2nd CO_2 Utilisation Seminar

ADEME
French Environment & Energy Management Agency

CO_2 Fuels & Materials
Resource & Energy EFFICIENCY

Working Group on CO_2 Utilisation

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CONCLUSIONS AND PERSPECTIVES

CO_2 Utilisation consists of a set of technologies that use **different qualities of carbon dioxide** (diluted, partially concentrated, ultra-pure) as **alternative raw material to hydrocarbons**. CO_2 is a potential resource for biological or chemical transformation processes (mineral carbonates, organic molecules, polymers, fuels).

These technologies aim to give a triple value to CO_2:

1. An **environmental value**, with less consumption of fossil fuels, lower CO_2 emissions and an improved carbon footprint of the products developed (without forgetting the other impacts).
2. An **economic value**, so that robust and sustainable business models can emerge.
3. A **societal value**, with the creation of employment and the protection of health of populations.

In 2014, CO_2 emissions from the combustion of fossil fuels and industry were at 35.9 ± 1.8 Gt CO_2, that is to say 60%, above the emissions of 1990. **By 2015, these emissions have stabilized at 35.7 ± 1.8 Gt CO_2**[1].

If sustainable business models emerge, it is estimated that between 2 and 4 per cent of CO_2 emissions could be used: **the utilisation of this CO_2 must be an action associated** with all the means used to fight climate change (energy efficiency, use of biomass, renewable energies, etc.).

The conclusions of the plenary session and of the workshops as well as the recommendations that came out of them, have been incorporated into the following summary table:

Research, Development and Innovation	• Demonstrators need to be deployed to remove technological locks and reduce the risk associated with industrialization. • Technological developments must be based on public-private collaborations. • CO_2 utilisation is supported at all stages of development, from the proof of concept in laboratory to the pre-industrial scale by French programs (ANR-Research National Agency, FUI- ministry fund, ADEME- French Agency of Environment and Energy management, PIA- Investments for Future, BPI- Bank of Investment for Future), European (Energy Union, SET Plan, H2020, ERANET) and by international initiatives (Mission Innovation). • France has less visibility than other countries concerning financing research in the field of CO_2 utilisation, however it will have invested € 42 millions (for a total project budget of € 95 million) in the last five years.
Industries and Business	• CO_2 utilisation is now a reality for some areas, illustrated by CRI, COVESTRO and Carbon 8: it is a vector for new growth drivers. • CO_2 utilisation technologies still require technical and environmental improvements but also regulation to support and transform the few successes into a large deployment. • The presence of many industrialists at the 2nd CO_2 Utilisation Seminar shows the willingness of the industry to reduce its emissions and / or utilise them. • The distribution of the constraints and benefits throughout the value chain should be defined according to 4 axes: level of CO_2 concentration, CO_2 avoidance, energy consumption, economic benefit.

[1] Global Carbon Project : http://www.globalcarbonproject.org/carbonbudget/archive/2015/GCP_budget_2015_v1.02.pdf

	• International groups can be a driving force behind the emergence of the industry of utilisation of CO_2. Indeed, they play a major role in the value chain, either as emitters, or as distributors of products or services. They are therefore key actors for the emergence of initiatives requiring a reduction of the carbon footprint of products and services. • The integration of CO_2 utilisation units within an industrial park will favour a reduction of conversion costs (material integration, energy, grouping of services, etc.)

Territories	• Territories seek to maintain their competitiveness while reducing their impacts on the environment.
	  ○ Le Havre Développement offers technological solutions for capturing CO_2 (from 1 kg/h to 1 t/h), which can be combined with R&D installations for CO_2 utilisation.
	  ○ Marseilles' industrial port district seeks to reduce its CO_2 emissions especially thanks to CO_2 capture and utilisation technologies (VASCO2 biological conversion project, JUPITER 1000 methanation project).
	• The territory favours the installation of CO_2 capture and utilisation units in terms of financial support, facilitating contact between companies.
	• There is a need to deploy a multi-vector intelligent network (methane from CO_2, H_2, heat, renewable electricity).
	• Multimodal connections at different levels of the territory (industrial port area, urban, rural and dwelling house) and multi-vectors (mobility and energy), coupled with renewable energies and capture technologies will contribute to the reduction of CO_2 emissions in a region.

Environment	• CO_2 utilisation has the potential to reduce CO_2 emissions. • Clear, rigorous and universally accepted environmental assessments must be carried out from the earliest stages of the technological development of CO_2 utilisation. • To emerge, the industry needs a lot of renewable energy resources in order to limit any transfer of impact. • Not only should CO_2 be utilised from the point of view of organic or inorganic chemical products derived from CO_2: one must also think in terms of services (in particular the use of renewable energies) and substitution of existing solutions.
Markets and Finances	• With the Paris Agreement, a real change is on the way, it is an opportunity for CO_2 utilisation to capture a part of the reorientation of financial flows ($ 5,000 billion necessary to keep the 2°C scenario by 2100). • The trend of a very low carbon price will reverse in the coming years thanks, in particular, to the COP21. • New financial initiatives emerge: Financial Stability Board, Institutional Investors Group on Climate Change, Portfolio Decarbonization Coalition, etc. • The Carbon Pricing Leadership Coalition, created at the COP21, aims to advance the agenda associated with the carbon price. • This carbon price must be stable and global in order to avoid distortions of competition. • In France, the Contribution Climat Energie is aiming for a CO_2 tax at 56 €/t in 2020 and 100 €/t in 2030 (it does not apply to emitters already subject to the ETS market).
Economy	• Business models are difficult to establish for many areas of CO_2 utilisation due to the high cost of the decarbonized energy source (e.g. hydrogen), the high cost of access to captured CO_2 and the current low price for fossil resources. • In terms of mineralization, the cost for access to captured CO_2 is still too high. • There is no financial incentive to buy a low-carbon product compared to a product of reference. • Investors need to be reassured about the risk associated with, notably, long-term securing of inputs, like CO_2.

Regulation	• In France, the Energy Transition for Green Growth Act (LTECV) provides a framework for technological innovations that reduce consumption of energy and CO_2 emissions. This new framework is also an opportunity for the utilisation of CO_2. • There is a need for standardization of regulation at European level, including the status of "waste" for CO_2 in an economy that wishes to be circular. • A label could help set up the industry. • There is no recognition of the reduction for the emitter who has captured his CO_2. o Lack of clarity or unfavourable regulation concerning the benefit of the reduction of CO_2 between the actors. o A lever for the industry is in the process of being set up since 2016 with the reform of public markets in which the life-cycle criterion is now taken into account[2].
Stakeholders	• CO_2 capture and utilisation projects should integrate, as early as possible in the project, new actors, in addition to industries, public research and national institutions: economic development agencies and civil society. • A European association for the transformation of CO_2 is being created (by now till June 2017). The goal of this association will be to assemble the efforts of all stakeholders to accelerate research, innovation and the development of markets for CO_2 utilisation solutions in Europe. • Demonstrators are needed to raise awareness in civil society, to reassure and to convince.

[2]Ordinance No. 2015-899 of 23 July 2015 relating to public procurement:
https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000030920376
Decree No. 2016-360 of 25 March 2016 relating to public procurement:
https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000032295952&categorieLien=id

SUMMARY

PLENARY SESSION

1. Words of welcome

G. Pignault, Director of the School of Chemistry, Physics and Electronics in Lyon recalls that his school is interested in the utilisation of CO_2 since 2009, year in which the Chair Sustainable Development and its "CO_2 Forum" initiative were created (led by A. Quadrelli and co-directed by C. Füssler).

If climate change is not under control, the consequences will leave a long lasting mark on the Earth. Besides the fast climbing temperature forecasted, it is an additional **600 million people suffering from malnutrition** on the horizon of 2080[3] and more than **250 million new displaced persons** by 2050[4].

G. Pignault announced finally that, the day before the 2nd CO_2 Utilisation Seminar, the official inauguration of the new **engineering federation IngéLySE**[5] took place.

D. Bonijoly, Deputy Director of the Georessources Division of BRGM and President of the Club CO_2, thanks G. Pignault for hosting this manifestation. The Club CO_2 was founded in 2002 at the initiative of the ADEME (Environment and Energy Management), with the support of IFP Energies Nouvelles and the BRGM (The French Geological Survey). Since 19th March 2016, the Club CO_2 has become an association of the 1901 law type. The association is presided by the BRGM with EDF and IFPEn, who respectively insure the secretariat and the treasury. The Club CO_2 brings actors in the industrial and research world together.

The CO_2 Club operates on three axes:

Spread of information	• Recommendations to the French authorities upstream of the COP21[6] • Online video on the CSCV (Capture, Storage and Utilisation Of CO_2)[7] • EUROPEAN CCS DAY WORKSHOP[8] in cooperation with Le Havre Development, CO_2GEONET and GCCSI • Seminars on CO_2 utilisation (Le Havre 2015[9], Lyon 2016)

[3] http://www.un.org/apps/newsFr/storyF.asp?NewsID=35999#.WEV_KLLhC70

[4] http://www.un.org/apps/newsFr/storyF.asp?NewsID=17960#.WEV-arLhC70

[5] http://www.ecam.fr/blog/inauguration-dingelyse-federation-dingenierie-a-laquelle-participe-labecam/

[6] http://www.captage-stockage-valorisation-co2.fr/sites/default/files/ClubCO2_RECOMMENDATIONS-COP21-FR_0.pdf

[7] https://www.youtube.com/watch?v=nVUZWZFatOQ

[8] http://www.captage-stockage-valorisation-co2.fr/content/european-ccs-day-workshop-compte-rendu-et-pr-sentations

[9] http://www.captage-stockage-valorisation-co2.fr/content/atelier-d-change-autour-de-la-valorisation-du-co2

Support for research	A 1,500 € prize is awarded each year to the best thesis on CSCV (Capture, Storage and Utilisation of CO_2), plus a financial contribution of € 1,000 for its publication.
Creation of workgroups	Communication, Impurities, Utilisation of CO_2, Strategy.

Three strong ideas were put forward by the Club CO_2 at the COP21:

- **Synergies** need to be developed in a sustainable way **between energy production** (bio-, geothermal and renewable) **and the CSCV** (Capture, Storage and Utilisation of CO_2).
- Research projects on breakthrough technologies on capture must be supported financially so that France retains its lead in technological development.
- A global program needs to be defined or catalysed in a collaborative way to produce an **assessment of the CO_2 storage capacity** and conduct **full-scale injection testing** in the most promising areas, particularly in deep saline aquifers.

The International Energy Agency (AIE) indicates that the 2°C threshold can be reached only by capturing and storing 4 Gt CO_2 / year by 2040 and 6 Gt / year by 2050[10]. Utilisation of CO_2 can act as a complement to the storage of CO_2, with a potential estimated at 1.5 Gt CO_2 / year. Among the most promising technologies in terms of quantity of CO_2 used, D. Bonijoly cites[11]:

- Enhanced hydrocarbon recovery (EOR, ECBM)
- Improved geothermal energy (use of CO_2 as a working fluid)
- Conversion of CO_2 into chemical products such as polymers, urea, etc.
- Conversion of CO_2 into liquid fuels (renewable methanol, formic acid)
- Mineralization (inorganic carbonates, concrete curing, carbonation of bauxite residues).
- Production of biomass (microalgae)

The Club CO_2 considers that **actions must be taken simultaneously for the short-term and the long term**, integrating capture, storage and utilisation of CO_2.

To conclude, Didier Bonijoly hopes that this 2nd CO_2 Utilisation Seminar will illustrate the industry's **efforts to reduce its greenhouse gas emissions**, by demonstrating that CO_2 utilisation can be a **solution that is technical, competitive and beneficial for the environment.**

[10] http://www.iea.org/publications/freepublications/publication/EnergyTechnologyPerspectives2016_ExecutiveSummary_EnglishVersion.pdf

[11] https://hub.globalccsinstitute.com/publications/accelerating-uptake-ccs-industrial-use-captured-carbondioxide/1-co2-reuse-technologies

2. CO_2 utilisation: context, regulatory framework and research implications

Paul Bonnetblanc is responsible for the development of the green technologies (geothermal energy and capture, storage and utilisation of CO_2) at the DGEC (General Management for Energy and Climate) at the Ministry of Environment, Energy and the Sea (MEEM).

The trend of a very low carbon price will reverse in the coming years, due to the new dynamic launched during the COP21. On 05/10/2016, 74 States representing 58.8% of the emissions of greenhouse gases have ratified the Paris Agreement.

Paul Bonnetblanc mentions also the creation of the "**Carbon Pricing Leadership Coalition**[12]" at the COP21, a partnership between governments, entrepreneurs and civil society organisations, whose goal among others is to promote and advance the politics of **pricing of carbon** (by an emission trading scheme or by tax). Today, this partnership brings together 27 government partners, 128 private industry partners and 50 strategic partners.

At the same time, the prospects for large-scale deployment of the CCS mark temporarily the pace in the European Union, which explains the interest in research and innovation concerning CO_2 utilisation (Action 9 "CCUS" of the European SET Plan[13], Horizon Prize for the utilisation of CO_2 (open until 03/04/2019)[14].

In 2012, France emitted 460 million tons of GHG (for the 3 main GHG: CO_2, CH_4 and N_2O, expressed in CO_2 equivalent), i.e. 7.3 tons / capita. This inventory, developed for the United Nations Framework Convention on Climate Change (UNFCCC), includes direct emissions from households (vehicles and heating), domestic production and emissions associated with export.

20% of inventory emissions could be captured and stored or utilised.

If, on the other hand, the carbon footprint is considered with the emissions associated with imports, but without taking in account the emissions associated with exports, it amounts to 671 Mt CO_2 equivalent, or 10.6 tons / capita.

France has recently decided to take into account the carbon footprint for its public policies follow-up:

- Article 173 of the Energy Transition Act for a Green Growth of 17th August 2015: "the **Low Carbon Strategy** [...] makes sure not to substitute the national effort of reduction, an increase in the carbon content of imports",
- The so-called "SAS" law of 13th April 2015 aims to take into account new wealth indicators, such as indicators of inequality, quality of life and sustainable development for the follow-up and evaluation of public policies,
- The **Stratégie Nationale de Transition Ecologique vers un Développement Durable (**National Strategy of Ecological Transition towards Sustainable Development**)** 2015-2020 integrates the carbon footprint in the monitoring of the "climate change issue"[15].

[12] http://www.carbonpricingleadership.org/
[13] https://setis.ec.europa.eu/system/files/issues_paper_action9_ccs_ccu.pdf
[14] https://ec.europa.eu/research/horizonprize/index.cfm?prize=co2reuse
[15] http://www.developpement-durable.gouv.fr/IMG/pdf/Empreinte_carbone.pdf

Law n° 2015-992 of 17th August 2015 relevant to the energy transition for green growth (LTECV)[16] "sets a target, for the integrated carbon component of the tax rates on consumption of energy products [...], to achieve a value of a ton of carbon at **56 € in 2020 and at 100 € in 2030**.

Two tools support LTECV:

- The National Low Carbon Strategy[17]: transversal policy recommendations, carbon footprint, R&D, carbon shadow price, reorientation of investment, citizen involvement, the role of local authorities in landscaping, etc.
- Long-term Energy Programming (over 5 years)[18], open for consultation between 15th September and 15th October 2016

Xavier Montagne is Deputy Scientific Director "Energy, Sustainability, Chemistry and Processes" within the General Management Research and Innovation (DGRI) of the Ministry of Higher Education and Research.

At the international level, the member countries of the **Mission Innovation**[19] met at the COP 22 to confirm their commitments to double public R&D funding for clean energy to an estimated 30 billion US $ in 2021.

In addition, 7 challenges were launched, including:

- **Carbon Capture Storage and Use Innovation Challenge** (Challenge 3)
- **Converting Sunlight Innovation Challenge to create storable solar fuels** (Challenge 5)

At European level, the capture and utilisation of CO_2 are addressed by the following tools:

- **Program H2020** (work package 2018-2020 in preparation)
- **ERANET "ACT**[20]**"** (Accelerating CCS technologies as a new low-carbon energy vector)
- **Energy Union**
- The **SET Plan** provides for **Action 9 concerning the CCS and the CCU**: "Step up research and innovation activities on the application of carbon capture and storage (CCS) and the commercial viability of carbon capture and use (CCU)"[21]

At the French level, Xavier Montagne recalled the objectives of the Energy Transition Act for Green Growth:

-40% GHG emissions in 2030 compared to 1990

-30% consumption of fossil fuels in 2030 compared to 2012

Increase in the share of renewable energies to 32% of the final energy consumption and 40% of electricity production

Reduction of final energy consumption by 50% in 2050

[16] https://www.legifrance.gouv.fr/affichTexte.do;jsessionid=349AA1286F865652DA5051F0540A4928.tpdila13v_3?cidTexte=JORFTEXT000031044385&categorieLien=id

[17] www.developpement-durable.gouv.fr/IMG/pdf/SNBC_Strategie_Nationale_Bas_Carbone_France_2015.pdf

[18] http://www.developpement-durable.gouv.fr/IMG/pdf/PPE-complet-1.pdf

[19] http://mission-innovation.net/ ; http://www.developpement-durable.gouv.fr/IMG/pdf/MI_COP22_Press_Release_-_14_November_2016-1.pdf

[20] http://www.act-ccs.eu/

[21] "Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European Energy System Transformation", EC Brussels, C(2015) 6317 final, 15.9.2015

-50% waste in landfill in 2025

Diversification of electricity production and reduction of the share of electricity of nuclear origin to 50% by 2025

In addition to the PPE and SNBC discussed in Paul Bonnetblanc's speech, France has developed its **Stratégie Nationale de la Recherche**[22] (National Research Strategy): initiated by the French Higher Education and Research Act of 22nd July 2013, the SNR aims to "meet the scientific, technological, environmental and societal challenges by maintaining a high level of fundamental research." This SNR is built around ten major societal challenges among which CO_2 utilisation can be considered many times:

1. Sober resource management and adaptation to climate change,
2. **Clean, safe and efficient energy**,
3. **Stimulate industrial renewal**,
4. Health and well-being,
5. Food security and demographic challenge,
6. **Mobility** and sustainable urban systems,
7. Information and communication society,
8. Innovative, integrative and adaptive companies,
9. A space ambition for Europe,
10. Freedom and safety of Europe, its citizens and its residents.

Xavier points out that the capture and utilisation of CO_2 is taken into account in challenge n ° 2:

- Dynamic management of energy systems
- Multi-scale governance of new energy systems
- Energy efficiency
- Reduction in the need for strategic materials
- **Decarbonisation of the energy and the chemical industry**

Moreover, LTECV specifies that France will adopt a **Stratégie Nationale pour la Recherche Energétique** (National Energy Research Strategy), in line with the SNR (to be specified in the field of energy), the SNBC and the PPE. The SNRE is built in consultation with the Regions. The SNRE must be finalized by the end of 2016. Among the SNRE's guidelines under discussion, Xavier Montagne mentions the following elements:

- Adopt a systemic approach and focus on the transversal issues that are energy-related (environmental, socio-economic, Digital revolution),
- Consolidate a community of energy research,
- Encourage public-private collaborations through research and industrial demonstrators
- Connect Research, Development and Innovation (RDI) policies to different scales (local, national, European and international).

The utilisation of CO_2 will be taken into account in the SNRE as one of the axes contributing to develop new renewable resources in a circular economic perspective.

Xavier Montagne concludes his intervention by drawing up a table of all the financial and non-financial means deployed in France that can support the emergence and development of a new industry of CO_2 utilisation. A support resulting on the one hand from public institutions and research institutes (EPIC- Etablissement Public à Intérêt Commercial), such as the CNRS, CEA,

[22] http://www.enseignementsuprecherche.gouv.fr/cid78733/strategienationalederecherchedixgrandsdefissocietaux.html

IFPEN and BRGM, and on the other through financial support at all stages of maturity of innovations:

ANR, National Research Agency	TRL (Technology Readiness Level) = 1-3
ADEME R&D	TRL = 4-6
ADEME PIA (Programme Investissements d'Avenir[23] (Investments For Futurethe Capture, Storage and Utilisation of CO_2 is identified in the theme "Green chemistry and Energy stakes") of PIA 2 (2015-2020).	TRL = 7-9
BPI PIAVE (Call for projects "Future Industrial Projects[24]" from Bank of Investments For Future)	TRL = 8-9

3. After the COP21: prospects for CO_2 utilisation

Benoît Leguet is the director of I4CE, the Institute for Climate Economics, the think tank working on the low-carbon economy, launched by the Caisse Des Dépôts (Deposits and Consignments Fund) and the Agence Française de Développement (French Development Agency).

After the ratification by the states of the Paris Agreement, the next step is its implementation through national policies and "Action Agenda" or Agenda of solutions. The Agenda of solutions brings together different non-governmental organizations such as local authorities, NGOs, citizens, etc.

Article 2 is an important article of the Paris Agreement if it is not the most important.

It consists of three points:

- Limitation of global warming below 2°C
- Promoting development trajectories that are low-carbon and resilient to climate change, in a way that does not threaten the food production.
- Alignment of financial flows with the two preceding points.

To achieve the goals of the agreement, it is necessary to leave about ¾ of the known fossil resources – unless to imagine a technology deployable on a very large scale capturing emissions. **This transition will be expensive: $ 5000 b / year of public and private investment only for infrastructure**. But these investments will have to be done anyway, and the investment cost of a "non-transition scenario" is of the same order of magnitude, without taking in account the additional costs related to climate impacts. The challenge of financing the energy transition is to **shift the funding flows** that are now going to "grey" **towards "green", and give incentives for this tipping over**.

A number of initiatives have emerged, that aim either to make the technologies and practices of low-carbon economically interesting (for example, by promoting the prices of carbon as the Carbon Pricing Leadership Coalition (CPLC)) does; or by facilitating the finance of low-carbon technologies and practices - and in reverse more difficult to finance carbon technologies and

[23] http://www.ademe.fr/entreprisesmondeagricole/innoverdevelopper/programmedinvestissementsdavenirpia/presentation

[24] http://www.bpifrance.fr/Actualites/Appels-a-projet-concours/Appel-a-projets-PIAVE-9657

practices (Climate Finance Day, initiatives of the Financial Stability Board, coalitions of investors, or NGOs like 350.org which is an NGO that aims to stop investments in fossil energy).

Benoit Leguet concludes his intervention with the space that has been opened to "low-carbon" technologies including the utilisation of CO_2. To arrive at the "Zero emission", a large part of the financial flows will be of private origin. It will be necessary to monitor national policies but also the initiatives of non-state organizations. Finance will not solve everything but nothing can be done without finance.

4. The vision of the CO_2 Forum

Alessandra Quadrelli is director of research of the French National Centre for Scientific Research, CNRS, in the laboratory C2P2 at CPE Lyon and chairwoman of the CPE Lyon Engineering School Sustanability Chair.

Alessandra Quadrelli recalls that the volume consumed by the utilisation of CO_2 is not negligible. In addition, the evaluation of the interest of a CO_2 utilisation technology via cost / price is not sufficient, the service rendered must also be taken into account.

The comparison between the price of a carbon-free product and that of a fossil product is not necessarily the only relevant one. The product of fossil origin being still reasonably associated with very competitive prices compared to the same carbon-free product, this comparison would render unnecessary any effort to develop low-carbon alternatives. If the primary objective is to increase the share of the renewable, then it is necessary to compare low-carbon technologies among themselves. The high price of "low-carbon" technology is understandable and justifies the need for public support policy.

Alessandra Quadrelli concludes that the reflection on the deployment of CO_2 utilisation technologies must take place at the territorial level with all actors, academics, industries, public authorities, etc., on renewable energy, CO_2 utilisation and business development themes.

5. Industrial examples of CO_2 utilisation

5.1 Recycling CO_2 into low-carbon intensity methanol: making sustainable transport possible

Philippe BOULANGER is in charge of European operations at Carbon Recycling International since 2014.

Philippe Boulanger opens his intervention with the Programmation pluriannuelle de l'énergie-PPE in France (Multiannual framework agreement on Energy), which represents an opportunity to put projects in place.

At the European level, ongoing work on the revision of the renewable liquid fuel directive recognizes "Power to liquids" as an advanced renewable fuel: see Annex 9 part A, Directive 2015/1513 dated 09/09/2015 with the mention: renewable fuels of non-organic origin and fuels derived from the capture and use of carbon dioxide.

France was the first country to implement this directive with ambitious goals of substitution of fossil fuels (gasoline / diesel) by advanced renewable fuels.

5.2 From dreams to reality: Covestro's activities in terms of CO_2 utilisation

Christoph GÜRTLER is currently heading a department in the field of process and product development dedicated to new catalytic processes at Covestro. Christoph GÜRTLER reminds us that the primary objective was to develop a CO_2 utilisation technology. The range of products targeted was polyurethanes which are widely used. To develop this new process of synthesis from CO_2, it took more than 40 years of research and from the low TRL[25] 4-5, economic evaluation was taken into account to ensure the success of the project.

A first pilot was built in 2010 and following the results obtained, it was decided to switch to an industrial scale. A production unit with a capacity of 5 000 tonnes/year was started in 2016. An environmental assessment was carried out which showed a lower carbon footprint of the product synthesized with CO_2.

Despite a difference in the chemical formula, the product has exactly the same foam properties and can therefore be substituted for polyurethane derived from hydrocarbons. The total market equals 13.3 million tons of which 3 million tons may be affected by this new CO_2-based polyurethane.

Even using of a small amount of CO_2 in the process has a positive impact on the carbon footprint of the final product. The product was marketed under the name Cardyon™ which stands for be**YON**d C**AR**bon **D**ioxide.

The next step is to diversify the range by adding features on the carbon chain of the polymer.

Christoph Gürtler concludes his talk with a new project, CroCO2PETs to increase the amount of CO_2 integrated in the product especially in the manufacture of elastomers. The product that stems from CO_2 has already been shown in various symposia / congresses. It could substitute a small part of the elastomers contained in various products like tires or plastics contained in cars.

A first environmental assessment shows a lower carbon footprint of this CO_2-based elastomer, thanks in particular to the change in the process using less water and energy. But there remains much work to be done to achieve a production of this new elastomer on industrial scale. Similarly, work is underway to manufacture new materials out of CO_2.

[25] TRL for Technology Readiness Level

5.3 Production of carbonate aggregates: state of play and prospects

Colin HILLS is Professor of Environment and Materials Engineering at the University of Greenwich. He is one of the founding directors of Carbon8 Systems.

Colin Hills starts his intervention with a brief history of the origins of the project with the carbonation of hazardous waste and treatment of contaminated soil. Next he recalls the requirements of the "End of Waste Act" for the declassification of the waste status of certain materials. Requirements include: technical specifications (conforming to the intended use), a need of the market, risk management and the ability to use carbonate materials instead of virgin stone.

By meeting the requirements of 'end of waste' it has been possible to manufacture and sell carbonated aggregates made from solid waste and mineralised CO_2 for 5 years. Supported by international patents, the accelerated carbonation process (*or* ACT) has underpinned the commercial process and its development in the UK. One of the issues to be overcome is the high cost of obtaining CO_2. As lower-cost options develop, including direct capture from flue gas, it will be possible to increase the CO_2 content of the aggregates (i.e. mineralise more of this gas in the reaction with solid waste).

Despite the carbonated aggregates being utilised in a bound product (concrete construction blocks), the aggregate must meet the specification agreed with the Environment Agency, including defined limits on the leaching of e.g. metals. The company keeps a detailed record of key performance criteria, including leaching performance, which is assessed by an independent certified laboratory as a condition of its licence. The manufactured carbonated aggregate is a suitable replacement for stone obtained from a quarry.

Colin Hills concludes his talk with a summary of issues to be addressed if the use of carbonated waste-based products is to be further developed in Europe. These include:

- Increase the availability of low-cost CO_2, including from point-source emissions.
- 'Normalise' the interpretation and implementation of "End of Waste" across Europe, as currently a process such as described, cannot operate in some European countries due to local and national regulations, including in France.
- Incentivise the building industry as it is very conservative and reluctance to use new materials.
- Develop a mechanism to incentivise the purchase of low carbon products compared with the conventional product, such as via an embodied carbon marking scheme.

6. Setup of a European Association on CO_2 Transformation

Damien DALLEMAGNE is currently coordinating the efforts to establish a European association for the transformation of CO_2.

As a result of the European project SCOT, the restitution of which took place during a seminar in Brussels on 29th June 2016, it was proposed to create a European association dedicated to the transformation of CO_2.

The aim of this association will be to aggregate the efforts of all stakeholders to accelerate research, innovation and the market development of CO_2 utilisation solutions in Europe.

Among the ambitions of the future association, Mr Dallemagne mentioned in particular the possibility of building a major European PPP dedicated to CO_2 utilisation.

This association, currently being formed as of this day, will be at the interface of the various organizations that are already interested, to varying degrees, in the utilisation of CO_2, namely:

- The European KICs (Knowledge and Innovation Communities): Climate KIC, Energy KIC, KIC Raw Materials
- Professional associations (CEFIC, Cembureau, Eurofer, BIC, etc.)
- Institutional public-private partnerships (Joint Undertakings): Fuel Cells & Hydrogen, Clean Sky 2, Bio-Based Industries (BBI)
- Contractual public-private partnerships: SPIRE, European Green Vehicles Initiative, Factories of the Future

Two main activities will bring together the participants (major groups, SMEs, clusters, port authorities, universities, federations, funders, etc.):

- Define and regularly update a common strategic roadmap
- Implement this road map through projects, mobilization of financial support, as well as advocacy, communication and training,

The formation consortium of the association is being set up, following which the foundations of the association will be laid down in terms of objectives, perimeter, roadmap, financing and business model, statutes. The association should be formally established for the summer of 2017.

7. Strategies of the French territories to deploy CO_2 Utilisation technologies

7.1 Capturing and utilising CO_2 in the territory of Le Havre: from research to industrial developments

Frédérick BERNARD is the industrial project manager in charge of chemical, petrochemical, energy and waste at the economic development agency Le Havre Développement (LHD). Frédérick Bernard began his intervention by recalling the key figures for the Havre territory, which emits 10 Mt of CO_2 / year for 26 sites of which 10 sites submitted to the ETS market. A European project, COCATE had been conducted by the region to assess the cost of implementing the capture, transport and storage of CO_2 for the emitters of the zone.

The problem of the territory lies in the control of its impacts on the environment and human health while sustaining industrial activities.

In this perspective, LHD has been working for 10 years on CO_2 capture projects. Among the projects supported can be named:

Project	Period	Budget	Goals
EU FP7 / COCATE	2010-2012	4.5 M€	Develop a network of small CO_2 emitters Evaluate a CO_2 transportation and storage network
Pilot of capture	2011-2013	-	Capture of CO_2 (1 kg / h) in post-combustion with an amine technology on flue gases of hazardous waste incineration factory of SEDIBEX
C2A2	2010-2014	22 M€	Capture of CO_2 (capacity: 7.5 kt / year) in post-combustion with an amine technology on flue gases from EDF's coal-fired power plant
CRYOCAP	2011-2016	30 M€	Capture of CO_2 by cryogenics (capacity: 100 kt / year) on a flow of SMR (Steam Methane Reforming of natural gas)

The agency also took part in the industrial chair CTSC (Capture, Transport, Storage of CO_2) between 2010 and 2015.

Le Havre Développement now offers:

- CO_2 capture technological solutions (from 1 kg / h to 1 t / h),
- That can be combined with R&D facilities for CO_2 utilisation.

7.2 CO_2 utilisation as a diversification lever for the industrial port of Fos

Sylvain PICHON works at the Directorate for planning of Marseille Fos Port Authority, for the mission "Projects and industries". He is the head of project PIICTO (Industrial and Innovation Platform of Caban Tonkin) which consists in developing an industrial port area of 1 200 hectares by innovation towards energy transition and industrial ecology.

Sylvain Pichon recalled the region's emissions with 13 Mt CO_2 / year for the industrial zone of Fos.

The port and the territory are now looking for new growth drivers faced with the decrease in oil flows (-20% of traffic since 2008). The capture and utilisation of CO_2 represent opportunities under evaluation. In addition to reducing CO_2 emissions, the Marseille Port Authority aims to reduce its SO_x, NO_x and particulates.

Current projects are listed below:

Project	Period	Budget	Goals
JUPITER 1000[26]	2015-2020	30 M€	Methanation pilot via: - 2 electrolysers of 0.5 MW for the production of H_2 with the surplus of electricity of renewable origin - 1 CO_2 capture unit - 1 methanation unit
PIICTO	2017-2019	26 M€	Creation of a steam network that would allow to avoid the emission of 70 000 t CO_2 and to save 400,000 MWh / year of natural gas.
VASCO$_2$	2015-2019	2 M€	Evaluation of the biological conversion of CO_2 from different industrial emitters to algae biomass; conversion into bio-crude and supply of raw materials for biorefinery (green chemistry).

[26] http://www.jupiter1000.com/en/accueil.html

WORKSHOPS SESSION

8. Presentation of the Goals of the Workshops

On the basis of the conclusions of the plenary session, two workshops conducted in parallel have allowed the participants to express themselves and to actively make propositions on two axes (Business & Territories) which should encourage the emergence and deployment of CO_2 utilisation as a new industry.

Two goals are expected:

1. Target the levers that can be implemented within an industrial park that will create a sustainable business model.
2. Make recommendations to deploy this new industry.

9. Business Workshop: "Can you develop your business of CO_2 utilisation?"

Animation: Laurent FORTI (IFPEN), Salvatore BERTUCCI (ARCELOR MITTAL), Frederick BERNARD (Le Havre Développement)

The workshop took place in two stages with:

1. An initial evaluation of the levers and locks of four of the main current tracks of chemical recovery of CO_2 (methanol, formic acid, polymers and mineral aggregates),
2. A brainstorming session on the potential for the removal of these locks thanks, in particular, to local synergies.

The levers and locks are listed in the following table:

Type of lever or lock	Methanol	Formic Acid	Polymers	Mineral Aggregates
Technology	Lever: technology on the scale of demonstrator	Lock: the technology of catalytic electroreduction of CO_2 is still at laboratory stage	Lever: integrated into a petrochemical site for access to CO_2 and epoxides	
Economy	Lock: in the case of decarbonized H_2 production, ex electrolysis of water operating on renewable electricity, cost of hydrogen is too high because of the high cost of electricity → need of H_2 fatal	Lock: low formic acid market (EU Market: 650 kt in 2013) → weak business model	Lock: competition with other substitutes for fossil polycarbonates	Leverage: a CO_2 partially concentrated (50% vol.) is acceptable → cost reduction Lock: Without integration, transport of raw mineral material and CO_2 will negatively impact the costs of carbonate product

Type of lever or lock	Methanol	Formic Acid	Polymers	Mineral Aggregates
Regulation	Requires an evolution in regulation concerning the use of methanol as fuel	-	-	-

Other elements discussed:

Technology:

- Chain of CO_2 abatement: there is no need for a single quality of concentrated CO_2 for each of the utilisation tracks. On the other hand, there is a need for national mapping of emitters and potential utilisation units.
- Energy chain: how to distribute energy throughout the value chain?
- Integration should reduce, on the one hand, the variable and fixed costs of CO_2 utilisation (use of waste heat, pooling of logistical means, administrative, etc.) and, on the other hand, investments.
- To go beyond the economic comparison of products resulting from CO_2 utilisation, we must compare the services that these products can provide.

Administrative and territories:

- From the moment when physical and administrative exchanges of CO_2 will take place between producers (emitters that have captured CO_2) and the utilising industries, a traceability system should be established.
- The territory should encourage the establishment of CO_2 capture and utilisation units in terms of :
    - Financial support,
    - Facilitation of contact between companies,
    - Participation in projects as a stakeholder.
- Need for a territorial platform
- Need to deploy demonstrators to remove technological locks and reduce the risk associated with industrialization

Economic and market:

- Value chain: how to distribute the value throughout the chain from the capture to the utilisation of CO_2?
- It is also noted that economic models are difficult to establish for many tracks of CO_2 utilisation compared to the same molecules from fossil resources. However, for molecules of high added value, utilisation is a reality.
- In general, there is a need for a stable CO_2 price over time and worldwide in order to avoid distortion of competition.
- International groups can be a vehicle for the emergence of the CO_2 utilisation industry. Indeed, they play a major role in the value chain either as emitters, or as distributors of products and services. They are key actors for the emergence of initiatives requiring a lowering of the carbon footprint of products and services.
- With regard to funding, on the basis of the conclusions of the morning session, it came out that the whole industry is already supported, from technologies at concept stage until the first industrialization.
- Investment risks: reassuring investors about long-term securing of inputs, including CO_2,
- Institutional players are ready to co-finance projects, however there is a lack of projects.
- A label could help set up the industry. How to qualify it: ACV? Taking in account the avoided CO_2 to compare with other industries?

Regulations:

- Chain of CO_2 abatement:

  - There is no recognition of the reduction for the emitter who has captured his CO_2.
  - Lack of clarity or unfavourable regulation concerning the profit of CO_2 reduction between actors.
- A lever for the industry is in the process of being put in place since 2016 with the reform of public markets in which the life-cycle criterion is now taken into account[27].
- Open-ended question: what would be the advantages or disadvantages of CO_2 as a waste?

Environment: environmental analysis is a key to better understanding the benefits of different tracks of CO_2 utilisation. However, even if the analysis of life cycle is standardized and used by the scientific community, it appears that:

- It is not used systematically and is very complex,
- Inventory data comes from multiple databases,
- These data are usually regional, preventing sharp analysis on national level,
- So that, when the results of environmental analysis of the tracks of CO_2 utilisation are presented worldwide, on the one hand the hypotheses are not or poorly formulated, on the other hand the methods of analysis (ACV, CO_2 footprint of direct and / or indirect emissions) are different, which reduces the relevance and blocks the emergence of a message that is clear, rigorous and shared by all
- Moreover, it should be noted that the CO_2 utilisation industry could be in competition with other substitutes for fossil molecules (e.g. biofuels).

Societal: it takes:

- Deploy demonstrators to raise awareness of CO_2 recycling, to reassure and to convince.
- Incorporate civil society representatives as new stakeholders into projects of the territory.

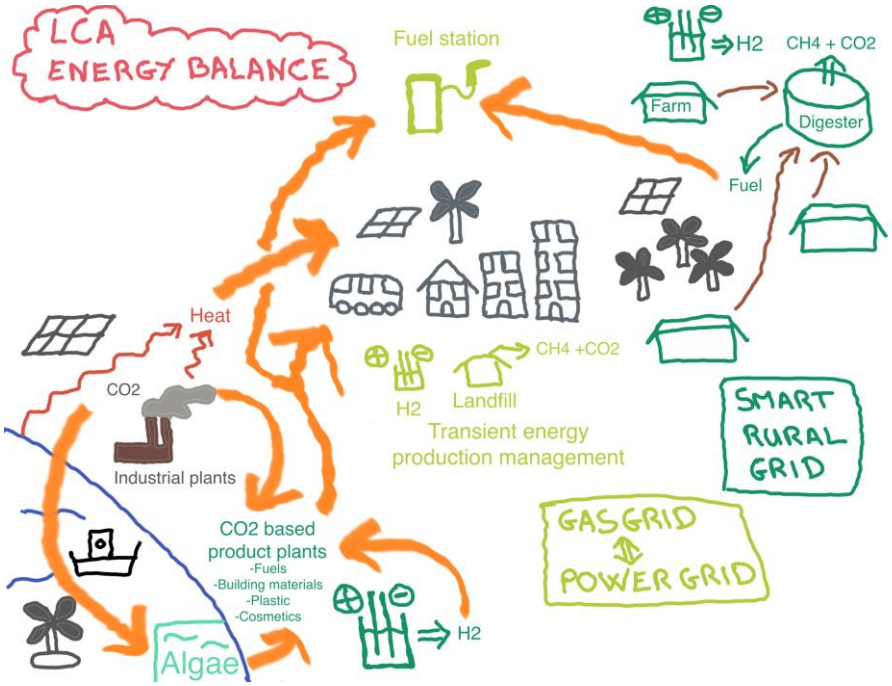
10. Territories Workshop: "Deploying CO_2 utilisation in a region"

Animation: Solène VALENTIN (AIR LIQUIDE), Alessandra QUADRELLI (CO_2 Forum), Aïcha EL KHAMLICHI (ADEME), Sylvain Pichon (GPMM)

The workshop took place in two stages with:

1. Conducting a "Future Search" analysis on four scales of the territory and the construction of four "future" scenarios:
   a) Residential house/ neighbourhood
   b) Rural environment
   c) Urban environment
   d) Industrial port area.
2. Integration of the four proposed scenarios into a regional strategy around a port area with the objective of contributing to CO_2 emission free transport and housing.

[27]Decree n° 2015-899 of July 23 2015 concerning public markets:
https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000030920376
Decree of application n°2016-360 of 25 March 25 2016 concerning public markets:
https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000032295952&categorieLien=id



In the first place, it is recalled that CO_2 utilisation is only feasible as long as the territory has industries. Without CO_2, this carbon source is no longer available for the production of new fuels, materials or essential specialty chemical products.

Focus on the Industrial Port Area (ZIP)

The strategy developed in the scope of this workshop is applied to the Mediterranean Sea (GPMM: Marseille Fos Port Authority).

A ZIP can provide different elements for an energy transition and a reduction in CO_2 emissions:

- Electricity produced by offshore wind farms or fields photovoltaic panels (large areas available),
- Heat / Cold produced by the thermal inertia of the sea,
- Recovery of residual heat from industries,
- CO_2 flows at different concentrations.

The production of liquid or gaseous renewable fuels is then possible by:

- Biological conversion of CO_2: algal fields in dedicated pods,
- Catalytic conversion of CO / CO_2 with association with H_2 ex-electrolysis of water (to absorb peaks of electricity of renewable origin).

The production of materials and polymers from captured CO_2 is also possible.

However, the deployment of a smart multi-vector network (methane, H_2, heat, electricity) and the systematization of an industrial ecology are inevitable to transform the port into an energy hub and of services. Of course, these interconnections lead to interdependence of the various port structures: the whole network is based on the sustainability of the actors, first and foremost, of the ZIP itself.

Interface between the ZIP and the urban environment

Between the ZIP and the city, multimodal energy networks will be needed to transport energy surpluses.

Cities will be the priority market for products manufactured in the ZIP, like CO_2-based materials and renewable fuels, thus promoting a short circuit from the manufacturer to the user.

In order to fit into the regional CO_2 reduction plan, cities must furthermore:

- Build passive buildings (energy efficiency) or even positive energy, coupled with the deployment of home automation to manage the energy production and consumption of households;
- Equip itself with renewable electricity generation;
- Develop waste methanation units for biogas (i.e. CH_4 and CO_2);
- Develop CO_2 to methane conversion units to absorb peaks of renewable electricity.

The transformation towards this city of the future will have to be eco-designed, which means that it will have to integrate the environment from its conception and at all stages of its life cycle[28]. Mobility must also be redesigned, as well as the behaviour towards mobility will need to be rethought. Public transport will be deployed and fed with renewable fuels produced from CO_2.

Interface between urban and rural areas

Rural areas extend over larger areas and to include them in the regional plan to reduce CO_2 emissions, it will be necessary to set up an intelligent network to link waste treatment units, power generation units and consumers, in order to limit losses and maximize energy production. This intelligent network will be based on units:

- Of Production of renewable energy (wind, photovoltaic),
- Of Energy storage,
- Of Methanation of biomass (in biogas). This biogas will be partially converted into Biofuel (GNV (Natural Gas for Vehicles) or LNG (Liquefied Natural Gas)) to feed agricultural vehicles directly.

The production of methane ex-CO_2 enabling the absorption of excess renewable energy can also be considered.

Rural areas characterized as food producing should not be in competition with this new industry of energy production (promotion AOC and Bio).

To sum up: the connection of the different levels of territory (industrial port area, urban, rural and dwelling house) with different vectors (electrical energy, thermal energy and gaseous or liquid fuels) is essential to reduce overall CO_2 emissions. It is important to note that the utilisation of CO_2 is an essential link to this connection. Indeed, CO_2 makes it possible to link electrical and heat energy to gaseous or liquid renewable fuel. It also makes it possible to produce materials with a limited carbon footprint.

Recommendations were made at three levels:

1. Need for demonstrators to control the risk associated with industrialization (capture, utilisation of CO_2 in methane, liquid fuels, mineral aggregates, chemical products of essence and speciality)
2. Investment:
    - In multimodal networks,
    - In fleets of vehicles that emit less CO_2 (H_2, GNV, LNG, electric),
    - Accompanying the transformation of cities of the future.
3. Adaptation of the regulation to define and promote products with significant environmental benefits.

[28]Afnor, 2014

11. Conclusions

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Daniel Clément thanks all the stakeholders who contributed to the 2nd CO_2 Utilisation Seminar: University Lyon I and its congress unit, CPE Lyon and finally the Organizing Committee, constituted by the Club CO_2, the ADEME and the CO_2 Forum. The success of this event is justified in particular by an important work of preparation and organization.

During the 1st CO_2 Utilisation Seminar held in Le Havre on May 4 2015[29], there was the recognition that CO_2 had a cost (its potential for nuisance) and a price (for example, the one associated with the Emission Trading Scheme of the European Union. However, it had not been demonstrated that CO_2 had any value.

Today, within the framework of this 2nd CO_2 Utilisation Seminar, one observes that CO_2 is beginning to be considered in terms of its financial and social value.

Three axes of CO_2 utilisation were presented today:

- In methanol, a molecule with an energy content prefiguring fuels with low carbon footprint (technology at the demonstration stage),
- In mineral aggregates for construction,
- In polymers

It is also the first time that the financial dimension is presented as a lever that can contribute to the utilisation of CO_2: the COP21 is often associated with the science of climate, with technologies, with adaptations, with North-South relations, but finance is not perceived as a lever or an angle of approach inseparable from the problem of climate change and of research, development and innovation projects.

Finance is at the heart of risk sharing accepted between communities and others investors.

Finally, the territories, with Le Havre Développement and the Grand Port Maritime de Marseille, have presented their assets - presence of industrial activities, services, infrastructures - and how they can promote the deployment of CO_2 utilisation units.

End of document

[29] http://www.captage-stockage-valorisation-co2.fr/sites/default/files/ACTES_ATELIERVALO_MAI2015.pdf