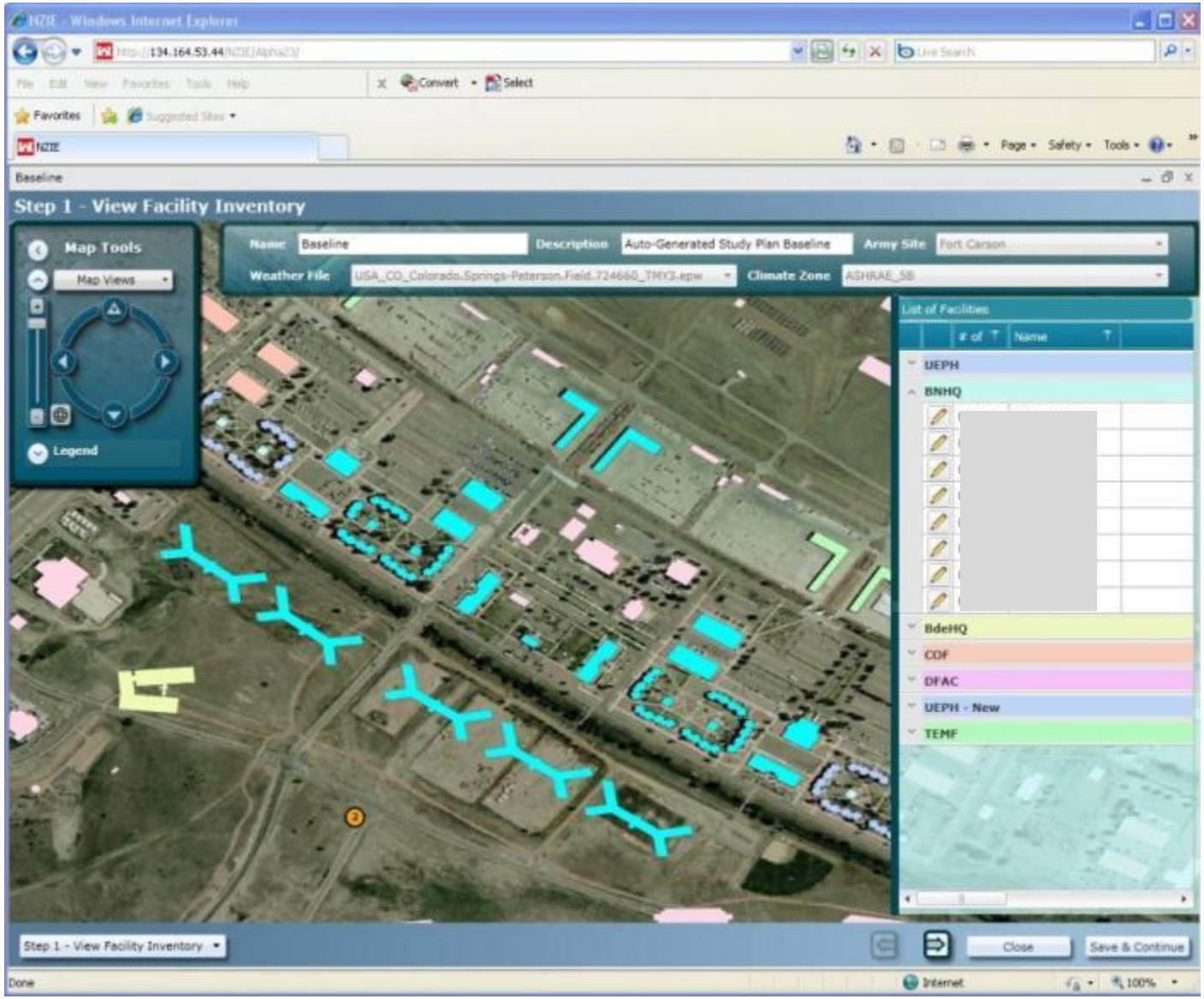
- **Debate over whether to conserve energy or generate it**
- **Need the lowest cost path to a building configuration which uses net-zero energy**
- **Point 4 is the Crossover Point: where generating renewable energy is more cost-effective than additional Energy Efficiency Measures or Net-Zero Ready. *Point 4 is normally at 60% to 80% savings depending on building and location***



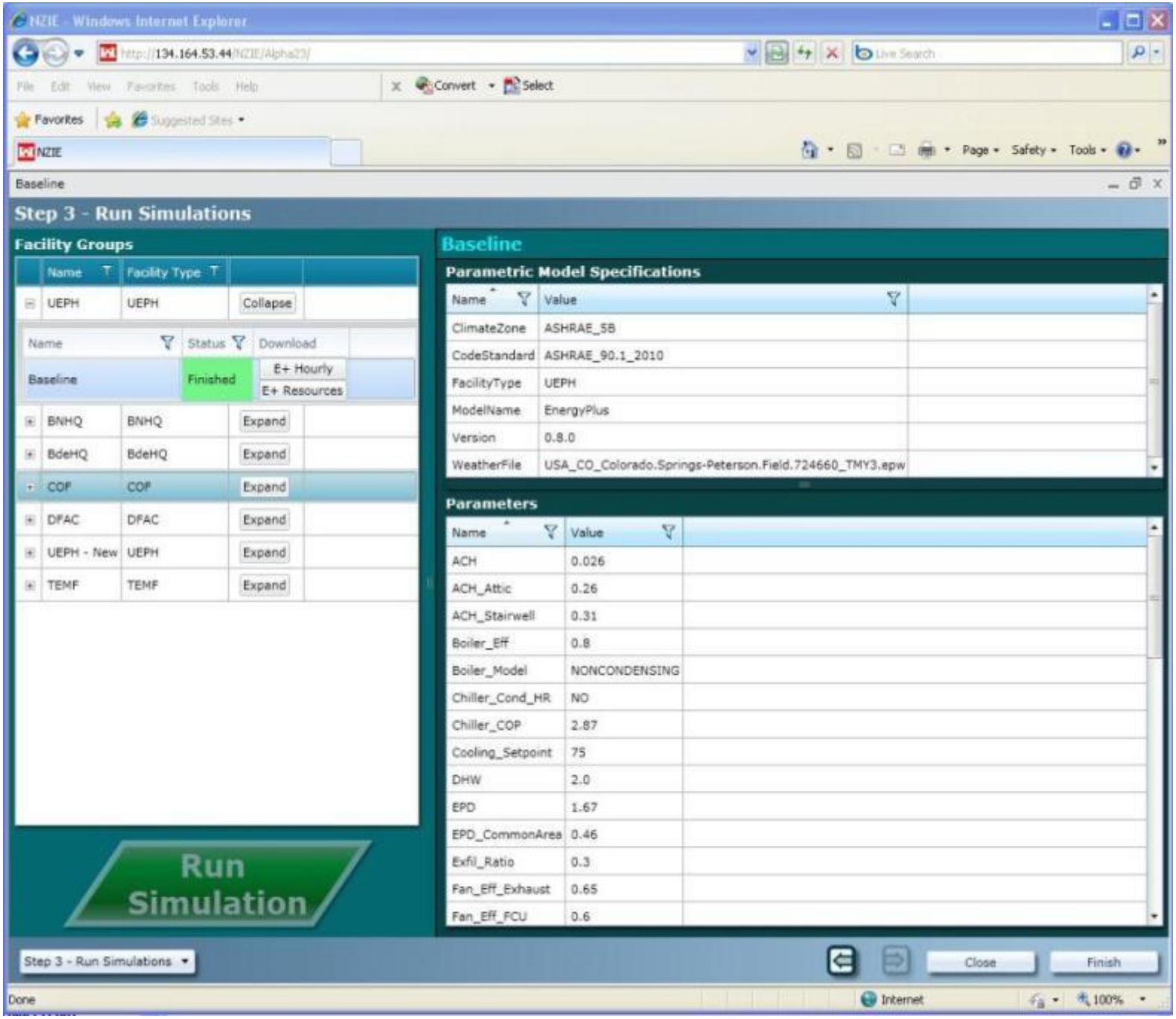
Finding your baseline

- NZI Load Estimation
- Metered data best!
- Usually need to estimate using models
- EnergyPlus, FEDS, DOE2/eQuest, Water Balance, SWARS,etc.
- Make sure model handles resolution required (e.g., 8760 hours)

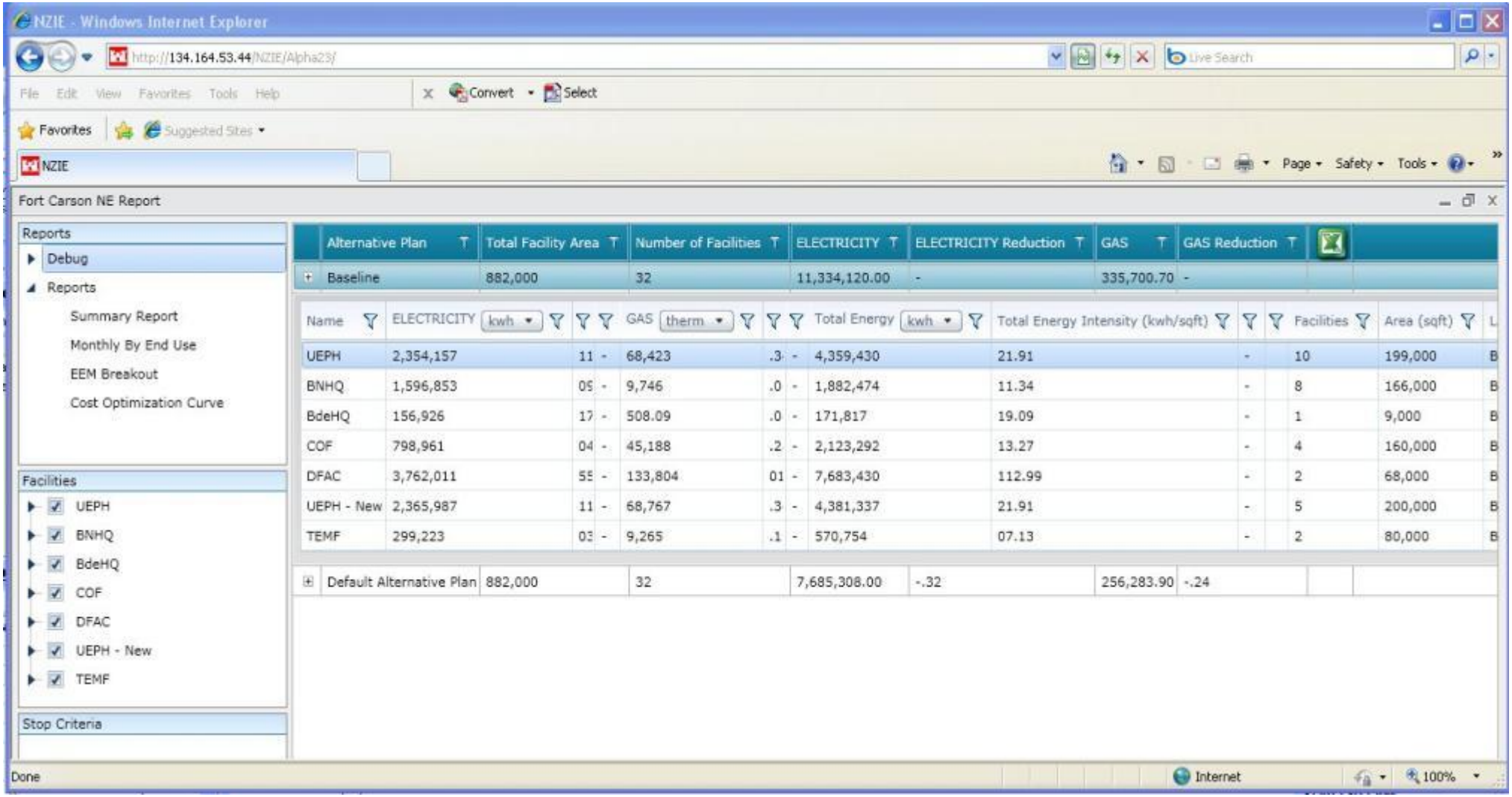
Inventory/Classify Building Types



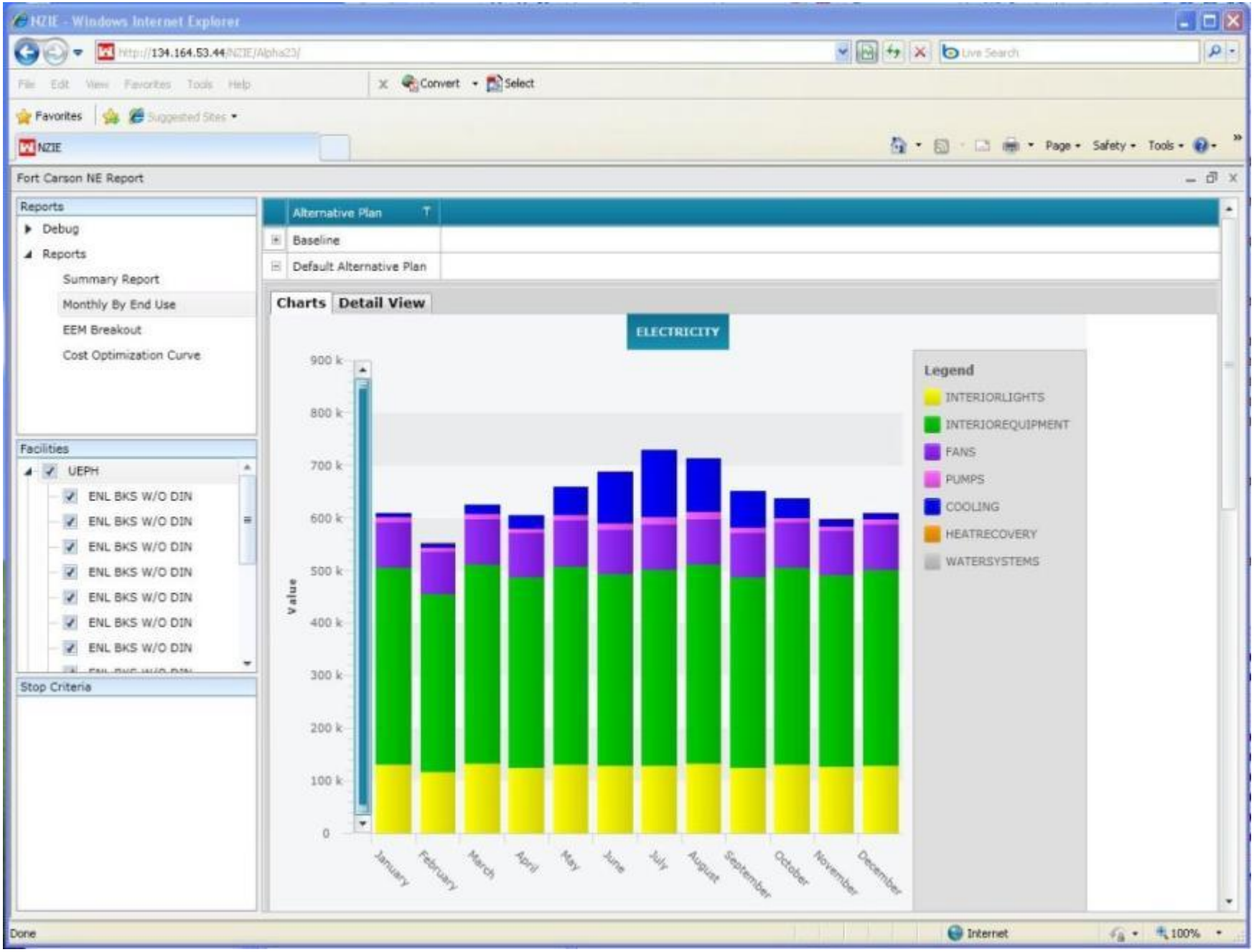
Run baseline to determine loads/flows



Review/Calibrate Baseline

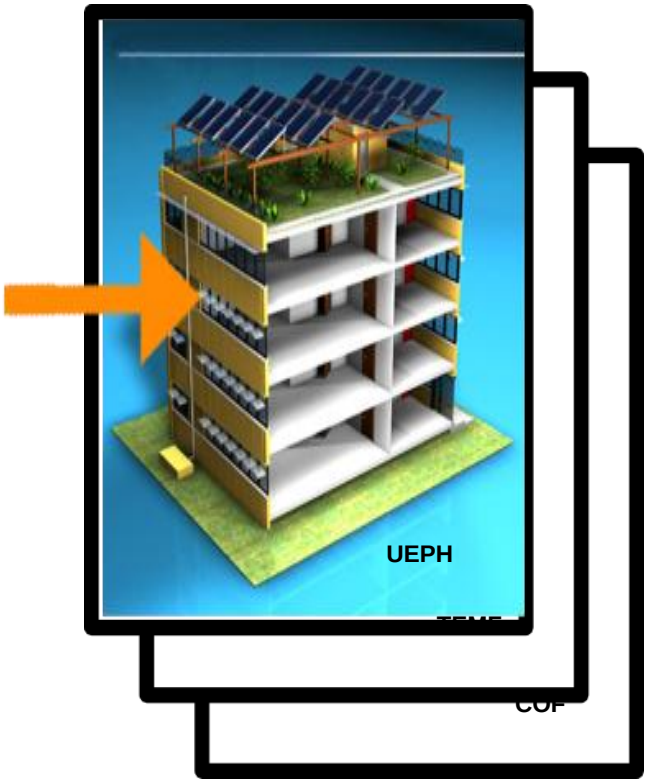


Review Load Profiles

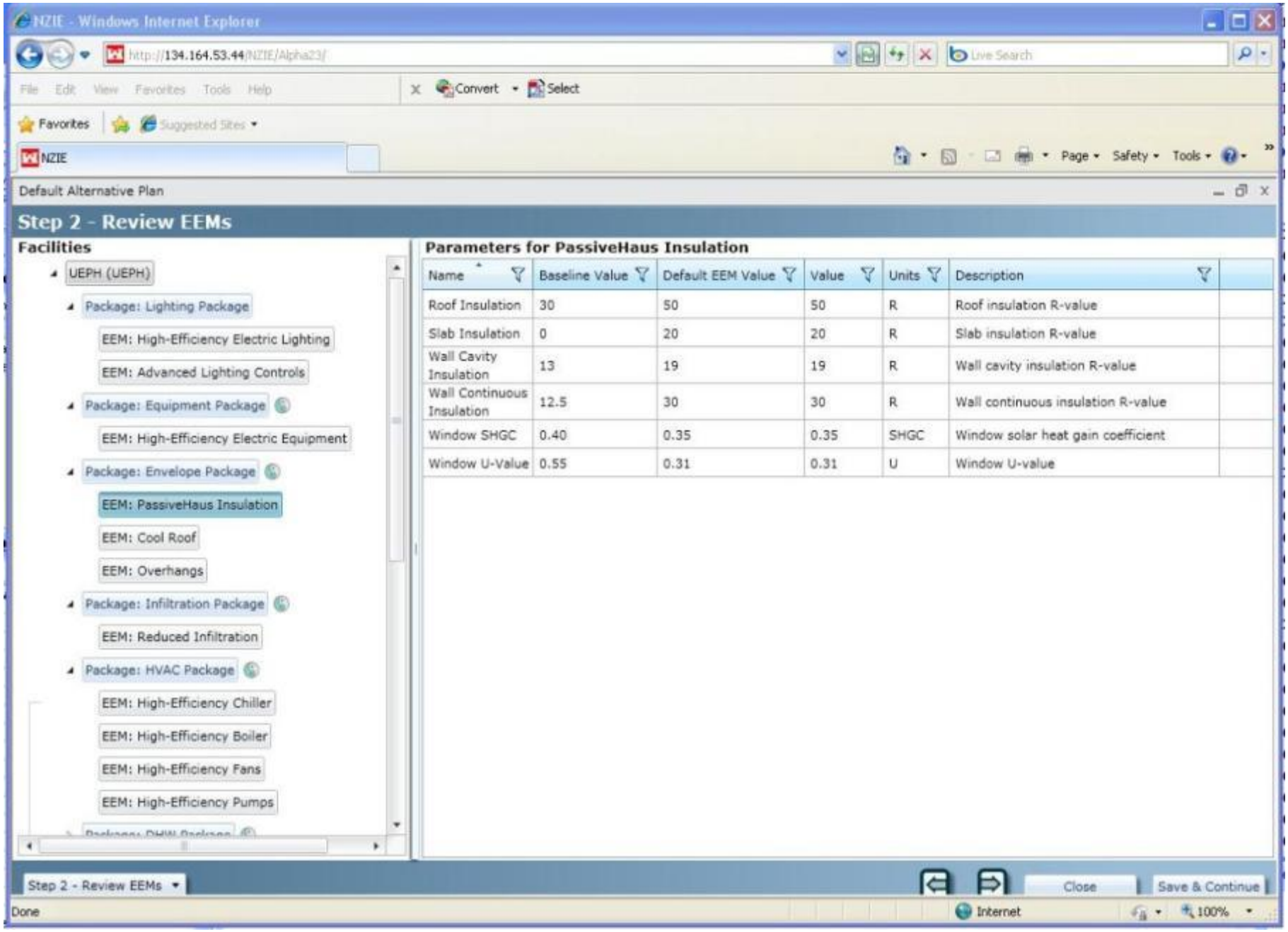


Predictive Model

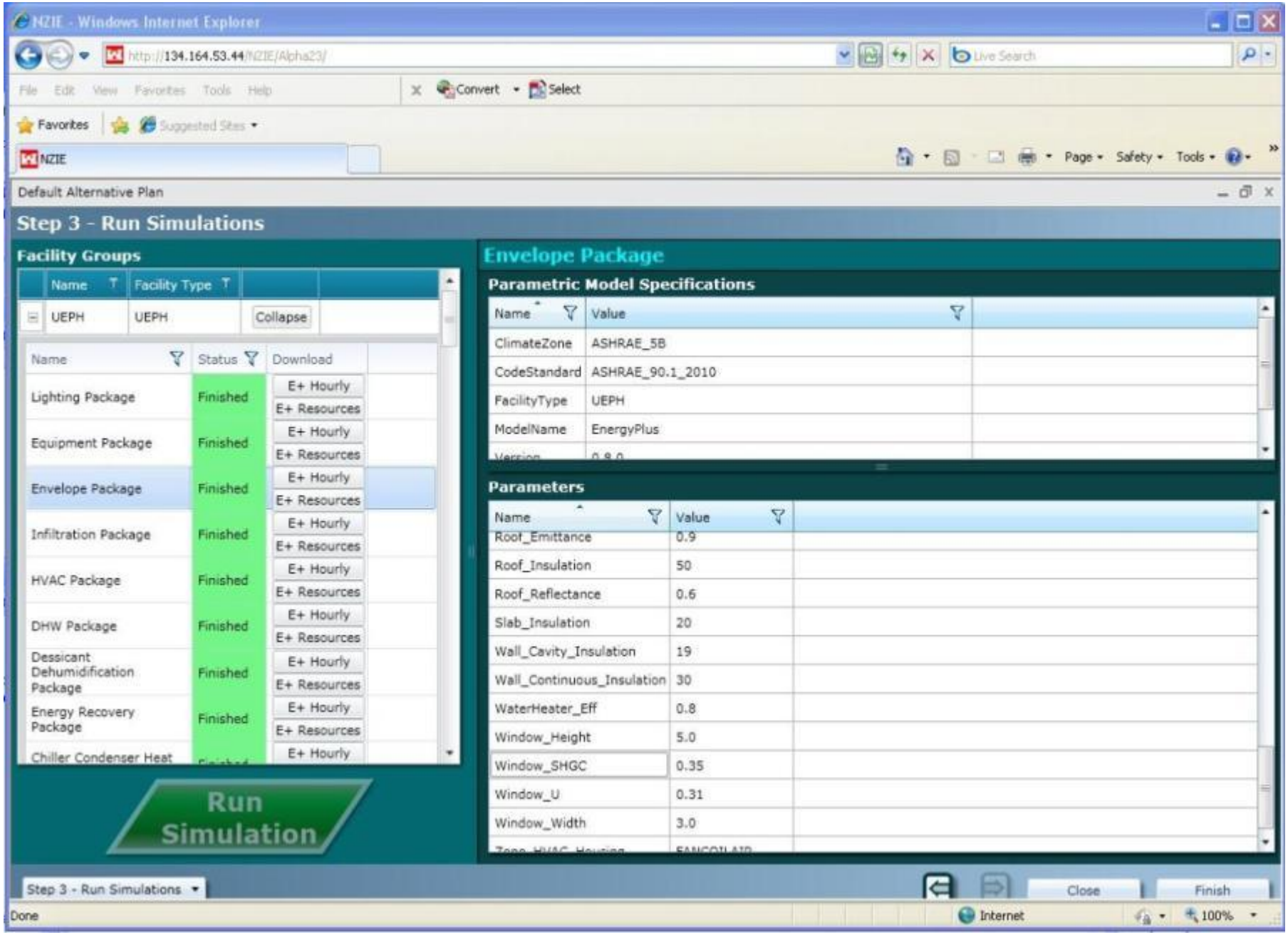
- Model Measures to be applied
- Energy, Water, Waste
- Best Practices, Technology, Behavior



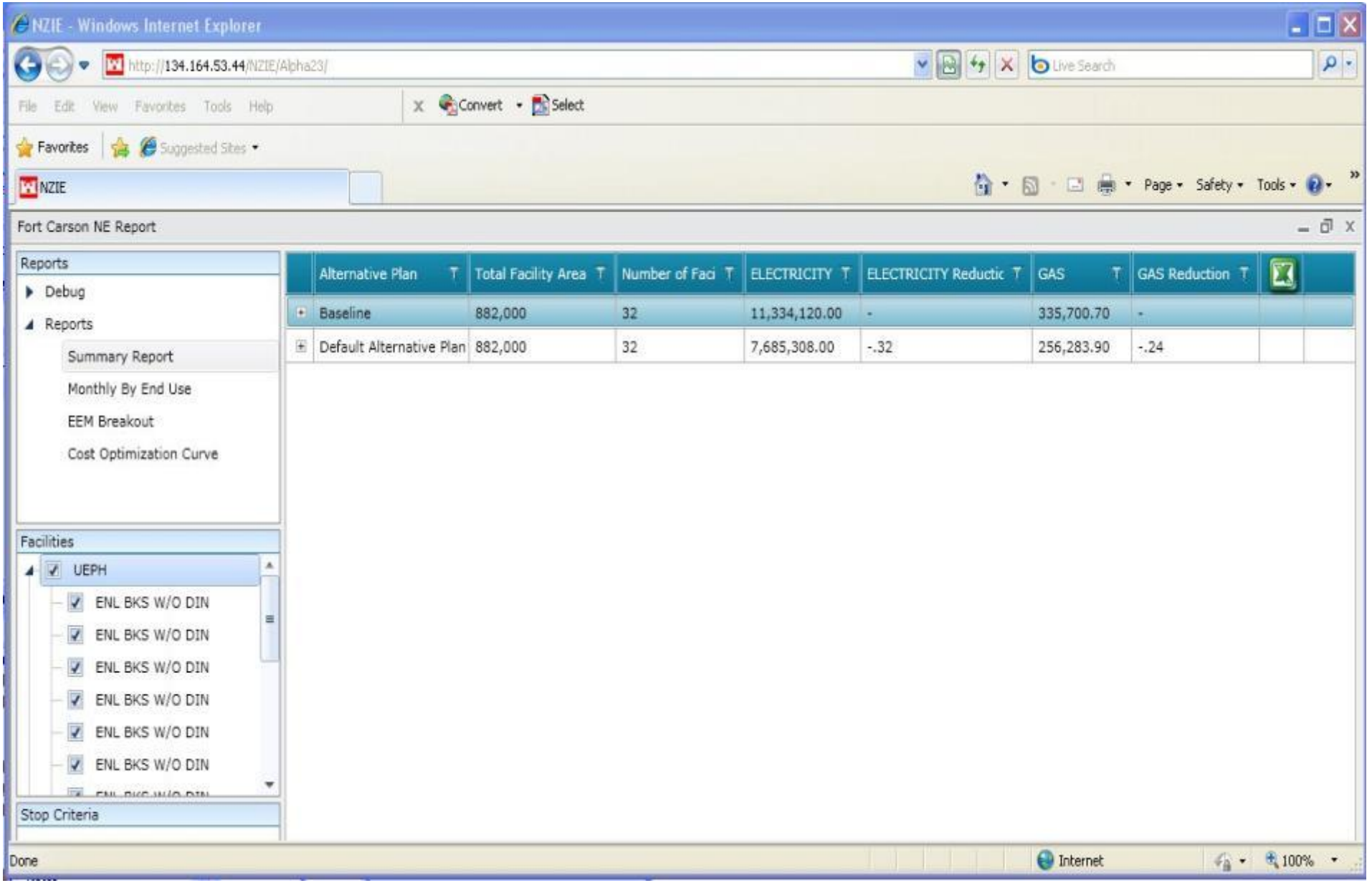
Review Measures to be Modeled



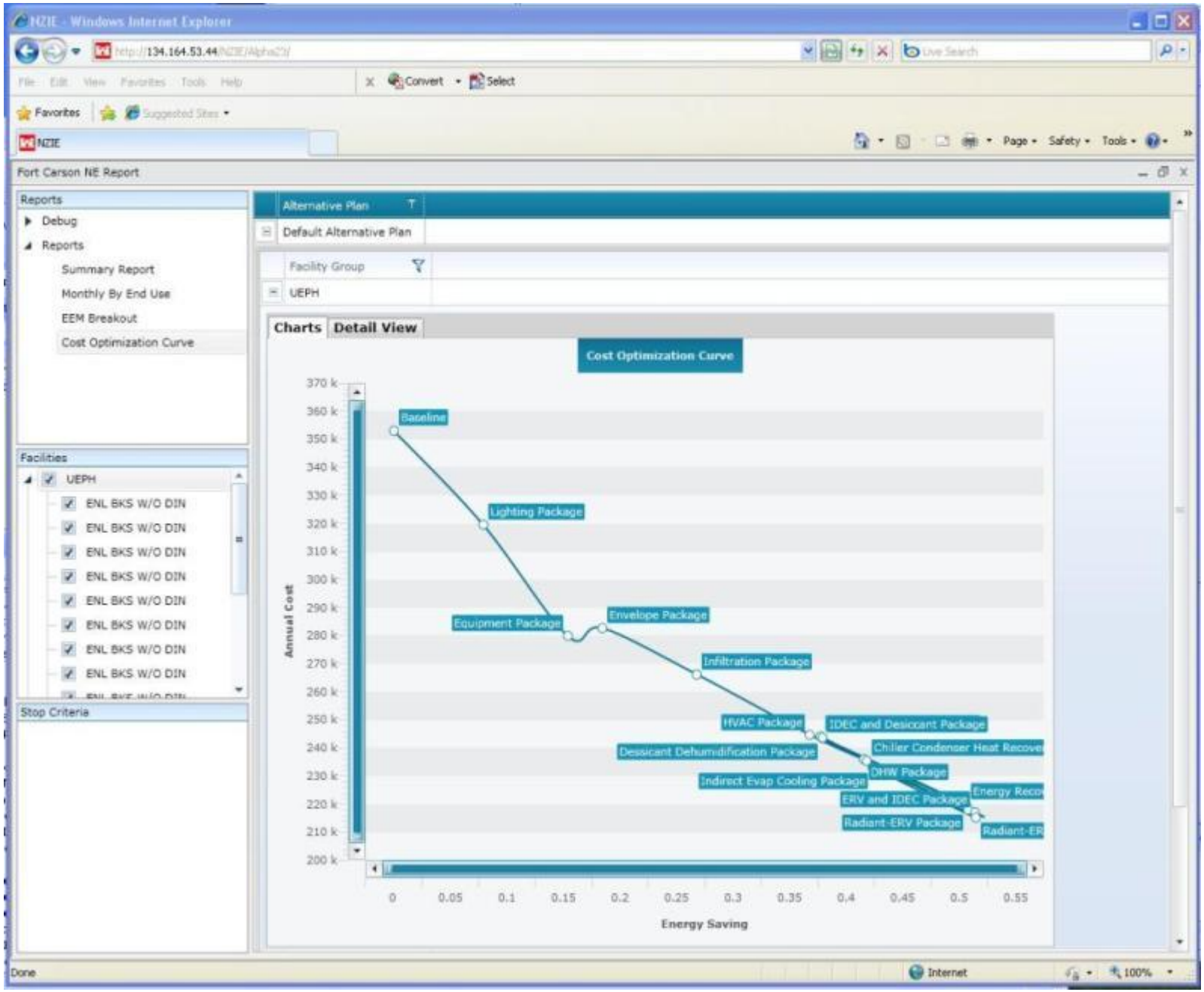
Simulation Predicts Performance & Cost



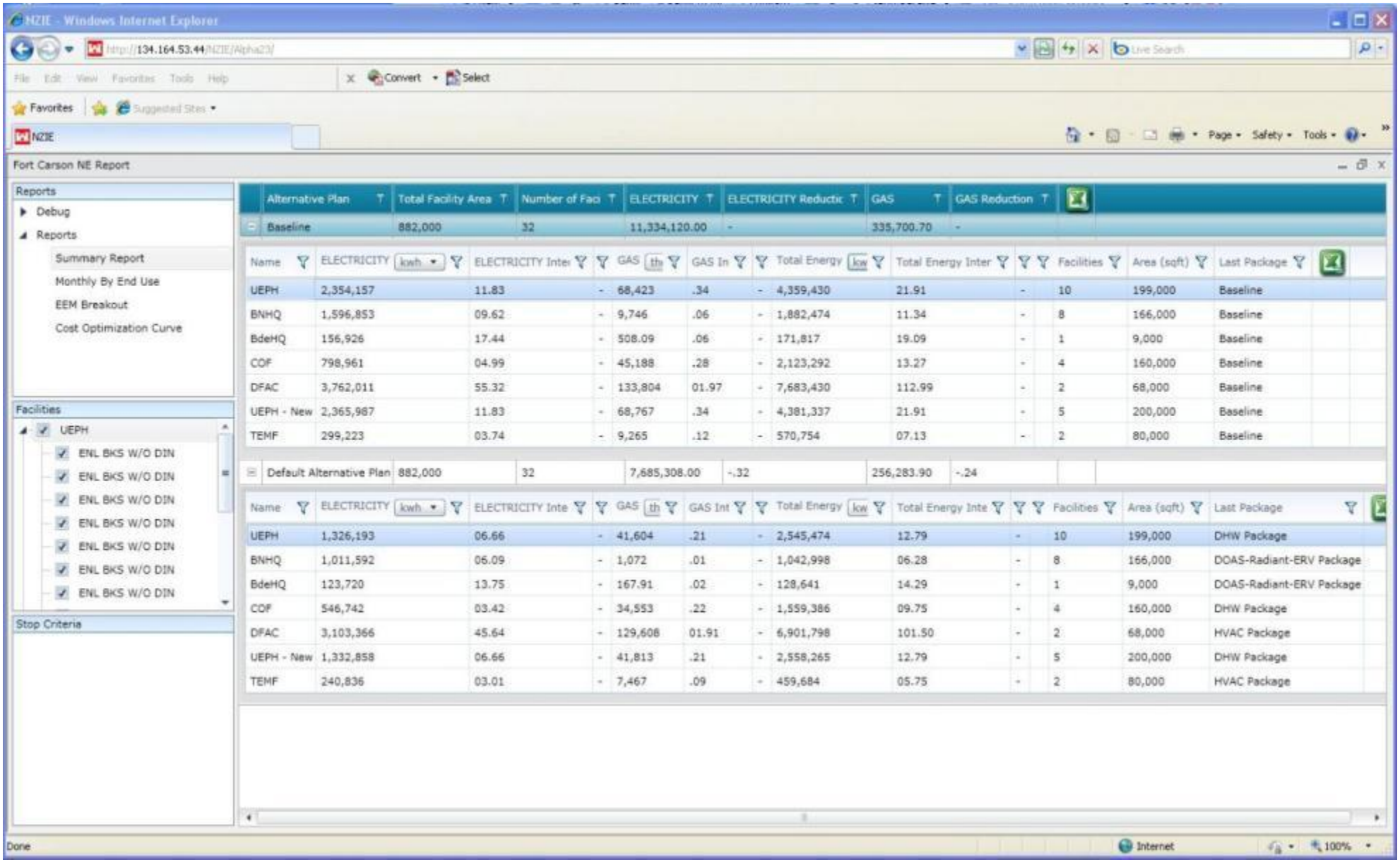
Compare Alternatives - Decision Criteria



Supporting Graphics



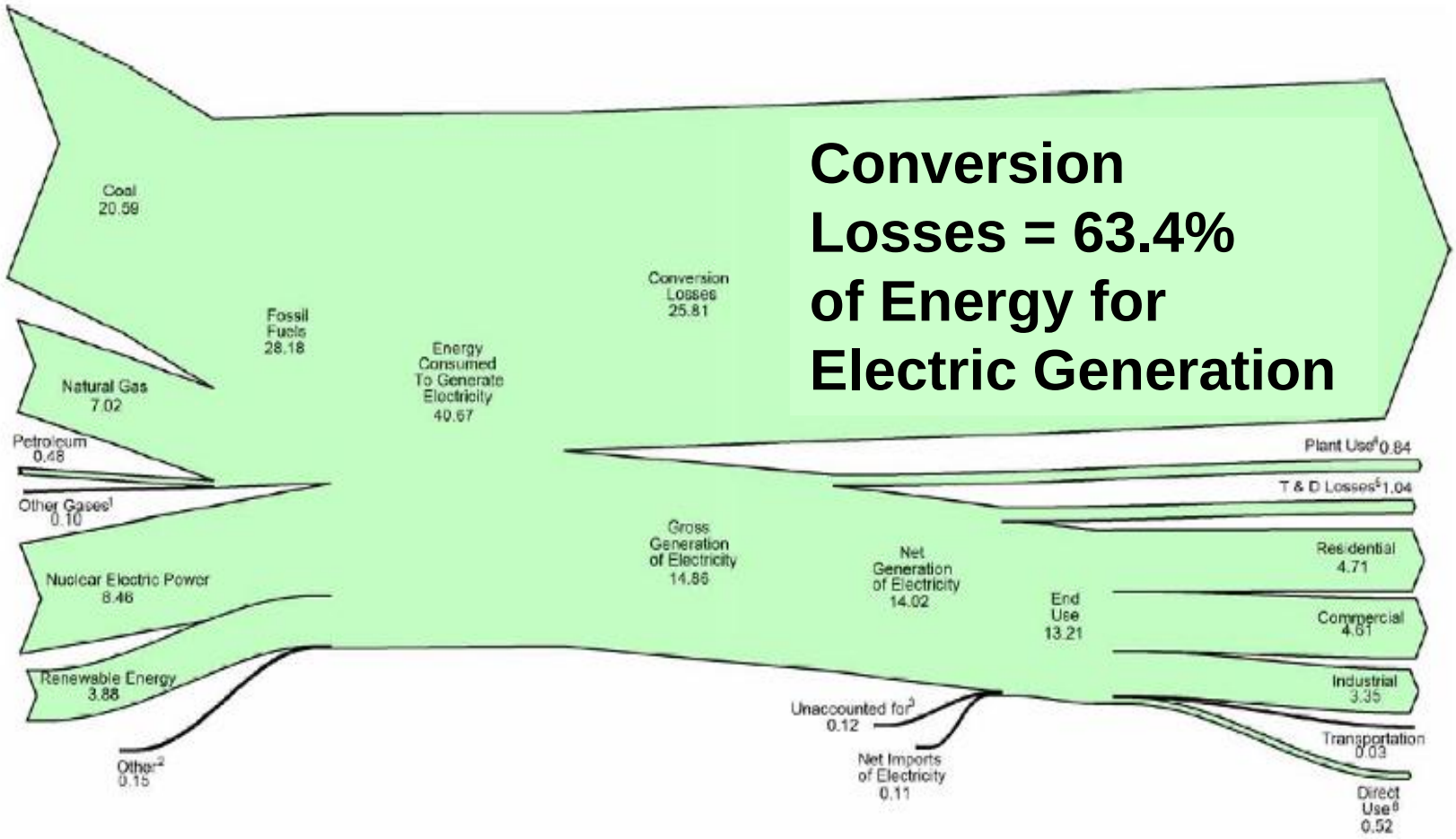
Supporting Data For Decision Criteria



Installation Level Optimization

- **Best Measures**
- **Sizes**
- **Operation Strategies**
- **Lowest Cost**
- **Models –**
  - **NZI Optimization Tool, POLIS, REO, FEDS, MODEST, MSW (Solid Waste), DSS (Water)**

Electricity Generation & Use in USA
Buildings are ~71% of total



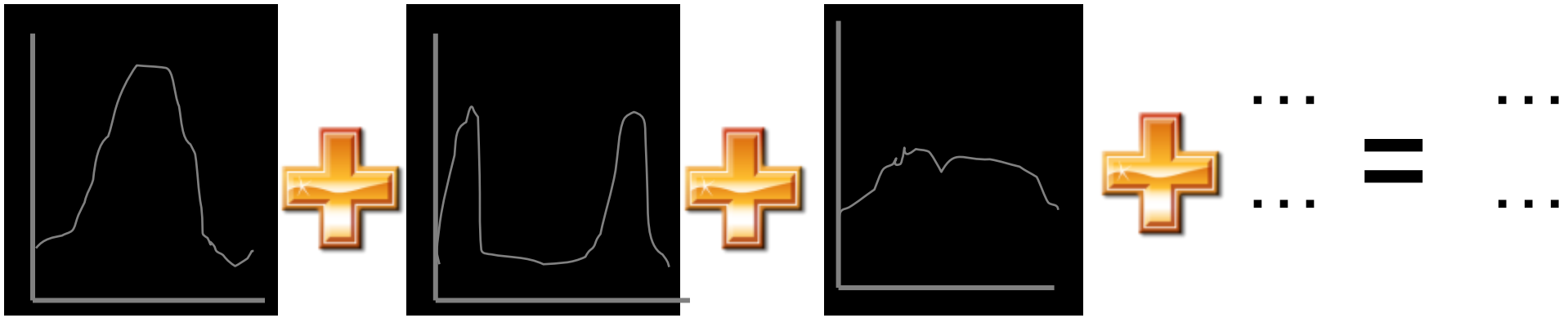
Trans & Dist Losses = 7.4% Net Gen Elec

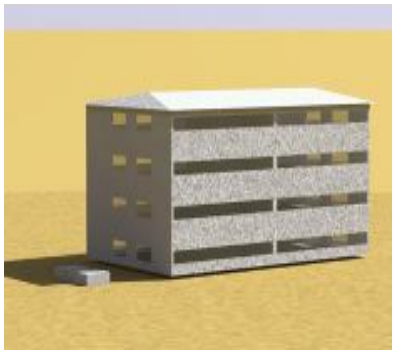
Buildings 70.6%

US DoE EIA 2008

Largest Cause of Greenhouse Gas

Building Cluster Analysis





Office Buildings …

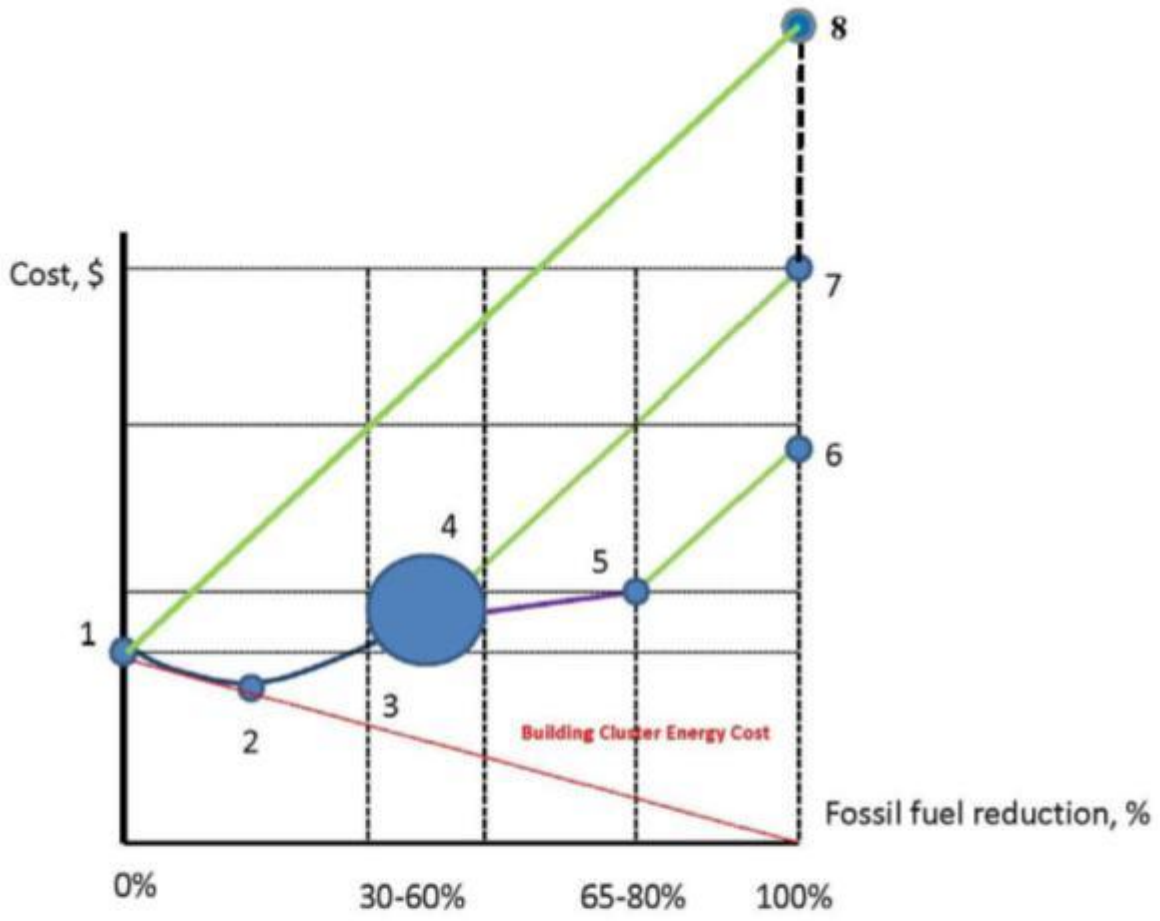
Barracks …

Maintenance Facility…

?

Other Facilities …

Building Cluster Fossil Fuel Optimization Process



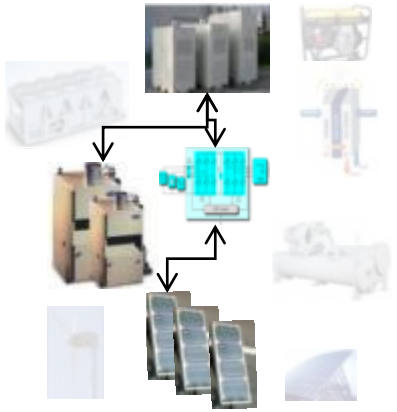
1 – Building prior to retrofit
2 - Building after retrofit with Business As Usual (BAU)
3 - Building after retrofit option to maintain the same annualized cost
4 - Building after maximum building site energy reduction retrofit
4-5 Building fossil fuel reduction due to Central Energy Plant (CEP) with co-generation
6 - NZE building connected to CEP with co-generation and a renewable energy source
7 - NZE building connected to a renewable energy source
8 - Building prior to retrofit connected to a renewable energy source

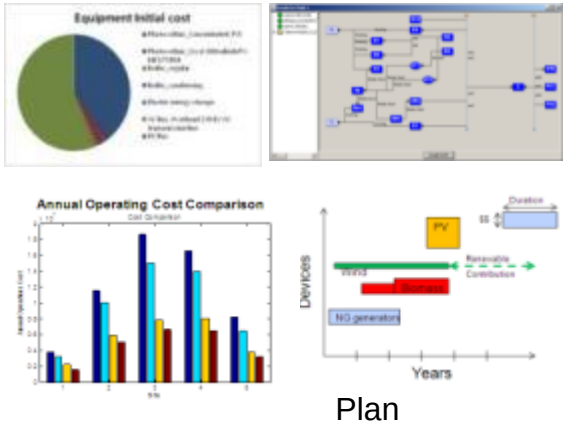
NZI Optimization Tool (NZI-Opt)

- Supply side equipment
- Lowest Life Cycle Cost
- To cluster or not to cluster
- Meet site constraints

- Heating
- Cooling
- Electic
- Critical Electric
- Water
  - Potable
  - Grey
  - Wastewater
- Solid Waste

- COGEN
- Biomass
- Solar PV
- Solar Thermal
- Wind
- Storage
- Fuel Cells, etc





Exploration Space ("Super-Structure")

Architecture(s) determined

Plan

Reporting & Implementation Plan

How it works

NZI-Opt begins with definitions for all possible equipment pieces that could serve the cluster demands. These definitions include region-independent parameters such as efficiency, energy inputs, and energy outputs. Some equipment examples are shown below.

Electric Chiller

Photovoltaic

Absorption Chiller

Gas Boiler

Organic Rankine Cycle

Diesel Generator

AC Bus

Fuel Cell

Wind Turbine

Gas Turbine

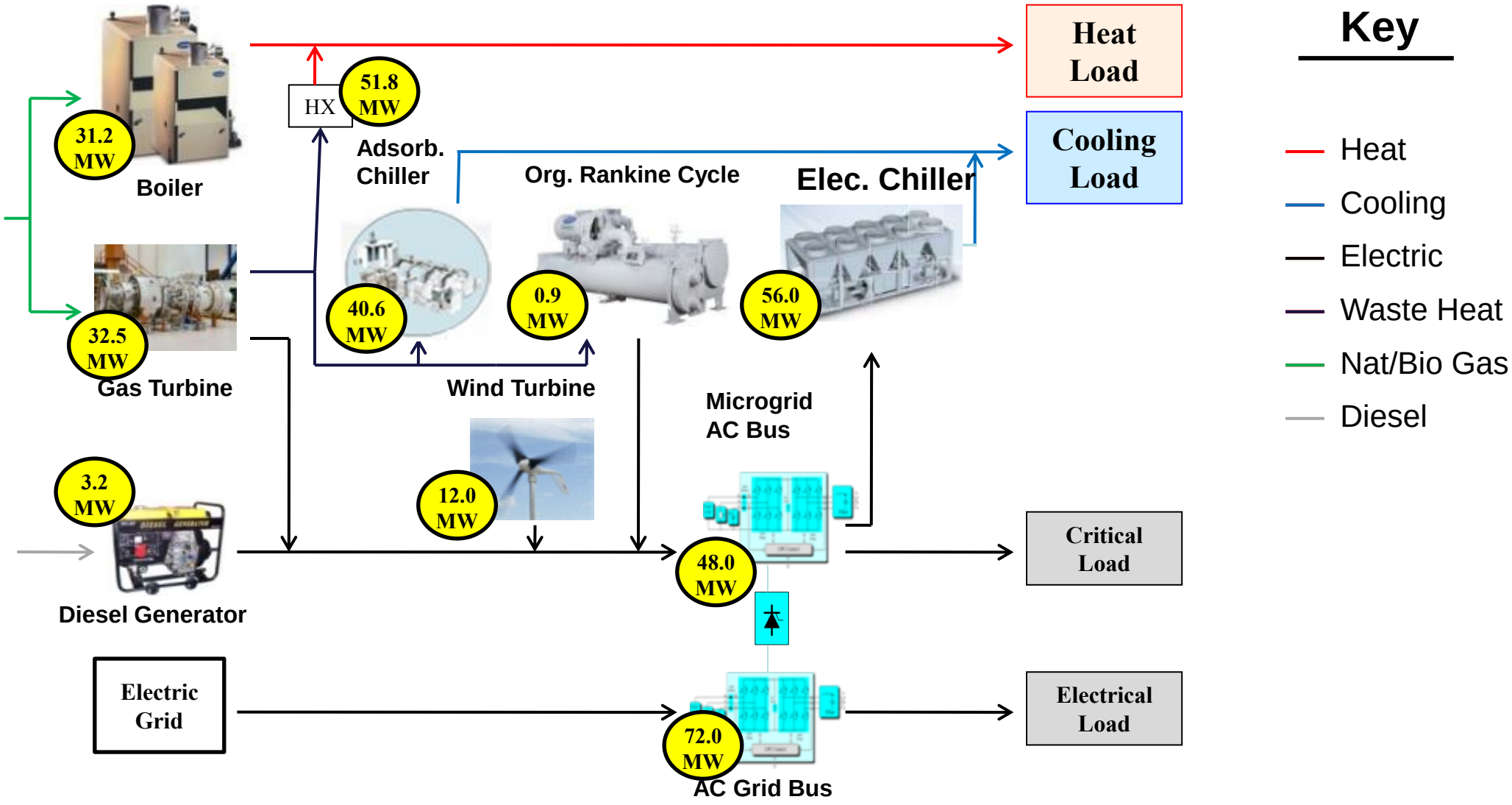
Electric Heater

Selecting a Supply Architecture

The optimization process determines the best suite of equipment by ensuring that the demands for heat, cooling, electric, etc are fulfilled at each of the 8760 hours in the year, while satisfying the additional environmental and legislative requirements.

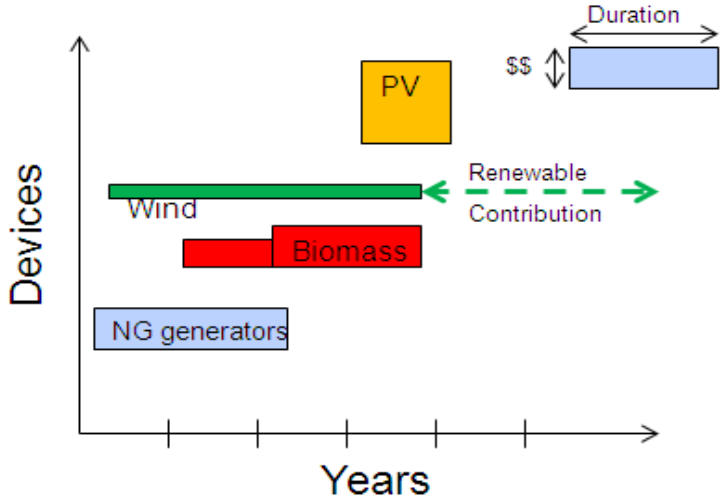
Sizing the Supply Equipment

Specific equipment pieces are sized and their interactions with each other are tracked throughout the year. The result is a complete "supply" solution that provides the sizing, initial cost, and operating cost of every piece of equipment in the lowest cost solution.

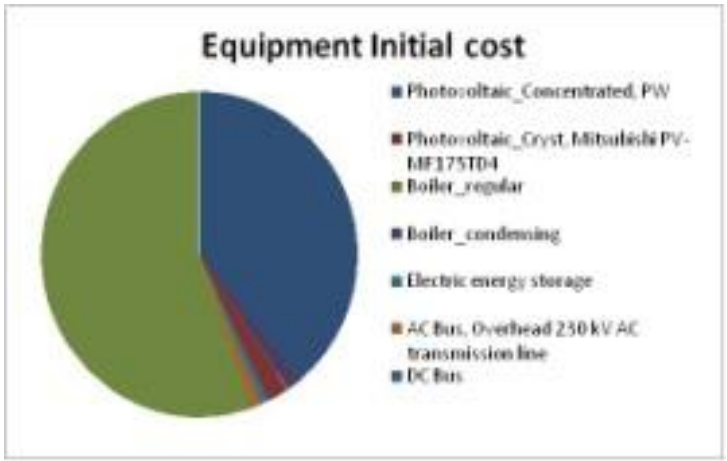


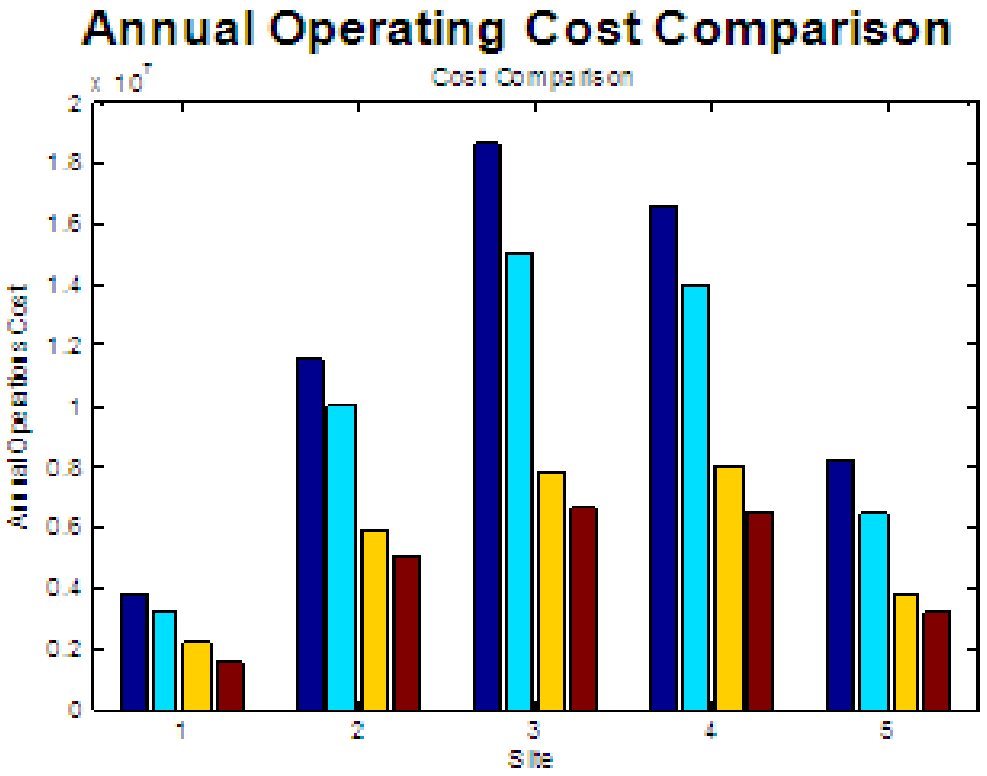
Orderly Approach

Once the equipment suite and sizing has been determined a post-process optimization can be run to determine the implementation schedule for the equipment. This process is meant to account for annual budget, progressive legislative requirements, and aging current equipment.

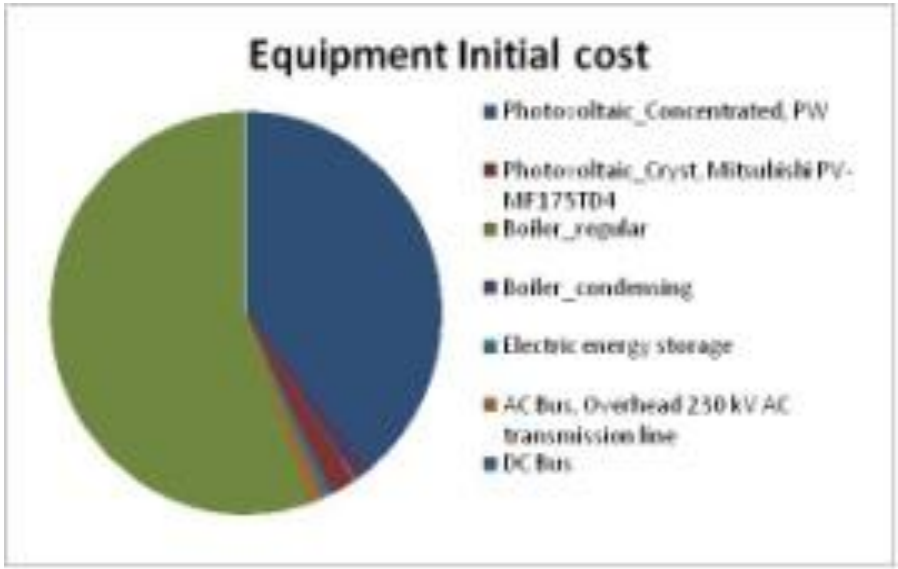


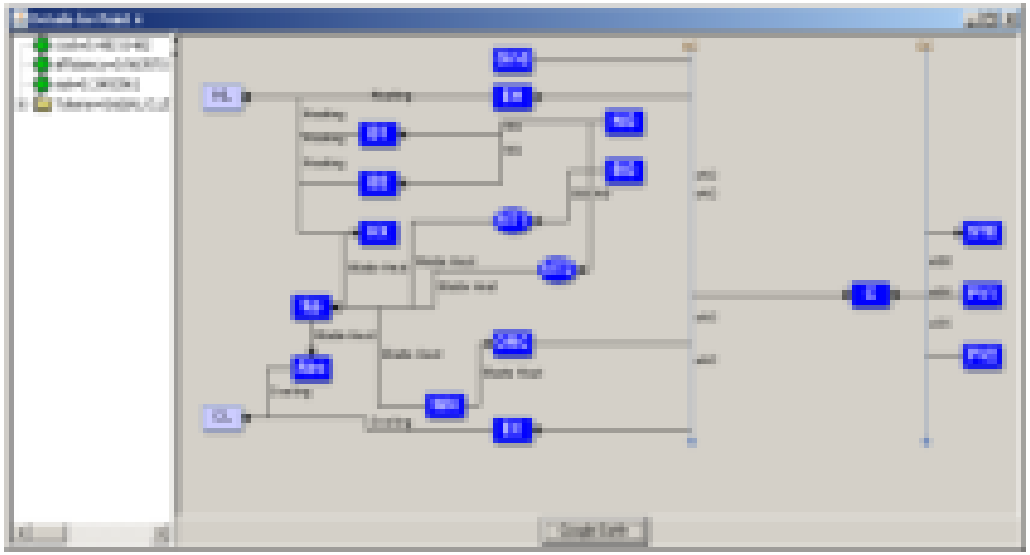
Plan

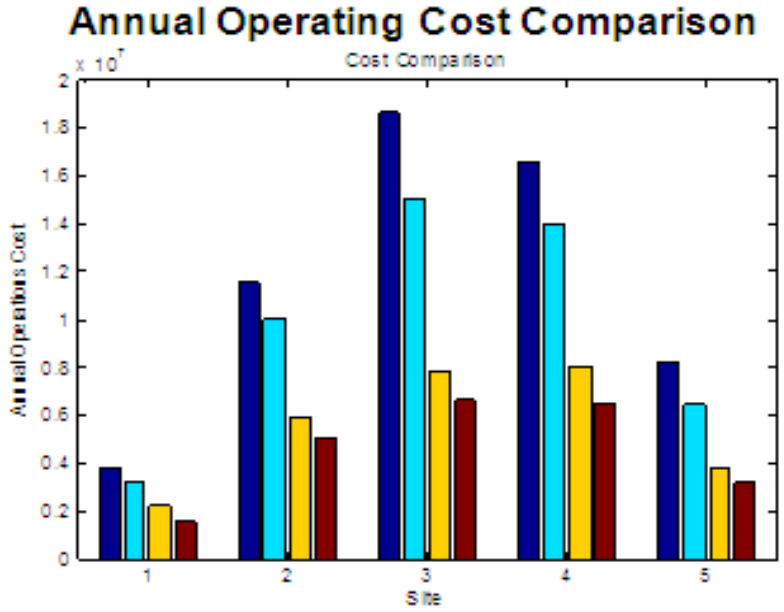


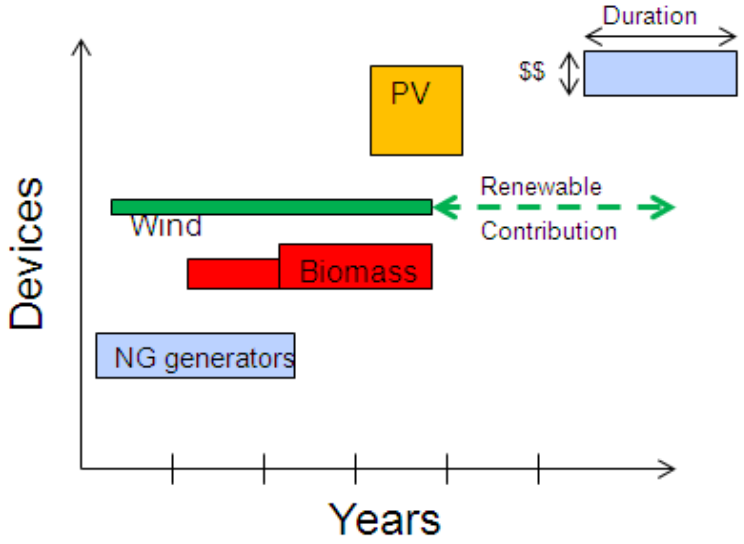


Reporting









Plan

USAG Fort Hunter Liggett is an Army Reserve installation in California's Central Coast region

Moffett Field
Mountain View

Parks RFTA
Dublin

Fort Hunter Liggett
Southern Monterey County

Federal Installation Energy & Sustainability Mandates

Mandate Topic	Energy & Sustainability Performance Target [Source]
Energy use in Federal buildings	• Reduce 3% per year to total by 30% by 2015 (2003 baseline) [EO 13423, EISA 2007]
GHG emission reduction	• Identify GHG emission reduction targets to be met by 2020 from 2008 baseline [EO 13514] • Army target – 34% [SA Memo to OSD]
Energy metering for improved energy management	• Meter electricity by Oct 2012 [EPACT 2005] • Meter natural gas and steam by Oct 2016 [EISA 2007]
Electricity use for federal government from renewable sources	• At least 3% of total electricity consumption (FY07-09), 5% (Fy10-12), 7.5% (FY13 +) [EPACT 2005, NDAA 2007]
Total consumption from renewable sources	• At least 50% of required annual renewable energy consumed from "new" renewable sources [EO 13423] • 25% by 2025 -"Sense of Congress" [EISA 2007], NDAA 2007
Hot water in new / renovated federal buildings from solar power	• 30% by 2015 if life cycle cost-effective [EISA 2007]
Fossil fuel use in new / renovated Federal buildings	• Reduce 55% by 2010; 100% by 2030 [EISA 2007]
Net zero buildings	• All new buildings entering design in 2020 and after achieve net zero energy by 2030 [EO 13514] • New federal buildings achieve net zero by 2030 [EISA 2007]
Fleet vehicle petroleum consumption	• Reduce 20% by 2015 (Base 2005) [EISA 2007] • Reduce by 2% per year thru FY2020 (Base 2005) [EO 13423, EO 13514]
Fleet vehicle alternative fuel use	• Increase 10% by 2015 (Base 2005) [EISA 2007] • Increase by 10% annually to reach 100% (Base 2005) [EO 13423]
Water consumption	• Reduce consumption intensity by 2% annually FY 08-FY 15 (2007 baseline) [EO 13423] • Reduce consumption by 2% annually for 26% total by FY 2020 (2007 baseline) [EO 13514]

Key to meeting the challenge ‘Master Planning for Net Zero’

- **Fort Hunter Liggett’s Commander is engaged and highly supportive**
- **Constant collaboration between the energy manager, environmental manager and the master planner**
- **Partnership with your local energy provider**
- **Support from the Army**

Net Zero Energy – the approach

- **Reduce consumption to the minimum amount possible – including changing behavior, retro-fitting facilities**
- **Re-purpose facilities – take under utilized facilities and repurpose them into more efficient use**
- **Produce for remaining demand, preferably utilizing renewable energy; solar, ground source heat pumps, geo-thermal, etc.**

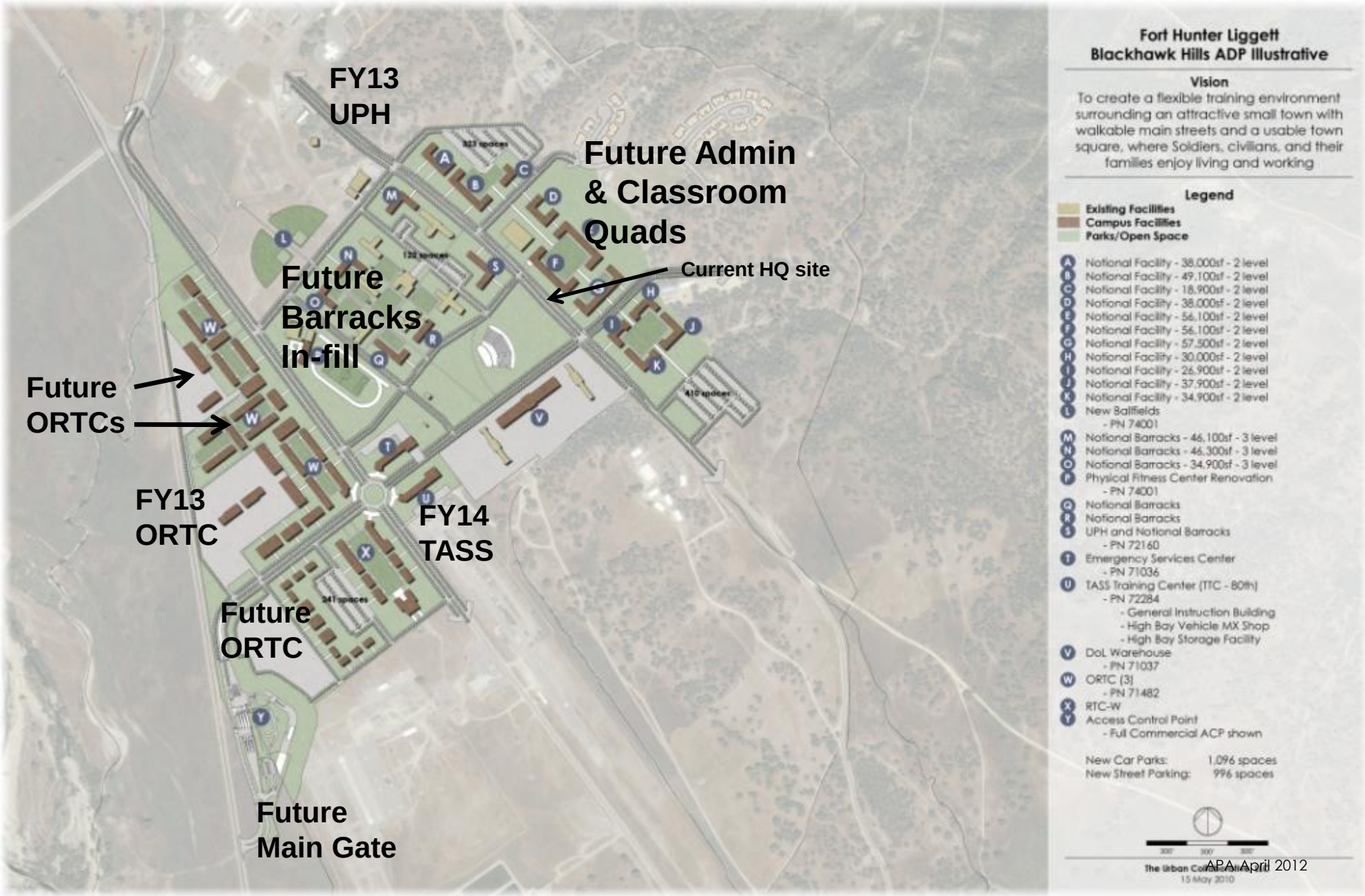
Additional factors:

- Staffing is always a challenge
- Understanding the issues / metrics
- How to get federal mandates into a master plan
- "It wasn't budgeted"
- Maximizing shrinking real estate
- It's difficult...

ACSIM policy: ...Create more compact urban communities that still meet security and safety factors. Planners will incorporate the following key principles of sustainable planning in their Master Plans, area development plans, and other planning products:

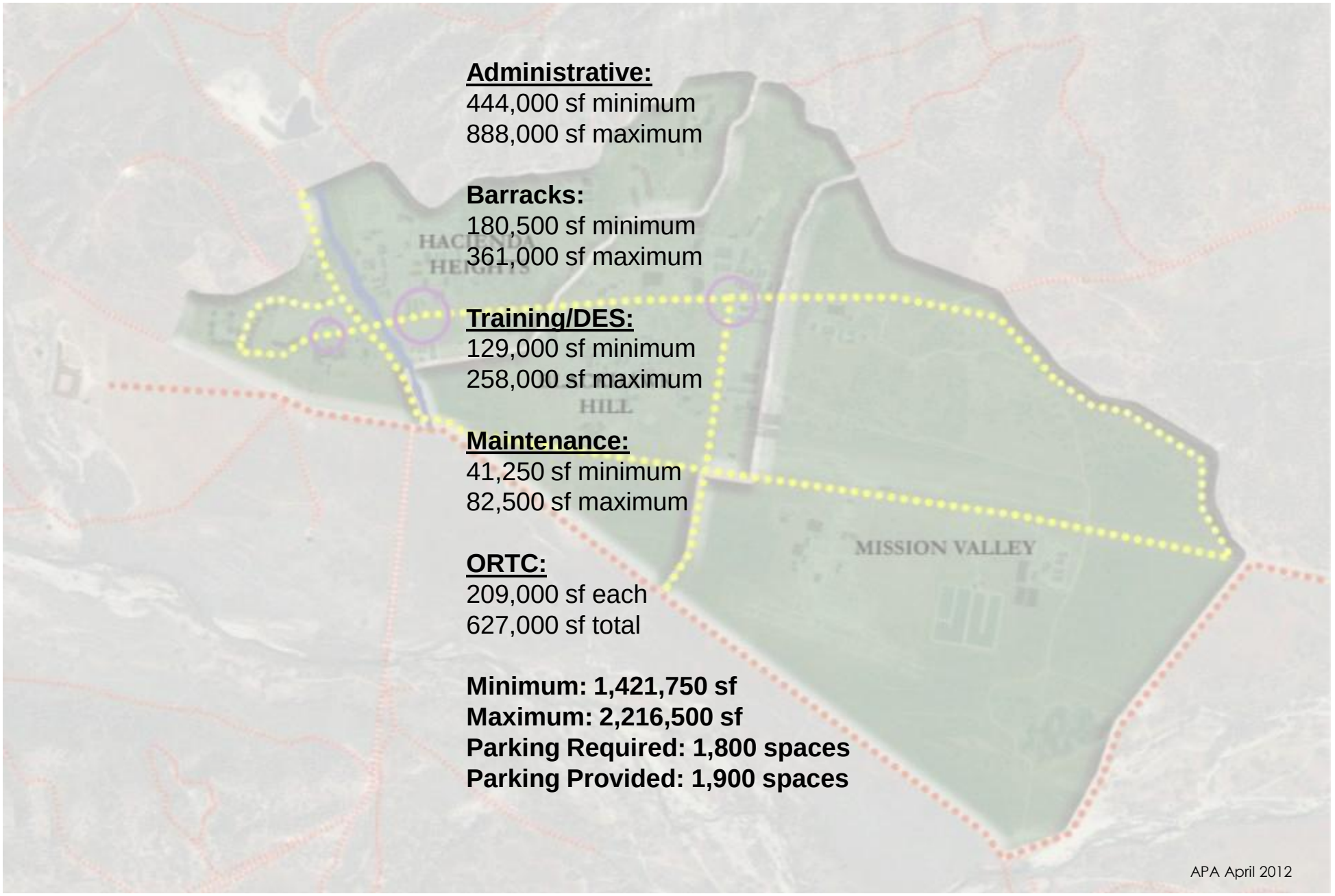
- **compact development**
- **infill development**
- **transit-oriented development**
- **horizontal and vertical mixed-uses**
- **connected transportation networks**
- **low impact development**
- **multi-story construction**
- **narrow buildings**

Blackhawk Hills Area Development Plan – Barracks, Classroom and Admin Quads



APA April 2012

Blackhawk Hills Buildout Potential = 2.2M SF



Administrative:
444,000 sf minimum
888,000 sf maximum

Barracks:
180,500 sf minimum
361,000 sf maximum

Training/DES:
129,000 sf minimum
258,000 sf maximum

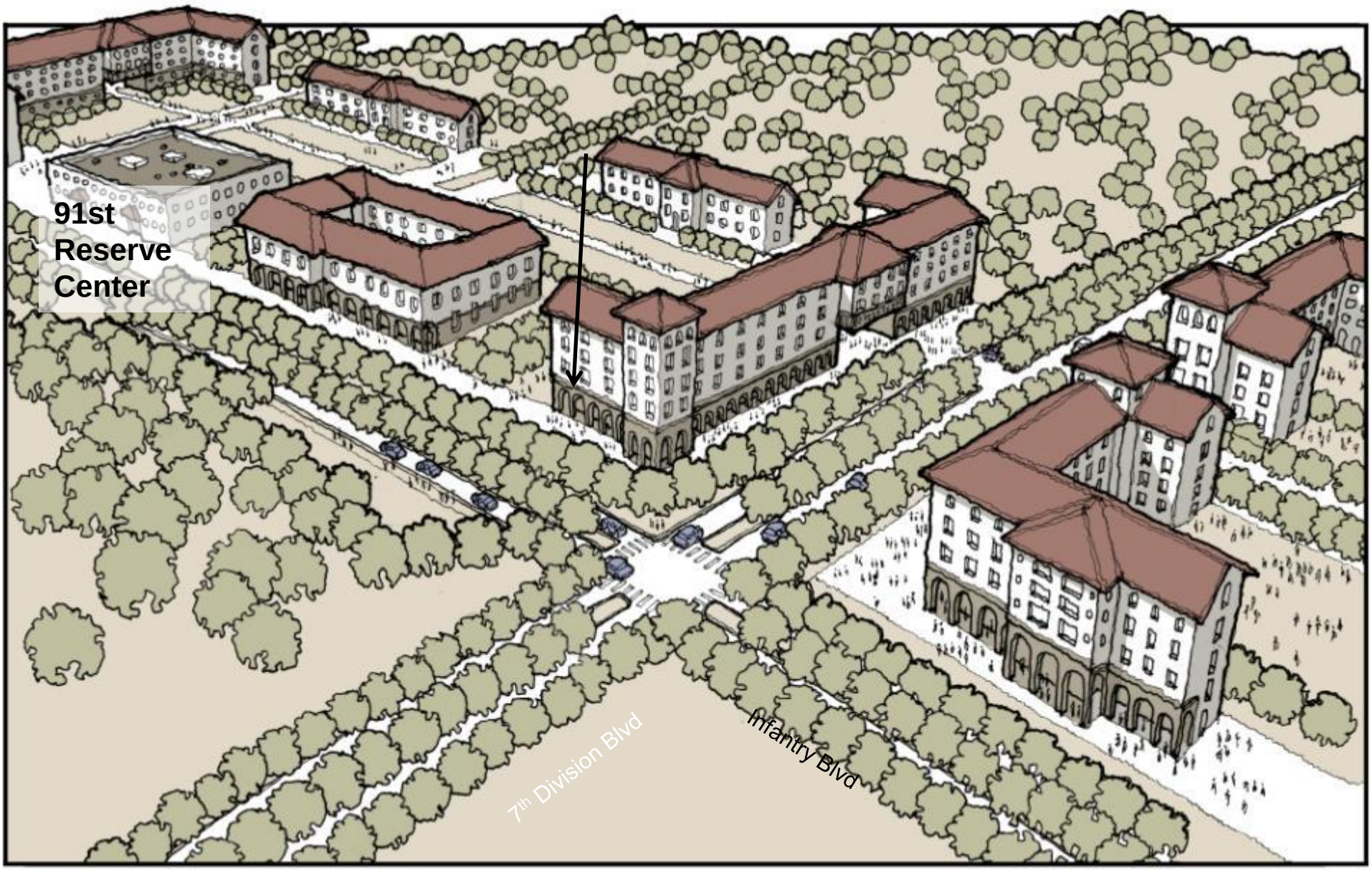
Maintenance:
41,250 sf minimum
82,500 sf maximum

ORTC:
209,000 sf each
627,000 sf total

Minimum: 1,421,750 sf
Maximum: 2,216,500 sf
Parking Required: 1,800 spaces
Parking Provided: 1,900 spaces

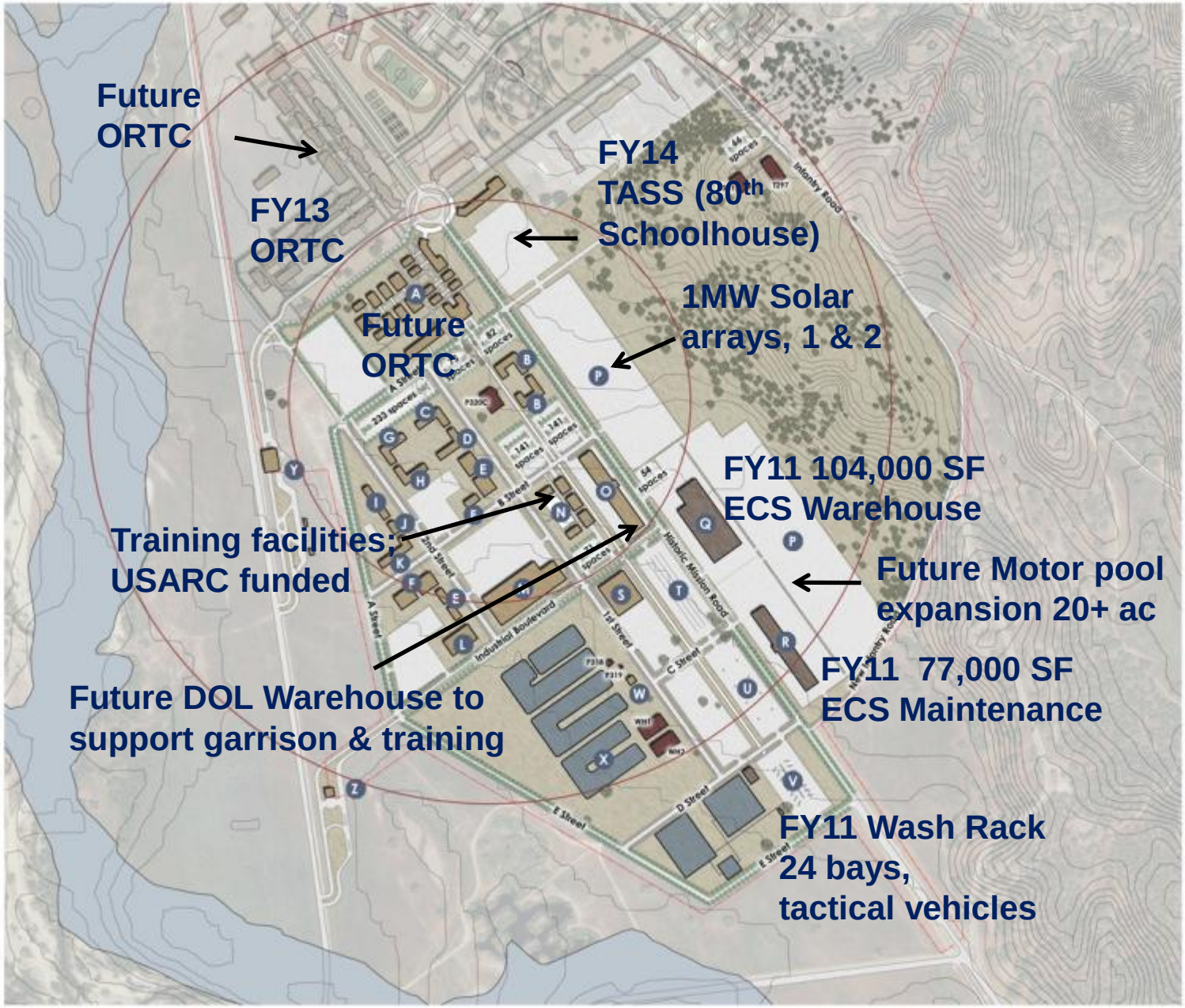
APA April 2012

Future Classroom/Admin Quad - 7th ID @ Infantry Rd



APA April 2012

Mission Valley ADP Illustrative Plan



Fort Hunter Liggett
Mission Valley ADP Illustrative

Vision

To create a flexible training environment surrounding an attractive small town with walkable main streets and a usable town square, where Soldiers, civilians, and their families enjoy living and working.

Legend

- Existing Facilities
- Projects In-Progress
- New Facilities
- Natural Open Space
- Existing Trees
- Street Trees
- Flood Zone Area - 100 Year
- Surface Water Centerline (SW Body N/A)
- 5- and 10-Minute Walk From P320C

- A RTC-W
- B Notional Facilities - 16,000sf / level; 2-3 levels
- C Notional Facility - 13,600sf / level; 2-3 levels
- D Notional Facility - 13,800sf / level; 2-3 levels
- E Notional Facilities - 13,100sf / level; 2-3 levels
- F Notional Facilities - 5,000sf / level; 2-3 levels
- G Notional Facility - 13,500sf / level; 2-3 levels
- H Notional Facility - 13,300sf / level; 2-3 levels
- I Notional Facility - 12,500sf / level; 2-3 levels
- J Notional Facility - 4,400sf / level; 2-3 levels
- K Notional Facility - 14,700sf / level; 2-3 levels
- L Notional Facility - 23,000sf / level; 2-3 levels
- M Notional Warehouse - 108,000sf / level; 2-3 levels
- N SIM Training Campus
- O DOL Warehouse - 61,500sf / level; 2-3 levels
- P ECS Vehicle Storage
- Q ECS Warehouse - 108,500sf / level; 1 level
- R ECS Maintenance Facility - 62,800sf / level; 1 level
- S Notional Warehouse - 46,000sf / level; 2-3 levels
- T Staging Area
- U POL
- V Installation Washrack
- W Remote Communications - 2,500sf
- X Wastewater Treatment Facility Expansion
- Y POV Access Control Point (ACP)
- Z Commercial Vehicle Access Control Point (ACP)

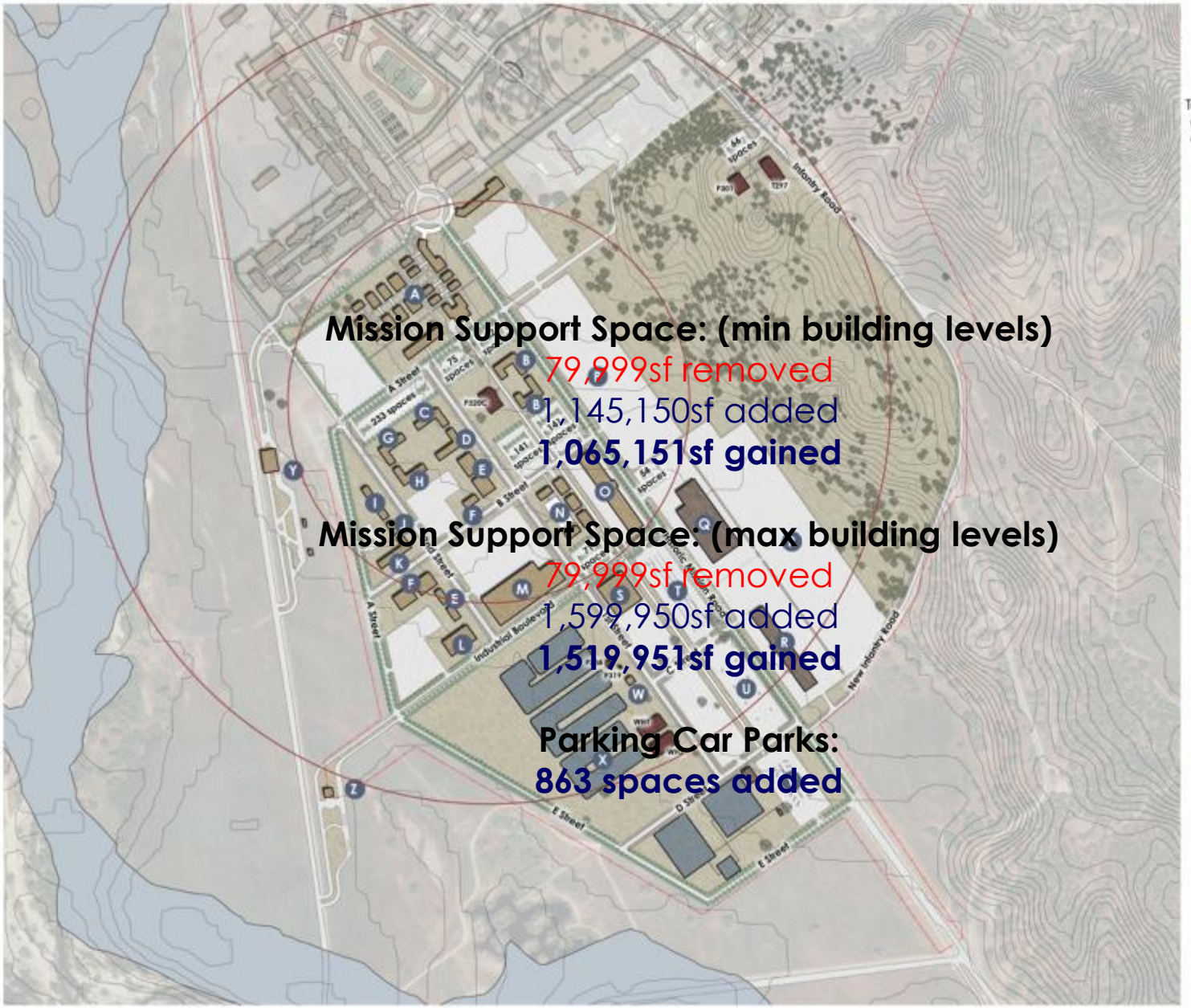
New Car Parks: 863 spaces

300' 300' 300'

The Urban Collaborative, LLC
5 November 2010

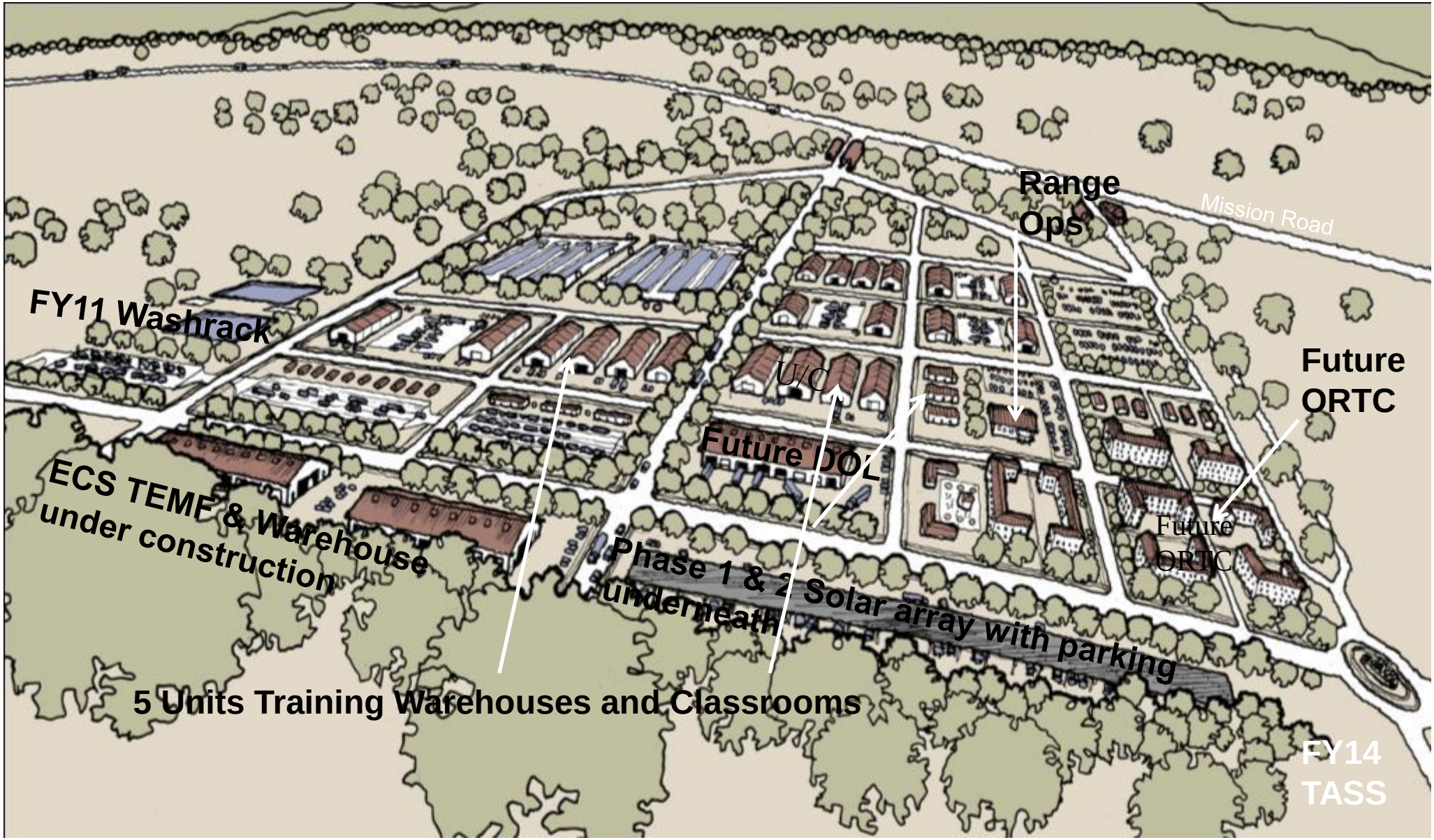
APA April 2012

Mission Valley Buildout Potential = 1.5M SF

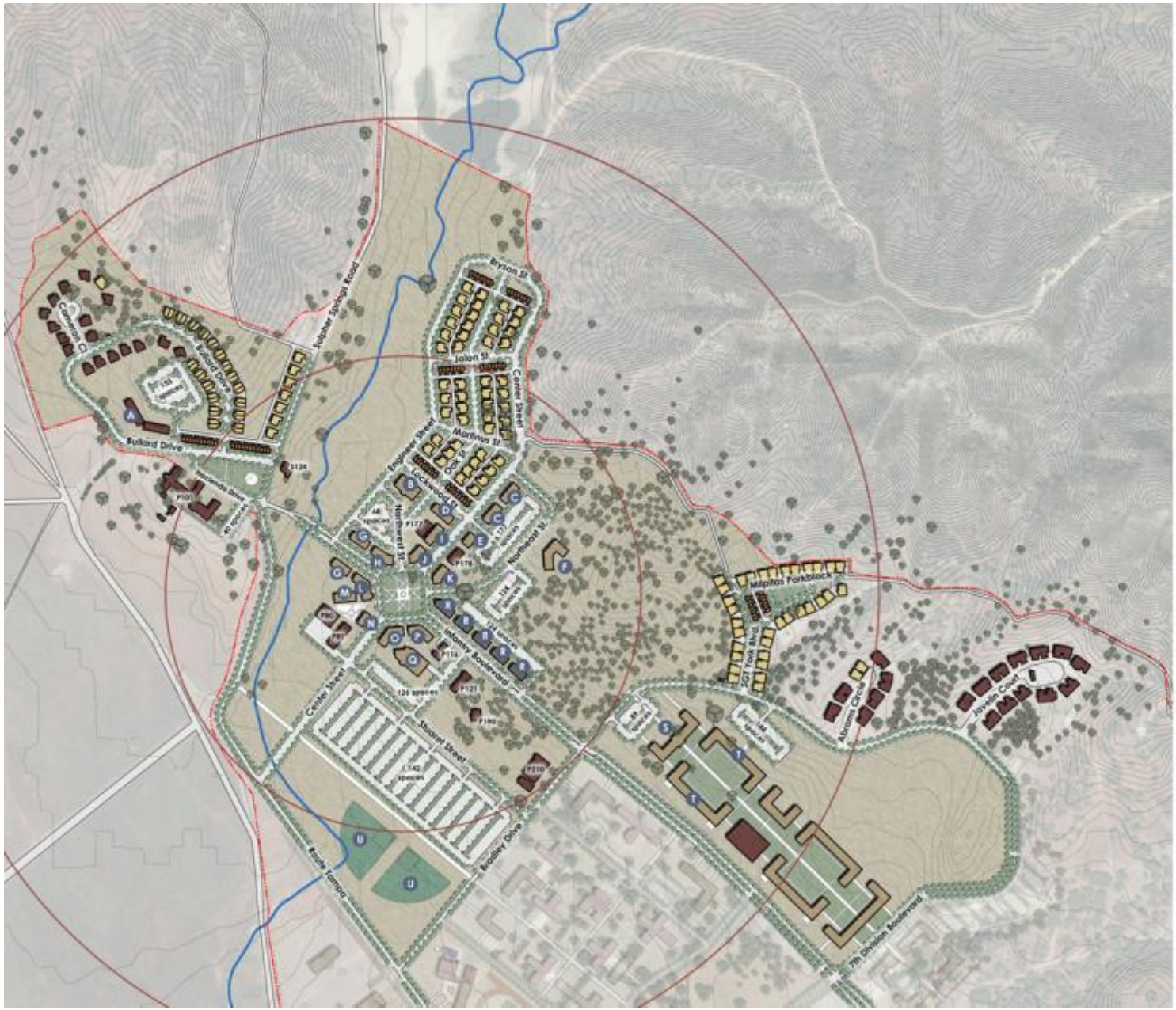


APA April 2012

Mission Valley Training Support Area



Hacienda Heights ADP Illustrative Plan



APA April 2012

Fort Hunter Liggett UPH

Fort Hunter Liggett

Baseline Data

- **Current Electrical Load 12M KwH**
- **Future Electric Load (MILCON) 6M KwH**
- **Thermal Load (propane/diesel) 11M KwH**

Total 29M KwH

"NZEI Roadmap"

- **Energy Conservation Projects (28%) 8M KwH**
- **Human Factor" Conservation (10%) 3M KwH**
- **UNICOR renewable projects (24%) 7M KwH**
- **ECIP Renewable Projects (38%) 11M KwH**

Total 29M KwH

Army NZEI Goal is 2020!

Renewable Energy Projects

Project Title	Energy Production	% towards NZEI
Energy Management Control System	Reduces energy use by 15%	15%
PH 3 1MW Solar PV Array w/initial EMCS	1.8M KwH produced	6.2%
Ph 4 1MW Solar PV Array w/initial "smart grid"	1.8M KwH produced	6.2%
Solar Hot Water (Barracks/DFAC)	1M KwH conserved	3.4%
Grid Energy Storage (Battery)	1.5M KwH stored	5.2%
Ground Source Heat Pumps	3M KwH conserved	10.3%

46.3% towards NZEI Goal

Incorporating NZI into Planning for Net Zero on Installations

Matthew Hiett
Graduate Research Assistant
University of Illinois, Urbana-Champaign
U.S. Corps of Engineers, ERDC-CERL
matthew.d.hiett@usace.army.mil

US Army Corps of Engineers
BUILDING STRONG®

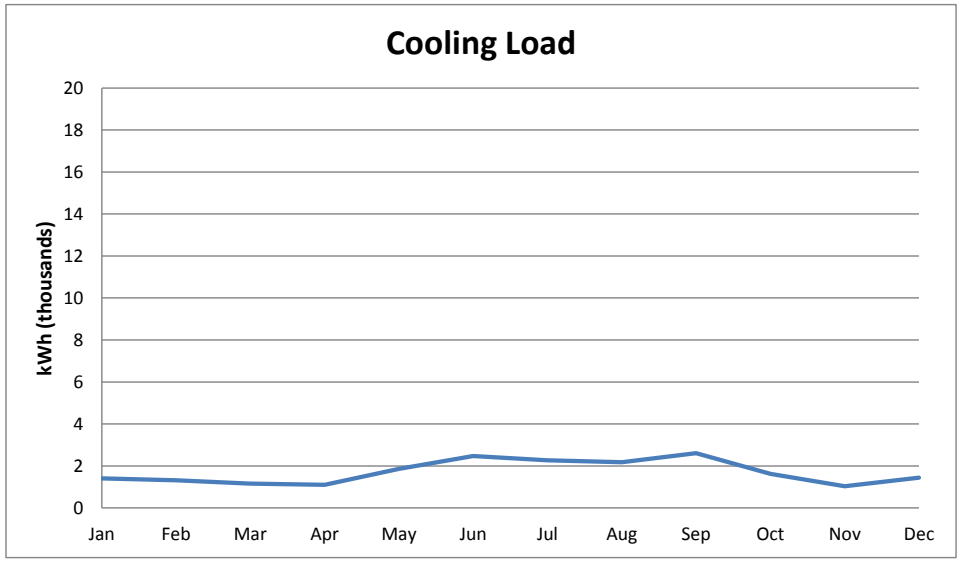
ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

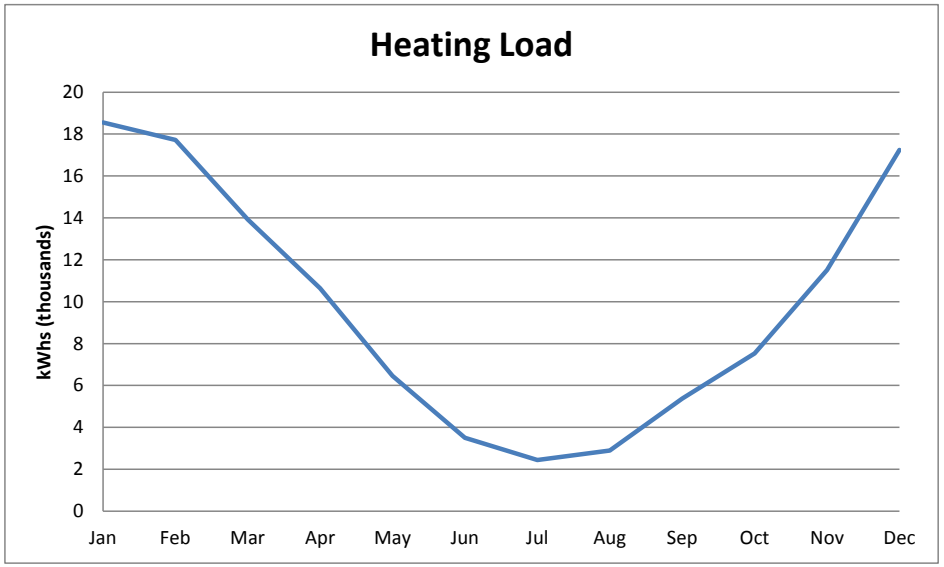
Planning in the Design Space

- If the process applied to a different installation, what would change?
  - Weather
  - Viability of renewable options (solar, wind, biomass)
  - Waste-energy conversion (available waste stream)
  - Installation electricity load (heating and cooling)
  - Electricity rates
    - Source fuel mixture (coal, nat. gas, nuclear, etc.)
  - Current infrastructure / physical compactness

Baseline model

- Baseline represents “typical” installation in the NE United States.





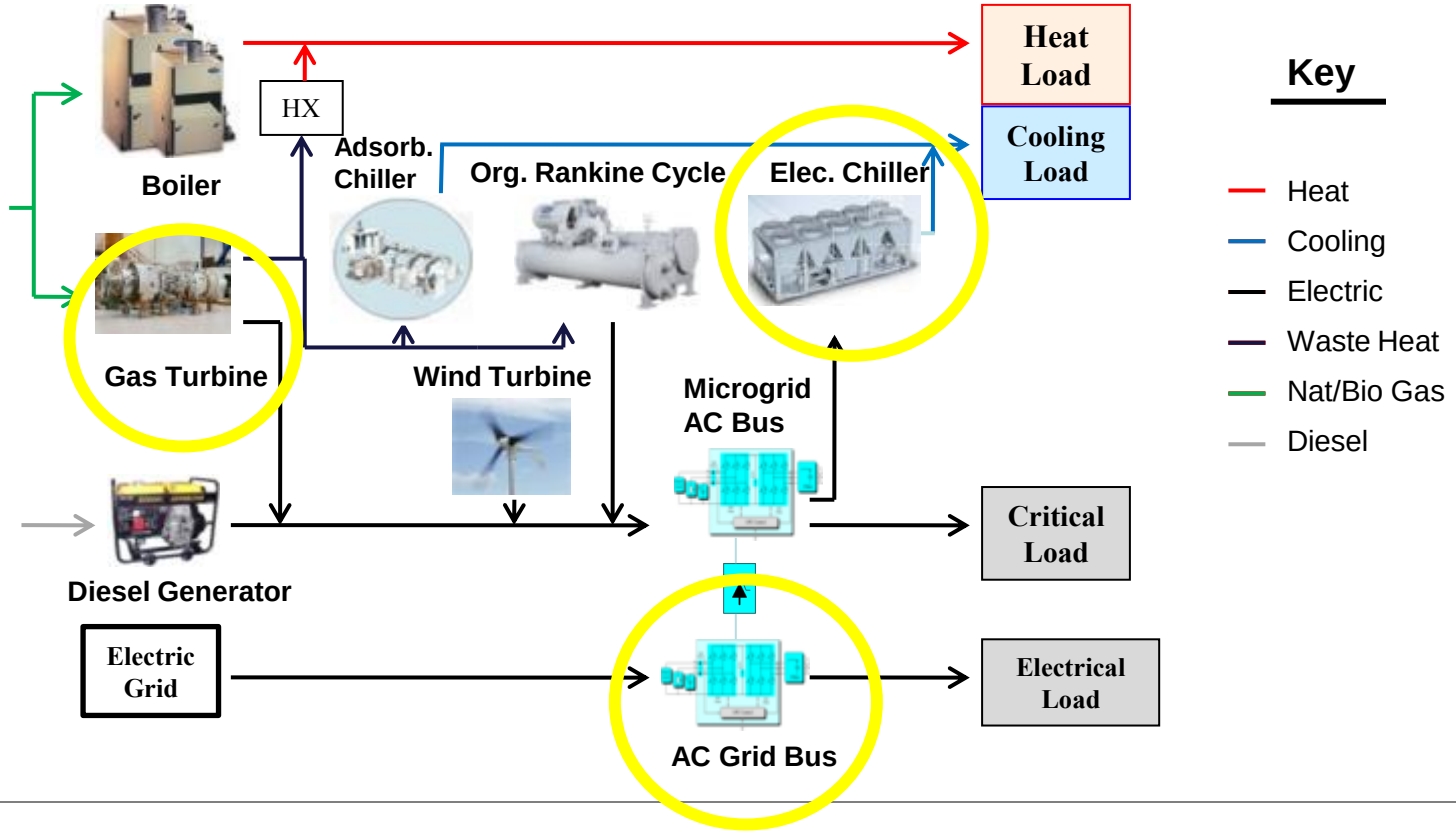
- Wind and solar resources are both marginal

Baseline model

- Model returns optimal mix of technologies and cost

1	Boil1	0
2	Boil2	0
3	Boil3	0
4	HeatE1	0
5	ACBus1	3
6	EChilr1	11
7	AChilr1	0
8	WPump1	2
9	EBatt1	0
10	GTurb1	0
11	GTurb2	0
12	GTurb3	0
13	IndGasTurb1	0
14	IndGasTurb2	2
15	IndGasTurb3	1
16	IndGasTurb3	0
17	IndGasTurb3	0
18	PhotoVolt1	0
19	DCtoAC1	0
20	WindTurb1	0
21	EfromGrid	0
22	EtoGrid	0
23	ACtoAC1	0
24	BackPressure	0
25	ExhaustBoiler	0
26	ExhaustBoiler	0
27	ExhaustBoiler	0
28	HeatExchanger	4

			Installed Cost	$ 13,058,500
			Operating Cost	$ 193,724,000
Total 30 Year Cost	$ 206,782,952		Maintenance	$ 3,917,550
Annual Cost	$ 6,892,765		Electricity	$ 30,960,500
			Natural Gas	$ 162,095,000
			Biogas	$ -

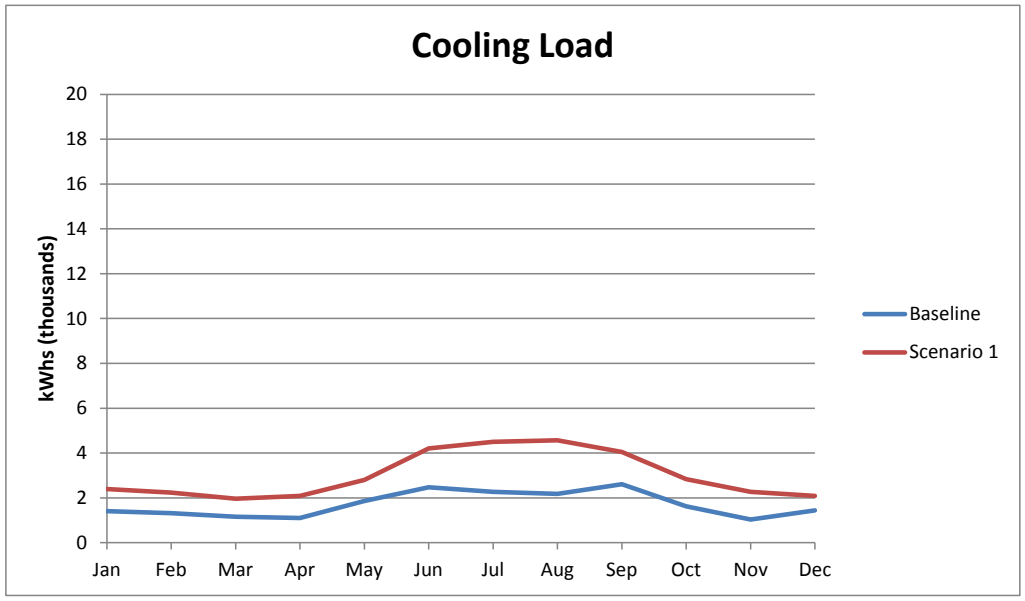


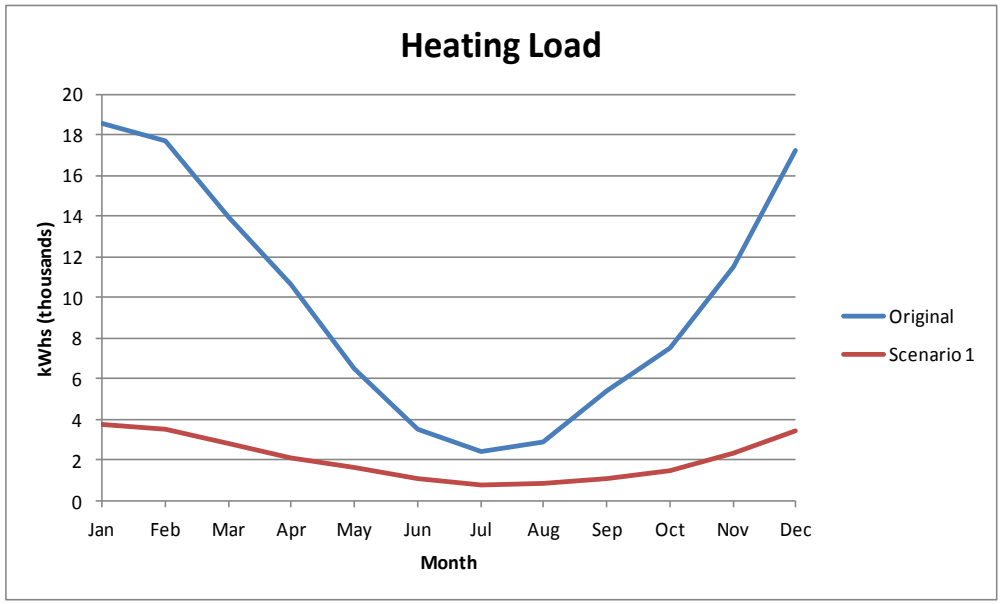
Group Input

- Imagine an installation in the SE, SW or NW United States.
- How does energy, water, and waste planning fit into your Master Planning process?
- How might heating/cooling/electric loads, weather, wind/solar, biomass resources or electricity rates impact the feedback?
- What are the most significant challenges one might experience planning for Net Zero?
  - Alternative financing methods?
  - Changes in policy?
- What additional analysis do you need to perform

Scenario 1- Change Loads

- What considerations would change if the process was applied to an installation in the SW?



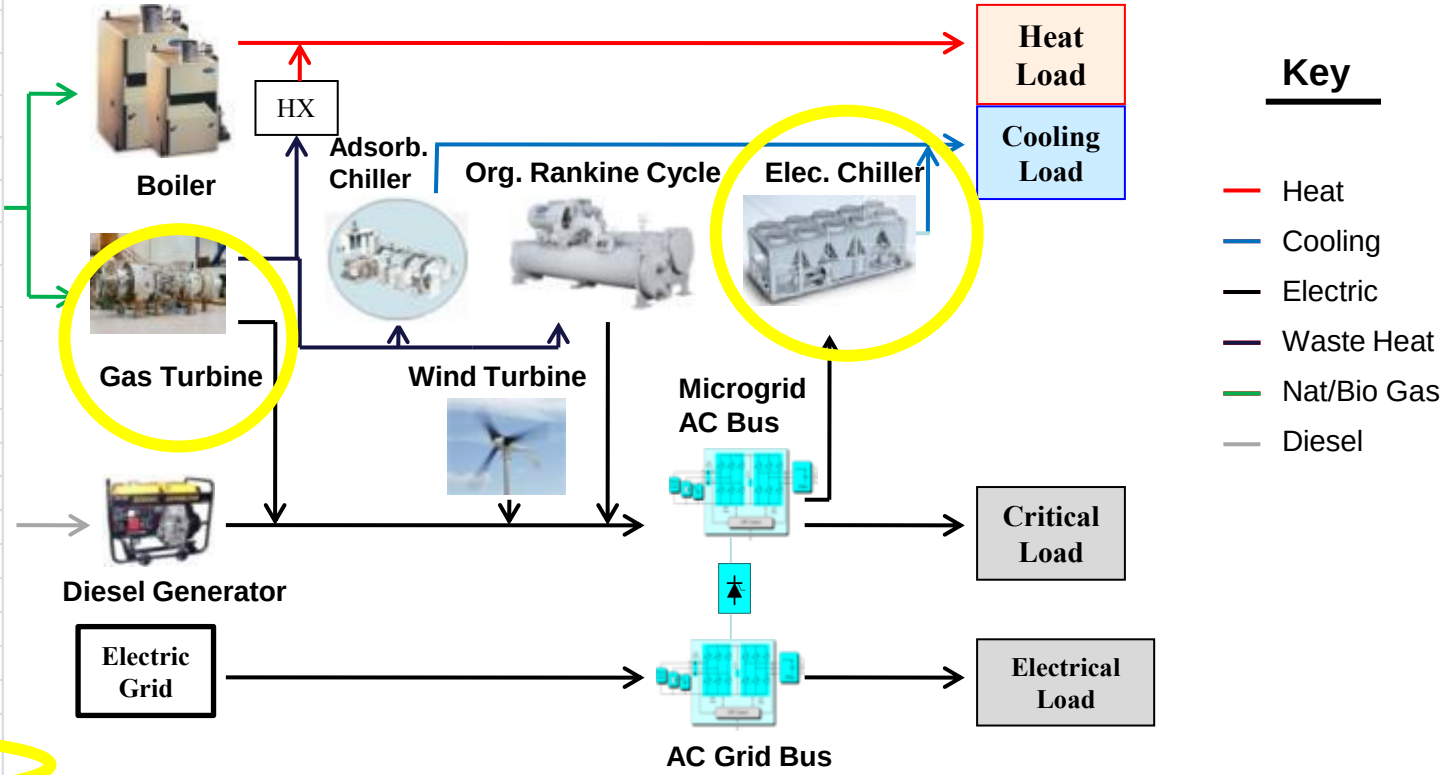


Scenario 1- Change Loads

- Significant increase in electric chillers
- Substantial heating load decrease = less cogeneration

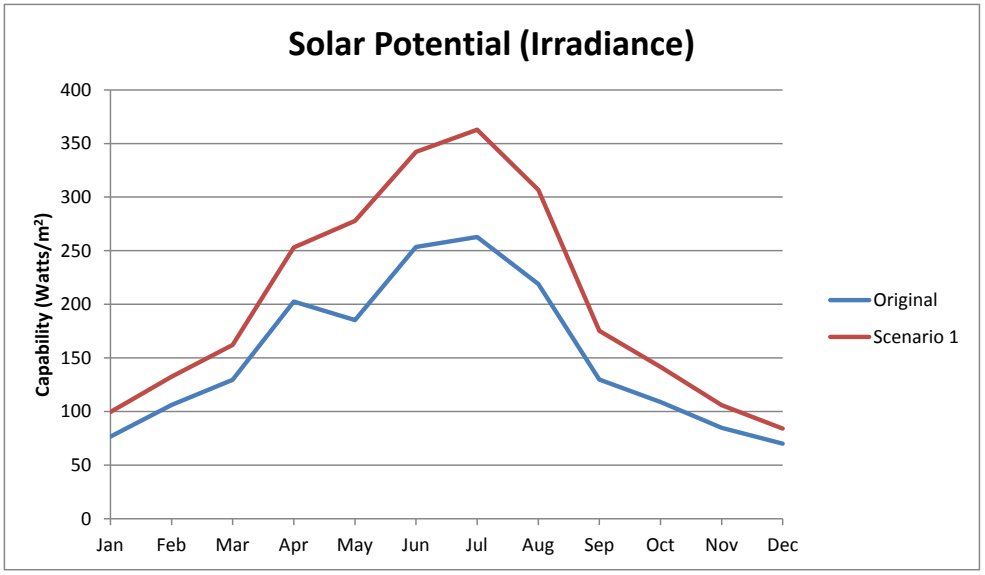
1	Boil1	0
2	Boil2	0
3	Boil3	0
4	HeatE1	0
5	ACBus1	3
6	EChilr1	22
7	AChilr1	0
8	WPump1	2
9	EBatt1	0
10	GTurb1	0
11	GTurb2	0
12	GTurb3	0
13	IndGasTurb1	0
14	IndGasTurb2	1
15	IndGasTurb3	0
16	IndGasTurb3	0
17	IndGasTurb3	0
18	PhotoVolt1	0
19	DCtoAC1	0
20	WindTurb1	0
21	EfromGrid	0
22	EtoGrid	0
23	ACtoAC1	0
24	BackPressure	0
25	ExhaustBoiler	0
26	ExhaustBoiler	0
27	ExhaustBoiler	0
28	HeatExchanger	2

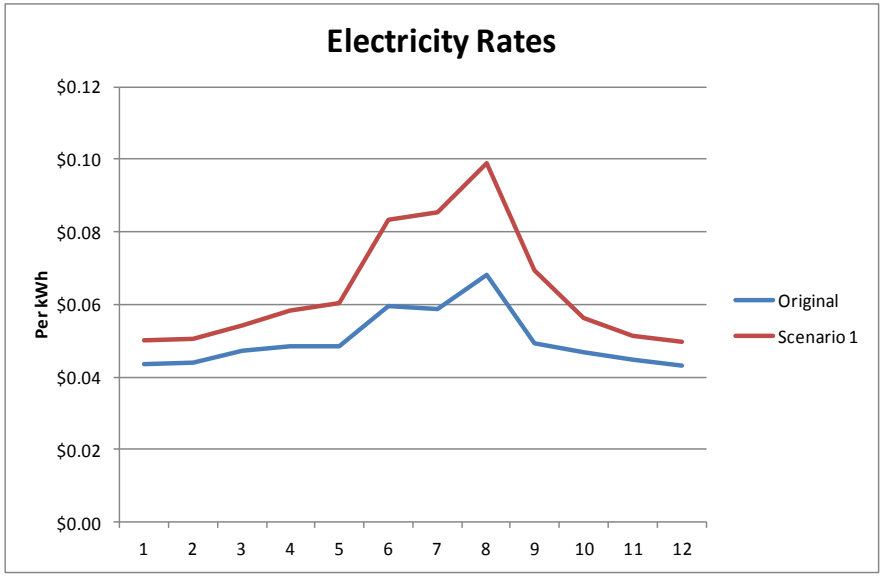
			Installed Cost	$ 6,985,000
			Operating Cost	$ 150,552,000
Total 30 Year Cost	$ 157,536,706		Maintenance	$ 2,095,500
Annual Cost	$ 5,251,224		Electricity	$ 111,923,000
			Natural Gas	$ 37,110,500
			Biogas	$ -



Scenario 2 – Renewables

- What happens if, in addition to increased loads, solar and wind potential increased?
- What if electricity rates also increased?



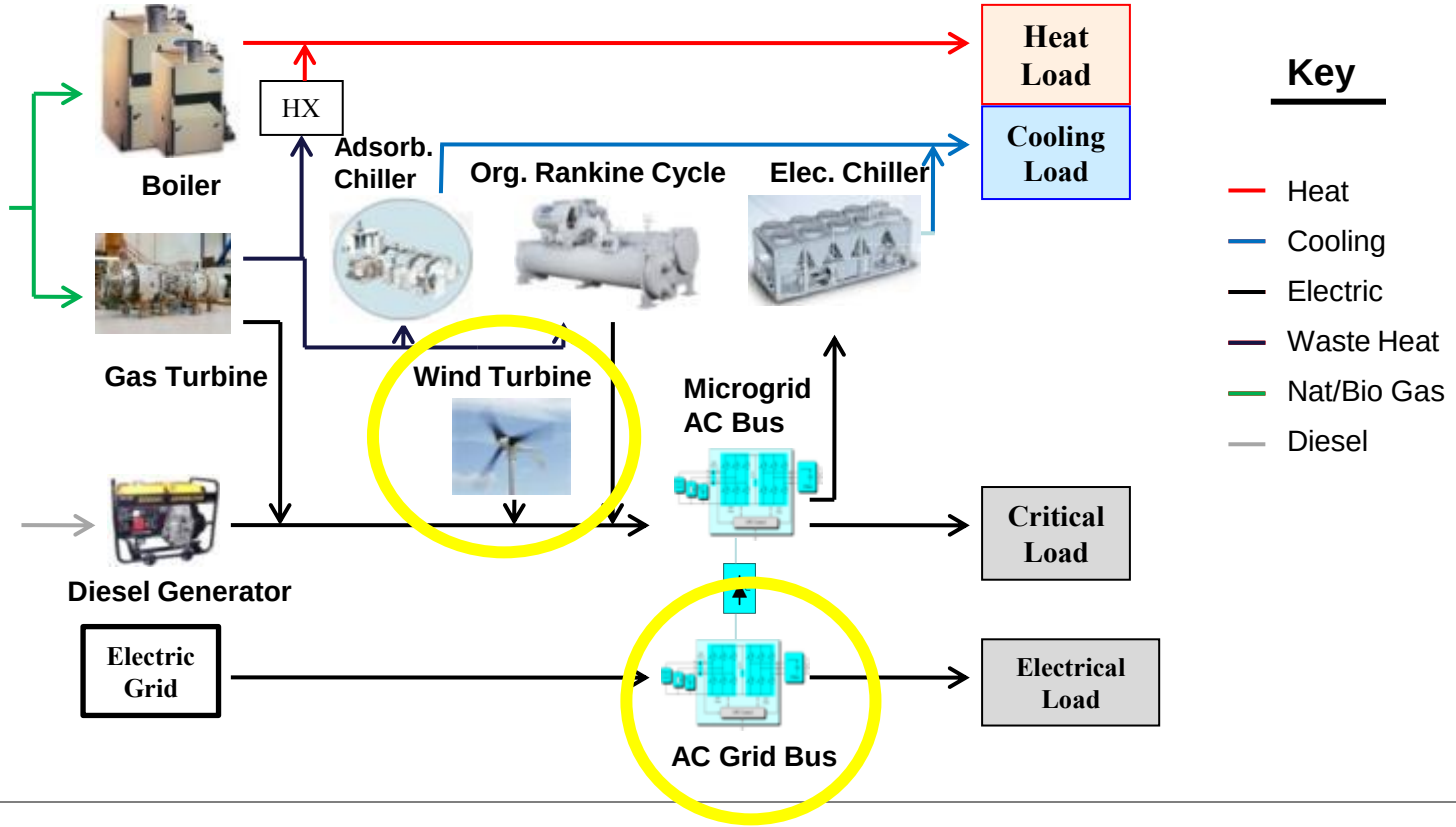


Scenario 2 – Renewables

- High price of solar = recommendation of wind turbines
- 30 year horizon necessary for payoff

1	Boil1	0
2	Boil2	0
3	Boil3	0
4	HeatE1	0
5	ACBus1	5
6	EChilr1	22
7	AChilr1	0
8	WPump1	2
9	EBatt1	0
10	GTurb1	0
11	GTurb2	0
12	GTurb3	0
13	IndGasTurb1	0
14	IndGasTurb2	1
15	IndGasTurb3	0
16	IndGasTurb3	0
17	IndGasTurb3	0
18	PhotoVolt1	0
19	DCtoAC1	0
20	WindTurb1	18
21	EfromGrid	0
22	EtoGrid	0
23	ACtoAC1	3
24	BackPressure	0
25	ExhaustBoiler	0
26	ExhaustBoiler	0
27	ExhaustBoiler	0
28	HeatExchanger	2

			Installed Cost	$ 97,741,000
			Operating Cost	$ 68,460,700
Total 30 Year Cost	$ 166,201,663		Maintenance	$ 29,322,300
Annual Cost	$ 5,540,055		Electricity	$ 1,569,300
			Natural Gas	$ 37,875,900
			Biogas	$ -

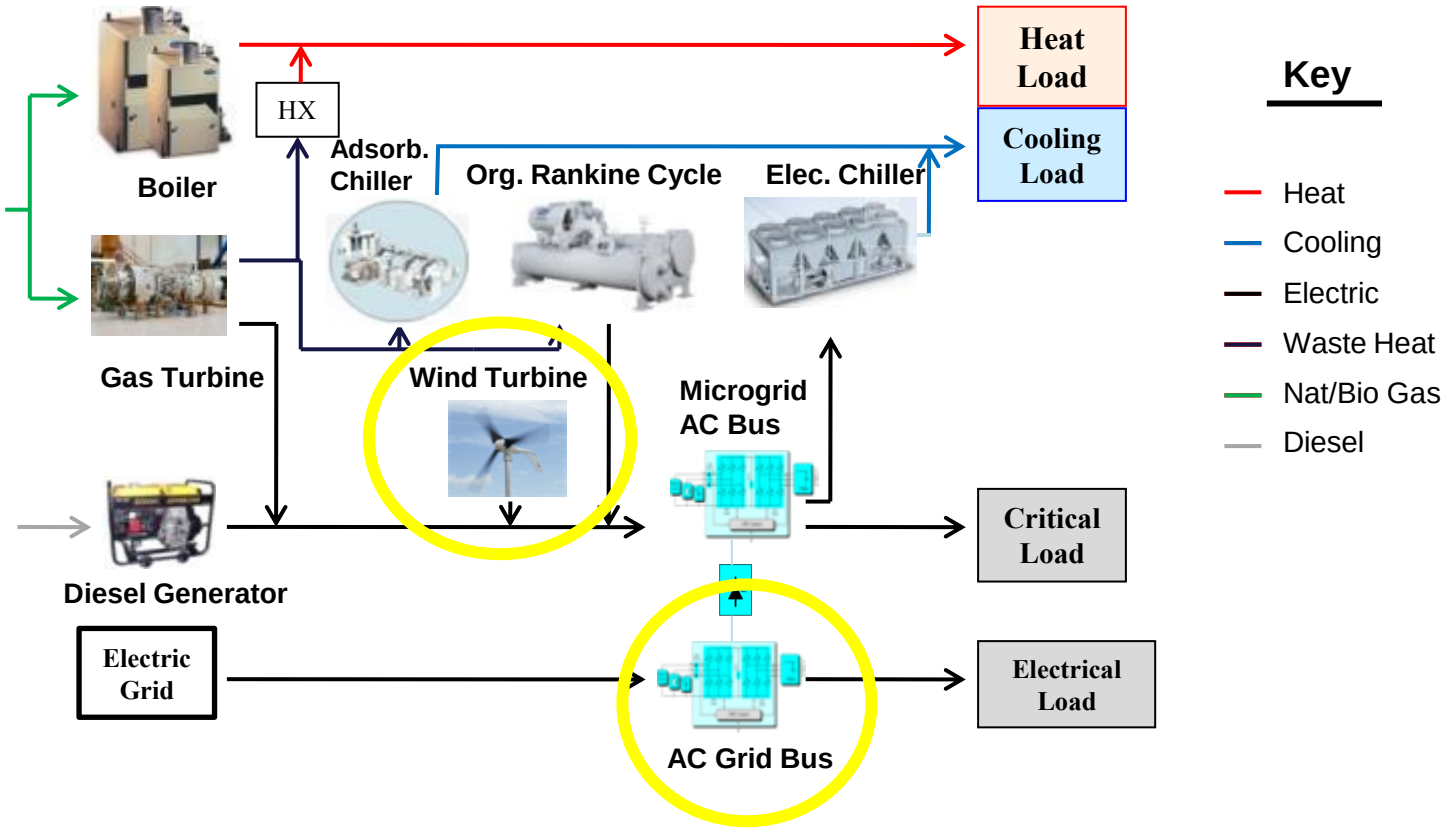


Scenario 3 – Required Renewables

- Requirement for Net Zero included – 100% energy to come from renewable sources

1	Boil1	0
2	Boil2	1
3	Boil3	0
4	HeatE1	1
5	ACBus1	7
6	EChilr1	22
7	AChilr1	0
8	WPump1	2
9	EBatt1	0
10	GTurb1	1
11	GTurb2	0
12	GTurb3	1
13	IndGasTurb1	0
14	IndGasTurb2	0
15	IndGasTurb3	0
16	IndGasTurb3	0
17	IndGasTurb3	2
18	PhotoVolt1	0
19	DCtoAC1	0
20	WindTurb1	23
21	EfromGrid	0
22	EtoGrid	0
23	ACtoAC1	4
24	BackPressure	0
25	ExhaustBoiler	0
26	ExhaustBoiler	0
27	ExhaustBoiler	0
28	HeatExchanger	1

			Installed Cost	$ 122,399,000
			Operating Cost	$ 100,586,000
Total 30 Year Cost	$ 222,984,607		Maintenance	$ 36,719,500
Annual Cost	$ 7,432,820		Electricity	$ 2,785,530
			Natural Gas	$ -
			Biogas	$ 60,011,400



Additional/Future Considerations

- Viability of other renewables (biofuels, solar-thermal, etc.)
- Storage of excess production “in the system”
  - Electric vehicle fleet
  - Hydrogen production
  - Hot water / steam production
- Others?

THANK YOU!

QUESTIONS?