SBS5322 Basics of Building Information Modelling

http://ibse.hk/SBS5322/

BIM and sustainable design

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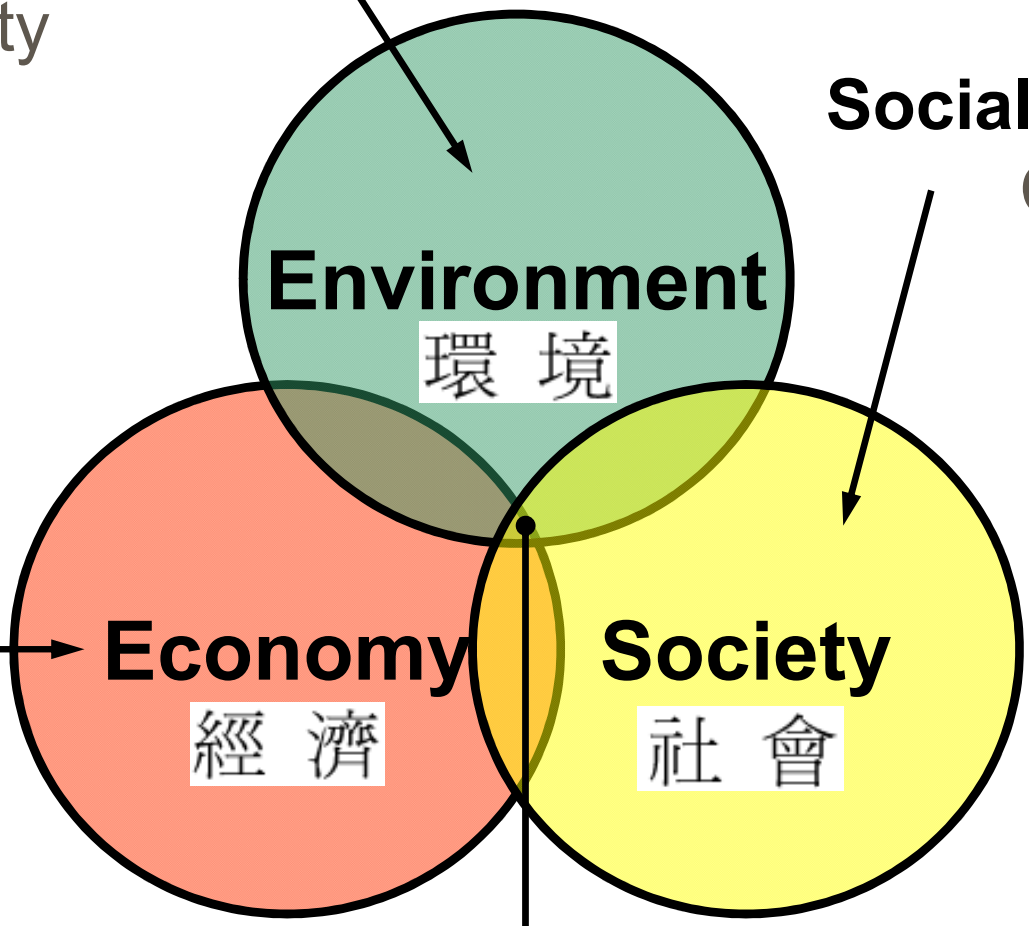
Contents

- 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



Social Sustainability

Cultural Identity
Empowerment
Accessibility
Stability
Equity

Economic Sustainability

Growth
Development
Productivity
Trickle-down

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

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

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

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

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

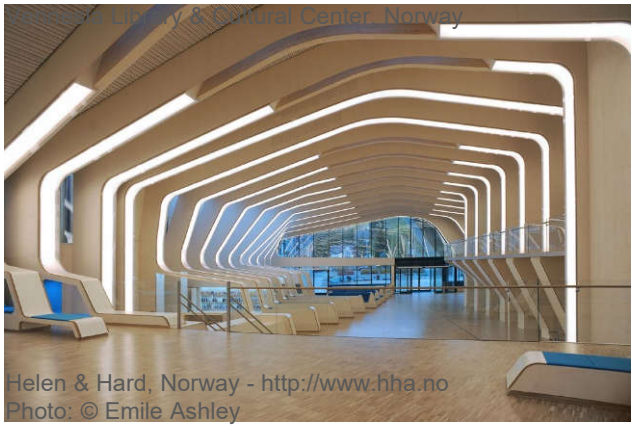
(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)

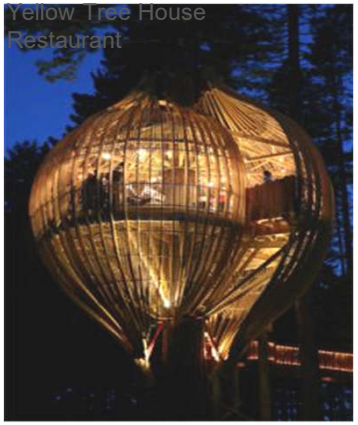
Sustainable design with BIM

- 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

(Source: Krygiel, E. and Nies, B., 2008. *Green BIM: Successful Sustainable Design with Building Information Modelling*, Wiley Publishing Inc., Indianapolis.)

Sustainable Design Disciplines





Pacific Environment

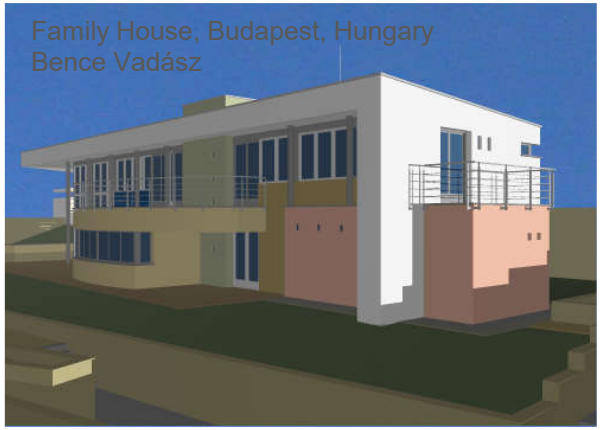
- Sustainable sites
- Water efficiency
- Energy and atmosphere
- Materials and resources
- Indoor environment
- Innovation in design
- Regional priority

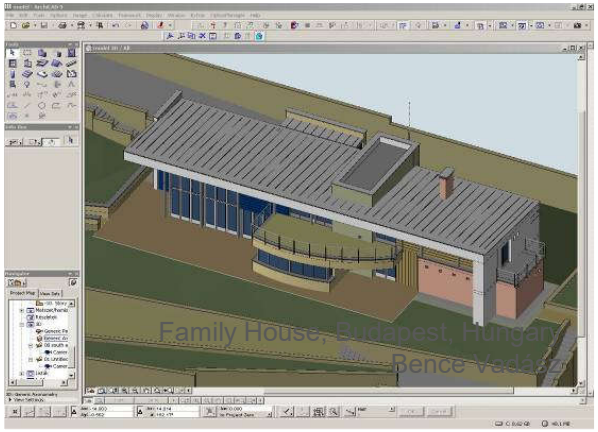
(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)

Sustainable Design with BIM

Building Information Modeling

Intelligent building model (virtual building)





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

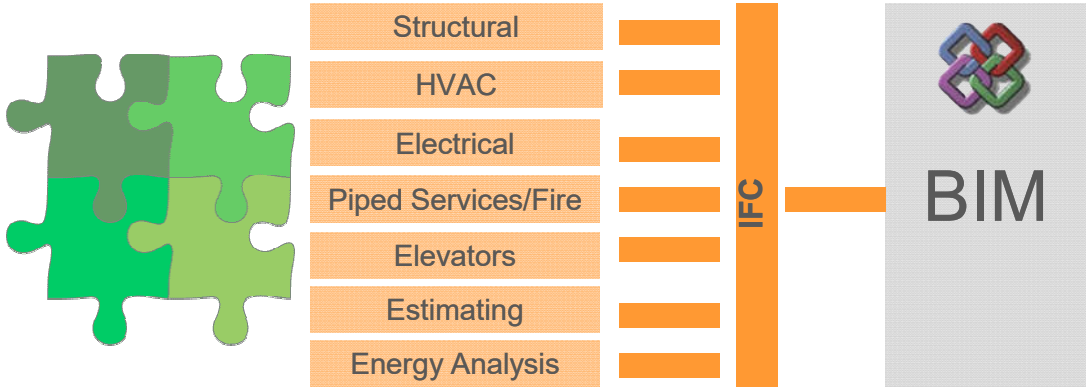
Sustainable design with BIM

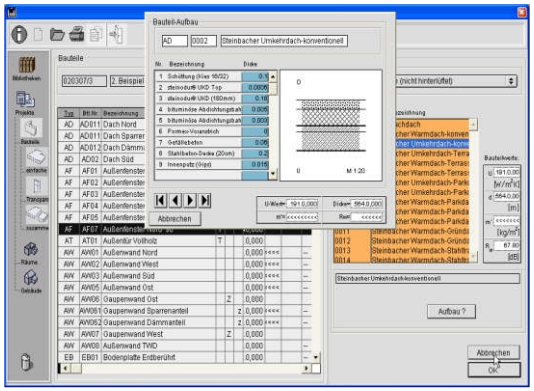
- BIM advantages include:
  - Ability to analyze
  - Ability to evaluate green buildings
  - Access to info to make sustainable decisions
- Performance analysis & evaluation
  - Merge of design & analysis = optimize building performance
  - Better quality of data = minimum errors and miscalculations

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

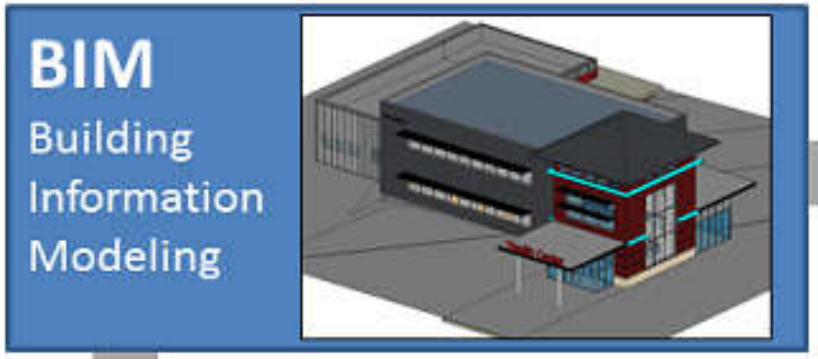
- Structural Engineering
- Collision Detection
- Code Checking
- Building Performance and energy simulations

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

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)

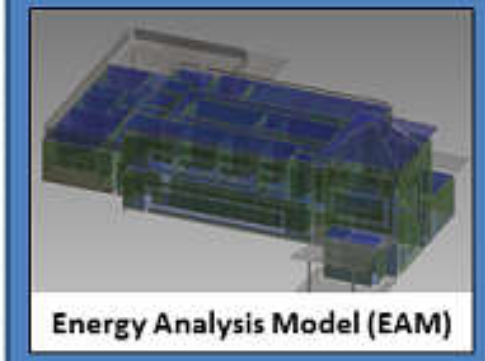


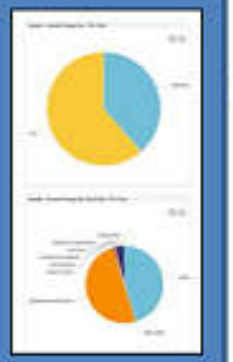
- Visualization
- Structural analysis
- Cost
- Documentation
- Fabrication/ Construction
- Etc...

Building Performance Analysis (BPA)

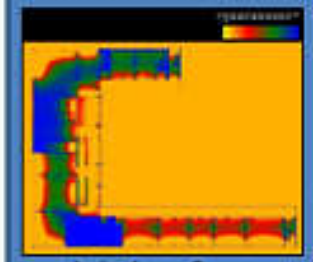
Whole Building Energy Analysis

- Conceptual Models
- Detailed Models

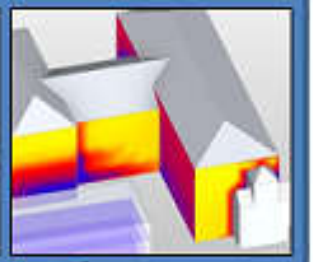


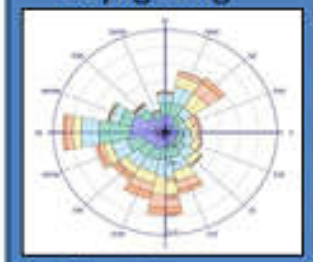


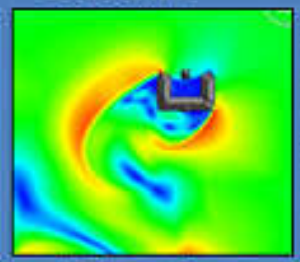
Other Performance Studies


Lighting & Daylighting


Sun & Shadows


Solar Radiation


Climate Analysis

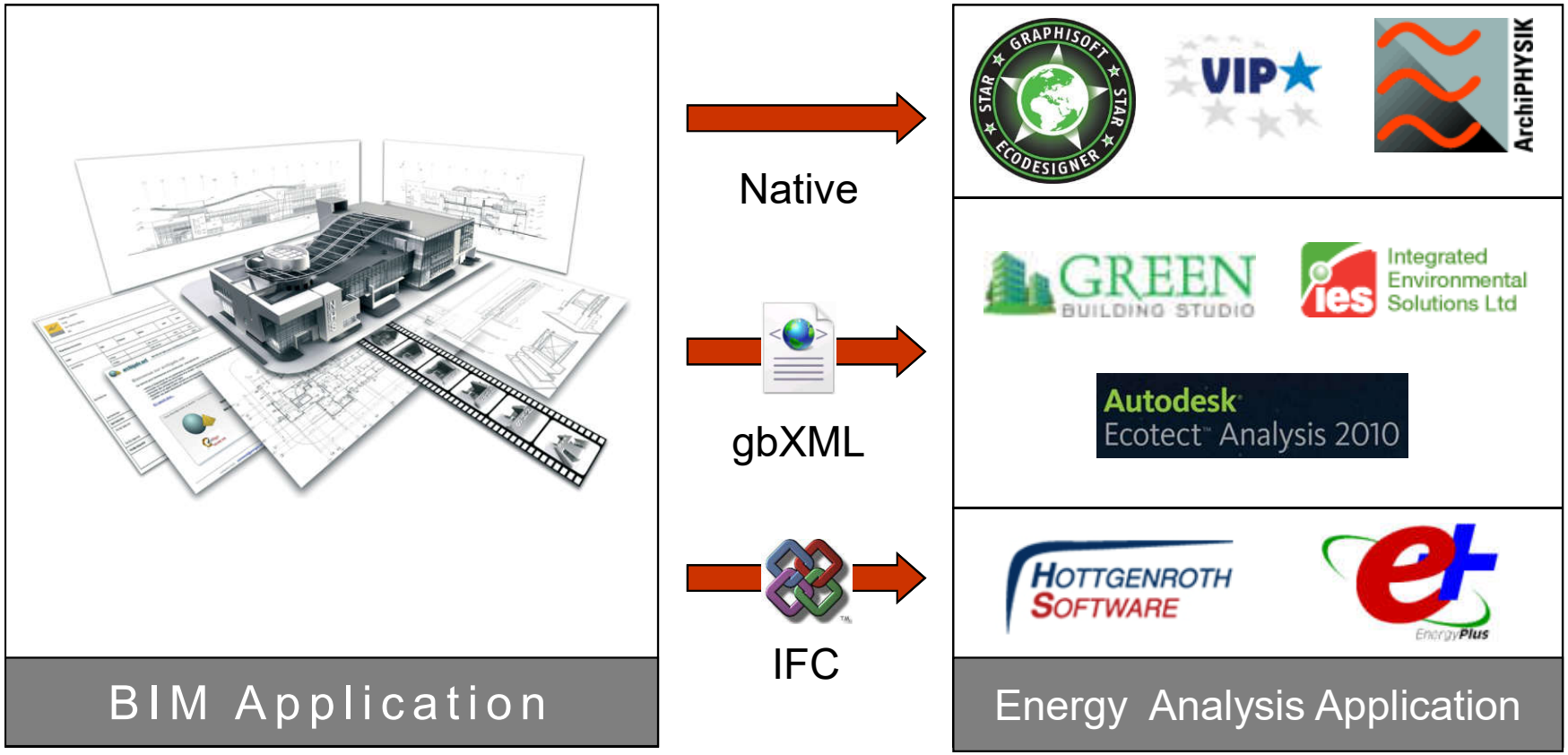

Airflow & Ventilation


Lifecycle Analysis

(Source: Building Performance Analysis (BPA) https://sustainabilityworkshop.autodesk.com/buildings/building-performance-analysis-bpa)

Sustainable Design with BIM

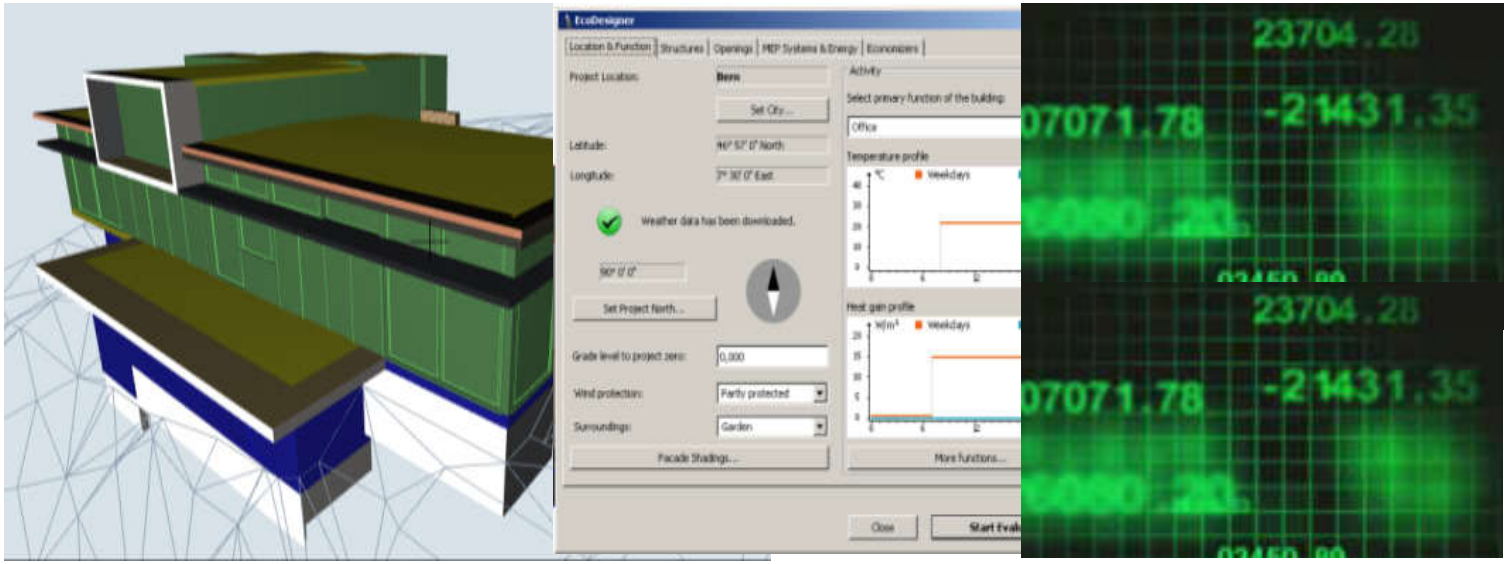
BIM and Energy Software Collaboration



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

Sustainable Design with BIM

BIM-Integrated Energy Simulation



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

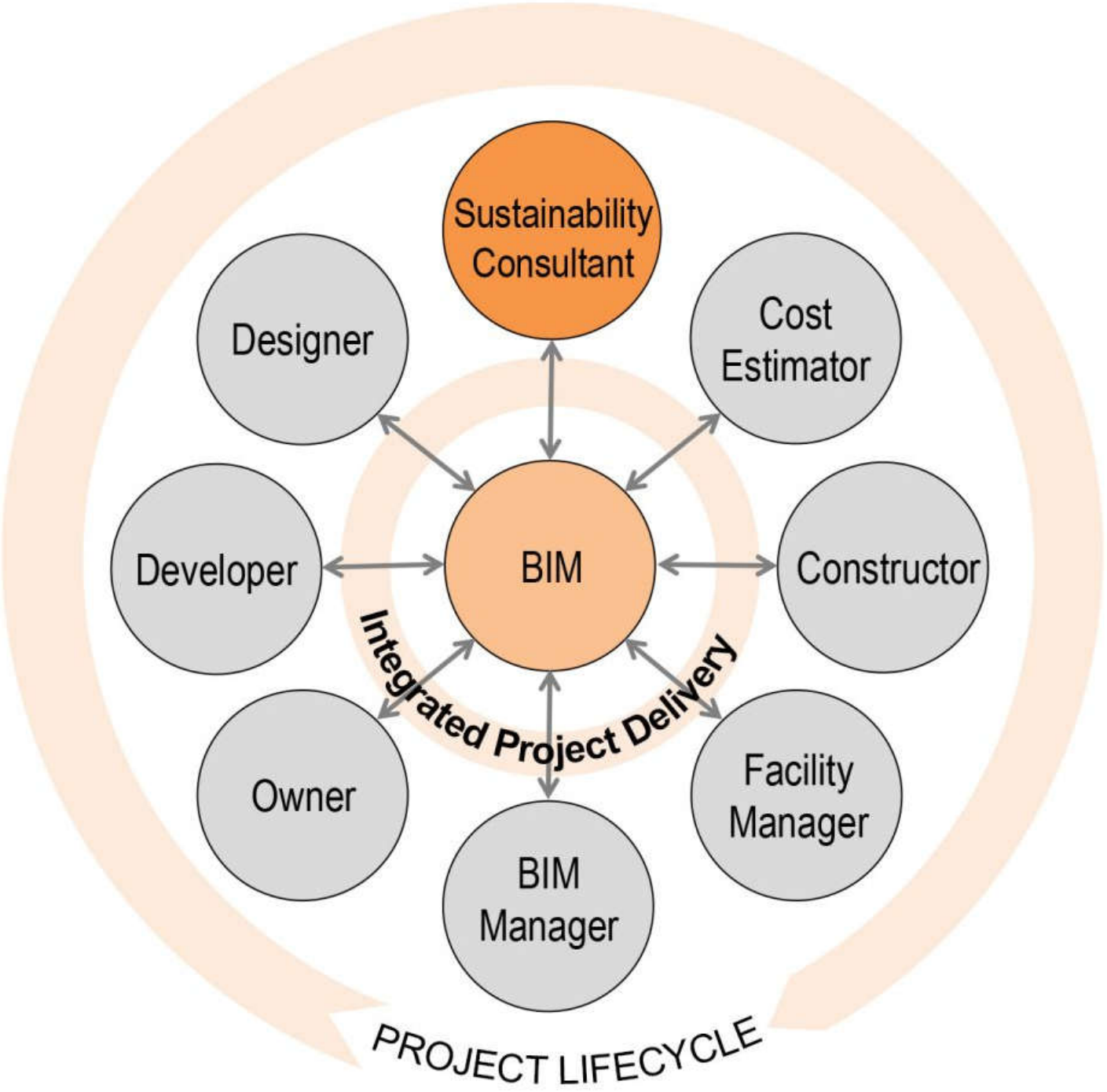
(Source: Graphisoft BIM Curriculum http://www.graphisoft.com/learning/bim-curriculum/)

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

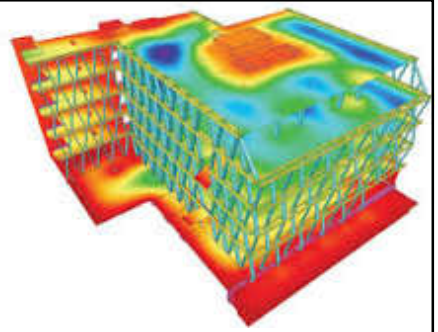
(Source: Bonenberg, W. Wei, X., 2015. Green BIM in sustainable infrastructure, *Procedia Manufacturing*, 3: 1654-1659.)

Sustainability consultant and BIM for integrated project delivery



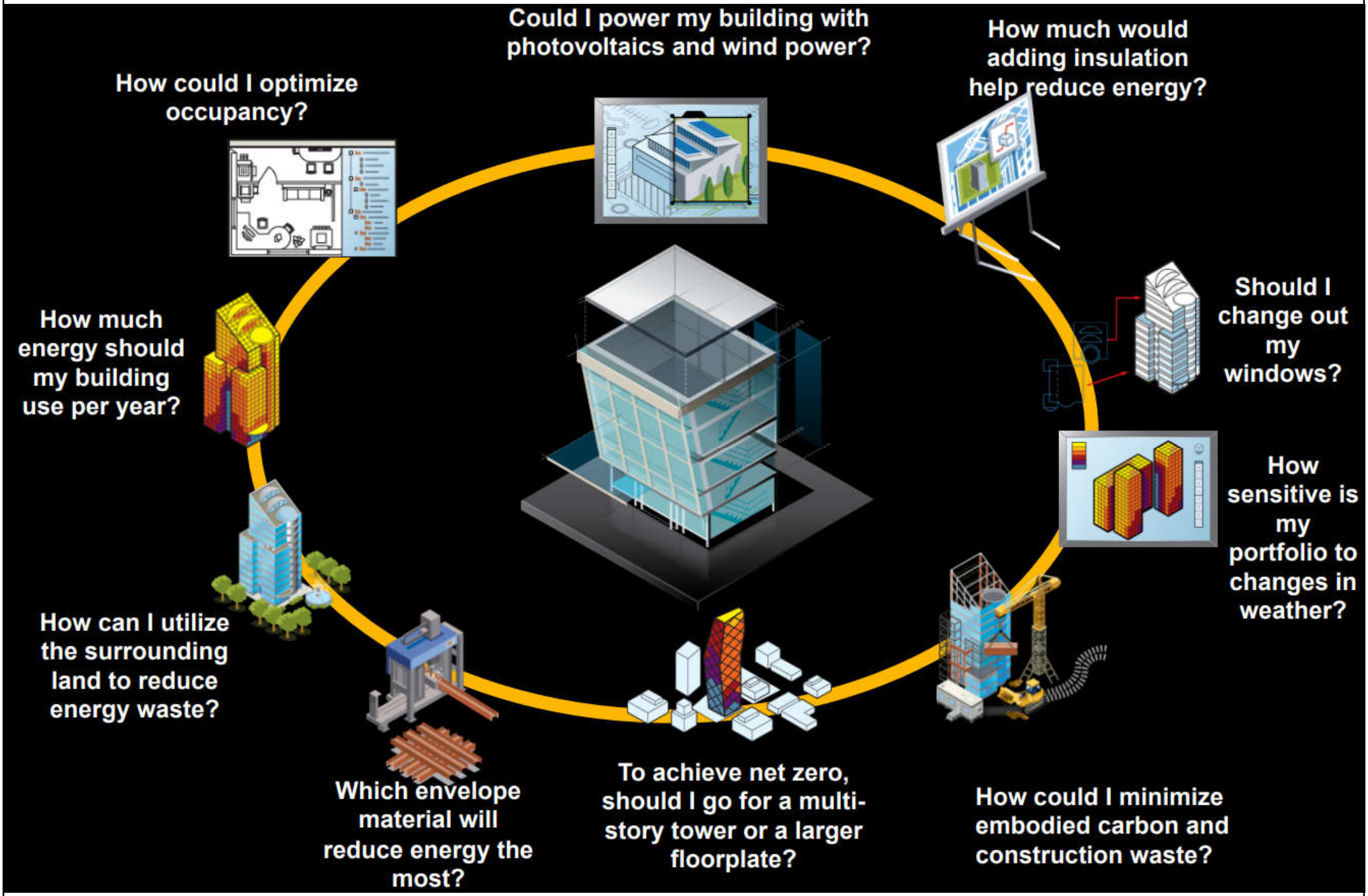
(Source: https://www.macrodesignstudio.it/2017/02/14/the-potential-of-bim-as-a-sustainable-design-tool/?lang=en)

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



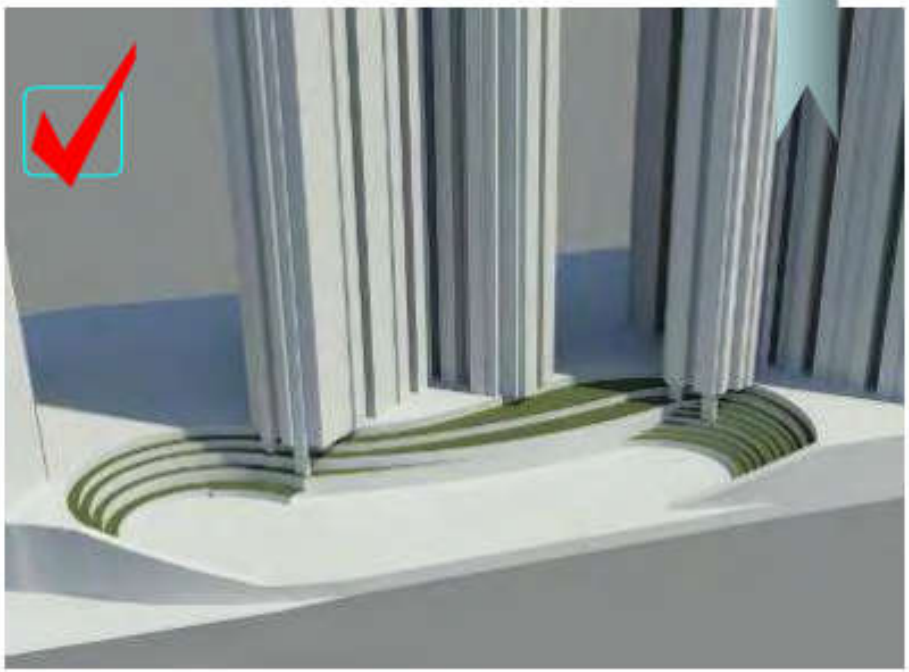
(Source: Autodesk)

Building performance analysis & evaluation at design phase

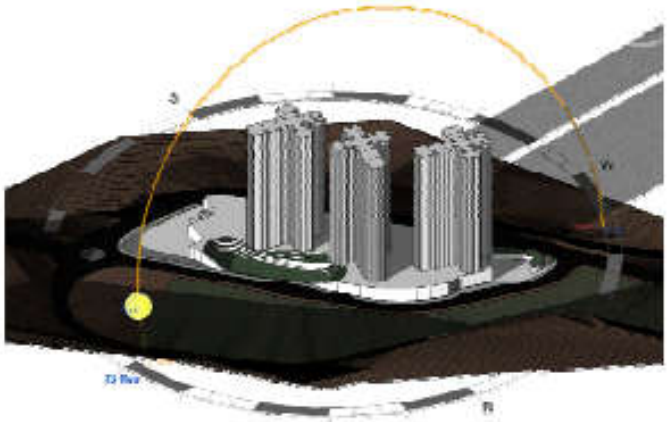
Energy modelling	Reducing energy needs and analyzing renewable energy options that can contribute to low energy costs
Building orientation	Reduce energy costs
Building massing	Analyze building form and optimize building envelope
Sustainable materials	Reduce materials needs and use recycled materials
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)

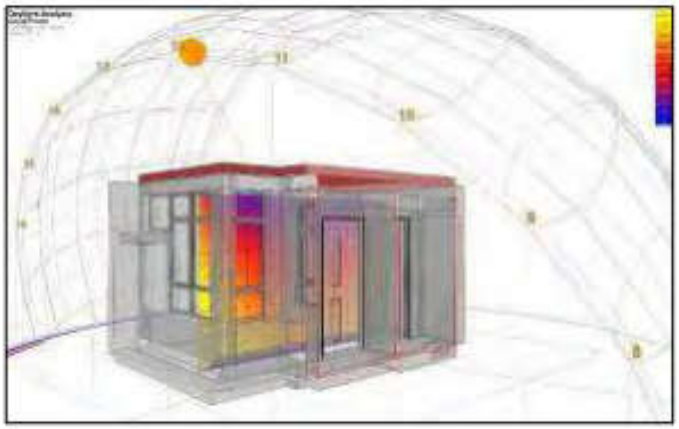
Studies on sunlight & shadow, daylight and wind flow

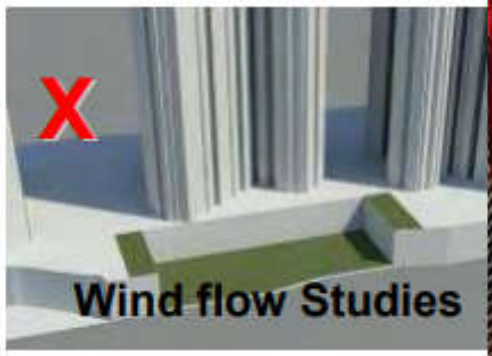


Sunlight & Shadow Studies

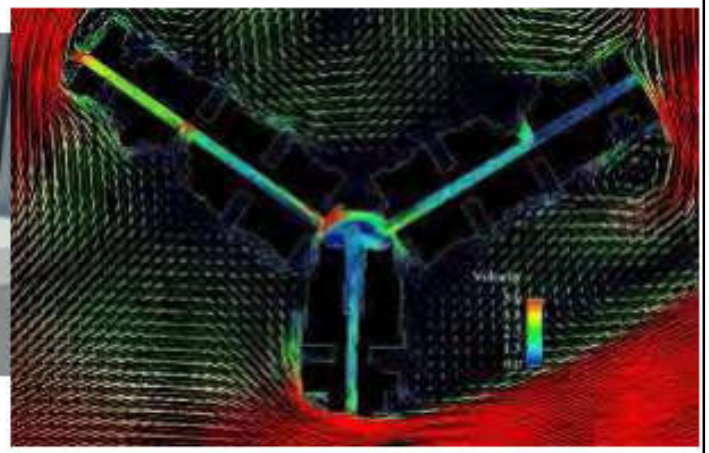


Daylight Analysis





Wind flow Studies



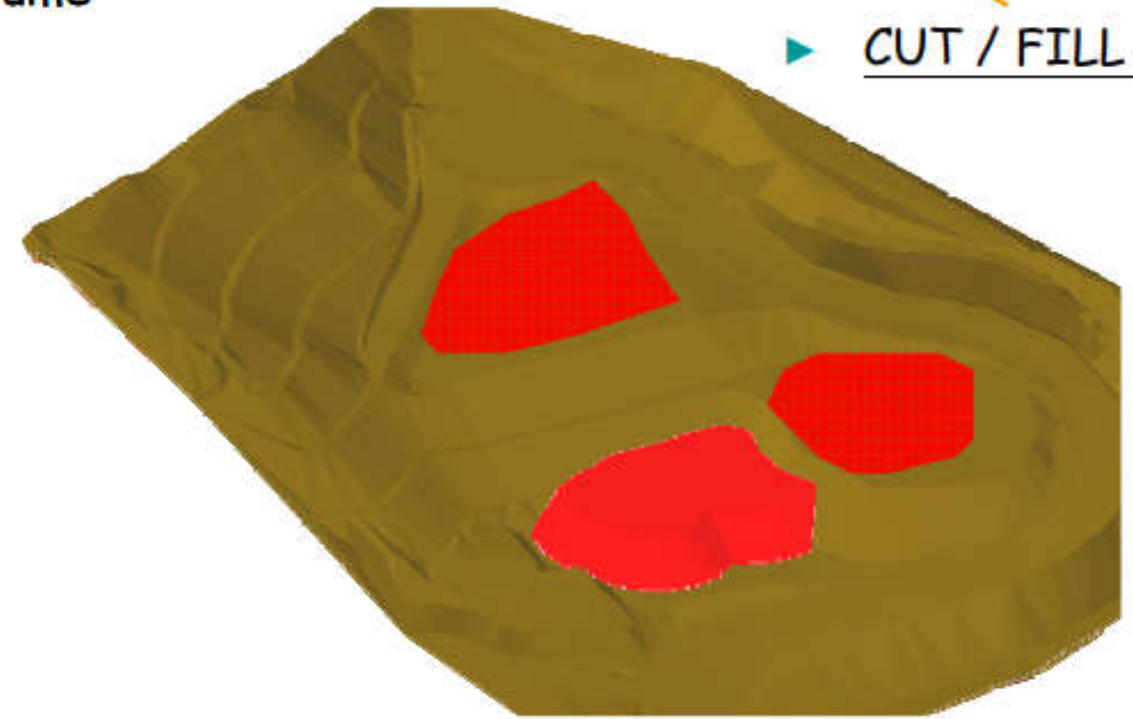
(Source: Ms Ada FUNG, Hong Kong Housing Authority, https://www.hkis.org.hk/hkis/general/events/bim2013/bim-2013af.pdf)

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

Balancing of Cut and Fill volume

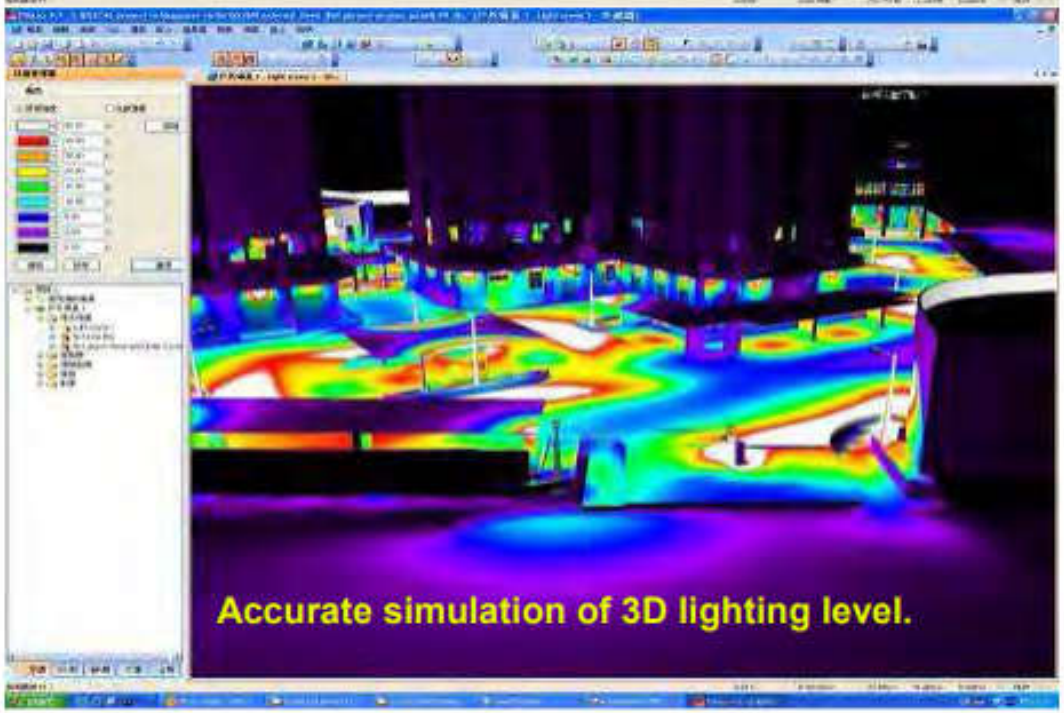
Schedule of Mass Concrete Fill for Footing						
Name	Mark	Projected Area	Surface area	Cut	Fill	Net cut/fill
Pad RFTG	Pad RFTG-4	2928m²	3122m²	0.00m³	22300m³	32m³
Pad RFTG	Pad RFTG-1	4587m²	4956m²	0.00m³	27300m³	50m³

- Excavation volume
- CUT / FILL volume of each Mass Fill

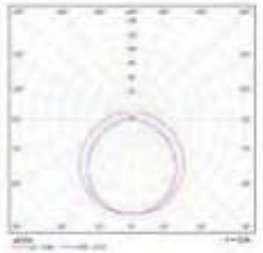


(Source: Ms Ada FUNG, Hong Kong Housing Authority, https://www.hkis.org.hk/hkis/general/events/bim2013/bim-2013af.pdf)

Optimize lighting design for energy saving

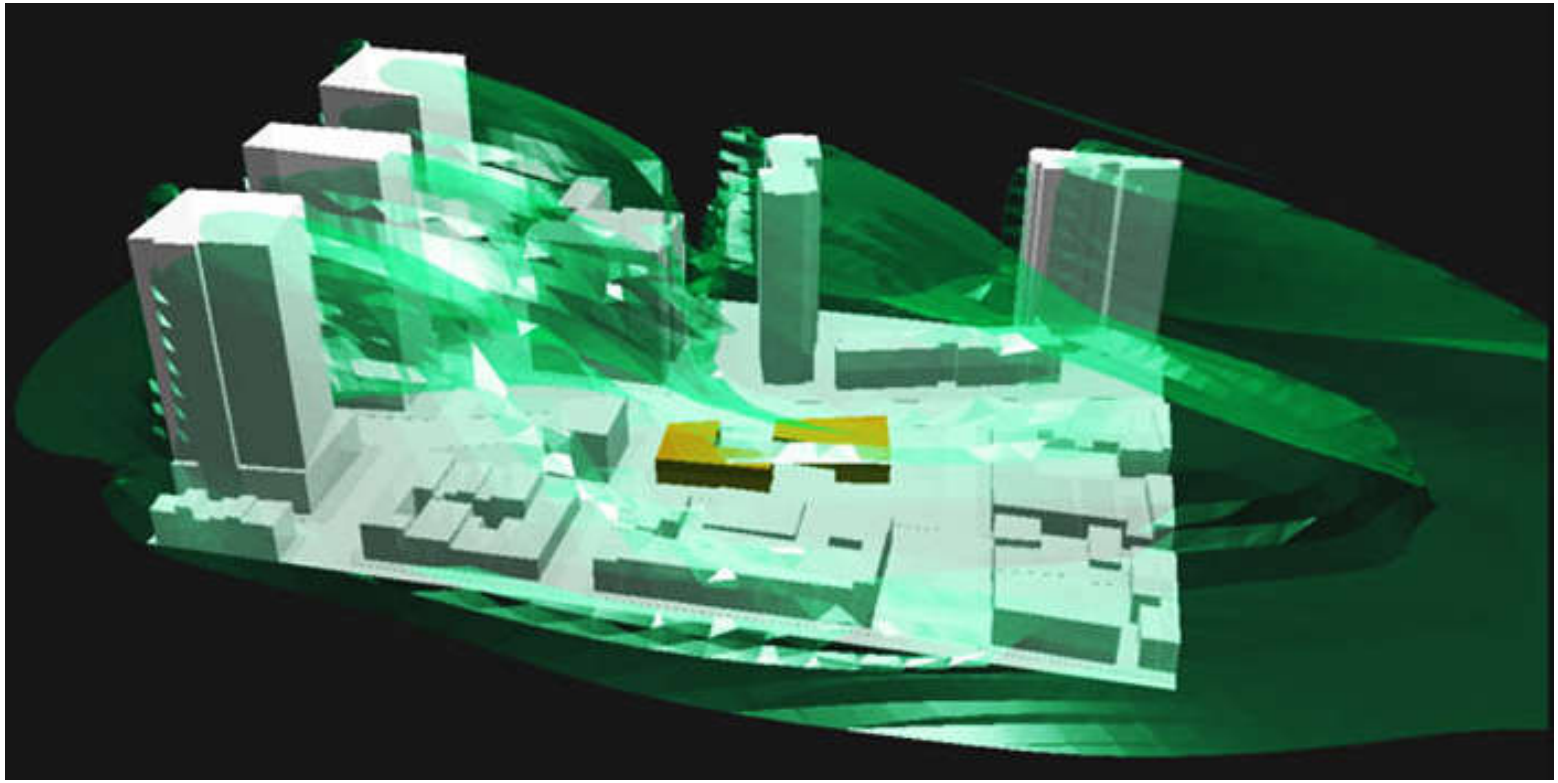


Development of more energy efficient lighting operation mode.

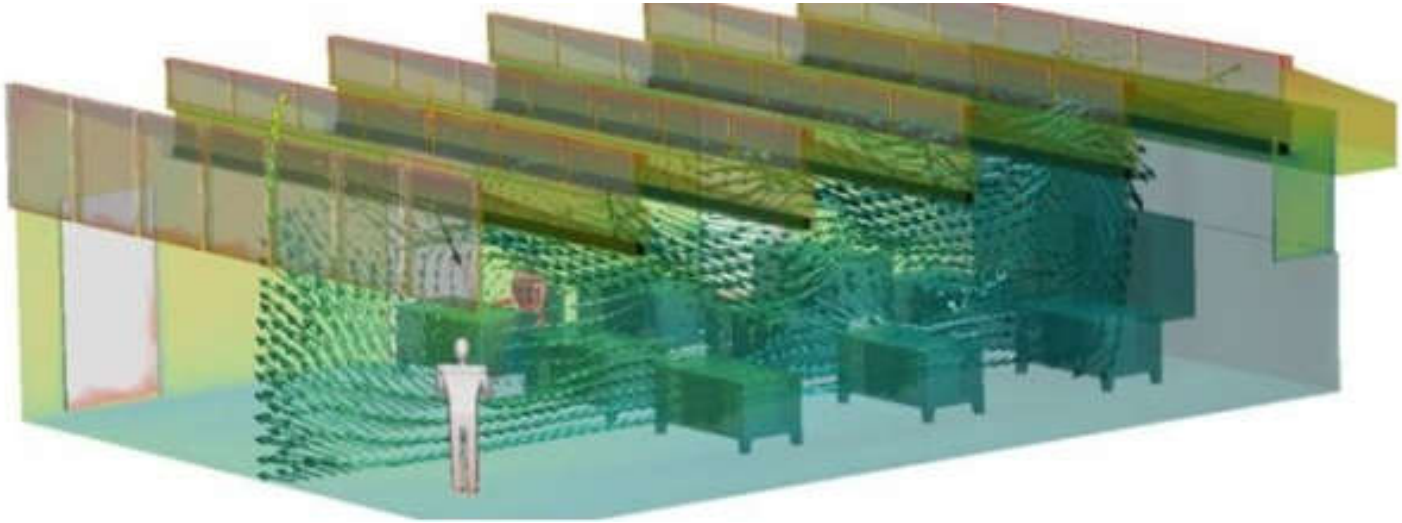


(Source: Ms Ada FUNG, Hong Kong Housing Authority, https://www.hkis.org.hk/hkis/general/events/bim2013/bim-2013af.pdf)

Wind & ventilation analysis in BIM



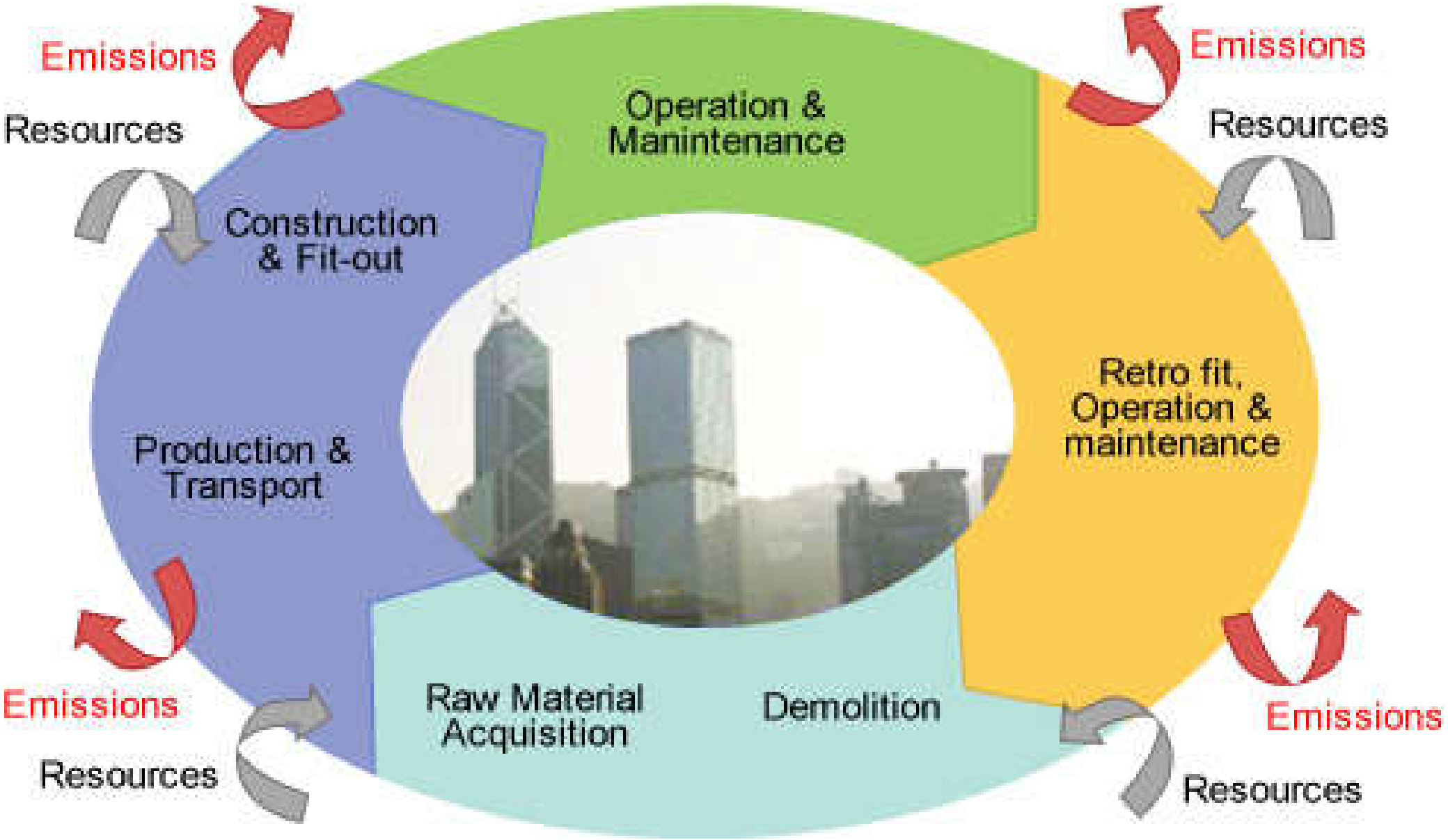
External air flow analysis



Internal air flow analysis

(Source: Viewpoint: Sustainable Building Design—Wind Analysis in BIM https://architosh.com/2015/06/viewpoint-sustainable-building-design-wind-analysis-in-bim/ Wind Analysis in BIM https://sustainabilityworkshop.autodesk.com/buildings/wind-analysis-bim)

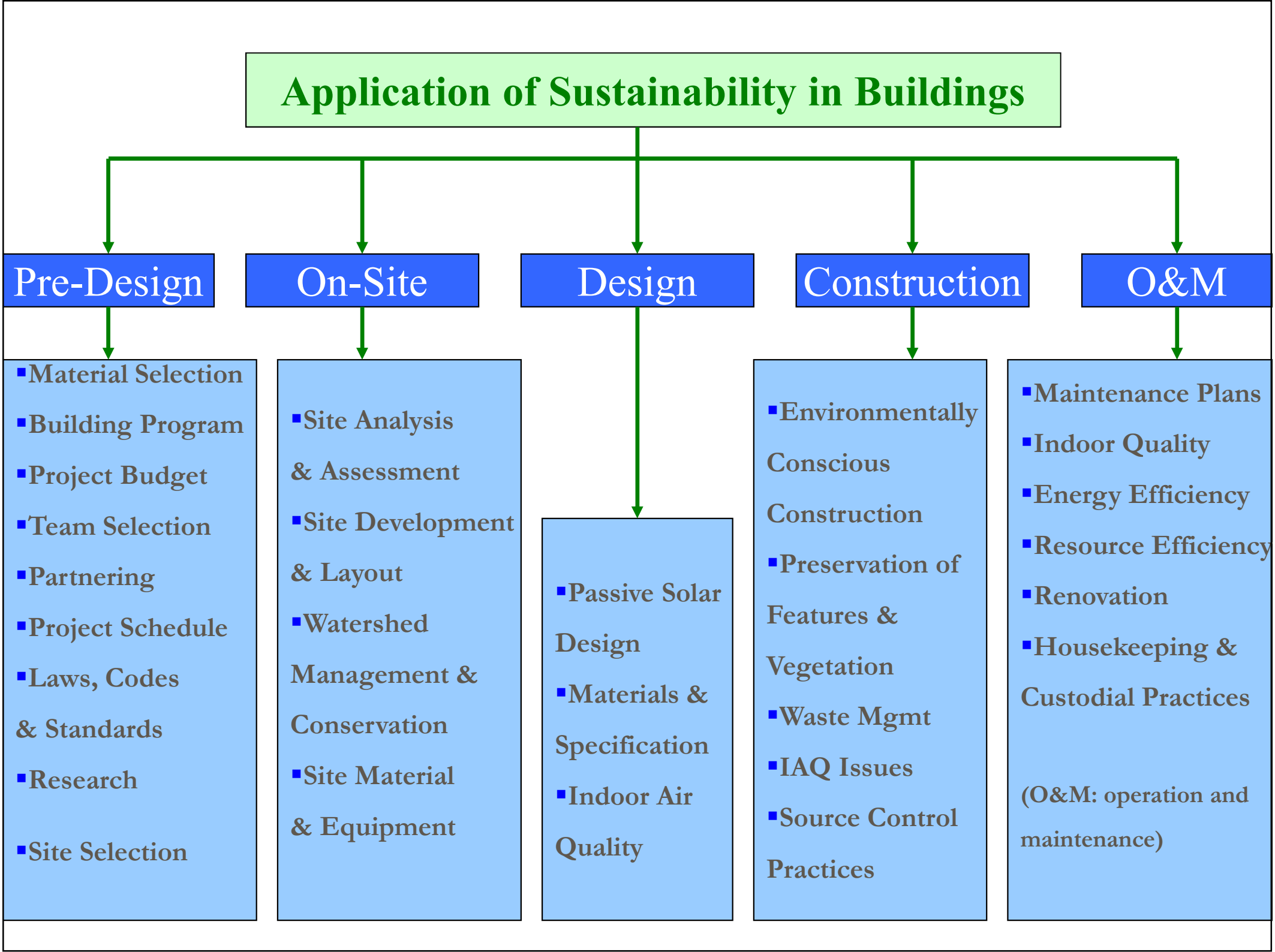
Life cycle assessment of buildings



(Source: http://www.energyland.emsd.gov.hk/en/building/assessment/)

Sustainable buildings lifecycle, technology, maturity

(Source: Autodesk)


Application of Sustainability in Buildings
Pre-Design
On-Site
Design
Construction
O&M
▪Material Selection
▪Building Program
▪Project Budget
▪Team Selection
▪Partnering
▪Project Schedule
▪Laws, Codes & Standards
▪Research
▪Site Selection
▪Site Analysis & Assessment
▪Site Development & Layout
▪Watershed Management & Conservation
▪Site Material & Equipment
▪Passive Solar Design
▪Materials & Specification
▪Indoor Air Quality
▪Environmentally Conscious Construction
▪Preservation of Features & Vegetation
▪Waste Mgmt
▪IAQ Issues
▪Source Control Practices
▪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

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

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

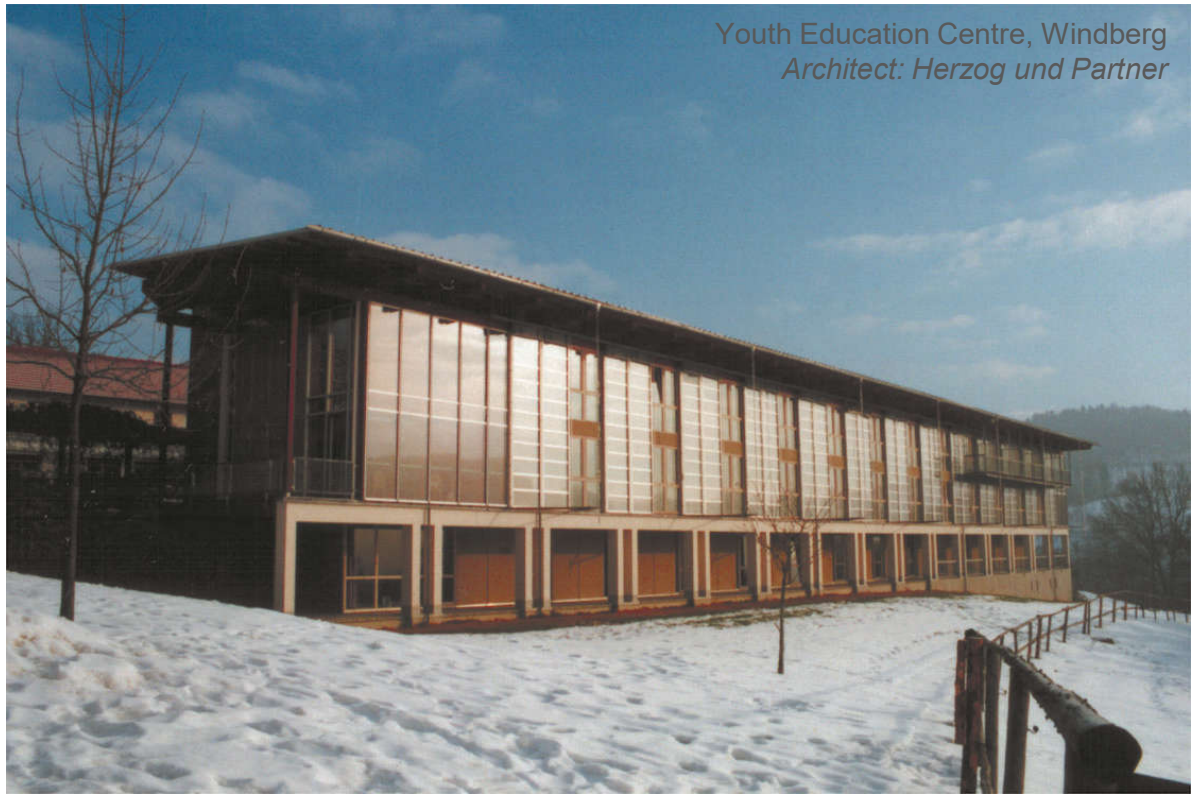
Life Cycle Cost (LCC)

- Construction
- Operation
- Maintenance
- End of life


Youth Education Centre, Windberg
Architect: Herzog und Partner

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

Economical Aspects of Sustainability


Youth Education Centre, Windberg
Architect: Herzog und Partner

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

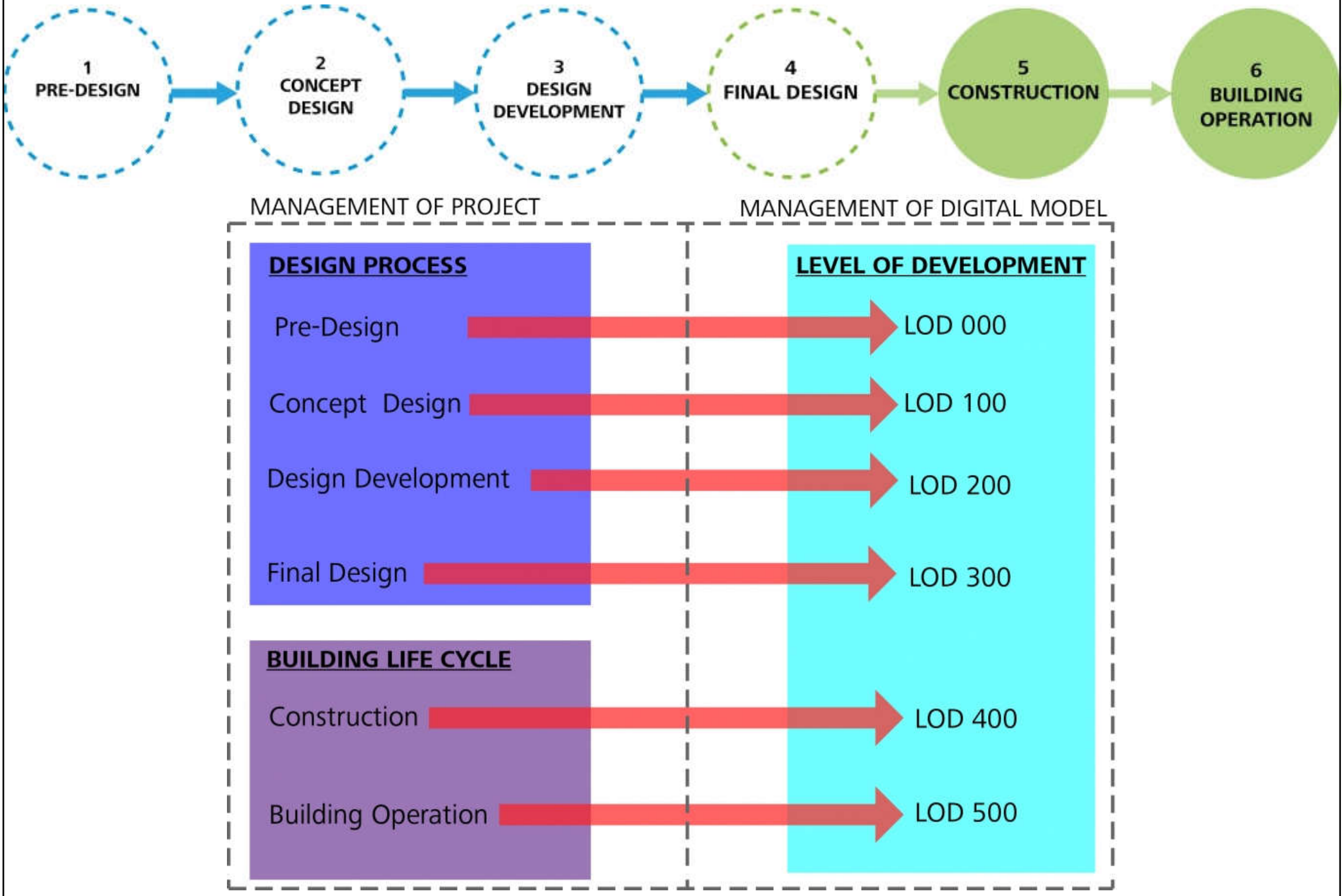
General Service Administration, U.S.

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

Analysis tools & workflow

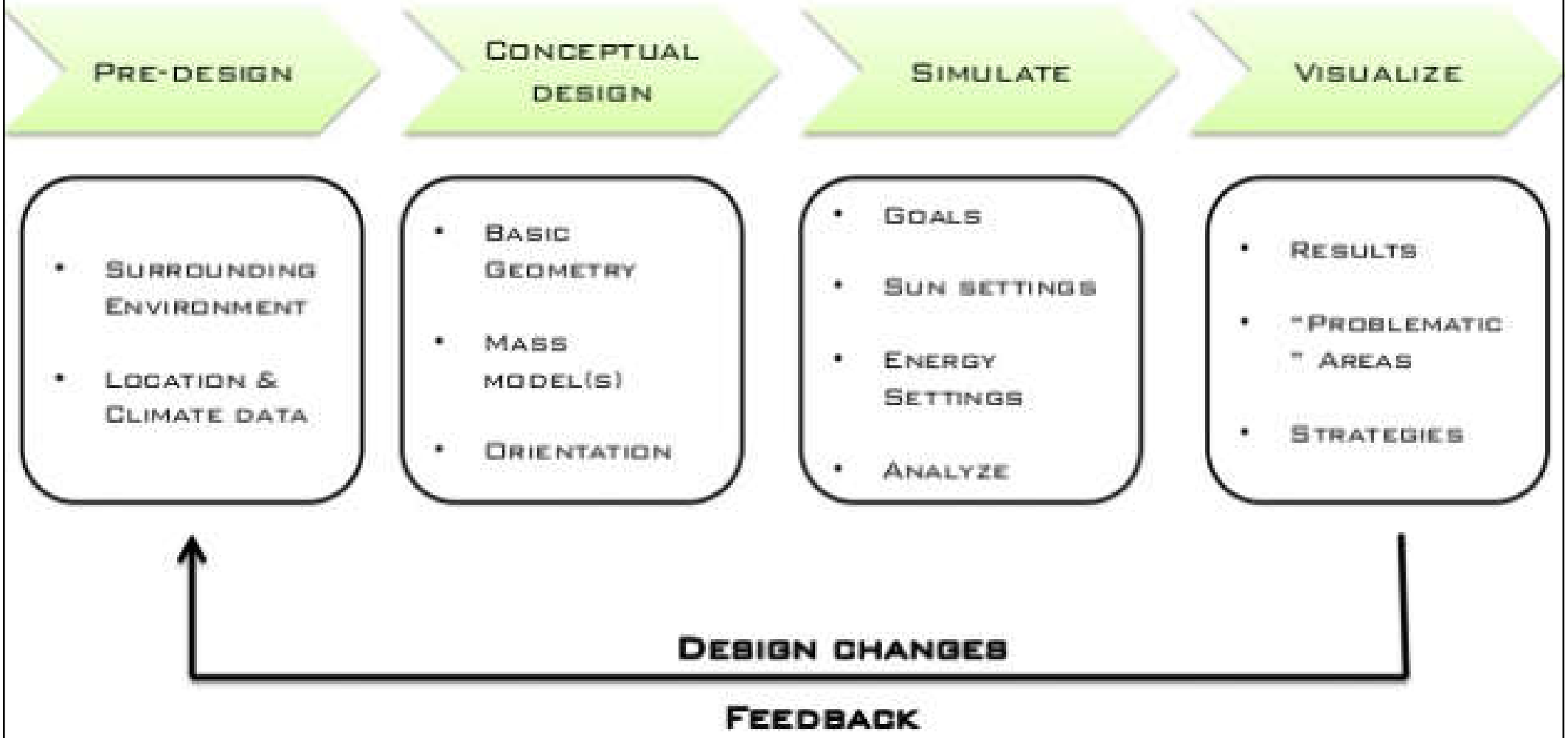
- Integrate sustainable design tasks with BIM
  - 1. Separate software: can use file exchange with BIM or is integrated with a BIM server using a specific interface. It is easy to realise and use
  - 2. The analysis function in BIM software: could be implemented by programming to BIM software
  - 3. 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



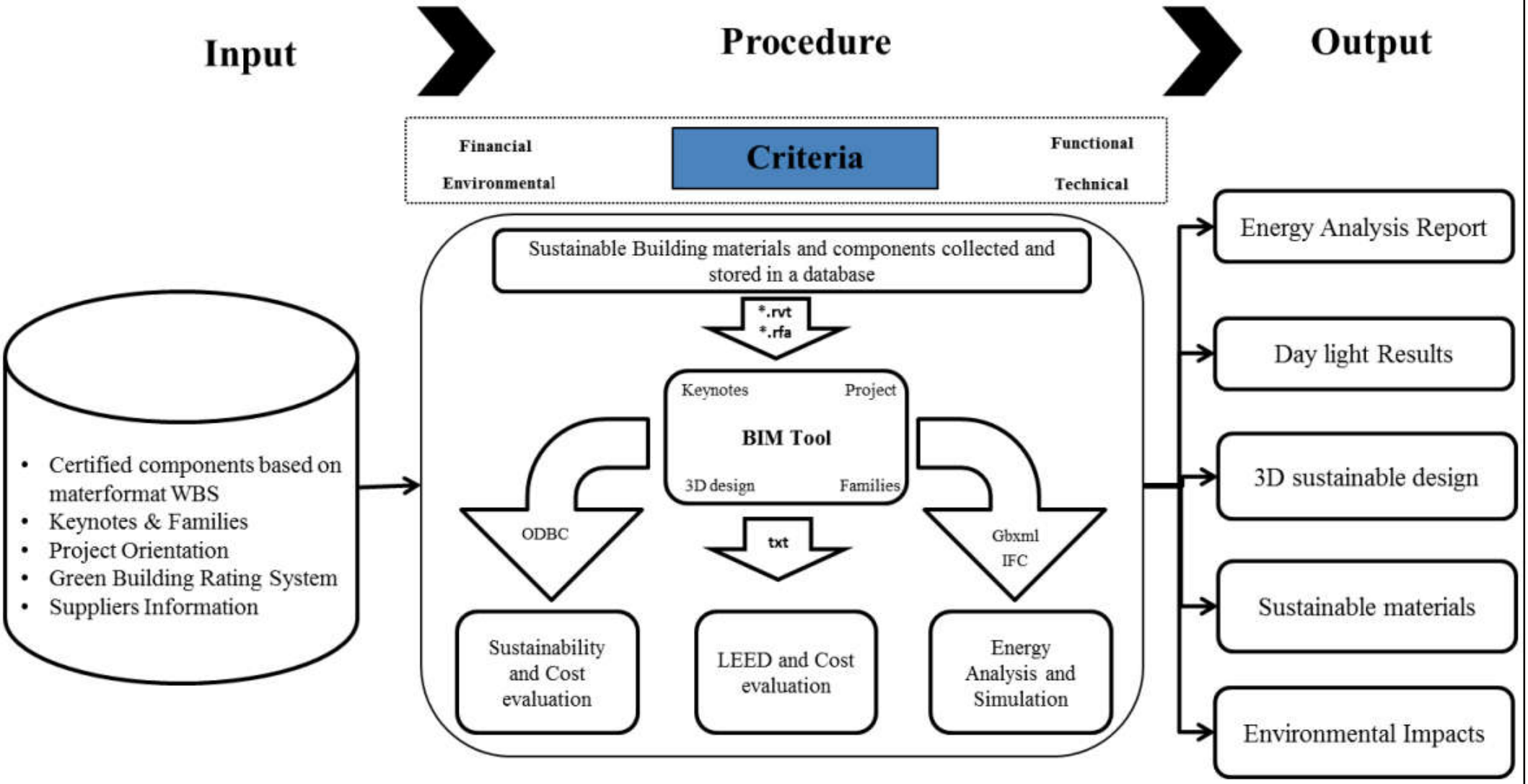
(Source: Project Phases & Level of Development https://sustainabilityworkshop.autodesk.com/buildings/project-phases-level-development)

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



(Source: Green BIM - Sustainability Through Integration https://www.slideshare.net/DimiF/green-bim-sustainability-through-integration-28248288)

Integrating BIM and energy analysis tools for sustainable building design



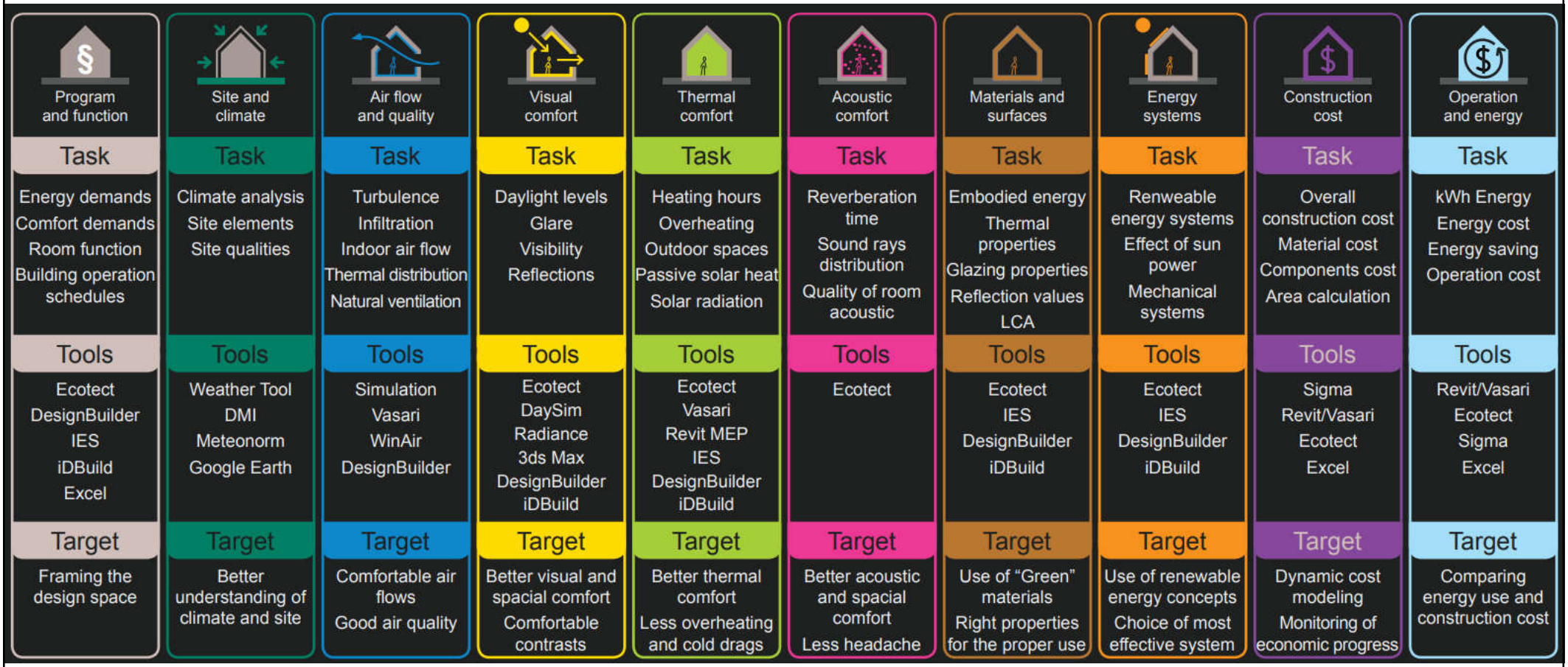
(Source: Jalaei, F. and Jrade, A., 2014. Integrating building information modeling (BIM) and energy analysis tools with green building certification system to conceptually design sustainable buildings, *Journal of Information Technology in Construction*, 19: 494-519. http://www.itcon.org/2014/29)

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

(Source: BPA Software Workflows https://sustainabilityworkshop.autodesk.com/buildings/bpa-software-workflows)

Mapping analysis tools to design themes

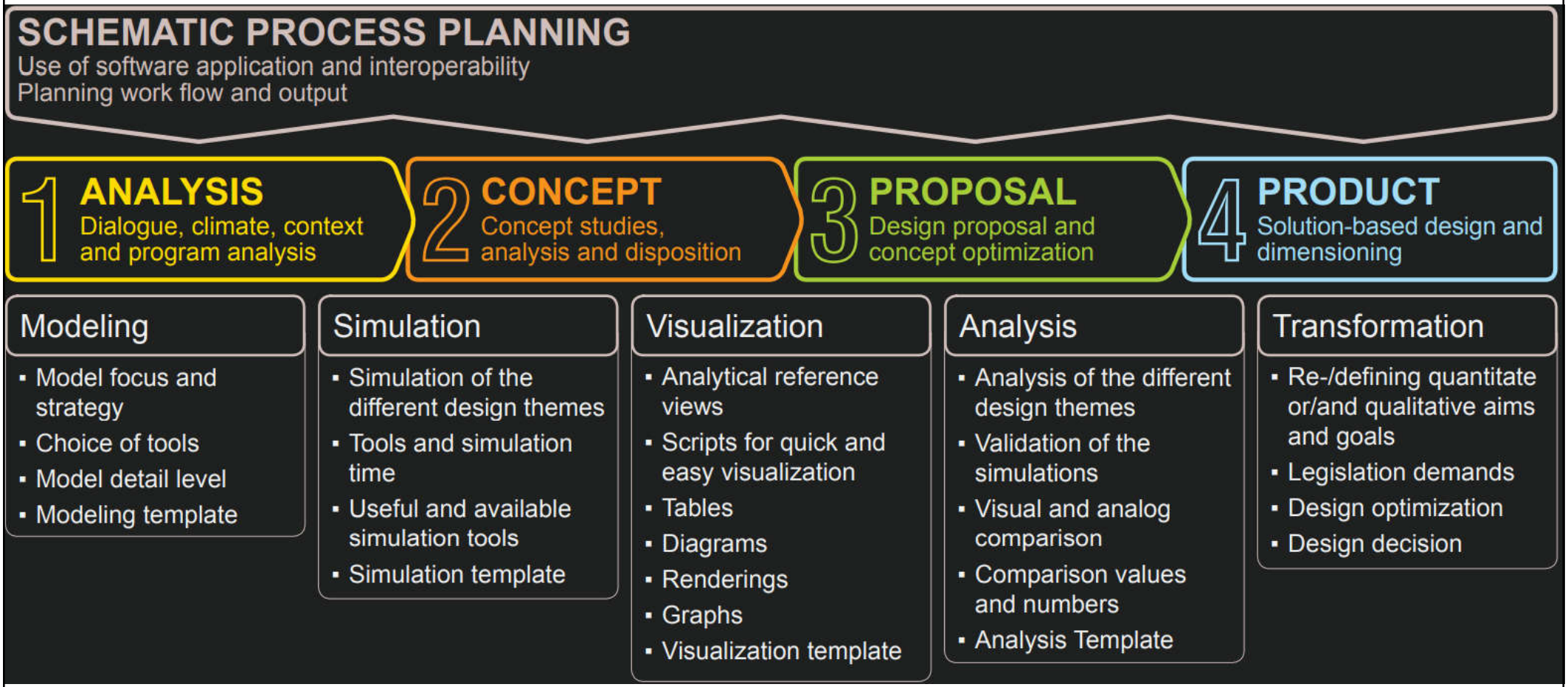


Strategy for sustainable design development:

- 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

(Source: AU Preso: Holistic BPA Workflows https://sustainabilityworkshop.autodesk.com/buildings/au-preso-holistic-bpa-workflows)

General process and workflow for sustainable building design



Inside:

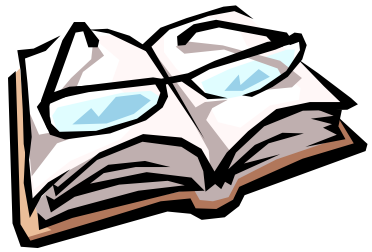
- Modelling
- Simulation
- Visualization
- Analysis
- Transformation

Outside:

- Communication
- Collaboration
- Holistic analysis
- Design optimization

(Source: AU Preso: Holistic BPA Workflows https://sustainabilityworkshop.autodesk.com/buildings/au-preso-holistic-bpa-workflows)

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