52126-Life Cycle Assessment of the modified Pedersen method–challenges of an alternative alumina production route

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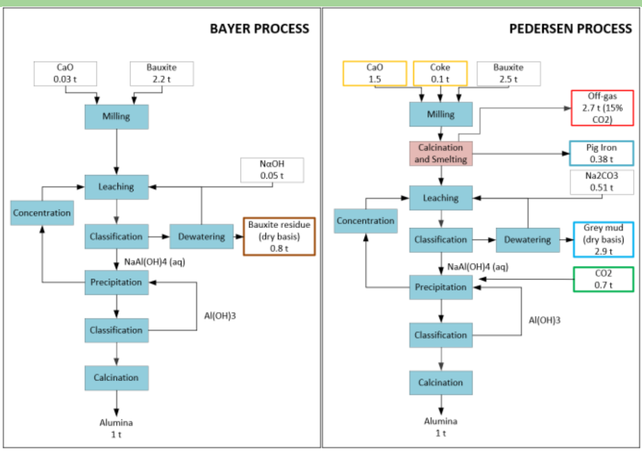
INTRODUCTION

Alumina is the intermediate product for aluminum metal. Bauxite ore is the main source of the current commercial alumina production process; Bayer process. More than 95% of alumina is being produced via this route. The generation of bauxite residue is the main environmental challenge associated with the Bayer process. High alkalinity, presence of heavy metals, potential radioactivity, handling, storage and transport issues inhibit its valorization up to a large extent. In the scope of ENSUREAL H2020-SPIRE-2017 project, an alternative process is studied; the modified Pedersen process (MPM). Pedersen process was run in Høyanger, Norway, for forty years (1928 - 1969). The process co-produces iron and a calcium-rich by-product; grey mud. Grey mud consists mostly of calcium carbonate. It can be used as supplementary cementitious material or as liming material in the agricultural sector (Vafeias et al., 2018). The process also utilizes CO_2. One of the alumina-containing sources that was tested within ENSUREAL project is Greek bauxite; a karst-diasporic, high quality (56 % Al_2O_3), high-iron, low-silica ore. The main inputs and outputs for Bayer were obtained based on European Aluminium Association (EAA) report for 2018. Calculated values were used for Pedersen, using HSC v.10.0.1.8 software. GaBi v.8.0 software was used for the assessment and the Ecoinvent 3.6 database and GaBi professional database were used as secondary sources.

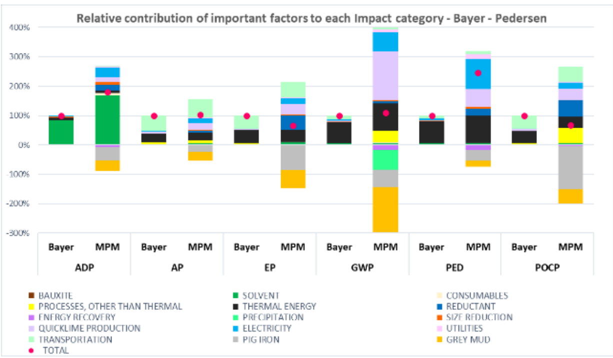
LIFE CYCLE INVENTORY



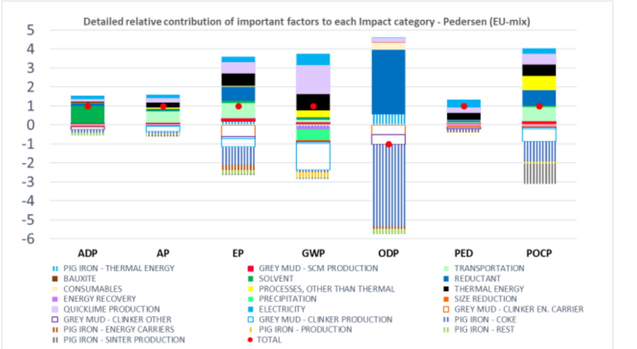
- Bauxite consumption in MPM is higher compared to Bayer. Leaching is the "limiting step" for MPM, with total alumina recovery 70 %.
- Higher quantity of quicklime is used in MPM, which partially reacts with sodium carbonate and ends up in the grey mud
- For Bayer, air emissions are mainly attributed to the combustion of the fuel
- Gases (mainly vapor) exit the MPM due to drying and decomposition of hydrates
- Carbon dioxide that is emitted is 15 % of the total air emissions for MPM
- MPM consumes CO_2, higher than that emitted from coke oxidation in smelting
- Indirect CO_2 emissions increase due to the fuel consumption for calcination
- Energy consumption for MPM is ab. 2 times higher than Bayer, but MPM co-produces pig iron and grey mud. "Credits" on the avoided production will be reflected and affect positively the Life Cycle Impact Assessment of MPM.

Energy consumption [GJ/t alumina]	Bayer	MPM
Diesel oil	0.003	
Electricity	0.51	6.9
Heavy oil	0.03	
Natural gas	8.94	8.1
Steam		4.5
Energy recovery from pyro		-2.4
Total energy input	9.4	17.1

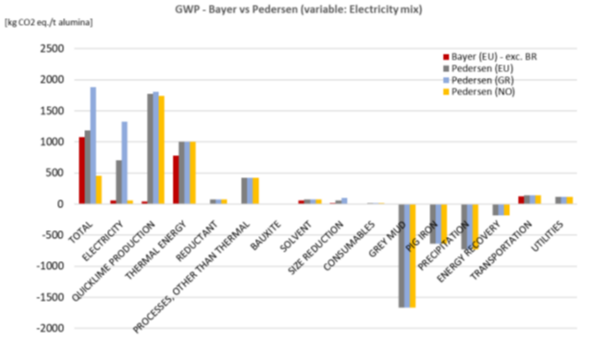
LIFE CYCLE IMPACT ASSESSMENT (LCIA)



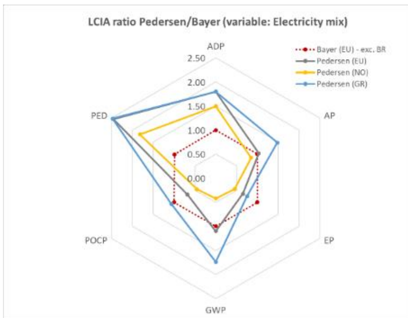
- The major contributor for ADP is NaOH for Bayer and Na2CO3 for MPM.
- Thermal energy demand and bauxite transportation affect AP and EP
- EP for MPM is affected by coke consumption, but the impact balances with the credits of the "avoided" coke that is consumed for commercial pig iron.
- PED is mainly affected by thermal energy, electricity and energy for quicklime calcination



- POCP and ODP for MPM are reduced compared to Bayer, mainly due to the lower coke consumption per ton of pig iron that was considered, compared to the pig iron commercial process that exist in the Ecoinvent database
- For EU mix in MPM, electricity mix contributes to the following categories as follows: ADP (7.1%), AP (6.6%), EP (6.6%), GWP (12.7%), POCP (6.1%) and PED (18.3%)



- GWP is significantly related to quicklime production, thermal energy, electricity and emissions from coke oxidation.
- Credits from the substitution of clinker with grey mud are significant for GWP, because grey mud does not need calcination, compared to the limestone for clinker production. This leads to energy credits and credits in direct CO2 emissions.
- For GWP, pig iron avoided emissions balance the emissions from smelting.
- Decarbonization reduces the impact of Pedersen compared to EU-mix for each category as follows: ADP (-15%), AP (-16%), EP (-27%), GWP (-54%), POCP (-29%) and PED (-23%).



CONCLUSIONS

Bauxite and quicklime consumption in MPM is higher compared to Bayer. Energy consumption for MPM is 2 times higher than Bayer. The performance of MPM is significantly affected by the quicklime consumption, thermal energy and electricity. However, the co-production of grey mud and pig iron makes MPM impact comparable to Bayer, with the substitution of clinker with grey mud, to significantly enhance the overall performance. The decarbonization of the electricity mix will affect significantly in a positive way the environmental performance of MPM and make MPM more sustainable in respect to the GWP, EP and AP impact categories.

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