Towards Securing Low Carbon Future

Dr Lubo Jankovic
Birmingham School of Architecture
and
Centre for Low Carbon Research at BIAD/TEE

BIRMINGHAM CITY University

The problem

- Response to climate change is needed but it is not happening on a sufficient scale

- There is sense that
  – climate change is a hard problem to solve
  – our targets are hard to achieve
  – our targets are far in the future

BIRMINGHAM CITY University

The talk

- Lessons learnt from monitoring and analysis of the Birmingham Zero Carbon House
- A reflection on the method for zero carbon design from my forthcoming book
- Ways forward towards securing low carbon future

BIRMINGHAM CITY University

Birmingham Zero Carbon House

- Designed by Architect John Christophers and his team
- Originally built 170 years ago
- Achieved Code for Sustainable Homes Level 6 through retrofit
- Winner of the RIBA Architecture Award 2010
- Featured extensively in the media
  - The Times “I have seen the future – and it’s in Birmingham”
  - New York Times: “An English House That Generates as Much as It Consumes”
  - This month's Ecotech magazine, issued by Architecture Today

BIRMINGHAM CITY University

Birmingham Zero Carbon House

- High level of thermal insulation keeps the heat in
- High amount of thermal mass smoothes out temperature fluctuations
- Solar gains from south west reduce space heating demand
- High air tightness + heat recovery ventilation
- Natural daylight
- Solar photovoltaic system generates electricity
- Solar thermal system heats domestic hot water
- Additional heating: Wood burning stove used only in very cold weather
- Energy efficient lighting
- Rainwater harvesting
- Material recycling

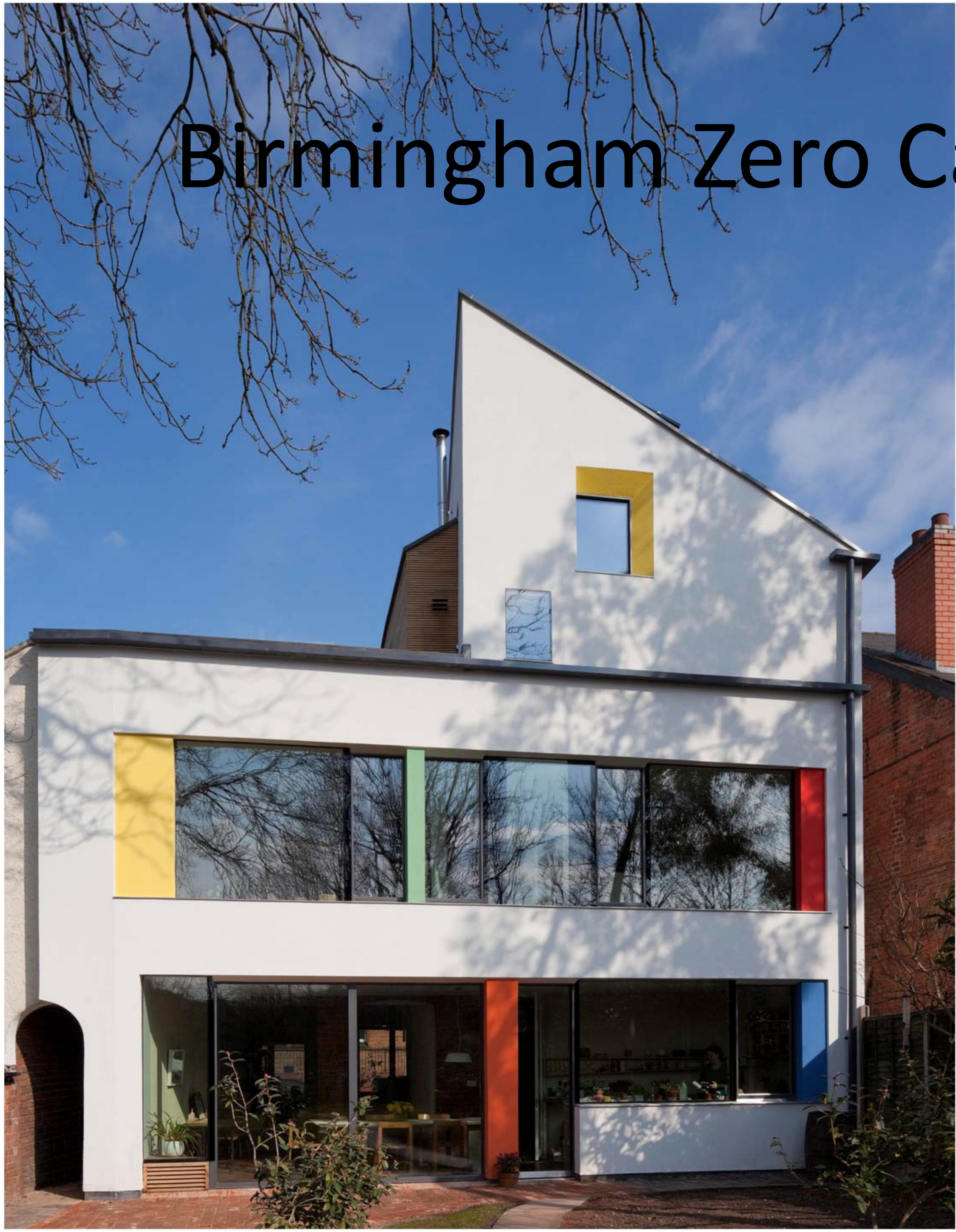
BIRMINGHAM CITY University




Main features



Birmingham Zero Carbon House



- This is the only retrofit zero carbon house in the UK
- BCU Centre for Low Carbon Research has secured funding for post occupancy evaluation

BIRMINGHAM CITY University

Post occupancy evaluation

The objectives are to

- increase our understanding of principles of zero carbon retrofit
- and to extrapolate the knowledge into a process that can be potentially rolled out to the rest of the UK

BIRMINGHAM CITY University

Post occupancy evaluation

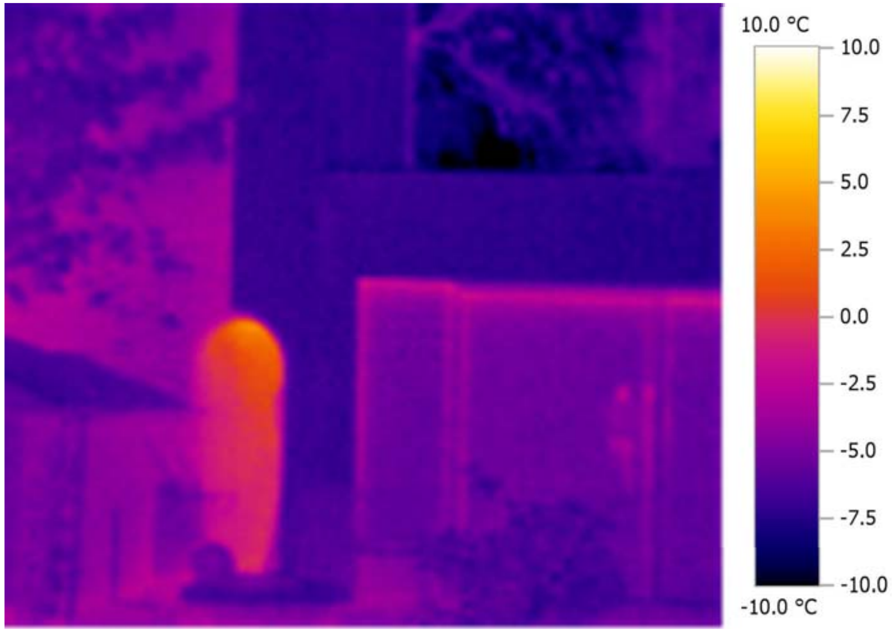
- Thermal imaging study
- Occupant study
- Continuous instrumental monitoring over the course of two years

Thermal imaging study

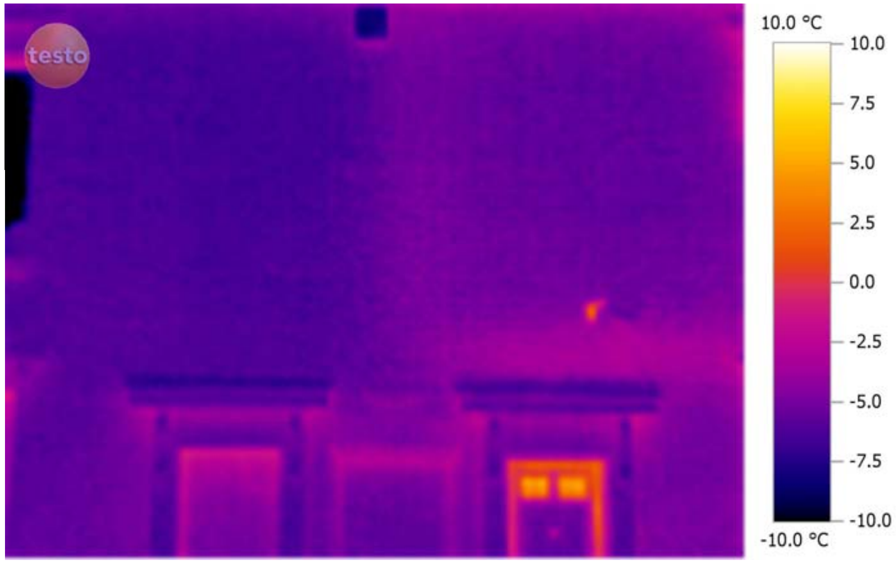
- Conducted in December 2010 and January 2011
- Over 250 thermal images collected and analysed
- To identify sources of heat losses within defects period

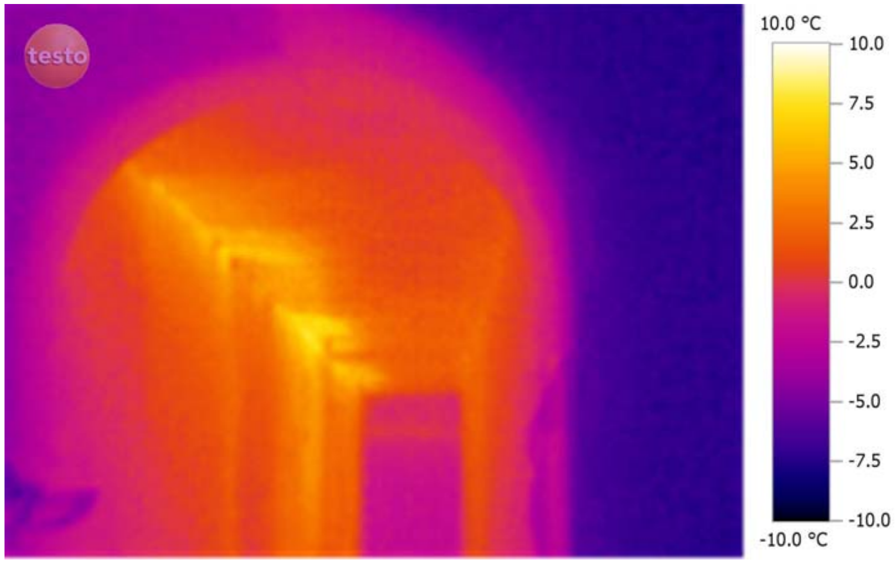
BIRMINGHAM CITY University

External thermal imaging study – dark is good



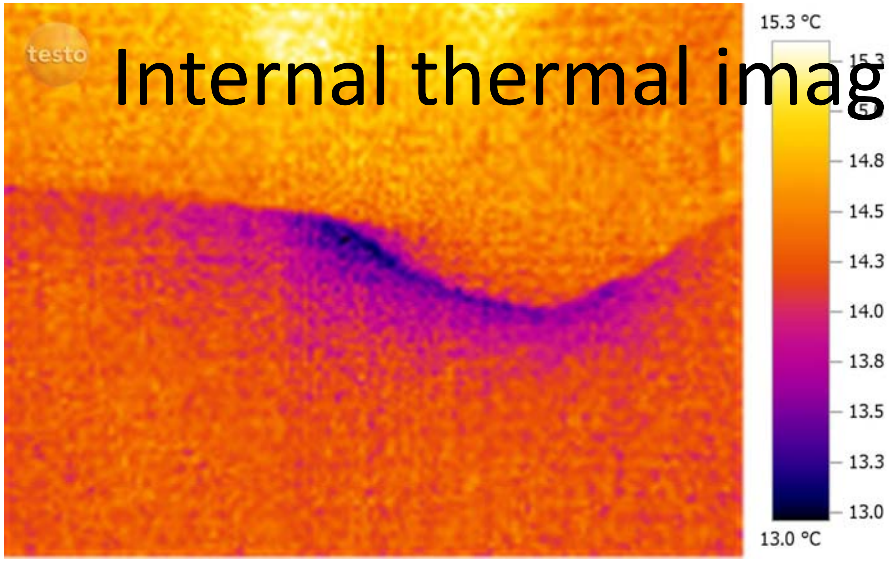
Comparison with house next door shows considerably lower heat losses from the Zero Carbon House



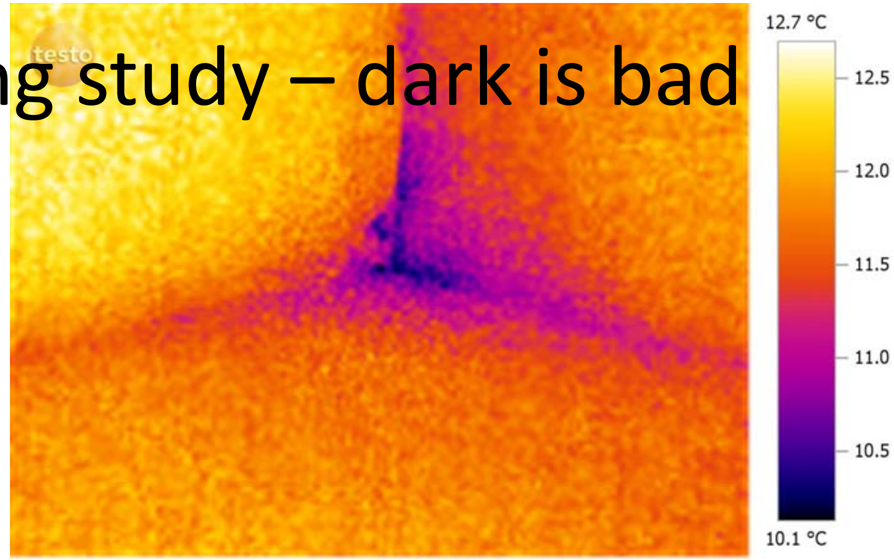


BIRMINGHAM CITY University

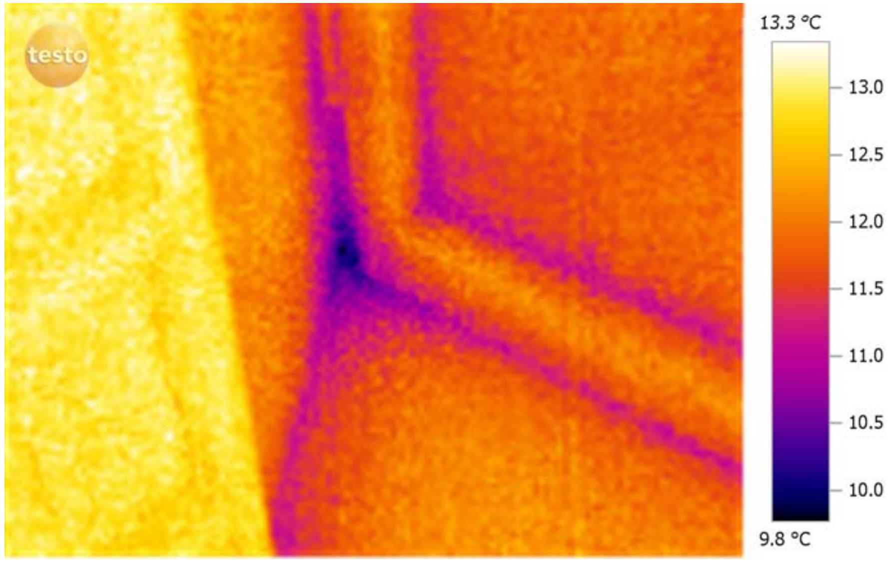
Internal thermal imaging study – dark is bad



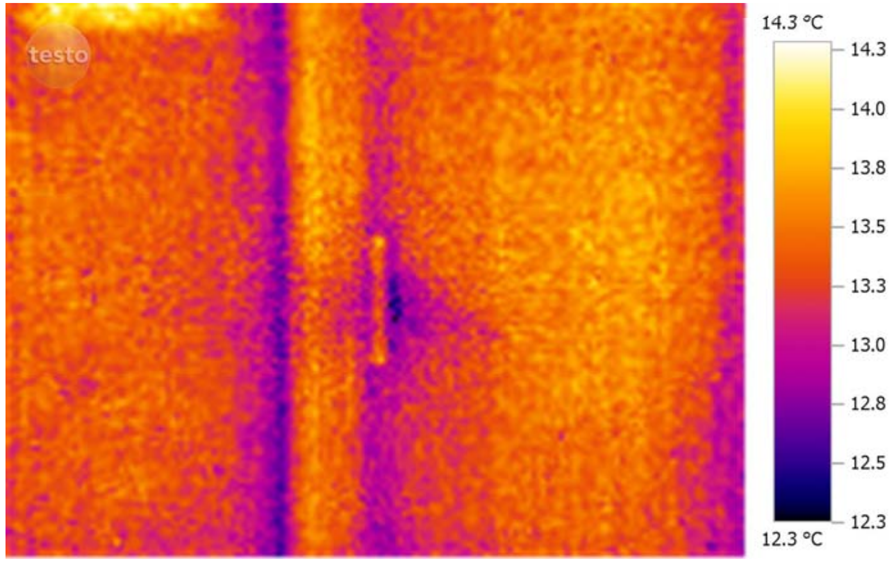
Every crack…



…every corner…



…every window…



… and every hinge matters

BIRMINGHAM CITY University

Continuous instrumental monitoring

Wireless sensors

- Internal parameters
  - Electricity production and consumption
  - Air temperatures
  - Air humidity
  - CO2 concentration
  - Water temperatures
  - Biomass heating output
- External parameters
  - Air temperature
  - Array plane solar radiation

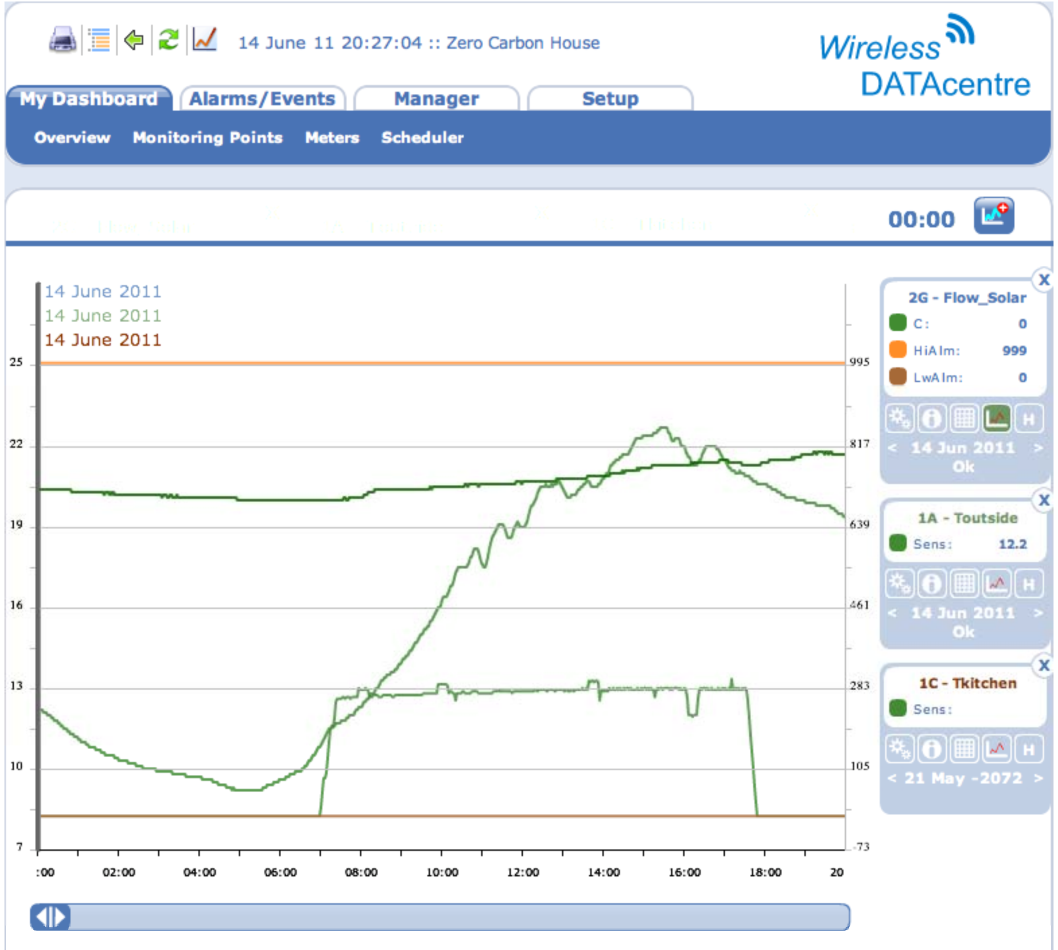
Wireless data logger

Web data transmission and access

BIRMINGHAM CITY University

Continuous instrumental monitoring

Continuous instrumental monitoring



BIRMINGHAM CITY University

Dynamic simulation models

- The only tools for integrated design
- Without calibration they are good for comparing one design option with another
- The Zero Carbon House model was calibrated using energy records
- The calibrated model was then used for performance evaluation

BIRMINGHAM CITY University

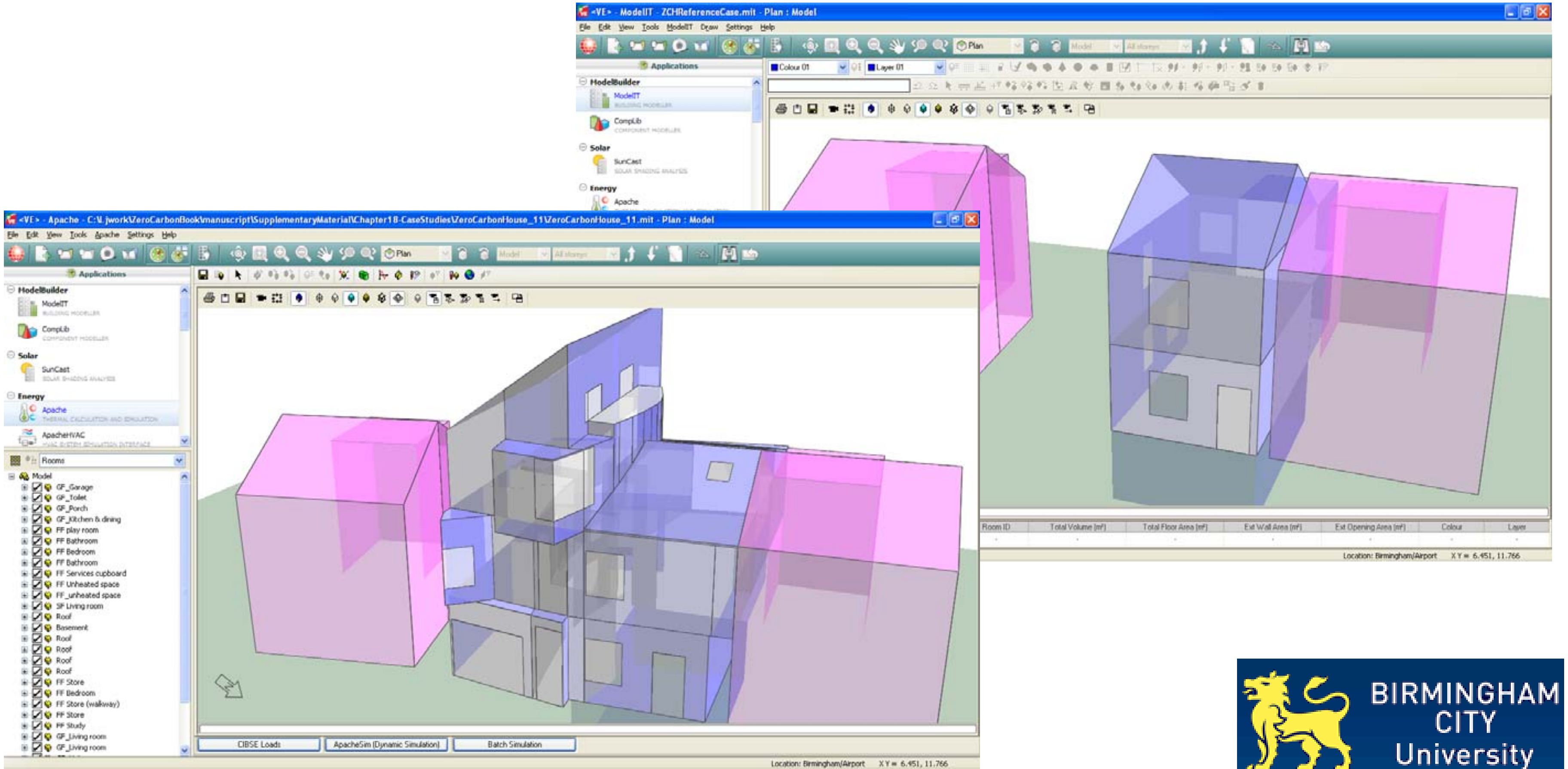
Calibration of dynamic simulation

- For model calibration we used:
  - Electricity production and consumption figures
  - Heating energy consumption figures
- Multiple annual simulation runs to determine:
  - Efficiency of the PV system that gives electricity production and consumption results with less than 1% error
  - Internal air temperature that gives heating energy consumption with less than 1% error

BIRMINGHAM CITY University

Dynamic simulation model

Models of the original house and retrofit house were created and annual performance evaluated



BIRMINGHAM CITY University

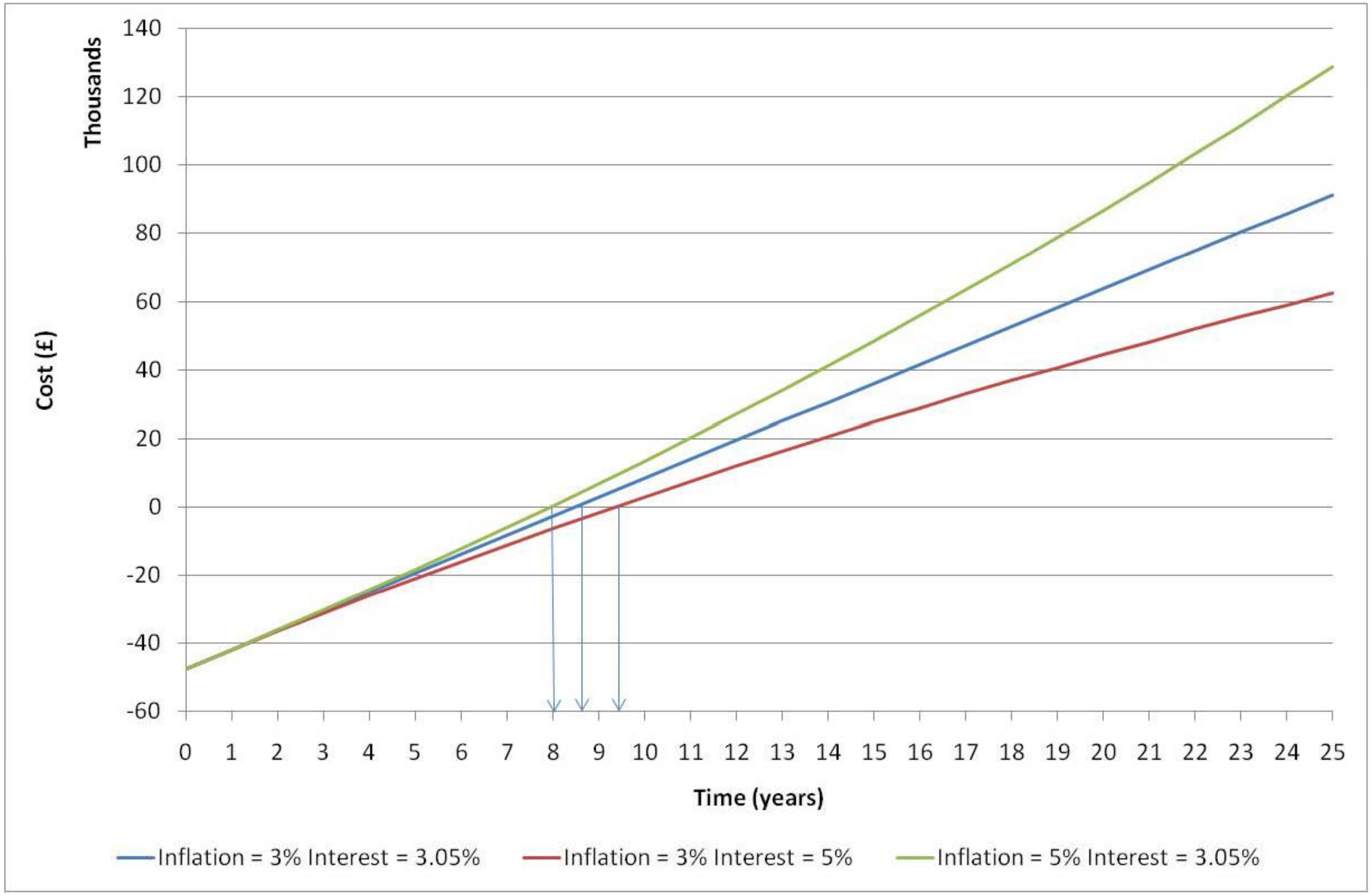
Building performance

Description	Units	Original house	Zero Carbon House
Total heating energy	MWh	59.43	1.78
Total electricity used	MWh	14.22	2.75
Total electricity generated	MWh		-4.06
Total electricity exported	MWh		-1.31
Boilers DHW energy with ST	MWh		3.78
Boilers DHW energy without ST	MWh	10.45	7.86
Solar thermal	MWh		-4.08
DHW demand	MWh	6.10	6.10
CO_2 emissions	$kgCO_2$	21,185.10	-661.60

BIRMINGHAM CITY University

Economic analysis

Initial investment (£)	*Life cycle cost (£)*	*Payback period (years)*	*Return on investment (%)*
47,345	91,380	8.60	93%

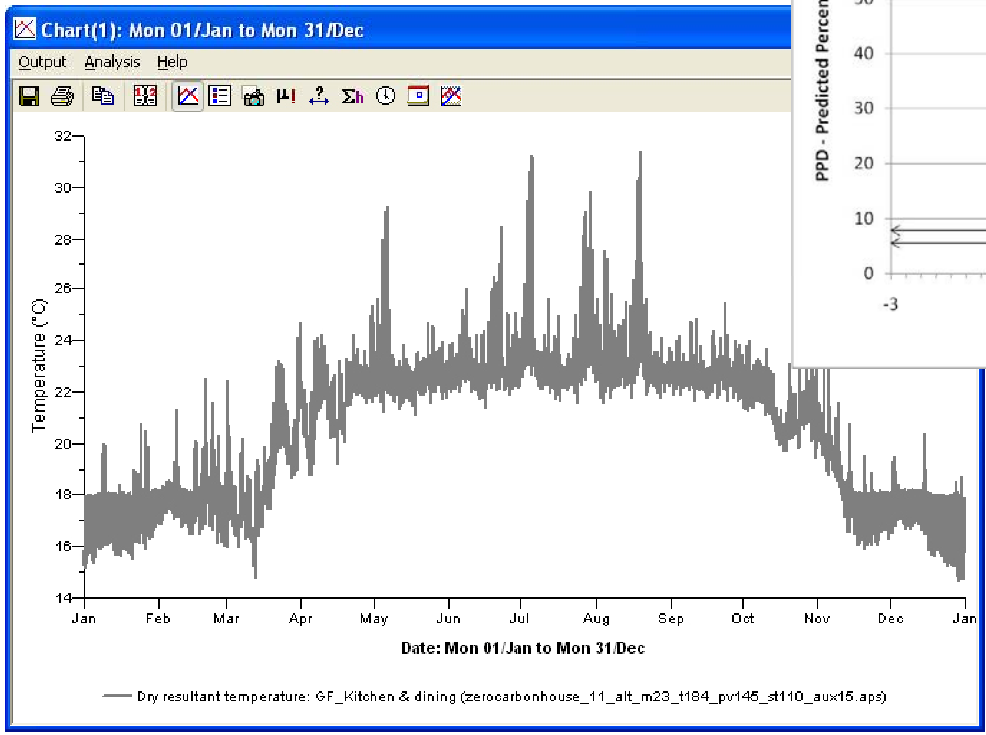


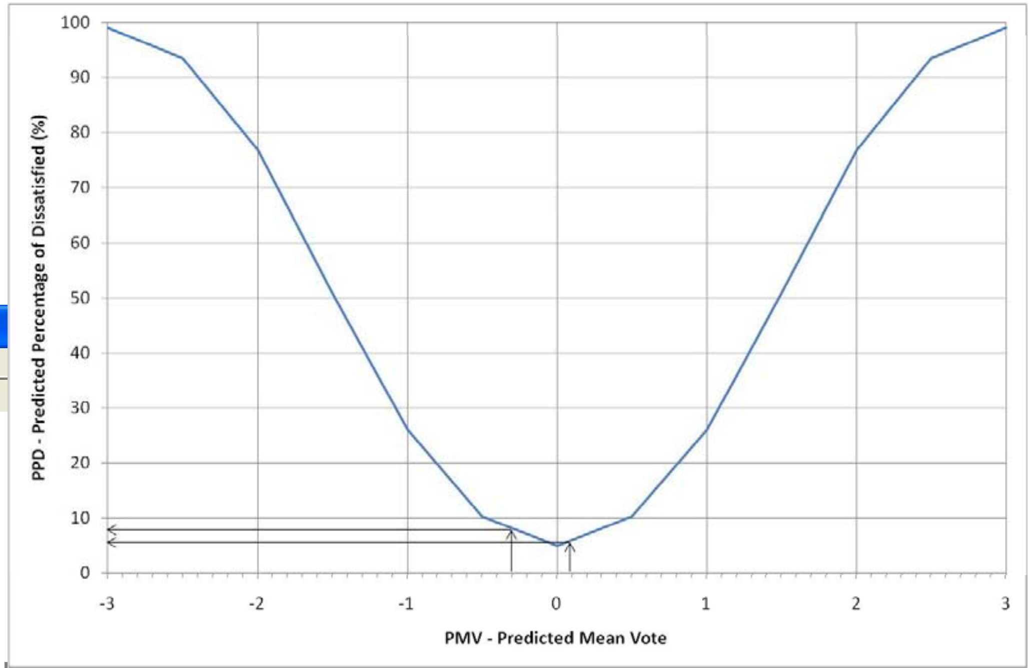
BIRMINGHAM CITY University

Occupant study

- Data collected through questionnaires about
  - Level of occupancy
  - Energy use patterns
  - Level of energy consciousness amongst occupants
  - Heating system performance
  - Summer versus winter living comfort
  - Ventilation performance
  - Daylighting performance
  - General comfort levels

Occupant study and comfort analysis





	PMV (-3 to +3)	*PPD (%)*	*Discrepancy from neutrality (%)*
Summer	0.09	5.17	0.17
Winter	-0.30	6.87	1.87

Pushing and poking the model

	Carbon emissions (kgCO2/year)
Will it be zero carbon is we increase internal temperature from 18.4 to 20 ^{o}C?	-652.6
Will it be zero carbon if we move it inside the polar circle? (Results for Rovaniemi, Finland)	-564.0

BIRMINGHAM CITY University

The next steps

- Monitoring to be conducted over two years to enable various analyses to be carried out
- Design guidelines to be generalised for retrofit applications

The Book "Designing zero carbon buildings using dynamic simulation methods"

- Zero Carbon House analysis is based on a method developed in my book
- This is a structured method for zero carbon design based on dynamic simulation
- To be published by Earthscan in January 2012

BIRMINGHAM CITY University

Step	Model version	Description	Total Yearly Energy Consumption (MWh)	Yearly Total Heating (MWh)	Yearly Total Electricity (MWh)	Electricity generated (MWh)	Electricity exported (MWh)	Total carbon dioxide emissions (kg	Absolute improvement (kg CO2)	Relative improvement (%)
1	a	gas heating, standard insulation	30.3	12.6	17.7			11653.3		
2	b	= a+ increased insulation	27.4	9.7	17.7			11089.9	563.4	4.8%
3	c	= b + increased lighting efficiency	23	12.8	10.2			7834.2	3255.7	27.9%
4	d	= c + daylight sensitive controls	22.2	13.3	8.9			7200.8	633.4	5.4%
5	e	air source heat pump	12.4	3.6	8.8			6418.2	782.6	6.7%
6	f	= e + 52 m2 monocrystalline PV system 15% efficiency, 13.8 deg inclination from horizontal	6.1	3.6	2.5	6.4		3057	3361.2	28.8%
7	g	= f + wind generator qr5 with maximum rating of 7.4 kW	5.8	3.6	2.2	6.6		2934.3	122.7	1.1%
8	h	= g + 3 more wind turbines, with combined total rating of 29.6 kW	5.1	3.6	1.5	7.3		2565.8	368.5	3.2%
9	e2	biomass heating, boiler efficiency 93%	22.2	13.3	8.9			4931.8	1486.4	12.8%
10	f2	= e2 + 52 m2 monocrystalline PV system: 15% efficiency, 13.8 deg inclination from horizontal	15.8	13.3	2.5	6.4		1570.7	3361.1	28.8%
11	g2	= f2 + wind generator qr5 with maximum rating of 7.4 kW	15.6	13.3	2.3	6.6		1447.9	122.8	1.1%
12	h2	= g2 + 3 more wind turbines, with combined total rating of 29.6 kW	14.9	13.3	1.6	7.3		1079.5	368.4	3.2%
13	i2	= h2 + super insulation	11.6	10.1	1.5	7.3		984.7	94.8	0.8%
14	j2	= i2 + additional 29 m2 monocrystalline PV system of 15% efficiency at 7.8 deg inclination	8.2	10.1	-1.9	10.7	1.9	-830.3	1815.0	15.6%
15	f3	= f2 + additional 29 m2 monocrystalline PV system of 15% efficiency at 7.8 deg inclination	12.4	13.3	-0.9	9.8	0.9	-244.2	1814.9	15.6%

BIRMINGHAM CITY University

Step	Model version	Description	Life cycle cost (£)	Payback period (years)
1	a	gas heating, standard insulation		
2	b	= a+ increased insulation	10,791	4
3	c	= b + increased lighting efficiency	10,091	5
4	d	= c + daylight sensitive controls	9,951	5
5	e	air source heat pump	5,551	11
6	f	= e + 52 m2 monocrystalline PV system 15% efficiency, 13.8 deg inclination from horizontal	32,555	6
7	g	= f + wind generator qr5 with maximum rating of 7.4 kW	3,996	21
8	h	= g + 3 more wind turbines, with combined total rating of 29.6 kW	-75,999	-
9	e2	biomass heating, boiler efficiency 93%	6,488	10
10	f2	= e2 + 52 m2 monocrystalline PV system: 15% efficiency, 13.8 deg inclination from horizontal	33,650	5
11	g2	= f2 + wind generator qr5 with maximum rating of 7.4 kW	4,933	20
12	h2	= g2 + 3 more wind turbines, with combined total rating of 29.6 kW	-75,062	-
13	i2	= h2 + super insulation	-86,799	-
14	j2	= i2 + additional 29 m2 monocrystalline PV system of 15% efficiency at 7.8 deg inclination	-72,107	-
15	f3	= f2 + additional 29 m2 monocrystalline PV system of 15% efficiency at 7.8 deg inclination	47,976	5

BIRMINGHAM CITY University

Barriers and Enablers

- We have the method but things are not yet happening
- What are the barriers and how to unlock the market?
- There aren't many people around who can
  - design zero carbon buildings with confidence and
  - demonstrate financial viability of zero carbon projects

How to unlock the market?

Education of more zero carbon designers will help

- Increase the number of true zero carbon schemes
- Demonstrate economic case for zero carbon
- This will
  - Attract investment
  - Stimulate market demand
  - Increase employment in corresponding supply chains

But what if the lights go out before we get there?

- The solar constant = 1353 W/m2
- Multiplied by the earth's cross-section gives 1.72529E+17 W of constant solar input
- Annual world energy consumption 5.22358E+20 J
- Division of the above two numbers gives time in seconds in which this solar input equates to world energy consumption
- In 2010 1 year = 50 minutes
- In 2035 1 year = 75 minutes

BIRMINGHAM CITY University

Concluding remarks

- There is enough energy
- We need to increase level of technological development to capture it
- We will not get there by making empty gestures
- …but by advanced education, research and investment
- …and by changing the way we do things

BIRMINGHAM CITY University

Concluding remarks

- Zero carbon design of new and retrofit buildings is perfectly possible and can be made economically viable today
- We don't need to wait till 2019 when all new buildings will need to be zero carbon
- Retrofit of existing buildings is much more urgent
- Economic viability of the retrofit can be ensured through a structured design process
- We need to change business and economic models
- We need more research, education and investment
- The scale of forthcoming change is equivalent to that of the industrial revolution

BIRMINGHAM CITY University

Final remarks

BIRMINGHAM CITY University

We Earthlings are working hard on depletion of our resources

BIRMINGHAM CITY University

…and have nowhere to move on

BIRMINGHAM CITY University

…and have no nearby neighbours

BIRMINGHAM CITY University

…to help us in troubled times

BIRMINGHAM CITY University

What happens next…

…is entirely up to YOU

Acknowledgements

- The work on monitoring the Birmingham Zero Carbon House is funded by Birmingham City University
- Thanks to Tektroniks of Nottingham for providing technical help with their instrumentation system
- We are grateful to John Christophers for providing access to his house for monitoring and for background material

BIRMINGHAM CITY University

Contact and further info

- BCU Centre for Low Carbon Research: http://www.biad.bcu.ac.uk/research/site/pages/clcr.php
- Birmingham Zero Carbon House: http://zch.org.uk/
- Forthcoming open days in the autumn – check the above web site