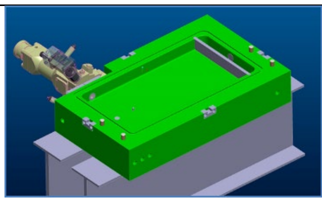
Action D2: Description of the activities undertaken and the results achieved under each Action

1.1.1. Action A: preparatory actions

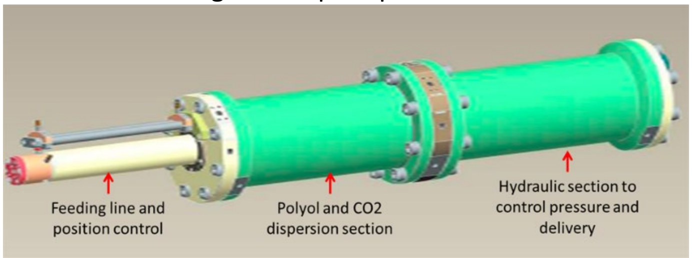
1.1.1.1. Action A1: Lab Testing and Parameter definition

Activities	- Preliminary pilot plant assembly at Afros facility - Foaming trials with CO_2 as blowing agent in different physical states - Metal-metal refrigerator structure approached. -Autoclave reactor v. 1.0 set up in Correggio Lab by DOW
Results	- Supercritical conditions are not needed during k12 foaming process at pilot plant. - Full metal refrigerator design coupled with a plastic thermal bridge breaker and a structural adhesive is required to implement the technology Reports on the results submitted as Technical Annexes to the Midterm Report
Schemes	Example of the design of the mold for k12 doors 

1.1.2. Action B: implementation actions

1.1.2.1. Action B1: Design of Pilot plant

Activities	- Autoclave batch foaming experiments at Dow Correggio laboratory - Dow collaboration with the external research institute ICBP - Additional foam fundamental studies with Dow Core R&D - Preliminary pilot plant equipment designs - Cabinet prototyping designs - Studies on refrigerator structure
Results	- Implementation plan agreed among the partners - Preliminary foaming process parameters defined - Preliminary design of pilot plant components and layout Reports on the results submitted as Technical Annexes to the Midterm Report

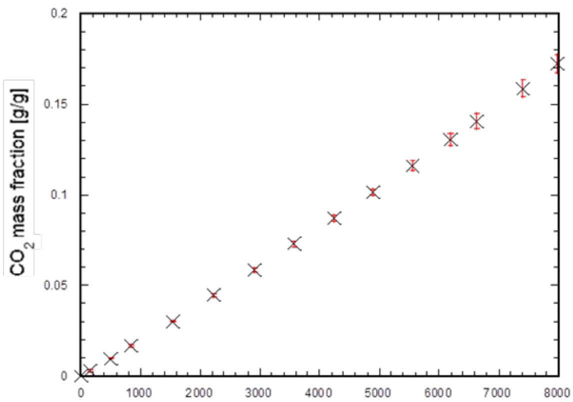
<table>
<tr><td>Comments</td><td>Dos-Mix unit designed for pilot plant solubilization of CO_2 in the polyol

</td></tr>
</table>

1.1.2.2. Action B2: Construction of Pilot plant and optimization

<table>
<tr><td>Activities</td><td>- Pilot plant realized and properly installed at Afros facility including high-pressure machine, batch cylinder for polyol/carbon dioxide sorption, high pressure mixing head, reaction accumulator, and mold.

- Additional pilot plant equipment component designed, realized and set up
- Pilot plant startup, four PU formulations tested
- New in-situ FT-NIR spectroscopy installed on ICBP laboratory reactor.
- Design and modeling of vacuum K12 door
- Design of standard production door
- Design of small K12 refrigerator
- Design of an improved version of an autoclave in Correggio Lab

- Design of the pilot line

- study on Vacuum / Tight issue to ensure vacuum tight on the entire structure</td></tr>
<tr><td>Results</td><td>- Pilot plant start up and foaming process parameters set up
-Pilot plant can solubilize up to 50% of CO_2 in the polyol and stand pressure up to 200 bar
- Molds, one reactor and a press with defined geometry designed were crafted</td></tr>
<tr><td>Schemes</td><td>Sorption Isotherm of the CO_2 in one of the polyol tested to achieve a perfect control of


the CO_2 blended in the polyol</td></tr>
<tr><td></td><td></td></tr>
</table>

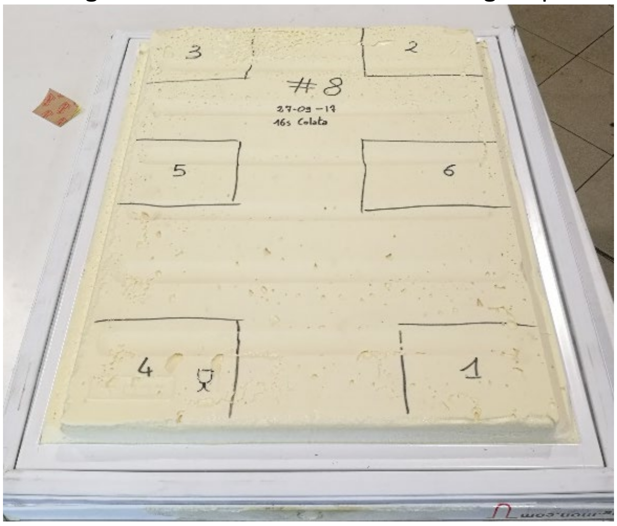
1.1.2.3. Action B3: Realization of proto-typing

Activities	According to new prototyping plan: - Laboratory foamed prototypes were realized in collaboration with ICBP at their small reactor in Naples. - Two hundreds 2D square foam prototypes were produced at pilot plant with four different polyurethane formulations - Fifteen foams prototypes with the additional batch foaming reactor installed in the pilot plant were produced with three different polyurethane formulations - Over 60 foam prototypes were produced with a 3L reactor mold to understand the effect of CO2 degassing process -Over 40 commercial standard door were foamed with k12 material to understand the behavior of the material in a commercial used mold -VIP panels were produced both in Correggio Lab of Dow and by an external validator (FIW) - 4 k12 sealed door were produced for under vacuum testing. -2 refrigerator were built with two manually with panels molded in the k12 door mold. -Studies on redesigning the cooling circuit to adapt to K12 requirements and on thermal design of the structure have been realized. -Prototypes have been designed to respond to all the specifications and requirements set up during project implementation, both at the laboratory and simulation level.
Results	More than 200 laboratory and 2D pilot plant foam prototypes produced, different testing condition explored with 3L reactor mold, the flowability and filling properties of the material have been studied for a commercial refrigerator door. Such huge amount of data helped us to reshape the process to achieve the goal. Door able to be kept under vacuum were produced A small refrigerator model has been designed and prototyped. The small size of the refrigerator assures avoiding any problem with the maximum capacity of the foam tank installed in the pilot plant and, in any case, guaranteed the possibility to proper demonstrate all the objectives and results of the K-12 project Details of the porotypes are explained in the Deliverables.

Comments	• 2 D prototype molded in the press	

1.1.2.4. Action B4: Prototypes Testing and Validation

Activities	Foam lab and 2D pilot plant prototypes testing: - density, open cell content, cell size (SEM instrument bought), - thermal conductivity profile versus vacuum level: Reverse Heat Leakage test (RHL) - Vacuum insulated Panels production and testing -Foam aging under vacuum test on doors and cabinets
Results	- At pilot plant two formulations give cell size of 40-60µm at density 130 g/l 150g/l: they still remains closed cell system hindering application of vacuum. Two formulations show an open cell content of 70-95% with 150-250 µm cell size distribution). These samples are tested under vacuum condition. - Measured foam thermal conductivity of 9mW/mK at vacuum level <1 mbar was encouraging for project success. - Equipment for vacuum insulation panels installed at Dow laboratory - New laboratory set up for vacuum testing at Whirlpool - External validation of the foam properties under vacuum - The results confirmed the data delivered by DOW, that means the formulation **24** (90 g/l at 0.2 mbar) has an approximate K(thermal conductivity) of 20(0.02 W/m°C), that is, the same as the standard foam (c-pentane). - The level of vacuum reached (see figure) is below the target level and however the K coefficient is high, according to DOW this is due to the density of the foam.

Comments	Commercial Refrigerator door full foamed with a rigid open cell material 

1.1.2.5. Action B5: Technology Industrial Validation and Refinement

Activities	- A chemistry development level as attested by the work of the Naples University and by the final success of the Dow Lab in producing samples of foam with cell size lower than 10 microns I the reactor modified and adapted in cooperation with Afros. - A mechanical and technological level attested by the degree of novelty and the success in designing , producing and using the machines composing the pilot plant and devices produced and used by the Afros Lab in cooperation with Dow and Whirlpool - An important and difficult step in the technology of producing and sealing a domestic refrigerator in a way suitable to be insulted by vacuum performed by Whirlpool.

1.1.3. Action C: Monitoring of the impact of the project actions

1.1.3.1. Action C1: Monitoring of project impact with respect to environment and LCA

<u>**Activities**</u>	The K12 team set the ground for LCA collecting foam and process data vs. reference (ENERG-ICE, the best PU insulation technology available in the market): -PU foam cell size, density, k-factor at ambient pressure and P<Pamb -Amount of Blowing Agent and GHG emissions -Process safety and energy included in the various steps This activity is entirely described in the Deliverable C1.1

1.1.3.2. *Action C2: Monitoring of project impact with respect to market and target audience*

Activities	Segments of interest beyond Domestic Appliance Refrigerators were chosen in agreement with all partners, the Technical Insulation segment of Refrigerated transportation has been selected for a first replication potential exercise.

1.1.3.3. *Action C3: Assessment of Socio-Economic Impact*

Activities	Refrigeration market analysis has started collecting data from CECED, the European Association of Domestic Appliance producers, and.
Results	Part of the data collected were shown the Mid Term Conference event held on May 18th, 2017

1.1.4. Communication and Dissemination actions

1.1.4.1. *Dissemination actions*

Activities	Beyond the achievements of technical and environmental objectives, the project partners are fully committed to disseminate results of the project, demonstrating the LIFE K-12 technology as one of the best-performing technology (or the best) available on the European and global market and showing the next competitive level for eco-design of CO2 blown foams for the Cold Appliance sector, in the spirit of art. 15 of Directive 2005/32/EC regarding the Eco-design of Energy using Products. For the communication and dissemination purposes, the following activities has been conducted during the whole Project implementation. 1. Definition of the Project Message and logo 2. Definition of project templates 3. Brochures and Posters 4. Notice board 5. Newsletter 6. Participation to Italian and European conferences /exhibitions 7. Publications 8. Midterm workshop 9. Final Event

1.1.4.2. *Website*

Activities	- Website created http://www.dow.com/en-us/k-12 and regularly updated - LIFE K12 Inner Section created and regularly used by partners based on Google Drive - Regular newsletters published on the site

1.1.4.3. *Layman's Report*

Activities	The Layman's report describes the project results in terms that are more accessible/readable to persons that are non-expert in the field of Chemistry and Cold Appliance manufacturing industry. The report has been produced at the

	end of the project, in paper (100 copies) and electronic version (in Italian and English), and it was distributed during the Final Event.

1.1.5. Project management and monitoring of the project progress

1.1.5.1. E.1 Technical and financial management

Activities	- Kick off meeting in Correggio; - Regular monthly meeting organized mostly at Afros facility; - 2 external monitoring visits, one at Whirlpool and one at Afros. - set up of the procedures for coordinating, scheduling and monitoring activities; - set up of the procedures for costs tracking, recording and controlling; - 1 Inception Report and 1 MTR submitted to the EC. - WHPL organizational changes management - amendment request

1.1.5.2. E.2 Networking with other EU projects

Activities	The networking activities started with an inventory of the LIFE+ / LIFE 2014-2020 and other EU databases (i.e. Eco-Innovation, Intelligent Energy Europe, FP7, Horizon2020) on the on-going or recently completed projects dealing with environmental impact reduction and a more efficient use of the resources. The most relevant projects have been identified through key words (e.g., energy efficiency, circular economy, insulation, industrial process, LCA, home appliances) and preliminarily listed to put in place possible contacts for future partnership and synergies, taking into account the confidentiality issues towards competitors and categories associations. In parallel, the project partners has structured cross links with their other similar EU funded initiatives with a twofold objective: build the K-12 project on already existing knowledge and mutually exploit and share the best practices and lessons learnt during the projects execution. The projects included in the Networking so far are 13. .A detailed description of Networking activities implementation and main results is provided on the deliverable E2.1 Networking Activities Report, submitted with this report.