Energy Use and CO₂ Emissions in Canadian Oil Refineries 1990, 1994 to 2015

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Executive Summary

In 1995, the Canadian Fuels Association (CFA) and the Canadian Industry Program for Energy Conservation (CIPEC) requested that CIEEDAC review energy use and carbon dioxide (CO₂) emissions data for the conventional petroleum refining industry. Since that time, CIEEDAC has generated an annual report based on data obtained under confidentiality agreements from all refineries.

Since 1998, the data collected by CIEEDAC have been sent to Statistics Canada (STC) to allow a respondent-level comparison of energy use data and to identify and resolve discrepancies. This feedback has enabled both STC and CIEEDAC to make appropriate corrections and improvements and produce a more consistent dataset.

In the past, STC provided CIEEDAC with a list of all refineries that submit data through the Refined Petroleum Products survey and for the RESD in NAICS 324110. At present, all refineries in Canada report to CIEEDAC. However, historical data from 1994 and 1995 were not available for one refinery. In 2001, a second refinery reduced its interaction with CIEEDAC which resulted in some necessary estimation of fuel-level data details, but total energy and emissions data are comprehensive and complete.

In an effort to improve reporting of both energy (in TJ) and CO₂ emissions, CIEEDAC updated its conversion coefficients as received from STC and Environment and Climate Change Canada for the 2015 data year. Historical reports preceding this date will show data inconsistent with this and future reports.

Energy

In 2015, total energy use in the Canadian petroleum refining industry dropped 1% from 2014 and is now 10% below 1990 levels, even with total production of refined petroleum products at least 6% higher than it was in 1990.

Carbon Dioxide

As energy use drops, so do aggregate CO₂ emissions which remained stable from 2014, but are 13% lower than 1990 levels. Emission levels were calculated using CO₂ conversion coefficients supplied by the refineries and Environment and Climate Change Canada (ECCC) applied to the physical quantity of each energy form consumed. As with the energy coefficients, the coefficients from different sources vary, but the estimation of emissions is very close. CIEEDAC and ECCC have cooperated to produce a better set of coefficients for ECCC use in their inventory report, based on the provision of these data from refinery personnel.

Production and Intensity Indicators of Energy and Emissions

As part of this analysis, CIEEDAC generates energy and CO₂ intensity figures on a per unit production (m³) basis. Refined petroleum product (RPP) production data are no longer available as disaggregated values since most of the data are considered confidential; analysis here uses Total Production data rather than Net Production data. These data
indicate that RPP production rose to a level 23% higher than 1990 by 2004, the peak year. In 2015, production has decreased to 6% above 1990 levels, but 14% below the 2004 peak year.

After four years of marginal increases from 2005 to 2009, energy used per unit production (i.e., overall efficiency) declined to nearly 16% below 1990 levels in 2015. The years of increases may have been due to the introduction of technologies to reduce the sulphur content of fuels to meet the targets of Government of Canada regulations for different refined petroleum products. As desulphurization generates no net increase in productivity, intensities were expected to rise. Personnel from CFA member companies suggest that, along with the introduction of these technologies, other efficiency improvements were made such that the net energy increase, in some cases, was minimal; one cannot attribute noted changes in energy intensity purely to this response to regulation.

The industry prefers to look at an intensity index generated by Solomon Associates (SA EII data). The method of calculation of this index changed in 2005/2006. 2006 data were still received under the old calculation scheme, but 2007 to 2013 data reflect this change. No adjustments were made to harmonize the data. The indices under the new methodology show increases up to 2010 and then decline thereafter such that the intensity has returned to close to what it was in 2007. The index still shows an overall intensity decline from 1990 of 14%, in spite of the methodological change. SA EII data were not available from one major refining company and no EII calculation for Canada could be provided since 2014. Since it appears that these data will not be available in the future, CIEEDAC recommends the use of the physical energy intensity indicator as a reasonable alternative.

With RPP production data altered from historical representations, CO₂ intensity indicators are down by about 18% per m³ of production since 1990, relatively stable from the previous year. An index of the carbon intensity of the fuels used indicates that it is roughly the same as it was in 1990, with little overall variation in that time. This suggests that fuel mix varies little year over year.
Acknowledgments

This report is funded primarily though the support of CIEEDAC by the Canadian Fuels Association, as well as other industry associations and government agencies such as Environment and Climate Change Canada. CIEEDAC thanks Natural Resources Canada who also supports CIEEDAC’s work generating reports on various other industry sectors.

In addition, CIEEDAC would also like to thank the following petroleum refining companies for their participation in this survey and report: Chevron Canada, Consumers Co-op Refinery, Énergie Valero, Husky Energy, Imperial Oil, Irving Oil, North Atlantic Refinery, Shell Canada, and Suncor Energy.
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Energy Use and CO₂ Emissions in Canadian Oil Refineries, 1990, 1994 to 2015

1 Introduction

CIEEDAC has provided annual reports on energy and CO₂ emissions for the petroleum refining industry since 1995. This year, 2015 data were received from 17 operative conventional oil refining facilities in nine (9) firms. Some refineries sent updates to historical data; these are included in the database.

The report identifies energy and CO₂ emission trends and indicators in the industry. It also highlights several data issues. As a result of CIEEDAC’s continued analysis and report, both Statistics Canada (STC) and Environment and Climate Change Canada (ECCC) have reviewed their energy use and CO₂ emissions data to improve their representation of industry energy and emissions data. CIEEDAC received permission from each refinery to provide STC with its detailed data set to allow a respondent-level comparison of use data and to identify and resolve discrepancies. This feedback has allowed both STC and CIEEDAC to make appropriate corrections and improvements to arrive at a more consistent set of data.

Because of this annual analysis, a consistent and comprehensive data set provides members of the industry with a clear picture of their energy use and CO₂ emissions. Several other benefits are realized from the analysis:

• It provides a consistent methodology to track overall energy use and CO₂ emissions in the industry;
• It permits comparison of data from STC and ECCC with data received directly from the refineries and identifies where discrepancies exist, permitting updates of these data when required;
• It provides a means for benchmarking within the industry outside of Solomon Associates’ more detailed analysis;
• It allows reviewers to focus on specific factors (e.g., use of fuel and non-fuel energy forms and their associated energy and CO₂ coefficients) that contribute to the determination of net refinery energy use and CO₂ emissions; and
• It provides for an independent and impartial assessment of industry performance.

2 Objectives

The objective of this work is to establish a consistent data set that reflects the industry’s energy use in Canada. The primary objectives of this report are:

1. To establish a consistent database of energy use and CO₂ emissions, by fuel type, for the Canadian conventional petroleum refining industry;
2. To show general trends in energy use and CO₂ emissions in the Canadian conventional petroleum refining industry;
3. To demonstrate the variability of data available within the industry and provide an opportunity for consistency; and

4. To identify confounding issues that prevents the generation of a clear energy and CO₂ picture of the industry.

## 3 Method

Canada’s nine conventional refining companies were surveyed on their fuel use, the associated energy, and their CO₂ coefficients. Consumers Co-op Refinery is an integrated complex with a refinery and two upgraders; data provided here represent only the conventional refinery although CIEEDAC does receive disaggregated data. While the 1994 and 1995 data for North Atlantic Refining Ltd. are unavailable, its data for other years are included in the dataset, therefore caution should be given when interpreting the reported 1994 and 1995 data. Recent changes to the industry include NOVA Chemicals ceasing refining operations in 2014, Imperial's Dartmouth facility ceasing operations in 2013, and Suncor purchasing Petro-Canada in 2009. The currently operating refining companies include:

- Chevron Canada
- Consumers Co-op Refinery
- Énergie Valero
- Husky Energy
- Imperial Oil
- Irving Oil
- North Atlantic Refinery
- Shell Canada
- Suncor Energy

CIEEDAC compiled the information, reviewed and analyzed each data set, and discussed problems with the various refineries until the data were deemed reliable and consistent for each petroleum refining company, between the companies, and with previous survey submissions. CIEEDAC compares its intensity indicators with those generated by Solomon Associates.

## 4 Results

The survey results and analysis are outlined in the tables of the appendix and summarized in the graphs below. To protect the confidentiality of the information provided by individual producers, no individual facility data are presented. Individual company reports of energy and CO₂ data are available to each refining company upon request.

The results in the tables of Appendix A are presented in two parts:

**Refinery Summary Sheets (Tables 1 and 2):**

Tables for 1990, 1994 to 2015 present an aggregate energy and CO₂ picture by fuel type for conventional refineries only (Table 1) provide a comparison of coefficients used to convert physical units of energy into energy (i.e., using higher and lower heating values) and the associated tonnes of CO₂ emitted (Table 2).
Year-by-year Comparisons: 1990, 1994 to 2015 (Tables 3 to 8):

These tables provide a time-series comparison of the data, including: energy use and CO₂ emissions by fuel type (Tables 3 and 4), industry production (Table 5) and the associated energy intensity and CO₂ intensity of the industry (Tables 6 and 7). The Solomon Associates Energy Intensity Index (EII) for the participating refineries in Canada is included up to 2013 (Table 8).

The following figures provide basic industry trends in energy use, CO₂ emissions, and their respective intensities. These figures are derived from the tables in Appendix A.

4.1 Energy Use and Intensity Based on Production

Figure 1 displays the general trend in energy use of the petroleum refining industry in Canada. Three different values of energy use for each year are presented, based on:

- lower heating values of each fuel, refinery calculations, LHV;
- higher heating values of each fuel, refinery calculations, HHV\textsubscript{Ref}; and
- higher heating values of each fuel, Statistics Canada values, HHV\textsubscript{STC}.

The latter two should be the same; variation in fuel coefficients causes the differences. Detailed energy by fuel type can be seen in the annual Table 1 series and the aggregate Table 3 in Appendix A.

In 2015, total energy use in the industry increased by 1% from 2014 and is now 15% lower than the peak year (2004) and 10% below energy use in 1990.

Long standing company waivers that allowed STC to release production data on refined petroleum products (RPP), even if that company could be identified, expired March
2013 and were not resigned by all firms. Thus, most of the data on production that have historically been available to the public are no longer available. Both STC and CFA are working toward a more complete resolution but, for 2013 and 2015, only total production data were available.¹

Figure 2 values were calculated based on the aggregate production of all refinery products, as supplied by STC (Table 5, Appendix A). Refinery energy intensity dropped significantly from 1990 through 1994, rising and falling marginally since that time. The low point in 2005 occurred just prior to increased demands to reduce sulphur content in refinery fuels, primarily the lighter oils. After four years of consistent increases in intensity, it dropped after 2009 to near 2005 levels in 2014 (see Figure 2 insert). 2015 saw an increase of 1% over 2014.

Figure 2: Energy Intensity of Canada’s Petroleum Refining Industry

Note: Physical units are GJ/m³ of production exclusive of producer-consumed fuels. Data for own consumption are not available for 2013 and 2015.

4.2 CO₂ Emissions and Intensity

Figure 3 presents the total CO₂ emissions of the industry as calculated using coefficients supplied by the refineries and ECCC for CO₂ emissions for each fuel type. A breakdown of these emissions by fuel type is detailed in Table 1 and in the aggregate Table 4 in Appendix A. The figure shows that total emissions are almost 13% lower than they were in 1990 and almost stable from last year to continue a declining trend begun in 2007. Details on fuel mix vary each year, but we note a trend more recently toward the use of natural gas. Note that one refinery does not provide details of energy use and

¹ Historically, CFA deemed production data to be Total Product minus Producer Consumed Product. We use this method directly where both values are available, and estimate Producer Consumed Product for those years that are considered confidential.
flare gas generation, resulting in uncertainty in CO₂ emissions by source. That said, total CO₂ emissions are provided by all refineries and are accurate.

**Figure 3: Total CO₂ Emissions from Canada's Petroleum Refining Industry**

As noted earlier, recent RPP production data on refinery use is considered confidential and we have made estimates where necessary to calculate a consistent total production value. Figure 4 shows that CO₂ intensity decreases steadily from 1996 to 2003, rises marginally to 2007, and then declines again to 2015. **The lowest intensity levels seen in the industry since 1990 were seen in 2014 and 2015.** While relatively consistent with the energy intensity values seen above (Fig. 2), this does not reflect changes as seen in SA EII indicators. **The 2015 intensity levels are about 18% below 1990 intensities.**
The decrease in intensity may result from a shift to less carbon-intense fuels (natural gas use is up 25% from 2005 (when it started increasing) and its share of total energy used is up 5% since that time). We do not, however, see a strong indication of that in our assessment of the carbon density of fuels; Figure 5 provides some detail on how carbon densities of fuels have changed since 1990. The figure shows that CO2 per unit of energy intensity levels have changed only marginally since 1990. In general, the fuel mix has remained relatively consistent over the period, but over the past decade the use of RFG and heavy fuel oils have declined so that 2015 has one of the lowest intensity levels since 1990. As noted, the details on fuel mix are not available from one of the refineries, which affects the accuracy of the intensity analysis.
In most refineries, the flaring of refinery fuel gases and the production of hydrogen also generate CO\textsubscript{2} emissions. Flare gas emissions are clearly marked on the data tables as non-fuel emissions (i.e., the energy released by their combustion is not captured in any way). These flare gas emissions in Table 1 are, as far as CIEEDAC can determine, included in the inventory of gases generated by Environment and Climate Change Canada, but the amounts are not explicitly found in the National Inventory Report.

Table 1: Refinery Emissions from Flare Gas (kt CO\textsubscript{2})

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</tr>
</thead>
<tbody>
<tr>
<td>Refinery coefficient</td>
<td>450</td>
<td>329</td>
<td>341</td>
<td>994</td>
<td>728</td>
<td>687</td>
<td>534</td>
<td>712</td>
<td>699</td>
<td>761</td>
</tr>
<tr>
<td>ECCC coefficient</td>
<td>349</td>
<td>257</td>
<td>291</td>
<td>685</td>
<td>617</td>
<td>625</td>
<td>508</td>
<td>615</td>
<td>562</td>
<td>622</td>
</tr>
</tbody>
</table>

* ECCC does not display these values; the coefficient used to convert the fuels burned into CO\textsubscript{2} emissions is the same as that used to evaluate emissions from the combustion of refinery fuel gas which varies from year to year.

Note: See Table 7a, 7b of Appendix A for all years.

Source: CIEEDAC Petroleum Refinery Database

Emissions generated in hydrogen production are sometimes included in the “Other” category, as well as in the “Non-fuel Use” category in the tables. Respondents were not always clear what the “Other” non-fuel use was, but in most cases these are fuels used to provide hydrogen. The “Other” category in the tables may also contain small amounts of refinery off-gas consumed as fuel in other activities. Thus, the emissions caused by hydrogen production may be improperly estimated because we are unsure whether the non-fuel use of several fuels – natural gas, refinery fuel gas, propane, and butane – are used to produce hydrogen. Table 2 provides the CO\textsubscript{2} emissions released because of this non-fuel use.
Table 2: Refinery Emissions from Non-fuel Use (kt CO\textsubscript{2})

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</tr>
</thead>
<tbody>
<tr>
<td>Refinery coefficient</td>
<td>1,018</td>
<td>918</td>
<td>917</td>
<td>969</td>
<td>753</td>
<td>846</td>
<td>835</td>
<td>634</td>
<td>702</td>
<td>660</td>
</tr>
<tr>
<td>ECCC coefficient</td>
<td>1,208</td>
<td>1,102</td>
<td>1,099</td>
<td>1,302</td>
<td>965</td>
<td>1,007</td>
<td>1,066</td>
<td>982</td>
<td>990</td>
<td>851</td>
</tr>
</tbody>
</table>

* These data may reflect emissions generated in the production of hydrogen but respondents did not always specify the use made of the fuels that were allocated to some non-fuel function. Because some refineries sell CO\textsubscript{2} as a commercial product and because input fuel coefficients vary between refineries and ECCC standards, the difference between the two values can be large, in some cases exceeding 50%.

Source: CIEEDAC Petroleum Refinery Database

**CAVEAT:** We do not receive detailed data for some refineries and some estimates had to be made to generate both Table 1 and 2 in this report. Even so, the data provide a good indication of the magnitude of the emissions from the combustion of non usable gases (flare gas) and the generation of hydrogen for the production process.

4.3 Summary Data Sheets - 1990, 1994 to 2015 (Tables 1 and 2 in Appendix A)

A comparison of the summary data sheets in this report (Tables 1 and 2 in Appendix A) with those in last year’s report indicates some changes in the data for 1990, 1994 to 2015. These are a result of revisions to historical data by several facilities and periodic review of our methodology.

Coefficients for coke in the appendix data tables show high variability because values shown in these tables represent two types of coke (petroleum coke and coke from catalytic crackers). In 1999, STC used input from previous CIEEDAC reports to revise its energy content factors for coke to distinguish between coke generated in refineries and that generated in oil sands operations. The HHV energy content for coke generated in refineries was revised to 37.09 GJ/t, while the energy content of upgrader coke was 33.05 GJ/t. Both were, up to that time, 35.34 GJ/t. These values have since been modified such that the coefficients vary over time. The official STC coefficient for Petroleum coke was 37.09 GJ/t for all years 1990 – 1997, 38.72 GJ/t for 1998 and 38.65 GJ/t for 1999 to the current year. Further investigation by STC resulted in changes in heat content of a number of other fuels.

Emissions coefficients used by ECCC have also been updated based on data obtained by CIEEDAC. The coefficients more closely reflect those provided to CIEEDAC by refinery personnel. The values for these coefficients can be found in the various tables reflecting emissions release in the appendices.

4.4 Use of Energy by Fuel Type (Table 3, Appendix A)

Energy use by fuel type presented in Table 3 reflects the total energy calculated using LHV, HHV\textsubscript{Ref}, and HHV\textsubscript{STC}.

LHV reflects only the energy applied to the process. The value for each fuel should be less than the HHV because LHV excludes the energy lost due to some characteristic of
the fuel (typically vaporization of water generated by combustion, but it may include contaminants, water in the fuel, etc.) from the total energy released to the environment through combustion. LHV provides a better picture of the actual efficiency of the technologies under analysis and permit further assessment regarding indicators generated by Solomon Associates (SA), where LHV is used. If one looks at energy data from alternative sources, the distinction between LHV and HHV is not always clear and the values provided are not defined as to the coefficients used when converting physical units to energy units. The matter becomes more complicated when all energy forms are provided as tons (tonnes) of oil equivalent (toe) because these factors vary as well.

SA also uses a heat equivalency measure for electricity based on standard efficiencies in fossil-fired generation plants, about 10 GJ/MWh. Because SA considers the LHV of the fossil fuel, the actual value used by SA is 9.59 GJ/MWh. This value skews the energy content of electricity from the norm (3.6 GJ/MWh), so the tables included in this report reflect the norm for electricity consumed. Any comparisons, however, to SA data utilize the same standard for electricity conversion that SA uses.

HHVs, on the other hand, recognize that all energy, whether applied to the process or not, is released to the environment upon combustion of the fuel. Thus, they are greater in magnitude than LHV for any fuel containing hydrogen. HHVs are often used for inter-industrial and international comparison. HHV analysis also uses 3.6 GJ/MWh as the conversion coefficient for electricity. This value is a direct energy conversion and does not consider efficiency losses in the production of electricity, since these generally occur off site.

The HHVs used in the STC calculation of total energy were obtained from the “Report on Energy Supply and Demand in Canada” (RESD, Statistics Canada, 2016) as modified by direct communication from STC. In the analysis of the survey results, if an HHV was not supplied by the refinery for a fuel, the STC HHV was used. Because the HHV supplied by the refinery is typically less than the HHV used by STC, this default could result in an over estimation of the energy use of the refinery in question.

The total energy use of Canada’s petroleum refining industry, reported by STC in the RESD and shown below Table 3, requires some explanation. Energy use in the industry is represented in the RESD in two places. Total primary and secondary energy consumed is represented on a line dedicated to refineries. The line for producer consumption of petroleum products represents producer consumption by both refineries and oil sands operations. CIEEDAC uses a split obtained from STC to calculate total energy use by the refining industry. Natural gas, used for some non-fuel purposes (e.g., feedstock to a hydrogen plant), is included in the line dedicated to refined products manufacturing.

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2 Historically, the data in this category represented energy consumed by only the conventional refining industry. However, the data have been updated such that it now also includes self-generated energy consumed by heavy oil and bitumen (oil sands) upgraders.
This interaction between CIEEDAC and STC minimizes differences in energy use between the two data sources. STC estimates of energy use for petroleum refineries may differ from CIEEDAC’s mainly due to the inclusion in STC’s estimates of energy use by refineries currently not participating in the CIEEDAC data collection exercise. The lines just below Table 3c provide values for the whole industry and the portion represented in CIEEDAC’s survey (an adjusted value). Note that STC Adjusted values were unavailable for RPP fuels for 2014 and 2015; unless this data becomes available again, this series will be discontinued in future reports since we are unable to collect this information elsewhere.

4.5 CO₂ Emissions (Table 4, Appendix A)
Table 4 compares total CO₂ emissions (in tonnes) by fuel for 1990, 1994 to 2015 as calculated using the facility-supplied coefficients and the coefficients supplied by Environment and Climate Change Canada (ECCC). These are not ECCC data, just the values calculated using refinery-supplied energy use and ECCC coefficients. The “Other” fuel shows a huge value for CO₂ compared to the energy value in Table 3. This is because most of these fuels are used as feed stocks in hydrogen plants where the energy is not counted while CO₂ is.

4.6 Production Values (Table 5, Appendix A)
The physical production quantities for conventional refineries in Table 5 were obtained from STC - Refined Petroleum Products Report, Catalogue no. 45-004 and online from CANSIM, Table 134-0004. Beginning in March, 2013, most of the data were deemed confidential and, for the first time since 1983, producer consumption of the various petroleum products is not available for all years. See section 4.1 above for a further explanation of this change. Therefore, the data in this table now only include values reflecting Total Production.

Production of commodities increased each year between 1996 and 2004. Since 2005, production levels show a declining trend, dropping to a level 6.4% above 1990, almost 14% lower than the peak production of 2004.

Real GDP data were received from Statistics Canada. In 2013, GDP data were updated to $2007 reference year from $2002. The $2007 values were, of course, significantly higher, so to produce a continuous data set CIEEDAC re-calculated historical values. In 2015, GDP was 4% higher than it was in 1990, and nearly the same as in 2014.

Historically, CIEEDAC received gross output (GO) data for conventional refineries from a private consultant but these are no longer available. STC publishes GO data but they are not released until three years after the year in question and are not useful in these analyses. CIEEDAC is cooperating with other federal agencies (ECCC and NRCan) to address this issue but for the current year, no GO data are provided.
4.7 Energy Intensity Factors (Table 6, Appendix A)

Tables 6a, 6b, and 6c tabulate energy indicators for Canada’s petroleum refining industry using, where available, three different denominators:

- Total Production (historically, it was Net Production);
- Real GDP, $2007 reference year; and
- Gross Output (defined as the total value of goods and services produced by an industry - a sum of industry’s inputs plus the change in value due to labour and capital investment); this data series is currently not available.

In Table 6a and 6b the energy intensity indicators are presented for the industry as calculated using both lower and higher heating values. More specifically, the data indicate the following characteristics for 2015 energy intensity:

- **Physical indicators suggest that intensities have declined 16% since 1990**, for both heat content coefficients used.
- **GDP indicators suggest that intensities have declined 14% since 1990**, for both heat content coefficients used.

Data received from Statistics Canada (below Table 3c) are used to generate intensities in Table 6d and 6e. The data reflect estimates for energy consumed by the refining sector universe as defined by STC and adjusted for the CIEEDAC universe.

4.8 CO₂ Intensity Factors (Table 7, Appendix A)

Tables 7a and 7b tabulate the CO₂ intensity indicators for Canada’s petroleum refining industry using, where available, three different denominators:

- Total Production (historically, it was Net Production),
- Real GDP, $2007 reference year and
- gross output; as noted above, this data series is not available for this year.

Table 7b shows that when using Environment and Climate Change Canada’s CO₂ coefficients the intensity varies only marginally from that generated when using coefficients provided by refinery personnel for the same production value (Figure 3 and 4). **More specifically, the data indicate that the CO₂ intensity per unit of physical production in 2015 was about 17%-18% below 1990 levels. Using a GDP denominator, the values are similar, around 15%-16% below 1990.**

Tables 7c and 7d assess the overall carbon density of the fuel used (i.e., emissions per unit energy). The density has varied over the last few years and shows a small decline more recently. Still, it remains within a few percent of what it was in 1990.

Note that emissions from flared gases and from the production of hydrogen are included in the assessment of intensity.
4.9 Solomon Associates EII (Table 8, Appendix A)

Since 2014, Solomon Associates Energy Intensity Index (SA EII) data have not been obtained from all refineries. CIEEDAC does not expect these data to be available in the future and thus will discontinue the SA EII component of the analysis. We provide here the data that have been made available up until 2013 as well as a more detailed comparison of these data with alternative data on intensity.

4.9.1 Existing Data

Table 8 in the appendix and Figure 5 below show SA EII aggregated for all participating petroleum facilities. The EII is not the same measure of performance as the energy intensities of Table 6, although they show roughly similar trends from 1990 to 2006; values diverge more from 2007 to current (the figure contains the physical unit index from Table 6 for comparison). Solomon Associates only generate EIIs for conventional refineries and not all the conventional refineries in Canada participate in the analysis.

Figure 6: Solomon Index for Canadian Refineries

![Graph showing Solomon Index for Canadian Refineries]

Note: The EII is the average of all industries that submit data to Solomon and Associates. The break between 2006 and 2007 data indicates a change in SA EII methodology.

In 2006, SA altered their methodology. After discussions with CFA, it was decided that the data would remain unaltered and the analysis show simply that a change in method had taken place. In Figure 6, we distinguish the SA EII data after 2007 as a separate dashed series.

Overall, the data indicate a steady national improvement of those refineries that submit to SA analyses. The decline in energy intensity was dramatic between 1990 and 1997, remained relatively consistent between 1998 and 2001. Thereafter, there was a marginal improvement until 2004, and relatively stable after. The SA indicator was about 20% lower in 2006 than it was in 1990.
With the change in method, the index rose from 89.3 in 2006 to 93.8 in 2007 (where 100 is the “standard” for processes efficiencies). After rising in 2008, there was a decline in the index until 2013, approaching the 2007 level again. Even with the change in methodology, the most recent value of the SA EII is 14% below what it was in 1990.

Solomon Indices shown here are different from those released to participants of the SA analysis. This is due to several factors, including SA’s method of aggregation and treatment of lube plants, both of which differs from CIEEDAC’s approach. Due to confidentiality restrictions, CIEEDAC is not able to receive or publish official SA indices for Canadian industry as a whole. The estimate provided here has been calculated as the weighted average of all participating plants that submit data to the CIEEDAC survey.

4.9.2 Comparing SA EII with alternatives

This report contains data on two other alternatives to the SA EII indicator.

1) A ratio of total energy used to total refinery production will provide an intensity indicator that is closest to the SA EII value. The correlation of these two data sets is relatively high (85% for the years 1990 - 2006, 55% for 2007 - 2013 and an overall correlation of 63%). The covariance is positive, meaning that these two values tend move in the same direction (i.e., if SA EII goes up in a year, the physical production value also goes up).

The relationship between physical production and energy use (LHV) is good (correlation is 80%, covariance is positive), increasing one’s confidence in the reliability of this value as an indicator of energy intensity.

2) A ratio of GDP data to energy also provides an intensity indicator. But there are a few issues when using this indicator:
   a) The GDP value may reflect more than just refineries because the NAICS code includes other petroleum-based facilities (e.g., asphalt plants, oil recycling refiners).
   b) The GDP to energy link is not always very strong since more than just energy use affects GDP, especially in the refining industry where the bulk of the energy used is self-generated and not purchased at market value.

The result is that GDP and energy use can move in different directions generating somewhat erroneous or at best inconclusive results. The correlation between GDP based indicators and SA EII is less than 50% in all cases.

Figure 7 compares the three intensity indicators for 1990 - 2013, and extends the non-SA indices to 2015. One can see that the GDP indicator is much more erratic than the others, making it a less reliable alternative to SA EII. The physical unit matches the SA EII more closely and tends to follow the same trends.
5 Data Problems, Issues, and Solutions

The following section discusses some of the data problems and issues that have arisen, either in this or previous analyses, and mentions some of the issues that have been resolved.

5.1 Collection and Transcription Problems

Several of the data submissions did not include the requested conversion coefficients (i.e., CO$_2$ and heating values). CIEEDAC made assumptions about their value, either by using previous submissions or using STC’s values. The survey is accompanied by a set of guidelines/algorithms that allow respondents to calculate HHV and CO$_2$ content.

5.2 Reporting of Specific Fuels and Emissions

The following issues were noted with respect to the reporting of specific fuels.

i) Flare Gas: Several respondents reported flare gas as a fuel but, by definition, it should be reported in the non-fuel use column. CIEEDAC simply updated the data set. That said, there are some who suggest that these fuels SHOULD be included in the total fuel used, that this is, in fact, an efficiency improvement opportunity.

Each refinery provides a coefficient for both energy and CO$_2$ emissions from flared gas. We note that flare gas quantities are not submitted to STC in their ICE surveys.

ii) Petroleum Coke and Coke on Catalytic Crackers: CIEEDAC receives disaggregated data on these two fuels and aggregates them in the data tables to protect confidentiality.

iii) On occasion, refinery fuel gas includes propane and butane. Some refineries disaggregate the fuel gas constituents such that propane and butane are reported
separately while others do not make such a distinction. CIEEDAC proposes that fuel gas should be given as a single value and that propane and butane should be reported if they could otherwise have been sold as commodities (i.e., they were recognized as being butane and propane streams at the time of combustion, as opposed to a mix of various off gases caught up in the refinery fuel gas stream).

iv) CIEEDAC would like to clarify the fuel use and emissions that result from hydrogen production. As discussed above, we are unsure whether the non-fuel use of several petroleum products – natural gas, refinery fuel gas, propane, and butane – is the result of hydrogen production. In future surveys, we encourage the refineries to provide information as to whether their non-fuel use of petroleum products is used for hydrogen production or not.

5.3 Energy Content and CO₂ Coefficients Issues

Issues pertaining to fuel energy content and CO₂ coefficients include:

i) Coke: CIEEDAC recommends that responding personnel use the provided spreadsheet calculation for all coke type fuels to provide both lower and higher heating values. The spreadsheet is delivered with the survey.

ii) Use of Default Coefficients: In some cases, the refineries did not provide energy or CO₂ coefficients. Here, CIEEDAC used STC coefficients for the HHV value for energy and Environment and Climate Change Canada coefficients for CO₂. In several situations, respondents provided HHVs where, in previous years, default STC or Environment and Climate Change Canada values were used. This has caused apparent changes in energy or CO₂ that are not a function of increased use of that fuel. In these cases, CIEEDAC undertakes further review with the submitting refineries.

iii) Estimate of CO₂ from Flare Gas: CIEEDAC has applied the same coefficient to flare gas as that ECCC uses to evaluate emissions from Refinery Fuel Gas. Note that ECCC does not report any emissions from flare gas – emissions reported here are estimates of what ECCC would report if they had data on flare gas emissions. See Table 1 for details.

6 Summary

Outside of the quality of the data submitted, measuring the use of energy and the release of CO₂ from Canada’s oil refining industry is dependent on several variables. These include:

- the energy coefficient used, i.e., HHV or LHV;
- the source of the energy coefficient, i.e., an estimate from the refinery or from Statistics Canada; and
the source of the CO₂ coefficient used, i.e., an estimate from the refinery or from Environment and Climate Change Canada.

Despite the variability introduced by these factors, a few general trends can be identified in the industry.

Energy: Total energy use in the Canadian petroleum refining industry in 2015 is about 10% lower than 1990. Data on RPP production useful in calculating intensity indicate that refineries were 16% more efficient than in 1990 based on production (m³).

Carbon Dioxide: CO₂ emissions from Canada’s refineries were stable from 2014 and are 13% below 1990 levels. From an intensity perspective, refineries have reduced the amount of CO₂ released per unit of production since 1990 by about 18% in 2015.

7 Reference List

Data obtained on line from CANSIM

______. 2017. Supply and disposition of refined petroleum products, CANSIM Table 134-0004, Ottawa.

APPENDIX A: Data Tables

Data Tables

• Tables 1, 2 Refinery Summary Data Sheet for each of the years 1990 to 2015
• Table 3: Use of Energy by Fuel Type: 1990, 1994 to 2015
• Table 4: CO₂ Emissions by Fuel Type 1990, 1994 to 2015
• Table 5: Production of Refineries and Upgraders 1990, 1994 to 2015
• Table 6: Petroleum Refining Industry Energy Intensity Indicators
  o Table 6a, 6b: Energy Intensity Factors: Industry Total
  o Table 6c, 6d: Energy Intensity Factors: Statistics Canada Data
• Table 7: Petroleum Refining Industry CO₂ Intensity Indicators
  o Table 7a, 7b: CO₂ Intensity per unit of production
  o Table 7c, 7d: CO₂ Intensity per unit of energy
• Table 8: EII from Solomon Associates Indices
APPENDIX B: Data Table Structure & Sample Calculations

Aggregate Summary Tables 1990, 1994 to 2015 (23 sets of Tables 1)

Inputs and Energy Use

Inputs

Received = sum of values received from all facilities.
Internally Produced = sum of values received from all facilities.
Steam Sold = sum of values received from all facilities.
Electricity Sold = sum of values received from all facilities.

Energy Use

Fuel Use = Received + Internally Produced + Steam Sold + Electricity Sold - Non-Fuel Use
Non-Fuel Use = sum of values received from all facilities.

Energy Content

LHV (Lower Heating Value)

Refinery Coeff. = Average of LHV received from all facilities
Total Energy (TJ) = Refinery Coeff * Fuel Use

HHV (Higher Heating Value)

Refinery Coeff. = Average of HHV received from all facilities
STC Coeff = STC value for the HHV of the particular fuel
Refinery Total (TJ) = Refinery Coeff * Fuel Use
STC Total (TJ) = STC Coeff * Fuel Use

CO₂ Coefficients Estimates

Refinery Fuel Use = Average CO₂ coefficient received from all facilities
Refinery Non-Fuel Use = Average non-fuel use CO₂ coefficient received from all facilities.

Environment and Climate Change Canada = Environment and Climate Change Canada CO₂ coefficient.

CO₂ Production

Refinery

Fuel Use (tonnes) = Refinery Coeff * Fuel Use
Non-Fuel Use (tonnes) = Refinery Non-Fuel Use Coeff * Non-Fuel Use
Total CO₂ (tonnes) = Fuel Use + Non-Fuel Use

Environment and Climate Change Canada
Total CO$_2$ (tonnes) = Environment and Climate Change Canada CO$_2$ coefficient * Fuel Use

(Note: In the Environment and Climate Change Canada CO$_2$ calculation, a non-fuel use CO$_2$ coefficient is assumed to be proportional to the refinery estimate of the non-fuel use coefficient.)

All Canada EII (Solomon Index) Calculation

Calculated for all participating conventional refineries in Canada.

- Actual Use = The total LHV energy use of all the facilities that participating with Solomon and Associates
- Standard Use = The total energy use of the equivalent Solomon standard refining facilities as supplied by each refinery.
- EII = Actual Use / Standard Use

Comparison of Coefficients (23 sets of Table 2)

A listing of the variation (max., min. and average) of LHV and CO$_2$ coefficients received from the facilities as observed in the submissions.

Use of Energy by Fuel Type (Table 3)

Time trend energy use by fuel type based LHV, HHV (Refinery) and HHV (STC) for Conventional Refineries. Values correspond to the totals obtained from 1990, 1994 to 2015 aggregate summary tables (23 sets of Table 1).

CO$_2$ Emissions by Fuel Type (Table 4)

Time trend CO$_2$ emissions by fuel type based Refinery and Environment and Climate Change Canada coefficients for Conventional Refineries. Values correspond to the totals obtained from 1990, 1994 to 2015 aggregate summary tables (23 sets of Table 1).

Production (Table 5)

Production values in m$^3$, $GDP in 2007 $millions as obtained from sources stated in table notes. Gross Output data were not available.

Petroleum Refining Industry Energy Intensity Factors (Table 6)

Calculation of energy intensities per m$^3$ and, where available, per $GDP (Gross Output not available). Intensities are also presented indexed with 1990=1 (i.e., normalized to 1990).

Petroleum Refining Industry CO$_2$ Intensity Factors (Table 7)

Calculation of CO$_2$ intensities per m$^3$ and, where available, per $GDP (Gross Output not available). Intensities are also presented indexed with 1990=1 (i.e. normalized to 1990)

Solomon EII (Table 8)
Ell values from 1990, 1994 to 2013 obtained from annual refinery summary tables as described above.

APPENDIX C: Survey Instructions

The following instructions accompanied the survey form and were sent to each respondent.