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## 1 Objectives

Innovative industrial process for the production of energy and materials increasingly integrate thermo-physical and biological processes into a single industrial application.

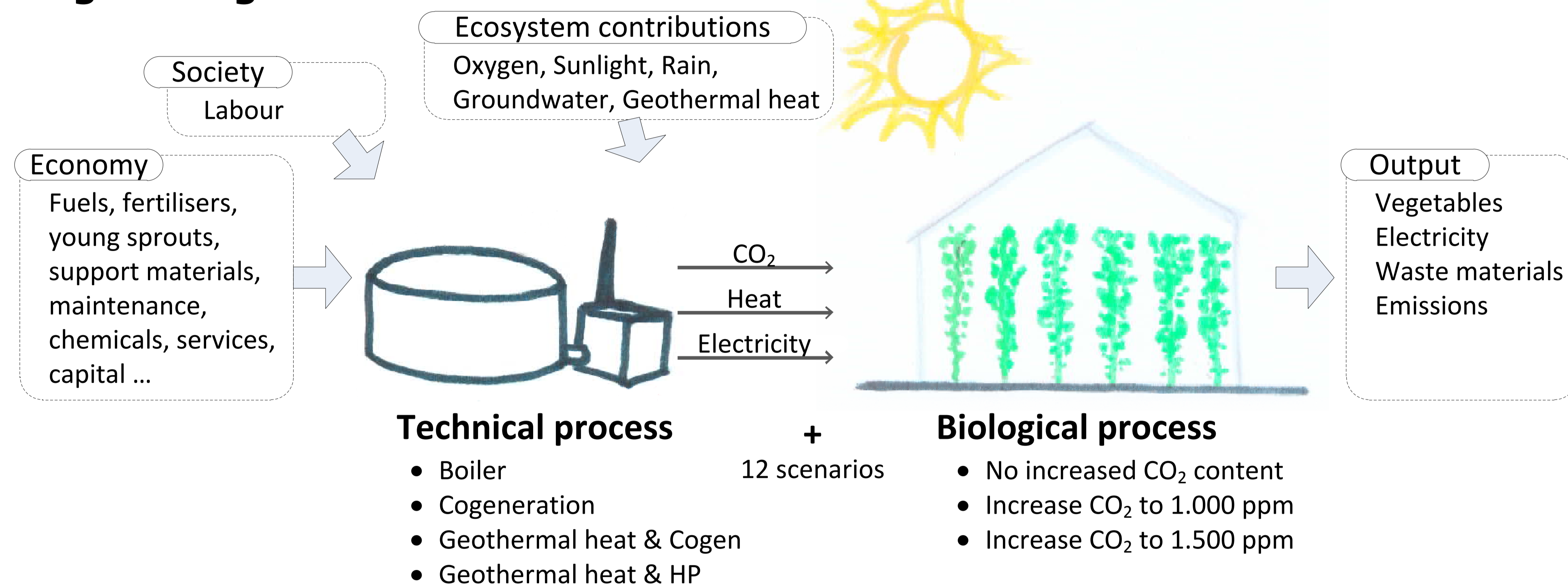
This project assesses both the economic potential and the impact these processes have on the natural ecosystems surrounding them. Where in economy mostly labour, capital and materials are considered as production resources, ecosystem services should be integrated in the equation as well. Two options are compared to integrate ecosystem services for the assessment of an industrial process.

## 2 Measuring input from ecosystem services

Contributions from ecosystems to the production process are here accounted for through flows of matter and energy. Included flows are sunlight, rain and groundwater, geothermal heat, oxygen and nitrogen from the atmosphere for the combustion process.

All inputs are accounted for based on their Cumulative Exergy Demand (CED). This approach includes all expenses of exergy during the life cycle of the input. The accounting of all inputs in exergy reflects a strict physical view of the exchanges between processes and with their environment.

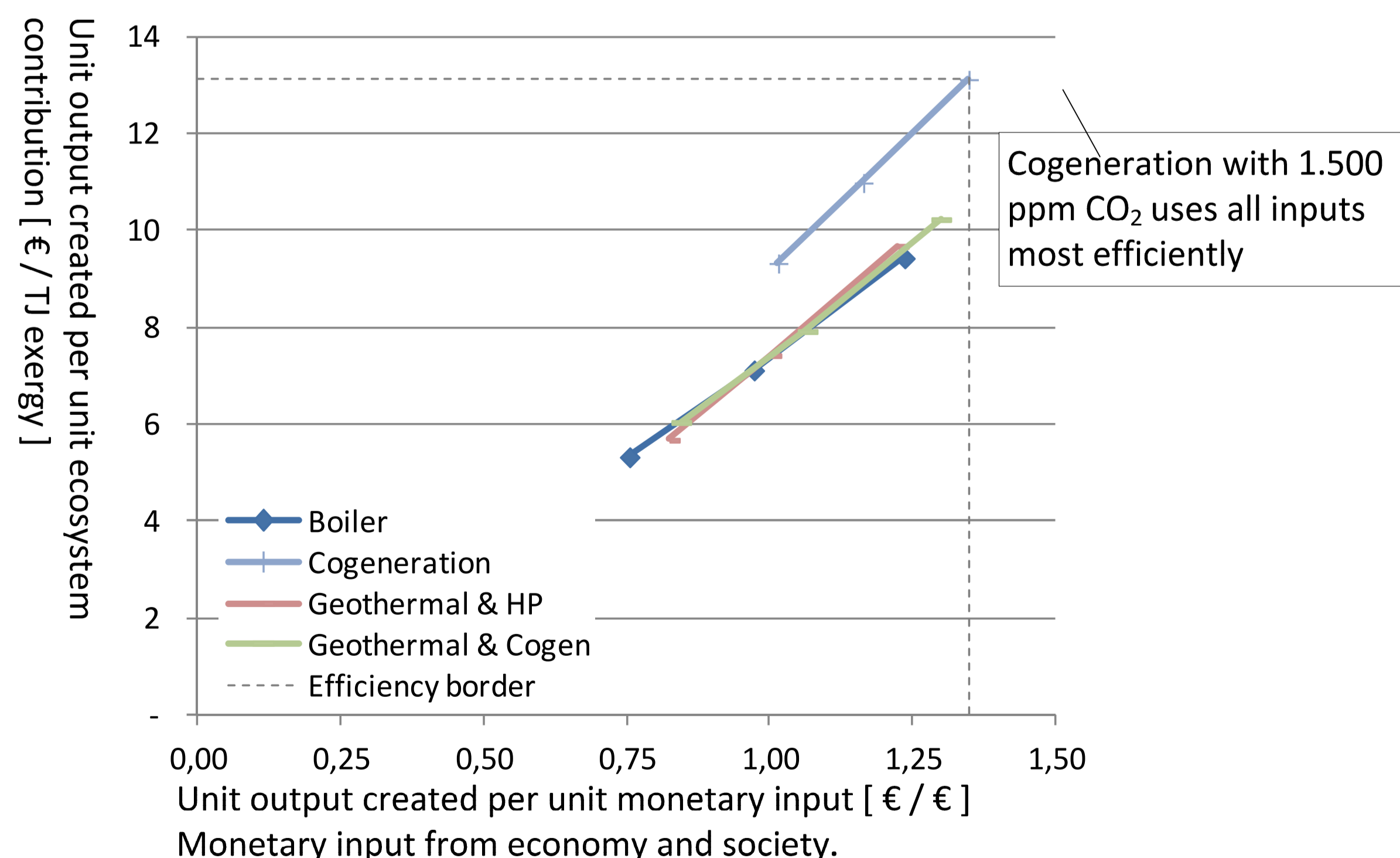
### Case-study : Vegetable greenhouse



## 3 Option 1 : Ecosystem services as a separate input

Economic efficiency can be analysed with Data Envelopment Analysis (DEA). This method allows the comparison of different production scenarios without the aggregation of all inputs with the same units.

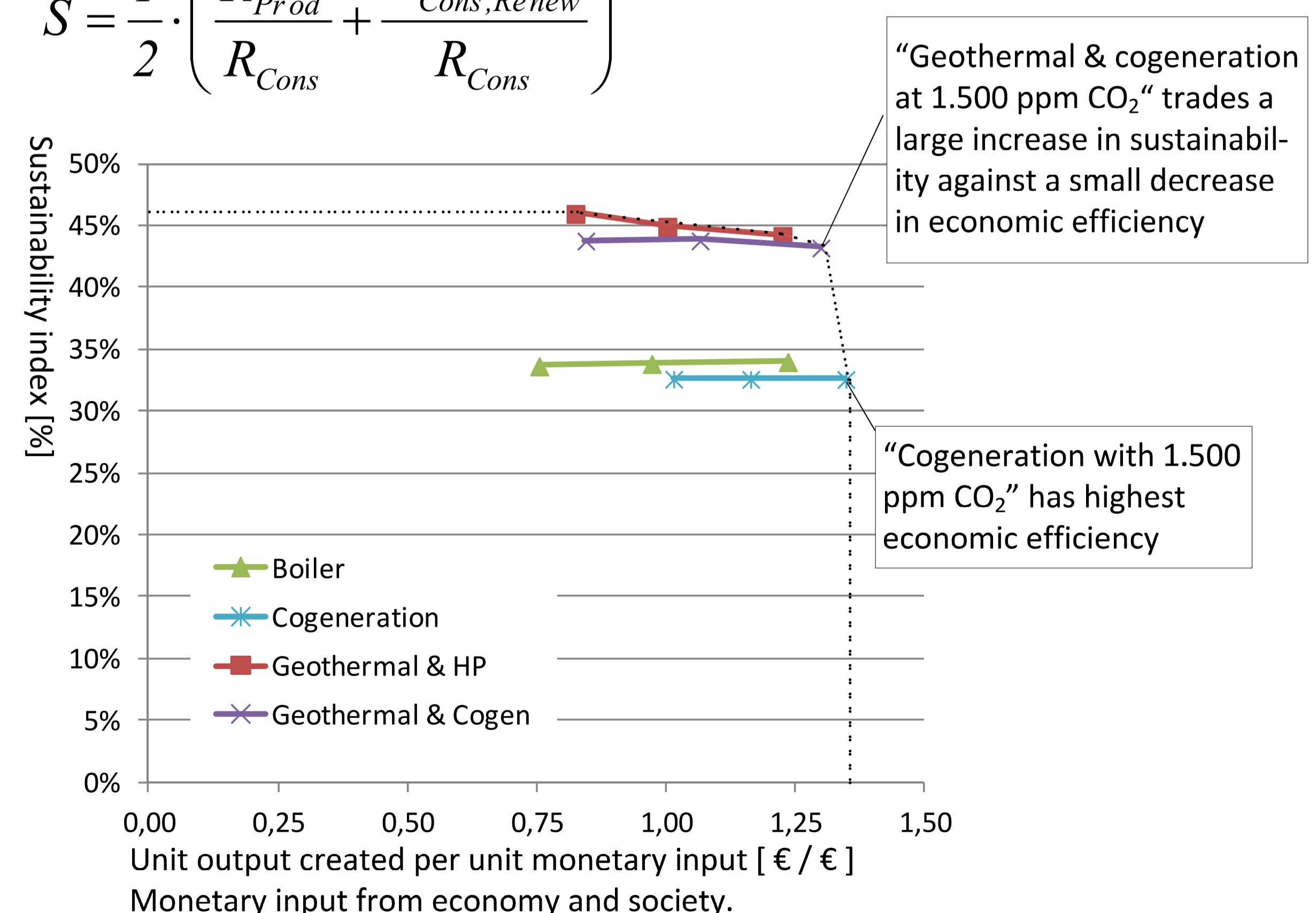
This projects looks at inputs from ecosystem services as a production input alongside labour, capital, raw materials etc..



## 4 Option 2 : Considering all transfers both in economic as in physical terms

The assessment is transformed from an efficiency analysis to a trade-off problem. The trade-off is analysed between the economic efficiency (considering all inputs in monetary terms) and the sustainability of the process (considering all inputs in physical terms). The sustainability is defined by a sustainability index in exergy terms, taking exergetic efficiency and renewability of resources into account.

$$S = \frac{1}{2} \cdot \left( \frac{R_{Prod}}{R_{Cons}} + \frac{R_{Cons, Renew}}{R_{Cons}} \right) \quad (\text{Dewulf, 2001})$$



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### References

Dewulf, J., Van Langenhove, H., Mulder, J., van den Berg, M.M.D., van der Kooi, H.J., de Swaan Arons, J., 2000. Illustrations towards quantifying the sustainability of technology. Green Chemistry 2, 108-114.