3.1 Publishable summary

3.1.1. Summary description of project context and objectives

ECOSHELL is concerned with the development of optimal structural solutions for superlight electric vehicles (category L6 and L7e), decreasing its environmental footprint and using an innovative bio-composite material for the vehicle body.

However, a body car lighter than 100Kg can allow the electric vehicles to have acceptable performances at an affordable price, due to lower power of the engine and lower energy consummation. This project aims at handling the first two major draw backs (production cost and safety) while further improving the associated environmental advantages via the application of innovative biodegradable materials for the vehicle body.

ECOSHELL partners work at the same time on:

- **The material**: finding the best material for such application: natural fiber, resin and glue
- **The structural parts**: defining the optimum geometry and architecture of the body and the optimum shape of the different parts
- **The vehicle**: defining the optimum shape and architecture.

The work is carried out throw three subprojects:

- **"Manufacturing"**: Manufacturing the material, manufacturing and assembling the parts of the body and assembling the car.
- **"Live cycle"**: Finding materials whose properties are in accordance with the vehicle live cycle, defining the parts of the body responding to the constraints of the vehicle live cycle and defining the vehicle, testing it against torsion, flexion and crash.
- **"End of live"**: defining the end of live for the material, the structural parts, and the car (disassembly)

3.1.2. Description of the work performed since the beginning of the project and main results achieved

Since the beginning of 201, the ECOSHELL partners started working, as expected, simultaneously on the three parts of the project: the materials, the structure and the vehicle, by focusing mainly on the main elements of each:

For the material research area, the main objective is to find materials of vegetal origins having potentially mechanical properties allowing them to be used in structural applications, and being able to be implemented thanks to the compatible processes with the constraints of the automobile: moderate cost and high rate of production. During this first period the consortium became especially attached to these two constraints: mechanical properties and process of production. Other requirements will be studied during the next period.

For the structure research area, the main objective is to build a structure whose mass does not exceed 80 kg, having a good steepness in twisting flexion, and geometry of parts compatible with the process of production, making possible the assembly of parts. This will allow having a first digital mock-up.

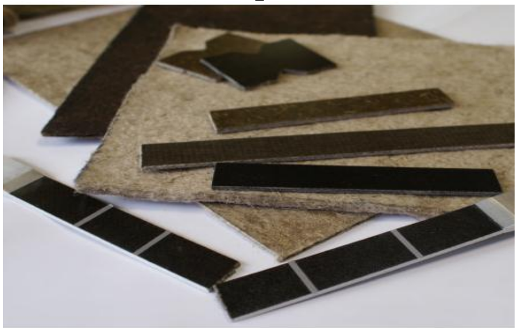
For the vehicle research area, the main objective is to realize the first digital mock-up of the vehicle, allowing us to make a first weight assessment and integrating the various versions of structures. This model has to allow us to describe the first diagram of assembly of the vehicle and define, for each post of assembly, the maximum time for the operation in order to reach the wished rate of production.

3.1.2.1. Work performed on the material research area

Research on natural fibers and resins

An important research work on fibers and natural resins was realized by the partners (VTT, MAHYTEC, CSIC, Fraunhofer, ENSTIB, Cranfield and CADLM). All these research works were gathered in two reports: *D2.1: Market review, characterization of existing materials and potential improvements, into new materials* and *D2.2 Investigations, process and tools.* They allowed selecting those materials most in agreement with our structural application and eliminating quickly the bio-sourced materials, whose performances are too far from our objectives. We decided to study: flax and hemp, two European natural fibers, bio-epoxy, polyamide, furanic and wood tannin based resin for the matrix.

Realization of samples and tests for the characterization:



On the basis of these researches, the ECOSHELL partners launched a campaign of tests allowing to estimate the composites realized with these materials according to the chosen processes. To feign parts coming from the SMC process we realized patches made with:

- Short fibers with rowing of flax and hemp + resin (Epobiox, PA, Furanique, tannin) 50/50
- Web of non fabric by flax or by hemp + resin (Epobiox, PA, Furanique, tannin) 50/50

These short or non-fabric fibers impregnated with resin will shape easily during the thermo compression allowing us to obtain the final part. The long fiber lends itself less to the thermo-compression and will rather be used with the technology RTM, allowing to obtain more raised mechanical performances. To estimate these performances, we realized patches of unidirectional and bidirectional weave impregnated with resin (Epobiox, PA, Furanique, tannin) 50/50.
With the RTM technology it is possible to realize sandwiches by placing foam between two patches of composite. We thus realized samples of foams on the basis of tannin resins and furanic resins. These foams can also contribute to the improvement of the performances of the SMC structure by being expanded in the hollow bodies formed by two SMC panels. Finally, samples of sticking plates have been realized to estimate the holding of the sticking: epoxy glue on epoxy resin, glue of tannin and furanic for natural resins.

Conclusion:

These first works allowed us to focus the material research area of our project. By keeping in mind the constraints of cost and rate of production imposed by the car industry, we had to design parts realized in SMC or RTM, at low cost. To realize these parts the materials which appear the most relevant are:

- **Flax fibers** for their mechanical characteristics, **hemp fibers** for their moderate cost.
- **Furanic resins and wood tannin based resins** for their cost and, belonging to the family of the phenolic, for their potential mechanical properties, their temperature resistance and their resistance to outside attacks.

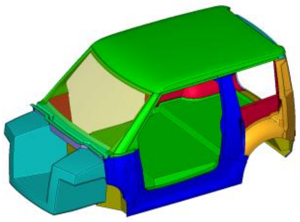
Parts bearing low constraints can be realized in SMC with short fibers stemming from the rowing of hemp or of non-weaved flax. Parts bearing intermediate constraints can be realized in SMC with short fibers outcome of rowing of flax. Parts bearing important constraints can be realized in RTM with the fabric flax fiber, unidirectional and bidirectional. Foam and glues will be based on furanic and/or tannin of wood. The realization of samples and tests allowed us to define a fictitious material achieving the wished mechanical properties, which serves as reference material for the calculation works and for the optimization on the vehicle structure.

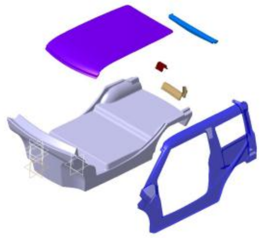
3.1.2.2. Work performed on the structure research area

Before the beginning of the project, CERGI started a definition of an electrical car able to receive a structure in composite: The Citi-zen. Thanks to the architecture of the vehicle and the numerical definition of its esthetical shapes, CERGI realized the digital definition of the assigned volume of the structure removing all the volume used by the others functions of the car. This volume is used to realize first trials of twisting and flexion to analyze the ways of the constraints in this volume.
In agreement with Fraunhofer, GERGI chose to design a first structure exclusively realized with the SMC technology. This structure realized with about 20 parts was given to the partners in June, 2011. It is in evaluation by the partners today by taking as characteristic material the fictitious material defined in the part material of the project (CADLM, GRM and Cranfield). Fraunhofer finalized the evaluation of cost and the feasibility of each part. From month 6 begin the definition of a structure fully made with RTM technology (7 parts). The evaluation of the feasibility and cost is today in progress with Fraunhofer.

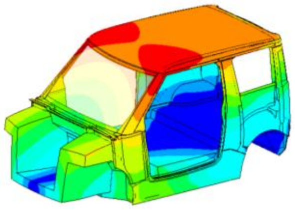

CITI-zen

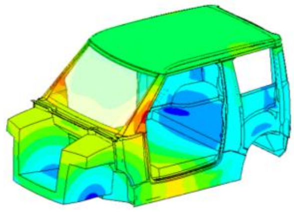

assigned volume

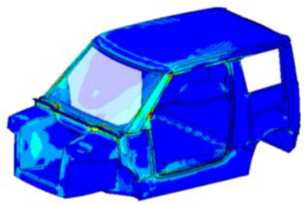

SMC BIW


RTM BIW

Work perform by GRM *"Baseline Assessment of ECOSHELL BIW"*


Static Torsion


Static Bending

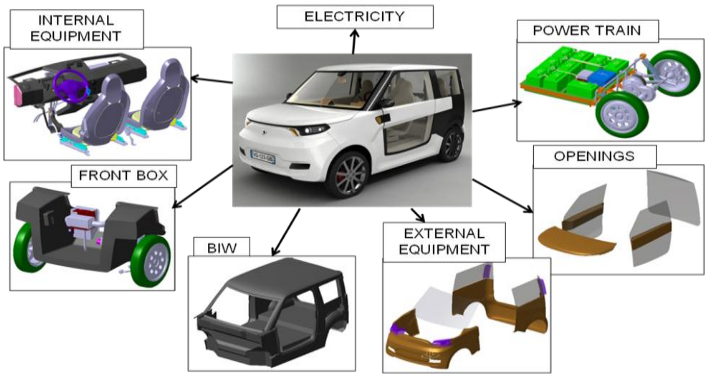

Linearised Front Crash

A baseline assessment of the ECOSHELL BIW has been performed in preparation for performing design optimisation studies. The baseline performance is encouraging; however, further development will be required in order to achieve the target stiffness defined. In addition of the SMC panels, foams had been added, the weight achieve without any optimisation is close to 100Kg.


Floor, Cowl and Roof foams

Conclusion:
The structure of the CITI-zen could be possible with a full SMC parts assembly, adding thee foams and with a material witch young modulus is 15GPa. The weight of this structure is close to 100Kg with a density of 1200Kg/m3. These results had been achieved before the optimization phase.

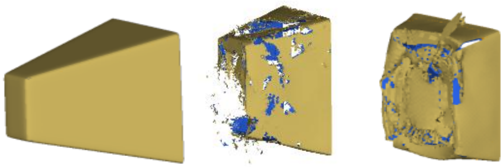
3.1.2.3. Description of the work performed on the vehicle research area:



The definition of the electrical car the CITI-zen realized by CERGI, a numerical mock up of the vehicle, has been designed and was available on September 2011. This numerical mock-up represents the first digital model corresponding to 60 % of the definition of the vehicle. The vehicle was divided into 6 perimeters with an objective of weight for each perimeter.

A bill of materials was informed and a first evaluation of the mass of the vehicle was realized. Every perimeter of the vehicle will be optimized to reduce the mass of the vehicle, and will evolve according to the needs of the structure. Finally, thanks to this first digital model, a first range of assembly of the vehicle was realized and the first requirements on mounting and assembling the vehicle have been written.

An important task has been performed on the front crash box, working on the stabilization of models and evaluation of the energy absorbed during the crash:



Nose-cones crash trials

Conclusion:

Regarding the current bill of materials of the car, we have an evaluation of weight of about 460Kg, which is quite close to the target. The energy absorbed by the first concept of crash box is quite close to the amount of energy we have to absorb during the front crash. These results are really encouraging and seem to show that the objectives of our project are achievable.

At the end of the project we expect to:

a) Have defined the formula and protocol of implementation for a new bio-based composite made of flax fibers and furan resin and/or tannin of wood based resin usable with SMC and RMT technologies for structural purpose. This material, using longue fiber (non-woven or woven) or short fibers may have an average young modulus close to 15GPa and a strength resistance close to 150MPa. This will allow:

- New European production of tannin of wood giving an additional value to the exploitation of forests and wood
- New European production of furan resin, allowing to value the waste treatment of the food-processing industry.
- Maintaining the European linen production by providing this sector with new outlets
- Giving the European composites sector new perspectives by producing materials in agreement with the legislation on the COV emission.

b) Have characterized and fully understood the behaviors of these new materials in numerous different conditions. This will allow:

- Having a real validation using numerical tools
- Proposing this material to different sectors like rail road, aeronautic, boat, trucks, street furniture, etc.

c) Have demonstrated the feasibility of the body of the vehicle. This will allow showing the interest of this material for a structural use.