

Energy Analysis and Reduction in the Built Environment: The case for BIM and Visualisation Technologies

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Centre of Construction Innovation and Research

Teesside University



University of the Year

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Teesside University



Centre for Construction Innovation & Research



Brief Introduction to the Centre for Construction Innovation and Research

The screenshot displays the CCIR website interface. At the top left is the CCIR logo, which includes a stylized 'U' and 'C' and the text 'UNIVERSITY OF TEESIDE'. Below the logo is the text 'UNIVERSITY OF TEESIDE'. To the right of the logo is a navigation menu with the following items: 'About the CCIR', 'People', 'Projects', 'Publications', 'Consultancy', 'Links', and 'Site Map'. The main content area features three 3D construction models: a large model of a building under construction with a crane, a smaller model of a building structure, and a model of a building with a red and green color scheme. Below the models is the text 'Specialising in Innovative Research for the Construction Industry'. At the bottom of the page are links for 'Home', 'FAQ', 'News', and 'Email Us', along with the text '© CCIR Copyright 2003, Terms and Conditions'.

www.tees.ac.uk/ccir

Aim

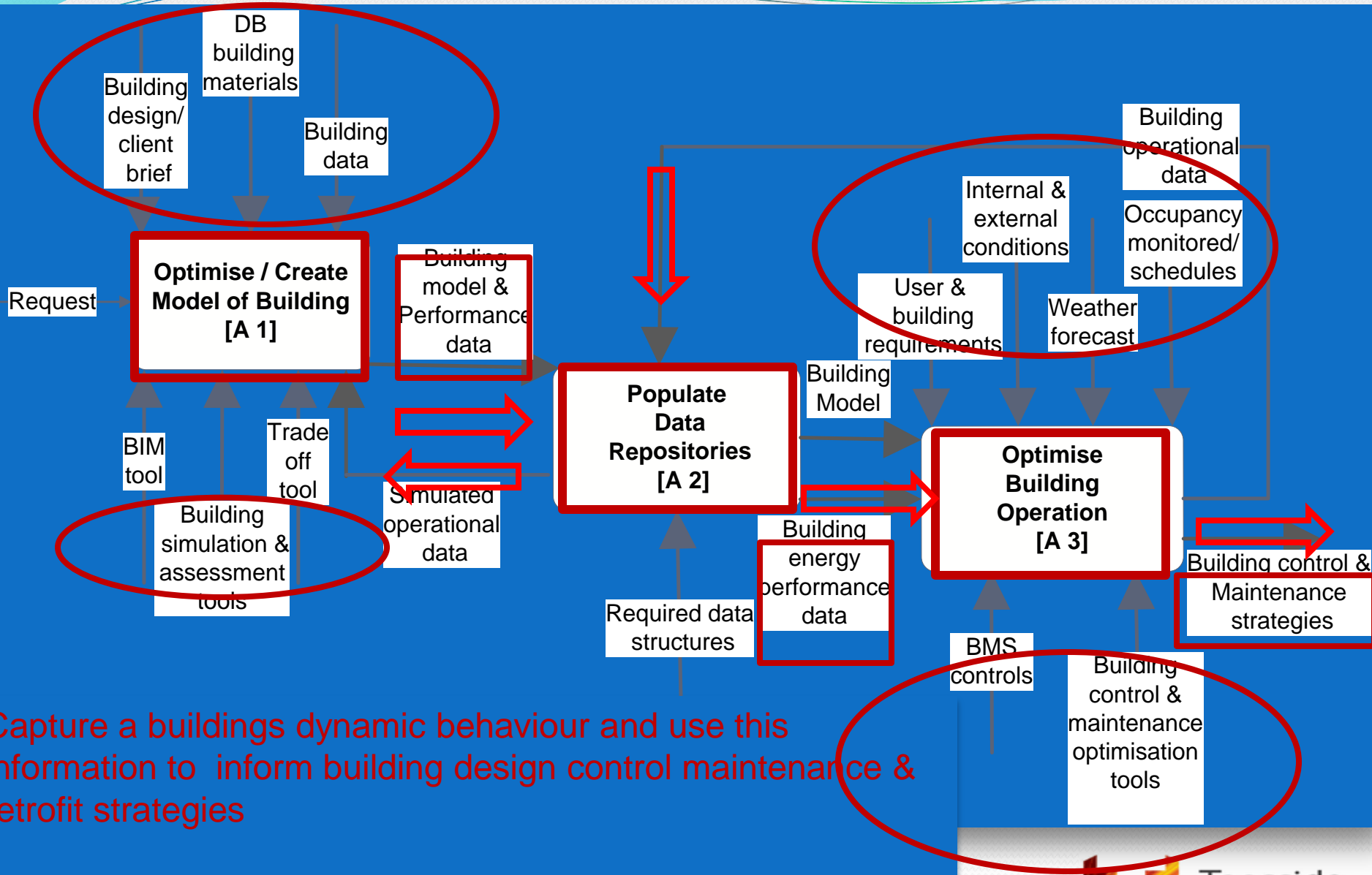
- Assess and ultimately reduce the energy consumption and CO₂ emissions in the Built Environment through the use of ICT (BIM, integrated databases, visualisation techniques and Geographical Information System) and intelligent approaches

Objectives

- Intelligent analysis of energy information for a single building (WLCA)
- Identification of tools and methods for the classification of domestic and non-domestic building stock in a neighbourhood;
- Identification of the energy profiling tools and techniques required to estimate energy consumption and CO₂ emissions from the building stock within the neighbourhood;
- Identification of energy efficiency and renewable energy interventions and their energy savings, CO₂ emission reduction potential and associated costs;
- The development of an optimisation approach to support stakeholder decision making in the selection of energy efficiency and renewable energy interventions;
- The development of a framework and prototype to integrate building classification and energy profiling techniques and an optimisation approach to select combination of energy efficiency and renewable energy interventions.

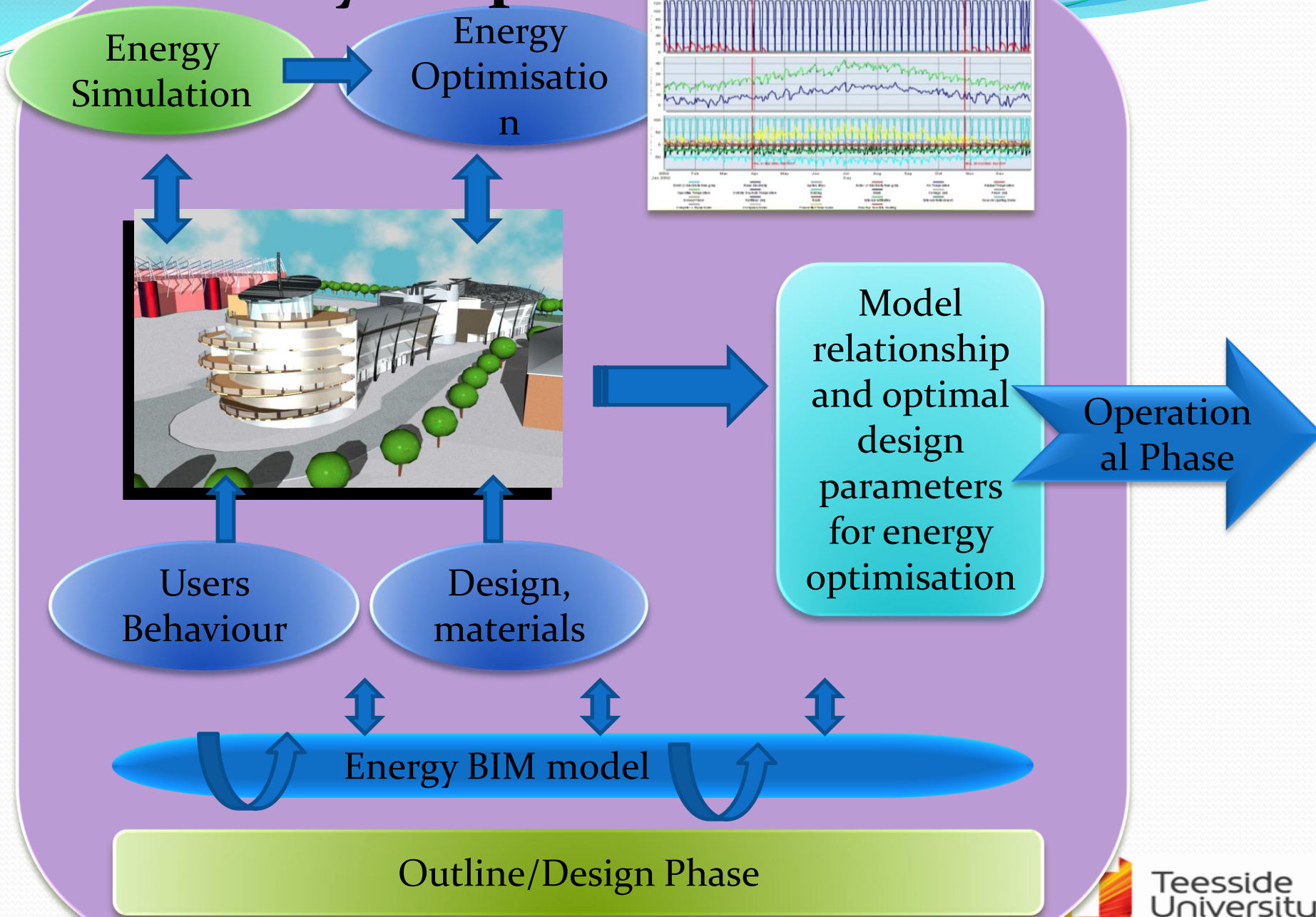
Intelligent Energy Analysis through the whole life cycle

Simulation and Optimisation throughout lifecycle

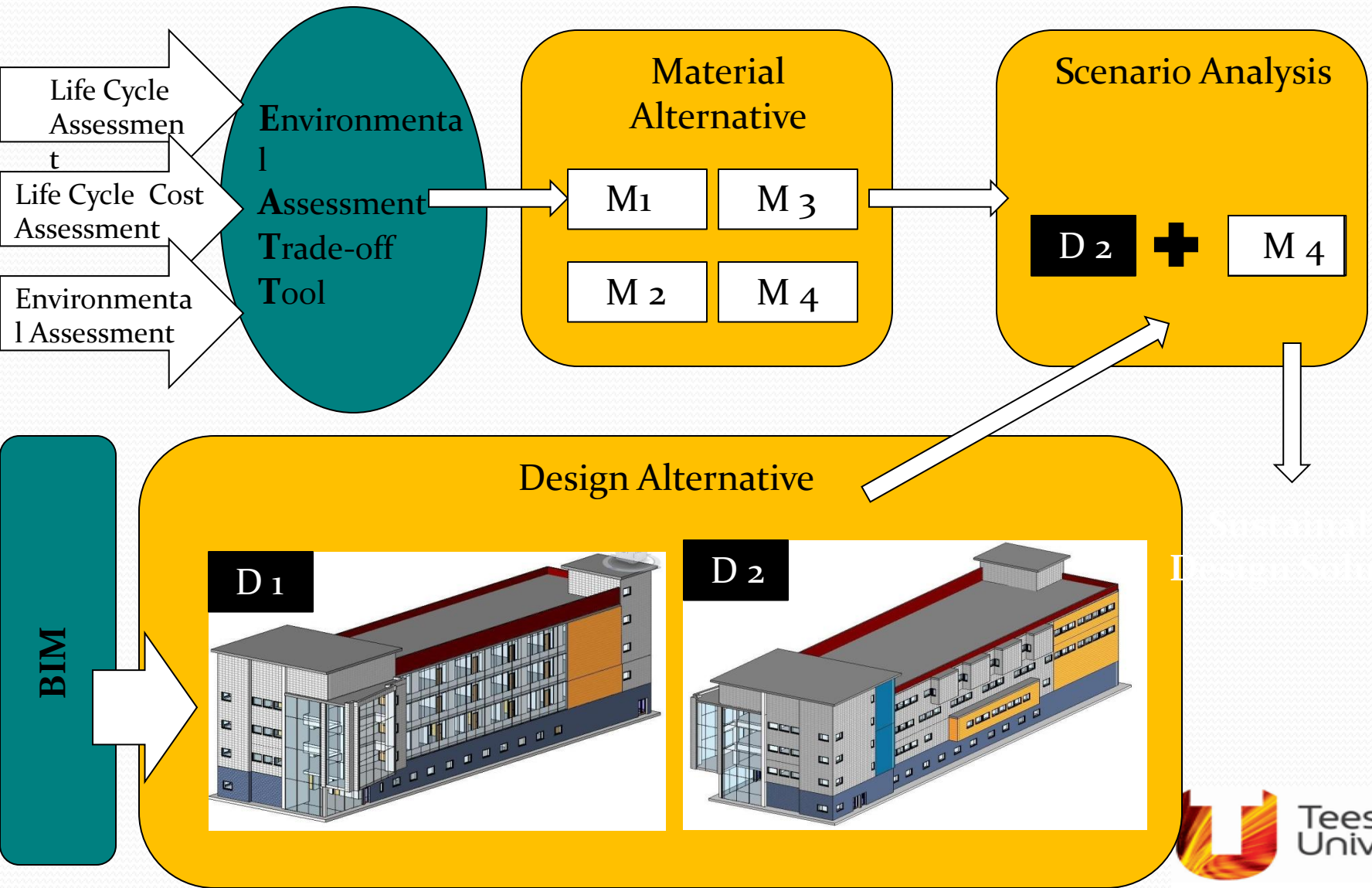


Capture a buildings dynamic behaviour and use this information to inform building design control maintenance & retrofit strategies

WLC Analysis: processes and functions



Process Flow Chart



IBMS

BIM server

Human interface

Core IBMS

BIM

Data Base

Plug-Ins

OPC Server

Data Acquisition

Wireless monitoring System

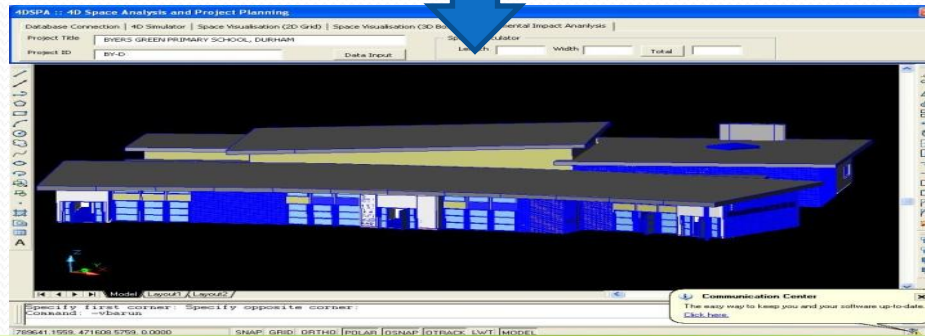
Equipment, SHW, HVAC, Shading...

HAS (Home Automation System)

Infrared Camera
Other raw data...

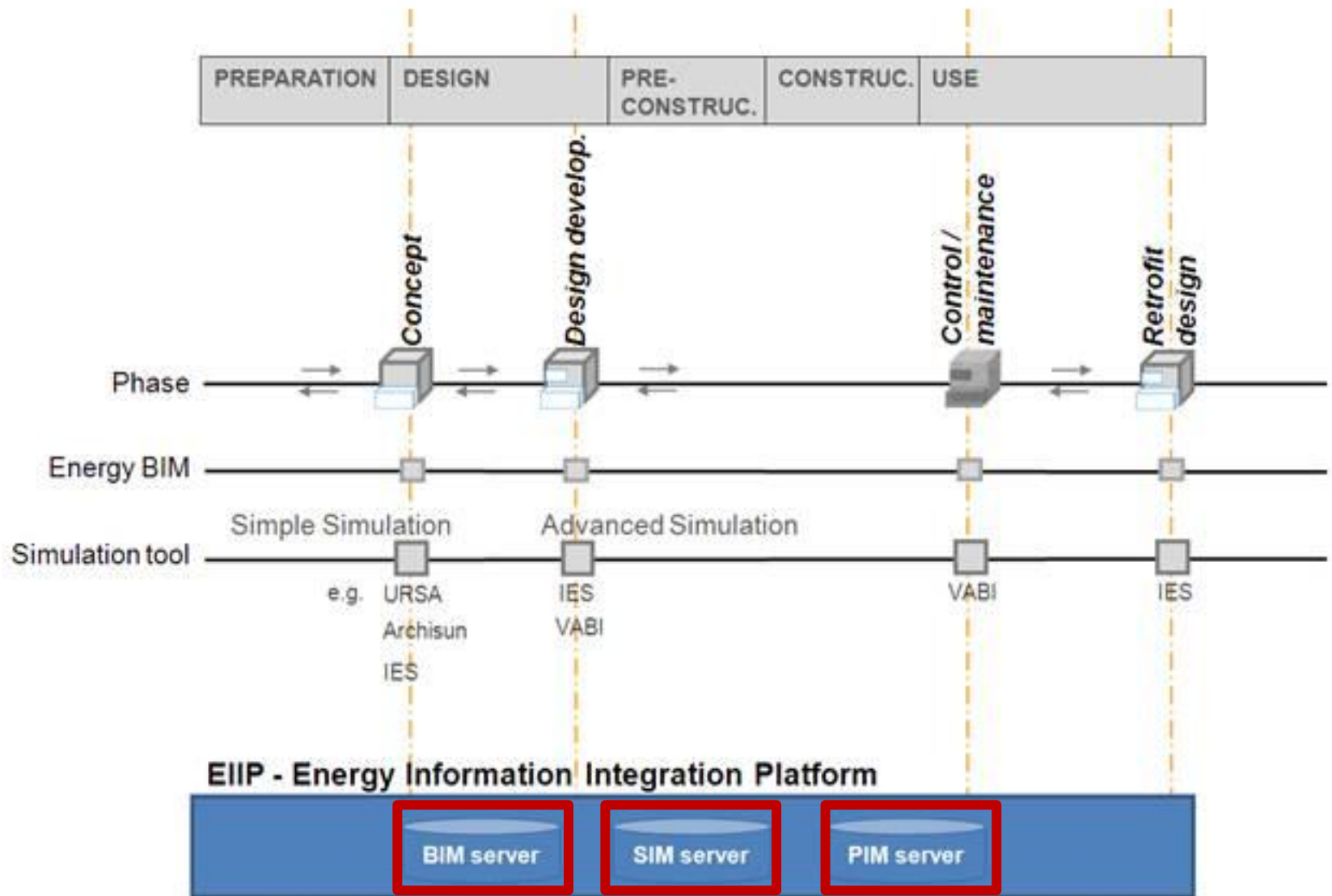
New Data

Design phase for new buildings



Operation Phase

Energy Information Platform



Energy Analysis and Reduction in the Urban Developments

Building Stock Classification

- It is widely acknowledged that similar type of buildings have comparable energy consumption levels;
- To identify the energy profile of an area, it is thus essential to classify the buildings into various categories;
- Building stock can be broadly classified into domestic and non-domestic building stock;
- Domestic stock can be further classified based on age, size and type;
- Non-domestic building stock can be further classified based on public sector, private sector and the nature of usage;

Urban Energy Analysis

- Building Classification
 - Domestic
 - Age
 - Size
 - Type
 - Non – domestic
 - Private Sector
 - Public Sector
- Energy Profiling
 - Domestic
 - BREDEM / SAP
 - Non Domestic
 - BREEAM

Energy Profiling

- For the domestic building stock, most widely used energy calculation engine is the Building Research Establishment Domestic Energy Model (BREDEM);
- Standard Assessment Procedure (SAP) is adopted by Government as the UK methodology for calculating the energy performance of domestic dwellings and is based on BREDEM;
- For the non-domestic building stock, Simplified Building Energy Model (SBEM) and Building Research Establishment Energy Assessment Model (BREEAM) is widely used;

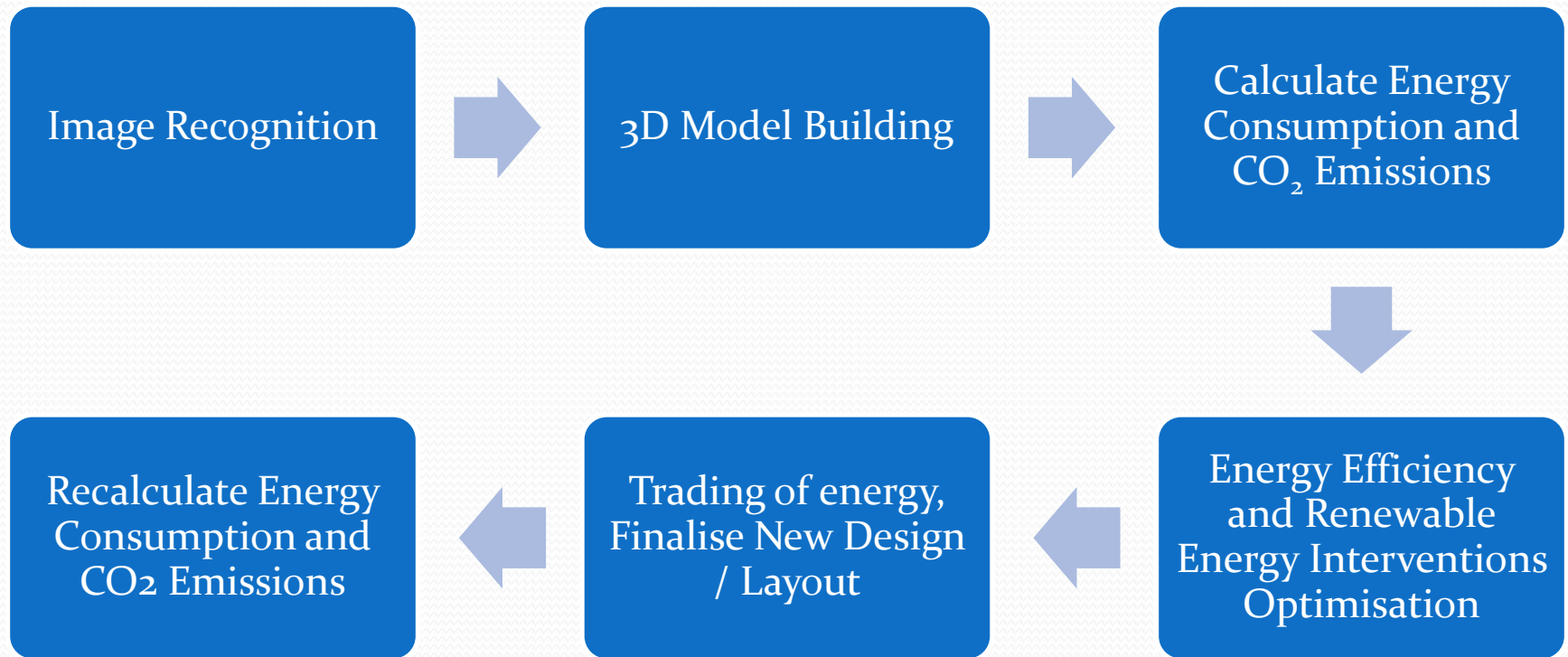
Gaps in Current Research

- Several models have been developed since the introduction of BREDEM in 1990's. However, most of them are targeted to energy reduction only in domestic building stock;
- These models rely on national statistics to identify the classes of buildings and their thermal levels;
- Thus, the models do not identify the energy profile on a geographical level i.e. Energy consumption is calculated only for the types of building stock and then aggregated. It does not necessarily tell how many types of buildings exist in a particular area and then their energy consumption;

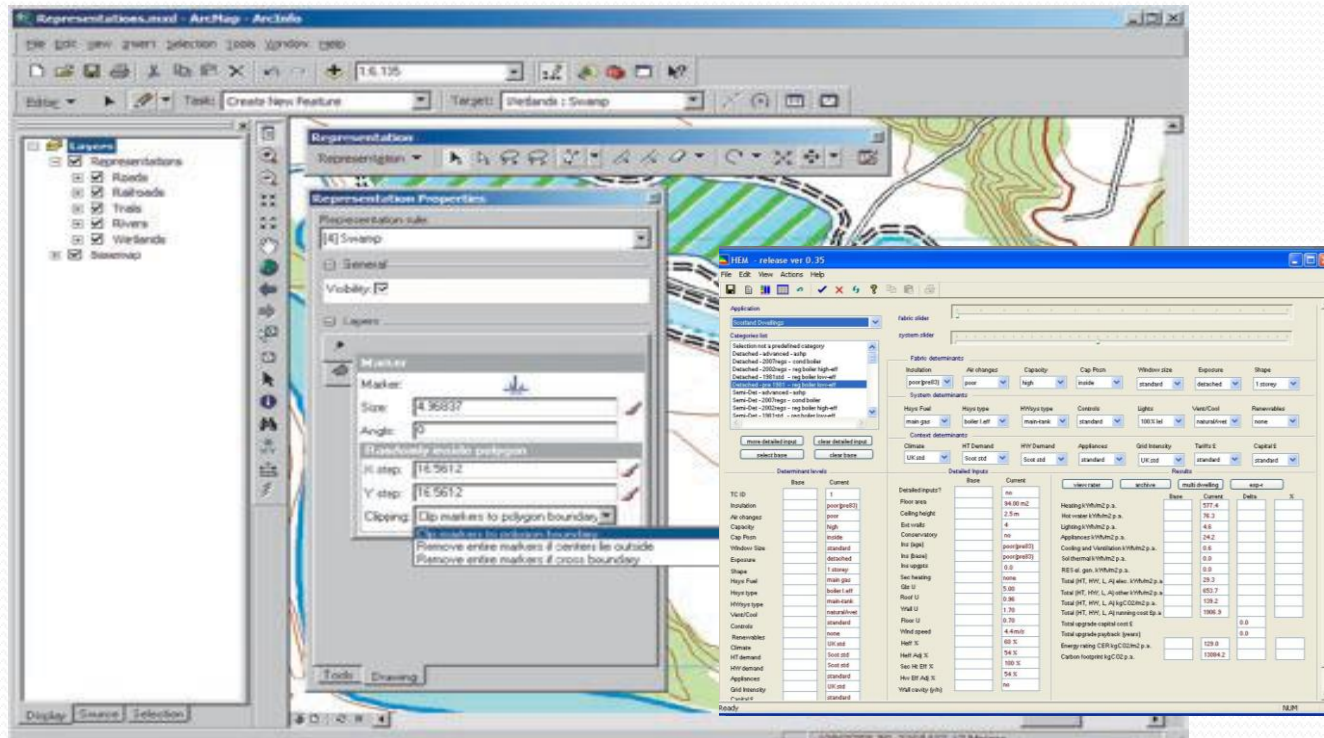
Way Forward

- To overcome the barrier of building identification and classification, it is proposed to identify and classify the building stock based on Ordnance Survey (OS) maps and aerial and terrestrial images through use of image recognition;
- The image recognition tools are integrated in GIS software such as ArcGIS / MapInfo which will provide an platform to input OS maps and aerial and terrestrial images;
- A virtual 3D model of the neighbourhood / city is being developed to undertake further energy calculations;
- Using Multi-Criteria Decision Analyses (MCDA) optimum energy efficiency and renewable energy interventions will be identified.

System Framework



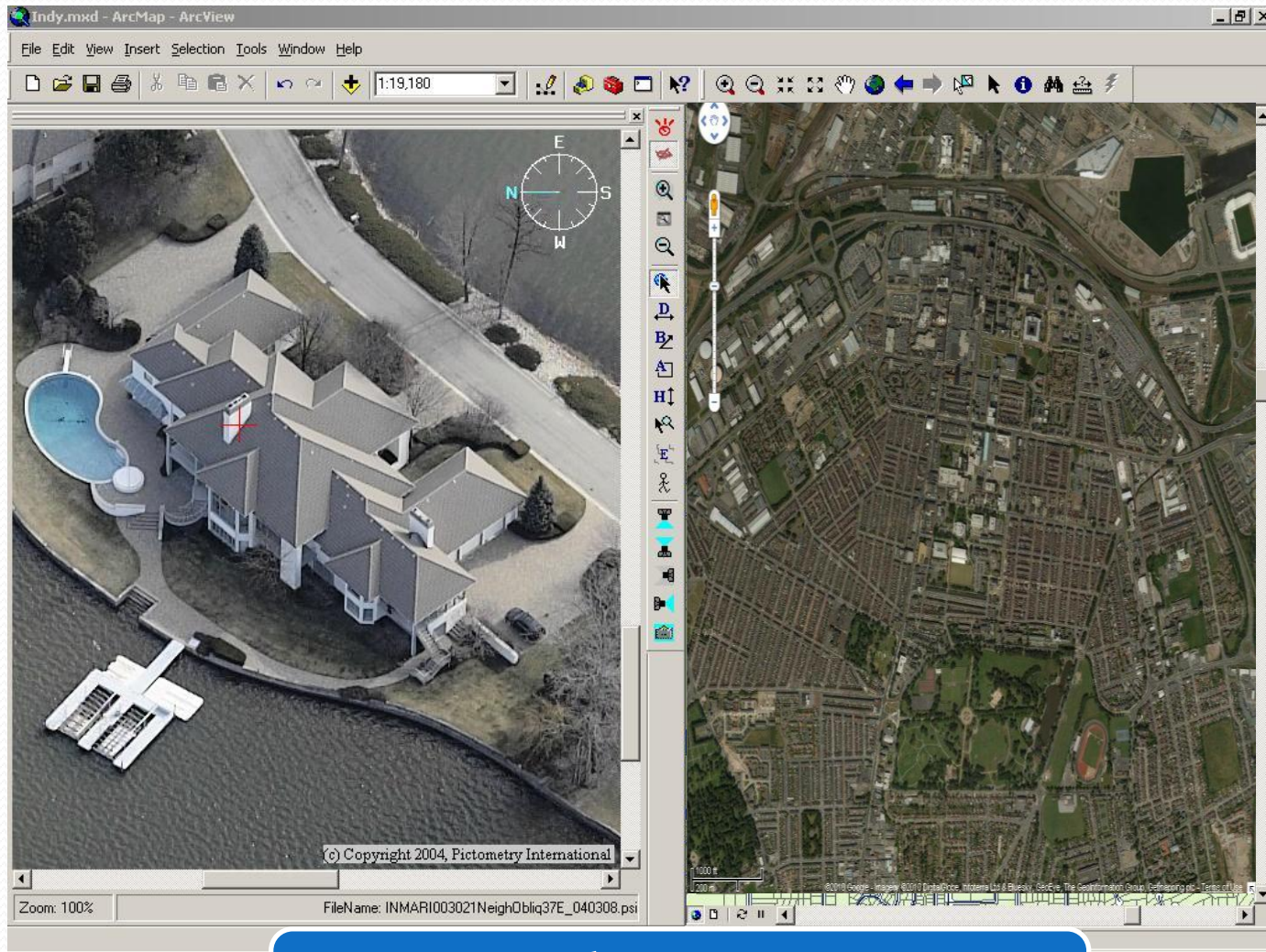
Tools Integration



Integrate Image Recognition / Processing (e.g. HALCON) and Energy Profiling Software (BREDEM and SAP) within GIS Software e.g. (ArcGIS / MapInfo)

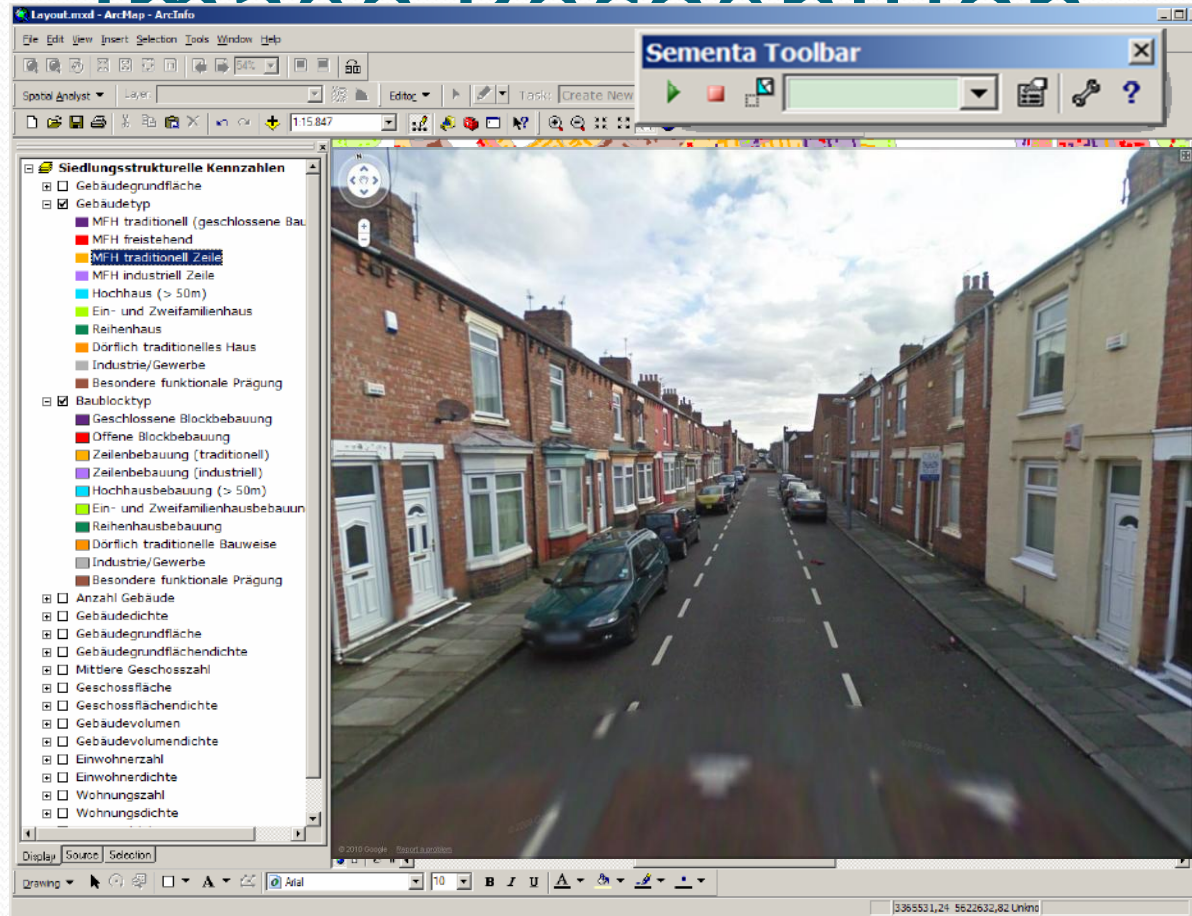


Image Recognition



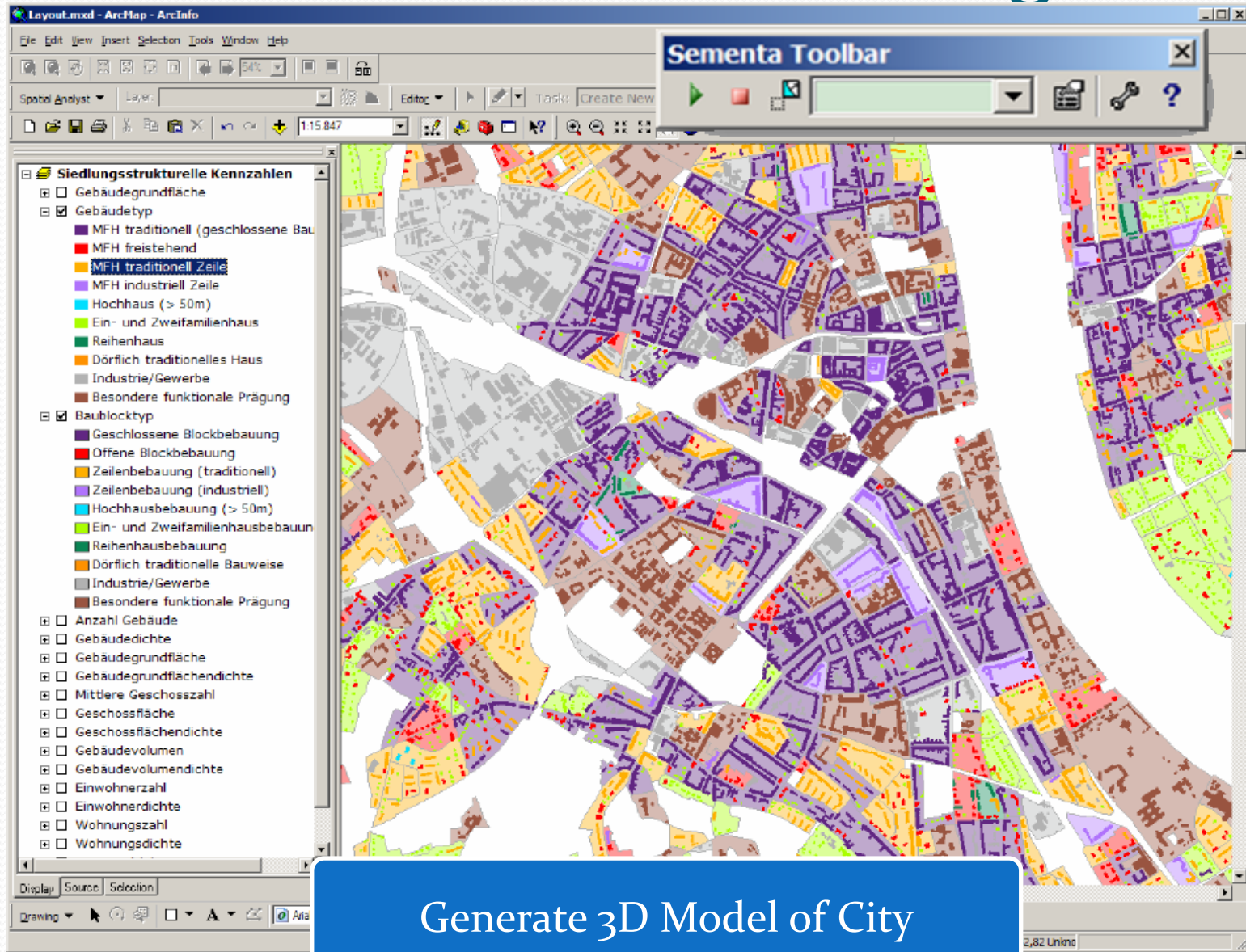
Import Ordinance Survey Maps
and Satellite Imagery in ArcGIS /
MapInfo

Image Recognition



Import Street View Images

3D Model Building



Building Classification

The screenshot displays the ArcMap interface with a map of a city area. The map is color-coded by building type: orange for traditional buildings, grey for industrial/commercial, and brown for buildings with special functional significance. Small colored dots on the map represent various building metrics. A 'Sementa Toolbar' is visible at the top right. The 'HEM' window is open, showing a detailed data table for building parameters.

TCID	Base	Current	Detailparameter	Base	Current	Unit	Delta	%
Position	poor (poor)	no	Floor area	101.20 (m ²)	Heating (VWHM ² a.)	577.4		
Air exchange	poor	no	Ceiling height	2.5 m	Hot water (VWHM ² a.)	76.3		
Capacity	high	high	Bas. walls	8	Lighting (VWHM ² a.)	4.9		
Cap. Perm	middle	no	Concealment	no	Appliances (VWHM ² a.)	24.2		
Window size	poor	poor (poor)	Ins. (light)	poor (poor)	Cooling and ventilation (VWHM ² a.)	0.0		
Exposure	no (Basic)	detached	Ins. (sound)	poor (poor)	Solar thermal (VWHM ² a.)	0.0		
Roofs	1 story	no	See heating	no	RE (a. gen. kWhM ² a.)	0.0		
Roofs Flat	no	no	Roof U	0.0	Total (HT, L, A, elec. kWhM ² a.)	28.3		
Roofs type	hatched left	no	Roof U	0.0	Total (HT, HW, L, A, elec. kWhM ² a.)	450.7		
Window type	multi-pane	no	Wall U	1.70	Total (HT, HW, L, A, elec. kWhM ² a.)	130.2		
WindowClad	non-thermal	no	Flow U	0.70	Total (HT, HW, L, A, elec. kWhM ² a.)	100.9		
Concrete	standard	no	4.4 kWh/m ²	0.0	Total upgrade capital cost (€)	0.0		
Reinforcement	no	no	Wall used	65.5	Total upgrade payback (years)			
Climate	UK std	no	Hall U	54.5	Energy saving (€ kWhM ² a.)	100.5		
HT demand	no std	no	Hall Adj. X	54.5	Custom (w/upgrade) kWhM ² a.)	1004.2		
HW demand	no std	no	See HT Adj. X	54.5				
Appliances	no std	no	HW HT Adj. X	54.5				
Grid intensity	UK std	no	Wall (ready (p/h))	no				

Legend:

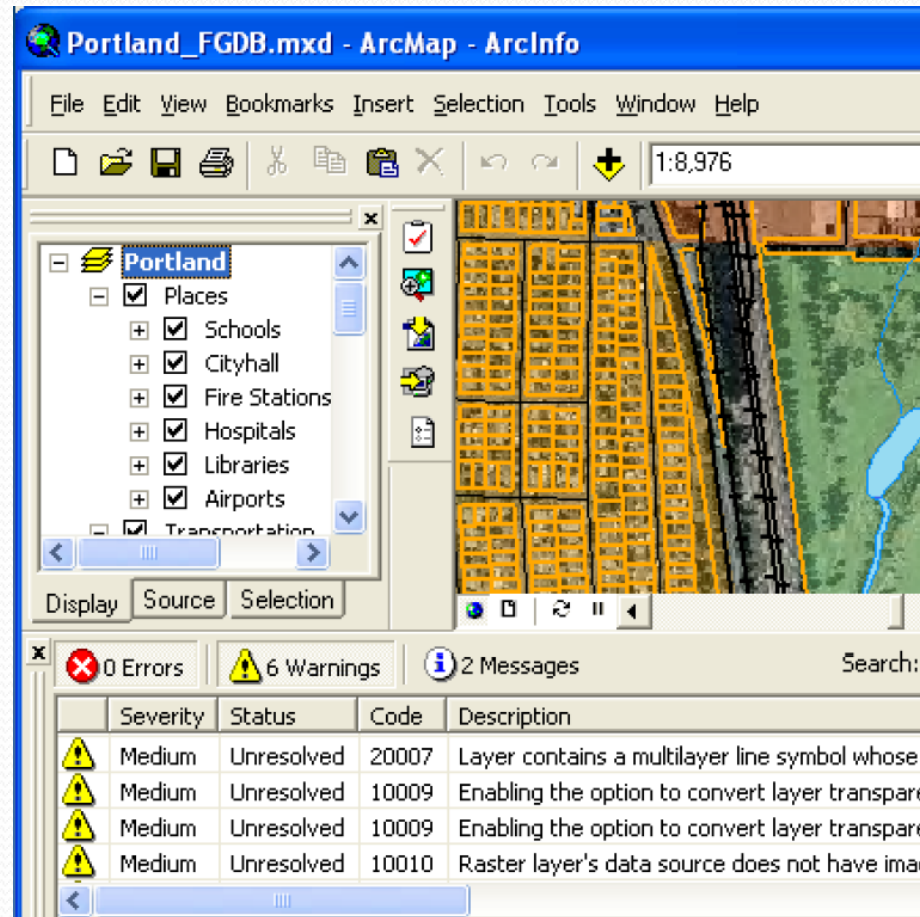
- Orange: Dorflisch traditionelle Bauweise
- Grey: Industrie/Gewerbe
- Brown: Besondere funktionale Prägung

Legend items (all checked):

- Anzahl Gebäude
- Gebäudedichte
- Gebäudegrundfläche
- Gebäudegrundflächendichte
- Mittlere Geschosshöhe
- Geschossfläche
- Geschossflächendichte
- Gebäudevolumen
- Gebäudevolumendichte
- Einwohnerzahl
- Einwohnerdichte
- Wohnungszahl
- Wohnungsdichte

Create Energy Profile of an Area

Optimisation



Identify the Optimum Energy Efficiency and Renewable Energy Interventions

Final Design

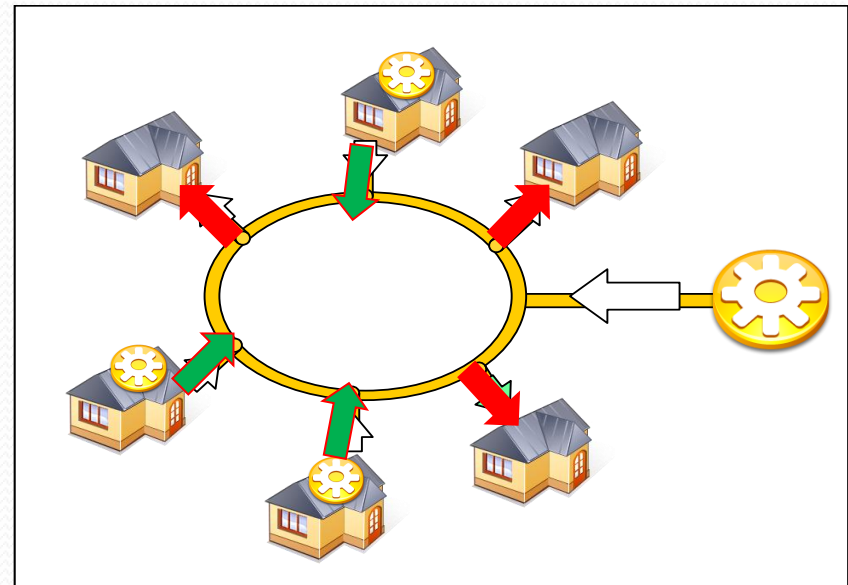
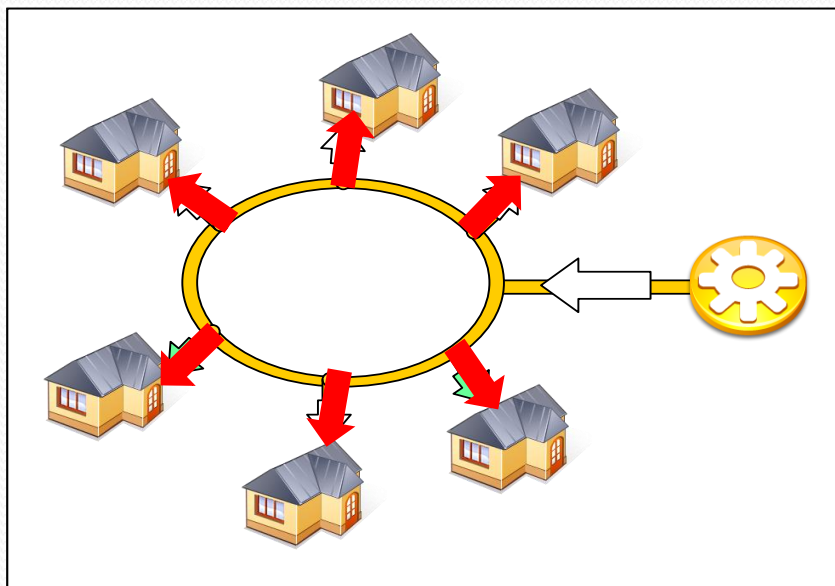
The screenshot displays the ArcMap interface with the Sementa Toolbar and HEM (Building Energy Model) software. The central map shows a city area with buildings color-coded according to their structural characteristics. The left panel, titled 'Siedlungsstrukturelle Kennzahlen', lists various building types and their characteristics, such as 'MFH traditionell (geschlossene Bau)', 'MFH freistehend', and 'Hochhaus (> 50m)'. The right panel, titled 'HEM release ver 0.35', shows a detailed energy profile with multiple columns of data, including 'Detailed inputs', 'Flow', and 'Results'. The HEM window displays a table with columns for 'Flow', 'Comment', and 'Results', and a 'Results' section with columns for 'Multi-building' and 'Single'.

Flow	Comment	Results
Floor area	34.00 m ²	157.4
Colony height	2.5 m	15.0
Grid width	4	4.0
Colony category	no	24.2
Use type	no (project)	0.0
Use (Bau)	no (project)	0.0
Use category	0.0	0.0
Use building	no	0.0
Floor U	0.30	23.0
Wind speed	1.30	0.0
Wind dir	0.70	106.0
Wind speed	4.4 m/s	0.0
Wind dir	60.0	0.0
See HE BR 1	14.0	108.2
See HE BR 2	14.0	106.0
See HE BR 3	14.0	108.2
See HE BR 4	14.0	108.2
See HE BR 5	14.0	108.2
See HE BR 6	14.0	108.2
See HE BR 7	14.0	108.2
See HE BR 8	14.0	108.2
See HE BR 9	14.0	108.2
See HE BR 10	14.0	108.2
See HE BR 11	14.0	108.2
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See HE BR 98	14.0	108.2
See HE BR 99	14.0	108.2
See HE BR 100	14.0	108.2

Recalculate Energy Profile of the Area including Energy Efficiency and Renewable Energy Measures

Concept of Urban energy analysis:

- Tools exist to manage distributed electricity production
- No tools to manage distributed heat production or heat trading



Conclusions

- BIM, Optimisation and visualisation of energy performance in both building operation and design set to play a major role in carbon footprint reduction.
- The research project is set to contribute to the 20% reduction by deploying ICT for energy efficient buildings
- WLCA for energy analysis in buildings is vital for any potential energy reduction.
- Neighborhood Management Systems for efficient distributed energy production and optimal energy transfers among buildings