Alberta Midstream Chemical Cluster
Site Requirements Study

Assessment of the Land Use, Infrastructure, and Logistics Requirements, Costs and Benefits for the Midstream Chemical Cluster in Alberta's Industrial Heartland

The City of Edmonton
Alberta Government
Alberta's Industrial Heartland
Government of Canada / Gouvernement du Canada

Date: October 2009
Calgary and Edmonton

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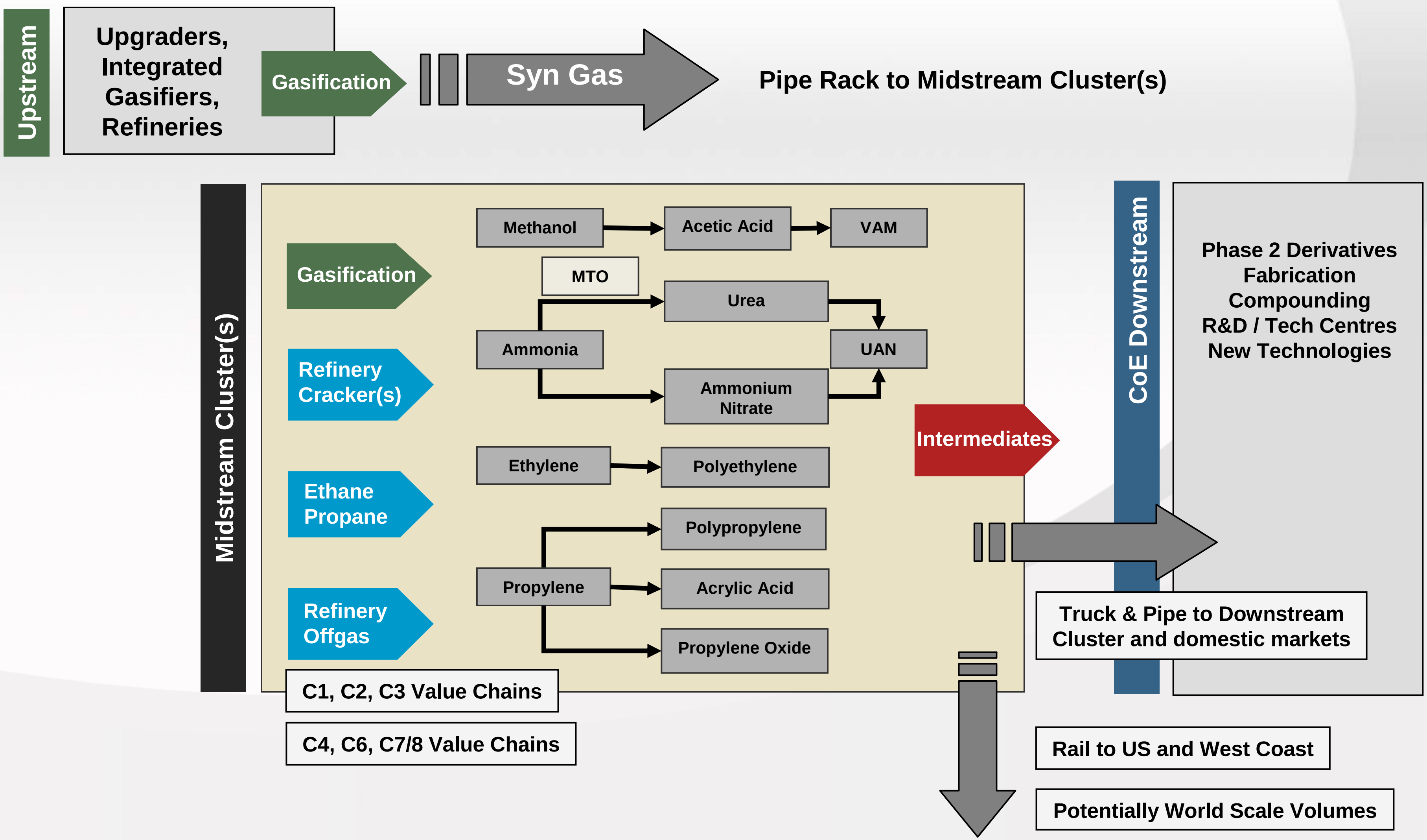
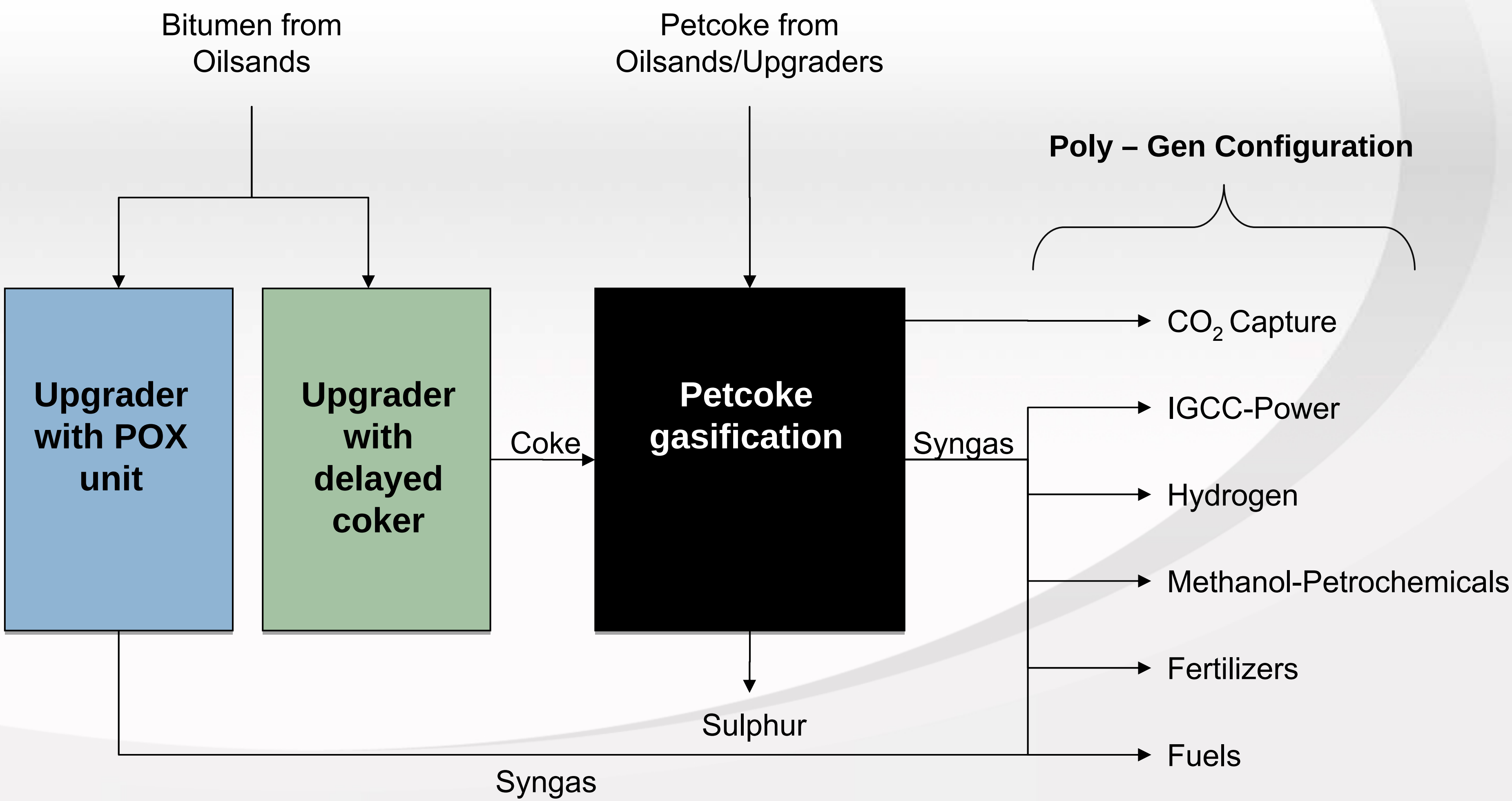
The Study was conducted in a six-stage work program

Stage	1 Assemble and Integrate inputs from other studies	2 Under-standing the Market potential and selecting products	3 Assess Best Practices from existing and emerging Clusters	4 Developing the Conceptual Midstream Cluster Concepts	5 Develop Land Use Infrastructure and Logistics plan	6 Socio-Economic Impact and Cost – Benefit analysis
Objectives	▪ **Integrate the findings of previous studies** into the basis for the Land Use Study	▪ Assess current and **long term supply/ demand for the products** that could be produced in the Midstream cluster	▪ Assess land use **best practice** in existing and emerging clusters and assemble key learnings	▪ Develop the **cluster con-figurations** based on the **feedstock scenarios** for investment in the period 2010 to 2040	▪ Develop the **Land Use site plan** and define the public and site specific infrastructure and logistics systems to move products to market	▪ Conduct detailed Socio-economic Analysis the goal of establishing the **cost-benefit** to the Capital Region

The Midstream cluster will become an important producer of commodities and intermediates for the CoE Cluster and North American Market



Petcoke or Residues from Upgrading could be key to Value-Add in Alberta's Midstream Chemical Cluster via a Poly-Gen configuration



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The globally significant chemical clusters rely on several key sources of competitiveness

Maximising the combination of these leads to "best in class"

Feedstock availability and flexibility

Market proximity, diversity and critical mass

Cluster **"Attributes"** – only manageable to a limited extent

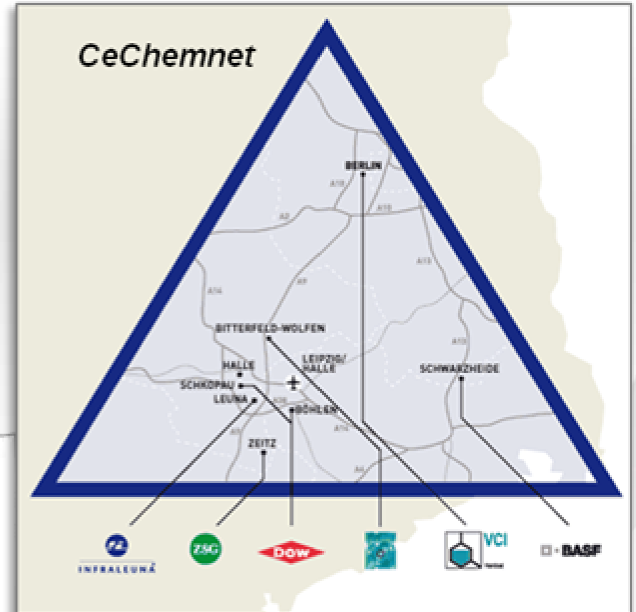
Supply Chain efficiency (feedstocks and products)

Cluster critical mass and operational efficiency

Cluster **"Key Performance Criteria"** – mostly manageable

Globally significant Chemical Clusters were analysed to develop key learning points on infrastructure and logistics "Best Practice"

Cluster Best Practice



Summary of Key Findings of the analysis of globally significant clusters relevant to the Midstream cluster (1/2)

- **Cluster Planning and Design**:
  - All successful on-purpose clusters have benefited from directed master-planning of their clusters
  - Phasing of development, has been favoured by the major on-purpose cluster developments to mitigate investment risk
- **Role of Government**:
  - Has played a central role in the development of on-purpose clusters
  - Has begun to intervene in the vision, mission and strategies of the evolved clusters, consciously directing planning and investment in infrastructure to support regional cluster focal points and environmental initiatives
  - Both government- and stakeholder-driven strategies are successfully employed. The common practice in both models is to follow a strongly consultative approach to the development of vision, mission, strategies and implementation

Summary of Key Findings of the analysis of globally significant clusters relevant to the Midstream cluster (2/2)

- **Infrastructure and Supply Chain**
  - Global Logistics Service Providers play a significant role in all successful clusters – this includes those clusters strongly directed by government.
  - The provision of pre-built infrastructure, and provision of utilities is considered fundamental to kick-starting clusters
- **Utilities:**
  - Most clusters have multiple supplies of electrical power from a regional grid and from power stations within the cluster
  - There is a clear trend toward centralisation of waste water management. In several cases government has played a significant role in directing and managing these activities
- **Investment Attraction**
  - Attracting anchor investors in feedstock preparation, integrated chemical production, logistics, utilities and services is important to build momentum in the cluster
  - Incentives are widely used, in many different forms, for investment attraction

Worst Practices were also identified in the globally significant clusters...

- No formal master planning of clusters with respect to site layout, location of logistics, infrastructure and on-purpose synergies of utilities and services
- Mismatch of public and site infrastructure requirements resulting in increased cost of feedstocks or product movements to market
- Lack of energy supply and infrastructure coordination – leads to inefficiencies
- Linear cluster expansion leads to uneconomic movement of product between cluster plants and logistics centres
- Cluster designed and developed around feedstock push instead of a market pull
- Overuse of incentives leading to the wrong kind of investments
- Lack of upstream or downstream integration resulting in poor operational efficiency

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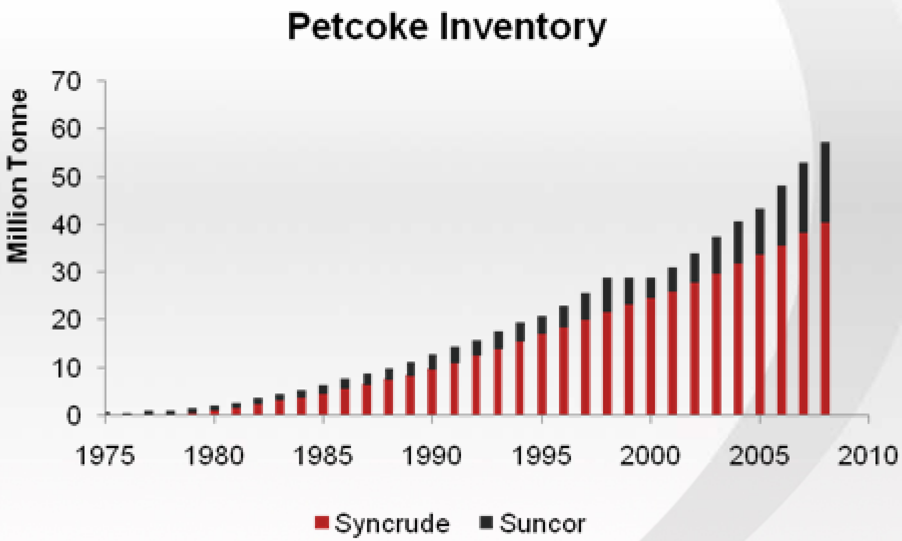
Long-term oil & gas price forecasts will allow the Capital Region to take advantage of feedstocks based on Upgrading

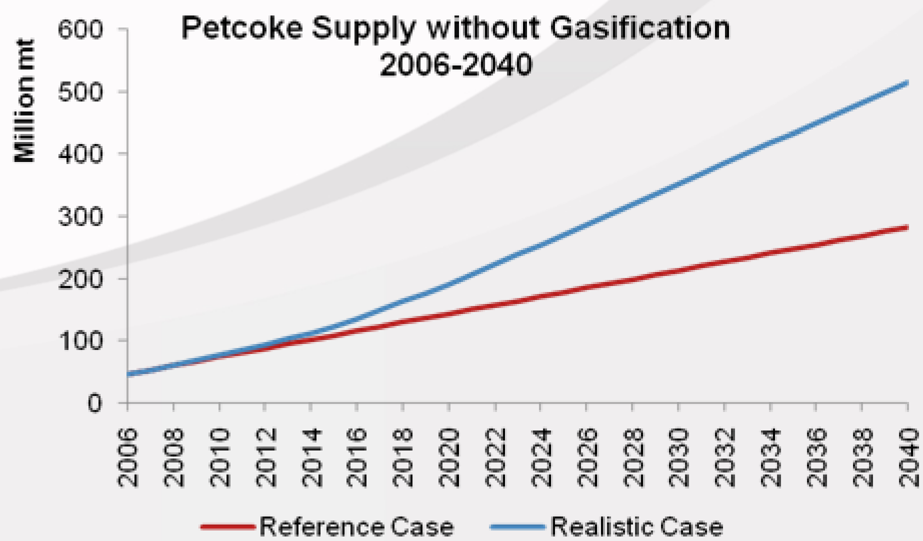
Upgrading		
Upgrading	**Off-gas**	▪ Provides a **key route to petrochemicals** ▪ **Immediately av**ailable ▪ Augmented by **gasification and steam cracking** in future
Upgrading	**Syngas based on petcoke**	▪ Highly attractive route to **globally competitive** methanol and ammonia and derivatives ▪ The **stranded nature and large volumes of the residues** could lead to a global centre for C1-3 petrochemicals ▪ A **zero or negative value of residues** will provide the basis for competing against other global advantaged locations ▪ The transport cost from Fort Mc Murray to the AIH **needs to be optimised** in order to sustain this advantage
Upgrading	**Steam cracking from SCO**	▪ Production of the C2, C3, C4 and C6/7/8 value chains and derivatives will be **highly competitive** ▪ Naphtha could be in **oversupply in Alberta** due to new refineries being required mainly for diesel production – leading to a significant opportunity

The growing stock-pile of Petcoke will be key to the development of a world scale chemical cluster

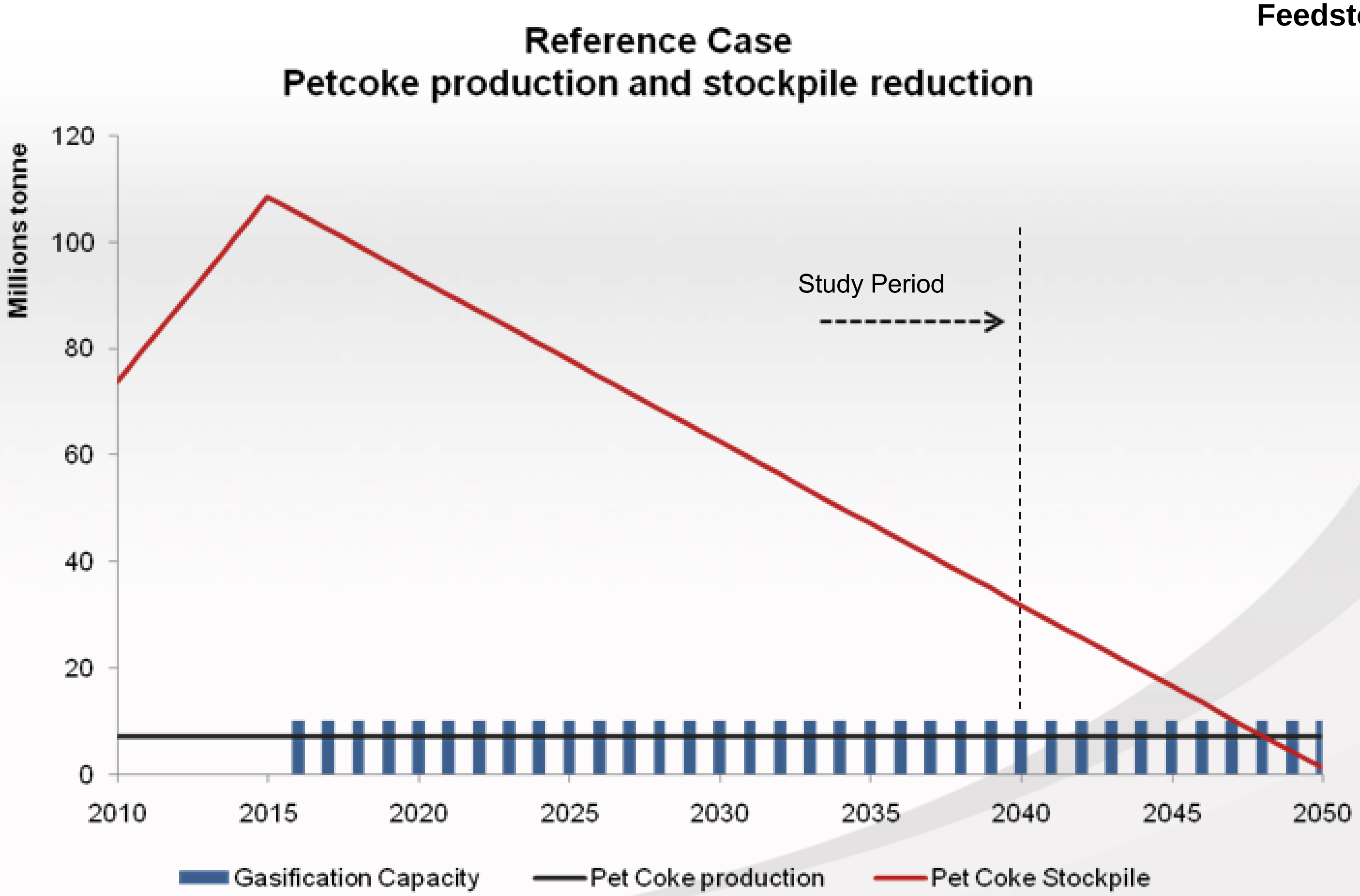
Feedstock Scenarios

- Inventory currently 57 million tonne
  - End 2008, source ERCB, July 2009
- Production ~ 6.0-6.5 million tonne pa
- Nominal third party sales
- Prime producers: Syncrude, Suncor
- Future producers to include existing expansions plus CNPL, Opti Nexen
- Forecast production:
  - 7 million tonne pa (Reference Case)
  - 16 million tonne pa (Realistic Case)
  - Stock-pile to reach over 500 million tonne by 2040 without gasification





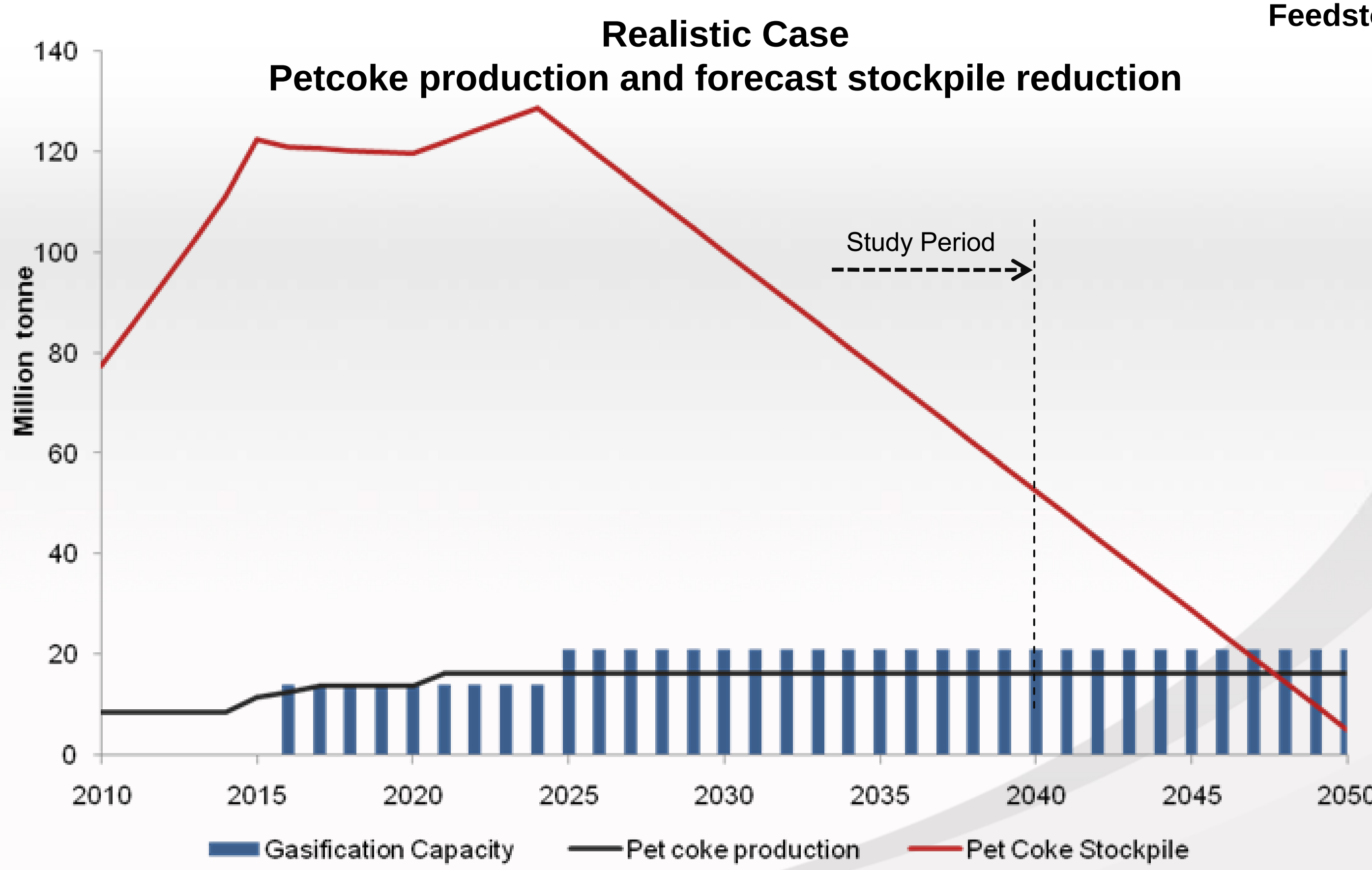
Reference Case Concept: 10 million tpa gasification capacity commencing in 2016



- In the Reference Case 10 million tpa gasification capacity is commissioned in 2016. No addition investment
- Petcoke production is 7 million tpa. Gasification capacity operates at 85%
- The accumulated petcoke stockpile reduces to zero post 2050.
- Gasification continues based on ongoing production of 7 million tpa, e.g. 70% operating rate

Realistic Case Concept: 14 million tonne gasification capacity initial investment with further 50% increase from 2025

Feedstock Scenarios



- In the Realistic Case 14 million tpa gasification capacity is commissioned in 2016, 7 million tpa in 2025
- Petcoke production is 16 million tpa. Gasification capacity operates at 85-90% (average 87.5%)
- The accumulated petcoke stockpile reduces to zero post 2050.
- Gasification continues based on ongoing production of 16 million tpa, e.g. 76% operating rate

The two Feedstock Scenarios can be summarised as follows:

Attributes	Reference Case	Realistic Case
Scale	Below world-scale c.a. 3 million tpa olefins	World-scale c.a. 10 million tpa olefins
Integration	Replacement of existing natural gas feedstock for ammonia and methanol imports for formaldehyde production	Feedstock replacement plus expansion of fertilizer value chain and feedstock for formaldehyde and acetic acid production
Energy	600MW	1200MW
Downstream	Limited derivative capability	Significant derivative capability
Pet coke	Stockpile reduced by 2050	Stockpile reduced by 2052
Refining	I major investment providing opportunity for world-scale steam cracker and derivatives	3 major investments allowing wide range of derivatives
Off-gases	Ability to develop world-scale polypropylene	Opportunity for 2 polypropylene plants plus additional C4 stream integration

- Significant upside to the Realistic Case is envisaged with higher levels of Upgrading investments
- The minimum world-scale petrochemical basis is regarded as 5-6 million tpa olefin equivalent
- The Reference Case concept is feedstock limited in terms of available petcoke for gasification

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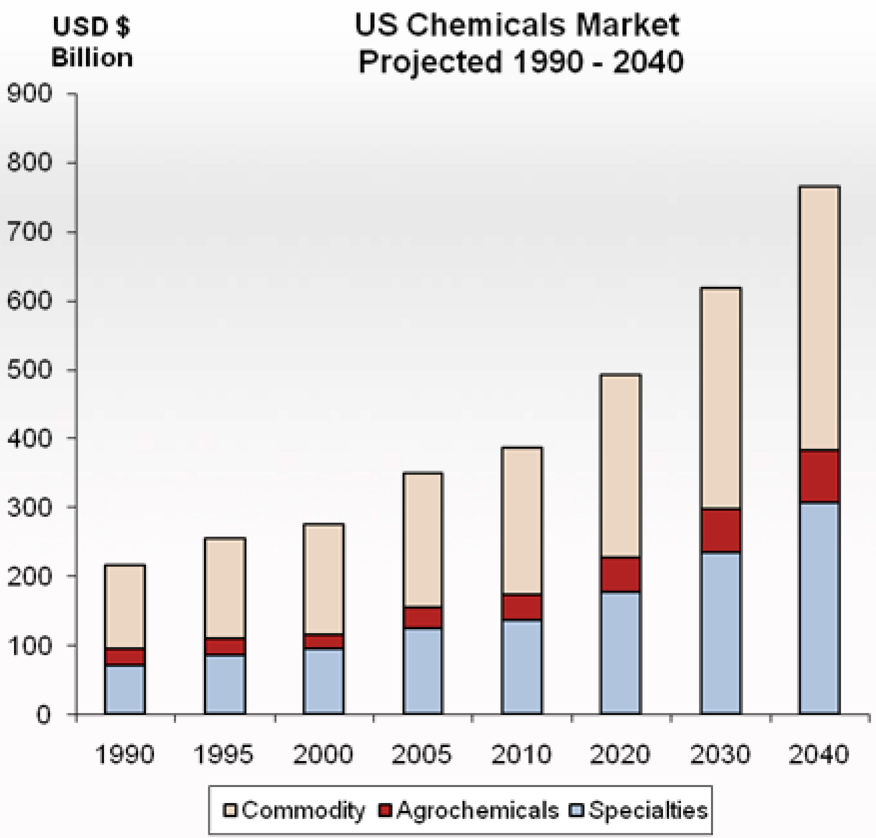
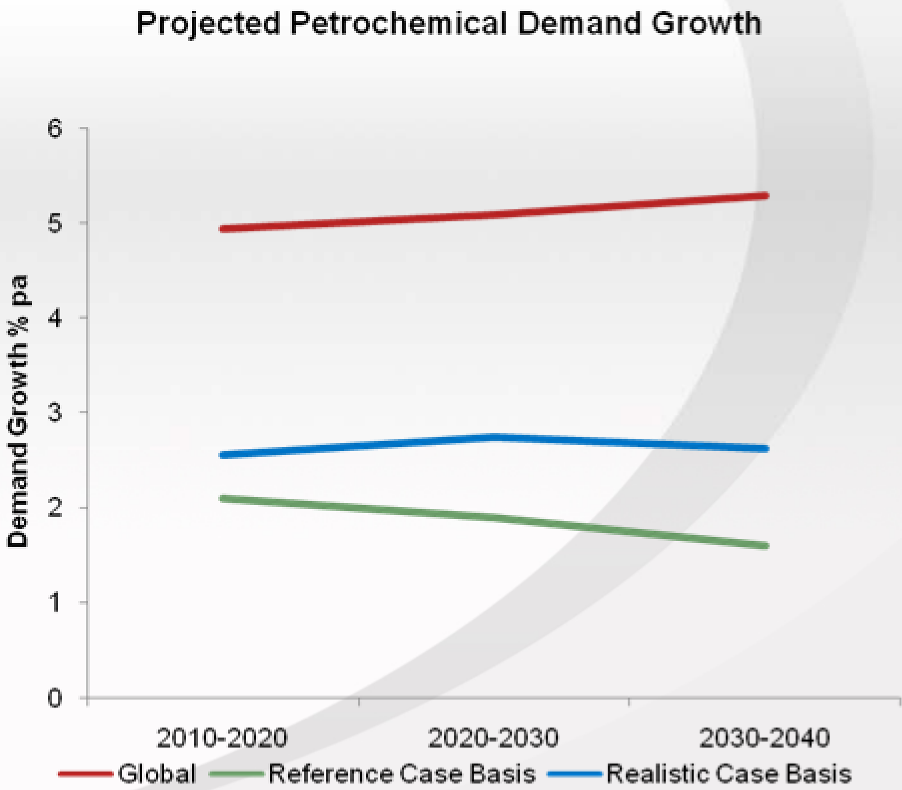
Approach and assumptions used to identify the most attractive products for the Midstream cluster for both Feedstock Scenarios

- A **detailed Supply – Demand analysis** was conducted on the products identified for the Midstream cluster under both the Reference and Realistic cases:
  - Long term growth rates were based on demand scenarios
  - Impact of the global economic crisis and the capacity bubble in the Middle East have been considered
- In both cases overall product demand within North America will require **significant investment to meet demand**
  - Replacement of some existing capacity due to age and/or poor economics is anticipated
- **Imports** - North America is forecast to maintain, but not increase, existing levels of chemical imports
- **Premise** - Alberta is able to capture 20-30% of North American petrochemical growth and investment based on gasification through MTO/MTP and up to 20% of traditional refinery/steam cracking related product slates

Demand growth for commodity petrochemicals in North America is lower than the overall global demand yet the market is significant





- Individual product demand in both the Reference and Realistic Cases have been derived from the projected commodity petrochemicals demand growth rates in North America using scenario analysis

Projected total number of world-scale plants required in North America to 2040 for the Reference Case

Product Selection

Products	Value Chain	Capacity kt	2010-2015	2015-2020	2020-2025	2025-2030	2030-2035	2035-2040
Methanol	C1	1000			1	1	1	1
Methanol (MTO/MTP)	C1	1500+		2-3	2-3	3-4	3-4	3-4
Ammonia	C1	1000		1	1	1	1	1
Urea	C1	500					1	
Polyethylenes (conventional)	C2	500	1	2	3	3	2	2
Polyethylenes (non-conventional)	C2	500		2	3	3	3	3
Ethylene Oxide/Glycol	C2	500		1		1		1
Polypropylene (conventional)	C3	400	2	2	2	2	2	2
Polypropylene (non-conventional)	C3	400		2	2	3	3	3
Propylene Oxide	C3	500		1		1	1	
Propylene Glycol	C3	200						
Acrylic Acid	C3	200	1	1	1	1	1	1
Acetic Acid	C1	600					1	
Maleic Anhydride	C4	80						
Benzene	C6	300		1	1	1	1	1
Phenol	C6	350		1	1	1	1	1
Cumene	C7	300		1	1	1	1	1
Toluene	C7	200			1	1		1
para Xylene	C8	600		1	1		1	1
ortho Xylene	C8	150		1		1		
BPA	C6	200	1		1	1		1
	Each coloured box represents one plant built in Alberta Midstream Cluster. Capacity stated as typical world-scale 2009 basis							

Post 2015 conventional feedstock (ethane/propane) will be limited and replaced by steam cracking (naphtha) and MTO/MTP

The projected higher growth will require earlier phasing and an increase in the number of plants in the Realistic Case

Product Selection

Products	Value Chain	Capacity kt	2010-2015	2015-2020	2020-2025	2025-2030	2030-2035	2035-2040
Methanol	C1	1000+		1	1	1	1	1
Methanol (MTO/MTP)	C1	1500+		2-3	3-4	3-4	4-5	4-5
Ammonia	C1	1000		1	1	1	1	1
Urea	C1	500			1		1	
Polyethylenes (conventional)	C2	500	1	2	3	3	3	3
Polyethylenes (non-conventional)	C2	500		2	3	4	5	5
Ethylene Oxide/Glycol	C2	500		1		1		1
Polypropylene (conventional)	C3	400	2	2	3	3	3	3
Polypropylene (non-conventional)	C3	400		2	3	4	5	5
Propylene Oxide	C3	500		1		1	1	1
Propylene Glycol	C3	200					1	
Acrylic Acid	C3	200	1	1	1	1	1	2
Acetic Acid	C1	600			1	1		1
Maleic Anhydride	C4	80			1			
Benzene	C6	300		1	1	1	1	1
Phenol	C6	350		1	1	1	1	1
Cumene	C6	300		1	1	1	1	1
Toluene	C7	200			1	1		1
para Xylene	C8	600		1	1		1	1
ortho Xylene	C8	150		1		1		
BPA	C6	200	1	1	1	1	1	2

Each coloured box represents one plant built in Alberta Midstream Cluster. Capacity stated as typical world-scale 2009 basis

Note: Post 2015 conventional feedstock (ethane/propane) will be limited and replaced by steam cracking (naphtha) and MTO/MTP

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The Reference Case is feedstock constrained resulting in relatively limited investment in the Midstream Cluster

Cluster Configurations

Construction and timing of investments - (not linear)

2015 | 2018 | 2020 | 2040

Upstream Refining

Off-gases
- Polypropylene

Gasification
- Methanol
- MTO/MTP
- Polypropylene

Power Hydrogen Syngas (NH3)

Steam Cracking
- Polyethylene
- Polypropylene
- EO/EG
- Toluene
- o Xylene
- p Xylene
- Cumene
- Phenol
- Acetone
- BPA

Legend
- Feedstock Process
- Product
- Third party Feedstocks
- 36 months construction assumed

The significant feedstock availability enables world scale investment in 3 phases in the Realistic Case

Cluster Configurations

Construction and timing of investments - (not linear)

2015 | 2018 | 2020 | 2025 | 2030 | 2035 | 2040

Upstream Refining (2018) | Upstream Refining (2030) | Upstream Refining (2040)

2015–2018

- Off-gases
  - Polypropylene
- Gasification
  - Methanol
  - MTO/MTP
  - Polypropylene
  - Formaldehyde
- Power Hydrogen Syngas (NH3)

2020

- Acetic Acid
- VAM
- Steam Cracking
  - Polyethylene(s)
  - Polypropylene
  - EO/EG
  - PO/PG (option)
  - Toluene
  - o & p Xylene
  - Cumene
  - Phenol
  - Acetone
  - BPA

2025

- Polypropylene
- Gasification
  - Methanol
  - MTO/MTP
  - PP/PO
  - Ammonia
  - Urea
  - AN
  - UAN

2030

- Acetic Acid
- VAM
- Steam Cracking
  - Polyethylene (s)
  - Polypropylene
  - EO/EG
  - PO/PG
  - Acrylic Acid
  - Benzene
  - BDO
  - Maleic Anhydride
  - Cyclohexane
  - PA
  - Cumene
  - BPA
  - Others

2040

- Steam Cracking
  - Polyethylene (s)
  - Polypropylene
  - PO/PG
  - Acrylic Acid
  - Toluene
  - o & p Xylene
  - Cumene
  - Phenol
  - Acetone
  - Others

Legend

- Feedstock Process
- Product
- Third party Feedstocks
- 36 months construction assumed

PP, PO and Acrylic Acid may be based on propylene derived from off-gases, MTP and steam cracking
Others include: Adipic Acid, Adiponitrile, Aniline MDI and Caprolactam
Ethylene may be used as a replacement feedstock for Polyethylenes and EO/EG (and LAOs) post 2025 rather than new builds

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Summary of Personnel, Land Use and Capex for the Reference Case Logistics systems

	Logistics Personnel requirements	Logistics Land Use requirements (ha)	Logistics Capex requirements (USD$m) excluding railcars
Solids	100	6	30
Liquids Site	80	7	25
Rail Site (solids)	Included in solids	Off site	40
Liquids Central (AILC)	150	25	350
Petcoke	50	55	150
Rail Central (Marshalling)	Included in liquids central	65	12
Total	**380**	**151**	**607**

Summary of the Personnel, Land Use and Capex requirements for the Realistic Case logistics systems

	Logistics Personnel requirements	Logistics Land Use requirements (ha)	Logistics Capex requirements (USD$m) excluding railcars
Solids	200	12	62
Fertilizers	100	5	50
Gasification	Included in Solids	Included in Solids	23
Liquids Site	160	15	75
Rail Site (solids)	included in Rail Central	Included in Rail Central	90
Liquids Central (AILC)	230	30	700
Petcoke	50	55	150
Rail Central (Marshalling)	Included in liquids central	103	22
Total	**740**	**220**	**1172**

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The Public and Site Specific Infrastructure have been defined independently of the location of the Upstream/Midstream location

Public (OSBL to the cluster)

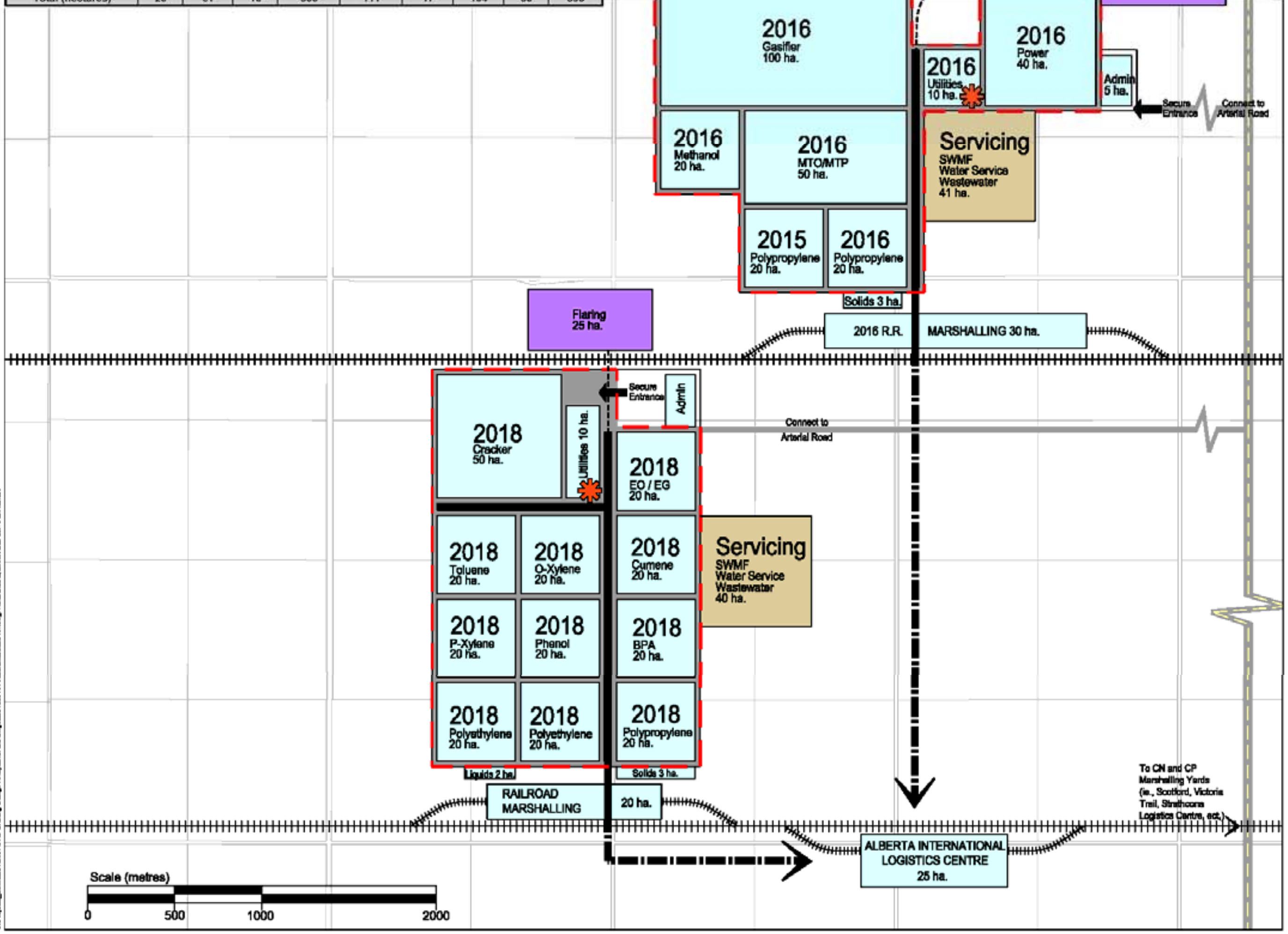
- **Utilities:** water, electricity, waste water, CO_2 pipelines
- **Infrastructure:** infrastructure corridors between clusters, pipe bridges, pipelines, roads, rail, marshalling yards
- **Environmental:** waste water, storm water, CO_2 capture
- **Land Use:** roads, rail, marshalling yards, utilities
- Upstream to Midstream to Downstream **Cluster inter-linkages**

Site Specific (ISBL to the cluster)

- **Utilities:** electricity, steam, natural gas, condensate, water
- **Infrastructure:** pipe bridges, pipelines, roads, rail
- **Environmental:** waste water, storm water, solid effluent, flue gases, liquid effluent, CO_2 capture, flares
- **Industrial gases:** oxygen, nitrogen, syngas, CO, H_2
- **Land Use:** plants, infrastructure, maintenance corridors
- **Emergency services:** fire-brigade, medical

Reference Case Concept Site Plan 2015-2020

Reference Case	Utilities	Offsite Services	Admin	Production Facility	Logistics / Marshalling	Pipe Corridor	Roadway	Flaring	Total (hectares)
Gasifier 2015-20	10	41	5	250	61	5	43	25	441
Cracker 2015-20	10	40	5	250	25	11	61	25	427
AB International Logistics					25				25
Total (hectares)	20	81	10	500	111	17	104	50	893



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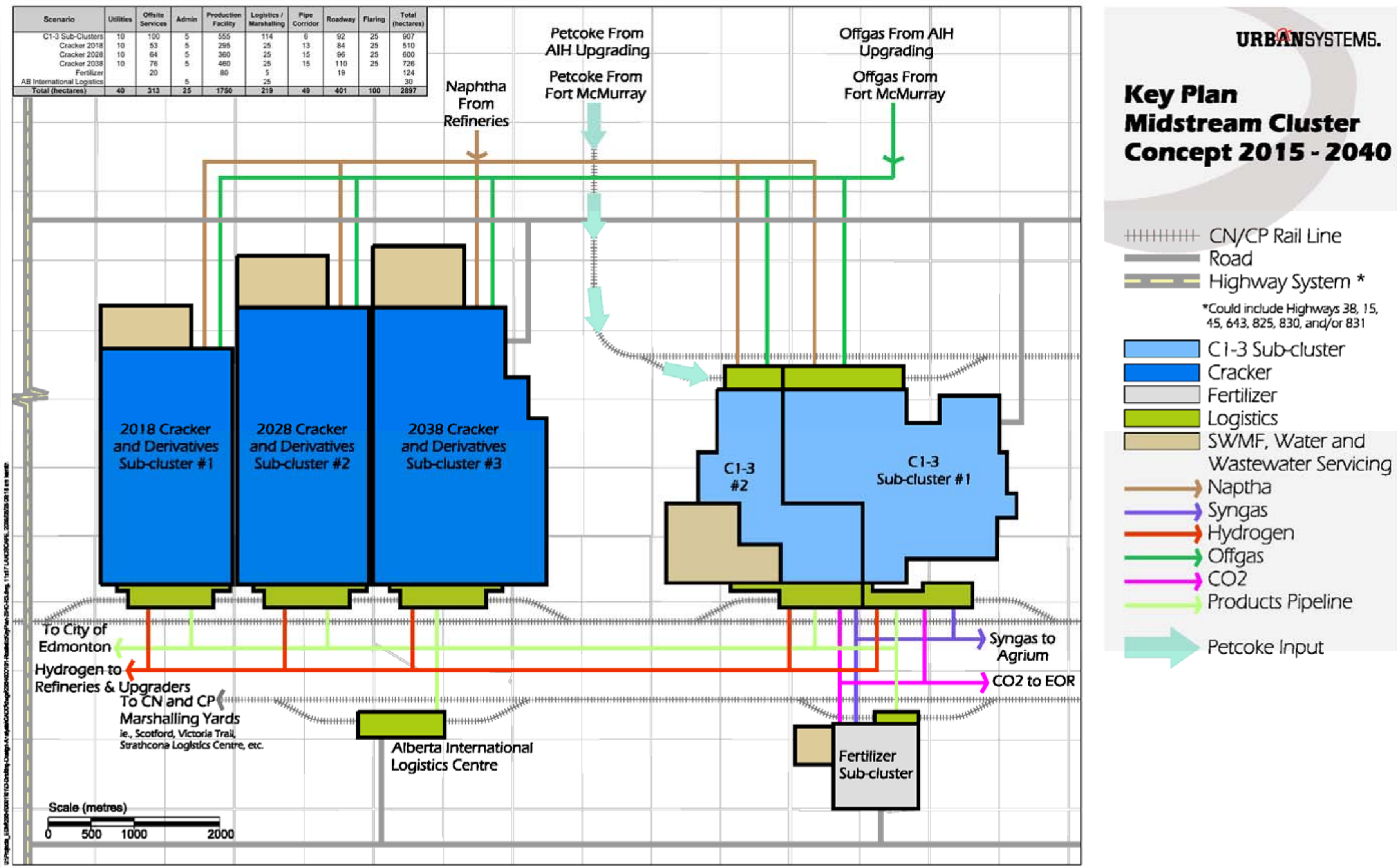
Reference Case 2015 - 2020 Cracker complex could be independent from the gasification development

- Secure Area
- Prime Pipe Corridor (40m)
- 2015
- Emergency Services
- CN/CP Rail Line
- Rail Spur
- SWMF, Water and Wastewater Servicing
- Flaring
- Product Pipe
- Road (30m)
- Highway System *

*Could include Highways 38, 15, 45, 643, 825, 830, and/or 831

Realistic Case Key Plan Midstream Cluster 2015 - 2040

Concept Site Plans



Scenario	Utilities	Offsite Services	Admin	Production Facility	Logistics / Marshalling	Pipe Corridor	Roadway	Flaring	Total (hectares)
C1-3 Sub-Clusters	10	100	5	555	114	6	92	25	907
Cracker 2018	10	53	5	296	25	13	84	25	510
Cracker 2028	10	64	5	360	25	15	96	25	600
Cracker 2038	10	76	5	460	25	15	110	25	726
Fertilizer		20		80	5		19		124
AB International Logistics			5		25				30
Total (hectares)	**40**	**313**	**25**	**1750**	**219**	**49**	**401**	**100**	**2897**

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By 2040 under the Reference Case the Midstream Cluster could generate annual revenues of $ 4.7 billion and taxes of $350 million

Sales	Revenues	Capex	Jobs	Land Use	Taxation	Infrastructure
11.9 million tonne pa	$4.7 billion pa	$11.4 billion	1125 direct	886 ha	$353 million pa	$1.2 billion cumulative
					$8.5 billion cumulative	

- Total investment is in period 2015-2020 with no additional growth envisaged
- Cracker and derivatives provides 28% sales volumes but 69% revenues, 42% capex
- Off gas availability (propylene) is utilised for polypropylene production
  - Incremental ethane/ethylene is used to supplement existing polyethylene and ethylene glycol facilities - not as new investments
- Impact on proposed CoE Cluster function of Cracker and derivatives investments
- Proportion of syngas feedstock used to replace existing NG feedstock at established fertilizer production (Agrium) and for power requirements
- Taxation includes income, corporation, land and property related taxes

In the Realistic Case Revenues could reach $18.4 billion and taxes $1.15 billion per year

Sales	Revenues	Capex	Jobs	Land Use	Taxation	Infrastructure
33.4 million tonne pa	$18.4 billion pa	$35.4 billion	2353 direct	2419 ha	$1.15 billion pa $18.9 billion cumulative	$2.3 billion cumulative

- Majority of investment is in period 2015-2025 with additional growth envisaged
- Cracker and derivatives provides 35% sales volumes but 65% revenues, 50% capex
- Off gas availability (propylene) is utilised for polypropylene production
  - Incremental ethane/ethylene is used to supplement existing polyethylene and ethylene glycol facilities - not as new investments but could be alternative cracker option
- Major impact on proposed CoE Cluster function of Cracker and derivatives investments
- Proportion of syngas feedstock used to replace existing NG feedstock at established fertilizer production (Agrium) plus new fertilizer investment and for power requirements
- Taxation includes income, corporation, land and property related taxes

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The Cost Benefit is based on the cumulative revenue earned by Government against the investment in infrastructure to support the cluster

Investment and Revenues for the period 2015 -2040	Units	Reference Case
Capex for Infrastructure	CAD $m	1,159
Tax from Land use and Infrastructure (Σ(tax from land use, property tax, logistics and piperacks, services)	CAD $m	4,908
Corporation Tax	CAD $m	3,252
Personal Income Tax	CAD $m	323
Total Tax	**CAD $m**	**8,483**
Tax earned per CAD spent on Infrastructure (Capex)		**7.32**
Assumes ROE of 1 for CAD:USD		

The Cost Benefit is based on the cumulative revenue earned by Government against the investment in infrastructure to support the cluster

Investment and Revenues for the period 2015 -2040	Units	Realistic Case
Capex for Infrastructure	CAD $m	2,297
Tax from Land use and Infrastructure (Σ(tax from land use, property tax, logistics and piperacks, services)	CAD $m	9,872
Corporation Tax	CAD $m	8,441
Personal Income Tax	CAD $m	547
Total Tax	**CAD $m**	**18,861**
Tax earned per CAD spent on Infrastructure (Capex)		**8.21**
Assumes ROE of 1 for CAD:USD		

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Observations and Conclusions (1/3)

- The **Reference Case** will enable only a modest Midstream cluster.
- The **Realistic Case** provides for a significant cluster in global terms second only to Jubail Industrial City in scale
- **Upgrader offgases will not provide sufficient critical mass** to support a stand-alone cluster
- **Petcoke provides a globally significant feedstock** source which will elevate Alberta to one of the largest petrochemical based clusters worldwide with stranded feedstock economics (Realistic case)
- A **diversified gasification platform** could provide energy, hydrogen, natural gas replacement for fertilizers and world-scale petrochemicals via MTO
- **Investment in refining** will satisfy growing diesel demand and provide **naphtha** feedstock

Observations and Conclusions (2/3)

- The **North American chemical market provides a robust demand opportunity** enabling a market share of ca. 30% of the incremental growth in demand to 2040 to be achieved
- The **cluster configurations** for both the Cases are primarily driven by **market demand in North America** balanced against the **feedstock supply**.
- The cluster configurations recognise that a single cluster producing ca 50 million tpa of final products **cannot be viably organised into a single entity** and the phasing will be required
- The cluster configurations **build in the principles of EID**, making maximum use of integration and synergy opportunities within the cluster
- **Centralisation of logistics infrastructure**, where it can easily be expanded with the growth of the cluster, leads to the **most efficient operation**

Observations and Conclusions (3/3)

- **Logistics services will be mostly outsourced in the cluster** – preferably to more than one party for each activity
- The **petcoke logistics system presents some challenges**, which will need to be addressed at an early stage by government
- **Rail is the primary transport mode** for final products to market. Competitive movement of products is key to success
- The **socio-economic analysis**, provides a realistic basis for further development of the Midstream Cluster.
- Both the Reference and Realistic Cases provide the region with an **attractive cost benefit opportunity** (Reference Case limited)

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