AN ANALYSIS OF RESULTS VARIABILITY IN ENERGY PERFORMANCE COMPLIANCE VERIFICATION TOOLS

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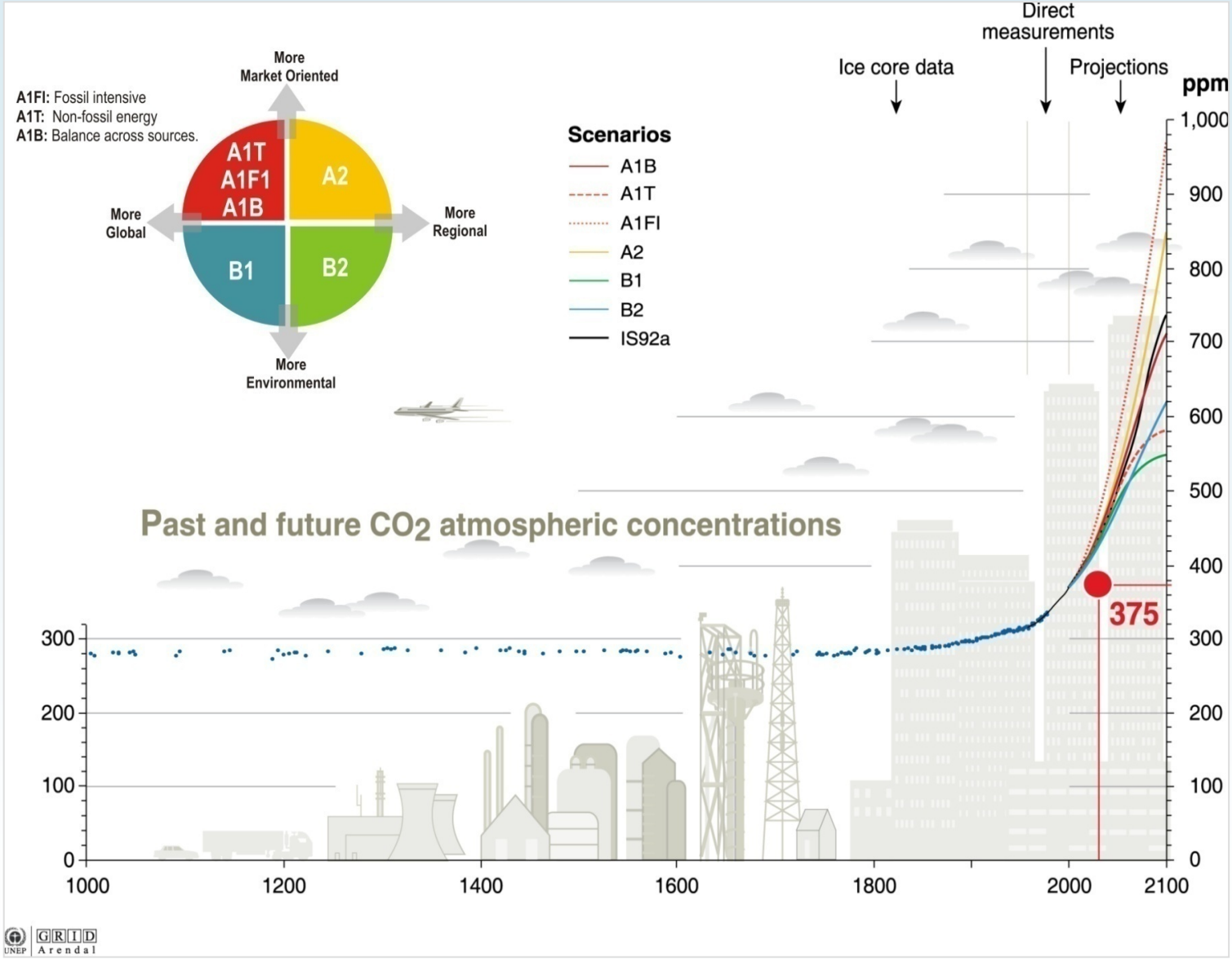
Overview

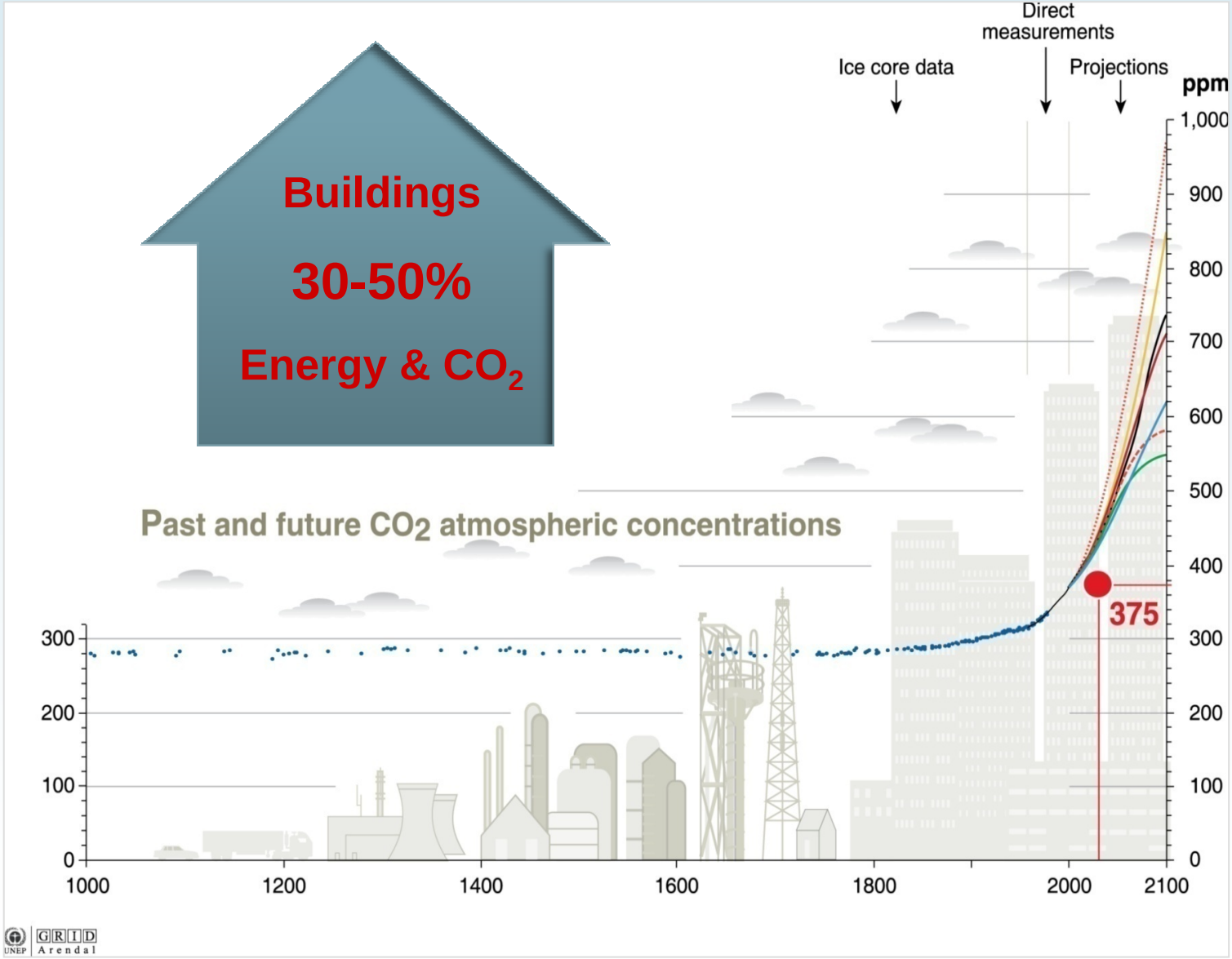
- **Background**
  - The Environmental Issue
  - UK Low Carbon Transition Plan
  - Zero Carbon Timeline
- **Part L2A**
- **Study Aims, Scope & Methodology**
- **Results Analysis**
- **Findings & Recommended Actions**

The Environmental Issue



Source: UNEP/Grid Arendal

The Environmental Issue



Source: UNEP/Grid Arendal

The UK Low Carbon Transition Plan

- The 2008 Climate Change Act
- Legally binding 'carbon budgets',
- Cut UK emissions by:

34% by 2020

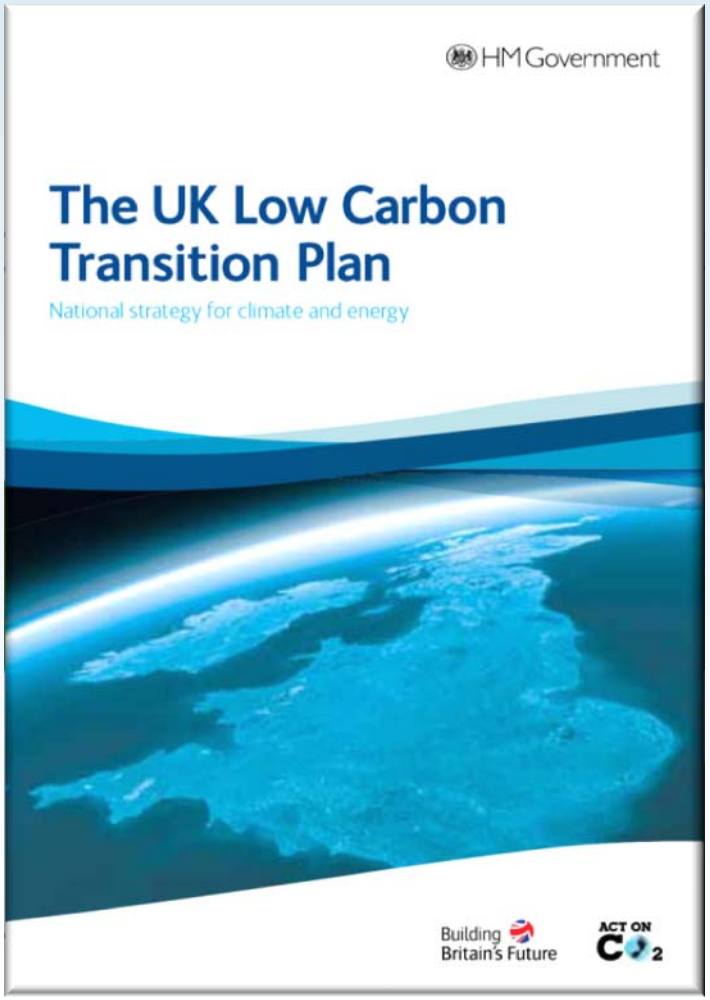
80% by 2050

Transport

Recycling

Energy

Buildings

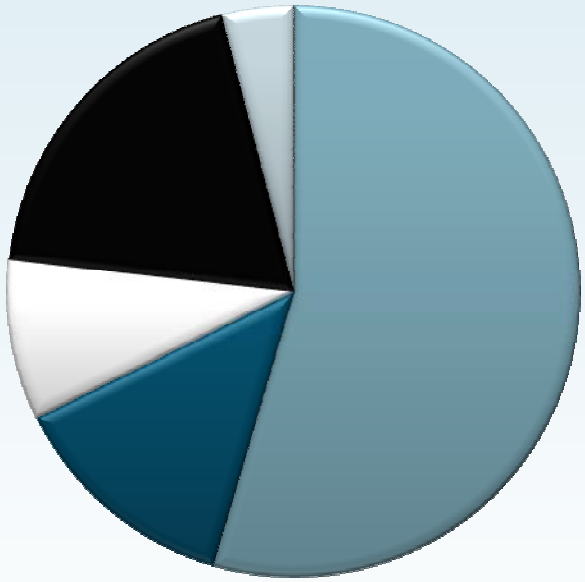


Zero Carbon Timeline

- **2002** • European Directive for Building Performance
- **2006** • Part L 2006 – National Calculation Methodology
- **2008** • Energy Performance Certificates
- **2010** • Part L 2010 & 25% energy/CO_2 improvement
- **2013** • 44% energy/CO_2 improvement in UK
- **2016** • UK Zero Carbon Domestic Sector
- **2019** • UK Zero Carbon Non-Domestic Sector
- **2020** • 20 % CO_2 emissions reduction in EU
- **2050** • 60% CO_2 emissions cut in UK

Zero Carbon

Share of 2018-2022 emissions savings



Zero Carbon Timeline

UCL

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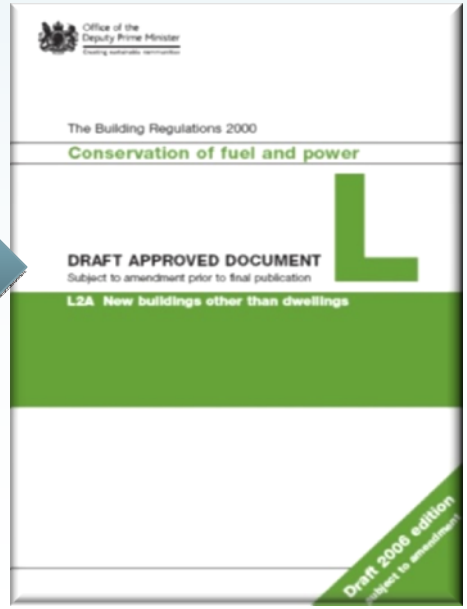
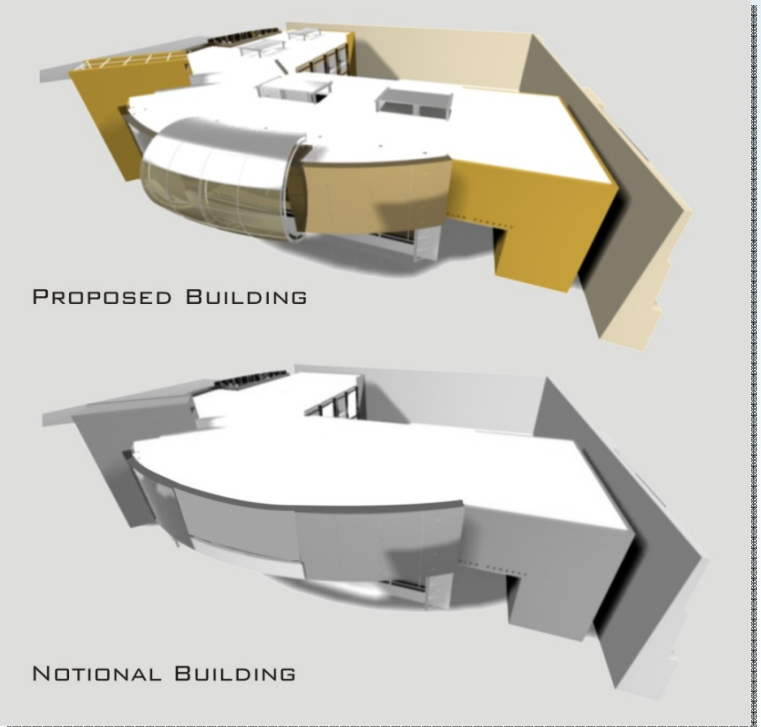
Zero Carbon



Part L2A: National Calculation Methodology

Simulate a proposed design, compare its performance (CO_2 emissions) to an equivalent notional (2002 compliant)

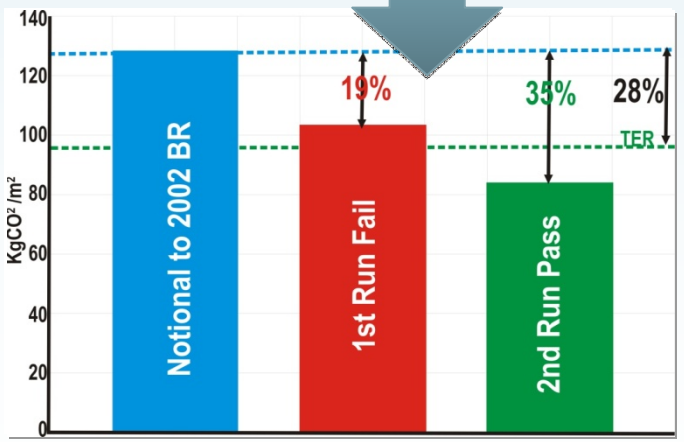


1-Simulate: Building & Generate Notional

2-Calculate:

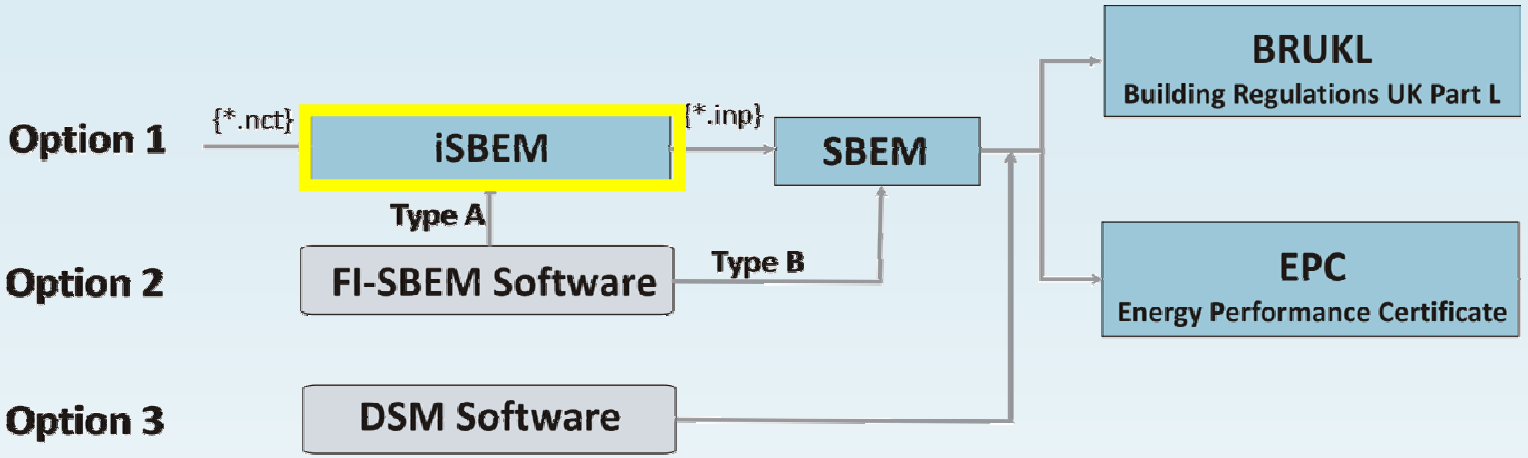
Benchmark for comparison:

Target Emission Rate (TER)



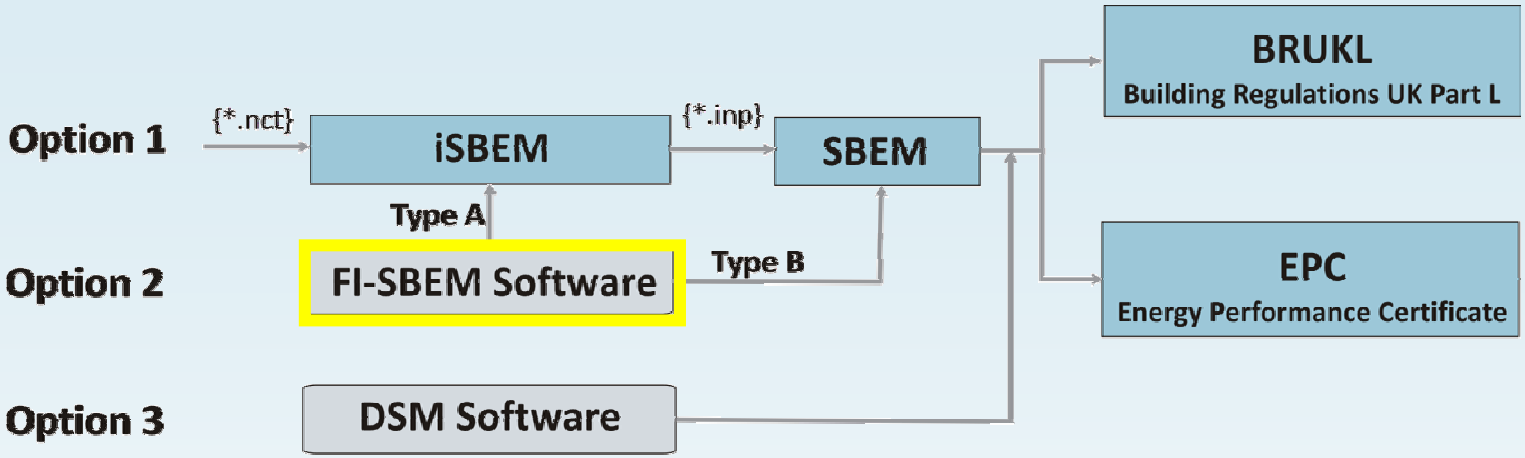
3-Compare: Determine Compliance

Part L2A: Simulation Tools



CLASS	INPUT METHOD/DATA	CALCULATION METHODOLOGY	OUTPUTS
SBEM	Non-graphical, Microsoft Access based forms.	Monthly Average	-BRUKL/SBEM outputs -Data reflection reports -EPC Certificates
FI-SBEM TYPE A	Front-end graphical interface is used for geometry input. Interfaces with iSBEM for additional input.	Monthly Average	-BRUKL/SBEM outputs -Data reflection reports -EPC Certificates
FI-SBEM TYPE B	A front-end graphical interface is used for building geometry & information input.		
DSM	3D CAD front-end modules allow building geometry to be input &/or imported from CAD packages, 3D BIM & other software.	Detailed Hourly	-BRUKL/SBEM outputs -Data reflection reports -EPC Certificates -Load /energy analysis

Part L2A: Simulation Tools



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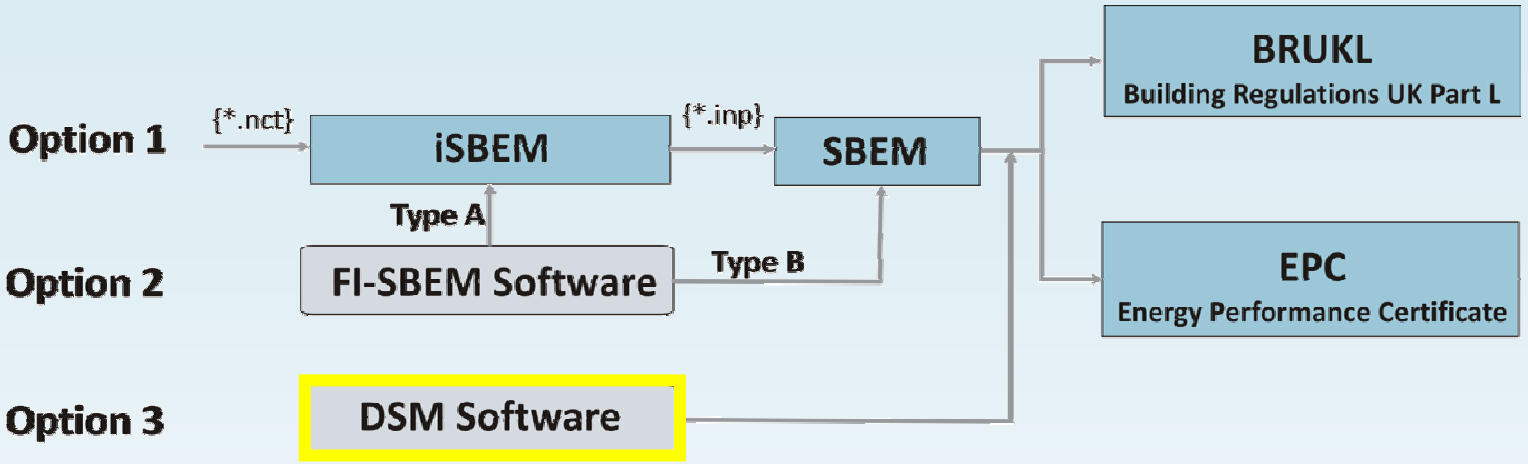

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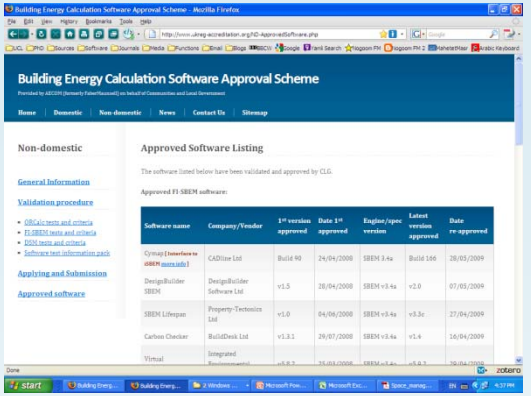
Study Aims

Project Goal

Investigate the extent of variability of

results produced by ADL2A accredited software



Context of Study

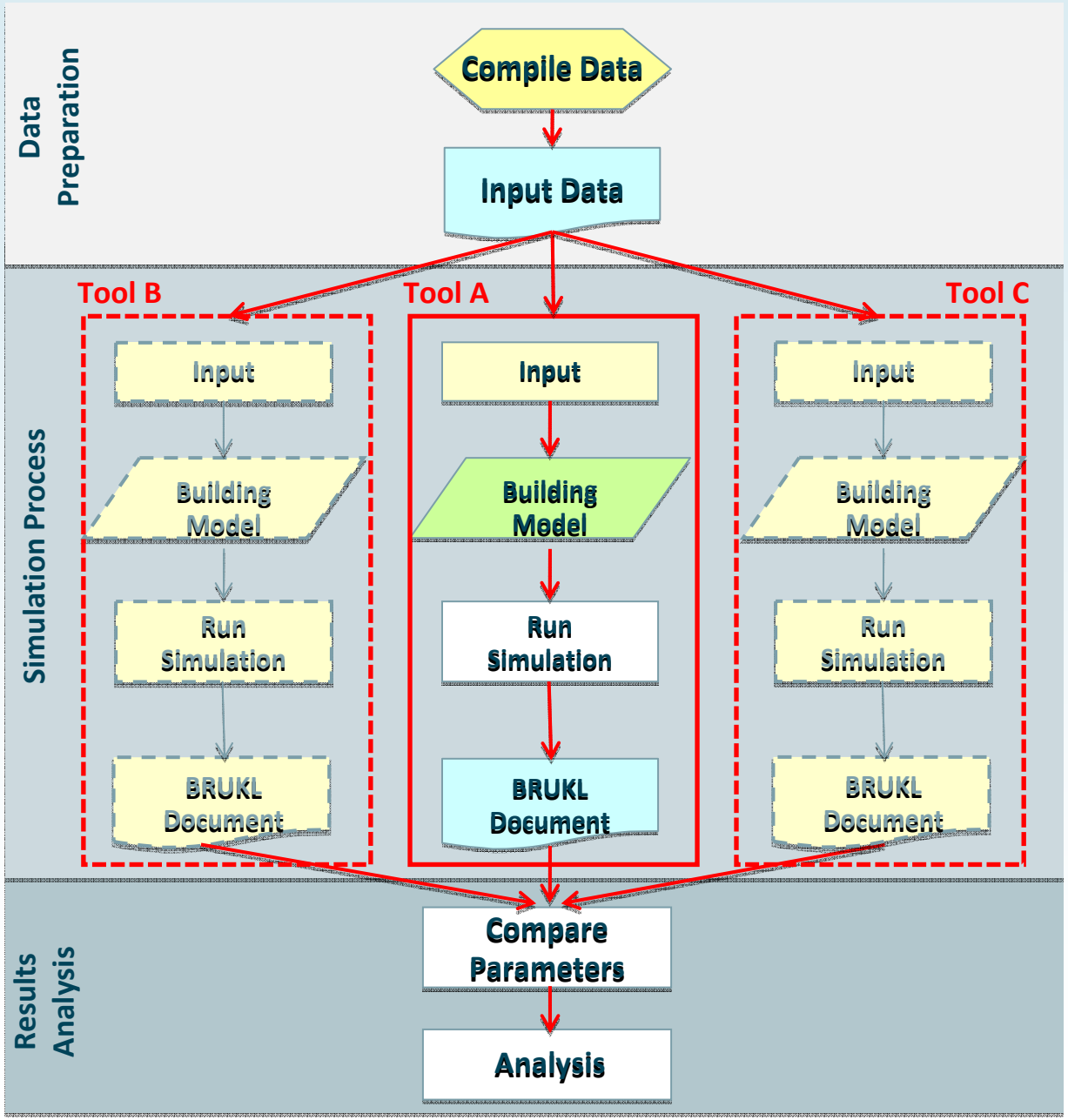
Tools accredited under the non-domestic building

energy calculation software approval scheme

Methodology

Inter-Modal Comparative Evaluation

Study Methodology



Study Scope & Implementation

12 Accredited Tools

SBEM

9 FI-SBEM

1 DSM/FI-SBEM

1 DSM

Single Modeller

Relevant Qualifications

(BSc. /MSc.)

3 Years + Experience

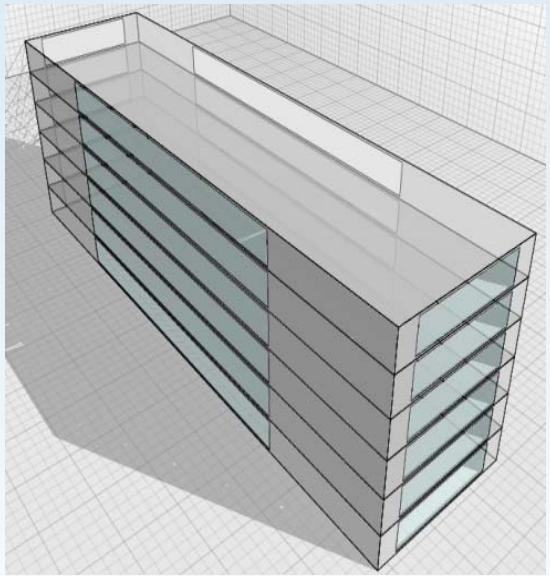
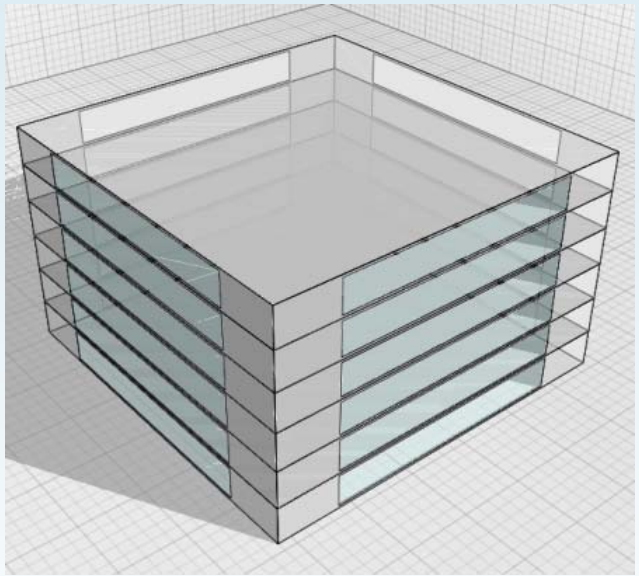
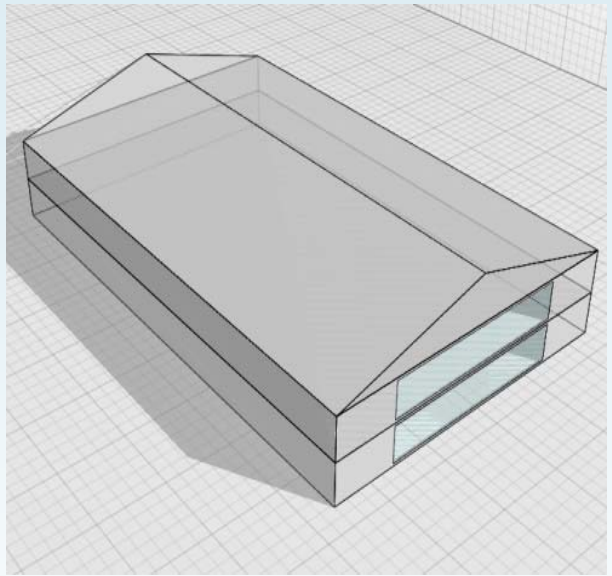
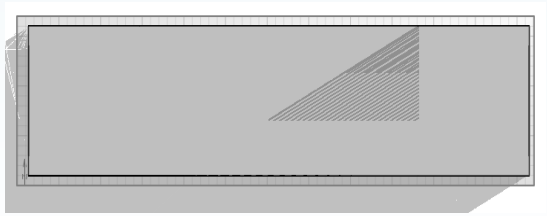
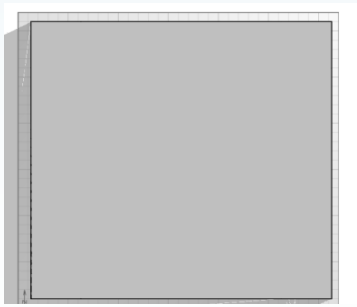
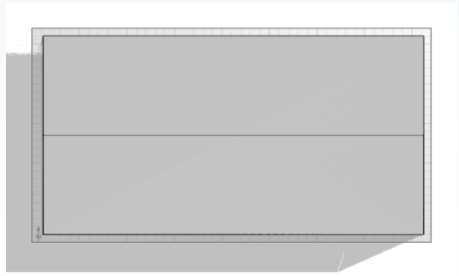
Minimal external tools

AutoCAD

PVSYST v4.33

SOFTWARE	VERSION	CLASS	CALCULATION ENGINE
SBEM (iSBEM)	3.3b	Default Tool	SBEM
Carbon Checker	1.3.1	FI-SBEM	SBEM
Cymap 2008	Build 90	FI-SBEM	SBEM
Design Builder	1.8.1	FI-SBEM	SBEM
Design Database	24.21	FI-SBEM	SBEM
Graphical iSBEM	14.0	FI-SBEM	SBEM
Pro EP Cert	24.21	FI-SBEM	SBEM
Quick EP Cert	24.21	FI-SBEM	SBEM
SBEM Lifespan	1.0	FI-SBEM	SBEM
Space Manager	2.59	FI-SBEM	SBEM
VE Virtual Environment	5.9	FI-SBEM/DSM	SBEM/Apache
TAS Building Designer	9.1.1	DSM	Tas Engine

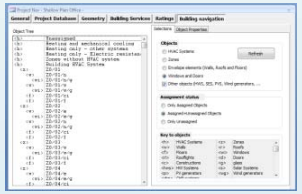
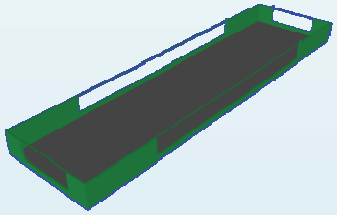
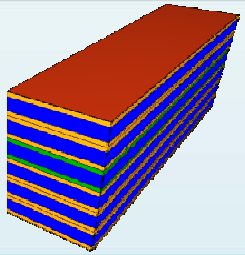
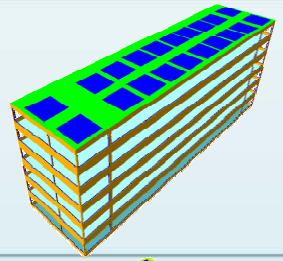
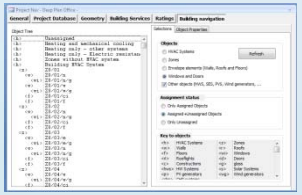
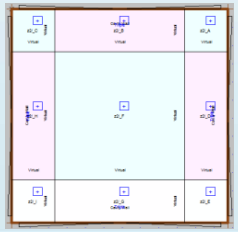
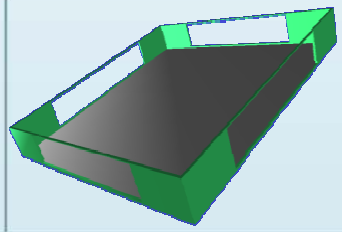
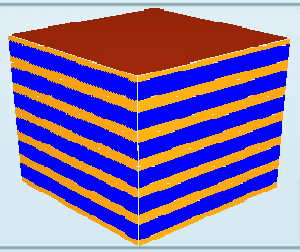
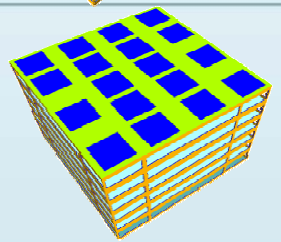
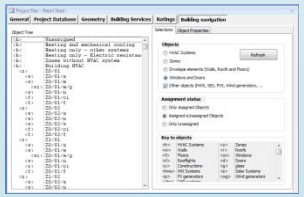
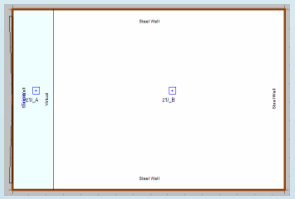
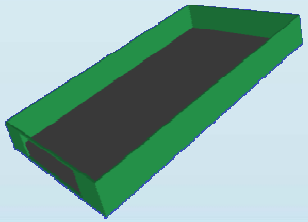
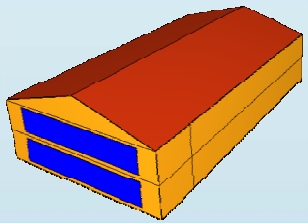
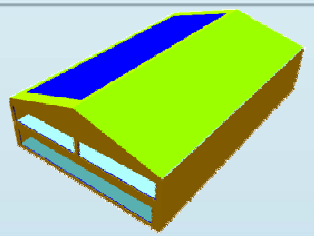
Variant Models

Variant 1	Variant 2	Variant 3
		
		
Office **Shallow Plan Side Lit**	**Office** **Deep Plan High Rise**	**Retail** **Shed with Sloped Roof**

Results : Model Representation

UCL

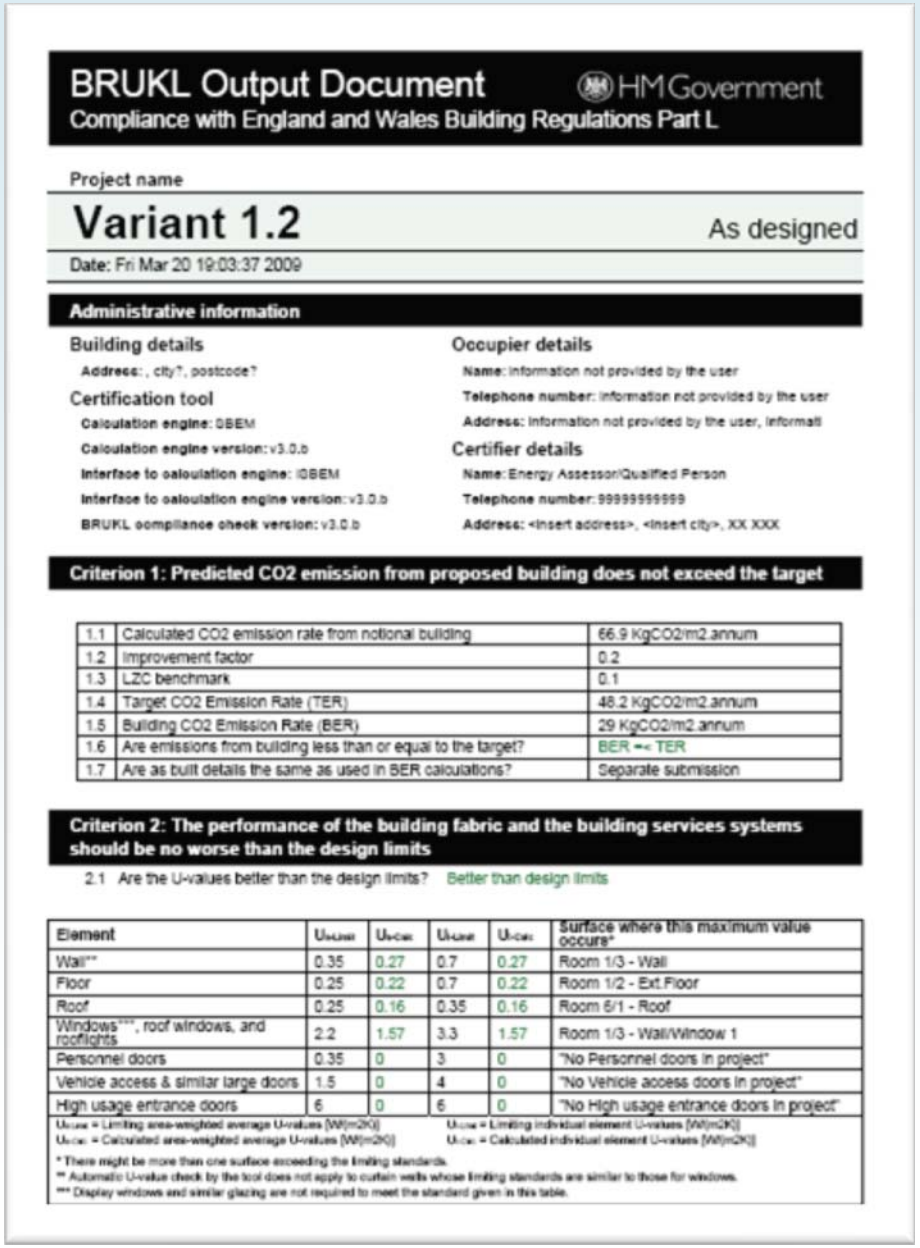
Degree of Detail

Type	NON-GRAPHICAL MODEL	SIMPLIFIED 2D FLOOR PLAN	2D FLOOR PLAN WITH 3D ZONE DISPLAY	ABSTRACT 3D MODEL	DETAILED 3D MODEL
Variant 1					
Variant 2					
Variant 3					
Description	•Building data represented in a structured object tree format	•2D floor plans are used to create building layout &assign building elements.	•2D floor plans are used to create building layout. •Built-in or external viewer allows visualisation of selected zones.	•Abstract 3D models with minimal detail. •Rendering libraries for material display.	•Increased detail , e.g shading patterns & PV panel distribution. •Rendering libraries for material display.
	iSBEM, QuickCert, SBEM Lifespan	GI-SBEM, Cymap, ProCert	Space Manger Design Database	CarbonChecker Designbuilder	Tas IES(VE)

Results: BRUKL Document Parameters

Parameters

- Notional, TER, BER CO_2 Emissions
- Fabric U-Values
- HVAC Systems Efficiencies
- Infiltration Checks
- Annual Energy Consumption
- Annual Energy Demand
- Building Global Parameters



BRUKL Output Document — HM Government

Compliance with England and Wales Building Regulations Part L

Project name

Variant 1.2 — As designed

Date: Fri Mar 20 19:03:37 2009

Administrative information

Building details

Address: , city?, postcode?

Certification tool

Calculation engine: DBEM

Calculation engine version: v3.0.b

Interface to calculation engine: IDBEM

Interface to calculation engine version: v3.0.b

BRUKL compliance check version: v3.0.b

Occupier details

Name: Information not provided by the user

Telephone number: Information not provided by the user

Address: Information not provided by the user, Informati

Certifier details

Name: Energy Assessor/Qualified Person

Telephone number: 99999999999

Address: <Insert address>, <Insert city>, XX XXX

Criterion 1: Predicted CO2 emission from proposed building does not exceed the target

1.1	Calculated CO2 emission rate from notional building	66.9 KgCO2/m2.annum
1.2	Improvement factor	0.2
1.3	LZC benchmark	0.1
1.4	Target CO2 Emission Rate (TER)	48.2 KgCO2/m2.annum
1.5	Building CO2 Emission Rate (BER)	29 KgCO2/m2.annum
1.6	Are emissions from building less than or equal to the target?	BER =< TER
1.7	Are as built details the same as used in BER calculations?	Separate submission

Criterion 2: The performance of the building fabric and the building services systems should be no worse than the design limits

2.1 Are the U-values better than the design limits? Better than design limits

Element	$U_{i,Limit}$	$U_{i,Calc}$	U_{Limit}	U_{Calc}	Surface where this maximum value occurs*
Wall**	0.35	0.27	0.7	0.27	Room 1/3 - Wall
Floor	0.25	0.22	0.7	0.22	Room 1/2 - Ext.Floor
Roof	0.25	0.16	0.35	0.16	Room 6/1 - Roof
Windows***, roof windows, and rooflights	2.2	1.57	3.3	1.57	Room 1/3 - Wall/Window 1
Personnel doors	0.35	0	3	0	"No Personnel doors in project"
Vehicle access & similar large doors	1.5	0	4	0	"No Vehicle access doors in project"
High usage entrance doors	6	0	6	0	"No High usage entrance doors in project"

U_{Limit} = Limiting area-weighted average U-values [W/m2K] $U_{i,Limit}$ = Limiting individual element U-values [W/m2K]

U_{Calc} = Calculated area-weighted average U-values [W/m2K] $U_{i,Calc}$ = Calculated individual element U-values [W/m2K]

* There might be more than one surface exceeding the limiting standards.

** Automatic U-value check by the tool does not apply to curtain walls whose limiting standards are similar to those for windows.

*** Display windows and similar glazing are not required to meet the standard given in this table.

Results: BRUKL Document Parameters

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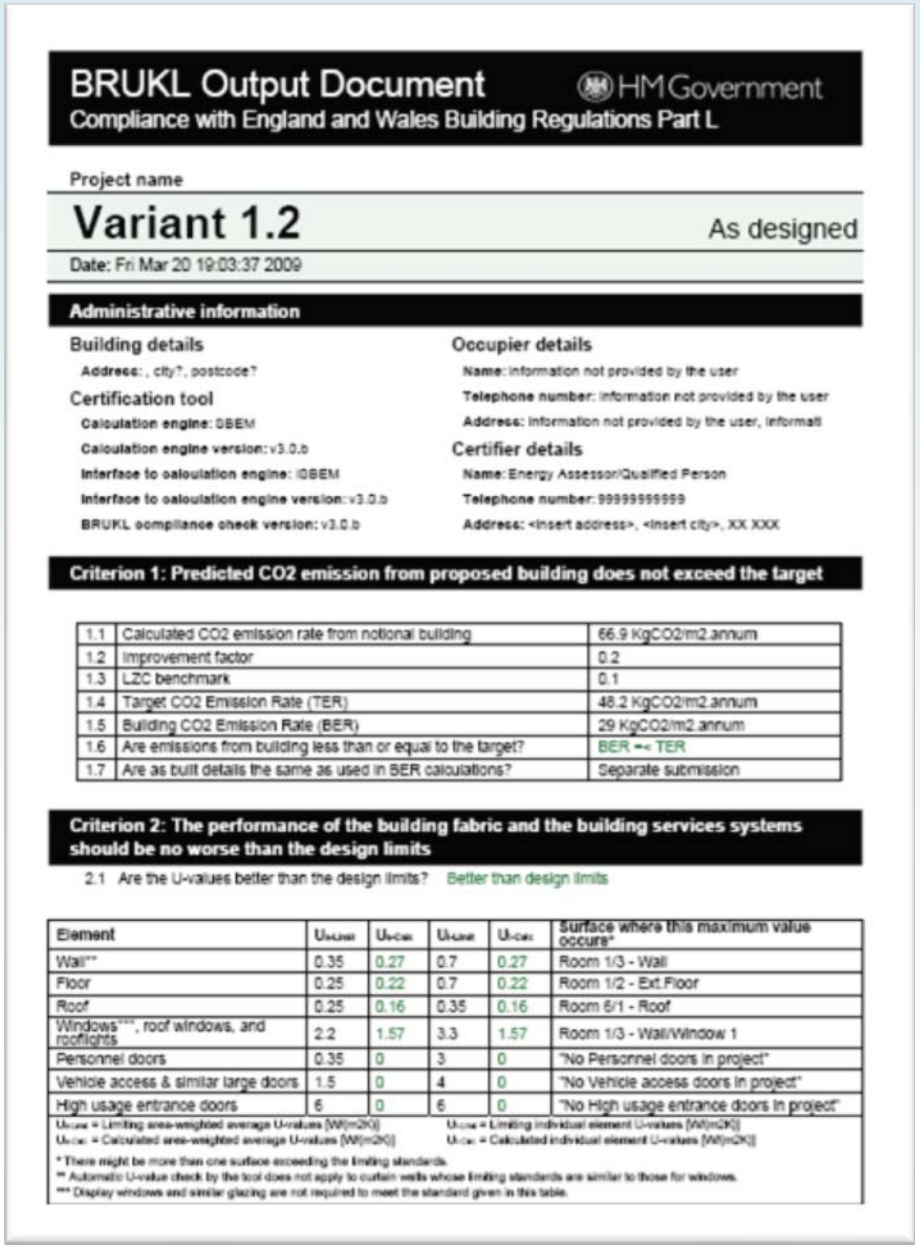

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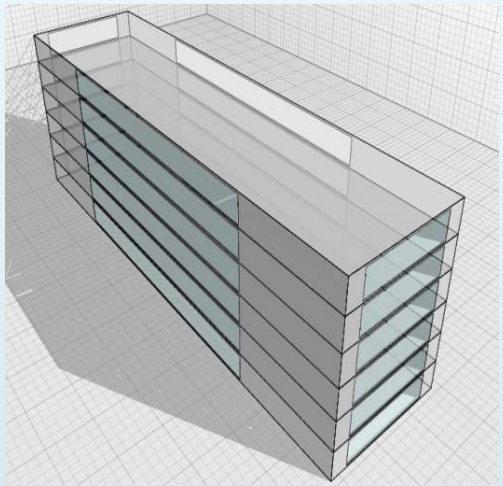
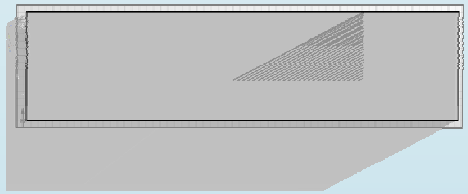
Results: BRUKL Document Parameters

CO_2 Emissions: TER = C_{NOT} x (1- improvement factor) x (1- LZC benchmark)



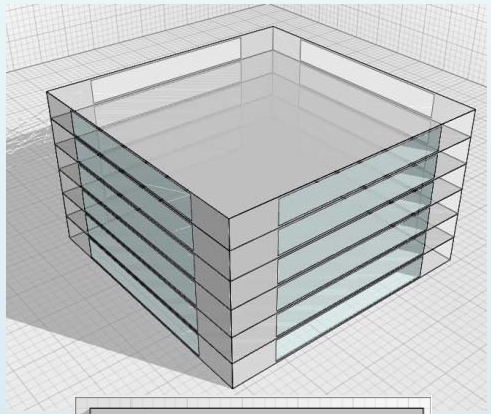


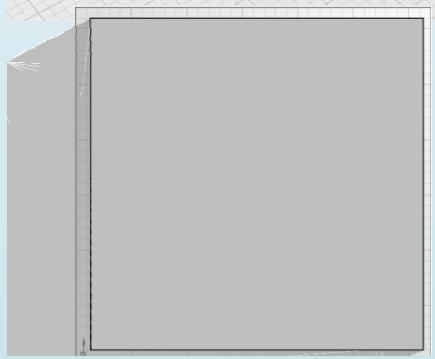
92 % Pass Rate

Variant 1 : Shallow Plan Office Building						
Tool	Emissions ($kgCO_2/m^2$.annum)				BER Improvement %	
	Notional	TER	BER	Pass/Fail	Notional	TER
A	75.3	54.2	53.9	Pass	28%	1%
B	72.9	52.5	28.6	Pass	61%	46%
C	69.9	50.4	37.2	Pass	47%	26%
D	89.3	64.3	50	Pass	44%	22%
E	108.6	78.2	60.4	Pass	44%	23%
F	88.8	63.9	53.2	Pass	40%	17%
G	88.8	63.9	54.4	Pass	39%	15%
H	88.9	64	54.2	Pass	39%	15%
I	73.4	52.8	47.7	Pass	35%	10%
J	89.4	64.4	61.1	Pass	32%	5%
K	89.5	64.5	34.4	Pass	62%	47%
L	43.6	31.4	32.6	Fail	25%	-4%
M	52.2	37.6	33.7	Pass	35%	10%

Results: BRUKL Document Parameters

CO_2 Emissions: TER = C_{NOT} x (1- improvement factor) x (1- LZC benchmark)



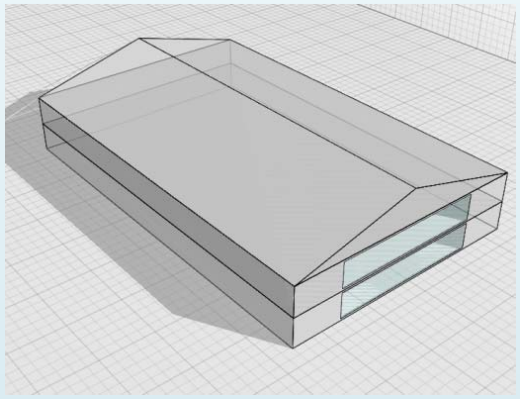


100 % Pass Rate

Variant 2 : Deep Plan High Rise Office Building						
Tool	Emissions ($kgCO_2/m^2$.annum)				BER Improvement %	
	Notional	TER	BER	Pass/Fail	Notional	TER
A	74.6	53.7	13.2	Pass	82%	75%
B	74.6	53.7	29.6	Pass	60%	45%
C	73.5	52.9	34.4	Pass	53%	35%
D	86.9	62.6	22	Pass	75%	65%
E	96.5	69.5	36.8	Pass	62%	47%
F	86.6	62.3	28.2	Pass	67%	55%
G	84.7	61	28.5	Pass	66%	53%
H	86.8	62.5	51.8	Pass	40%	17%
I	76.2	54.8	42.3	Pass	44%	23%
J	98.7	71.1	62.2	Pass	37%	13%
K	87.4	62.9	32.7	Pass	63%	48%
L	53.1	38.2	26.1	Pass	51%	32%
M	38.8	27.9	19.5	Pass	50%	30%

Results: BRUKL Document Parameters

CO_2 Emissions: TER = C_{NOT} x (1- improvement factor) x (1- LZC benchmark)

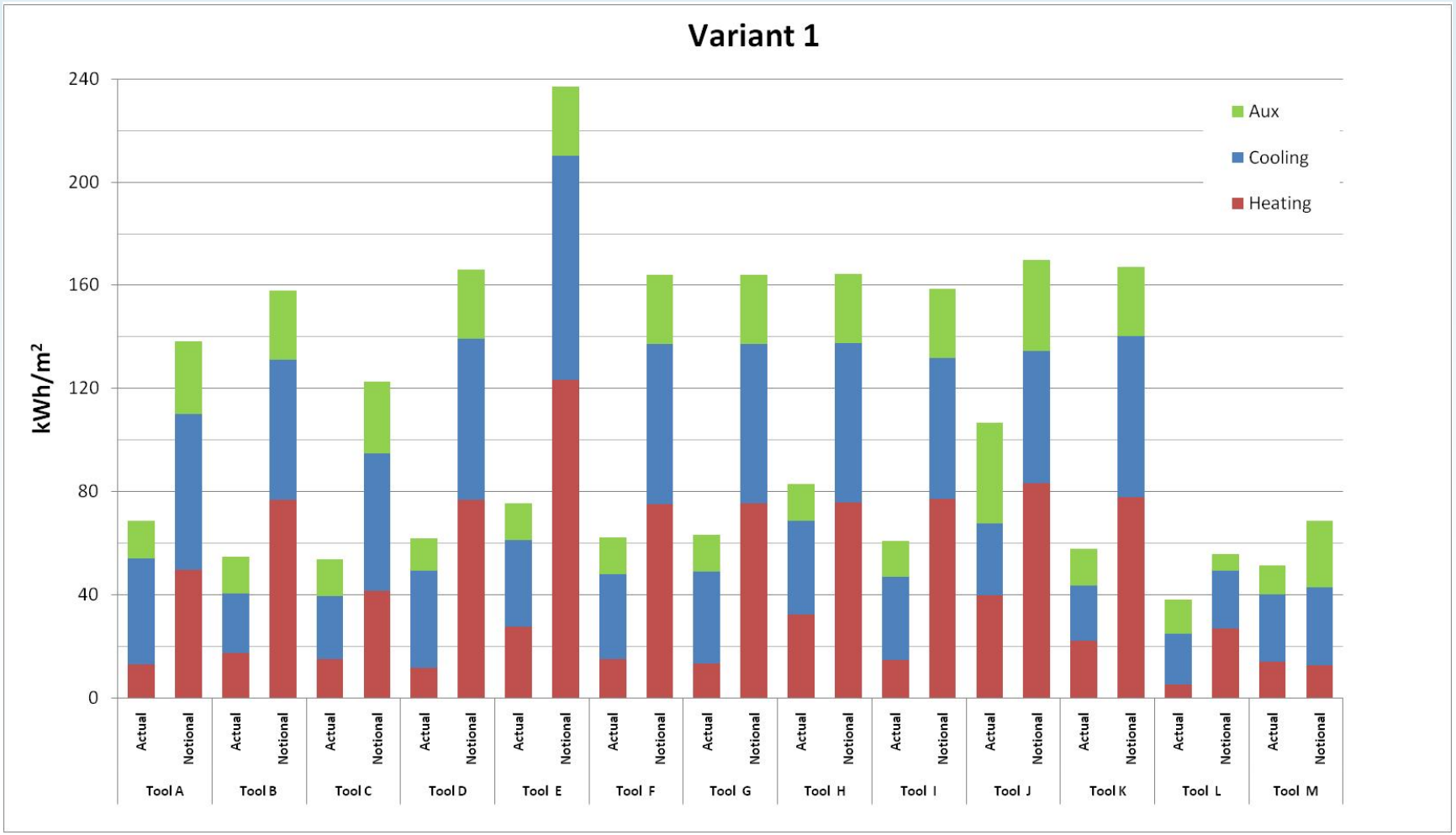


69 % Pass Rate

Variant 3 : Retail Shed						
Tool	Emissions ($kgCO_2/m^2$.annum)				BER Improvement %	
	Notional	TER	BER	Pass/Fail	Notional	TER
A	170.5	122.7	111.7	Pass	34%	9%
B	108.1	77.9	80.0	Fail	26%	-3%
C	170.2	122.5	116.2	Pass	32%	5%
D	157.6	113.5	74.2	Pass	53%	35%
E	165.4	119.1	105.4	Pass	36%	12%
F	162.3	116.8	125.5	Fail	23%	-7%
G	162	116.6	123.7	Fail	24%	-6%
H	161.9	116.6	105.7	Pass	35%	9%
I	171	123.1	104.1	Pass	39%	15%
J	106.6	76.7	84.2	Fail	21%	-10%
K	150.5	108.4	58.9	Pass	61%	46%
L	93.3	67.2	52.8	Pass	43%	21%
M	77.2	55.7	39.4	Pass	49%	29%

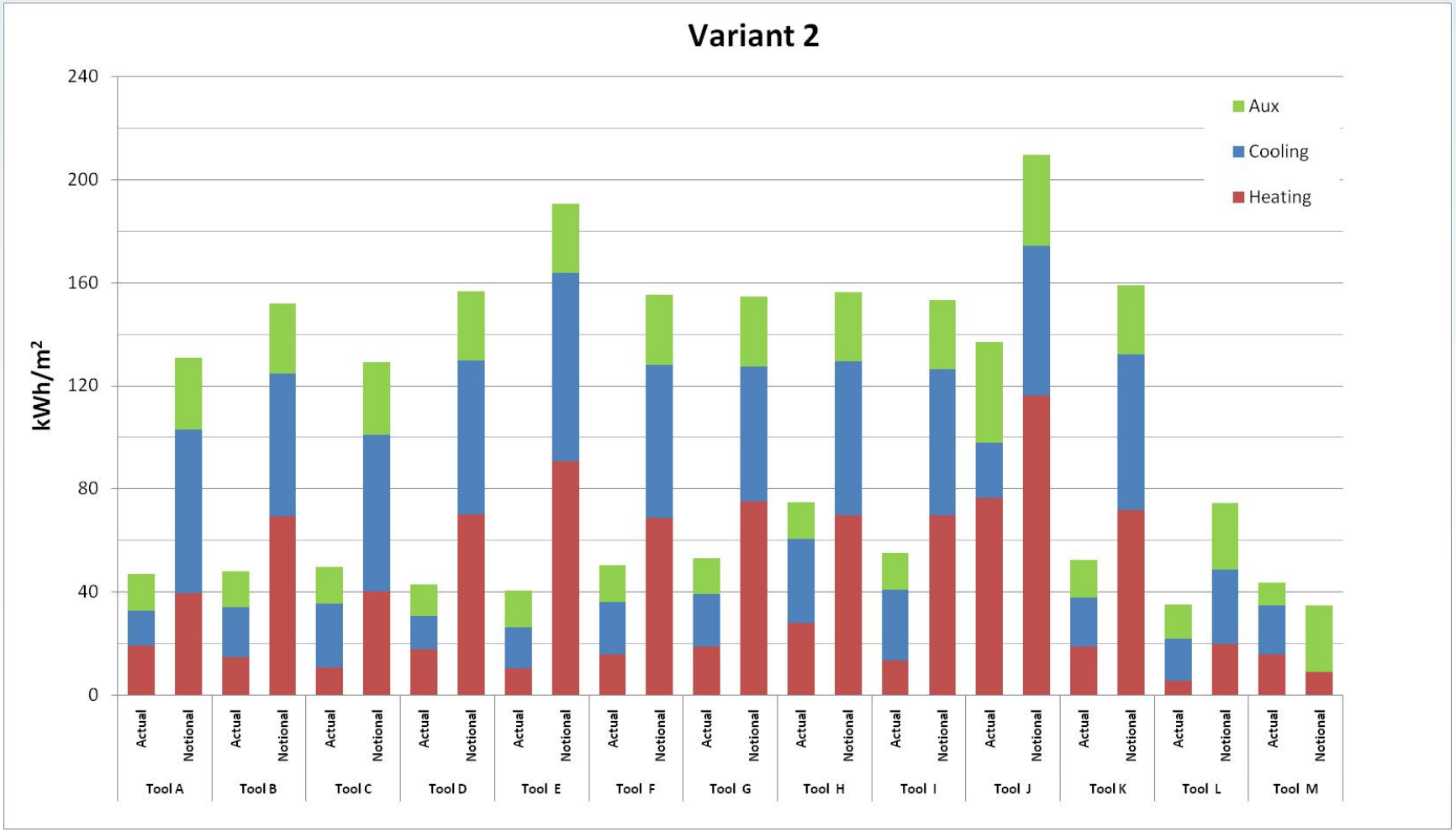
Results: BRUKL Document Parameters

Annual Energy Consumption (kWh/m²): Inherent building characteristics (use, geometry & fabric) + HVAC system type & system efficiencies.



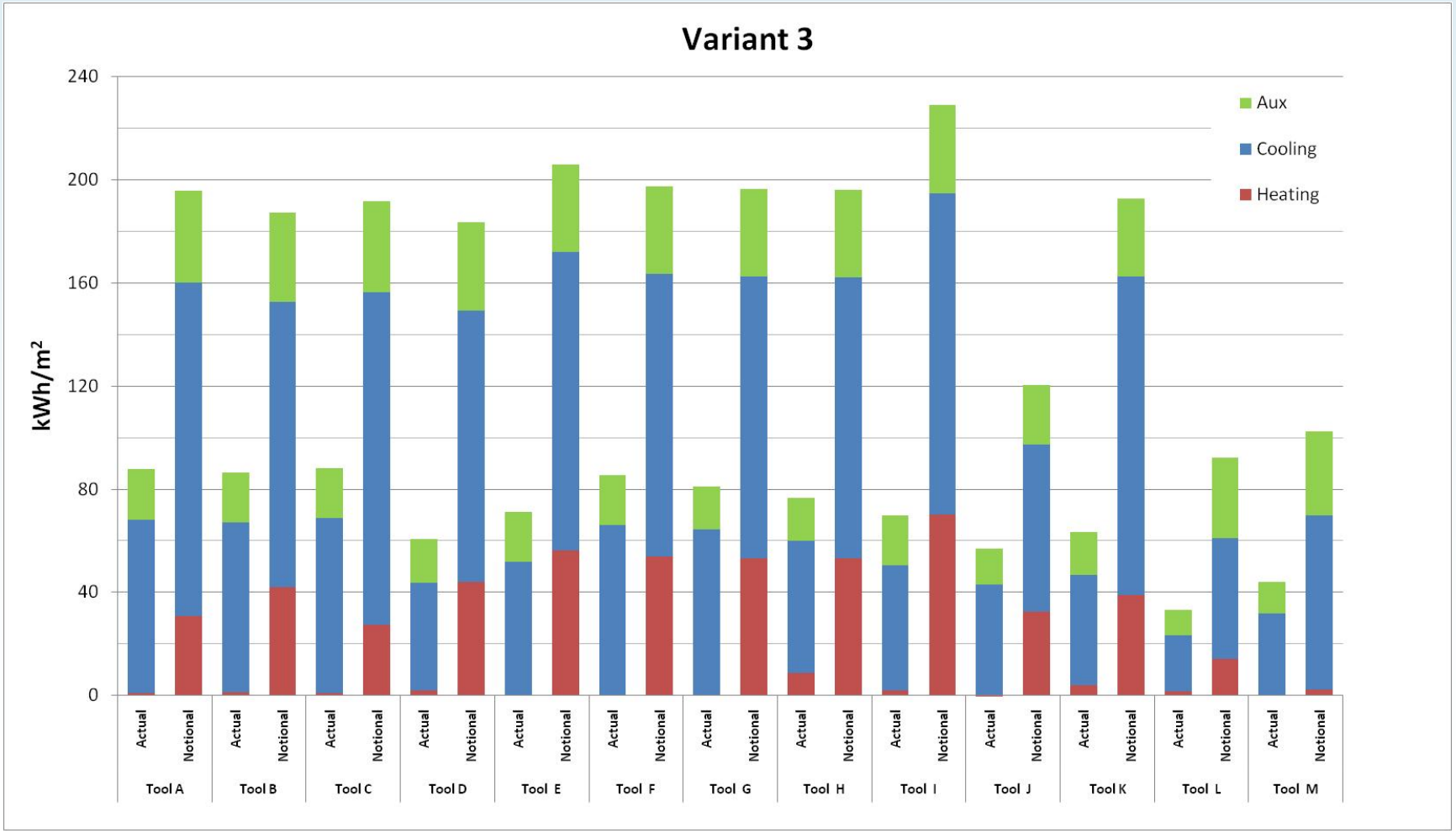
Results: BRUKL Document Parameters

Annual Energy Consumption (kWh/m²): Inherent building characteristics (use, geometry & fabric) + HVAC system type & system efficiencies.



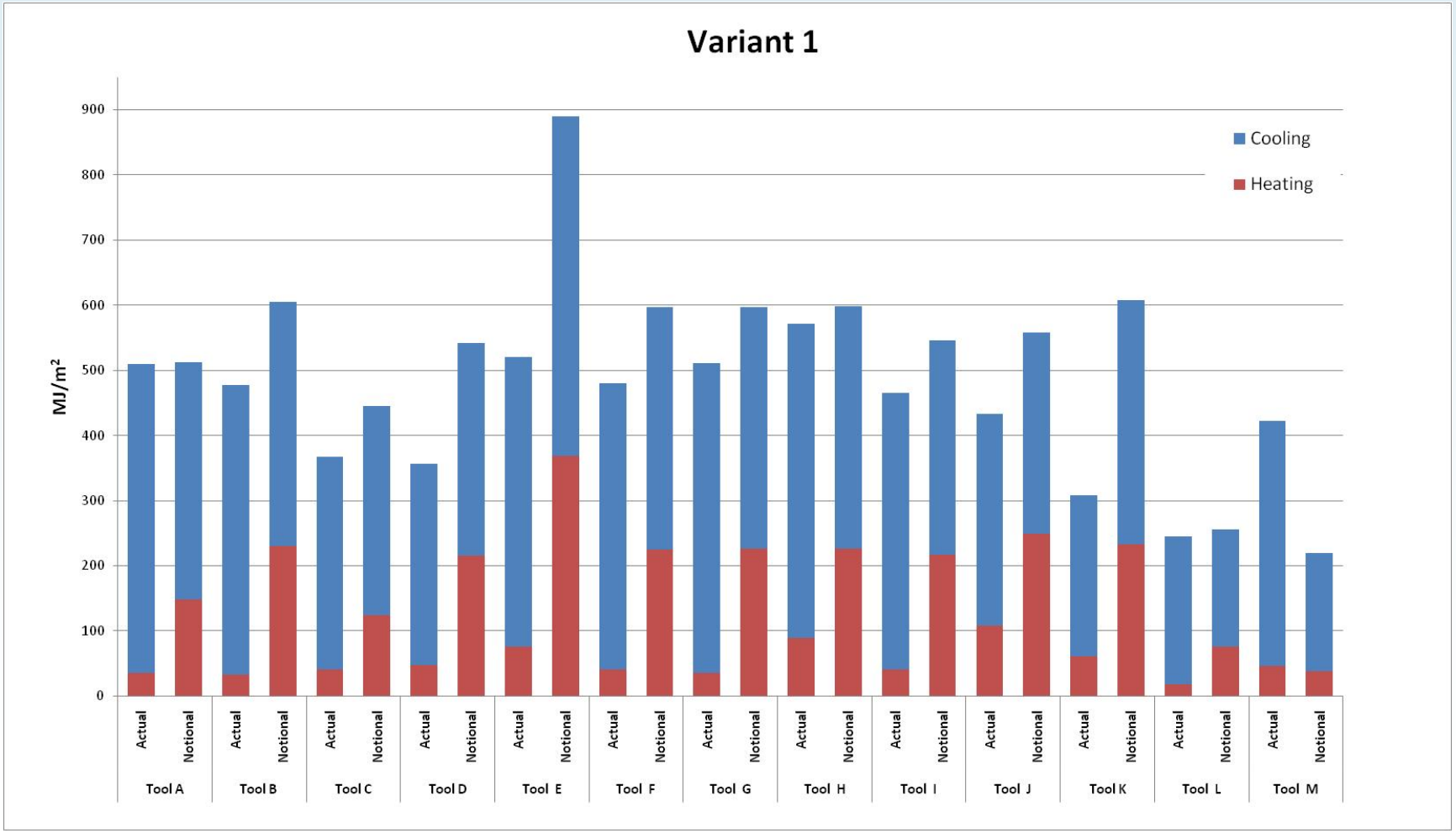
Results: BRUKL Document Parameters

Annual Energy Consumption (kWh/m²): Inherent building characteristics (use, geometry & fabric) + HVAC system type & system efficiencies.



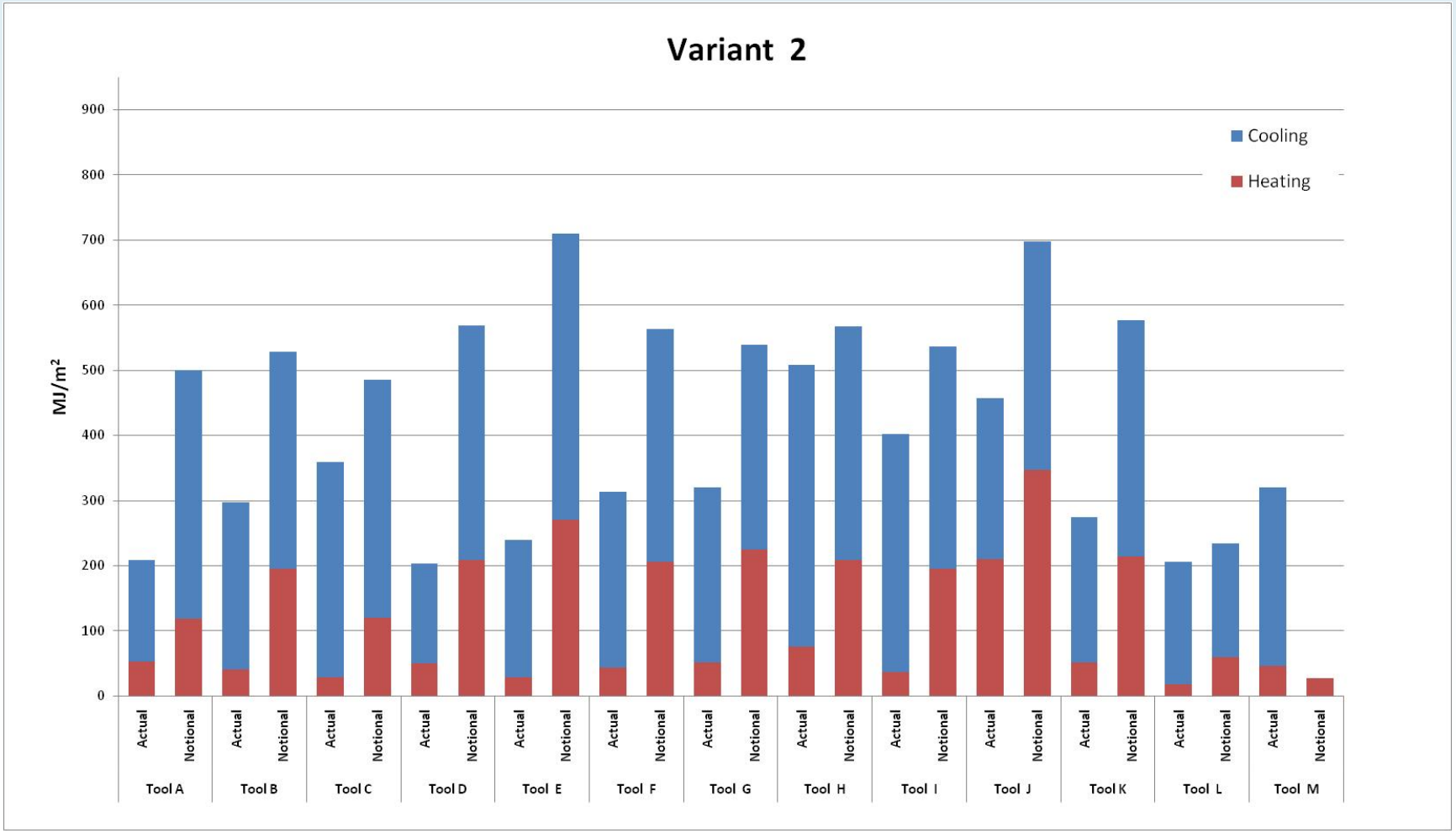
Results: BRUKL Document Parameters

Annual Energy Demand (MJ/m2): Inherent building characteristics (use, geometry & fabric)



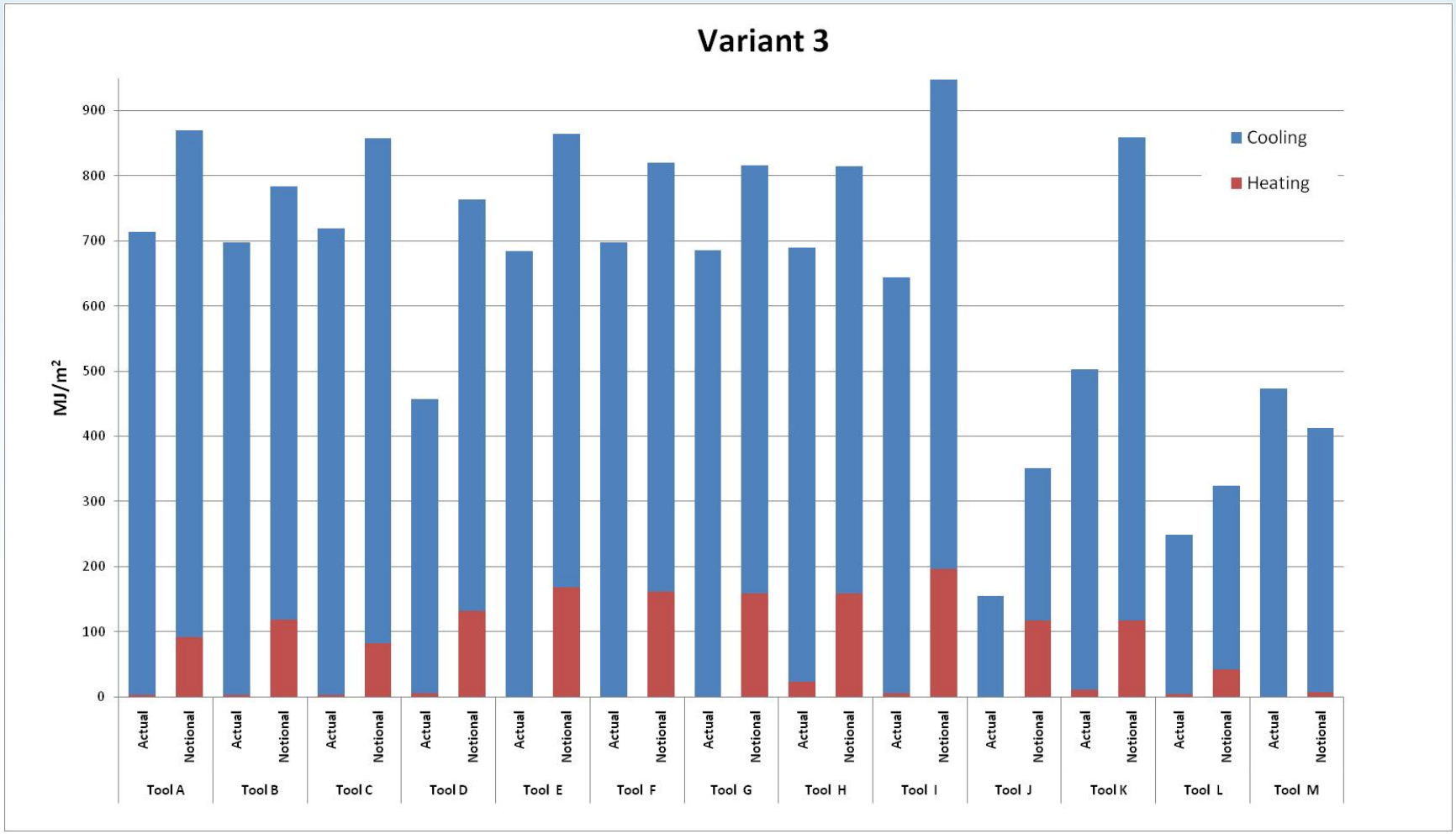
Results: BRUKL Document Parameters

Annual Energy Demand (MJ/m2): Inherent building characteristics (use, geometry & fabric)



Results: BRUKL Document Parameters

Annual Energy Demand (MJ/m2): Inherent building characteristics (use, geometry & fabric)



Material U-Values

Variant	Element	Modelling Assumption	Calculated Values Range			
		U-Value	Area Weighted U-Value		Individual U-Value	
			Low	High	Low	High
1	Walls	0.27	0.24	0.35	0.24	0.35
	Floors	0.22	0.11	0.25	0.15	0.35
	Roof	0.16	0.09	0.16	0.09	0.16
	Glazing	1.529	0.8	1.53	0.95	1.53
2	Walls	0.27	0.23	0.27	0.23	0.27
	Floors	0.22	0.11	0.25	0.15	0.25
	Roof	0.16	0.09	0.16	0.09	0.16
	Glazing	1.529	0.78	1.53	0.95	1.53
3	Walls	0.27	0.23	0.27	0.23	0.27
	Floors	0.22	0.11	0.25	0.14	0.25
	Roof	0.13	_	0.13	_	0.13
	Glazing	1.529	0.31	1.53	0.98	1.53

Geometry

	Areas			External Areas		
Tool	Variant 1	Variant 2	Variant 3	Variant 1	Variant 2	Variant 3
A	5400	5400	2000	6858	4464	3040
B	5400	5400	3000	5130	4464	4157
C	5315	5257	1970	4905	4381	2868
D	5139	5257	2292	3352	3067	4079
E	5400	5400	2000	10089	6684	3160
F	5400	5257	1947	5066	4405	3003
G	5400	900	2000	5095	1338	3040
H	5400	5400	2000	5130	4464	3040
I	5400	5400	2000	5130	4464	4338
J	5400	5400	3098	7388	13464	n/a
K	5400	5400	2000	5130	4464	3040
L	5400	5400	2000	5130	4464	3159
M	5310	5445	2897	5074	4487	3112
Correct Values	**5400**	**5400**	**2000**	**5130**	**4464**	**3166**

Min	5139	900	1947	3352	1338	2868
Max	5400	5445	3098	10089	13464	4338
Min Variation	5%	83%	3%	35%	70%	9%
Max Variation	0%	-1%	-55%	-97%	-202%	-37%

Results Summary

Parameter	Expected results	Actual results
CO_2 Emissions	Concurrence/close similarity between NOT, TER & BER within same tool class	Significant variations both between & within tool groups for all benchmark figures
	Similarity between results of SBEM & FI-SBEMs	Inconsistencies & significantly lower predictions for DSMs
	Uniformity in Pass/Fail result for each variant	Inconsistency in Pass/Fail result for each variant
U-Values	Consistent calculated area weighted and individual U-Values for all tools	Inconsistencies between calculated area weighted and individual U-Values for all tools
HVAC Systems Performance	Similarity in annual energy demand & consumption for the ACT & NOT within same tool class	A large degree of variability for both the ACT & NOT

Findings & Recommendations

Findings

1. Limitations in the scope of applicability of accredited tools
2. A lack of input data standardisation
3. Variability between tool results

Actions

1. Extending the applicability of FI-SBEMS
2. Development of more rigorous accreditation procedures
3. Measures to increase the validity &consistency of results
    - Unit standardisation, revision of problematic input requirements, embedded validation & comparative benchmarks

Future Work: Compare results with another modeller/single-model sensitivity analysis (effect of changes in key input variables on generated results)

Thank You

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Useful Sites

- Building Energy Calculation Software Approval Scheme (UK):
  http://www.ukregaccreditation.org
- Complex Built Environment Systems:
  http://www.cbes.ucl.ac.uk/