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1 Executive summary

The building sector consumes 40% of Europe’s energy. With rising energy prices and greater focus on energy efficiency the building sector offers the single largest potential for energy savings. The use of passive heating and cooling techniques such as thermal mass in building construction and refurbishment are strongly encouraged. Passive techniques such as thermal mass offer the potential to save up to 50% of energy used in heating and cooling. However, there is a barrier to its effective implementation. In order for thermal mass to work effectively the concrete and brick surfaces must be in contact with ambient air and kept free of insulation, including conventional mineral wool type sound absorbers. The acoustics reverberations (echoes) however caused by this can affect the health and work efficiency of inhabitants and in some severe cases rendering the building uninhabitable. Whilst there are some high end solutions to the problem, primarily thick polymer or metal panels, these are too expensive in all but high end applications. There is an urgent and growing need for a low cost, high performance acoustic absorber that allows thermal mass techniques to work effectively yet is at a price comparable to low end mineral wool solutions.
The SMEs in this project represent a supply chain, and together with three RTDs they have developed just such a new type of sound absorber, for public and commercial non-residential buildings, Echo2eco. The solution uses an array of laser cut micro slits of a certain width in a film of a certain thickness.

The scientific and technical foundations of the Echo2eco project were defined and the implications of material formulation, its optimisation for laser cutting and acoustic modelling were investigated. It was ensured that all appropriate end user and legislative requirements were understood and adhered to from the outset.

The laser process technology and the film formulation for the Echo2Eco solution were developed and optimised for the intended use.

It is concluded that the acoustic, dimensional, physical (including fire performance), mechanical, and aesthetic properties of the Echo2Eco system are conducive to providing a highly cost effective acoustic absorption system manufactured in non-toxic recyclable materials.

The end result of the project is an thin polymer, sound absorbing film that can be stretched in ceilings, on walls, on windows and improve energy use in the building at the same time as it absorb sound.

It has been shown in simulations that using the Echo2eco film in ceilings make buildings able to save up to 17% of annual needed cooling energy in UK and up to 19% in cooling energy in Germany just by installing the Echo2eco film instead of covering the ceiling with traditional mineral wool tiles.

This benefit will show directly on a company’s energy bill, but also help one building alone to save vast amounts of CO_2-tonne emissions year.

2 Summary description of project context and objectives

The building sector consumes 40% of Europe’s energy. With rising energy prices and greater focus on energy efficiency the building sector offers the single largest potential for energy savings. This is reflected in the Energy Performance of Buildings Directive, EPBD, 2002/91/EC. This Directive strongly encourages the use of passive heating and cooling techniques such as thermal mass in building construction and refurbishment. Passive techniques such as thermal mass offer the potential to save up to 50% of energy used in heating and cooling. However, there is a barrier to its effective implementation. In order for thermal mass to work effectively the concrete and brick surfaces must be in contact with ambient air and kept free of insulation, including conventional mineral wool type sound absorbers. The acoustics reverberations (echos) however caused by this can affect the health and work efficiency of inhabitants and in some severe cases rendering the building uninhabitable. Whilst there are some high end solutions to the problem, primarily thick polymer or metal panels, these are too expensive in all but high end applications. There is an urgent and growing need for a low cost, high performance acoustic absorber that allows thermal mass techniques to work effectively yet is at a price comparable to low end mineral wool solutions. The SMEs in this project have come together as a supply chain to develop just such a new type of sound absorber, for public and commercial non-residential buildings, Echo2eco. This solution will use an array of laser cut perforations, of a certain width in a film of a certain thickness.

There are significant technical challenges in achieving this solution, however with our research partners and innovations in multi-layer polymer material formulation/lamination and novel laser beam/optics configurations we are confident we will be successful.

The project consortium consists of 5 SME partners and 3 RTD performers. An overview of the partners in the consortium is given in Table 1.

Table 1 – Partners in the Echo2Eco consortium

SME company	Value chain area
Nowofol (DE)	Polymer film producer and project coordinator
DeAmp (N)	Development and sales of high end sound absorbing panels in hard materials.
GRG acoustics (RPG) (UK)	Manufacturing and distributing of a full range of acoustic products
MLT (DE)	System manufacturer/integrator for tailor made laser material processing systems.
Skelly and Couch (UK)	Consultancy specialised in all aspects of architectural acoustics, sound reproduction and the control of noise and vibration.
RTD organisation	Technology area
National Centre for Laser Applications	A technology centre in the field of laser materials processing
Anglia Ruskin University of Cambridge and Chelmsford	Sound and Audio Engineering Research Group (SEARG) and Built Environment Research Group (BERG)
Norner as	An international, independent innovation company covering R&D and operation of the whole value chain of polymers.

2.1 Project objectives

The primary objective of the Echo2eco project was to develop a novel, low cost, (€20/m2 installed cost) high performance sound absorber based on a polymer film with laser cut micro perforations that will enable passive heating and cooling techniques, including thermal mass to be used effectively in the construction industry. The solution will also be transparent / translucent to promote the flow of natural light and will be free of fibres that could adversely affect health. In order to be successful Echo2eco will need to achieve the following objectives. We have defined these objectives in a SMART format so that we can assess our progress in achieving them and specifically validate them in the programme of work and milestones.

Scientific Objectives:

1. ***Acoustic knowledge with micro perforation:*** Whilst detailed knowledge exists with respect to conventional sound attenuator performance we need to increase the understanding of acoustic performance of polymer films with micro perforation. Other factors to understand are panel thickness, rigidity, durability, dimension stability, perforation geometry, uniformity and distribution.

2. ***Laser/Polymer material interactions***: To gain an understanding of the complex interface and reaction between the laser source, its energy and the impact that has on the polymer material to be cut. Knowledge already exists as to ease of cut relating to straightforward polymer materials, including polycarbonate and polyolefin. However, we need to understand the effect of the laser in complex polymer formulations (including anti-static agents, flame retardants and UV stabilisers) in conjunction with laminate polymer films, the first optimised for creep resistance and tensile strength and the second for tear resistance and impact strength.

Technical Objectives:

3. **Laser cutting system**, Our preliminary research and system modelling confirms that we will require a laser cutting system, comprising laser source, beam distribution optics, splitters and focussing heads that will capable of cutting a polymer film of minimum width 500mm, maximum width 1000mm with a set pattern of perforations.

- Perforation precision
- Distribution of the perforations
- Speed of laser cut: 1m/s process film speed (at full 1000mm film width)

4. **Polymer film formulation and construction:** In order to meet the known end user requirements in terms of architectural form and visual appearance, legislative requirements and the demands of the construction sector the polymer film will be formulated to the specification in Table 2 below:-

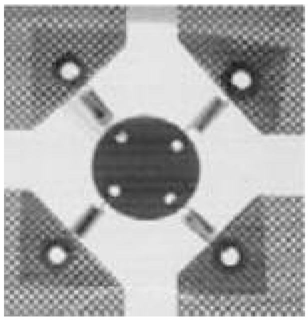
Table 2 - *Specification of film formulation. Some mechanical properties given as MD/TD= Machine direction and Transverse direction*

Mechanical properties:	
Tensile modulus: >1000 />1000 MPa	Dart drop impact strength: >500g
Tensile strength: >200/>35 MPa	Elmendorf tear resistance: >1/>1
Creep resistance at 9 MPa load: < 2% / <10%	Coefficient of friction, COF >0,5<1 Surface tension (if printing needed) 42 dyn
Puncture resistance Total penetration energy: 2J Max force: 10N	Haze: < 10 Gloss: > 80% Transparency: >90%
Specification needed for service condition, 10 years' service life and fire classification (obtained by additives):	
Antistatic performance, tested according to ASTM D257: Surface resistivity < 10^{12} Ù (20ºC / 50% RH)	

UV stability, tested according to ISO 4892-2:	Energy to failure > 38GJ/m^2
Fungi/bacteria resistant, tested according to EN ISO 846:	No growth
Fire classification tested according to DIN 4102 :	B1 s2, d1

We anticipate based upon the knowledge from our research partners that this is likely to be achieved
Acoustic Performance:

- Sound absorption coefficient: of 0.6 : over frequency range : 50Hz – 4KHz
- Sound absorption coefficient of 0.8 : 250Hz – 1Khz (normal range of human voice)
- Attenuation/reverberation performance to class C ISO 354 and ISO11654



5. **Echo2eco Film Fixing system:** Capable of providing a simple, cost effective and rapid installation for the film attenuator sheet such that it can be rapidly installed on site, provides a permanent installation and is compliant to mechanical forces applied to the film.

6. **Exploitation / Commercialisation objectives**

Our overriding commercial objectives are to develop the Echo2eco sound absorber with the performance levels of the leading sound attenuators at a price point of the lowest.

Specifically ;-

Target manufacturing cost: €2.2m2 (€1.7 film and €0.5m2 laser cutting)

Selling price: € 10 /m2

Target installed price: € 20 / m2

To stimulate demand for 4 million m2 of Eco2eco sound absorbers by the end of year 5, post project completion.

3 Description of main S&T results / foreground

3.1 Scientific characterisation

The scientific and technical foundations of the Echo2eco project were defined and the implications of material formulation, its optimisation for laser cutting and acoustic modelling were investigated. It was ensured that all appropriate end user and legislative requirements were understood and adhered to from the outset.

Critical requirements of the construction sector

The findings concerning the characterisation of the construction industry's requirements for the Echo2Eco product .were summarized. The critical requirements of the construction sector are provided and this contributes substantially to the product related criteria summarised in the Characterisation Protocols.

Legislation, performance and test standards relevant to the product are summarised, deleterious materials lists to be avoided are described and the properties of competitors' materials currently available are tabulated. The target criteria to be achieved by the Echo2Eco product are defined.

The Consortium agreed that the fire performance of the Echo2Eco product will be one of the key acceptability criteria for market acceptance and it is concluded that the product must equal or exceed the properties determined by competitor solutions.

Findings from questionnaires representing the views of 29 acoustic professionals are also described.

Research indicates that buildings with large voids, and massive construction achieved energy savings of 23% compared to theoretical models of identical buildings of steel and metal cladding construction.

Laser scoping trials

A basic understanding and knowledge of laser micro-perforation of the acoustic absorber panel application based on a series of laser perforation trials and experiments are provided. This knowledge underpinned the future research in the project in relation to polymer formulation, acoustic perforation geometry, and the laser production system.
A specific laser technology has been selected for further process development based on scoping trials and input of the project partners. The reasons for this selection are primarily lowest process cost and highest throughput. Figure 1 shows a photograph of a prototype laser workstation in NUIG used for scoping trials.

A baseline in terms of process capability and throughput (cutting feed rate) has been determined based on cutting trials on various polymer types.
Key points include:
Cutting efficiency for various polymers were found to vary greatly, additives also affected the cutting speed and thus had to be tested extensively adding several variables to the balancing of performance of the polymer versus cutting speed.

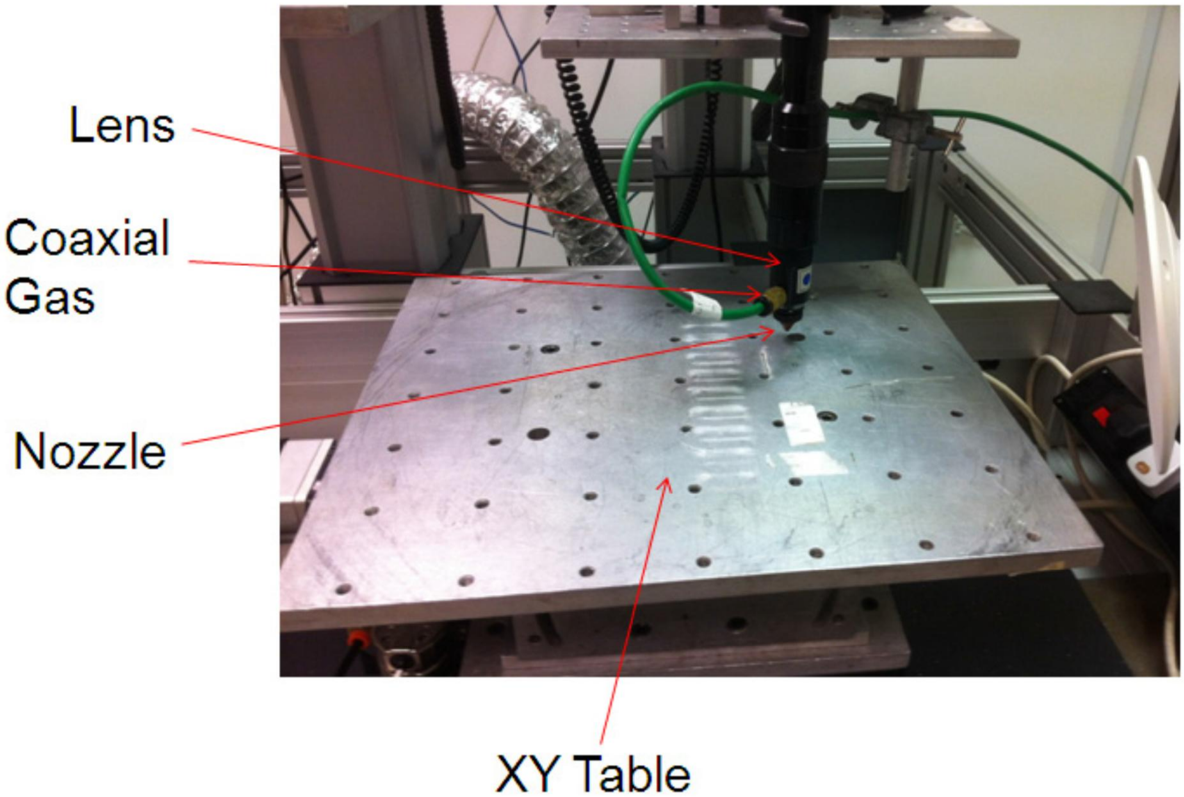


Figure 1 - Photograph of prototype laser workstation in NUIG used for scoping trials.

<u>Polymer material formulation</u>

Research was carried out to define the optimum polymer material, in order to achieve the mechanical properties required by the sector and the customers (including life, dimensional stability, rigidity, durability, creep, tear resistance, UV stability, and optical clarity/opacity).
The laser process is identified as a key process in this project therefore design for laser manufacture is being integrated into the material development cycle, to ensure that the material can be laser processed as required and conversely that the laser process will not negatively impact the performance of the product. A scientific understanding of the laser machining process for the types of polymer material systems being developed for this project has been gained.

The polymer formulation and properties for this application have been investigated. Selection of polymer type was done, and various films were produced for the scoping trials on the laser perforation trials. The state of the art film from the market was analysed and characterised, and the results were used as a bench mark in the development work.

The fire performance of materials for interior use is decisive, and it was well known that fire retarding additives had to be included in the film recipe. It was decided by the consortium partners that the flame retardants used should be halogen free. Screening trials with various flame retardants were carried out, and promising results were found. However, it was seen as a main challenge in the further development work to obtain the required fire performance for the film. Figure 2 shows an illustration of the vertical flame test used in the fire performance screening trials.

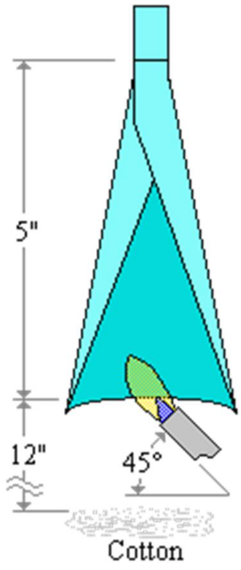


Figure 2 - Illustration of the vertical flame test for thin materials

<u>Baseline laser process parameters</u>

A baseline set of laser process parameters for machining precise perforations in polymer film material that is representative of the final acoustic absorber design was generated. Specifically the laser process parameters identify the laser configuration, laser power, and cutting speeds that can be used to provide the desired process outputs. The information:

- Underpinned the design of the laser workstation
- Aided design of final polymer material formulation
- Provided costing information for laser perforating process
- Provided information on expected throughput and volume production

Prototype acoustic samples were produced for acoustic impedance tube testing which performed as predicted by the software model.

The optimal wavelength was selected following laser testing as the development of the polymer formulation progressed. Techniques such as FT-IR and laser transmission testing can be used to assess the laser absorbance This can provide useful information for the design of the polymer material formulation to ensure it is laser friendly in terms of cutting efficiency.

Analysis of laser cutting trials for various materials was conducted and for example it was shown that some materials had a much higher laser cutting efficiency (at least x2.5). The material thickness also has a significant impact on the laser power required for perforation thus the final acoustic absorber design targets the minimum thickness in order to maximise laser cutting efficiency.

Software model for the acoustic performance

The Echo2eco consortium aims to develop a new acoustic absorber made of a thin polymer panel which presents a novel take on micro perforation that is quicker to manufacture than the current patterns.. Its operation will still be based on the so-called 'Helmholtz resonance' effect.
The need of developing a software modelling tool able to simulate the acoustic absorption produced by the polymer panel and, thus, facilitate the optimization of the panel parameters in order to maximize acoustic absorption was shown.

In order to obtain a reliable software model for the acoustic performance and an optimized design for the perforated panel, the following tasks have been accomplished:

1. Existing models of acoustic absorption by micro-perforated panel and of the effect of vibrations have been reviewed.
2. A suitable mathematical model for acoustic absorption, based on a combination of existing models, has been proposed and implemented in software.
3. The software model has been verified using experimental measurements in a standing wave tube.
4. Based on simulation and experimental results, two panel configurations, optimized for acoustic performance, have been proposed.

The current study resulted in the adoption of and combination of two known models for perforated panels; the combined model was implemented in software using Matlab.

The parametric studies conducted with the software model showed that the magnitude of acoustic absorption can be controlled through the dimensions and distribution of perforations over the panel, while the resonance frequency can be controlled by changing the depth of the cavity behind the panel. The main practical implication of these results is that, in order to achieve a wider absorption band in an installation of the product, corresponding to class C or above, it is recommended to consider a few cavity depths in the same room. Figure 3 shows the definition of different absorption classes.

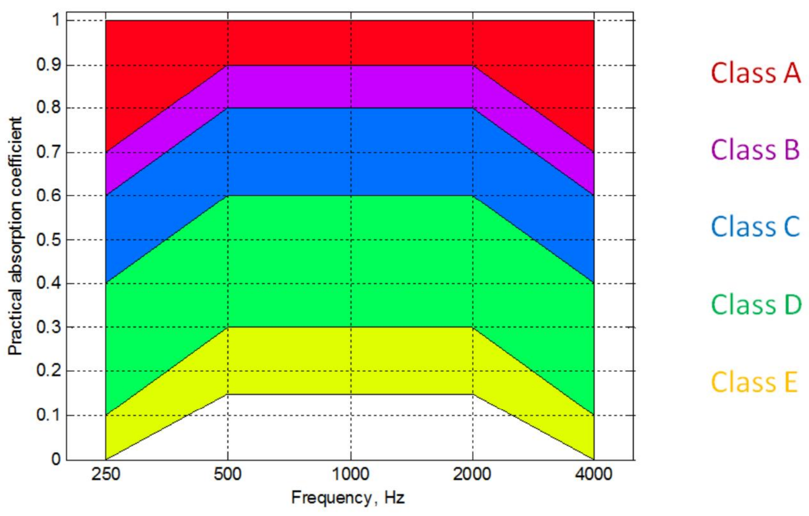


Figure 3 - Definition of absorption classes.

The software model has been validated experimentally through testing a number of panel configurations in an impedance tube. The experimental and simulated acoustic absorption profiles agree well, therefore the model can be used to refine the acoustically well performing configurations and adapt their parameters to suit fabrication constraints (e.g. material thickness, energy and cost reduction). Two configurations have been proposed for further product development. Figure 4 shows the test setup for impedance tube testing. ~~**Fehler! Verweisquelle konnte nicht gefunden werden.**~~

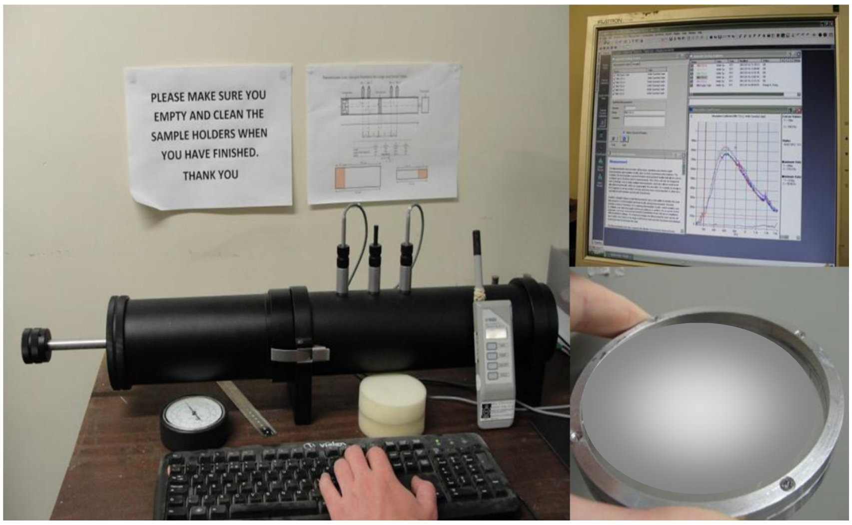


Figure 4 - Test setup for impedance tube testing.

3.2 Development of polymer film

<u>Material selection</u>

A number of different polymer materials were tested and evaluated as single film layers and in coextruded film combinations.

It was found that by combining different materials an optimal balance of mechanical properties for the Echo2Eco solution could be obtained.

The mechanical properties are dependent on the materials selected, the conditions in the film production process and the conditions in the MDO stretching process. The material evaluation is based on polymer films without perforations, and work to develop a robustness specification for films with this perforation geometry was carried out.

<u>Additive formulation</u>

Development of the optimal additive formulation for the Echo2Eco film became a more challenging task than foreseen, especially with respect to the fire performance, where the specification defined in WP1 required that a halogen free flame retardant should be used.

Fire performance, UV protection and antistatic properties were defined as key properties.

A polymer film which fulfils the defined specification has been successfully developed, and the obtained requirements were:

- Fire classification according to EN 13823:
    - B – s1, d0
- UV-stability according to ISO4892-2:
    - >3.8 GJ/m2
- Antistatic performance according to ASTM D257:
    - < 1012 Ohm

<u>Pilot scale film production</u>

A scale up to the pilot film production lines at Nowofol was done. The scale up was based on preliminary trials on film recipes and acoustic calculations.

The raw materials were selected and combined based on the previous development work in order to get the best possible processing (quality and output) and best properties that can be achieved for the final product. For example good tensile strength, impact strength, tear resistance, robustness and shrinkage, each in machine and transverse direction.

To meet the general requirements on the film used for construction the required additives (flame retardants, UV stabilizers and antistatic agents) were included in the film formulation.

A good compatibility between core- and outside layers for the raw materials were found. As flame retardant a halogen free additive which does not need to be declared was used.

There is an improvement potential regarding the film recipe, especially concerning the flame retardant (FR).

The mechanical and thermal properties of the films are in a good range, especially the shrinkage behaviour is very good for indoor application.

<u>Properties of the Echo2Eco film</u>

The Echo2Eco film has been developed in a close cooperation between the RTDs and the SMEs.

The final film is a softer film than originally specified, with a tensile modulus at a level of 250 – 400 MPa. The soft appearance of the film was appreciated by the SME partners, who are operating in the relevant market, and has a practical knowledge of the requirements.

The other mechanical properties of non-perforated Echo2Eco film (dart drop impact, puncture resistance and Elmendorf tear resistance) are better than the values given in the film specification.

The current film solution is translucent and not transparent. This has been discussed and decided in the consortium as being fully usable in ceiling and for light diffusion/shading.

A robustness test where the dart drop impact equipment was used has been developed. The test showed that the perforated Echo2Eco film is more robust than the bench mark film it was compared to. A picture of the robustness test is given in Figure 5.

The fire performance specification B S1 D0 has been achieved with halogen free flame retardants in a test carried out at an external institute, SP in Sweden. A picture of the fire test at SP after 20 min exposure is shown in Figure 6.
The UV stability is better for Echo2Eco film than for the bench mark film. The specification for antistatic behaviour has been achieved.

In the description of work it was assumed that the final Echo2Eco film would be a laminate. During the development of the film it was verified and concluded that the required properties could be obtained without some of the initially planned work. This means fewer process steps in the production of the Echo2Eco solution and improved cost performance.

Figure 5 – Robustness test

Figure 6 - From the fire testing of the Echo2Eco film, after 20 minutes of fire exposure.

3.3 Development of laser process technology

Specification of laser process requirements

There are a number of inputs and drivers for the laser process and the impact of these factors has been assessed in order that the specification of the process can be improved.

The perforation geometry and pattern for the acoustic panel are the critical factors in the product and the laser process must be capable of producing this cost-effectively. Feedback on laser processing constraints and capability to the acoustic design stage is an important step for process optimization.

The material interaction with the laser and the safety of the by-products is also an important factor which determines the design and efficiency of the laser process. Again feedback on the laser process to material design is important.

A very low target cost has been set for the laser perforation process which underpins the design and throughput efficiency requirements of the process. Process design worksheets have been developed to predict challenges and to aid the development of the process.

The Echo2eco product is aimed at a high volume market (in the region of 4 Mm^2 per annum) and the expected levels of production must be achievable for the system design and this is incorporated in the design worksheets. The impact of the product volume on the process cost is also available.

The laser process quality and tolerance requirements have been identified and expected values have been determined that fulfil the demands of the product. The process window must be robust in order that a high-throughput low-cost product is achievable.

Optimisation of the laser process

The laser perforation process is a key aspect of the Echo2eco project and impacts the acoustic performance, mechanical performance, and cost of the acoustic panel product. Therefore it is critical that the laser process is fully optimised to ensure that the best results are obtained.

The acoustic performance of the panel can be achieved by a multitude of designs and it has been shown that by selecting the optimal design for laser manufacture significant improvements in process efficiency (up to 33%) can be obtained.

The laser power required to perforate a polymer material is proportional to the thickness of the polymer therefore the minimal possible thickness of 180 µm has been chosen to best suit the laser process while taking all other functional aspects into consideration (acoustic, mechanical, etc.). This provides up to an ~33% increase in laser slitting efficiency.
The fume and residues generated from the laser processing of polymers can be deleterious to health. However a chemical analysis of laser perforated samples by an external institute has shown that the residue from the laser processing is within acceptable safety limits.

In conclusion based on the laser process development and optimisation detailed in the project it has been shown that the needed and very low target costs can be achieved using a custom designed laser system.

Design of laser beam delivery system.
The design of the laser beam delivery system for future implementation in a full production system for the Echo2eco product has been outlined. This design work supports the full system design.
The developmental laser system at NUIG was used as a test-bed for producing numerous demonstrator samples of the Echo2Eco panel. This sample production was also used to assist and verify the laser beam delivery design.
The outline design and specification of the laser beam delivery system has been presented for use in the development of the full production system. On samples machined with this design the measurement of the perforation pattern has shown that the achievable tolerance of the laser system is within acceptable levels and the specification of the Echo2eco panel is achievable.
A design concept based on the beam delivery design and optimised process has been presented for a full production system that will fulfil the process requirements. The design is based on a hybrid reel-to-reel system. In Figure 7 a concept reel-to-reel system with 5 laser machining heads are shown.

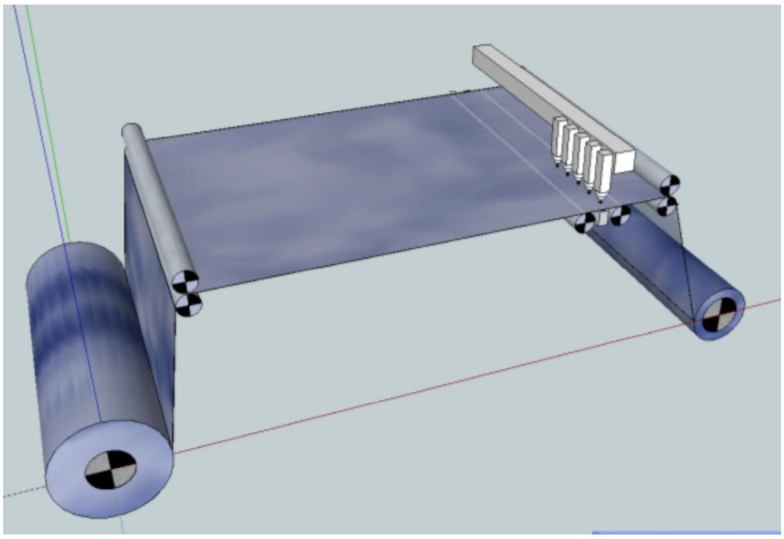


Figure 7 - Concept for reel-to-reel system with 5 laser machining heads.

Implementation of parallel processing concept

The implementation of a prototype micro perforation system at NUIG has been outlined. This system has enabled the technology development and the system design. It also acted as a process demonstrator and has generated samples for assessment and testing.

The prototype system has been utilised to generate numerous samples for testing and demonstration the design of the full scale system was however significantly different in solutions for higher throughput efficiency.

Design of laser perforation system

A complete laser cutting system based on the outcome of laboratory scale research and testing from WP3, Development of laser process technology has been outlined.

Several systems were designed in order to satisfy the expected commercial production volumes during the project start up and normal production phases. Essential periphery systems such as exhaust, filtering and cooling were also explored and included in the machine design.

3.4 Development film fixing and mounting system

Film fixing and mounting system

A film fixing and mounting system has been developed for the Echo2Eco product.

The design principles for the film fixing and mounting system development are based on the following requirements:

- Modularity (expandable system).
- Flexibility (allowing mounting in different orientations, i.e. wall, ceiling).
- Functionality (accommodating different cavity depths to vary the acoustic performance).
- Versatility (adaptable to use a single or multiple layers in the same mounting system).
- Easy to install (avoiding complicating setups and tooling).
- Minimum Cost (minimised for a competitive approach to the market).
- Robustness (metal frame pins).

The film will be fixed to the mounting system by extension springs through eyelets positioned at the corners of the Echo2Eco film. Alternatively, extruded plastic poster holders could be used where edge tension is required. The springs will be freely hooked directly to the mounting pins.

3.5 Integration, testing and technology validation

Acoustic performance

It is seen from the performance test data that further design iteration is required to achieve the optimal performance capability of the Echo2Eco system.
A 100% active area should be designed into the product (at present the effective active area is only 80% of the overall panel area). Precision engineered mountings should be manufactured to reduce film sag and a smaller panel size could be considered. Various cavity multiples and cavity depths should also be trialled in order to realise the full potential of this acoustic absorber.

Compliance with test standards and building standards.

An overview of the properties and potential of a prototype Echo2Eco system for dissemination to the public has been made.
It is concluded that the acoustic, dimensional, physical (including fire performance), mechanical, and aesthetic properties of the Echo2Eco system are conducive to providing a highly cost effective acoustic absorption system manufactured in non-toxic recyclable materials.

An overview of the potential for energy and carbon savings and calculations suggest that where thermal mass insulating ceilings are replaced by the Echo2Eco system, artificial cooling could potentially be reduced by 49% and energy costs could potentially be reduced by 19% equating to a carbon saving of 0.38 Kg CO2 / m2 year.
The acceptability of the appearance and robustness of the Echo2Eco installation, and its long term use, will be determined by end-users perceptions of this cost effective system.
The bottom line is that 19% energy saving could potentially be achieved by installing
this fire resistant* B S1 D0, potentially Class B acoustic absorption system at a highly competitive supply cost.

(* Indicative sample testing has been carried out to achieve BS1d0).

4 Potential impact and main dissemination activities and exploitation results

4.1 Potential impact on society:

The Echo2eco project and consortium participators set out to develop an answer to the EU's ever stricter energy policies. One of the areas the EU can save most energy is to reduce its buildings energy consumption. ***40% of Europe's energy consumption is purely consumed by buildings***, by improving new and refurbished buildings a huge energy saving can be made with ever smarter and leaner solutions. This change has been pushed by the EU through the EU directive 2002/91/EC "The energy performance of buildings".

Echo2eco set out to solve a challenge that arises when a building is refurbished or newly built to save energy passively in concrete walls and ceilings. The easiest way to passively store energy (heat) in a building is to remove the traditional mineral wool false ceilings and expose the floor slabs between each building floor. The concrete can now slowly absorb the heat from an overheated room (due to sunlight, people, equipment) and cool the room at a more practical temperature without using any extra energy.

The alternative is to actively cool the building with the HVAC system (using even more energy) or through active heat exchange systems like flowing water through wells drilled in the ground. Other passive solutions could be sun screening that at the same time removes natural light that is wanted in the room.

The problem that arises with passive energy storage is that large hard surfaces are now exposed to the room and significantly change the acoustic properties of the room to the worse, increasing the reverberation time in the room drastically. The Echo2eco proposal seeked funds to find a solution that combines ***good acoustics and passive thermal mass utilisation.***

The end result of the project is an thin polymer, sound absorbing film that can be stretched in ceilings, on walls, on windows and improve energy use in the building at the same time as it absorb sounds.

If we could manage this in project Echo2eco it would it would offer the largest single potential for reduced energy consumption and improved efficiency.

Rising prices of energy and a growing focus and awareness of energy consumption of buildings through legislation, the EU Directive 2002/91/EC, “The energy performance of buildings”, EPBD, has heightened this awareness further. This Directive, which came into force in 2006, provides a common framework for calculating the energy performance of buildings across Europe, and sets minimum standards in new and refurbished buildings.

The directive contains a number of different regulations and tools on energy performance that impact on the design and operation of buildings.

Of strategic importance to Echo2eco is that the EPBD requires that governments, designers and clients take action by applying passive heating and cooling techniques such as thermal mass. Furthermore, the EPBD states that attaining good energy performance must not conflict with the quality of the indoor environment.

The Echo2eco project have developed a product that answers to these challenges and energy studies performed by the RTD Anglia Ruskin University have shown in simulations that using the Echo2eco film in ceilings make buildings able to save up to 17% of annual needed cooling energy in UK and up to 19% in cooling energy in Germany just by installing the Echo2eco film instead of covering the ceiling with traditional mineral wool tiles.

This benefit will show directly on a company’s energy bill, but also help one building alone to save vast amounts of CO_2***-tonne emissions year.***

Saving energy is what this project is all about at the core. Not only can this sound absorber save energy, but the thin 0,2 mm thick product reduces material use down to a few percent of existing products,

The product can be shipped compactly, and its light weight and low volume makes it green in all aspects of transportation.

The resulting product:

A sound absorbing thin film for spanning in ceilings, windows and walls that also makes energy saving possible by utilisation of a buildings passive thermal mass.

- **Film thickness ~0,2mm**
- **Perforation degree less than 2%**
- **Finish: transparent, translucent, opaque, digitally printed**
- **Benefit: Acoustic absorption, energy saving, decoration and sun shading**
- **No dust accumulation nor emission**
- **No phthalates, chlorinated , brominated additives**
- **UV stable**
- **Anti-static**
- **No humidity restrictions**
- **Cleanable**
- **Robust to physical touch**

- **Both sides smooth for light transmission and dust repelling**
- **light reflective for daylight utilisation**
- **Single layer, Class C sound absorption ISO 354**
- **Double layer , class B, ISO 354**

The primary market segment for the new sound absorption product is therefore the construction market.
The solution will be applicable both in public buildings and in commercial buildings. Good aco ustic conditions are important both in schools, other educational buildings and in office buildings, where people spend a significant part of the day, and where concentration, and speech eligibility are important factors.

Noise is recognised as the number one complaint in the indoor work environment. Acoustical conditions are controlled by regulations, requiring all non-residential buildings to have sound absorbing elements installed.

According to architects they are aesthetically unpleasing because of their inability to exploit daylight and general lack of flexibility in shape, colour and materials. Nonetheless, they have to be implemented in lack of better alternatives.

So, not only is there a strong and growing need for our solution, supported by legislation, the re are no competing solutions that can effectively solve the problem and meet those needs. This is why we believe
Echo2eco will not only enable energy efficient building techniques to be more wisely used. It will also improve the quality of the indoor environment, but crucially it will provide us with a highly differentiated product that will generate increased market share and profitability for us as a consortium and Europe's economy as a whole.

4.2 Dissemination activities:

The goal of "dissemination" (mentioned fully in the Dissemination Plan, Section A) is to promote and raise awareness about the project achievements, and communicate its benefits to the targeted stakeholder communities.

Echo2Eco target groups are in addition to reporting to the EC; Authorities (governmental law regulators), the building industry (owners, contractors, influencers, service providers, consultants), the research sector and the general public users/occupants of European commercial buildings, these are people who will increasingly demand and seek new solutions and accelerate the creation, management and deployment of new products, technologies, services and business models of the future "green building market".

Examples of above mentioned target groups in need of Echo2eco information:

- EU & States policy makers (governmental regulators)
- Government-owned and privately owned buildings (building owners)
- Building contractors
- Architects, Acousticians, building climate engineers , HSE-organisations, Media (influencers)

- Certification and Labelling systems (regulators)
- General population (virtually anybody working in a public building)

The project results will be of great interest not only to Building market professionals but also to local, general European population with respect to the vast global discussion about man-made climate change.

Target group/ Tool	European Commission	Authorities	Building Market Industry	Research sector	General public
Website	X	X	X	X	X
Deliverables -restricted	X				
Deliverables -public	X	X	X	X	X
Technical &Scientific Publications		X	X	X	
Trade shows, fairs, expos			X	X	
Echo2Eco Workshops			X	X	
Social media			X	X	X
Brochure (posters, leaflets, flyers)		X	X	X	X
Printed and online press					X

4.2.1 Scientific publications

Journal focus	Journal title and web link	Professional article D6.3	Scientific paper D6.4	Distribution (INT, EU, D, IE, N, UK, other)	Abstract managed by (initials)	Editorial input by (initials)	Article Title or Scope (keywords)	Target date
ACOUSTICS	Journal of the Acoustical Society of America		X	World	RT	SC	A slotted membrane acoustic absorber for controlling reverberation in schools and offices	2015
	Applied Acoustics		X	World	RT	SC	Design, simulation and verification of acoustic absorber products	2015
	Journal of the Audio Engineering Society		X	World	RT	SC	(reserve Journal in case not published in above)	2015
ARCHITECTURE & DESIGN	'AJ ' - http://www.architectsjournal.co.uk	X		UK	AEC	RT AEC CJB SC	'Innovative product' news item	after Patent
	'Building' - http://www.building.co.uk	X		UK	AEC	RT AEC CJB SC	'Innovative product' news item	after Patent
ENERGY & SUSTAINABILITY	Int Jnl of Env Cultural Economic & social Sustainability		X	INT	CJB	CJB	An experimental approach to thermal mass performance in indoor environments.	February 20th – abstract deadline. Conference Jan 2015
	Journal of Building Performance Simulation		X	INT	CJB	CJB	Energy saving performance of thermal mass. A simulation approach.	2015
	Energy and Buildings		X	INT	CJB	CJB	Assessing the effect of internal fittings on thermal mass.	2015
MANUFACTURING & PROCESSING								
Laser perforation	ICALEO 2014 International Congress on Applications of Lasers & Electro-Optics; 19-23 October 2014, San Diego, USA			INT	AJC	AJC	Investigation of the effect of laser wavelength on the cutting efficiency of polymer films.	April 10^{th} 2014 – abstract deadline
MATERIALS & TESTING								
	Fire resistance in plastics	X	X		HØ	HØ	A new developed system for flame retardancy in polymer films	April 28^{th} 2014 - abstract deadline

	Norner News	X			JN	JN,OJM	Article in Norner News about Norner's Participation in Echo2eco and the product benefits	Sept 2014 Edition

4.2.2 Dissemination activities

Network focus	Network title and web link	Network reach (INT, EU, D, IE, N, UK, other)	Input coordinated by (initials)	Input required by (initials)	Scope (keywords) or intent	Target date
ACOUSTICS						
	Internoise Conference	World	RT	SC	Networking with respect to Echo2Eco process and product	Aug 2015
	Euronoise	Europe/World	RT	SC	Networking with respect to Echo2Eco process and product	June 2015
	Reproduced Sound - Institute of Acoustics Convention	UK/Europe	RT	SC	Networking with respect to Echo2Eco process and product	Oct 2014
	Techniacustia	Europe / World	RT	SC	Networking with respect to Echo2Eco process and product	Oct 2014
	Acoustic Conference ICASSP Florence	Europe/World	MM	MM, BAF	Networking with respect to Echo2Eco process and product	May 2014
ARCHITECTURE & DESIGN						
	100% Design UK	Europe/UK	MM	MM	Networking with respect to Echo2Eco customer contacts	sept 2014
	Surface Design Show	Europe/UK	MM	MM	Networking with respect to Echo2Eco customer contacts	Feb 2015
MANUFACTURING & PROCESSING						
	Euro Expo	EU/Scand	BAF	BAF	Networking with respect to Echo2eco materials, manuf. and processing	Jan 30th 2014
	Interpack 2014	EU	WH	WH	Networking with respect to Echo2eco materials, manuf. and processing. MLT Booth	May 2014
GENERAL	Anglia Ruskin Annual Research Conference - Communicating your research 2014	uk	AEC CJB	AEC CJB RT SC	Communication networks	completed jan 14

4.2.3 List of Patent applications, Trademarks, Registered Designs and Exploitable foreground (CONFIDENTIAL)

At the end of the Echo2eco project the patent is ready for filing, but is in final review stage at the SMEs. A design protection and final name for the film, total solution or a proposed Joint Venture Company is still to be decided.

Type of IP	Name/ID	Legal Entity	Applicant/Owner	Date	Completion at EU-project end
Webpage	www.echo2eco.com	Nordic Hosting	Deamp /SME Consortium	March 2012	100%
Patent application for sound absorbing effect	Draft title "Sound absorbing micro perforated thin film polymer"	European Patent Organisation - EPO	Deamp / SME Consortium	March 2014	80%
Design protection	Draft title " Perforation pattern in acoustic polymer film"	Community Design EU	Deamp AS / SME consortium	2014	20%[1]
Product Name/logo	Echo2eco name and visual logo	SME Consortium	SME Consortium Joint ownership	N/A	20%[2]

4.2.4 Exploitable foreground (CONFIDENTIAL)

The direct outputs of the project are the results of the Work Packages listed under, this is the entire research basis and strategic plan for the way forward for the SMEs.

Type of IP	Name/ID	Legal Entity	Applicant/Owner	Date	Completion at EU-project end
Confidential Polymer recipe	WP 2 & WP1	SME Consortium Trade Secret	SME Consortium Joint ownership	Jan2014	80-90%
Confidential Laser machinery setup and process	WP 3 & WP4	SME Consortium Trade Secret	SME Consortium Joint ownership	Jan2014	95%
Confidential Acoustic performance	WP 5 & WP1	SME Consortium	SME Consortium Joint ownership	Jan2014	100%

[1] Can be filed up to 6 months after product publication.

[2] The Echo2eco name is currently regarded as a project name, the future product name and possible joint venture company name can be changed to more suitable names. The current name is not deemed vital at this stage, but holding web domain names are securities in avoiding other companies to "hijack" the name.

prediction deliverables		Trade Secret			
Dissemination and Exploitation plans, including Business plan	D 6,2	SME Consortium	RTD and SME joint ownership	Jan2014	100%
Publications	D6.3, D6.4, D6.5 ,D7.5,D 7.6	SME Consortium	SME joint ownership	Jan2014	100%

4.2.4.1 Polymer film (CONFIDENTIAL)

The recipe developed in WP2 will be a trade secret jointly owned by the SME consortium. In the polymer film industry the most common method of protection is secrecy since a patent would disclose how a recipe is done and give the competition both insight to how a challenge is solved, but also open up grey areas where a similar solution possibly can be found outside the patented recipe.

Any competitor with sufficient recourses can analyse the film to find its components, but one will never find the exact formulation and balance of additives. It is believed that you can get to 80% of the recipe, but the final 20% will require extensive testing to find the balance of crucial additives for UV stability, anti-static and fire retardation. *If* these final 20% were found weathering tests and other time and recourses consuming building product tests would also be required for the film to be marketable as a like for like product.

The consortium therefore sees secrecy as the best protection of the recipe.

4.2.4.2 Laser system setup(CONFIDENTIAL)

The laser system designed and developed in WP 3 and 4 outlines a unique laser set-up for thin film perforation. The amount of precise perforations requires a coil to coil fed machinery with an unusual design due to the specific requirements of this product. Patenting the machine set-up would reveal more than it hides as a trade secret.

Holding the setup, design and cost of the machinery a trade secret will reveal as little information to competitors as possible.

4.2.4.3 Mounting system

The mounting system developed in WP4 and WP5 is a modular version of the already existing stand-off and spring solutions for stretching polymer films on the market. Patent searches have revealed that the existing competitor Microsorber tried to patent a stand-off and spring mounting system, but the patenting process was discontinued. This is most probably because the lack of novelty and “innovation height”.

The mounting system will not be actively protected since it is not believed to have any substantial degree of innovation at its current state.

4.2.5 Total system with acoustic effect

The total system with acoustic effect is in itself not patentable, but the film's acoustic effect with novel micro perforated geometry is believed to have innovation height in how it solves existing products challenges with dust accumulation due to one side being rough.

The perforations are narrower than the thickness of the film, this is not achievable with mechanical hot needle perforation since mechanical perforation is normally only achievable for width or diameters down to or equal to the material thickness.

The perforation pattern and the utilisation of long perforations instead of circular holes is also not obvious to a person skilled in the art, this is also given by the fact that no thin film product in the market exists with other perforation designs than circular perforations.

The patent will be written with the original patent for thicker panels in mind to show differences and novelty over the existing patent's claims.

Since the perforation pattern will be revealed instantly upon publication the parties involved in acoustics have in this project insisted that the acoustic effect and the method to achieve it must be protected with a EPO + PCT application (after 1 year).

A Community Design protection for "perforation pattern in thin acoustic film" could also become the strongest protection since these are low cost and can last decades longer than a 20year patent.

At the time of writing no protection has been filed due to the extensive discussions on patenting, the application as at the current time being written. For this reason no reference number from the EPO is available.

4.2.6 Total system with acoustic effect and energy saving

During the project WP1 research has been performed on the potential of combining the film in ceilings to make passive heating and cooling of the room possible.

The results show that the film has minimal impact on convection and little to no impact on radiation of heat, however the data is very complex to present to customers due to large numbers of variables (type of building, local climate, window orientation, etc. etc.) involved in an analysis.

The use of thin polymer films in ceilings are not novel as existing products on the market tell passive thermal mass utilisation is possible. Echo2eco's research shows that energy needed to cool a building in Europe can be reduced by 5-50%, this could be significant but the models are raw and only indicative.

For the exploitation phase this is an area that needs more know-how to be built, which is mentioned in the business plan as an area of further work and funding. The communication, to building owners and other potential customers, must be simple and convey that there are energy benefits of the product when applied correctly and integrated in the early design phase of the building.

4.2.7 Acoustic software modelling

The acoustic effect of the polymer film and the micro perforation will be described in WP1 and tested and proven and certified in WP5. The certification data can be published to customers as soon as the patent application is filed.

The internal software or mathematical acoustic prediction model will be held a trade secret for future development of new application areas, new materials or new perforation patterns.

Exploitation results:

The Echo2eco project will lead to the following exploitable results:

- A physical first product (or product range) of a micro perforated sound absorbing polymer film for ceiling or wall application.
- An acoustic software or foreground document, for internal use, explaining the basic functions and possibilities with the technology.
- Documents describing all product characterisation protocols and all building sector requirements for marketable products
- An internal document on the process of micro perforating a polymer film and the technical description of the needed equipment to build such an automated system for large scale manufacturing.
- An internal document on the material composition of the micro perforated film properties, composition and manufacturing process.

The SMEs represent a near finished value chain from raw material to installed product at the end-customer.

The SME consortium decided that since we already represent a near full value chain we want to start slow to grow organically and jointly promote the product through our natural positions in the value chain presented chronologically from raw material to sale:

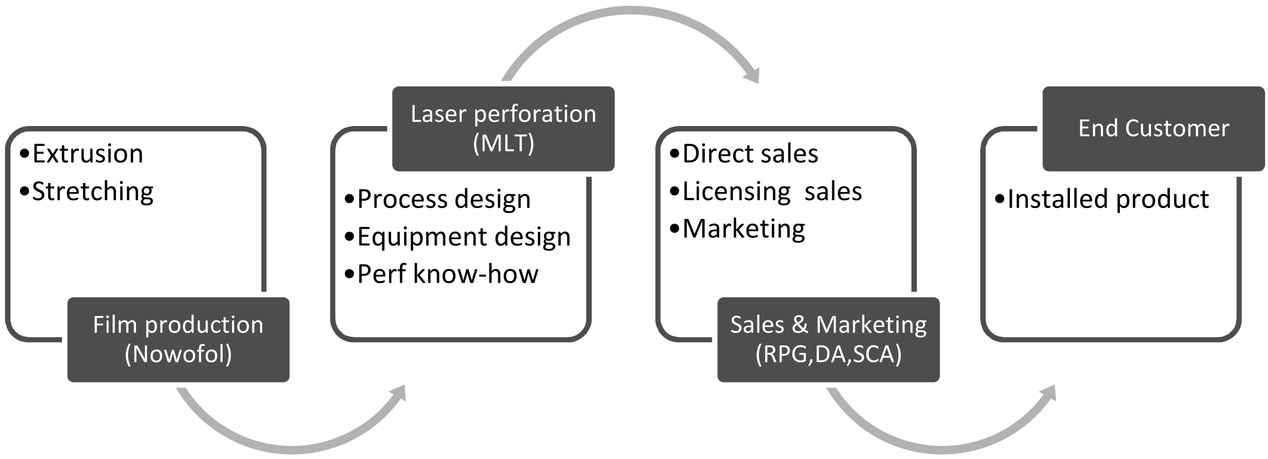


Figure 4: Echo2eco product value chain

Nowofol:

Main role post Project completion: Nowofol main role of exploitation is using the foreground for the polymer film, manufacture the film and sell it to the laser perforation company (MLT or sub-contractor).

Nowofol is responsible for the further development of film recipe (additives) to get a finished and sellable product. In addition a development for optimizing the film planarity is necessary for the laser perforation process. A pre-heating equipment must be installed in the laser machinery. Preliminary test will be done at Nowofol to search the needed parameters like temperature and dwell time.

General role during and after the project: Nowofol implemented the proposals from Norner for film recipe and structure in their production process, optimizing the proposals for film processing. After the project Nowofol will develop the requirements further to get a product for large-scale production.

Nowofol will produce sample films for demonstration purposes in public rooms.

MLT:

Main role post Project completion: MLT are experts in laser machinery for thin materials and will be able to design the perforation pattern process and needed machinery for a larger scale production. MLT can provide the start-up low scale perforation of single sheets (at a 3rd party) until a confirmation on further up-scaling is acquired. MLT will then be able to provide the complete machinery that can perforate films from roll to roll. This machinery can potentially be installed in RPG Europe's new facilities or MLTs facilities for a start-up period.

MLTs main role of exploitation is building and selling laser perforation machinery for paper and polymer industry. This project could require a significant investment in a 350k Euros laser machinery from early start-up. This capital need will be discussed in the Business Plan "Echofilm" in the Appendix.

General role during and after the project: Inform laser manufacturing business sector of the new architectural market opened up by MLT’s participation. Permanent installation at offices, samples and demo wall at expos

RPG:

Main role post Project completion: RPG will be the main sales and marketing organisation for the Echo2eco products along with selling installation equipment and installation services. Using the network of RPG representatives the product and information can reach out to the American, Middle-Eastern and Asian markets.

RPG will be willing to have the laser perforation equipment at their site should a large scale manufacturing solution be needed.

RPG will split the profits of the sales according to an agreed key between the SMEs.

General role during and after the project: Inform customers of new technology, provide samples and information leaflets or brochure. Permanent installation in offices, demo product for expos.

Deamp:

Main role post Project completion: Deamp will support RPG in the sales and marketing work, especially focusing on Scandinavia. Knowledge of new areas of use, product development and project management will support RPG.

Deamp will continue managing the IPR situation for existing or new products until a new organisational structure is formed in a new company or co-operation agreement.

General role during and after the project: Raise awareness amongst customers, architects and acousticians. Permanent installation at offices. Attend acoustic and green building symposiums. Hand out samples and leaflets, website news, portable demo installation for sales meetings and expos. Contact local general media and building magazines, contact the NTNU magazine “Gemini” where the micro perforated technology first was invented.

SC acoustics:

Main role post Project completion: SC Acoustics will provide knowledge of building codes and how the business works. They can offer calculation services for projects, design services and produce “white papers” disseminating the product and information in a neutral way to as many as possible.

General role during and after the project: Inform acoustic community of their contribution to the Echo2eco project, propose the product into future building specs. Permanent installation at office, lobby or meeting room.

5 Address of project public website and relevant contact details

The address of the project public website is:

http://echo2eco.wordpress.com/

For general enquiries and questions contact the project exploitation manager
Bjørn A. Fløtre: flotre(insert “@”)deamp.com

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