Investigating the Global and Specific Carbon Dioxide (CO$_2$) Emissions from the Petroleum Downstream Industry of Kuwait

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Presentation Agenda

1. Introductory Remark
2. Objectives of this work
3. Methods of estimation and calculations
4. Results obtained and analysis
5. Conclusions & Future Work
Our Solar System
GHGs

- Sunlight heats the earth
- Some of sun’s energy is *reradiated* from surface.
- GHGs *absorb* this energy
- GHGs *reradiate* some escaping energy back towards surface, making the temperature warmer

Original slide from PCC (Washington University)
Human-caused Global Warming

Original slide from PCC (Washington University)

US: 4% of world’s total population
25% of the world’s greenhouse gases

China: 25% of the world’s population
8.5% of the world’s greenhouse gases (since 1950)

TIME magazine, 2001
Introductory Remark

- A member of OPEC, Kuwait is the world's 10th largest oil producer.
- Kuwait's economy is heavily dependent on petroleum export revenues.
- Energy policy is set by the Supreme Petroleum Council.
- KPC manages domestic and foreign petroleum investments.
Motivation & Work Objectives

1. Study the current routes of processing in the petroleum refining industry in Kuwait and detail all CO$_2$ sources in the refinery sites;

2. Estimate the amount of CO$_2$ emissions based on the sources identified from each refinery; and

3. Develop specific EF for units based on carbon contribution.
Methods

1. HP Units:
\[ C_nH_{2n+2} + n H_2O \Leftrightarrow n CO + (2n + 1) H_2 \]
\[ CO + H_2O \Leftrightarrow CO_2 + 2H_2 \]
\[ HPC = HPR.UC \]

2. FCC:
\[ CFP = 0.158 OC \cdot cf \cdot SG.UC \]

3. Flaring:
\[ FCE = 3.12 \ (RT) \]

4. Heaters & Furnaces:

<table>
<thead>
<tr>
<th>Fuel</th>
<th>CO₂ (kg/GJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>50.6</td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>68.6</td>
</tr>
<tr>
<td>LPG</td>
<td>58.7</td>
</tr>
</tbody>
</table>

Table 1: Emission factors for CO₂ based on fuel type used in this work.
Current Refineries Assessment

Table 2: Existing Refineries in Kuwait Key Characteristics.

<table>
<thead>
<tr>
<th>Refinery</th>
<th>MAA</th>
<th>SHU</th>
<th>MAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Area (km²)</td>
<td>10.5</td>
<td>1.3</td>
<td>7.8</td>
</tr>
<tr>
<td>Year of Commissioning</td>
<td>1949</td>
<td>1966</td>
<td>1958</td>
</tr>
<tr>
<td>Refining Capacity (Mbpd)</td>
<td>466</td>
<td>200</td>
<td>270</td>
</tr>
</tbody>
</table>

Sources were allocated and identified based on the following categories:

1. Hydrogen Production via SMR.
2. Fluid Catalytic Cracking (FCC) Unit in MAA Refinery
3. Heaters (Units' Utilities)
4. Flaring.
5. Acid gas removal process.
6. Electrical import (not within refinery boundaries).
## Assessment Results

Table 3: Carbon Dioxide (CO₂) Emission (Million Tons per Annum) from the Three Existing Refineries in Kuwait

<table>
<thead>
<tr>
<th>Source</th>
<th>MAA</th>
<th>SHU</th>
<th>MAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid Catalytic Cracking (FCC)</td>
<td>0.33</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Fired Heaters</td>
<td>3.55</td>
<td>2.45</td>
<td>2.12</td>
</tr>
<tr>
<td>Acid Gas Removal (AGR)</td>
<td>0.03-1.16</td>
<td>0.01</td>
<td>N/A</td>
</tr>
<tr>
<td>Flaring</td>
<td>0.07</td>
<td>0.03</td>
<td>0.04</td>
</tr>
<tr>
<td>Hydrogen Production (HP) Units</td>
<td>0.71</td>
<td>0.73</td>
<td>0.72</td>
</tr>
<tr>
<td>Electricity Load</td>
<td>770</td>
<td>379</td>
<td>573</td>
</tr>
<tr>
<td>Total (Mtpa)</td>
<td>3.78</td>
<td>3.22</td>
<td>2.88</td>
</tr>
<tr>
<td>% of Total in Kuwait (w/o Electrical Import)</td>
<td>48</td>
<td>28</td>
<td>24</td>
</tr>
</tbody>
</table>
Source Distribution Among Each Refinery

- MAA, due to various sources gives a classical representation of refinery carbon distribution.

- Amount of emission from flaring is related to refinery capacity.

- HP units feed effect.

- Utilities are always a major contributor.
Results Discussion

• HP units’ contribution in the country is evenly spread between the three refineries (Fig.4).

• Heaters emission from MAA account for 50% of the total in Kuwait.

• Hydrogen generation and topping units constitute the majority of carbon emission from their utilities.
Specific Efs:

- Distillation units were formulated based on the heaters and furnaces direct heat (energy) supply to the units.

- Atmospheric and vacuum distillation use about 45% of refineries energy due to topping separation units.

- SMR is also one of the most energy intensive operations in refineries, where H₂ is produced.

<table>
<thead>
<tr>
<th>Process</th>
<th>Specific CO₂ emission</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmospheric Distillation</td>
<td>CE = 1.4 TP</td>
<td></td>
</tr>
<tr>
<td>Vacuum Distillation</td>
<td>CE = 1.5 TP</td>
<td></td>
</tr>
<tr>
<td>Hydrogen Production (HP) via SMR</td>
<td>CE = 112 TP + 0.25(HP)</td>
<td>Throughput and production rate are based on million tons per hour.</td>
</tr>
<tr>
<td>Hydrocracking</td>
<td>CE = 1.1 TP</td>
<td>Hydrocracking uses about 54 m³H₂/m³feed (Gary and Handwerk, 1994); which should be added to the formulation depending on the unit throughput.</td>
</tr>
<tr>
<td>Residual Desulfurization</td>
<td>CE = 0.28 TP</td>
<td>Desulfurization H₂ flow should be added depending on the unit throughput.</td>
</tr>
</tbody>
</table>
Conclusions I

- Refineries face a lot of challenges in carbon emissions mitigation especially when considering the changes in fuel mix, energy process, increasing fuel quality demands and heavier crude feeds.

- The emission rates of these refineries were estimated at 3.78, 3.2 and 2.88 mtpa.

- The specific refinery emission rate could be estimated for MAA, SHU and MAB at 8.1, 16 and 1.6 ton CO$_2$/bbl processed per day.
Conclusions II

• The estimates show Kuwait’s downstream sector as a major carbon emitter that needs energy and operation optimization in a more environmentally friendly manner.

• The analysis revealed that utilities (mainly fired heaters) in current operating refineries constitute the major share of carbon emissions (62-74%).

• This could be managed with an energy optimization strategy and a collection of stack gases that could reduce the carbon footprint of this structure in the near future.
• HP units, which can contribute up to 25% of current refineries carbon load, can be an ideal candidate for capture projects in the future.

• Operational utilities and space availability are two major advantages for such units to be considered for future capture projects.

• Optimally, carbon emissions will reduce in Kuwait after taking into account direct heat requirements of units in the near future for better utilization of recovered heat.
Thank you