**Scenario analysis of carbon capture, utilization (particularly producing methane and methanol) and storage (CCUS) systems**

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**Highlights**

* Exploring new proposed model for the carbon capture utilization and storage supply chain.
* Optimal layouts for carbon supply chains in Germany and Italy
* Product revenues and incentives strongly influence the supply chain design.

**1. Introduction**

A carbon dioxide economy has been proposed, characterized by the use of renewable energies as the basis for a circular economy. Atmospheric carbon dioxide reduction can be achieved by storage or by utilization: through production of methanol, methane and a range of other products [1]. Leonzio et al. [2, 3] developed a CCUS supply chain model including options of storage and utilization. The model has been developed for Germany including methanol, concrete, wheat, lignin, polyurethane, calcium carbonate, urea and also for Italy where methane is produced. In paper we evaluated the effects of a carbon tax, economic incentives and revenue on the system outputs of supply chains in Germany and Italy.

**2. Methods**

The mathematical model was used to determine optimal volumes of captured CO2 and products [2, 3] and CO2 sources they should be taken from. The objective function is the sum of total costs less the revenues, carbon tax and economic incentives. The mixed integer linear programming models are solved in AIMMS software.

**3. Results and discussion**

A local sensitivity analysis was carried out for the CCUS supply chain in Italy considering three levels of carbon tax (20 euro/ton, 40 euro/ton and 80 euro/ton) and economic incentives (240 euro/MWh, 270 euro/MWh and 300 euro/MWh). The minimum target for CO2 reduction is 77 Mton/year; CO2 that is not captured is released into the atmosphere. Results (Table 1) show that system source locations change with tax rates and economic incentives. Also the total value and methane production are affected: at low, average and high level of these parameters the total values are respectively 12.8 billion euro/year, -2.43 billion euro/year and -70.7 billion euro/year, while methane production is 22.5 Mton/year, 22.5 Mton/year and 101.8 Mton/year. For high values of tax and economic incentives at optimal profit all possible CO2 is captured and sent to the utilization section. Results for changing only carbon tax show that only the total value is affected, while system topology (CO2 source locations) and methane production are constant.

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| --- | --- | --- |
|  | To utilization (methane production) | To storage |
| Carbon tax/Economic incentives | Low values | Average values | High values | Low values | Average values | High values |
| CO2 source | Puglia  | Sicily | Sicily | Veneto | Sardinia | All regions | Lombardy | Lombardy | - |
| Capture technology | MEA | MEA | MEA | MEA | MEA | MEA | PSA | MEA | - |
| CO2 captured (Mton/year) | 61.8 | 0.024 | 37.4 | 20.3 | 4.17 | 279 | 15.2 | 15.2 | - |

**Table 1.** Results of sensitivity analysis for CCUS supply chain in Italy with Malossa San Bartolomeo as storage site

Similar results are found for the CCUS supply chain producing only methanol in Germany (Table 2). The minimum target for CO2 reduction is 160 Mton/year and CO2 not captured is released into the atmosphere. The total value is 16.3 billion euro/year, -30 billion euro/year and -0.197 trillion euro/year respectively for the low, average and high level of the parameters, while methanol production is respectively 203 Mton/year, 968 Mton/year and 968 Mton/year. A sensitivity analysis was again performed: results show that when changing the price of methanol the total value is changed with system topology.

|  |  |  |
| --- | --- | --- |
|  | To utilization (methanol production) | To storage |
| Carbon tax/Economic incentives | Low values | Average values | High values | Low values | Average value | High values |
| CO2 source | Dusseldorf | All regions | All regions | Magdeburg | - | - |
| Capture technology | MEA  | MEA | MEA | MEA | - | - |
| CO2 captured (Mton/year) | 140 | 665 | 665 | 20.3 | - | - |

**Table 2.** Results of sensitivity analysis for CCUS supply chain producing only methanol in Germany

For a CCUS supply chain producing different products in Germany it was found carbon tax and revenues lead to a full possible capture of CO2 and all CO2 is sent to utilization. For increased carbon tax only the total value is increased. Changing the sales prices of products according to market value causes predicted values for lignin and wheat production change.

**4. Conclusions**

For the cases studied in this work carbon tax affects only the total value while changing economic incentives and product revenues also changes the system topology. Model optimization is a useful decision support tool for CCUS investment decisions.

**References**

[1] J. Patricioa, A. Angelis-Dimakisb, A. Castillo-Castillo, Y. Kalmykovaa, L. Rosadoa, Region prioritization for the development of carbon capture and utilization technologies, Journal of CO2 Utilization 17 (2017) 50–59. [2] G. Leonzio, P.U. Foscolo, E. Zondervan, An outlook towards 2030: optimization and design of a CCUS supply chain in Germany. CCE (under review) [3] G. Leonzio, P.U. Foscolo, E. Zondervan, Under what conditions CCUS supply chain is feasible? The case of Italy, C.E.R.D., Under review.