

Carbon-Dioxide Management Network in Hungary

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The detrimental environmental effect of the CO₂ emitted into the atmosphere is a well-known problem. To answer the challenges of environmental protection, University of Miskolc, Hungary, established a network called “Environmental carbon-dioxide partnership” (eco2p.eu) so that this organization contributes to

- The solution of the global warming problem,
- Storage of renewable energy,
- Production of materials on renewable basis.

To complete these goals the CO₂ can be the key molecule, the called platform molecule that is used for the solution of these challenges. The CO₂ can be transformed to either formic acid, methanol or natural gas, methane. These molecules can be used for the storage and production of energy or other chemicals.

Beside the technological aims there are significant management activities on macroeconomic level, too. The efficient use of the technological solutions at the fluctuating circumstances of the renewable energy production should be determined. The split ratio between energy storage and/or renewable material production is also a key issue for the macroeconomic studies.

1. Introduction

Sustainability and sustainable development play an important role in the social and technological development of our age. Energy and raw material supplies have paramount importance and it should be solved on a secure and renewable basis.

Energy production is nowadays mostly solved by the burning of fossil-based primary energy carriers releasing significant amount of carbon dioxide the so called anthropogenic one. To avoid this kind of emission and to ensure the security of energy supply, alternatives to energy production on a renewable basis become increasingly important. Their efficient use, however, can be solved only by the efficient storage of energy, typically the storage of electricity.

It is also possible to produce raw materials on a renewable basis in connection with energy storage. In the realization of the energy and raw material economy, the circular economy's philosophy has to be also followed, just like in the nature, where typically only as circuits are existing and almost no waste is produced. It is strange but our important energy carriers like crude oil and coal are all waste of the nature since they are not consumed by any natural circuit. Figure 1 shows a schematic view of the circular economy, where

- Make,
- Use and
- Return

are the key steps of the circular economy. However, when circular economy is considered, beside the technical problems there are management problems, research targets, too.

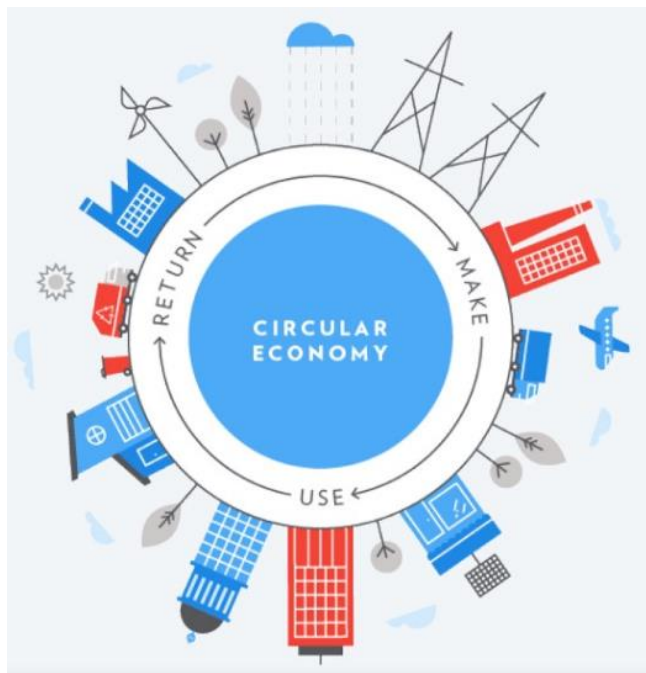


Figure 1: Circular economy, business solution (Simons, 2018)

2. Why CO₂? The solution for the technical problems of circular economy

The current environmental challenges, as a part of the circular economy, are the following:

- Reducing carbon dioxide emissions from anthropogenic sources,
- Efficient storage of renewable energy,
- Manufacture of renewable raw materials that can be carried out simultaneously with energy storage.

All these three problems can be solved if the CO₂ is considered as the platform molecule of the circular economy in the course of the solution of these issues. This CO₂ based circular energy and raw material economy should be contemplated on two levels based on team work:

- Technology level,
- Macroeconomic level.

On the technological level, the basic elements of the carbon dioxide based circular energy economy should be worked out and efficiently matched, such as:

- CCU, Carbon Capture and Utilization, this can be efficiently applied at such technologies where large amount of carbon-dioxide is emitted in a concentrated place, so called point like emission, for example, thermal power plants, cement plants (Nagy and Mizsey, 2013);
- Application of clean coal technologies, enabling them to recycle CO₂ and recycle them as a platform molecule;
- Exploration of the carbon capture capacity of algae;
- Production of hydrogen by means of water electrolysis using renewable electricity;
- Conversion of CO₂ with hydrogen into methane (natural gas) or methanol having a higher energy density than that of the natural gas;
- Methane and / or methanol produced for energy production are the basis for renewable raw material supply;
- Energy production from the produced methane or methanol;
- Production of renewable raw materials, see the Methanol economy by Olah (2005).

These individual elements require intensive technological research, in which the connection between each element is to be explored and examined. CO₂ is always present in each element and it becomes therefore the platform molecule of the circular economy dealing with the issues above.

The European Commission (EC) is searching for cost-efficient ways to make the European economy more climate-friendly and less energy-consuming by creating a low-carbon economy roadmap. This future plan suggests that the EU should decrease the greenhouse gas emissions to 80 % below 1990 levels by 2050. The first milestone to achieve this goal is 40 % emissions cut by 2030. All sectors need to contribute. Figure 2 shows that the power sector has the biggest potential for cutting emissions. Radical action in this sector could almost totally eliminate CO₂ emissions by 2050 (EC, 2018).

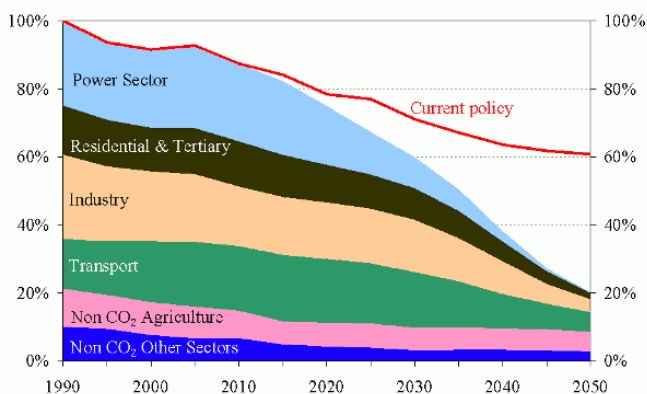


Figure 2. Possible 80 % cut in greenhouse gas emissions in the EU (100 % = 1990). Source: EC Climate Action: 2050 Low-Carbon Economy

In Hungary, the amount of CO₂ emitted dropped by nearly 40 % between 1985 and 2014. Figure 3 shows the radical fall that occurred between 1985 and 2000, because of the slackening of the heavily polluting Hungarian heavy industry (Young et al., 2018). Apart from the backdrop of lower backlogs since 2000, Hungary's CO₂ emissions have been continuously dropping (NRG Report, 2017).

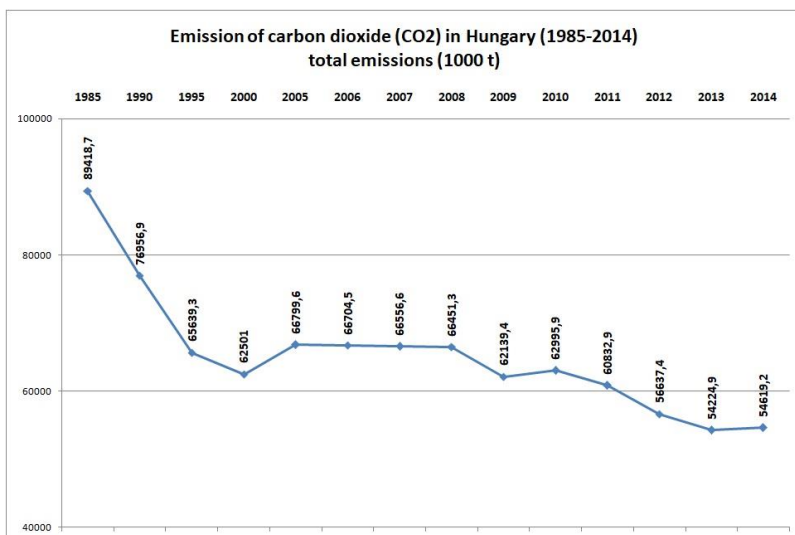


Figure 3. Emissions of CO₂ in Hungary. Source: NRG Report (2017)

2.1 Solutions for energy storage

If renewable energy production is considered sun, wind, water and biomass are the most convenient alternatives. As long as the utilization of biomass and water can be rationalized and used according to the needs, the sun and wind energies are strongly depending on the actual weather conditions. For instance, it cannot get solar current over the night or wind energy if wind is not blowing.

On the other hand, if the weather conditions are excellent for electricity production on solar or wind bases it can take place what already happened in Germany and the United Kingdom that the renewable electricity production was so enormous that the price of the electricity was negative for a while.

All the five targets we aimed at in this project application can be solved if consider the CO₂, it is as a platform molecule. It should be captured and used for energy storage purposes. This idea is not new since the nature already solved this problem and the way of the solution is the photosynthesis. It is needed just to copy this procedure and renewable raw materials can be also produced.

The electrical energy can be stored in different ways. Figure 4 presents the features of the storage alternatives. Figure 4 clearly shows that on a large scale we have to solve somehow the photosynthesis on industrial level

where CO₂ is the platform molecule. The CO₂ is converted with reduction into primary energy carrier molecules. Specht proposed methane, that is, the natural gas.

Specht et al. (2009) proposed a circle process where CO₂ is captured and converted into methane. Methane is the molecule of natural gas, so it has the advantage to use the existing natural gas network. A schematic view of the energy storage loop is presented in Figure 5.

Carbon capture processes are also the part of the system but if the SNG network is already solved the CO₂ can recycle in the loop and no new CO₂ source is required if only energy is stored. However, if renewable raw materials are also produced, CO₂ make up is required. That is, CO₂ capture can be completed somewhere out of the SNG loop.

In the frame of the technical part of the Platform, there is a study

- The SNG loop with systematic systems engineering tools, that is, it is needed to make flowsheeting,
- Parametric study is completed and the effects of different technological parameters are investigated like electrolysis, reaction conversion rate,
- Overall efficiency is calculated,
- Other energy carrier compounds like methanol, hydrogen,
- Comparison of the efficiencies of the different SNG, or energy carrier molecule
- scale up problems,
- Effect of energy storage and recovery over renewable raw material production,
- Optimal split ratio between energy storage and raw material production.

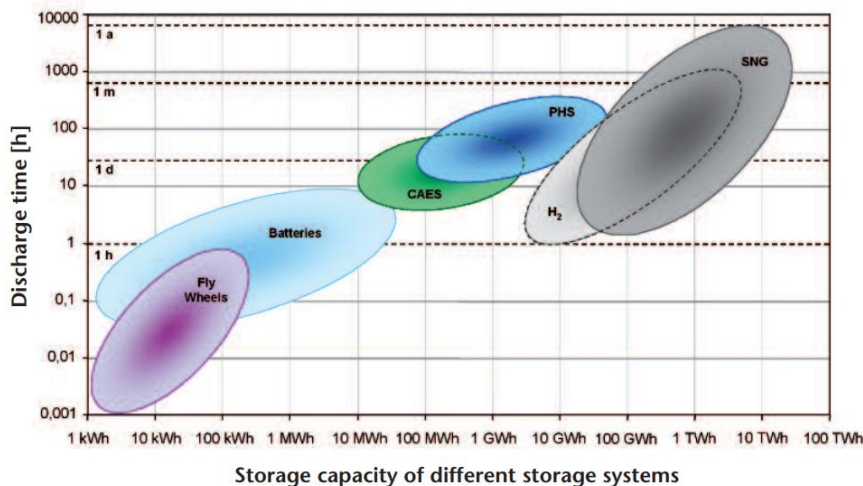


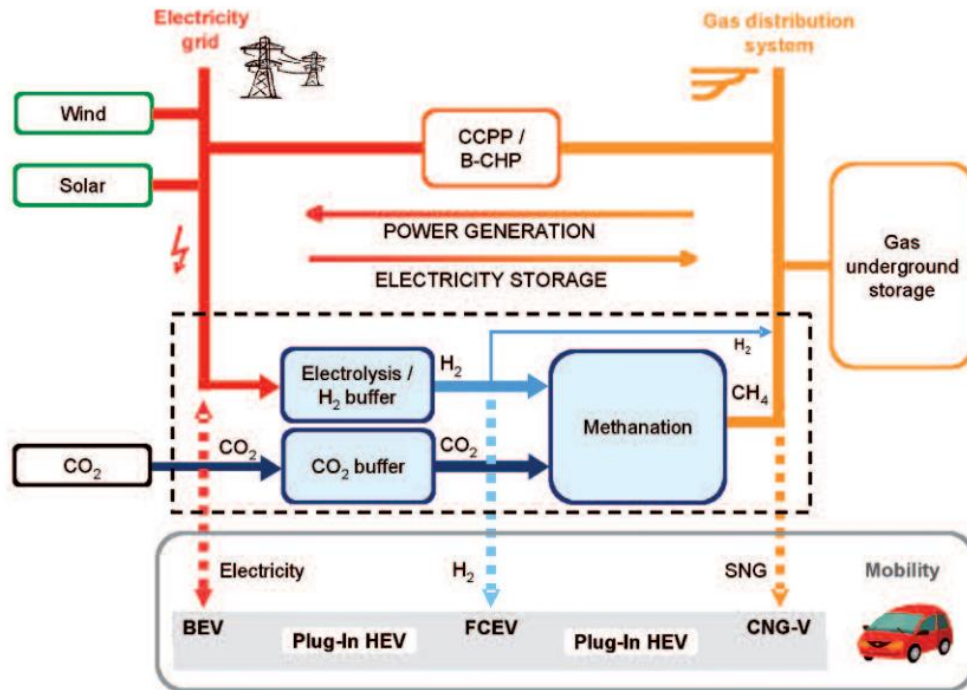
Figure 4 Features of different energy storage alternatives. CAES: Compressed Air Energy Storage, PHS: Pumped Hydro Storage, H₂, SNG: Substitute Natural Gas

3. Management on macroeconomic level

The solutions developed on the technological level should be coordinated on macroeconomic level where management tools are to be applied. In the course of such a management activity the principles of the circular economy should be always followed. Today the circular economy should be built into the business since serious managers think about the following principles (Simons, WSP, 2018):

- Business resilience. If we use only natural resources in the production, our business is not resilient. The recycle and reuse of materials is a key issue. The waste is raw material, actually.
- Costs and growth. If the philosophy of circular economy is applied, materials are reused, and our business will be more resilient. On the other hand, new production ways are detected that are usually cheaper, new business opportunities are developed creating thousands of new jobs.
- Customer demands. The environmental customer demands now such goods that have less ecological footprint. This is especially true in the cases of huge investments, where legal tools are also applied to influence customer demands. the reuse of materials reduces carbon and ecological footprint. There are certain products where materials can be even excluded, for instance electronic tools replaces paper, CD, etc.

- Innovation support. The hottest priorities of today's governments are the motivation and support of innovation that move the business towards the introduction and development of circular economy.
- Leadership and legacy. Nowadays the developed countries consume three or four times more natural resources than the amount that would be sustainable on the long term. Of course, this cannot go on for a long time. Business management should force the innovation and operation towards materially sustainable economy using different tools, if needed legal tools as well (Simons, WSP, 2018).



CCPP:	Combined Cycle Power Plant
B-CHP:	Block-Type Combined Heat and Power Station
BEV:	Battery Electric Vehicle
FCEV:	Fuel Cell Electric Vehicle
CNG-V:	Compressed Natural Gas Vehicle
Plug-In HEV:	Plug-In Hybrid Electric Vehicle; Especial: Plug-In Electric Drive Motor Vehicles/Range-Extended Electric Vehicle

Figure 5: SNG network and its infrastructure and operation

In the case of our Carbon dioxide partnership network the management have to focus on the macroeconomic level to the following:

- Examination and definition of the conditions of effective application of the methodology defined at the technological level. These conditions define the circumstances of the effective and economic matching of the renewable energy generated on a fluctuating way and the consumption having a different phase than that of the energy production;
- Researching the economical parameters of renewable raw material production completing simultaneously with the energy storage, the split ration of energy storage and raw material production and its relation to energy storage is also an important issue of the research;
- Identification of the economic circumstances of carbon dioxide capture, recovery, electrolysis, energy storage and the economic feasibility of raw material production;
- The impact and the social importance of circular energy management on consumption.

4. Establishment of the “Environmental Carbon Dioxide Partnership

On the 10th of January 2018 the University of Miskolc established the Environmental Carbon Dioxide Partnership. The partners are: one domestic university and four national and international companies located in

the neighborhood of the university. The companies are huge chemical companies and they contribute significantly to the Hungarian GDP. So the Partnership had a good start.

The aims are ambitious: the Partnership wants to study the environmental problems like

- Global warming,
- Carbon capture,
- Renewable energy,
- Storage of renewable energy,
- Renewable raw materials,
- Security of energy and raw material supplies.

The Partnerships wants to find solutions for these problems where the principles described in points 1-3 are applied and followed. Both technological and management problems are studied and solutions are generated. The Partnership offers a forum for the partners to get easily to know each other's, information exchange in the fields of problem definition and solutions. The Partnership enables the partners to generate new project applications, innovations and alternatives for problem solutions. The Partnership is open for everybody and new partners are welcome.

5. Conclusions

The concern about the life of our children and grandchildren leads us to the recognition that we have to solve several challenging problems of our age. Among them there are serious phenomenon and technical/technological problems. The Environmental Carbon Dioxide Partnership is aiming at the solutions of environmental problems of today where the carbon dioxide as platform molecule can be used for the simultaneous solution of different problems.

The problem solutions elaborated on the technological level, however, should be coordinated and managed on macroeconomic level so that the innovations and product development will be efficient and economic. Beside the new technical and technological solutions their management plays also an important role for the sake of efficient problem solutions and innovations.

Acknowledgments

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