Axens
IFP Group Technologies

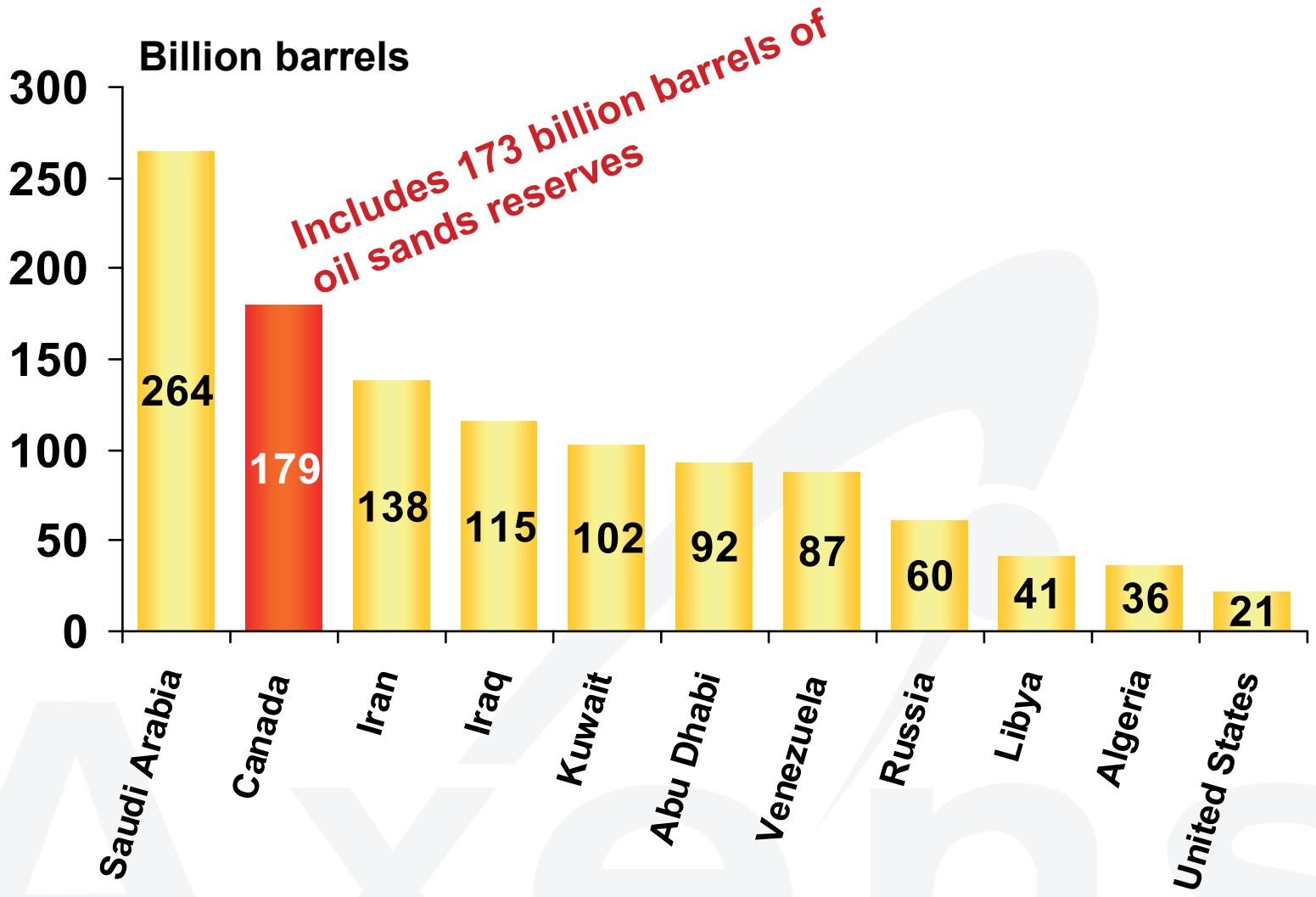
Upgrading Options & Economics for Heavy Crudes Conversion

Nicolas Thevenot

Agenda

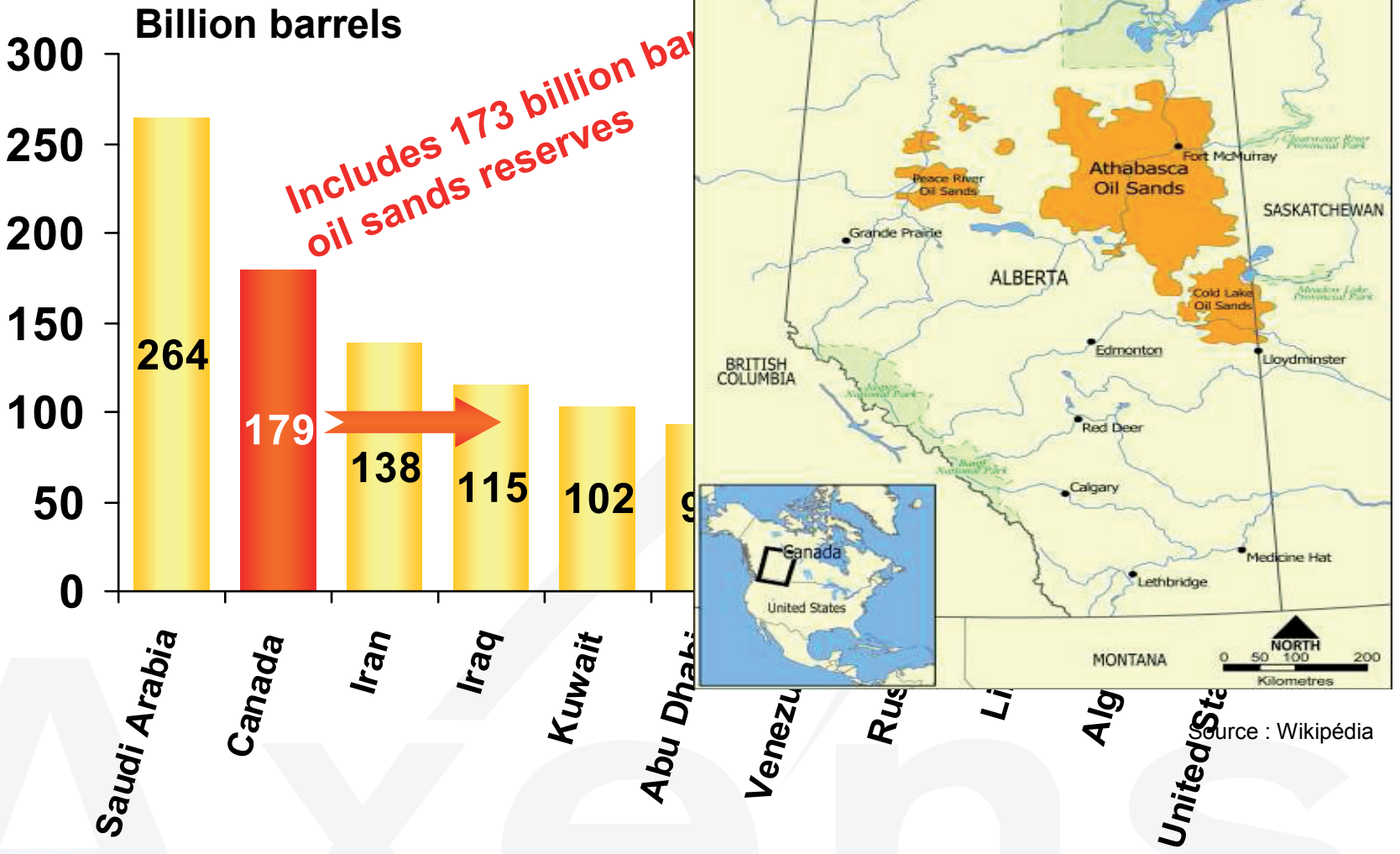
- Context
- Upgrading options for diesel production
  - Conversion solutions
  - H_2 production options (SMR & POX)
- Economic evaluations
  - Conversion schemes profitability
  - Impact of H_2 production mode
- Sensitivity studies

Crude Oil Reserves by Country



Source : CAPP, Oil & Gas Journal, Dec. 2007

Athabasca Oil Sands Location



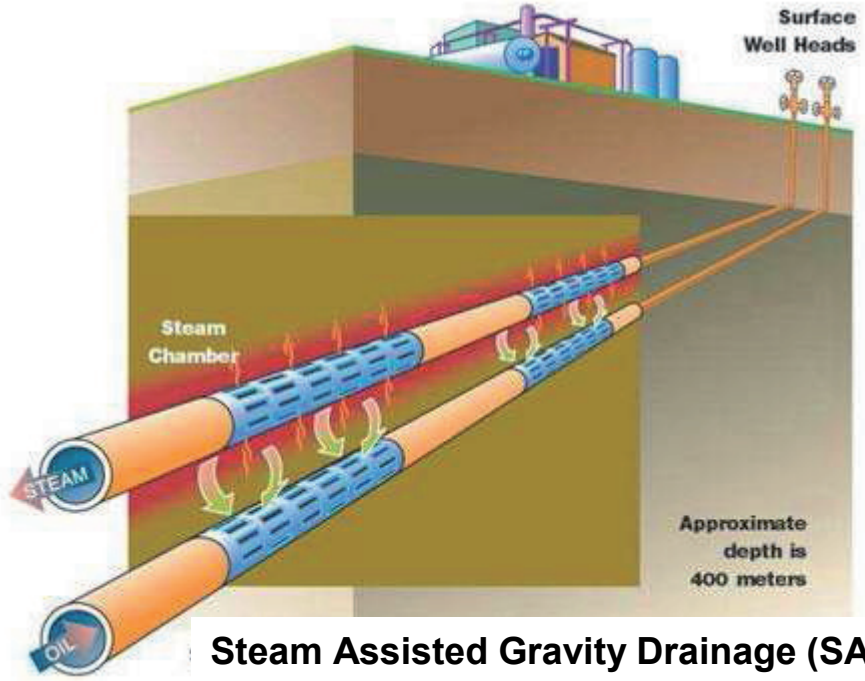
Source : Wikipédia

Source : CAPP, Oil & Gas Journal, Dec. 2007

Two Production Pathways

Mining

Extraction

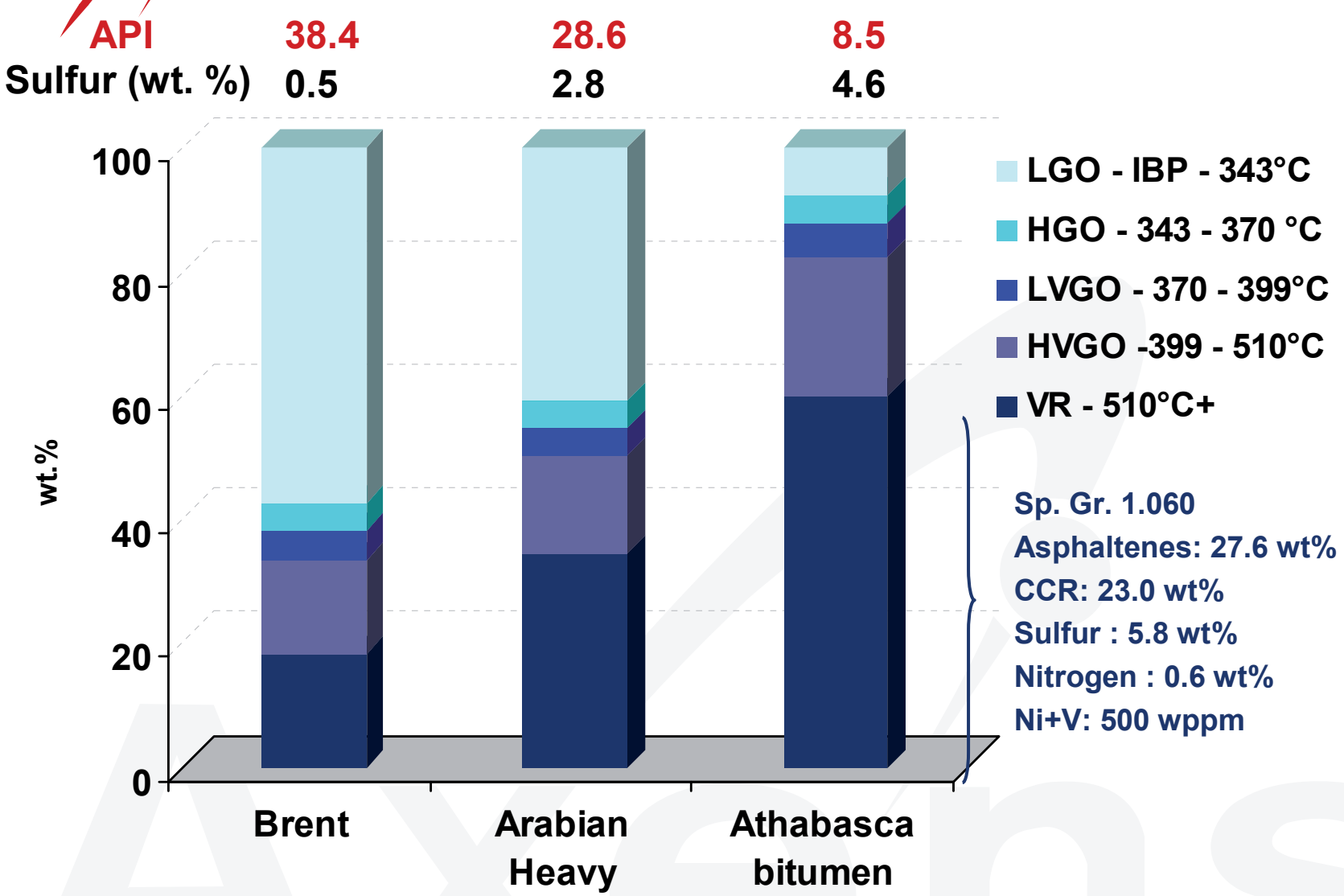


Steam Assisted Gravity Drainage (SAGD)

Source : ConocoPhillips

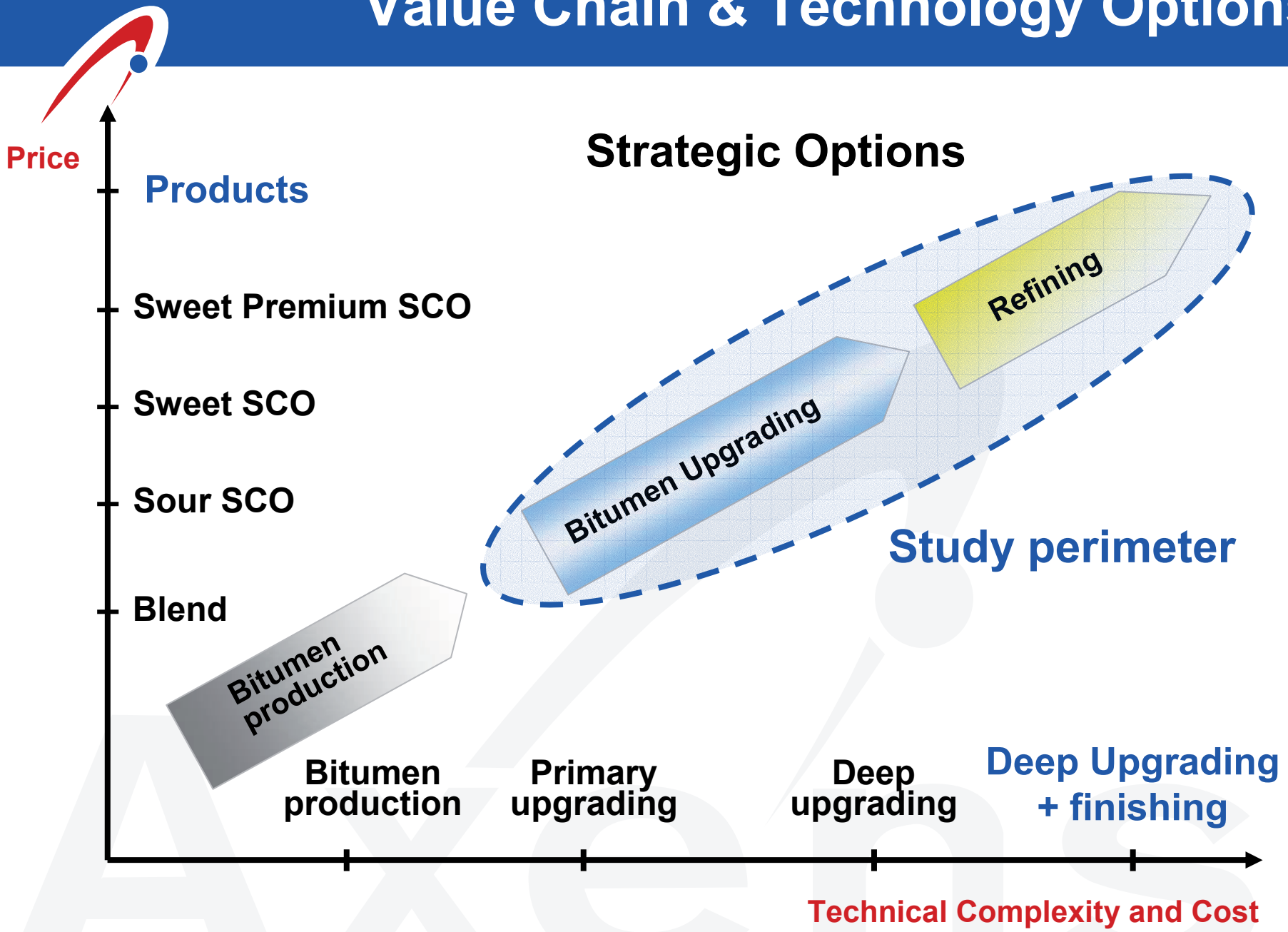
Bitumen

Comparative Crude Compositions



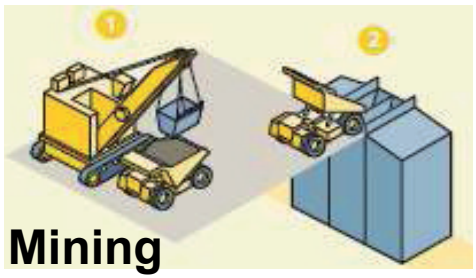
Source: IFP

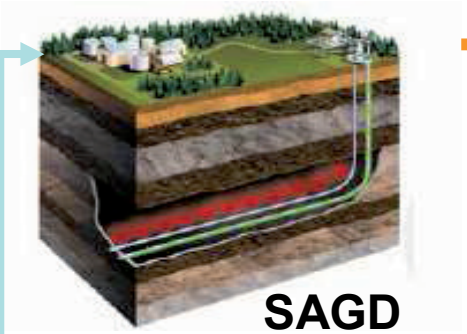
Value Chain & Technology Options

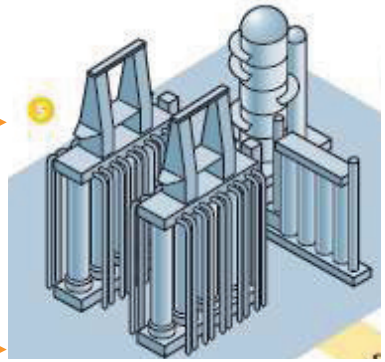


Canadian Oil Sands

Offsite Deep Upgrading + Finishing Steps



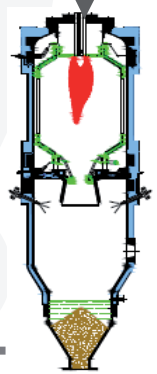




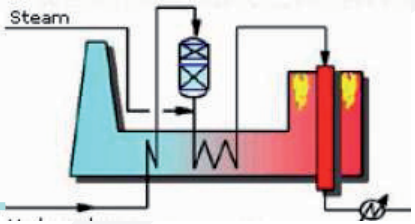
SCO

Finished products

Residue



H_2



SMR

Gasifier

Nat. gas

Nat. gas

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- **Upgrading options for diesel production**
  - **Conversion solutions**
  - **H_2 production options (SMR & POX)**
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- Sensitivity studies

Bases for Case Study

- Feedstock: 200,000 b/d (1338 t/h) of Athabasca bitumen
- Upgrader + refining not integrated with bitumen production
- Conversion options oriented towards diesel production
- High quality products, corresponding to bottomless SCO with API>42, for US market
- Hydrogen production, 3 options evaluated:
  - SMR
  - POX of residues
  - a combination of SMR & POX when the quantity of available residue is not sufficient

SMR=steam methane reforming, POX=partial oxidation, SCO=SynCrude Oil

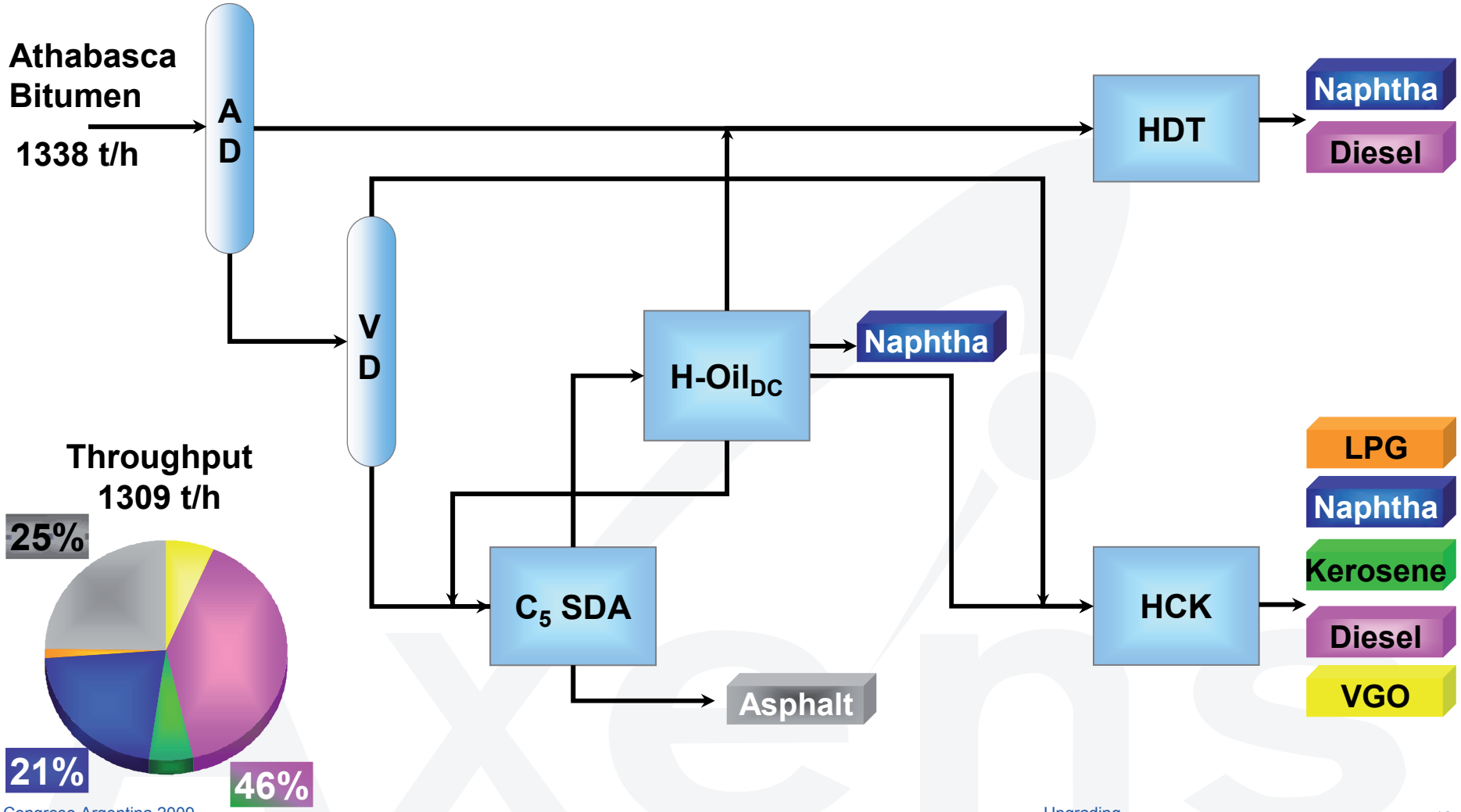
Axens' Technologies Glossary

- **Prime-D = Diesel hydrotreating**
- **H-Oil$_{DC}$ = Ebullated bed technology for Deasphalted Oil (DAO) & heavy Vacuum Gas-Oil (VGO) hydrocracking**
- **H-Oil$_{RC}$ = Ebullated bed technology for resid hydrocracking**
- **Solvahl = Solvent Deasphalting (SDA)**
- **HyK = High conversion hydrocracking**
- **HDHPLUS = Slurry technology for deep Vacuum Residue (VR) Hydrocracking**
- **SHP = Sequential Hydro-Processing**

SDA + H-Oil$_{DC}$ Scheme

400,000 Nm^3/h H_2

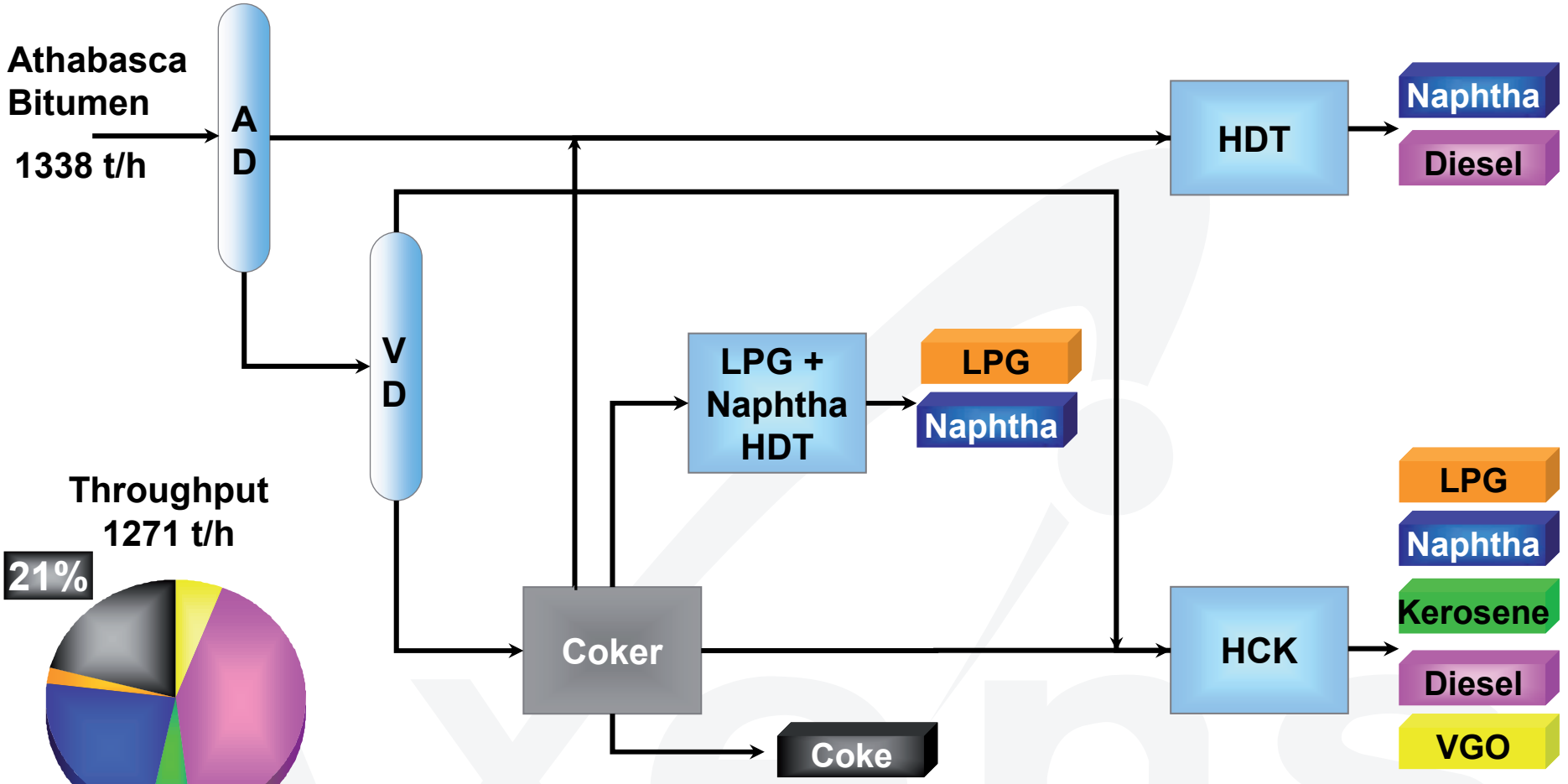
- SMR: 4*100,000 Nm^3/h
- POX: 1680 MWth from Asphalt



Coker Scheme

300,000 Nm^3/h H_2

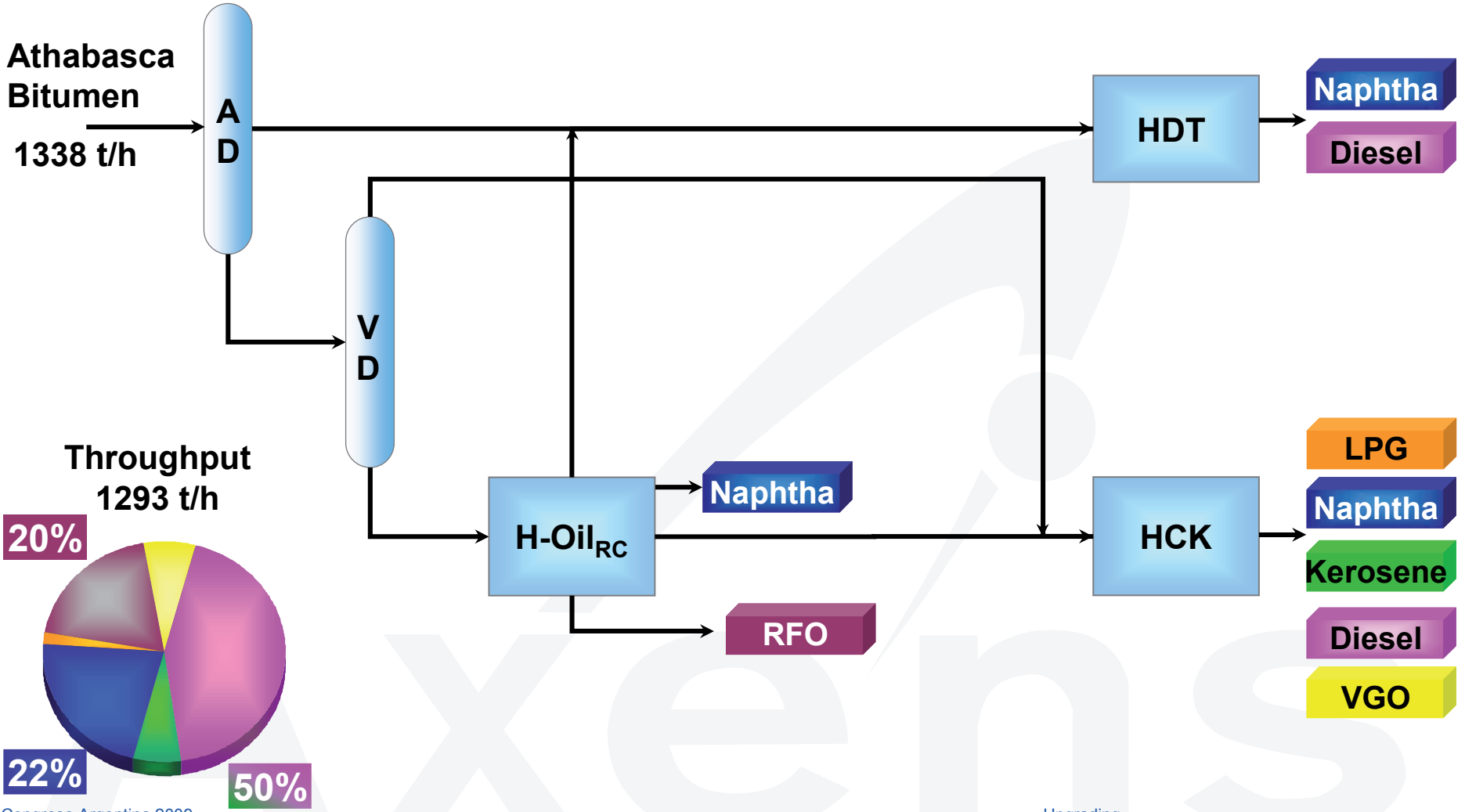
- SMR: 2*150,000 Nm^3/h
- POX: 1200 MWth from Coke



H-Oil$_{RC}$ Scheme

480,000 Nm^3/h H_2

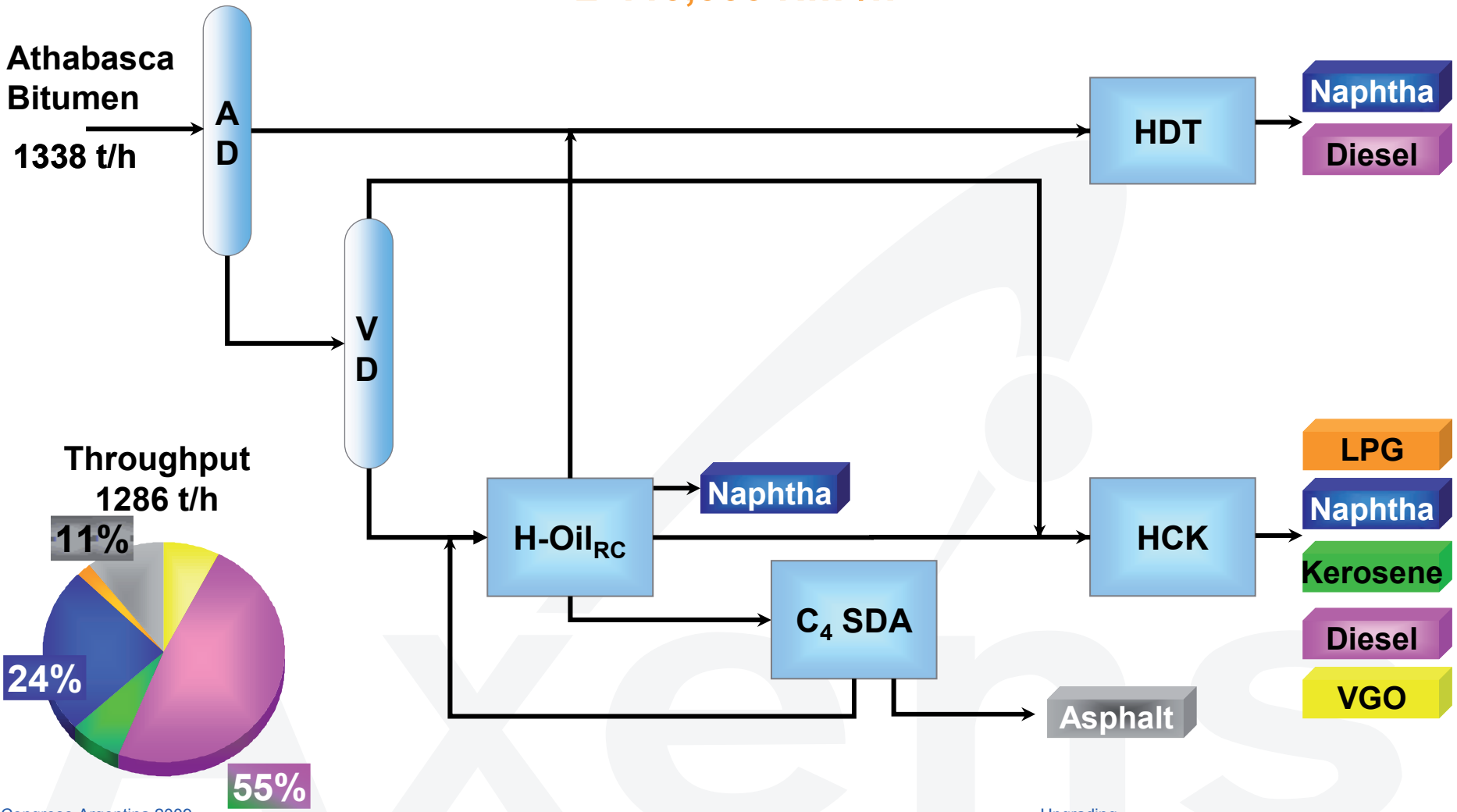
- SMR: 4*120,000 Nm^3/h
- POX: 2190 MWth from RFO



H-Oil$_{RC}$ + SDA Scheme

520,000 Nm^3/h H_2

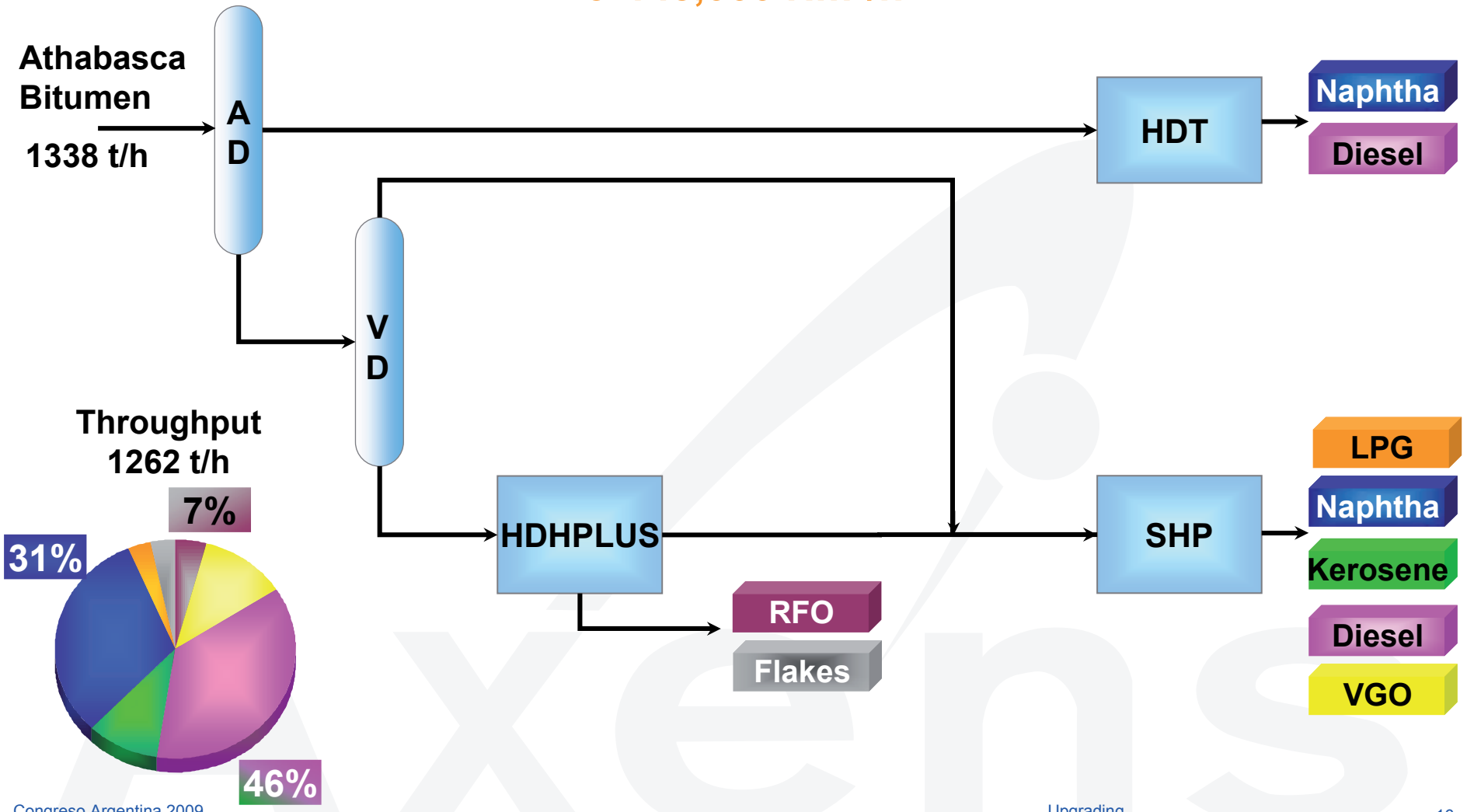
- SMR: 4*130,000 Nm^3/h
- POX + SMR: 1260 MWth from Asphalt + 2*110,000 Nm^3/h



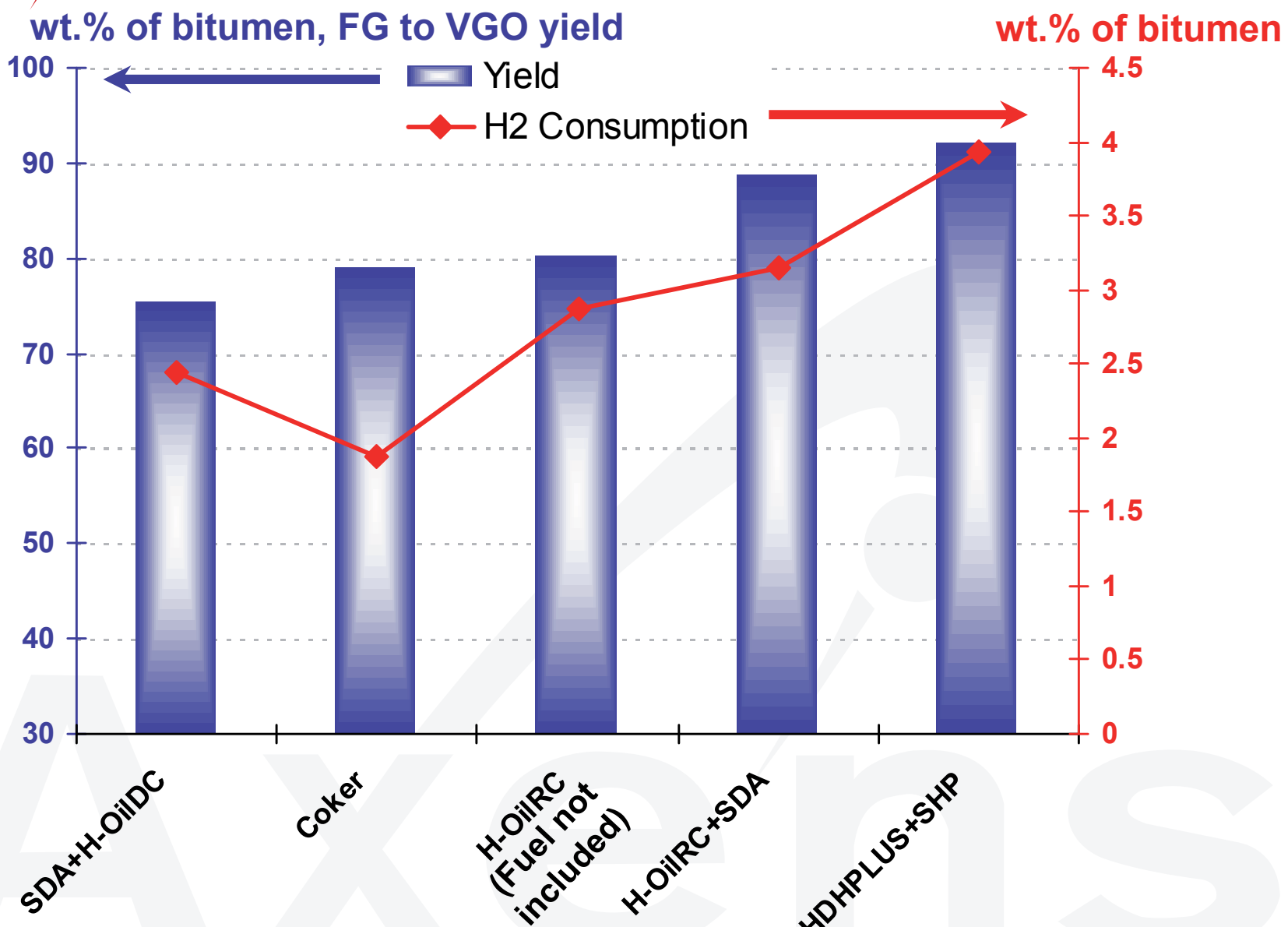
HDHPLUS + SHP Scheme

630,000 Nm³/h H_2

- SMR: 6*105,000 Nm³/h
- POX + SMR: 880 MWth from Flakes + 3*145,000 Nm³/h



Conversion & H_2 Consumption



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- **Economic evaluations**
  - **Conversion schemes' profitability**
  - **Impact of H_2 production mode**
- Sensitivity studies

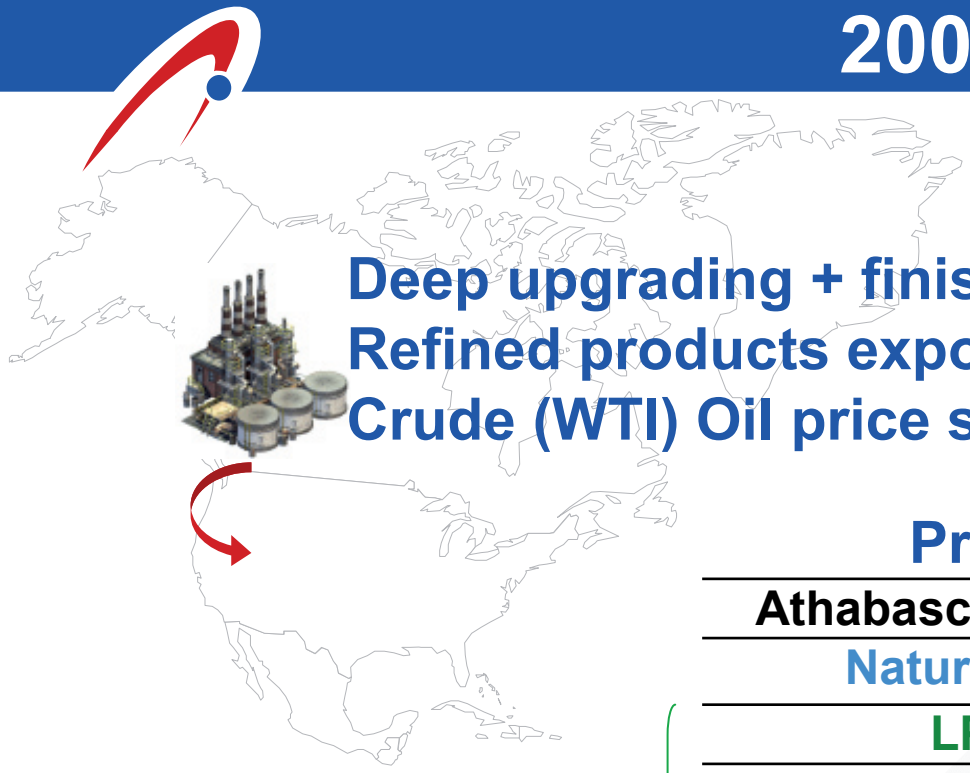
Economic Assumptions & Methods

- **Economic evaluations based on:**
  - **Discounted Cash Flow (DCF) analysis**
  - **Profitability index comparisons (NPV, IRR)**
  - **Price scenarios based on averaged values (between 2004 and 2008*) for:**
    - ***Investment, catalysts, utilities***
    - ***Feedstock, finished products***

- **Discounted Cash Flow (DCF) analysis**
  - **10% contingencies**
  - **Depreciation period: 15 years**
  - **Project duration: 29 years**
  - **Discount rate: 12%**
  - **Tax Rate: 40% for Canada**
  - **Construction duration: 4 years**

*** average 1st half of 2008**

Product Price Considerations
2007 Scenario – Base Case



Deep upgrading + finishing steps located in Canada
Refined products exported to the US
Crude (WTI) Oil price scenario: 72 US $/bbl

Price Considerations

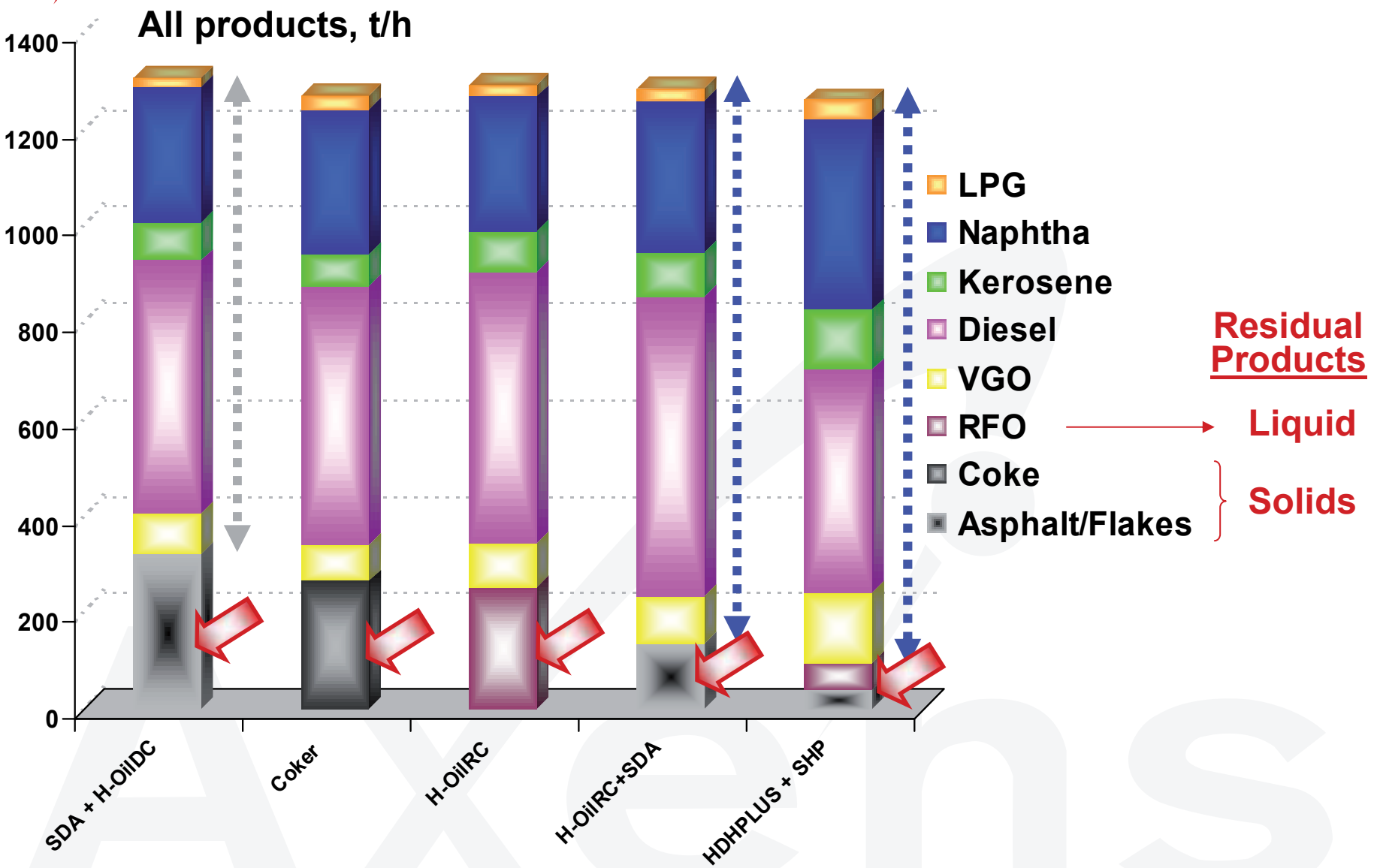
Athabasca Bitumen	30 US $/bbl
Natural Gas	7.0 US $/MMBtu
LPG	622
Naphtha	672
Kerosene	693
Diesel	639
VGO	574
HSFO (n°6, S cont. <3.5 wt%)	323
RFO*	131
Asphalt / Flakes / Coke	0
CO_2 Penalty	30 US$/t CO_2 eq.

US $/t

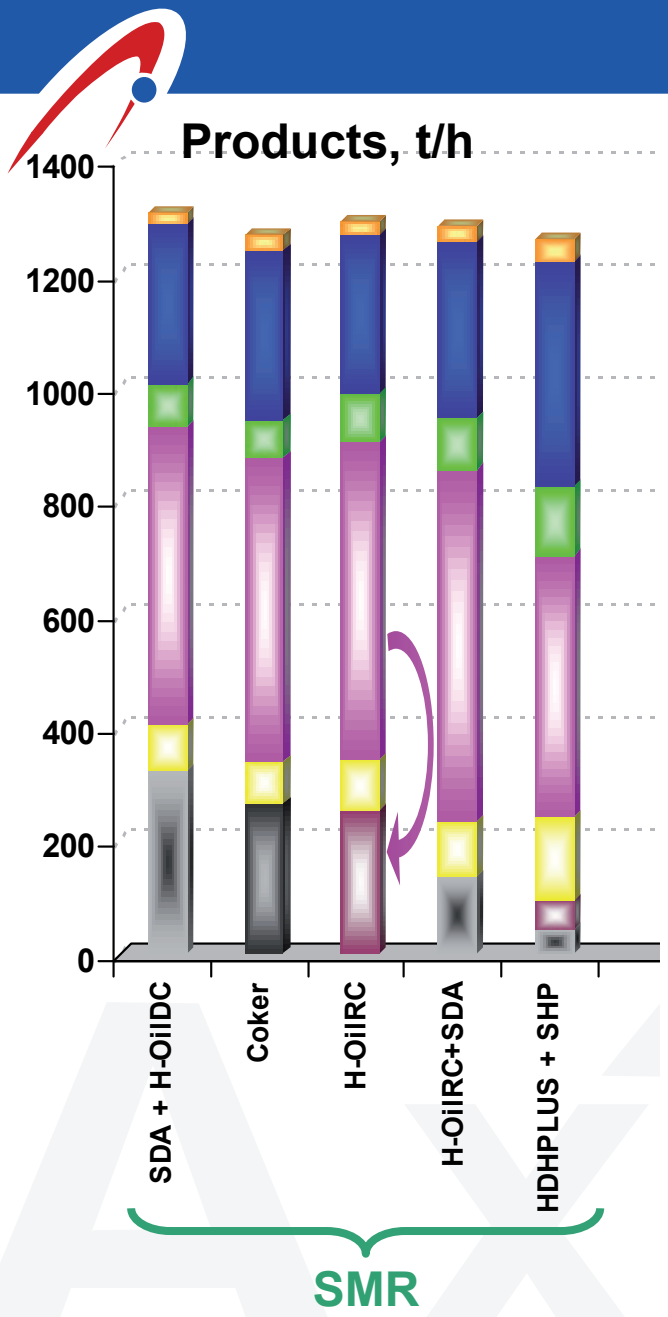
included transport cost
Canada ⇨ US = 15 US $/t

*** Net back estimation**

Product Throughputs



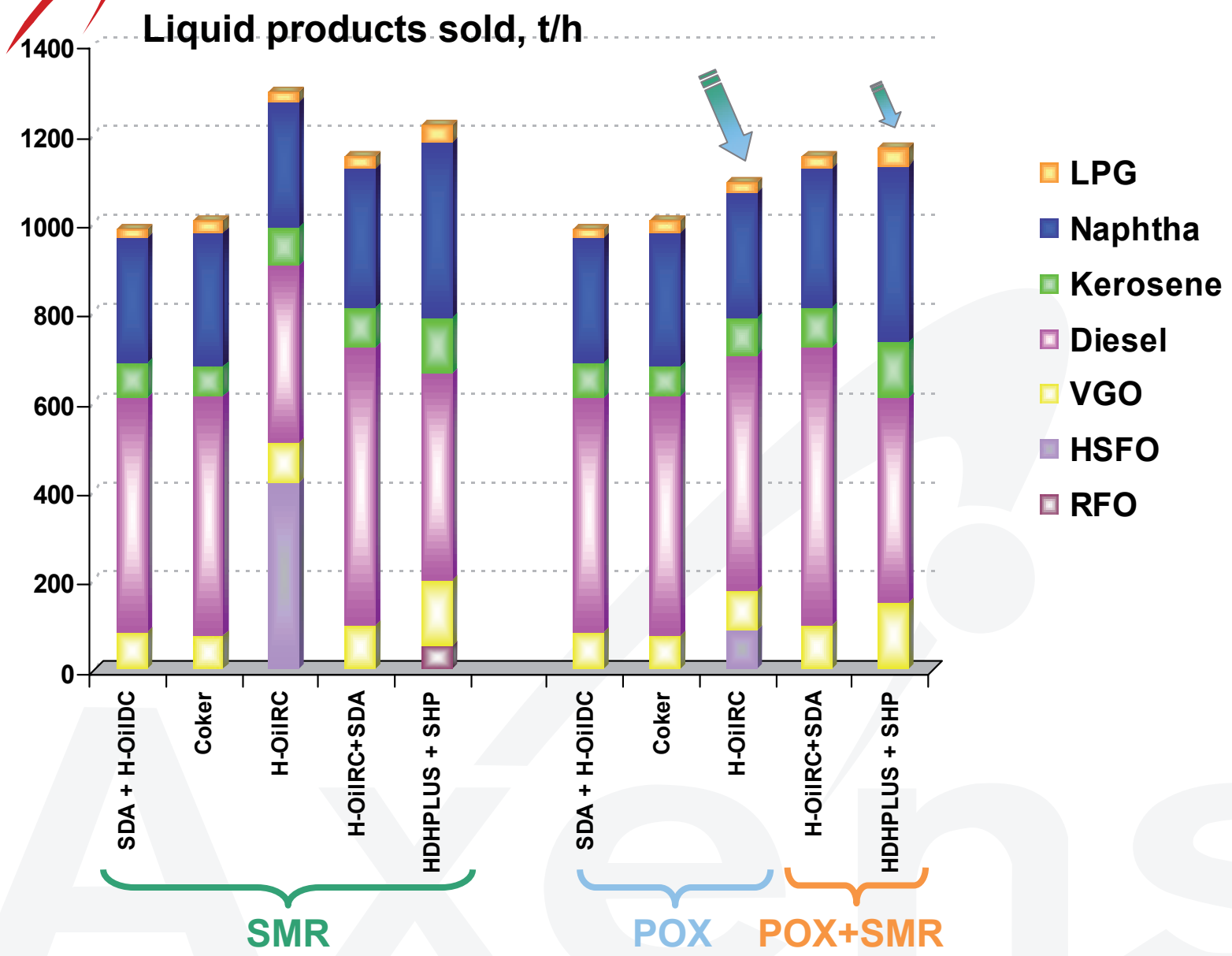
Product Throughputs



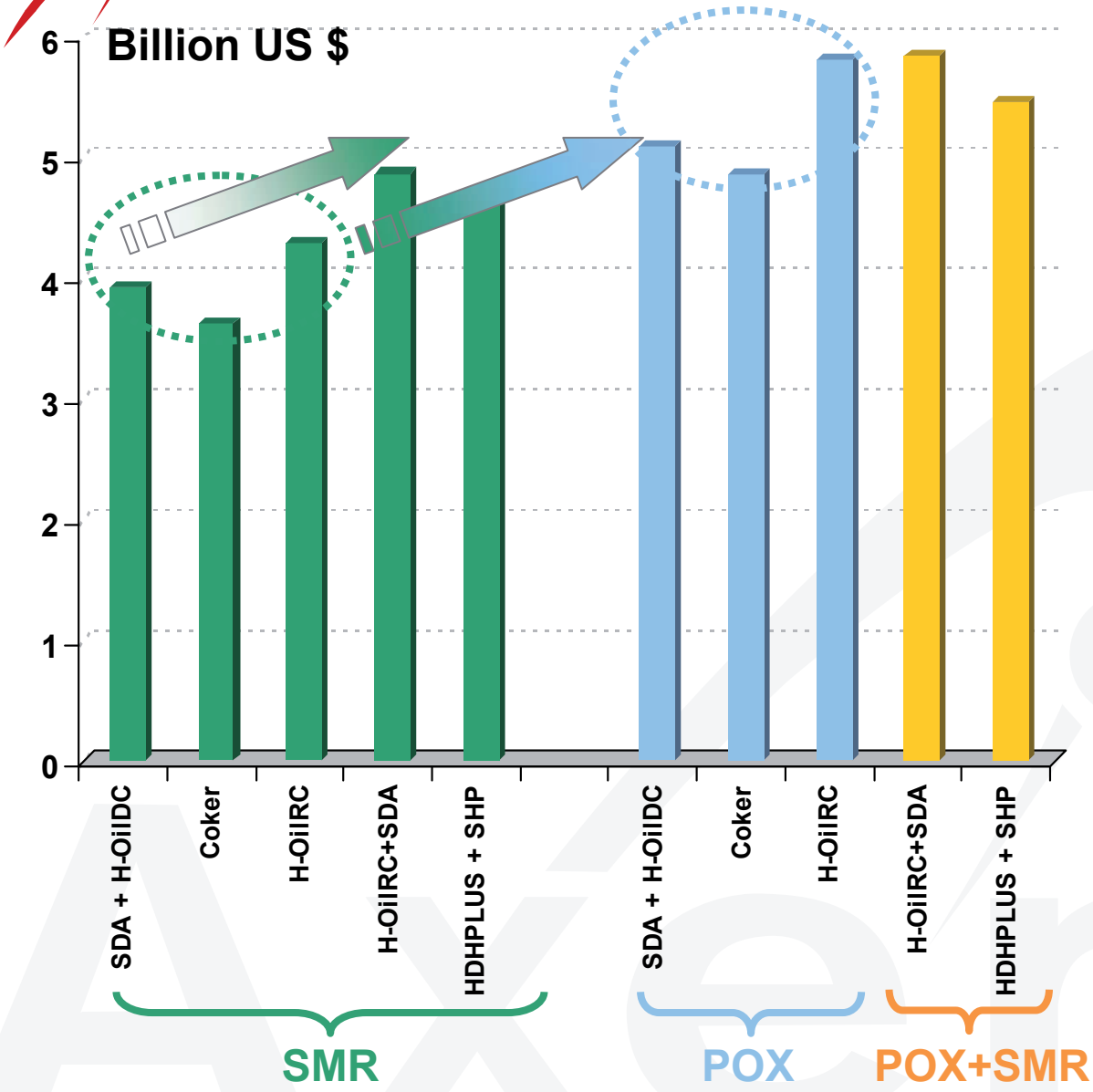
- LPG
- Naphtha
- Kerosene
- Diesel
- VGO
- HSFO
- RFO
- Coke
- Asphalt/Flakes

H-Oil$_{RC}$ Scheme RFO to be fluxed with H-Oil$_{RC}$ gas oil to produce HSFO

Liquid Products Sold



Total Capital Investment (TCI) 2007 Scenario – Base Case

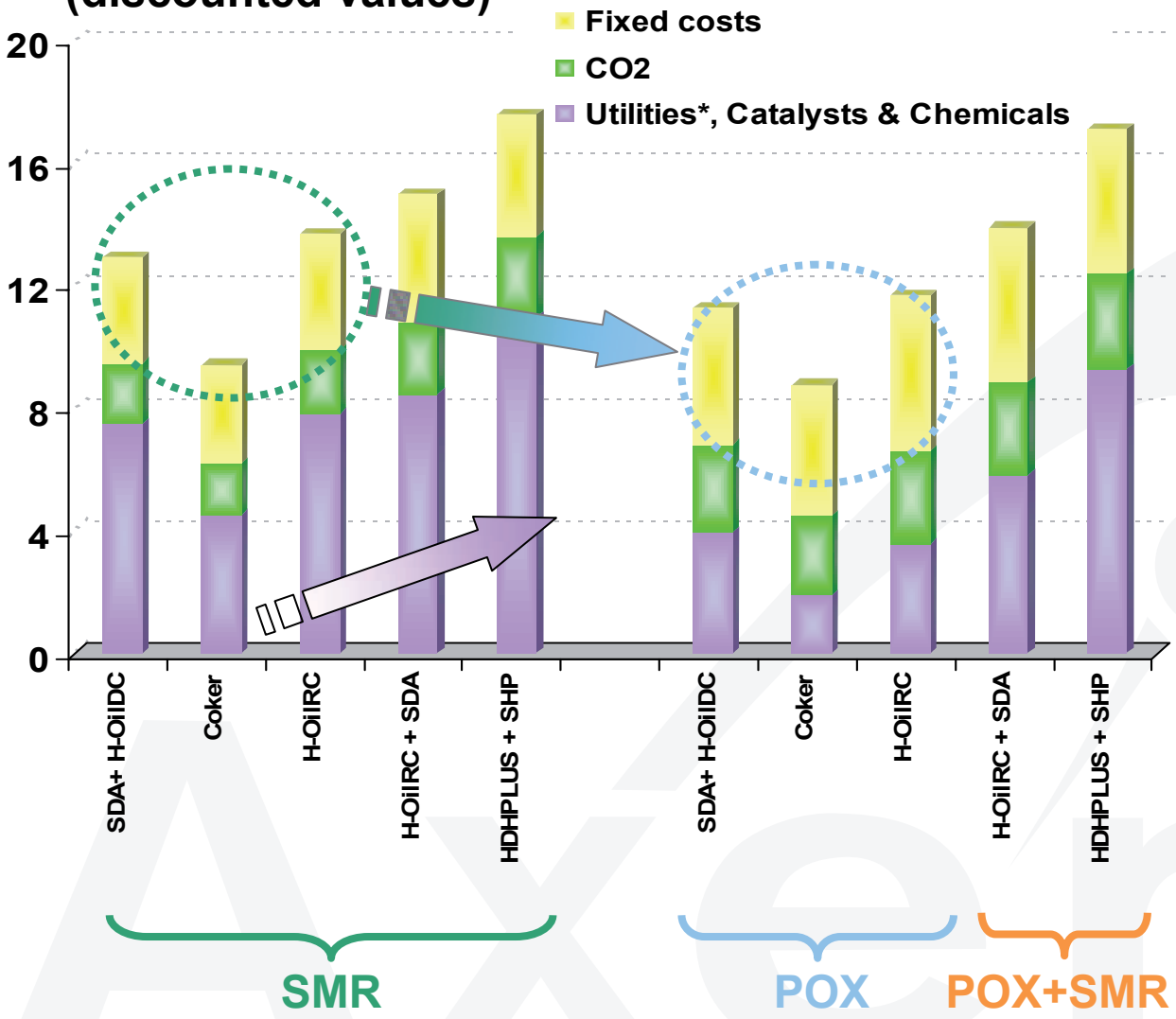


TCI includes:

- ISBL investment
- Off Sites
- Engineering fees
- Contractor fees
- Contingency
- Interest during construction
- Start-up costs
- Working capital

- The higher the residue conversion the higher the TCI
- POX option increases TCI by ~ 30%
- In POX SDA is 2-3 times higher than SMR

OPEX
2007 Scenario – Base Case

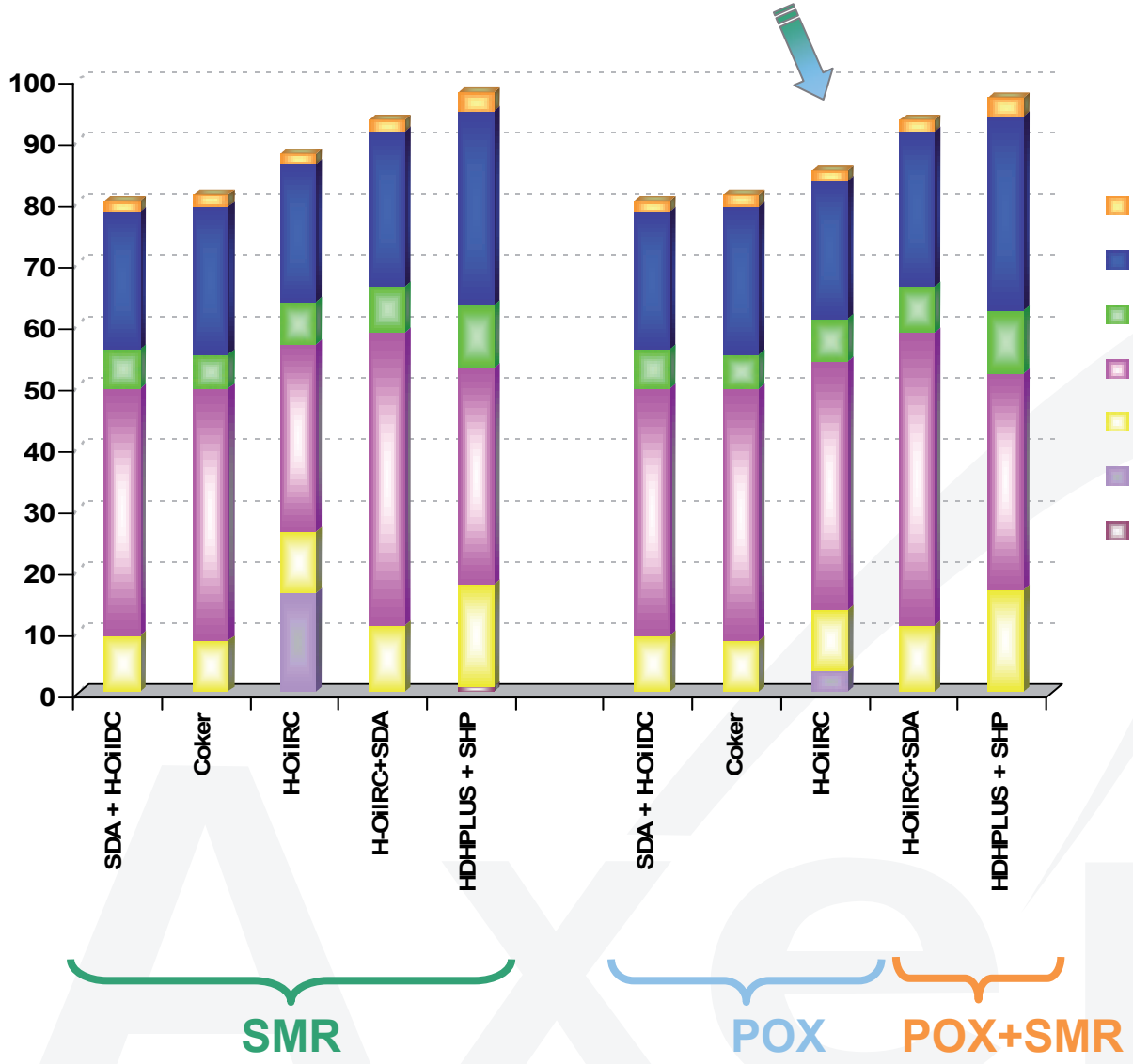


- OPEX closely linked to the H_2 consumption
- POX option enables OPEX savings between 0.5 to 2 US $/bbl compared to SMR

* mainly natural gas

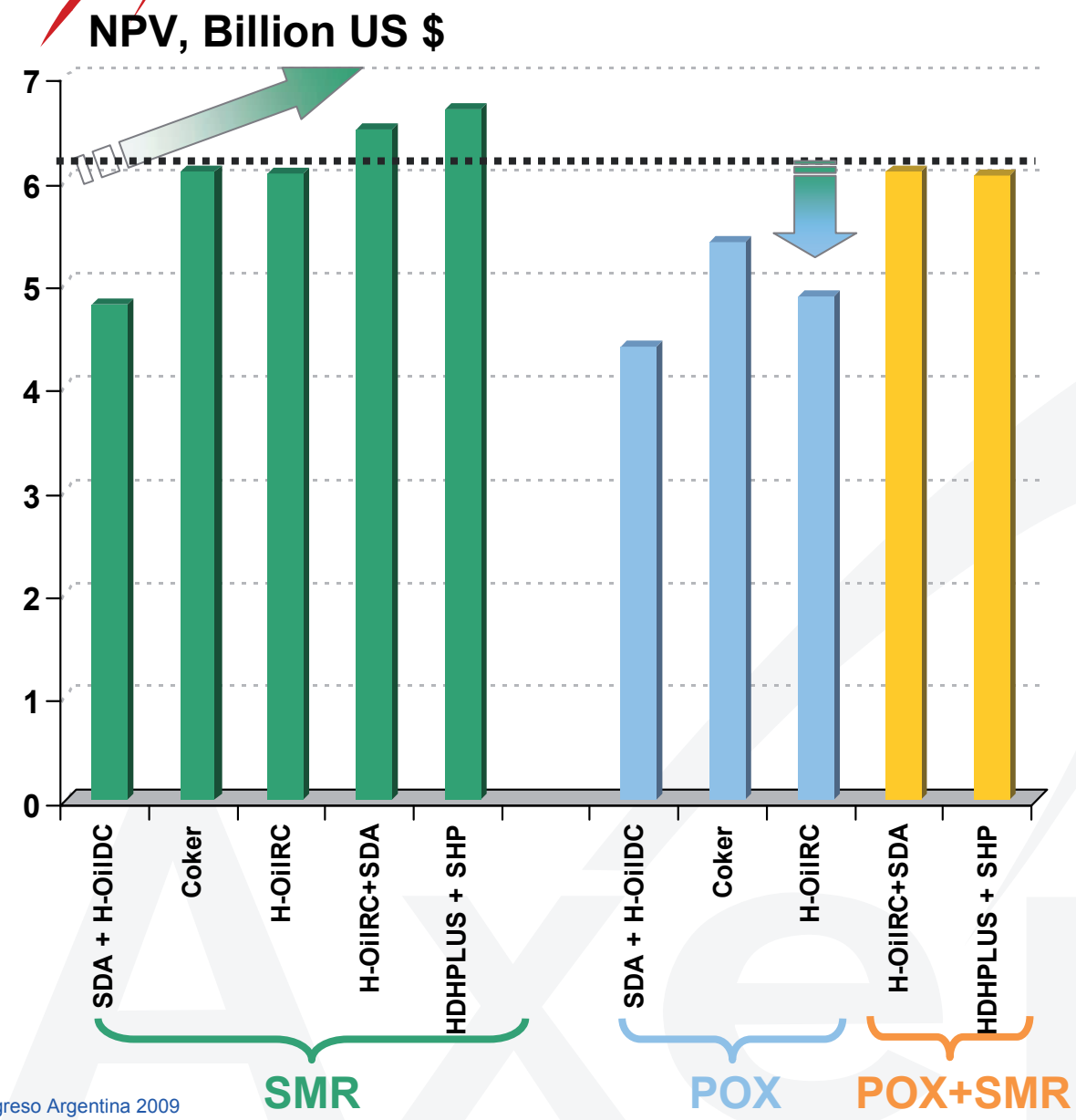
Product Revenues 2007 Scenario – Base Case

US $/bbl Feed (discounted values)



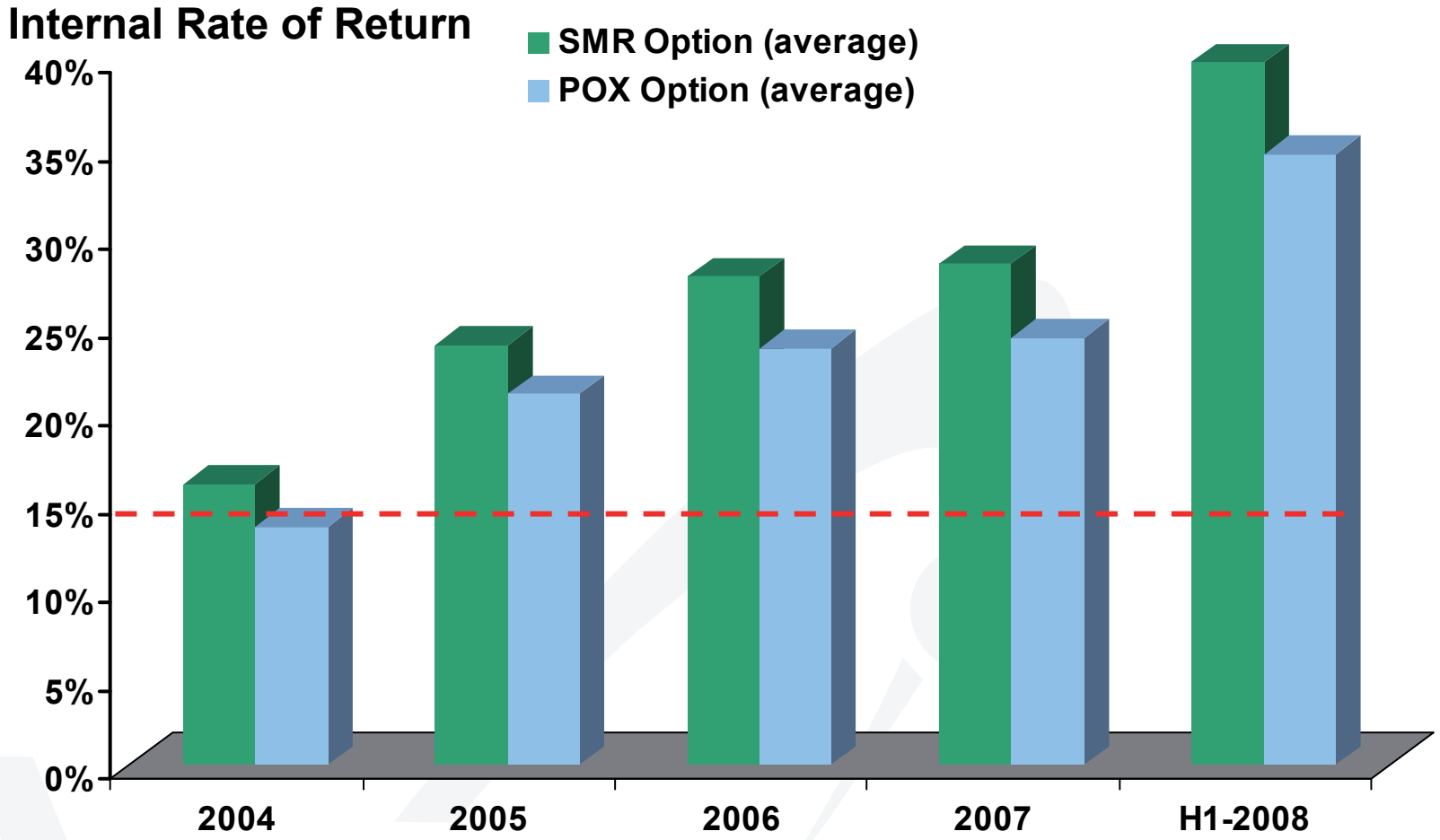
- Product revenues mainly related to liquid yields
- SMR & POX options lead to equivalent product revenues except for H-Oil$_{RC}$ based scheme

Economic Results – NPV
2007 Scenario – Base Case



- NPV related to product revenues i.e. liquid yields
- With natural gas price @ 7.0 US $/MMBtu POX option provides lower NPV

Average IRR since 2004
SMR vs. POX Options – 2007 Scenario



	2004	2005	2006	2007	H1-2008
WTI (US $/bbl)	41	56	66	72	106
Nat. Gas (US $/MMBtu)	5.9	8.8	6.7	7.0	9.5

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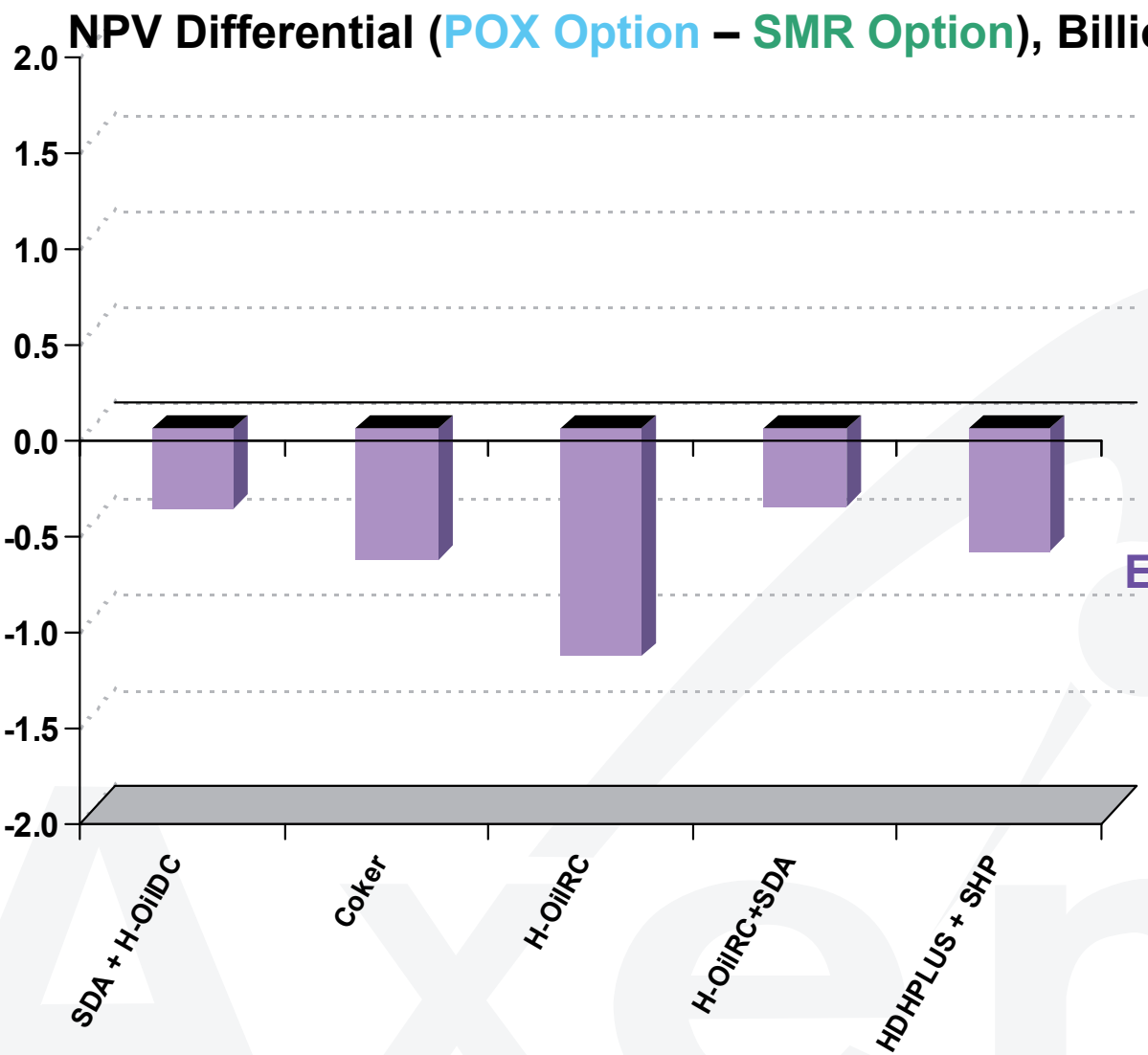
- **Sensitivity studies**

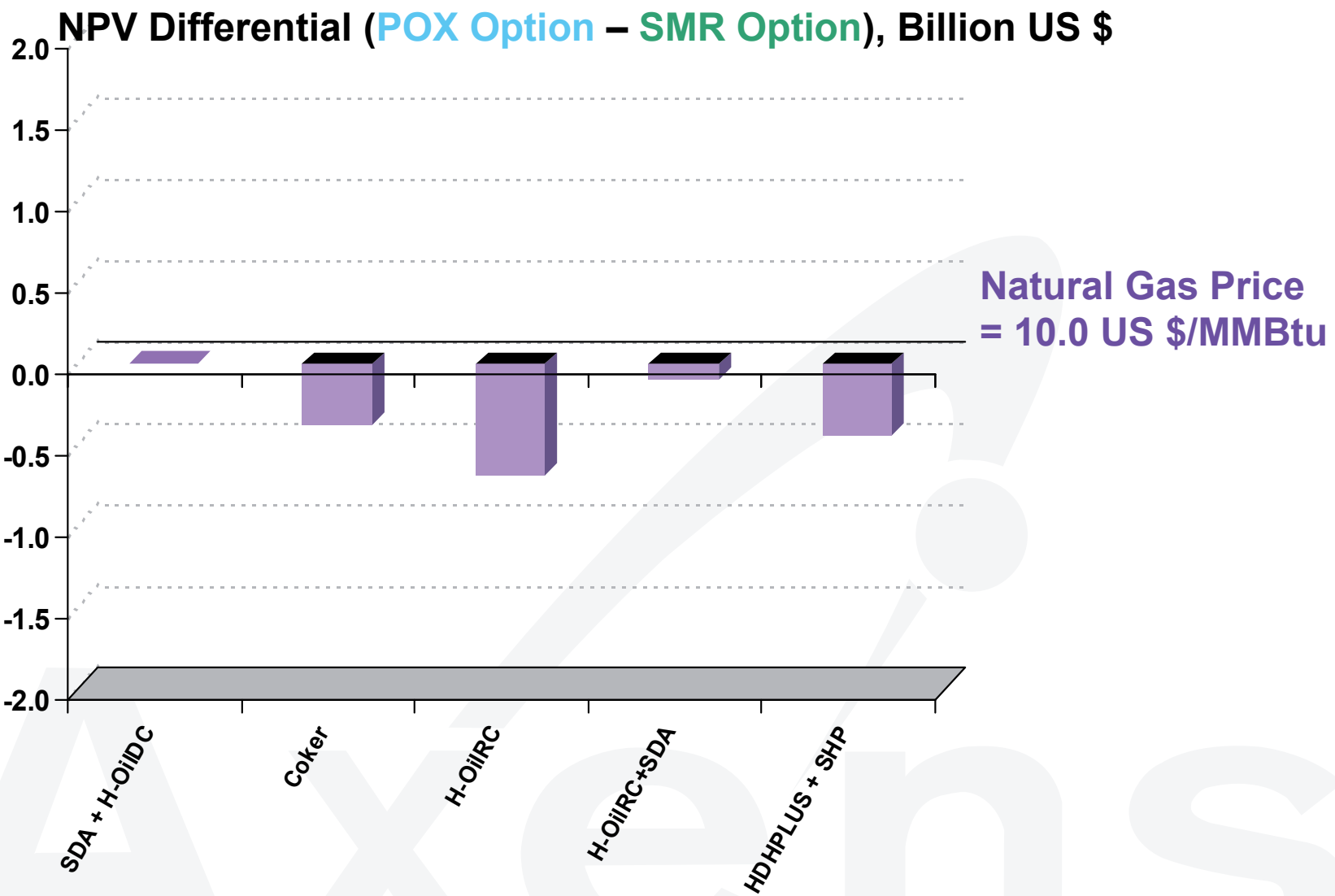
Natural Gas Price Sensitivity
NPV – 2007 Scenario – Base Case



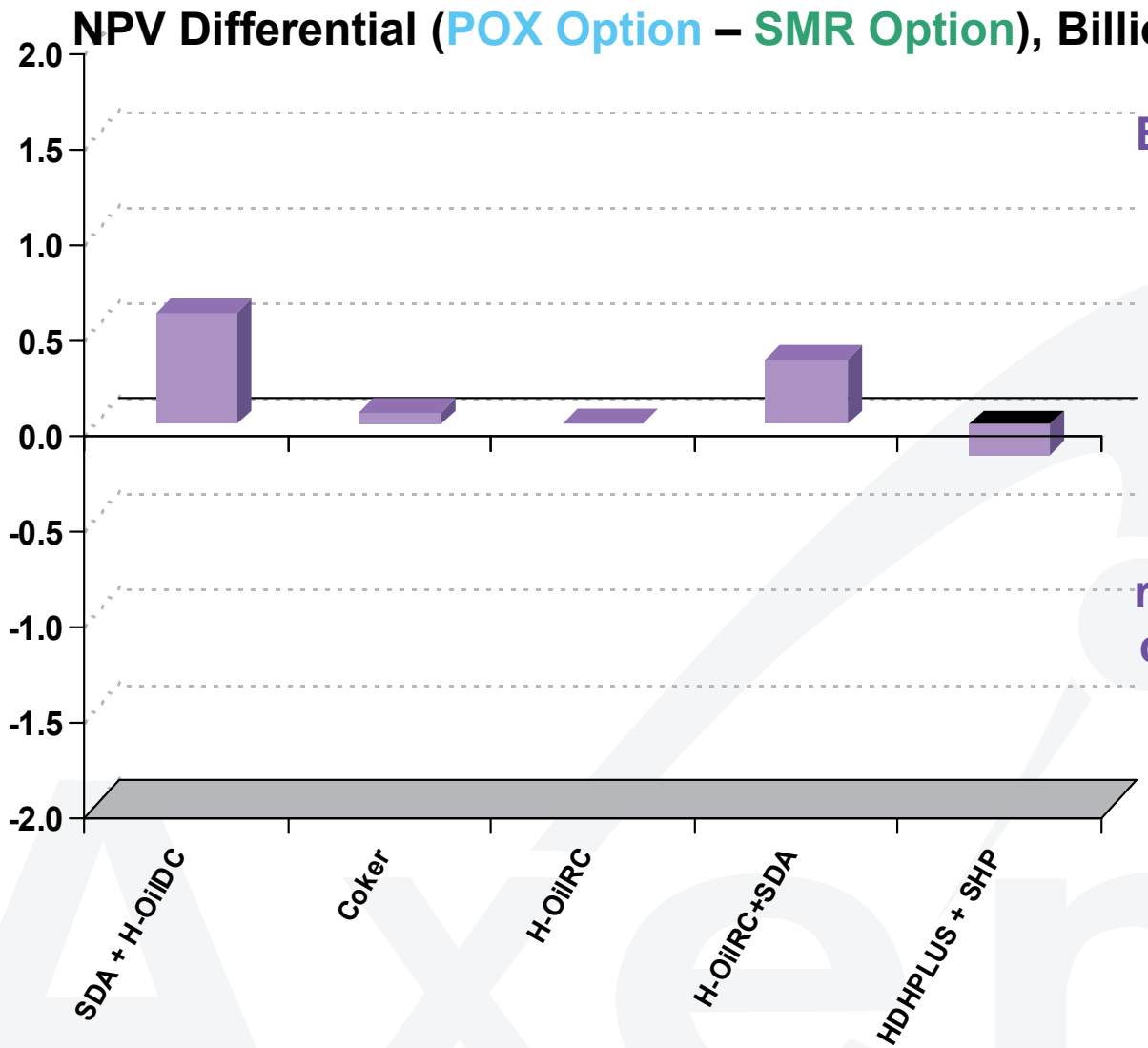
Base Case Natural Gas Price = 7.0 US $/MMBtu

Economics favor SMR option

Natural Gas Price Sensitivity
NPV – 2007 Scenario



Natural Gas Price Sensitivity
NPV – 2007 Scenario

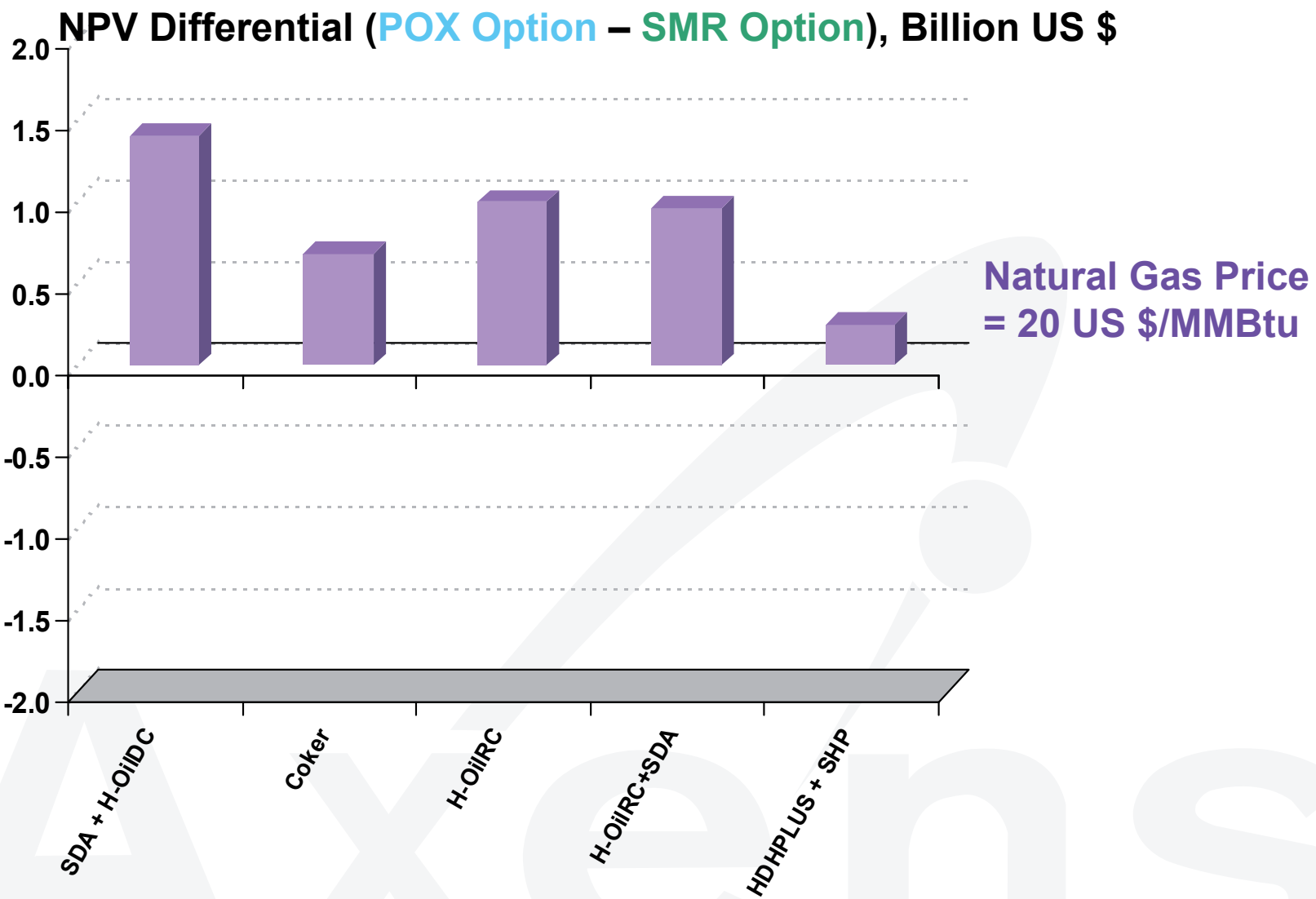


Economics favorable for POX option

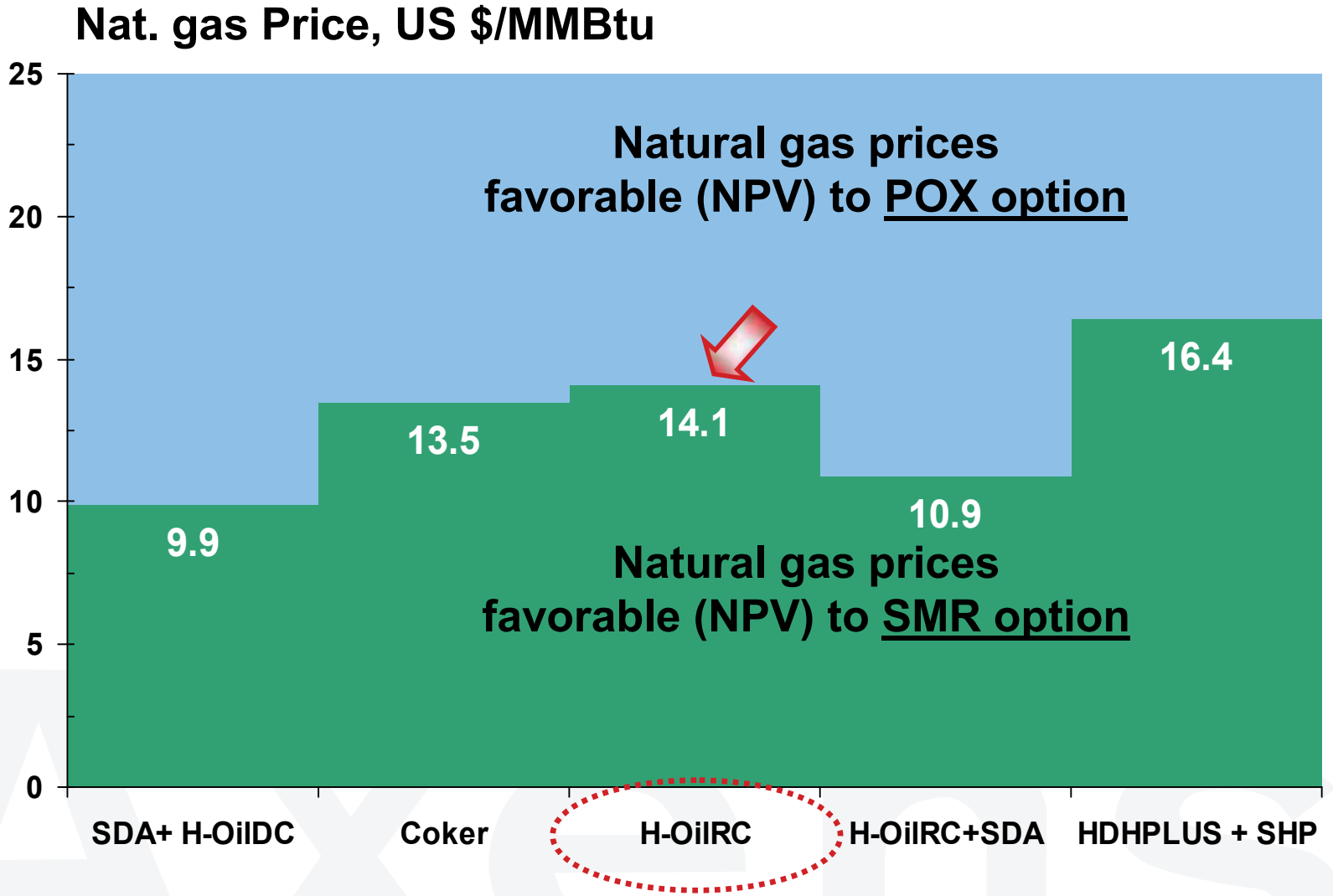
Natural Gas Price = 14.1 US $/MMBtu

Breakeven point reached for 4 of the 5 conversion schemes

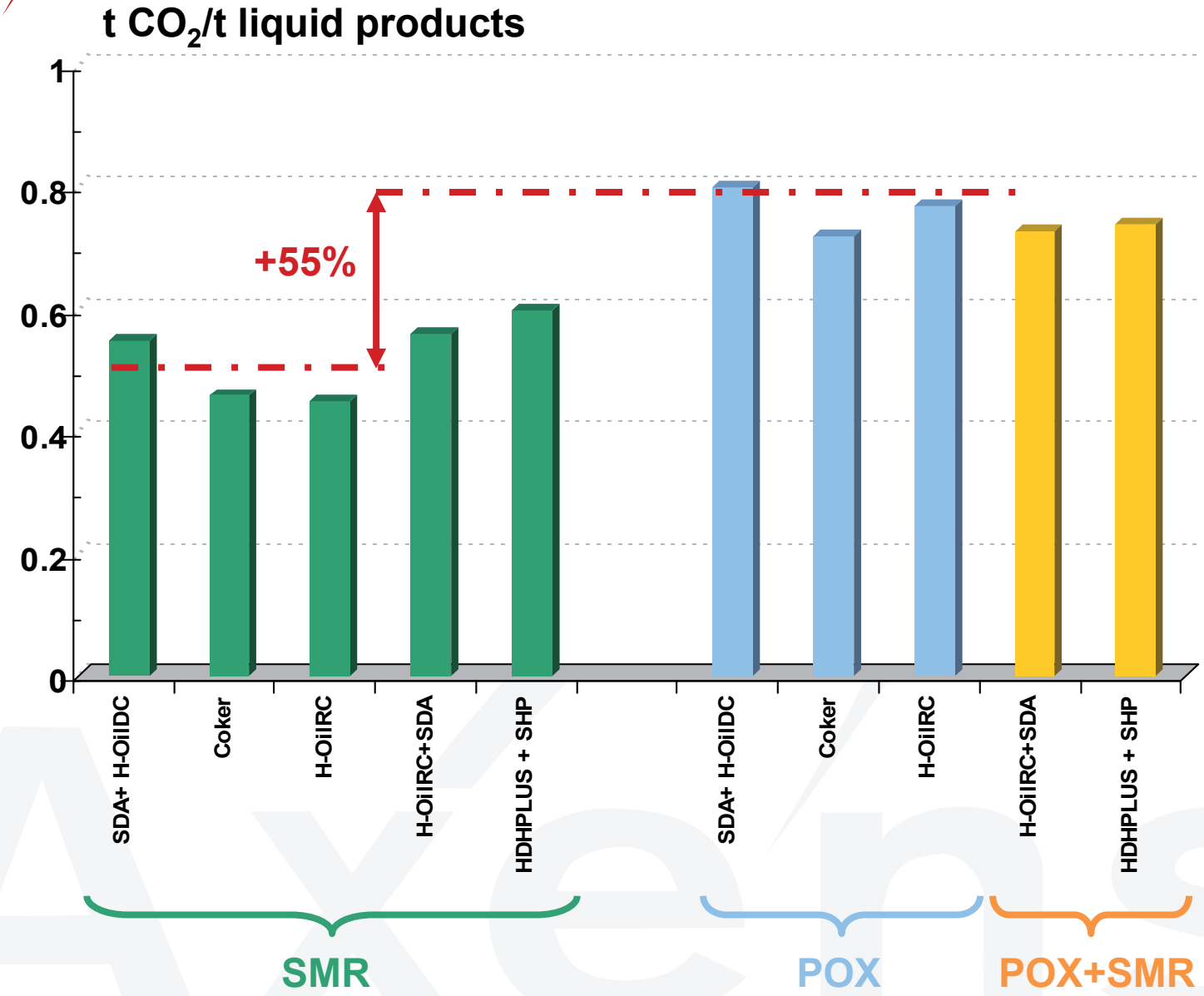
Natural Gas Price Sensitivity
NPV – 2007 Scenario



2007 Scenario - SMR vs. POX Options Breakeven Natural Gas Price for NPV



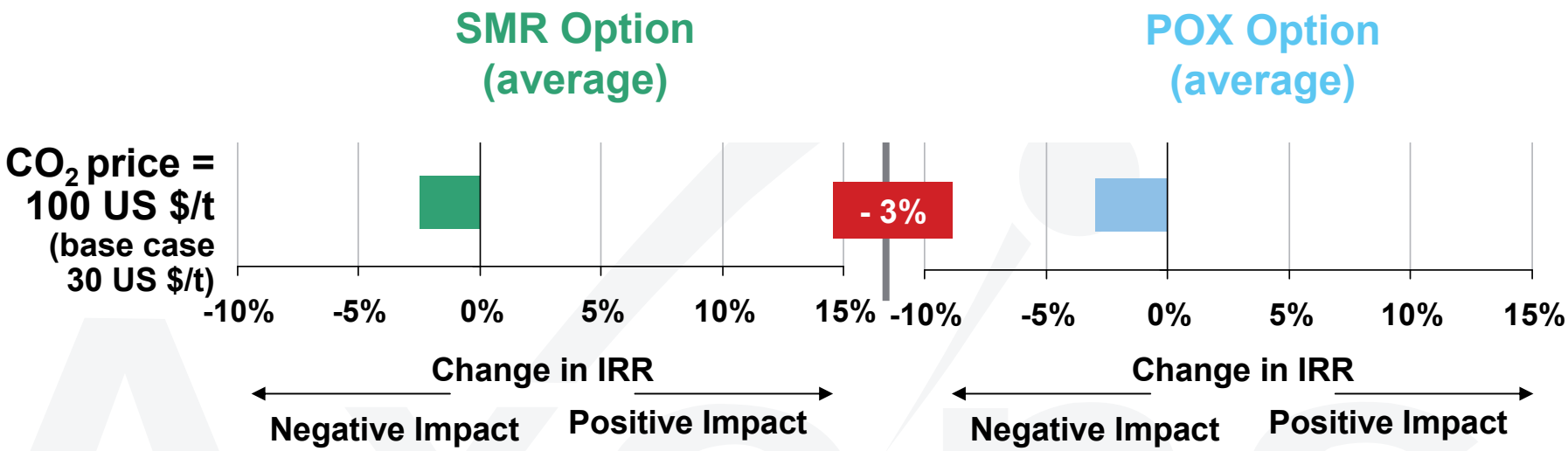
CO_2 Emissions at the Upgrader + Refinery Gates



Sensitivity Studies 2007 Scenario

SMR Option (average)

POX Option (average)



Conclusion

- **Since 2005, all options studied are profitable (IRR > 20%)**
- **Conversion schemes' NPV ranking is closely linked to conversion levels & liquid throughputs**
  - **the higher conversion & liquid throughputs, the higher the NPV**
  - **H-Oil$_{RC}$+SDA and HDHPLUS+SHP are the most profitable schemes…**

    …but CAPEX is higher

- **H_2 production options**
  - **For isolated locations, production of H_2 via residue gasification is inevitable**
  - **If natural gas is available, its cost is crucial**