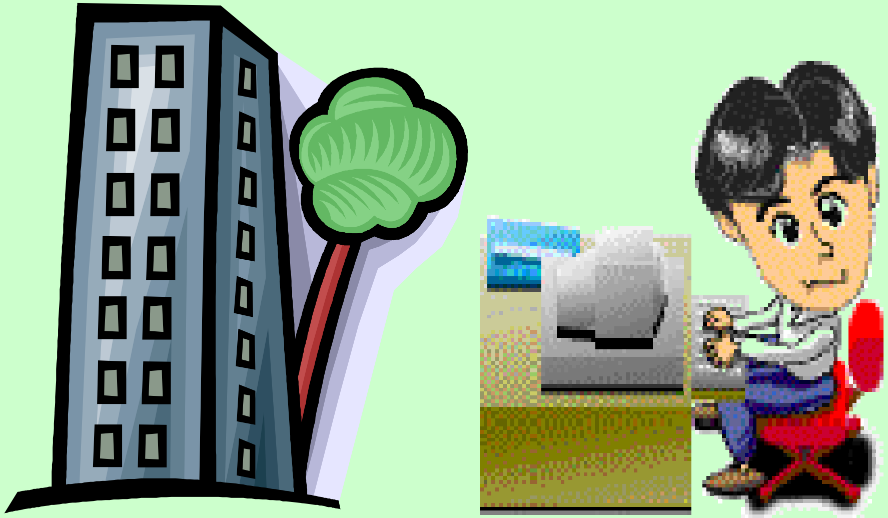
SBS5322 Basics of Building Information Modelling

http://ibse.hk/SBS5322/



Building energy analysis

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- Building energy performance
- Building energy regulations
- Building energy calculations
- Predesign energy analysis
- BIM and energy analysis

Building Energy Performance

Critical Design Parameters:

Fixed:

- Climate of location
- Occupancy behavior
- Process energy
- Required air change rate
- Allowed indoor climate variation range

Constraint:

- Wind
- Surroundings (plants, buildings, surfaces etc.)

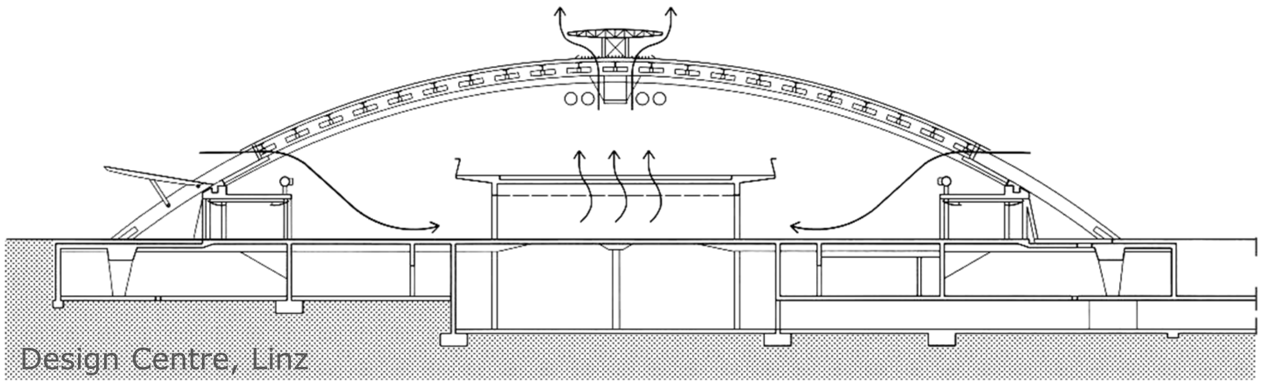
(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)

Building Energy Performance

Critical Design Parameters:

Alterable by the Architect

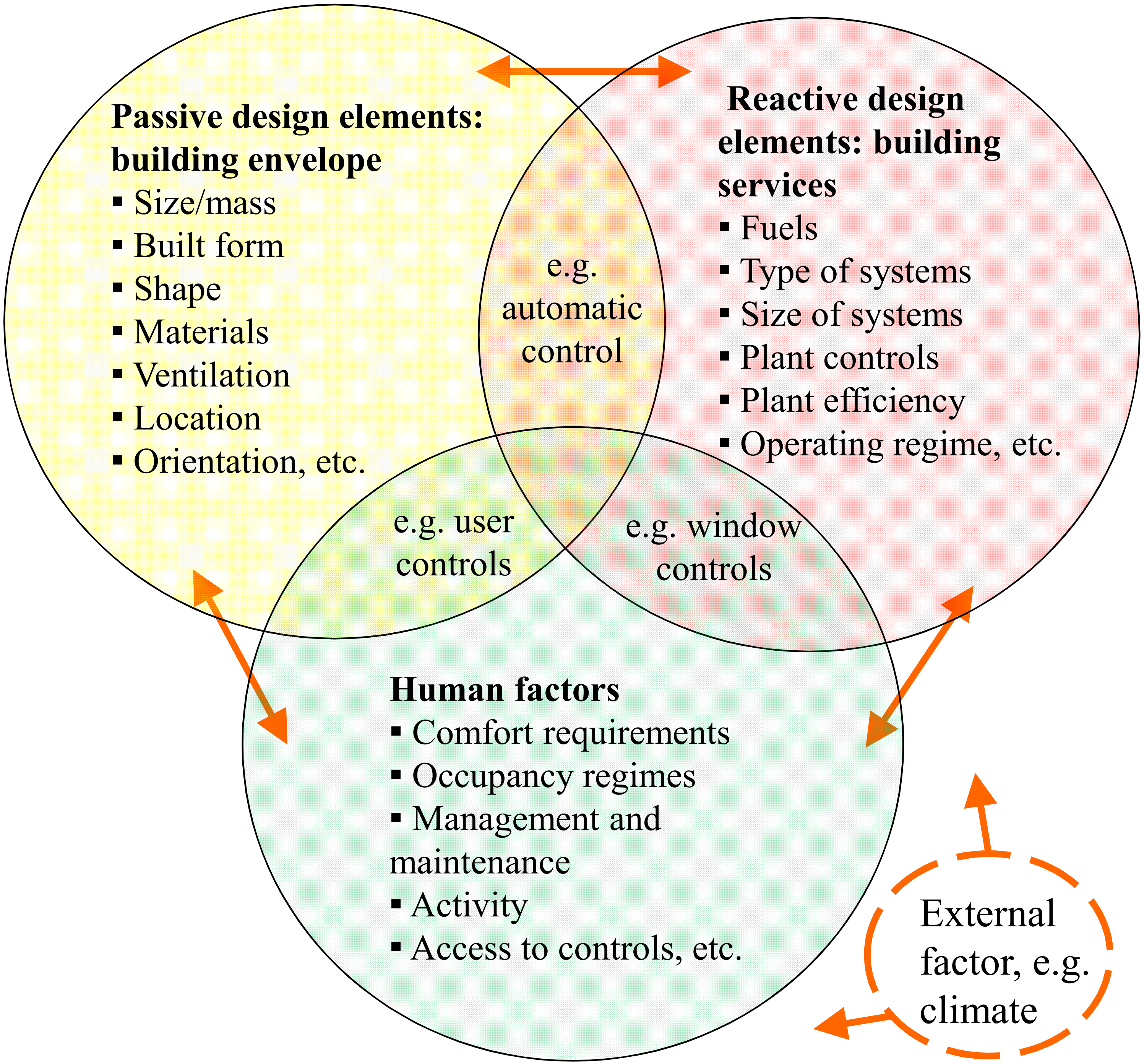
- Building orientation
- Building shape
- Physical properties of the building envelope
- Zoning
- Day-lighting
  - Glazing ratio
  - Glazing orientation
- MEP systems (general strategy)



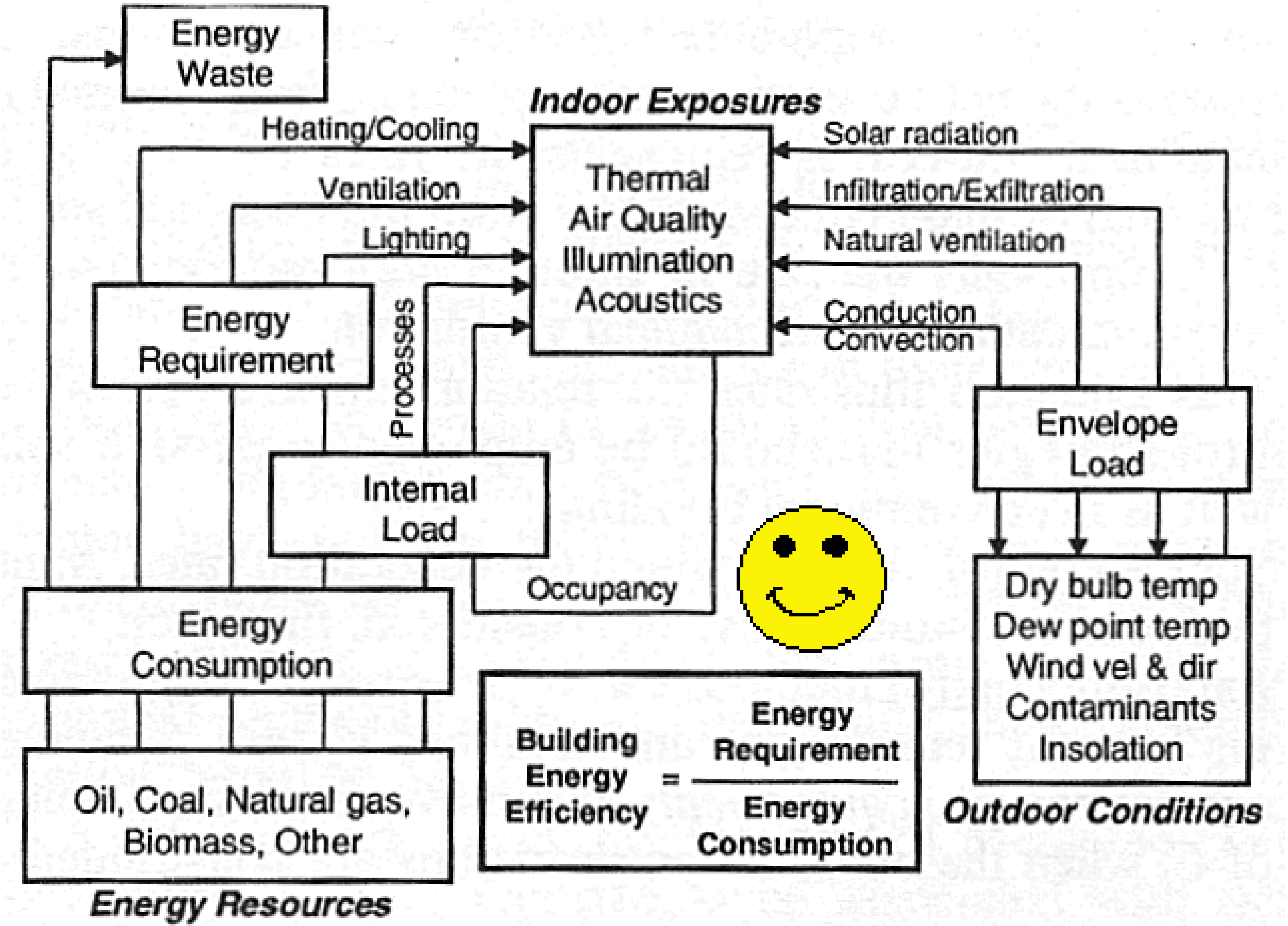
(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)

Key factors influencing energy consumption

(Adapted from Energy Efficiency in Buildings: CIBSE Guide F)

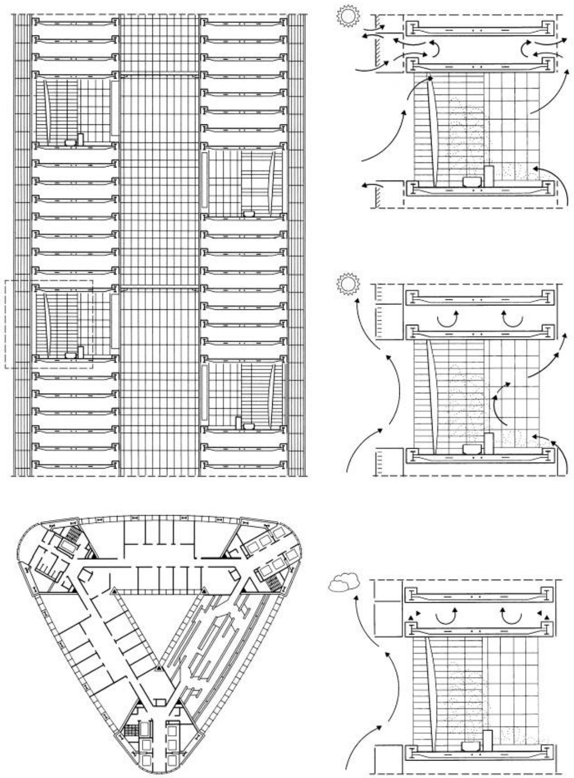


Energy flow and concept in buildings



Building Energy Performance

Benchmarks - Low Energy Houses



Commerzbank, Frankfurt am Main
Sir Norman Foster and Partners

- Less than 30kWh/m^2 energy consumed for heating annually
- Consumes less than 50% energy compared to conventional alternative

(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)

Building Energy Performance

Benchmarks – Passive house

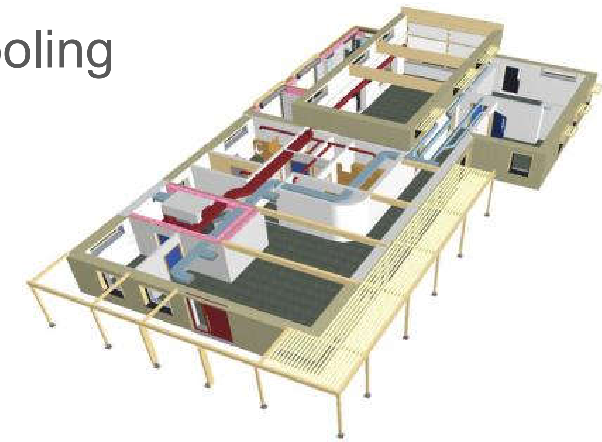
No conventional heating or cooling

less than 30 kWh/m^2 energy consumed for heating/cooling

Extremely low primary energy consumption

less than 120 kWh/m^2

Airtight construction

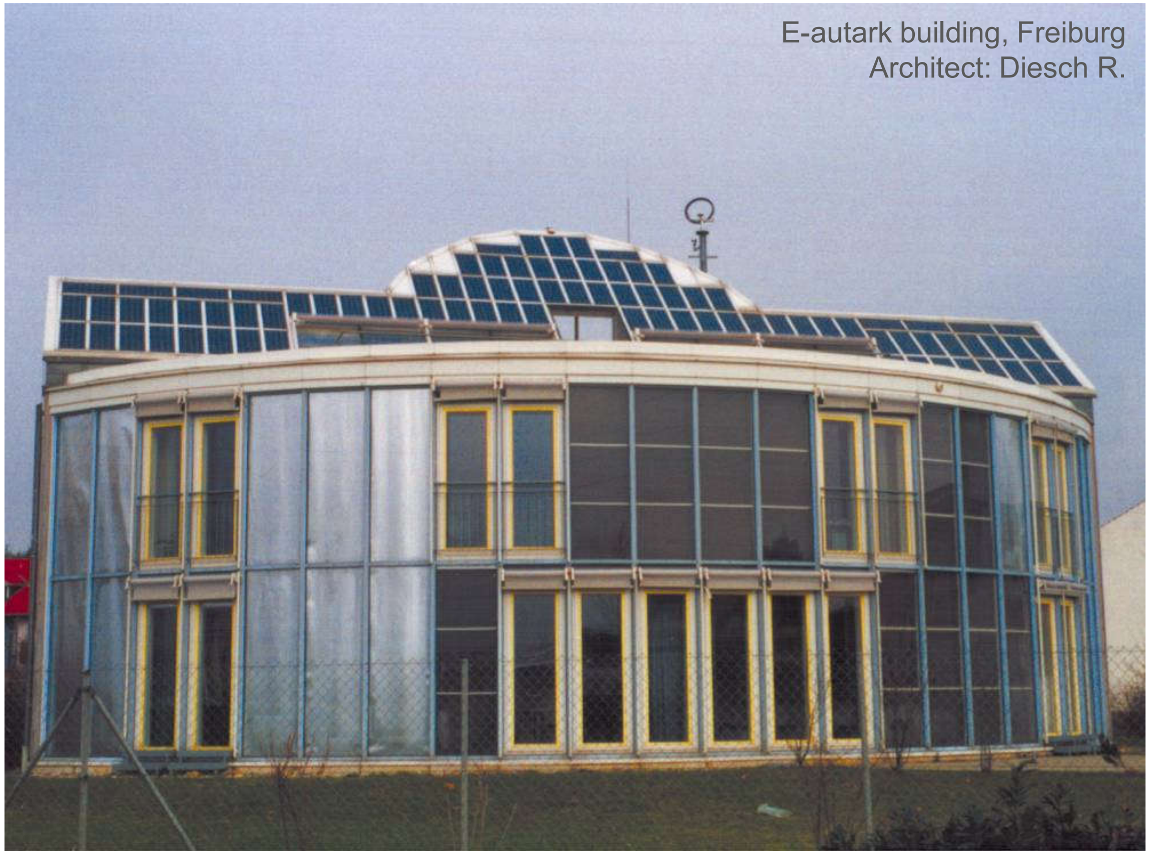


(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)

Building Energy Performance

Benchmarks - Net Zero Buildings

- Zero net energy consumption
- Zero CO2 emission
- Can be used separately from the grid supply
- Enough energy produced on- site
- Super-low energy demand



(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)

Building Energy Regulations

Objectives Defined by Legislation

EU - Climate & Energy objectives by 2020:

- 20% less greenhouse gas emissions
- 20% energy savings
- all new buildings must be net zero buildings

US - all new federal buildings must be at least Silver LEED certified

(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)

Building Energy Regulations

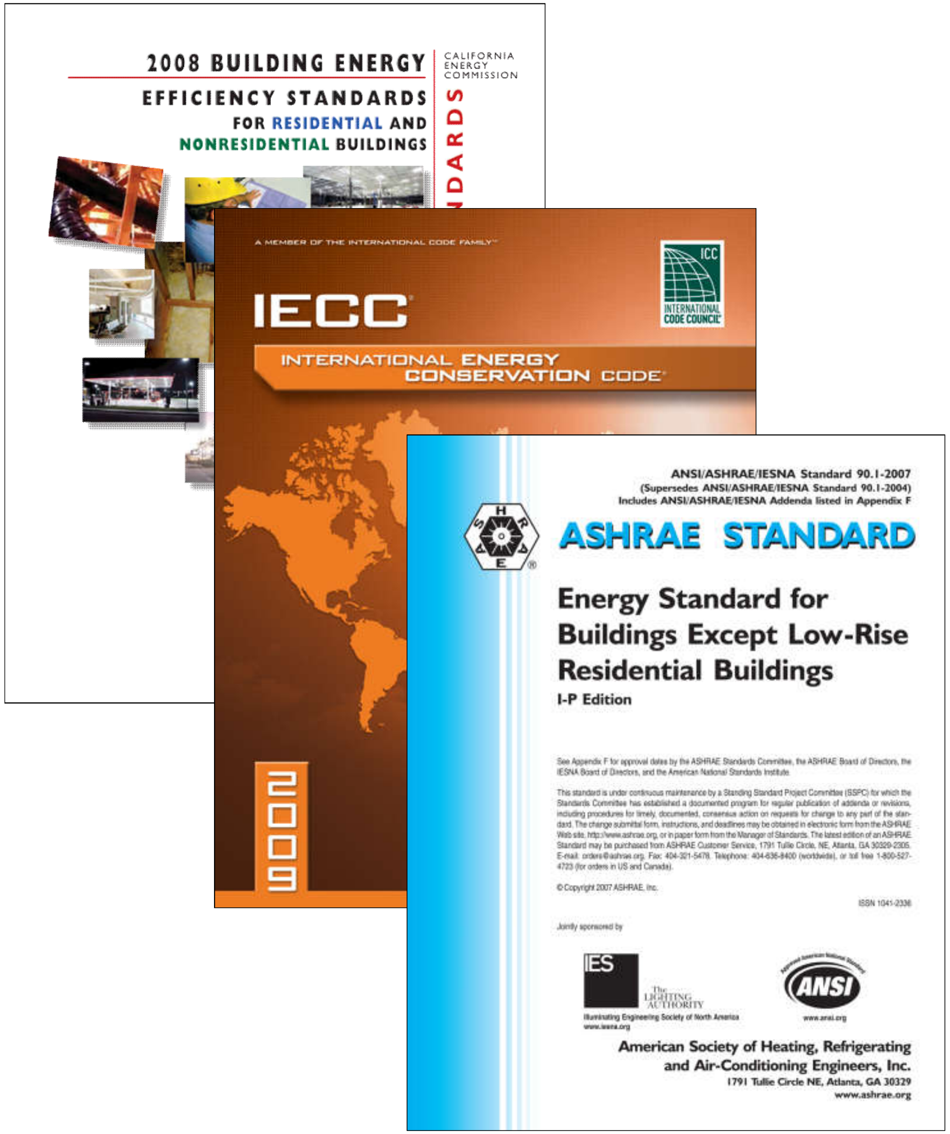
Standards

Define calculation methods and minimum requirements:

- Regional (country-specific) vs. global standards
- Mandatory vs. voluntary standards
- Minimum requirements are getting stricter

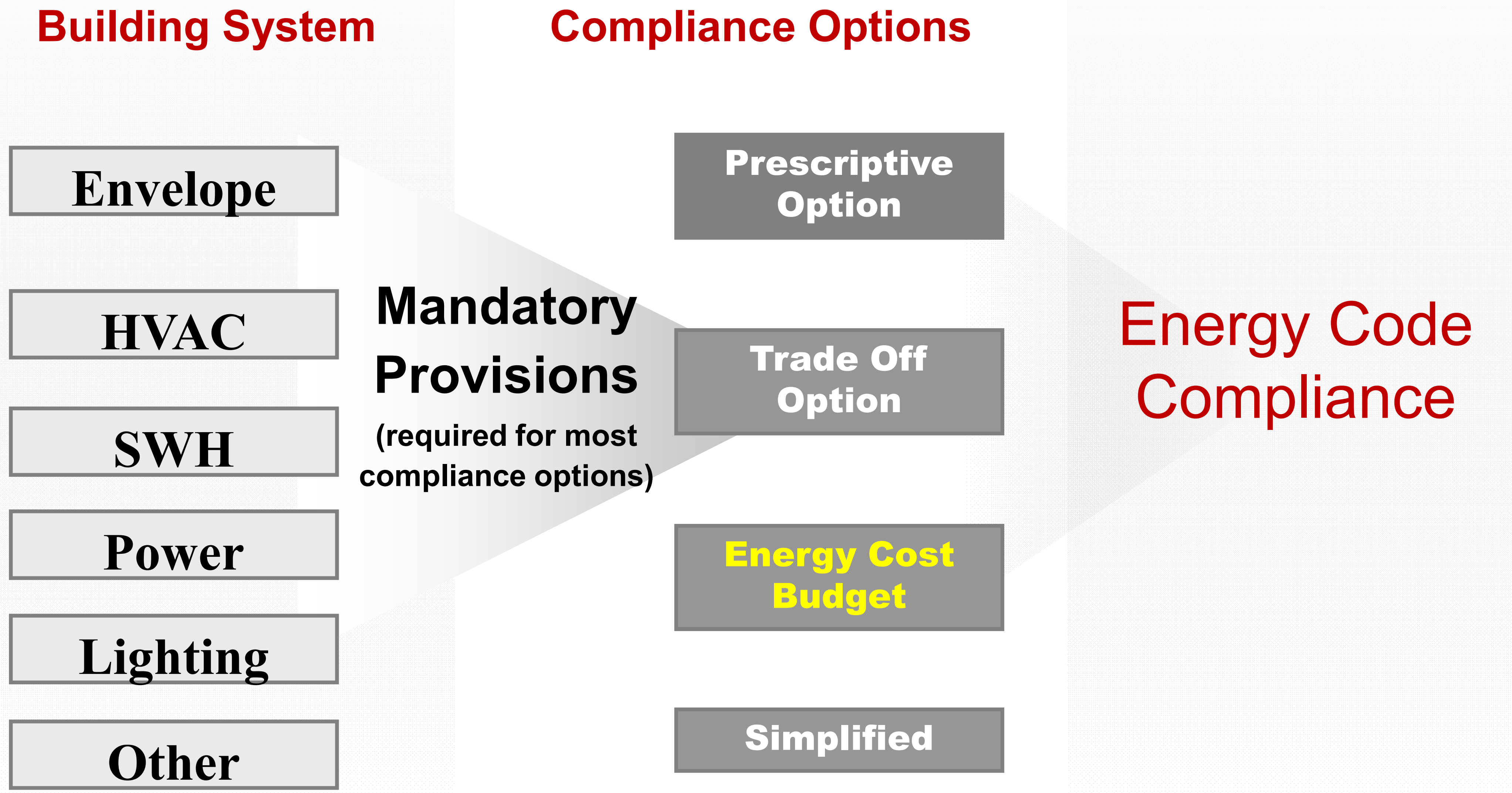
(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)

Building Energy Codes, e.g. ASHRAE 90.1, International Energy Conservation Code (IECC), California Title 24



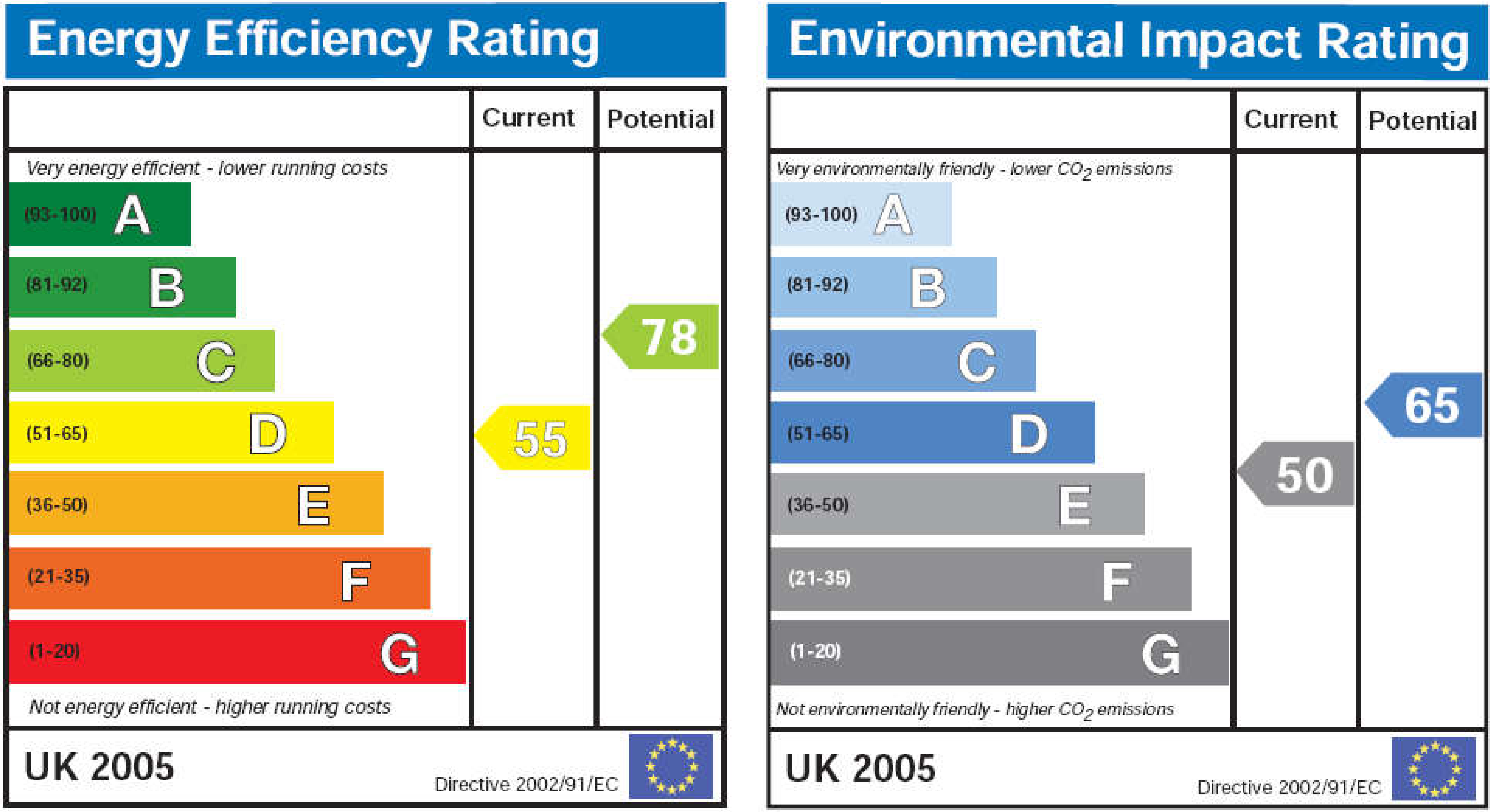
(Source: Mr. Kent W. Peterson, former ASHRAE President)

ASHRAE 90.1 compliance approaches



(Source: US Department of Energy)

Energy efficiency rating and environmental impact rating in UK



(Source: www.energysavingtrust.org.uk)

(Source: EMSD) (See http://www.beeo.emsd.gov.hk for details)

Building Energy Calculations

Stationery Method:

Energy balance for the heating and the cooling season separately

Manual data input exclusively

Usage requires professional expertise

Regional

- Limited to a narrow climate range

Not truly integrated in architecture

- Executed only a couple of times for a project
- Not used to improve the project but only to document it

ahol a még nem magyarázott elemek

72	az éves fűtési hőfokhid ezredrésze – 3. melléklet B) szerint [hK/a],
n	légcsereszám – 3. melléklet C IV. 1. táblázata szerint [1/h],
σ	a leszabályozott fűtés miatti csökkentő tényező, 3. melléklet C IV. 1. táblázat szerint,
4,4	a fűtési idény hosszának ezredrésze – 3. melléklet B) szerint [h/a],
q_b	belső hőnyereség – 3. melléklet C IV. 1. táblázata szerint (W/m²).

Nettó fűtési energiaigény fajlagos értéke: q_f [kWh/m²a]

A fajlagos érték a fűtési energiaigény nettó alapterületre vetített hányada:

$$q_f = \frac{Q_F}{A_N} \quad [\text{kWh/m}^2\text{a}]$$

Ez a jellemző kiválóan alkalmas különböző épületek összehasonlítására.

2. változat, a fűtés éves nettó hőenergiaigénye: Q_F [kWh/a]

$$Q_F = 72 \cdot V(q + 0{,}35 \cdot n)\sigma - 4{,}4 \cdot A_N \cdot q_b \quad [\text{kWh/a}]$$

$$Q_F = 72 \cdot 257{,}63(0{,}515 + 0{,}35 \cdot 0{,}5)0{,}9 - 4{,}4 \cdot 97{,}22 \cdot 5 = 9380 \quad [\text{kWh/a}]$$

A nettó fűtési energiaigény fajlagos értéke: q_f [kWh/m²a]

$$q_f = \frac{Q_F}{A_N} \quad [\text{kWh/m}^2\text{a}]$$

$$q_f = \frac{9380}{97{,}22} = 96{,}49 \quad [\text{kWh/m}^2\text{a}]$$

3. változat, a fűtés éves nettó hőenergiaigénye: Q_F [kWh/a]

$$Q_F = 72 \cdot 257{,}63(0{,}514 + 0{,}35 \cdot 0{,}5)0{,}9 - 4{,}4 \cdot 97{,}22 \cdot 5 = 9369 \quad [\text{kWh/a}]$$

A nettó fűtési energiaigény fajlagos értéke: q_f [kWh/m²a]

$$q_f = \frac{9369}{97{,}22} = 96{,}37 \quad [\text{kWh/m}^2\text{a}]$$

8. A fűtési rendszer veszteségei (ld. 10. pontban)

9. A fűtési rendszer villamos segédenergia-igénye (ld. 10. pontban)

Fajlagos hőveszteségtényező ΣA/V alapján meghatározott követelményértéke: q = 0,53 (W/m3K)		
Az épületre egyszerűsített eljárással kiszámolt fajlagos hőveszteség-tényezők: **q (W/m3K) → II. követelmény**		
1. változat:	2. változat:	3. változat:
q = 0,564 (W/m3K) nem felel meg!	q = 0,515 (W/m3K) megfelel	q = 0,514 (W/m3K) megfelel
Fűtés éves nettó energiaigénye: Q_F (kWh/a)		
	Q_F = 9380 (kWh/a)	Q_F = 9369 (kWh/a)
Fűtési rendszerrel fedezendő nettó hőenergia-igény fajlagos értéke: q_f (kWh/m2a)		
	q_f = 96,49 (kWh/m2a)	q_f = 96,37 (kWh/m2a)
Nyári sugárzásos hőterhelés: $Q_{\text{sdnyár}}$ (W)		
$Q_{\text{sdnyár}}$ = 545,66 (W)		
Belső és külső hőmérséklet napi középértékeinek különbsége nyárra: $\Delta t_{\text{bnyár}}$ (W) → IV. köv.		
	$\Delta t_{\text{bnyár}}$ = 1,08 (W) megfelel	$\Delta t_{\text{bnyár}}$ = 1,08 (W) megfelel
Fűtés primerenergia-igénye: E_F (kWh/m2a)		
	E_F = 140,09 (kWh/m2a)	E_F = 139,94 (kWh/m2a)
Melegvízellátás primerenergia-igénye: E_{HMV} (kWh/m2a)		
	E_{HMV} = 42,41 (kWh/m2a)	E_{HMV} = 42,41 (kWh/m2a)
Az összesített energetikai jellemző ΣA/V alapján meghatározott követelményértéke: $E_{\text{pköv}}$ = 213,8 (kWh/m2a)		
Összesített energetikai jellemző az épületre: E_p (kWh/m2a) → III. követelmény		
	E_p = 182,51 (kWh/m2a) megfelel	E_p = 182,353 (kWh/m2a) megfelel
Minősítés: $E_p/E_{\text{pköv}}$ (%) besorolás és jellemzés:		
	85% → B a követelménynél jobb	85% → B a követelménynél jobb

(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)

Building Energy Calculations

Dynamic Simulation Method:

Energy balance for every hour throughout a year

Semi-automated data input

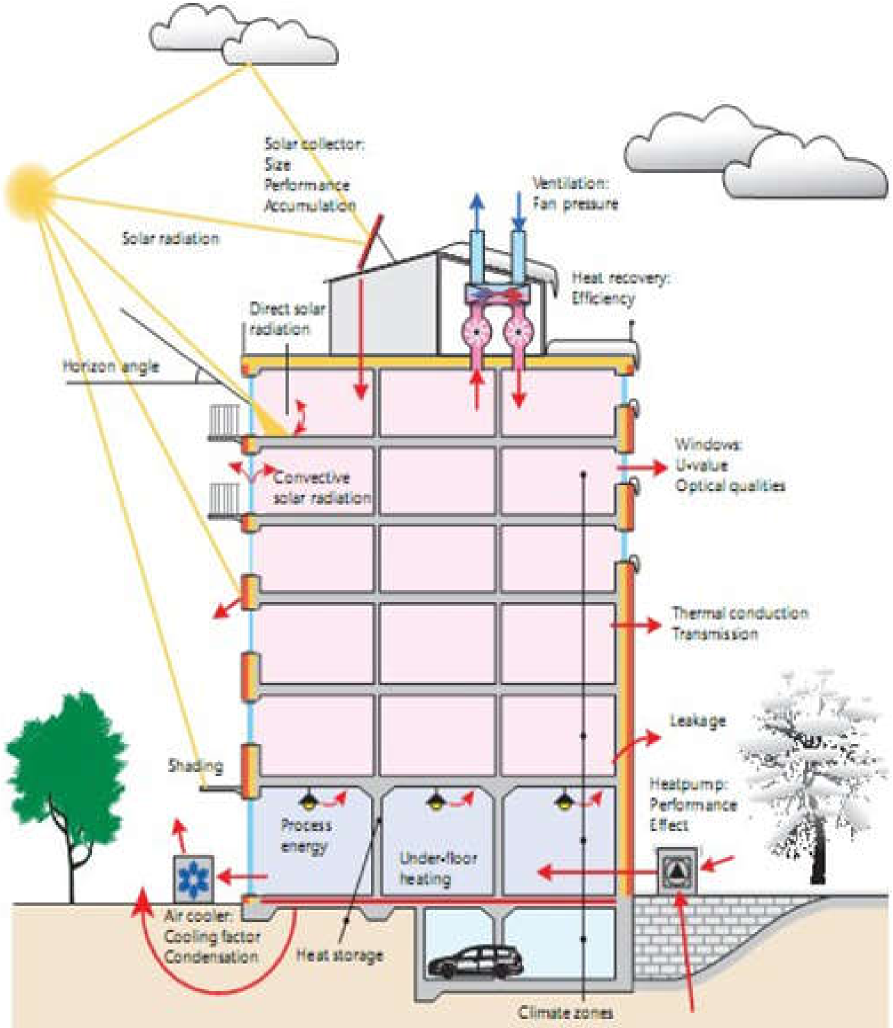
User-friendly solutions exist

Global

- Can be used in all climates

Truly integrated in architecture

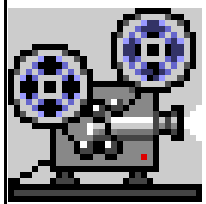
- Executed several times for a project
- Explore what-if scenarios for design optimization



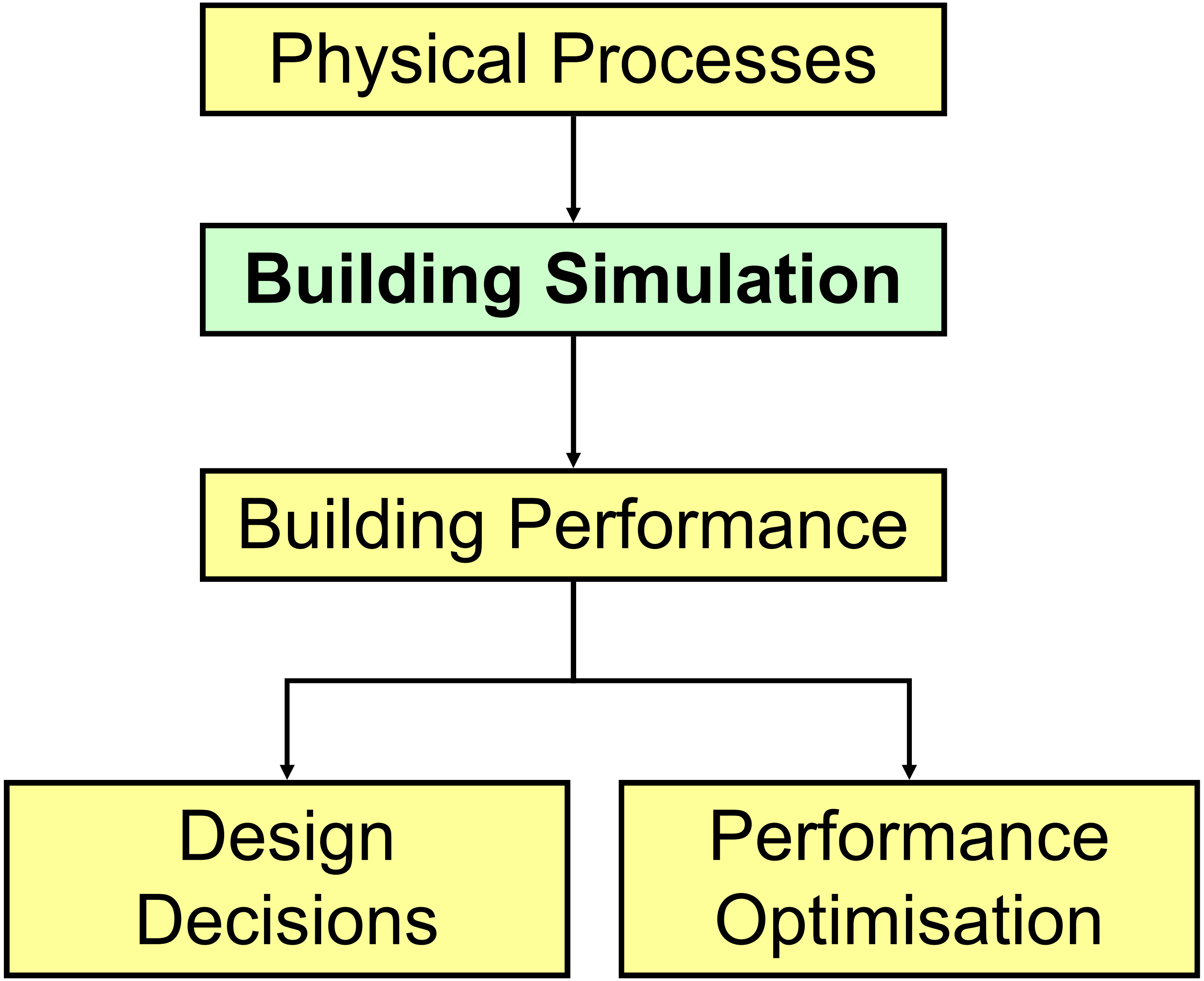
(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)

Building energy calculations

- Building energy simulation/modelling
  - Analysis of energy performance of building using computer modelling and simulation techniques
- Many issues can be studied, such as:
  - Thermal performance (e.g. bldg. fabric, glazing)
  - Comfort and indoor environment
  - Ventilation and infiltration
  - Daylighting and overshadowing
  - Energy consumption of building systems

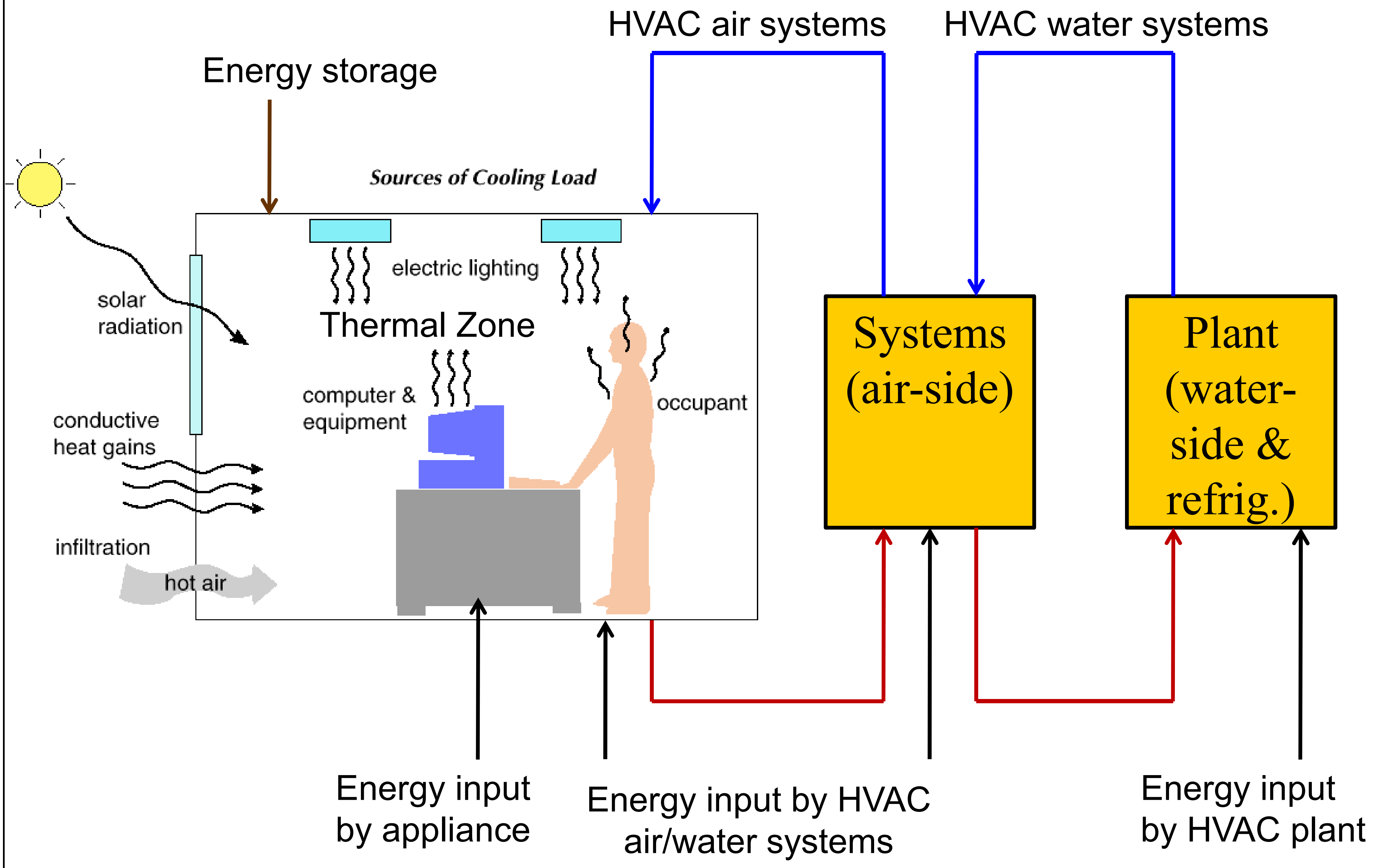


(Video: What is Energy Modeling? (2:05) http://youtu.be/vli6ckgBzdY)



* Simulation enables the performance of the building to be established before critical design decisions are taken, enabling optimum building performance to be obtained

Building energy simulation process



Building Energy Simulation Software

ENERGY-10

blast

EnergyPlus

DOE-2

Solar-5

ESP-r

ENER-WIN©

Hourly Energy Simulation Program for Buildings

TRNSYS

Carrier

E-20-II & HAP

HOT2000

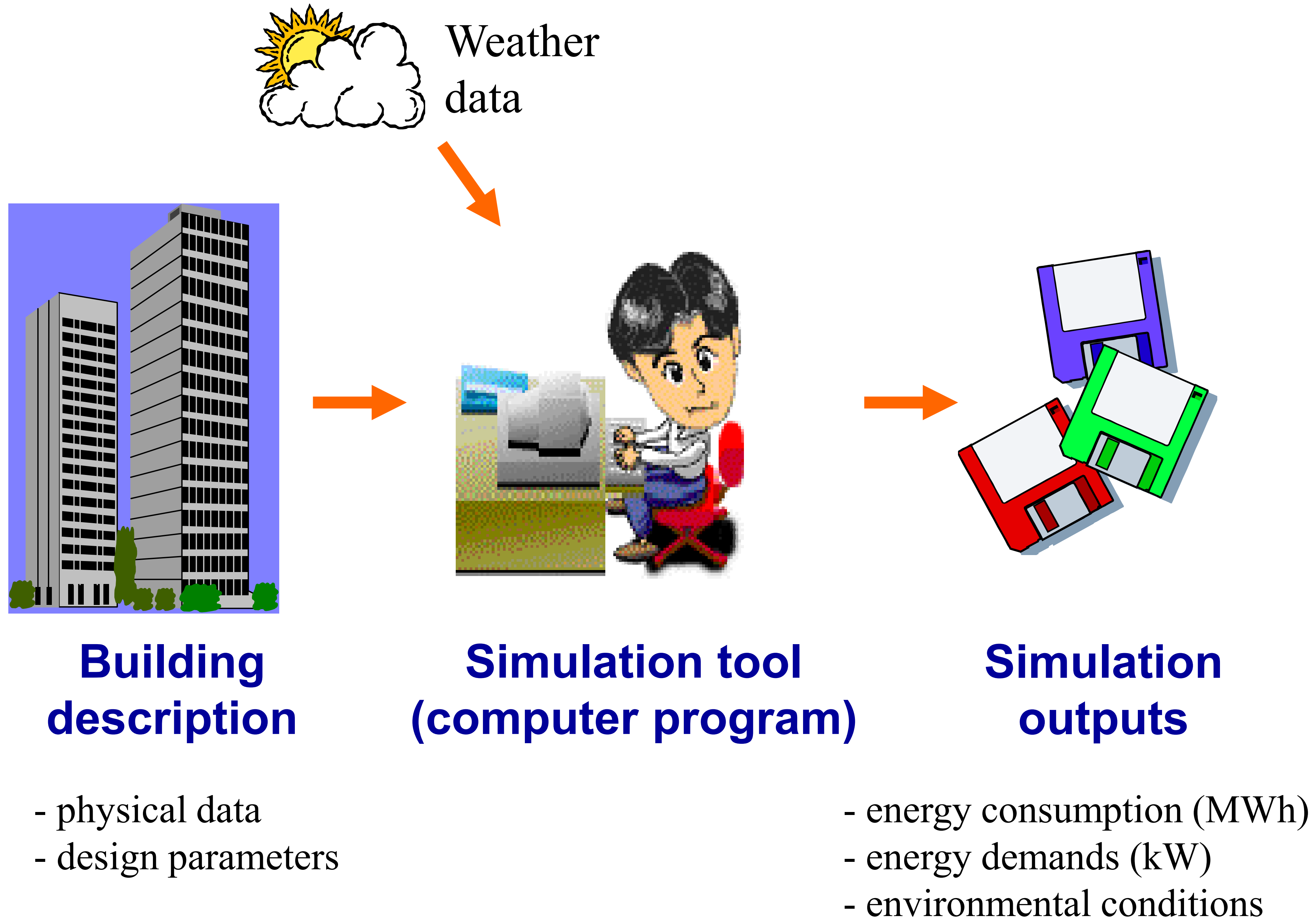
TRANE

TRACE 700

ADELINE

Tas

EE4


Weather data
Building description
Simulation tool (computer program)
Simulation outputs
- physical data
- design parameters
- energy consumption (MWh)
- energy demands (kW)
- environmental conditions

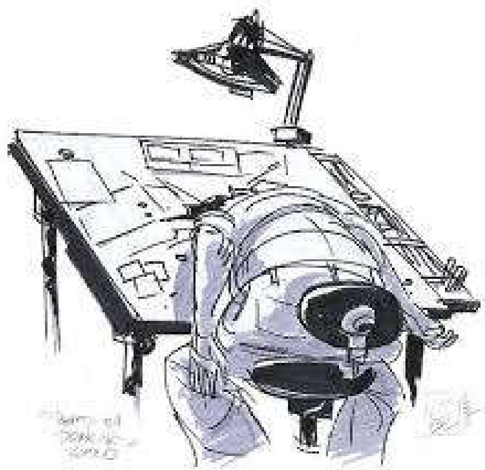
Garbage In, Garbage Out (GIGO)

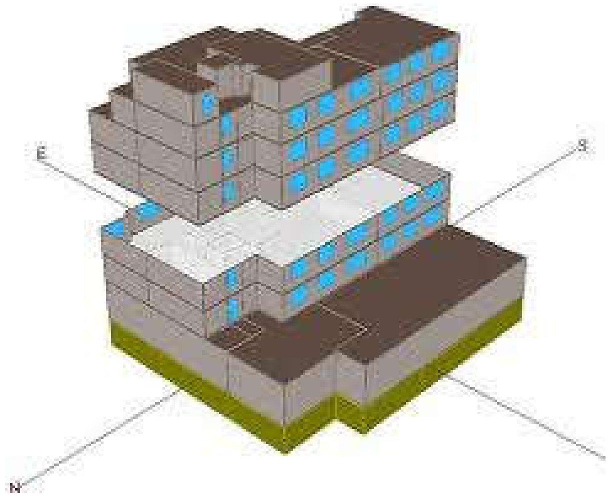
Predesign energy analysis

- Use general information about the building and site to estimate energy performance, characterize energy uses, and identify potential energy savings opportunities
- The objective is to use results to develop design concepts that minimize energy loads and costs from the outset
- Results also provide important guidance for setting energy performance goals

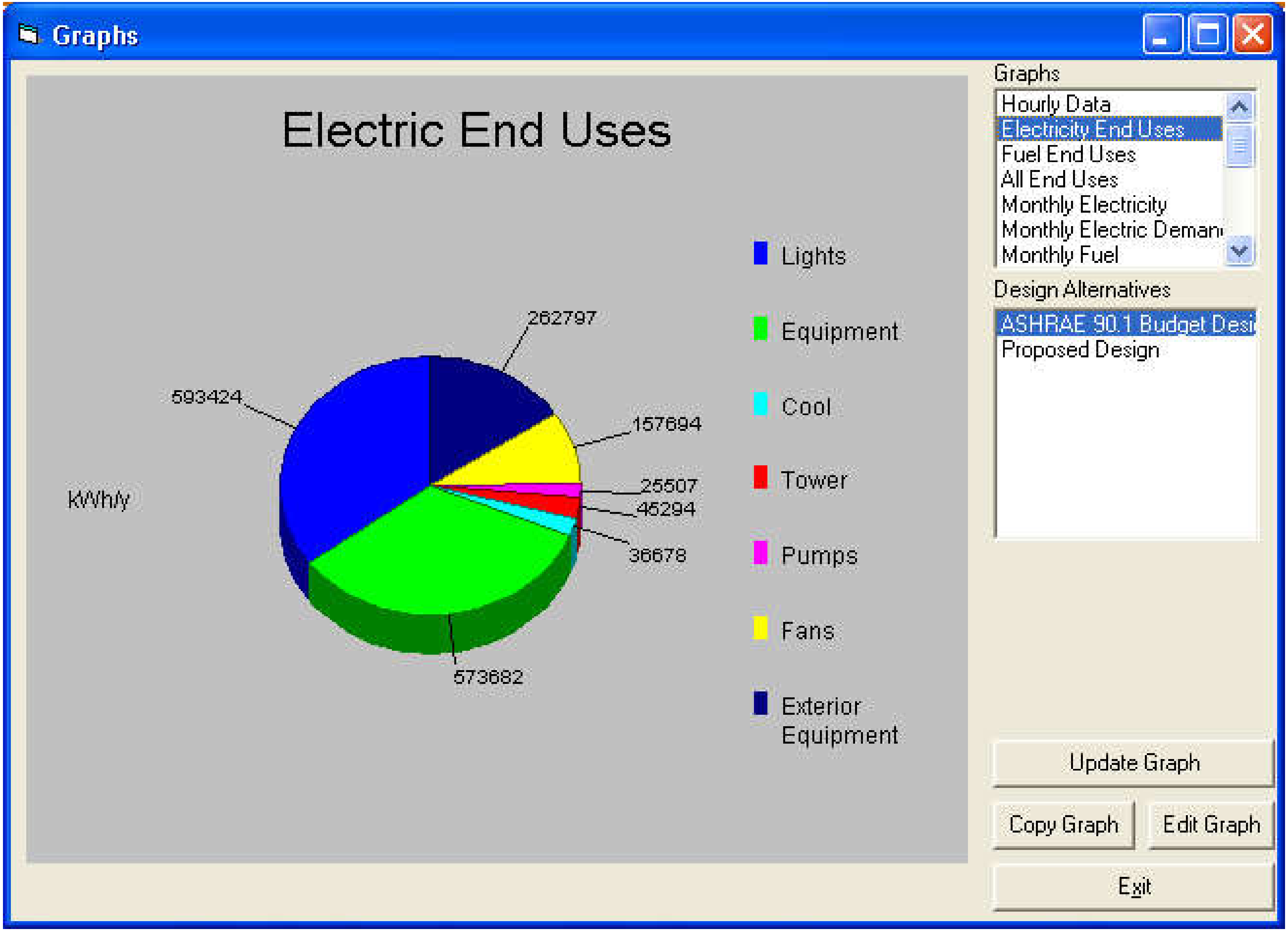
Predesign energy analysis

- Predesign energy model is a simplified sketch of a potential building
- Results are best used to compare and explore alternatives and will not necessarily be representative of the actual performance

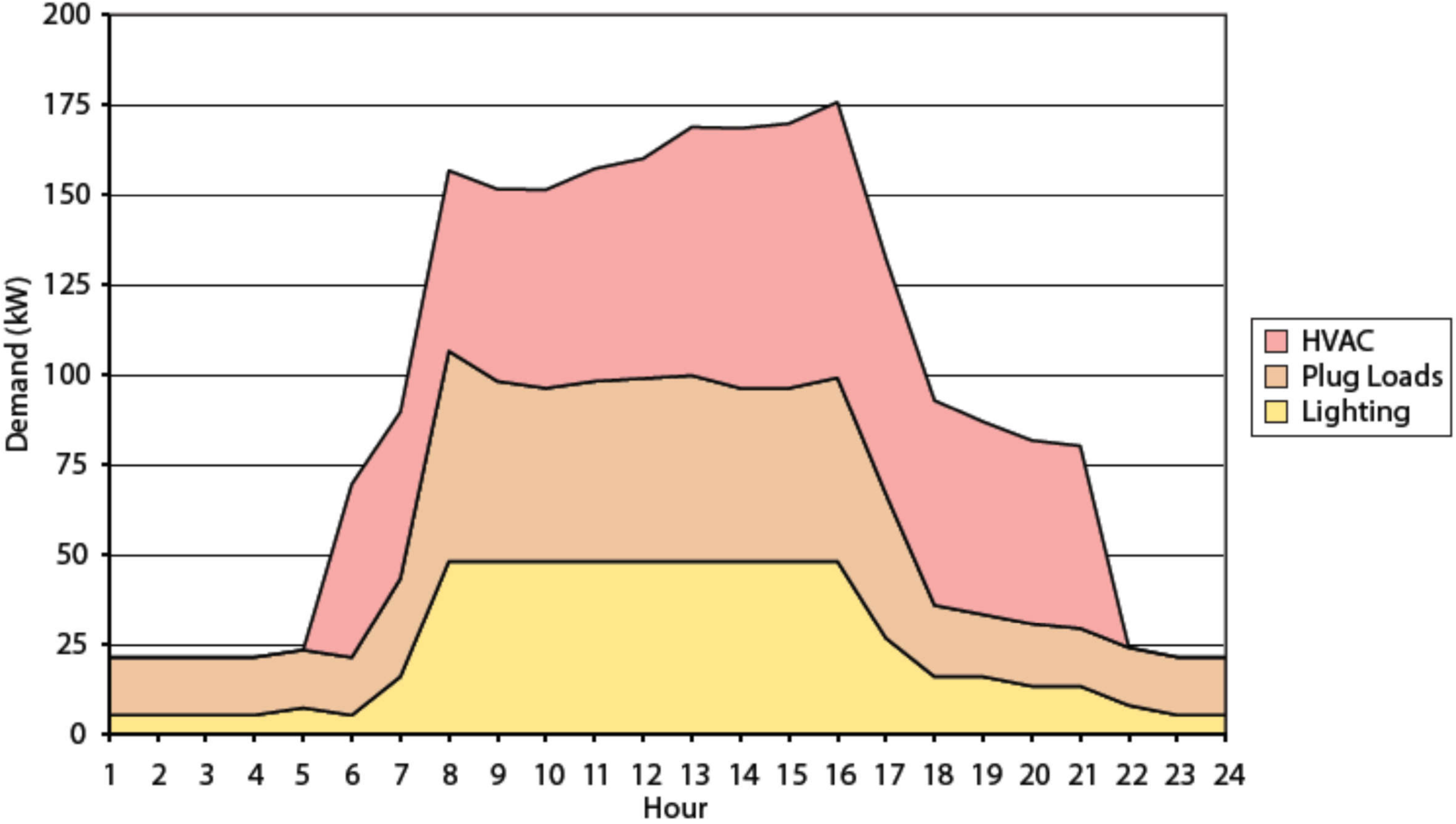




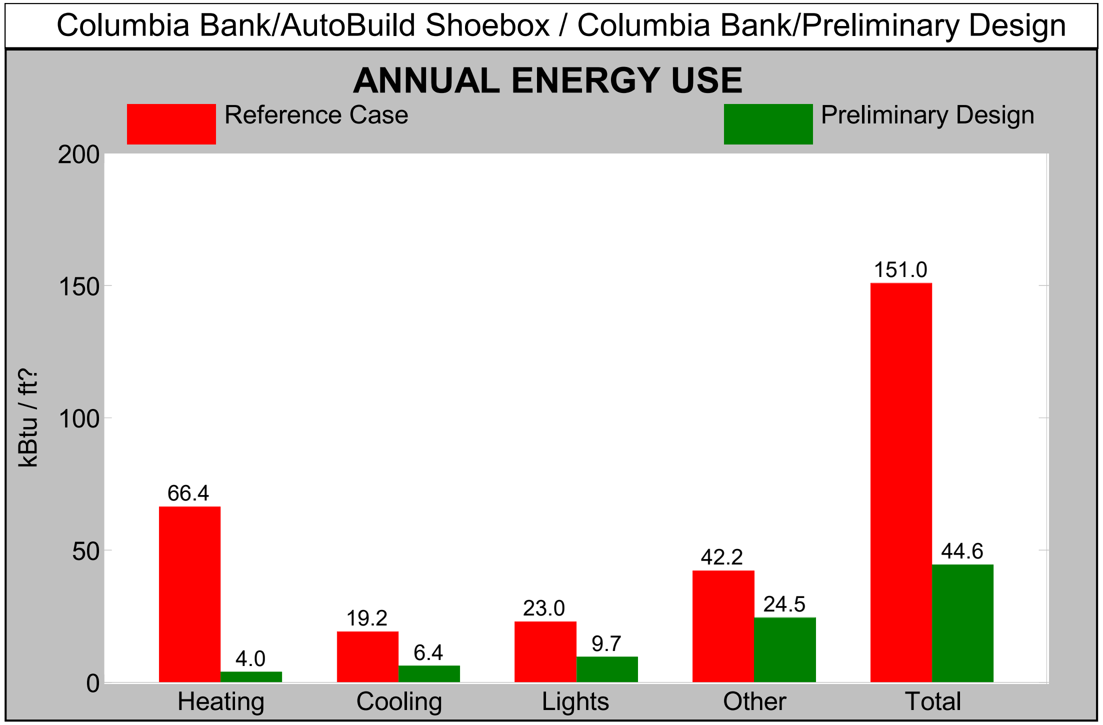
Breakdown of end-use energy consumption

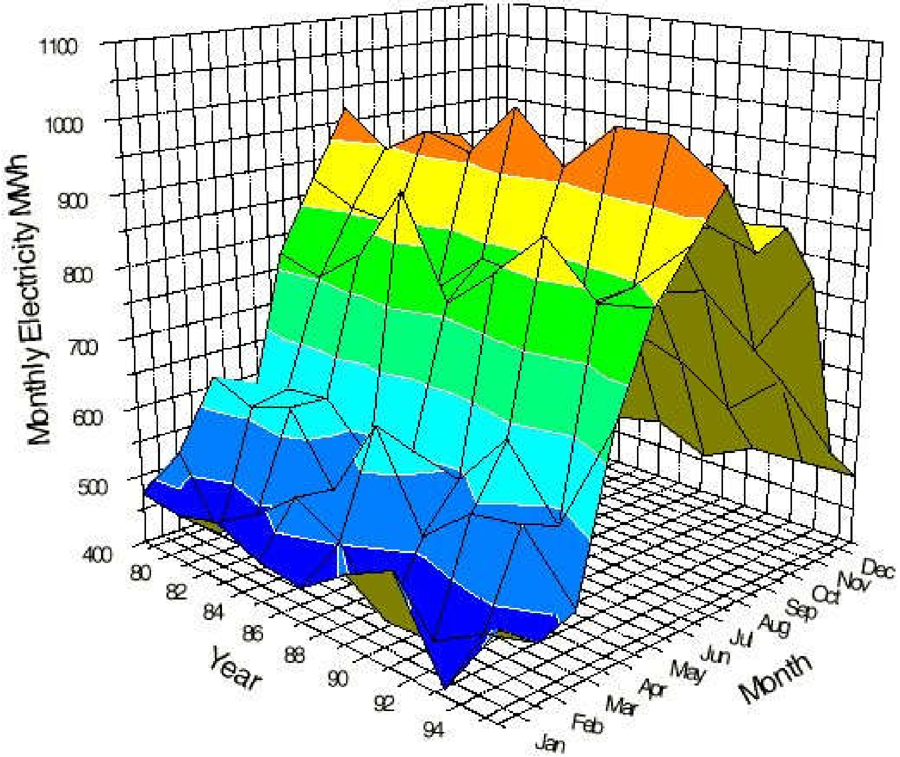


Peak day demand profile



(Source: Lindsey, G., et al., 2009. *A Handbook for Planning and Conducting Charrettes for High-Performance Projects*)





Presentation of results from building energy simulation

Summary of analysis/modelling tools

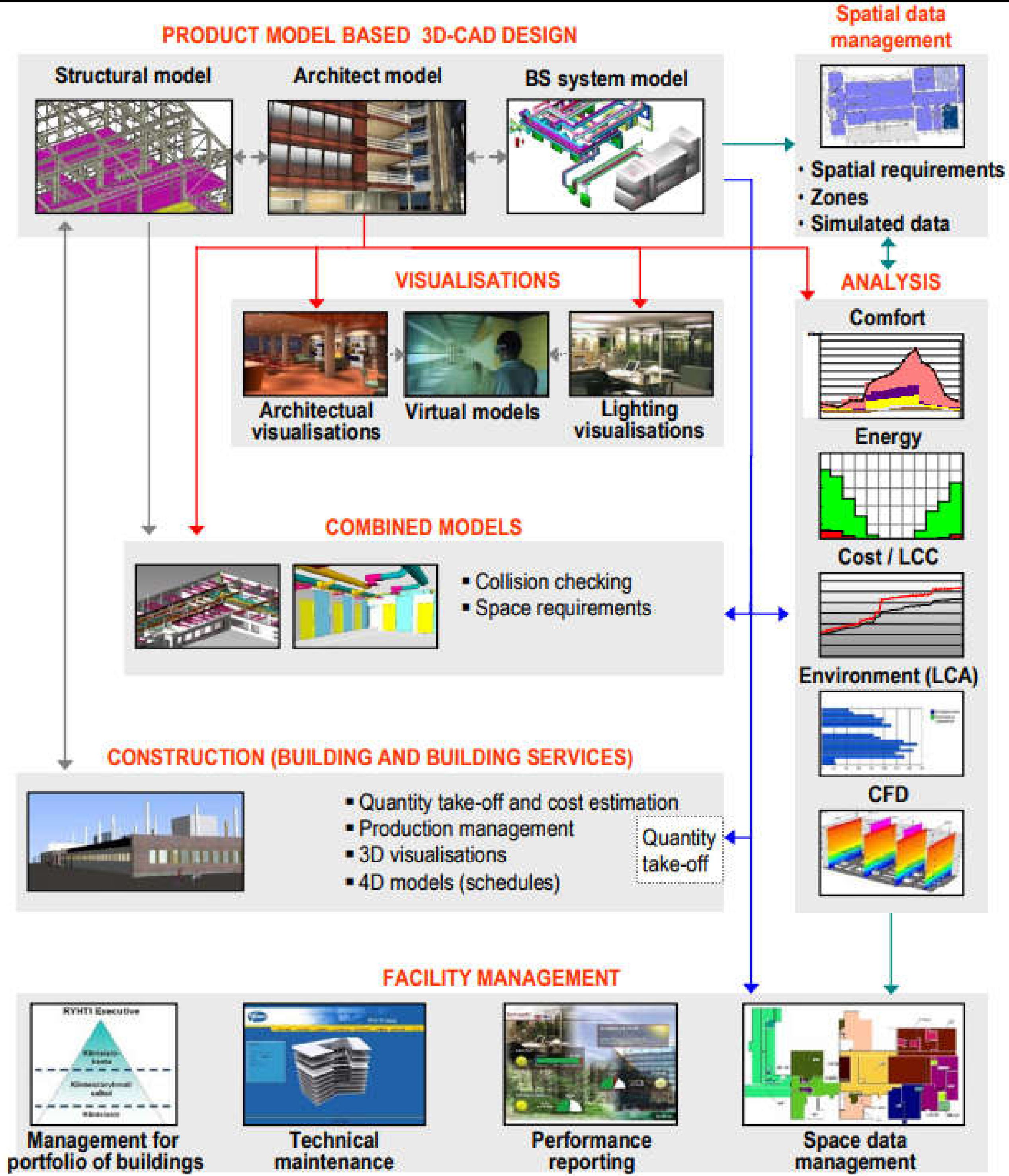
Stage	Requirements	Tools	Checks
Scoping	-Quick analysis -Comparative results -Reduce alternatives -Control strategy modelling (simple)	-Ecotect -Energy-10 -eQUEST	-kWh/m^2 -Energy cost -Payback or other financial measure
System design	-Accurate output -Industry-accepted methods	-Carrier HAP -TRACE 700	-design flow -Load intensity
Energy/cost analysis	-Accurate -Industry-accepted methods -Flexible -Modelling of complex control strategies -Energy code compliance -For existing buildings too	-DOE-2 -EnergyPlus -Carrier HAP -TRACE 700	-Detailed kWh/m^2 -Detailed energy cost -Economic indexes
Monitoring	-Simplicity -Intuitive interface -Interoperable	-BACnet -Building automation	-Trended operating characteristics -Benchmark comparison

(Adapted from ASHRAE, 2006. *ASHRAE GreenGuide*)

BIM and energy analysis

- Use of BIM for facility energy analysis
  - In the facility design phase which one or more building energy simulation programs use a properly adjusted BIM model to conduct energy assessments for the current building design
  - The core goal is to inspect building energy standard compatibility and seek opportunities to optimize proposed design to reduce structure's life-cycle costs

(Source: Facility Energy Analysis http://bim.psu.edu/Uses/Energy_Analysis.aspx)



Energy analysis has an important role in the use of BIM

(Source: Laine, T. and Karola, A., 2007. Benefits of building information models in energy analysis, In *Proceedings of Clima 2007 WellBeing Indoors*, 8 pages. https://www.irbnet.de/daten/iconda/CIB8170.pdf)

BIM and energy analysis

- Combining BIM and energy analysis can potentially increase efficiency and accuracy, but can be time consuming and tedious if not done properly
  - Before the BIM model is created, it is important to determine which software is best for the desired energy analysis
  - The BIM model may need to be simplified in different ways for different software

(Source: Leveraging BIM for Energy Analysis https://sustainabilityworkshop.autodesk.com/sites/default/files/core-page-files/leveragingbimforenergyanalysis.pdf)

Export file type that the energy analysis tool requires from BIM software

Software	Export from BIM software
Green Building Studio (GBS)	gbXML
eQUEST	gbXML --> GBS (DOE-2 file)
Ecotect Analysis	gbXML or .DXF file (best for sloped ceilings)
CFD design	Directly from BIM software via add-in

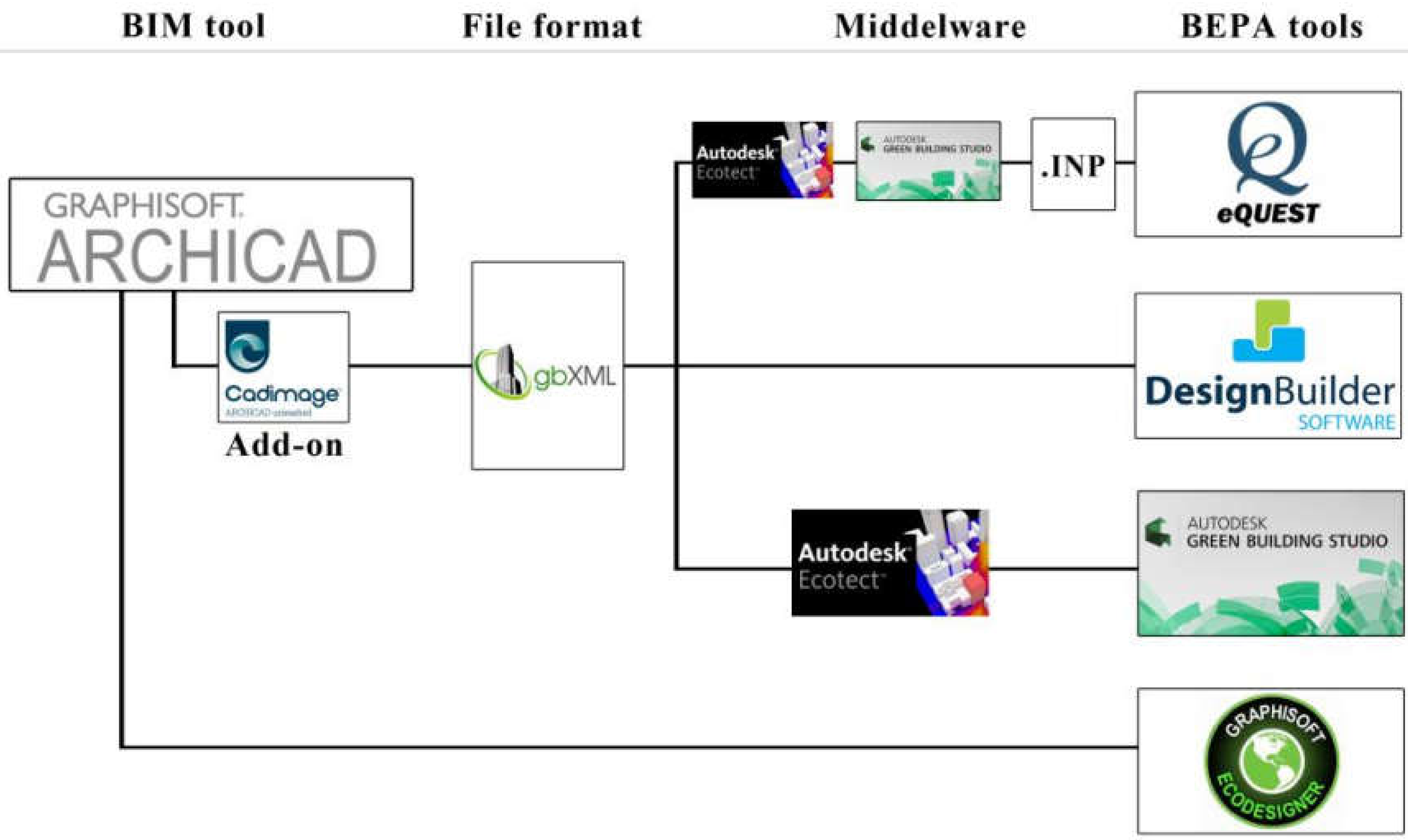
Note:
The .DXF export from BIM software is most useful for odd geometries for use in Ecotect. However, gbXML is usually the preferred output.

Consideration for interoperability of energy analysis tools:

1. Integrate with BIM software (e.g. Revit, ArchiCAD and SketchUp)
2. Exchange or import files (e.g. DXF and gbXML)
3. Accuracy of translation (e.g. geometry, materials, openings)
4. Default data, libraries and weather information
5. Potential for customization (e.g. for special cases)
6. Provide feedbacks for potential design change to improve energy efficiency

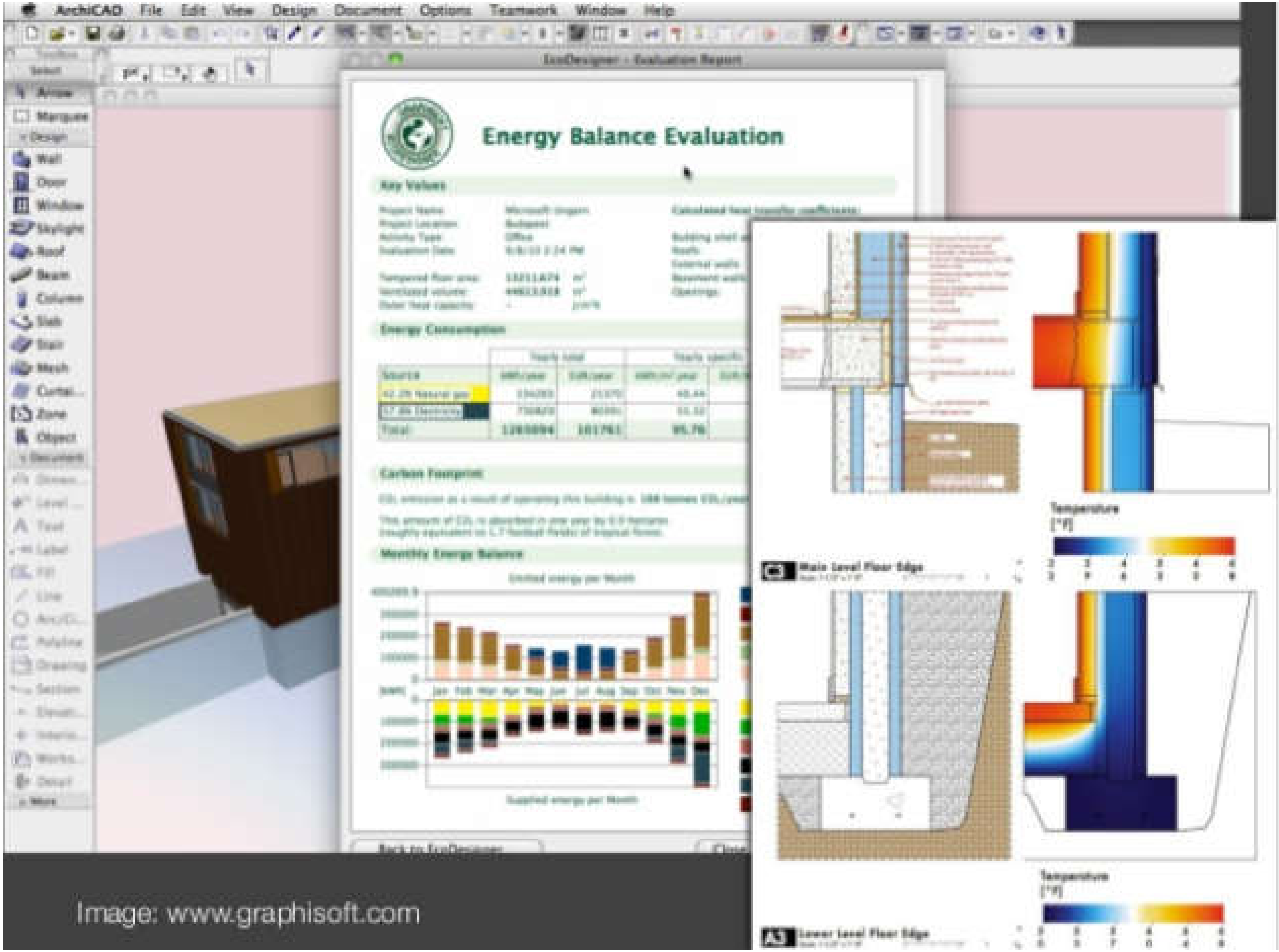
(Source: Leveraging BIM for Energy Analysis https://sustainabilityworkshop.autodesk.com/sites/default/files/core-page-files/leveragingbimforenergyanalysis.pdf)

An example of linking a BIM software to building energy analysis tools



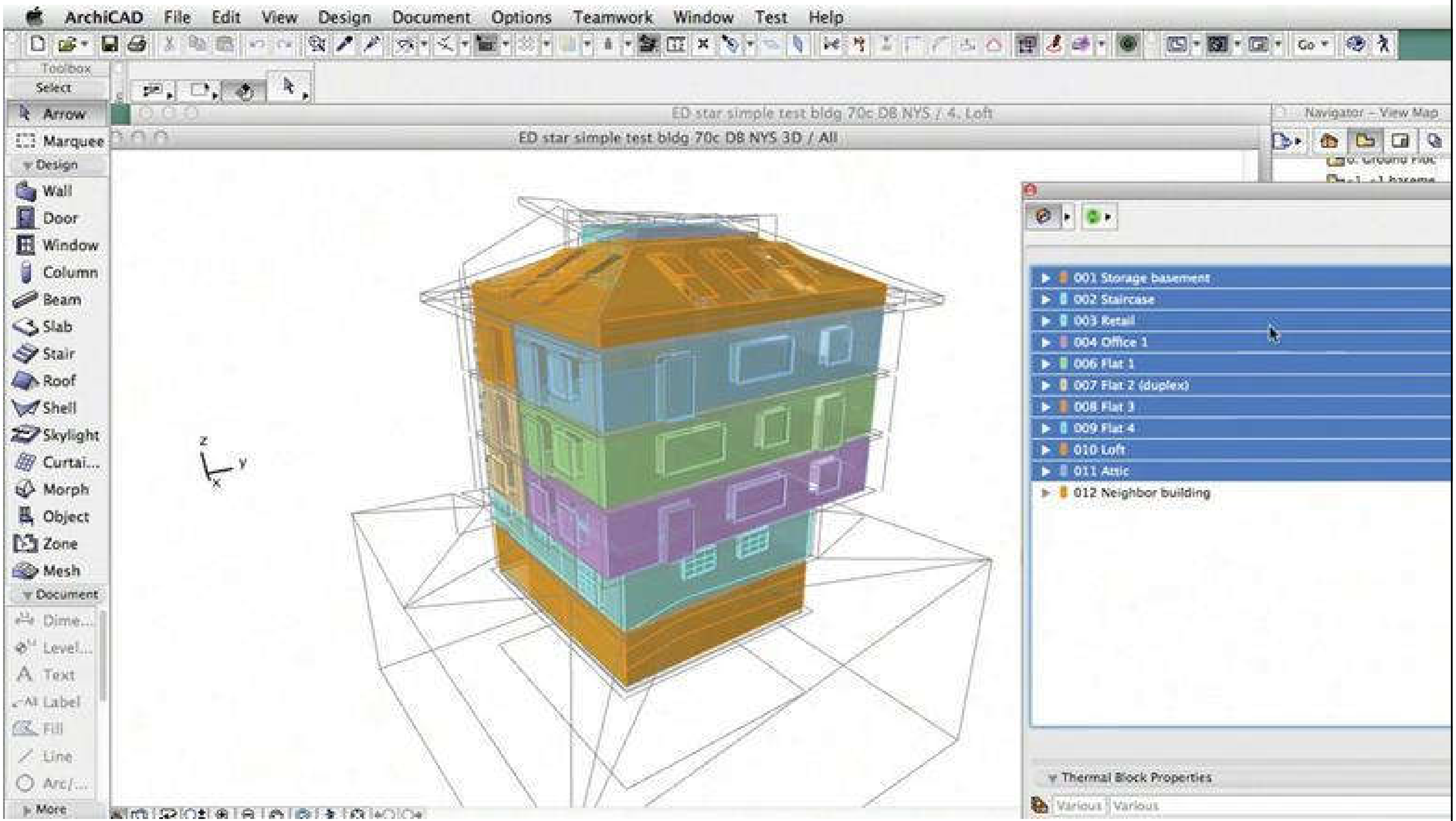
(Source: Reta, T., 2017. *Leveraging a Building Information Model to Carry Out Building Energy Performance Analysis*, BEng Thesis, Helsinki Metropolia University of Applied Sciences, Helsinki, Finland. https://www.theseus.fi/bitstream/handle/10024/130367/Tibebe_Reta.pdf)

Energy balance evaluation on BIM software



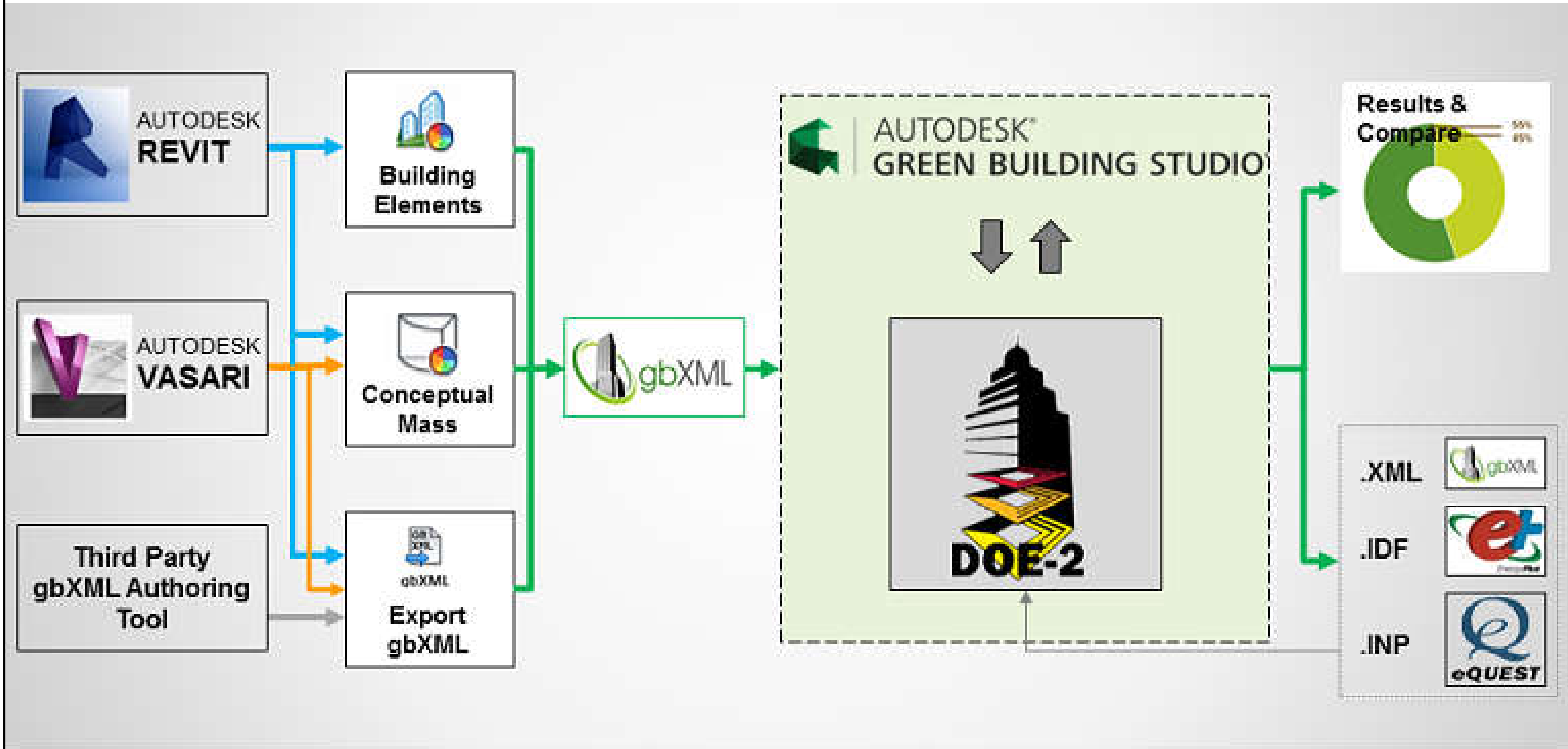
(Source: Graphisoft http://www.graphisoft.com/)

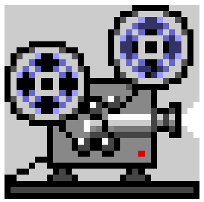
Multiple thermal block building energy model shown in BIM software



(Source: Graphisoft http://www.graphisoft.com/)

Energy analysis workflows

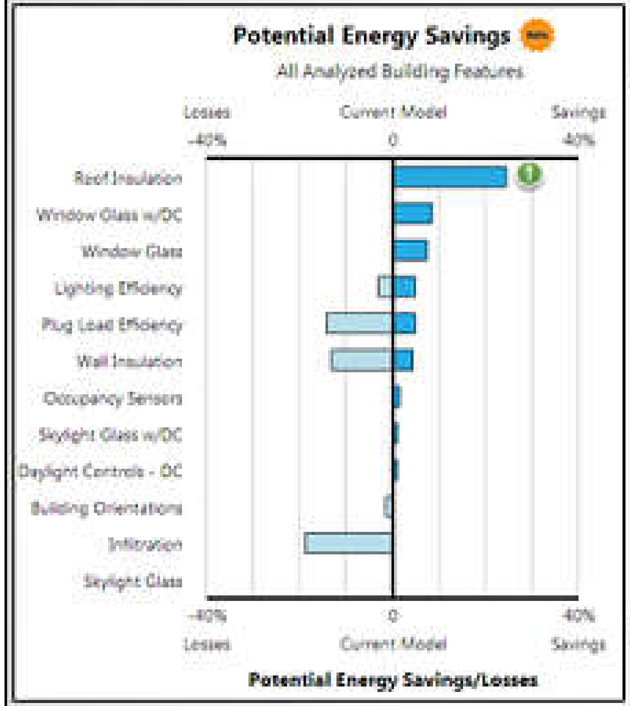


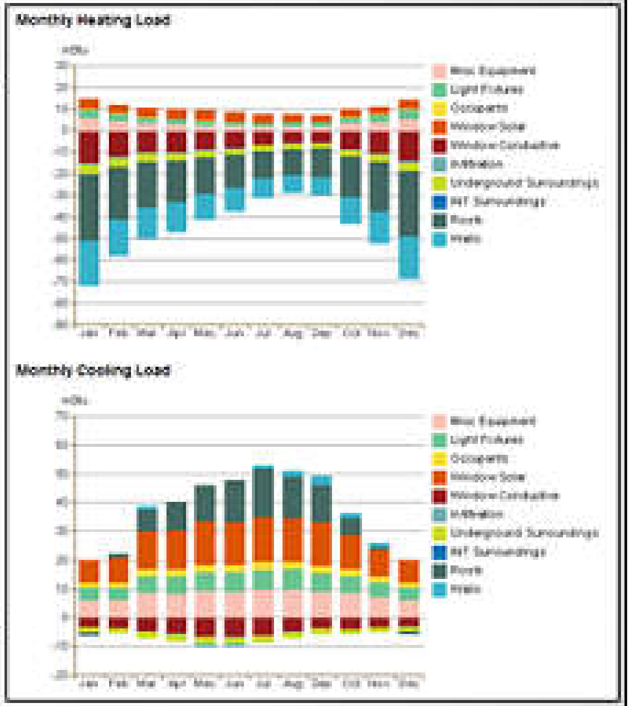


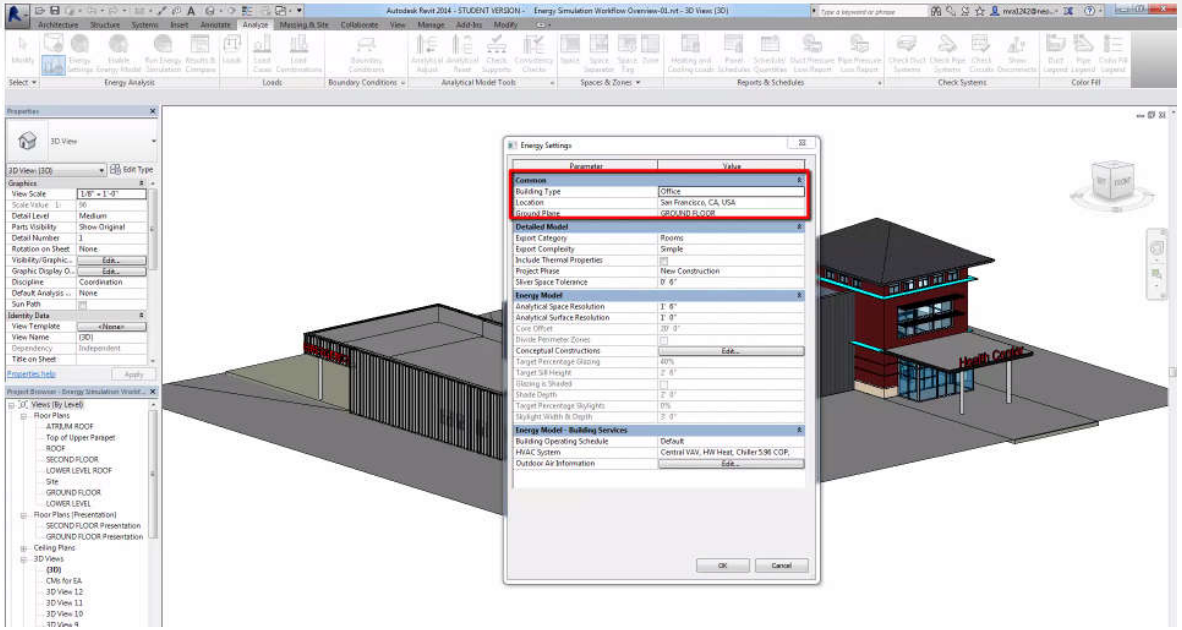
(Video: Energy Simulation Workflow Overview (5:59) https://youtu.be/nldU3ZIQpbg)

(Source: Getting Started with Autodesk Energy Analysis
http://help.autodesk.com/view/BUILDING_PERFORMANCE_ANALYSIS/ENU/?guid=GUID-E85A114E-BA0D-4811-B1A5-4EE26462708A)

Results of energy analysis and decision-making

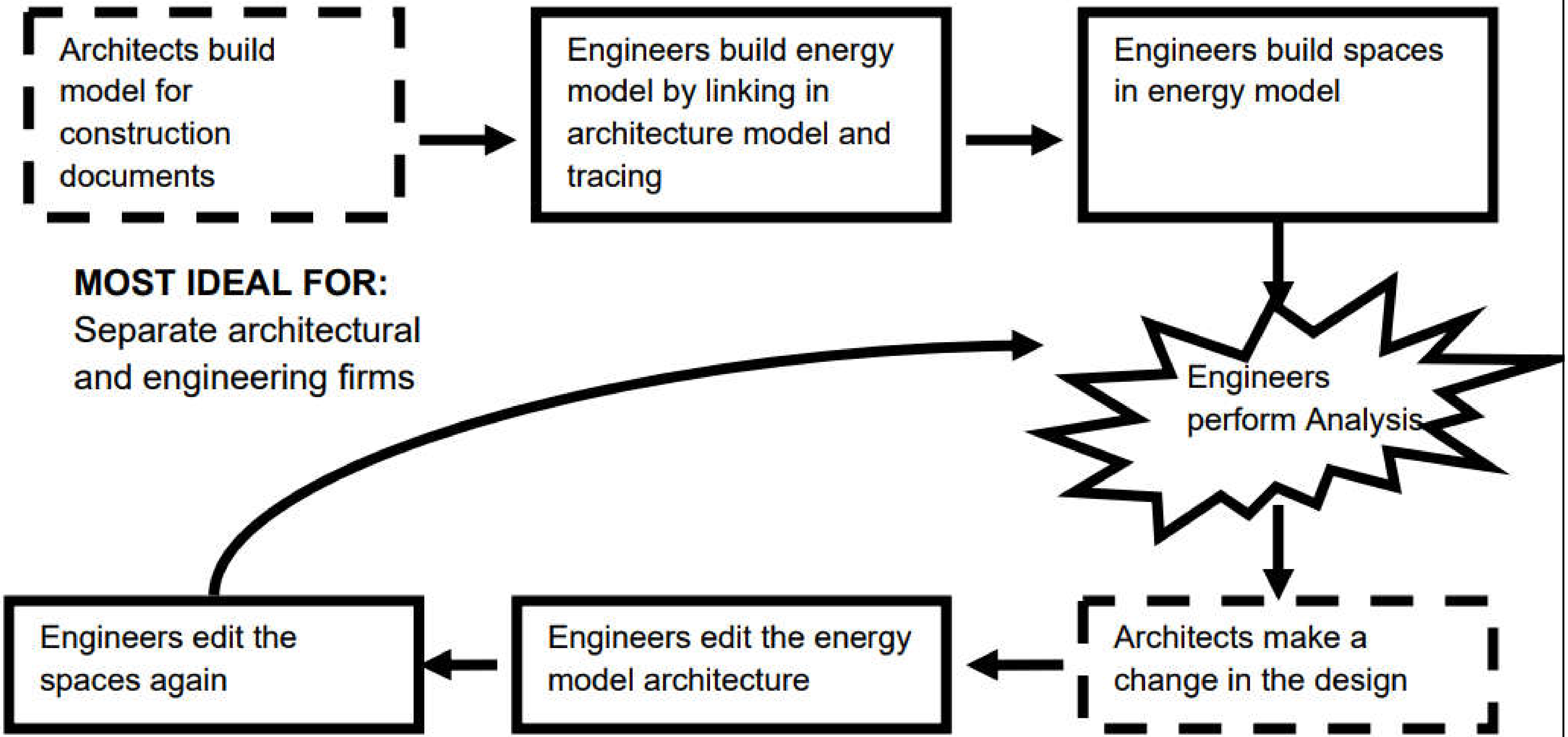






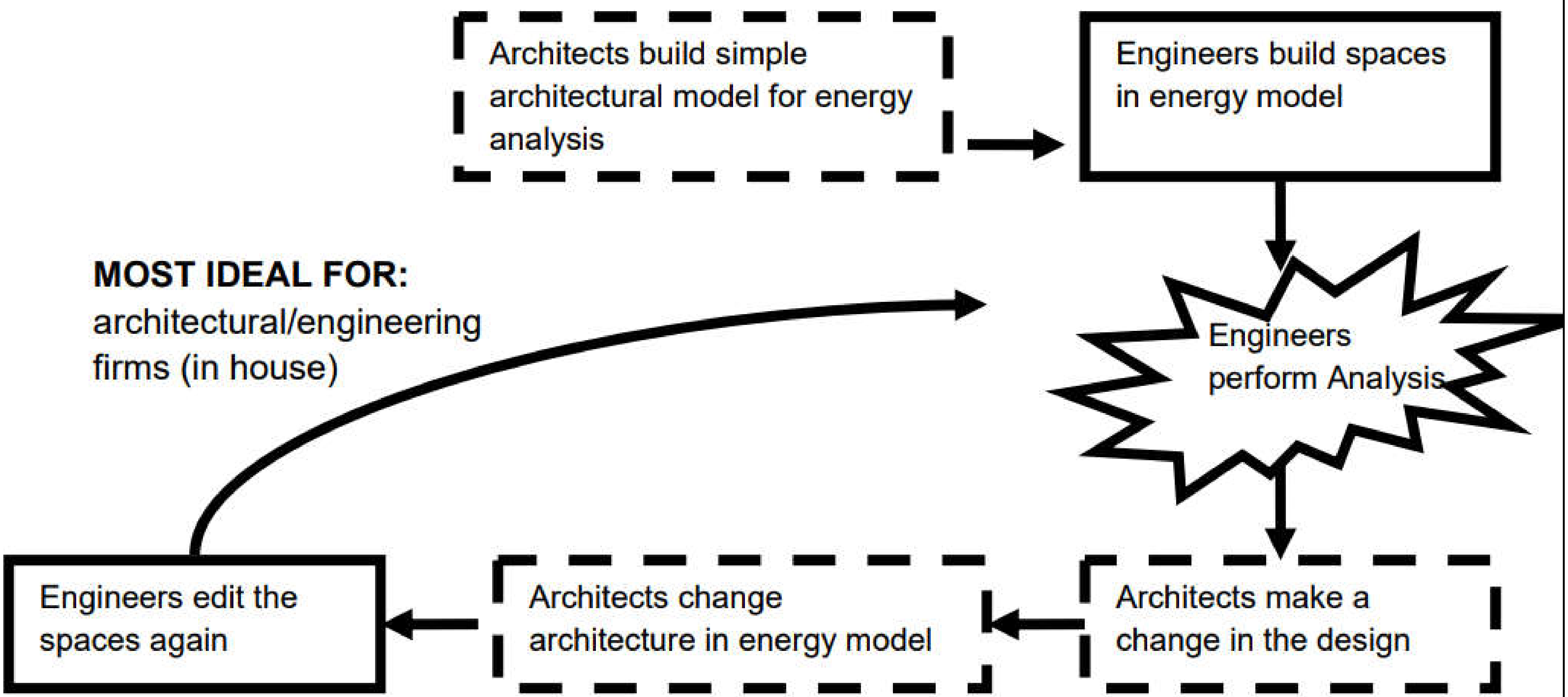
(Source: Getting Started with Autodesk Energy Analysis
http://help.autodesk.com/view/BUILDING_PERFORMANCE_ANALYSIS/ENU/?guid=GUID-E85A114E-BA0D-4811-B1A5-4EE26462708A)

Workflow 1: for separate architectural and engineering firms



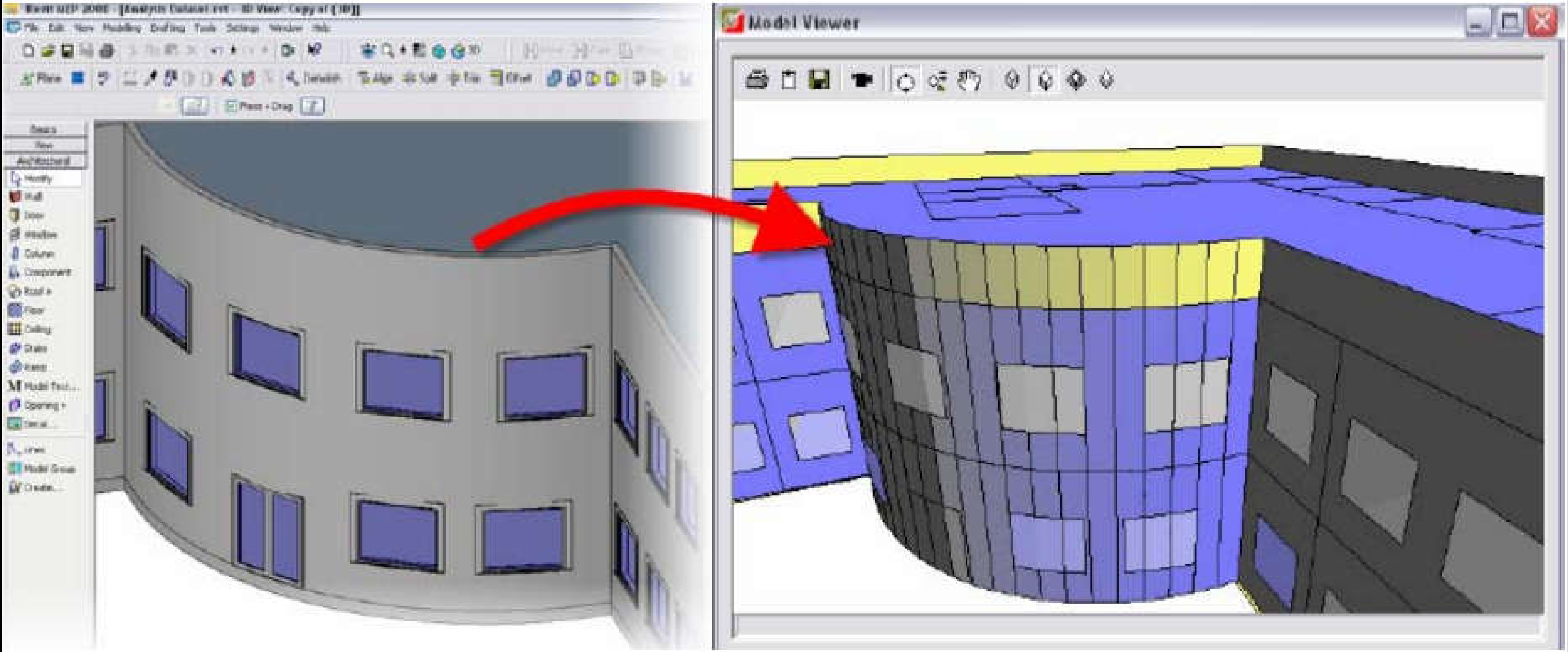
(Source: Leveraging BIM for Energy Analysis https://sustainabilityworkshop.autodesk.com/sites/default/files/core-page-files/leveragingbimforenergyanalysis.pdf)

Workflow 2: for architectural/engineering firms (in house)



(Source: Leveraging BIM for Energy Analysis https://sustainabilityworkshop.autodesk.com/sites/default/files/core-page-files/leveragingbimforenergyanalysis.pdf)

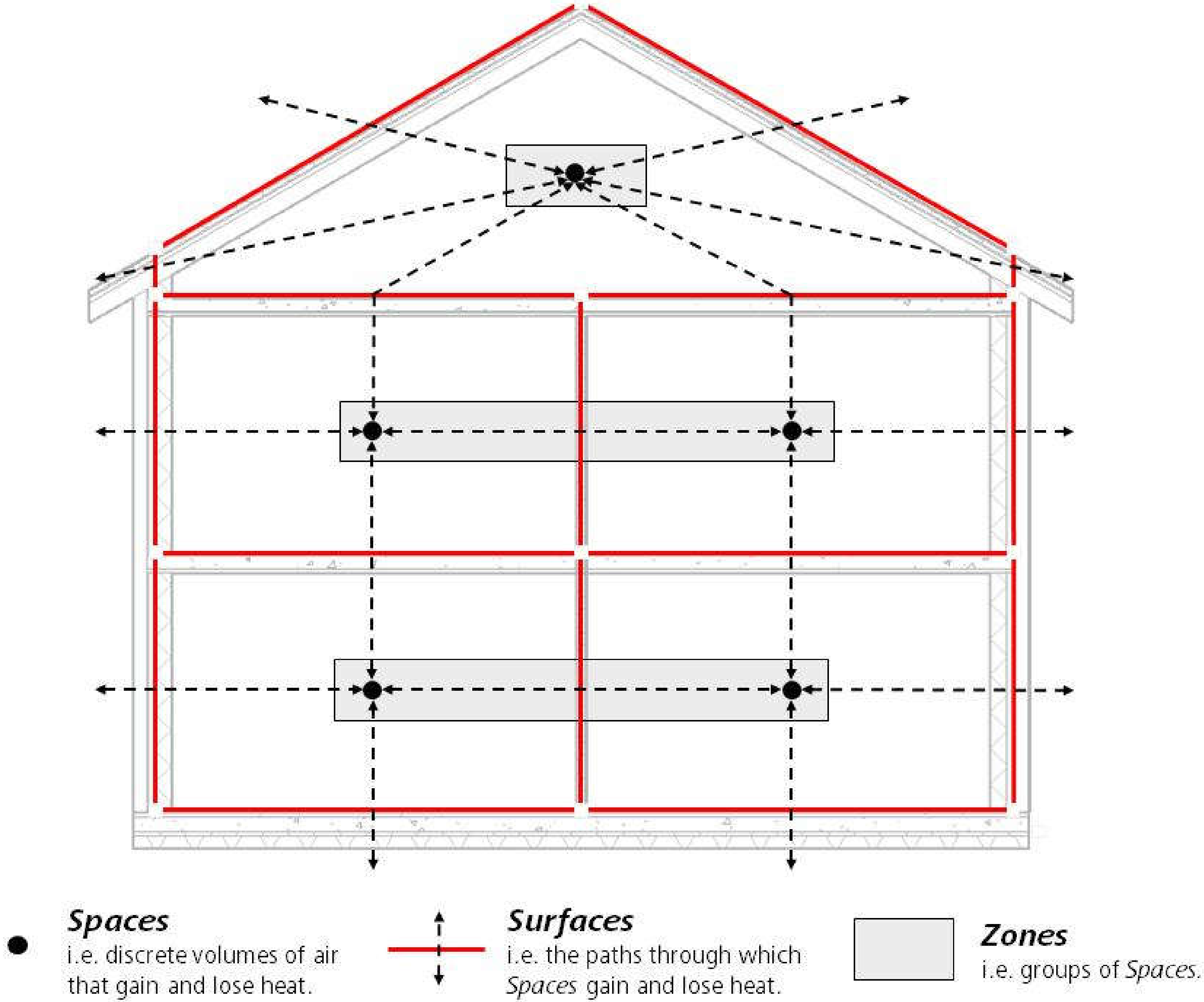
SIMPLIFY the energy model for the analysis: curved wall conversion



The methods of modeling the energy model may result in a model that does not visually look like the actual design, but provides the correct information for the analysis to be done. For example, a curved shading device may have to be split up into multiple small rectangular pieces.

(Source: Leveraging BIM for Energy Analysis https://sustainabilityworkshop.autodesk.com/sites/default/files/core-page-files/leveragingbimforenergyanalysis.pdf)

Geometry modelling and energy analysis model (EAM)

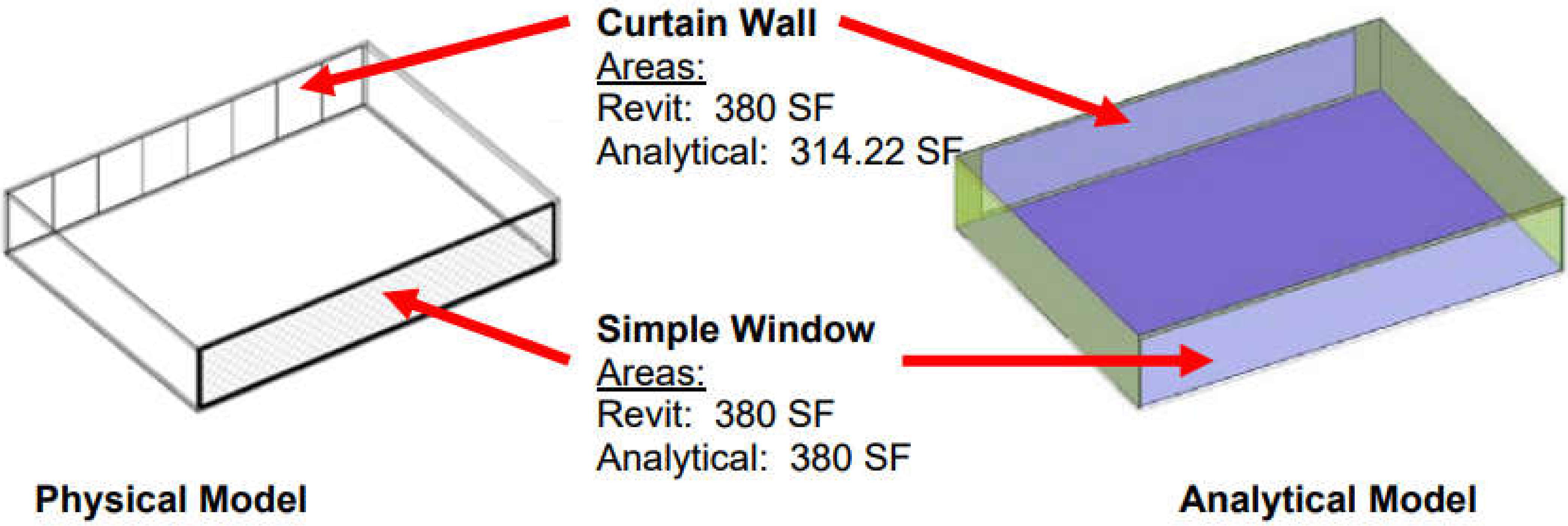


(Source: From BIM to BPA: What is an 'Energy Analysis Model' (EAM)? http://autodesk.typepad.com/bpa/2013/12/from-bim-to-bpa-what-is-an-energy-analysis-model-eam.html)

BIM and energy analysis

- Building energy models for large buildings are more prone to have errors in the export to an energy analysis tool
- For multilevel buildings, spaces should be added to one level at a time and exported to the tool (e.g. eQUEST) to check that the spaces translate properly
  - It is easier to troubleshoot areas that have errors when spaces are added in this manner

Curtain walls are "converted" into surfaces and openings in the analytical model



The Curtain Wall object does not maintain the proper area. The simple window should be used to represent Curtain Wall by extending the window from the floor to the next level. One reason that the curtain wall area may be incorrect is that the mullions are being accounted for in the glazing area, but even when the grid pattern is set to none, the area is still reduced.

(Source: Leveraging BIM for Energy Analysis https://sustainabilityworkshop.autodesk.com/sites/default/files/core-page-files/leveragingbimforenergyanalysis.pdf)

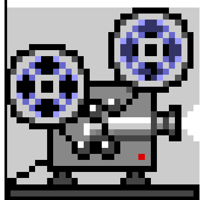
Information available in different design phases in BIM energy modelling

Design phase	**Preliminary design**	**Early design**	**Detailed design**
Information available	Total floor areas, building shape, orientation and so on	HVAC, occupancy schedule, outside air flow per person, outside air flow per floor area, outside air change per hour value, number of users, and so on	Detailed types of HVAC, walls, roof construction, lighting efficiency, lighting control, equipment power density value, light power density value, equipment efficiency, daylighting control, occupancy sensor, glazing, window to wall ratio, and so on
Accuracy of energy modelling	Low	Medium	High

(Source: Adapted from Kim, H. *et al.*, 2016. BIM IFC information mapping to building energy analysis (BEA) model with manually extended material information, *Automation in Construction*, 68:183-193.)

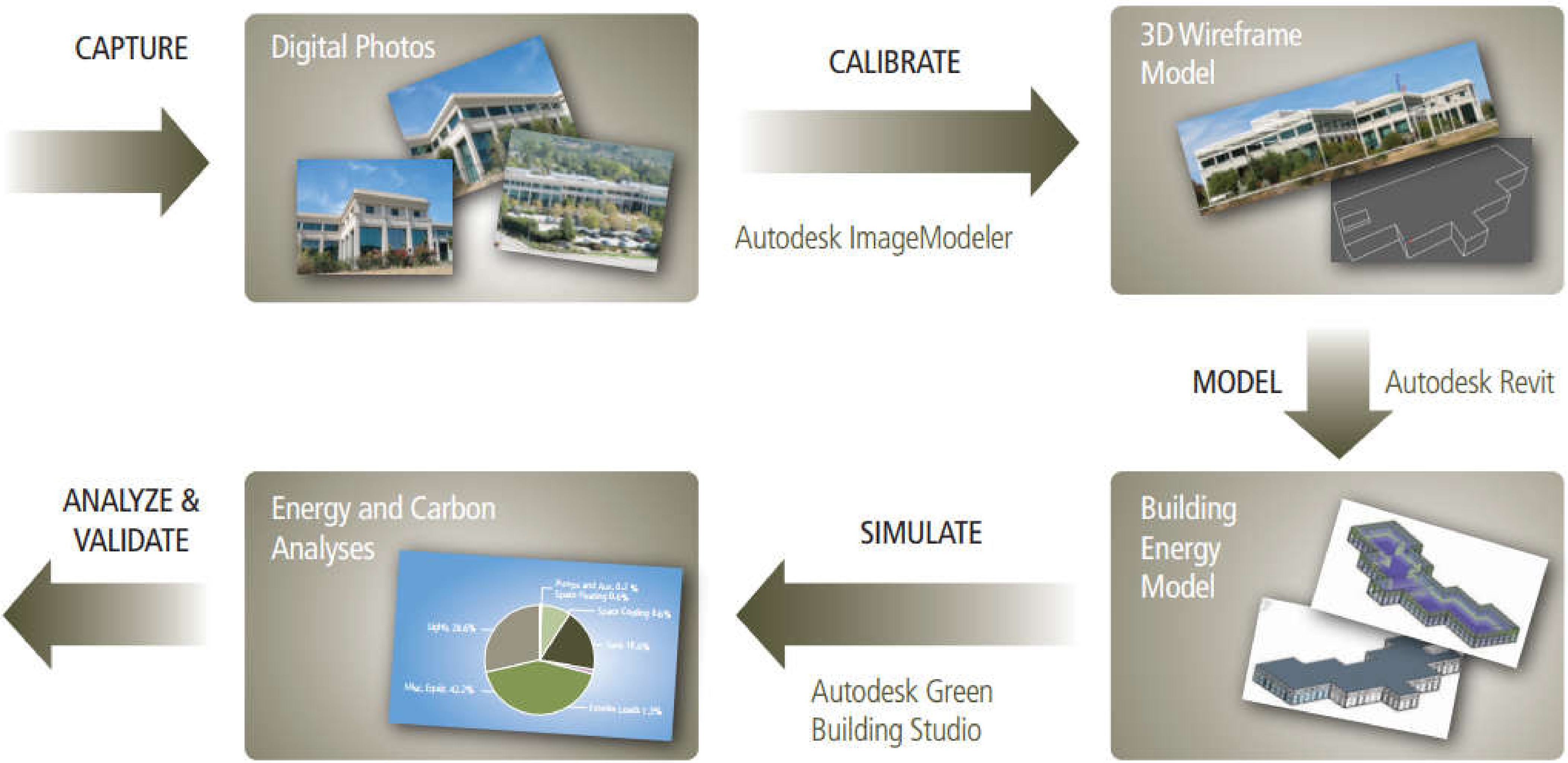
BIM and energy analysis

- Rapid energy modelling (REM)
  - Evaluate numerous design alternatives with less time and cost
  - Shortcut to estimating actual energy use
  - Focus on retrofitting of existing buildings
- Analyse the building energy characteristics
  - 1. Model (capture by digital photos)
  - 2. Evaluate (building energy model)
  - 3. Report (energy & carbon analysis)



(Video: Rapid Energy Modeling for Buildings with Autodesk Software (1:35) https://youtu.be/bq-zGXosSZc)

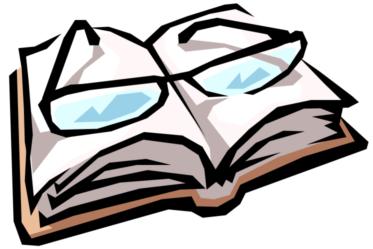
Rapid energy modelling (REM) for existing buildings



(See also: Absolute beginners: Rapid Energy Modelling https://aecmag.com/59-features/1120-absolute-beginners-rapid-energy-modelling)

(Source: Rapid Energy Modeling for Existing Buildings: Testing the Business and Environmental Potential through an Experiment at Autodesk: Executive Summary. http://images.autodesk.com/adsk/files/rem_executive_summary.pdf)

Further reading



- Getting Started with Autodesk Energy Analysis
  - http://help.autodesk.com/view/BUILDING_PERFORMANCE_ANALYSIS/ENU/?guid=GUID-E85A114E-BA0D-4811-B1A5-4EE26462708A
- Leveraging BIM for Energy Analysis
  - https://sustainabilityworkshop.autodesk.com/sites/default/files/core-page-files/leveragingbimforenergyanalysis.pdf
- Autodesk Insight - High performance and sustainable building design analysis
  - https://insight.autodesk.com/oneenergy
  - Sample Insights https://insight.autodesk.com/oneenergy/Sample