DEVELOPING ADVANCED BIO-BASED COMPOSITES

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WILSON BENESCH

NEXT GENERATION ADVANCED COMPOSITE TECHNOLOGIES -*The Future is Bio Carbon* -

BBI JU
Bio-based Industries Consortium
Horizon 2020 European Union Funding for Research & Innovation

Final Event *– Videoconference – 9th February 2022*

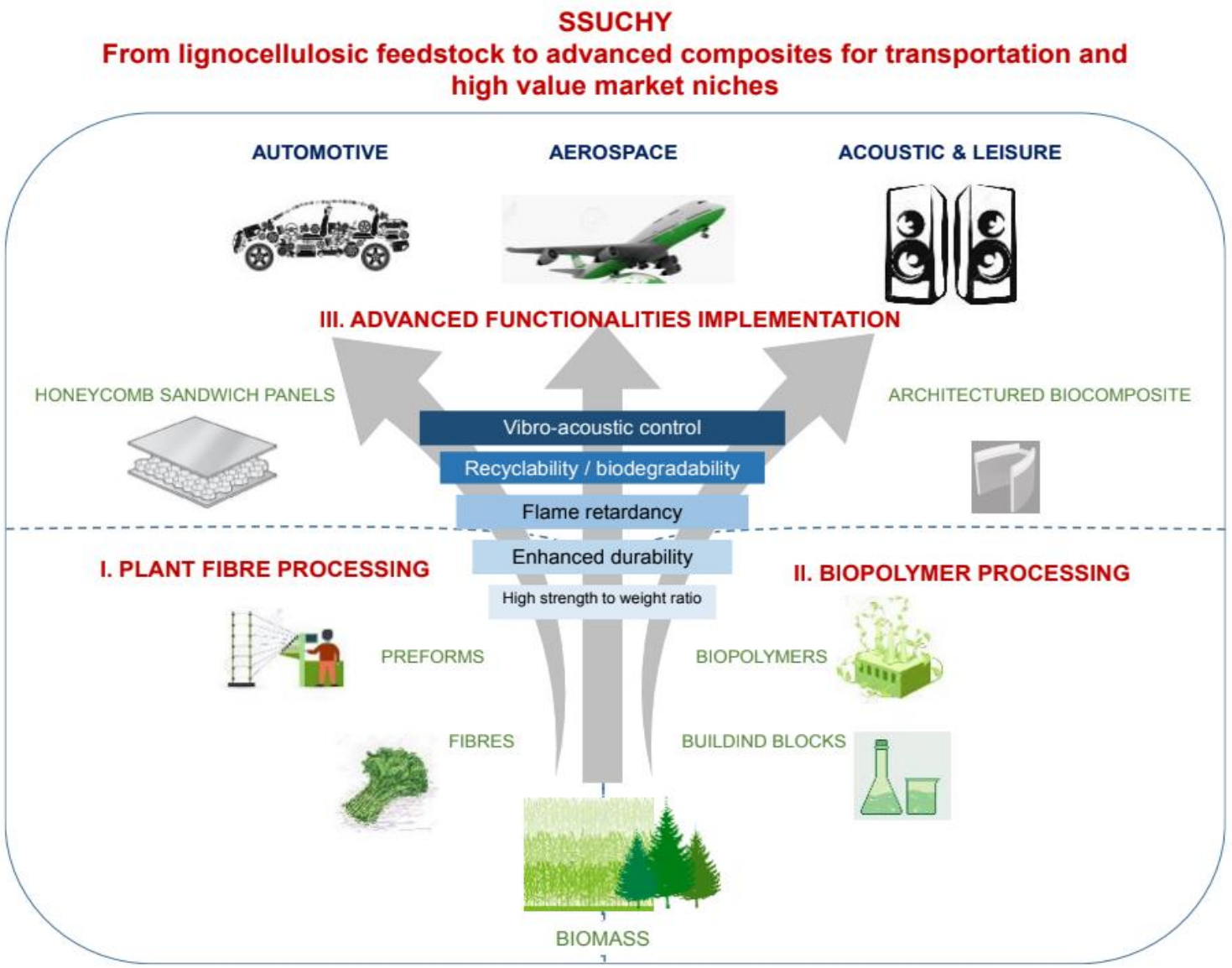
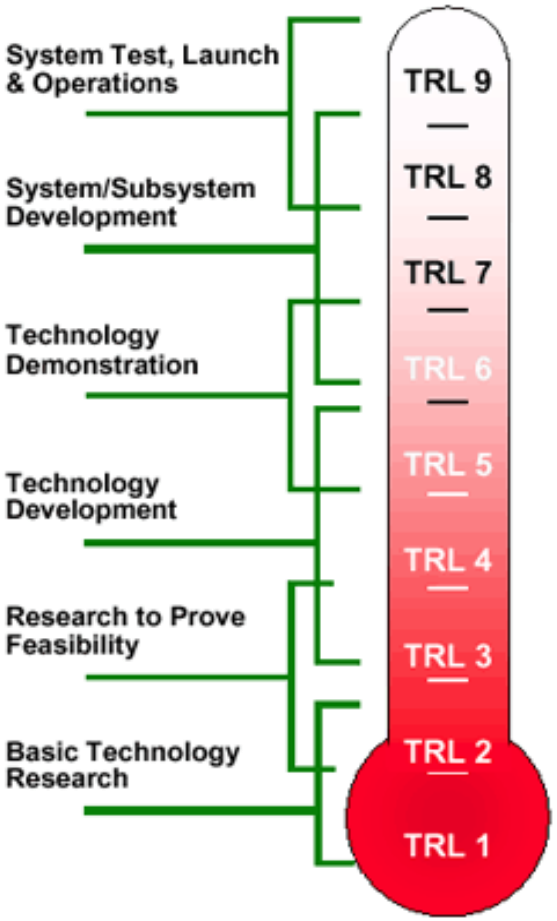


Figure 2: Positioning along the Value Chain, key material developments and application fields addresses in the project SSUCHY

TECHNICAL READINESS LEVEL (TRL)



For clarity, the TRL graphic will appear at the left hand side of the slide to indicate where progress has been made to a new level of readiness.

This Presentation will focus exclusively on the main activities and achievements of the project.

Several URL's are provided at the end of the presentation that may be useful to those wishing to gatherer further information regarding the companies recent activities.

THE WILSON BENESCH BRIEF

Wilson Benesch's brief was to bring more than 20 years of manufacturing expertise in VRTM Production Technologies in carbon composite systems to the SSUCHY Project.

One of the main Objectives of the Project was to produce both component parts and working systems that could be measured and subsequently evaluated against the Benchmark Oil based systems that are currently used by Wilson Benesch and indeed most of the composite industries. A number of twin systems would be created to enable comparative assessment that could demonstrate that bio derived materials could deliver a real alternative to Oil based systems.

The Key Aim or Outcome of this work would be to overcome the challenge of not only realising a new State of The Art performance in terms of the mechanical properties of the A.C.T. (Advanced Composite Technology) Monocoque, but also to produce the world's first Bio Composite Monocoque, with the capability of being recycled.

WILSON BENESCH CAPABILITY

Wilson Benesch was founded in 1989 as a research, design and manufacturing company. To day, the company manufactures all of its own components from Falcon House a Pre War Art Deco building that has been restored and repurposed by Wilson Benesch.

WILSON BENESCH COLLABORATION

Wilson Benesch has a track record of collaborative R&D projects that have provided the company with significant funding to innovate. Without doubt the companies success in winning public funding is due in no small part to the strong collaborative links that extend well beyond the UK with numerous academics within Universities and applied engineering in advanced manufacturing companies.

A good example is the material developed for the Torus cone. For this, a unique carbon fibre cloth woven exclusively for Wilson Benesch was collaboratively developed to enable complex geometry to be realised in thermo formed systems that use PET as the matrix.

WILSON BENESCH MANUFACTURING

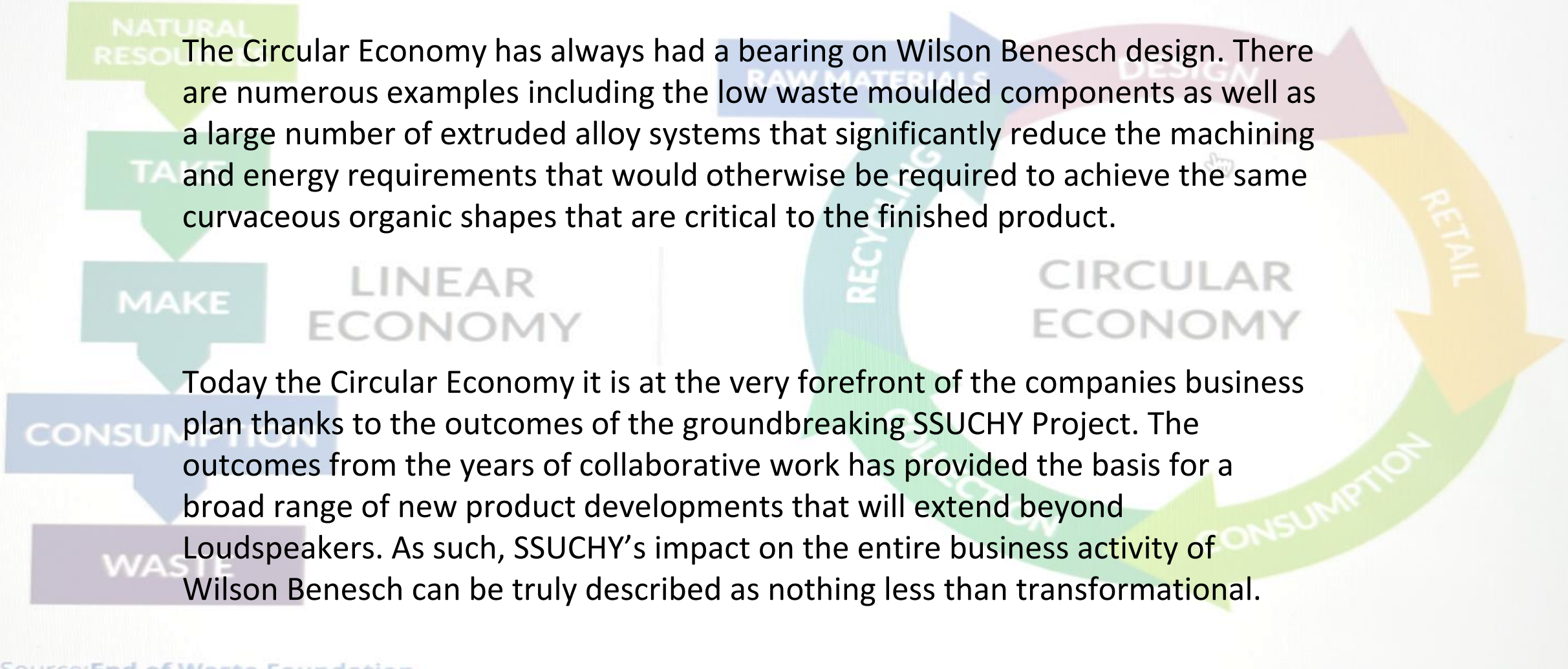
Wilson Benesch uses state of the Art Dassault Software as well as Generative design techniques that exploit super-computers to develop its components which are then manufactured within its extensive CNC machine shop or within additive manufacturing technologies.

The moulding technologies that are required to manufacture the composite systems are also created by Wilson Benesch engineering. This uniquely capability would be central to meeting the challenges of the SSUCHY Project.

WILSON BENESCH & THE FUTURE OF MANUFACTURING

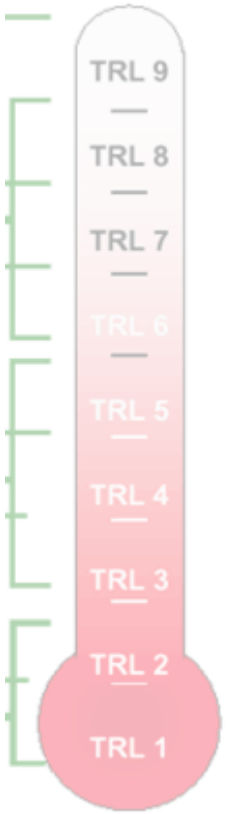
The Circular Economy has always had a bearing on Wilson Benesch design. There are numerous examples including the low waste moulded components as well as a large number of extruded alloy systems that significantly reduce the machining and energy requirements that would otherwise be required to achieve the same curvaceous organic shapes that are critical to the finished product.

Today the Circular Economy it is at the very forefront of the companies business plan thanks to the outcomes of the groundbreaking SSUCHY Project. The outcomes from the years of collaborative work has provided the basis for a broad range of new product developments that will extend beyond Loudspeakers. As such, SSUCHY's impact on the entire business activity of Wilson Benesch can be truly described as nothing less than transformational.



THE APPROACH (TRL 2)

2017



After discussions on how to approach the project it was agreed that a number of systems or “twins” would be required. Twins would provide direct comparisons to be achieved that would inform the team. By understanding the differences between the old and the new materials a specification could then be created and a fully operational A.C.T. One Evolution speaker built that could then be used to validate the predictions. The first Twin was built using oil based materials and shipped **August 2017**. In addition, a multiple number of Carbon Monocoque samples were also provided to Professor Morvan Ouisse of the Femto Institute in Bescanson.

The Femto Institute team would subject the Loudspeaker and the material samples to structural vibration analysis in order to create the mechanical characteristics of the first twin. Using Finite Elements analysis it has been possible for material content of the numerous iterations of Bio Composite systems to be predicted prior to being produced by Wilson Benesch.

MODULAR DESIGN

After several years of R&D the Original A.C.T. ONE Loudspeaker introduced the **Modular System** to the loudspeaker design vocabulary in 1994. The Modular System is radically different to the ubiquitous **Monolithic** design approach. The Modular design facilitates evolutionary improvements with each design building upon the strengths of its predecessor. The concept is founded upon a large number of interconnecting, complex geometrical, finished parts. The original A.C.T. One used individual sides comprised of Pre-preg carbon with a Nomex core which was demonstrated to be superior to aluminium honeycomb. It was superseded by the Carbon Monocque after a PERA Ltd led collaborative R&D project. A handful of organisations were working with RTM in the U.K. at this time. The Monocoque is a key part in multiple designs that are able to evolve and improve in accordance with technological advances much like a Porsche 911

IMPORTANT ADDITION TO PLAN OF WORK

AUTUMN 2019

MEETING AT TARBES

The monocoque is far more complex than a simple flat panel. For this reason it was proposed that the consortium should accelerate the work by using the Precision as a research tool. The proposed work would not displace the agreed commitment to the project of developing the replacement for the Carbon Monocoque which would be key to the commercialisation of the Bio Composites. It would instead be an additional block of work. The proposal was agreed and Wilson Benesch committed to providing the flat panels and Precision Loudspeaker Twins to the Femto Institute at the earliest opportunity.

VACUUM INFUSION ROOM AND EQUIPMENT

A room was dedicated to the Infusion process with cutting table roll holders and materials storage facilities.

In order to create the flat panel an 2m x 1.3m water heated aluminium vacuum infusion table was built with a glass surface. The silicon bag frame was fabricated from steel and a 2mm silicon bag with entry and exit point facilities for both vacuum and infusion inlet. A 3 phase water heating system enabled both heating and cooling.

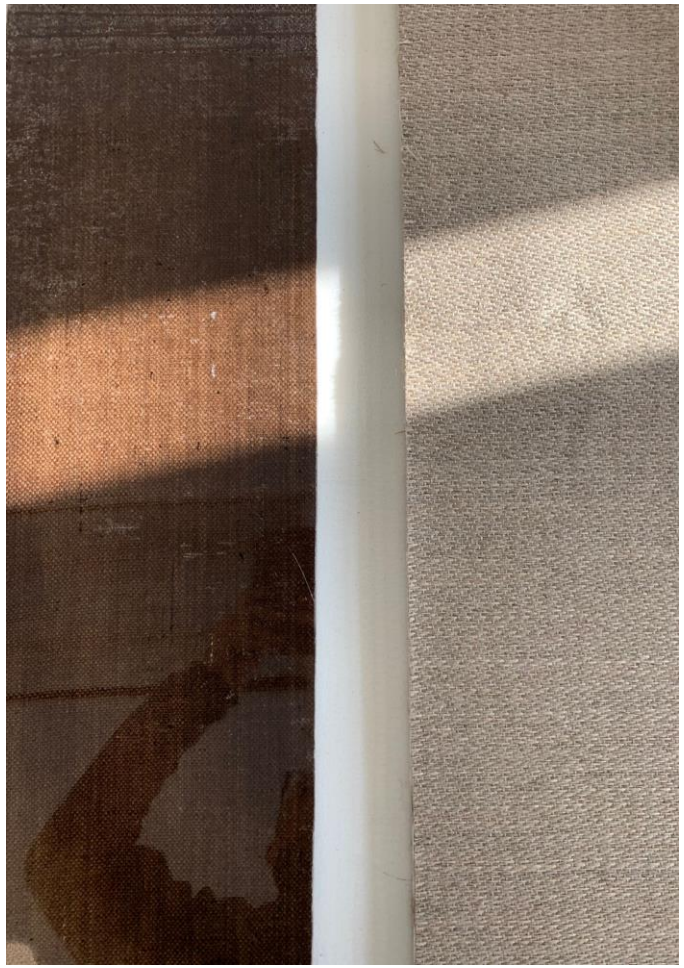
Matrix Composites in Bristol provided all the bio resin materials and Armacel P.E.T.

The images of the finished moulded parts shown on the next slide were taken on **September 2nd 2019**.

PET & SSUCHY FLAX DRY PACK ON HOT PLATE

VACUUM INFUSED BIO COMPOSITE SANDWICH

COMPARISON OF DRY AND FINISHED PARTS



C19 IMPACT

Wilson Benesch adapted very early to new working practices in **February**. SSUCHY relevant changes.

- Additional premises were rented that would provide double the floor space in **May**.
- With new working cells and reduced vector points and clear protocols all staff were able to continue work throughout all the lockdowns.
- All the VRTM including all the post processing plant and equipment was relocated into new facilities within the new building.
- The new VRTM rooms were built to provide for full temperature control and extraction.
- Although some delays were impossible to avoid the work on SSUCHY was not severely impeded.
- The image to the right is dated **March 23rd.**

PRECISION RESEARCH TOOL (TRL 3)

The Tarbes decision in **March 2019** allowed the Test Tool to be realised in less than a year and within months of receiving the first materials from Linificio Italy. The fully working models and component parts were shipped to the Femto Institute in **August 2020** amidst the height of the COVID restrictions in the U.K.

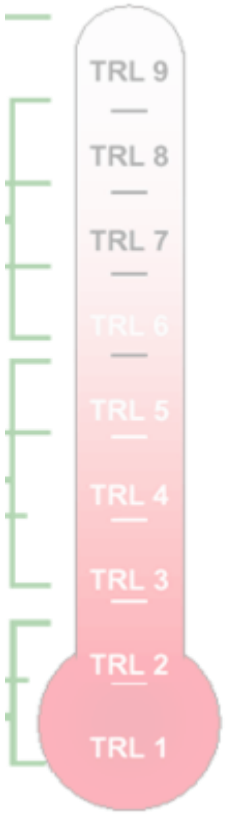
1 Plywood system and 1 Bio-Composite, (twin systems) enabled the first analysis of the behaviour of the new materials and provided the team with some early indications of the quantity of materials that would be required to match the mechanical properties of the oil based systems of the Monocoque

INFRASTRUCTURE - THE SHIFT FROM OIL BASED TO BIO BASED VRTM SYSTEMS

The new premises allowed Wilson Benesch to reduce the processing margin for error by a number of important actions some of which are highlighted below:-

- A new temperature controlled working environment with full extraction.
- The complete refurbishment/ recalibration by Composite Integration LTD of the CiJect injection system which had to move from processing oil based materials to totally different Bio-Based resins with completely different parameters for processing.
- The cutting facilities for preparation of the many different bio materials and recycled materials that would be required to create the different systems.
- Systems for moving 250kg barrels of resin.
- All the plant required for post processing including horizontal bandsaw, vertical bandsaw, Milling machine fitted with Diamond trimming wheel.

ANALYSIS TRL 4



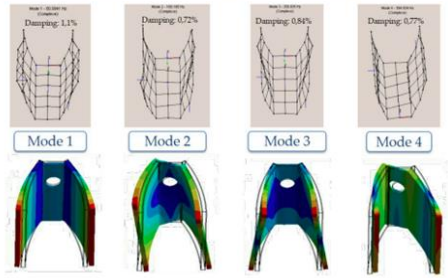
3D Finite Element analysis was used to predict the behaviour of the monocoque at the Femto Institute. The image to the right is one example of the kind of data that was subsequently harvested by Professor Morvan Ouisse and his team from the actual structures. Being able to validate the predictive model is critical to the optimisation process. Being able to predict how to improve the next monocoque will respond to acoustic excitation enables the iterative optimisation process.

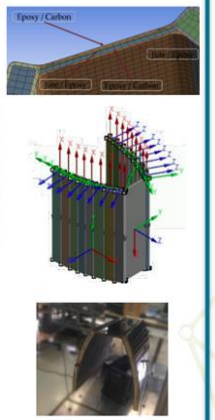
BACK TO ACT ONE PROTOTYPE

Replacement of current monocoque used in WB ACT ONE by a SSUCHY monocoque

Use of results from experimental modal analysis for (3D) FEM updating of reference structure

FEM		Experiments / Reference ACT ONE (petro-based)	
Mode #	Natural frequency (Hz)	Natural frequency (Hz)	Modal damping (%)
1	79.4	80.0	1.10
2	163.6	160.0	0.72
3	247.8	258.9	0.84
4	331.9	394.8	0.77
5	457.3	493.0	0.85
6	714.9	756.2	1.80





Experimental setup for vibration tests

✅ Good correlation obtained, FEM validated for SSUCHY-based material design of the ACT ONE

Updated skin properties from FEM sandwich model

Reference monocoque mass=1.57 kg, Static stiffness = 12.8 N/mm

3mm H4 skins / 12mm PET core mass=1.24 kg, Static stiffness =15.75 N/mm

3mm FGUD 4 skins (90°, 0°, 90°, 0°) / 12mm PET core mass=1.53 kg, Static stiffness =15.5 N/mm

Exp. Reference ACT ONE		3mm H4 skins / 12mm PET core		3mm FGUD/ 12mm PET core	
Mode #	Natural frequency (Hz)	Natural frequency (Hz)	Shift (%)	Natural frequency (Hz)	Shift (%)
1	80.0	70.5	-11.8	74,33	-7.1
2	160.0	144.1	-9.9	127,9	-20.1
3	258.9	249.7	-3.5	214,4	-17.2
4	394.8	371.4	-5.9	380,6	-3.6
5	493.0	477.5	-3.1	449,2	-8.9
6	756.2	831.2	+9.9	784,22	+3.7

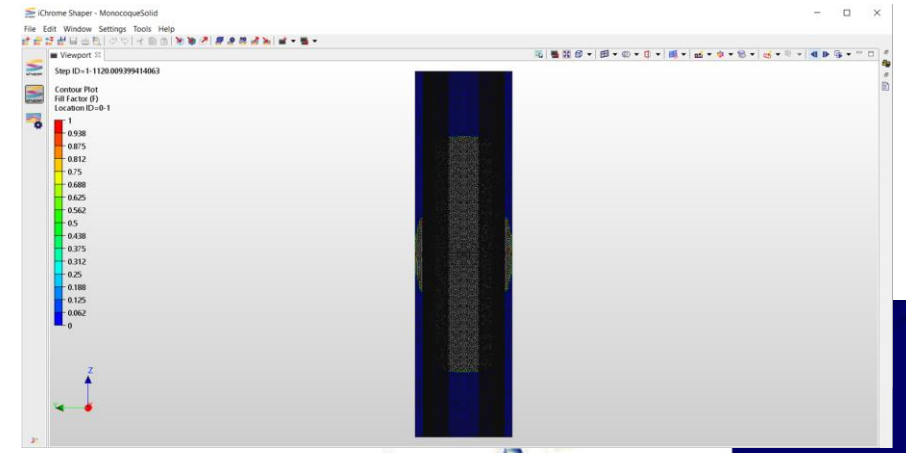
✅ SSUCHY materials can provide similar mass & static stiffness. Damping is expected to be x2.

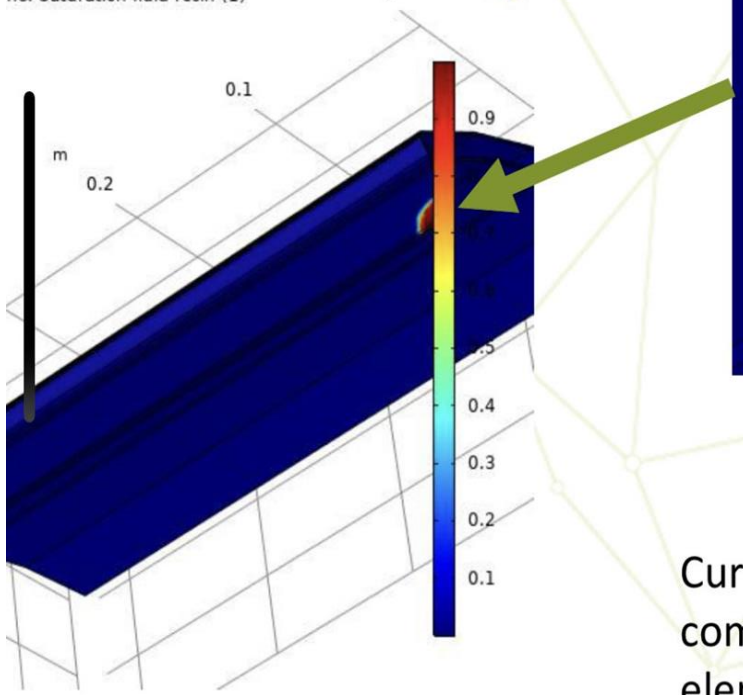
⛔ Keeping 3mm thick skins will result in a reduction of the first eigenfrequencies (that could even be increased by a reduction of the mechanical properties due to the manufacturing process). Thicker skins are recommended.

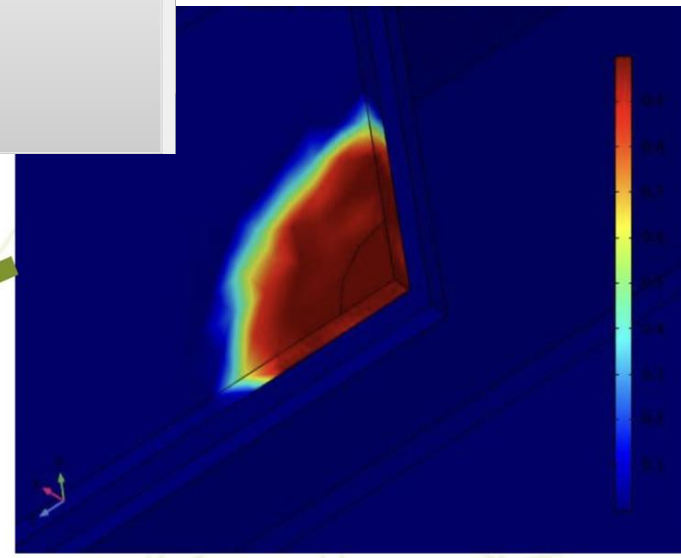
ANALYSIS

Infusing resin is a black art. However, thanks to the pioneering work by Professor Fabrizio Scarpa and Dr Chrystel Remillat of Bristol University it was possible to “see” for the first time how the resin would flow.

There are many variables in VRTM temperature, viscosity, permeability for example. Being able to predict the processing parameters required by the new materials significantly reduced the development time and the loss of very limited / expensive materials. 3D Finite Element analysis was then invaluable in many ways.

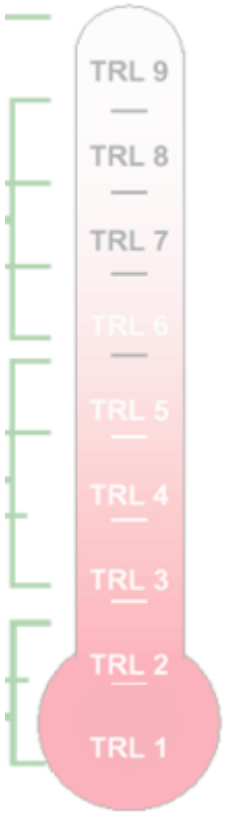






Currently looking at HPC facility to complete RTM solution with 3D FE elements

A.C.T. ONE E / BIO COMPOSITE TWIN. (TRL 7)



The Hemp Fabric arrived at Wilson Benesch in **August 2021**. The VRTM system was working non stop for several weeks to achieve the earliest useable systems which were then supplied for production of the A.C.T One E twin.

The assembled system plus numerous additional test components were shipped to the Femto Institute **October 2021.**

Image right shows the A.C.T. One E top box of the system with PET core side wall.

MONOCOQUE PRODUCTION

The slide shows the end view of the Monocque after the end caps have been removed.

It can be seen that this component is comprised of different core materials. This is one of many components with different constituent parts that were provided to the Femto Institute in order to gather data on the behaviour and subsequently enable the full optimisation the Monocque system.

POST PROCESSING CHALLENGES (TRL 8)

Post processing challenges. required new techniques and cutting tools.

The large image presents one of the biggest issues. The mould tool required alterations to the geometry to reduce the trimming to the absolute minimum.

Image far right shows how even basic sawing is more challenging.

SUMMARY

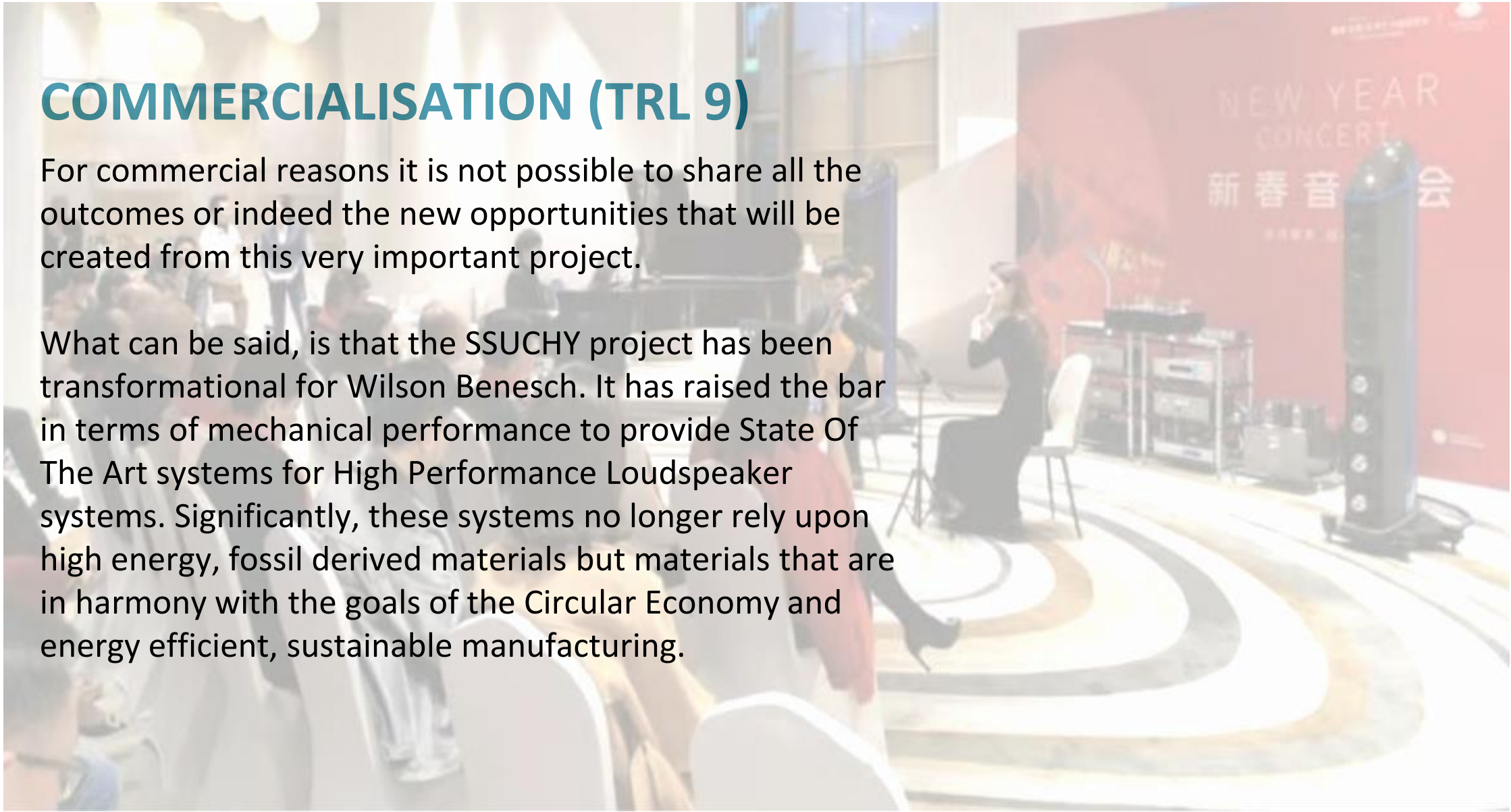
The new structures developed out of SSUCHY should be described as a **Next Generation** materials science, as they are capable of achieving similar mechanical properties to Oil-based systems, while at the same time delivering significantly (Orders of magnitude) superior damping capabilities. Moreover, the possibility now exists for a degree of tuning of the structure that was not previously possible.

The audio industry is a relatively small market, however the results from this work could lead to many new applications in a multitude of other industries. As the world races to move away from fossil-based materials science to the new Bio-Economy, the work that has been accomplished as a result of SSUCHY will undoubtedly provide a significant contribution towards the goals of sustainable manufacturing and the aims of the Circular Economy.

OUTCOMES

“The SSUCHY project team has been able to not only meet the aims and objectives set out in the original Project Plan, but to also go well beyond this to achieve market-ready finished parts (TRL 9)”

Craig Milnes,
Design Director: Wilson Benesch



COMMERCIALISATION (TRL 9)

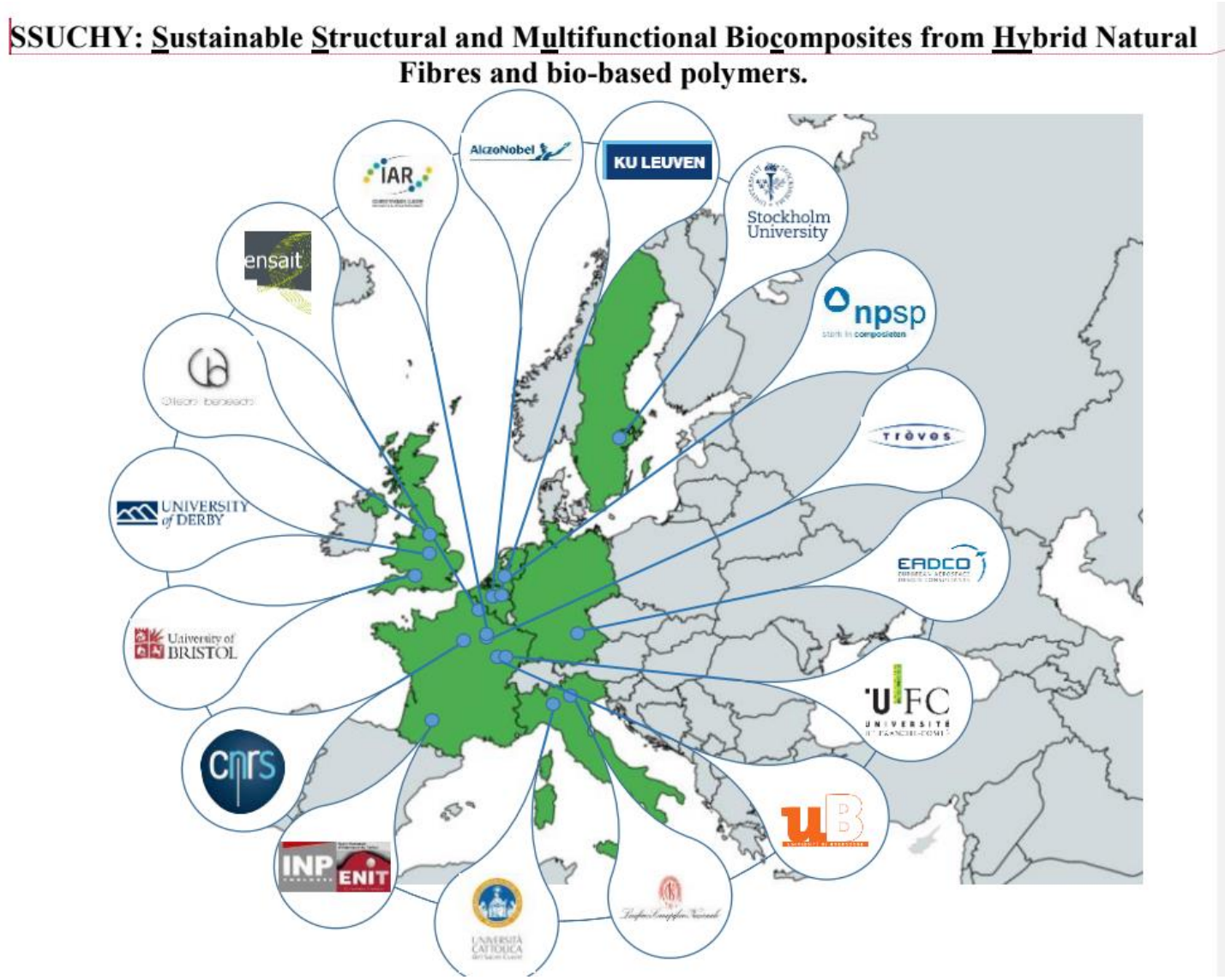
For commercial reasons it is not possible to share all the outcomes or indeed the new opportunities that will be created from this very important project.

What can be said, is that the SSUCHY project has been transformational for Wilson Benesch. It has raised the bar in terms of mechanical performance to provide State Of The Art systems for High Performance Loudspeaker systems. Significantly, these systems no longer rely upon high energy, fossil derived materials but materials that are in harmony with the goals of the Circular Economy and energy efficient, sustainable manufacturing.

THANK YOU

To all the Partners for your support in this Project.

In particular to Vincent Placet and his Team, Professor Fabrizio Scarpa and team and Professor Morvan Ouisse and team.



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for Research & Innovation

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