CANADIAN ENERGY RESEARCH INSTITUTE

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SUPPLY COSTS AND EMISSION PROFILES OF PETROCHEMICAL PRODUCTS IN SELECTED HUBS






Canadian Energy Research Institute | Relevant • Independent • Objective

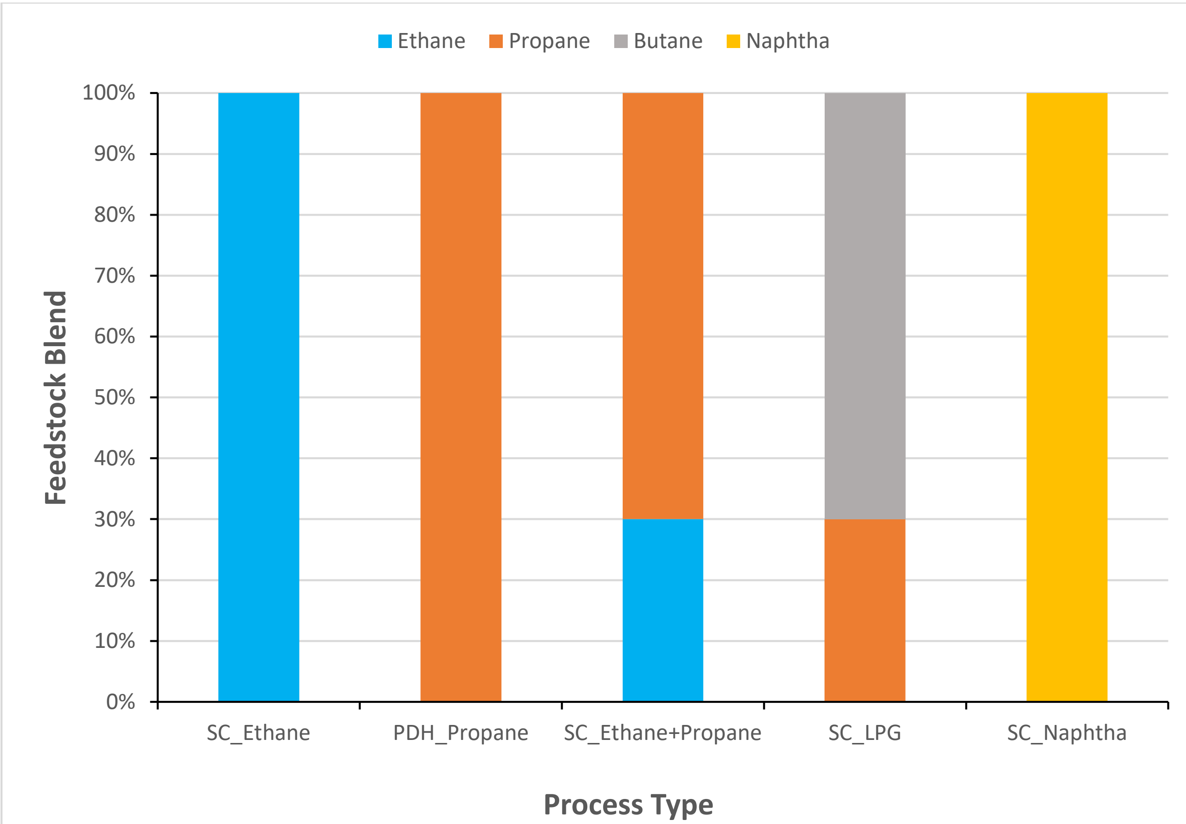
Executive Summary

CERI commissioned this study to quantify greenhouse gas (GHG) emissions from petrochemical processes and evaluate supply costs of products from various processing pathways and petrochemical hubs. The hubs assessed are Alberta Industrial Heartland in Alberta, Sarnia/Corunna (Ontario), the United States Gulf Coast (USGC), and South Korean hubs. Environmental impact is evaluated in terms of carbon dioxide, methane and nitrous oxide emissions from the petrochemical sector. The economic impact is assessed through indicative product supply costs at both the plant gate and at potential destination markets. The United States and China are considered destination markets.

To achieve the objectives of the study, CERI adopted a hub-level analysis approach. We modelled hypothetical integrated petrochemical facilities in each of the hubs, observing jurisdictional differences in the supply cost model and considering various processing pathways for single and mixed feedstocks. Figure E.1 shows the feedstock options speculatively treated in each of the hubs to produce polyethylene (PE via steam cracking[1]) and polypropylene (PP via propane dehydrogenation[2]) as the primary/main products for which the supply costs are computed.

[1] Denoted in the figure and subsequently as SC
[2] Denoted in the figure and subsequently as PDH

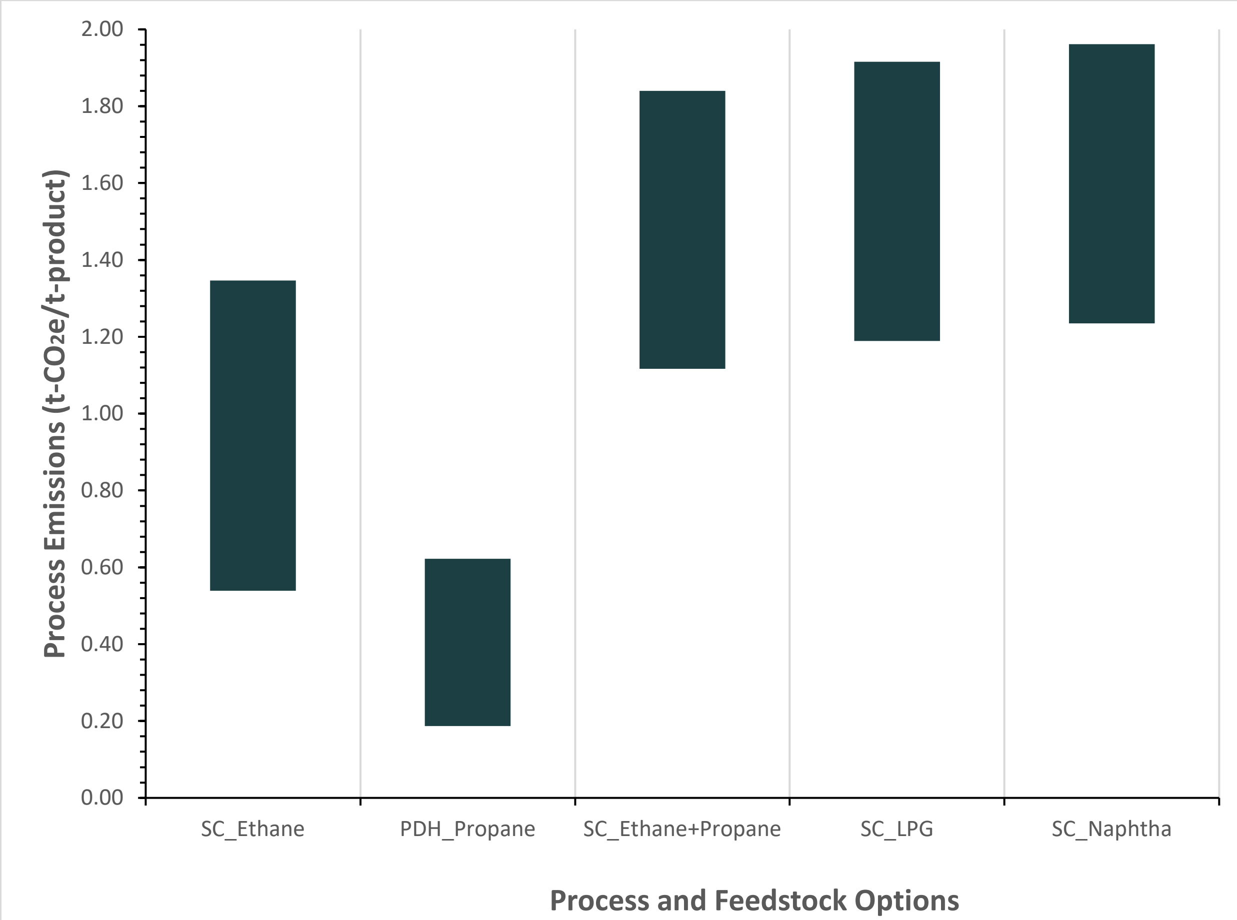
Figure E.1: Feedstock Compositions for Steam Cracking and Propane Dehydrogenation Processes



CERI also quantified co-products from each processing pathway and ran four supply cost scenarios to capture jurisdictional variabilities, carbon tax and the ability to obtain additional revenues from sales of co-products. The feedstock and process combinations (per Figure E.1), in addition to their integrated polymerization units, constitute the five hypothetical facilities assessed for each of the four hubs of focus in our product supply cost modelling.

Emission intensities of processing pathways capture the differences in processing technologies, fuel types, electricity requirements and sources. Figure E.2 shows the ranges of GHG emissions for each process and feedstock combination. Natural gas combined cycle (NGCC), coal and cogen are the three types of electricity sources incorporated in our current modelling, however, NGCC is used as the benchmark electricity source for most facilities. The process emissions include those from the production of olefin monomers and the subsequent polymerization step. Process emissions are expressed in per tonne of the main product.

Figure E.2: Ranges of Process GHG Emissions for Different Process and Feedstock Options



The PDH process for on-purpose polypropylene has the lowest GHG emission intensity ranging between 0.19-0.62 t-CO_2e/t. Polyethylene from ethane cracking plants has the next lowest intensity ranging from 0.54 to 1.35 t-CO_2e/t. Polyethylene from naphtha cracking has the highest GHG intensity ranging between 1.24 to 1.96 t-CO_2e/t. However, naphtha cracking has a wider product spread relative to the other cracking feedstocks. Therefore, if overall emissions were to be allocated to all high-value products using any of the standard life cycle analysis (LCA) methods (such as system expansion, substitution or partitioning), the intensities based on each high-value chemical would be lower. Nevertheless, our approach in this study is to quantify total processing emissions based on the main product for each feedstock processing pathway.

The primary sources of GHG emissions in a petrochemical plant are process heaters, boilers, cooling towers, catalyst regeneration vents, gas purge/flare systems, MSS (maintenance, start-up and shutdown) emissions, and process fugitives. Based on EPA prevention of significant deterioration (PSD) filings, fugitive emissions may account for up to 5% of total facility GHG emissions (Trinity Consultants 2012, 2012; US EPA 2014; Chevron Phillips 2018; US EPA 2012; Environmental Resources Management 2014). Depending on the process and technology in use, methane and nitrous oxide emissions account for between 0.1% to about 2% of total carbon dioxide equivalent (CO2e) emissions.

Figures E.3 and E.4 show two supply cost assessment scenarios where a carbon tax is either excluded (NCNC) or included (CTNC) without considering the sales of co-products in both cases in the model. The NCNC scenario captures the jurisdictional impacts of constructing and operating the petrochemical facilities in Alberta, Ontario, USGC, and South Korea. Polyethylene and polypropylene average plant gate supply costs for all hubs in NCNC are $1,881/t and $1,772/t, whereas in CTNC they are $1,918/t and $1,811/t, respectively. The indicative supply costs are higher when the carbon tax is included in the model. However, other variables such as feedstock costs and co-product sales revenue have bigger effects on costs compared to a carbon tax.

Figure E.3: Indicative NCNC Supply Costs per Jurisdiction and Feed Type, Plant Gate (2018 Constant Dollars)

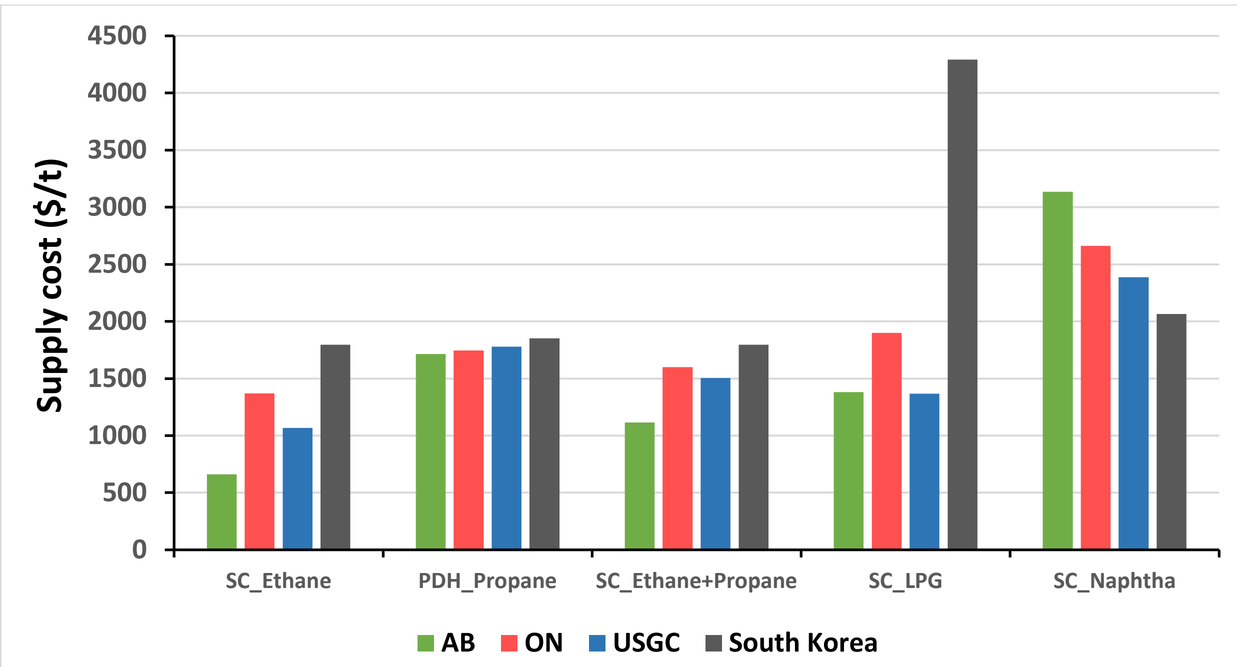
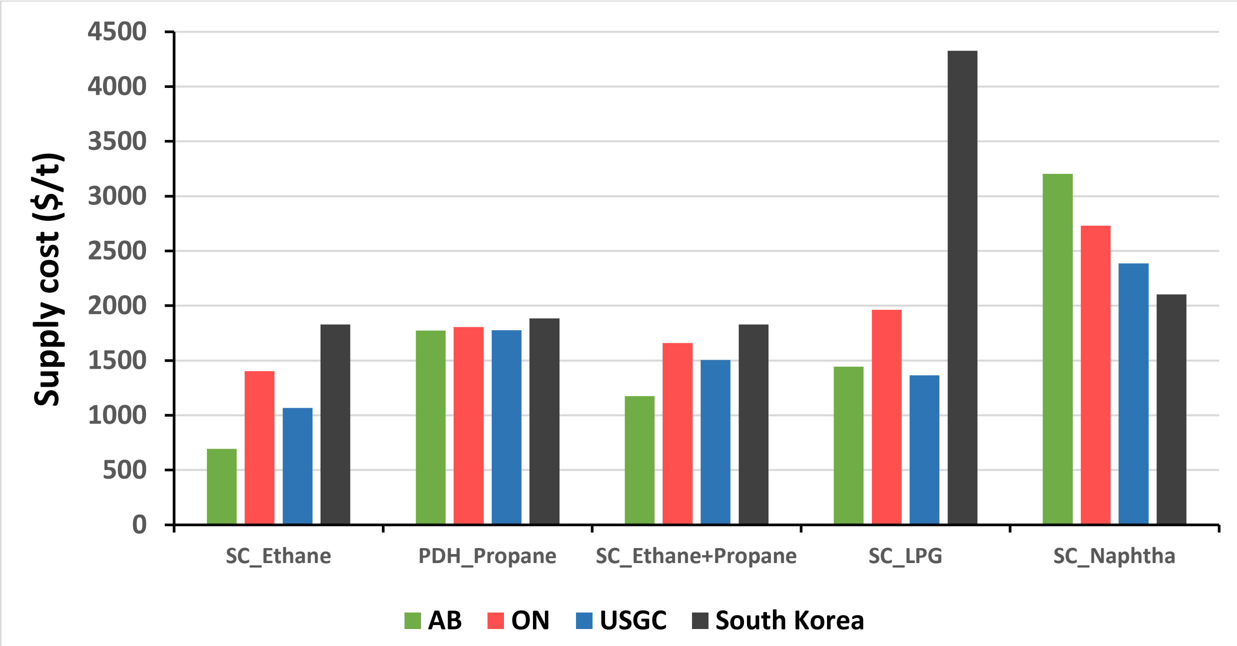


Figure E.4: Indicative CTNC Supply Costs per Jurisdiction and Feed Type, Plant Gate (2018 Constant Dollars)



Overall, a carbon tax has the most impact on Canadian supply costs despite the predominant processing of the lower GHG-intensity gas-based feedstocks in Canadian petrochemical hubs. Thus, this stems from the higher price of CO_2e emissions in Canada, compared to the other jurisdictions. CERI also assessed two other scenarios with the carbon tax and co-product revenue (CTCS), and no carbon tax with co-product revenue (NCCS). This is discussed further in Chapter 5.

The availability of cheaper NGL feedstocks in producing areas such as Alberta and the USGC results in lower PE supply costs for ethane and ethane+propane cracking plants. In the absence of a carbon tax, PP supply costs at Canadian and USGC facility gates are quite similar – albeit, slightly higher for USGC plants but more pronounced for a South Korean plant due to feedstock cost.

Landed supply costs provide a perspective of the indicative supply costs at the destination market for produced PE and PP using the five feed options and transported to the USGC or China for sales. The shipping/freight cost (SFC) is added to the supply costs obtained for each of the assessment scenarios to obtain the supply cost at the destination market. CERI's SFC estimates were based on information available in the public domain, as well as feedback from CERI interviews with petrochemical industry experts. Table E.1 shows the base case shipping/freight costs (SFC) for transporting PE and PP from the four petrochemical hubs studied by CERI to the USGC and China. CERI's base case SFC is based on the average between the low and high SFC (shown in Appendix A). Canadian hubs have the advantage to ship to China against USGC, and the advantage to shipping products to the USGC against South Korea.

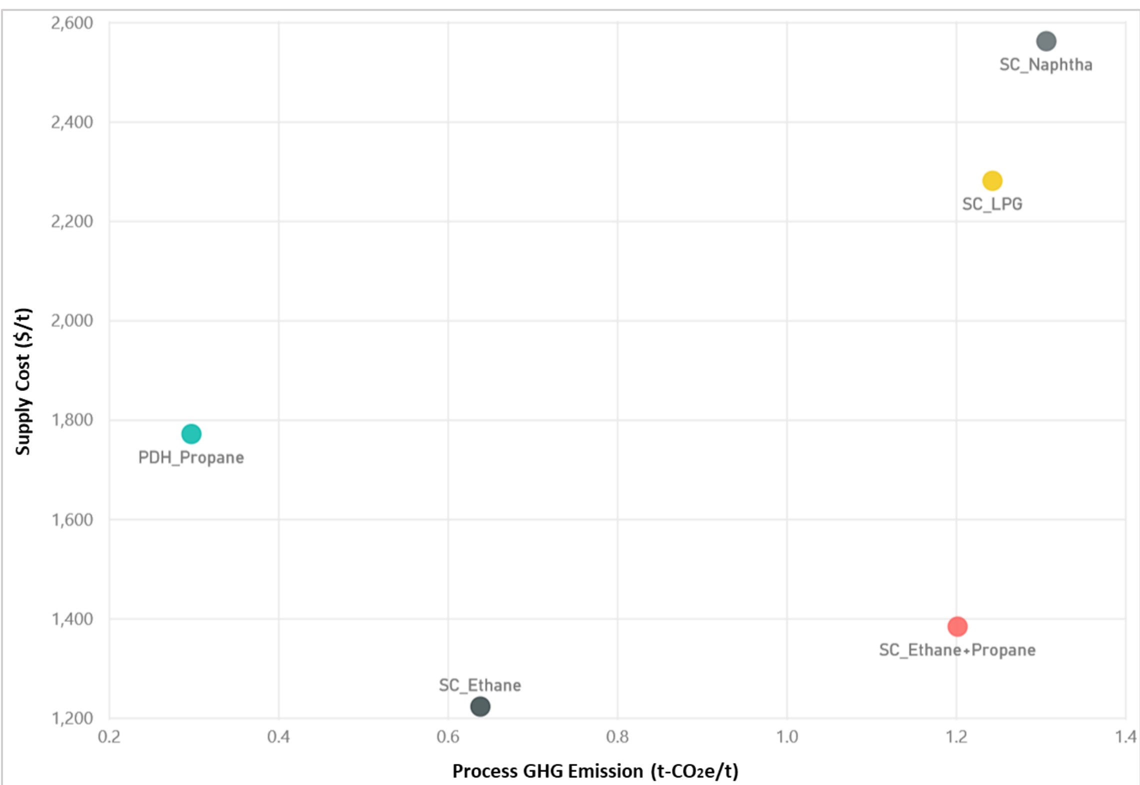
Table E.1: PE and PP Outbound Average Transportation Costs

	USGC (Texas)				China			
	PE		PP		PE		PP	
Origin	**$/t**	**$/lb**	**$/t**	**$/lb**	**$/t**	**$/lb**	**$/t**	**$/lb**
Alberta	13	0.006	18	0.008	23	0.010	28	0.013
Ontario	14	0.006	19	0.009	26	0.012	30	0.014
USGC	8	0.003	11	0.005	31	0.014	35	0.016
South Korea	26	0.012	29	0.013	18	0.008	22	0.010

If one takes the average supply cost across all the hubs, for each process and feedstock option under the NCNC scenario, the economic and environmental performance indicators of each feedstock processing pathway can be visualized and compared – as in Figure E.5 – with reduced effects of jurisdictional differences on the cost for each process and feedstock combination.

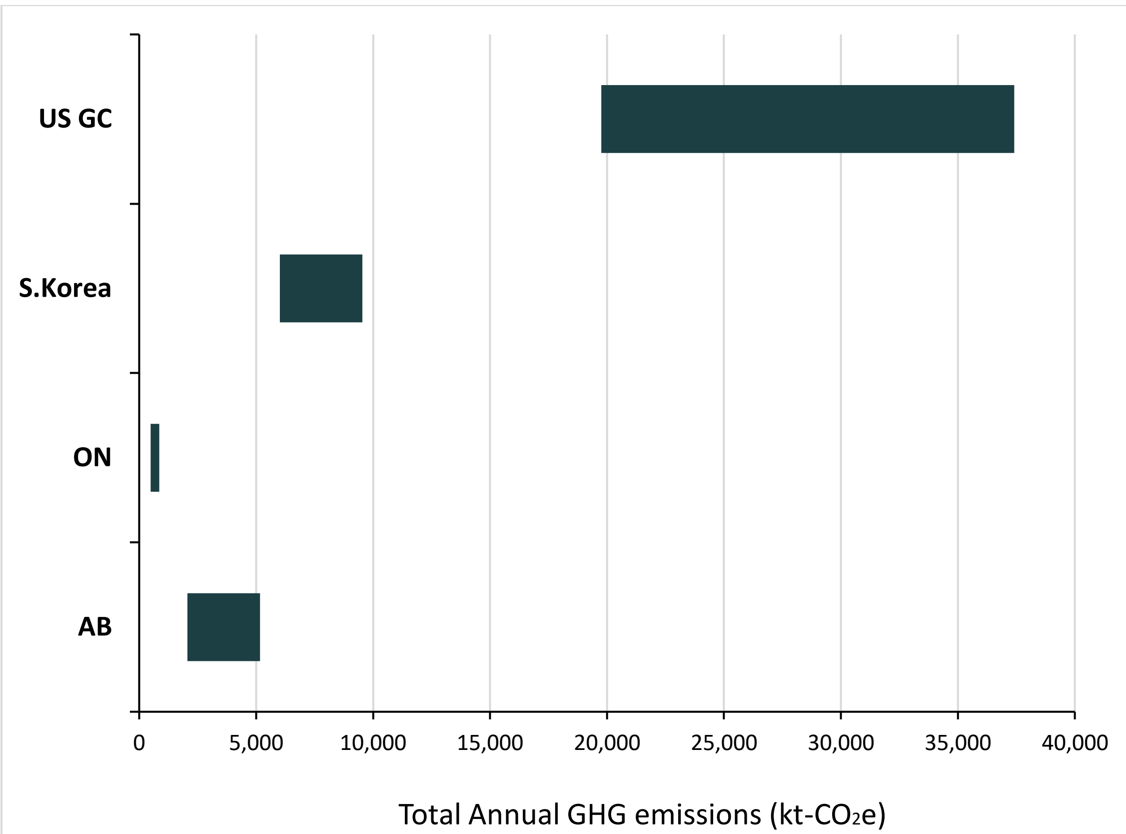
Processes using gas-based feedstocks have lower emissions and supply costs as against LPG and naphtha, which have higher energy requirements. For the PE and PP production studied here, steam cracking of ethane feed and propane dehydrogenation have the lowest economic and GHG emission intensities relative to the other production pathways.

Figure E.5: Average Supply Cost and GHG Emissions by Process and Feedstock Options



Considering the compositions of processing capacities in the four petrochemical hubs studied here, CERI can estimate their total annual GHG emissions at defined utilization levels. In consonance with our supply cost modelling assumption, we apply a 90% capacity utilization factor to the most recently available data on processing capacities at the hubs as reported by (Koottungal 2015) and (Morse 2017). By combining the ranges of emission intensities of each processing pathway with the total products generated therein, CERI evaluated total annual emissions in each hub, as shown in Figure E.6.

Figure E.6: Total Annual GHG Emissions from Petrochemical Hubs (2016 capacities basis)



Total annual GHG emissions are highest for the USGC, in the range of 19.8 Mt CO_2e to 37.4 Mt CO_2e. Seconded by South Korean hubs with emissions ranging between 6.0 Mt CO_2e and 9.5 Mt CO_2e. Canadian petrochemical hubs have the lowest annual GHG emissions with the Ontario hub emitting between 0.5 Mt CO_2e to 0.9 Mt CO_2e, whereas the Alberta hub emits between 2.1 Mt CO_2e to 5.2 Mt CO_2e.