EUROPEAN COMMISSION
DIRECTORATE-GENERAL FOR RESEARCH & INNOVATION

Directorate I - Climate Action and Resource Efficiency
Unit I.2 – Eco-Innovation

Brussels, 31 March 2017

Report of the workshop "What makes a successful eco-technological European project?" Brussels, 20th March 2017

Wojciech Klimek and Petros Mamalis, DG RTD, Eco-innovation Unit – I.2

On 20th March 2017, the Environmental Directorate of DG Research and Innovation - Unit I.2 in cooperation with EASME organized in Brussels a whole-day-long workshop on "What makes a successful eco-technological European project".

Research and industrial project partners summed up experiences from successful FP7 eco-technological projects and presented their key aspects/success factors to the ongoing Horizon 2020 projects, especially to demonstration projects' consortia. The idea was to broadly display some key aspects of project implementation that are common to different eco-technological research branches, the stress being laid on the process engineering approach, on economic analysis of the developed solutions and on due collaboration between researchers and the industrial end-users. Aspects related to project structure and to process scale-up were also discussed. It was an occasion to make a further step to the widening and networking of eco-technological community, to enable direct contacts with other coordinators/researchers with the aim to generate new interesting project ideas and – for the Commission – to develop new approaches for the H2020 calls to come.

I. RESULTS OF THE WORKSHOP

In the workshop 31 participants took part (FP7 and H2020 projects' coordinators and partners from academia and industry, industrial RTO, companies and SPIRE representatives) plus twelve EC and EASME executive agency officers. Seventeen presentations were given, six of which by ongoing H2020 projects (see agenda attached).

Welcoming the audience, Mr. Wojciech Klimek, Research Programme Officer (RTD.I2) said that the objective of the workshop was to:

- discuss with the environmental programme's research community the success factors of exemplary FP7 projects were,

- share certain common, reproducible engineer's approaches that proved to be important for successful prototype development, often even in their further industrial uptake, in various areas of environmental technologies, be it in water, waste or different resource efficiency topics.

- pass in a way the baton to the EASME colleagues who are now implementing H2020 projects.

The opening presentation by **Dr. Bart Geerligs (ECN)**, the coordinator of **Cu-PV (www.sustainablepv.eu/cu-pv) project**[1]**,** underlined the importance of having a right mix of skills in the project consortium. In Cu-PV project, the specific partners pooled their complementary competences along the value chain of photovoltaic panels production and recycling. Their lean consortium succeeded in developing a set of technologies reducing markedly the rare metals

[1] See all projects presentations attached

consumption (and costs) in these processes, while retaining the current performance of the modules. Most of these processes, esp. regarding back contact cells technologies, will be developed further towards industrial applications. The project had to face a challenge of e.g. significant drop in PV modules prizes in 2010-12 due to the relocation of PV businesses to Asia, of relatively low value of materials to be recycled or of lack of "end of WEEE" regulations in this field.

Following three presentations showcased the benefits of a "process approach" in the design of different eco-technological projects. By regarding the envisaged sorting/processing plant as a flowsheet the researchers can easily see the process stages, their technical requirements, economic contribution to the profitability of the whole targeted technology, process windows and bottlenecks:

- **Dr. Jean Yves Escabasse (CEA)**, the former researcher of Papiertechnische Stiftung, Munich and coordinator of **SORT IT project**, discussed the development of the automated paper sorting plant tailored to the real, industrial requirements regarding the composition of the targeted fractions, their yields and purities. Their process design was so robust that the industrial partner decided to invest huge additional budget to develop directly a prototype 3-stage process of 2000 t/month throughput. It finally achieved above 3000 t/month industrial capacity, meeting consistently the quality criteria beyond those achieved in conventional manual paper sorting.

- **Dr. Francesco Di Maio (TU Delft)** – coordinator of **C2CA (www.c2ca.eu) project,** discussed the results of their successful attempt to solve the problem of recycling demolition concrete waste back into high-grade products. Through a successful adaptation and development of the earlier Advanced Dry Recovery (ADR) process[2], the C2CA project worked out a cost efficient option for each of the resulting fractions: coarse and fine aggregates, and fines. By respective modifications of concrete recipe they demonstrated that recycled aggregate can give concrete of similar mechanical strength and only slightly lower durability, while the finer fractions can be used in the construction material production or as a lime substitute in the cement kiln. The mobile ADR unit developed in this project is currently used at an industrial scale by their lead industrial partner STRUKTON. Their newly developed business model, based on eliminating redundant transport and ownership change costs, sets the standards in European CDW recycled concrete processing.

- **Dr. Liesbeth Horckmans (VITO),** coordinator of the **REFRASORT (www.refrasort.eu) project ,** discussed – on the example of their developments in the automated refractory bricks sorting and the excellent cooperation between technology providers, industrial end-user and refractory materials manufacturer – the importance of the product validation expertise that must support on a daily basis and verify in the end all the activities linked to assembling and commissioning the prototype in the end-user's premises. She emphasized also a truly "hands-on" involvement of the technology providers in the commissioning trials as a key to the success, and that projects should not be shy to adapt their work plans to actual developments..

Next, two cases of the process scale-up were presented by **Mr. Cesare Freda and Mr. Giacinto Cornacchia (ENEA)**. The first case came from **TyGRe (www.tygre.eu) project** that developed an energy-integrated process of spent tyre gasification and char conversion to silicon carbide, useful ceramic material, via a carbothermal synthesis in a plasma reactor. Namely this last process required extensive scale-up investigations in order to find a right way to good yields in a pilot scale. A patent application has been filed for the resulting solution.

The second case was related to a carbon fibres recovery from waste composites via pyrolysis of the polymer matrix in controlled conditions. The research was funded by Basilicata region as from 2000. Four stages of scale-up from laboratory batch process to a continuous industrial plant were discussed. After the continuous pilot stage, the patent licence was sold to a private company Karborek RCF who, winning the interest from aircraft industry (Boeing Company and Alenia Aeronautica) invested 4

[2] This centrifugal-force-driven classification process patented by TU Delft, overcoming the problem with moist fines, is used on a commercial scale for non-ferrous metals recovery from incinerator bottom ashes by Inashco BV, another TU Delft spin-off and C2CA project partner (http://www.iswa.org/uploads/tx_iswaknowledgebase/paper34.pdf)

MEUR (since 2009 onwards) in an industrial plant in Apulia recovering 770 t of carbon fibres per year.

In an "afterword" to the presentation of ENEA, Mr. Klimek (RTD) briefly explained the idea of process scale-up as elaborated in the chemical engineering showing a few examples of similarity criteria used in process scale-up different applications[3].

Next presentation, given by **Ms. Serena Sgarioto, Research Manager of RELIGHT** company, a leading Italian WEEE recycler, depicted their participation in numerous EU research projects like e.g.: FP7 **ILLUMINATE (www.illuminate-project.com),** (on automated lamp sorting) and **HydroWEEE DEMO (www.resoutech.com), RECLAIM (www.re-claim.eu),** and H2020 **REMAGHIC (www.remaghic-project.eu)** projects on rare earth metal recycling from WEEE. RELIGHT collaborates actively and systematically with different research teams hosting in their premises pilot scale lines and trials. Thus, the company benefits from the access to new technologies and process equipment, while the researchers' ideas get validated in an industrial environment. Ms. Sgarioto pointed out that volatile REE prices are an obstacle to the wider commercial recovery of these metals in Europe.

Next speech was by **Mr. Jaap Vandehoek, CEO of Urban Mining Corporation,** a spin-off company of TU Delft and a VC investor SynVase. He presented a spin-off company's viewpoint on process development towards commercialisation, on the example of industrial trials of the Magnetic Density Separation (MDS) process developed by TU Delft and the consortium of **W2PLASTICS project**. Hydraulic classification in a colloidal hematite suspension in an external magnetic field (parallel to the gravitational field lines) enables – via a vertical density gradient in the magnetic fluid – a simultaneous separation of heterogeneous input flows into several density fractions. Their density difference may be as low as 7 kg/m3 that the result of this process is in principle not influenced by size, shape or colour of the particle. Solids of density lower or higher than water may be separated in the MDS unit. Currently, small scale industrial trials are performed in Bucharest and 4 times bigger ones in the Netherlands. An interesting feature of the latter is that UMC's investments in operational costs will be repaid in 5 years. Mr. Vandehoek advised i.a. to consider the economic feasibility from the very start and to focus on large scale applications with a commercial potential big enough to cope with possible overruns on initial budget.

An interesting insight into a big industrial company's perspective in EU funded eco-technological research was given by **Mr. Pascal Dauthuille, Director of Projects of SUEZ Environment**, who discussed how the SUEZ group cooperation with academia/research centres looks like and also the specificity of management of industrial research project in comparison to the academic research. The three European research centres of SUEZ collaborate with European RTOs to collect emerging solutions that can be interesting for their business lines. Obviously, only pilot trials (TRL 5-6) and demonstrators (TRL7-8) are of interest. The participation in collaborative projects allows SUEZ to save 2-3 years of their internal research over a given solution and also to save resources for the "death valley" part of development. SUEZ main challenges & strategic paths are:

- Water (Reuse, Micro-Pollutants issues, Smart Plants and Cities, and Decentralised Treatment Plants)

[3] Interested readers may consult specialist literature e.g. http://www.gmpru.com/Process/ProcessScale-Up.pdf presentations e.g.: https://www.slideshare.net/jodoua/scale-up-challenges-in-chemical-engineering-the-role-of-chemical-engineers-in-the-21st-century
or take part in the dedicated conferences, e.g.:
https://scientificupdate.co.uk/index.php/conferences/conferences-and-workshops/details/283-scale-up-of-chemical-processes.html

- Recycling & Recovery (Waste Electrical and Electronic Equipment (WEEE), Construction and Demolition Waste (C&DW), Packaging waste in particular plastics and Organic Waste).

Selection of project ideas is severe (for the recent H2020 call SUEZ got 40 proposals to be a project partner). The process starts with looking for best ideas (in comparison to the state of the art, but also with a very good narrative), best partners and the best impact of the proposal (value for the company, esp. high TRL is required; also value for clients and value for policy).

About 7% of their R&D budget comes from EU funding, another 5% from venture capital.

Another block of presentations was dedicated to the multi-objective projects. For this purpose, 3 examples were given allowing for a comparison of project size, selected scope of research area and its diversity, and also number of partners:

- **Dr. Giuseppe Mininni (CNR – IRSA)** presented the **ROUTES project** dedicated to various aspects of sludge management. This project succeeded in bringing several processes to the pilot-full scale (e.g. in co-digestion with organic fraction of municipal waste, in ammonia stripping from liquid side-streams, wet oxidation, alternated cycles in water and sludge lines) and achieved important results in sludge safety indicators. Regarding the selection of right research topics he advised to consider aspects like a reasonable possibility for implementation on actual scale; breakthrough innovation vs innovative application of existing procedures (based on the sound knowledge of the state of the art); impact on regulatory side in terms of solving practical problems (not creating new ones); and selection of the best partners to carry out the chosen research. He stressed the importance of a very hard work by all the scientists and the coordinator, starting from the preparation of the proposal; good mix between research teams and (sectoral) SMEs; and a multidisciplinary approach. Executive Research Plan prepared by each partner before getting a coordinator's approval to start a given activity was recommended as a useful project coordination tool.

– **Dr. Bernd Kopacek (ISL)** compared his experiences of his coordinating a very large **ZeroWIN (www.zerowin.eu) project** (of 30 partners) on industrial networks to improve the resource efficiency in electronics, automotive, photovoltaics and construction sectors, with a more focused **HydroWEEE Demo (www.resoutech.com) project** (of 9 partners) on developing methods for REE recycling from various electric/electronic waste streams (see RELIGHT presentation above). He pointed out that a good consortium should have partners that are representing the complete value chain; no direct competitors in the same geographical area; a common vision/goal and it should not to be too large both in size and in variety of approaches to the topic. He stressed also the importance of the coordinator's ability to be a “translator“ between research and industrial partners and having also enough technical and market knowledge to follow the vision/implement the goals (so that he "guides and not only “administers“ the project"). Dr. Kopacek also listed as one main challenge in the latter project a radical change of market conditions (decrease in price for rare earth metals, LED replacing fluorescent lamps) that occurred during the project lifespan.

- **Dr. Lampros Koutas, (Post-doctoral Research Associate, Dept. of Civil & Structural Engineering, University of Sheffield)** presented the **ANAGENNISI (www.anagennisi.org) project** exploring several innovative solutions to reuse all tyre components (rubber, steel cord and wire, textile reinforcement) in high value concrete applications with reduced environmental impact. The presentation focused on the overall objectives and challenges of the Anagennisi project, highlighting managerial issues of big consortia as well as project dissemination of the scientific findings. Key elements of how to manage successful eco-technological EU projects were presented with emphasis on the coordinator’s role. The dynamic evolution of ideas (and risk) in the project space was discussed

and advice was given on how to deal with new research ideas that may develop during the project. Dr. Koutas emphasised the role of research coordination (use standardised materials and methods - poor results can "kill" a product's credibility in consumer world; apply LCA and performance-cost balance; ensure work being done in other places, policy makers, users, designers are informed - industry will contact you for potential applications and offer demonstration sites).

In the last round of the presentation the highlights from six **H2020 projects** were shown:

- **FISSAC** (https://fissacproject.eu/en/) – by **Dr. Edith Guedella Bustumante (ACCIONA Construcción)**: Industrial symbiosis approach via total/partial replacement of virgin feedstock by high-purity secondary ones, to obtain new green cost-effective construction materials will be developed. The outcome will be validated through five different case studies comprising the manufacturing processes, the technical performance tests of the new products and their implementation at a real scale in construction applications. Dr. Guedella emphasized the use of SPIRE roadmap KPIs to measure the results achieved.

- **HISER** (www.hiserproject.eu) – by **Dr. David García Estevez (Tecnalia)**: The main objective in HISER is to develop and demonstrate novel cost-effective holistic solutions for a higher recovery of raw materials from ever more complex construction and demolition waste (C&DW) by considering circular economy approaches throughout the value chain. By merging ideas from FP7 IRCOW and C2CA projects, HISER will develop a set of solutions to increase the quality of recycled concrete, ceramic fraction, plasterboard (gypsum), wood fibres, glass and mineral wool. which is essential to achieve high replacement ratio and to win technological/market acceptance. It will also take into account the non-technological aspects (market, standardization, certification, traceability, environmental footprint).

HISER International Conference: Advances in Recycling and Management of Construction and Demolition Waste is going to take place on 21-23 June 2017, at Delft University of Technology: http://www.citg.tudelft.nl/en/current/events/events-materials-environment/hiser-international-conference/

- **SMARTPLANT (www.smart-plant.eu)** – by **Prof. Francesco Fatone (University of Technology of Marche, Ancona)** - Its objective is to scale-up eco-innovative and energy-efficient solutions to renovate existing wastewater treatment plants and to close the circular value chain by using low-carbon techniques to recover materials like polyhydroxyalkanoates (PHA), sludge plastics composites, bioenergy, and for nutrients and water reuse. Technologies and systems will be automated to optimise resource recovery and demonstrated in 7+2 pilot systems in operating five municipal waste water treatment plants in the Netherlands, UK, Italy, Spain, Greece and Israel. In the discussion, possible customers' acceptance issues were mentioned for sludge-derived products, depending on their application.

- **CABRISS (https://www.spire2030.eu/cabriss)** – by **Dr. J.-P. Rakotoniaina (CEA)** - The project's goal is to recover critical raw materials in PV modules production and recycling, such as silver, indium and silicon[4], by re-using recovered materials as new feedstock for PV or by offering them as feedstock to other industries. These CRM form a minor portion of the PV module mass, but their value and the amount to be recovered can be significant. New processes for the fabrication of innovative PV cells will be also developed and optimized (until TRL 6). In total 5 exploitable results have been

[4] broken silicon wafers from spent PV panels and production scrap, or kerf from sawing silicon ingots into wafers

identified until now, and business models for them will be developed based on a circular economy and industrial symbiosis concepts.

- **ECWRTI (www.ecwrti.eu)** – by **Ms. Agata van Oosten-Siedlecka**, (ISPT - Institute for Sustainable Process Technology): The project demonstrates the EColoRO concept of re-use of water from the textile industry effluents through electrocoagulation followed by ultra-filtration and the reverse osmosis. The water consumption reduction potential reaches 90%. A series of pilot scale (1m3/h) is ongoing and full industrial scale demonstrations of the EColoRO concept are foreseen first at a textile mill in Belgium and later at a textile mill in Italy. Parallel to the demonstration, a commercialization package is being developed. The package includes the economic feasibility analysis, sustainability analysis and the training package.

- **METGROW PLUS (www.metgrowplus.eu)** - by **Ms. Päivi Kinnunen (VTT)**: The objective of METGROW+ is to create, demonstrate and validate an industrially viable, flexible New Metallurgical Systems Toolbox. to valorise EU's low-grade, polymetallic primary and secondary resources (ores and industrial waste like slags and sludges). This toolbox allows to smartly combine pyro-, hydro-, electro-, bio-, solvo- and ionometallurgical unit operations, as well as to include residual matrix valorisation technologies.

Mr. Klimek (RTD) remarked that (after FP7 REEcover project) this is another case of combining minerals and waste processing. As suggested some time ago by Dr. Robert Crawford in FP7 COLABATS project, many new rare metals recovery routes that are now prohibitively expensive for WEEE recyclers, may become economically feasible as a side-activity in ore processing plants using similar technologies (or just as a result of price drop from mass production of the extractants/solvents used).

Final discussion

In the final discussion the participants highlighted important questions such as EoW criteria vs. REACH rules for waste-derived products; EU regulations on plastics, not sufficiently stressing the quality requirements of recyclates and thus limiting the uptake of new advanced sorting technologies; innovation-friendly simplified procedure for permits regarding trials in university premises in Delft LCA use in environmental assessment in FP7/H2020 projects. Many of these issues call for a dialogue between the stakeholders and the EC or e.g. EU standardization bodies like CEN-CENELEC. Mr. Petros Mamalis (RTD) informed the audience of the ongoing EC initiatives on Innovation Deals, Innovation Principle, as well as on the possibilities of cooperation with Technical Working Groups of CEN-CENELEC (direct contacts: Mr. Ashok Ganesh, Director – Innovation and Mrs. Andrea Gulacsi). Mr. Klimek (RTD) also mentioned ongoing DG GROW initiatives of the EU Circular Economy Action Plan: Strategy on Plastics in Circular Economy (contact: Eric Liègeois, GROW), voluntary Construction and Demolition Waste Management Protocol and Pre-Demolition Audit Guidelines (contact: Vincent Basuyau, GROW). Mr. Vincenzo Gente (EASME) explained that right options for Life Cycle Assessment (LCA) in projects should be adopted, following the re-phrased call requirement of "life cycle thinking".

II. CONCLUSIONS OF THE WORKSHOP

English Wikipedia, after listing a dozen of meanings of the word *technology*, concludes with a remark: "*Technologies are not usually exclusively products of science, because they have to satisfy*

requirements such as utility, usability, and safety". It means that a technology, if it is to truly merit this name, needs to be practically viable. This workshop discussed on numerous examples how to accomplish it.

The presentations from successful FP7 projects outlined a common logic for preparation and implementation of European eco-technological projects aimed at maximisation of practically applicable outcomes – be it the case of water, waste or resource efficiency technologies. They showed a way from the project idea selection and the selection of consortium partners according to the competences needed, to setting up initial experimental stage (usually a lab scale), its further scale-up (pilot plant or industrial demonstrator) and product/process validation. Each of these stages is accompanied by appropriate analyses of S/T progress beyond the state-of-the-art (benchmarking done usually with an active participation of industrial partners/end-users), profitability assessments and environmental aspects analysis (LCA thinking). Another characteristic feature of the presented projects was their "innovation along the value chain" approach and their orientation on new business models.

At a laboratory trials scale a thorough understanding of the physical side of the process is crucial in order to notice its particular features that can later become your key to innovation. On the basis of the state-of-the-art and of end-users' requirements it is usually easy for researchers to figure a general model of a targeted process. Yet, later on, experimental trials validate their assumptions and allow to develop (or not) the real shape of a technically feasible and economically viable new processing method. Learning the industrial approach, the researchers realize the importance of initial economic assessment as a key criterion of choice for their research topics.

Once this is achieved and validated, a transfer to a pilot/demonstrator phase should be done as soon as possible. It is the result of this phase that the industrial partners are most interested in as potential investors. FP7 projects' experience shows that it requires excellent engineering skills and capacities, a sufficient research infrastructure and organization level to perform long-lasting large scale trials, a secured supply of raw materials for these trials and - last not least – a comfortably tailored budget for equipment and enough time for its purchase, assembling and integration.

The application of more pilot-plant-oriented approach seems to incite the interest of industrial companies who start to see profits from participation in EC-funded projects. RELIGHT, a WEEE recycling SME from Lombardy region hosted several FP projects – to a mutual benefit. Technology providers had an opportunity to test their solutions at a technical scale in RELIGHT premises; RELIGHT got access to new equipment and technologies that widen their technological capacities.

Big companies like SUEZ Environment are of course interested rather in solutions than in basic research, so they target groups are processes starting from a pilot plant (TRL5-6) or technical demonstrator (TRL 7) level. This may explain a relatively lower participation of SUEZ in FP projects in comparison with e.g. LIFE+ projects.

This shows clearly that any follow-up research funding from Structural Funds money ("synergies between H2020 and Structural Funds" targeted in the EC strategy) can only be possible on condition that H2020 will yield at least technically and economically promising pilot scale tests' results.

For obvious reason, projects focused on the development of one technology usually prevail in FP calls. Yet, in some areas of particularly broad spectrum of possible technologies and customer safety issues to be addressed – like water research or food processing, but also in e.g. construction engineering – multi objective projects, exploring a well-defined and not too big area of applications may also give

very good results. In such exploratory projects, a strong consortium with the access to top level knowledge in the field, able to perform a correct project developments' benchmarking against the industrial state of the art, is essential. Promising solutions resulting from such a research can be then developed further via more focused demonstration projects.

Six ongoing H2020 projects' representatives (FISSAC, HISER, SMARTPLANT, CABRISS, ECWRTI and METGROW PLUS) showed promising interim results and interest in achieving possibly high TRL for the processes/products they are developing. As important landmarks in their research they listed i.a. improvements along the value chain, looking at operational costs and not at the compliance with environmental regulations alone, long term business model development based on industrial symbiosis, use of mobile plants, comprehensive solutions including even a valorisation of residues from waste processing.

All presenters laid stress on the collaboration between RTOs and industrial partners/end-users that is essential to understand the specific needs of a given sector, the material requirements, equipment used, testing methods, standards applied and regulations to be taken into account (e.g. REACH).

What we may retain from this exchange of experiences?

Important points regarding sound project's preparation and implementation which were discussed in workshop presentations might be arranged along the project progress line as follows:

- analysis of what predecessors did (state of the art) - prior to the proposal stage and then continuously throughout the project

- preliminary results and what is achievable in say 3 years project (clear scientific/economic target(s))

- active end-user participation from proposal preparation onwards

- early identification of end-user's requirements, relevant standards and national regulations

- due assessment of lab scale results; economic and sustainability aspects

- comprehensive understanding of the process – physical nature, potential to meet objectives, mass balances, process efficiency indicators;

- sound scale-up approach and its clear concept; risk management

- ensuring raw materials availability for trials

- safety aspects

- permits - if applicable

- equipment needed and its due commissioning[5] (also important: budgetary margin)

- proper planning, organization and monitoring of pilot trials;

- mass balances, thorough techno-economic analysis of results of these trials (technical feasibility, and profitability);

- recycled product validation vs. virgin material, in terms of quality and price;

[5] i.e. commissioning each module in the process integration phase and also the whole demonstrator plant

- sustainability analysis (with a proper use of "life cycle thinking") - products by-products, waste valorisation options

- synthetic presentation of costs and benefits analysis of the resulting solutions, readable for potential end-users

- regulatory barriers and standardization issues.

Acknowledgments

Authors wish to thank Ms. Violeta Kuzmickaite and Mr. Tomáš Turecki for their help with taking notes and for their comments to the text; and for EASME colleagues, in particular to Mr. Vincenzo Gente and Mr. Marcin Sadowski, for their contribution to the preparation of this workshop.