Keystone XL Assessment

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Final Report - Appendix

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Abbreviations & Acronyms Used in this Report

bbl	barrel
bpd	barrels per day
mbd	million barrels per day
tpa	tonnes per annum
mtpa	million tonnes per annum
DOE	Department of Energy
DOS	Department of State
EPA	Environmental Protection Agency
PADD	Petroleum Administration for Defense Districts
BC	British Columbia
CAPP	Canadian Association of Petroleum Producers
NEB	Canadian National Energy Board
WC	Western Canada
WCSB	Western Canadian Sedimentary Basin
ETP	Department of Energy's Energy Technology Perspectives Model
WORLD	EnSys' World Oil Refining Logistics & Demand Model

1 Overview of EnSys & WORLD Model

1.1 EnSys' Experience

EnSys is an independent consultancy led by senior experts with substantial oil industry and refining backgrounds and which specializes in providing analyses and projections to support strategic industry-related decisions most frequently at national, international and global levels. Our focus is on regulatory, climate, investment, economic, trade, supply, demand and technology developments and how these impact refining and oil markets.

EnSys brings to bear an essentially unique track record of refining sector analyses including global studies using EnSys' WORLD model that stretch back to 1987. These include a long history of analyses for US government agencies:

- DOE Offices of Strategic Petroleum Reserve and Energy Emergencies – several analyses of real and hypothetical emergencies from 1987 through 2005
- DOE, Oak Ridge Laboratory and U.S. Navy – a series of analyses and support to ORNL studies of regulations for reformulated and military fuels spanning the mid 1980's through early 2000's
- Argonne National Laboratory – assessment of potential carbon regime impacts on the global petroleum industry as part of the lead up to Kyoto
- EIA - supply of EnSys' WORLD model in 1992, support on NEMS and WORLD including re-supply of updated WORLD model in 2006
- EPA - several analyses of US fuels regulations including most recently on marine fuels and to support the US 2009 ECA submission to the International Maritime Organisation

as well as a wide span of public and private sector clients including:

- US DOE, EIA, EPA etc. as above
- World Bank, Inter American Development Bank, International Maritime Organisation
- Private sector oil and specialty companies: ExxonMobil, ConocoPhillips, Marathon, Koch, Amerada Hess, Shell, BP, Total, Afton Chemical, ARCO Chemical
- American Petroleum Institute – fuel and climate regulation studies
- National oil companies and energy ministries: Abu Dhabi, Qatar, Tunisia, Ecuador, Trinidad
- OPEC Secretariat (annual World Oil Outlooks)
- Bloomberg (daily refining netbacks)

- State of New York, City of New York, Suffolk County, State of New Hampshire.

Our stress is on impartial analysis in all our assignments and our goal in this study was to apply our best judgment to assess how the drivers of industry economics would lead to changes in the US, Canadian and global oil sector under different scenarios.

1.2 EnSys *WORLD* Model

WORLD is an advanced modeling system which captures and simulates the global and interlinked nature of today's and tomorrow's downstream oil industry. The model provides projections of global refining developments, crude and product flows, pricing and refining margins as shown in Figure 1-1. It is a highly flexible system, with the ability to model short, medium, and long-term forecasts. The model works by combining top down scenarios for projected oil price/supply and demand over the next twenty years with bottom up detail on crude oils, non-crudes, (NGL's, biofuels, etc.), refining, transportation, product demand and quality.

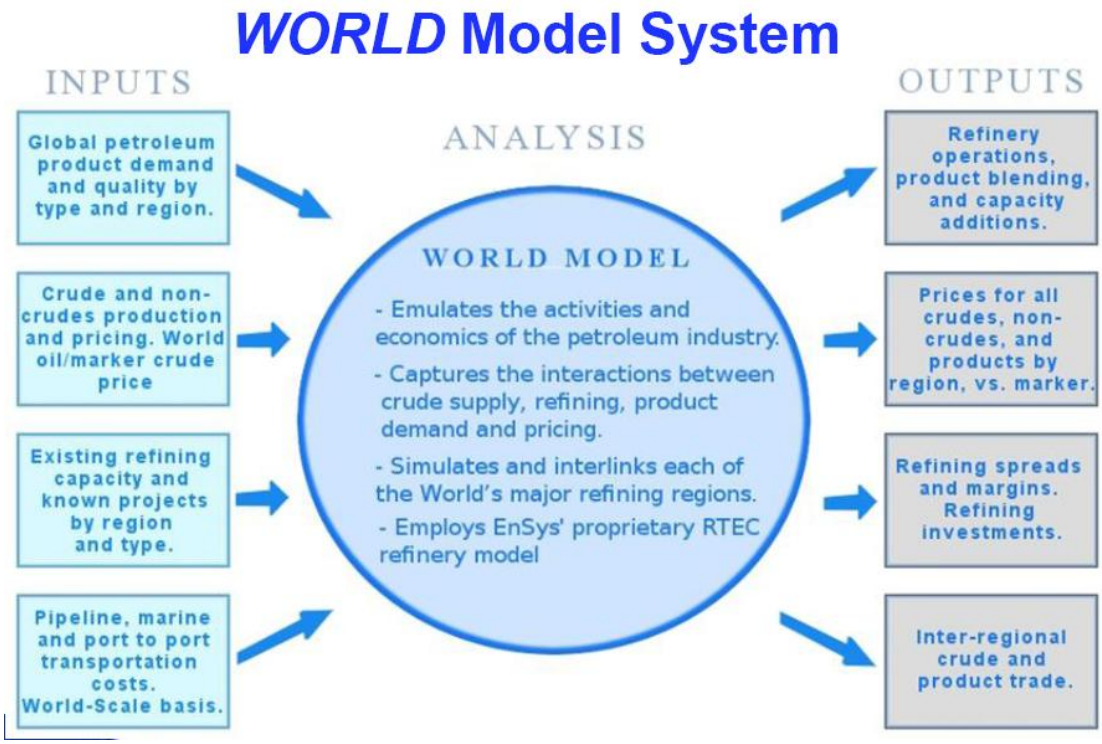


Figure 1-1

The version of WORLD used for this study for the Department of Energy comprised 22 regions with detail oriented to the US and Canada, including discrete representation of each PADD, Canada East and Canada West, (Figure 1-2), plus sub-PADD groupings for US refineries.

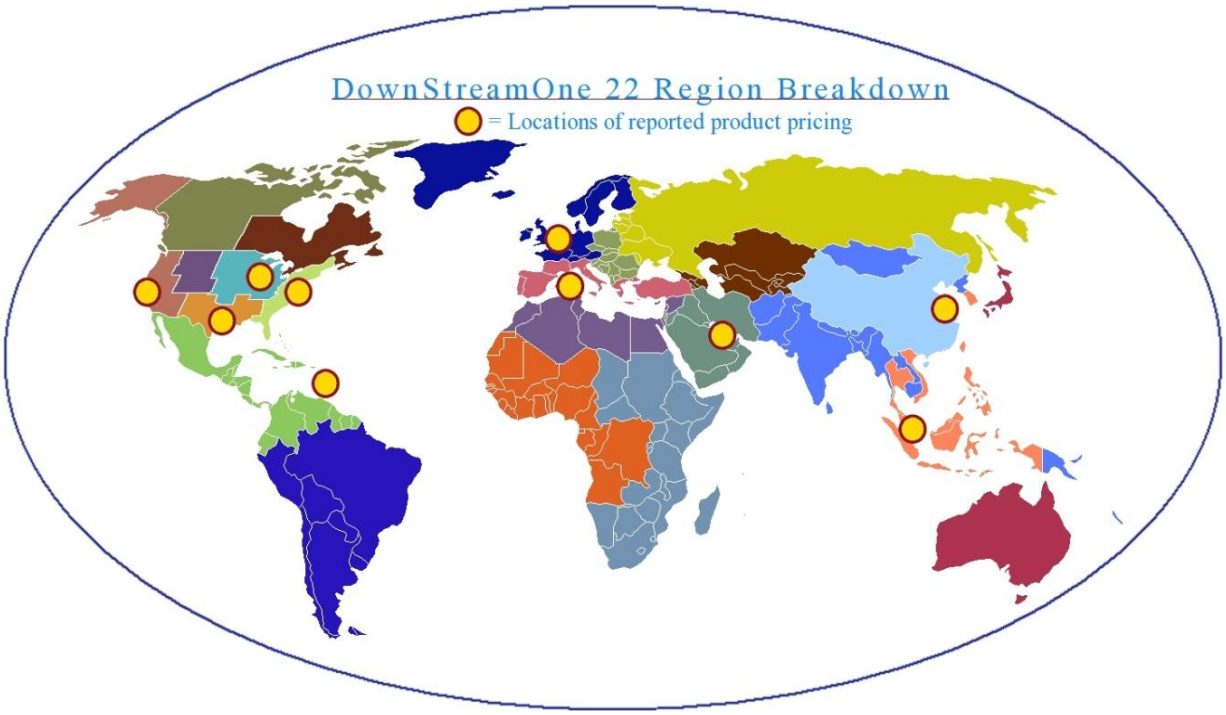


Figure 1-2

2 Study Starting Point, Set Up and Specific Premises

2.1 Reference Basis & Premises

This study used the following for its starting point:

- Employed the latest US-oriented version of WORLD:
  - 5 US PADD's, Canada East & Canada West plus 15 other world regions for a total of 22
  - Sub-PADD detailed breakdown / grouping of US refineries, total of 18 US refining groups
  - One refining aggregate group for each region outside US including Canada East & West
- Top level world regional supply/demand/world oil price outlook based on EIA Annual Energy Outlook 2010 Reference Case
- Alternative US low demand outlook taken from a March 2010 EPA report[1] examining more aggressive measures to cut transport fuel demand in the US supplemented by global demand and world oil price adjustments generated using the DOE ETP model (See Section 2.3.5)
- Detail of crude supply, non-crudes supply, product demand mix and quality, refining capacity and projects, crude and product transportation (mainly marine and inter-regional pipelines) basis and outlook built up from multiple sources as extensively applied in recent EnSys studies
- WORLD cases for 2010, 2015, 2020, 2025 and 2030 from recent EnSys studies

To best fit the model to the DOE study, several checks and adjustments were made, including:

- **AEO 2010 and the more recent IEO 2010 projections were compared and selected adjustments made**
  - The starting basis in WORLD at the beginning of the assignment was the AEO 2010 Reference Case (produced December 2009). Versus this, there are a range of specific differences in supply and demand projections by region in the 2010 EIA International Energy Outlook (IEO); for instance slightly lower total global demand by 2030. Because of the relatively limited differences between the two outlooks, and because of the limited time available and the focus on the USA and Canada, EnSys took the decision to move to the IEO 2010 basis only on a few parameters which potentially would materially impact the study, specifically:

[1] EPA Analysis of the Transportation Sector, Greenhouse Gas and Oil Reduction Scenarios, February 10, 2010, last updated March 18, 2010, in response to September 2009 request from Senator Kerry.

- The AEO global demand was retained, leading to a projected 90.9 million bpd by 2015 (versus 88.7 in the IEO) and 105.9 million bpd in 2030 (versus 103.9 in the IEO). The AEO medium term outlook was also compared with and found to be closely in line with the then latest EIA Short Term Energy Outlook (June 2010) and the IEA's June 2010 Medium Term outlook.
- USA demand outlook was not altered as it is the same in both AEO and IEO
- Canadian product demand outlook was retained at the AEO levels. (The IEO has lower growth rates, 2020 demand 2.2 million bpd versus 2.37 in the AEI, 2030 demand 2.3 million bpd versus 2.55 in the AEO.)
    - Global, South American and US biofuels/ethanol production were tuned to IEO as were coal-to-liquids (CTL), gas-to-liquids (GTL) and shale oil. This was because the AEO does not contain specific regional projections for these fuels. AEO and IEO have the same projections for US biofuels.

- USA liquids production:
    - AEO and IEO have the same projections for US conventional liquids supply – so AEO retained
    - AEO projections were used as the basis for projecting US production by region/state
        - However, AEO 2010 Table 113 shows near term declining crude production for the Rocky Mountain region despite the fact that ND (Bakken) production is rising rapidly. The table then has the region's production rising steadily long term. An adjustment was made wherein the short term dip in production projected in the AEO was replaced by an increase. Longer term AEO values were left unchanged[2].

- **Canada total liquids and oil sands production**. Since Canada's oil sands production is at the center of this study, projections from the IEO and Canadian sources, notably CAPP and the Alberta Energy Resources Conservation Board (ERCB), were compared. The AEO does not contain explicit projections for Canadian oil sands, only "North American non-conventional"
    - The IEO projections for Canadian oil sands production have lower growth than those from CAPP on which many export pipeline projects are being based. Since the CAPP projection reflects the Canadian industry's latest "best estimate" forecast, and includes a series of projects reactivated or initiated since the beginning of 2010, the CAPP projections were used. Table 2-1 below summarizes the CAPP projections and provides comparison with the IEO

[2] Given Bakken crude projections made available since these premises were set, it appears that the projections used in the model cases were likely to have understated future Bakken production. This is further discussed in the main Report, Section 3.2.3.2.

- Versus their 2009 outlook, the 2010 CAPP projection contains a lower proportion of fully upgraded light synthetic crude (SCO) and higher proportions of bitumen blends. This shift reflects delays and cancellations to a number of upgrading projects and the anticipation of growing available supplies of diluent.
- Details from 2010 and 2009 CAPP and related projections were used to arrive at a breakdown of bitumen blends between DilBit and SynBit. (DilBit is a blend of naphtha/condensate and bitumen, SynBit of SCO with bitumen.) Expected growing availability of condensates/diluents, from the Enbridge Southern Lights project and from CN Rail imports via Kitimat British Columbia as well as from western Canadian condensate itself has led to a shift to higher proportions of DilBit, less SynBit
- The CAPP projections used were very close to those already in WORLD
- Specific Western Canadian crude grades used were:
    - Conventional:
        - mixed (light) sweet
        - mixed (medium) sour
        - heavy
    - Oil sands:
        - synthetic fully upgraded
        - bitumen blends:
            - Western Canadian Select (WCS does include some conventional streams but is listed by CAPP under oil sands grades and volumes)
            - SynBit blend
            - DilBit blend (includes Cold Lake and Athabasca)

Table 2-1 summarizes the projection used for WCSB crude supply. Note, this relates to what CAPP terms as <u>supply</u> of streams to market downstream of upgraders and blending, not to raw <u>production</u>. Also, the CAPP projections went through 2025 and were extrapolated to 2030.

CAPP Crude Oil Forecast, Markets & Pipelines, June 2010							
CAPP Western Canadian Crude Oil Supply Forecast 2010 – 2025							
Blended Supply to Trunk Pipelines and Markets							
thousand barrels per day Actuals Forecast							
	2008	2009	2010	2015	2020	2025	2030
CONVENTIONAL							
Total Light and Medium	589	559	546	489	423	371	*325*
Net Conventional Heavy to Market	350	311	288	221	172	133	*103*
TOTAL CONVENTIONAL	939	870	834	710	595	505	*428*
Year on year Lt/Med	3.2%	-5.1%	-2.3%	-2.8%	-2.8%	-2.6%	-2.6%
Year on year Conv Hvy	-8.4%	-11.1%	-7.4%	-4.7%	-5.5%	-5.0%	-5.1%
OIL SANDS							
Percent SCO	37.2%	40.3%	43.0%	34.9%	31.5%	30.0%	*28.5%*
Upgraded Light Synthetic (SCO)	556	653	745	896	1,014	1,206	*1,260*
Bitumen Blends	937	970	986	1,669	2,202	2,818	*3,160*
TOTAL OIL SANDS AND UPGRADERS	**1,493**	**1,622**	**1,731**	**2,565**	**3,216**	**4,024**	***4,420***
c.f. IEO Canada Oil Sands/Bitumen	*1,510*			*2,360*	*2,870*	*3,490*	*4,240*
WESTERN CANADA OIL SUPPLY	2,432	2,493	2,565	3,275	3,811	4,528	*4,848*
ATLANTIC CANADA OIL PRODUCTION	342	268	250	190	190	145	*106*
Year on year Atlantic Canada	-7.3%	-21.6%	-6.7%	-2.6%	-15.6%	-6.5%	*-6.0%*
TOTAL CANADA OIL SUPPLY	**2,774**	**2,761**	**2,815**	**3,465**	**4,001**	**4,673**	***4,954***
Notes:							
CAPP separately projects Western Canada crude production and supply to market.							
EnSys used the supply to market figures, i.e. the net output from blending and upgrading.							
Projections for 2030 are EnSys extrapoloations based on DOE guidance.							
Bitumen blends include both DilBit and SynBit types - further split out in WORLD.							

Table 2-1

- **Canadian crude flows into US refineries, grouping of US refineries**
  - Detailed EIA crude oil imports data for 2009 were analyzed and compared with Canadian Association of Petroleum Producers (CAPP) data for Canadian oil production and flows into US regions
    - Reconciliation was essentially exact

- These enabled EnSys to identify US refineries receiving Canadian crude by type and volume

- Taking into account
  - current routings and intake of Canadian crudes, (especially identified heavy and synthetic grades)
  - known US refinery projects for conversion to take Canadian heavy/oil sands and
  - projected pipeline developments, especially potential Keystone XL to US Gulf Coast Houston, Port Arthur area
- US sub-PADD refinery groupings in WORLD were adjusted to best fit the needs of the study. Table 2-2 summarizes the sub-PADD refinery groupings used

WORLD US Refinery Groupings for DOE Analysis

Groups	Operating Refineries in Group	Total Capacity bpcd	Average W Can Crude as % of Capacity
P1-Coastal/Lo Can	12	1,542,300	n.a.
P1-HiCan	2	76,700	93%
P2-East-LoCan	6	862,000	3%
P2-East-HiCan	7	1,501,650	55%
P2-North	4	484,250	53%
P2-South	8	778,700	6%
P3-GC Mid Med/Swt	10	1,564,112	4%
P3-GC East Med/Swt	4	278,100	4%
P3-GC Mid Sour/Coking	12	3,815,690	3%
P3-GC East Sour/Coking	6	1,456,500	5%
P3-GC West	4	737,050	1%
P3-Small/Inland	14	542,000	n.a.
P4	15	603,000	47%
P5-AK	6	382,175	n.a.
P5-WA	5	623,200	19%
P5-CA/HI Small/Inland/Swt	9	274,500	2%
P5-CA Hvy Sour	11	1,802,525	5%
Total	135	17,324,452	

Note: capacities and active refineries reflect recent definite closures

Note: all WORLD results reporting is by PADD

Table 2-2

- **Canadian crude export routes, projects, capacities and tariffs**
  - 2009 Canadian crude flows were used as guidelines / basis for forward reference and scenario cases
  - Current and projected Canadian pipeline export routes were reviewed and best estimate start up dates and capacities developed for projects under each Scenario
  - Several sources were reviewed including: CAPP, Enbridge and TransCanada applications to the Canadian NEB, industry, consultant and press reports
  - Factual information on Keystone and KXL was reviewed directly with TransCanada in November. The information confirmed differed slightly from that assumed in WORLD model cases but did not materially alter results
  - Tariff information for the various export routes was taken from CAPP 2010 forecast and from published tariffs.

2.2 Pipeline Projects

The pipeline projects identified and considered in this study were discussed extensively in the main report. Additional diagrams are provided below for several of the projects.

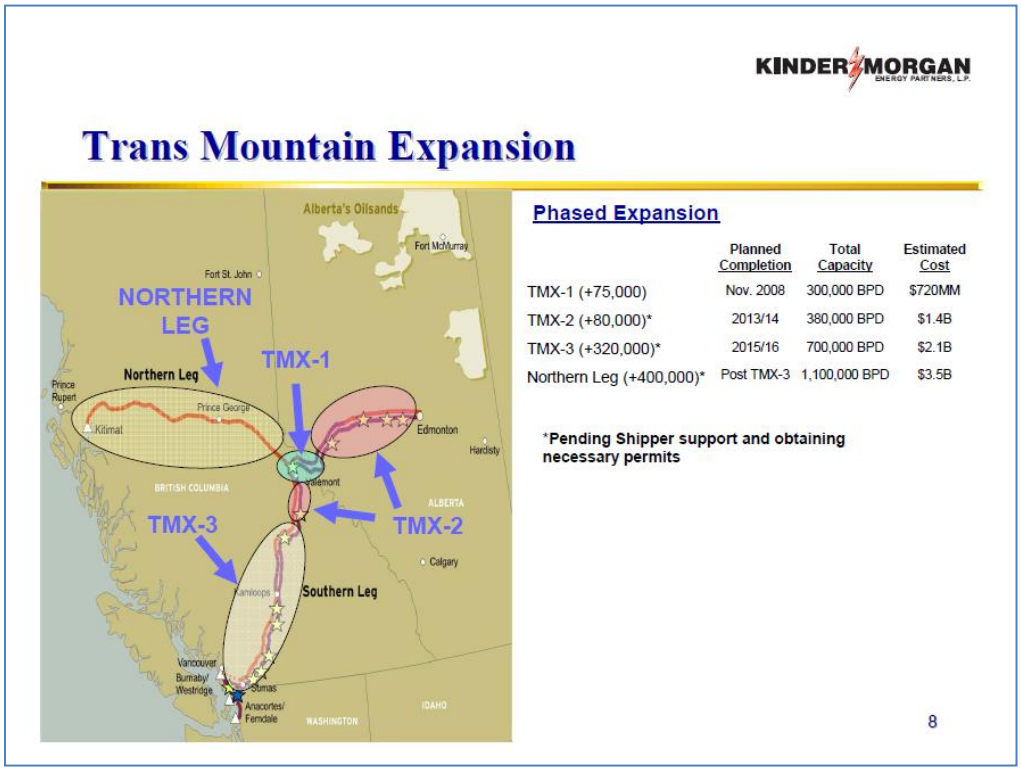

KINDER MORGAN
ENERGY PARTNERS, L.P.
Trans Mountain Expansion
Alberta's Oilsands
Fort McMurray
Fort St. John
NORTHERN LEG
TMX-1
Northern Leg
Prince Rupert
Prince George
Kitimat
Edmonton
Hardisty
BRITISH COLUMBIA
Valemont
ALBERTA
TMX-3
TMX-2
Calgary
Kamloops
Southern Leg
Vancouver
Burnaby/ Westridge
Sumas
Anacortes/ Ferndale
WASHINGTON
IDAHO
Phased Expansion
Planned Completion
Total Capacity
Estimated Cost
TMX-1 (+75,000) Nov. 2008 300,000 BPD $720MM
TMX-2 (+80,000)* 2013/14 380,000 BPD $1.4B
TMX-3 (+320,000)* 2015/16 700,000 BPD $2.1B
Northern Leg (+400,000)* Post TMX-3 1,100,000 BPD $3.5B
*Pending Shipper support and obtaining necessary permits
8

Figure 2-1

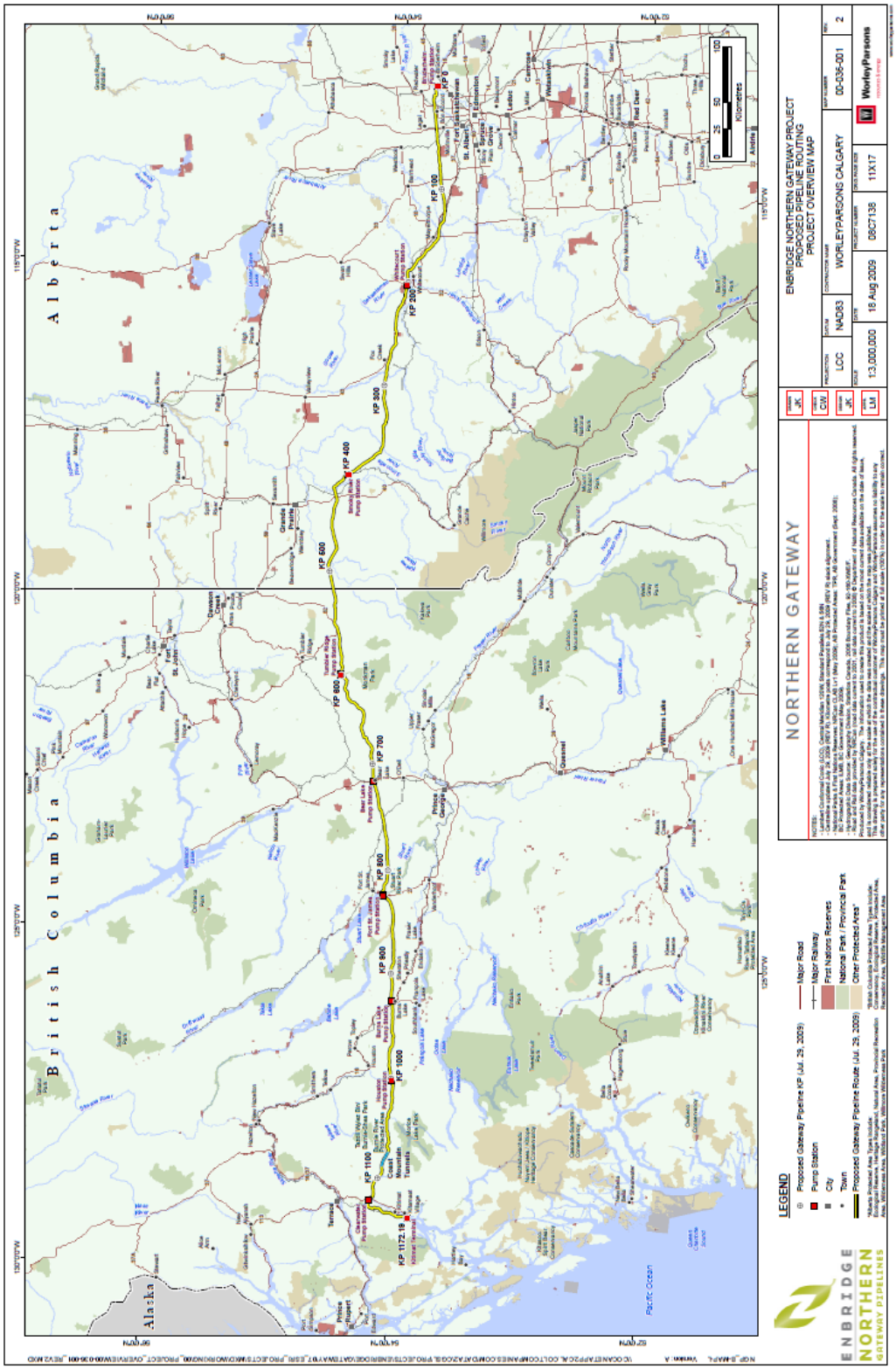

Alberta
British Columbia
Alaska
Pacific Ocean
KP 0
KP 100
KP 200
KP 300
KP 400
KP 500
KP 600
KP 700
KP 800
KP 900
KP 1000
KP 1100
KP 1172.19
Kilometers
NORTHERN GATEWAY
ENBRIDGE NORTHERN GATEWAY PROJECT
PROPOSED PIPELINE ROUTING
PROJECT OVERVIEW MAP
LEGEND
Major Road
Major Railway
First Nations Reserves
National Park / Provincial Park
Other Protected Areas
Proposed Gateway Pipeline Route (Jul. 29, 2009)
Pump Station
City
Town
ENBRIDGE
NORTHERN
GATEWAY PIPELINES
WorleyParsons
NAD83
LCC
13,000,000
18 Aug 2009
0807138
11X17
D0-036-001
2

Figure 2-2

PAA Bakken North Project & Existing Bakken Area Assets

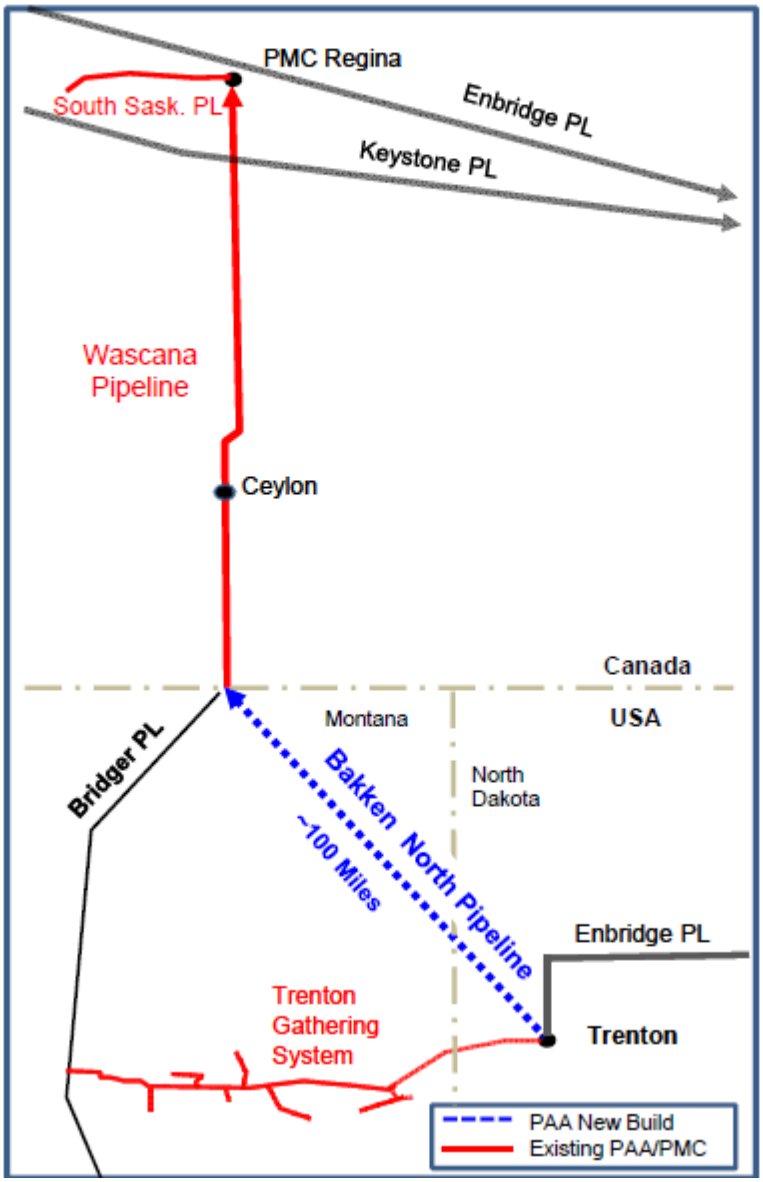


Figure 2-3

TransCanada
in business to deliver
Oil Pipelines
Legend
KeystoneXL
True Companies
Quintana Proposal
0
25
50
Miles
Proposed Marketlink Facilities
Baker Tank Farm
Baker
Plains
Butte
Little Missouri
Belle Fourche
Poplar
Keystone XL
Quintana Proposal
Montana
North Dakota
South Dakota
Minot
Garrison
Washburn
Mandan
Bismarck
Mobridge
Kenmare
Stanley
Toga
Crosby
Williston
Watford City
Sidney
Plentywood
Wolf Point
Miles City
Glendive
Beach
Dickinson
Hazen
Beulah
Mott
Hettinger
Lemmon
Bowman

Figure 2-4

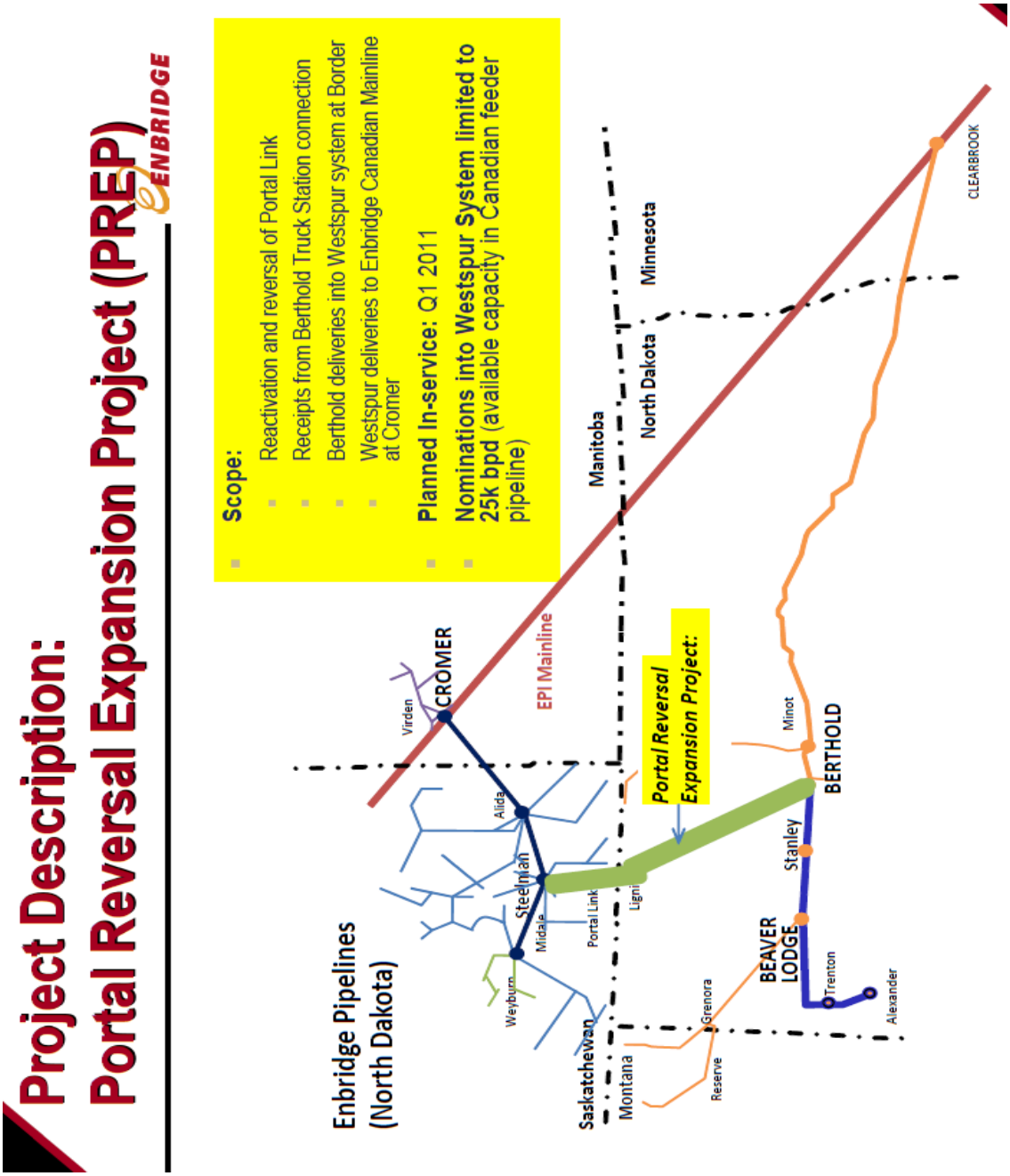

Project Description:
Portal Reversal Expansion Project (PREP)
ENBRIDGE
Scope:
Reactivation and reversal of Portal Link
Receipts from Berthold Truck Station connection
Berthold deliveries into Westspur system at Border
Westspur deliveries to Enbridge Canadian Mainline at Cromer
Planned In-service: Q1 2011
Nominations into Westspur System limited to 25k bpd (available capacity in Canadian feeder pipeline)
Enbridge Pipelines (North Dakota)
Virden
CROMER
Alida
Steelman
Weyburn
Midale
Portal Link
Saskatchewan
Montana
EPI Mainline
Manitoba
North Dakota
Minnesota
Portal Reversal Expansion Project:
Grenora
Reserve
Minot
BERTHOLD
Stanley
BEAVER LODGE
Trenton
Alexander
CLEARBROOK

Figure 2-5

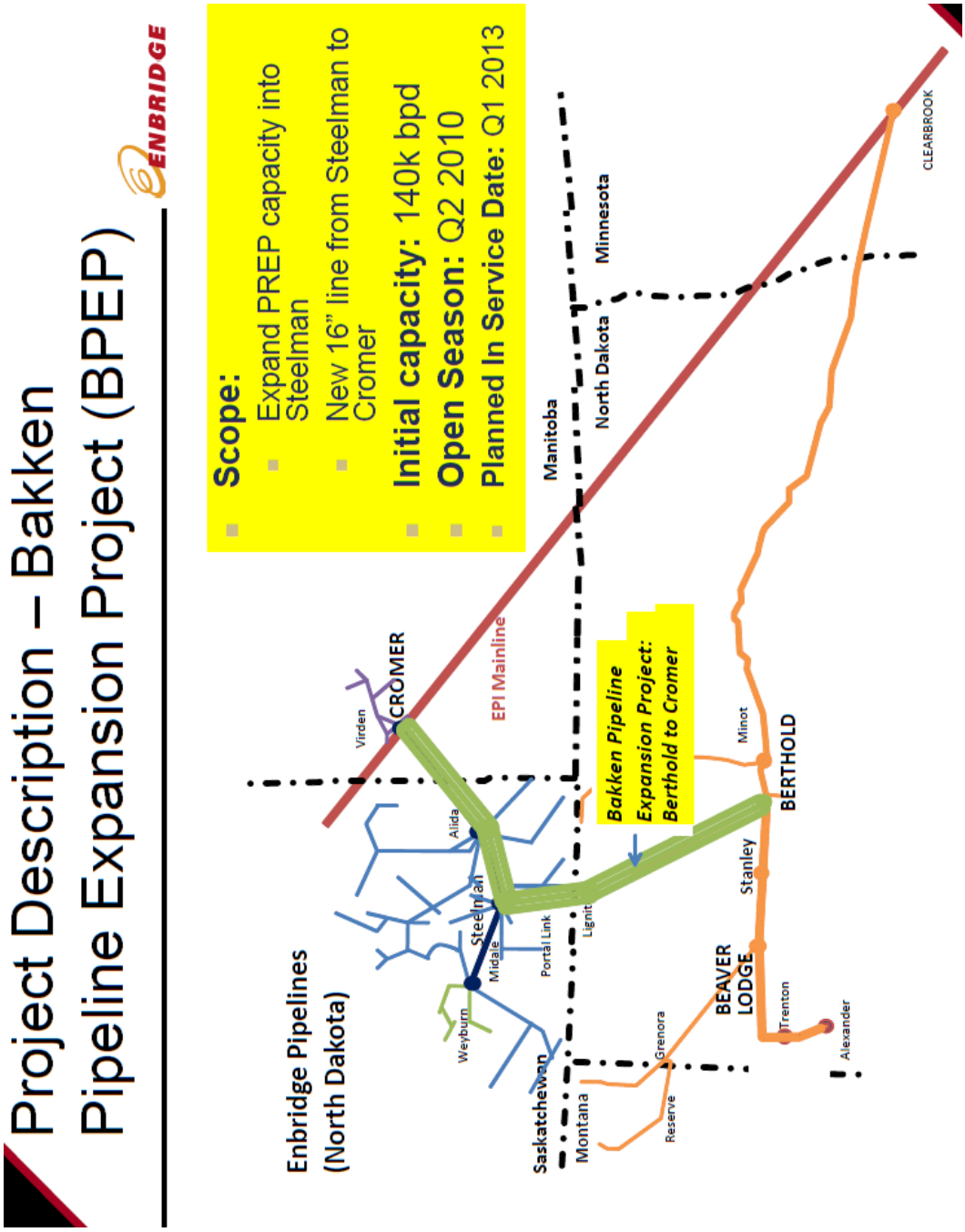


Figure 2-6

Source: Enbridge Pipelines (North Dakota), Ashok Anand, Senior Manager, Petroleum Quality & Service Metrics, COQA Presentation, June 10th2010

2.3 WORLD Model Modifications

A series of specific adjustments was made to the EnSys WORLD model for this study. These included adapting to and setting up the EIA, EPA and CAPP bases described in the previous section but also a series of further detailed adjustments. These were made both at the start of and during the course of the study, based in part on initial case results.

2.3.1 Pipeline Capacities & Routings

Section 3.2 of the main Report provides extensive coverage of the pipeline projects considered in this study. The following notes provide additional selected commentary.

- **Enbridge** plans for line expansions ex ND **Bakken** region were reviewed and updated. The Initial cases already embodied the planned capacity expansions. The expanding crude volumes out of ND via Enbridge Bakken expansions (Figures 2-5 and 2-6) will take up capacity on the EPL Mainline system. Part of the expanded volumes will in fact flow directly east through the line that joins the EPL at Clearbrook, Minnesota, south of the US/Canada border, part will flow north from ND joining EPL in Canada before flowing back into the US, thereby making a double border crossing. This detail was ignored in the EnSys WORLD simulation which had all the expansion effectively staying in the US and joining the EPL in the US.
- **Transmountain** (TM) base line capacity for crude was cut by 30,000 bpd[3] to reflect capacity used for moving products (which are considered to be delivered "locally" in WORLD within the WCan region)
    - The amount of TM capacity used for product was assumed to remain constant i.e. TMX expansions were assumed dedicated to expanding only crude volumes. This is line with Kinder Morgan Canada statements that they would expect expansions to be dedicated to crude not product

2.3.2 Condensate/Diluent Balance

WORLD model set up was adjusted to fully account for the condensate needed for DilBit production.

There is a span of uncertainty between future supply mix of DilBit versus SynBit. Earlier CAPP projections were showing higher proportions of future SynBit production and less DilBit compared to

[3] Product movements on the Transmountain line have been dropping steadily in recent years, dipping below 50,000 bpd in 2010. A flat figure of 30,000 bpd was used across the future modeling horizons.

current projections. Earlier projections also included an expectation that several new upgraders would be built in Western Canada. Further, several years ago, the Enbridge Southern Lights diluent line project did not exist nor did the Enbridge Northern Gateway proposal with its line that would bring diluent in from Asia to WCSB. Thus earlier projections were built on the basis that there would be limited condensate available beyond WCSB production and that there would be significant SCO present for use as diluent (for SynBit).

The EnSys projections for WCSB production were based on 2010 and 2009 CAPP data and related studies. The underlying premise is that significant condensate/diluent volumes will be available (including streams that are recycled) and that, consequently, SynBit will comprise a small proportion of bitumen blends and DilBit a high proportion. DilBit contains typically 25% condensate/naphtha diluent (and SynBit around 50% SCO). CAPP have WCSB condensate production slowly declining from around 157,000 bpd in 2010 to 129,000 bpd in 2030. At 25%, this is sufficient to support an average of around 520,000 bpd of DilBit. The Enbridge Southern Lights pipeline is currently in start-up. This will bring a mix of condensate and refinery naphtha diluents back up from the Chicago area to Hardisty/Edmonton. Initial capacity is 180,000 bpd of which around 80,000 bpd is reported to be committed. The system has been designed to be expandable to 330,000 bpd. Today around 27,000 bpd of condensate is reported as moving into WCSB via rail. This is understood to be coming at least in part from Kitimat via CN Rail. This may continue to move into WCSB. Growing US and shale gas production may also provide additional condensate volumes over time.

Thus, looking ahead to 2030, potential available condensate from within the US and Canada (which may well include recycled volumes via the Southern Lights line) totals around 460,000 bpd, possibly higher allowing for supplies from say Bakken shale and other developing areas. At 25% diluent concentration, this is sufficient to support at least 1.8 million bpd of DilBit and possibly 2 million bpd without resorting to additional condensate supplies. Potential additional sources could include condensates shipped up from the US Gulf Coast and potentially condensates from Asia. The Enbridge Northern Gateway project currently includes a 195,000 bpd diluent line that would run parallel to the WCSB crude line running west to Kitimat and would bring Asian condensate in to WCSB on the tanker “back haul” leg. EnSys’ projection, derived from CAPP data, is for 2.13 million bpd DilBit by 2030. This is therefore not inconsistent with potentially available diluent supplies and transportation systems. Our projection of a relatively small proportion of SynBit (7-10% of total bitumen blends) plus WCS, (which is a SynDilBit blend with some conventional), at 21-33%, thus appears a plausible outlook and one which is consistent with latest WCSB plans for less upgrading and for growth in WCS volumes.

The “condensate balance” was captured in WORLD by subtracting out of supply not only essentially all Western Canadian condensate but also volumes from PADDs 2, 3 and 4 plus supplemental volumes from outside the US, notably Asia. Again, the extent to which raw condensate production is needed versus diluent recycled as refinery naphtha (yielded from the diluent in the DilBit) is uncertain. Some degree of recycling is anticipated and, the higher the degree of recycling, the less the impacts are on “new”

condensate diluents that need to be supplied. The assumption that was built in to EnSys' diluent balance was that the proportion of recycling would gradually increase over time.

2.3.3 (Relative) Freight versus Pipeline Costs

In part spurred by the Barr Report for the NPRA[4], the parameters used to escalate real (constant dollar) tanker and pipeline costs over time were reviewed. Two escalation factors were used. A factor based on growth in natural gas prices was used to escalate real (constant dollar) pipeline tariffs, this since pipeline operations use predominantly natural gas and electricity for fuel. A second factor was developed for tanker costs using change in crude oil price, this since marine bunker fuels are derived from crude oil. In both cases the variations in cost of natural gas or crude oil were applied as a power factor well below one to reflect that both transport modes embody other significant cost components. The resulting average annual (real) escalation rate was 0.8% p.a. for pipeline tariffs versus current (2010) levels. For tanker rates, the resulting escalation factors versus 2010 were in the range of 2-3% p.a. for shorter term horizons, leveling out to around 1.3% p.a. 2010 to 2030, driven by EIA's growth profile for crude oil prices (i.e. higher increases in the earlier years). The higher tanker escalation rates, relative to those for pipelines, reflect the higher rate of increase in crude costs relative to natural gas in the EIA AEO 2010. In addition, the escalation in tanker rates reflects anticipated increases over time in marine fuel supply costs resulting from MARPOL AnnexVI with its regulations for progressively tightening sulfur standards[5].

2.3.4 Marine Bunkers Outlook

One outcome of EnSys' work since 2006 with the EPA, API and IMO on marine fuels was the development by team members of rigorous present day consumptions and projections for marine fuels consumption worldwide. These analyses, which have been extensively supported by other experts, show that early 2000's global marine fuels consumption was at a level essentially twice that reported by the IEA (i.e. around 370 mmtpa versus the 140 mmtpa level per the IEA). The data indicate that this is a matter of misreporting of barrels rather than missing barrels, i.e. fuels actually consumed for marine bunkers are reported under other categories. Today, the misreporting has little consequence. However, when projected, the impact on future global oil demand total and mix is important because of the

[4] Low Carbon Fuel Standard "Crude Shuffle" Greenhouse Gas Impacts Analysis, Barr Engineering Company, June 2010

[5] The extent to which future ECA and global emissions standards are met by fuels modification versus via exhaust gas treatment (on-board scrubbing) is still an unknown. EnSys assumed a partial move toward use of lower sulfur fuels.

differences in growth rates between inland and marine heavy (residual/IFO) fuels. The IEA have acknowledged that there is a problem with their statistics. The projections developed by the RTI/Navigistics/EnSys team for the EPA have now been effectively endorsed by the IMO whose own projections are very similar.

Several recent EnSys WORLD studies have been run by first tuning to the "IEA basis" forecast for each future horizon (thus if the EIA's projection for 2015 is say 95 million bpd tuning to match that) and then switching to the "IMO basis" for marine fuels. The further out into the future, the more switching to the IMO basis raises projected global oil demand and the proportion within that of residual / IFO fuels on the basis of no change in marine fuels quality. So the basis to be used must be selected, either IEA or IMO.

In addition, while the MARPOL AnnexVI rules are clear, they leave open major uncertainty on (a) the timing of required conversion of the global standard to 0.5% sulfur and (b) the extent to which compliance may be achieved by either modifying fuels – to 0.1% for ECA fuel and 0.5% for non-ECA areas, in both cases meaning conversion to marine distillates – and/or by employing on-board scrubbing. The latter would allow certainly non-ECA fuels to stay at their current standards.

For the purposes of this study for the DOE, EnSys used the following assumptions regarding marine fuels:

- Marine fuels demand outlook is on the "IEA" basis. Although the "IMO" basis is arguably the more correct, EnSys wished to steer clear of entering into a potential debate around marine fuels and total global demand targets that would be inconsistent with EIA's projections
- Regarding quality / fuel mix:
    - All ECA fuels standards met by fuel use at the 0.1% sulfur standard
    - By 2015, USA/Canada ECA's in operation, in addition to the 2 northern European ECA's
    - By 2020, other additional ECA's in operation but global 0.5% sulfur standard deferred until after 2020
    - By 2025 through 2030, there is progressive increase in the proportion of IFO shifted to marine distillate but this is not total, reflecting that compliance is partly through fuel conversion, partly through scrubbing.

This quality outlook contains significant uncertainty but, EnSys believes, represents a "middle of the road" projection that avoids either of the potential extremes of total scrubbing or total IFO conversion to marine distillate.

2.3.5 EPA Low Demand Outlook

A second "**Low Demand**" outlook was also applied to assess the impacts of a US petroleum outlook entailing much reduced consumption of transport fuels. This was based on a February/March 2010 study by the EPA[6] which involved the examination of "more aggressive fuel economy standards and policies to address vehicle miles traveled". Projections were used from the EPA's Scenario A, leading to reductions in US consumption versus the AEO 2010 outlook starting post 2015 and reaching 1.2 mbd by 2020 and 4.0 mbd by 2030. The US demand reductions are detailed in Table 2-3 while Table 2-4 summarizes key details of both the AEO and Low Demand outlooks.

The AEO and Low Demand outlooks for US demand are compared in Figures 2-7 and 2-8. As can be seen, the impact is predominantly on transport fuels led by a 2.8 mbd reduction in gasoline consumption. Under the AEO outlook, US petroleum demand continues to slowly increase, although associated growth in supply of biofuels under the RFS-2 mandate means projected ex-refinery demand for products is essentially flat. Under the Low Demand outlook, a marked reduction in US demand begins to take hold after 2015 and continues through 2030.

Since WORLD comprises an integrated global approach, the impacts of the projected reduction in US demand on the global supply system were estimated using the Department of Energy's ETP model as applied by Brookhaven National Laboratory. US demand reduction was taken to cut world oil price which in turn led to small increases in oil demand in non-US regions. The effects are summarized in Table 2-4. The net global oil demand reduction in 2030 was 3.7 mbd. On the supply side, ETP projections were for the reduction to be met primarily by cuts in OPEC crude production, notably from the Middle East; further that there would be small reductions in US, Canadian and other non-OPEC supplies, including those for biofuels. As indicated in Table 2-4, total Canadian oil production was projected to be cut by 0.2 mbd by 2030, principally oil sands streams.

Total Liquids Demand Reductions

million bbl/d oil equivalent

	2010	2015	2020	2025	2030
Gasoline	0.000	0.176	0.831	1.810	2.765
Distillate	0.000	0.001	0.120	0.223	0.460
Jet Fuel	0.000	0.095	0.190	0.380	0.760
Fuel oil	0.000	0.000	0.006	0.011	0.023
Other	0.000	0.000	0.005	0.009	0.018
Total	**0.000**	**0.272**	**1.152**	**2.433**	**4.027**

Table 2-3

[6] EPA Analysis of the Transportation Sector, Greenhouse Gas and Oil Reduction Scenarios, February 10, 2010, last updated March 18, 2010, in response to September 2009 request from Senator Kerry.

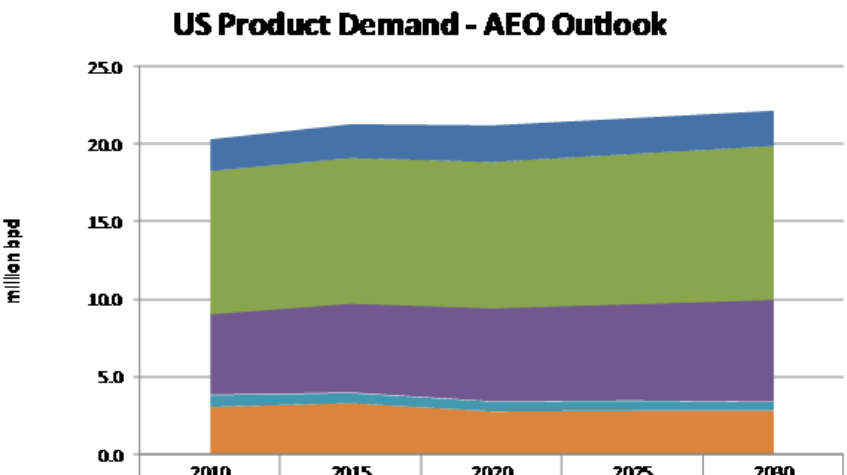
Summary of AEO and Low Demand Projections

	AEO Outlook (6)			**Low Demand Outlook** (7)		
	2010	2020	2030	2010	2020	2030
World oil price $/bbl (1)	$ 67.40	$ 98.14	$ 111.49	$ 67.40	$ 96.80	$ 107.00
Liquids demand						
million bpd						
USA (50 states)	19.2	20.6	21.5	19.2	19.4	17.5
Canada	2.3	2.4	2.5	2.3	2.4	2.6
other OECD (2)	24.8	25.7	25.8	24.8	25.7	25.9
China	8.5	12.4	15.8	8.5	12.4	15.8
other non-OECD	31.0	34.6	40.3	31.0	34.7	40.4
Global	85.9	95.6	105.9	85.9	94.5	102.2
Canada crude oil supply (3)						
Conventional (4)	1.10	0.82	0.54	1.10	0.80	0.51
Oil Sands (5)	1.73	3.22	4.42	1.73	3.15	4.25
Total	2.83	4.04	4.96	2.83	3.95	4.76

Notes:

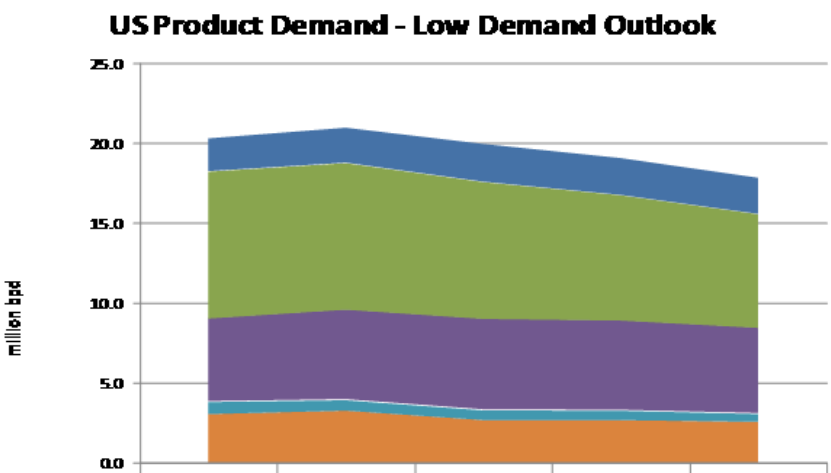
1. World oil price taken as price of US imported crude oil. Values are constant dollars $ 2008
2. Comprises: Mexico, Europe, Japan, South Korea, Australia, New Zealand
3. Projections to 2025 taken from CAPP 2010 Report Growth projection, 2030 estimates via extrapolation
4. Include both Western and Eastern Canada
5. Comprises blended / upgraded supply streams to market not raw production
6. Basis EIA Annual Energy Outlook 2010 Reference Case
7. Basis EPA Analysis of the Transportation Sector, Greenhouse Gas and Oil Reduction Scenarios, February 10, 2010, last updated March 18, 2010

Table 2-4



	2010	2015	2020	2025	2030
LPG	2.0	2.2	2.4	2.3	2.3
Gasoline/E85	9.2	9.3	9.4	9.6	9.9
Jet/ Distillate	5.2	5.8	6.0	6.2	6.6
Residual Fuel	0.8	0.7	0.6	0.6	0.6
Other	3.1	3.3	2.8	2.8	2.8

Figure 2-8



	2010	2015	2020	2025	2030
LPG	2.0	2.2	2.3	2.3	2.3
Gasoline/E85	9.2	9.2	8.6	7.8	7.1
Jet/ Distillate	5.2	5.7	5.7	5.7	5.4
Residual Fuel	0.8	0.7	0.6	0.6	0.5
Other	3.1	3.3	2.7	2.7	2.6

Figure 2-7

3 WORLD Model Results

Set out below is the full suite of results from WORLD 2030 cases showing the impacts of different pipeline scenarios on WCSB crude oil routings into Canadian refineries, US refineries by PADD and Asia; also total non-Canadian crude and product imports and total Middle Eastern crude imports.

Figure 3-1 shows flows for 2009 as a point of reference. Charts are then presented in pairs putting together results from corresponding scenarios under respectively AEO (reference) and Low Demand (EPA) outlooks. Figures 3-2 and 3-3 show the AEO and Low Demand 2030 results for the KXL scenario which was used as a central or reference scenario. Circles and arrows on the charts, plus associated comments, highlight significant changes versus the KXL AEO outlook case.

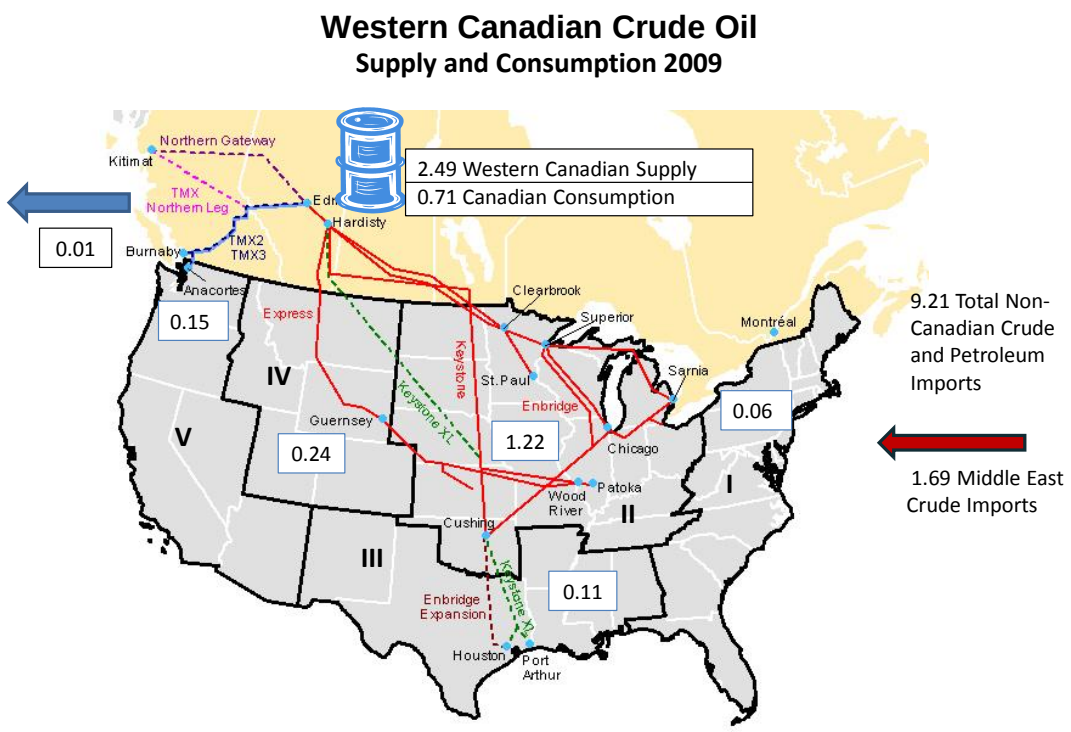


Figure 3-1

Reference Outlook

KXL 2030

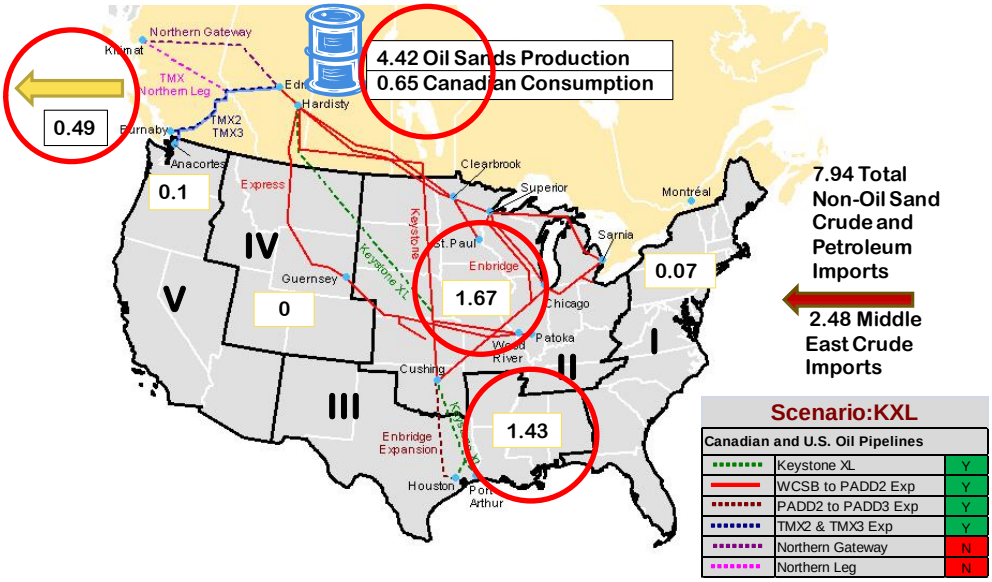


Figure 3-2

Low Demand Outlook

Low Demand KXL 2030

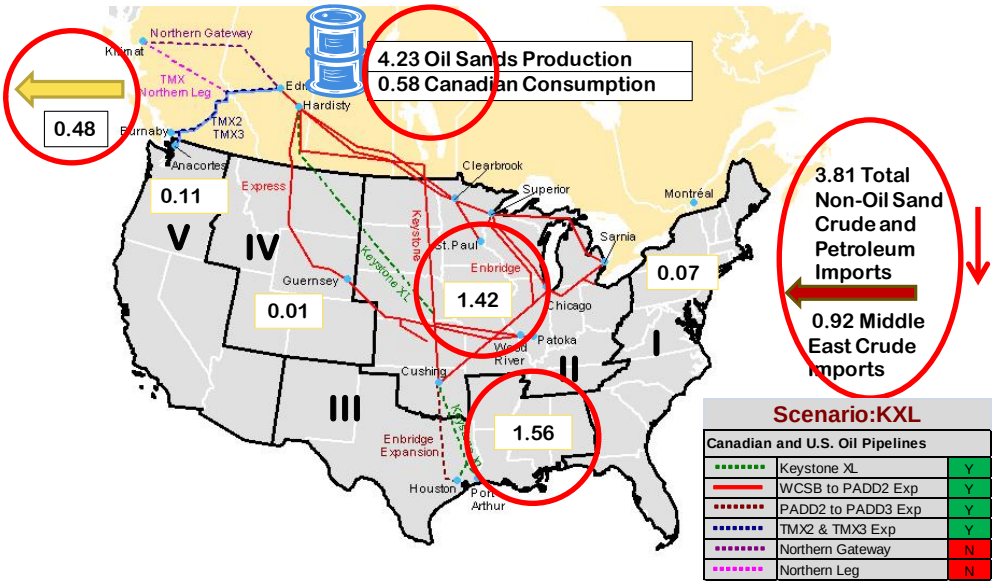


Figure 3-3

The AEO versus Low Demand KXL results highlight that there is some redistribution of WCSB oil sands streams between PADD2 and PADD3 between the two demand outlooks but that total WCSB oil sands imports into the USA remain almost unchanged. Under Low Demand, WCSB oil sands intake into PADD2 is lower, because of the reduced demand in the region. PADD3 refineries process more WCSB oil sands under Low Demand. Product demand in PADD3 is also reduced, as it is across the whole of the USA, but – with no change in line capacity to take WCSB crudes to Asia – essentially the volumes PADD2 can no longer economically handle are processed in PADD3, backing out crudes from the Middle East and other non-Canadian sources.

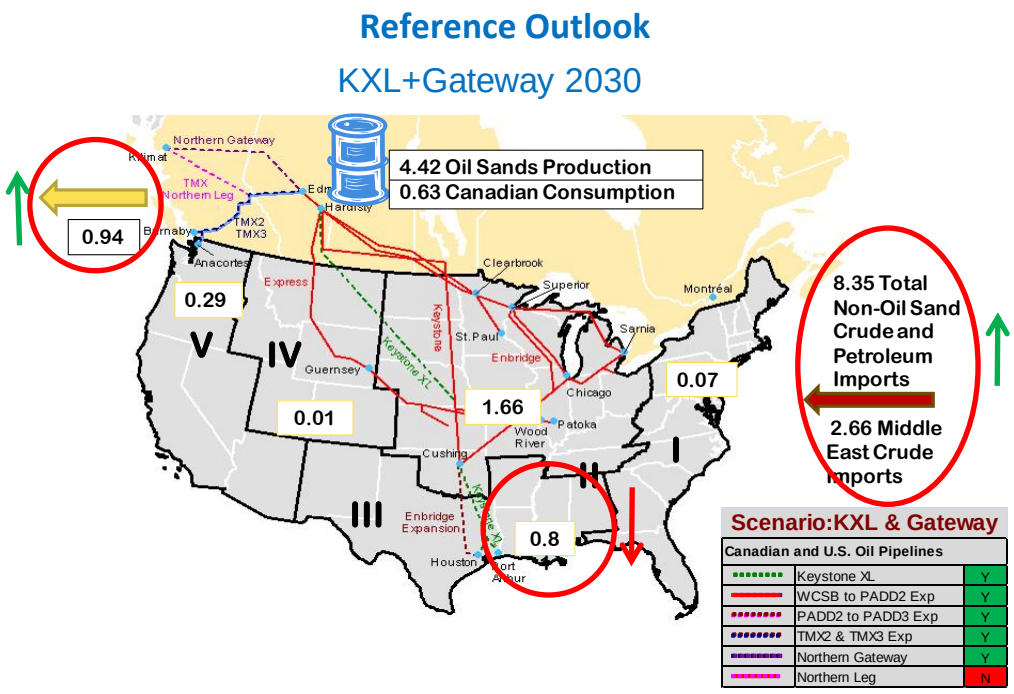


Figure 3-4

Scenario: Keystone XL + Gateway; Adding the Northern Gateway expansion increases exports to Asia by about 0.5 mbd at the expense of exports to U.S. PADD 3. Total US non oil sand crudes and product imports increase by close to 0.4 mbd.

Low Demand Outlook

Low Demand KXL+ Gateway 2030

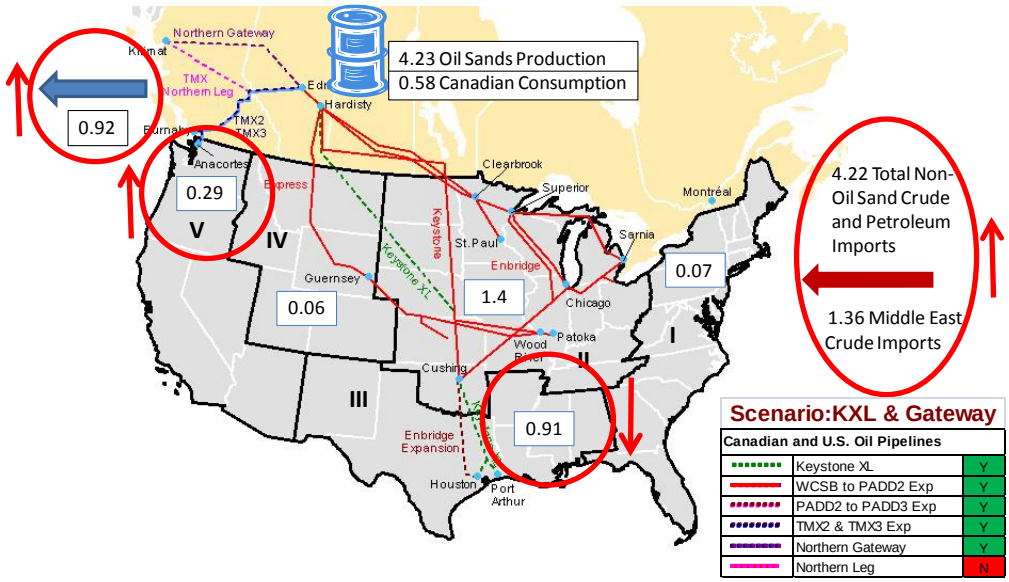


Figure 3-5

Scenario: Low Demand Keystone XL + Gateway; Adding the Northern Gateway expansion increases exports to Asia by about 0.5 mbd at the expense of exports to U.S. PADD 3 relative to the Low Demand KXL scenario. Total US non oil sand crudes and product imports increase by 0.4 mbd. The impacts in terms of import/export changes are the same as in the AEO demand scenarios.

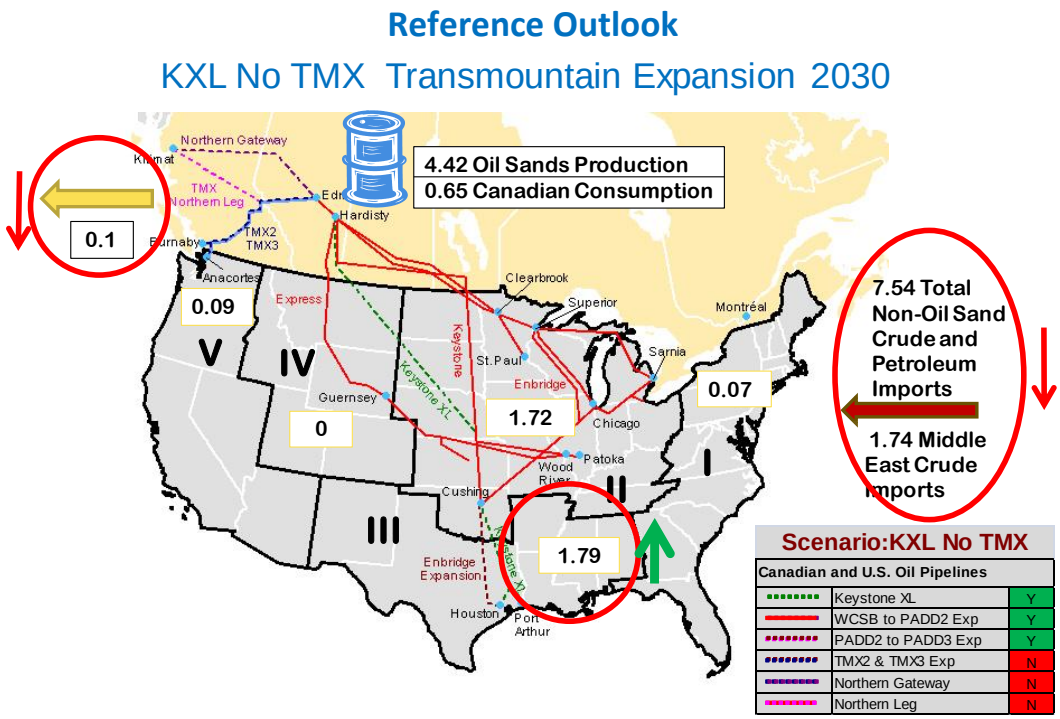


Figure 3-6

Scenario: Keystone XL + No TMX Exp; Asian exports do not increase above today's limited levels. Versus the KXL scenario, they are diverted primarily to U.S. PADD 3 by about 0.4 mbd. Middle East crude imports to U.S. decline.

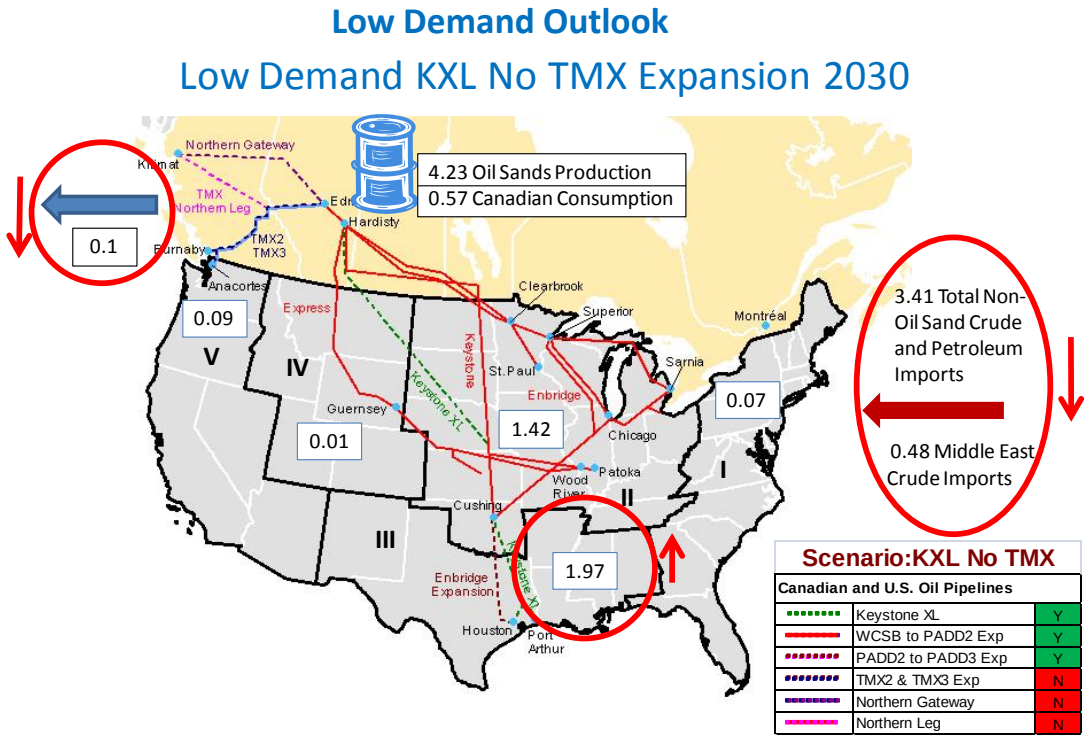


Figure 3-7

Scenario: Low Demand Keystone XL No TMX Exp; Asian exports are diverted primarily to U.S. PADD 3 by about 0.4 mbd. Middle East crude imports to U.S. decline. Results are the same as for the AEO demand scenario above.

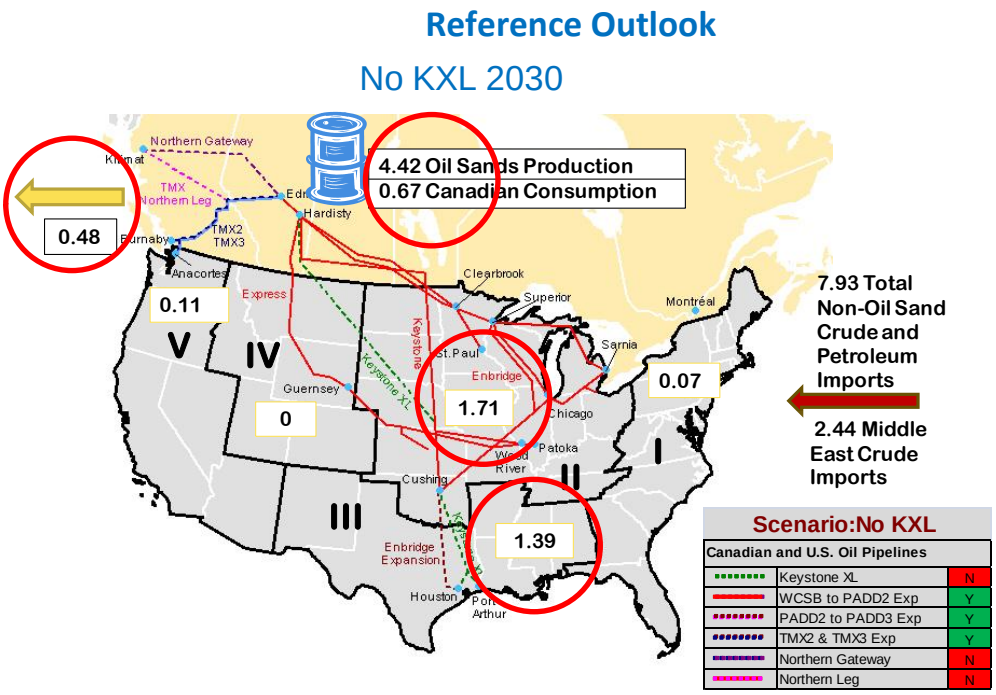


Figure 3-8

Scenario: No Keystone XL; Minimal impact relative to the KXL scenario, existing pipeline capacity expands to accommodate exports of oil sands to U.S. resulting in crude oil flows very similar to those under KXL.

Low Demand Outlook

Low Demand No KXL 2030

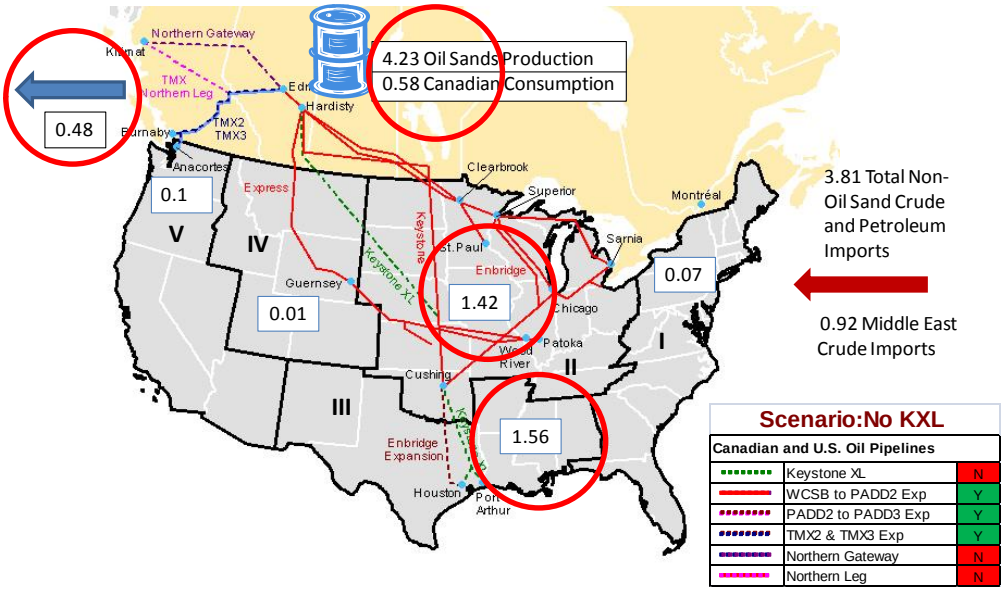


Figure 3-9

Scenario: Low Demand No Keystone XL; Minimal impact relative to the Low Demand KXL scenario, existing pipeline capacity expands to accommodate exports of oil sands to U.S.

Reference Outlook

No KXL Hi Asia 2030

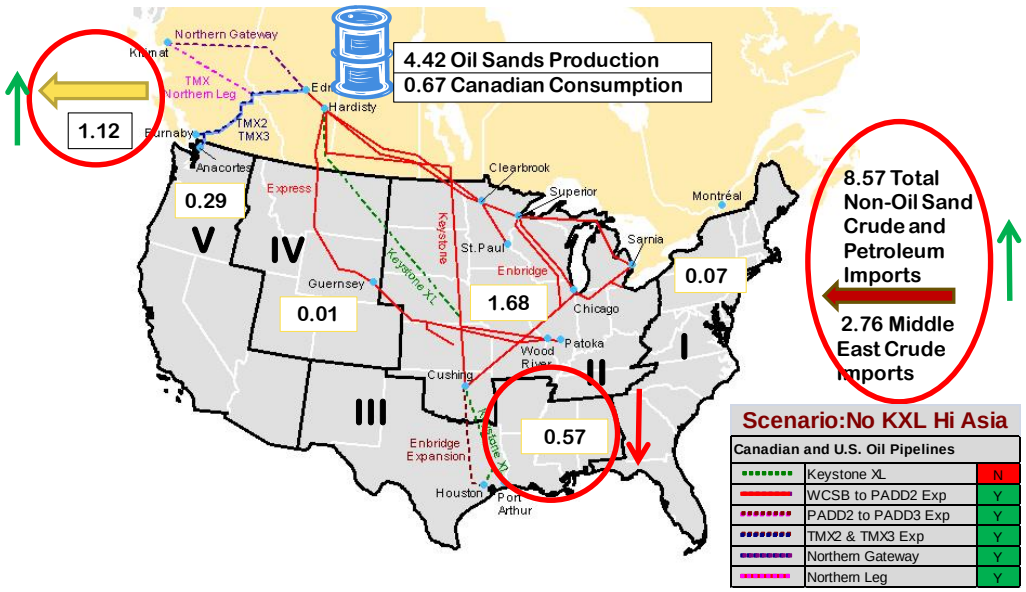


Figure 3-10

Scenario: No Keystone Hi Asia; Exports of oil sands crudes to Asia reach levels over 1 mbd at the expense of exports to U.S. PADD 3. Total petroleum and Middle Eastern crude imports to the U.S. increase. Preliminary WORLD cases showed that WCSB exports to Asia could go higher if pipeline capacity to the BC coast were available.

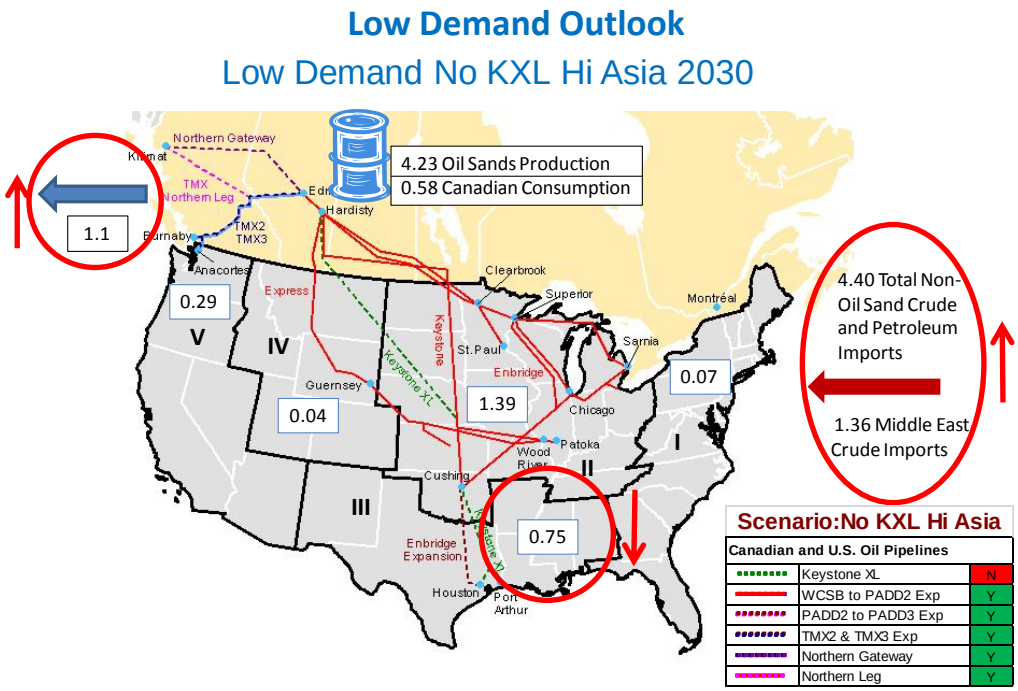


Figure 3-11

Scenario: Low Demand No Keystone Hi Asia; Additional exports of oil sands crudes to Asia at the expense of exports to U.S. PADD 3. Total petroleum and Middle Eastern crude imports to the U.S. increase.

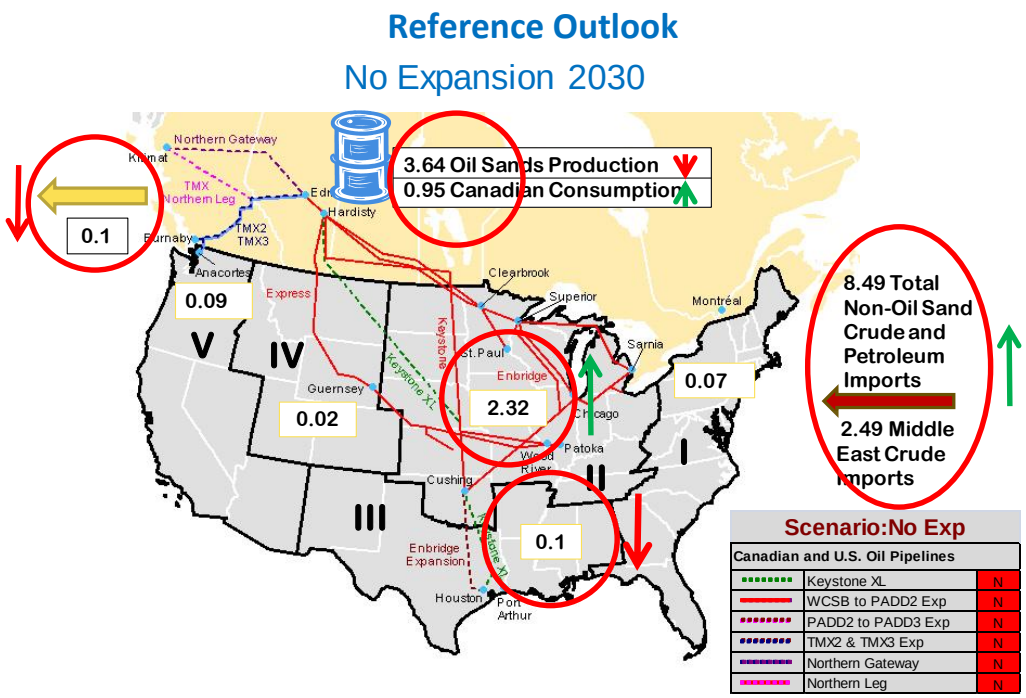


Figure 3-12

Scenario: No Expansion; Oil sands production declines by 0.75 mbd, Canadian consumption and exports to PADD 2 increase to make maximum use of existing available pipeline capacities. Canadian exports of oils sands to Asia and U.S. PADD 3 decline significantly. Total petroleum and Middle Eastern Crude imports to the U.S. increase. This is the only scenario where oil sands production declines significantly.

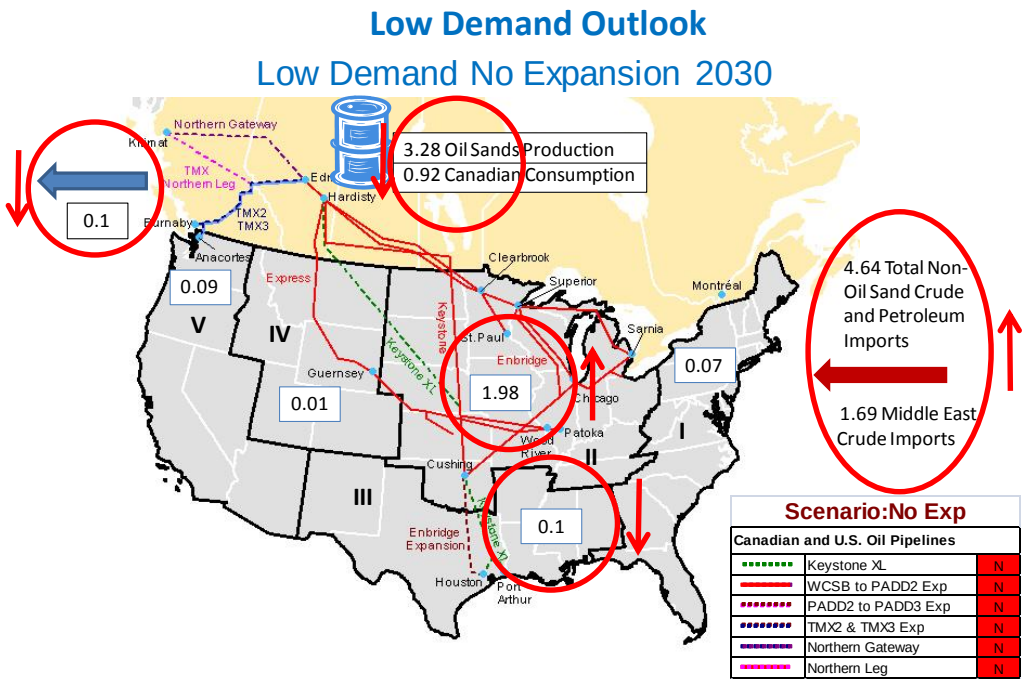


Figure 3-13

Scenario: Low Demand No Expansion; Oil sands production declines by 0.95 mbd, Canadian consumption and exports to PADD 2 increase. Canadian exports of oils sands to Asia and U.S. PADD 3 decline significantly. Total petroleum and Middle Eastern Crude imports to the U.S. increase. This is the only low demand scenario where oil sands production declines significantly.

Reference Outlook

No Expansion, Except PADD II to PADDIII and TMX 2030

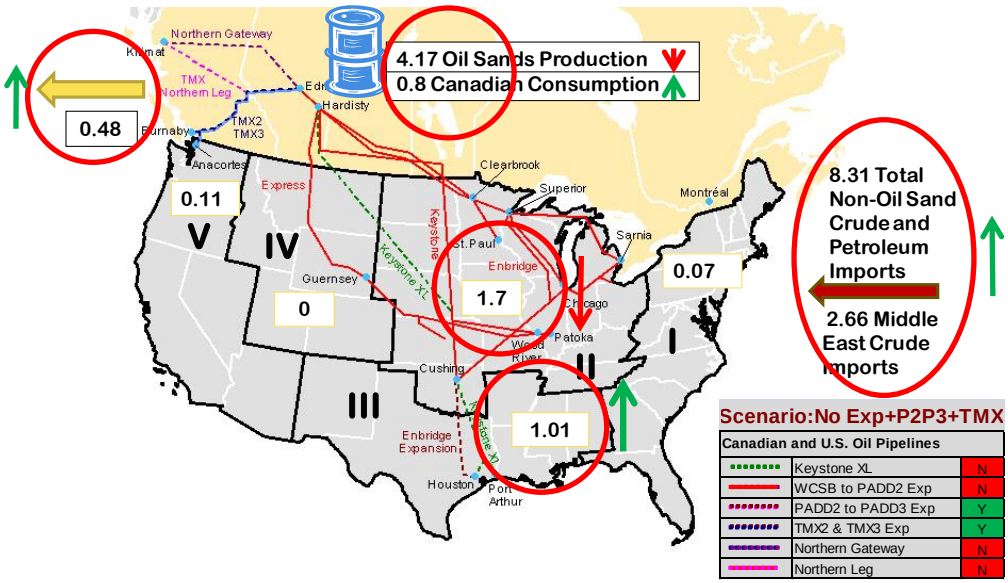


Figure 3-14

Scenario: No Expansion +P2P3 + TMX; Relative to the full No Expansion scenario oil sands production increases 0.6 mbd. As a result oil sands output is only cut slightly (by 0.17 mbd) versus the assumed full production level of 4.42 mbd. Versus No Expansion, exports of oil sands are shifted from U.S. PADD 2 and Canadian consumption to Asia and U.S. PADD 3, i.e. dispositions are closer to those obtaining under the KXL scenario. Total non oil sand crudes imports drop slightly versus No Expansion and increase slightly versus KXL scenario.

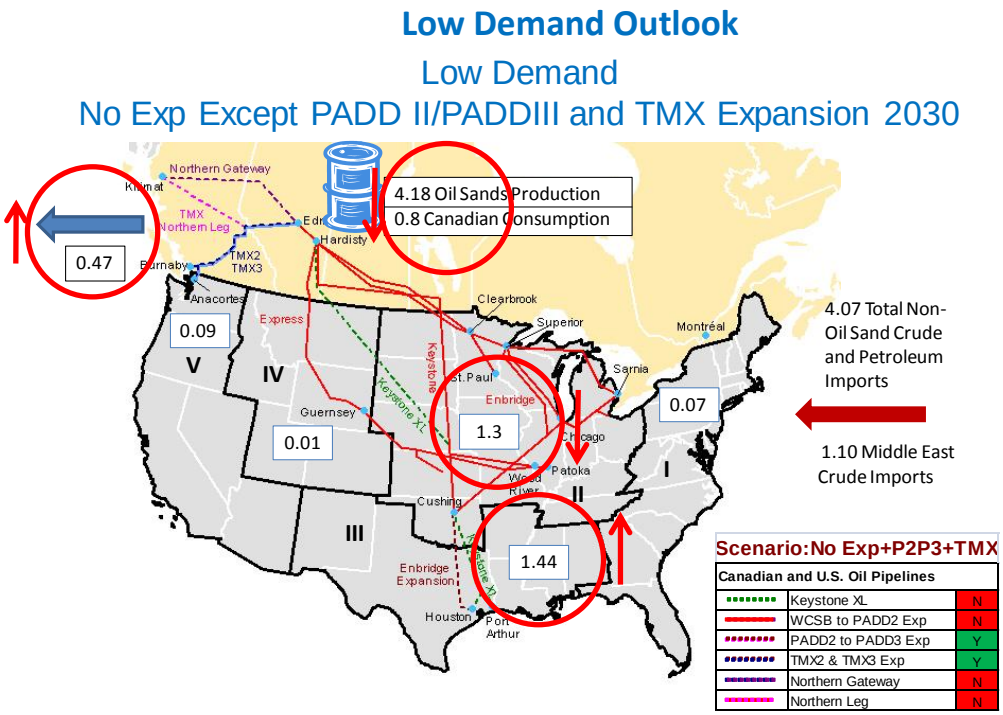


Figure 3-15

Scenario: No Expansion +P2P3 + TMX; Relative to the low demand No Expansion scenario oil sands production increases 0.9 mbd such that reduction versus projected full production is minor. Versus No Expansion, exports of oil sands are shifted from U.S. PADD 2 to Asia and U.S. PADD 3. Total non oil sand crudes imports decline appreciably versus No Expansion and increase slightly versus KXL.

4 Estimated Life-Cycle Carbon Emissions

The WORLD model does not contain endogenous lifecycle analysis (LCA) of GHG emissions. Brookhaven National Laboratory (BNL) used the DOE version of the Energy Technology Perspective (ETP) model to evaluate the global changes in LCA GHG emissions for the Keystone XL analysis scenarios, following the methodology and lifecycle GHG assumptions used to evaluate the indirect impacts of GHG emission from changes in petroleum product consumption in the RFS2.[7] The ETP was calibrated to replicate the WORLD model petroleum market results and then calculated the LCA GHG emissions for each scenario. The ETP model is a MARKAL-based model that was developed by the International Energy Agency and was modified and updated for DOE[8],[9]. It is a partial equilibrium model that incorporates a representation of the physical energy system and represents the flow of energy carriers through the energy infrastructure from the resource base through the various energy conversion technologies to the end-user.

The DOE ETP model consists of fifteen world regions. These are broken out as: United States; Canada, Mexico; IEA Europe; Japan; South Korea; Australia/New Zealand; Central and South America; Eastern Europe; Former Soviet Union; Middle East; China; India; Other Developing Asia; and Africa. The model runs through 2050 in five year increments, though only results through 2030 were displayed to remain consistent with the EnSys modeling. While all major energy sources are covered, including coal, oil, natural gas, nuclear power, and renewable energy, the purpose of this study was to isolate the impact of various petroleum market perturbations resulting from the analyzed scenarios on total worldwide transportation sector greenhouse gas emissions.

THE DOE ETP model GHG emissions changes were determined using the LCA values consistent with EPA's Renewable Fuel Standard Program (RFS2) Final Rule. Lifecycle GHG emissions for transportation fuels may be grouped into five general areas: material acquisition, raw material transport, liquid fuel production, product transport and vehicle operation.[10] Changes in upstream emissions (comprising the first two categories listed above) were calculated across scenarios using the modeled feedstock production changes from ETP and emissions factors for various crude oils as established by EPA.

Because ETP aggregates countries into regions for modeling simplicity, emissions accounting for regions was estimated by taking the average LCA GHG emissions for crude oils produced in the countries in each region. For example, upstream values for crudes produced from Africa were estimated by taking the

[7] Petroleum Indirect Impacts Analysis (February 1, 2010), EPA-HQ-OAR-2005-0161-3156
[8] IEA, 2006. Energy Technology Perspectives 2006. Organisation for Economic Cooperation and Development (OECD)/IEA, Paris, France.
[9] IEA, 2008. Energy Technology Perspectives 2008. OECD/IEA, Paris, France.
[10] DOE/NETL, An Evaluation of the Extraction, Transport and Refining of Imported Crude Oils and the Impact on Life Cycle Greenhouse Gas Emissions, March 27, 2009, DOE/NETL-2009/1362

average of the values for Nigeria, Angola, and Algeria. Table 4-1 shows the upstream GHG emission factors by region. Given the focus of this study, Canadian oil sands were treated separately from the rest of their geographic region. Downstream GHG emissions, including refining and combustion, were calculated endogenously.

Upstream Oil Production Lifecycle GHG Emissions (kg CO2e / mmBtu LHV)

	Crude oil	Bitumen
Africa	16.5	
Australia	6.0	
Canada	5.7	20.8
China	9.9	
Central and South America	7.0	18.3
Non-OECD Europe	6.2	
Former Soviet Union	8.0	
India	10.0	
Japan	6.0	
Middle East	6.5	
Mexico	8.4	
Other Developing Asia	10.0	
South Korea	-	
United States	5.7	
OECD-Europe	6.2	

Note: While not technically upstream, the values above include 0.8 kg CO2e/million Btu for all feedstocks to reflect transportation of products not otherwise accounted for in the ETP model.

Source: Personal Communication from EPA "Crude Oil LCAs for ETP" dated 2 October 2009.

Table 4-1

Results may be seen in Figures 4-1 through 4-12. Overall transportation sector emissions in 2030 were projected to be 10,400 mtpa in the Low Demand scenario and 11,100 mtpa CO2e in the AEO Base Case. Only in the No Expansion scenarios were changes in the world GHG emissions greater than 20 mtpa (0.2%). In the other scenarios, reductions in domestic GHG emissions were balanced by GHG increases in the rest of the world. In particular, the No KXL vs KXL scenario shows changes at the limits of modeling precision.

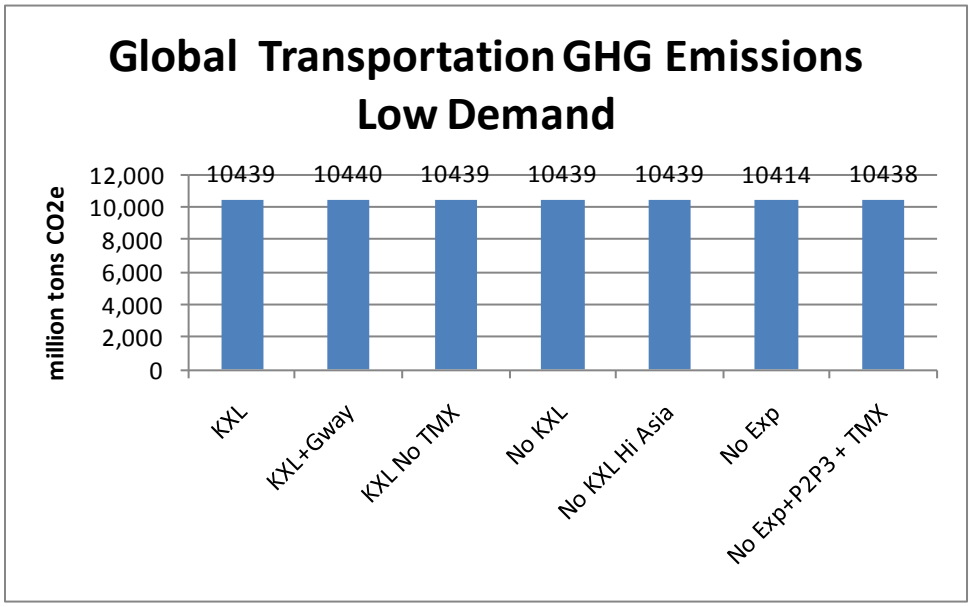


Figure 4-1

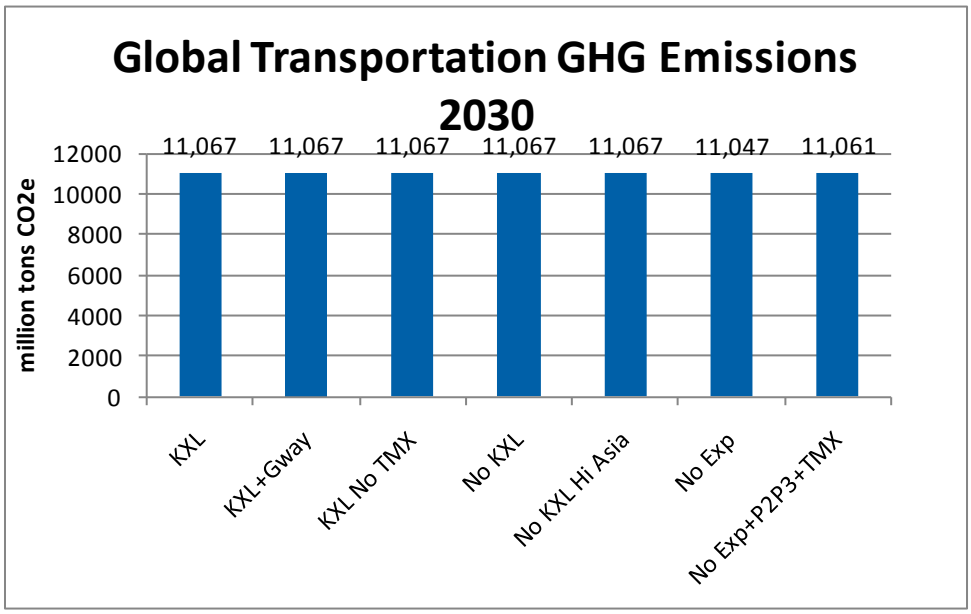
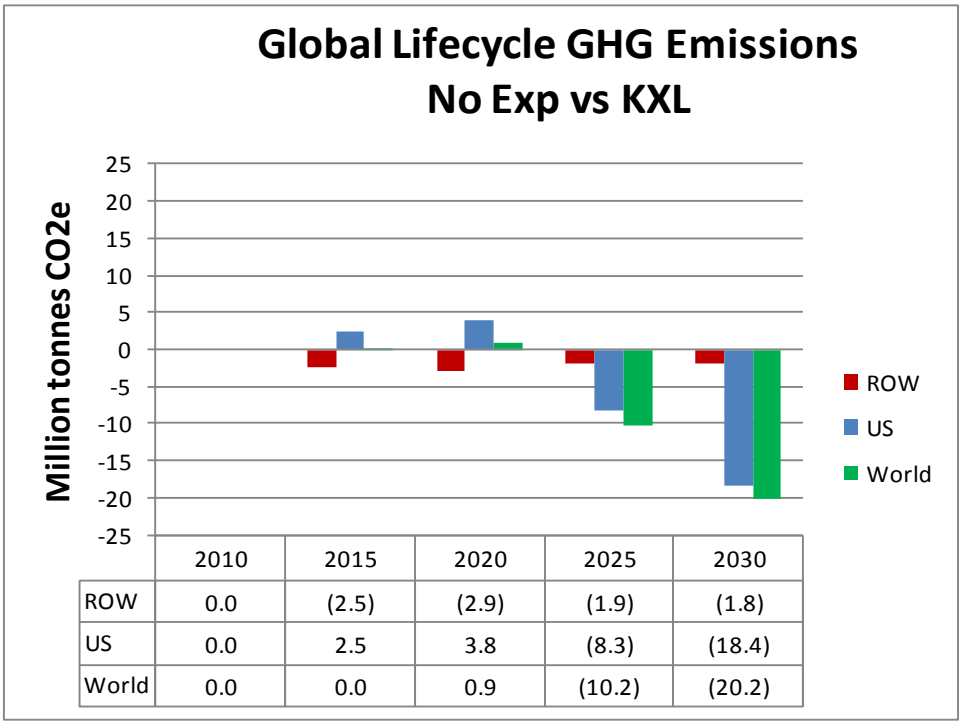
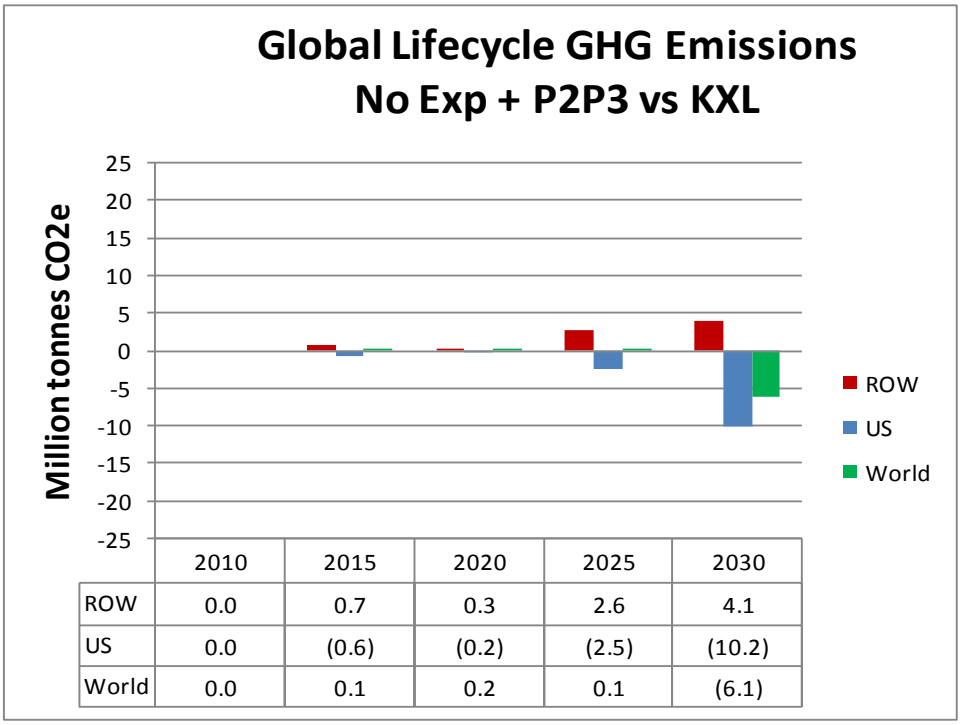


Figure 4-2



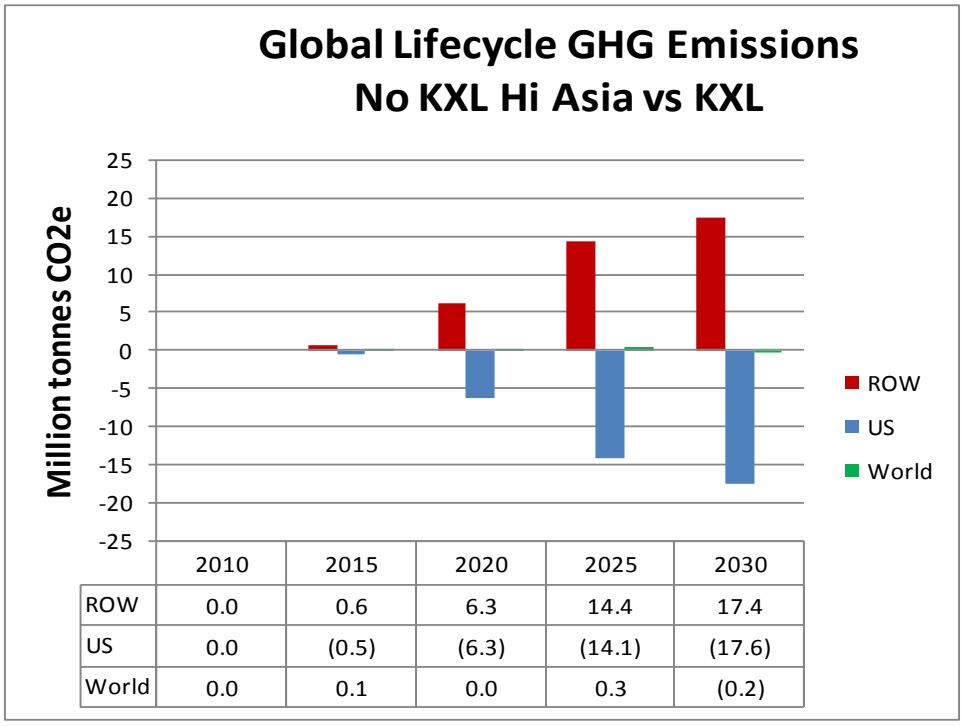
	2010	2015	2020	2025	2030
ROW	0.0	(2.5)	(2.9)	(1.9)	(1.8)
US	0.0	2.5	3.8	(8.3)	(18.4)
World	0.0	0.0	0.9	(10.2)	(20.2)

Figure 4-3



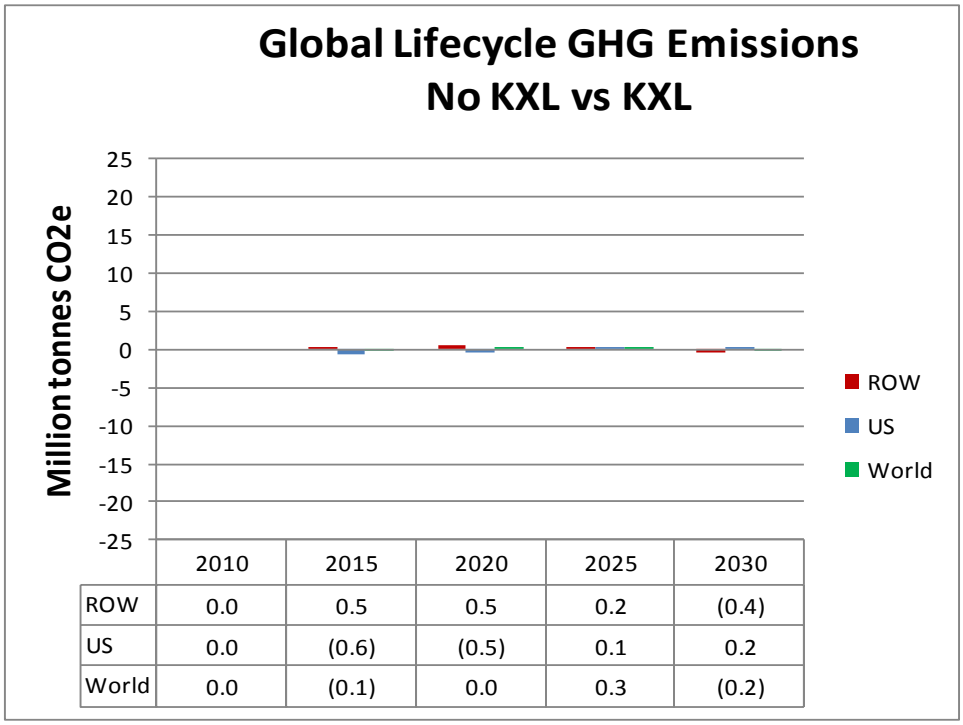
	2010	2015	2020	2025	2030
ROW	0.0	0.7	0.3	2.6	4.1
US	0.0	(0.6)	(0.2)	(2.5)	(10.2)
World	0.0	0.1	0.2	0.1	(6.1)

Figure 4-4



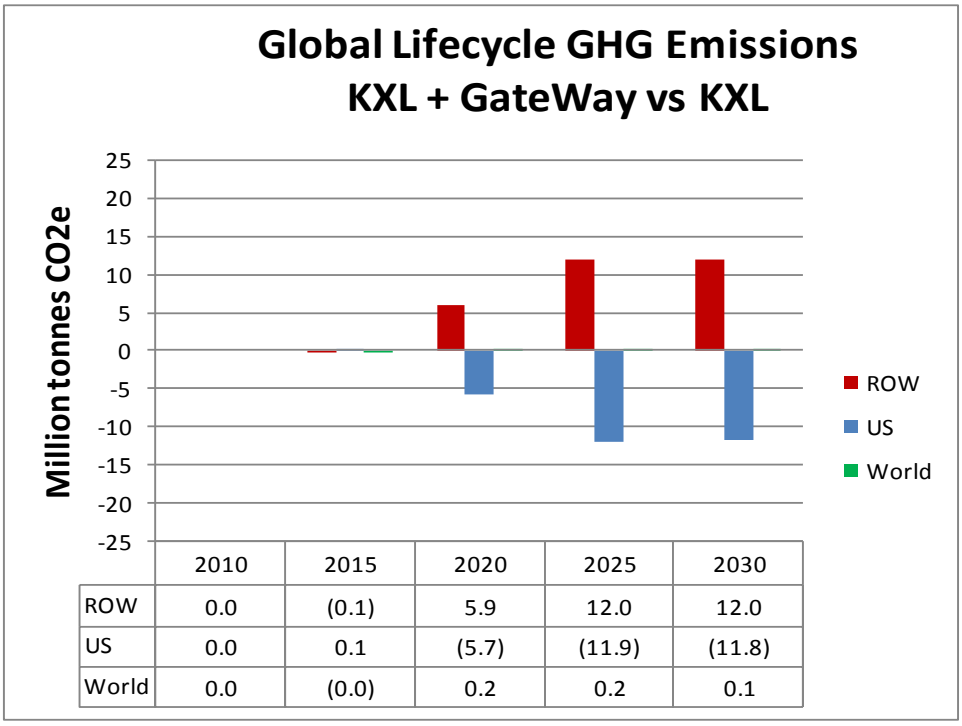
	2010	2015	2020	2025	2030
ROW	0.0	0.6	6.3	14.4	17.4
US	0.0	(0.5)	(6.3)	(14.1)	(17.6)
World	0.0	0.1	0.0	0.3	(0.2)

Figure 4-5



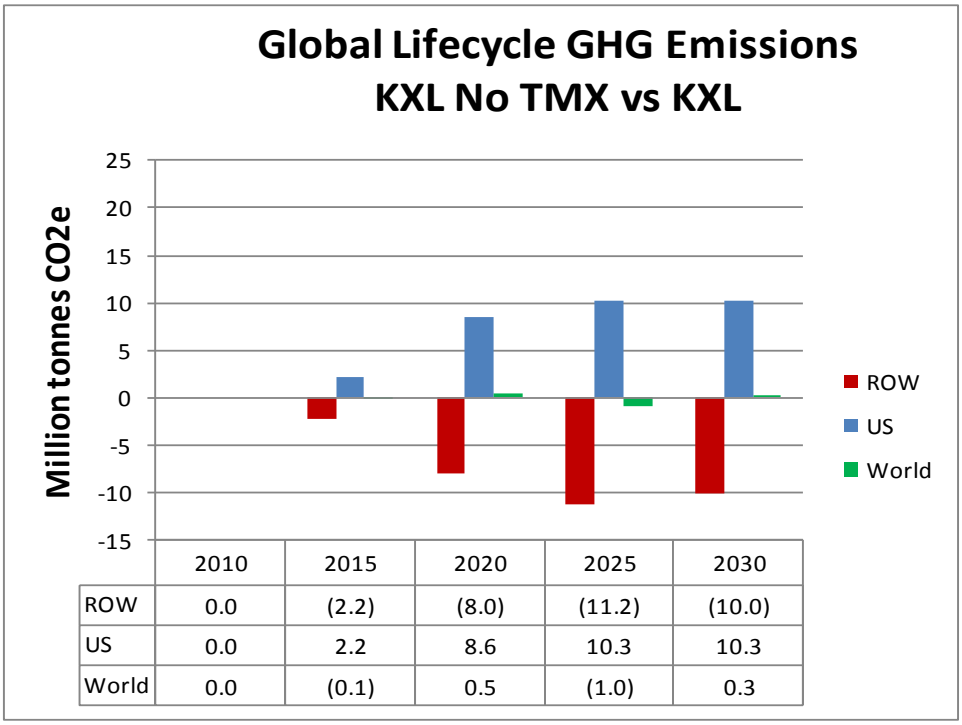
	2010	2015	2020	2025	2030
ROW	0.0	0.5	0.5	0.2	(0.4)
US	0.0	(0.6)	(0.5)	0.1	0.2
World	0.0	(0.1)	0.0	0.3	(0.2)

Figure 4-6



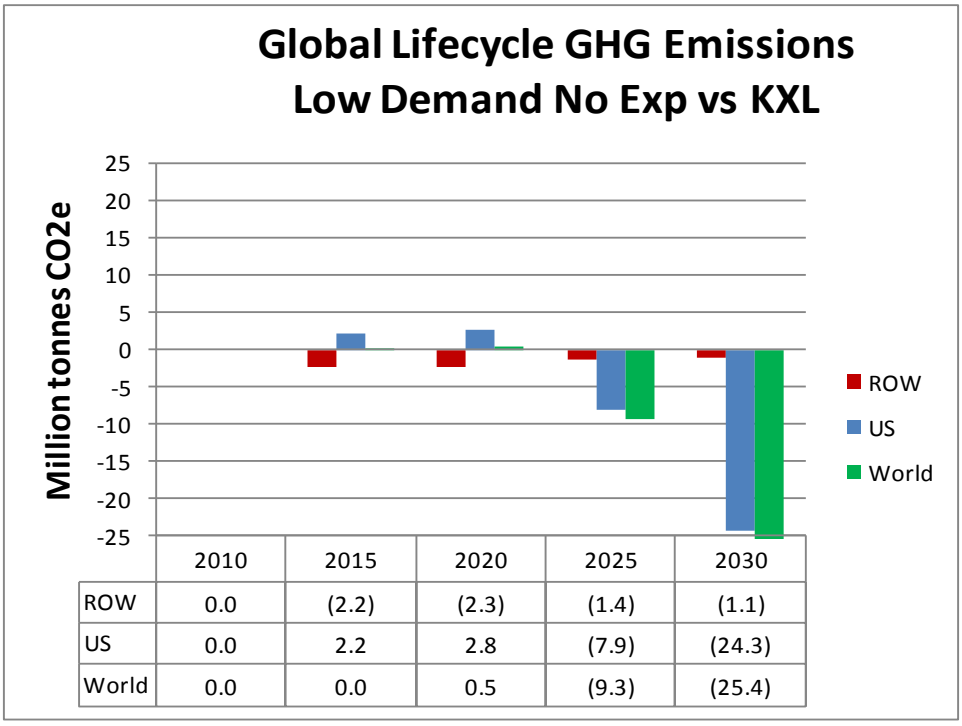
	2010	2015	2020	2025	2030
ROW	0.0	(0.1)	5.9	12.0	12.0
US	0.0	0.1	(5.7)	(11.9)	(11.8)
World	0.0	(0.0)	0.2	0.2	0.1

Figure 4-7



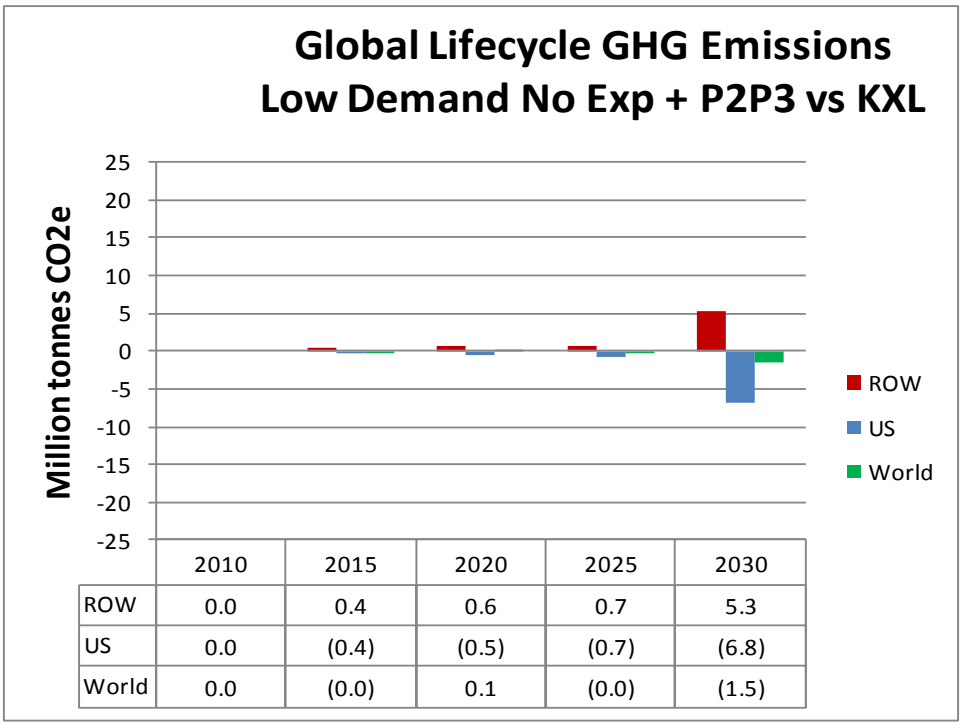
	2010	2015	2020	2025	2030
ROW	0.0	(2.2)	(8.0)	(11.2)	(10.0)
US	0.0	2.2	8.6	10.3	10.3
World	0.0	(0.1)	0.5	(1.0)	0.3

Figure 4-8



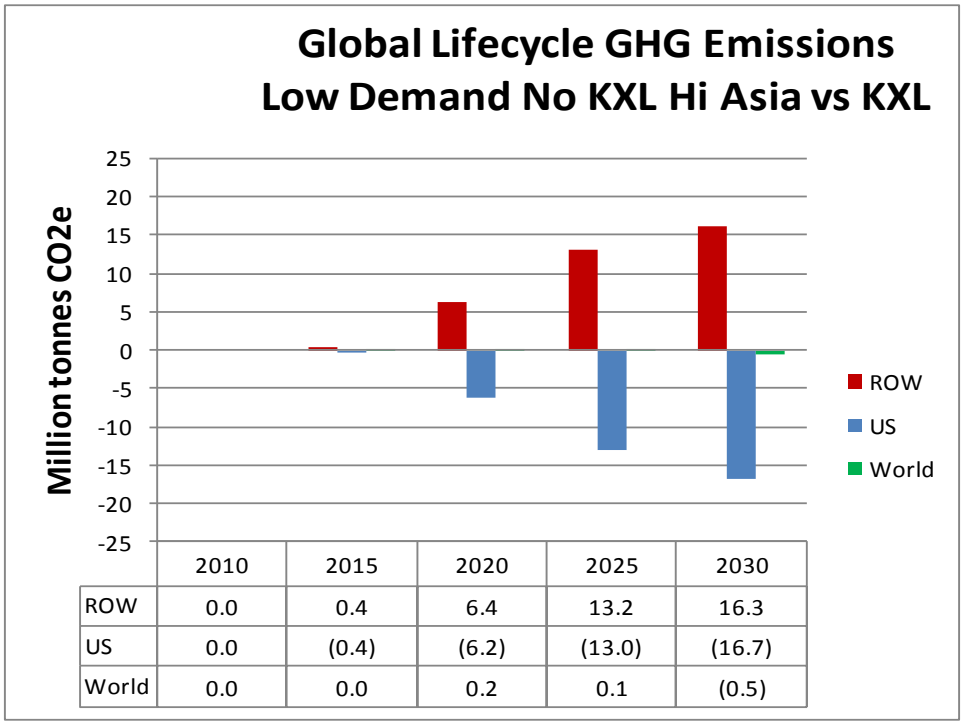
	2010	2015	2020	2025	2030
ROW	0.0	(2.2)	(2.3)	(1.4)	(1.1)
US	0.0	2.2	2.8	(7.9)	(24.3)
World	0.0	0.0	0.5	(9.3)	(25.4)

Figure 4-9



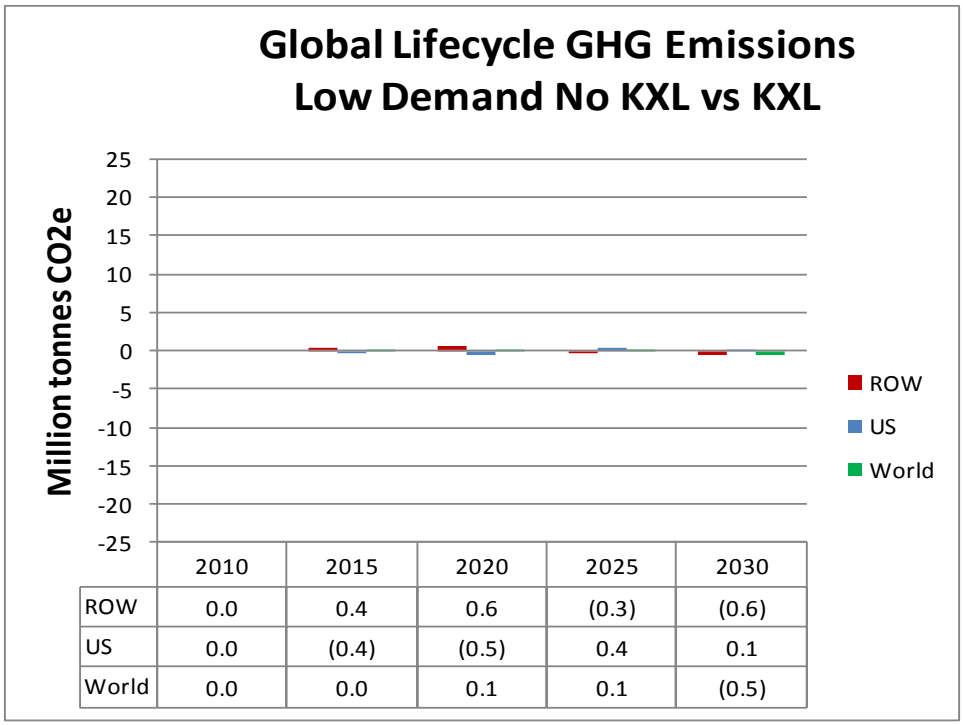
	2010	2015	2020	2025	2030
ROW	0.0	0.4	0.6	0.7	5.3
US	0.0	(0.4)	(0.5)	(0.7)	(6.8)
World	0.0	(0.0)	0.1	(0.0)	(1.5)

Figure 4-10



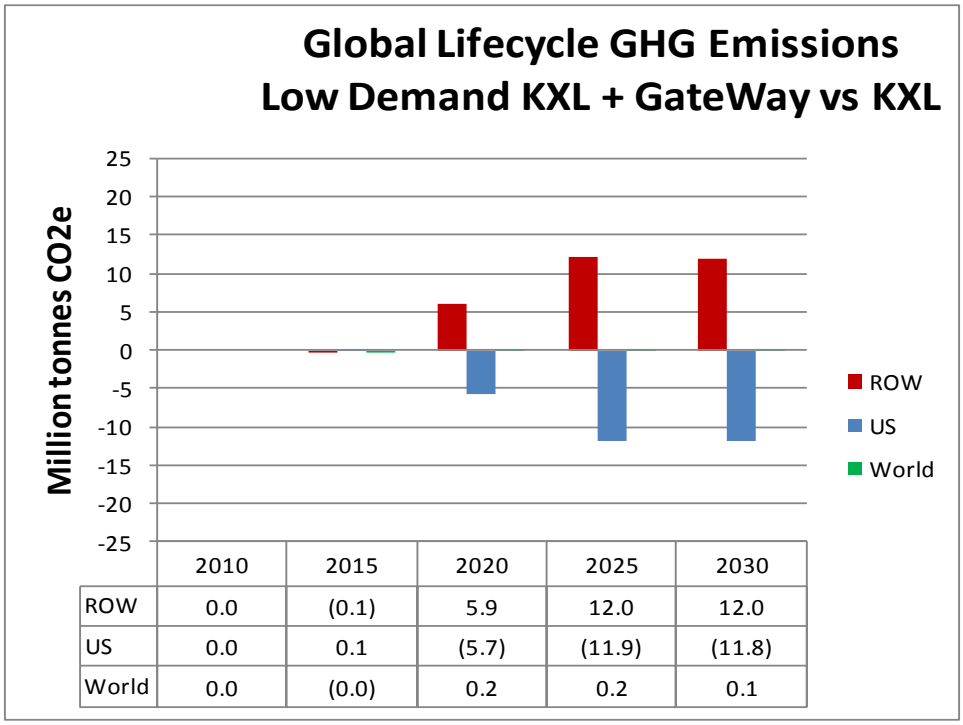
	2010	2015	2020	2025	2030
ROW	0.0	0.4	6.4	13.2	16.3
US	0.0	(0.4)	(6.2)	(13.0)	(16.7)
World	0.0	0.0	0.2	0.1	(0.5)

Figure 4-11



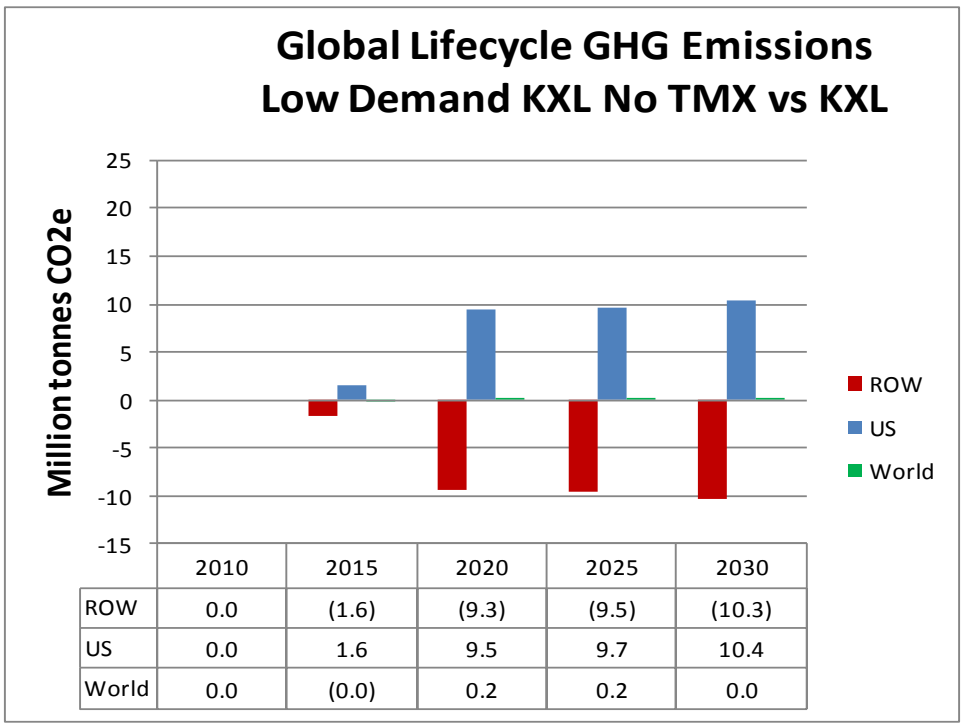
	2010	2015	2020	2025	2030
ROW	0.0	0.4	0.6	(0.3)	(0.6)
US	0.0	(0.4)	(0.5)	0.4	0.1
World	0.0	0.0	0.1	0.1	(0.5)

Figure 4-12



	2010	2015	2020	2025	2030
ROW	0.0	(0.1)	5.9	12.0	12.0
US	0.0	0.1	(5.7)	(11.9)	(11.8)
World	0.0	(0.0)	0.2	0.2	0.1

Figure 4-13



	2010	2015	2020	2025	2030
ROW	0.0	(1.6)	(9.3)	(9.5)	(10.3)
US	0.0	1.6	9.5	9.7	10.4
World	0.0	(0.0)	0.2	0.2	0.0

Figure 4-14