Energy Generating Building Envelopes

Daniel Pillai
Director
Sustainable Building Envelope Centre (SBEC)

Drivers for change

The drivers for renewable energy in buildings

- Buildings account for 40% of energy use and CO_2 emissions.
- In Northern Europe one half of the building's energy is used for space heating/cooling.
- Reduction in demand for space heating and substitution of remaining demand by a renewable source is required to meet 20% CO_2 reduction target set for 2020.
- Part L of the Building Regulations ongoing review and revision reflects the need for better building delivery

Drivers for change

- Energy White Paper
  - Addresses climate change & maintaining an affordable energy supply.
- “Building a Greener Future”
  - Three step plan for achieving a Zero carbon goal by 2019.
- Climate Change Bill
  - Establishes 2020 and 2050 goals as legal targets.
- UK Targets
  - Government target to reduce CO_2 by 20% by 2010, 30% by 2020 and 80% by 2050.
- EU Targets
  - European Council set new EU target of 20% reduction in CO_2 by 2020 and 20% renewable energy target for 2020.
  - Energy Performance of Buildings Directive
- BREEAM

Drivers for Change

Changes in Part L – England and Wales Building Regulations

2002. Air tightness testing requirement first introduced.

All buildings over 1000 m^2 to achieve maximum of 10 $m^3/m^2/h$

Compliance is based on elemental approach

2006. Introduction of CO_2 emissions targets based on 25% improvement over 2002 Notional Building

Development of Nation Calculation Methodology and SBEM for calculation of CO_2 emissions

All buildings over 500 m^2 to achieve maximum of 10 $m^3/m^2/h$

2010. 2010 Notional Buildings specification to calculate TER

Aggregate 25% reduction in CO_2 from 2006

2013. Further reduction in CO2 emissions

2016. Zero carbon for Dwellings

2019. Zero carbon for Buildings other than Dwellings

Operational Energy

Approved Document Part L 2013 – Future Proposals
20% notional building (government preferred option)

Element	2002 Notional	2010 Notional	Backstop	Side lit Heat only	Side lit Heat + Cool	Top lit
Roof	0.25	0.18	0.25	0.16	0.18	0.16
Wall	0.25	0.26	0.35	0.20	0.26	0.20
Floor	0.25	0.22	0.25	0.22	0.22	0.20
Window	2.2	N/A	2.2	1.6 (10%FF)	1.8 (10%FF)	N/A
Rooflight	2.2	1.8	2.2	N/A	N/A	1.6 (15%FF)
Air permeability	10	5	10	3	5	3

Diminishing returns on passive approach beyond a certain level

The Scenario

- The Sun is the single most important source of renewable energy.
- The building envelope can be used to capture, store and dissipate solar energy to meet the aim of zero carbon buildings.

- **The Vision**
- Change the role of the building envelope from passive conservation of fuel and energy to an active and dynamic role.
- To turn buildings into power stations.

Pivoted around the building fabric as a generating opportunity

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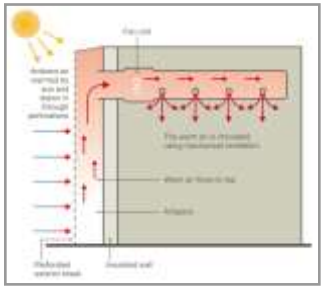
Generation

- Transpired solar collectors (TSC)
- Photovoltaics (PV)
- TSC and PV combined
- Thermo electric devices
- Thermodynamic panels

Parallel/Boost Generation

- Conventional gas boilers/blowers
- Biomass boilers
- Heat pumps for space heating and hot water



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Areas of Focus

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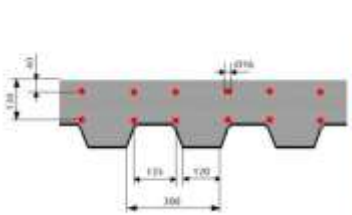
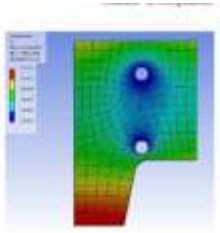
Storage

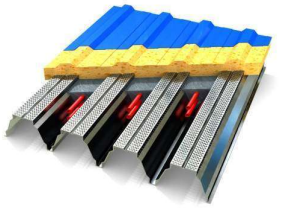
- Phase change materials (PCM, diurnal passive storage)
- Foundation/ground thermal storage (with ground source heat pumps)
- Water (diurnal thermal storage)
- Thermo chemical (inter seasonal)
- Accumulators (electricity storage)

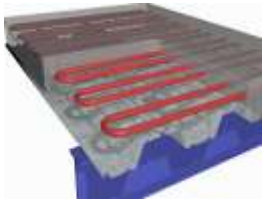




Release

- High temp wet systems
- Warm air systems
- Low temp wet systems using high emission steel surfaces





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Colorcoat Renew SC®

Harness the sun
to heat your building

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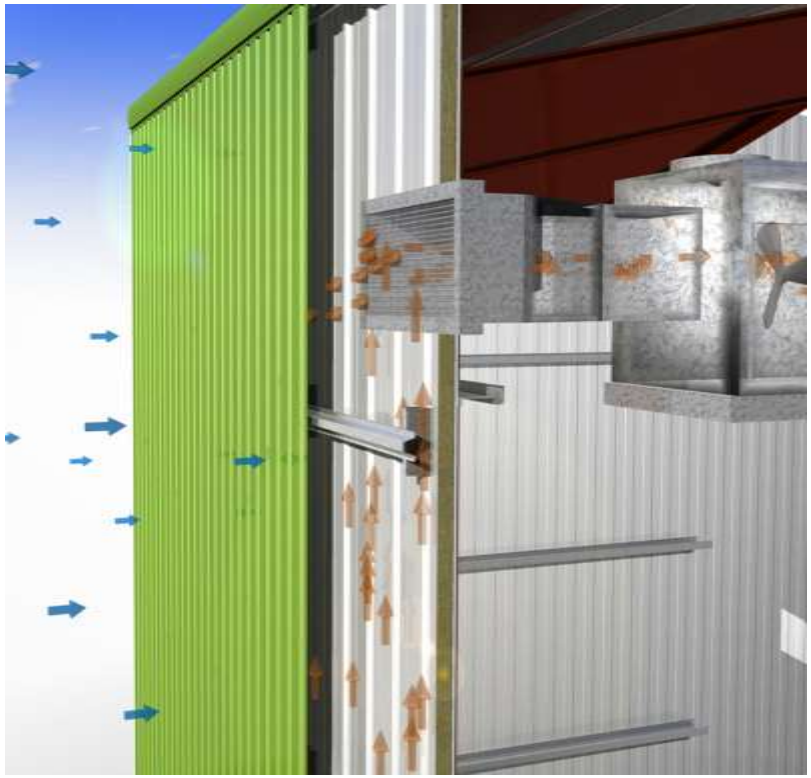
TSC History

- Originated in Canada 20+ years ago
- Many projects currently in use within US & Canada
- Now the leading solar heating technology in Canada
- Predominantly used in industrial sector, commercial sector & agricultural sector
- Considerable residential uptake in last 10 years in North America
- 2010 residential uptake in Canada exceeded liquid collector sales (m^2)
- A few examples in Europe at present but slow to develop

What is Transpired Solar Collector?

- Micro-perforated active solar collector
- An external skin with optimised perforations to absorb and trap solar energy and convert it into heat
- An active solar air heater through the use of a fan to draw air through the perforations
- Drawn air is warmed as it passes through the collector and is then distributed within the building
- Installed onto southerly facing walls and roofs
- Available in a range of colours



How does transpired solar collector work

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What buildings is it suitable for?

- Primarily suited to buildings where ventilated, fresh air is used to deliver space heating.
- It can be fitted to any building, new build or retro fit that has a requirement for space heating during the day.
- As the system uses solar energy to generate heat, there is simply a requirement for a southerly facing unshaded wall elevation for installation of the collector.

Government Incentives

- There is already provision for the inclusion of a TSC in SBEM
- Solar air heaters are included within SAP as back pass collector. Development work is underway with BRE to include TSC within SAP

- DECC have been requested to consider the TSC system for support under the Renewable Heat Incentive (RHI)
- Other EU governments will be lobbied for incentive supports as appropriate

Transpired Solar Collector Characteristics

Key characteristics of collector

- Energy delivered by a transpired solar collector is affected by:
  - Size of collector
    - Approx 30m max length per inlet
    - Approx 8-10m max height
  - Size of cavity (150-180mm is optimum cavity depth)
  - Surface coating - absorbance, material, porosity
  - Orientation
  - Weather parameters

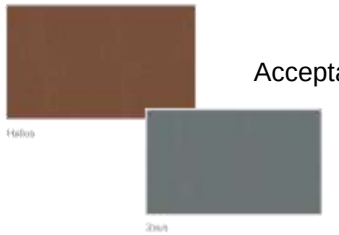
Absorbance

- Pre-finished steel type and colour affects how much heat is absorbed.

Colorcoat Prisma®	Solarthermal Performance
Black	Very High
Kronos	
Anthracite	High
Clover	
Slate Grey	
Chocolate Brown	
Atlantis	
Helios	Good
Alaska Grey	
Zeus	
Denim	
Oxide Red	
Anthracite Matt	
Terracotta Matt	
Grey Aluminium	
Pegasus	
Orion	Moderate
Copprium Matt	
Ephyra	
Athena	Low
Aquarius	
Oyster	
Silver Metallic	
Sirius	
Cream	
Hamlet	
White	

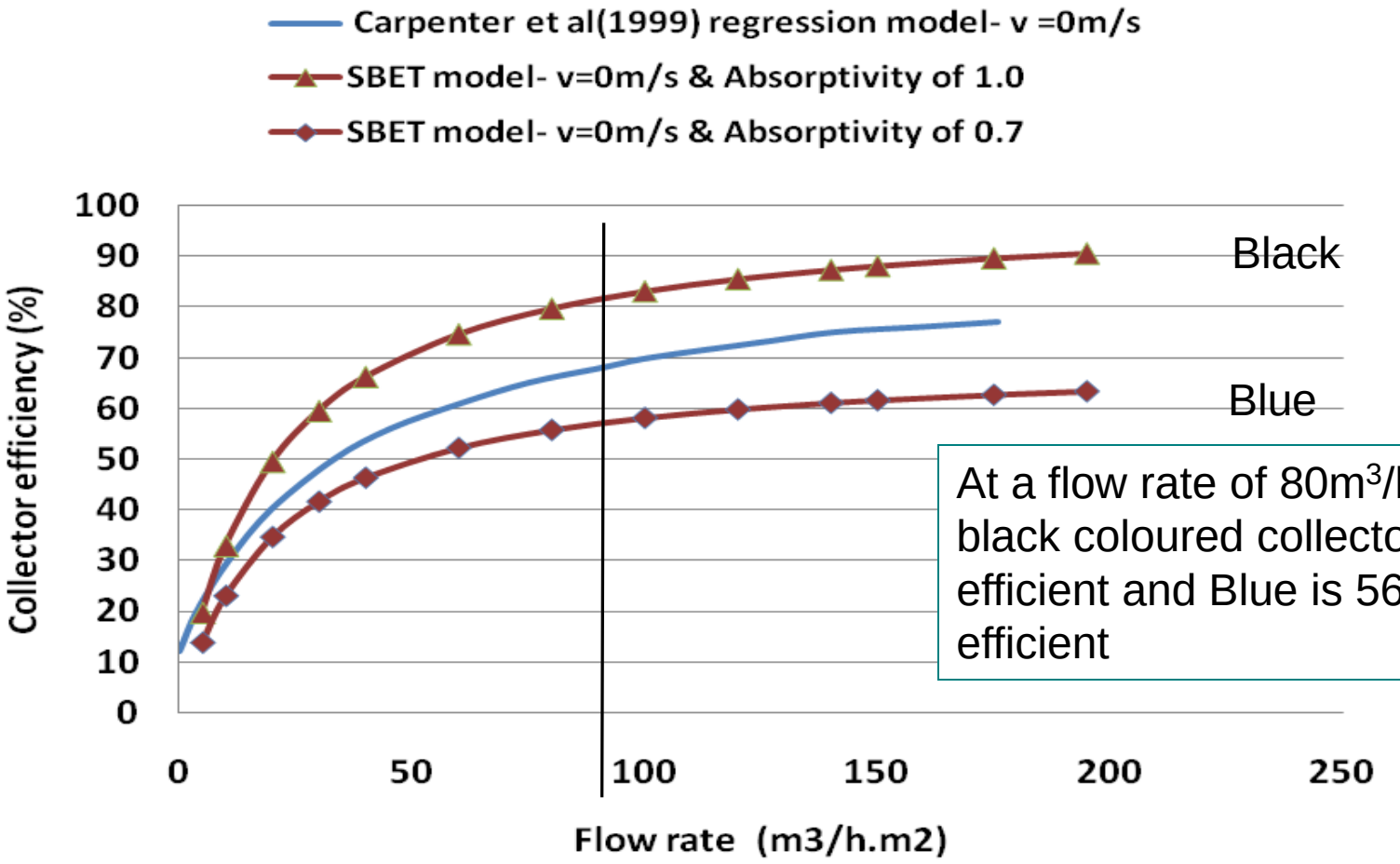
Highly Efficient

Good Efficiency



Acceptable

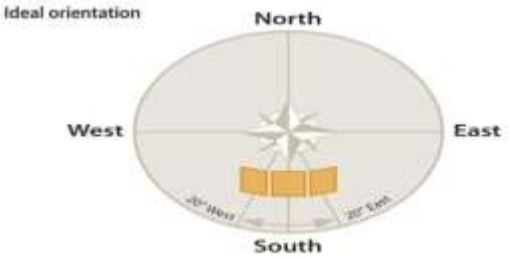
Absorptivity



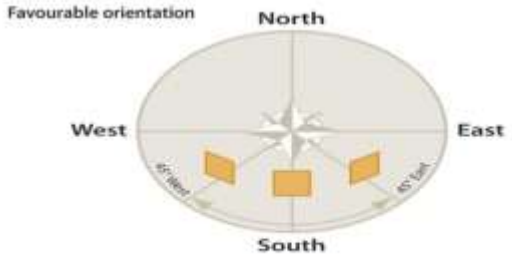
At a flow rate of 80m^3/hm^2 black coloured collector is 80% efficient and Blue is 56% efficient

Orientation

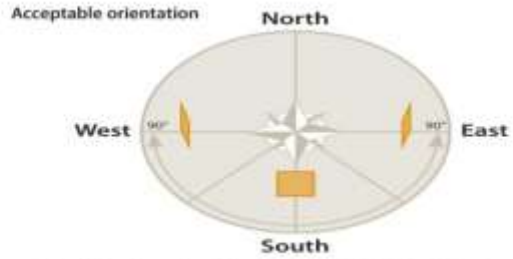
- The most efficient orientation is due south, but the system will still work in other orientations - a larger collector area (or darker colour) may be required to deliver an equivalent amount of heat as for due south.
- If choice restricted to East or West wall, decision based on sun in the morning or evening.



Facing due South, East to West variation 20°, 96% - 100% solar gain.



Facing South East to South West, variation 45°, 80% - 100% solar gain.



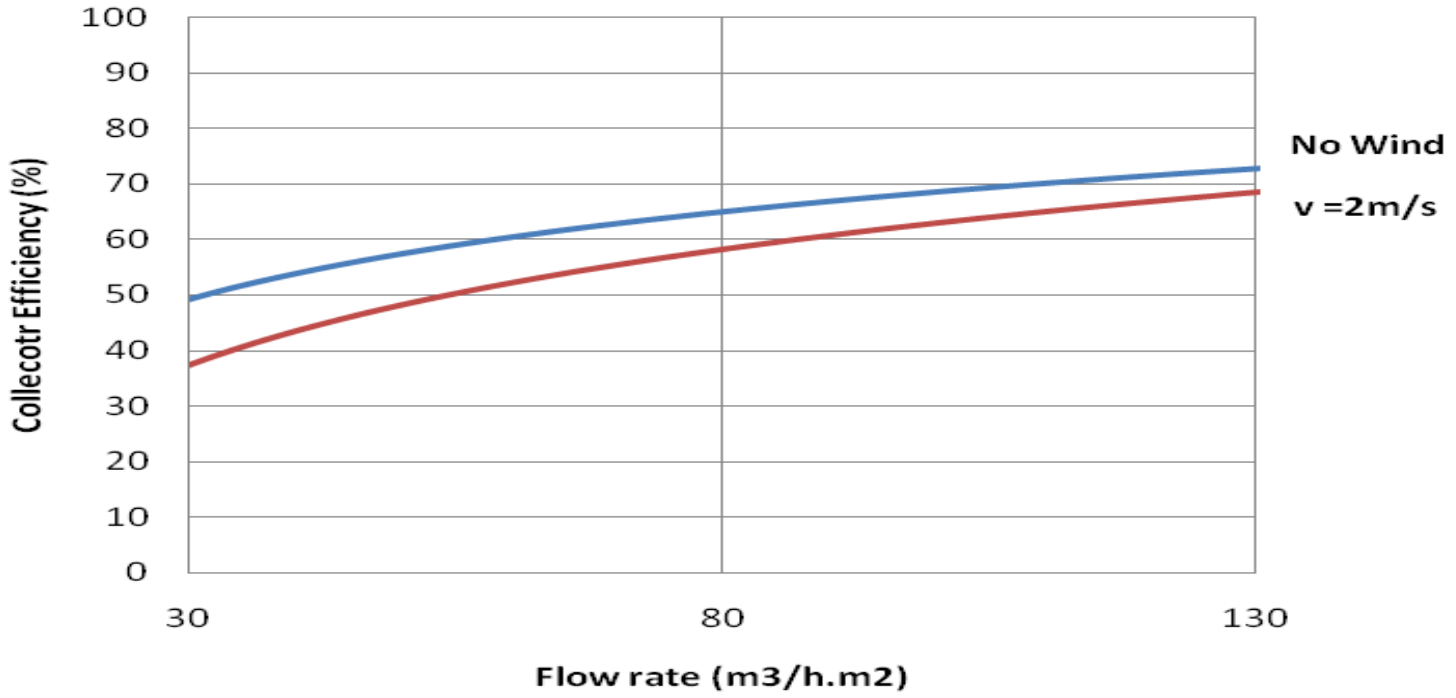
East facing through to West facing, variation 90°, 60% solar gain.

Climatic conditions

- In terms of the external climate, performance of Colorcoat Renew SC® is affected by:
  - Ambient temperature
  - Solar radiation
  - Rain
  - Humidity
  - Sky temperature
  - Wind effect

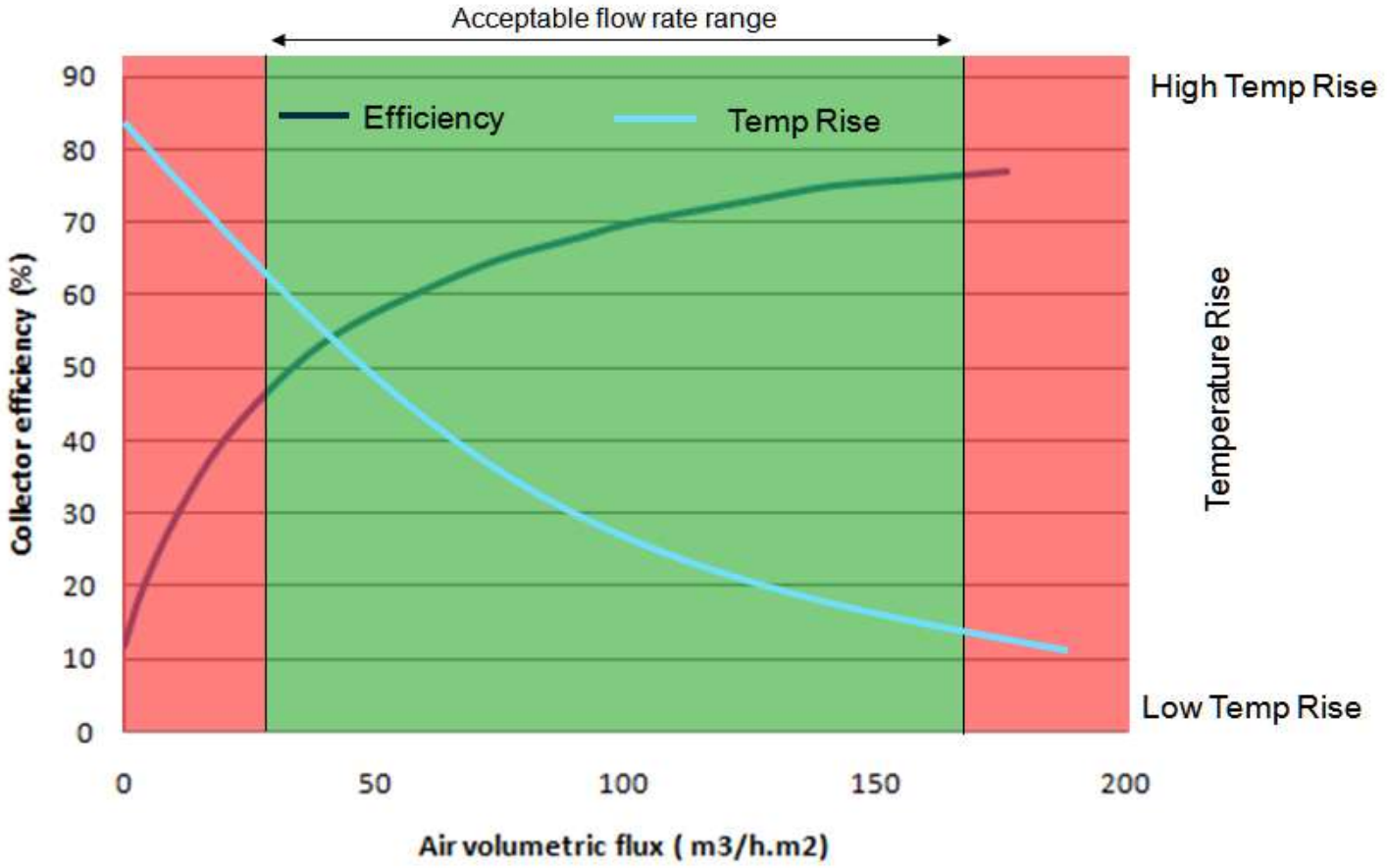
Performance Parameters – Wind

- High wind degrades performance
- Wind causes delaminating of the heated boundary layer
- At a flow rate of 80m^3/h/m^2 with no wind, for this colour collector the efficiency is 65%.
- At a wind speed of 2m/s (approx 4.5mph) the efficiency is 58%

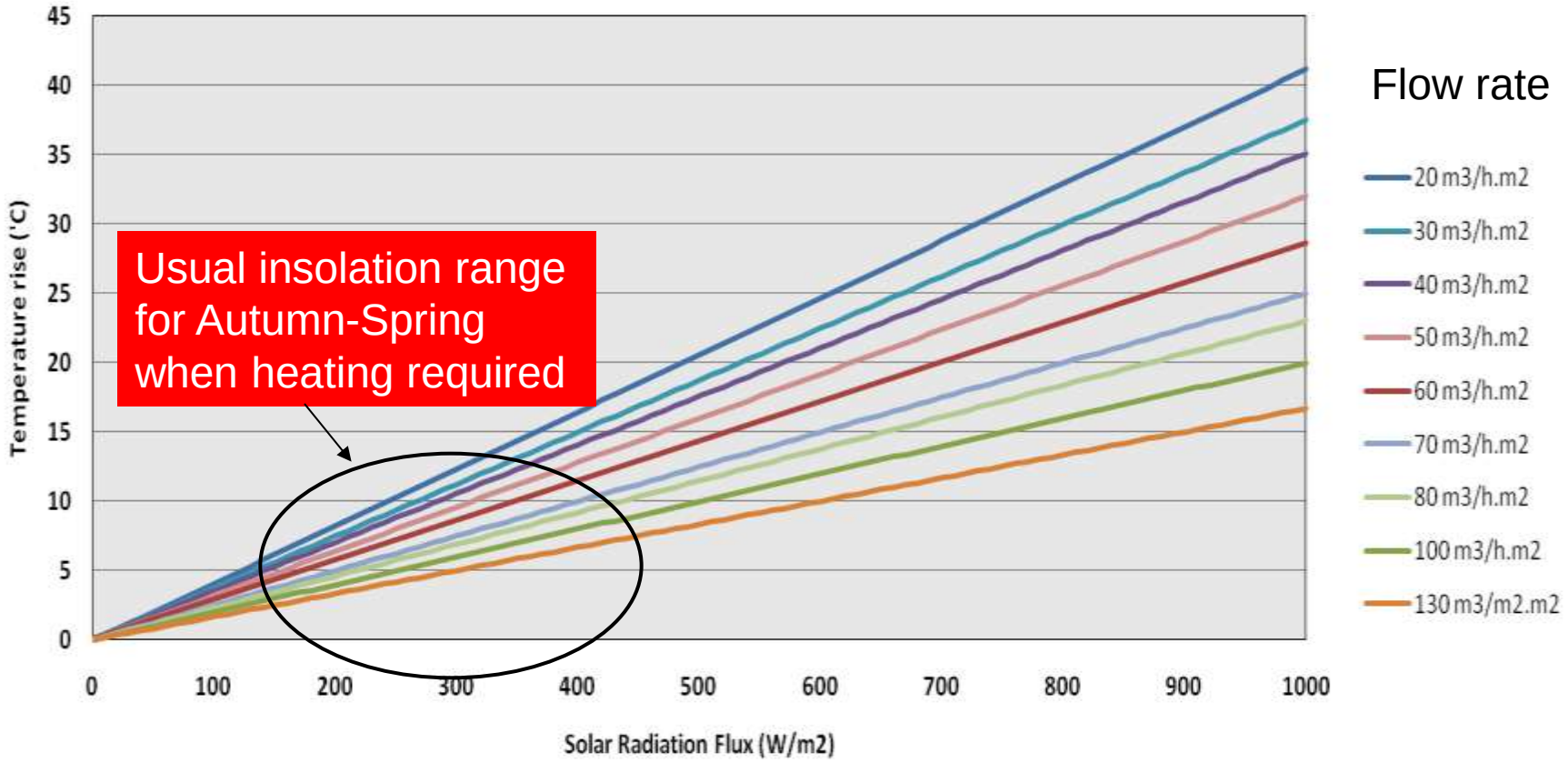


Performance Parameters – Temperature Rise

- Temperature lift stated as above ambient air temperature
- Temperature lift decreases with increased air flow



Performance Parameters – Insolation & Temperature Rise

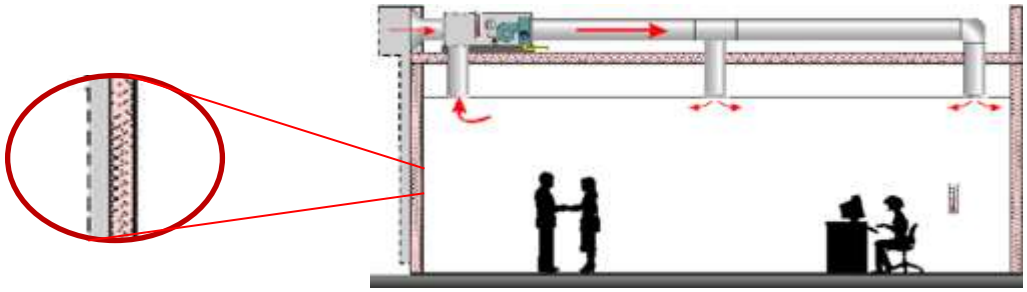


Additional benefits

Economic benefit: Fabric Loss Recapture

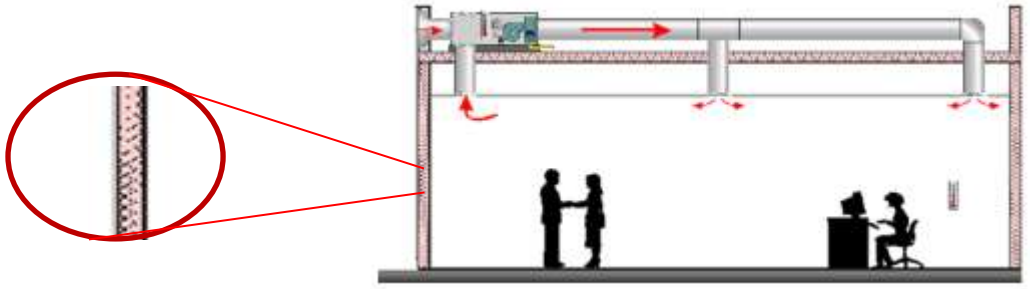
- Fabric losses due to heat conduction prevented under area of collector as cavity temperature higher than inside of building.
- Fabric losses can also be recovered from below the collector.

Collector wall



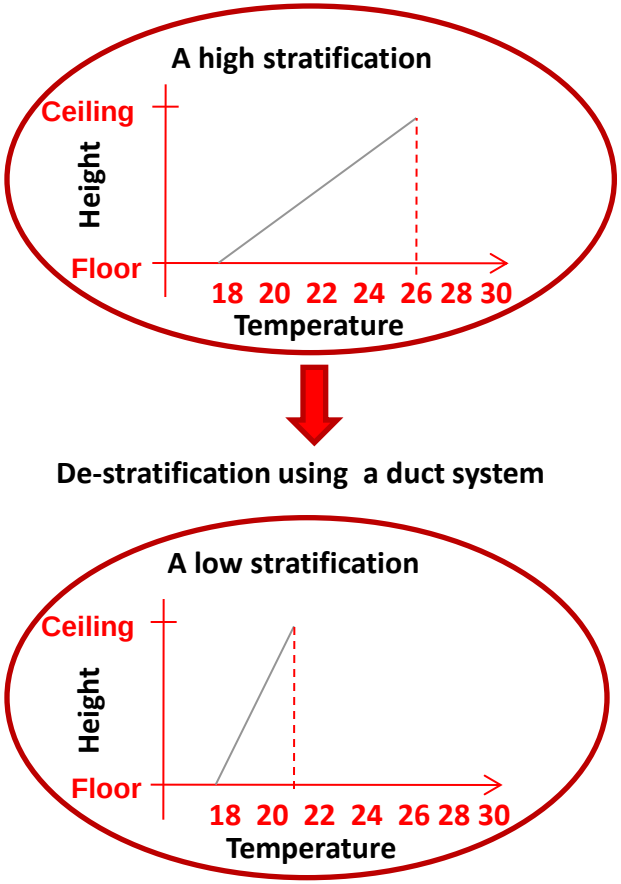
VS

Normal wall



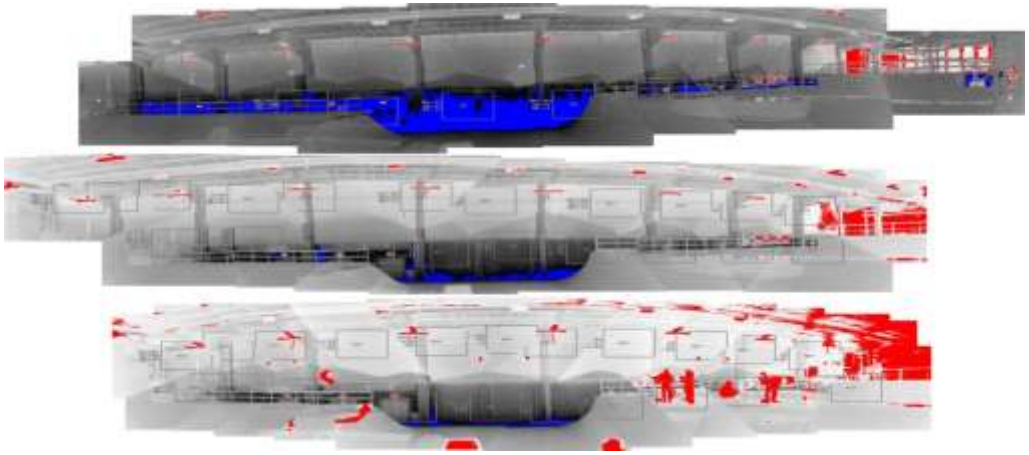
Economic benefit: Destratification

- Stratified temperature can cause a high infiltration loss and higher conduction losses at roof level.



General benefits

- Positive pressure created by the operation of the Transpired Collector system reduces infiltration of external cold air.
- In summer collector acts as a form of solar shading to the relevant wall elevation, additionally night time purge with cold air can cool fabric of building – reduces cooling loads in the day.
- Low operational costs. The solar energy used is free, the only additional costs are the low running costs of the fan.
- Reduction of forced and natural ambient ventilation air heat load.




Sustainable
Building
Envelope
Centre
The system
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TSC components
Design tool

- Tata Steel have developed user-friendly software model based on weather data specific to building location.
- The simplicity enables our partners to determine the optimised system design.
- Benefits:
  - Enables feasibility studies, design and specification of the Colorcoat Renew SC® solar air heating system.
  - Enables optimisation of renewable energy output at lowest cost.
  - Developed for European design practices and construction standards.
  - Uses specific system data for accurate prediction of renewable energy delivery, CO_2 savings and payback periods.
  - Sizes collector for required energy output.
  - Simple to use.

Indicative Sizing of TSC – Ready Reckoner

Ventilation Requirement l/s/person	Air Change Rate
l/s x 3600	Volume of Building?
Required m^3/hr flow rate	Required m^3/hr flow rate
Pick TSC flow rate High lift or high flow?	Pick TSC flow rate High lift or high flow?

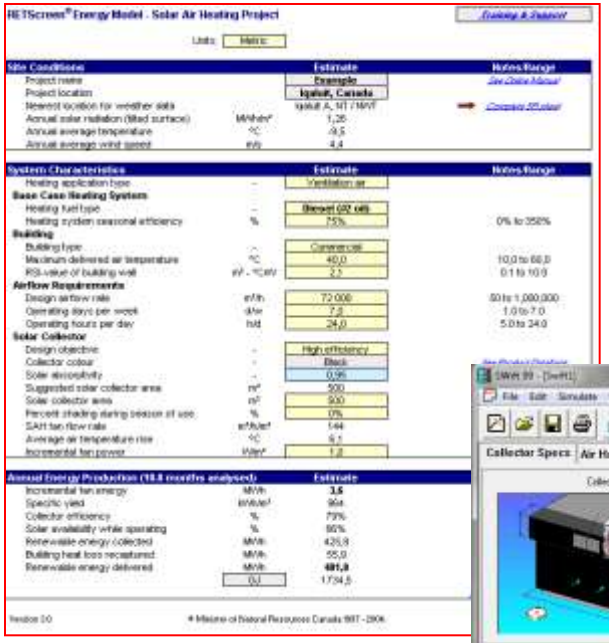
High 150m^3/hr/m^2	Medium 100m^3/hr/m^2	Low 50m^3/hr/m^2

Indicative Collector Size

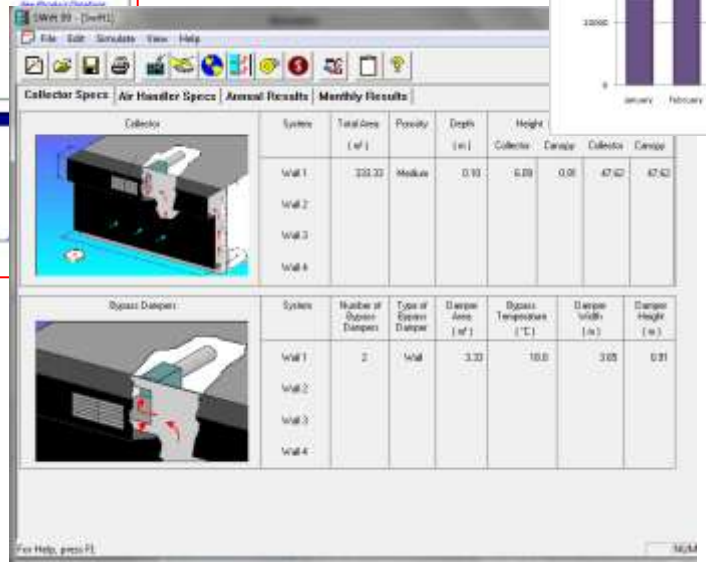
Calculation Software

Sustainable Building Envelope Centre

RETScreen



SBET – Sustainable Building Evaluation Tool



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Ariennir yn rhannol gan Lywodraeth Cynulliad Cymru
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TSC components
Control System

- We provide a pre-engineered control system solution to reduce design time and costs and ensure a consistency of performance.
- Controls and powers the operation of Colorcoat Renew SC®.
- Maximises delivery of renewable heat from the Colorcoat Renew SC®.
- Can provide metering, monitoring and networking to enable energy measurement and system performance review.
- 6 different versions to suit different situations - all supplied with necessary documentation for installation, commissioning and operation.

Control Equipment

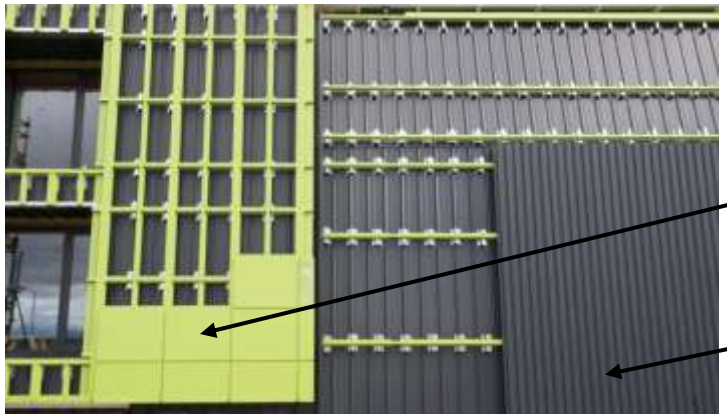
- Control Panel
  - Power
  - Control
- Instrumentation
  - Temperatures (insertion, contact and space)
  - Pyranometer
  - Differential pressure
  - Flow sensor
  - Humidity
- Outputs
  - Drives
  - Actuators
  - Metering

Modes of operation

Parallel system	Series system
Supplementary system	Pre-heat system
Triggers at higher set point	Triggers at lower set point
Delivers solar heated air and overrides main heating system	Reduces load on primary heating system

Grey zone…covered in control system

Colorcoat Renew SC® at SBEC



Transpired solar collectors during installation at SBEC featuring:

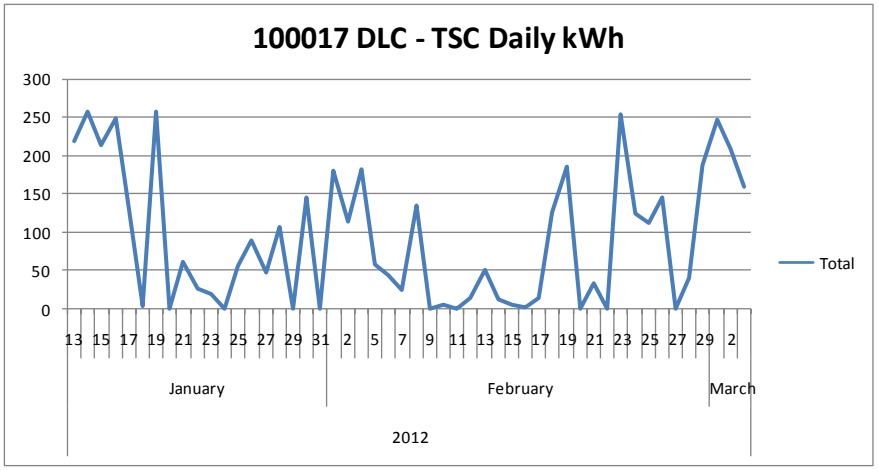
- Façade profile collector in Colorcoat Prisma® in Linden Green
- Trapezoidal profile collector in Colorcoat Prisma® in Anthracite Grey.

Finished building

- Colorcoat Renew SC® provides heat to 4 independent zones within the building
- Allowing measurement of renewable heat demand for boost, storage and heat dissipation
- The installed areas can typically provide 39MWh of heat per year (enough to heat two 3 bed houses for a year)

Colorcoat Renew SC® at Deeside Leisure Centre

- 214m^2 system installation
- Trapezoidal profiled Colorcoat Prisma® in Slate Grey
- Generated 5717kWh heat in Feb 2012 (26kWh/m^2 in Feb).
- Performance in line with prediction

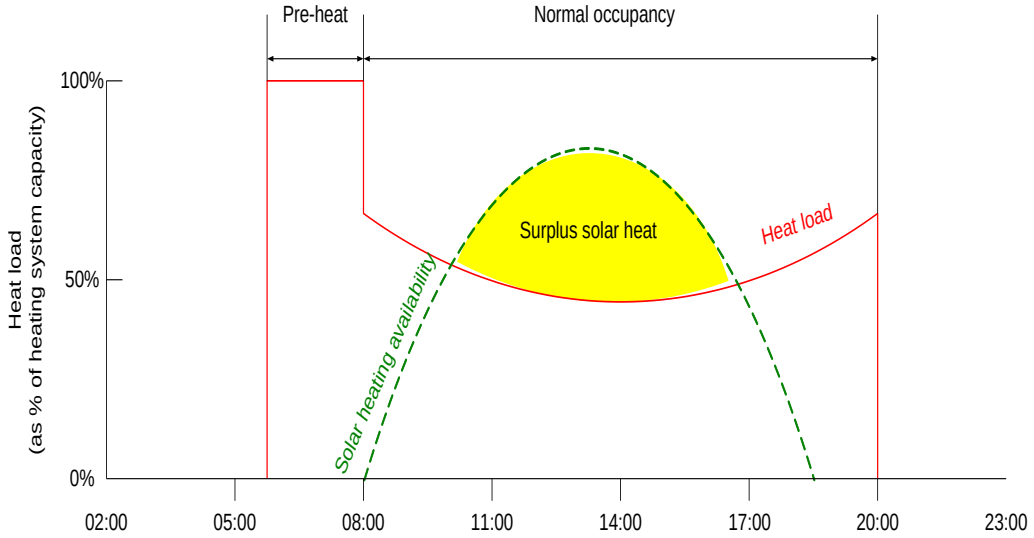


Key benefits

- A highly efficient renewable energy system:
  - Up to **75%** instantaneous efficiency
  - 1m^2 of collector area can deliver upto **250kWh heat per annum**
- Payback typically <10 years without the need for Government financial incentives.
- Average embodied carbon payback of 4 months.
- Lowest cost solution to achieving National targets for CO_2 emission reduction and Local targets for renewable energy
  - In UK this includes achievement of Target Emission Rates (TER) and Merton Rule.
- Includes specially developed design software for accurate prediction of renewable energy delivery, CO_2 savings and payback periods.
- Includes ‘plug and play’ standard control system solution to reduce design time and costs, and ensure consistency of performance.

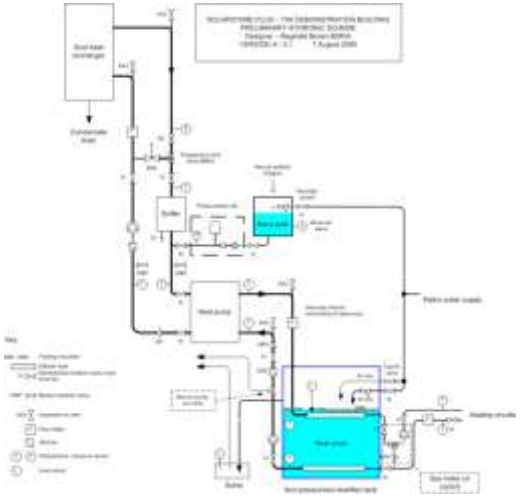
What inspired Solarstore Plus?

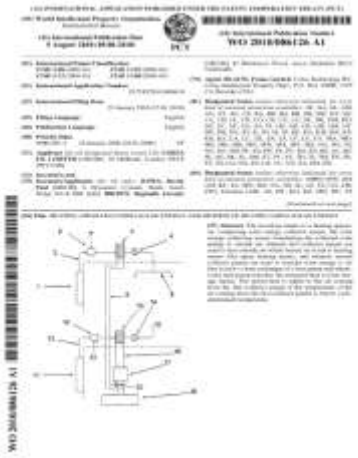
- Increasing the overall energy performance of the system and to pre-heat the buildings ahead of the sun being available the following day
- Maximise the collector surface area on a building to increase the volumes of high margin, pre-coated steel that can be sold
- Find a way to achieve a cooling effect – which would be especially useful for hotter regions, and developing countries where grid-based solutions can be both costly and impractical



The Solution

- Use two collectors
  - To provide pre-heated ventilation air
  - To feed dedicated storage system
- Heat pump to increase the water store temperature
- This reduces the store size to a practicable level
- A reversible heat pump could allow a cooling effect
- Patented invention with R Brown of BSRIA





How to demonstrate?

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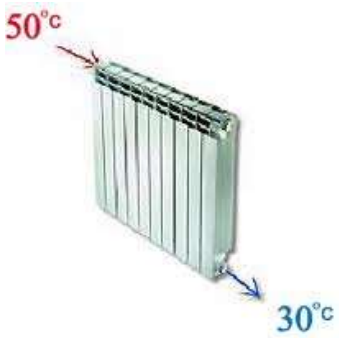
How does it work?

Pre-heated air pulled through heat exchanger fan unit

Water to water heat pump used to increase water temperature to 50^{o}C

Energy stored in 20000litre water tank

How to use the heat stored?

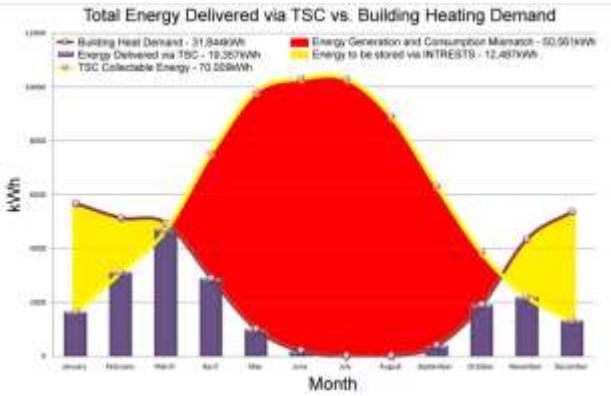


- Suitable for low temperature heating circuits
  - Low temp radiators
  - Underfloor heating

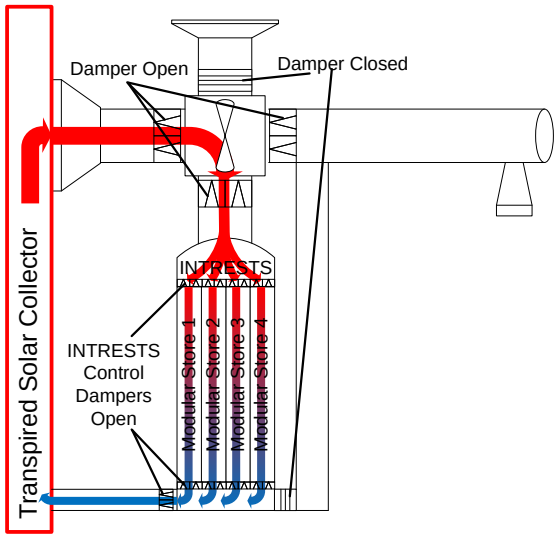
- In this case low temperature convectors are used

Future Projects - INTRESTS

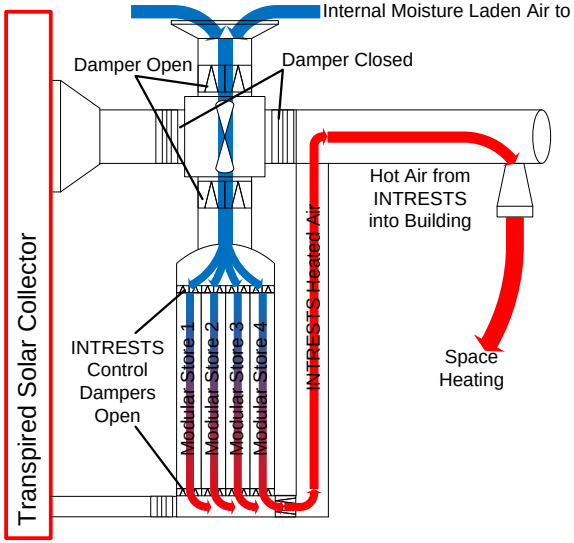
- Interseasonal Thermochemical Storage System
- TSB funded £914k
- 3yr project – lab to full building demonstration
- Tata Steel, BASF, E.ON, ETL, University of Nottingham

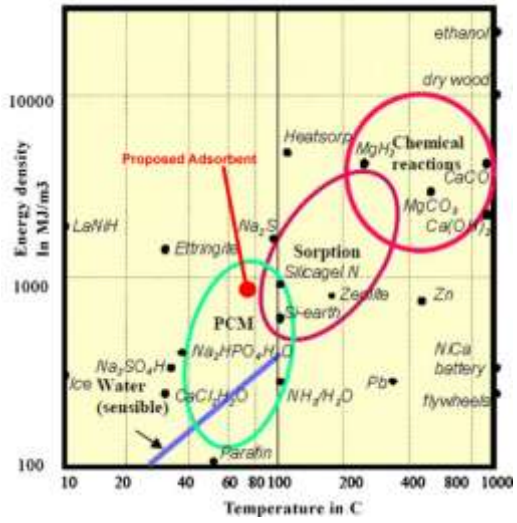


INTRESTS + TSC Operation – Charging



INTRESTS + TSC Winter Operation - Discharging





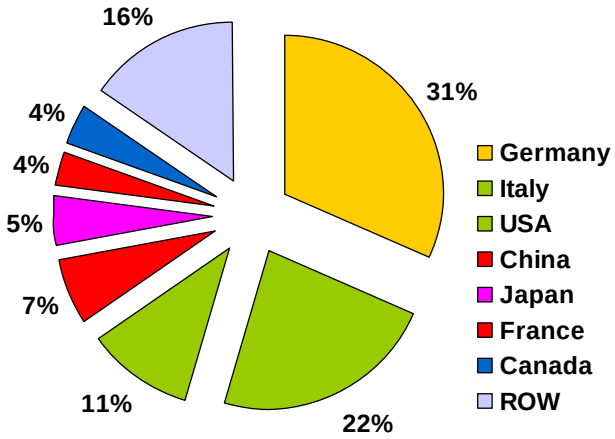
Photovoltaics

PV Market Share 2011

Globally 2011

- Total installations of PV reach in excess of 40 GW
- Growth from 2010 – 33%
- Expected growth >2011 25% - Year on Year

Installations in 2011 (market share)

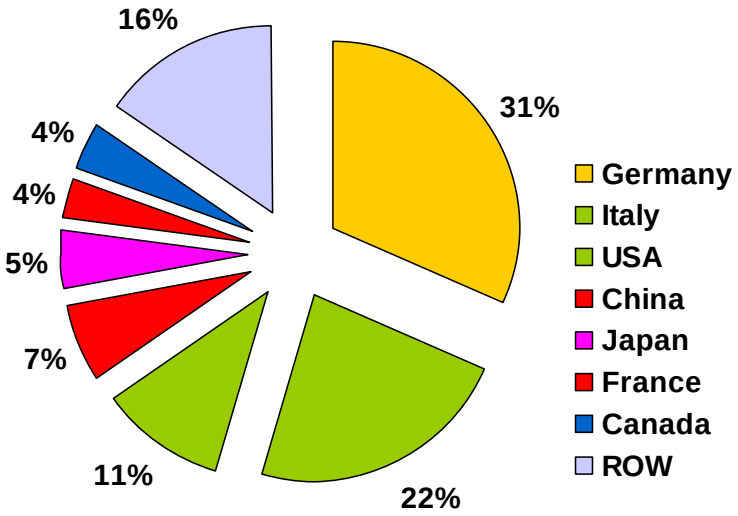


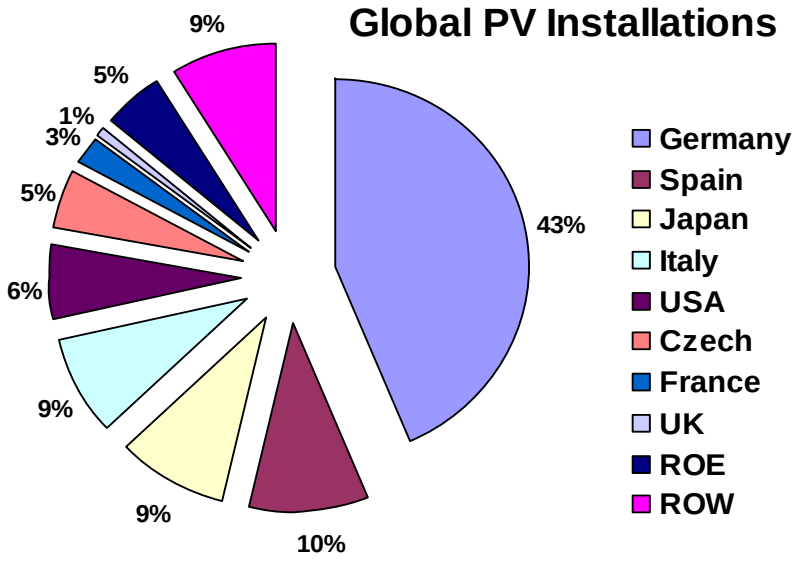
UK total exceeds 300MWp in 2011

Germany exceeds 7GWp in 2011

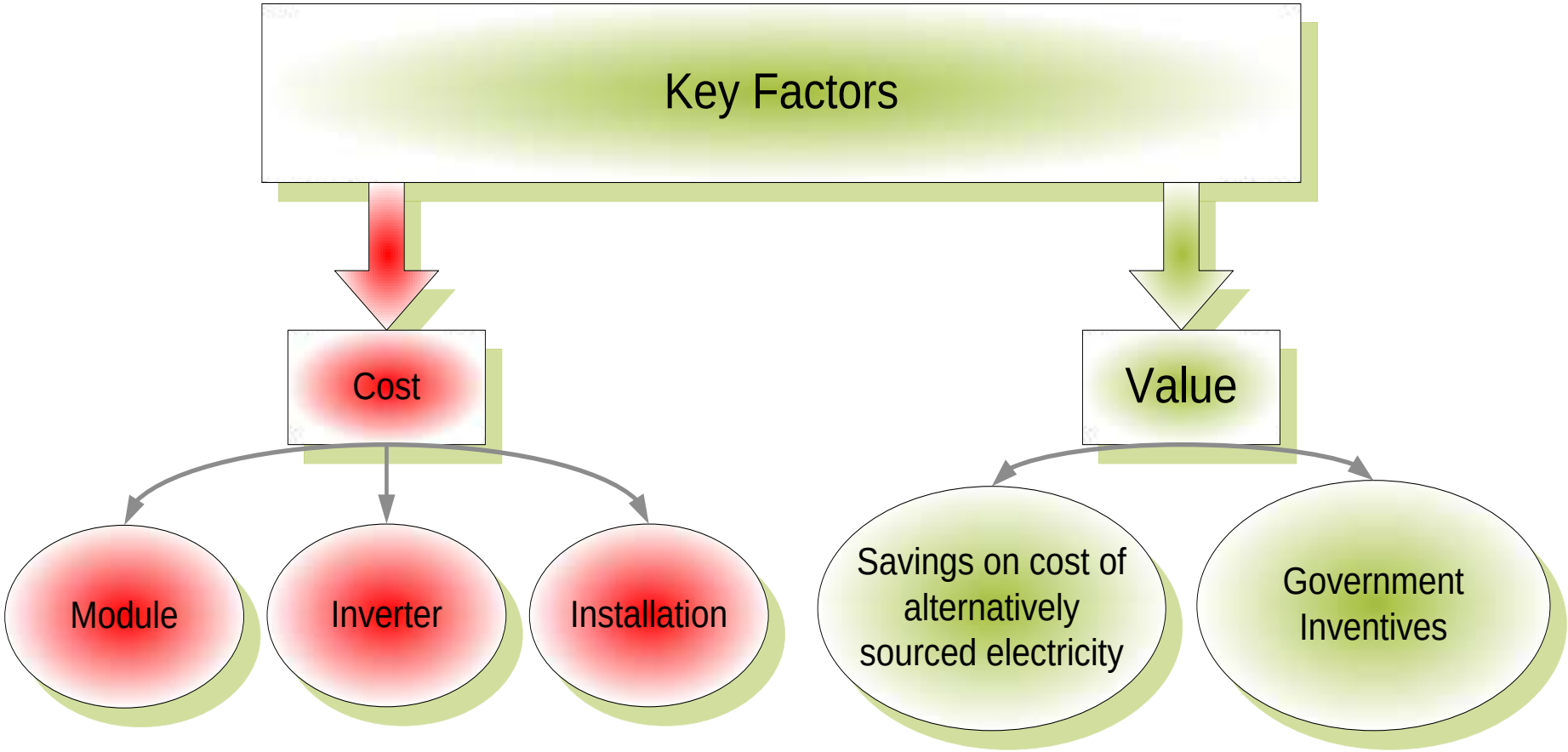
PV Market Dynamics

Installations in 2011 (market share)





PV Installation



Commercial & Industrial Installations

Mono & Poly Crystalline

Efficiency ~ 14% - 15%

Amorphous Silicone (a-Si)

Efficiency ~6%

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Traditional mounting systems / Crystalline panels

- Sub frame required
- Mechanically fixed therefore penetrations through roof sheet

- Generally load on roof 20 – 30 kg/m2
- Framed PV panels add to load
- Many suppliers available with varying quality & efficiency (10 – 15%)

Panel sizes approx 1.50m – 2.00m x 1.00m

Amorphous Silicon (a-Si)

Typically :

High Temperature and Low Light Performance

Industry standard limited power output warranty:

90% at 10 years, 84% at 20 years, 80% at 25 years (of minimum power)

Performance Characteristics

Efficiency circa 6% - 7%

Construction Characteristics

Flexible laminate

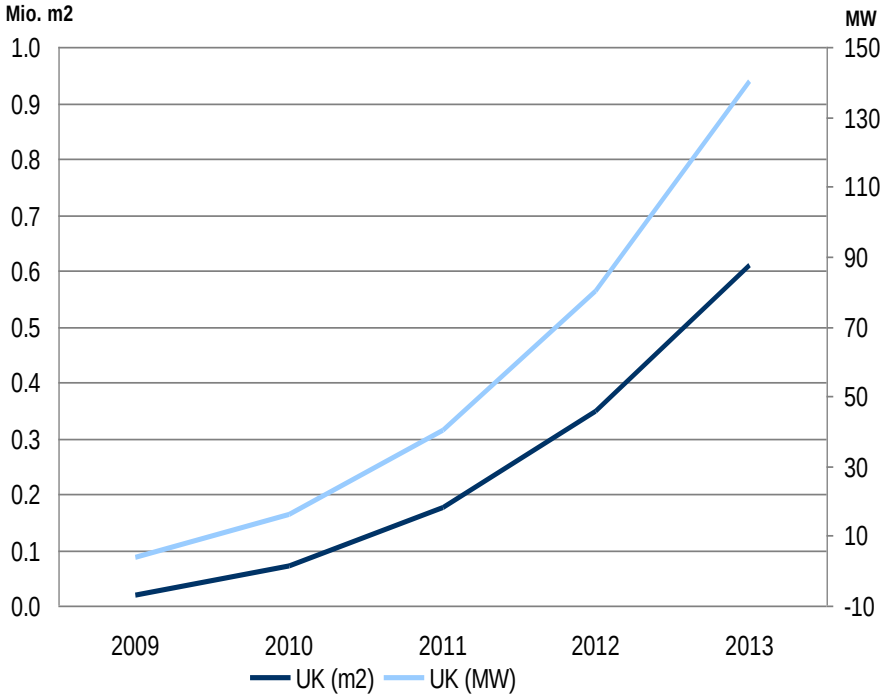
Weight: 3.5 – 4.0 kg/m2

UK Market Potential for Industrial Roofs

For bitumen, metal, membrane roofs

- Potential of ca. 400,000 m^2 2012
- Strong growth past 2013

Photovoltaic Market on Industrial Roofs
- UK -

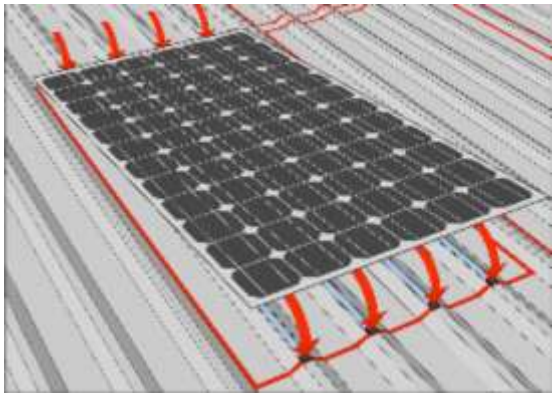


Source: EPIA August 2011

Crystalline panel with controlled direct adhesion

Controlled installation process

1



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2

4

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Further Development of Crystalline PV

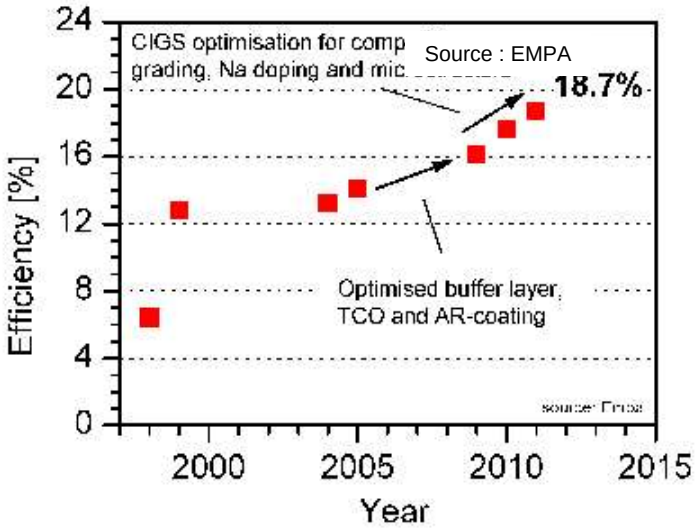
Correction of slope

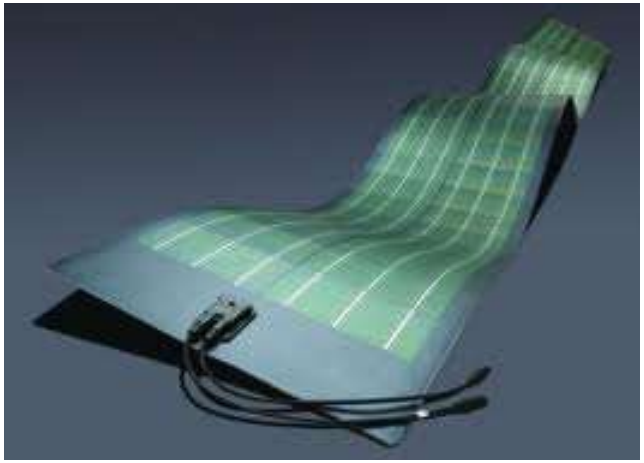
Lightweight directly bonded

Commercial / Industrial sector

- Cost reductions through plug and play technology
- Development of new photovoltaic technology
- Integrated solar systems
- Building envelope integrated solutions
- Sustainable Buildings

Emerging Technologies

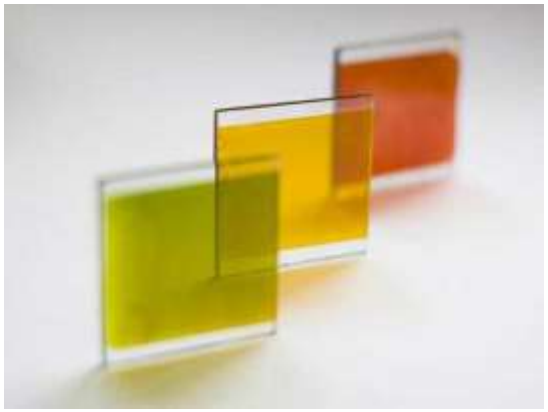


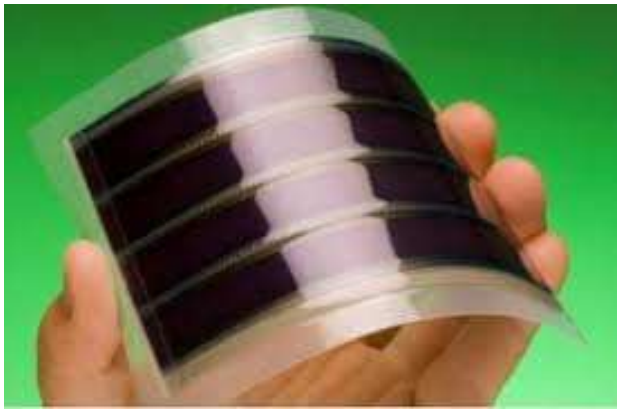


C.I.G.S.
(Copper, Indium, Gallium, Selenide)

Efficiency ~ 12% - 15%
Can perform in lower light levels

Developing New Technologies





Gallium Arsenide (GaAs)

Space grade
High efficiency
High cost

Tandem cells

Theoretical efficiency
>30%

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Building Integrated Solutions

Sustainable Building Envelope Centre

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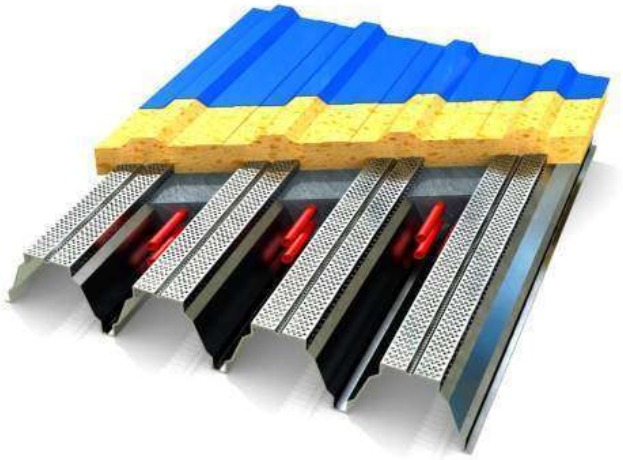
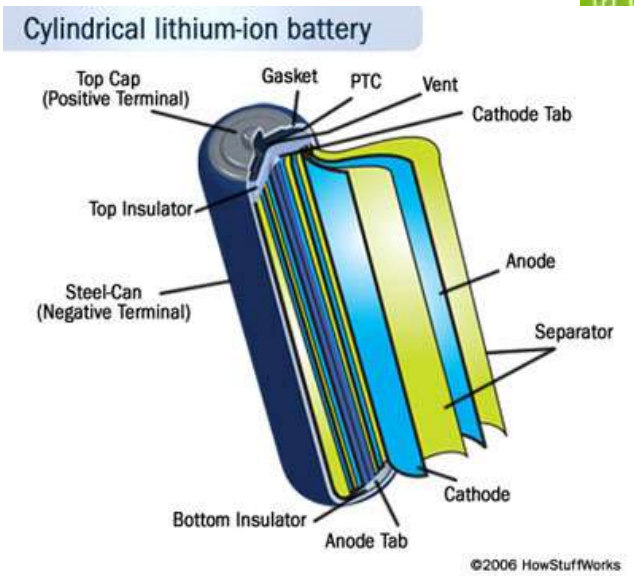
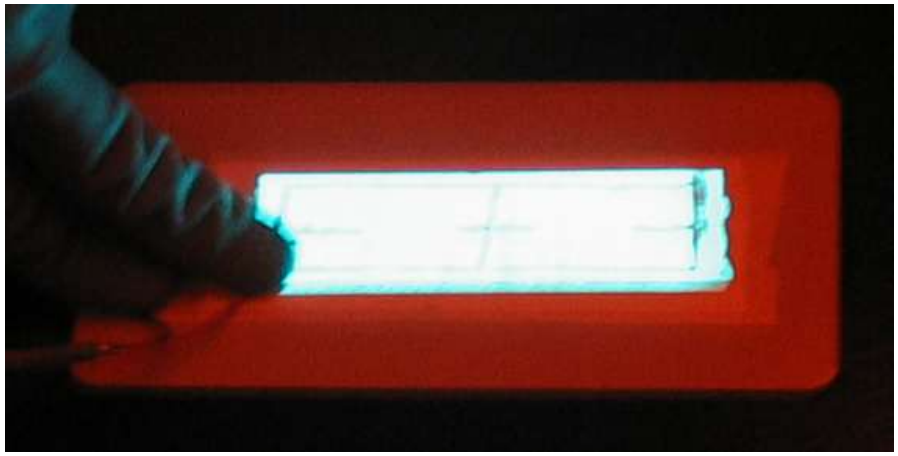
Sustainable Building Envelope Centre







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Under floor Heating
Space Heat Generation
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