

SBS5322 Basics of Building Information Modelling

<http://ibse.hk/SBS5322/>



BIM and sustainable design



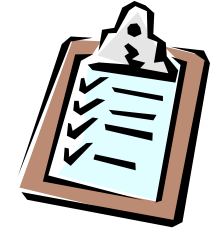
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Jan 2018

Contents



- Environmental impact & architecture
- Sustainable design with BIM
- BIM supported analysis
- Environ & economic aspects
- Analysis tools & workflow

Three dimensions of sustainability

Environmental Sustainability

Ecosystem integrity
Carrying capacity
Biodiversity

Environment

環境

Social Sustainability

Cultural Identity
Empowerment
Accessibility
Stability
Equity

Society

社會

Economic Sustainability

Growth
Development
Productivity
Trickle-down

Economy

經濟

Human Well Being

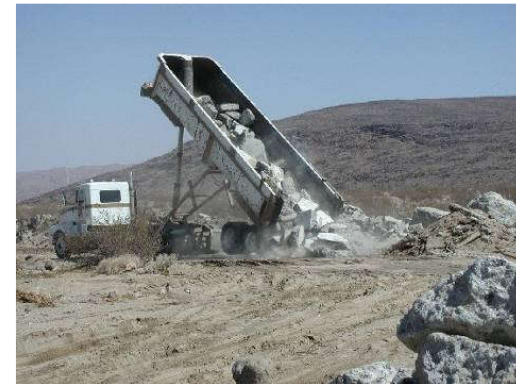


Environmental Impact of Buildings

More people live in urban areas than in rural areas

40% of global raw materials is consumed by buildings

We are running out of fossil energy sources



*„Our generation must be committed to the task of bringing urban areas into balance with the natural environment.”**

**United Nations Environment publication, World Environment Day 2005*

(See also: Environmental Issues & Building Design <https://sustainabilityworkshop.autodesk.com/buildings/environmental-issues-building-design>)

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

Environment and Architecture

Historic Overview:

Traditional architecture:

protective, resists external impacts, small windows

Modern architecture:

large windows, insufficient construction technology, large energy consumption, bad indoor climate

1980s:

counter-balancing bad indoor climate with air conditioning and heating

Sequential Design Process

design disciplines do their job one after the other

Environment and Architecture

Historic Overview:

1973-74 energy crisis:

energy over-consumption becomes an issue

Building energy research:

study and simulation of energy currents through the building envelope

Sustainable buildings:

minimal environmental impact
design, construction and maintenance

Simultaneous Design Process

activities of design disciplines overlap to optimize efficiency and save time

Environment and Architecture

Architectural Design Guidelines:

- **Functional:** constructional, operational
- **Human:** safety and security, health, comfort
- **Cultural:** aesthetics, social context

- **Ecological:** energy use, energy sources, building materials, water management, waste and pollution management

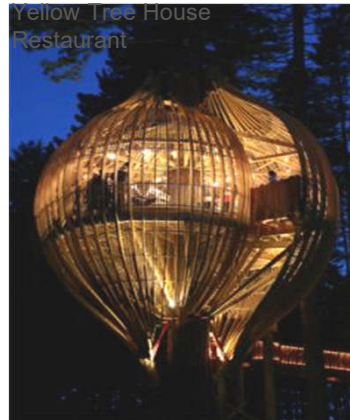
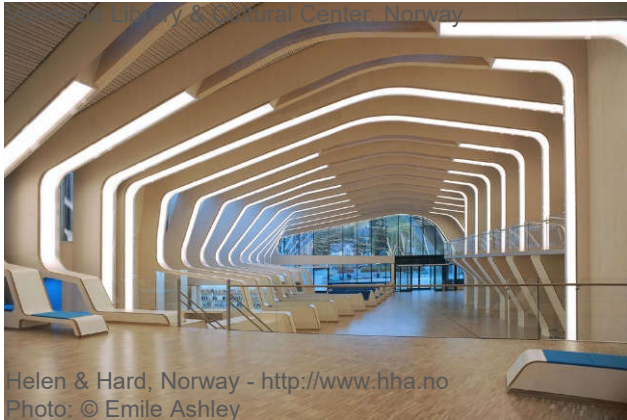
- **Economical:** profit, life cycle cost

Sustainable design with BIM



- Sustainable design considerations:
 - Understand climate, culture and place
 - Understand the building typology
 - Reduce the resource consumption need
 - Use free local resources and natural systems
 - Use efficient man made systems
 - Apply renewable energy generation systems
 - Offset negative impacts

Sustainable Design Disciplines

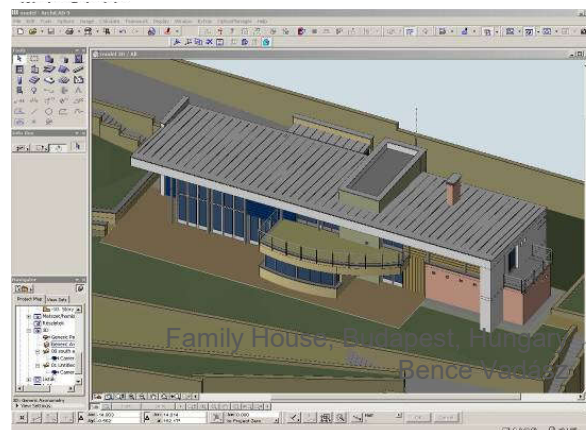


- Sustainable sites
- Water efficiency
- Energy and atmosphere
- Materials and resources
- Indoor environment
- Innovation in design
- Regional priority

Sustainable Design with BIM

Building Information Modeling

Intelligent building model (virtual building)



Sustainable design with BIM

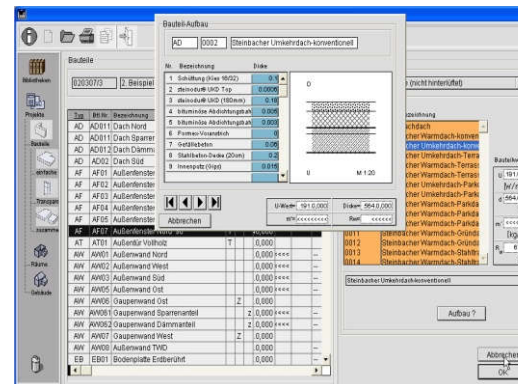
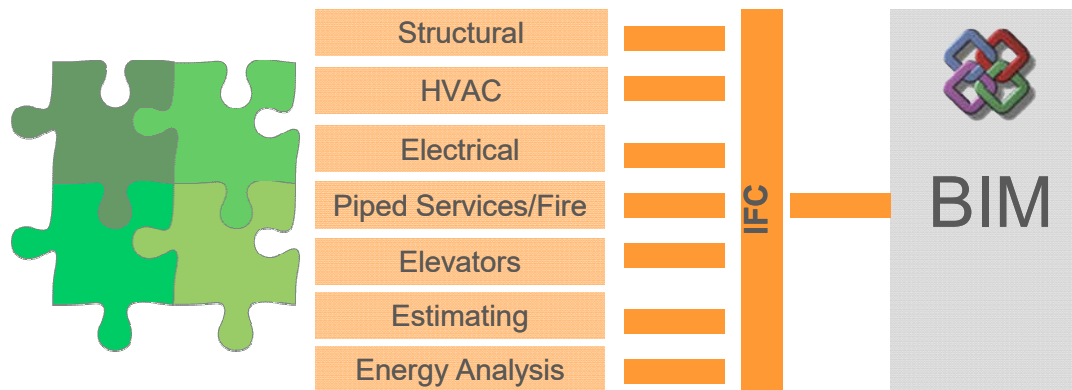


- BIM advantages include:
 - Ability to analyze
 - Ability to evaluate green buildings
 - Access to info to make sustainable decisions
- Performance analysis & evaluation
 - Merge of design & analysis = optimize building performance
 - Better quality of data = minimum errors and miscalculations

Sustainable Design with BIM

BIM as Collaborative Foundation

- Sharing and exchange of BIM information e.g. to execute simulations
- Strategic cooperation between software vendors



←←← BIM

- Structural Engineering
- Collision Detection
- Code Checking
- Building Performance and energy simulations


Sustainable design with BIM



- BIM enables sustainable design analysis
 - BIM provides important data and information for design projects and also encompasses several important functions for building performance and sustainable design analysis
 - Common software tools:
 - Autodesk Ecotect
 - Autodesk Green Building Studio (GBS)
 - Integrated Environmental Solutions (IES) Virtual Environment (VE)

BIM and Building Performance Analysis (BPA)

BIM
Building Information Modeling

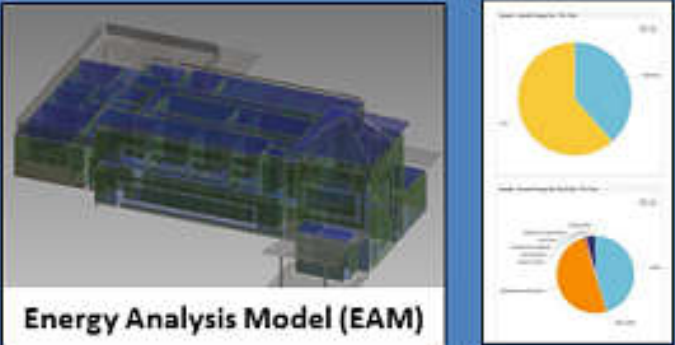


- Visualization
- Structural analysis
- Cost
- Documentation
- Fabrication/Construction
- Etc...

Building Performance Analysis (BPA)

Whole Building Energy Analysis

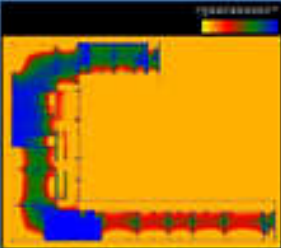

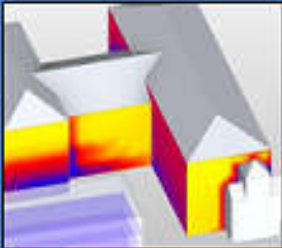
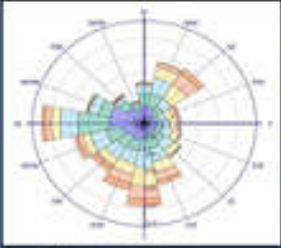
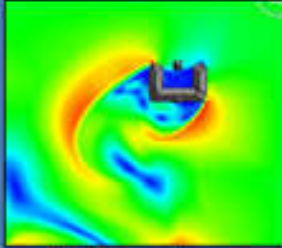

- Conceptual Models
- Detailed Models



Energy Analysis Model (EAM)

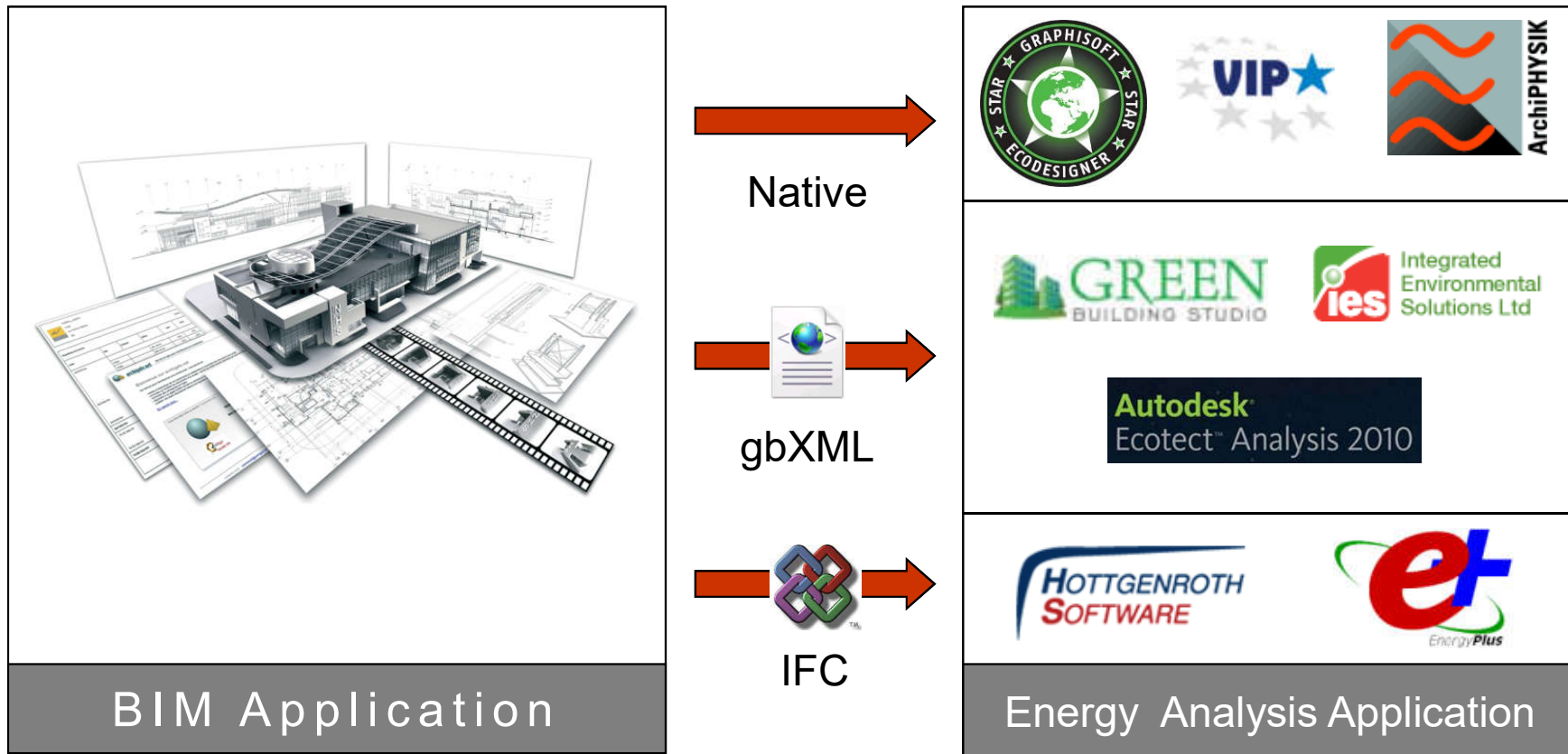
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Other Performance Studies

 <p>Lighting & Daylighting</p>	 <p>Sun & Shadows</p>	 <p>Solar Radiation</p>
 <p>Climate Analysis</p>	 <p>Airflow & Ventilation</p>	 <p>Lifecycle Analysis</p>

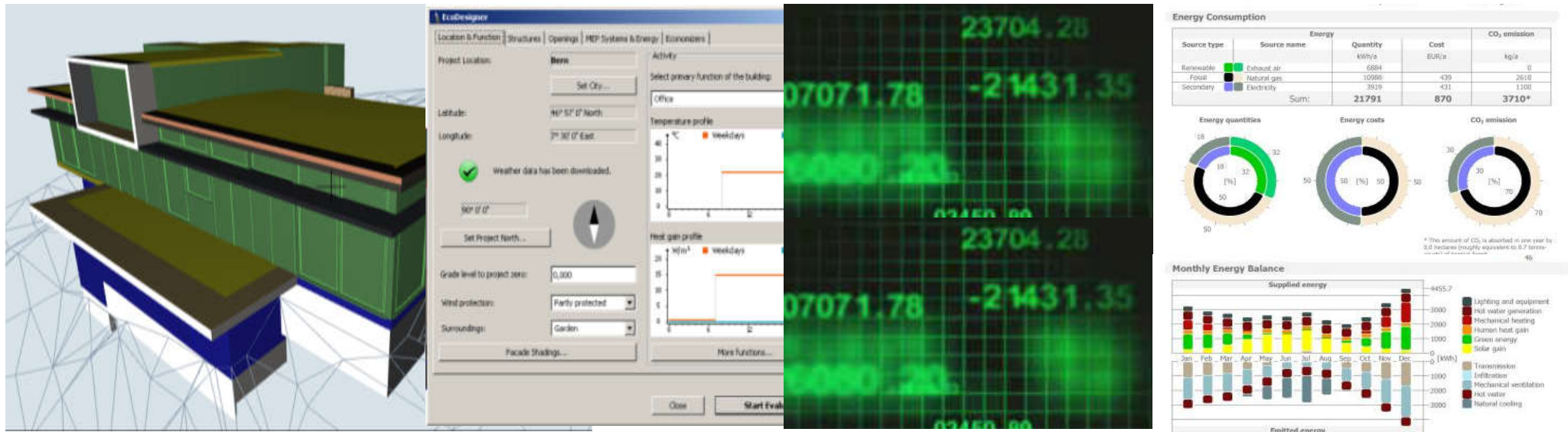
Sustainable Design with BIM

BIM and Energy Software Collaboration



Sustainable Design with BIM

BIM-Integrated Energy Simulation



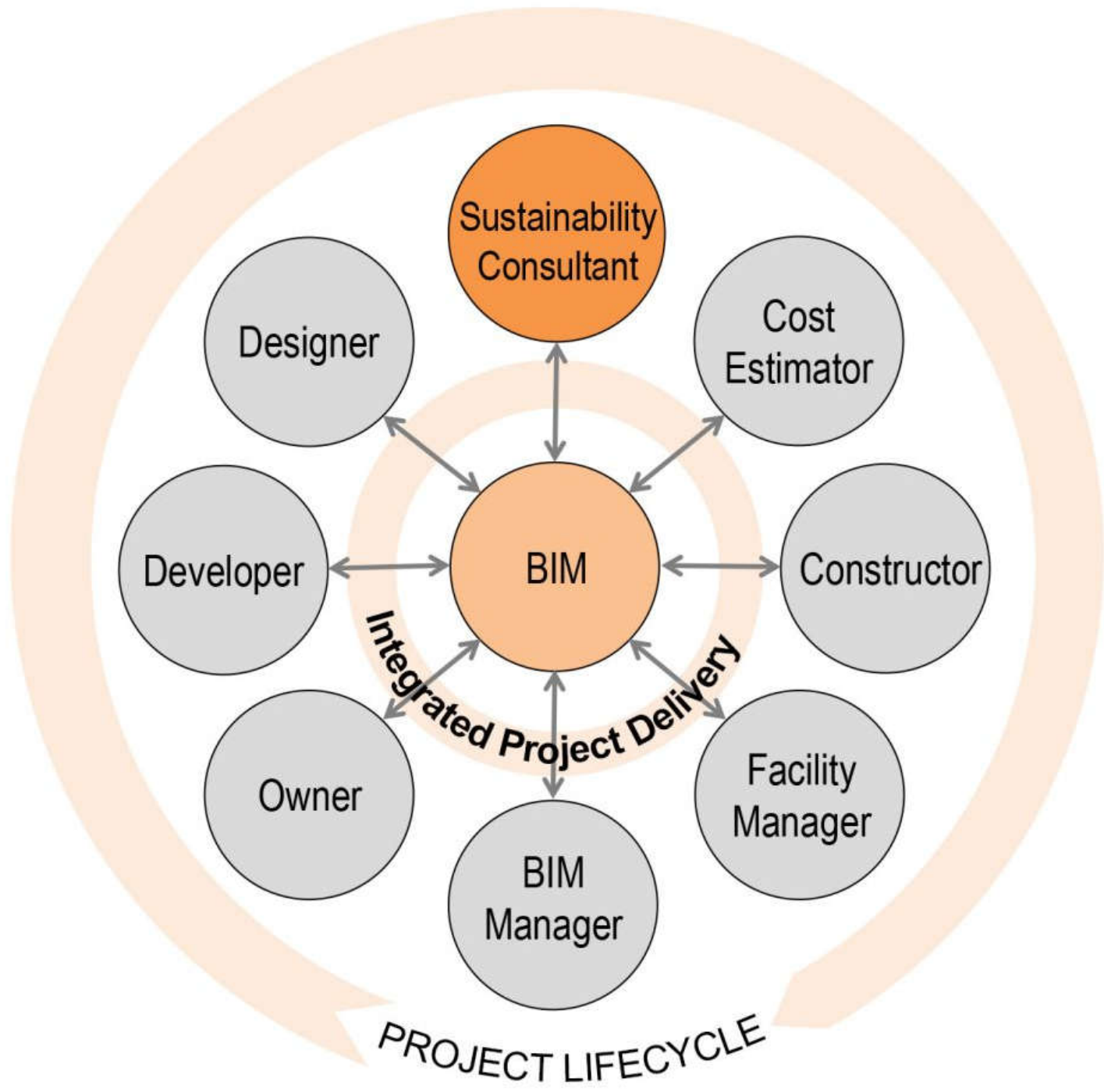
- Model geometry analysis
- Additional data input
- Annual hourly energy simulation
- Results

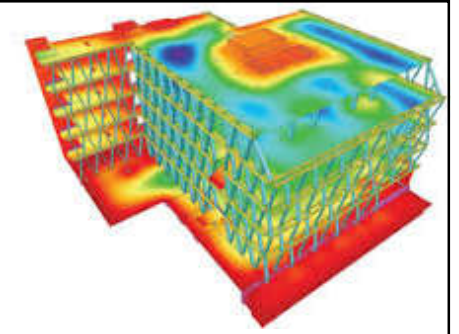
Sustainable design with BIM



- **Green BIM** in sustainable infrastructure
 - Planning site location and analysis
 - Planning building design and analysis
 - The use of natural ventilation, natural lighting and shading effective measures
 - The use of solar energy
 - Rainwater recycling and waste recycling
 - The use of permeable ground & green materials
 - Focusing on ecological maintenance
 - Energy-efficiency and performance analysis

Sustainability consultant and BIM for integrated project delivery





BIM supported analysis

- BIM can be used for:
 - Decision making
 - e.g. placement, orientation and massing of site/building (by evaluating overshadowing, solar access, prevailing wind using 3D visualization & energy analysis)
 - Building performance analysis
 - Fenestration orientation, heat loss/gain, daylight
 - Planning for renewable energy systems
 - e.g. shading & visual impact
 - Rating compliance (green building assessment)

Example of early sustainable design decisions

Could I power my building with photovoltaics and wind power?

How much would adding insulation help reduce energy?

How could I optimize occupancy?

Should I change out my windows?

How much energy should my building use per year?

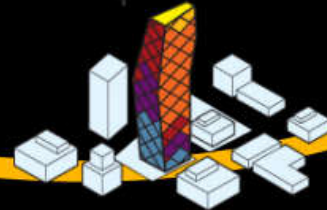
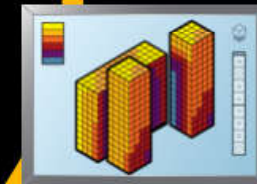
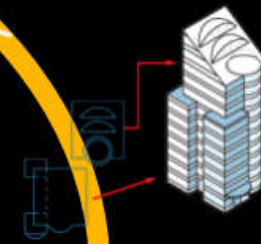
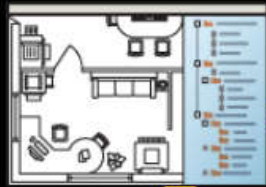
How sensitive is my portfolio to changes in weather?

How can I utilize the surrounding land to reduce energy waste?

Which envelope material will reduce energy the most?

To achieve net zero, should I go for a multi-story tower or a larger floorplate?

How could I minimize embodied carbon and construction waste?



Building performance analysis & evaluation at design phase

Energy modelling	Reducing energy needs and analyzing renewable energy options that can contribute to low energy costs
Building orientation	Reduce energy costs
Building massing	Analyze building form and optimize building envelope
Sustainable materials	Reduce materials needs and use recycled materials
Site and logistics management	Reduce waste and carbon footprint
Daylight & lighting analysis	Reduce energy costs & improve indoor environment
Wind & ventilation analysis	Optimize wind/ventilation effects to enhance air flow and air quality
Water analysis	Reduce water needs & recycling in the building
Economic analysis	Forecast financial impacts
Life cycle analysis	Evaluate life cycle performance & impacts

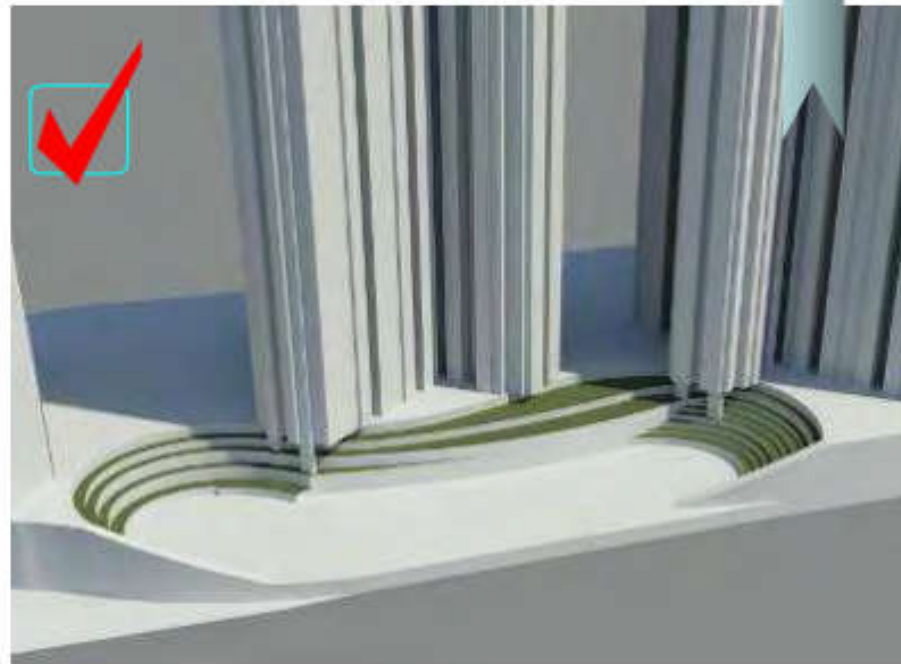
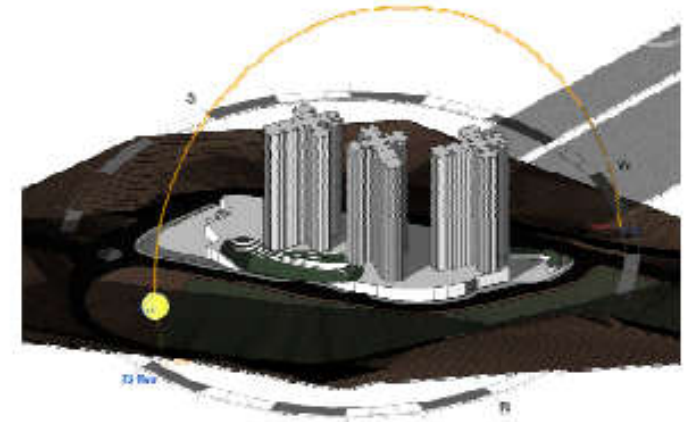
(Videos: Conduct a LEED daylighting analysis directly from Revit (3:48) <https://youtu.be/L3x15tcRJCg>;

A Quick Introduction To Insight & Revit's Energy Modeling and Analysis Tools | Autodesk (21:44) <https://youtu.be/FNqS0K-Cr2Q>)

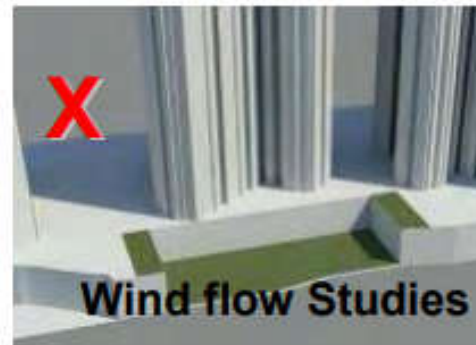
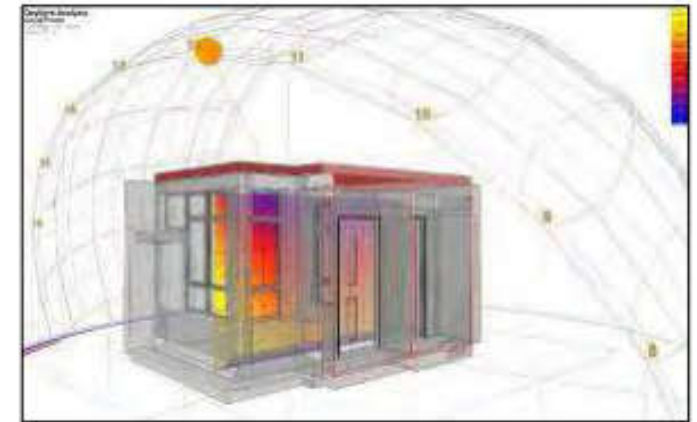
Studies on sunlight & shadow, daylight and wind flow



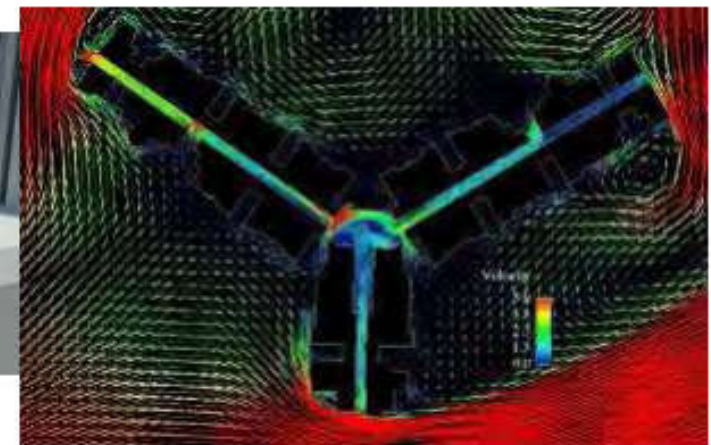
Sunlight & Shadow Studies



Daylight Analysis



Wind flow Studies



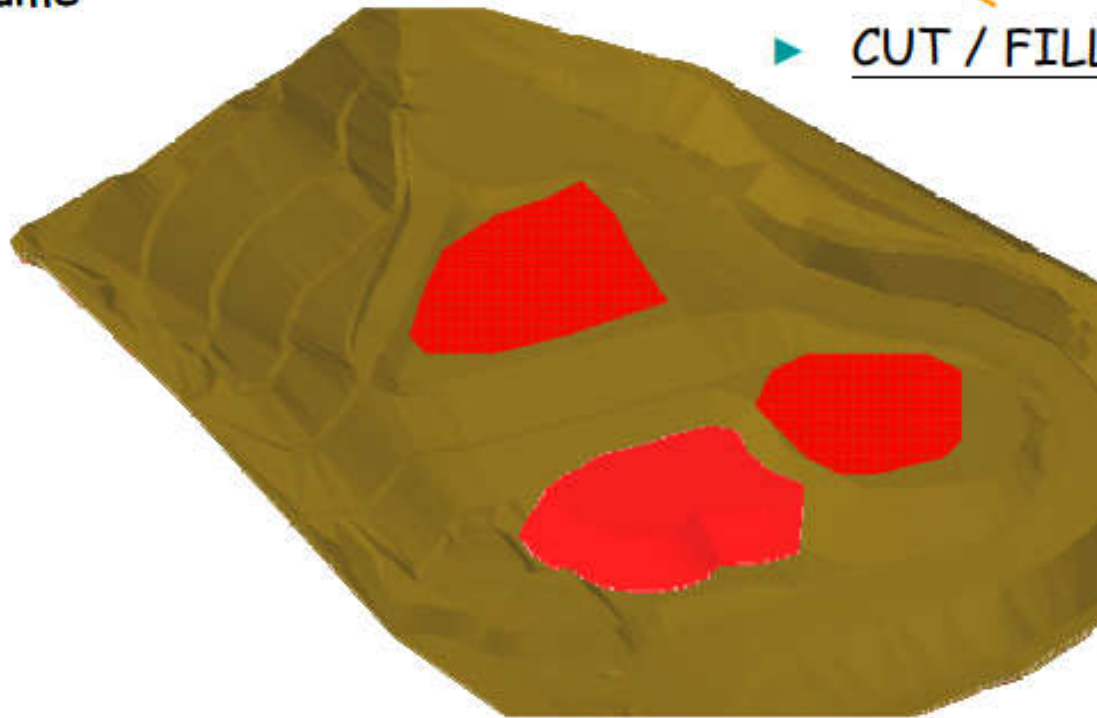
Enhance cost control and environmental protection for “cut and fill”

Balancing of Cut and Fill volume

Schedule of Mass Concrete Fill for Footing						
Name	Mark	Projected Area	Surface area	Cut	Fill	Net cut/fill
Pad RFTG	Pad RFTG-4	2928m ²	3122m ²	0.00m ³	22300m ³	32m ³
Pad RFTG	Pad RFTG-1	4587m ²	4956m ²	0.00m ³	27300m ³	50m ³
Pad RFTG	Pad RFTG-1	4587m ²	4956m ²	0.00m ³	27300m ³	50m ³

► Excavation volume

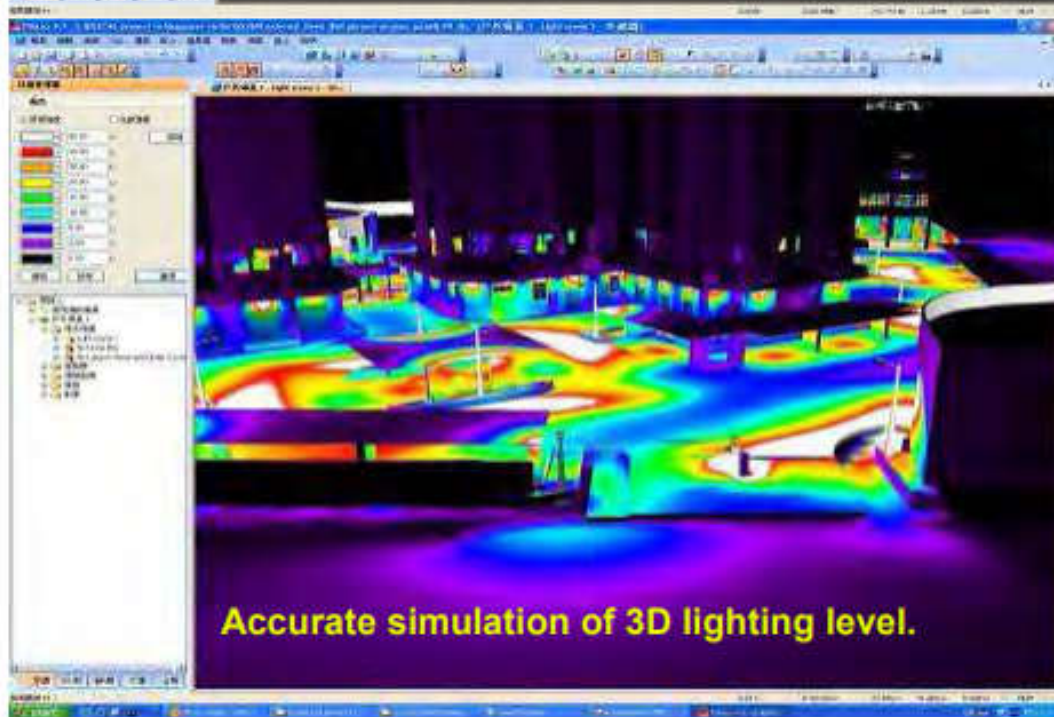
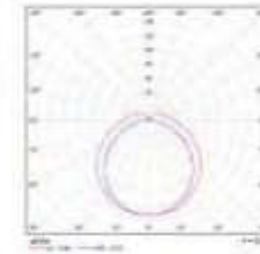
► CUT / FILL volume of each Mass Fill



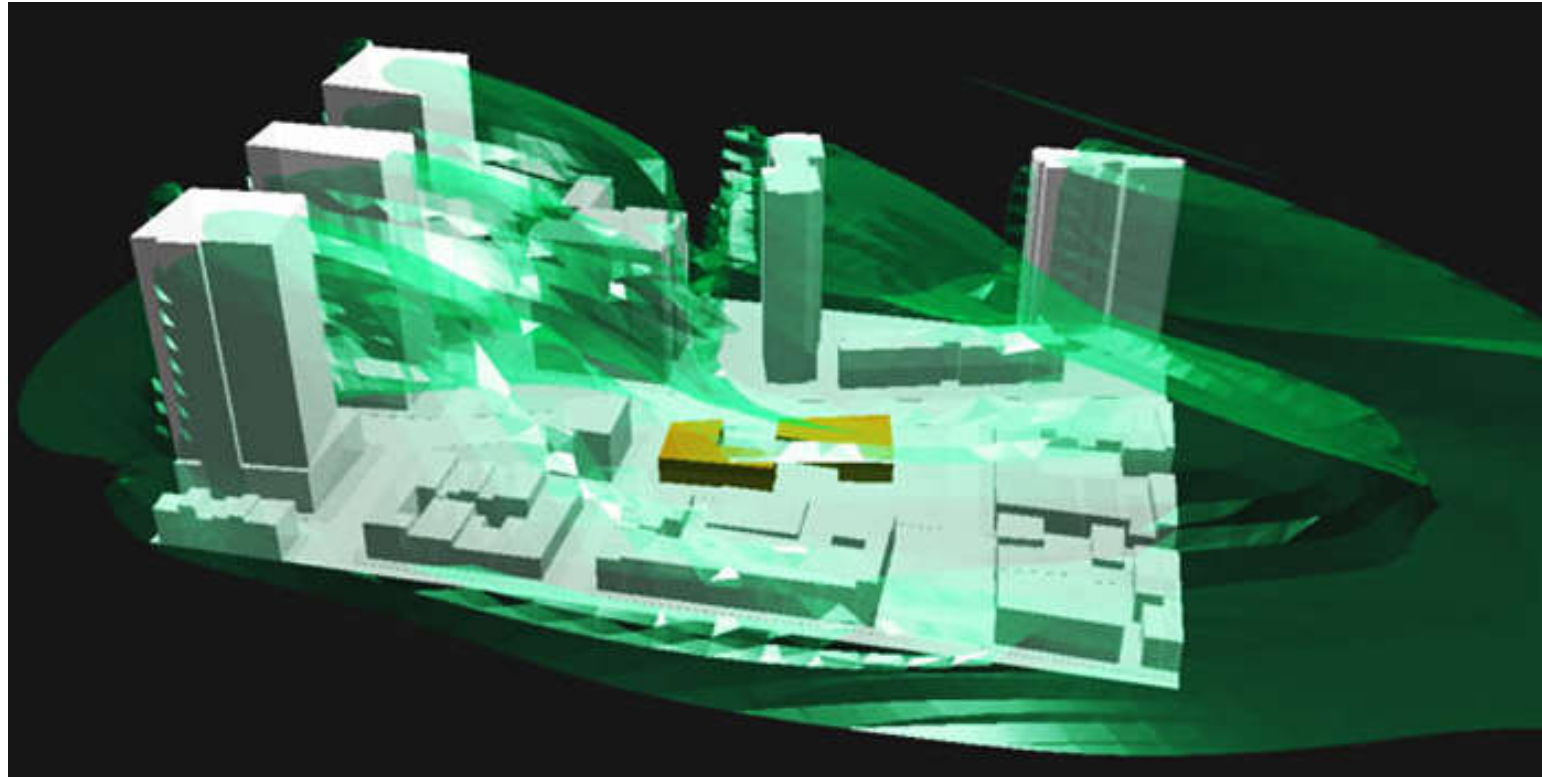
Optimize lighting design for energy saving



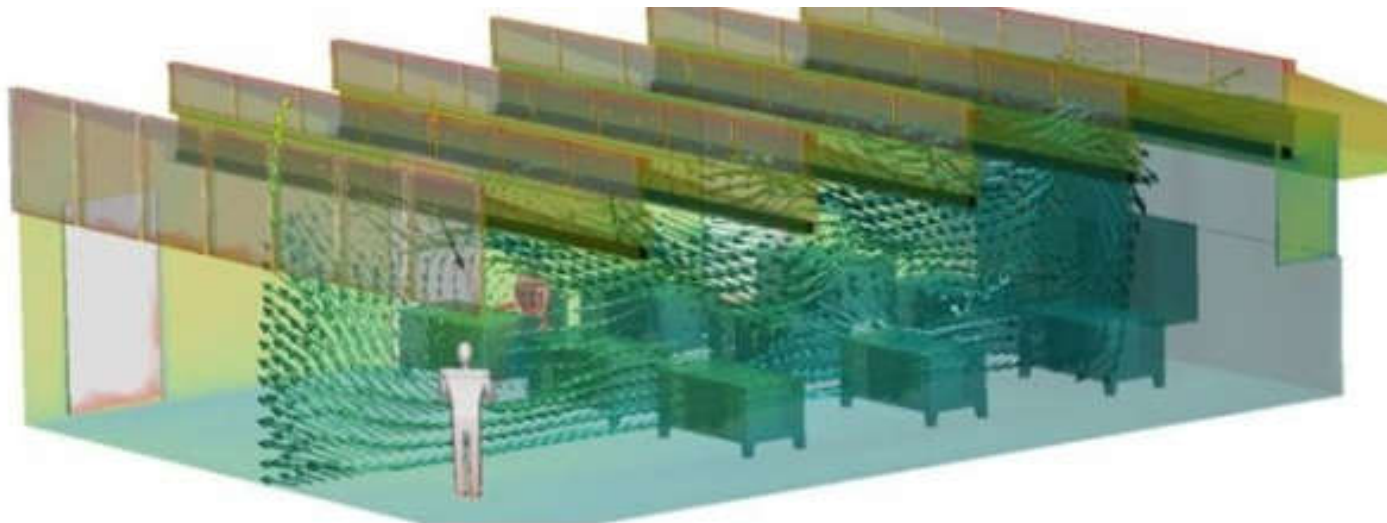
Development of more energy efficient lighting operation mode.



Wind & ventilation analysis in BIM



External
air flow
analysis



Internal
air flow
analysis

Life cycle assessment of buildings



Sustainable buildings lifecycle, technology, maturity



Application of Sustainability in Buildings

Pre-Design

- Material Selection
- Building Program
- Project Budget
- Team Selection
- Partnering
- Project Schedule
- Laws, Codes & Standards
- Research
- Site Selection

On-Site

- Site Analysis & Assessment
- Site Development & Layout
- Watershed Management & Conservation
- Site Material & Equipment

Design

- Passive Solar Design
- Materials & Specification
- Indoor Air Quality

Construction

- Environmentally Conscious Construction
- Preservation of Features & Vegetation
- Waste Mgmt Practices
- IAQ Issues
- Source Control Practices

O&M

- Maintenance Plans
 - Indoor Quality
 - Energy Efficiency
 - Resource Efficiency
 - Renovation
 - Housekeeping & Custodial Practices
- (O&M: operation and maintenance)

Building analysis & evaluation at construction & operation phases

Continuous analysis for environmental effects	Evaluate the environmental effects (e.g. air & noise pollution) & propose methods to lower them
Thorough design details	Minimize construction defects to reduce the ongoing operational costs and ensure a faster, safer construction
Material take-offs	Enable off-site fabrication using a co-ordinated model to eliminate over-ordering, reduce waste, allow off cut materials to be reused or recycled, and to achieve fewer deliveries to and less waste removal from site
Monitoring & recording building performance	Including water/wastewater, energy and carbon emission, to support better decisions for improvements
Updated alterations & changes to the building	Additions/adjustments made to building can be easily tracked and recorded
Seasonal commission and maintenance	Plan maintenance activities that can be synchronized minimizing cost and disruption of occupants
Access to sustainable information	Engage occupants and management with access to sustainability information and dashboards in their buildings

Environ & economic aspects



- Waste reduction
 - Prefabrication
 - Material optimization
 - Buildability
- Embodied energy/carbon
 - Material selection
 - Life-cycle carbon/environmental impact
 - Whole life costs



Environ & economic aspects



- Parametric modelling & sustainable design
 - Form finding using BIM parametric modelling
 - Façade design
 - Analysis of aesthetics (w/ visualization)
- Rating compliance
 - Native BIM checking
 - Semi-native BIM checking
 - Export IFC or gbXML for analysis or visual check
 - Rule-based checking tools (apply custom rules)

Economical Aspects of Sustainability

A typical office building costs about three times its initial cost to operate and maintain over 30 years.

Carefully implemented sustainable design only costs 2% more to build but may pay back the original investment 10 times over.

Reduced energy consumption due to strategic green investments has a stronger effect on the Life Cycle Cost than the original investment.

„If the team members involved know what they are doing, you can go pretty far down the path of creating a green building without adding extra costs at all. „

Environmental Building News editor Nadav Malin

Economical Aspects of Sustainability

Life Cycle Analysis

Energy calculations and cost simulations can be used concurrently to ensure that energy-conservation and capital goals are met.

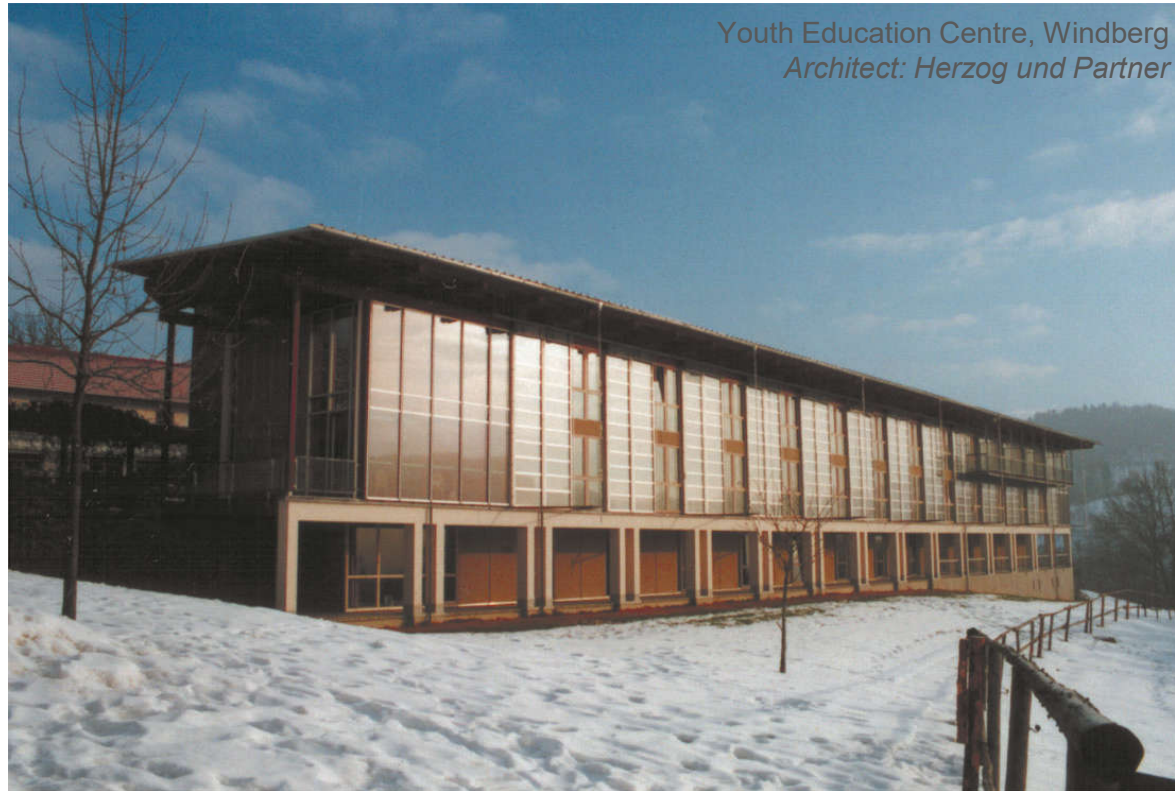
Whole Life Cost = LCC + Profit + non construction cost

Life Cycle Cost (LCC)

- Construction
- Operation
- Maintenance
- End of life



Economical Aspects of Sustainability



„Going ‘green’ pays off: sustainable design benefits people, the environment, and the bottom line. „

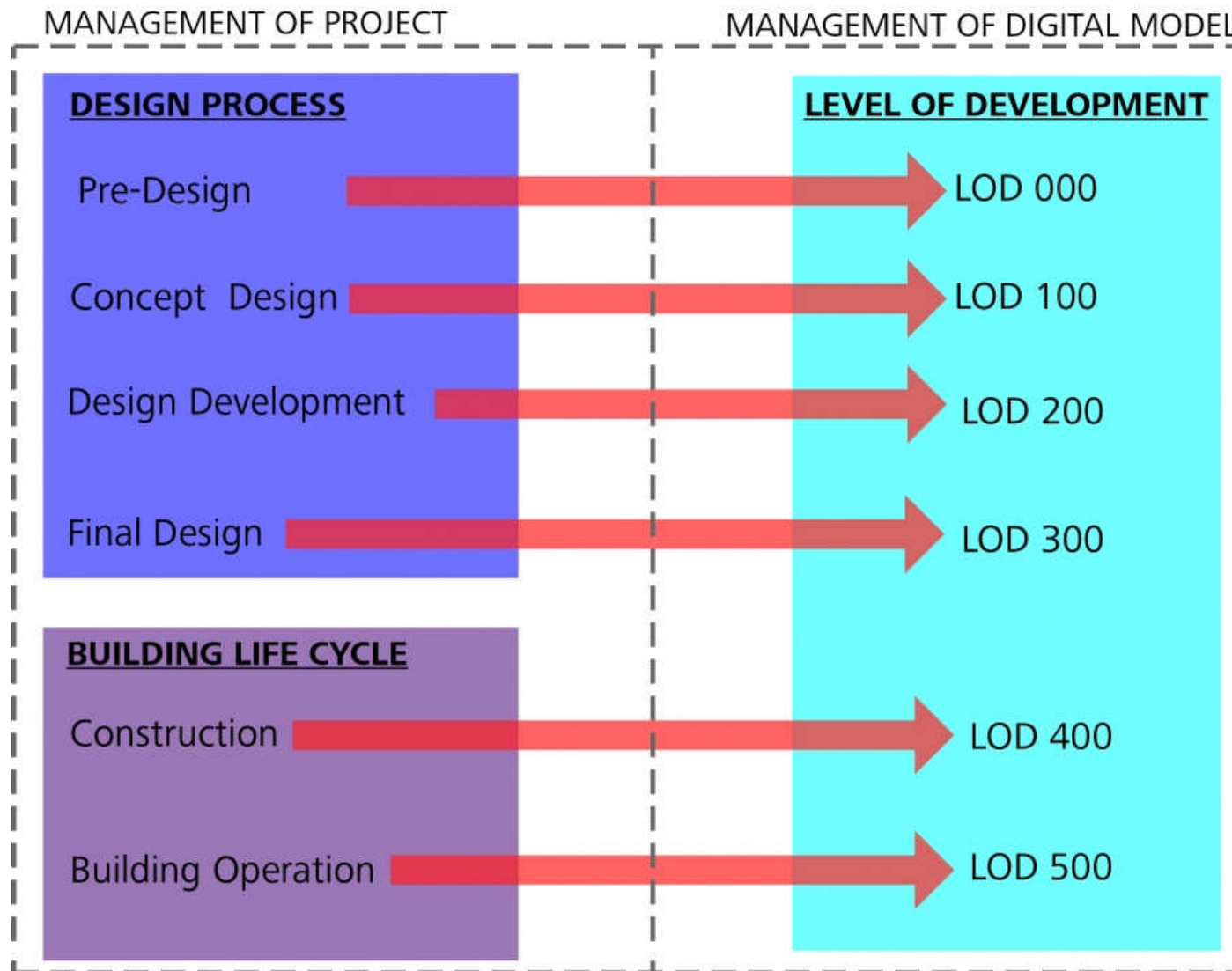
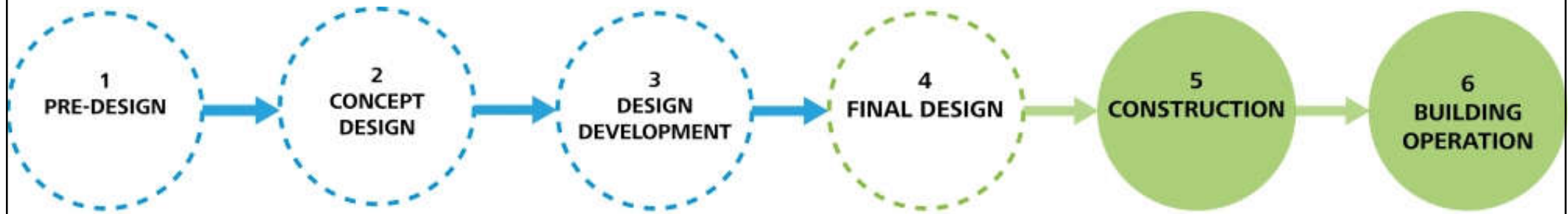
General Service Administration, U.S.

Analysis tools & workflow

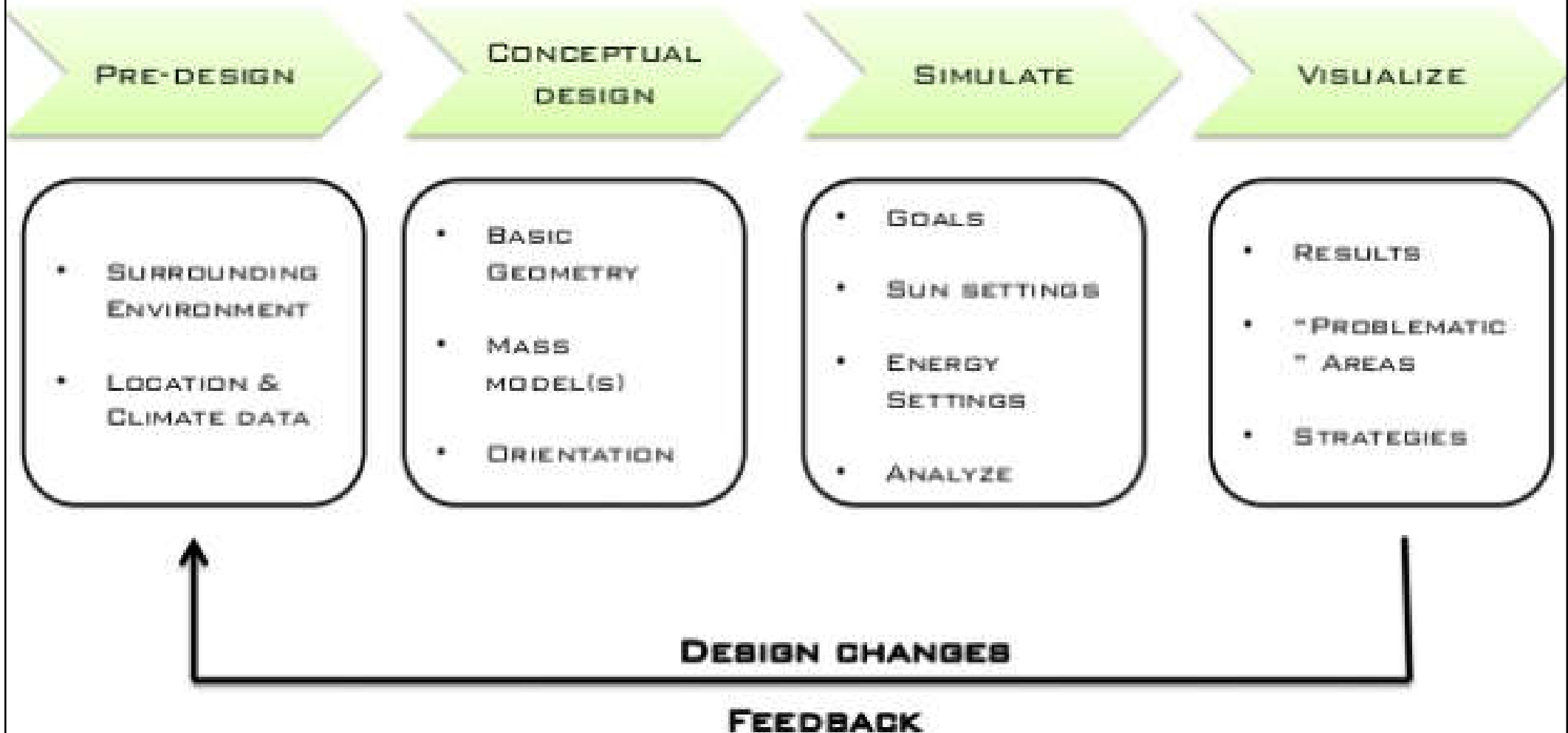


- Integrate sustainable design tasks with BIM
 - 1. Separate software: can use file exchange with BIM or is integrated with a BIM server using a specific interface. It is easy to realise and use
 - 2. The analysis function in BIM software: could be implemented by programming to BIM software
 - 3. Integration with help of parametric formats: an intermediate solution that allows representing not only product information but also calculations used in the analysis

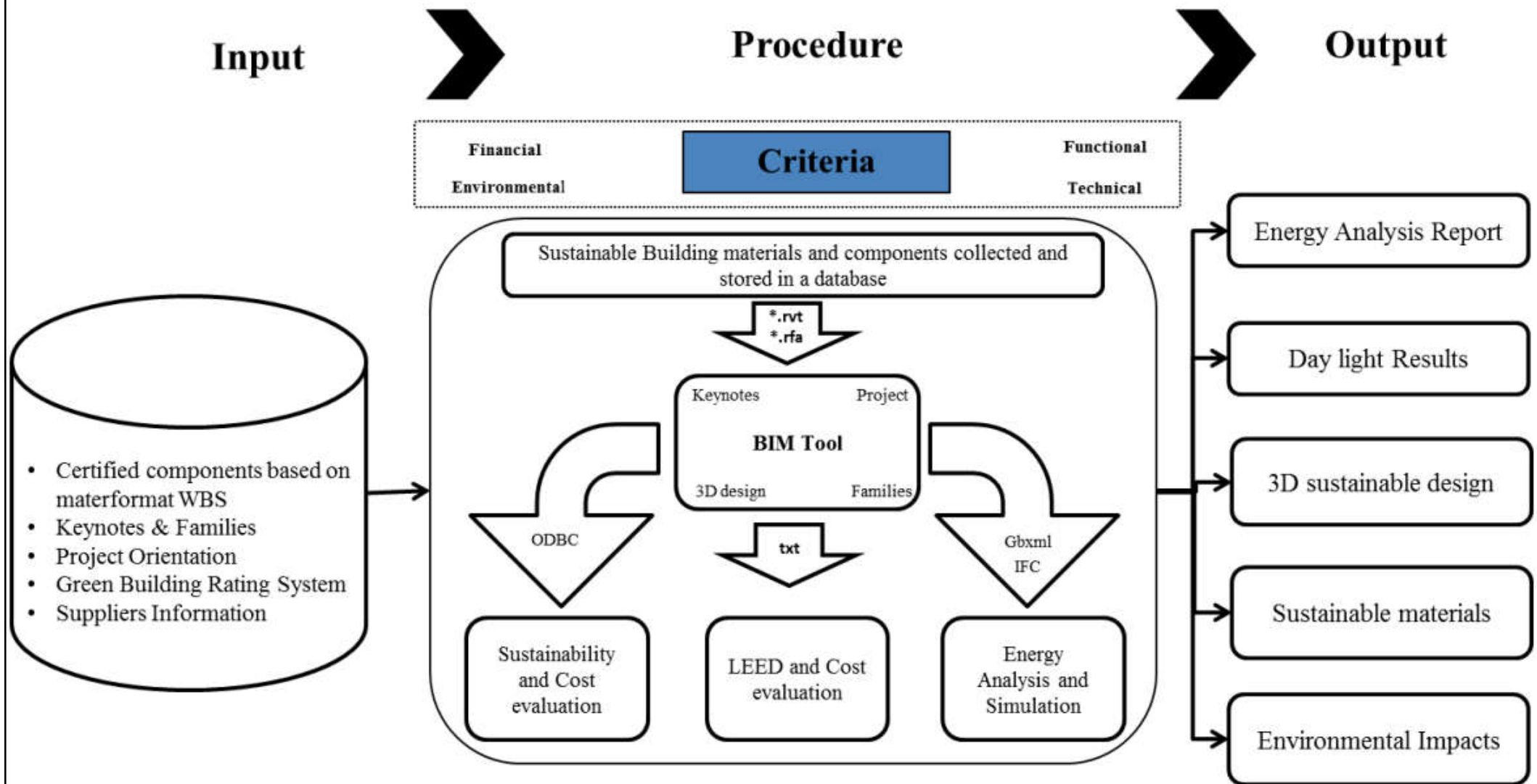
Typical project phases and level of development



Basic workflow of analysis at pre-design and conceptual design stages



Integrating BIM and energy analysis tools for sustainable building design



(Source: Jalaei, F. and Jrade, A., 2014. Integrating building information modeling (BIM) and energy analysis tools with green building certification system to conceptually design sustainable buildings, *Journal of Information Technology in Construction*, 19: 494-519.

<http://www.itcon.org/2014/29>)

Analysis tools & workflow



- Analysis process using BIM and workflows
 - Knowing goals and metrics
 - Using tools for simulation & analysis
 - Design optimization decisions
- May need to use different models and different tools for different types of analysis, at different points of time in the process

Mapping analysis tools to design themes

Program and function	Site and climate	Air flow and quality	Visual comfort	Thermal comfort	Acoustic comfort	Materials and surfaces	Energy systems	Construction cost	Operation and energy
Task	Task	Task	Task	Task	Task	Task	Task	Task	Task
Energy demands Comfort demands Room function Building operation schedules	Climate analysis Site elements Site qualities	Turbulence Infiltration Indoor air flow Thermal distribution Natural ventilation	Daylight levels Glare Visibility Reflections	Heating hours Overheating Outdoor spaces Passive solar heat Solar radiation	Reverberation time Sound rays distribution Quality of room acoustic	Embodied energy Thermal properties Glazing properties Reflection values LCA	Renewable energy systems Effect of sun power Mechanical systems	Overall construction cost Material cost Components cost Area calculation	kWh Energy Energy cost Energy saving Operation cost
Tools	Tools	Tools	Tools	Tools	Tools	Tools	Tools	Tools	Tools
Ecotect DesignBuilder IES iDBuild Excel	Weather Tool DMI Meteonorm Google Earth	Simulation Vasari WinAir DesignBuilder	Ecotect DaySim Radiance 3ds Max DesignBuilder iDBuild	Ecotect Vasari Revit MEP IES DesignBuilder iDBuild	Ecotect	Ecotect IES DesignBuilder iDBuild	Ecotect IES DesignBuilder iDBuild	Sigma Revit/Vasari Ecotect Excel	Revit/Vasari Ecotect Sigma Excel
Target	Target	Target	Target	Target	Target	Target	Target	Target	Target
Framing the design space	Better understanding of climate and site	Comfortable air flows Good air quality	Better visual and spacial comfort Comfortable contrasts	Better thermal comfort Less overheating and cold drags	Better acoustic and spacial comfort Less headache	Use of "Green" materials Right properties for the proper use	Use of renewable energy concepts Choice of most effective system	Dynamic cost modeling Monitoring of economic progress	Comparing energy use and construction cost

Strategy for sustainable design development:

- Create an overview over possible tools
- Getting a technical understanding
- Mapping different tools possibilities and limitations
- Create understanding of interoperability
- Mapping tools to a design themes and processes

General process and workflow for sustainable building design

SCHEMATIC PROCESS PLANNING

Use of software application and interoperability
Planning work flow and output

1 ANALYSIS
Dialogue, climate, context
and program analysis

2 CONCEPT
Concept studies,
analysis and disposition

3 PROPOSAL
Design proposal and
concept optimization

4 PRODUCT
Solution-based design and
dimensioning

Modeling

- Model focus and strategy
- Choice of tools
- Model detail level
- Modeling template

Simulation

- Simulation of the different design themes
- Tools and simulation time
- Useful and available simulation tools
- Simulation template

Visualization

- Analytical reference views
- Scripts for quick and easy visualization
- Tables
- Diagrams
- Renderings
- Graphs
- Visualization template

Analysis

- Analysis of the different design themes
- Validation of the simulations
- Visual and analog comparison
- Comparison values and numbers
- Analysis Template

Transformation

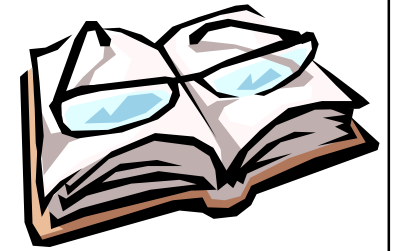
- Re-/defining quantitate or/and qualitative aims and goals
- Legislation demands
- Design optimization
- Design decision

Inside:

- Modelling
- Simulation
- Visualization
- Analysis
- Transformation

Outside:

- Communication
- Collaboration
- Holistic analysis
- Design optimization



Further reading

- BIM as a Framework for Sustainable Design
 - http://www.susted.com/wordpress/content/bim-as-a-framework-for-sustainable-design_2012_03/
- Autodesk Sustainability Workshop
 - <https://sustainabilityworkshop.autodesk.com/>
 - Building Design
<https://sustainabilityworkshop.autodesk.com/building-design>
 - BPA Software Workflows
<https://sustainabilityworkshop.autodesk.com/buildings/bpa-software-workflows>
 - Revit tools for BPA
<https://sustainabilityworkshop.autodesk.com/buildings/revit-tools-bpa>