



European Cooperation in the field of Scientific and Technical Research



**Building Integration of Solar Thermal Systems – TU1205 – BISTS**


# Building Integration of Solar Thermal Systems (BISTS): Case Study reviews

Dr Mervyn Smyth



COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract





European Cooperation in the field of Scientific and Technical Research



**Building Integration of Solar Thermal Systems – TU1205 – BISTS**

**A solar thermal system is considered to be building integrated, if for a building component this is a prerequisite for the integrity of the building's functionality.**








COST is supported by the EU RTD Framework Programme



ESF provides the COST Office through an EC contract

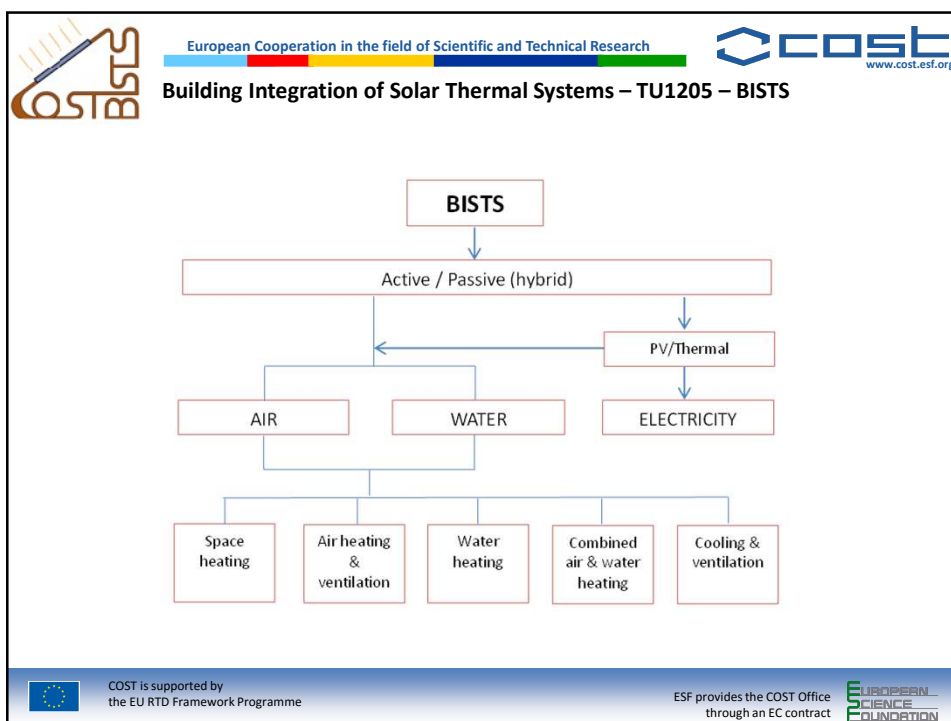


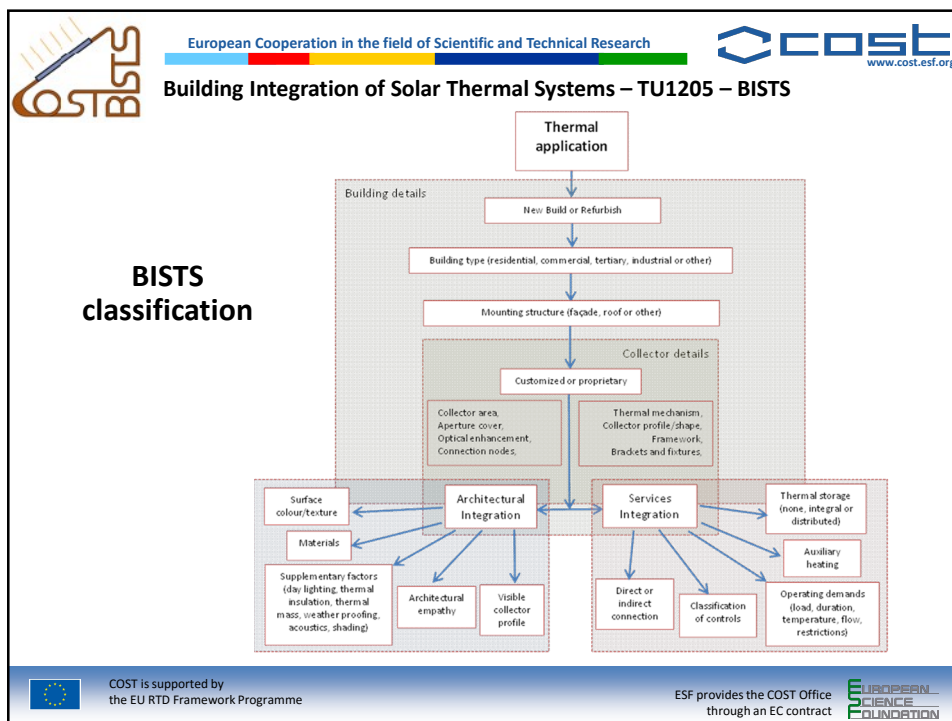

 European Cooperation in the field of Scientific and Technical Research  
**Building Integration of Solar Thermal Systems – TU1205 – BISTS**


**Over 94 case studies submitted to date**  
**86 have been allocated reference numbers and reviewed**  
**64 are of direct relevance**  
**The remainder are model or support material**

**Not a quantitative analysis .... but  
rather indicative**

 COST is supported by the EU RTD Framework Programme
 
 ESF provides the COST Office through an EC contract





**BISTS**

European Cooperation in the field of Scientific and Technical Research

**cost**  
www.cost.esf.org

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**


COST action TU1205  
Building Integrated Solar Thermal Systems

BIST ref number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
<b>BIST Description</b>																											
<b>Application</b>																											
air heating	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
water heating	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
comb-system	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
cooling/ventilation	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ventilation (mechanical, natural, hybrid)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ventilation mode (supply, exhaust, buffer)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
BIPV/T	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
linked (auxiliary system)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
<b>Type</b>																											
active	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
passive	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
hybrid	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
concentration	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
other	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
<b>Services Integration</b>																											
direct supply	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1


COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract

EUROPEAN SCIENCE FOUNDATION



European Cooperation in the field of Scientific and Technical Research


  
www.cost.esf.org

Building Integration of Solar Thermal Systems – TU1205 – BISTS

BISTS Combinations


				Installed on ...					
				Wall		Roof		Other	
				New	Refurbishment	New	Refurbishment	New	Refurbishment
Output	Air	Air heating	Active	5 off	3 off	5 off	4 off	2 off	2 off
			Passive	3 off	1 off	2 off	1 off		
		Combi systems	Active	1 off		6 off	2 off		
			Passive						
	Water	Water heating	Active	11 off	4 off	17 off	5 off	5 off	4 off
			Passive	1 off	1 off	2 off		2 off	1 off
		Cooling	Active	5 off	2 off	3 off	1 off		
			Passive	3 off	1 off	2 off	1 off	1 off	
	Electricity	PV/T	Active						
			Passive	2 off	1 off	1 off			


In addition, a further 15 systems have been described as being Hybrid in operation and 3 system utilised some form of solar concentration




COST is supported by  
the EU RTD Framework Programme

ESF provides the COST Office  
through an EC contract

































European Cooperation in the field of Scientific and Technical Research




## Building Integration of Solar Thermal Systems – TU1205 – BISTS


				Installed element					
				Façade		Roof		Other	
				New	Retrofit	New	Retrofit	New	Retrofit
OUTPUT	AIR	Air heating & ventilation	Active						
			Passive						
		Space heating	Active						
			Passive						
	WATER	Combined air and water heating	Active						
			Passive						
		Water heating	Active						
			Passive						
		Cooling & ventilation	Active						
			Passive						
	ELECTRICITY	PV/T	Active						
			Passive						



COST is supported by  
the EU RTD Framework Programme


ESF provides the COST Office  
through an EC contract






European Cooperation in the field of Scientific and Technical Research

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**




# BIST Description

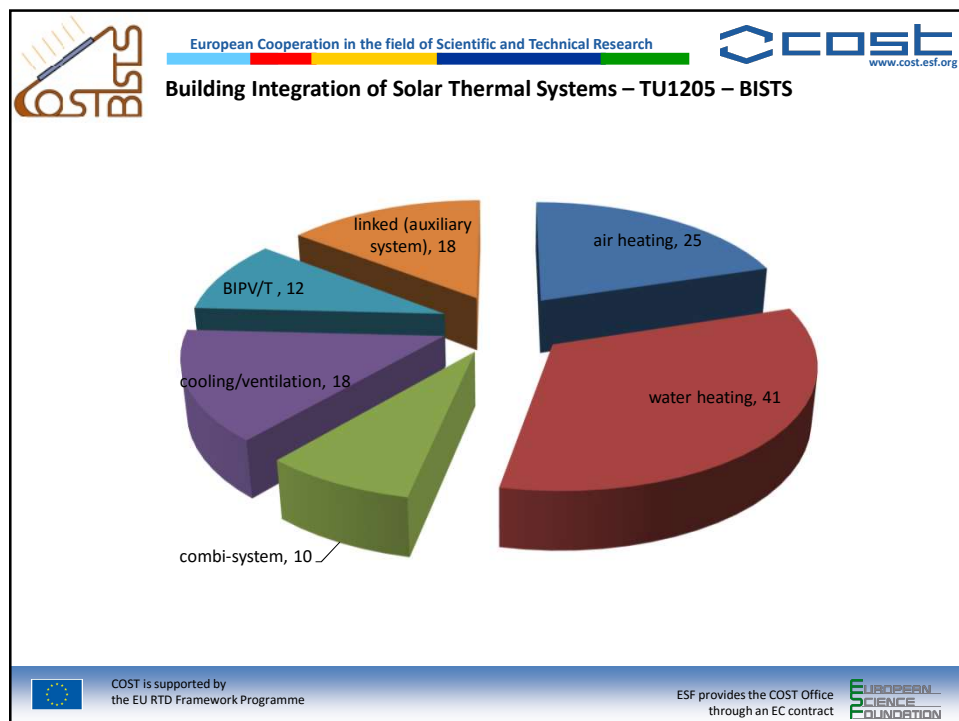
## Application



COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract






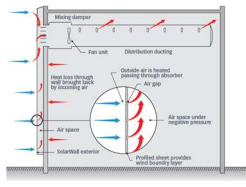
European Cooperation in the field of Scientific and Technical Research

**BIST** **COST** [www.cost.esf.org](http://www.cost.esf.org)

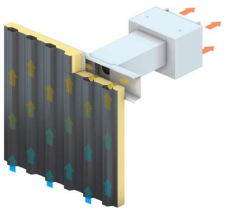

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**

**Air heating**


Transpired façade collector, Canada


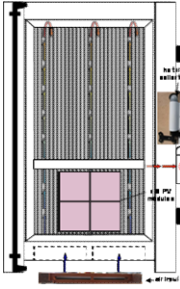
Façade crown collector, UK

PVT roof collector, Canada



Window shutter, France

COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract

EUROPEAN SCIENCE FOUNDATION

European Cooperation in the field of Scientific and Technical Research

**BIST** **COST** [www.cost.esf.org](http://www.cost.esf.org)

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**

**Water heating**

Shading device, France



Ridge tiles, Holland



Solar balustrade, USA



Integrated roof tiles, China



Unglazed façade collector, Switzerland




Flat plate collector, Ireland



COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract

EUROPEAN SCIENCE FOUNDATION



European Cooperation in the field of Scientific and Technical Research

**BISTS** **COST** [www.cost.esf.org](http://www.cost.esf.org)

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**

### Combi-system

hot water outlet

WAF solar facade

collecting pipe

insulation

masonry

cold water inlet

air

Roof combined air/water collector

Wall combined air/water collector

connection sheet

insulation

heat transfer pipe

collecting pipe

substructure

COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract

EUROPEAN SCIENCE FOUNDATION

European Cooperation in the field of Scientific and Technical Research

**BISTS** **COST** [www.cost.esf.org](http://www.cost.esf.org)

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**

### Cooling/ventilation/shading

Solar thermal glass, France

Solar awning, USA

Desiccant Ventilated Façade

Radiant cooling, Japan

Solar facade blinds, USA

COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract

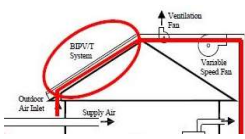
EUROPEAN SCIENCE FOUNDATION

European Cooperation in the field of Scientific and Technical Research


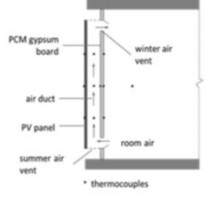
**BIST** **COST** [www.cost.esf.org](http://www.cost.esf.org)

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**


**Building Integrated PV/Thermal**



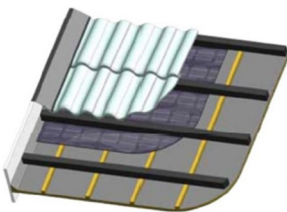
PV roof air heating, Canada

PV air heating, Portugal



PV water heating, Sweden



COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract


EUROPEAN SCIENCE FOUNDATION

European Cooperation in the field of Scientific and Technical Research

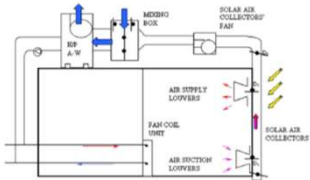
**BIST** **COST** [www.cost.esf.org](http://www.cost.esf.org)

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**

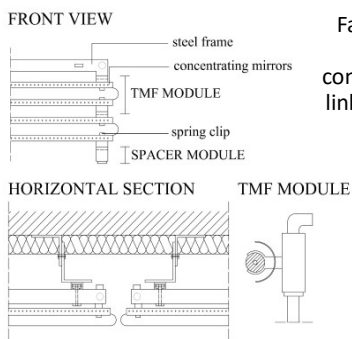
**Linked systems**



District heating, Sweden



Air heat pump on the roof, Greece

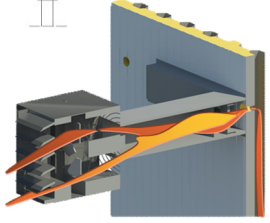


Front view

Horizontal section

TMF module

Façade integrated solar thermal concentrated system linked to absorption chiller, Italy



Kingspan facade linked to auxiliary air heater, UK

COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract

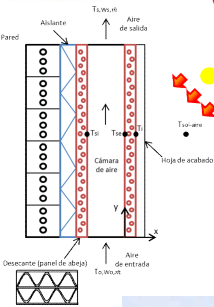
EUROPEAN SCIENCE FOUNDATION



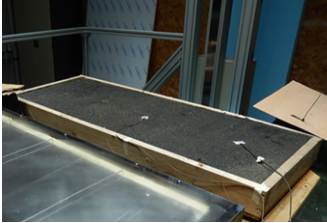
European Cooperation in the field of Scientific and Technical Research

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**


**Other**



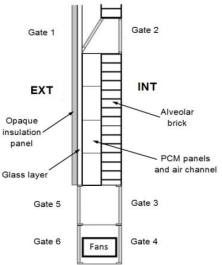
**Desiccant Ventilated Façade**



**NCT asphalt collector, UK**



**Integrated photo-bioreactor, Germany**



**PCM envelopes, Spain**

COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract

**EUROPEAN SCIENCE FOUNDATION**

European Cooperation in the field of Scientific and Technical Research

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**

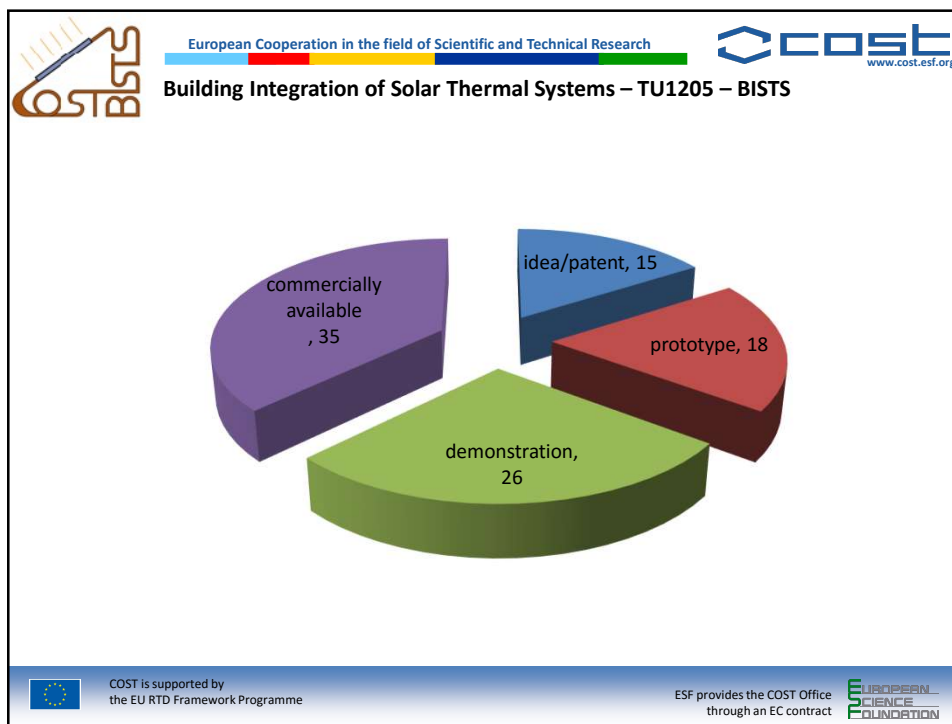
# BIST Description

## Stage of development

COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract

**EUROPEAN SCIENCE FOUNDATION**



European Cooperation in the field of Scientific and Technical Research

**BISTS** **cost**  
www.cost.esf.org

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**

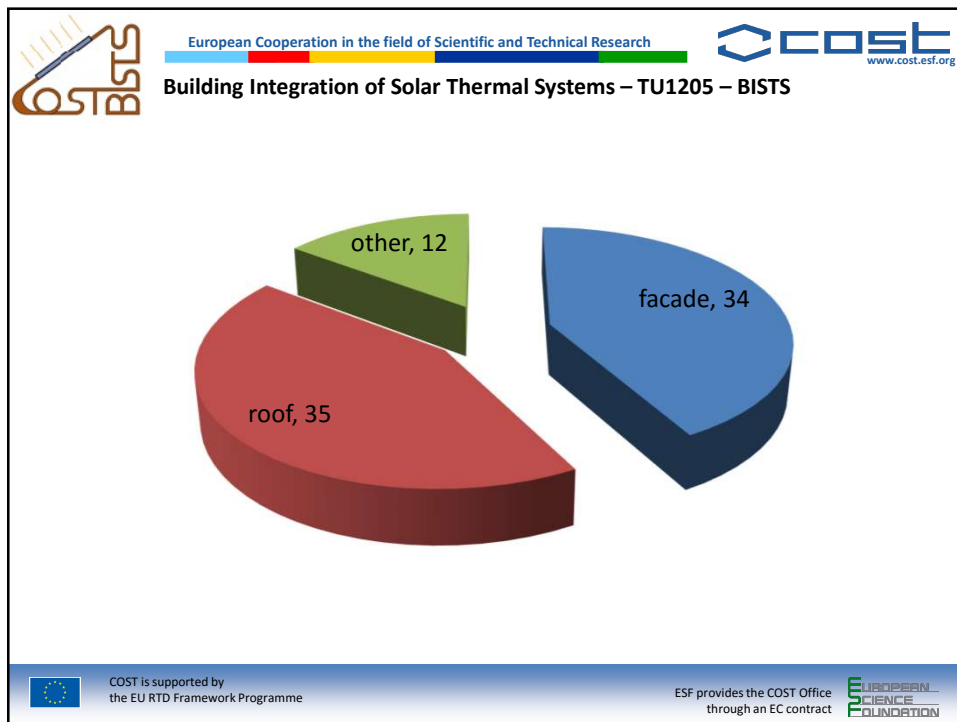
# BIST Description



## Collector building element

COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract

EUROPEAN SCIENCE FOUNDATION





 European Cooperation in the field of Scientific and Technical Research  [www.cost.esf.org](http://www.cost.esf.org)

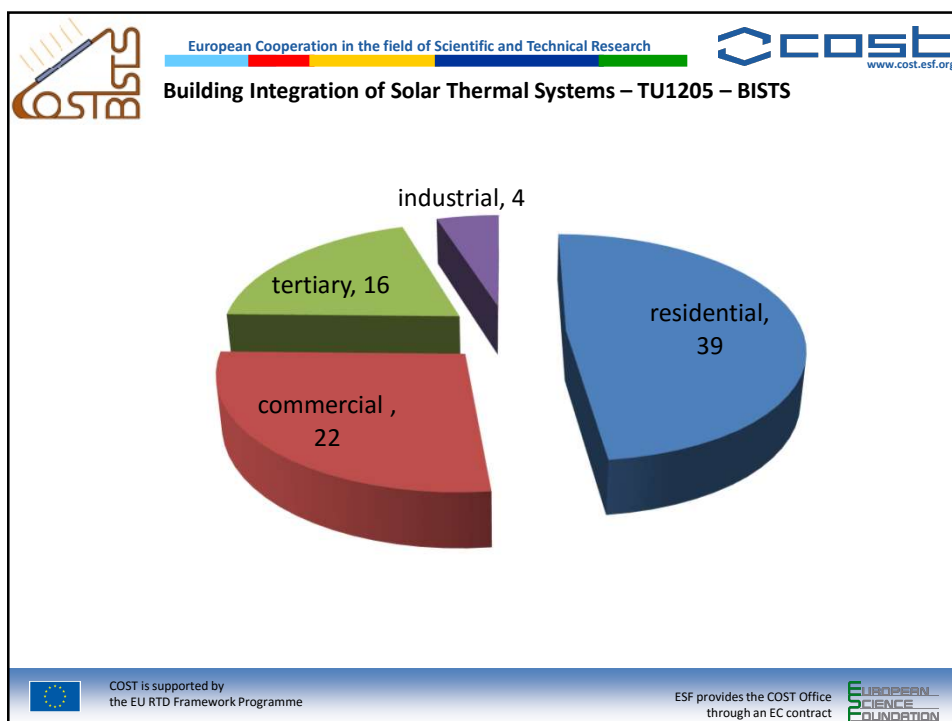
**Building Integration of Solar Thermal Systems – TU1205 – BISTS**


# Architectural integration

## Building type

 COST is supported by the EU RTD Framework Programme


ESF provides the COST Office through an EC contract 






European Cooperation in the field of Scientific and Technical Research

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**




# Architectural integration


## Building physics



COST is supported by the EU RTD Framework Programme


ESF provides the COST Office through an EC contract

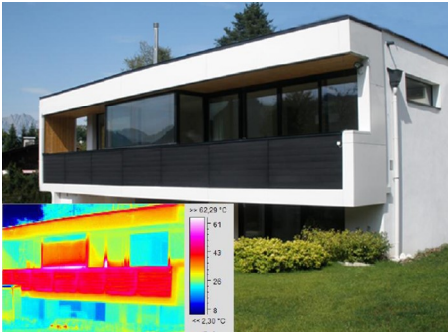




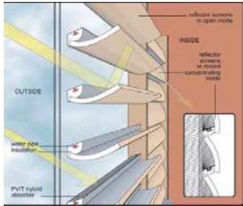
European Cooperation in the field of Scientific and Technical Research

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**

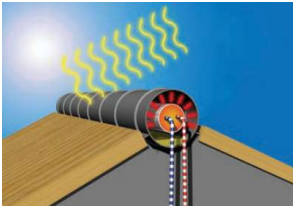





Structure: Combined air/water balcony



Shading: PVT window blinds, Sweden




Integral storage: ICS ridge collector, Holland



COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract



European Cooperation in the field of Scientific and Technical Research

**BIST** **COST** [www.cost.esf.org](http://www.cost.esf.org)

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**

**Insulation**

Significant back panel insulation, Portugal

PVT back panel insulation, Brazil

Transpired air collector with and without back insulation

Solar-comb insulation, Austria

© Conserv Engineering Inc. 2012

COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract

EUROPEAN SCIENCE FOUNDATION

European Cooperation in the field of Scientific and Technical Research

**BIST** **COST** [www.cost.esf.org](http://www.cost.esf.org)

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**

# Architectural integration

## Building Architectural Integration

COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract

EUROPEAN SCIENCE FOUNDATION




European Cooperation in the field of Scientific and Technical Research

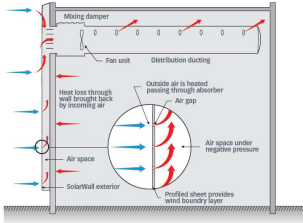
**BISTS** **cost**  
www.cost.esf.org

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**


**Architectural empathy?**




Obvious, but the north side is covered with the same stainless steel elements but not thermally active



Invisible transpired wall collector



Blended, mounted in the apex ridge of pitched roof



Out of sight

COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract

EUROPEAN SCIENCE FOUNDATION

European Cooperation in the field of Scientific and Technical Research

**BISTS** **cost**  
www.cost.esf.org

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**


# Locations

COST is supported by the EU RTD Framework Programme


ESF provides the COST Office through an EC contract

EUROPEAN SCIENCE FOUNDATION





European Cooperation in the field of Scientific and Technical Research





Building Integration of Solar Thermal Systems – TU1205 – BISTS


# Wider considerations

COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract

European Cooperation in the field of Scientific and Technical Research



Building Integration of Solar Thermal Systems – TU1205 – BISTS


## Areas of obvious technological development and deployment

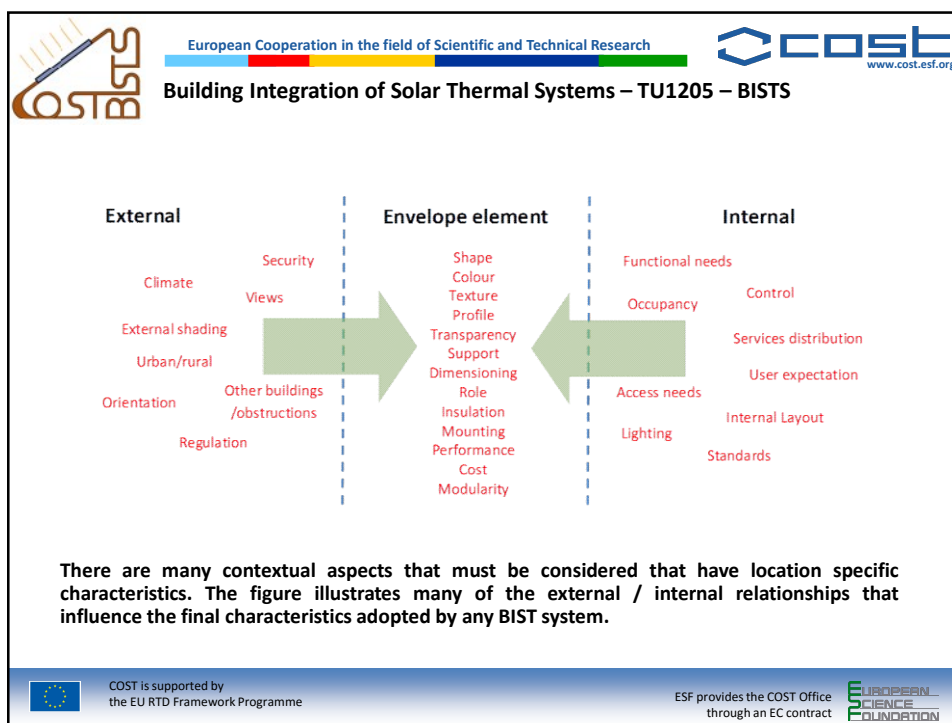
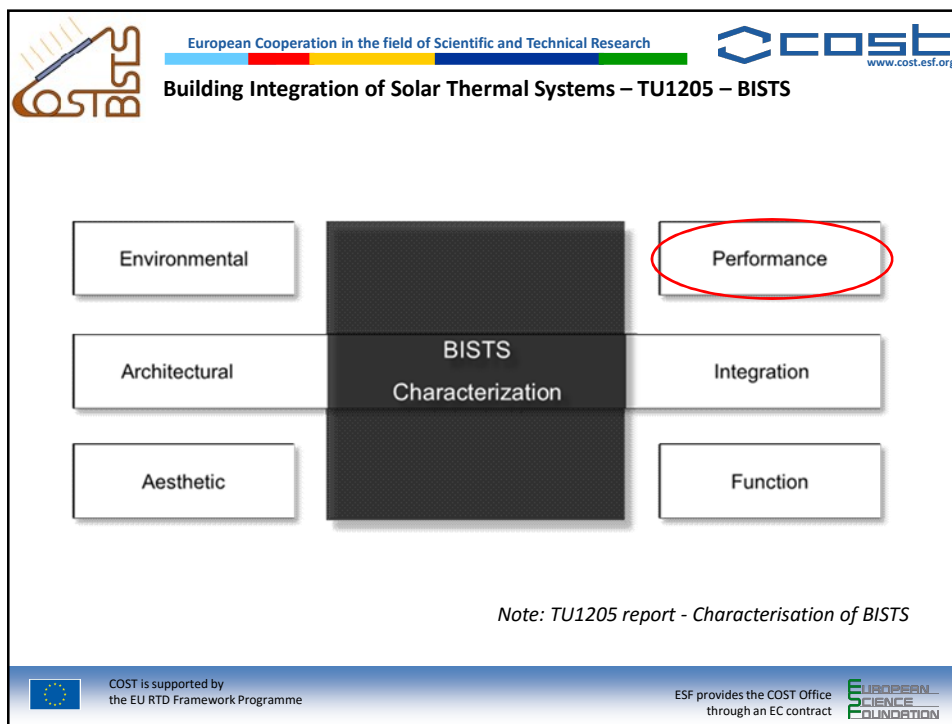
### Minimal work published in


- Economics.....some on capital costs and running costs, nothing on payback and maintenance
- Some on embodied energy, nothing on sustainable materials, environmental impact, fire safety
- Some on project motivation, nothing on social impact or legislation

COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract









European Cooperation in the field of Scientific and Technical Research

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**




www.cost.esf.org


# Performance



COST is supported by  
the EU RTD Framework Programme


ESF provides the COST Office  
through an EC contract





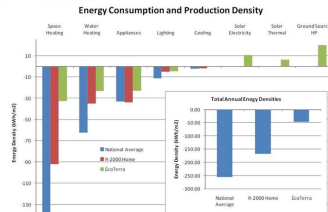
European Cooperation in the field of Scientific and Technical Research

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**

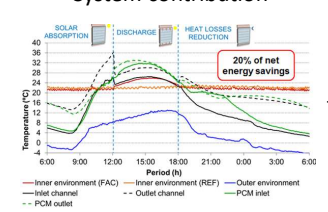


www.cost.esf.org

**Energy Consumption and Production Density**

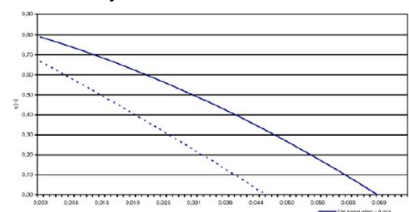


**System contribution**

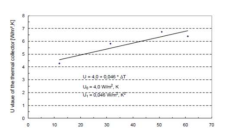


U <sub>en</sub>	0	10	20	30	40	50	60	70
K <sub>ib</sub> (t)=	1,00	1,03	1,11	1,18	1,25	1,28	1,26	0,19
K <sub>ib</sub> (s)=	1,00	1,00	1,00	0,99	0,98	0,95	0,89	0,76

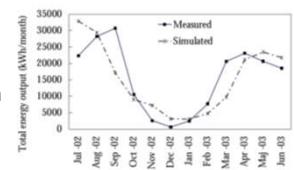
**Collector efficiency**



**Heat loss coefficient**




**Comparison**




**Temperature vs time**


**IAM**




COST is supported by  
the EU RTD Framework Programme

ESF provides the COST Office  
through an EC contract







European Cooperation in the field of Scientific and Technical Research



**Building Integration of Solar Thermal Systems – TU1205 – BISTS**





# Case Studies




COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract




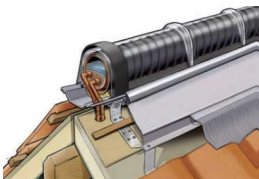


European Cooperation in the field of Scientific and Technical Research



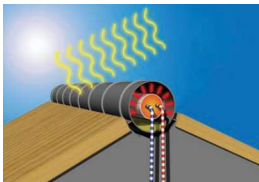
**Building Integration of Solar Thermal Systems – TU1205 – BISTS**






## The Eco-Nok

**Roof ridge ICS solar water heating module.**  
**Residential, new build and passive or active**  
**Each module is 1.5m long 270mm in diameter**  
**The effective collection area per module is 0.36 m<sup>2</sup>**  
**Annual energy collection (3 modules) in Holland is 2.1GJ**  
**Up to 50% annual savings on hot water energy consumption**  
**The unit cost is Euro 420 with a family sized system costing up to Euro 3000 fully installed**




## CASE STUDY 1



COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract



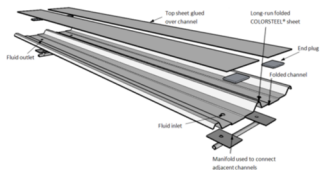


European Cooperation in the field of Scientific and Technical Research

**BIST** **COST** [www.cost.esf.org](http://www.cost.esf.org)

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**

### Building Integrated Solar Heating and Radiant Cooling Collector




Developed to be directly integrated into a troughed sheet metal roof

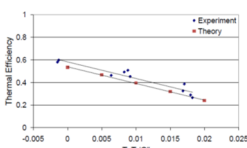
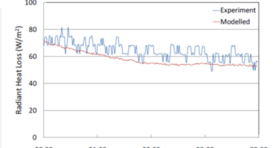
Unglazed solar water heater during the day

Unglazed radiant cooling panel at night

Separate heat and coolth storage



#### CASE STUDY 2a

COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract

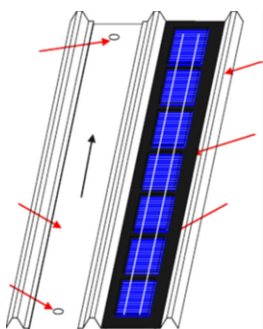
EUROPEAN SCIENCE FOUNDATION

European Cooperation in the field of Scientific and Technical Research

**BIST** **COST** [www.cost.esf.org](http://www.cost.esf.org)

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**

### The BIPVT roof collector



Simple fabrication process with holes drilled into the trough and connection nipples to connect to a manifold

Water or air heating

Laminated PV cells on top of the absorber sheet

Low-iron-glass aperture cover

#### CASE STUDY 2b

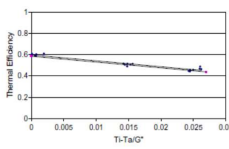


Fig. 5. Experimental and theoretical thermal efficiency of a glazed BIPVT collector.

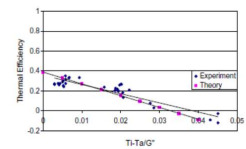


Fig. 6. Experimental and theoretical thermal efficiency of an unglazed BIPVT collector.

COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract

EUROPEAN SCIENCE FOUNDATION

European Cooperation in the field of Scientific and Technical Research

**COST** www.cost.esf.org

Building Integration of Solar Thermal Systems – TU1205 – BISTS

### The building integrated (solar thermal) cooling facade

Fan-assisted system that consists of two vertical plenums.

The first plenum was made of black aluminium (absorber) transpired plate and a sandtile wall (evaporative pad)

The second plenum is formed by the sandtile wall (with water-resistant layer) and the building wall

Energy consumption to generate 1 kW of cooling that cooled the air to 293K is only 52 W

### CASE STUDY 3

COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract

EUROPEAN SCIENCE FOUNDATION

European Cooperation in the field of Scientific and Technical Research

**COST** www.cost.esf.org

Building Integration of Solar Thermal Systems – TU1205 – BISTS

### The OM solar integrated dwelling

In heating mode, fresh outdoor air enters under the roof and flows upward in contact with the metal roof sheet, passing through an upper glazed section (to improve collection) whereupon the heated air enters roof ridge duct to the AHU


In cooling mode, outdoor air is drawn through the roof channels at night-time, sub-cooled using radiant cooling, and directed into the space to be cooled via the underfloor channels

### CASE STUDY 4

COST is supported by the EU RTD Framework Programme


ESF provides the COST Office through an EC contract

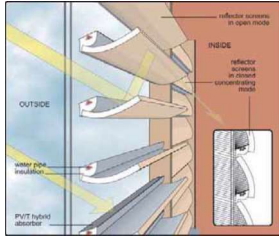

EUROPEAN SCIENCE FOUNDATION



European Cooperation in the field of Scientific and Technical Research

**Building Integration of Solar Thermal Systems – TU1205 – BISTS**



**CASE STUDY 5**

### The Solar Window


**PVT Solar Window with day lighting control and additional envelope insulation**

**The reflectors have an optical concentration factor of 2.45**

**U value can be reduced from 2.8 to 1.2 W/m<sup>2</sup>K with the reflectors closed**


**The annual transmittance through the window is estimated to 609 kWh/m<sup>2</sup>, of which 10% is PV delivery, 20% as active solar heat and 30% as net passive space heating**


**Production costs for the Solar Window excluding the glazing are estimated to approximately €250/m<sup>2</sup>**



COST is supported by the EU RTD Framework Programme


ESF provides the COST Office through an EC contract





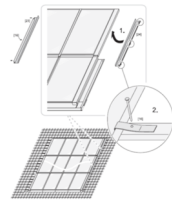
European Cooperation in the field of Scientific and Technical Research


**Building Integration of Solar Thermal Systems – TU1205 – BISTS**



## Case Studies – observations...so far


- Wide range of interesting concepts/systems** (although some repetition of the same system on different buildings)
- Limited information**
- BIST description** (generally good, less regarding the building detailing)
- Sizing procedure** (minimal)
- Building physics** (secondary consideration)
- Physical connection** (some detailing, but minimal)
- Costs - economic, environmental, social** (limited)
- Performance** (wide variation)
- Aesthetics** (missing)
- Distribution** (exclusively developed world)







COST is supported by the EU RTD Framework Programme

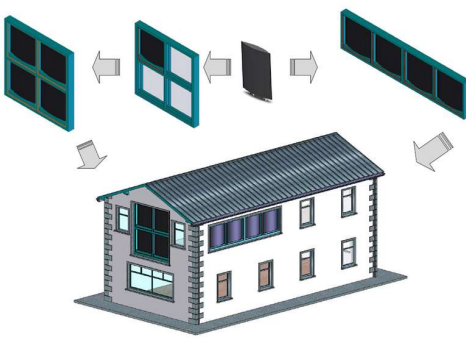
ESF provides the COST Office through an EC contract








 European Cooperation in the field of Scientific and Technical Research  
**Building Integration of Solar Thermal Systems – TU1205 – BISTS**


## COST TU1205 Working Case Studies....


- Project 1 - Solar Thermal Façade System
- Project 2 - Hybrid PV/T/solar Thermal façade module
- Project 3 - Solar Plenum
- Project 4 - Concentrating PV/T Glazing
- Project 5 - Evacuated Tube Collector integration




 COST is supported by the EU RTD Framework Programme
 
 ESF provides the COST Office through an EC contract
 


 European Cooperation in the field of Scientific and Technical Research  
**Building Integration of Solar Thermal Systems – TU1205 – BISTS**


# Thank you


 COST is supported by the EU RTD Framework Programme
 
 ESF provides the COST Office through an EC contract
 