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Strategies to Modeling

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ASHRAE Standard 189 Committee Member

Presentation Overview

- Energy Modeling Program & Strategies
- Energy Targets in Courthouses
- Energy Target Optimization Process
- Courthouse Energy Modeling Inputs
- Energy Targets – New Buildings
- Energy Targets – Existing Buildings
- Conclusion

Energy Modeling
Programs & Strategies

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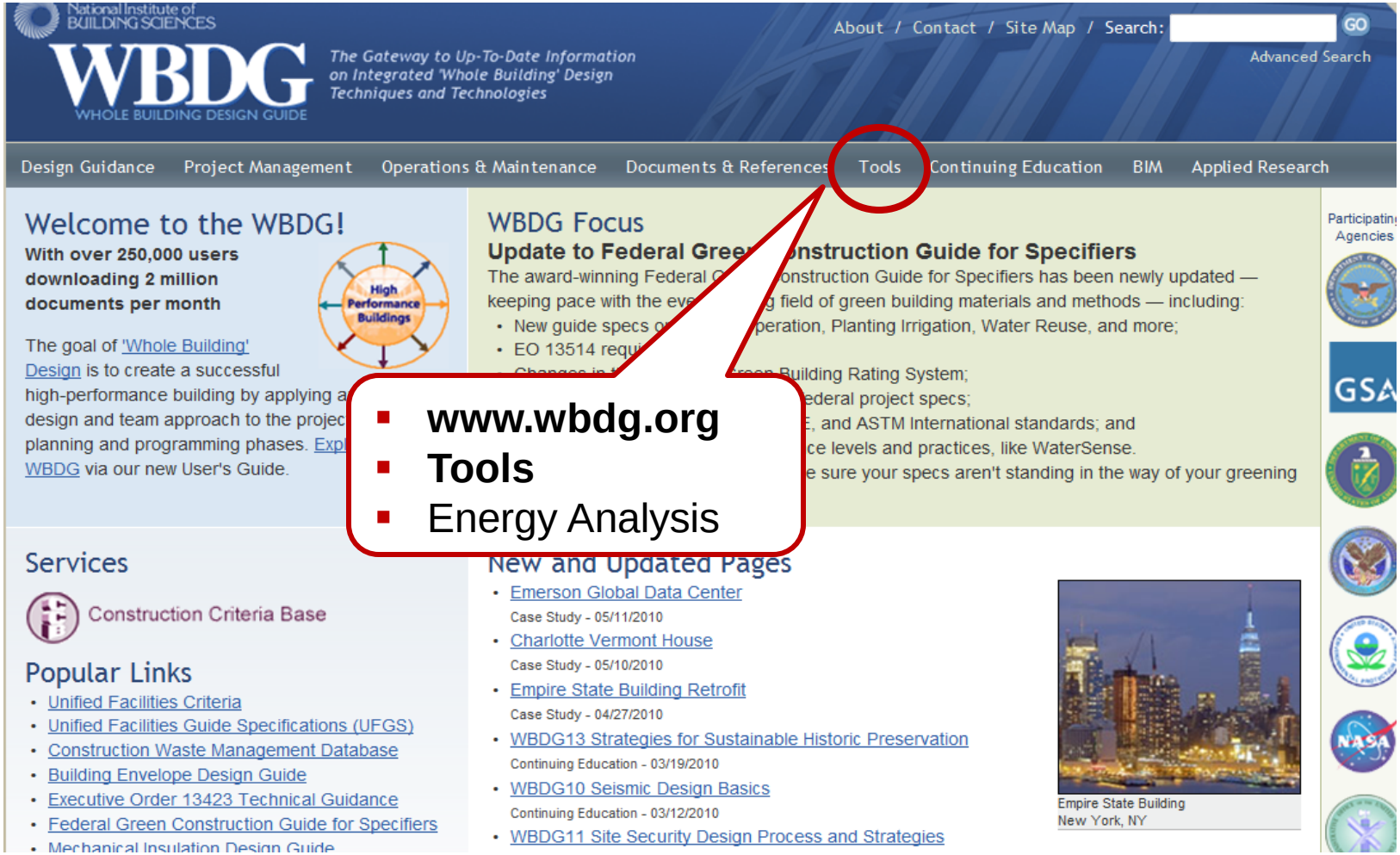
Energy Modeling Programs

- Some of the Programs available in the Industry*:
  - **DOE-2.1** (Building Energy Modeling Program from LBNL; Recognized as the Industry Standard)
  - **ECOTECT** (Environmental Design Tool with Solar, Thermal, Lighting, Acoustic, and Cost Analysis Functions; from CRBE, UK)
  - **ENERGY-10** (Conceptual Design Tool for Residential and Small Commercial Buildings; from NREL)
  - **EnergyPlus** (Energy Modeling Program Based on the Most Popular Features and Capabilities of BLAST and DOE-2; from DOE)
  - **eQUEST/DOE-2.2** (the Most Popular Program in the U.S. Uses DOE-2.2 as Simulation Engine; from JJH&A)
  - **ESP-r** (General Purpose Simulation Environment from University of Strathclyde, U.K.; more popular in Europe and Asia)
  - **HAP** (Integrated Design and Energy Simulation Tool; from Carrier)
  - **IES <VE>** (General Purpose Simulation Environment; from IES, UK)
  - **TRACE 700** (Integrated Design and Energy Simulation Tool; from Trane)
  - **TRNSYS** (Energy Simulation Program with Mod. Structure; from Univ. of Wisconsin)

** Reference: Building Energy Software Tools Directory (www1.eere.energy.gov/buildings)*

Where to Find These Tools…



- **www.wbdg.org**
- **Tools**
- Energy Analysis

BIM: The Next Paradigm

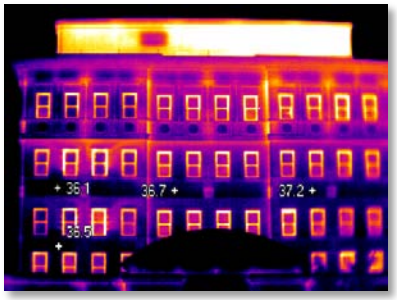
- Building Information Modeling
  - Instead of Separate Design and Modeling Actions, Design will Automatically Generate Energy Models
  - Must Learn to Use Data-Base Features within BIM Platforms (Not there yet…Software Enhancements still needed, and there are currently too many non-expert BIM Users)
  - There are Current Limitations, but it's Coming
  - Example: Green Building Studio (Links Architectural 3-D CAD Designs with Energy Analysis - Creates Input Files for Major Energy Simulation Programs)

Modeling Failures

- Must Accurately Profile & Understand Energy Use, e.g.
  - Energy Use Driven by Hours of Operation: Schedules must be realistic
  - Heating & AC are Impacted by OA Use: Envelope Integrity, Building Pressure, Ventilation Control
  - Lighting: Efficient Lighting Fixtures - Occupancy Controlled, Commissioned Sensors
- Virtually No Occupant/Operator Coordination/Commitment
  - Poor Interior Design Choices (Partitioning, Colors, Furnishings…)
  - Special Operations – Effective Zone Definition
- Designer Ignorance / Manufacturer Hype
  - Some Technologies Have Limited Application
    - *UFAD is Not for Multi-story, Normal Business-hour Buildings*
    - *Natural Lighting Benefit vs. Glazing Heat Transfer/Glare*
  - Conflicting Sustainability Principles/Principals
    - *Outside Air Use vs. Tempering Costs*
    - *Natural Light vs. Heat Transfer*
    - *AHU's off Occupied Floors Force Vertical Zones*
    - *Inaccessible HVAC Components are Units that will not be Maintained Regularly, and as such, will not Perform as Simulated*

Space Heating
Lighting
Space Cooling
Misc. Equipment
Misc. Uses
Water Heating
Ventilation Fans
Pumps & Aux.
Cooling Tower

Modeling Failures



- Poor Zone Control
  - Must Be Able to Turn Space “On”–“Off”
  - Must Group Like-Space Operations
  - Zones Should Be Optimized for Time of Day, Day of Week, Event Cycles
- Heat Recovery – Heat Exchange
  - Ensure Cooling Tower Free Cooling Can Work with Chillers - On
  - Make Sure Maintenance Staff Can Handle Cleaning and Controls
- Excessive Use of Outside Air
  - Infiltration - Poor Envelope Construction
  - Over-Ventilation, Over Pressurization (Lack of Control)
  - No Use of CO_2 Sensors for Ventilation, nor CO Sensors for Garage & Upper Floors – Controlling Garage Exhaust
  - No Considered Use of Dedicated Ventilation Systems
- Building Automation
  - Provide Equipment & Controls that the Operating Staff can Understand
  - Ensure Extended Service Support After Installation (1 Year, Option for More)

Energy Modeling Targets in Courthouses

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Energy Modeling Targets in Courthouses

- Energy Consumption in Courthouses Varies Considerably
  - Energy Consumption in Courthouses Vary from 30,000 Btu/ft^2/yr to 150,000 Btu/ft^2/yr (*considering involved space types, climate, outdoor air use, operating hours, building features, system types, and zone control*)
- Prediction and Achievement are Not the Same
  - Modeled Energy Target Projections Can Be Made to Vary Between 50% - 100% By Assumptions *(infiltration, ventilation control, operating hours, zone control, solar shading & natural lighting control)*
  - Buildings are Not Being Operated as Modeled

Courthouse Name	Location	Annual Energy Use
Alfred A. Arraj	Denver, CO	101,000 kBtu/ft^2
Nathaniel R. Jones	Youngstown, OH	71,400 kBtu/ft^2
Wayne L. Morse	Eugene, OR	30,500 kBtu/ft^2

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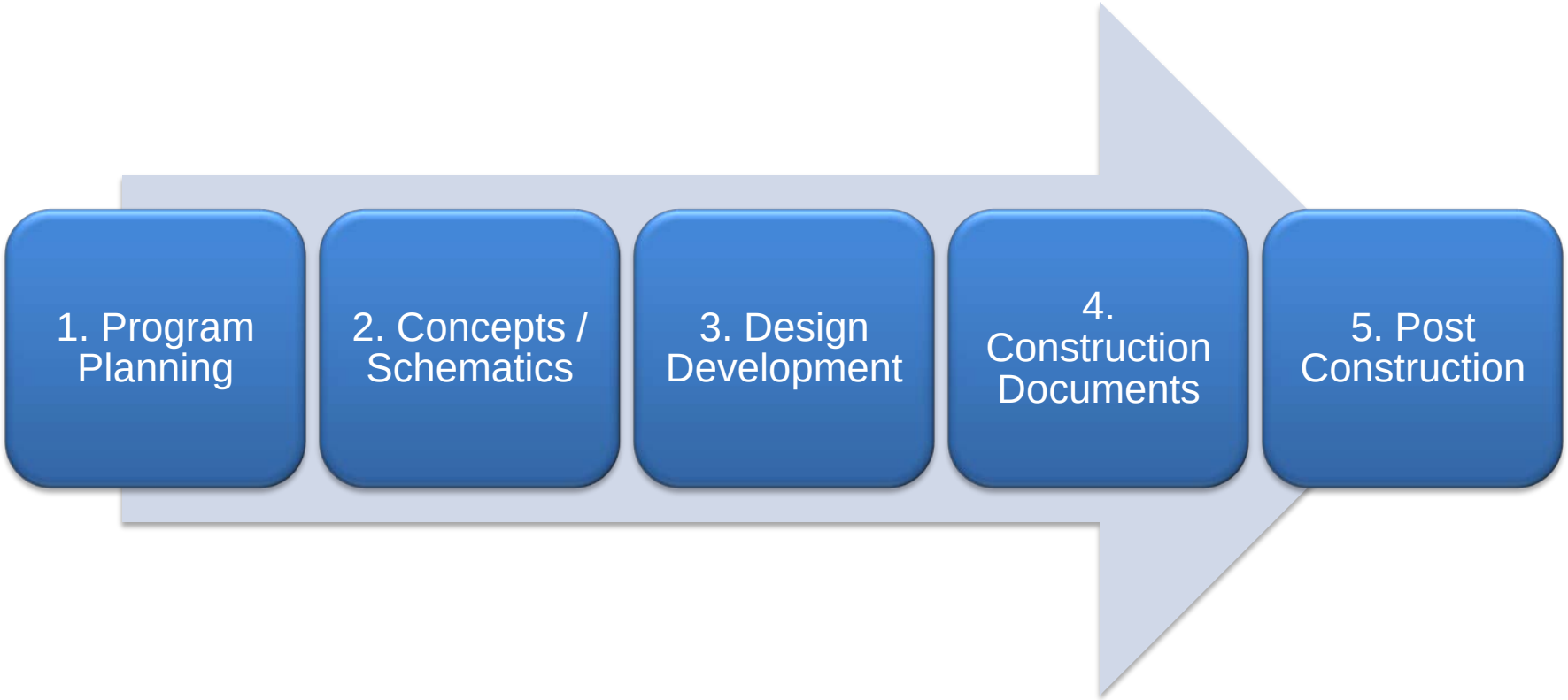
Energy Target Optimization Process

Energy Target Optimization Process



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Energy Target Optimization Process

Program Planning

Program Planning Methods Used to Set Design Directives:

- A Fixed National/Regional Mandate – "One Program Fits All"
  - Intended more to Instill *Energy Consciousness*, not Predict Energy Use
  - Interior Parking Area, Special Space Loads, Can Impact Attainment
- Modeled/Set by Individual Programming Studies
  - Intended to Predict Actual Energy Use
  - Dependent on Assumption Accuracy
- Benchmarked to Similar Courthouses (Data Bases Include: Regional, CBECS, 'Energy Star,' or GSA's Courthouse Inventory)
  - Realistic Expectations are Assured, but
  - Goal Attainment Models still Subject to Assumption Accuracy

1. Program Planning | 2. Concepts / Schematics | 3. Design Development | 4. Construction Documents | 5. Post Construction

Energy Target Optimization Process

Concepts / Schematics

The Following Early Design Decisions Impact Energy Use:

- Consider Multiple Concepts, Massing Strategies
- Configuration/Location of HVAC Components for Zone Control
- Consider Centralized and Decentralized Plant Equipment
- Basic Fenestration Strategies: Quantities, Orientations, Types (U-Factors), Shading Concepts, Security Needs (e.g. OA Intake locations)
- Consider Day-Lighting Effectiveness
- Rotate Building within Site Constraints

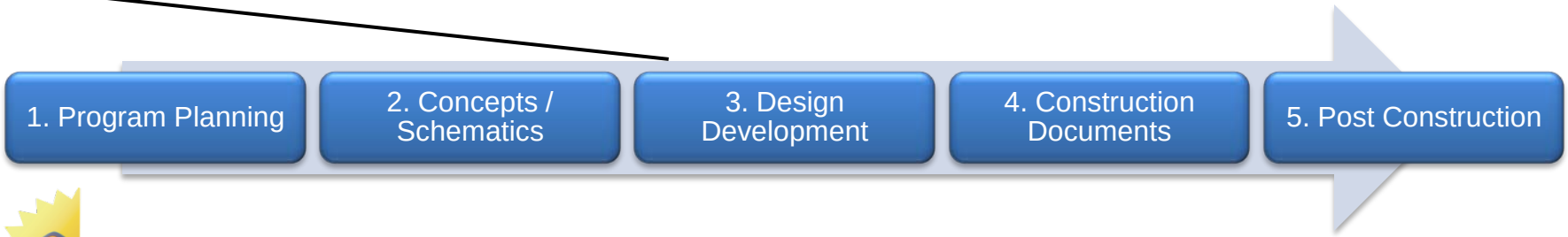
1. Program Planning
2. Concepts / Schematics
3. Design Development
4. Construction Documents
5. Post Construction

Energy Target Optimization Process

Design Development

During this Phase, Extensive Modeling and Analysis Serves to Select Assemblies/Systems:

- Envelope Features (Walls and Roofing)
- Glazing Types, Quantities *(Conductance, Reflectance, Emissivity, etc.)*
- Air-Side HVAC Systems (e.g. VAV system types, Ventilation & Pressurization Balance, Renewable Energy Technologies, and Economizer Use, etc.)
- Consider Primary and Secondary Pumping Control
- Zones Must Be Set for Varying Space Type Loads and Off-Hour Operations



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Energy Target Optimization Process

Construction Documents

Update Energy Models Considering Latest Design - Make the Design Match the Model

- Revise Operating Schedules (Consider Changes +/- in Hours)
- Optimize Pumping System Reduce Friction Losses, Ensure VFD
- Optimize the Air Side, Reduce Pressure Losses
- Verify Free Cooling Modes, and/or Use of Heat Exchangers
- Optimize Chiller, Boiler Efficiencies and Load Balance
- Update Actual Lighting Loads; Consider Placements of Occupancy Sensors and Natural Lighting Control Locations
- Verify that BAS Features & Metering Support Modeled Systems
- Require Commissioning Services

1. Program Planning
2. Concepts / Schematics
3. Design Development
4. Construction Documents
5. Post Construction

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Energy Target Optimization Process

Post Construction

Measure and Validate all the Energy Consumption of Systems and Subsystems

- Re-Commission all Equipment, Systems, and Controls
- Re-Commission Building Envelope (Thermography)
- Identify Current Operating Conditions
- Model and Profile Annual Energy Consumption of all Equipment and Systems, Compare with Design Assumptions
- Modify Model Until the Projected and Actual Consumption are Within 10%, then Model Improvement Options and Establish Cost Effectiveness

1. Program Planning
2. Concepts / Schematics
3. Design Development
4. Construction Documents
5. Post Construction

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Courthouse Energy Modeling Inputs

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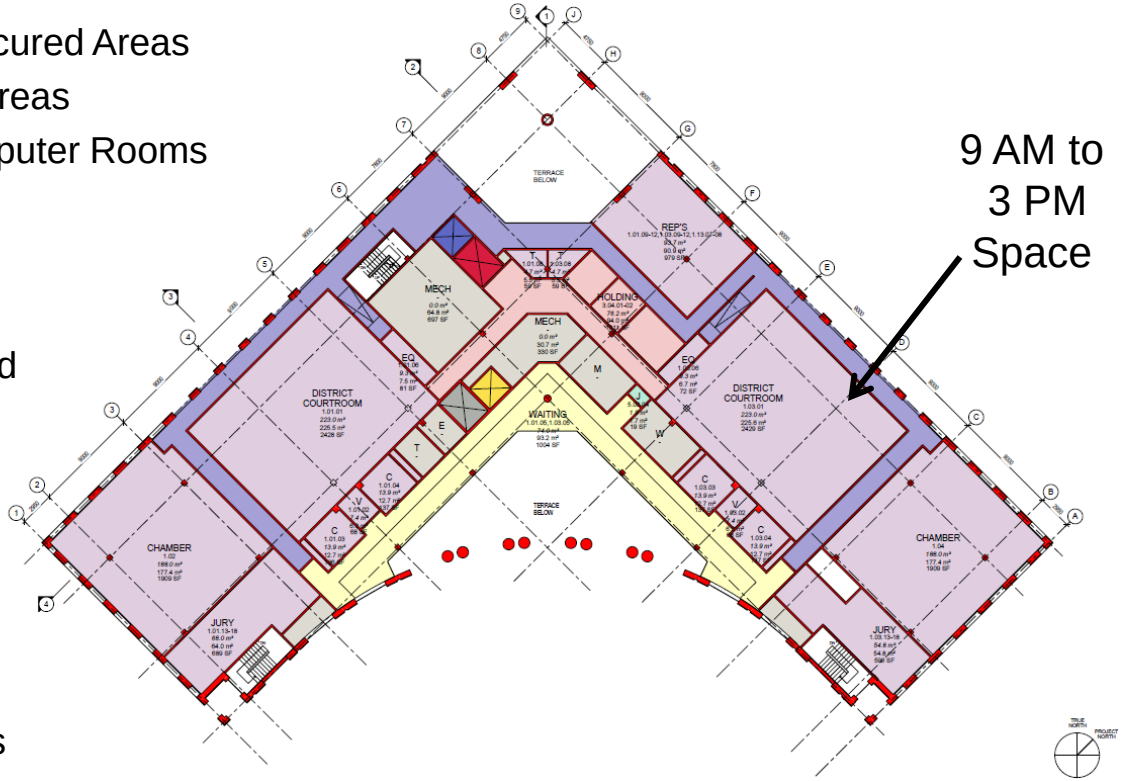
Courthouse Energy Modeling Inputs

- Generally in Courthouses, Operating Hours Vary Significantly and have High on Impact Energy Consumption. These Operating Hours Should be Correctly Programmed. Spaces Include…
  - 24/7 spaces:
    - Marshall and High Secured Areas
    - Jail Cells or Holding Areas
    - Data Centers Or Computer Rooms
    - Telephone Closets
  - 9 AM to 3 PM spaces:
    - Courtrooms
    - Judge's Chambers and other support areas
  - 8 AM to 6 PM spaces:
    - Offices
    - Libraries
    - Fitness rooms
    - Office of Clerks
    - Miscellaneous Spaces



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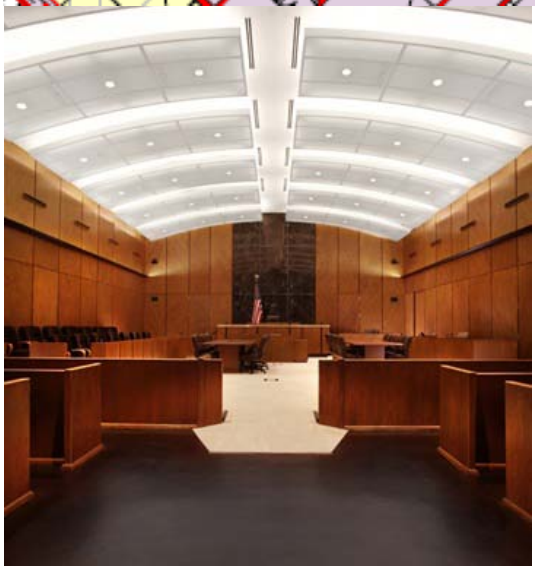
Courthouse Loads

- Courtroom Interior Space Loads Vary Considerably and Systems Must Be Selected to Mitigate These Loads
- Example of Loads for Various Spaces:
  - 24/7 Spaces:
    - High Plug Loads in Security and Marshall Areas
    - Computer Rooms Operate 24 Hours and Loads Vary from 50 Watts to 100 Watts Per Square Foot
    - HVAC 24/7 which includes AHUs, Dedicated Chiller, System Operate Boiler and Pumps
    - Lighting Vary from .9 to 1.4 Watts Per Square Foot During the Day
    - Telephone Closets with Considerable Electrical Loads and Operate 24/7
    - Input the Loads Properly with its Respective Zone Along with its Variance During the Day

Courthouse Loads

- 9 AM to 3 PM Spaces:
  - High Occupancy – Concentrated People Loads in the Back of the Courtroom - Less in the Front
  - Light Loads: 0.9 to 1.3 W/ft^2
  - Concentrated Areas for Plug Loads in the Judge's Area, Jury Box, and AV Equip Location
  - No Plug Loads in the Back Areas
- 8 AM to 6 PM Spaces:
  - Plug Loads include Laptops, Computers, Xerox, Printers
  - Libraries: Control of Humidity (Reheat, Density or Occupied)
  - Fitness Center
    - Heavy Latent Loads
    - Vary the Loads
    - People Loads Max. during Lunch, Morning, and Evening Hours



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Courthouse Loads

- Appendix A of PBS P-100

Table A6-2: BUILDING INTERNAL LOAD CRITERIA (INPUT)

Internal Loads			
Lighting	Lighting power densities	Interior	Comply with Table 6.1
	LED and emergency lighting	0.8 W per sign	
Equipment load	Receptacle load		Comply with Table 6.2
Occupancy	Occupancy	Area	Persons/1000Sft
		Office	5
		Reception	30
		Main entry lobbies	10
		Auditorium	150
		Courtrooms	70
		Libraries	10
		Lobbies	150
		Coffee stations	20
		Conference/Meeting	50
		Cafeteria	100
		Computer lab	25
	Sensible load per person	245 Btu/hr	ASHRAE Handbook - Fundamentals
	Latent load per person	205 Btu/hr	ASHRAE Handbook - Fundamentals

Table A6-3: BUILDING MISCELLANEOUS LOADS CRITERIA (INPUT)

Miscellaneous Loads		
Elevator	passenger	20hp
	freight	40hp
Exterior lighting		Comply with Table 6.1a in P100
Daylighting		
Daylighting	Area to be daylit	25% of floor area, using photo sensors

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Energy Targets – New Buildings

Energy Targets - New Buildings

Example: New US Courthouse – Jefferson City, MO

- Concepts/Schematic Phase:
  - Project the Energy Consumption and Targets at This Level and Optimize It, Utilize the Same Program from Start to Finish
  - Utilize Available Functional Data and Advice the Architect of Impact of Various Configurations, such as Square, Rectangle, and Octagon
  - Assume an HVAC System at this Concept-level
  - Optimize Envelope for Various Glazing Options
  - Utilize Renewable Energy if Possible such as Photovoltaic or GSHP
  - Utilize Orientation – Rotate the Building
  - Landscape -Trees at least 20 Feet Above Grade on East and West Sides

Energy Targets - New Buildings

Example: New US Courthouse – Jefferson City, MO

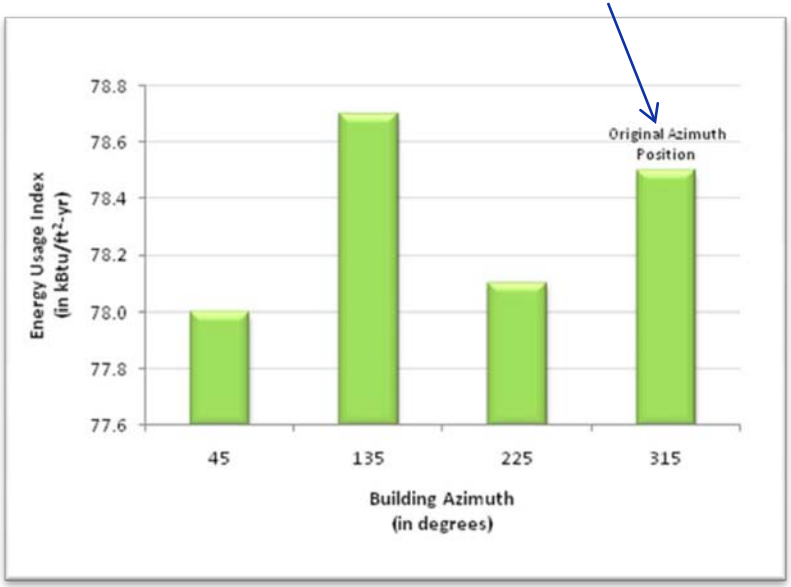
- Concepts/Schematic Phase:
  - Several Alternatives Considered to Reduce the Energy Consumption Impact:
    1. ASHRAE 90.1-2007 for Floors and Doors, R-30 for Walls and R-49 for Roof
    2. Windows Recessed [Setback of 0.3 m (1 ft)] or Overhang
    3. Reduce Glass Area (20% on East and West Façades)
    4. Added Additional Thermal Mass on all the Floors
    5. Composite of the Alternatives 1 through 4

Energy Targets - New Buildings

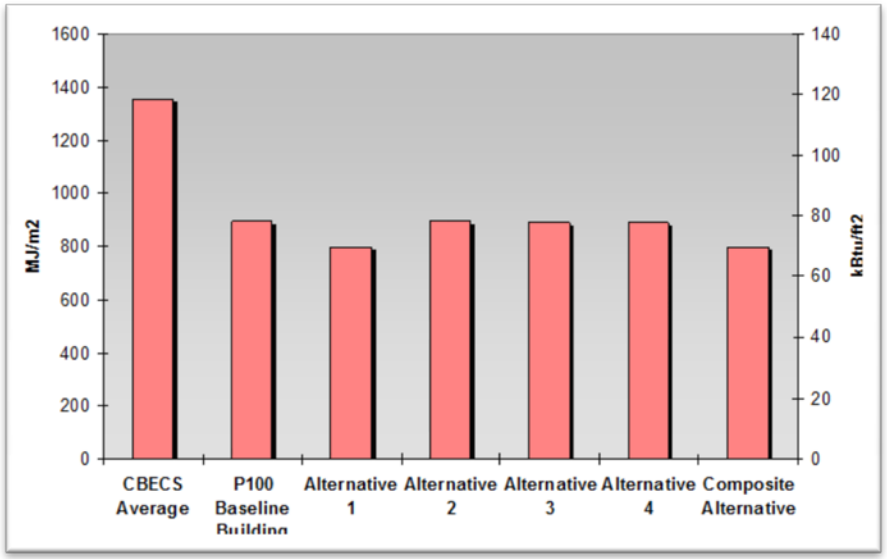
Example: New US Courthouse – Jefferson City, MO

- Concepts/Schematic Phase:
  - Results Below Indicate the Savings and Energy Consumption for Different Alternatives

Main Entrance: South



Impact of Building Orientation



Annual Energy Consumption of the Different Alternatives

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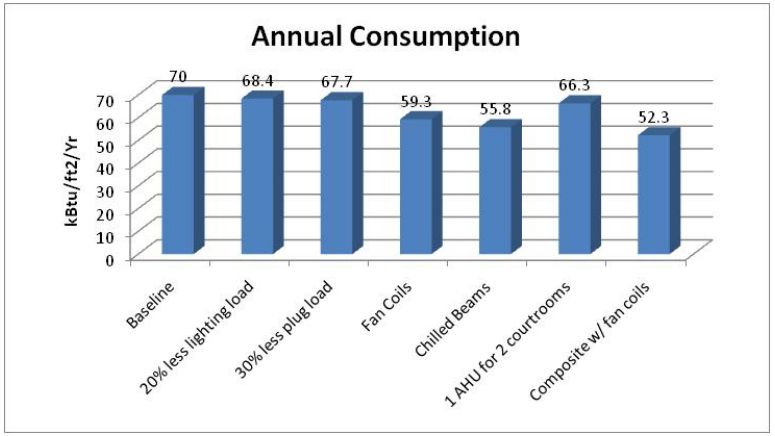
Energy Targets - New Buildings

Example: New US Courthouse – Jefferson City, MO

- Design Development Phase:
  - Several System Alternatives are Considered and Optimized:
    - Zoning Property for Proper System Selection
    - System such as VAV, Fan Coil Units, Chilled Beams, Single AHU, Multi AHU on Every Floor
      - One AHU for Two Courtrooms
      - Separate Unit for Each Function
    - Electrical
      - Lighting 0.9 – 1.2 Watt
      - Plug Loads, Input



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Energy Targets - New Buildings

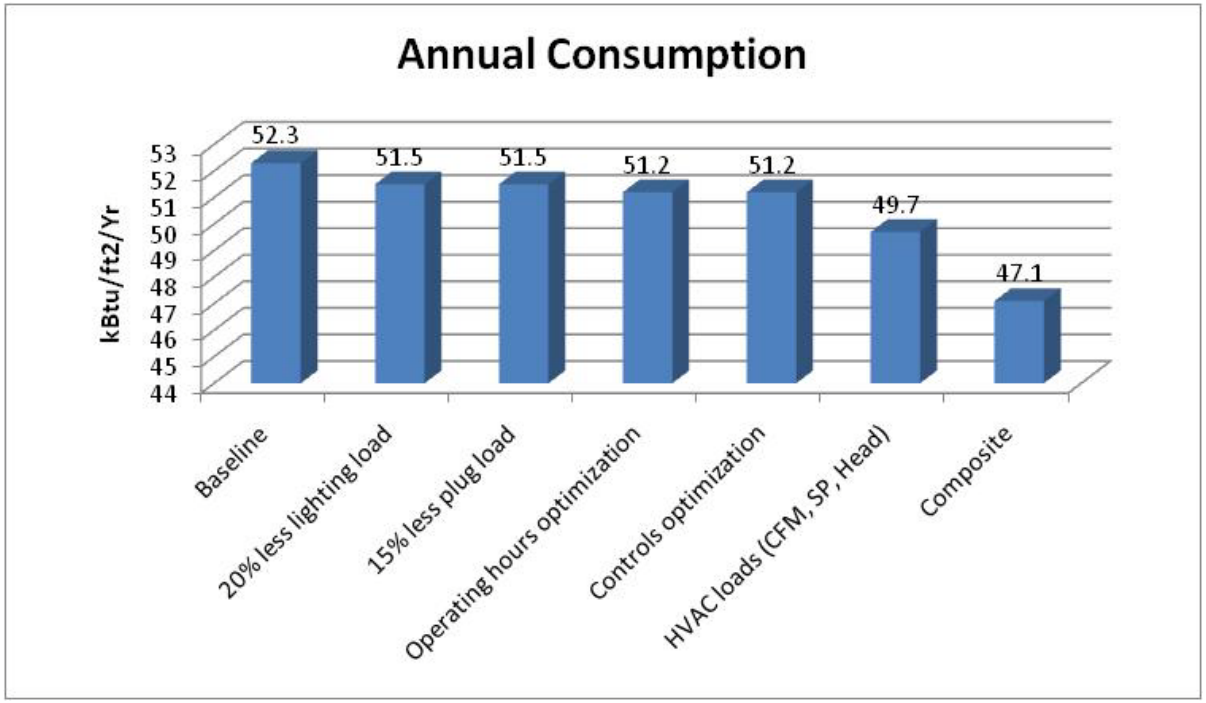
Example: New US Courthouse – Jefferson City, MO

- Construction Documents: Optimize the Lighting, HVAC, Pumping, Elevator and Other Systems
  - Calculate the Energy Targets for Actual System and Equipment Shown
  - Actual HVAC Loads (CFM, SP, Head, etc.)
  - Actual Operating Hours Suitable for Courthouses 24/7, 9 AM to 3 PM, and 8 AM to 6 PM
  - Actual Lighting, LED Lights, Daylighting
    - Calculate wattage from the Drawings
  - Actual Plug Loads: Laptops, Computers, Xerox, Printers

Energy Targets - New Buildings

Example: New US Courthouse – Jefferson City, MO

- Construction Documents – Energy Consumption after Optimization



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Energy Targets
Existing Buildings

Energy Targets
Existing Buildings

Example: John McCormack Post Office/Courthouse
Boston, MA
Construction Document Phase

- Complete Modernization
- Collect all the Existing Utility Data and Calculate the Existing Energy Consumption Per Square Footage Estimated to be 85 kBtu/ft^2/yr
- Model the Building to Comply with Codes (PBS P-100, ASHRAE 90.1)
- Energy Consumption Reduced to 61 kBtu/ft^2/yr
- Analyzed 9 EEMs with the Objective to Further Reducing Building Energy Consumption from 61,000 Btu/ft^2/yr to 43,000 Btu/ft^2/yr

Energy Targets
Existing Buildings

Example: John McCormack Post Office/Courthouse
Boston, MA
Construction Document Phase

- Optimize the Lighting, HVAC, Pumping, and Other Systems
- Actual HVAC Loads (CFM, SP, Head, etc.)
- Actual Operating Hours Suitable for Courthouses 24/7, 9 AM to 3 PM, and 8 AM to 6 PM
- Actual Lighting, LED Lights, Daylighting to be Calculated from the Drawings
  - Actual Operating Schedules to be Used for Modeling
- Actual Plug Loads: Calculated Laptops, Computers, Xerox, Printers

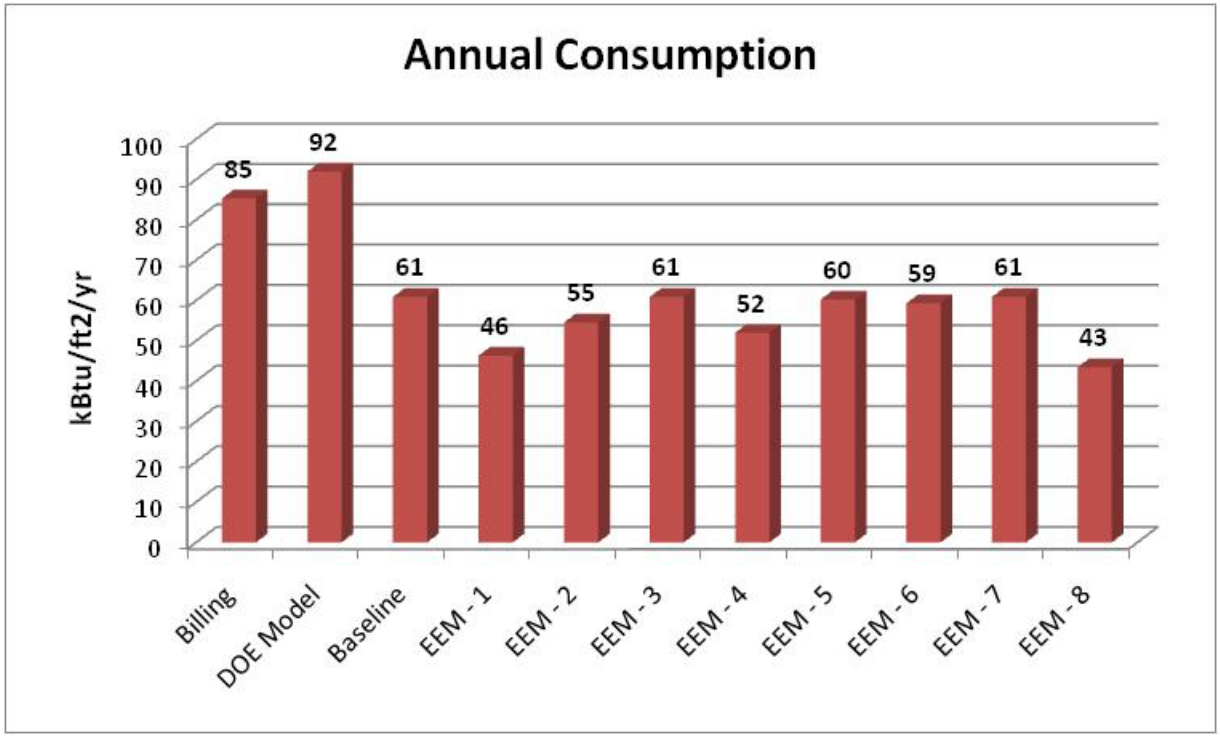
Energy Targets
Existing Buildings

Example: John McCormack Post Office/Courthouse
Boston, MA
Construction Document Phase

- Energy Efficiency Measures Analyzed:
  1. Absorption Chillers, Water-cooled Centrifugal Chillers, Multi-Task Chillers
  2. Four High-efficiency Boilers in lieu of Central Steam
  3. 100% of the Lights on Daylighting Controls
  4. VAV Systems in lieu of Multi-zone Units
  5. Replace Domestic Water Heat Exchanger with New Ground Source Heat Pump
  6. New VSDs on the Chiller Pumps
  7. Replace T8 Lighting with new T5 Lighting in Areas with High Ceiling
  8. Composite of All EEMs

Energy Targets
Existing Buildings

Example: John McCormack Post Office/Courthouse – Boston, MA



Calculated Annual Energy Consumption

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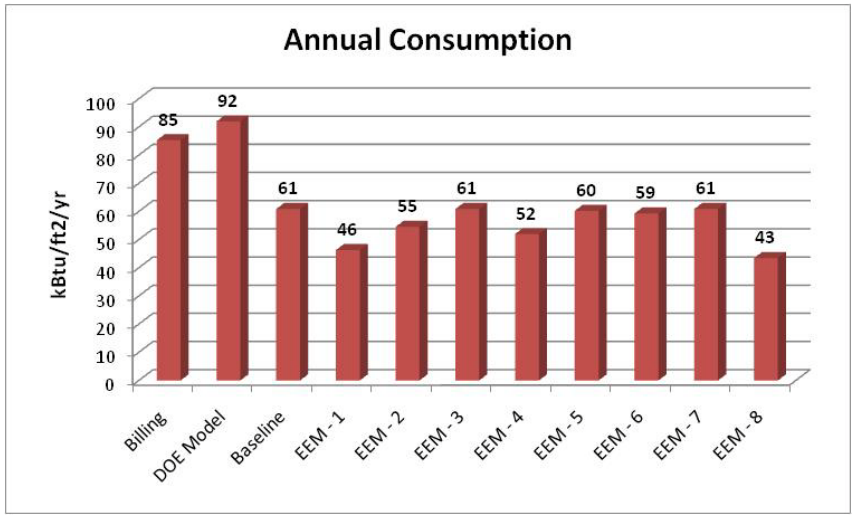
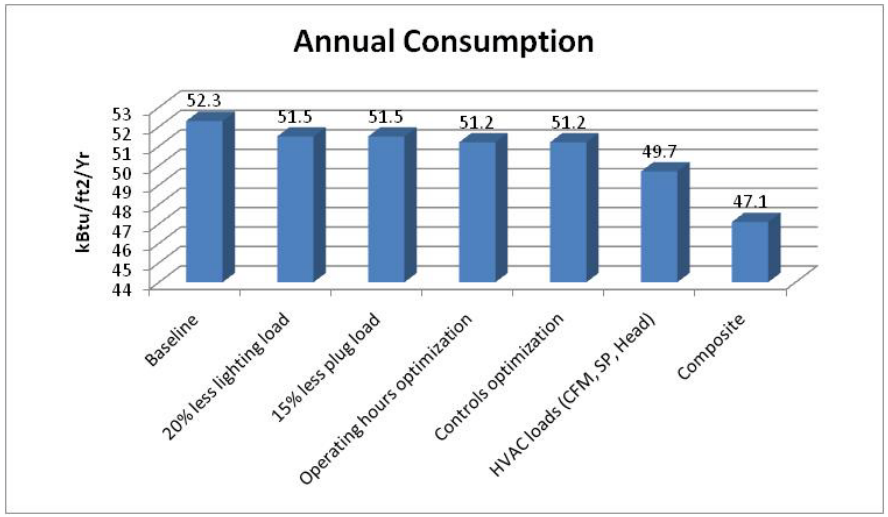
Conclusion

- By Introducing the Optimization Process from Construction Documents to Post Occupancy, Energy Consumption can be Reduced 10 - 50%



Existing Buildings



New Buildings

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Conclusion

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