**Conceptual study on coal power plant transformation to metal power plant; A look into the future**

P. Awad1\*, R.G. Baltazar1, I.D. Garcia1, E. Dijkman1, P.L.J. Swinkels

*TU Delft, Chemical Engineering Department, Van der Maasweg 9, 2629 HZ  Delft, Netherlands*

*\*Corresponding author: p.w.a.awad@tudelft.nl*

**Highlights**

* Iron oxide power plant conceptual design
* Reduced carbon emission power plant
* Reduction of iron oxide with carbon monoxide from dry methane reforming

**1. Introduction**

Greenhouse gases have been exhibiting a rapid increase recently. Coupled with the will to ensure security of energy supply, governments are trying to change the source of energy to other fuels, reducing the production and emission of these gases. As part of these efforts the Dutch government decided in May 2017 to stop using coal for electricity generation in the very near future.

The objective of this work is to assess the feasibility of a swift shift from coal-fired power plants to metal fuels power plants. A preliminary conceptual design is performed taking as a reference the existent Uniper’s coal power plant in Rotterdam, the Netherlands.

**2. Methods**

For this project the Delft Design Map method is used [1]. The general approach of this method is to explore a wide range of options hierarchically. It consists of different design levels, from which the following are used in this work: Project Framing, Costumer Wants, Input-Output Structure, Subprocesses, Task Network, Unit Network and Process Integration.

Regarding the design itself, current assets of the existing coal plant was maximized. Preliminary and shortcut design methods were used whenever appropriate and preliminary cost estimations (±35%) were applied. Three main critical design decisions characterize the project outline, reflecting the final process design and the respective economic evaluation.

1. Input-output structure.

Process options are examined using input-output diagrams to decide on metal fuel type(s), regeneration need, extent and percentage of regeneration. Low cost of iron ore (mainly FeO), coupled with its oxidation stability and geographic availability are the main reasons for selecting it as the main raw material. It was also decided to use regeneration to FeO instead of reduction to pure Fe after some high-level mass balance and cost analysis calculations. Iron Oxide regeneration allows for a significant reduction of both required metal fuel needed as well as the waste stream.

A number of reducing agents and methods for regenerating the Fe2O3 combustion product were evaluated: hydrogen, carbon monoxide, iron electrolysis, micro-organisms and biomass. Then, carbon monoxide produced from dry methane reforming was selected due to the advanced development stage of the reduction reaction and low investment. The production of CO is advantageous since it uses carbon dioxide to produce carbon monoxide, with hydrogen as by-product. A cyclic process was designed in order to minimize CO2 emissions and introduce a flexibility of using CH4 potentially from a bio source as a supplementary fuel to the process.

1. Process thermodynamics

Introduction of the Brayton cycle to the current existing Rankine cycle was another important decision. Furthermore, using exhaust gases from the furnace to heat the medium pressure steam results in a higher energy produced per raw material consumed. The absence of any carbon source creates an opportunity to use a turbine in this stream due to higher density providing higher separation efficiency upstream of the turbine. The combination of these two factors result in an increase in efficiency from 47% to 60%, primarily caused by the steam temperature upgrade.

1. Waste treatment

The purge stream from the iron cycle is considered as an added-value stream to the steel industry. Compared to the conventional inlet iron ore stream, produced iron oxide waste (Fe2O3) from this process is richer in oxygen and has a lower impurity content. Therefore, it can be sold at an interesting price to the steel industry. Furthermore, this reduces the demand for mining in the steel industry.

**3. Results and discussion**

Preliminary design and cost evaluation for this conceptual design resulted in a -1300 M€ NPV which is unacceptable for an investment. Raw material demand proved to be the largest cost driver. However, the project was initiated with future scenario’s in mind. It was already known at the start that currently it is not yet economically feasible. The question was how far from economic feasibility it actually is, and what needs to change before it will become economically feasible, and when this is expected to take place. Carbon tax used in this work was set around €50/ton but it is uncertain when this will shift to higher values. A significant reduction on the raw material price would change NPV drastically. This can be achieved by researching other sources for the raw material, such as metal scraps from the car industry.

**4. Conclusions**

A metal fuel power plant as a replacement for a coal-fired power plant proved to be economically infeasible under the current circumstances and market values. However, when compared to conventional coal power plant, of which NPV is zero for €72/ton carbon tax, it reaches the same (negative) NPV once carbon tax is €103/ton. Figure 1 shows the relationship between NPV values and carbon tax values for both a conventional coal power plant and metal fuel one.

**References**

1. J. Harmsen, A.B. de Haan, P.L.J.Swinkels, Product and Process Design, De Gruyter, Berlin, 2018