

# CAE 465/526 Building Energy Conservation Technologies

## Fall 2022

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**November 16, 2022**  
LCCA and measure installation

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**Dr. Mohammad Heidarinejad, Ph.D., P.E.**  
Civil, Architectural and Environmental Engineering  
Illinois Institute of Technology

[muh182@iit.edu](mailto:muh182@iit.edu)

# **ANNOUNCEMENT**

# Announcement

**BUROHAPPOLD**  
ENGINEERING



## Energy Engineering and Commissioning in Buildings

### **SPEAKER**

Energy Engineer, LEED AP

**Aaron Kachler**

### **WHEN**

**November 17<sup>th</sup>, 2022**

**12:40 pm – 1:40 pm**

### **WHERE**

**John T. Rettaliata  
Engineering Center,  
RE 242**

### **TALK ABOUT**

- ✓ Work Experiences
- ✓ Energy Modeling
- ✓ Careers in Energy Engineering and Commissioning
- ✓ Tips for P.E. exam

For more information, feel free to contact ASHRAE official email  
[ashrae\\_iit@iit.edu](mailto:ashrae_iit@iit.edu)



Interested in Joining

# **PROJECT & EXAM**

# Project & Exam

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- Project Part 2 submission due tonight
- Assignment 5 is posted (you can submit as your group)
- Final presentation date is finalized
- Thanks to AI for sharing his CVRMSE and NMBE code

# **INTRODUCTION TO LIFE-CYCLE ASSESSMENT (LCA)**

# Intro to LCA

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- Life-cycle analysis is **defined** as “*a methodology to evaluate the environmental effects associated with any given industrial activity from the initial gathering of raw materials from the earth until the point at which all residuals are returned to the earth*”

# Intro to LCA

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- LCA is known as:
  - Life-cycle assessment
  - Cradle-to-grave analysis



# Intro to LCA

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- LCA usually has four phases of:
  - Goal and scope
  - Inventory analyses
  - Impact assessments
  - Interpretation

# Intro to LCA

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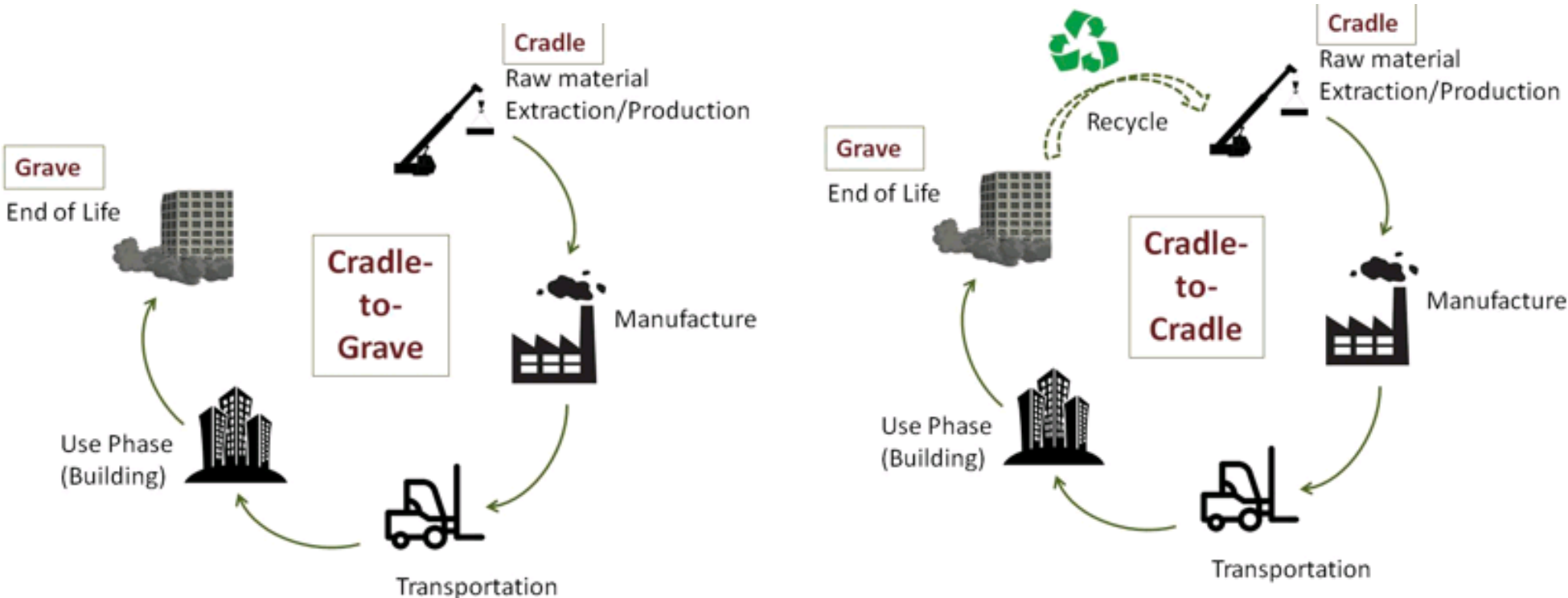
- The detailed description of the phases are:
  - ❑ Goal and scope definitions to identify purposes, audiences, and system boundaries
  - ❑ Inventory analyses known as LCI requires data collection and calculations to quantify materials and energy inputs and outputs of a building systems
  - ❑ Impact assessments phase evaluates the significance of potential impacts based on the LCI
  - ❑ Interpretation phase to evaluate findings and establish final conclusions and recommendations

# Intro to LCA

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- In the context of buildings first the system boundaries need to be defined
- Typical comprehensive building life-cycle assessment covers:
  - Material manufacture
  - Transportation
  - Construction
  - Operation
  - Maintenance
  - Demolition

# LCA Phases



# **BUILDING LIFE-CYCLE COST ANALYSIS (LCCA)**

# Building Life-Cycle Cost Analysis

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- Similar to the building projects, there are different phases of in the calculation of LCCA:
  - Capital “initial” cost
  - Transportation cost One time
  - Fuel cost
  - Operational cost Recurring
  - Maintenance and repair cost
  - Demolition “resale or salvage” cost One time
  - Finance cost Recurring
  - Non-monetary cost (e.g., rebates, taxes) Depends

# Building Life-Cycle Cost Analysis

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- What's the purpose of LCCA?

*“Select viable alternatives that may have high initial costs but low operational and maintenance costs”*

- Examples are:
  - Glazing
  - Efficient HVAC systems

# Building Life-Cycle Cost Analysis

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- What are the examples of alternatives:
  - Different types of systems and components
  - Various efficiency
  - The choice of repair or replacement
  - Consideration of all alternatives



# Building Life-Cycle Cost Analysis

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- Why do we use LCCA?
  - Requirements of federal and states or private sectors
  - Evaluation of alternatives suggested by the ASHRAE Energy Codes
  - Beneficial for the calculation of Return of Investment (ROI)

# Building Life-Cycle Cost Analysis Tools

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- Early stage design construction costs should follow supported industry formats:
  - ❑ UNIFORMAT II (ASTM) mostly in the US and Canada
  - ❑ Levels 1 and 2 NRM1 (RICS) mostly in the UK

NISTIR 6389



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## **UNIFORMAT II Elemental Classification for Building Specifications, Cost Estimating, and Cost Analysis**

Robert P. Charette  
Harold E. Marshall

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# Capital Cost

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- Capital costs for HVAC equipment more difficult than other mass-produced items. Special considerations:
  - Various size of equipment
  - Optimal design and cost

# Capital Cost

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- Capital cost is calculated as:

$$C = C_{ref} \left( \frac{S}{S_{ref}} \right)^m$$

- ❑  $C$ : the cost at size  $S$
- ❑  $C_{ref}$ : the cost at a reference size  $S_{ref}$
- ❑  $m$ : the exponent varies between 0.5 – 1 (~0.6 recommended)
- ❑ This software is a good resource:

<http://www.hcbcentral.com/hcb/hcb.htm>

# Capital Cost

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- It is important to consider the concept of “unit operations”, meaning to group certain portions of a project.
- The components of unit operations are “unit assemblies” are itemized, priced, and plotted by size of unit operation.  
For example:
  - ❑ Unit Operation = Boiler
  - ❑ Unit Assemblies = Burner, air intake, flue, shut of valves, piping, fuel supply, expansion tank, water make up valves, deaerator

# Fuel Cost

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- Consider energy rates for
  - Electricity
  - Natural gas
  - Steam
  - Chilled water

# Fuel Cost

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- Type of rates for electricity
  - Flat rates
  - Tiered
  - Demand response
  - Time of Use (TOU)

# Maintenance and Life Cost

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- Examples of maintenance and operational costs:
  - Labor (e.g., technician to see the HVAC system)
  - Services
  - Supplies (e.g., air filter replacement)
  - Repair (e.g., repairs beyond warranty)



# Maintenance and Life Cost

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- Different sources are:
  - ❑ Building Owners, and Managers Association International (BOMA): <https://www.boma.org/>
  - ❑ RSMeans: <https://www.rsmeans.com/>
  - ❑ National Institute of Buildings Sciences:  
<https://www.wbdg.org/design-objectives/cost-effective/utilize-cost-value-engineering>
  - ❑ Open BIM Cost Estimator:  
[http://open-bim-cost-estimator.en.cype.com/open\\_bim\\_cost\\_estimator\\_method\\_us\\_ed.htm](http://open-bim-cost-estimator.en.cype.com/open_bim_cost_estimator_method_us_ed.htm)

# Maintenance and Life Cost

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| Subsystem Categories   | Average Life Cycle |
|--|--------------------|
| 1a. Roofing – Tile.....  | 80 years           |
| 1b. Roofing – Metal, Concrete .....                            | 50 years           |
| 1c. Roofing – Membrane, Built-up, Shingle, Bitumen, Foam ..... | 20 years           |
| 2a. Building Exteriors, Doors, and Windows (Hard).....         | 80 years           |
| 2b. Building Exteriors (Soft) .....                            | 20 years           |
| 3. Elevators and Conveying Systems .....                       | 25 years           |
| 4. HVAC – Equipment and Controls.....                          | 20 years           |
| 5. HVAC – Distribution Systems.....                            | 40 years           |
| 6. Electrical Equipment .....                                  | 30 years           |
| 7. Plumbing Fixtures .....                                     | 30 years           |
| 8. Plumbing – Rough-in .....                                   | 50 years           |
| 9. Fire Protection Systems .....                               | 40 years           |
| 10. Fire Detection Systems .....                               | 20 years           |
| 11. Built-in Specialties and Equipment.....                    | 25 years           |
| 12. Interior Finishes.....                                     | 15 years           |

# Maintenance and Life Cost

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- Examples of life expectancies are:

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| <b>Equipment Type</b>               | <b>Median Service Life (Years)</b> |
|-------------------------------------|------------------------------------|
| DX air distribution equipment       | >24                                |
| Chillers, centrifugal               | >25                                |
| Cooling towers                      | >22                                |
| Gas hot water boiler, steel         | >22                                |
| Pneumatic electronic controls       | >7                                 |
| Portable electric hot water heaters | >21                                |

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# Building Life Cycle Cost Analysis Example



ASHRAE Owning and Operating Cost Database  
Equipment Life/Maintenance Cost Survey  
ASHRAE Research Project 1237-TRP

## Database Main Page

Project Summary

Preferences

## Model Your Building

### Service Life Data

by System Type

### Maintenance Cost Data

by All Options

by Region

by State

by BOMA Class

by Function

by Size

## HVAC Equipment List

## Related Documentation

Download Database

Submit HVAC Data

## ASHRAE: Service Life and Maintenance Cost Database

The purpose of this database is to provide current information on service life and maintenance costs of typical HVAC equipment. Engineers depend on accurate owning and operating data to make decisions involving the life cycle and functionality of buildings. However, lack of sufficient up-to-date data makes it difficult to provide a solid basis for those decisions. Previous efforts to collect data through traditional survey methods have produced less than acceptable results.

See more details of goals of this project here: [here](#)

### Main Features:

- **Equipment Service Life Evaluation** ([here](#)): Creates both lists and summaries of service life data customized to match specific criteria.
- **HVAC Maintenance Cost Evaluation** ([here](#)): Creates both lists and summaries of maintenance data customized to match specific criteria.
- **Submit HVAC Data** ([here](#)): The database is open for public data submissions. Registration is required.

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# Building Life Cycle Cost Analysis Example

- ASHRAE data is collected through RP-1237:

| Air Distribution Equipment                               | Total       | Currently in Service |                       |           |            |            |           |          | Replaced     |                        |           |            |            |           |           |
|--|-------------|----------------------|-----------------------|-----------|------------|------------|-----------|----------|--------------|------------------------|-----------|------------|------------|-----------|-----------|
|  |             | No. of Units         | Equipment Age (years) |           |            |            |           |          | No. of Units | Age at Removal (years) |           |            |            |           |           |
|  |             |                      | Mean                  | Median    | Std Dev    | 95% C.I.   | Maximum   | Minimum  |              | Mean                   | Median    | Std Dev    | 95% C.I.   | Maximum   | Minimum   |
| Air handling unit, constant volume                       | 209         | 182                  | 22                    | 20        | 10.3       | 1.5        | 43        | 3        | 27           | 47                     | 52        | 8.0        | 3.0        | 52        | 26        |
| Air handling unit, dual duct                             | 15          | 5                    | 34                    | 34        | 7.4        | 6.5        | 42        | 22       | 10           | 27                     | 27        | 0.5        | 0.3        | 27        | 26        |
| Air handling unit, multizone                             | 208         | 178                  | 20                    | 20        | 5.9        | 0.9        | 31        | 3        | 30           | 64                     | 64        | 0.0        | n/a        | 64        | 64        |
| Air handling unit, variable air volume                   | 831         | 819                  | 17                    | 18        | 6.2        | 0.4        | 35        | 0        | 12           | 18                     | 19        | 2.7        | 1.5        | 20        | 12        |
| Air handling unit, variable volume, variable temperature | 61          | 61                   | 16                    | 17        | 9.0        | 2.2        | 31        | 1        | 0            | n/a                    | n/a       | n/a        | n/a        | n/a       | n/a       |
| Fan coil unit  | 2452        | 1252                 | 6                     | 5         | 3.8        | 0.2        | 25        | 3        | 1200         | 52                     | 52        | 0.0        | n/a        | 52        | 52        |
| Heat pump, air-to-air                                    | 161         | 25                   | 16                    | 17        | 3.4        | 1.3        | 17        | 0        | 136          | 12                     | 12        | 0.4        | 0.1        | 17        | 12        |
| Heat pump, water-source                                  | 1234        | 1129                 | 17                    | 18        | 6.0        | 0.4        | 24        | 1        | 105          | 17                     | 17        | 0.2        | 0.0        | 17        | 16        |
| Packaged DX unit, air-cooled                             | 32          | 32                   | 12                    | 14        | 5.9        | 2.0        | 24        | 3        | 0            | n/a                    | n/a       | n/a        | n/a        | n/a       | n/a       |
| Packaged DX unit, rooftop                                | 164         | 131                  | 11                    | 9         | 6.6        | 1.1        | 22        | 0        | 33           | 21                     | 20        | 2.8        | 0.9        | 27        | 14        |
| Packaged DX unit, water-cooled                           | 187         | 177                  | 14                    | 17        | 9.0        | 1.3        | 32        | 1        | 10           | 22                     | 22        | 0.0        | n/a        | 22        | 22        |
| Split DX system  | 129         | 129                  | 16                    | 16        | 1.1        | 0.2        | 21        | 12       | 0            | n/a                    | n/a       | n/a        | n/a        | n/a       | n/a       |
| <b>Total</b>   | <b>5683</b> | <b>4120</b>          | <b>14</b>             | <b>16</b> | <b>5.9</b> | <b>0.2</b> | <b>43</b> | <b>0</b> | <b>1563</b>  | <b>45</b>              | <b>52</b> | <b>1.1</b> | <b>0.1</b> | <b>64</b> | <b>12</b> |
| <b>AHUs Total</b>  | <b>1324</b> | <b>1245</b>          | <b>18</b>             | <b>18</b> | <b>7.0</b> | <b>0.4</b> | <b>43</b> | <b>0</b> | <b>79</b>    | <b>46</b>              | <b>52</b> | <b>4.7</b> | <b>1.0</b> | <b>64</b> | <b>12</b> |
| <b>DX Units Total</b>                                    | <b>1907</b> | <b>1623</b>          | <b>16</b>             | <b>18</b> | <b>6.2</b> | <b>0.3</b> | <b>32</b> | <b>0</b> | <b>284</b>   | <b>15</b>              | <b>17</b> | <b>1.0</b> | <b>0.1</b> | <b>27</b> | <b>12</b> |

# Building Life Cycle Cost Analysis Example

- ASHRAE data is collected through RP-1237:

| Cooling Equipment                                 | Total      | Currently in Service |                       |           |            |            |           |          | Replaced     |                        |           |            |            |           |          |
|---|------------|----------------------|-----------------------|-----------|------------|------------|-----------|----------|--------------|------------------------|-----------|------------|------------|-----------|----------|
|   |            | No. of Units         | Equipment Age (years) |           |            |            |           |          | No. of Units | Age at Removal (years) |           |            |            |           |          |
|   |            |                      | Mean                  | Median    | Std Dev    | 95% C.I.   | Maximum   | Minimum  |              | Mean                   | Median    | Std Dev    | 95% C.I.   | Maximum   | Minimum  |
| Chiller, absorption, indirect-fired, single-stage | 6          | 6                    | 35                    | 35        | 0.0        | n/a        | 35        | 35       | 0            | n/a                    | n/a       | n/a        | n/a        | n/a       | n/a      |
| Chiller, air-cooled reciprocating                 | 9          | 8                    | 6                     | 7         | 4.2        | 2.9        | 15        | 1        | 1            | 11                     | 11        | n/a        | n/a        | 11        | 11       |
| Chiller, air-cooled rotary (screw)                | 8          | 8                    | 8                     | 5         | 9.4        | 6.5        | 29        | 2        | 0            | n/a                    | n/a       | n/a        | n/a        | n/a       | n/a      |
| Chiller, centrifugal                              | 234        | 200                  | 15                    | 17        | 7.7        | 1.1        | 35        | 0        | 34           | 28                     | 27        | 4.3        | 1.4        | 52        | 7        |
| Chiller, water-cooled reciprocating               | 7          | 7                    | 18                    | 14        | 10.9       | 8.1        | 32        | 3        | 0            | n/a                    | n/a       | n/a        | n/a        | n/a       | n/a      |
| Chiller, water-cooled rotary (screw)              | 7          | 5                    | 9                     | 13        | 5.5        | 4.8        | 13        | 3        | 2            | 23                     | 23        | 4.8        | 6.6        | 23        | 23       |
| <b>Total</b>                                      | <b>271</b> | <b>234</b>           | <b>15</b>             | <b>16</b> | <b>7.6</b> | <b>1.0</b> | <b>35</b> | <b>0</b> | <b>37</b>    | <b>27</b>              | <b>25</b> | <b>4.2</b> | <b>1.3</b> | <b>52</b> | <b>7</b> |
| <b>Centrifugal Chiller Total</b>                  | <b>234</b> | <b>200</b>           | <b>15</b>             | <b>17</b> | <b>7.7</b> | <b>1.1</b> | <b>35</b> | <b>0</b> | <b>34</b>    | <b>28</b>              | <b>27</b> | <b>4.3</b> | <b>1.4</b> | <b>52</b> | <b>7</b> |

# Building Life Cycle Cost Analysis Example

- ASHRAE data is collected through RP-1237:

| tel:139%20109%2017%20117%2093%2016                 | Total      | Currently in Service |                       |           |             |            |           |          | Replaced     |                        |           |            |            |           |           |
|--|------------|----------------------|-----------------------|-----------|-------------|------------|-----------|----------|--------------|------------------------|-----------|------------|------------|-----------|-----------|
|  |            | No. of Units         | Equipment Age (years) |           |             |            |           |          | No. of Units | Age at Removal (years) |           |            |            |           |           |
|  |            |                      | Mean                  | Median    | Std Dev     | 95% C.I.   | Maximum   | Minimum  |              | Mean                   | Median    | Std Dev    | 95% C.I.   | Maximum   | Minimum   |
| Boiler, electric hot water                         | 4          | 4                    | 16                    | 19        | 7.6         | 7.5        | 22        | 5        | 0            | n/a                    | n/a       | n/a        | n/a        | n/a       | n/a       |
| Boiler, cast iron                                  | 18         | 12                   | 23                    | 22        | 9.3         | 5.3        | 32        | 1        | 6            | 33                     | 34        | 1.0        | 0.8        | 34        | 31        |
| Boiler, steel fire-tube, forced draft, hot water   | 18         | 10                   | 11                    | 9         | 6.8         | 4.2        | 20        | 4        | 8            | 14                     | 10        | 6.1        | 4.2        | 25        | 10        |
| Boiler, steel fire-tube, forced draft, steam       | 10         | 10                   | 34                    | 35        | 8.5         | 5.2        | 43        | 20       | 0            | n/a                    | n/a       | n/a        | n/a        | n/a       | n/a       |
| Boiler, steel fire-tube, natural draft, hot water  | 12         | 11                   | 14                    | 14        | 4.0         | 2.4        | 21        | 9        | 1            | 15                     | 15        | n/a        | n/a        | 15        | 15        |
| Boiler, steel water-tube, forced draft, hot water  | 27         | 24                   | 12                    | 3         | 14.0        | 5.6        | 42        | 1        | 3            | 18                     | 16        | 0.9        | 1.0        | 21        | 16        |
| Boiler, steel water-tube, forced draft, steam      | 3          | 3                    | 34                    | 35        | 1.2         | 1.3        | 35        | 33       | 0            | n/a                    | n/a       | n/a        | n/a        | n/a       | n/a       |
| Boiler, steel water-tube, natural draft, hot water | 47         | 35                   | 13                    | 15        | 11.2        | 3.7        | 37        | 0        | 12           | 17                     | 17        | 2.9        | 1.6        | 23        | 11        |
| <b>Total</b>                                       | <b>139</b> | <b>109</b>           | <b>17</b>             | <b>17</b> | <b>10.2</b> | <b>1.9</b> | <b>43</b> | <b>0</b> | <b>30</b>    | <b>19</b>              | <b>17</b> | <b>4.7</b> | <b>1.7</b> | <b>34</b> | <b>10</b> |
| <b>Steel Gas-Fired Boilers Total</b>               | <b>117</b> | <b>93</b>            | <b>16</b>             | <b>15</b> | <b>10.4</b> | <b>2.1</b> | <b>43</b> | <b>0</b> | <b>24</b>    | <b>16</b>              | <b>16</b> | <b>5.2</b> | <b>2.1</b> | <b>25</b> | <b>10</b> |

# **PRESENT VALUE**



# Present Value

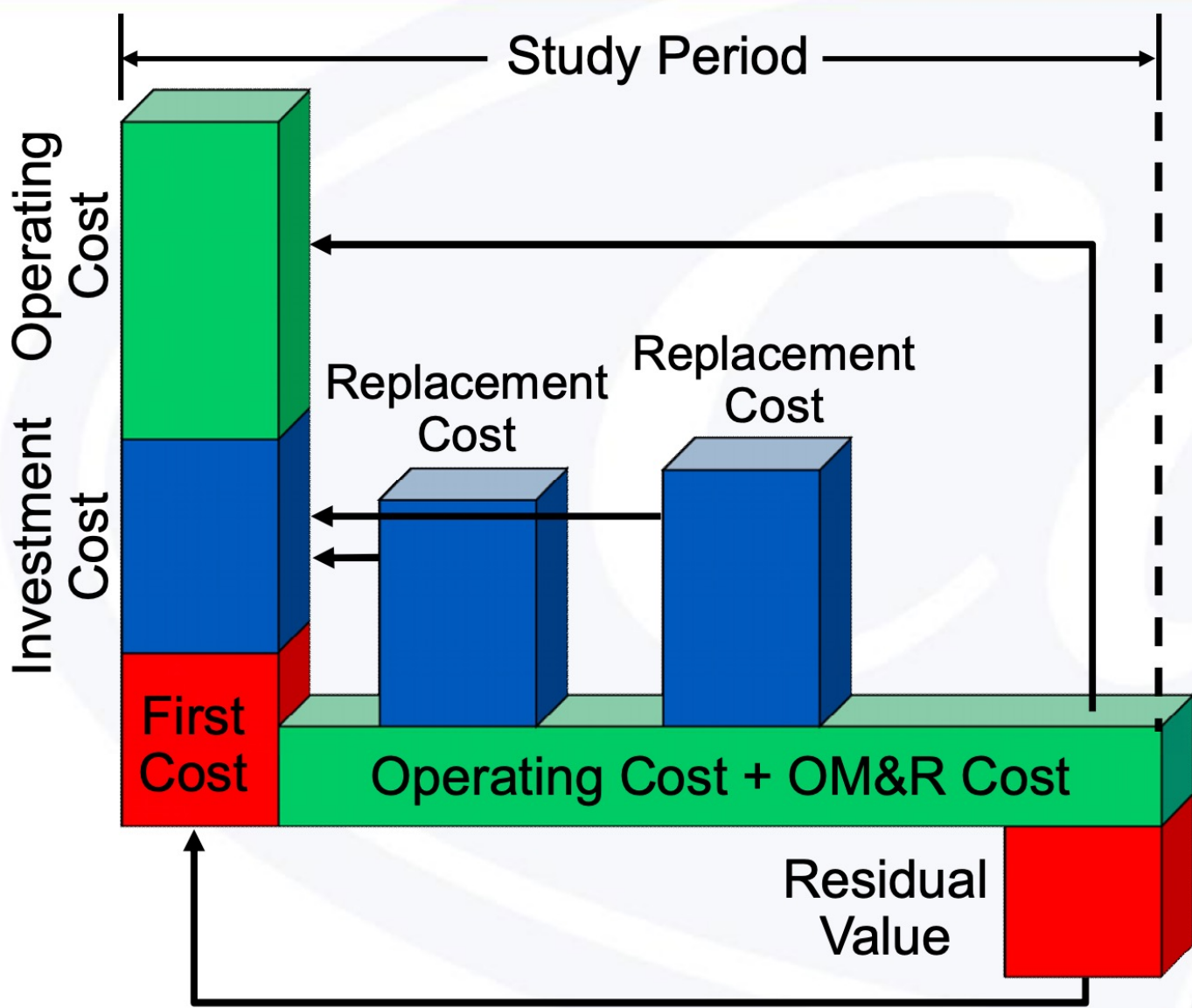
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- **Present value** (PV) or present discounted value is a future amount of money that has been discounted to reflect its current value, as if it existed today.
- The present value is always less than or equal to the future value

$$PV = \frac{C}{(1 + i)^n}$$

- ❑  $C$ : is the future amount of money that must be discounted
- ❑  $n$ : is the number of compounding periods between the present date and the future date
- ❑  $i$ : is the interest rate for one compounding period

# Present Value



# Net Present Value

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- **Net present value** (NPV) of a time series of cash flows, both incoming and outgoing, is defined as the sum of the present values of the individual cash flows of the same entity:

$$NPV(i, N) = \sum_{t=0}^N \frac{R_t}{(1+i)^t}$$

- ❑  $t$ : The time of the cash flow
- ❑  $i$ : The discount rate (the rate of return that could be earned on an investment in the financial markets with similar risk.); the opportunity cost of capital
- ❑  $R_t$ : The net cash flow i.e. cash inflow – cash outflow, at time  $t$

# Net Present Value

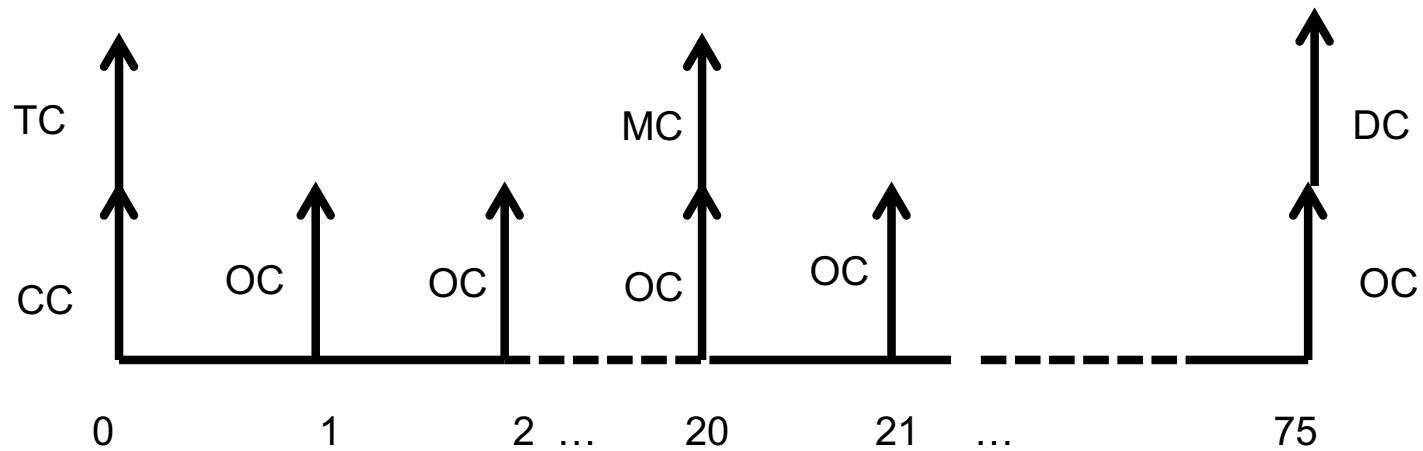
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| If...     | It means...   | Then...   |
|-----------|---|---|
| $NPV > 0$ | the investment would add value to the firm                    | the project may be accepted   |
| $NPV < 0$ | the investment would subtract value from the firm             | the project should be rejected  |
| $NPV = 0$ | the investment would neither gain nor lose value for the firm | We should be indifferent in the decision whether to accept or reject the project. This project adds no monetary value. Decision should be based on other criteria, e.g., strategic positioning or other factors not explicitly included in the calculation. |

# Net Present Value

---

- Draw the cash flow:



# MEASURE INSTALLATIONS

# Measure Installations

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- Two options:
  - Parametric Analysis Tool (PAT)
  - OpenStudio Measure tab

# **PARAMETRIC ANALYSIS TOOL (PAT)**



# PAT

## Parametric Analysis Tool (PAT) Interface Guide

PAT removes the need to hand edit each model to try out different architectures, energy efficiency measures, and mechanical systems. PAT applies scripts to your baseline model and lets you quickly compare many alternatives. OpenStudio has developed a workflow that allows energy modelers to create and run a customized parametric analysis using commercially available cloud computing services. This workflow will enable anyone to perform powerful parametric studies in a reasonable time for a relatively low cost.

Creating a Project

Loading a Baseline Model

Organize and Edit Measures for Project

Select Measures and Create Design Alternatives

Run Simulations

Create and View Reports

Running on the Cloud

Viewing Results

Publications

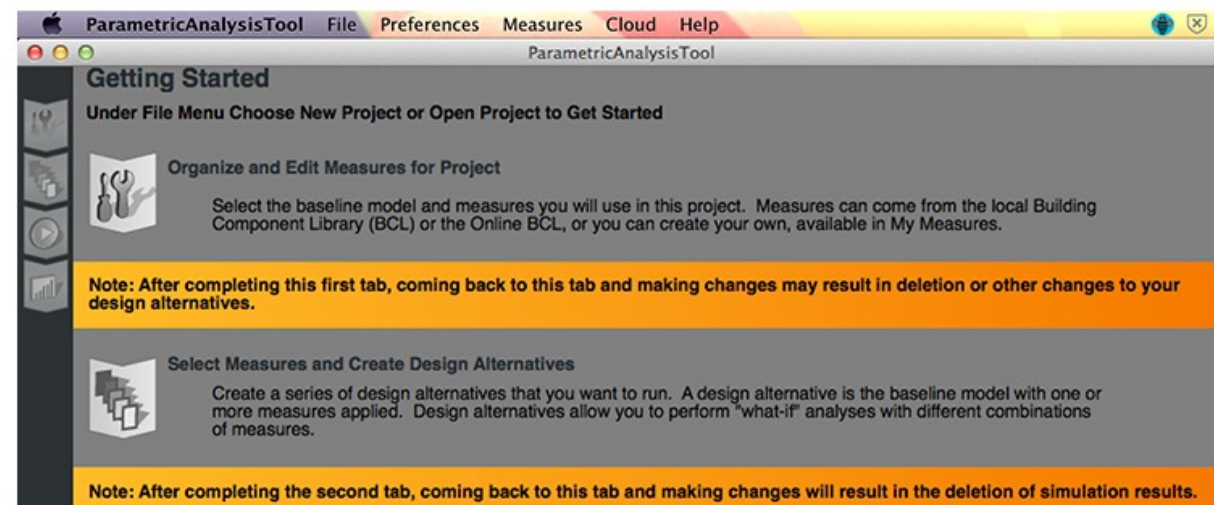
[Back to OpenStudio®](#)

### Creating a Project

The [Parametric Analysis Tool Quick Start Guide \(PDF\)](#) provides an introduction to the interface and workflow for creating multiple design alternatives from a seed model.

When you first open PAT you will see the screen below. It shows the workflow:

1. Organize and edit measures for project
2. Select measures and create design alternatives
3. Run simulations
4. Create and view reports



# PAT

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***How many of you have watched any videos related to OpenStudio?***

<https://www.youtube.com/user/NRELOpenStudio/videos>

# PAT

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- Useful links:

- [https://www.youtube.com/watch?v=3rmEIK\\_OB28](https://www.youtube.com/watch?v=3rmEIK_OB28)
- <https://www.youtube.com/watch?v=4g5nJzDoh58>
- <https://www.youtube.com/watch?v=9WgUhiJ785I>
- <https://www.youtube.com/watch?v=0lINfGNe5x0>

# PAT

- Useful instructions:

The screenshot shows the OpenStudio SDK User Docs website. The navigation bar at the top includes 'OpenStudio® SDK User Docs', 'Getting Started', 'Reference', and 'Help'. The left sidebar contains a list of links: 'Create a Project', 'Open an Existing Project', 'Interface Overview', 'Load a Seed Model and Weather File', 'Add Measures and Create Measure Options' (highlighted), 'Create Design Alternatives', 'Adding Outputs in Manual Mode', 'Running an Analysis Locally', 'View Analysis Reports', 'View OpenStudio Server', 'Menu Bar Functions', and 'Algorithmic Mode'. Below the sidebar is a button 'Back to OpenStudio.net' and a link 'Go to the OpenStudio Application® Documentation'. The main content area features the heading 'Parametric Analysis Tool (PAT) Interface Guide' and a paragraph: 'OpenStudio's PAT allows you to quickly try out and compare manually specified combinations of measures, optimize designs, calibrate models, perform parametric sensitivity analysis, and much more. Manually specified combinations of measures may be run locally on your computer. Algorithmic analyses (e.g. optimization, design of experiments, etc) can be run by connecting to a separately provisioned instance of the OpenStudio server.' Below this is the section 'Create a Project' with the text: 'When you launch PAT you have the option to create a new project or open an existing project.' A screenshot of the PAT application interface is shown, featuring a 'Select a Project' dialog box with the text 'Create a new or open an existing project' and three buttons: 'Make New Project', 'Open Existing Project', and 'Cancel'.

# PAT

- You can download it form here:

The screenshot shows the GitHub interface for the repository `NREL / OpenStudio-PAT`. The repository is public and has 13 watchers, 9 forks, and 15 stars. The navigation bar includes links for Code, Issues (68), Pull requests (5), Actions, Projects, Wiki, Security, and Insights. The 'Releases' tab is active, and a search box for releases is present. The latest release, `OpenStudio-PAT v3.5.0`, is highlighted with a 'Latest' badge. It was published 6 days ago by user `tijcolem` with commit `v3.5.0` and SHA `1413a7c`. A 'Compare' button is available. The 'What's Changed' section lists the following updates:

- Upgrade Node v18 by `@bstein` in `#218`
- Upgrade electron to v20 by `@bstein` in `#223`
- Migrate from bower to npm by `@bstein` in `#224`
- Upgrade dependencies to latest stable versions by `@bstein` in `#228`
- `#231`: Fix grid on Options page by `@bstein` in `#232`
- `#235`: Use "npx gulp" instead of relying on executable script by `@bstein` in `#236`
- updates for OS SDK 3.5.0 by `@tijcolem` in `#240`

<https://github.com/NREL/OpenStudio-PAT/releases>

# PAT

- You can define measure alternatives:

The screenshot displays the ParametricAnalysisTool (PAT) interface. At the top, the window title is "ParametricAnalysisTool". The main area is titled "Lecture13" and contains several configuration options:

- Analysis:** A dropdown menu set to "Manual".
- Default Seed Model:** A dropdown menu set to "baseline\_sys05.osm".
- Default Weather File:** A dropdown menu set to "USA\_IL\_Chicago-OHare.Intl.AP.725300\_TMY3.epw".

Below these options, there is a "Project Measures and Options" section with a "Check for Updates" button. Underneath, the "OpenStudio Measures" section includes a "+ Add Measure" button. A list of measures is shown, with "Increase R-value of Insulation for Exterior Walls to a Specific Value" selected and expanded. This measure has a sub-option "Increase R-value of Insulation for Exterior Walls to a Specific" which is also expanded. Below this, there are buttons for "+ Add Measure Option", "Duplicate Option", and "Duplicate Measure & Option". A "Descriptions" section is also visible.

At the bottom, the "Model To Base Inputs On" dropdown is set to "baseline\_sys05.osm". A table displays the configuration for the selected measure and its options:

| Argument Name  | Units... | Short Name | Variable...                         | Option 1                            |
|--|----------|------------|-------------------------------------|-------------------------------------|
|  |          |            | All <input type="checkbox"/>        | <input checked="" type="checkbox"/> |
|  |          |            |                                     | Option 1 Name                       |
|  |          |            |                                     | Option 1 Description: Set the R-... |
| Insulation R-value (ft^2*h*R/Btu).                       |          |            | <input checked="" type="checkbox"/> | 13                                  |
| Allow both increase and decrease in R-value to rea...    |          |            | <input checked="" type="checkbox"/> | false                               |
| Increase in Material and Installation Costs for Const... |          |            | <input checked="" type="checkbox"/> | 0                                   |

# PAT

- Those who are interested in automated calibration or coding (Optional)

NREL / **OpenStudio-PAT** Public

<> Code Issues 68 Pull requests 5 Actions Projects Wiki Security Insights

develop 29 branches 23 tags Go to file Add file <> Code

tijcolem Merge pull request #240 from NREL/3.5.0 3a295c9 6 days ago 1,341 commits

<https://github.com/NREL/OpenStudio-PAT>

NREL / **OpenStudio-analysis-spreadsheet** Public

<> Code Issues Pull requests 1 Actions Projects Wiki Security Insights

develop 9 branches 26 tags Go to file Add file <> Code

brianlball update gemfile for analysis gem rc19 f81bd3f on May 4, 2017 679 commits

|                     |                                      |             |
|---------------------|--------------------------------------|-------------|
| Calibration_example | Adding a missing measure back in.    | 6 years ago |
| documentation       | remove _uncertain from template.xlsx | 7 years ago |
| measures            | debugging 2.0 stuff                  | 6 years ago |

<https://github.com/NREL/OpenStudio-analysis-spreadsheet>

# **OPENSTUDIO MEASURE OPTION**



# OpenStudio Measure Option

- You can also use the OpenStudio App

