



# Comparative Analysis: EnergyPlus and Facility Energy Decision System

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# Outline

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- 1) General Overview of FEDS and EnergyPlus
- 2) Case Studies
- 3) Comparison of Results
- 4) Conclusions

# 1.1a FEDS – General Overview

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## Purpose and Applications

- Facility Energy Decision System (FEDS) was developed for the Department of Energy (DOE) by the Pacific Northwest National Laboratory
- Designed to rapidly determine Energy Consumption Characteristics and present suggestions for possible retrofit opportunities
- The key attraction of FEDS is its ability to model individual buildings as well as multiple building sets which allows for the rapid examination of multiple structures.

# 1.1b FEDS – General Overview

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## Advantages/Disadvantages

- Possess both Minimum and Maximum input detail levels
  - Rapid building simulations based on minimal building information
- Maximum input level allows for greater manipulation of the model
- Contains a large database of energy-system configurations

# 1.1c FEDS – General Overview

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## Advantages/Disadvantages

- Definition of Building Parameters
  - Building size
  - Fuel types and efficiencies of Heating and cooling systems
  - Lighting equipment type and density
  - Simple Building Envelop Characteristics: U-Values
  - Ventilation Statistics: Fan Pressures, Infiltration rates, Fan Efficiency Etcetera

# 1.1d FEDS – General Overview

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## Advantages/Disadvantages

- Whether using the minimum or maximum level of input detail, the same type of output results are produced
- Energy Consumption Breakdown is limited to Annual Results
  - Heating
  - Cooling
  - Lighting
  - Ventilation
  - Miscellaneous Equipment
  - Service Hot Water

# 1.1e FEDS – General Overview

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## Advantages/Disadvantages

- Building parameter definition is limited purely to the inputs available
- Testing of retrofit opportunities is restricted

# 1.2a EnergyPlus – General Overview

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## Purpose and Applications

- EnergyPlus has been developed for the U.S. Department of Energy
- EnergyPlus is an energy analysis and thermal load simulation tool
- It takes in building information and performs calculations to determine a buildings heating and cooling loads, as well as the energy consumption of all primary and secondary systems.

# 1.2b EnergyPlus – General Overview

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## Advantages/Disadvantages

- The input of data into EnergyPlus is complex
- Details about Geometry, wall construction, windows positioning, and material properties can significantly effect the results
- Building envelope must be defined layer by layer
- Geometric Coordinates of building geometry must be assumed or known
- HVAC system details are also complex but can be simplified by using COMPACT HVAC description capabilities

# 1.2c EnergyPlus – General Overview

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## Advantages/Disadvantages

- The inputs required to successfully run EnergyPlus include
  - Geometric Data
  - Envelope material Descriptions
  - HVAC System Details
  - System Scheduling
  - Numerous Others

# 1.2d EnergyPlus – General Overview

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## Advantages/Disadvantages

- A large variety of output results are available
- Detailed metering reports can break down energy consumption.
- Comprehensive information on gains and losses
- Ability to define specific weather characteristics



## 2. Case Studies

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- To analyze the adequacy of each program for simulating energy consumption, nine office buildings with energy consumption data were identified
- Nine buildings were built between 1931 and 1986 and modeled using FEDS and EnergyPlus
- Buildings represent the construction practices at the time of construction providing a broad spectrum of office buildings

## 2.1a Available Input data

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Each building was defined according to a set of parameters broken down into the following Categories:

- Building Envelope
- Distribution Systems
- Electrical Systems
- Natural Gas/Fuel Oil Systems
- Service Hot Water

## 2.1b Available Input data

	Building #1	Building #2	Building #3
<b>General Description</b>			
<b>Vintage</b>	1931 – 1933	1958	1958 -1960
<b>No. Floors</b>	5 + 2 Below ground	4 + 2 Below Ground	12 + 2 Below Ground
<b>Area, Volume</b>	59,185(m <sup>2</sup> ),207,148(m <sup>3</sup> )	12,184(m <sup>2</sup> ), 42,644(m <sup>3</sup> )	36,700(m <sup>2</sup> ),128,450(m <sup>3</sup> )
<b>Envelope</b>			
<b>Wall Type</b> <b>U-Value</b>	Brick on Granite 0.55	Brick/Granite Paneling 0.342	Concrete Block/Granite 0.61
<b>Roof Type</b> <b>U-Value</b>	Built-up roofing on Concrete slab 0.47	Brick/Granite Paneling 0.346	Built-up roofing Concrete slab 0.55
<b>Window Type</b> <b>U-Value</b> <b>% to Wall</b>	Double Glazed 3.2 40*	Double glazed 2.89 20	Double glazed 3.57 50*
<b>Distribution System Type</b>			
<b>Description</b>	Combination AHU and Pumps	Combination AHU and Pumps	Combination AHU and Pumps

# 2.1c Available Input data

	Building #1	Building #2	Building #3
<b>Electrical Systems</b>			
<b>Lighting (W/m<sup>2</sup>)</b>	8.0 ***	11.5*	5.0***
<b>Equipment Loads (W/m<sup>2</sup>)</b>	40**	20**	25**
<b>Chiller Type</b>	Chilled Water	Direct Expansion	Chilled Water
<b>Capacity</b>	3830kW	50 Tons	3x1054kW
<b>COP</b>	1.8*	1.8*	1.8*
<b>Secondary Fuel Systems</b>			
<b>Boiler Fuel</b>	Natural Gas	Natural Gas	Natural gas
<b>Capacity</b>	Total 5690kW	2(150HP)	3x2000kW
<b>Type</b>	Hot Water	Hot Water	Steam
<b>Efficiency</b>	0.65*	66%	0.85
<b>Miscellaneous</b>			
<b>SHW Fuel</b>	Electricity	Natural Gas	Electricity
<b>System Schedule</b>	Ventilation system on constantly	Setback 18 C, Off Eve. and Weekends	No setback, Off Eve. and Weekends



# 2.1d Available Input data

	Building #4	Building #5	Building #6
<b>General Description</b>			
<b>Vintage</b>	1963 and 1970	1970	1974
<b>No. Floors</b>	3 and 5 + 1 B-G	12 + 1 Below Ground	12 and 3 + 2 B-G
<b>Area, Volume</b>	11760(m <sup>2</sup> ), 41160(m <sup>3</sup> )	11,185(m <sup>2</sup> ), 39,148(m <sup>3</sup> )	24,600(m <sup>2</sup> ), 86,100(m <sup>3</sup> )
<b>Envelope</b>			
<b>Wall Type</b> <b>U-Value</b>	Brick on Concrete Block 0.48	Concrete on Concrete 0.278	Concrete on Concrete 0.43
<b>Roof Type</b> <b>U-Value</b>	Built-up roofing Concrete slab 0.289	Elastomer with granite Flagstones 0.356	Built-up roofing Concrete slab 0.289
<b>Window</b> <b>U-Value</b> <b>To Wall %</b>	Double Glazed 3.44 24 and 27	Double Glazed 3.333 40*	Double glazed 2.78 24
<b>Distribution System Type</b>			
<b>Description</b>	Air handling unit	Combination AHU and Pumps	Combination AHU and Pumps

# 2.1e Available Input data

	Building #4	Building #5	Building #6
<b>Electrical Systems</b>			
Lighting (W/m <sup>2</sup> )	16*	8.44***	17.5***
Equip. Loads (W/m <sup>2</sup> )	10**	20**	55**
Chiller Type	Centrifugal	Chiller Water	Absorption Cooler
Capacity	965kW	284 Tons	2263kW
COP	1.8*	1.8*	1.8*
<b>Secondary Fuel Systems</b>			
Boiler Fuel	Fuel Oil	Natural Gas	Natural gas
Capacity	980kW	100BHP	2x2451kW
Type	Steam	Hot Water	Steam
Efficiency	0.60	0.70	0.65
<b>Miscellaneous</b>			
SHW Fuel	Electricity	Electricity	Electricity
System Schedule	No setback, Off Eve. and Weekends	No Setback, Off Eve. and Weekends	No setback, Off Eve. and Weekends



# 2.1f Available Input data

	Building #7	Building #8	Building #9
<b>General Description</b>			
<b>Vintage</b>	1976	1981	1985 - 1986
<b>No. Floors</b>	3	3	2
<b>Gross, Volume</b>	12,322(m <sup>2</sup> ), 43,127(m <sup>3</sup> )	19,510(m <sup>2</sup> ), 68,285(m <sup>3</sup> )	3,456(m <sup>2</sup> ), 12,096(m <sup>3</sup> )
<b>Envelope</b>			
<b>Wall Type</b> <b>U-Value</b>	Prefabricated Concrete 0.303	Brick on Concrete block 0.303	Anodized Aluminium 0.213
<b>Roof Type</b> <b>U-Value</b>	Membrane, w/asphalt and gravel 0.286	Concrete Flagstones on steel bridging 0.286	Membrane, w/asphalt and gravel 0.284
<b>Window Type</b> <b>U-Value</b> <b>% to Wall</b>	Double Glazed 3.45 17.7	Double Glazed 1.575 37.1	Double glazed 1.57 30
<b>Distribution System Type</b>			
<b>Description</b>	Combination AHU and Pumps	Combination AHU and Pumps	Radiant heating System and AHU

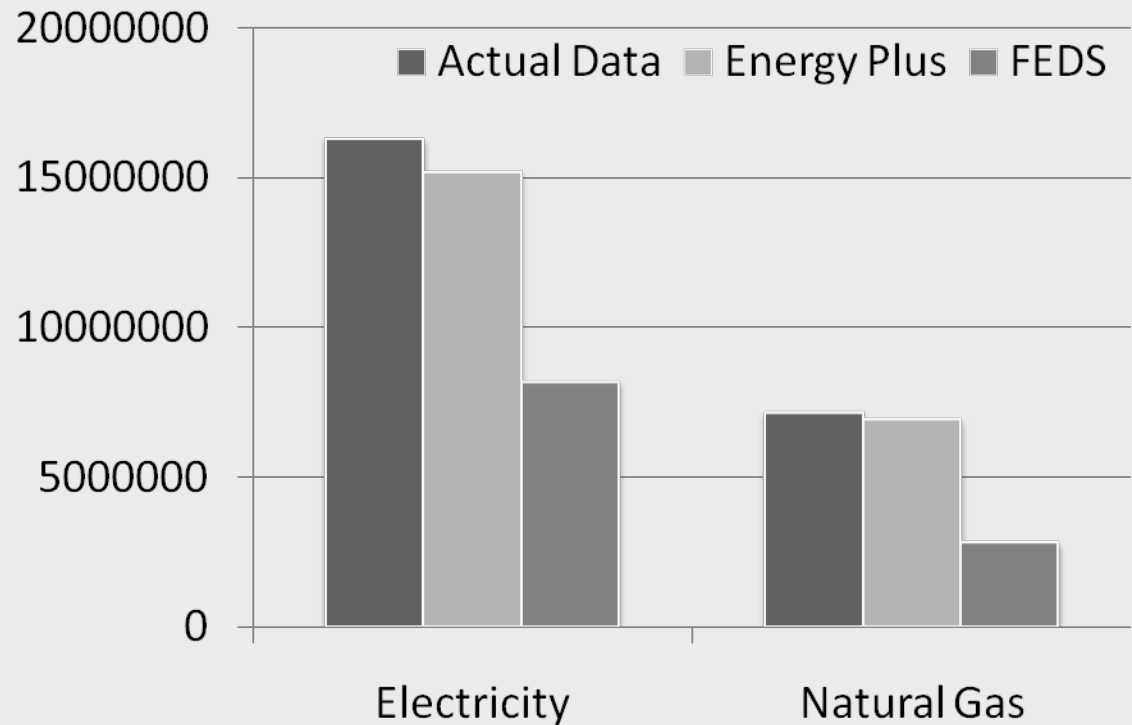
# 2.1g Available Input data

	Building #7	Building #8	Building #9
<b>Electrical Systems</b>			
Lighting (W/m2)	16.4***	10.92***	16.2***
Equipment Loads (W/m2)	20**	36**	10*
Chiller Type Capacity COP	Chiller Water 4x50Tons 1.8*	Centrifugal 430 Tons 1.8*	Direct Expansion 90 Tons 1.8*
<b>Secondary Fuel Systems</b>			
Boiler Fuel Capacity Type Efficiency	Fuel Oil 2x125BHP Hot Water 0.65*	Natural Gas 53 BHP Hot Water 0.60*	Electricity 246.5 kW Hot Water 0.95 *
<b>Miscellaneous</b>			
SHW Fuel	Electricity	Electricity	Electricity
System Schedule	Ventilation system on constantly	No setback, Off Eve. and Weekends	Setback 18 C, Off Eve. and Weekends



# 2.2a Modeling Results Using FEDS and EnergyPlus

Building #1	
Area (m2)	59,185
Wall U-Value (w/m2-C)	0.55
Roof U-Value (w/m2-C)	0.47
Window U-Value (w/m2-C)	3.2
Lighting Load	8.0
Equipment Load	40
Chiller COP	1.8
Boiler Efficiency	0.65

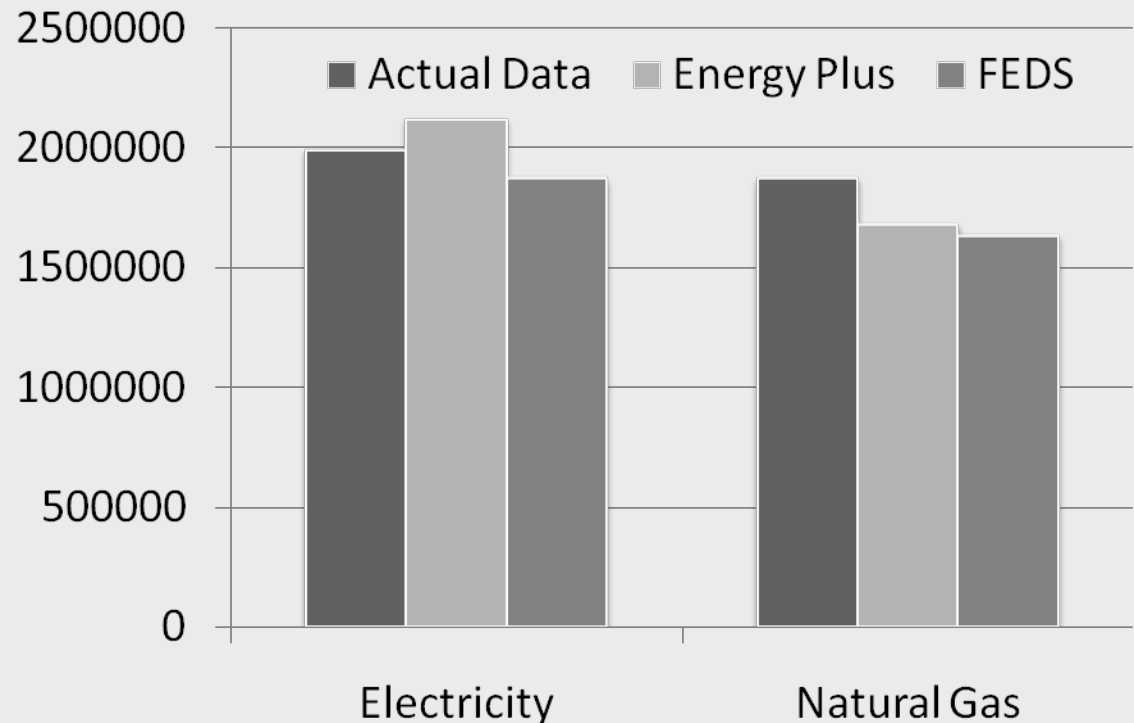


Percent Error	EnergyPlus	FEDS
Electricity	-6.9%	-49.8%
Natural Gas	-3.2%	-61.0%



## 2.2b Modeling Results Using FEDS and EnergyPlus

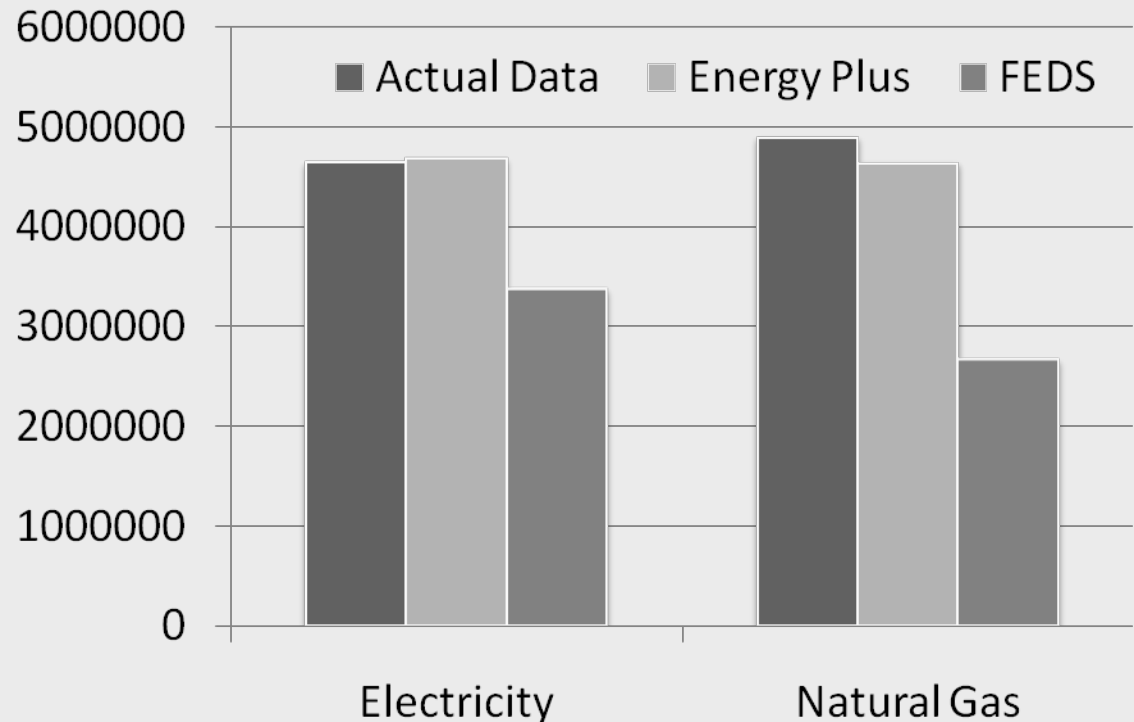
Building #2	
Area (m2)	12,184
Wall U-Value (w/m2-C)	0.342
Roof U-Value (w/m2-C)	0.346
Window U-Value (w/m2-C)	2.89
Lighting Load	9.0
Equipment Load	20
Chiller COP	1.8
Boiler Efficiency	0.66



Percent Error	EnergyPlus	FEDS
Electricity	6.5%	-6.0%
Natural Gas	-10.3%	-11.8%

## 2.2c Modeling Results Using FEDS and EnergyPlus

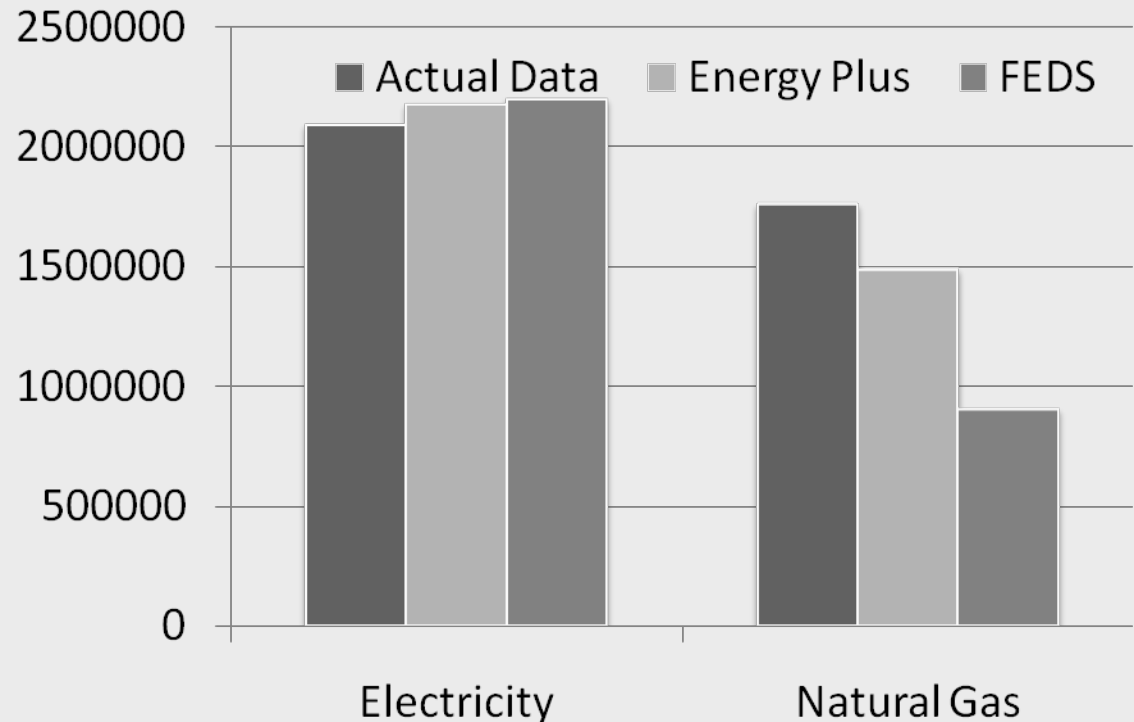
Building #3	
Area (m2)	36,700
Wall U-Value (w/m2-C)	0.61
Roof U-Value (w/m2-C)	0.55
Window U-Value (w/m2-C)	3.57
Lighting Load	5.0
Equipment Load	25
Chiller COP	1.8
Boiler Efficiency	0.85



Percent Error	EnergyPlus	FEDS
Electricity	0.9%	-27.3%
Natural Gas	-5.2%	-45.6%

## 2.2d Modeling Results Using FEDS and EnergyPlus

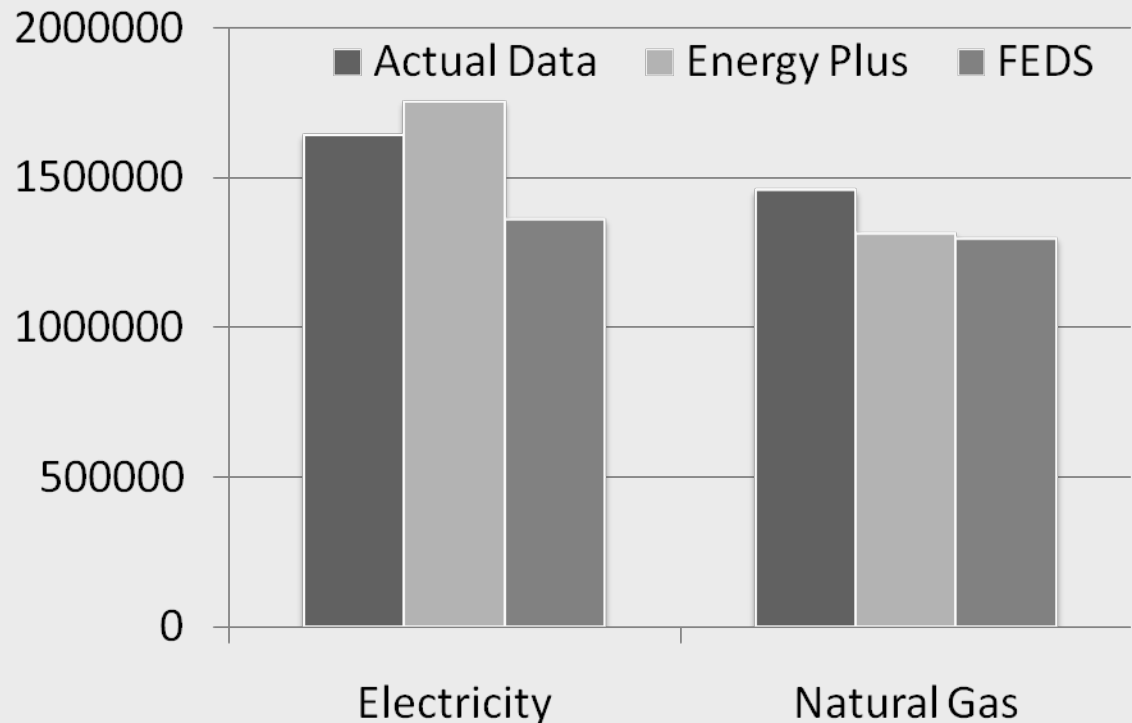
Building #4	
Area (m2)	11,760
Wall U-Value (w/m2-C)	0.48
Roof U-Value (w/m2-C)	0.289
Window U-Value (w/m2-C)	2.89
Lighting Load	3.44
Equipment Load	10
Chiller COP	1.8
Boiler Efficiency	0.60



Percent Error	Energy Plus	FEDS
Electricity	4%	5%
Natural Gas	-15%	-49%

## 2.2e Modeling Results Using FEDS and EnergyPlus

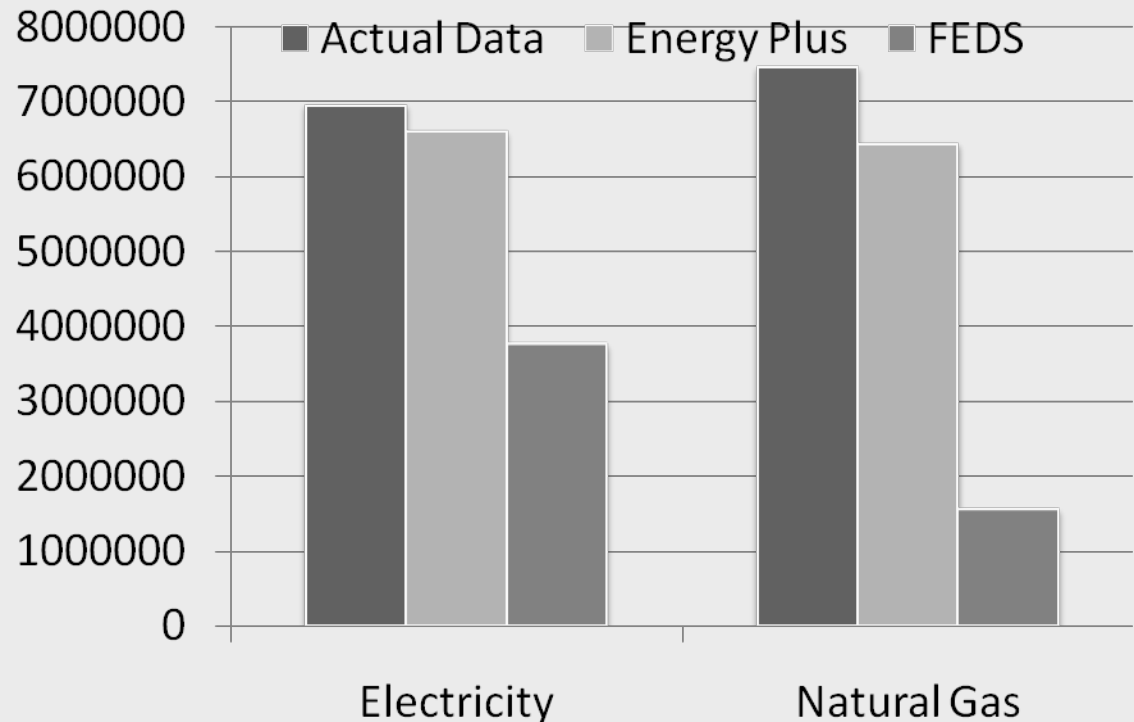
Building #5	
Area (m <sup>2</sup> )	11,185
Wall U-Value (w/m <sup>2</sup> -C)	0.278
Roof U-Value (w/m <sup>2</sup> -C)	0.356
Window U-Value (w/m <sup>2</sup> -C)	3.33
Lighting Load	8.44
Equipment Load	20
Chiller COP	1.8
Boiler Efficiency	0.70



Percent Error	EnergyPlus	FEDS
Electricity	6.8%	-17.1%
Natural Gas	-10.0%	-10.9%

# 2.2f Modeling Results Using FEDS and EnergyPlus

Building #6	
Area (m2)	24,600
Wall U-Value (w/m2-C)	0.43
Roof U-Value (w/m2-C)	0.289
Window U-Value (w/m2-C)	2.78
Lighting Load	17.5
Equipment Load	55
Chiller COP	1.8
Boiler Efficiency	0.65

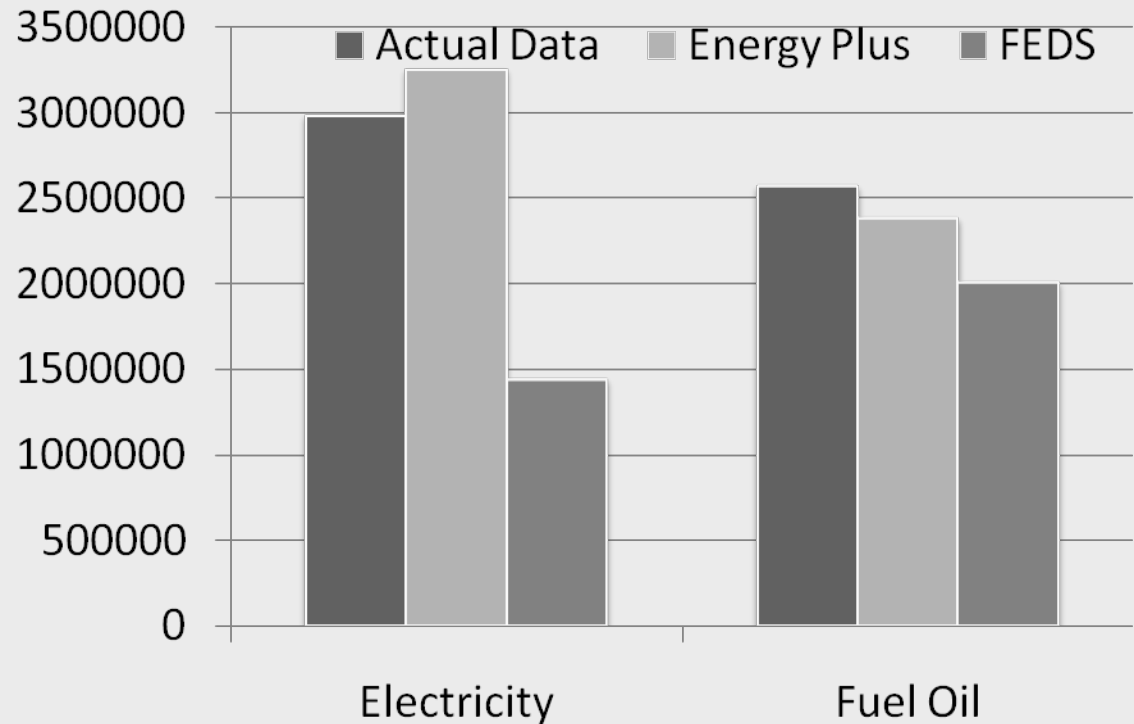


Percent Error	Energy Plus	FEDS
Electricity	-5%	-46%
Natural Gas	-14%	79%



# 2.2g Modeling Results Using FEDS and EnergyPlus

Building #7	
Area (m2)	12,322
Wall U-Value (w/m2-C)	0.303
Roof U-Value (w/m2-C)	0.286
Window U-Value (w/m2-C)	3.45
Lighting Load	16.4
Equipment Load	20
Chiller COP	1.8
Boiler Efficiency	0.65

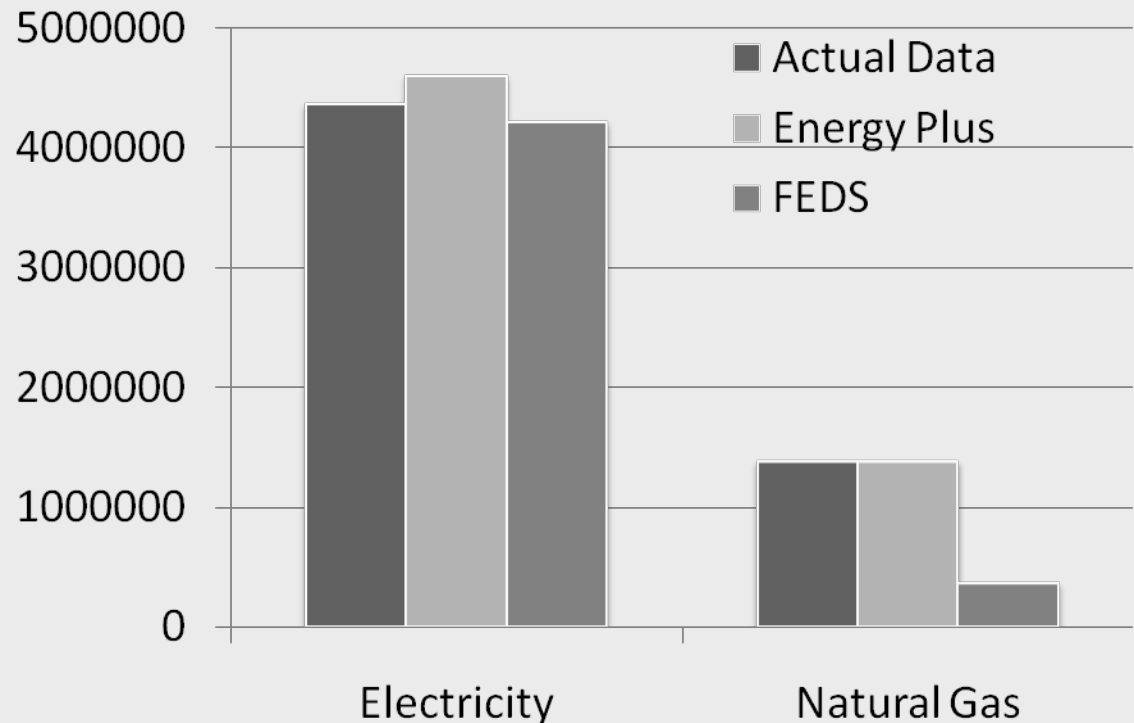


Percent Error	EnergyPlus	FEDS
Electricity	9.04%	-51.7%
Natural Gas	-7.24%	-21.8%



# 2.2h Modeling Results Using FEDS and EnergyPlus

Building #8	
Area (m2)	19,510
Wall U-Value (w/m2-C)	0.303
Roof U-Value (w/m2-C)	0.286
Window U-Value (w/m2-C)	1.575
Lighting Load	10.92
Equipment Load	36
Chiller COP	1.8
Boiler Efficiency	0.60

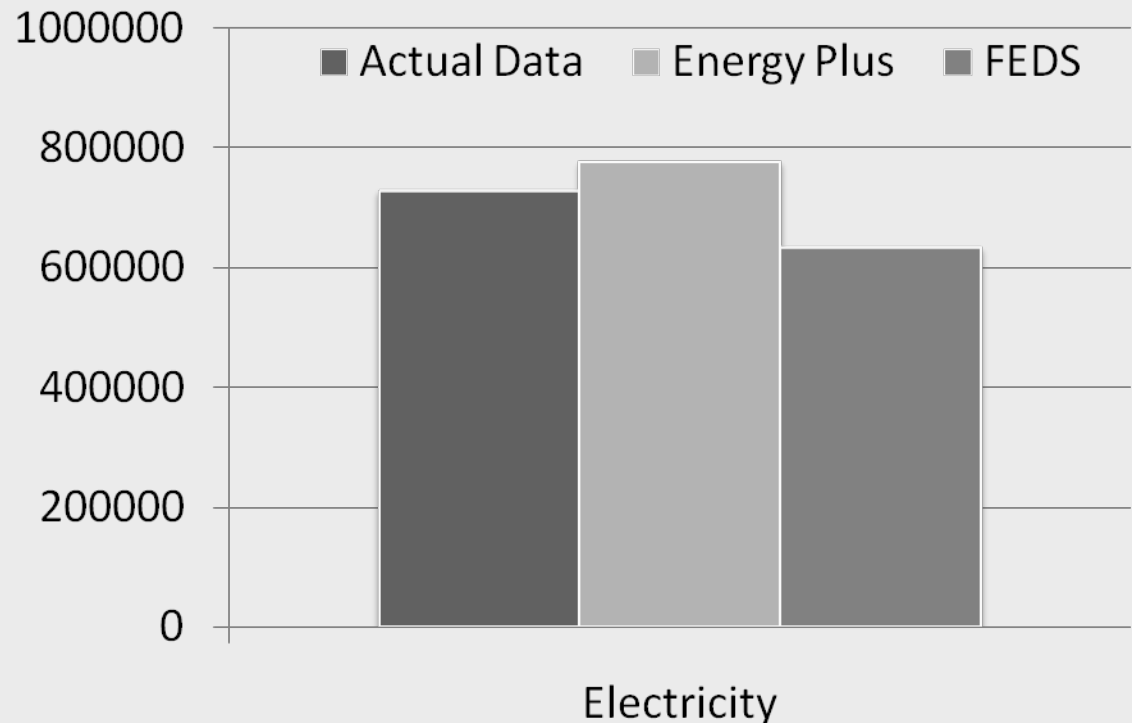


Percent Error	EnergyPlus	FEDS
Electricity	5.3%	-3.5%
Natural Gas	0.0%	-73.7%



## 2.2i Modeling Results Using FEDS and EnergyPlus

Building #9	
Area (m <sup>2</sup> )	3,456
Wall U-Value (w/m <sup>2</sup> -C)	0.213
Roof U-Value (w/m <sup>2</sup> -C)	0.284
Window U-Value (w/m <sup>2</sup> -C)	1.57
Lighting Load	16.2
Equipment Load	10
Chiller COP	1.8
Boiler Efficiency	0.95



Percent Error	EnergyPlus	FEDS
Electricity	7%	-13%

# 3a Comparison of Results

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## FEDS and Energy Plus

- used the same input data
- produced significantly different results

Possible reasons for discrepancies are explored



## 3b Comparison of Results

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EnergyPlus results yielded more representative annual consumption data

- Considers all aspects of building operation
- High level of manipulation of building component variables
- Models consumption based on user defined weather data



# 3c Comparison of Results

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FEDS consistently yielded lower consumption values

- FEDS does not take into consideration all aspect of building operation.
- Only certain building systems are modeled
- Total building energy consumption is not calculated
- Exact weather files are unavailable



# 4a Conclusions

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## EnergyPlus

- High level of manipulation
- Can model a vast majority of building system configurations
- Advanced scheduling capabilities
- Able to define weather data
- Flexible output of total energy consumption
- Not easy to use



# 4b Conclusions

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## FEDS

- Lacks some output details
- Rapid definition of buildings
- Consumption values are lower than expected
- Limited weather data for Canada
- Easy to use



# 5. Acknowledgments

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Questions?

