Contents of the presentation

- Introduction (EPBD – NZEB)
- RES in buildings - Advantages / Disadvantages
- Building Integration of RES
- The example of PV systems
- Solar thermal systems integration
- COST Action TU1205
- Conclusions
European Union Directives

- Building energy consumption is **40%** of primary requirements in EU.
- Following the implementation of the Energy Performance of Buildings Directive (**EPBD**), developing effective energy alternatives for buildings is imperative.
- **EPBD** requires that RES are actively promoted in offsetting conventional fossil fuel use in buildings.
EPBD and NZEB

• Effectively, EPBD require that buildings should have an energy performance certificate (similar to domestic appliances) specifying:
  – the energy consumption of the building and
  – putting the building into a class

• Furthermore the recast of EPBD specifies that by the year 2020 the buildings in EU should be of nearly zero energy consumption.

• Meeting building electrical and thermal loads will be primarily achieved through an extensive use of renewables, following standard building energy saving measures.
The term Nearly Zero Energy Buildings (NZEB) is not firmly specified in the recast but it is generally expected to have an energy consumption of about 15 kWh/m²-a.

Countries outside EU, like Canada, move even further and speak of ZEB, i.e., this is a building that produces all the energy it spends or even Positive Energy Buildings (PEB), producing more energy than it requires in a year.

There are also other definitions like Net ZEB....
An ideal NZEB should have:

- Low building-related energy needs through the use of:
  - Natural lighting and ventilation,
  - Optimal passive heating and cooling through the use of thermal mass and insulation
- Efficient building energy systems including domestic appliances, heating and cooling systems.
- Adequately sized RES.
- The capability of RES to be connected to a flexible energy infrastructure, like electricity grid.
- Extensive use of RES in buildings has advantages and disadvantages ….
Advantages

- Offer local generation of heat and electricity so transmission losses are minimized.
- Renewable energy systems are friendly to the environment.
- The building owner can install a high-tech system by taking advantage of the various subsidies that exists or would exist.
- The energy consumption expenditure for the building is minimized or it is not existent (for 100% coverage).
- The overall value of a property increases tremendously.
- The building can be of a higher class concerning energy performance certificate.
- As the energy performance certificate and the class of the building are related to the amount of rent or price requested, a higher income can result for the owner.
- There may be substantial income to the building owner by selling the electricity produced (for grid connected systems).
Disadvantages

• The initial expenditure for the building is higher.
• The owner usually has to pay the expenditure for the RES and then apply to get the money back from subsidies.
• Problems with respect to the space availability to install the RES systems required – integration.
• There may be problems related to the installation of RES on the building structure – for integrated systems (fire and noise protection).
• Most RES system will require periodic maintenance, which creates extra worries and costs for the building owner.
  ➢ On existing buildings, there may be disruption of existing services.
  ➢ Building integration may require specialist training for the installers.
Renewable Energy Systems (RES)

- Among the renewable energy resources, solar energy is the most essential and prerequisite resource of sustainable energy because of its abundance and sustainability.
- The systems that are usually employed in buildings are photovoltaics and solar thermal collectors.
- Photovoltaic systems can supply the electricity required to the building or the generated electricity can be fed/sold to the grid (preferred).
- Solar thermal systems (STS) can supply thermal energy for space heating, cooling and the provision of hot water for the needs of a house/building.
Building Integration of RES

• The advantages of building integration of RES are:
  – More space is available on the building for the installation of the required area of the RES systems.
  – The traditional building component is replaced by the RES one, which increases the economic viability of the systems.
• Coupled with aesthetic and architectural challenges of building integration, many practical issues need to be resolved:
  – Rain-water sealing and
  – Protection from overheating (avoiding increased cooling loads during summer) - the extra thermal energy can also be used for the heating of the building in winter.
Building Integration of RES

• With respect to façade application, as RES are latitude dependant, due to solar incidence angle effects, these needs to be considered as countries closer to the equator have high incidence angles (the sun is higher on the sky) but more energy is available compared to higher latitude countries.

• The adoption of building integration of RES can fundamentally change the accepted solar installation methodologies that affect residential and commercial buildings throughout the world.

• The single most important benefit originating from this idea is the increased adoption of RES in buildings.
The example of photovoltaics

- The usual way to install a PV system on a building/house is to install it with brackets on a flat roof or on top of a sloping roof.

- The former is more pleasing aesthetically but the idea of building integration systems is to be able to replace a building element with the PV system and thus increase the prospect of the RES system.

- Originally, one of the best typical applications considered to integrate PV on buildings was as a shading device. → Photo
Shading

- PVs are installed over south facing windows of buildings, replacing the traditional overhangs and provide shade on the windows and electricity from the PVs which are located at the optimal direction and angle to provide the maximum shading but also the maximum radiation capture.
Building Integrated PV (BIPV)

- Integration improves the cost effectiveness by having the PV panels provide additional functions which involve active solar heating and day-lighting.
- Recognized methods are:
- Integrating the PV Panels into the Building Envelope (BIPV).
  - This strategy involves the replacement of roof shingles or wall cladding with PV panels.
  - It has significant advantages over the more usual “add-on” strategy - not only does it eliminate an extra component (e.g., shingles), it also eliminates penetrations of a pre-existing envelope that are required in order to attach the panel to the building.
Integrating Heat Collection Functions into the PV Panel (BIPV/T).

– PV panels typically convert from about 6 to 18 % of the incident solar energy to electrical energy, and the remaining (normally lost as heat to the environment) is available to be captured as useful heat.

– In this strategy, a coolant fluid, such as water or air, is circulated behind the panel, extracting useful heat.

– The coolant also serves to lower the temperature of the panel which is beneficial, because the panel efficiency decreases with higher panel temperature.

– Two applications fall into this category; one using the PV as a roof (PV roof) and one as a façade (PV façade) of the building.
BIPV/T

(a) PV roof

(b) PV façade
• **Integrating Light Transmission Functions into the PV Panel (BIPV/L).**
  
  – This strategy uses special PV panels (semitransparent PV windows) that transmit sunlight.
  
  – This strategy also draws on the fact that only a fraction of the incident solar energy goes into electricity, and the remainder can be used for other purposes - in this case for useful light, with consequent savings.
  
  – Thin-film PV cells that let some sunlight through are commercially available for this purpose.
  
  – A major challenge is limiting the temperature rise of the windows, and controlling the impact of the associated heat gains, during times when building cooling is required.
  
  – Compared to normal windows, these windows have a reduced light transmission and can therefore function as shading devices.
BIPV/L

(a) Day-lighting (b) Day-lighting and ventilation

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Solar Thermal Systems (STS)

• The solar collecting methodologies that can be applied in buildings are:
  – The simple thermosiphonic units,
  – Forced circulation systems employing flat plate collectors,
  – Integrated collector storage units,
  – Evacuated tube collector systems and
  – Various low concentration compound parabolic units.

• Cyprus is a world champion with respect to the extensive use of solar water heating systems, but no attempt of building integration is made.
Solar water heating in Cyprus

Coverage: 93% (domestic sector), 50% (hotel industry)
Solar water heaters-applications

Installed solar collector (m² per inhabitant)

- EU
- Greece
- Israel
- Cyprus

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Some attempts to improve aesthetics
Evacuated tube collectors—similar situation

(a) Flat roof
(b) Sloping roof
Building Integration of STS

- The benefits of solar water heating systems are well known but one area of concern has been their integration.
- Most solar collecting components are mounted on building roofs with no attempt to incorporate them into the building envelope, as shown in previous figures.
- In many instances these are actually seen as a foreign element on the building roof.
- Many architects, irrespective of the potential benefits, object to this use of renewable energy systems due to this fact alone.
- The problem will be even more serious, when solar space heating and cooling systems are used which required much more solar collectors.
Problems - considerations of STS integration

- Amount of thermal energy collected and at what temperature range.
- Resistance to wind-driven rain penetration.
- If the underlying base layer is transparent, calculation of light and solar energy characteristics.
- Calculation of thermal resistance and thermal transmittance characteristics of the construction (overall heat transfer coefficient).
- Fire protection classification and fire protection from hot components in contact with flammable materials.
- Noise attenuation.
Building Integration of STS

• It is therefore necessary to find ways to better integrate solar collectors within the building envelope and/or structures which should be done in a way that blends into the aesthetic appearance and form of the building architecture in the most cost effective way.

• Various solutions to integrate these collectors on the building structure are proposed but none of them is actually tried until today.

• Various such designs can be seen next….
Transpired air solar collector

- Transpired air solar collector diagram showing the flow of hot air, fan, plenum, ambient air, perforations, perforated absorber (metal plate), and building wall.
Wall integration of ETC
Solar Decathlon
Roof integration-Flat plate collector
New ideas
Combine for the need of extra insulation
A house in Switzerland
Another example
STS integration-new ideas

(a) Flat reflectors on sloping roofs
(b) CPC reflectors on roof of a building
CPC integration-new ideas

(c) CPC reflectors on building façade
(d) CPC reflectors under balconies
COST – Cooperation in Science and Technology

- COST mainly finances networking activities
- All research done by own funding

COST action TU1205 (April 2013-April 2017)

So far we have:

- 19 EU countries participating (COST-countries)
- 2 non-COST countries (USA and Canada)
- Action proposed and chaired by Cyprus
Objectives

- **Main objective:** The creation of a platform from which a working environment is developed that generates methods to study the integration of STS in buildings.
- Development of new novel STS solutions suitable for building integration across three generic European regions.
- Definition of a set of key parameters for the BISTS characterization, taking into consideration the thermal performance, building functionality and aesthetic aspects.
- Development of standardised range of methodologies for evaluating BISTS.
- Modelling and simulation of STS (optical and thermal) for different building integration scenarios and for the developed solutions.
- Application of developed STS solutions for building integration including fabrication, characterisation and demonstration of prototypes to the extent that own research funding allows.
- Dissemination of Action activities (symposium, conference, website and various publications).

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Motivation

- The collective concentration of resources and the targeted focusing of scientists who are involved in the design, development and evaluation of solar thermal systems.

- The Action will foster and accelerate long-term (technological) advancement in STS mainly through experimentation, simulation and demonstration of viable systems for full incorporation and integration into the traditional building envelope.

- Feasible solutions will also consider:
  - economic constraints, resulting in cost effective BISTS,
  - structural integrity, weather impact protection, fire and noise protection.

→ The most important benefit of this Action is the increased adoption of RES/STS in buildings.
Geographic coverage

- Three generic European regions are considered, to fully explore the Pan-European nature of STS integration:
  - Southern Mediterranean,
  - Central Continental and
  - Northern Maritime Europe.

- The Action consortium presents a critical mass of European knowledge, expertise, resources, skills and R&D in the area of STS, which will support the creation of innovative ideas and concepts.

- The Action is expected to attract interest from other Actions, like the PCM and material engineers (color absorbers).

These present distinct characteristics with respect to BISTS as all STS are sensitive to incidence angle effects which are strongly related to the latitude.
Scientific Program

- Three scientific areas:
  1. Development of new innovative methods for building integration of STS;
  2. Modelling and simulation of new BISTS and their behaviour as a renewable energy system (RES);
  3. Investigation of new applications for innovative integration of STS in various application areas like domestic, commercial and industrial buildings.

- Three Working Groups (WG) will be set up to coordinate research within each theme and a fourth one is dedicated to dissemination activities.

- More details: http://www.tu1205-bists.eu/
  www.cost.eu/domains_actions/tud/Actions/TU1205
Conclusions

• The EPBD requires that RES are actively promoted in offsetting conventional fossil fuel use in buildings.
• A better appreciation of RES integration will directly support this objective, leading to an increased uptake in the application of renewables in buildings.
• This uptake in RES in buildings is expected to rise dramatically in the next few years.
• This is further augmented by a recast of the Directive which specifies that the buildings in EU should be of nearly zero energy consumption.
Conclusions

➢ Meeting building thermal loads will be primarily achieved through an extensive use of renewables, following standard building energy saving measures.

➢ Both PV and STS are expected to take a leading role in providing the electrical and thermal energy needs.

➢ A number of ideas have been tried and others are at the concept stage - generally more R&D effort is needed.

➢ In the coming years more and more of these solutions/ideas will find their way in the market in view of the implementation of the EU directives.
Thank you for your attention.

• Any questions please…

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