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Advances on Technologies for Building Energy Efficiency: Eco Insulation, GRP and Thermostatic Insulation Systems, and Uptake Potential in Developing Countries

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Sustainable Design of the Built Environment

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MARE Project International Workshop in Athens, Greece, 22 & 23 February 2016

Agenda

- Introduction
- (1) Research investigating life cycle costing and carbon footprint of an eco insulation product and it benefits in building energy efficiency;
- (2) Research measuring thermal performance of a GRP (Glass Reinforced Plastic) cavity lintel relative to steel in-situ in a typical dwelling and compare findings, and quantify savings in energy terms;
- (3) Research investigating the impact of Thermostatic Insulation System (TIS) on a typical UK dwelling in terms of energy efficiency;

BUILDING FOR THE FUTURE (BftF) PROJECTS

The University Of Sheffield.

EPSRC
Engineering and Physical Sciences Research Council

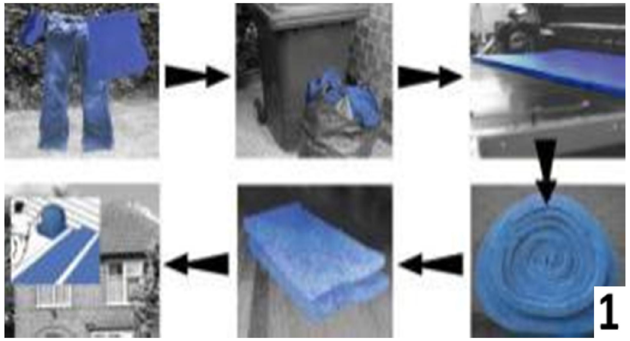
BEAU
BUILDING ENVIRONMENTS ANALYSIS UNIT

The EPSRC Knowledge Transfer Account (KTA) funded Innovation Awards are part of an scheme in the area of 'Building for the Future', business-led and aimed to develop innovative products, processes or technology under this theme. These BftF projects conducted between BEAU research centre at the University of Sheffield and SMEs such as Recovery Insulation Ltd, Esulation Technologies Ltd, and Material Edge Ltd.

(1) This KTA funded Innovation project is seeking to work with Recovery Insulation Ltd to conduct a short research investigating life cycle costing and carbon footprint of INNO-THERM® product.

(2) This KTA funded Innovation project is seeking to work with Material Edge Ltd to conduct a short research measuring thermal performance of a GRP (Glass Reinforced Plastic) cavity lintel relative to steel in-situ in a typical dwelling and compare findings, and quantify savings.

(3) This KTA funded Innovation project is seeking to work with Esulation Technologies Ltd to conduct a short research investigating the impact of Thermostatic Insulation System (TIS) on a typical UK dwelling in terms of energy efficiency.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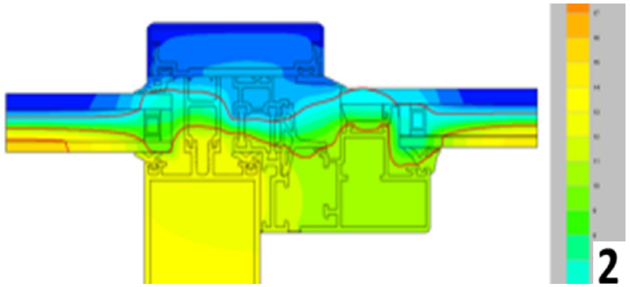
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ECO INSULATION
INNO-THERM®

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A SENSIBLE APPROACH TO LOW CARBON AND HEALTHY BUILDINGS

Thermal Insulation

- Reduces energy usage
- Lowers heating costs
- Reduces CO_2 emissions

Applying an LCA to an insulation product is vital to following the principles of a Circular Economy

(Ellen Macarthur Foundation, 2013).

Our studies showed the importance of considering CO_2 emissions impact of products in all stages of their life e.g. sourcing energy from sustainable sources in the supply chain.

Research has found:

- Correlation between poorly conceived energy saving measures
- Indoor air quality
- Rise in asthma and allergic diseases in the UK.

(Sharpe et al. 2015)

In the **specification of an insulation**, e.g. quantity surveyors, homeowners, often do not take into consideration the CO_2 emissions used:

- in the manufacturing supply chain
- energy consumption used
- looking at price only

It is essential to establish a true value for the energy/CO_2 emissions savings in use of a low carbon [LC] insulation to define the full environmental/economic benefits of a LC insulation.

In a world where lower carbon and healthy buildings are valued, to quote W.E. Deming (1994):

"If you improve quality, costs will go down and value goes up".

"With INNO-THERM® we have found a product that happily answers four of our objectives as the product is manufactured in the UK, creating employment opportunities and producing an environmentally friendly insulation. In fact as ***INNO-THERM has slightly better thermal properties we were able to reduce the timber stud sizes, which in turn offset some of the cost while still achieving very good U – values.*** *"*

whitedesign Nick James – White Design Architects

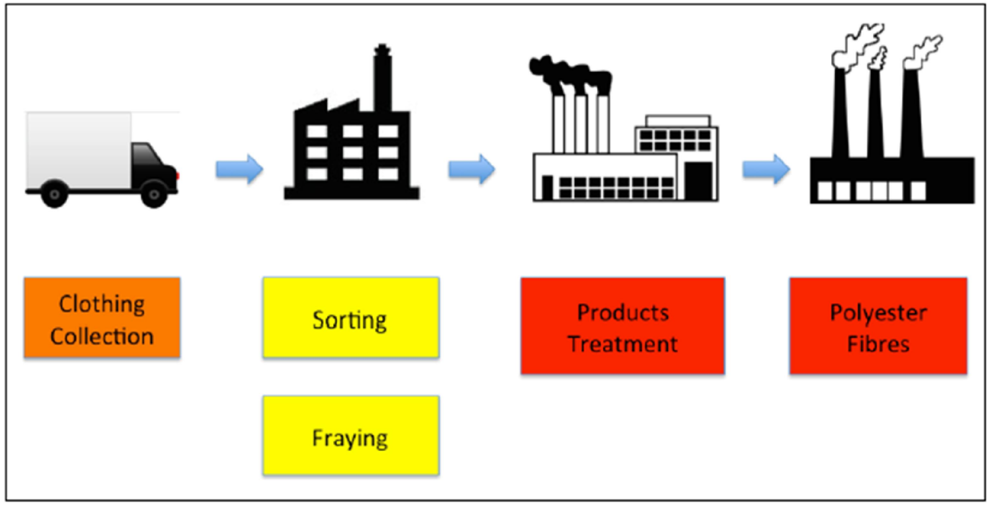
Inno-Therm®/Metisse® is an thermal and acoustic insulation manufactured from 80% recycled denim/cotton.

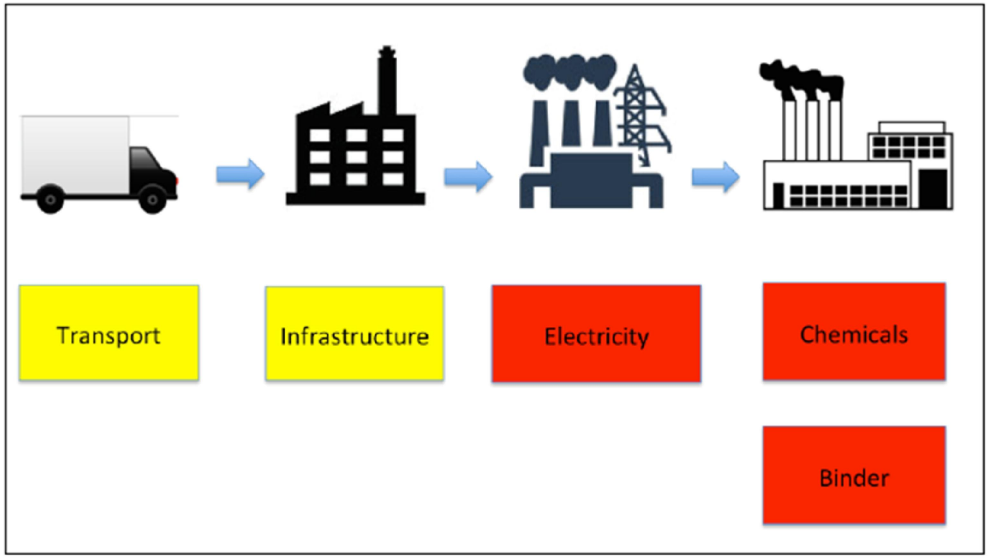
[i.e. 3 jean's/m² for 100mm thickness]

The raw material is sourced in France by Le Relais.

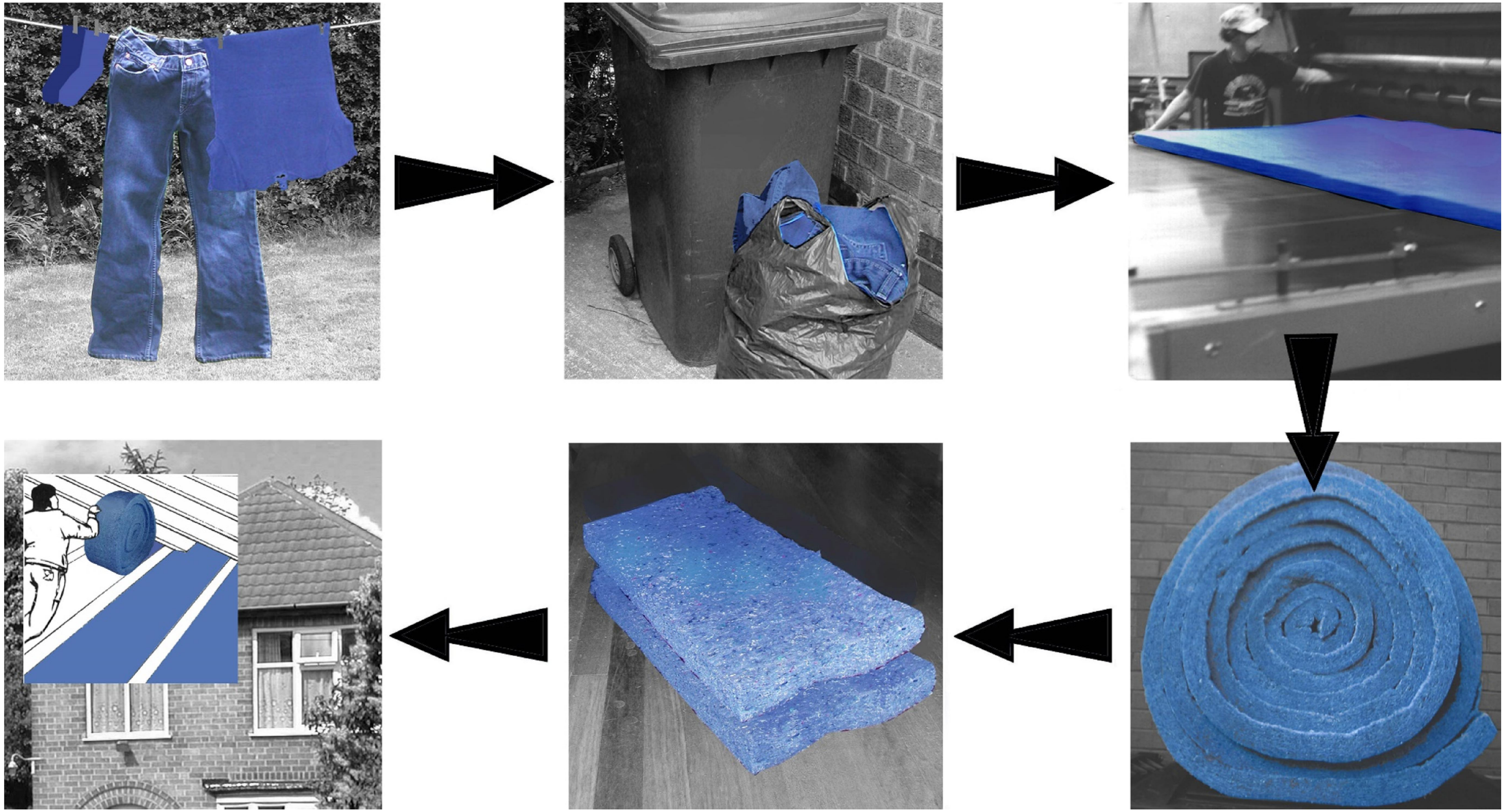
Supply Chain Carbon Map

Inno-Therm®

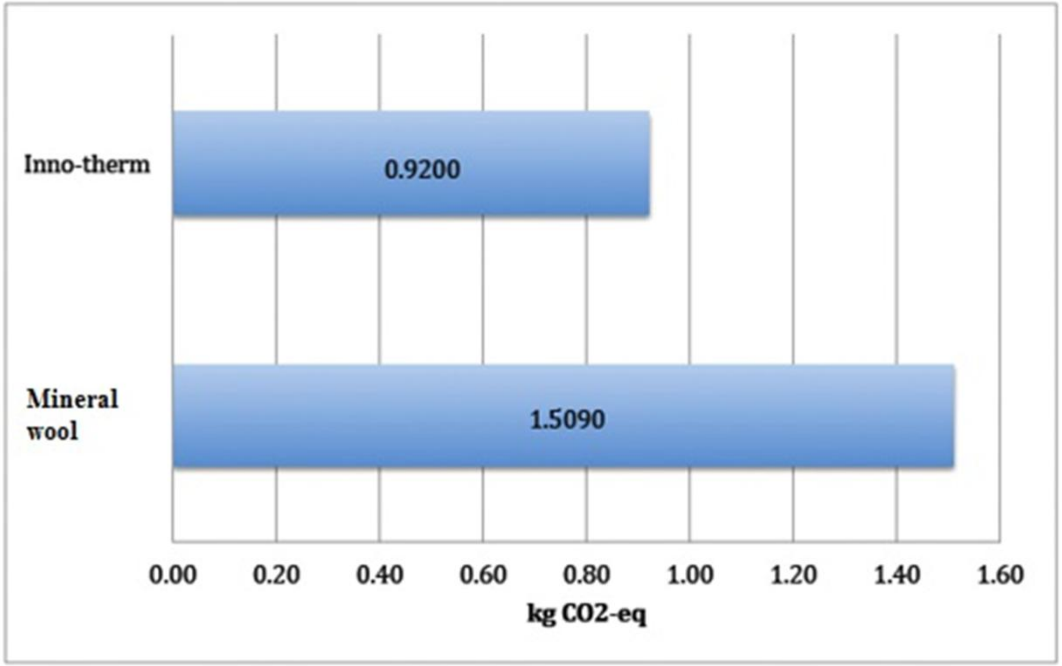




Mineral Wool



Environmental Impact of Inno-Therm® Compared to a Mineral Wool Insulation Material



Source: Dissertation submitted in 2015, in part requirement for the Degree of MSc Logistics and Supply Chain Management of the University of Sheffield by Muhammad Haneef Abdul Nasi

Recycled Cotton/Denim Insulation

Recovery Insulation Ltd was established in 2002
as a company and **social enterprise**
to manufacture a thermal/acoustic ‘eco’
low carbon [LC] non-itch insulation made
from the reuse/recycled cotton/denim.

Sustainable insulation

GLASS REINFORCED PLASTIC (GRP)
Fulbrook GRP Lintel - The Litel®

The University Of Sheffield.

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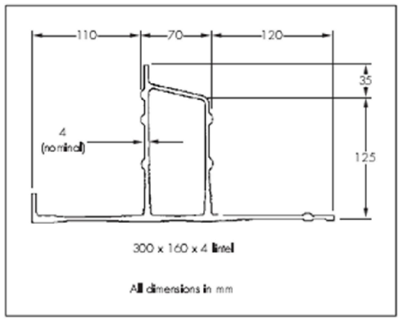
GRP Lintel (The Litel®)

This GRP lintel, the Litel®, is made of glass reinforced plastic which makes it high load bearing yet lightweight and has a profile and a mass of 5.96 kg/m. It is suitable for use in external or internal walls of 100mm brick/block work with a 75mm to 100mm cavity, and clear openings of between 400mm to 1700mm, to support walls, floors, roofs, or a combination of these, above window or door openings.

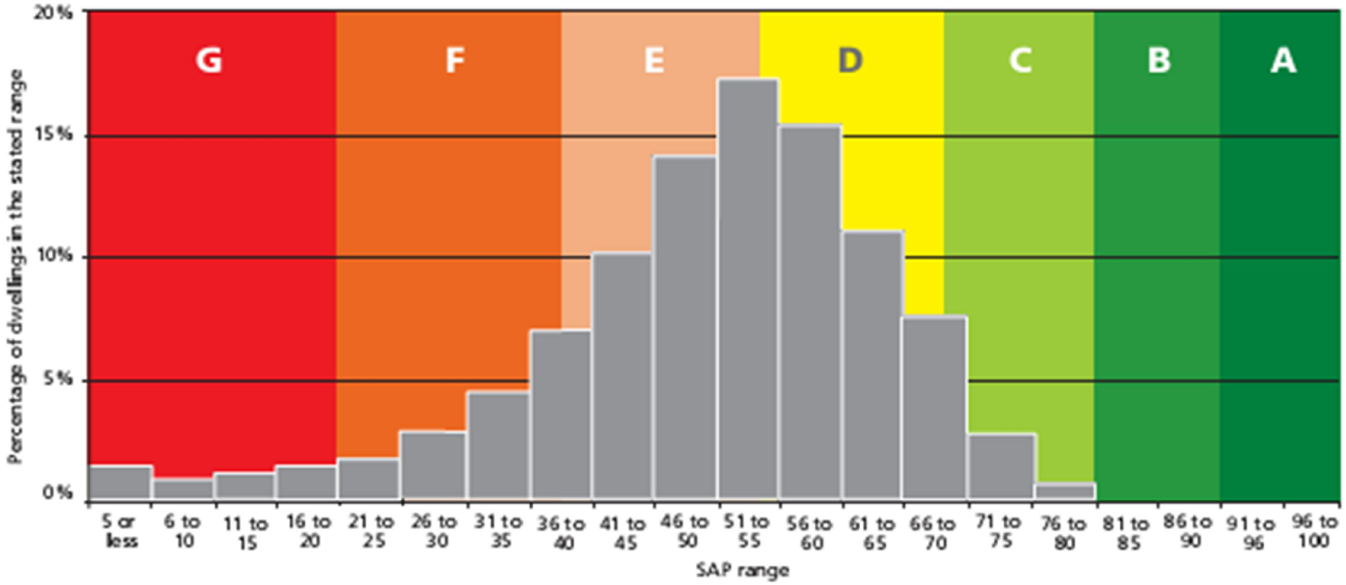


The thermal characteristic of a GRP lintel comparing with a typical Steel lintel. The Litel® has a very low heat transmitter rate. Thus, it is possible to reduce the effect of thermal bridging by replacing a common Steel lintel with a GRP lintel.

Thermal characteristic of GRP lintel; the Litel®*

Comparison of GRP Lintel with common Steel Lintel	CO_2 emissions (kg CO_2 per kg)	U value (W/m^2K)	Linear Thermal Bridge Heat Loss Ψ Psi value (W/mK)
Steel Lintel	1.91	2.94*	0.287
GRP Lintel	5.5	0.833	0.04
* Minimum R-value for the lintel is 0.34 m^2K/W (http://litel.co.uk/).			

Improving thermal properties of building fabric through tightening building regulations has been one way forward when tackling energy efficiency in new build homes in the last 10 years; however, there are still more to be done to improve energy efficiency in the existing housing stock in order to meet CO_2 reduction targets.

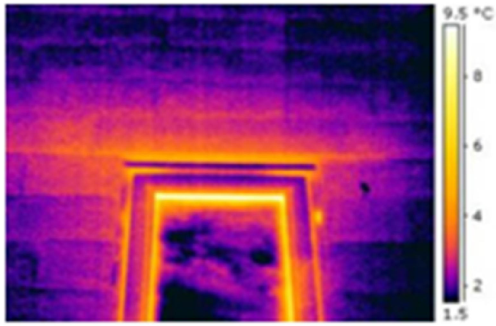


Performance of the UK's existing housing stock
(Source: Energy Saving Trust)

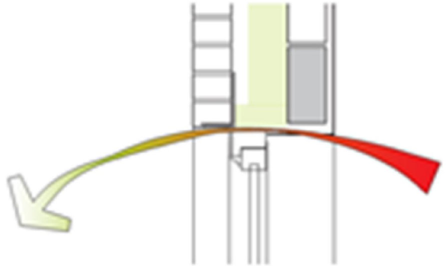
Thermal Insulation

- Thermal bridging
- Airtightness

a) Thermal bridging at lintel



b) Infrared (IR) image of steel lintel over a window opening



c) Air infiltration at lintel

Common thermal bridges and air infiltration at/around lintels

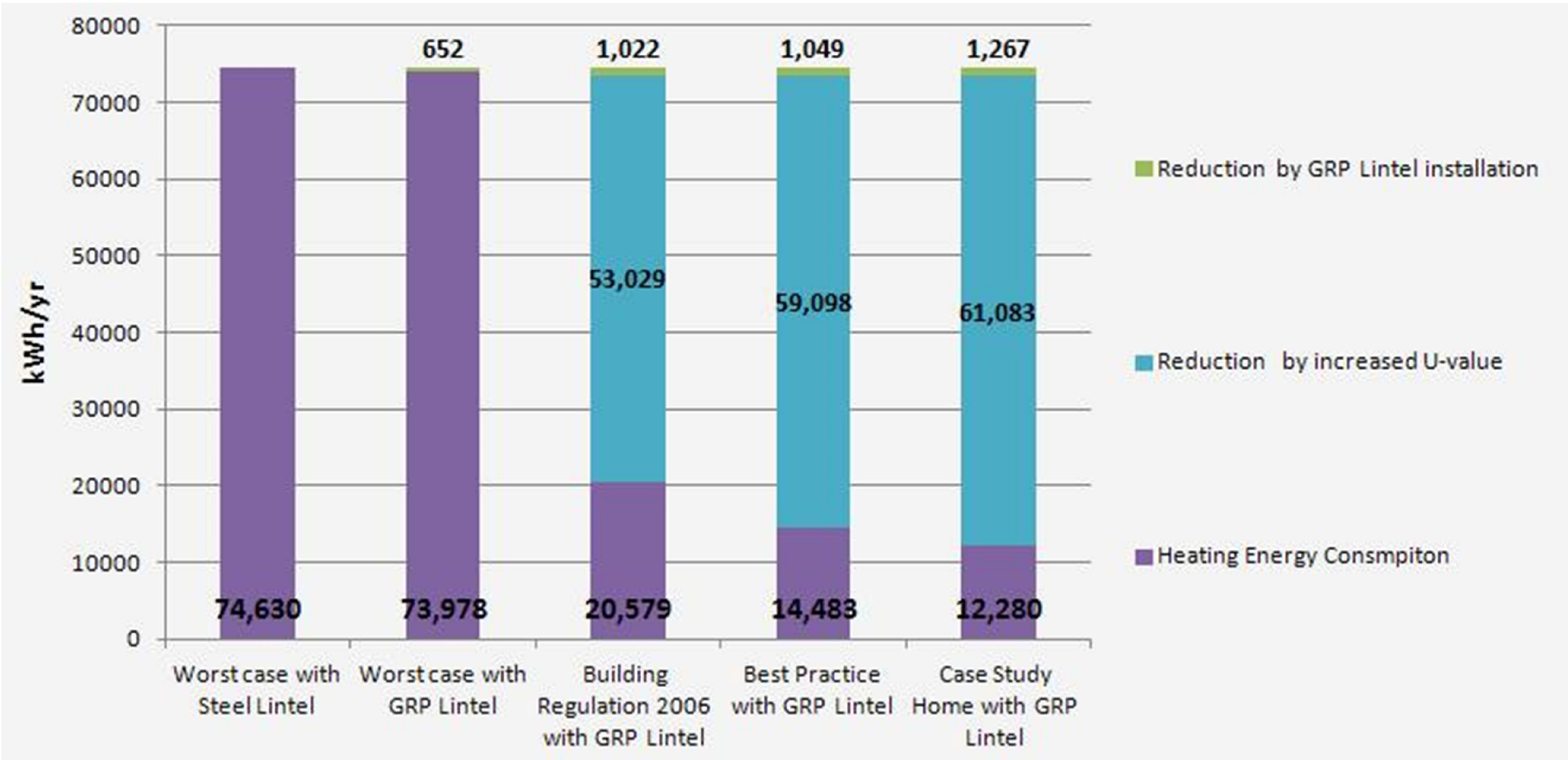
Air permeability standards

Standards	Maximum air permeability $m^3/(h.m^2)$ @ 50Pa
Approved Document L1A of Building Regulations (2010).	10 (0.5 ach -1)
Energy Saving Trust (naturally ventilated)	7 (0.35 ach-1)
Energy Saving Trust (mechanical ventilated with heat recovery unit)	4 (0.2 ach-1)
The Netherlands	6 (0.3 ach-1)
Germany (air changes per hour at 50 Pa)	1.8 ~ 3.8 (n50 h-1)
PassivHaus	<1 (0.1 ach-1)
Super E (Canada) (air changes per hour at 50 Pa)	1.5 (0.075 h-1)

Unit price and CO_2 emissions from energy sources in SAP 2009.

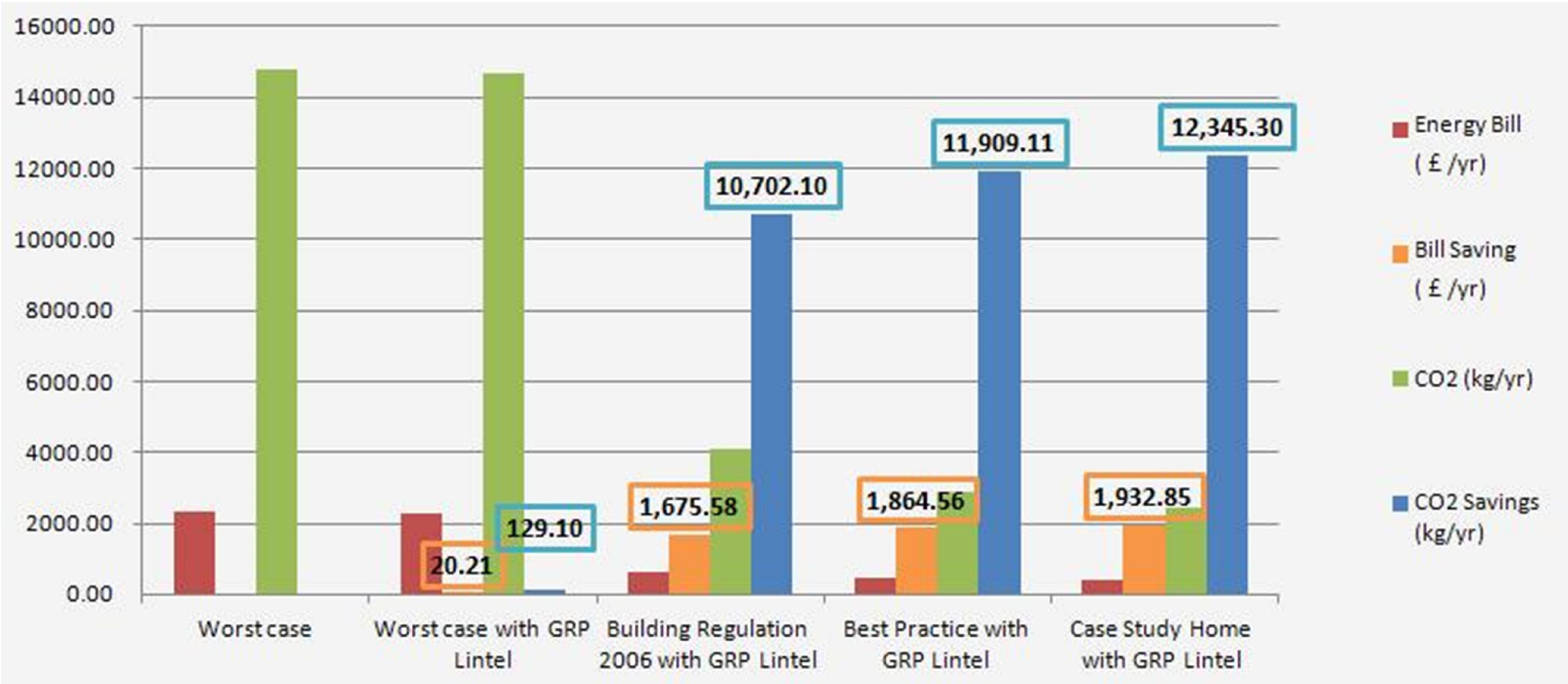
	Unit price (p/kWh)	CO_2 emissions (kg/kWh)
Gas	3.10	0.198
Source: SAP 2009		

The best case scenario which is the case study home with the GRP lintel shows savings of a further 10% of heating energy consumption and this provides a clear view on why a highly insulated dwelling should consider reducing thermal bridging. Well detailed and constructed buildings would result in huge reductions in heating energy consumption with additional reductions obtainable from eliminating thermal bridging.



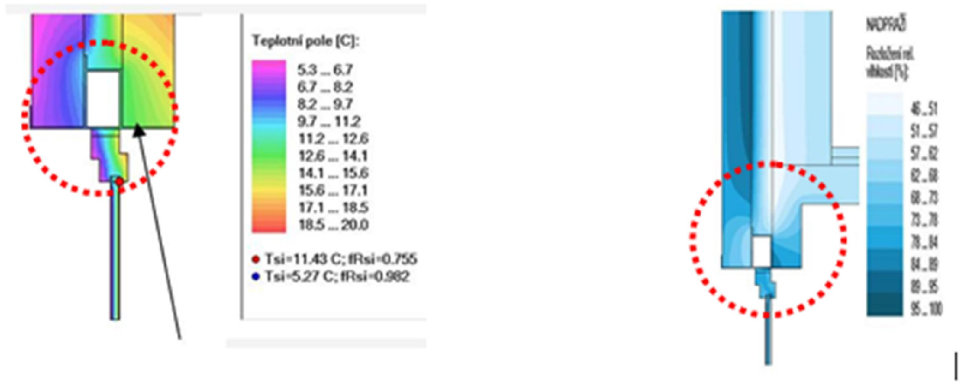
Heating energy consumption and reduction breakdown

After introducing insulation into the building fabric, there are significant savings in energy bills that can be made and again reduction in CO_2 emissions. As mentioned, most of the reductions were made by increasing building fabric's thermal properties but the GRP lintel has contributed further reduction in heating energy bills and CO_2 emissions

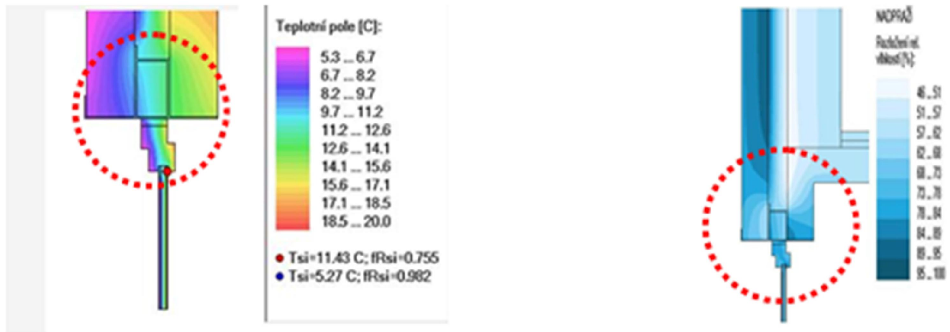


Overall energy bill and CO_2 savings

Two-dimensional Temperature (°C) and Relative Humidity (RH) profiles through the GRP lintel under winter conditions have been simulated. The boundary conditions are as follows: temperature for internal and external is 20°C and 5°C; RH for internal and external is 55% and 84% respectively.



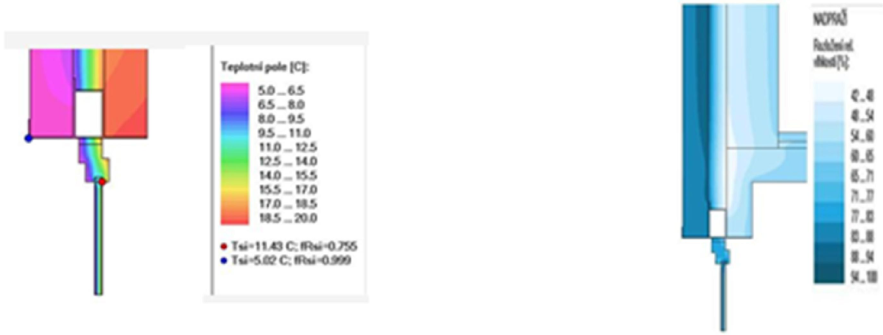
a) Steel lintel



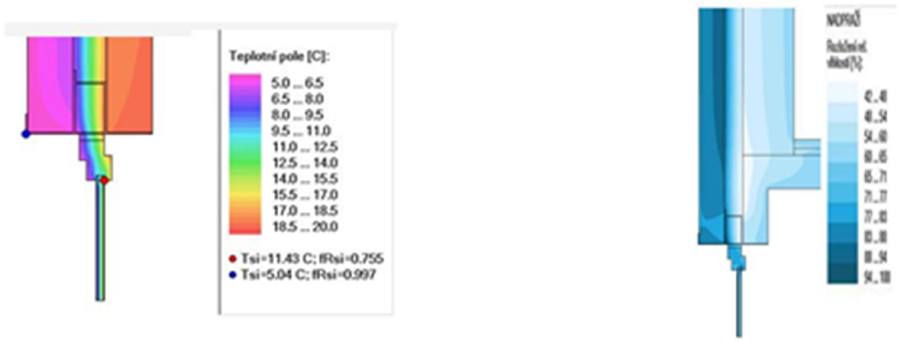
b) Steel lintel filled with insulation

Temperature and RH distribution

On the contrary, the window with a GRP lintel shows better performance and it almost eliminates thermal bridging. The internal wall surface temperature is almost the same with room temperatures and RH levels that are within an acceptable range without any condensation problems. To prevent interstitial condensation between external brick and cavity insulation layer, vapour barriers should be installed.



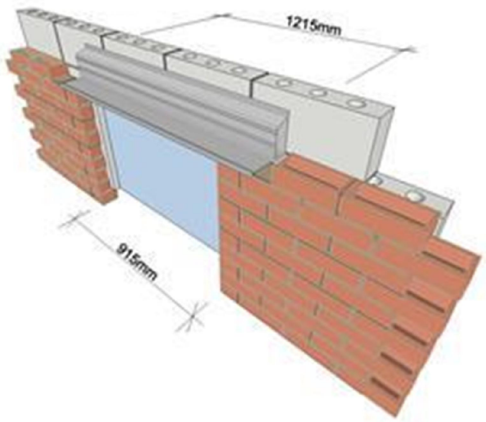
c) GRP lintel



d) GRP lintel filled with insulation

Temperature and RH distribution

Litel® – Material Edge Ltd. Litel lintels remove the cold bridge associated with the use of steel lintels over windows and door openings. The savings on energy to heat a dwelling can be as much as 10% every year of the buildings life simply by choosing to fit GRP Litel lintels instead of steel ones. GRP is strong and load bearing and Litel U (Universal) are BBA approved for spans of up to 1.7m, with provision to span up to 3m. Light in weight, easy to carry and safer than sharp steel they are ideal for the energy conscious self builder being used in exactly the same way as a standard cavity wall lintel. Cavity sizes available are 90-110mm and 140-160 or 240-260mm.



THERMOSTATIC INSULATING SYSTEM (TIS)

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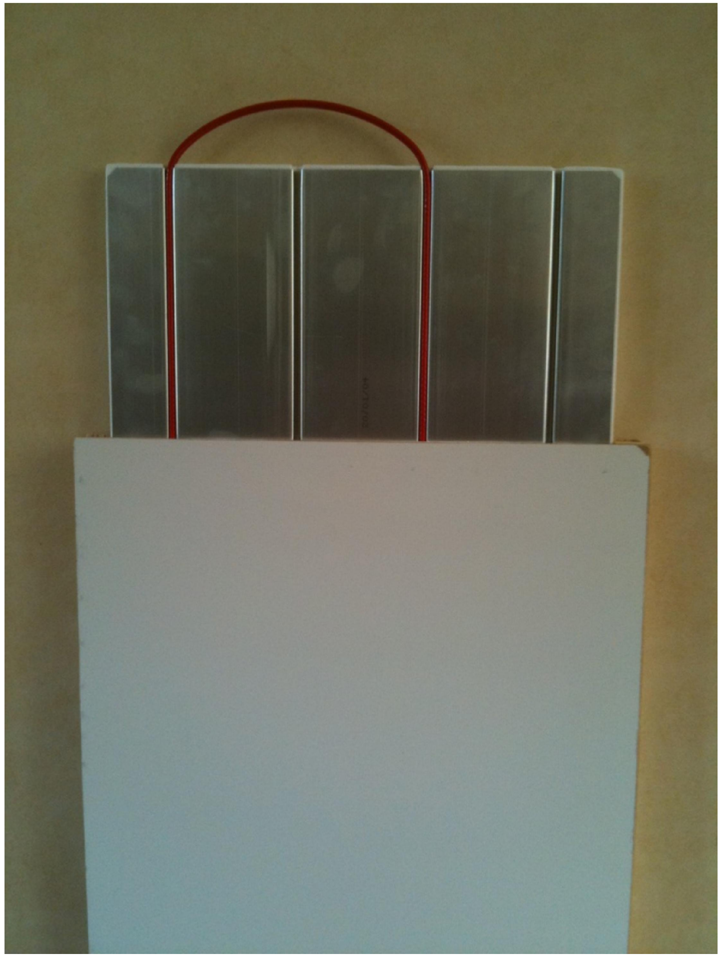
Thermostatic Insulation System (TIS)

- Developed by Esulation Technologies Ltd with following objectives:
- Maintain the building’s internal temperature using less energy than conventional heating systems.
- Splitting up space heating into TWO independent systems.
- The TIS system enables a building to maintain its temperature level WITHOUT heating the air in the building.
- To limit the heating requirement to the U-value of the building fabric (for maintaining temperature).
- Providing a simple and low maintenance alternative to conventional heating systems.

Sample TIS Panel



Principle of the 'Neutral Thermal Gradient'

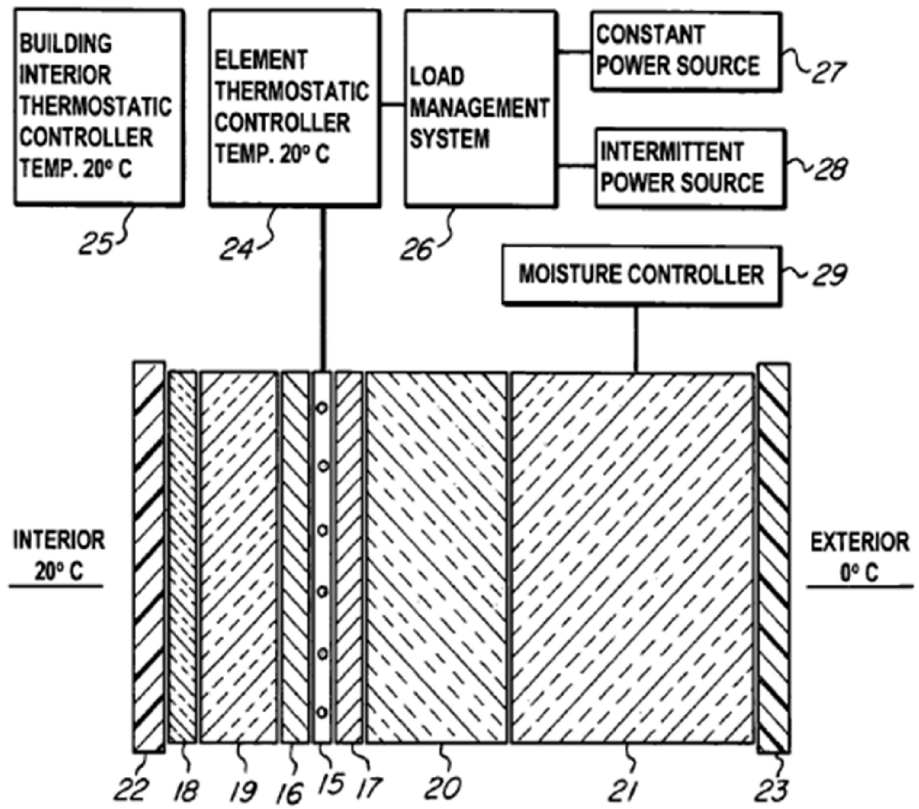


FIG. 3

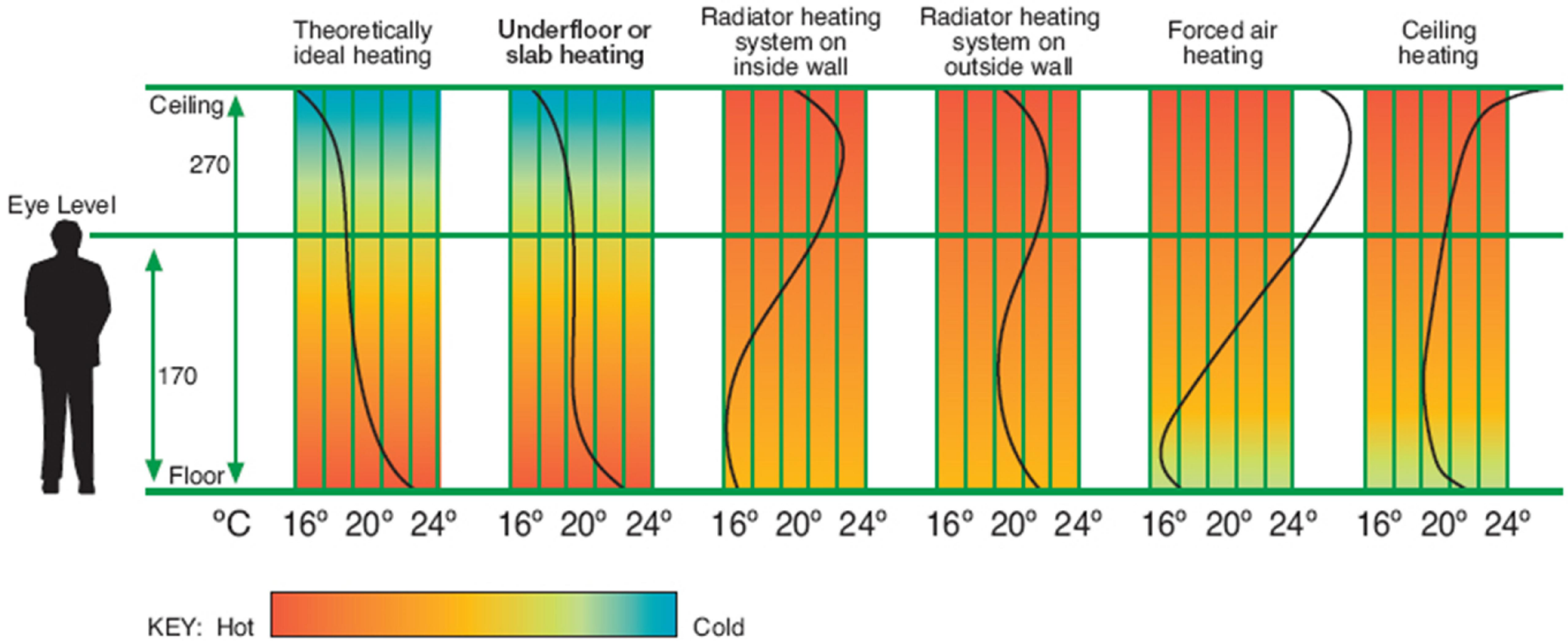
TIS Technology

- Patented: GB 2399827 & US 7576301
- Direct delivery of heat to the building fabric using electricity.
- Assembly creates a heated layer with +/- 1°C
- Typical consumption rate of 2 to 4 Watts/m^2
- Example: Townhouse has 100 m^2 of wall/roof and U-value of 0.2 Watts/K/m^2. Average winter Temp 7°C. To maintain 20°C = 100x0.2x13 = 260 Watts. Winter time is 5000 hours = 1300 kWh

TIS Advantages

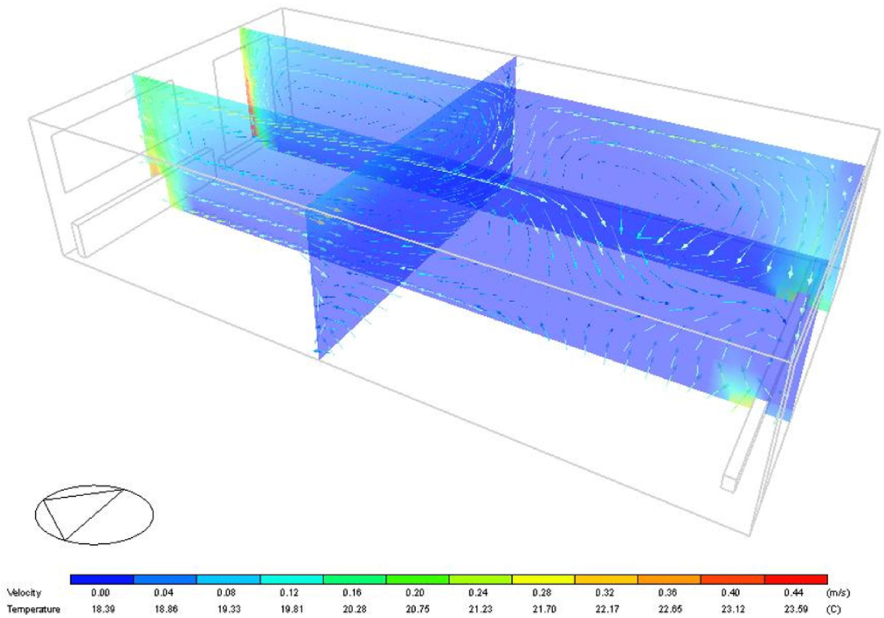
- Operates as an independent system;
- Potential reduction in space heating energy of 65% for new build and 45% for retrofits;
- Predictable winter energy bills;
- Thermal comfort from 20C wall/ceiling temperatures + eliminates thermal cycling;
- Provides a constant electrical load for intermittent renewable electricity devices.

In most buildings, heating and hot water account for the largest energy demand and therefore CO_2 emissions from heating systems are often very high. Space heating loads are generally reduced by various measures such as improving U-values and airtightness, increased boiler efficiencies and improved heating controls. However, due to increasing fuel prices, there are constant costs and GHG (Greenhouse Gas) emissions from such system/control whilst meeting the comfort demands of the building occupants.

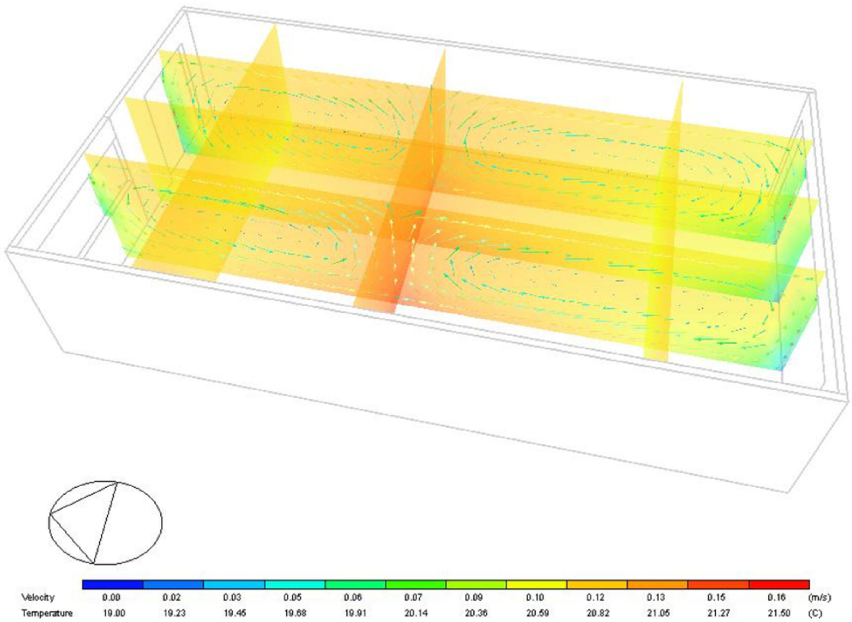


Vertical Air Temperature Gradients

Predictably, radiators struggled to maintain comfortable levels of temperature and provided an even distribution across the room at 20°C. However, TIS at 20°C was able to provide an even distribution of 20°C room temperature



Internal temperature distribution of radiators heating system



Internal temperature distribution of TIS

Adapted building standards (u-value and ac/h).

	No Insulation	2006 Building Regulation	Best Practice
Wall	2.071	0.35	0.25
Floor	1.463	0.25	0.15
Roof	1.54 (flat) 2.93 (pitch)	0.25 (flat) 0.16 (pitch)	0.15 (flat) 0.15 (pitch)
Window/Door	6.121	1.978	1.978
Air Infiltration	1	0.5	0.3

Areas of case study homes' building elements.

	Wall area (m^2)	Opening area (m^2)*	TFA (m^2)
Case Study Flat	72.8	11.7	69.6
Case Study House	148.5	20.5	139.2

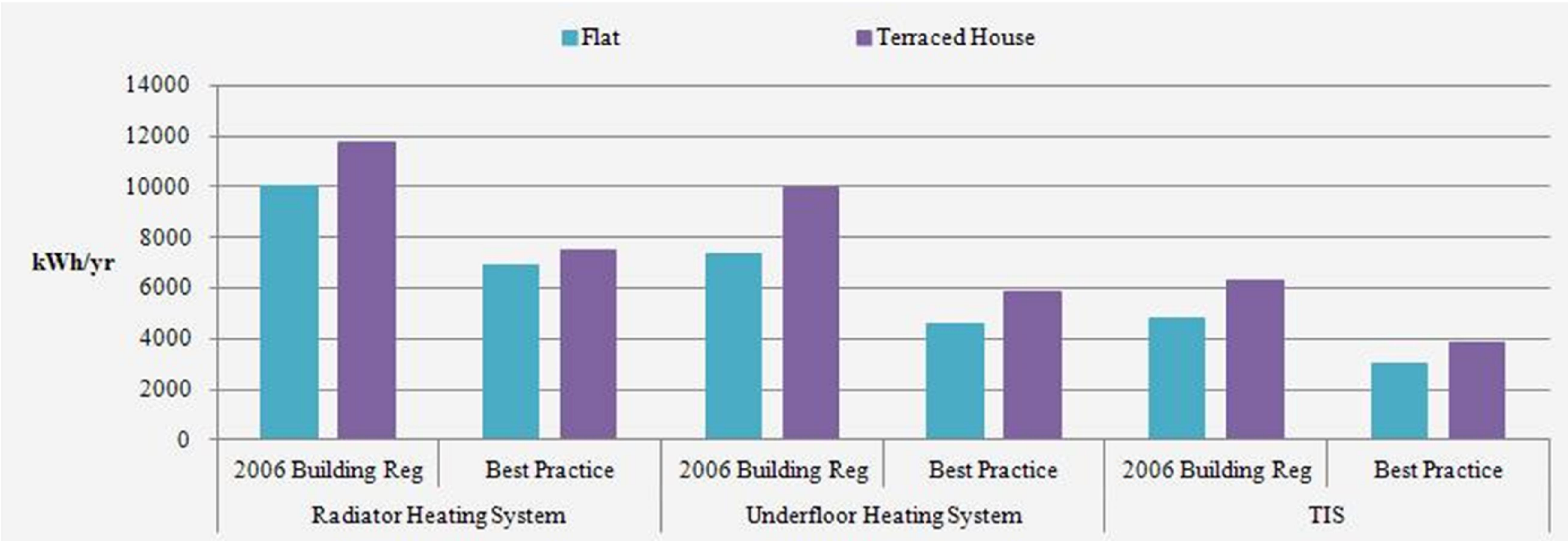
* The areas are included windows and external door.

In addition, to calculate the renewable electricity generated from PV panels, SAP 2009 method is used and from Wind turbine, power curve method is used. To calculate the energy generated from a wind turbine in DesignBuilder, London weather data has been applied to estimate the wind speed on an hourly basis. Please note that the wind turbine's cut-in speed is 3 m/s and the cut-off speed is 25 m/s due to preventing any damage that may occur from strong winds.

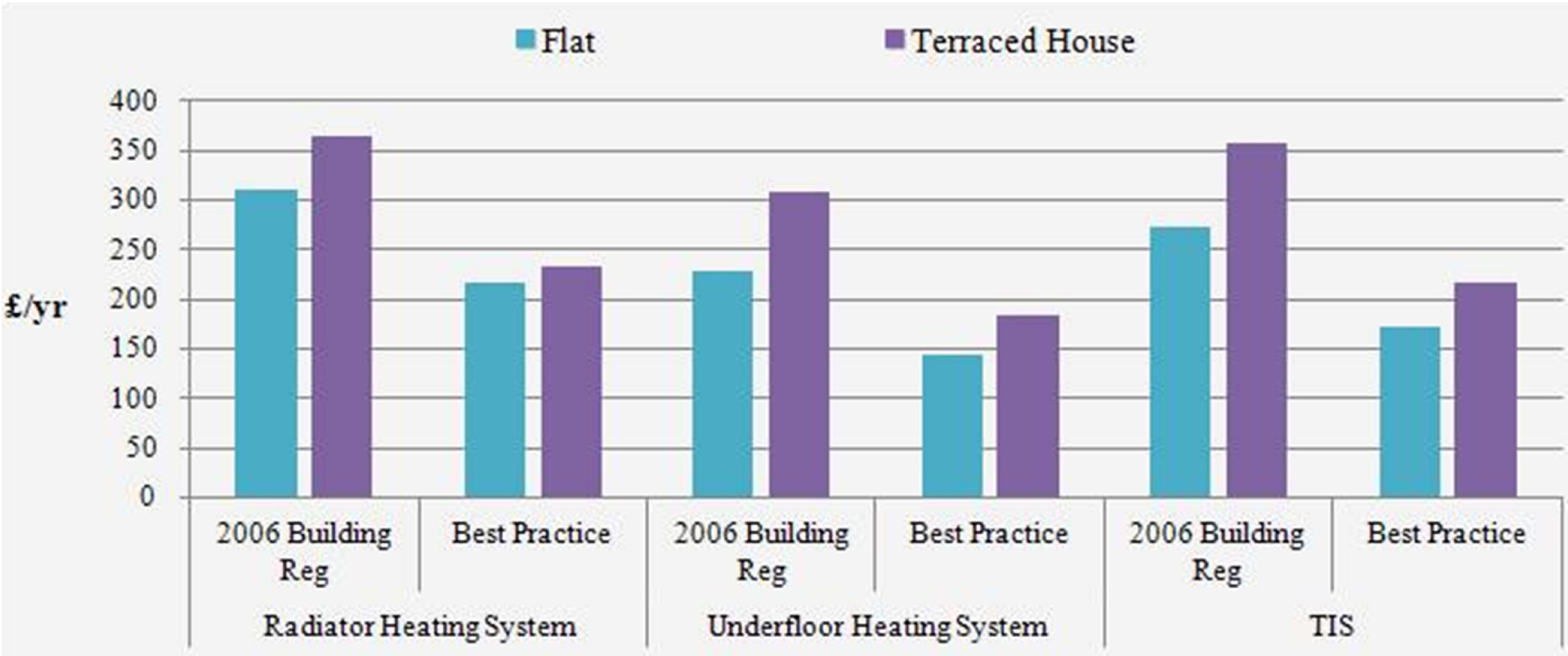
Unit price and CO_2 emissions from energy sources in SAP 2009

	Unit price (p/kWh)	CO_2 kg/kWh
Gas	3.10	0.198
Electricity	11.46 (standard)	0.517
	12.82 (7 hour tariff, high rate)	
	11.83 (10 hour tariff, high rate)	
	5.64 (24 hour heating tariff)	
Source: SAP 2009		

The heating energy consumption considering 'No Insulation' cases is showing some interesting results where underfloor heating system with no insulation is the highest; higher than others due to huge amount of heat escaping from a non-insulated floor, which means that the heat losses through floor before heating the space. However, when insulation is introduced in the building fabrics, the radiator heating system has the most energy demand because of its water temperatures are running at higher level as it requires 75°C with relatively small area of emitters. The 'No Insulation' case is to show the benefit of retrofitting old houses with TIS.



Heating energy consumption considering all three cases



Heating energy consumption excluding 'No Insulation' case

Flat's TIS heating energy consumption by structure types

TIS Market

- Can be adapted to any type of new or existing building.
- New homes 200,000? (Self build 20,000).
- Existing homes 24 million (4 million solid walls).
- Industrial & Commercial buildings 700,000.
- Priorities: New pre-fab homes, retrofit homes, metal clad buildings.

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The British University in Dubai

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Many Thanks.

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