Master Planning for Resiliency and Sustainability through Net Zero Modeling – NZP Tool™

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Definitions

- **Framing Goal** – A target goal for analysis. Not a commitment or decision.

- **Baseline** – A snapshot of the current energy use situation. The baseline is one reference point used to evaluate alternative futures.

- **Future Base Case** – The baseline extended to include already-funded renovation as well as planned construction and demolition activities. The base case is a future reference point for “business as usual.”

- **Alternative(s)** – A set of energy measures to be compared against the base case
  - Better, Best, Others

- **Site Energy** – Energy measured at the point of use.

- **Source Energy** – Energy measured at the point it is generated (takes into account conversion and transmission losses).

- **District/Cluster** – A group of buildings to be served by a microgrid/ heating/cooling loop (or some combination of these)
The NZP Tool: Installation Sustainability and Resiliency Planner

- Web based tool that assists in energy, water, and waste (EW2) planning
- Easy to use after setup
- Projects EW2 usage, flows
- Provides ROI analysis for EW2 conservation measures
- Integrates with Master Planning Process
- Identifies a roadmap and projects
- Integrated Solid Waste and Water
- Integrated into Corps of Engineers sustainability planning process
Framing Goals can be setup to cover the range from Business As Usual all the way to Net Zero. They can be analyzed anywhere in between as desired.

Costing is also done from a planning analysis of ~$/ft2 to detailed project analysis done by Corps costing branch.
OSD Installation Energy Plans Memo, 31 March 2016

- OSD memo requiring all services to report in one year each agencies' plan to implementing an energy plan tied to the master plan by 2018.
OSD Installation Energy Plans Memo, 31 March 2016

- Phase 1: Identify the team, tasks, deliverables, and goals
- Phase 2: Establish baseline and future base case
- Phase 3: Analyze gaps and alternative scenarios
- Phase 4: Develop and sequence projects and activities
- Phase 5: Assemble review and finalize document
- Phase 6: Execution and maintenance of the IEP
NZP Tool Process

**Phase 1:**
Establish Planning Goals

**Phase 2:**
Establish Baseline and Future Base Case

**Phase 3:**
Analyze alternative scenarios

**Phase 4 & 5:**
Produce & Finalize Integrated Plan Documents

**Phase 6:**
Maintenance of IEP

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

Optimize Building Energy Efficiency

Optimize Supply and Distribution System Mix

To the Commercial Goal

Installation Boundary

Wind Farm

Battery Storage

Geothermal

Photovoltaics / Solar Thermal

Thermal Storage

Supports
### Energy and Sustainability Goals (example)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>2040 Base Case</th>
<th>2040 Target</th>
<th>Comments</th>
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<tr>
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<td>Reference</td>
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<td>“Forty by Forty”</td>
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<td>Source Energy Use</td>
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<td>216,444 MWh</td>
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<td>Net Zero</td>
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<tr>
<td>Scope 1 &amp; 2 Emissions</td>
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<td>Net Zero</td>
<td></td>
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<td>Gov’t Analysis Life Cycle Cost Effective</td>
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<tr>
<td>Internal Rate of Return</td>
<td>NA</td>
<td>5%</td>
<td>Calculated over plan period</td>
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<tr>
<td>Energy Security</td>
<td>Acceptable</td>
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<td>“Security and Efficiency”</td>
</tr>
<tr>
<td>Quality, reliability, resilience</td>
<td>NA</td>
<td>No change</td>
<td>Thermal and electric Equal or better than baseline</td>
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</table>
Cost-Optimizing Zero Energy Buildings
Integrating EEM’s that are Net Zero Ready Cost Effective

1. business as usual or the base case
2. least life cycle cost option
3. achieved the same total annual cost as your base case building, but the building at point 3 is more energy efficient and often more comfortable.
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
Building Simulation Process

1. Gather baseline information

2. Simulate baseline and EEM packages

3. Generate Cost/Energy curve and SIR for EEM packages

4. Select optimal EEM package for each building type

5. Initial building analysis complete. Prepare load profiles to pass to next phase for cluster analysis
Description of Alternative Scenarios
PNSY (Cold Weather example)

1. Baseline:
   - Existing buildings and central plant equipment are simulated.

2. Basecase:
   - Buildings with planned construction, renovation, and demolition. Existing central plant equipment provides a “status quo” used as a comparison for the remaining scenarios.

3. District Steam:
   - Buildings with a modern steam system. One existing natural gas turbine is replaced with two natural gas reciprocating engines with approximately half the electrical output capacity each.

4. District hot water and spot steam (District Hot Water):
   - Buildings with a modern hot water system and spot steam generation to meet process loads. Central plant same as District Steam scenario.

5. Decentralized:
   - Buildings with decentralized boilers/furnaces and spot steam generation to meet process load. The same level of electrical backup is still required (15.4 MW for the installation, as in the existing central plant).

   - Buildings with a modern hot water system and lowest equivalent annual cost equipment to meet net zero fossil fuel goals. Only analyzed using the NZP tool.
Description of Alternatives
JBPHH (Warm Weather Example)

1. Baseline:
   • Existing buildings are simulated. No heating.

2. Basecase:
   • Buildings with planned construction, renovation, and demolition. No existing central plant or cooling systems.

3. Better Case:
   • Minor EEM improvements to buildings.

4. Best Case:
   • Aggressive EEM improvements to buildings.

5. Best Case w/ 50% renewables:
   • Meet half of best case electrical loads with non-fossil fuel source.

6. Best Case net zero:
   • Buildings with a modern hot water system and lowest equivalent annual cost equipment to meet net zero fossil fuel goals. Only analyzed using the NZP tool.
Study Setup and Information

Study Name: Joint Base Pearl Harbor Hickam - Ford Island Test (986)
Param Version: 0.38.0
NZI Opt Version: 0.9.0
Created By: Garston, Timothy W
Modified By: Case, Mike
Last Edited: 10/27/2015 10:44 AM
Description: N/A
Baseline Year: 2015
Study Duration: 40 Years
Public Access

Location and Meteorological Data

Location: Joint Base Pearl Harbor Hickam - Ford Island
Weather File: USA_HI_Honolulu.Intl.AP.911820_TMY3.epw
Climate Zone: ASHRAE 1A
Soil Type: 
ET: 0 in. (%)   Average Temperature:  0 °F

Study Goals:
• Fifty Percent renewable energy by 2020
• Reduce Energy Use Intensity by 50%

This Study Includes:
- Energy
  - Water
  - Waste
  - Stormwater

Completed Study Information Progress
- Baseline
- EEMs

Building Optimization Progress

Installation or Subsection Progress
- Clusters Defined
Many DoD Installations in system, with weather
Adding Facilities is Easy

Map Viewers and building lists

Baseline, Basecase, and alternatives

Building types
Uses Available GIS information

Import from GIS or draw in
Compare “as-is” to future scenarios

Present Day

Planned
Energy Efficiency Measures (EEM)

- Often called Energy Conservation Measures (ECM)
- Applied to a facility to decrease energy use
- Can be applied as Packages or Bundles
  - Cherry-picking
  - Energy Service Company (ESCOs)
- Must be analyzed as a system
- Implementation costs
  - Many measures not cost effective on their own
  - Deep retrofit
- Opportunity for benchmarking
Energy Strategies

- Reduction (EEMs)
  - Insulation & Infiltration
  - Lighting & Daylighting
  - Lighting
  - High-Efficiency Equip
  - High-Efficiency HVAC
  - Energy Recovery
  - Dedicated Outside Air Systems
  - Cool Roofs
  - Metering
  - Building Automation

- Supply & distribution
  - Renewable energy - PV
  - Cogeneration/CHP
  - Large and Small-Scale District Energy
  - Thermal Storage
  - Biomass
  - Wind
Rates and Consumption

Tabs for Energy, Water and Waste input completed
Configuration of measures

PARAMS model dynamically configures GUI and defines interface to simulation on JOB SERVER

Energy Efficiency Measures
Simulations on server farm

- Over 1000 simulations run at a time (about 100 in parallel)
- Status of all running simulations tracked
- Can download files for debugging
Package Selection

View comparison of packages of measures and select preferred choice.
Building Level Reports

Most commonly used reports and graphics for analysis of buildings

Compare baseline and all alternatives
Installation-wide Analysis: Clusters

Click Here to Create a New Cluster

Remaining Buildings
- N/A
- Number of Buildings: 403
- Ground Coverage: 311,912
- Total Electrical Load: 65,154
- Total Space Heating Load: 24,905
- Total DHW Load: 41,729
- Total Heating Load Density:
- Total Cooling Load Density:

South Cluster
- N/A
- Number of Buildings: 23
- Ground Coverage: 6,570
- Total Electrical Load: 7,748
- Total Space Heating Load: 4,612
- Total Cooling Load Density:
- Total Heating Load Density:

Specker Cluster
- N/A
- Number of Buildings: 46
- Ground Coverage: 2,917
- Total Electrical Load: 8,502
- Total Space Heating Load: 6,002
- Total DHW Load: 6,083
- Total Cooling Load Density:
- Total Heating Load Density:
Choosing Equipment to Include in Optimization
Set Constraints for Optimization

Baseline Clusters

Constraints Defined
Instructions

Baseline Clusters

Baseline Remaining Buildings Constraints and Basic Economic Values

Energy Security
Critical Electric Maximum Load: 0.00 kW

Environmental / Renewable (Annual)
Renewable Target: 0.00 %
Max. Carbon Footprint: 100,000,000.00 tCa

Basic Economic Values
Project Lifetime: 0.00 YY
Int. Rate: 5.00 %

Redundancy Factors
Additional Heating: 1.00
Additional Cooling: 1.00
Cluster Optimization

Net Zero Planner

Study: Fort Leonard Wood Sustainability Study...

Cluster Optimizations

- Not Started
- Successful
- Queued
- Initialized
- Running

24 Total Optimizations

Instructions

Optimizations
- Base Case
- Remaining Building
- South Cluster
- Specker
- West Cluster

Downloads
- Loads.dat
- Irradiance.dat
- devices.dat
- StorageDevices.dat
- PotableWaterConsumption.dat
- WindTurbinePower1.dat
- EGridEnRate.dat
- ElectricDemandRatesFile.dat
- Fuels.dat
- AdditionalConstraints.txt
- nzi-opt-parse.xml
- nzi-opt.mod
- nzi-opt.log
- nzi-opt-parse.log
- nzi-opt.out
- ScaledCluster8760.xls

Reset
Installation Optimization Process

1. Integrate all building energy demands

2. Use energy density to identify possible clusters

3. Determine potential cluster equipment packages for installations and region

4. Generate alternative equipment configurations, including centralized and decentralized options

5. Optimize equipment size and pipe sizes
   - Electric, thermal, hydraulic, economic simulations

6. Calculate SIR_{cluster} & EEMs
NZI Optimization Tool (NZI-Opt)

NZI-Opt is an optimization tool that is used to find the lowest life cycle-cost equipment suite to meet the “cluster level” demands while meeting a set of defined constraints. Cluster level demands can include heating, cooling, electric, critical electric, water, waste, etc.
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
- Organic Rankine Cycle
- Gas Boiler
- Absorption Chiller
- Diesel Generator
- AC Bus
- Fuel Cell
- Wind Turbine
- Gas Turbine
- Photovoltaic
- Electric Heater
Installation Specific Inputs

Load profiles are input to provide the demands that must be met by the “supply” equipment. Weather data provides the necessary information for determining the potential of renewable sources. Economic data provides regionally specific information on utility cost schedules, equipment installation and maintenance costs, and fuel prices.
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.

- Electric Chiller
- Photovoltaic
- Absorption Chiller
- Gas Boiler
- Organic Rankine Cycle
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- 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.

Key
- **Heat**
- **Cooling**
- **Electric**
- **Waste Heat**
- **Nat/Bio Gas**
- **Diesel**
Cluster Results

Installation Results - Energy Comparison

<table>
<thead>
<tr>
<th>Energy Overview</th>
<th>Study Plan</th>
<th>Natural Gas (kWh)</th>
<th>Peak Natural Gas (kW)</th>
<th>Electricity (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study List</td>
<td>Study Information</td>
<td>Installation or Subsection</td>
<td>Decision Analysis</td>
<td>Generate Planning Forms</td>
</tr>
<tr>
<td>Details</td>
<td>Cluster</td>
<td>Networks</td>
<td>Equipment &amp; Measure</td>
<td>Constraints</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Results</td>
</tr>
</tbody>
</table>

### Annual Energy Comparison

- **Energy:** kWh
- **Power:** kW

### Study Plan

- **Basel Case:** 20
- **Baseline:** 20
- **Building EEMs High:** 110
- **Building EEMs Realistic:** 110
- **Building EEMs Realistic with AIT Barracks added:** 116

### Cluster

- **Remaining Buildings:** 64
- **South Cluster:** 17
- **Specker Cluster:** 21

### Equipment

- **ACRes:** 20,000 kW x 1
- **Air_Elec_CHL_2:** 352.00 kW x 1
- **Air_Elec_CHL_4:** 1,055 kW x 1
- **Bld0:** 100.00 kW x 2
- **Bld2:** 2,500 kW x 3
- **ExistingBoilers:** 6,056 kW x 2
- **ExistingChillers:** 3,340 kW x 2
### Decision Analysis Results - Clustering Report

#### Annual Energy Comparison

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Investment</th>
<th>Total Equivalent Annual Cost</th>
<th>Total Source Energy</th>
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<tbody>
<tr>
<td>Baseline</td>
<td>0</td>
<td>22,619,526</td>
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<tr>
<td>Building EEMs High</td>
<td>261,232,464</td>
<td>28,404,150</td>
<td>600,465</td>
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<td>Building EEMs Realistic</td>
<td>282,582,176</td>
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<td>Building EEMs Realistic with AIT Barracks added</td>
<td>264,259,856</td>
<td>25,324,252</td>
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<tr>
<td>Building EEMs Realistic with AIT Barracks MTHW</td>
<td>259,427,952</td>
<td>24,283,958</td>
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<tr>
<td>Building EEMs Realistic with AIT Barracks MTHW (Baseline)</td>
<td>262,438,288</td>
<td>23,980,960</td>
<td>460,346</td>
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</table>

#### Update

- [Update](#)

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**Back** **Continue**
Cluster Results
Cold Climate

Natural Gas Recipe Engine CHP

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Devices</th>
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<tbody>
<tr>
<td>Baseline</td>
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<tr>
<td>Basecase</td>
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<tr>
<td>Building EEMs</td>
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<td>District Steam</td>
<td>20</td>
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<tr>
<td>District Hot Water</td>
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<table>
<thead>
<tr>
<th>Cluster</th>
<th>Devices</th>
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<tbody>
<tr>
<td>Current Steam Network</td>
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<table>
<thead>
<tr>
<th>Type</th>
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<td>Input\Output ExistingDieselGen</td>
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Cluster Results - Warm Climate

50% Net Zero

Net Zero

Flow Battery (expensive electricity)
DECISION ANALYSIS FOR PORTSMOUTH NAVAL SHIPYARD (PNSY)
PNSY Aerial View
Building Representation in NZP
Description of Alternative Scenarios

1. Baseline:
   - Existing buildings and central plant equipment is simulated.

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   - Buildings with decentralized boilers/furnaces and spot steam generation to meet process load. The same level of electrical backup is still required (15.4 MW for the installation, as in the existing central plant).

   - Buildings with a modern hot water system and lowest equivalent annual cost equipment to meet net zero fossil fuel goals. Only analyzed using the NZP tool.
District System Network: Sizing and Routing

Current Steam...
N/A
Number of Buildings: 108
Ground Coverage: 10,503,564 sqft
Total Electrical Load: 75,098,760 kWh/Yr
Total Space Heating Load: 48,935,636 kWh/Yr
Total DHW Load: 668,773 kWh/Yr
Total Cooling Load: 3,952,798 kWh/Yr
Total Heating Load Density: 4.72 kWh/Yr/sqft
Total Cooling Load Density: 0.38 kWh/Yr/sqft
Total Electrical Peak: 19,237 kWh/Yr
Total Cooling Peak: 11,542 kWh/Yr
Total Space Heating Peak: 109,141 kWh/Yr
Decision Model

Centralized systems allow for higher energy security and flexibility.

Decentralized attractive when done building by building and allows for “site energy” use reduction.
Multi-Criteria Decision Analysis
Cool Weather Example

- Uses quantitative data from NZP models
- Qualitative data can be used (e.g. stakeholder opinions)
- Sensitivity analysis can be conducted on importance of different metrics.
Multi-Criteria Decision Analysis
Warm Weather Example

- Net zero best choice based on equal weighting between energy and cost
- 50% new zero crosses to best at about 91% weighting on cost
NZP Tool Conclusions

- Do not make short term decisions without a long term plan
- Simple Interface to POWERFUL underlying tools, i.e. EnergyPlus, AMPL, CPLEX, etc.
- NZP Tool analysis currently available through U.S. Army Corps of Engineers
- NZP Tool already follows the OSD Installation Energy Plans Memo
YouTube Live Demo

https://www.youtube.com/channel/UC2sdFPLVc5TENXyuRL4SzNw
Conclusions

- Do not make short term decisions without a long term plan

- NZP Tool makes the data collection for energy and cost analysis faster and easier

- Simple Interface to POWERFUL underlying tools, i.e. EnergyPlus, AMPL, CPLEX, etc.