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POLYSOL Report Summary

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Periodic Report Summary - POLYSOL (Development of a modular, all-POLYmer SOLar thermal collector for domestic hot water preparation and space heating)

Project context and objectives:

Solar thermal systems are increasingly common and are, to the general public, probably the most visible renewable energy system. Moreover, compared to biomass they have distinct user benefits when it comes to domestic heating or hot water provision as they do not need physical feedstock. The project focus is to develop a novel modular, all-polymer glazed solar thermal collector that can directly substitute a conventional metallic solar thermal collector for domestic heating and hot water applications. The following summarises the work carried out over the first nine month period.

In order to select the best materials to be tested, a literature review was carried out. The main objective of the preliminary trials was to evaluate the effects of the doping nanoreinforcements on the thermal conductivity values using melt blending due to its cost effectiveness, fast production and environmental benefits. Ten formulations were developed and thermal conductivity measurements were carried out on all the samples and a polymer, doping material and concentration identified.

To allow heat transfer to the absorber a five layer PVD selective coating was developed on three different types of substrates (glass microscope slides, aluminium sheets and doped polymer samples) and specular reflectance spectral measurements carried out. Work is continuing to optimise these on the doped polymer sample being used for the absorber.

Three different geometries of conceptual absorbers and heat transfer channels were modelled. Each had different volume flows of the heat transfer fluid and thermal conductivity of the absorber materials. All 3 designs fulfilled the requirements regarding pressure loss (dp < 70 mbar at 30 l/(h m?)) and performance (F' > 0.95) using a polymer with a thermal conductivity of 0.6 W/(m K).

Four solar thermal systems (two systems for domestic hot water and two systems for domestic hot water and space heating) have been implemented in TRNSYS. Simulations have been carried out for all four systems and for three locations (Athens, Stockholm and Wurzburg) for a wide variation of collector area and storage volume. The fractional energy savings were calculated for each system and will be used as a benchmark for further investigations

Five different polymers were selected and referenced against ABS to determine the most appropriate for the casing of the solar panel. A range of mechanical tests were carried out at ambient temperature. Aging trials were also carried out on the samples at a 85°C and 120°C for up to 500 hrs at relative humidity and UV light between 0 - 250hrs. The tests indicated that two of the polymers could be used as a potential alternative to ABS. Both polymers had superior mechanical properties and UV resistance compared to ABS. Creep tests were also carried out over 98 days under constant load and at ambient temperature an elevated temperature of 65°C to determine the creep. Based on the results, the same two polymers showed the best results in terms of elongation.

Two concept casing designs 'stepped' and 'E' shaped profiles were designed to provide speed and simplicity to the assembly and production of the all plastic solar panel casing. The 'atepped' shaped profile was chosen as the best concept.

A mechanical simulation of the preferred absorber geometry (tubes) was carried out and it identified that both the stresses and deformations were far below the critic admissible values.

A market analysis report was prepared that sought to sharpen understanding of the true opportunity for the POLYSOL technology in the European solar thermal market for households. It examines aspects of the industry and market which have an influence on the prospects for the innovation. Many of the conclusions can be applied to commercial as well as residential premises and 15 conclusions were made. A preliminary plan for the use of dissemination and exploitation has also been prepared.

Project results:

Overview of work package technical progress

The following summarises the work carried out over the first nine month period. The objectives of each work package are recalled followed by the activities carried out on each task, and any deviations and corrective actions.

Work package 1: Preparatory research, and experimental validation

Heat transfer rates through polymer absorber body as a function of polymer material have been conducted and the main conclusions from this work task are the following:

- Carbon based nanoreinforcements show better thermal conductivity enhancement than ceramic ones.
- The results show that using expanded graphite we can increase neat polymer thermal conductivity by three times.

A selective coating was developed on three different types of substrates: glass microscope slides, aluminium sheets and doped PET samples. Since the properties of the selective coatings depend on the tandem: substrate - coating, the above mentioned procedures will be repeated again on polycarbonate samples being developed in WP4.

Three different absorber geometries were modelled with different volume flows of the heat transfer fluid and thermal conductivity of the absorber materials. All 3 designs fulfil the requirements regarding pressure loss (dp < 70 mbar at 30 l/(h m?)) and performance (F' > 0.95) using a polymer with a thermal conductivity of 0.6 W/(m K).

Four solar thermal systems (two systems for domestic hot water and two systems for domestic hot water and space heating) have been implemented in TRNSYS. Simulations have been carried out for all four systems and for three locations (Athens, Stockholm and Wurzburg) for a wide variation of collector area and storage volume. The implemented solar thermal systems can be used as bench mark for the comparison with the upcoming all polymeric collector.

Choice of material for casing manufacture

Five different polymers were selected which included HDPE, Polystyrene, HIPS, ASA and PBT. ABS was used as a reference. Mechanical, creep and ageing testing was carried out on each. Crastin (PBT) and Kibilac (ASA) emerged as best alternatives compared to ABS as a reference, based on both the mechanical properties and also their UV stability. Creep test on all was conducted for the period of 98 days both at ambient temperature and at 65°C. ASA and PBT showed the best creep performance. However cost vs. performance / site decisions have to be made.

Two concept casing designs were designed to provide speed and simplicity to the assembly and production of the all plastic solar panel casing. It is designed without the need for any mechanical fixings and is intended that the casing will be bonded together using a UV resistant adhesive. The two concepts were:

a) 'stepped' shaped and
b) 'E' shaped profile design.

The 'stepped' shaped profile was the preferred option.

Work package 2: Develop selective coating for polymeric absorber profile

A problem was identified when using PET as a polymer for the absorber. After consultation, trials and FEA modelling it has been agreed that a doped polycarbonate will be used for the absorber. Plasma need to wait for the new samples of the doped PC based sample compositions proposed for the absorber in order to develop new selective functional coating(s).

Develop process for coating application: This task has been delayed due to the withdrawal of solar tubes - lead.

Work package 3: Design polymer absorber profile, collector casing and transparent cover

Mechanical simulation of the absorber has been carried out and a preferred configuration has been chosen subject to positive results from the final simulations.

Work package 4: Development of co-extrusion and doping process

Melt blending has been selected for the nanocomposites preparation method due to its cost effectiveness, fast production and environmental benefits, being a solvent-free process. Indeed, melt blending use high temperature and high shear forces to disperse nanoreinforcements in a thermoplastic polymer matrix, using conventional equipment for industrial polymer processing (twin extruder and injection machines).

The mechanical simulations carried out on the absorber design, showed that PET material could not fulfil for the requested specifications (120oC and 6 bar of pressure). New materials particularly polycarbonate are being investigated.

Work package 7: Innovation related activities

The market analysis and evaluation report seeks to sharpen understanding of the true opportunity for the POLYSOL technology in the European solar thermal market for households. It examines aspects of the industry and market which have an influence on the prospects for the innovation. Many of the conclusions and additional information can be applied to commercial as well as residential premises. Fifteen conclusions were drawn.

The interim deliverable 7.2 (Interim use, dissemination and exploitation plan for SAFERUBBER) has been written. To determine the exploitation expectations for each SME organization, a questionnaire was sent to each partner for completion and the results were compiled and included in D7.2. The deliverable document has been uploaded onto the website and has been completed with contributions from all partners. This is a 'living document' and will be updated every quarter.

Potential impact:

The projects overall aim is to develop an all-polymer solar thermal collector suitable for domestic hot water and/or heating contribution with the following end-user benefits:

i) user cost saving of at least 25 % compared to metallic collectors (on a per kWh thermal basis);
ii) weight saving of approximately 30 % compared to existing metallic collectors (also on a per kWh thermal basis);
iii) a footprint no more than 150 % compared to existing metallic collectors;
iv) modular design enabling improved integration within existing and new building designs.

POLYSOL will therefore result in benefits for the whole supply chain ranging from end-users (improved return on investment and reduced payback period); to installers (i.e. lower weight makes installation easier); architects (improved building integration); producers (improved economies of scale in polymer component production, reduced assembly cost, increased sales potential) and finally local, national and European governments (increased market penetration of RES in order to achieve EC targets of 20 % market penetration by 2020; reduced need for subsidies to attain desired RES market growth).

The EC and Member States have made a clear commitment to achieve RES market penetration targets by 2020. As heating accounts for close to 50 % of overall EU final energy demand, it seems obvious that it will be important to increase market penetration of RES that provide heat. Of these solar thermal is an important, but so far underutilised option (others are biomass and geothermal). This is especially true in a domestic setting where solar thermal is often the most practical option considering that biomass requires manual feedstock replenishment. A medium growth scenario is most likely considering the growth rates achieved over the past decade. Based on this scenario and an average price of EUR 750 per m2 (cost of installed component excluding auxiliary system), we therefore anticipate a market potential of 22 million m2 of new capacity in 2020 which will be worth EUR 16.5 billion in the same year. This would result in at least 250 000 solar thermal related jobs by that time in Europe alone.

Impact in theory

POLYSOL should be able to compete with any existing metallic collector and for any domestic heating and hot water application. However, in reality there will be specific market sectors that will suit POLYSOL and others that will not:

- POLYSOL will be most relevant to households with sufficient roof space to handle > 4 - 6 m2. as well as the associated thermal storage. Hence, for very small dwellings with significant space constraints, metallic collectors will be more effective.
- POLYSOL will be most suitable for households in Central or Southern European countries where solar energy is more abundant compared to Northern Europe where evacuated tubes or CPC collectors are probably a better solution.
- Due to the cost savings achieved POLYSOL will be well suited to solar combi-systems which require large surface areas of collector space. These are systems that provide a contribution to both space heating and hot water provision.

These assumptions may limit the overall market approximately 60 % of the total market potential for solar thermal systems. However, due to the significantly improved cost / benefit ratio of POLYSOL, it is anticipated that the project can increase the overall available potential market by 30 %, i.e. consumers who would previously be uninterested in solar thermal systems due to the high investment required.

Although it is predicted that POLYSOL will benefit the whole supply chain including other stakeholders such as local, national and European governments to date none of these benefits have been acheived. The predicted socio-economic impact and the wider societal implications of the project are as follows: First of all, making solar thermal systems more financially attractive will encourage market penetration which will help achieve ambitious RES targets. Not only will this reduce fossil fuel consumption and associated GHG emissions, it will also reduce the need for government subsidies to support market penetration. The project benefits are therefore not confined to the POLYSOL consortium but include significant wider economic and environmental benefits. Based on our expected market penetration of 289 600 collectors within the first decade of commercialisation we aim to achieve a financial return (profit) of close to EUR 80 million for the POLYSOL consortium and our licensees. The following is a summary of the benefits to Europe as a whole.

Environmental impact:

Overall household heating and hot water needs amount to approximately 30 % of total European energy consumption. CO2 emissions are a function of a wide range of factors which vary significantly. However, on average each kWh of combusted gas will result in approximately 0.2 kg of CO2 emissions whereas a kWh of generated electricity yields emissions of 0.43 kg of CO2 and heating oil in 0.24 kg of CO2. If we assume that 50 % of the POLYSOL systems displace gas; 30 % displace electric heating and the remaining 20 % heating oil then by 2022, we will be reducing annual CO2 emissions by 168 460 tonnes (per annum).

However, this is just the saving achieved due to increased market penetration of solar thermal systems and does not take into consideration the savings achieved by displacing carbon intensive aluminium. Every kilogram of aluminium results in 12 kg of CO2 compared to around 8 kg for an average polymer and just 2 kg for recycled polymer waste. If we assume that we can displace 5 kg of aluminium in each collector and replace it with a combination of virgin and waste polymer than we could basically halve the carbon footprint per collector (aluminium component only).

Employment:

According to ESTIF every 80 kW (thermal) of newly installed capacity. Based on our sales forecasts, POLYSOL could contribute to over 6500 new and retained EU-based jobs within manufacturing, assembly and installation over 10 years post project.

Exports:

POLYSOL will be an alternative to metallic solar thermal collectors that are produced in Europe as well as in the far East. We will maintain production within the EU, which means that we can displace imports of collectors from non-EU countries. Simultaneously, we aim to start exporting EU-made POLYSOL collectors to non-EU countries. In addition, we also aim to sell licenses to non -European manufacturer but will ensure that these products are not exported back to the EU.

Energy cost and security of supply:

It is evident that energy prices are likely to increase significantly over the next 10 - 20 years. Moreover, these increases are expected to be above average inflation which means that they will drive up the prices of a wide range of products and services. As a result, energy costs will increase as a proportion of average net income. This is clearly undesirable. POLYSOL will be a means of reducing fossil energy consumption thereby reducing the overall impact of increasing energy prices. Reducing fossil energy consumption also reduces Europe's excessive reliance on imported gas and oil.

Project website: http://www.fp7-polysol.eu

Related information

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