PROJECT FINAL REPORT

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4.1 Final publishable summary report

Executive summary

The SustainComp (Development of Sustainable Composite Materials) project was a large-scale collaborative project within the EU 7^{th} frame work programme. This four year project started on September 1, 2008, and had a total budget of 9.4 million Euro of which the funding from the European Commission was 6.5 million Euro. The overall aim of the project was to develop new types of sustainable composite materials for a wide range of applications. The target materials were:

- Nano-reinforced foams
- Nanostructured composites
- Nanostructured membranes and aerogels

The SustainComp has generated a lot of important results. Here follows a list of some of the success stories:

- SustainComp has demonstrated a continuous process for making a bio-composite material that can be used in several applications. In this project this was demonstrated by two applications – a bus seat and a violin finger board. For these demonstrators the sustainability is improved. A decision has been taken by one of the SustainComp partners to upscale this process in Sastamala in Finland.
- SustainComp has shown that fibres and plastics can successfully be mixed in sheet form (commingled) and then fed into a compounding extruder to get a homogenous material. This way of mixing fibres and polymers was quite easy to make in large scale on already existing machinery (with smaller adjustments).
- A demonstrated process for making microfibrillated cellulose (MFC) in pilot scale. Two pilot factories are now available.
- Demonstration that PLA based materials have the intrinsic properties to be foamed by different physical 'clean' and solvent-free processes, being batch foaming, continuous extrusion foaming or pre-expansion followed by block moulding. Furthermore, some obtained products were of lower density than a chemically foamed polymer which was a requirement for the envisaged packaging applications. A wide range of foam densities could be obtained for neat PLA and cellulose/PLA composite foams. During the project full scale trials have been carried out.
- Free-standing layer-by-layer (LbL) containing MFC-films have been prepared and characterized in terms of their structural and mechanical properties. This constitutes a huge step forward toward optically transparent, flexible paper-like materials whose properties can be further fine-tuned for different applications.
- Demonstrated lab-scale preparation of MFC-based aerogels with a dramatically increased specific surface area (from 70 m^2/g to 220 m^2/g and in one case to 480 m^2/g), using new procedures for drying.

Summary description of project context and objectives

The SustainComp (Development of Sustainable Composite Materials) project was a large-scale collaborative project within the EU 7th frame work programme. The overall aim of the project was to develop new types of sustainable composite materials for a wide range of applications, and it had the ambition to integrate today's large enterprises on the raw material and end-use sides (e.g. pulp mills and packaging manufacturers) and small and medium sized enterprises on the composite processing side (e.g. compounders and composite manufacturers). This four year project started on September 1, 2008, and had a total budget of 9.4 million Euro of which the funding from the European Commission was 6.5 million Euro.

This was the project logotype:

SustainComp

SustainComp objectives

The **first objective** for SustainComp was to combine ecodesign, innovative materials solutions and process developments to develop new advanced demonstrators of sustainable products within each of the following product families:

- Nano-reinforced foams – to replace styrofoams in the packaging and construction sector.
- Nanostructured composites – e.g. electrical and general household appliances, and fast rotating consumer goods.
- Moulded type of composites – to establish advanced cellulose reinforced biocomposites in e.g. the transportation (vehicles) and construction sectors.
- High throughput nanostructured membranes with designed selectivity – for small scale liquid applications in the medical field to large scale municipal applications.
- Stimuli-responsive aerogels – e.g. for noise/vibration dampening.

The project also addressed several generic problems in the sustainable composites sector. The **second objective** was to solve some of these generic problems in order to significantly widening the property space of sustainable biocomposites, resulting in larger potential markets for these materials.

The **third objective** was to:

- Minimize the environmental impact by the application of an ecodesign perspective for the conceived new products.
- Reach markets not directly targeted by the project, since it was expected that a successful, cost-effective manufacture of microfibrillated cellulose will be useful in other sectors such as the food sector (rheology modifiers) and the paper/board and coating sectors.

Description of the main S&T results/foregrounds

Project structure

The SustainComp project aimed at introducing new sustainable materials to replace existing fossil-based ones. In order to improve sustainability only bioplastics (polylactide; PLA, starch-based polyesters; Mater-Bi, etc.) has been worked with – both as neat polymer and reinforced with cellulose components. The cellulose components used have been either wood-based fibres or nanocellulosics (microfibrillated cellulose (MFC)). The reinforcement has been done in order to improve the mechanical properties and the thermal stability of the polymers.

Even though, material development has been dealt with, the emphasis has been on adaption and development of the processes. The processes studied have been foaming (continuous foaming, batch foaming, particle foaming), conventional plastic forming (extrusion, injection moulding and compression moulding), and forming of nanostructured films and aerogels. Also processing of tailored nanocellulosics and wood-fibres has been worked with.

The project has been executed in five interconnected work packages as illustrated in figure 1.

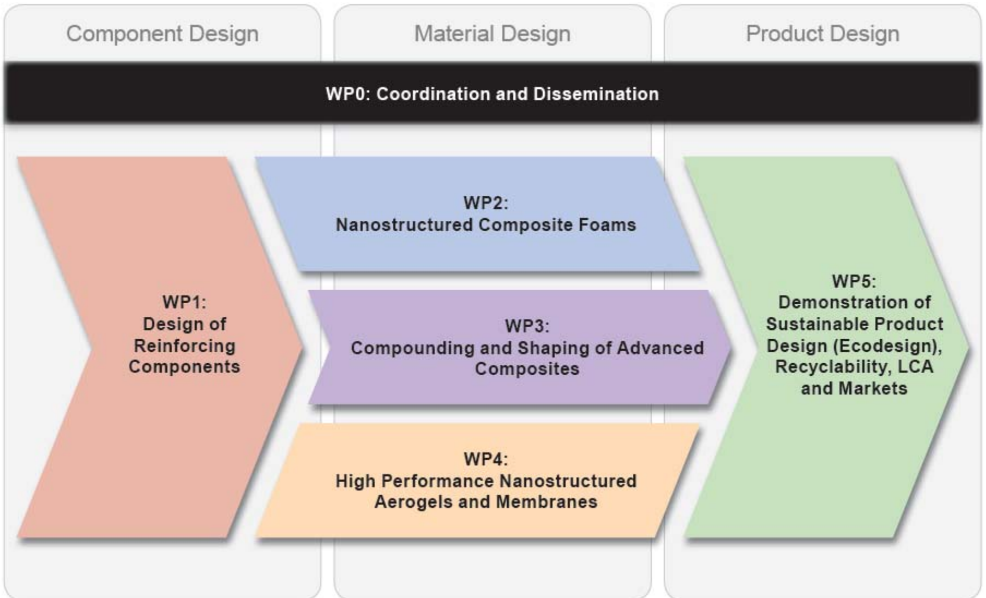

Figure 1: SustainComp project structure.

Design of reinforcing components (Work package 1)

Objective

The general objective of WP1 was to design the reinforcing elements of the composites. This included manufacture of different nanocellulosics and compatibilizing the microfibrillar cellulose (MFC) and wood-based fibres to the matrix material used in WP2 and WP3. WP1 acted as the supplier of material to the other WPs. The partners in WP1 were Borregaard, BASF, EMPA, Polykemi and Innventia (WP leader).

Nanocellulose development

One of the aims in WP1 was to produce MFC reinforcing elements and to modify the surface of these elements to suit compatibilization treatments or membrane/aerogel manufacture. Two partners (Borregaard and Innventia) have pilot capacities to produce MFC. Borregaard has been responsible for pilot-scale quantities and Innventia for specialised lab-quantities

Compatibilization/dispersion

Another aim for WP1 has been to do chemical/physical treatments of cellulosic fibres and MFC to make them suitable as reinforcing elements in bio-(nano) composites and their manufacturing. Focus has been to hinder cellulosic fibres to hornify ("re-crystallisation" of the fibrils) during isolation (removal of water) of the fibrils. When nanocellulose is dried the cooperative bonding between the crystallites prevents full dispersion of the nanofibrils in the matrix. Dispersion of MFC on the nanostructural level is necessary to produce a composite material which utilises the MFC materials full potential. The general approach has been to modify the MFC in order to block the hornification in order to get the desired dispersion into the matrix. Another approach has been wet-mixing of the MFC with the matrix material. Some promising systems were identified but still more work is needed to be able to utilize the full potential of the MFC in composites. The wood-fibres on the other hand do not have the same challenges and full-scale fluffing has been performed followed by pelletizing.

Nanostructured composite foams (Work package 2)

Objective

WP2 overall objective was to develop advanced cellular polymers and composite foams based on renewable resources, for application in the fields of packaging, insulation, displays and core materials. Materials formulation and compounds were developed for their potential of being processed into cellular structures. Fundamental foaming phenomena were studied for various materials (polyesters, composites with wood (WF) or microfibrillated cellulose MFC)) and different foaming processes. Scaling up to lab-scale processes and industrial lines was a driving objective of WP2. Demonstrators will validate the results. The partners in WP2 has been EPFL (WP-leader), 3A Composites, Innventia, SINTEF, Novamont, KTH, SCA, and Aalto University.

Compounding

Different compounding strategies for producing composites of PLA-wood-fibres/PLA-MFC have been investigated with the objective to obtain optimum preforms for the foaming processes. Wet-mixing both in lab and pilot scale has been an important approach to introduce wood-fibres and MFC to the matrix in the preparation of pre-forms.

Physical foaming

The main foaming strategy has been physical foaming using supercritical CO_2. Batch foaming on a specially developed autoclave allowed evaluation of the different preforms, to determine the processing windows of the different neat and compounded materials and to identify the key parameters controlling the foam formation and performance. During the project several different foaming processes have been addressed including continuous foaming in lab scale, full scale industrial co-extrusion foaming, lab and pilot scale production of particle foams using pre-expanded beads (see figure 2 and 3). Several interesting materials have been demonstrated, especially for neat polymers. The challenge has been to prevent degradation of the PLA-material during the processing. The fibres stabilise the foam morphology even though another challenge for the composites has been to enable foaming at low densities.

Figure 2: Expanded PLA/wood-fibre composite particle foams.

Figure 3: Full scale production of sustainable foam display panels.

Biodegradability

These activities have been focused on the definition and selection of the best test to verify the biodegrability of the materials developed in the project. The selected method simulates an intensive aerobic composting process. Pieces of a plastic sample have been composted with the synthetic waste (sawdust, rabbit food, starch, sugar, urea, oil). The weight loss of the material was considered as disintegrated material. Foamed samples were analysed according to the procedure and all the products passed the tests. After 90 days, the disintegration, after cleaning and drying, was measured to be larger than 90% as required by the standard EN 13432.

Compounding and shaping of advanced composites (Work package 3)

Objective

The overall objective for WP3 was to develop advanced light-weight, biocomposite-material-based demonstrators and technological solutions with industrially desired and controlled properties combined with ecodesign features. Such high performance concepts will open up for new advanced applications of wood-based fibre biocomposites in furniture, building, advanced packaging, safety and healthy and vehicle applications. New process concepts to improve compounding and subsequent processing of cellulosic fibres and thermoplastics have been developed. Of special interest are more energy efficient and property preserving operations in order to increase the overall competitiveness of biobased composite materials. The partners in WP3 have been Innventia, Elastopoli, EPFL, K-tron, Novamont, PFI, Polykemi, and SINTEF (WP-leader).

Materials formulations

In this part of the project different approaches to mix and add fibres and MFC to the polymer matrix in order to prepare compounds for extrusion and injection moulding have been studied. For wood-fibre-reinforced composites this has included full scale fluffing of fibres enabling the project to work with dried and separated fibres. The fluffed fibres, which are problematic to feed to extruders, have been pelletized to simplify feeding together with polymer pellets (see figure 4). Different approaches to reduce fibre degradation during the different processing steps have been studied.

Figure 4: Examples of compounds prepared in the SustainComp project.

Another approach has been wet-mixing of wood-fibres with PLA and then form sheets using a paper-making-like process. This approach has been very successful and several trials in pilot scale have been carried out (see figure 5) and upscaling of the process will be done after the project.

Figure 5: Rolls of wet-mixed wood-fibres and PLA. The sheet material was produced in pilot-scale on a paper machine.

Matrix material optimization

Even though, PLA has been the most important biopolymer in this project; other matrices have also been tried. For starch-based matrices (Mater-Bi) reinforced with wood fibres, the best polymer formulation and the process parameters for the composite production have been defined. Work to evaluate the mouldability of this new composite has been carried out as well. In particular, the pellets were first characterized in order to have all useful information for the injection moulding simulations.

Modelling

The purpose of this subtask was to investigate the connection between material morphology and composition on one hand and mechanical properties on the other. A set of experiments have been performed where MFC reinforced composites are studied using several imaging techniques, e.g. ESEM and X-ray 3D microtomography (μCT scanning), mechanical testing and DSC. The results have then been further used in the development of micromechanical models describing MFC containing composites.

High performance of nanostructured aerogels and membranes (Work package 4)

Objective

The main objective of WP4 was to develop high performance nanostructured layer-by-layer films, membranes and aerogels for wide range applications. WP4 performed activities for developing processes for high-tech applications such as design of high throughput structured nanocellulosic membranes with a controlled molecular selectivity, stimuli-responsive aerogels etc. Also, membranes with interactive properties were formed by combining nanocellulose with interactive nanoparticles/polymers. Finally, a scientific base/model describing the factors controlling the formation of these structures have been developed. Activities include design of aerogels with controlled structure, nanocellulose functionalization and layer-by layer (LbL) fabrication of nanostructured membranes. The partners in WP4 have been CNRS (WP-leader), KTH, and Aalto University.

Nanostructured thin films

One of the approaches has been to develop new types of nanostructured thin films (free-standing and on surfaces; see figure 6), either using a papermaking type of process or by utilising the layer-by-layer technique including both the positively and the negatively charged MFC-fibrils. In order to change the properties of the films different chemical modification of MFC was performed. Of the many modifications carried out during the project, the one leading to the preparation of bioinspired wet adhesion promoting MFCs was selected as the most promising for applications.

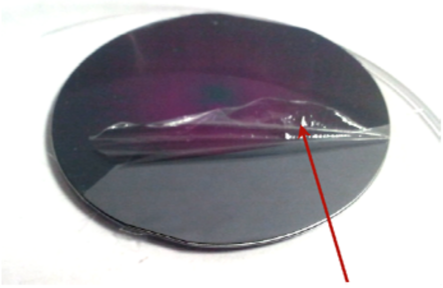

Figure 6: Example of free-standing thin film made using the layer-by-layer technique from MFC.

Nanostructured aerogels

MFC-based aerogels (see figure 7) with wet stability and controlled pore size interesting for membrane applications was one of the approaches studied. The challenge has been to be able to prepare aerogels with controlled structural properties (pore sizes, mechanical properties etc.) and to improve the wet-stability of the aerogels.

One of the most successful developments on aerogels was the preparation of aerogels of high surface area. The specific surface area has been increased dramatically, from 70 to 220 m^2/g and in one case to 480 m^2/g, using the new procedures for drying.

Another challenge in membrane science is to fabricate membranes with high throughput and high selectivity. This problem arises from the dilemma that efficient separation required very small pores which naturally restricts the flux through any good separation layer. This is because well performing separation layers must have a minimum thickness to maintain mechanical integrity, which forces to compromise between mechanical stability and flux. This challenge has been addressed by in controlled way combining the nanostructured aerogels with the thin films in combination with chemical modifications.

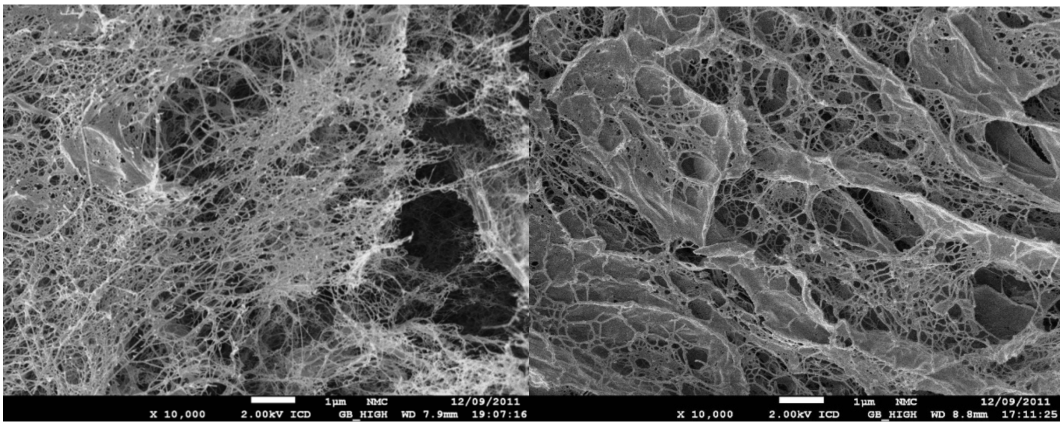

Figure 7: SEM images of MFC aerogel (2.3%), cross-section image.

Demonstration of sustainable product design (EcoDesign), recyclability, LCA, and markets (Work package 5)

Objective

The main objective of WP5 was the development of new products by taking sustainable criteria (economic, environmental and social aspects) into account. Eco-design methodology was the actual training force of this Work Package since it ensured that the advanced end-use products achieved showed the desirable properties concerning environmental, economic and social impacts optimised from its development/design step. The partners in WP5 was Novamont (WP-leader), ITENE, Innventia, SCA, 3A Composites, Elastopoli, Borregaard, SCA, Polykemi, and K-Tron.

EcoDesign and sustainability

EcoDesign was a key element of the entire SustainComp-project, becoming more and more important as the research and development of the new materials progressed towards the definition of the final demonstrators.

It is commonly recognized that an ecodesign approach is most efficient when applied in the early stages of the development of a material, a product or the definition of a service, as it helps combining the required technical properties taking into account environmental, economic and social aspects.

During the first two years of the project (2008-2010), the research WPs and the industrial partners performed the preliminary tests and gathered useful data, selecting a number of possible solutions and process lines to be followed in the next two years.

WP5 was in charge of developing and applying a methodology for this specific project and, in 2010, performed an initial sustainability assessment to identify the main aspects to be faced with ecodesign, in order to improve the overall sustainability of the SustainComp demonstrators and materials. The sustainability assessment was based on Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and Social Life Cycle Assessment (SLCA) for a proper assessment of the potential environmental, economic and social impacts, respectively. After this analysis the SustainComp ecodesign approach was developed and became an easy-to-use support for the industrial partners involved in the project.

The main areas where the ecodesign approach focused on were:

- Technical properties/performance of the materials for the selected applications
- Amount of raw materials used (percentage and total weight)
- Possibility to redirect the materials to composting chains
- Possible issues solved with the use of SustainComp materials
    - Littering
    - Suitability for transport and logistics of packaged products
    - Technical suitability for engineering applications
    - Food contamination of plastics in food packaging and catering applications
    - Other issues

The entire ecodesign approach was continuously refined and improved following the partners' needs and the materials development and has been the basis of several intermediate sustainability evaluations during 2010-2012.

The WP5 developed and provided the partners a so-called “ecodesign matrix”, a simple scheme that was aimed at keeping track of the main changes, goals and improvements in the development of the materials.

These documents, filled in by the partners, were also a valid basis for communication with the WP5, in order to prepare the intermediate evaluations to support the research and guide the partners toward improvements from the environmental, economic and social points of view.

Demonstrator work

With regard the demonstrator work, the tasks were started by looking at potential applications of the materials developed in the project. Additionally, all industrial partners involved in demonstrator work were informed about the ecodesign strategy to be implemented during the course of the project by specific ecodesign meetings. Main ecodesign steps and the data collection procedure for the demonstration work where presented in these meetings. As an outcome of these meetings several possible demonstrators were proposed. The continuous feedback of the industrial partners was used to update the sustainability assessment based on LCA, LCC, and SLCA accordingly to the advances in the new SustainComp materials as well as the manufacturing techniques (process lines). The above mentioned ecodesign strategy was used to identify those areas in which there was a room for improvement. As a result of the demonstrator work an estimation of the sustainability of the prototypes obtained compared to the current benchmark products was obtained. This was performed by a sustainability matrix that addressed the LCA, LCC and SLCA aspects which were classified in accordance to a coloured scale.

Even though the demonstrators developed in the project are just prototypes at lab scale with still a big room for improvement, it was clear that the new SustainComp materials offered a promising solution from a sustainability point of view. In fact, all the demonstrators have shown improvements in certain areas related to environmental impact (LCA), cost (LCC) and social assessment (SLCA). However is necessary to focus to the entire raw materials supply chain and not only on the manufacturing stage of the final product. This is mainly due to the fact that forestry/agriculture practices play an important role in the production of MFC and wood fibres as well as in the manufacturing on biopolymer matrix used (PLA and Mater-Bi). This fact confirmed the suitability of the life cycle approach selected in WP5. Other important outcome is that applications that can lead to controlled end-of-life (leading to material recovery by composting) shown better opportunities for the nano-biocomposite materials developed in SustainComp.

Demonstrators

In order to demonstrate the new materials and processes and to integrate the different efforts in the project seven demonstrators, physical objects, were developed. Five of them were ecodesigned and the sustainability evaluation was applied in accordance with the methodology suggested in WP5 based on a triple bottom approach: environmental impact (LCA), economic impact (LCC) and social impact (SLCA).

The final sustainability results were summarized using the above mentioned sustainability matrix combining LCA, LCC, and SLCA. For LCA and LCC, in case of an improvement, this is presented as “≤ bench” (=better than the benchmark). When the results of the new material are worse than the benchmark material these are presented in percent compared to the benchmark (0-25%, 25-50%, 50-100%, or >100%; percentage worse than the benchmark). For the SLCA, the difference have instead be presented by arrows (↑=better than the benchmark; ↓=worse than the benchmark; −=same as the benchmark). To illustrate the differences, the percentage values have also been accompnied with different colours. The table below describes how the sustainability results have been presented and the coloured scale used.

It should be noted that the sustainability results of the demonstrators are based on the prototypes obtained at laboratory scale. Therefore there is still a room for improvement for all of them. A detailed description of the sustainability assessments are found in the public Deliverable 5.9 (see SustainComp website).

LCA, LCC	≤ bench. >0 - 25% >25 - 50% >50 - 100% >100%			
SLCA	↑ Improvement	↑ Slight improvement	— No changes	↓ Deterioration

Demonstrator A – Foams for cushioning

Materials to replace expanded polystyrene (EPS) in packaging applications. Injection moulded foams were produced with starch and cellulose materials. In parallel cushioning inserts for packaging based on PLA and E-PLA/MFC has been manufactured with success via a novel expanded polylactide (E-PLA) process (see figure 8).

Figure 8: Cushioning demonstrator (Demonstrator A).

In terms of sustainability it was observed that the new bio-based foam compared to the EPS benchmark got a better results in most of the environmental impact categories (LCA) like Global Warming Potential (GWP), Photochemical Ozone Formation (POCP) and Abiotic Depletion Potential (ADP). There was also a sligt increase in terms of costs (LCC) due to the fact that for the time being PLA cost is higher than the EPS. Furthermore, more raw materials need to be handled for processing the demonstrator compared to the EPS benchmark. In case of social impact (SLCA) it is expected an improvement in all the categories selected including avoiding of unhealthy volatile compounds released from EPS manufacturing which means better working and living conditions.

There were also a couple new aspects to be considered as room for improvement of the current demonstrator:

- Manufacturing costs can be reduced to about the half with a more effective cooling system, since may reduce production cycle time.
- To be further analysed increased use of WF as reinforcing agent:
  - In order to reduce the weight of the foam required keeping the strength and shock absorbing properties,
  - Reducing the amount of PLA used which will result in a cost minimization due to the lower cost of raw materials used.

LCA		LCC		SLCA	
Acidification (AP)	>0 - 25%	Raw materials	>25 -50%	Working conditions and education	↑
Global Warming Potential (GWP 100)	≤ bench.	Manufacturing	>0 - 25%	Local community and living conditions at local community	↑
Eutrophication (EP)	>100%	Distribution and logistics	≤ bench.	Market satisfaction	↑
Photochemical Ozone Formation (POCP)	≤ bench.	End-of-life (Incineration)	>0 - 25%	Technology and supply chain development	↑
Stratospheric Ozone Depletion (ODP)	>100%	End-of-life (Composting)	≤ bench.	End-of-life responsibility	↑
Abiotic Depletion Potential (ADP)	≤ bench.	Total LCC (Incineration)	>0 - 25%		

Demonstrator B – Foam sheets

Improved Mater-Bi biopolymer products to replace conventional industrial protective packaging. Foam sheets of biodegradable and compostable polymers (Mater-Bi) and composites (Mater-Bi/Wood fibres) have been developed and characterised (see figure 9). Demonstrator production at industrial level was stopped since the required modifications of the continuous process line were beyond the scope of this project. Of this reason this demonstrator is a laboratory scale demonstrator and therefore no sustainability analysis was carried out.

Figure 9: Foam packaging demonstrator (Demonstrator B).

Demonstrator C – Foam display panel

Continuous processing of foam sheets and panels of Mater-Bi and PLA has been investigated. After process optimisation, PLA foams offered a compromise in terms of cell morphology, mechanical performance and surface finish, than the Mater-Bi composite materials. Full-scale trials were carried out during the project and the produced panels were printed on (see figure 10).

Figure 10: Printed foam display panel demonstrator (Demonstrator C).

Looking at the environmental performance the best results were observed in case of Abiotic Depletion Potential (ADP) impact category due to the fact that of the biogenic nature of the demonstrator which requires less amount of fossil resources. The performance in GWP and POCP was almost similar to the benchmark (i.e. PS display panel) although worse in the remaining impact categories. This is connected to the higher density that the new material has. Further devlopments are needed to reduce the density in order to improve the LCA profile. For the same reason the new material is worse in terms of costs (LCC). However, it is expected that the social impact (SLCA) is better, since it will promote the development of new technologies, new supply chains, marketing of renewable materials and new waste management routes.

Therefore the main rooms for improvement in this case, are directly connected to the further research for the reduction of the density. The cells structure and surface quality are also other aspects that need improvement even though in the case of surface quality the printability tests were successful.

LCA		LCC		SLCA	
Acidification (AP)	>50 – 100%	Raw materials	>100%	Working conditions and education	↑
Global Warming Potential (GWP 100)	>0 - 25%	Manufacturing	>0 - 25%	Local community and living conditions at local community	—
Eutrophication (EP)	>100%	Distribution and logistics	≤ bench.	Market satisfaction	↑
Photochemical Ozone Formation (POCP)	>0 - 25%	End-of-life (Incineration)	>25 - 50%	Technology and supply chain development	↑
Stratospheric Ozone Depletion (ODP)	>100%	End-of-life (Composting)	≤ bench.	End-of-life responsibility	↑
Abiotic Depletion Potential (ADP)	≤ bench.	Total LCC (Incineration)	>100%		

Demonstrator D – Lego building block

Pellets made from a PLA and wood fibre (70/30) compound. These pellets can be used further in injection moulding of plastic parts (e.g. for LEGO toy building blocks; see figure 11).

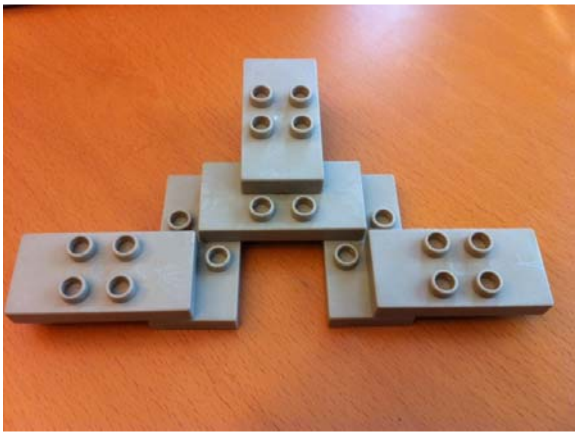

Figure 11: Lego building block demonstrator (Demonstrator D).

In terms of sustainability the new bio-based material compared to the bechmark (ABS LEGO building blocks) lower enviromental impact (LCA) is observed in GWP and ADP, mainly due to the fact of the biogenic nature of the raw materials used in the demonstrator. Better results were also observed in POCP impact categories but worse in the remaining impact categories. In terms of costs (LCC), the new demonstrator was slightly expensive than the benchmark (less than 25%) although it is expected that in an industrial production line the manufacturing costs of the demonstrator will be at the same level than the benchmark. In case of SLCA it is expected an improvement on new consumption patterns aimed at green products. It is also expected the creation of new supply chains between forest/agricultural sector and the industry, as well as the development of new technologies in the fibre area.

The main rooms for improvement for this demonstrator were related to:

- The development of optimized equipment for fibre compounding
- The use of surface modified fibres aimed at better dispersion
- The improvement on the production of commingled sheets

LCA		LCC		SLCA	
Acidification (AP)	>25 - 50%	Raw materials	>0 - 25%	Working conditions and education	—
Global Warming Potential (GWP 100)	≤ bench.	Manufacturing	≤ bench.	Local community and living conditions at local community	—
Eutrophication (EP)	>100%	Distribution and logistics	>0 - 25%	Market satisfaction	↑
Photochemical Ozone Formation (POCP)	≤ bench.	End-of-life (Incineration)	>50 - 100%	Technology and supply chain development	↑
Stratospheric Ozone Depletion (ODP)	>100%	Total LCC (incineration)	>0 - 25%	End-of-life responsibility	—
Abiotic Depletion Potential (ADP)	≤ bench.				

Demonstrator E - Bus seat

A sustainable compression moulded composite to be used as bus seat body work for Volvo Carrus city bus, with small modifications adjustable for other buses and trams (see figure 12). The new material developed for this seat enables 30% reduction in seat weight compared to existing parts with a competitive cost structure. The new material is PLA-MFC-cellulose sheets having excellent sustainability and being biodegradable.

Figure 12: Bus seat demonstrator (Demonstrator E).

In terms of sustainability it was observed an higher environmental, economic and social preferability of the new material compared to the benchmark (glass-fibre-reinforced resin city-bus seat profile) since the enviromental impact was lower for all enviromental catagories, as well as the costs along its life cycle. This is mainly due to the fact that the demonstrator does not use glass fibre renforced resin anymore, which is a expensive material with high energy and resource consumption requirements. It should be pointed out that manufacturing cost were significantly reduced since the number of processing steps and the amount of raw material for manufacturing is lower than in the benchmark. Furthermore it is also expected to reduce further manufacturing costs by the combination of Variotherm technology and the usage of multiple cavity moulds. This will reduce production cycle time and therefore the labour costs. Furthermore it is expected an improvement of social impact mainly due to the fact that the new demonstrator will avoid the hazardous chemicals required for the manufacturing of the benchmark, which will improve working and living conditions. This was an important result from SustainComp.

For this demonstrator the main rooms for improvement were related to the optimization of the manufacturing process itself when scale-up at industrial level.

LCA		LCC		SLCA	
Acidification (AP)	≤ bench.	Raw materials	≤ bench.	Working conditions and education	↑
Global Warming Potential (GWP 100)	≤ bench.	Manufacturing	≤ bench.	Local community and living conditions at local community	↑
Eutrophication (EP)	≤ bench.	Distribution and logistics	≤ bench.	Market satisfaction	↑
Photochemical Ozone Formation (POCP)	≤ bench.	End-of-life (Composting)	≤ bench.	Technology and supply chain development	↑
Stratospheric Ozone Depletion (ODP)	≤ bench.	Total LCC (composting)	≤ bench.	End-of-life responsibility	↑
Abiotic Depletion Potential (ADP)	≤ bench.				

Demonstrator F - Cutleries for catering applications

Injection moulded biodegradable and compostable starch based material (in pellet form) reinforced with wood fibres (see figure 13).

Figure 13: Cutlery demonstrator (Demonstrator F).

In terms of sustainability it was observed that the new bio-based composite material got a better results on GWP and ADP due to the bio-based nature of the raw materials used. Results were slightly worse (less than 25%) for AP and POCP. The remaining impact categories showed higher impacts. With regard LCC, a cost increase was observed due to the fact that the raw materials for the demonstrator have higher costs than the HIPS benchmark. Moreover, higher amounts of raw materials were required for processing of the demonstrator compared to the benchmark. On the contrary an improvement is expected in almost all social impact categories by run of learning/information programmes to employees and consumers.

However there is still a room for improvement. Main actions should be aimed at:

- Increase thermal resistance
- Reduce the thickness in order to minimize the raw materials use and consequently the costs.

LCA		LCC		SLCA	
Acidification (AP)	>0 - 25%	Raw materials	>50 - 100%	Working conditions and education	↑
Global Warming Potential (GWP 100)	≤ bench.	Manufacturing	>0 - 25%	Local community and living conditions at local community	↑
Eutrophication (EP)	>50 - 100%	Distribution and logistics	>0 - 25%	Market satisfaction	↑
Photochemical Ozone Formation (POCP)	>0 - 25%	End-of-life (Composting)	≤ bench.	Technology and supply chain development	↑
Stratospheric Ozone Depletion (ODP)	>100%	Total LCC (Composting)	>25 - 50%	End-of-life responsibility	—
Abiotic Depletion Potential (ADP)	≤ bench.				

Demonstrator G - Violin fingerboard

Rare ebony and rosewood is replaced in musical instrument components by PLA-MFC-cellulose granulates having excellent sustainability and competitive cost structure (see figure 14).

Figure 14: Finger board demonstrator (Demonstrator G).

No sustainability analysis was made for the violin fingerboard demonstrator since this application was identified in the end of the project. But it is clear that the costs will be reduced and since rare ebony and rosewood the long transportation distances is replaced by a composite material produced closer, the environmental impact is most likely reduced. Furthermore, this demonstrator is based on the same material as Demonstrator E and shares several of its processing steps. Thereby the sustainability is considered improved in a similar manner as Demonstrator E.

Success stories

The SustainComp has generated a lot of important results. Here follows a list of some of the success stories:

- SustainComp has demonstrated a continuous process for making a bio-composite material using a papermaking process that can be used in several applications. In this project, this was demonstrated by two applications – a bus seat and a violin finger board. For these demonstrators the sustainability is improved. A decision has been taken by one of the SustainComp partners to upscale this process in Sastamala in Finland.
- SustainComp has shown that fibres and plastics can successfully be mixed in sheet form (commingled) and then fed into a compounding extruder to get a homogenous material. This way of mixing fibres and polymers was quite easy to make in large scale on already existing machinery (with smaller adjustments).
- A demonstrated process for making microfibrillated cellulose (MFC) in pilot scale. Two pilot factories are now available.
- Demonstration that PLA based materials have the intrinsic properties to be foamed by different physical 'clean' and solvent-free processes, being batch foaming, continuous extrusion foaming or pre-expansion followed by block moulding. Furthermore, some obtained products were of lower density than a chemically foamed polymer which was a requirement for the envisaged packaging applications. A wide range of foam densities could be obtained for neat PLA and cellulose/PLA composite foams. During the project full scale trials have been carried out.
- Free-standing layer-by-layer (LbL) containing MFC-films have been prepared and characterized in terms of their structural and mechanical properties. This constitutes a huge step forward toward optically transparent, flexible paper-like materials whose properties can further be fine-tuned for different applications.
- Demonstrated lab-scale preparation of MFC-based aerogels with a dramatically increased specific surface area (from 70 m^2/g to 220 m^2/g and in one case to480 m^2/g), using new procedures for drying.

Important understandings gained

The SustainComp has also improved the general knowledge of the materials studied. Some of the most important understandings that are results from SustainComp are:

- Demonstration that MFC is compatible with PLA without chemical modifications.
- Understanding that spray-drying, with current technology, is most likely not a viable technical procedure due to capacity limitations. Due to viscosity issues, it is only possible to load MFC at a very low dry content.
- Identification that wet-mixing MFC and PLA is a viable way to prepare nanocomposites.
- The positive effect of the cellulose networks, of chain extenders and of adequate foaming parameters to somehow compensate the degradation of the polymers during wet compounding and processing was the result.
- The determined rheology of the different polymers and composites offered a tool not only to select the composition of foamable materials but to tune the foaming parameters like temperature or chain-extender content to be within the adequate foaming processing window.

- The influence of materials composition and conditioning, foaming temperature, CO_2 pressure and content, depressurization rates, cooling conditions etc. on final foam properties was deeply investigated for all the foaming processes. By this, nucleation, growth and stabilisation of foam cells could be better understood and controlled.
- The parameters for scaled-up processes like continuous foaming of sheets or two step expansion of block foams were also determined and their influence on final foam density and performance was studied in detail. For example, how to reduce the melting temperature to compensate for the plasticization of the PLA by the CO_2 or how the added fillers change the foam morphology were determined for the exploitation cases described below.
- Proper and stable feeding of various grades of wood fibre reinforced PLA material could be realized using a correct configuration of feeders. However, more emphasis needs to be made in the ability for extruder uptake.
- More realistic understanding of possibilities of MFC and realizing challenges related to re-dispersion of dried MFC in composite applications.
- Significant improvements in tensile properties of PLA possible with wood fibres.

Potential impact

General considerations

When considering the impact of the SustainComp project the developments must be placed in a larger context. When the SustainComp project was started, MFC was a laboratory scale product, PLA was a fairly new polymer for industrial use in extrusion and injection moulding, there were no exploited foaming qualities of PLA, and composite materials of PLA and MFC had not been studied.

In terms of MFC production, the processes have been upscaled during the course of the project and today several companies have erected pre-commercial/demonstration factories for its production. The use of MFC in composites was a conceived application. The SustainComp project has been part of this development. MFC as material is believed to have a large impact and be an important product in the future for the forest-based industry. Even though, all technical issues when it comes to composite manufacture have not been solved, the SustainComp project has increased the knowledge and serves as a platform for further developments. The fact that MFC-production now has been upscaled by several companies will result in that the price of the product will go down. This will enhance the likelihood for MFC to be used in composite applications once the technical issues have been solved is higher.

The fibre-reinforced composites offer a “faster” route, since there are here less challenges to overcome compared to nano-reinforced composites. It has also been shown that property-wise PLA/wood-fibre composites have properties in the property range of commercial non-biobased composites and plastics (see figure 15). Wet-mixing trials in SustainComp of wood fibres and PLA and then produce sheets on a paper-machine have shown to be an effective compounding route. One of the studied preforms has in parallel to SustainComp been upscaled and commercial qualities where wood-fibres and PLA-fibres are mixed are now available. This means that the processes developed in SustainComp to take this fibre-mixture and prepare composites is now closer to commercialisation.

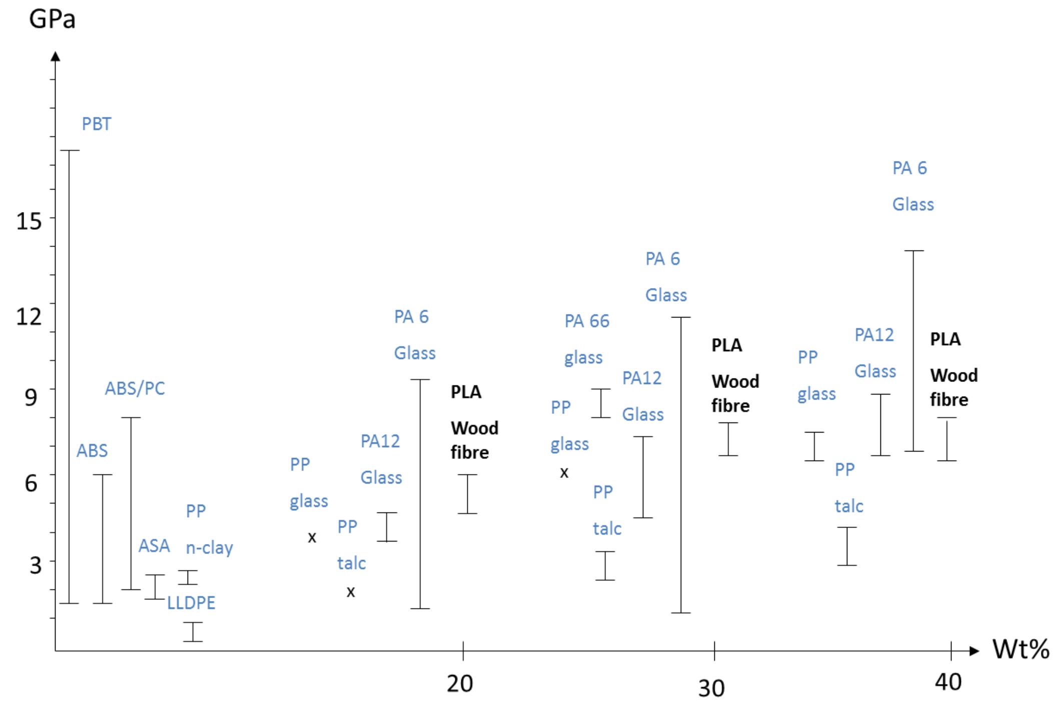

Figure 15: Flexural modulus for PLA/wood fibre composite compared to differend neat fossil-based plastics and glass fibre reinforced composites. The x-axis represents the added amount of wood fibre or glass fibre.

Specific impacts

Redispersible dry MFC

As described above there is a large potential for MFC in general. At this point in time, the primary bulk application of MFC is for paper applications where a typical installation for a paper mill could be in the size order of 5000 tonnes/year. However, this is for never-dried MFC. For composite applications a dried and redispersible MFC is desired (if not wet-mixing is utilized). It is believed that at this point in time, the initial production volume for dried and redispersible MFC is in the order of 2000-6000 tonnes/year.

Debonder for MFC

In order to enable redispersion of MFC a debonder is needed. The debonder can be produced in tonnes scale.

PLA foams for replacement of EPS

The total production of expanded polystyrene (EPS) in Europe is 1,600,000 tonnes/year (Eumeps 2008). Of this, about 400,000 tonnes is used for packaging, which is the second largest application for EPS after construction materials. The production volume of EPS has been stable over the last years. While volumes of traditional packaging has decreased in Western Europe, there is a growing demand for shape-moulded construction details of EPS that combine excellent insulation and good mechanical properties at a low density.

Expanded PLA (E-PLA) is a good substitute for EPS with respect to shock protection and insulation. E-PLA has great potential to take a substantial share of the European EPS market. Property wise it will be possible to substitute at least 25% of EPS packaging and 10% of the EPS construction materials, corresponding to about 250,000 tonnes/year of EPS. The availability and price of PLA resins need, however, to be improved in order to reach these levels. The total world production of PLA is today around 300,000 tonnes and the polymer price starts at about 1900 EUR/tonne, i.e. around 20% more expensive than conventional polystyrene. This means that high volume cost driven applications are less suited initially. Instead E-PLA foams will enter the market as a niche product in volumes up to 10,000 tonnes/year.

Display panel

Today, the SMART-X® (3A Composites) product represents a significant market for the display application, with a volume of more than 400,000 m^2 a year, with an average of 600 tonnes of material used. As an estimated potential market, a 10% market share could be substituted by the green display panel, which would represent a production volume of 60 tonnes/year of PLA.

Bus seat

In a normal year in Europe around 15,000 busses and trams are built (globally nearly 100,000 busses/year). In the average, there are in one bus or tram 40 seats (globally around 4 million seats/year). Bus seat bodywork weights about 400 g, so the total potential material use would be 1600 tonnes/year giving. Based on the potential market price the turnover could be around 20 MEUR/year in seat bodywork sales.

If we take into account the other seat components suitable for the material produced in SustainComp, backs and cockpits, we have a sales potential for the material of 4000 tonnes/year and the turnover potential for the components of 65 MEUR/year. The favourable weight/strength ratio gives the end product the same mechanical properties with ~30% weight. This is especially important for automotive applications where weight is one of the most important factors in fuel consumption

Wider application areas include other vehicle components, like door panels, dash board parts, inner linings, where weight and structural performance are important. Today, cars typically have 50 kg polymer composites per car, which means a potential of 3,000,000 tonnes/year. With our set and repeatable mechanical values that technical designers can use in their calculations open new application areas in light weight structural components. Already 10 % of the potential markets make 300,000 tonnes/year (about 600 MEUR/year material sales and 3000 MEUR/year component sales).

Cutleries for catering applications

In Italy the consumption of disposable tableware was approximately 25 billion items/year (AIPPM, 2006), that means 30,000-35,000 tonnes/year of polystyrene (80 %) and polypropylene (5 %). The market distribution in Europe is: Italy: 20 %, Germany: 15 %, France: 15 %, Spain: 10 %, United Kingdom: 10 %. The potential market for this new product is, considering the difference in weight, about 40,000 tonnes/year only in Italy.

Violin fingerboard

The global production of violins is several millions of instruments annually, but our target group will be in the beginning of the middle and high class violins, presenting some hundreds of thousands of fingerboards yearly. The weight of a typical violin fingerboard is 200 g, which means a potential material use of 50 tonne of granulate/year, presenting a market value of 300,000 EUR/year for the material and 1,500,000 EUR/year for the fingerboards

The potential in other components is huge, and the quality of the material has been tested already as well in several other components, like:

- fingerboards for guitars, violas
- necks for guitars
- keys for marimba
- pegs, chinrests, tailpieces for violin
- bridges for violin and guitars
- shells and hoops for drums

Common for all these applications is the replacement of rare wood like ebony, blackwood and rosewood. The use of these rare trees will with time be more expensive and difficult because of the strict certification needed for the instrument wood. The average price increase in these rare wood types has lately been 30–50 % annually. Good quality wood is disappearing and although the plantation of these trees has been started, these rare trees need 200–300 years, before they can be harvested for instrument use. Furthermore, the waste in rare wood is about 70–80%, because only a small share of the wood has the needed quality.

The replacement of rare wood will also grow faster because of the new legal limitations, based on the fact that only in USA, the criminals are trading yearly 10–15 billion USD with rare wood.

Lego toy building block

The market for this kind of pellet product can be substantial and the different number of end applications is difficult to estimate. Other possible fields for this material can be any case where the material's stiffness is of highest priority, e.g. carrier modules in an automobile door panel. The limitation is when the part is subjected to higher temperatures or needs to have good impact strength. Another possible market could be applications where there is a risk for the product to end up in the environment due to how it is used, e.g. golf pegs.

A normal route for implementing a new material in an existing product will be to mould a short series of products. If the material can be processed on existing equipment and the part properties fit the original (size, mechanically, chemical resistance, visually), a larger material batch will be produced and put on the market for a full trial throughout the value chain. For markets such as the automotive and medical the route is longer. Almost always, there is a standard that applies, which includes a lot of tests that are time and cost consuming.

Biodegradable MFC-aerogels with high surface area

The specific surface area of MFC aerogels has been dramatically increased within SustainComp, from 70 m^2/g to 220 m^2/g and in one case 480 m^2/g, using new procedures for drying.

For commercial exploitation, the following technical developments are required in order have stable membranes of commercial potential. A) Chemical modification of the MFC surface in order to avoid collapse during variations in humidity conditions or drying of the membranes. B) Chemical stabilization of membranes in order to maintain mechanical stability in liquid environment.

Due to their high porosity, aerogels generally have exceptional physical properties such as low thermal conductivity and low dielectric permittivity. They are used in a wide range of applications such as in electronic devices, for catalysis, and in acoustic, thermal, and optical applications. Besides the general applications of aerogels, MFC-based aerogels could be used in medical, cosmetic, pharmaceuticals and other applications where biodegradable and biocompatible materials are important.

Project public website and contact details

The SustainComp project has an open website available on www.sustaincomp.eu and www.sustaincomp.com. On the website, information about the project vision, goals, consortium and events are published. Also, open results are available for download. The coordinating organisation was Innventia, and the coordinator was Mikael Ankerfors (mikael.ankerfors@innventia.com, Tel: +46 8 676 72 61).

This was the project logotype:

SustainComp consortium

The SustainComp project was executed by a consortium composed of 17 organisations from eight European countries. The involved organisations are listed below:

Industrial partners

- 3A Composites, Switzerland
    - Contact person: Fabienne Browne
    - E-mail: fabienne.browne@3AComposites.com
- Borregaard, Norway
    - Contact person: Hans-Henrik ∅vrebø
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- Elastopoli, Finland
    - Contact person: Timo Ture
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- K-Tron, Switzerland
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- BASF, Germany
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Research institutes

- Innventia, Sweden (Coordinator)
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- EMPA (Eidgenössische Materialprüfungs- und Forschungsanstalt), Switzerland
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- ITENE (Instituto Tecnologico del Embalaje, Transporte Y Logistica), Spain
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Universities

- EPFL (Ecole Polytechnique Fédérale de Lausanne), Switzerland
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4.2 Use and dissemination of foreground

Section A (public)

An important aspect of SustainComp has been to inform as much as possible of the results to the public. This is important since SustainComp will generate new knowledge, competence and methodology as well as new advanced materials and thus opening new possible industrial fields and markets to be exploited. This is done in different ways as will be described below

Open strategic conferences

In order to spread open results generated in SustainComp, two open conferences were arranged during the project. The first conference was arranged in October 26-27, 2010, in Trondheim, Norway and the second one was arranged in June 14-15, 2012, in Stockholm, Sweden.

SustainComp web site

The SustainComp project has an open website available on www.sustaincomp.eu and www.sustaincomp.com. On the website, information about the project vision, goals, consortium and events have been published. Also, open results are available for download.

Forest-based sector technology platform - FTP

The Coordinator will make sure that non-confidential information about the project is included in the FTP Project Database (www.ftpdatabase.org).

Publications and conference contributions

The main route for informing the public about results from SustainComp is publishing in scientific peer-reviewed journals. During the project, 20 scientific papers have been submitted (or are to be submitted shortly) to peer-reviewed journals; to date, 13 of them have been published or accepted for publication. A full list of these publications is found in Template A1. Besides these publications, 43 public deliverable reports have been posted on the SustainComp website.

Furthermore, 22 oral presentations have been given at international conferences. A full list of these conference contributions is found in Template A2.

Student examinations

The main work performed by the universities and by some of the research institutes will be done by post-graduate students (PhD-students and Licentiate students) and as result the Project will generate new doctors, licentiates, and MSc within in the field of advanced composites. SustainComp has generated 11 examinated students (1 PhD, 1 Lic. Eng. and 9 MSc). Furthermore, more students have been involved and within a short time span after SustainComp yet another 5 exanimated PhD students will have been generated. The theses are listed in Template A2.

New projects

In a large scale project such as SustainComp it is natural that the research will nurture new ideas and identify challenges. Some of these new ideas and identified challenges will be further studied in new projects. These new projects will be executed by new consortia, but will include one or several SustainComp partners as key actors. In the table below, the new projects as to date are listed.

New project/project application	SustainComp results continued with	SustainComp partners involved
EU-project NanoBarrier	*Biopolymers/MFC in barrier applications in food packaging. Sustainability assessments.*	*SINTEF (coordinator), Innventia, ITENE, Elastopoli, Borregaard, SCA*
PLA foaming project	*SustainComp has demonstrated the good processing and mechanical properties of PLA*	*SINTEF*
BBraun	*High flux separation membranes, but not with MFC*	*CNRS*
EU-project LbL-Brane	*High flux separation membranes, but not with MFC*	*CNRS (Innventia might be involved)*
A new international collaboration lightweight aerogels project	*MFC aerogels with emphasis on nanostructural tailoring and the closed-cell lightweight aerogels*	*KTH, Aalto University.*
NRP66 project, Ultra-light particleboard	*Expanded PLA as a rigid core for particle board in a new on-line process.*	*EPFL*
WoodWisdom, project	*Filters based on NFC and foams based on PLA and NCC*	*SCA, KTH, Aalto University*
New EU-project application NAWECOMP	*Elastopoli's results in SustainComp*	*Elastopoli, Innventia, SINTEF*
KTI/CTI (Swiss) project, composite materials	*Functionalization of MFC for composite applications*	*EMPA*
Lightweight and fire retardant organic/inorganic foams and composites	*Thin films of inorganic and organic fibrils in combination with foams of nanocellulose*	*KTH*
EU-project Innobite	*Transforming urban and agricultural residues into high performance biomaterials for green composites*	*EMPA*
EU-project Nanoselect	*Functional membranes/ filters with anti/ low fouling surfaces for water purification*	*EMPA*

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
1	*Long and entangled native cellulose I nanofibers allow flexible aerogels and hierarchically porous templates for functionalities*	*Pääkkö, M. (note nowadays Kettunen)*	*Soft Matter*	*4(12)*	*RSC*	*International*	*2008*	*2492-2499*	*10.1039/B810371B*	*No*
2	*Solid state nanofibers based on self-assemblies: from cleaving from self-assemblies to multilevel hierarchical constructs*	*Ikkala, O.*	*Faraday Dicussions*	*143*	*RCS*	*International*	*2009*	*95-107*	*10.1039/B905204F*	*No*
3	*Synthesis and characterization of bionanocomposites with tunable properties from poly(lactic acid) and acetylated microfibrillated cellulose*	*Tingaut, P.*	*Biomacromolecules*	*11(2)*	*ACS*	*International*	*2010*	*454-464*	*10.1021/bm901186u*	*No*
4	*Making flexible magnetic aerogels and stiff magnetic nanopaper using cellulose nanofibrils as templates*	*Olsson, R. T., (Ikkala, O.)*	*Nature Nanotechnology*	*5(8)*	*Nature Publishing Group*	*International*	*2010*	*584-588*	*10.1038/nnano.2010.155*	*No*
5	*Water of functionalized microfibrillated cellulose as blowing agent for the elaboration of poly(lactic acid) biocomposites*	*Boissard, C.*	*Journal of Reinforced Plastics and Composites*	*30(8)*	*Sage journals*	*International*	*2011*	*709-719*	*10.1177/0731684411407233*	*No*
6	*The potential of wood fibers as reinforcement in cellular biopolymers.*	*Neagu, R. C.*	*Journal of Cellular Plastics*	*48(1)*	*Sage journals*	*International*	*2011*	*71-103*	*10.1177/0021955X11431172*	*Yes*

[1] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).
[2] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

7	Photoswitchable superabsorbency based on nanocellulose aerogels, advanced functional materials	Kettunen, M (previously Pääkkö)	Advanced Functional Materials	21(3)	Wiley	International	2011	510-517	10.1002/adfm.201001431	No
8	Design and characterization of cellulose nanofibril-based free-standing films prepared by layer-by-layer deposition technique	Karabulut, E.	Soft Matter	7 (2012)	Royal Society of Chemistry	International	2011	3467-3474	10.1039/C0SM01355B	No
9	Polylactide latex/nanofibrillated cellulose bionanocomposites of high nanofibrillated cellulose content and nanopaper network structure prepared by papermaking route	Larsson,K.	Journal of Applied Polymer Science	125(3)	Wiley	International	2012	2460-2466	10.1002/app.36413	No
10	Cellular biocomposites from polylactide and microfibrillated cellulose	Boissard, CIR,	Journal of Cellular Plastics	48(5)	SAGE	International	2012	445-458	10.1177/0021955X12448190	No
11	Adhesive layer-by-layer films of carboxymethylated cellulose nanofibril-dopamine covalent bioconjugates inspired by marine mussel threads	Karabulut, E.	ACS Nano	6 (6)	American Chemical Society	International	2012	4731-4739	10.1021/nn204620j	No
12	In-plane orientation in layer-by-layer assembled films induced by grazing incidence spraying	Decher, G.	Nature Nanotechnology	To be published	Nature publishing group	International	2012	To be published	To be published	No
13	LbL functionalised aerogels	Decher, G .	Langmuir	To be published	ACS Publications	International	2012/2013	To be published	To be published	No
14	Nanofiltration using separation membranes covered with LbL films with gradient porosity.	Decher, G.	Langmuir	To be published	ACS Publications	International	2012/2013	To be published	To be published	No
15	Tough nanocellulose materials based on Layer-by-layer deposition	Hua, J.	To be submitted	To be published	To be published	International	2013	To be published	To be published	-
16	Nanocellulose aerogels: Controlling structure, mechanical properties	Kettunen, M.	To be submitted	To be published	To be published	International	2013	To be published	To be published	-
17	Interaction of debonded MFC powders with polyesters	Fleischmann, S.	To be submitted	To be published	To be published	International	2013	To be published	To be published	-
18	Dynamic rheology in carboxymethylated cellulose nanofibril dispersions: The elastic gel and viscous states	Hiekka-taipale, P. (Kettunen Ikkala)	Biomacro-molecules (under revision)	Under revision	Biomacro-molecules	International	2012	To be published	To be published	No

19	A method for estimating the fibre length in fibre-PLA composites.	Chinga-Carrasco, G.	Journal of Microscopy (accepted)	Accepted	Wiley	International	2012	To be published	To be published	No
20	Physical extruder foaming of poly(lactic acid) - Processing and foam properties	Larsen, Å.	Polymer Engineering and Science (accepted)	Accepted for publication 20120829	Wiley-Blackwell	International	2012	To be published	To be published	No

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[3]	Main leader	Title	Date	Place	Type of audience[4]	Size of audience	Countries addressed
1	*Oral presentation*	*Ankerfors, M.*	*SustainComp – "Development of Sustainable Composite Materials" - An EU 7th Framework Programme Project*	*24-26 June, 2008*	*Zellcheming 103rd Annual meeting and Expo, Wies-baden, Germany*	*Scientific Community, Industry*	*Unknown*	*International*
2	*Oral presentation*	*Ankerfors, M.*	*EU-Project SustainComp*	*30 September, 2008*	*Workshop on green and wood-based com-posites, Pfinztal, Germany*	*Scientific Community, Industry*	*Unknown*	*International*
3	*Oral presentation*	*Ankerfors, M.*	*New materials from the development of microfibrillar cellulose (MFC)*	*27-29 October, 2008*	*COST Action E50: Cell wall macromolecules and reaction wood. Workshop Characterisation and application of cell wall macromolecules, Dübendorf, Swtzerland*	*Scientific Community, Industry*	*Unknown*	*International*

[3] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.
[4] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias ('multiple choices' is possible.

4	*Oral presentation*	*Ankerfors, M.*	*Development of nanocellulose for the use in sustainable composites*	*12-13 November, 2008*	*Recent advances in fibrillar nanocellulose research - Characterisation and applications, Trondheim, Norway*	*Scientific Community, Industry*	*Unknown*	*International*
5	*Oral presentation*	*Ankerfors, M.*	*SustainComp – A new large scale EU project*	*12-13 November, 2008*	*STFI-Packforsk Research Semi-nar Stockholm, Sweden*	*Industry*	*Unknown*	*International*
6	*Oral presentation*	*Ankerfors, M.*	*Nanocellulosa – Vad är det och vilka är planerna?*	*26 January, 2009*	*PPIs stormöte 2009, Stockholm, Sweden*	*Industry*	*Unknown*	*Sweden*
7	*Oral presentation*	*Lindström, T.*	*Nanocellulose developments in Scandinavia*	*10-12 Juni, 2009*	*7th International Paper and Coa-ting Chemistry Symposium, Hamilton, Canada*	*Scientific Community, Industry*	*Unknown*	*International*
8	*Oral presentation*	*Neagu R.C.*	*Processing and mechanical properties of novel wood fibre composites foams*	*27-31 July, 2009*	*17th International Conference on Composite Materials (ICCM17), Edinburgh, UK*	*Scientific Community, Industry*	*Unknown*	*International*
9	*Oral presentation*	*Pääkkö, M. Ikkala, O*	*Native cellulose I nanofibers allow flexible aerogels and hierarchically porous templates for functionalities*	*16-20 August,2009*	*238th ACS National Meeting ,Washington, DC, United States,*	*Scientific Community, Industry*	*Unknown*	*International*
10	*Oral presentation*	*Ankerfors, M.*	*Boosting research through international networks – examples from SustainComp and DesignCell*	*21-22 September, 2009*	*Innventia Research Seminar 2009, Stockholm, Sweden*	*Industry*	*Unknown*	*International*

11	Oral presentation	Ankerfors, M.	Manufacture and possible uses of microfibrillar cellulose (MFC) in the paper and packaging sector	21-24 September, 2009	Polysaccharides as a Source of Advanced Materials, Åbo, Finland	Scientific Community, Industry	Unknown	International
12	Oral presentation	Ankerfors, M.	Nanocellulose in tomorrow's sustainable materials	9 November, 2009	FTP conference, Researcher forum, Stockholm, Sweden	Scientific Community, Industry	Unknown	International
13	Oral presentation	Pääkkö, M.	Flexible and hierarchically porous nanocellulose aerogels: Templates for functionalities	21-25 March,2010	239th ACS National Meeting,San Francisco, CA, United States	Scientific Community, Industry	Unknown	International
14	Oral presentation	Larsson, K.	Properties of bionanocomposites made from poly(lactide) latex and microfibrillated cellulose	27-29 September, 2010	2010 TAPPI International Conference on Nanotechnology for the Forest Product Industry ,Espoo, Finland	Scientific Community, Industry	Unknown	International
15	Conference	Innventia AB	First Open Conference, SustainComp	26-27 October, 2010	Trondheim, Norway	Members of the SustainComp consortium	55	International
16	Oral presentation	Neagu R.C.	Novel biodegradable wood fibre polylactic acid foam sandwich composites	21-26 August, 2011	The 18th International Conference on Composite Materials (ICCM18),Jeju Island, Korea	Scientific Community, Industry	Unknown	International
17	Oral presentation	Karabulut, E.	Layer-by-Layer films of carboxymethylated cellulose nanofibril-dopamine hybrid conjugates	4-9 September, 2011	25th European Conference Colloid and Interface Society (ECIS),Berlin, Germany	Scientific Community, Industry	Unknown	International

18	Oral presentation	Boissard C.I.R.	Foaming biocomposites of microfibrillated cellulose and polylactic acid	21-23 September, 2011	3rd International Conference on Biofoams (Biofoams 2011),Capri, Italy	Scientific Community, Industry	Unknown	International
19	Oral presentation	Berglund, L.	Cellulose nanofiber networks – structure, properties and applications	28-30 September, 2011	BioEnvironmental Polymer Society (BEPS),Vienna, Austria	Scientific Community, Industry	Unknown	International
20	Oral presentation	Larsen, Å.	Physical extruder foaming of poly(lactic acid)-processing and foam properties	14-15 November, 2011	Eurotec 2011Barcelona, Spain	Scientific Community, Industry	Unknown	Spain
21	Licentiate thesis	Karabulut, E.	Tailored layer-by-layer films of nanofibrillated celllose	20 December,2011	KTH Royal Institute of Technology, Stockholm, Sweden	Scientific Community	-	Sweden
22	Oral presentation	Berglund, L.	Wet-stability of nanofibrillated cellulose-based aerogels controlled by chemical functionalization and layer-by-layer self-assembly	25-29 March, 2012	243rd ACS National Meeting ,San Diego, CA, USA	Scientific Community, Industry	Unknown	International
23	MSc. Thesis	Pallon, L.	Modification of nanofibrillated cellulose to avoid cocrystallisation and reduce viscosity	2012	Lund University, Lund, Sweden	Scientific Community, Industry	-	Sweden
24	PhD Thesis	Boissard, C.	Processing of sustainable cellular biocomposites	2012	EPFL, Switzerland	Scientific Community,	-	Switzerland
25	Oral presentation	Berglund, L.	Biocomposites from small building blocks	27-31 May 2012	International Conf on Biobased Polymers and Composites, “Biocomposites from small building blocks” (BiPoCo),Lake Balton, Hungary	Scientific Community, Industry	Unknown	International

26	Oral presentation	Larsen, Å.	Physical extruder foaming of poly(lactic acid) - Processing and foam properties	9-12 July, 2012	9th International Symposium on Polyelectrolytes – ISP2012, Lausanne, Switzerland	Scientific Community, Industry	Unknown	International
27	Conference	Innventia AB	SustainComp final open conference	14-15 June, 2012	Stockholm, Sweden	Public conference	59	International
28	Article	SPCI magazine	Boosting business with science	No 6, 2012	Sweden	Scientific Community, Industry	Unknown	Sweden
29	Press release	Mundo Plast Magazine	SustainComp develops new applications for the European bioplastics and forest based industry	September ,2012	Spain	Scientific Community, Industry, Media	Unknown	International
30	Press release	Infoambiental.es	SustainComp develops new applications for the European bioplastics and forest based industry	September ,2012	Spain	Scientific Community, Industry, Media	Unknown	International
31	Press release	Alimarket	SustainComp develops new applications for the European bioplastics and forest based industry	September ,2012	Spain	Scientific Community, Industry, Media	Unknown	International
32	Press release	El Mundo Ecológico.es Diario de la Economía Sostenible	SustainComp develops new applications for the European bioplastics and forest based industry	September ,2012	Spain	Scientific Community, Industry, Media	Unknown	International
33	Press release	Club Darwin.net	SustainComp develops new applications for the European bioplastics and forest based industry	September ,2012	Spain	Scientific Community, Industry, Media	Unknown	International
34	Press release	RDi Press	SustainComp develops new applications for the European bioplastics and forest based industry	September ,2012	Spain	Scientific Community, Industry, Media	Unknown	International
35	Press release	Econoticias.com	SustainComp develops new applications for the European bioplastics and forest based industry	September ,2012	Spain	Scientific Community, Industry, Media	Unknown	International

36	*MSc. Thesis*	*Karzami, P.*	*Biopolymer reinforced composites based on poly(lactic acid) and cellulose/lignocellulosic sources*	*2012*	*KTH, Stockholm, Sweden*	*Scientific Community, Industry*	*-*	*Sweden*
37	*MSc. Thesis*	*Bertolla L.*	*Manufacture and charactherization of wood fibers/PLA foams sandwich composites for packaging applications*	*2010*	*EPFL, Lausanne, Switzerland*	*Scientific Community, Industry*	*-*	*Switzerland, Sweden*
38	*MSc. Thesis*	*Ohran M.*	*Polylactide foams reinforced with wood fibers or microfibrillated cellulose*	*2010*	*Uppsala Univesity, Uppsala, Sweden*	*Scientific Community, Industry*	*-*	*Sweden*
39	*MSc. Thesis*	*Övergård-Vikström E.*	*Effects of polymer blends on composite properties", Master thesis*	*Ongoing, planned to finish 2013*	*KTH, Stockholm, Sweden*	*Scientific Community, Industry*	*-*	*Sweden*
40	*PhD thesis*	*Kettunen, M.*	*To be decided*	*Ongoing, planned to finish Spring 2013*	*Aalto University, Espoo, Finland*	*Scientific Community, Industry*	*-*	*Finland*
41	*PhD thesis*	*Hua, J,*	*Bio-inspired functional materials*	*Ongoing, planned to finish November 2013*	*Aalto University, Espoo, Finland*	*Scientific Community, Industry*	*-*	*Finland*
42	*PhD thesis*	*Wang, M.*	*To be decided*	*Ongoing, planned to finish Spring 2014*	*Aalto University, Espoo, Finland*	*Scientific Community, Industry*	*-*	*Finland*
43	*MSc. Thesis*	*De Giorgy, Y.*	*Biocomposites of cellulose and polylactide*	*2012*	*EPFL, Lausanne, Switzerland*	*Scientific Community, Industry*	*-*	*Switzerland*
44	*MSc. Thesis*	*Genoud, M.*	*Compounding and foaming of microfibrillated cellulose and polylactic acid biocomposites*	*2011*	*EPFL, Lausanne, Switzerland*	*Scientific Community, Industry*	*-*	*Switzerland*
45	*MSc. Thesis*	*Gascou, T.*	*Optimizing wood fiber/polylactic acid composite processing for foaming applications*	*2008*	*EPFL, Lausanne, Switzerland*	*Scientific Community, Industry*	*-*	*Switzerland, Sweden*

46	MSc. Thesis	Cuénoud, M.	Processing and mechanical properties of novel wood fiber composites foams	2008	EPFL, Lausanne, Switzerland	Scientific Community, Industry	-	Switzerland, Sweden
47	Press release	Innventia AB	New European project develops innovative advanced sustainable wood-based composite materials using nanotechnology	27 August, 2008	Innventia, Stockholm, Sweden	Scientific Community, Industry, Media	-	International
48	PhD thesis	Blell, R.	MFC based nanomaterials	13 November, 2012	UdS, Strasburg, France	Scientific Community, Industry	-	France
47	PhD thesis	Karabulut, E.	To be decided	2014	KTH, Stockholm, Sweden	Scientific Community, Industry	-	Sweden