SYSTEMS ANALYSIS OF ALTERNATIVE FUELS PRODUCTION FROM HEAVY HYDROCARBONS IN SAUDI ARABIA

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Overview

According to the IEA, transportation is the only sector in which CO_2 emissions continue to rise annually, as shown in Figure (1) [1]. The introduction of stringent regulations on emissions of CO_2 will require the transition to cleaner combustion processes and the use of cleaner fuels [2]. Heavy hydrocarbons resources are widely available in Saudi Arabia and they are also commonly produced from crude oil distillation processes. Cracking of these hydrocarbons requires expensive use of hydrogen and high temperature processing to increase the yield of gasoline. Furthermore, the combustion of heavy hydrocarbons results in large emissions of CO_2 compared with the combustion of natural gas or light fuels. The future demand for clean fuels including blended gasoline and diesel [2] would require oil refineries to alter their existing processes to maintain their market share while meeting future fuel demands and specifications. In this work, systems analysis of the gasification of heavy hydrocarbons is conducted followed by the conversion of syngas to methanol and other clean fuels. The specific cases considered in this work are in Saudi Arabia where methanol is currently produced from natural gas. The aim is to maximise refining profitability while enhancing the economic and environmental sustainability of refinery produced fuels. Results show that exiting resources of heavy oil produced from Saudi Aramco refineries may supply methanol needed for gasoline blending accounting for 11% of world methanol production at constant demand growth of 1% even when introducing the constraint of CO_2 emissions costs. Additional aspects of this work include the scenario analysis of limiting CO_2 emissions, investment and operating costs, and resource availability.

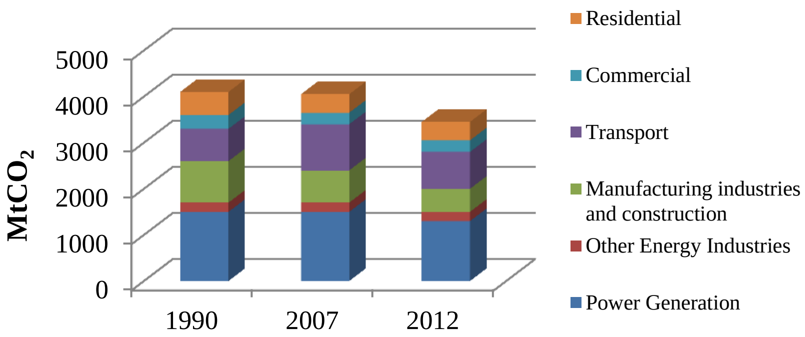

Figure 1: IEA projections on CO_2 emissions from fuel combustion in the EU [1]

Methods

The LP optimisation Model for Energy Supply Strategies And their General Environmental Impact (MESSAGE), which was developed by the International Institute of Applied Systems Analysis (IIASA), was used to conduct the economic analysis of the production system shown in Figure (2). The system was developed so that it converts heavy hydrocarbon resources into oxygenated fuels, hydrogen, and other syngas-derived products such as methanol, DME, and ammonia. Partial oxidation (POX) is selected as a process of choice to oxidise hydrocarbons in order produce syngas. Autothermal reforming (ATR) may also be used if the syngas ratio is to be adjusted to increase the yield of hydrogen through the water gas shift reaction. Two blending processes are assumed to be used to produce blended gasoline and diesel to meet requirements of transport sector. In addition, Hydrogen can be mixed with natural gas to produce hythane for cleaner combustion. Mass balance calculations are conducted using the Aspen HYSYS model which makes use of the Peng-Robinson equation of state [3].

Table 1: Main data input for MESSAGE

Modelling parameters	Parameter data input
Technologies	Steam reforming, Partial oxidation. Methanol synthesis, Haber process, Methanol dehydration, Water-gas-shift
Main Constraints	Costs on CO_2 emissions, resource availability, production costs, market demand
Energy Forms	Heavy hydrocarbons, Natural gas, Syngas, Methanol, Hydrogen, DME, Ammonia
General input	Discount rate: 4, Investment time: shifted
Resources	Heavy hydrocarbons, natural gas

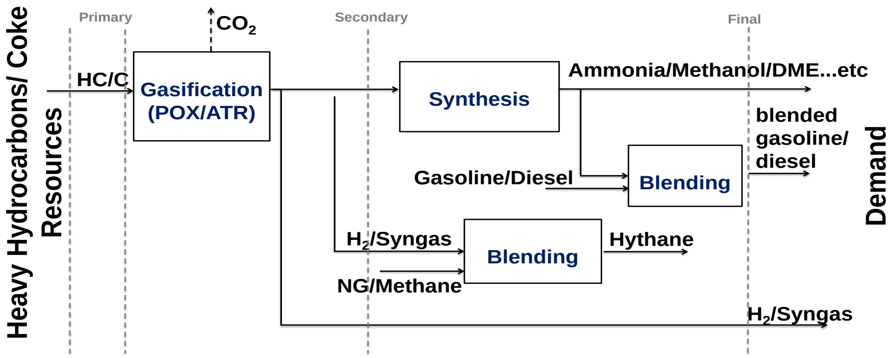

Figure 2: Proposed system for gasification of hydrocarbons and alternative fuels production and blending

Results

The results shown in Figure (3) show a projection of methanol supply between 2015 and 2040 using both natural gas reforming and partial oxidation of heavy hydrocarbons. The optimisation trend shows that the use of reforming technology and light hydrocarbons can reduce CO_2 emissions. However, the resource availability of such resources makes it necessary for the Kingdom to consider gasification of heavy hydrocarbons to reduce the carbon emissions. The reason is that more CO_2 is produced from steam reforming of natural gas, compared with partial oxidation of hydrocarbons where its yield can be reduced by avoiding the water gas shift reaction. Results also show that the kingdom can meet global methanol demand for gasoline blending by considering the gasification of heavy hydrocarbons produced from its oil refineries even when introducing the limits on CO_2 emissions.

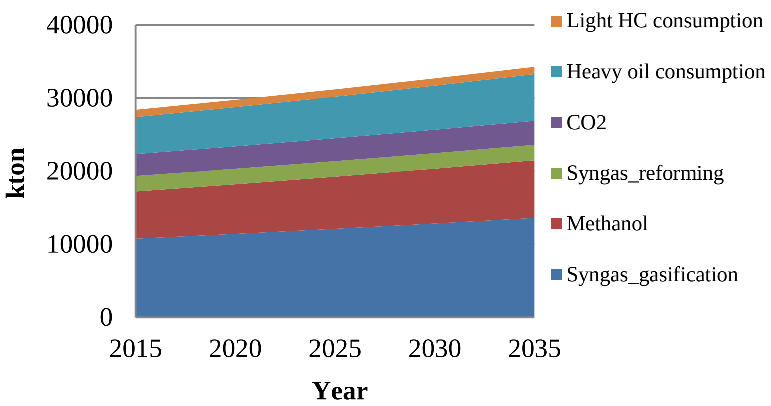

Figure 3: Projection for syngas production followed by methanol synthesis and its associated CO_2 emissions

Conclusion

An optimisation case for production of alternative fuels from existing hydrocarbons resources was conducted using the LP optimisation model MESSAGE under CO_2 emissions constraints. Results show the Saudi Arabia can potentially maximise its share in the refined products market by investing in alternative fuel production from existing heavy hydrocarbon resources. While the share of light hydrocarbons consumption is fixed, the model results show that the share of heavy hydrocarbons needs to increase to meet increasing demand for alternative fuels while meeting its CO_2 emissions targets.

References

[1] IEA Statistics, (2014): "CO_2 emissions from fuel combustion-highlights", *IEA, Paris* *http://www.iea.org/publications/freepublications/publication/co2-emissions-from-fuel-combustion-highlights-2014.html* , *Accessed December (2014).*

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