Integration, Analysis, and Optimization of Energy Loads, Distribution, and Supply

Andrew Nelson
U.S. Army Engineer Research and Development Center
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Think Beyond the Building

Don’t make short term decisions without a long term plan
Energy Planning Process

1. Establish Planning Goals
   - Integrated Plan
   - Projects
   - Sequence
   - Schedule
   - Costs
   - Risk
   - DD1391

2. Establish Baseline & Base Case
   - Building
   - Geography
   - Utilities
   - Cost Data
   - Water
   - Waste
   - Greenhouse Gas

3. Optimize Energy Efficiency

4. Optimize Supply and Distribution System Mix

5. Produce Integrated Plan
   - Integrated Plan
   - Projects
   - Sequence
   - Schedule
   - Costs
   - Risk
   - DD1391

Focus for Integration

Execute, Track, Measure

Supports

Iterate over Building Measures

Establish Planning Goals

Optimize Energy Efficiency

Optimize Supply and Distribution System Mix

Establish Baseline & Base Case

To the Commercial Grid

Integration Boundary

Wind Farm

Sub-Station

Battery Storage

Photovoltaics / Solar Thermal

Geothermal

Geothermal

Geothermal

Geothermal

Geothermal

Geothermal

Geothermal

Installation Boundary
Goals, Baseline, Base Case, and Alternatives

• **Goals** – Metrics that guide the analysis of alternatives. Net Zero Energy, Site Energy, Source Energy, Renewables, etc.

• **Baseline** – A synthetic “typical” year. May be derived from several years representative of one or two years energy use.

• **Base Case** – A projection of future usage given “business as usual” policies.
  – Plan horizon (typically 25-40 years)
  – Planned construction
  – Planned demolition
  – Building renovation, consolidation, and mission change.

• **Alternatives**
  – Better Case – reduce energy demand on buildings using cost effective EEMS that meet mission requirements (goals)
  – Best Case – reduce total energy usage further using supply and distribution strategies (cogeneration, solar, wind, storage, etc.)
  – Many more alternatives may (and should) be explored.
SMPL/NZP Tool

- Web based tool that assists in installation-wide energy, water, and waste planning
- Easy to use after setup
- Projects energy, water and waste usage or streams before and after measures are applied.
- Estimates costs and returns for ROI analysis
- Integrates with the Master Planning process
- Provides data to create a roadmap and projects

Master Facility Map

Energy Cluster View
The SMPL/NZP Tool is used extensively by USACE

Fort Leonard Wood

West Point USMA

Waterways Experiment Station

- Schofield Barracks
- Fort Hood
- Presidio at Monterey
- NASA Johnson Space Center
- Lakenheath AFB, UK
- Camp As Saliyah, Qatar
- MCAS Iwakuni, Japan

Fort Hunter Liggett

Portsmouth Naval Shipyard
NZP™ Tool directly supports Phases 1-3 and 6. It provides supporting data for phases 4 and 5.

- Phase 1: Identify the team, tasks, deliverables, and goals
- Phase 2: Establish baseline and future base case
- Phase 3: Establish alternative scenarios and analyze gaps
  - Phase 4: Develop and sequence projects and activities
  - Phase 5: Assemble review and finalize document
- Phase 6: Execution and maintenance of the Installation Energy Plan (allows iteration on the plan due to unforeseen circumstances)
Select Facilities to Include in Study

- Use mouse to choose facilities from GIS
- User can draw in planned facilities and include information about them

Selection menus

Menu to draw in facilities if not already in map
Compare Baseline and Future Alternatives

Today

Future

- Demolish
- Planned
NZP™ Automatically Simulates “Packages” of Efficiency Measures

- Measures vary by facility type and climate zone
- Costs per package based on delta from standard
- User can change parameters and costs to reflect higher or lower efficiencies
- Costs and efficiency effects are cumulative as packages are combined

Packages of bundled measures

Cost for this package

Default values can be changed by the user
Despite facility area increase of 44%:

- EUI and total energy use decreased by 43%
- Requires additional investment of ~$72M
- Annualized cost decreased by 20%
Facility Load Analysis

Compare Electrical Load Duration Curves

- Many Installations are constrained by their connection to the commercial grid
- Resilience is improved by lowering electrical power peak loads

Curves y-axes scaled to be approximately equivalent

Baseline: 8140 kW
Base Case: 10,673 kW
High Efficiency: 7,650 kW

44% more conditioned facility area than baseline
Loads were determined in the previous section.
What is the most cost effective way to meet those loads?

- **Distribution**
  - Electrical Power Grid?
  - Decentralized Heating/ Cooling (Natural Gas Grid)?
  - District Heating/Cooling?

- **Storage**
  - Thermal
  - Electrical

- **Supply**
  - Renewables?
    - Solar
    - Wind
    - Biomass
    - Etc.
  - Fossil Fuels?
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 $SIR_{\text{cluster}}$ & EEMs
The NZP™ Tool Can Optimize “Clusters”

- A cluster is a group of facilities and systems selected by the user.
- NZP™ calculates loads.
- The tool has a database of distribution, supply, and storage options.
- User can add technologies on the fly.
- Optimization uses Mixed-Integer Linear Programming (MILP) to meet the loads at the lowest cost.
- Technology neutral.
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.

Exploration Space (“Super-Structure”)

Architecture(s) determined

Reporting & Implementation Plan
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**
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
- Diesel Generator
- AC Bus
- Fuel Cell
- Wind Turbine
- Gas Turbine
- Electric Heater
Selecting a Supply Architecture

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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**

Energy Exchange: Federal Sustainability for the Next Decade
NZP™ displays a list of equipment to meet facility loads.

Natural Gas Reciprocating Engine CHP.
### Decision Support Example

- NZP™ produces an “analysis of alternatives” decision matrix
- Includes site and source energy, investment, and data for LCC and Simple payback
- In this example, converting district steam to hot water is the most LCC effective alternative.

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>SI Units NZP Energy (MWh/yr)</th>
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<tbody>
<tr>
<td></td>
<td>Total Fossil Fuel + Biomass Fuel</td>
</tr>
<tr>
<td>Baseline</td>
<td>258,810</td>
</tr>
<tr>
<td>Basecase</td>
<td>259,424</td>
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<tr>
<td>District Steam</td>
<td>196,254</td>
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<tr>
<td>District Hot Water</td>
<td>188,011</td>
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<tr>
<td>Decentralized</td>
<td>45,564</td>
</tr>
<tr>
<td>Net Zero Fossil Fuel</td>
<td>2,828 /303,132</td>
</tr>
</tbody>
</table>
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.
• Questions?