Unlocking Heavy Oil Value
Challenges and Technologies

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April 12, 2012 • Bogota

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Agenda

- **Relevance of Heavy and Extra Heavy Oil Resources in Latin America**
- **Drivers of heavy and extra heavy oil in the region**
- **Enabling Technologies and their environmental impact**
- **Infrastructure, Costs and Fiscal regimes**

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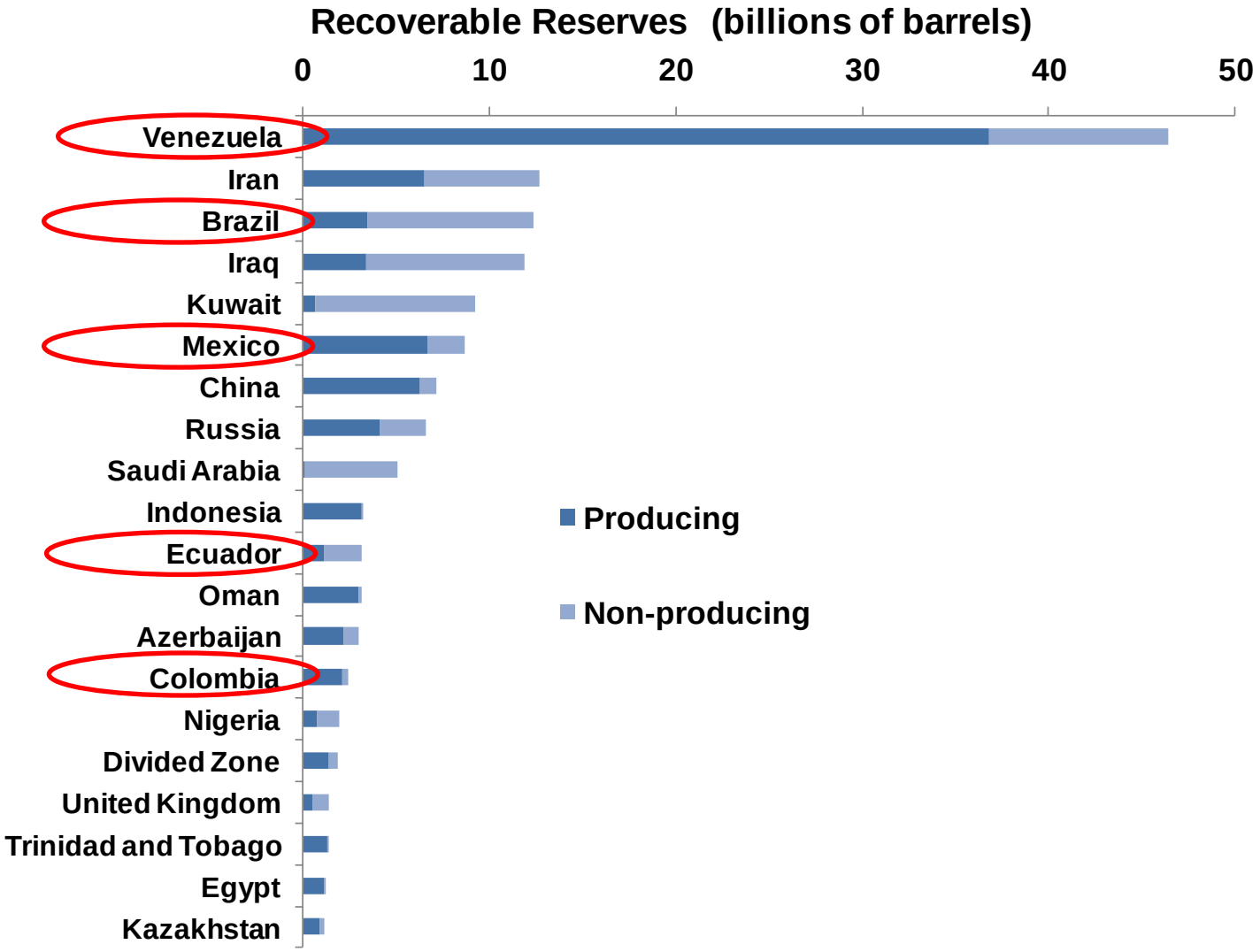
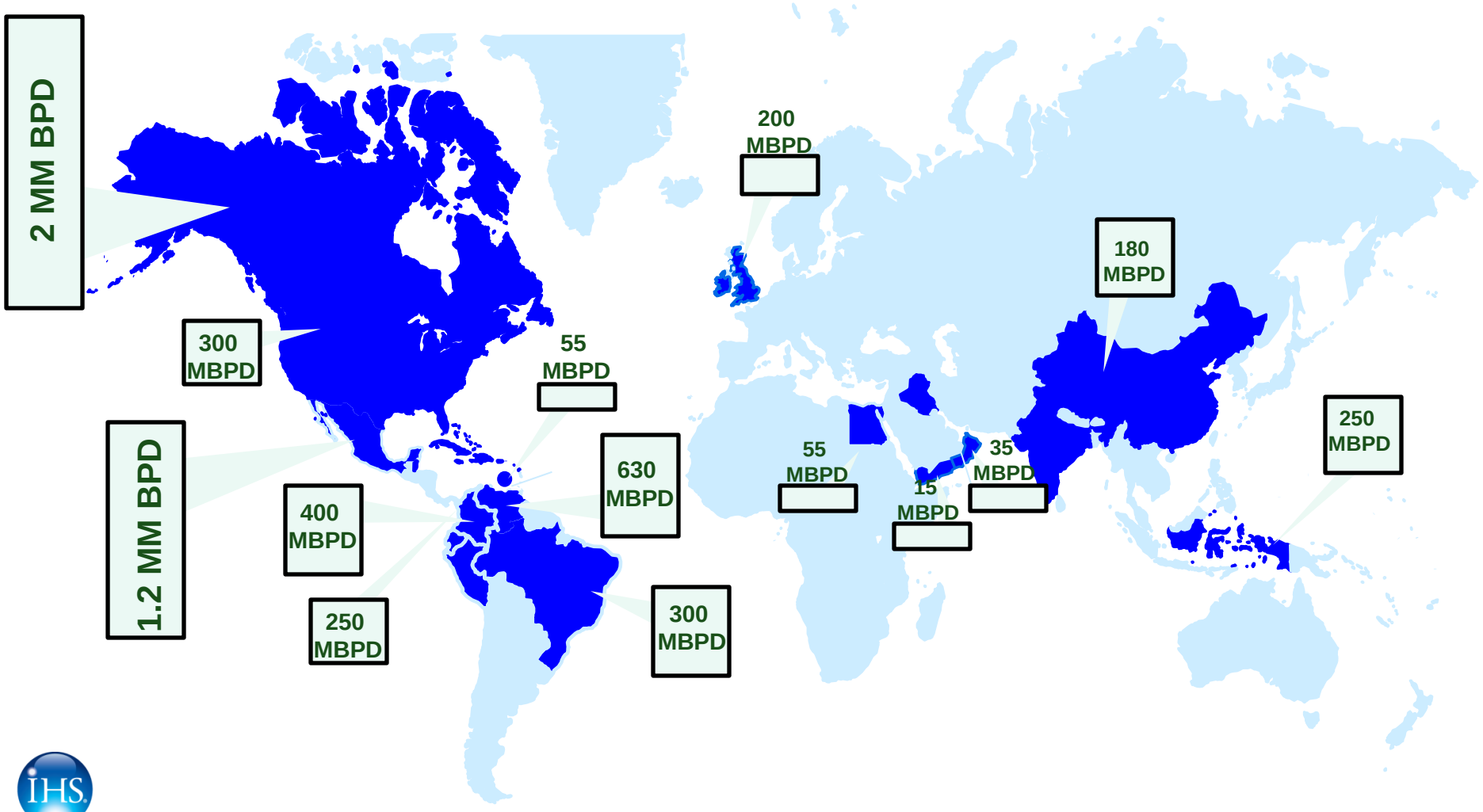
A Significant Share of Heavy Oil Reserves Are in Latin American Countries



Source: IHS CERA.

Most Relevant Heavy Oil Producers are Also in Latin America



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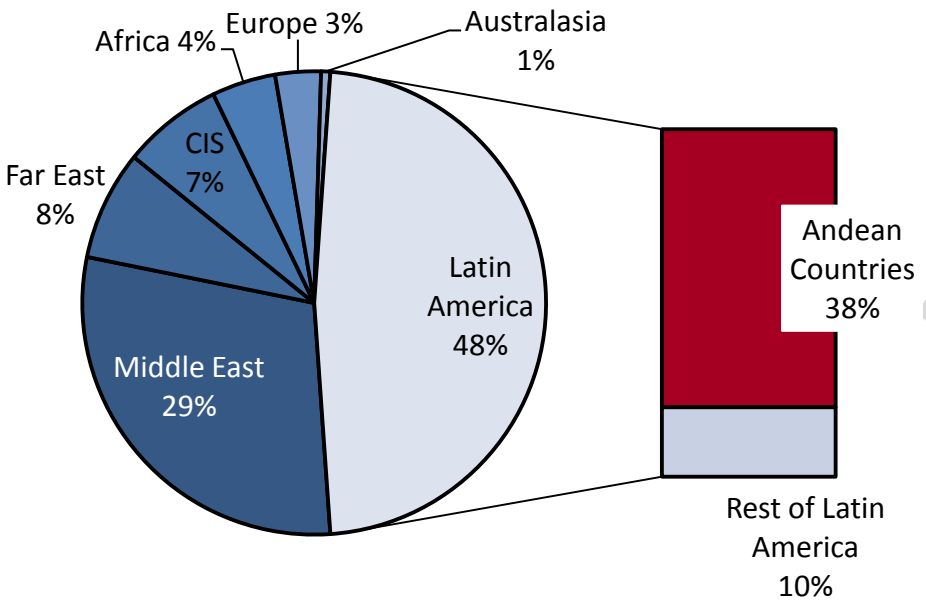
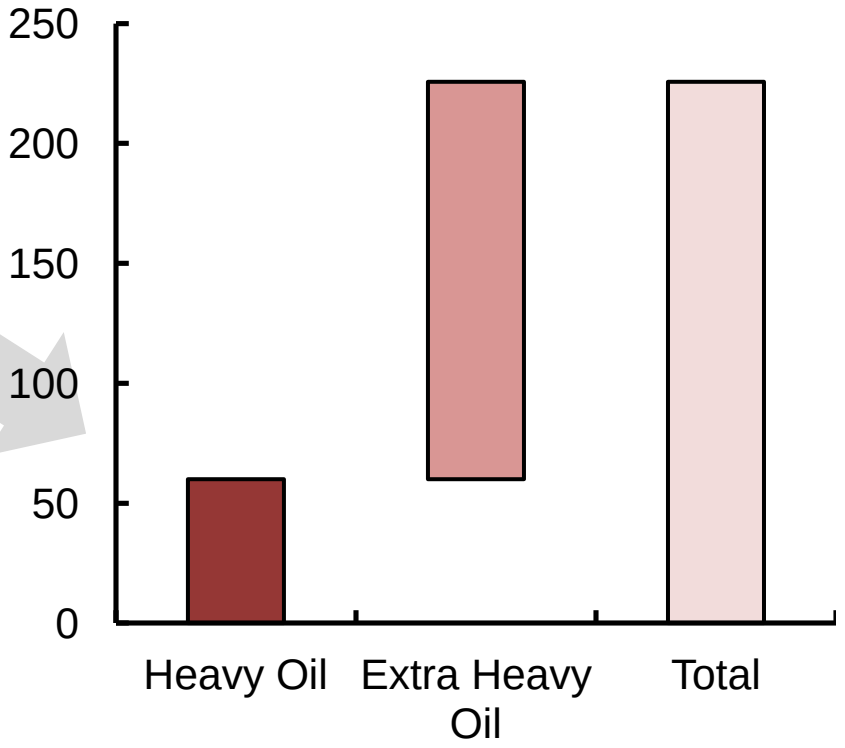
Andean Countries Dominate Heavy Oil Resources in the World

World Heavy Oil 2P Remaining Recoverable Reserves* (184 Billion Barrels)



The potential is even larger when Extra Heavy Oil Reserves are included
230 Billion Barrels = 76% of Reserves



•Includes Oil with API grades from 22 to 12 API
** Extra heavy oil are Oil with API grade equal or below 11

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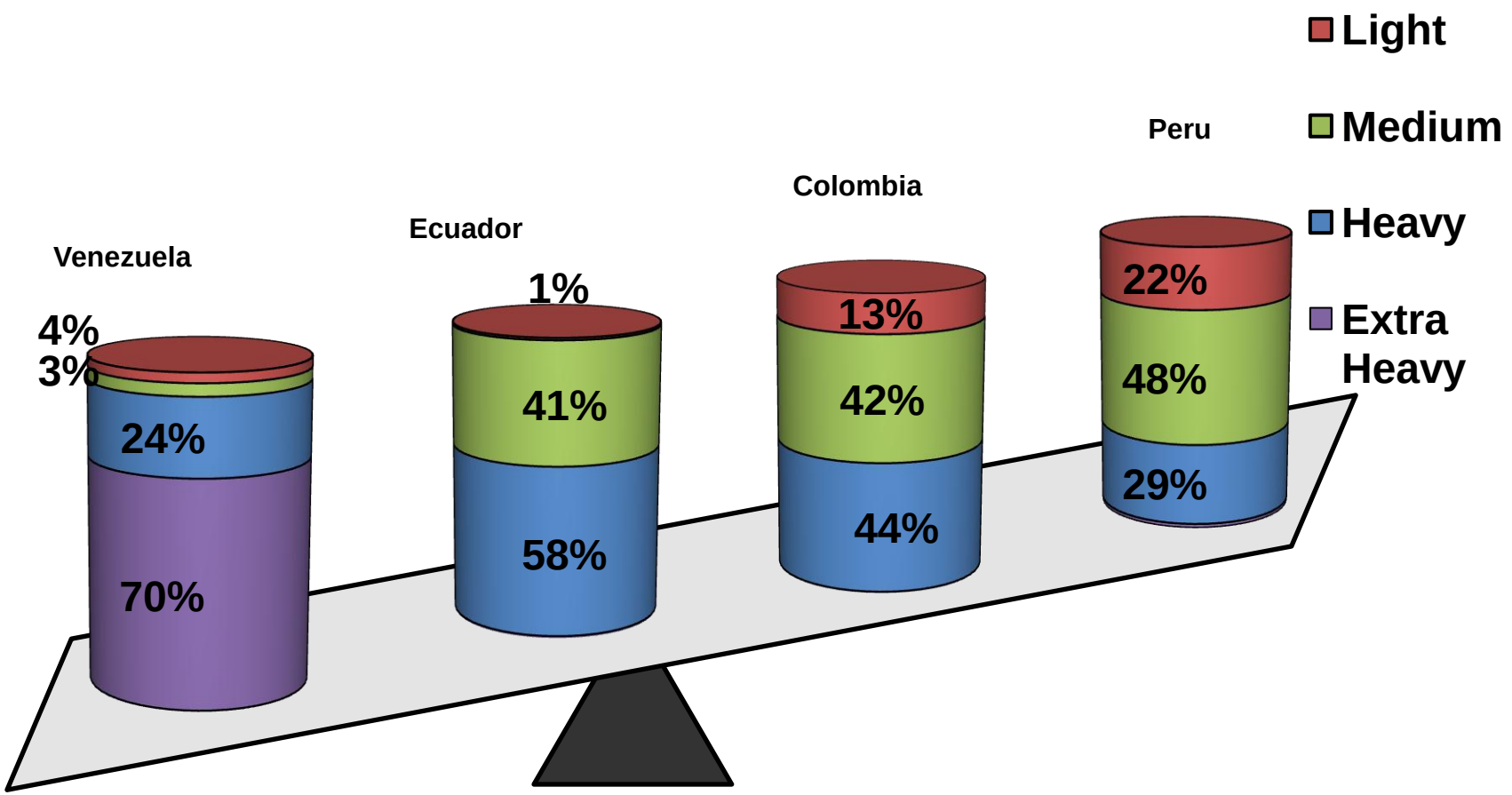
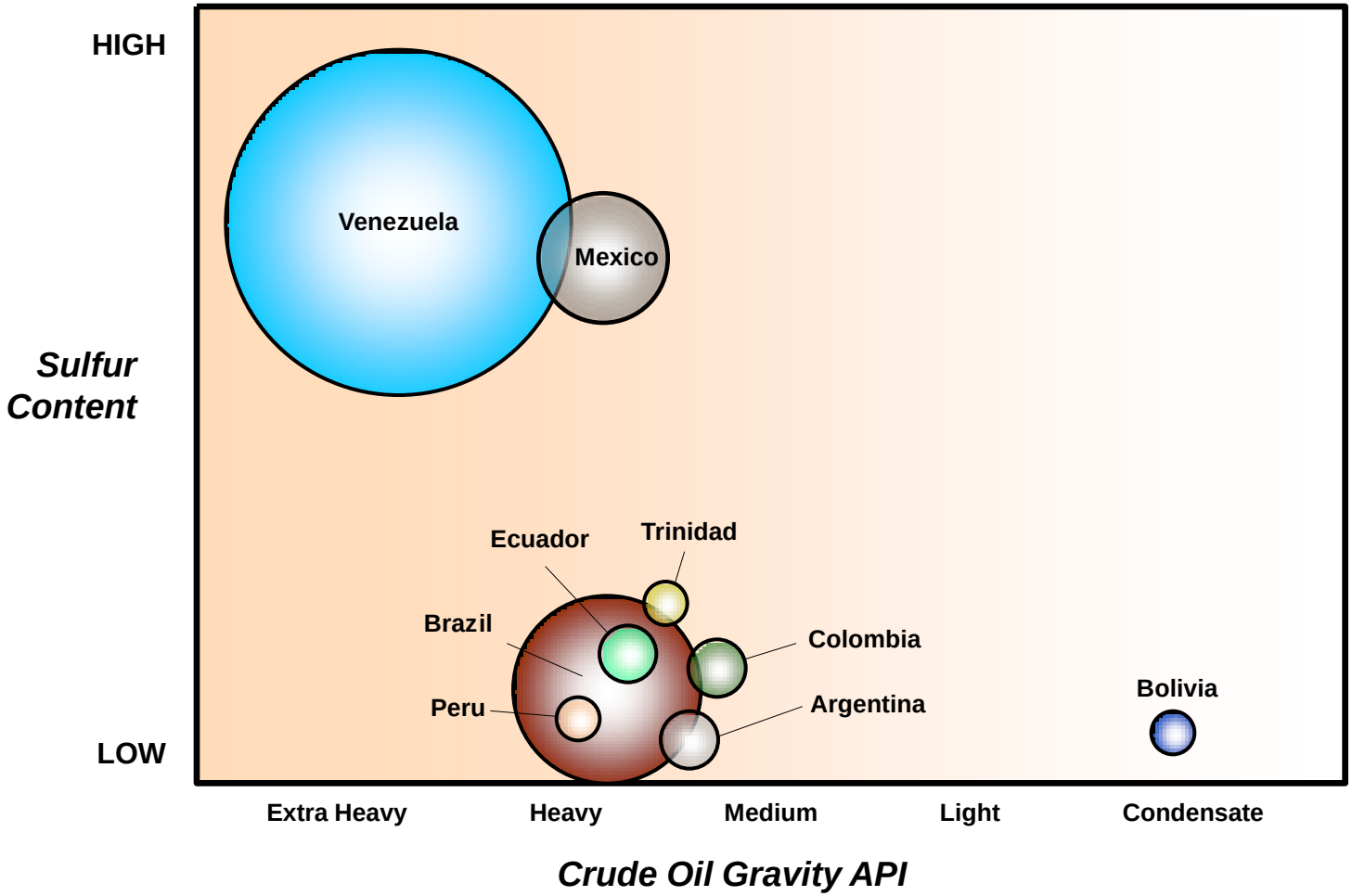
Most of the Remaining Oil Reserves in the Region are Heavy or Extra Heavy, but some countries are lighter than others

Composition of Remaining Oil Recoverable Reserves according to API type



Latin America Oil Resource Base Characteristics (weighted average)



Source: Cambridge Energy Research Associates.
Note: Relative amount of crude oil resources are shown by circle

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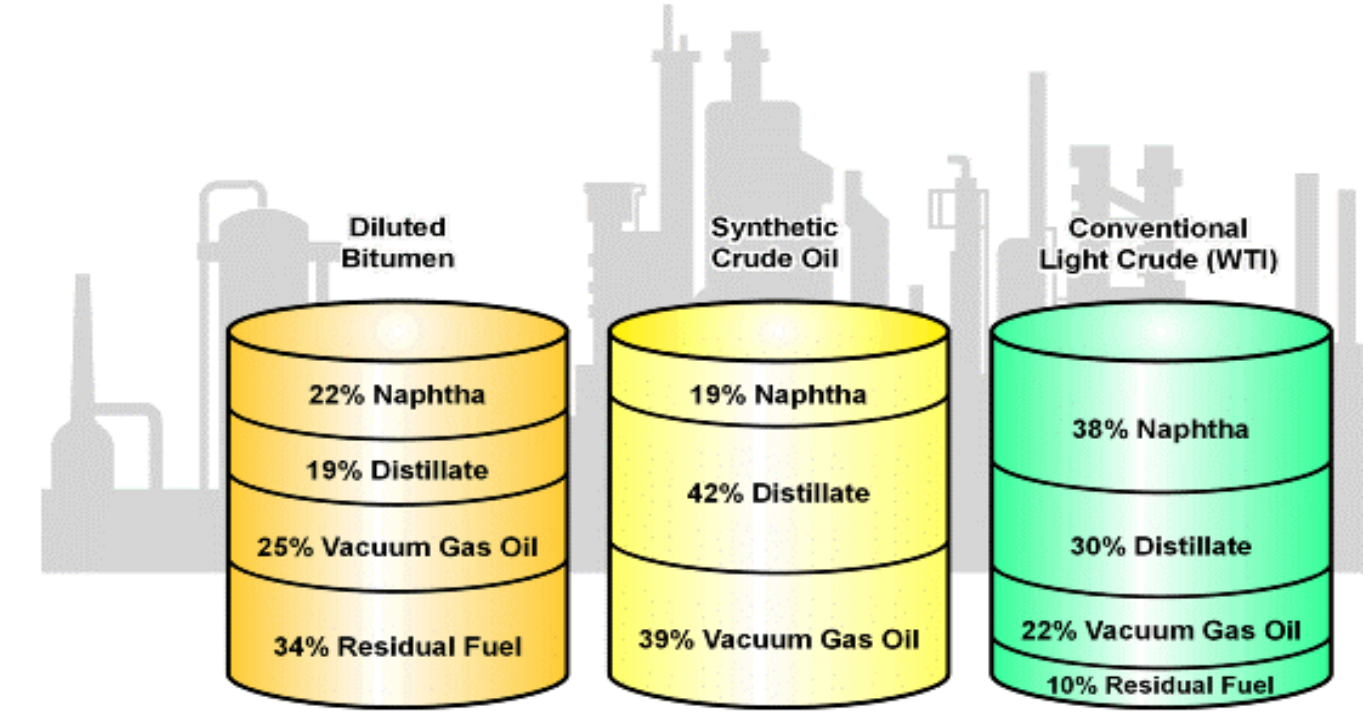
EHO Must be Industrially Transformed Before It Can Be Marketed Competitively....



ADVANTAGES	• High margin feedstock	• Premium low-sulfur feed	• Industry benchmark
DISADVANTAGES	• Expensive conversion capacity required	• Gasoline yield low	• Expensive feedstock • Diminishing supply

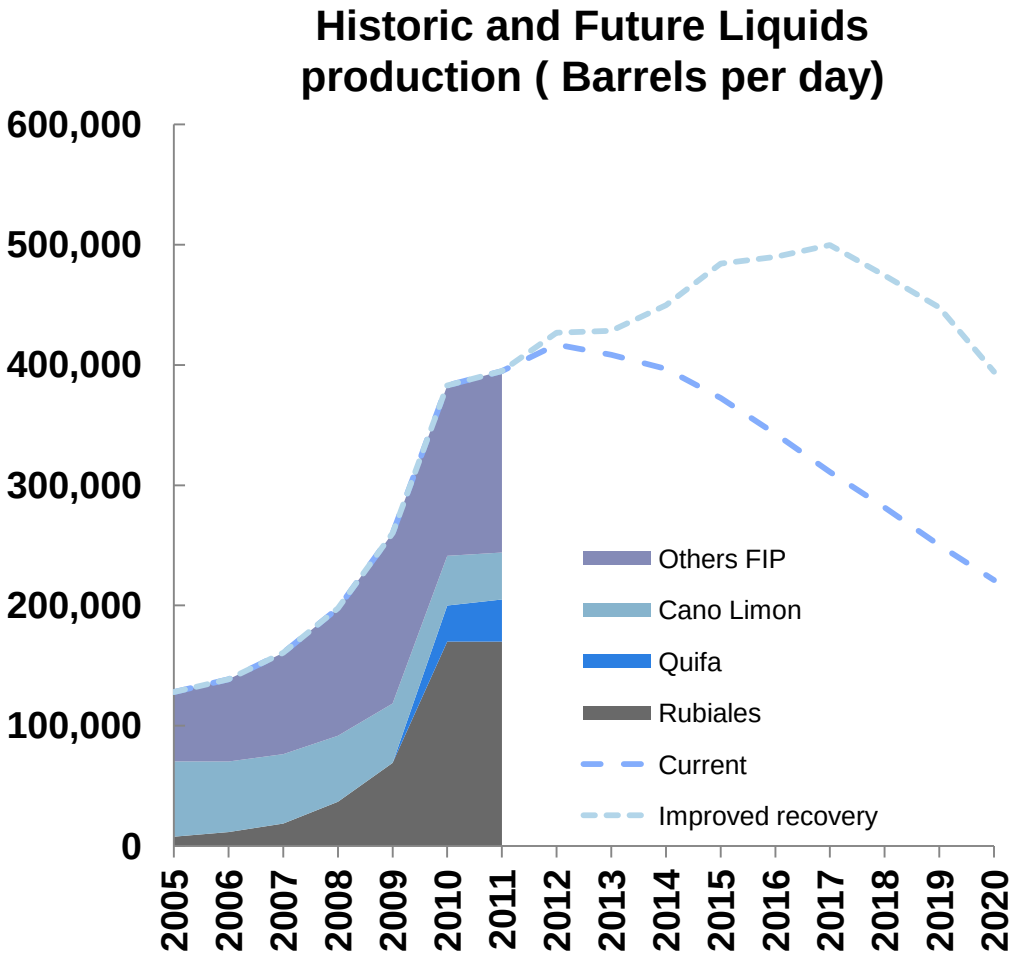
Source: Cambridge Energy Research Associates.
60713-11

Where Are Heavy and EHO Opportunities in the Region?

The cases of Colombia and Venezuela

Colombia Llanos Basin: Historic and Future Production

- The production in the sub-basin is rising pushed by expansion projects in producing fields like Quifa and Rubiales (Pacific Rubiales).
- **Potential upside in production depends on the recovery factors . Current recovery using cold production and horizontal wells is less than 20%.**
- **Main recent discoveries are Ambar (OOIP 660 MMbbl) , Zircon (OOIP 245MMbbl), Redondo (OOIP235 MMBbl) and Sabanero (OOIP180MMbbl). The actual recoverable reserves will depend on the production approach used. If they reach 40 % recovery rate, 2P recovery could overpass 500 MMbl**
- **Further discoveries and developments in blocks on west side of the basin, close to Venezuelan border will also increase future production(blocks CPE-1 a CPE-8)**



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IOCs and Other Privately-run Companies

North America

Country	Company	Sample Activities and Segments
USA	Chevron	EHO E&P and upgrading, LNG train
USA	Harvest NR	Oil and gas E&P, acquisitions
USA	Shell	EHO exploration, downstream
CAN	PetroFalcon	Oil exploration and services

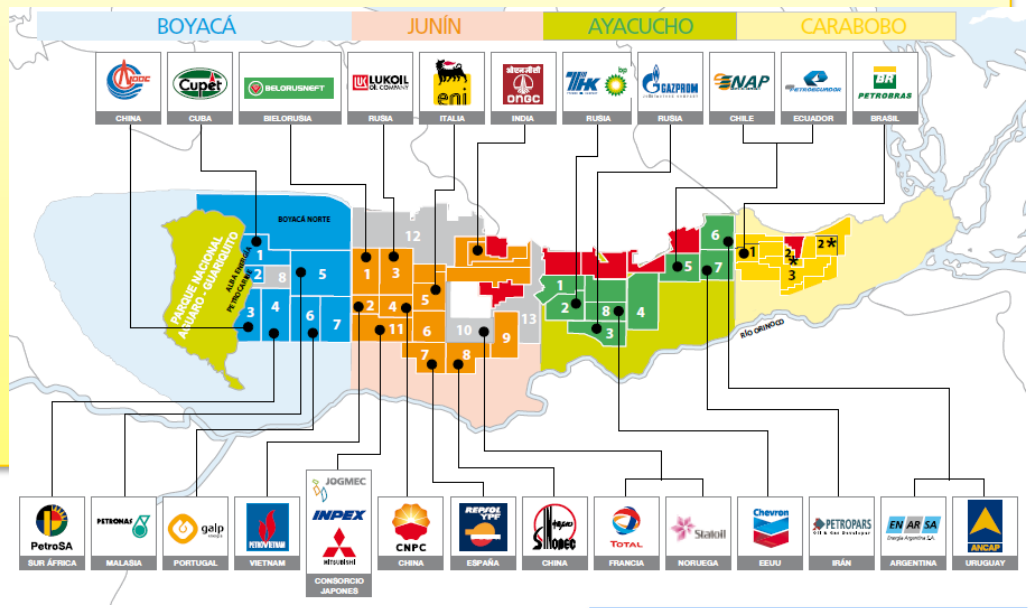
Europe

Country	Company	Sample Activities and Segments
RUS	Gazprom	EHO and gas E&P
ITA	Eni	EHO E&P, LNG train (to be confirmed)
SPA	Repsol-YPF	EHO and gas E&P
RUS	Lukoil, TNK-BP, Surgutneftegas	Part of the Russian Consortium that will develop the Junin-6 project with PDVSA
FRA	Total	EHO E&P and upgrading, gas exploration
FRA	Perenco	EHO E&P and upgrading, gas exploration
FRA	Maurel & Prom	Oil and gas E&P

Asia

Country	Company	Sample Activities and Segments
JAP	Teikoku	Gas E&P
JAP	Inpex, Mitsui, Mitsubishi	LNG train 1
KOR	Kogas	Gas E&P

IOCs Participation in Venezuela's Orinoco Oil Belt:



Sample Regional and Local Players with Presence in Venezuela:

Country	Company	Sample Activities
ARG	Pluspetrol	E&P
VEN	Petrocumarebo	Oil and gas E&P
VEN	Ypergas	Gas development
VEN	Suelopetrol	EHO E&P and upgrading
VEN	Inelectra	Tech services
COL	Ecopetrol	E&P

Venezuela's Oil & Gas Competitive Enrivonment

The Venezuelan government has pressed on private players' interests by increasing PDVSA's stakes in the majority of E&P projects. It has therefore pushed for the migration of contracts, and in some cases, the expropriation of private-owned assets. Some of the major IOCs have filed arbitration claims against Venezuela at the ICSID and ICC in search for appropriate compensation.

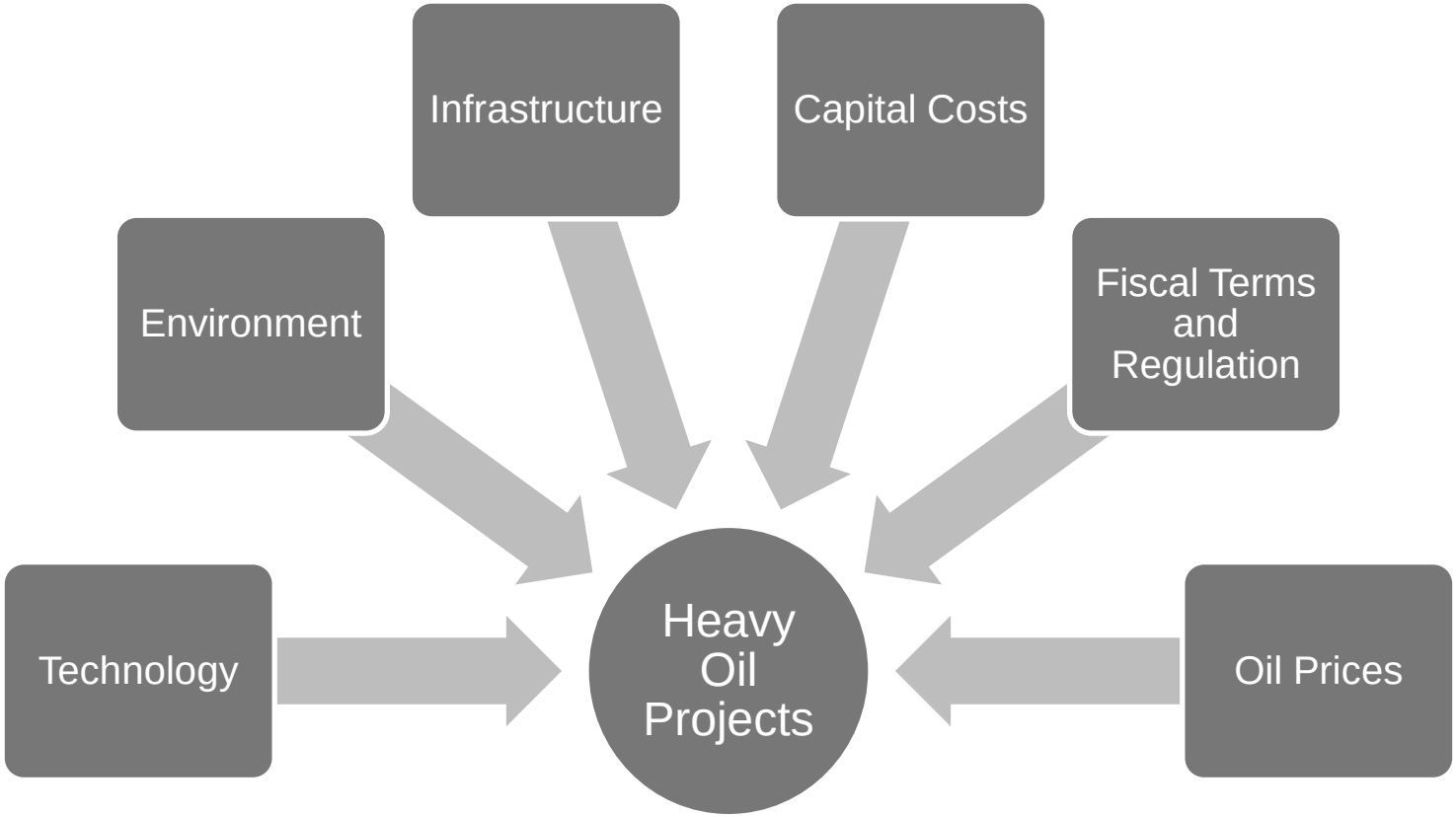
Source: IHS CERA, IHS Energy-EDIN, IHS Global Insight, IHS Herold, PDVSA.

*Players lists are non-exhaustive. Listed players include major shareholders/operators according to net recoverable oil and gas reserves.

Main Heavy Oil Projects Driving Future Capacity Growth in the Region (II)

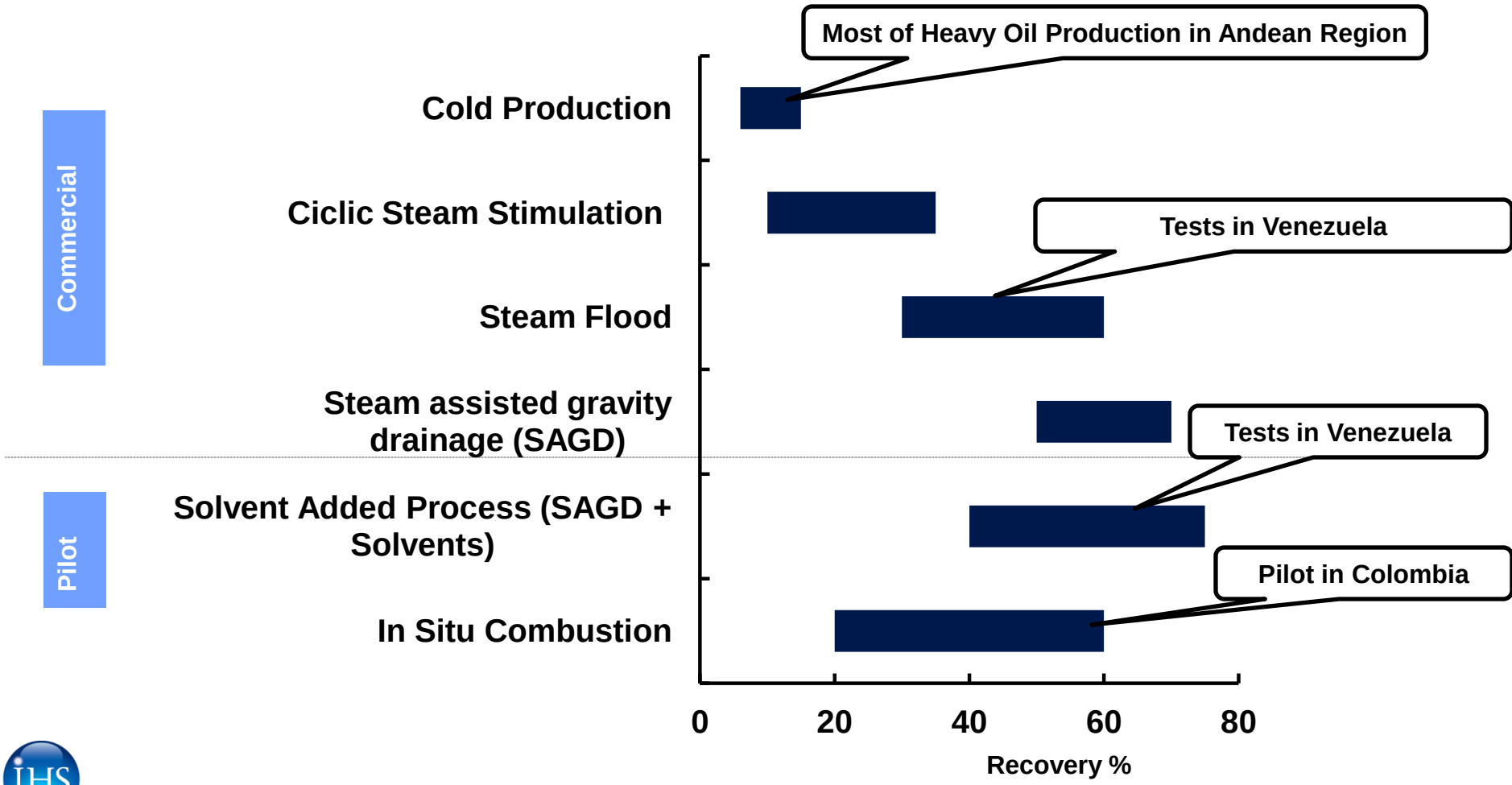
Project	Country	PDVSA Partners	Start Date* IPP	Additional Capacity (kbd)
Carabobo 1	Venezuela	Repsol YPF ONGC Videsh Petronas Indian Oil Oil India Ltd	2015	400
Carabobo 3	Venezuela	Chevron Mitsubishi Inpex Suelopetrol	2015	400
Junin 4	Venezuela	CNPC	2016	400
Junin 6	Venezuela	Surgutneftegas Rosfnet Gazprom BP	2015	450
Junin 5	Venezuela	ENI	2014	240
Junin 2	Venezuela	Petrovietnam	2013	200

What are the Challenges and How Can They be Best Managed?



Technologies Driving EHO and HO Development

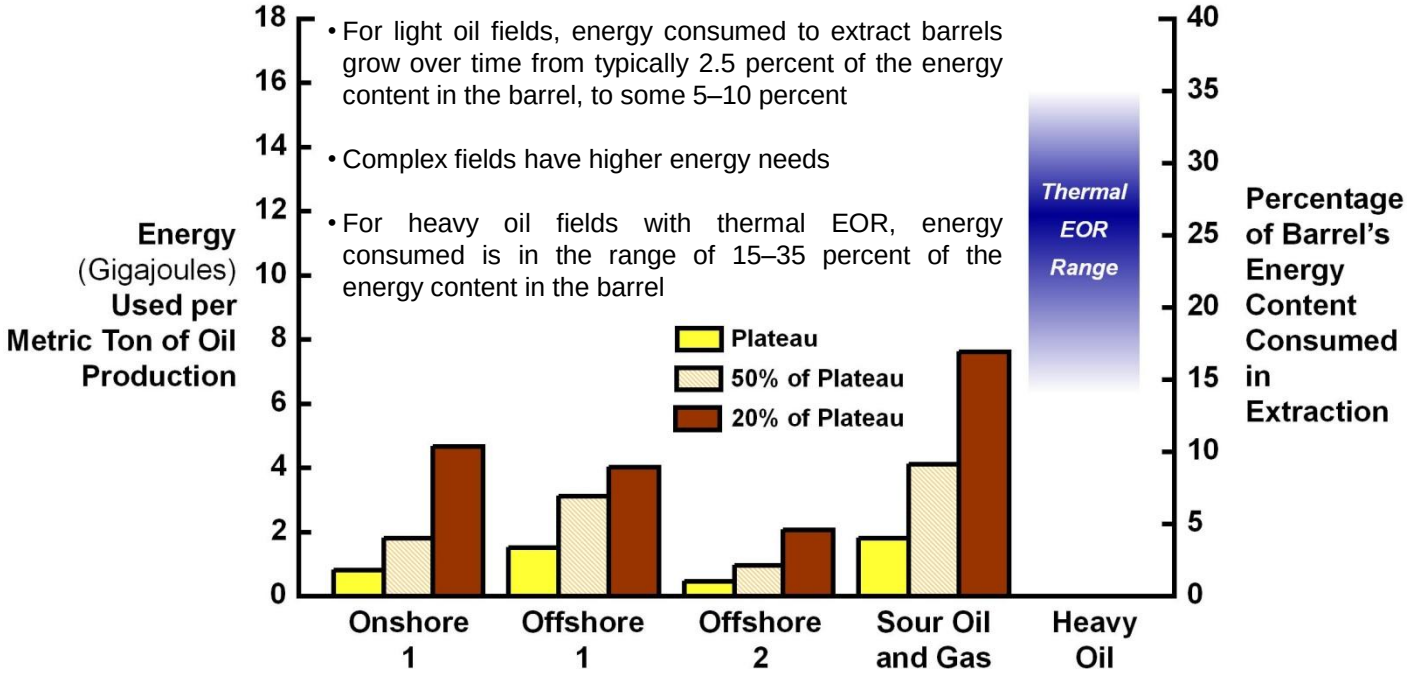
Technology has a great upside potential in unlocking reserves in the region



Source: NPC Global Oil and Gas Study (2007); Pacific Rubilaes (2011)

Oilfield Energy Intensity Varies by Field Type and Increases Multi-fold During Field Life

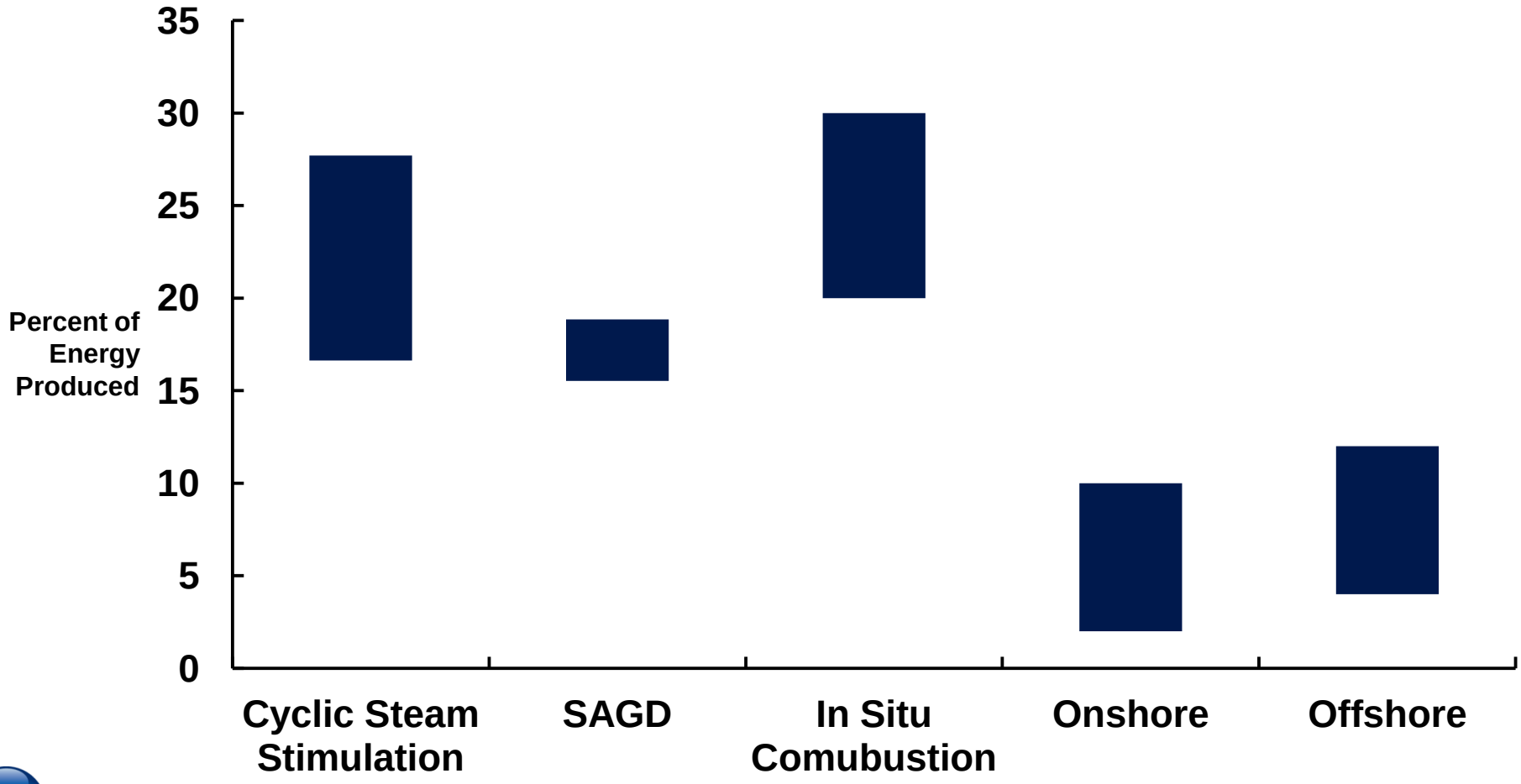
Oilfield Energy Intensity Trends by Field Type and Maturity



- Thermal EOR projects require steam and power and have the highest energy intensity of all the segments.

- Thermal Processes are associated predominantly with the production of heavy oils (e.g. in California, Venezuela, Indonesia, and Kuwait) and oil sands (e.g. in Canada). In specialized situations, these techniques are occasionally applied to help extraction of light oils.

Heavy Oil Technologies Energy Consumption



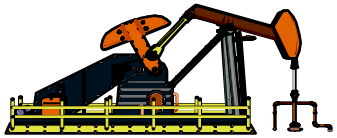
Source: NPC Global Oil and Gas Study (2007), Nimin Energy Corporation (2011), IHS CERA

Hot Producing and Upgrading EHO Consumes a Significant Amount of Natural Gas

Producing

1,200,000 BPD of Synthetic Oil requires at least 1.8 Bcfd of Natural Gas

1500 Cubic feet Gas per Bbl EHO

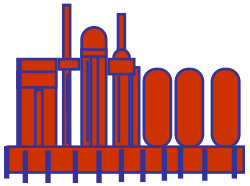


EHO 8.5Deg API + HOT

450 Cubic feet Gas per Bbl Syncrude

Hydrogen Manufacturing

80 Cubic feet Gas per Bbl Syncrude

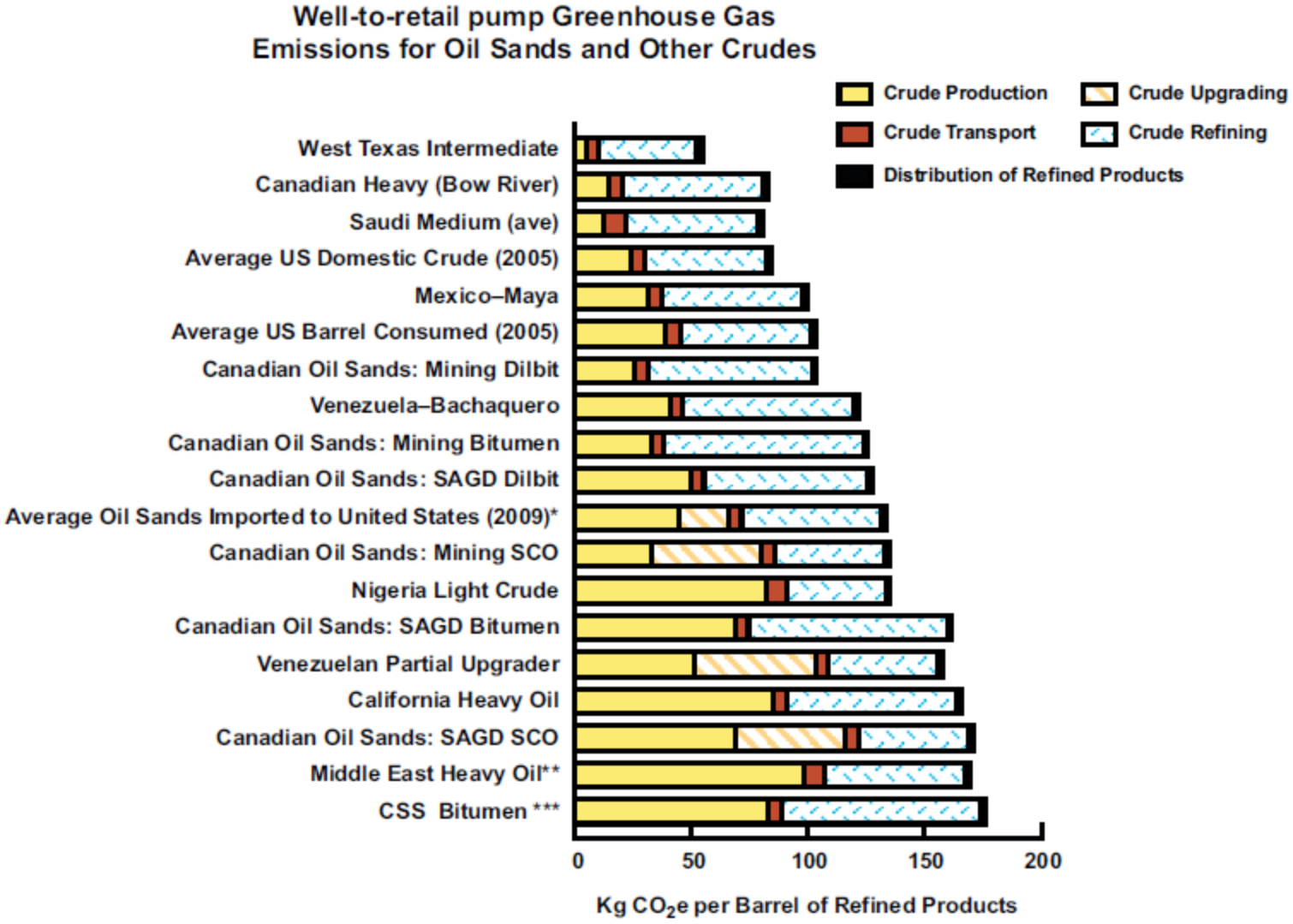


Delayed Coking + *MHC*

2,000 Cubic feet / Bbl SCO

= 1.8 Bcfd

The production of Heavy Oil tends to have higher GHG emissions



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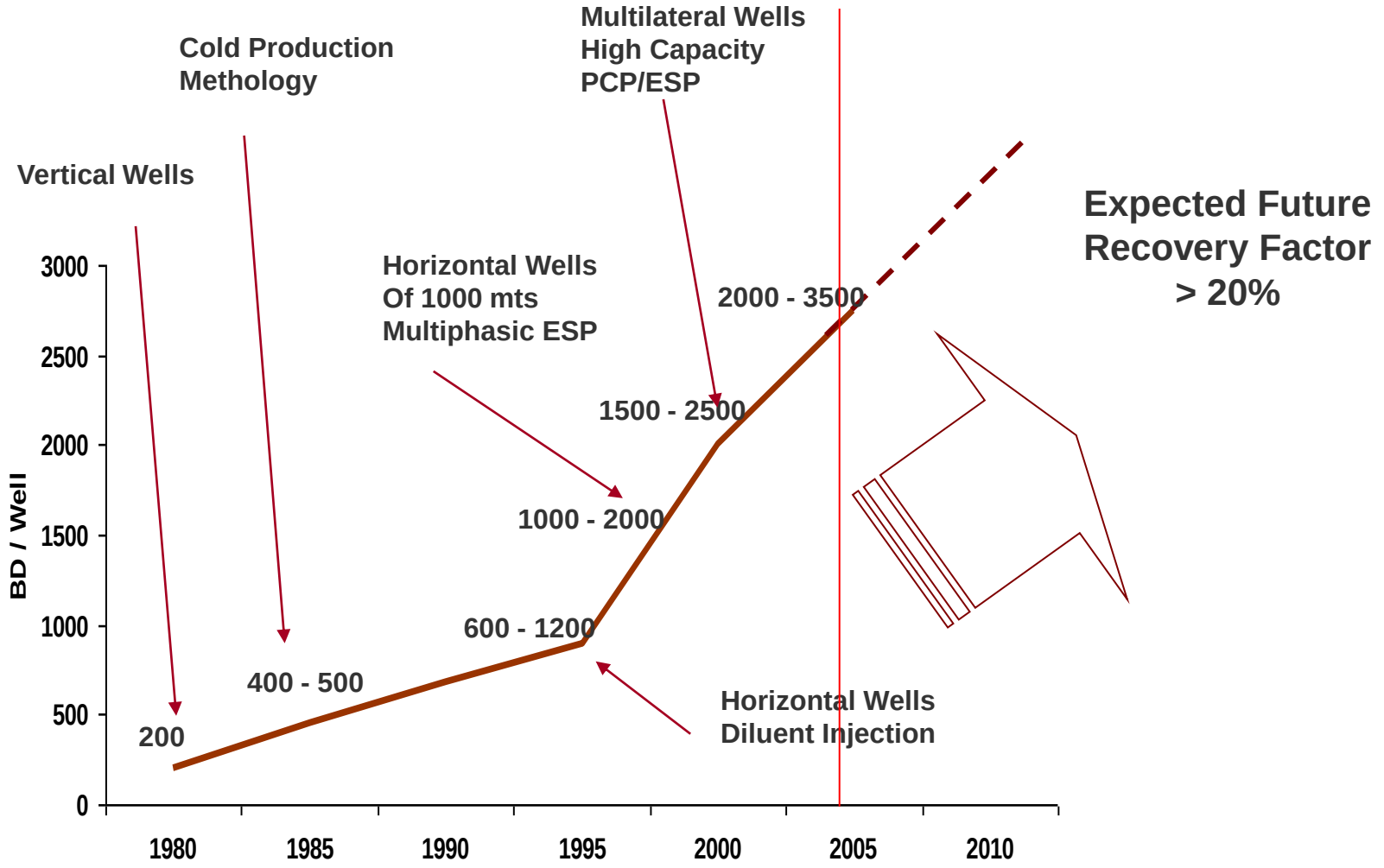
EHO Production Technique: Well Productivity Evolution



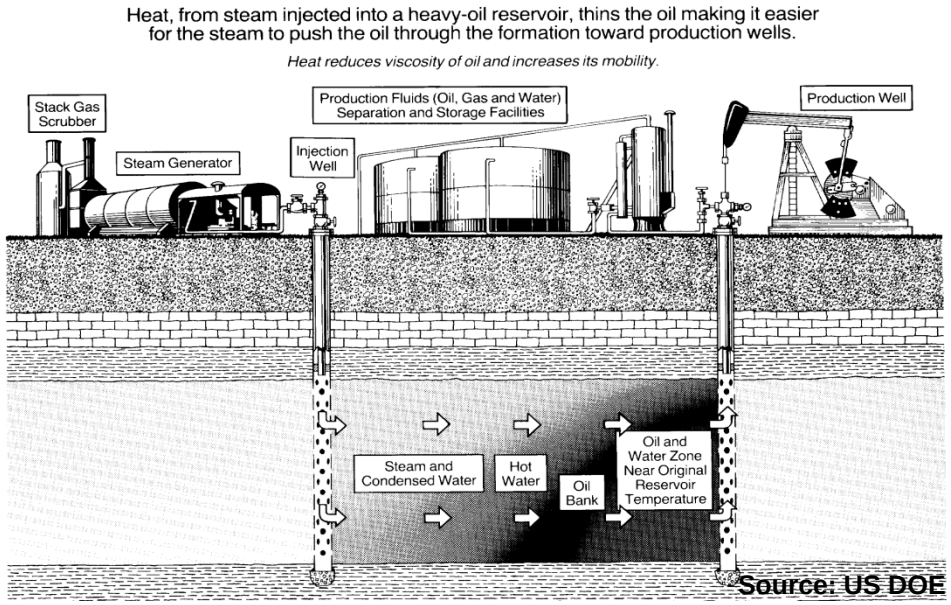
Thermal EOR: Steamflooding

Description of Technology:

"Recovery by steamflooding is commonly used in heavy-oil reservoirs containing oil whose high viscosity is a limiting factor for achieving commercial oil-producing rates. It has also been considered, however, as a method for recovering additional light oil. High-temperature steam is continuously injected into a reservoir. As the steam loses heat to the formation, it condenses into hot water, which, coupled with the continuous supply of steam behind it, provides the drive to move the oil to production wells.

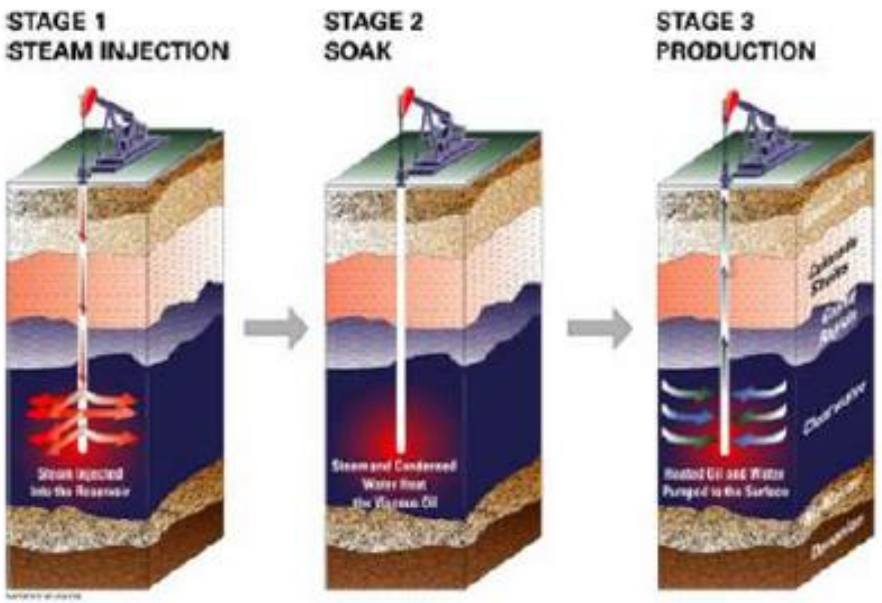
An added bonus from the use of steam in both steamflooding and cyclic steam stimulation is the flushing of liners and casing perforations, as well as the reduction of deposits that may build up in the wells. Possible flow restrictions to oil production through the wells are thus reduced."
US Department of Energy

Some evidence of applicability to lighter oils.



Pros	Cons
High recovery factors (50-60% OIP)	high surface facility costs - requires special safety measures.

Cyclic Steam Stimulation CSS (Huff 'n' Puff) Exxon Cold Lake – Alberta Oil Sands



Attributes	CSS
Wells required	One
Well type	Deviated or horizontal
Steam pressure	Above fracture pressure

- High pressure, high rate with multiple recovery mechanisms
  - compaction drive
  - solution gas drive
  - gravity drainage
- Steam heats bitumen to allow flow (4 - 6 weeks)
- Soak (several weeks) allows heat to contact more bitumen
- Production period lengths increase from few months in early cycles to two years in last cycles
- Well life; 12 -15 cycles and 20 years

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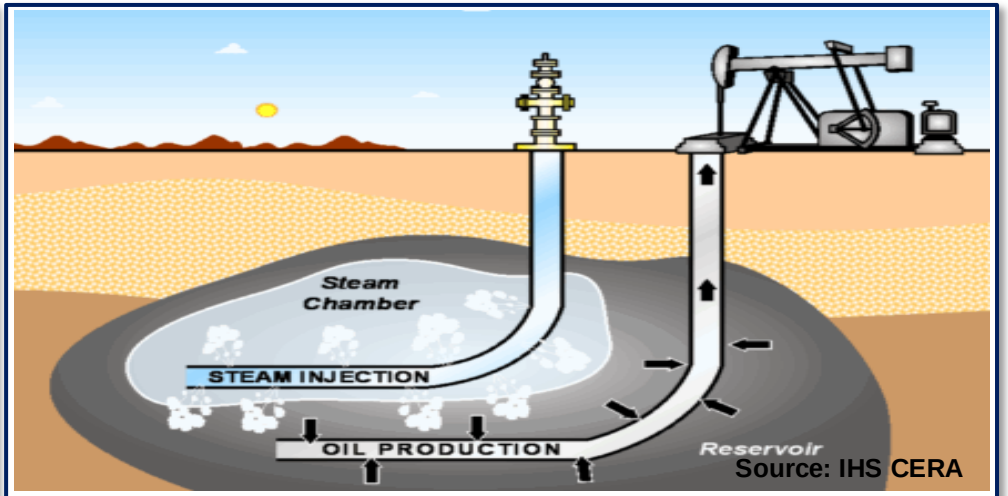
Thermal EOR: Steam Assisted Gravity Drainage (SAGD)

Description of Technology:
Two parallel, horizontal, wells are drilled – one a few meters above the other. Steam is injected along the upper well leading the bitumen to drain down into the lower well.
Primarily applicable for heavy oil only – higher viscosity prevents the formation of a steam chamber.

VAPEX: A vertical upper well can also be combined with a horizontal lower well. This method can use a mix of solvents instead of steam (using solvent + N2 or CO2).



History: First applied in Alberta's oil sands

Locations: Canadian oil sands,

Pros	Cons
High recovery rates (up to 60% of OIP)	Mainly oil sands
Widely tested	High vertical permeability needed
	Highly energy and water intensive

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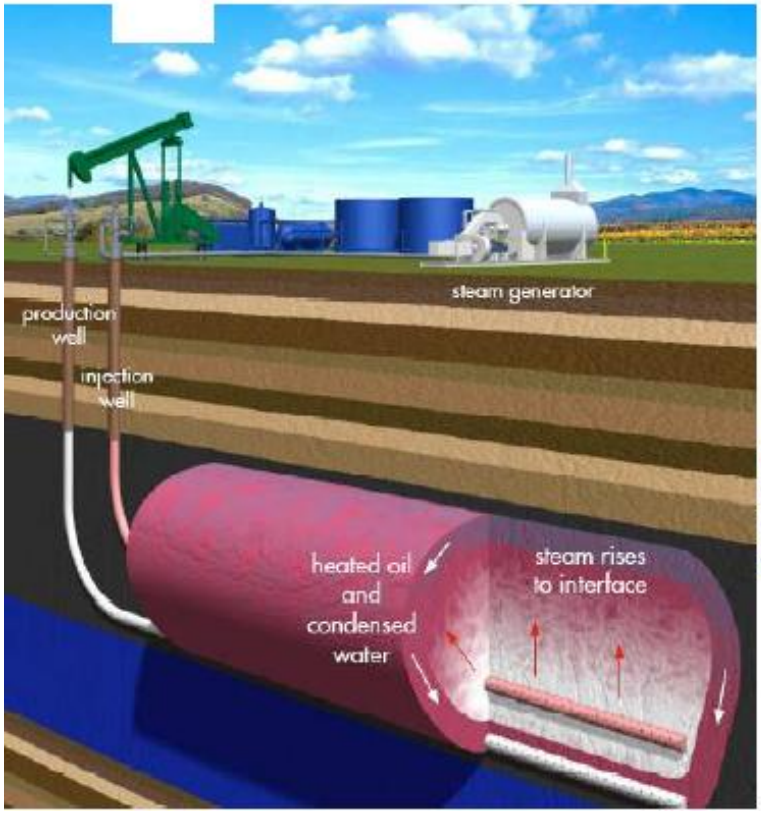
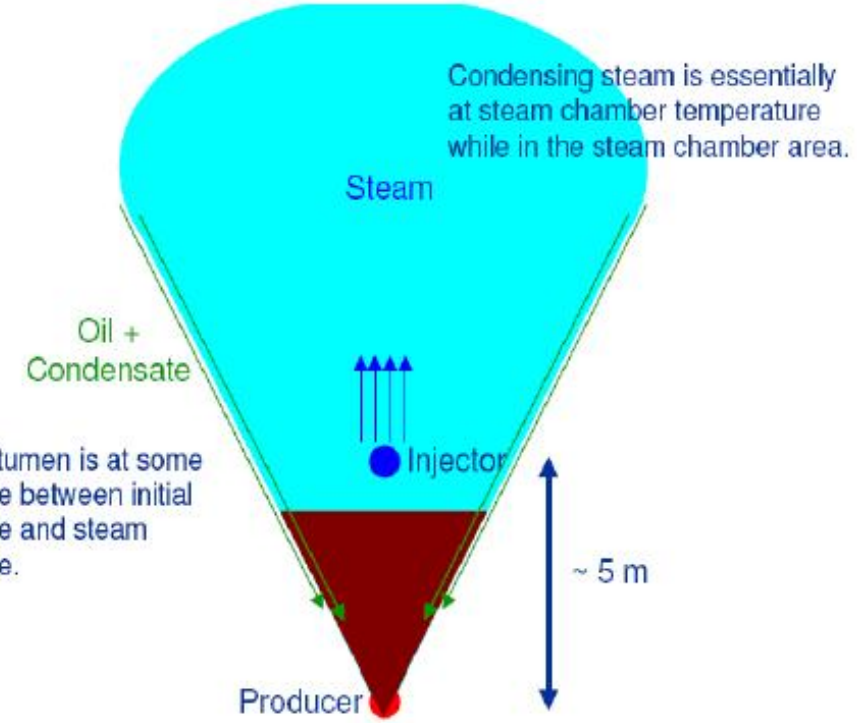
SAGD: Steam Assisted Gravity Drainage Widely used in Athabasca Sands



Draining bitumen is at some temperature between initial temperature and steam temperature.



12 in projects in full production; 4 in pilot production; High recovery factors: 40-50% routine; 80% potential.

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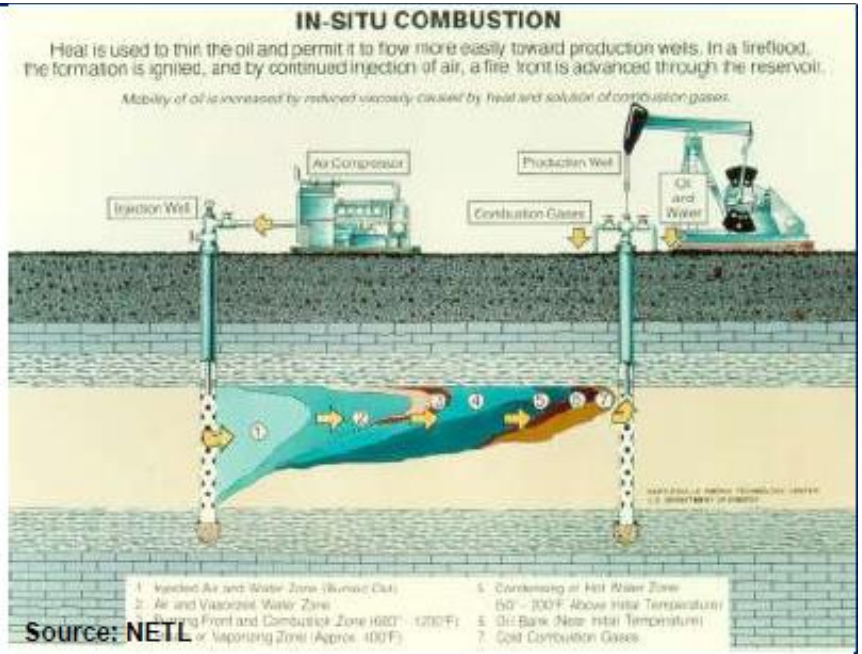
In Situ Combustion

Description of Technology:

Involves igniting a fire in the reservoir and injecting air to sustain and move it away from the well. Combustion may be spontaneous or induced by heat depending on oil properties. Burns about 10% of the least desirable fraction of the oil and upgrades the rest.

Variation s forward combustion and waterflooding (COFCAW). The heat lowers the viscosity of the oil, the products are removed to mix and upgrade the heavy crude, burn the coke and supply the pressure to inject air into the reservoir.

Coke deposition is critical – not deposited in sufficient volumes, the combustion may not be sustained. If excessive, then rate of advance will be slow. Oil saturation and porosity must be high to minimize heat loss. It is a difficult process to regulate, possibly early breakthrough.



Source: NETL

History: Initially used in US and Canada, heavy oil

Applications: Steady increase past decade in lighter oils in the US and with trials in Indonesia, China, and is planned in onshore Brazil.

Pros	Cons
Growing confidence and proven track record	Operational issues –well plugging (oil cracking,) sand and wax production, corrosion, emulsions, acidic water
Use for a wide range of crudes	Not well proven in carbonates
	Environmental issues - gases

Sources:
Taber (1997) – EOR screening Criteria Revisited (SPE 353851 & SPE 39234), Manrique et al (2010) EOR:Status and opportunities (SPE 130113) Petroleum Handbook (H.B. Bradley); US DoE

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Infrastructure, Costs and Taxation

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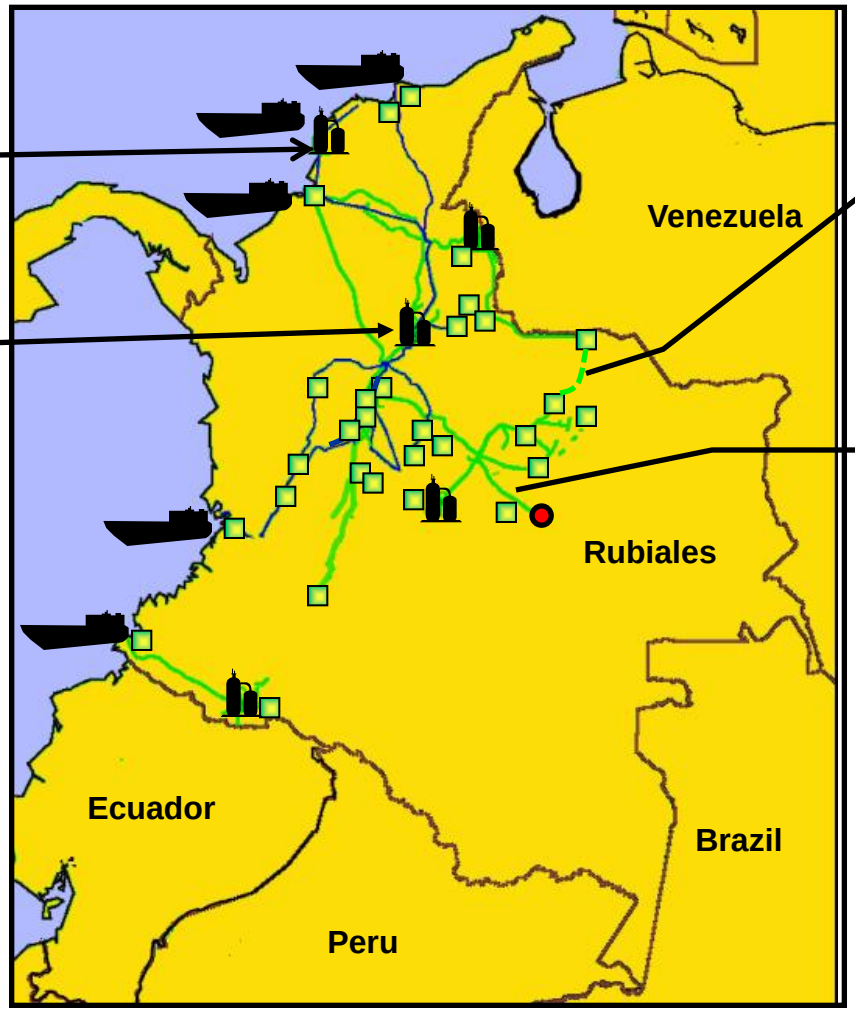
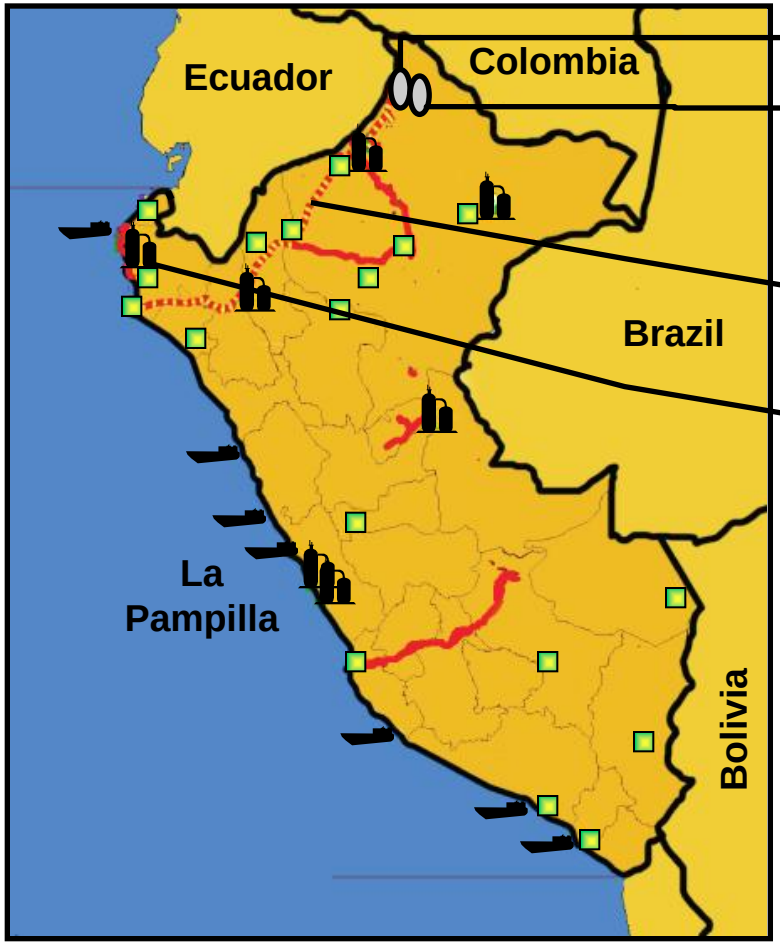
Infrastructure investments are also critical to the development of heavy oil projects in Colombia



In Peru, Infrastructure will also be crucial for heavy oil developments

- Refineries
- Pipelines (crude, NGLs, refined products)
- Storage
- Terminals
- Planned pipelines (crude, NGLs, refined products)



Block 67 (Dorado, Paisha, Pirana

Block 39 (Raya, Buena Vista)

Oleoducto Nor Peruano

Expansion of Talara Refinery (2016)

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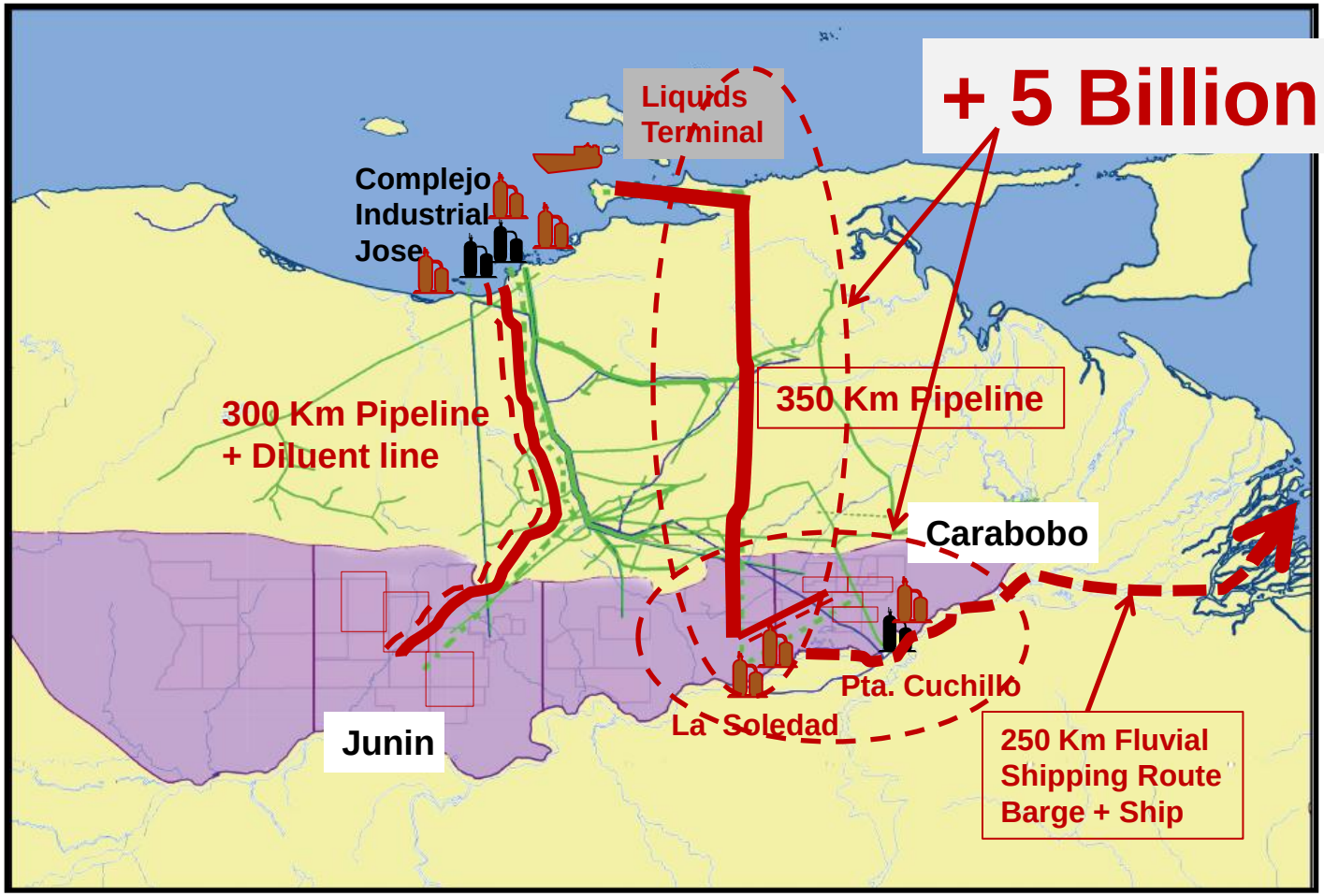
Venezuela: impractical and expensive solution that will have to be built from scratch



Source: EDIN, IHS CERA.

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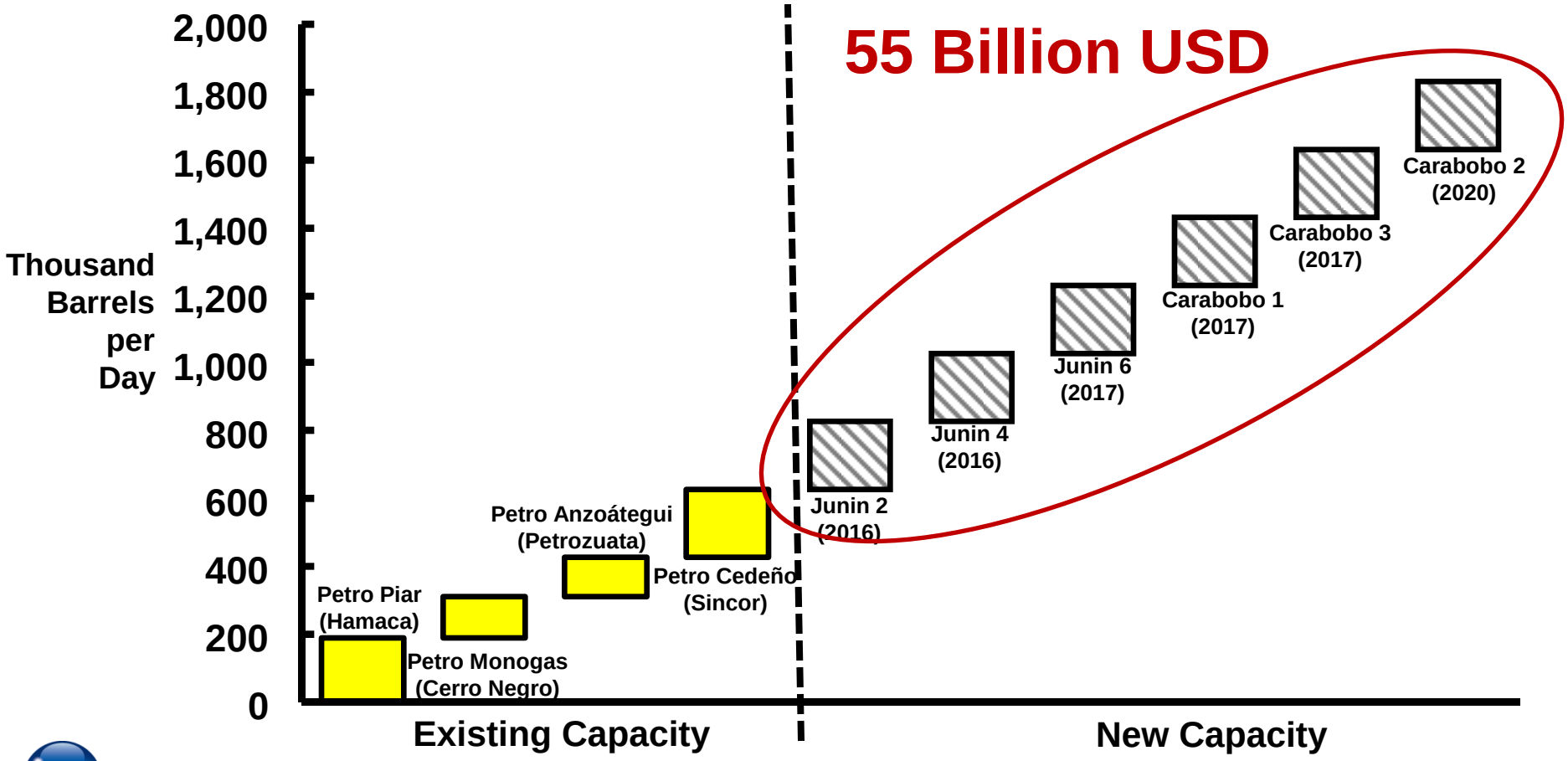
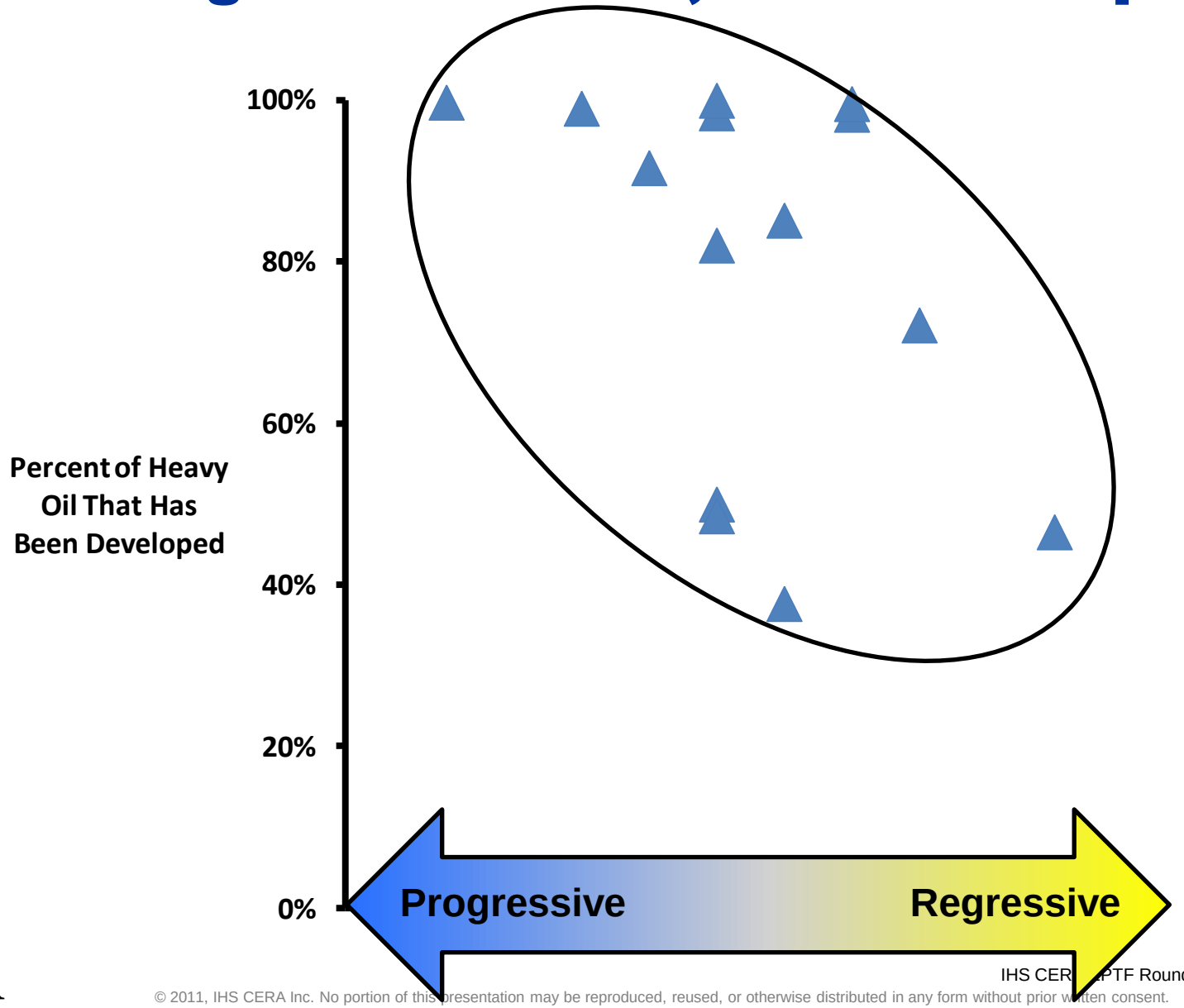
Venezuela: Extra-heavy Oil Upgrading Facilities Outlook*

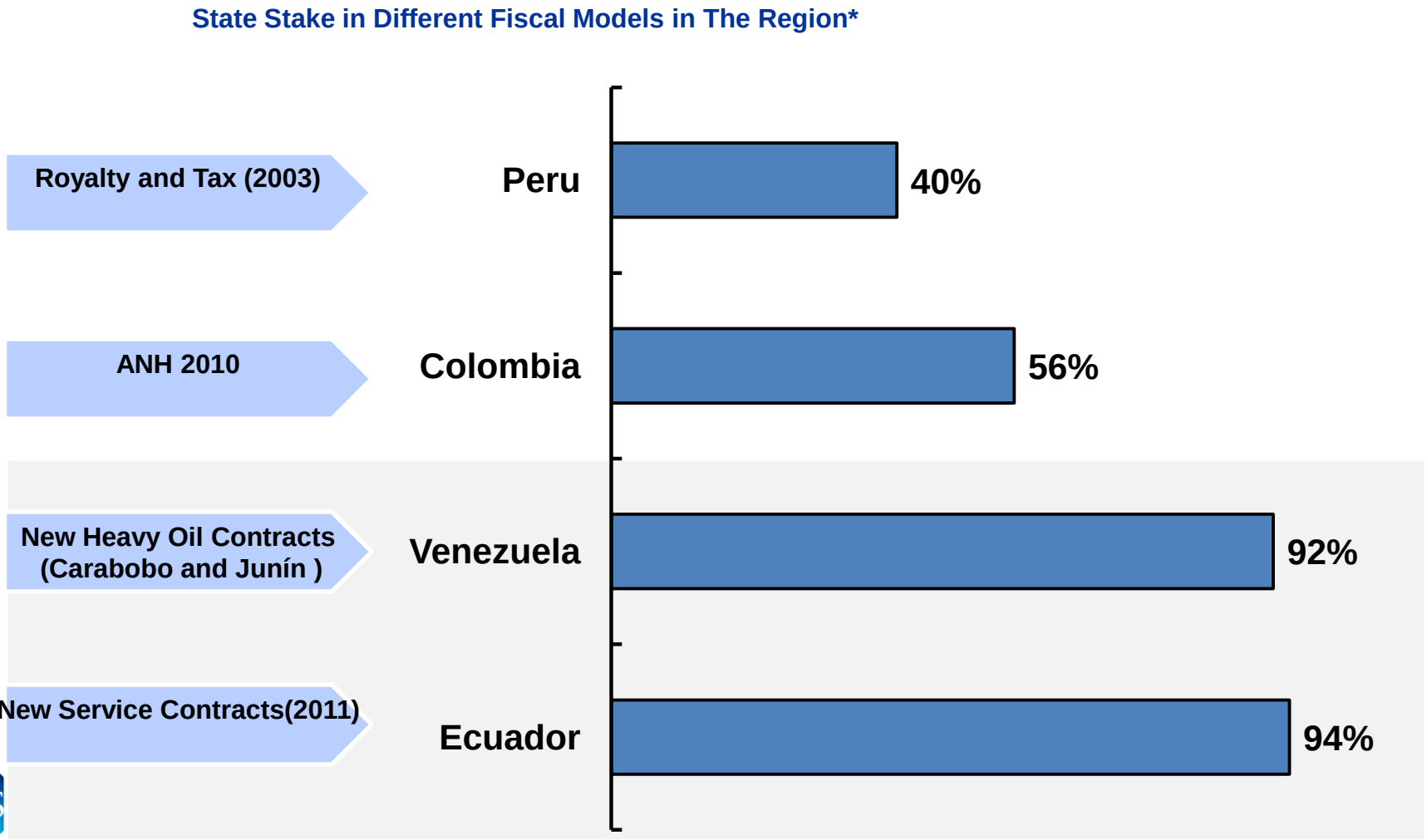


Source: IHS CERA. PDVSA 2010 annual report.
*Announced capacity.

More Progressive Terms, More Development



State Take will be Crucial for Heavy Oil Developments in the Region



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Adjustments to New Service Contracts Determine Future Growth in Ecuador

Service Payment

- Contractors must hand over their output to the state in exchange for a fee per barrel
- Payments may be in cash, in kind, or a mixture of both
- **Contractors bear all financial risks and operational expenses**

Taxes and duties

- **Sovereignty margin: 25 percent of gross income**
- **Labor participation and additional contributions for regional development**
- **Flat 25 percent income tax rate according to new Internal Tax Regime Law (as amended by July 2010 decree**

- **Contractors may not book reserves**
- **Contractors may no longer file a case before the World Bank's ICSID**
- **Investments must be guaranteed through E&P activities and development plans**
- **Local content: 95 percent of operating/administrative workforce and 75 percent of technical personnel must be Ecuadorian citizens**

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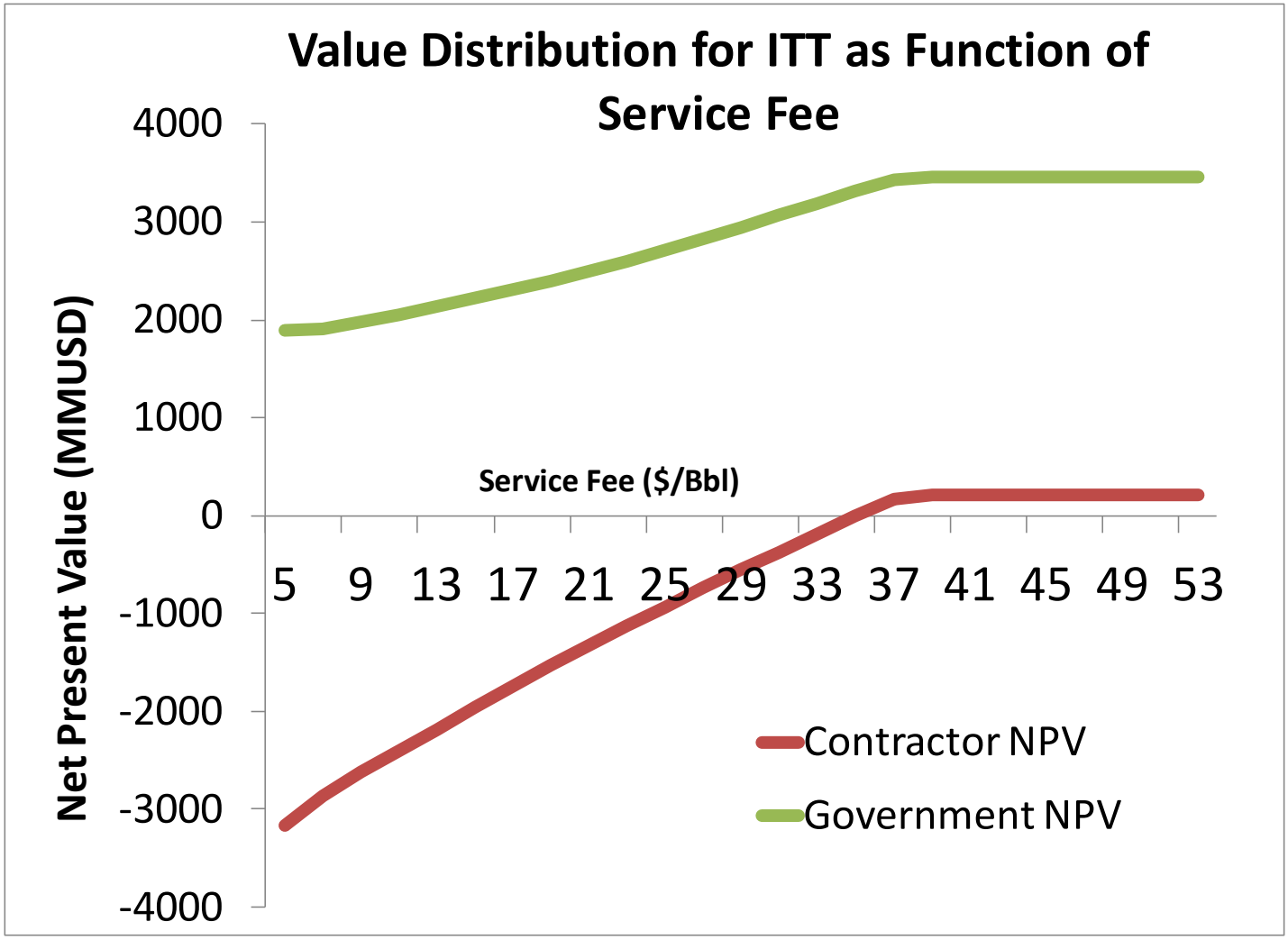
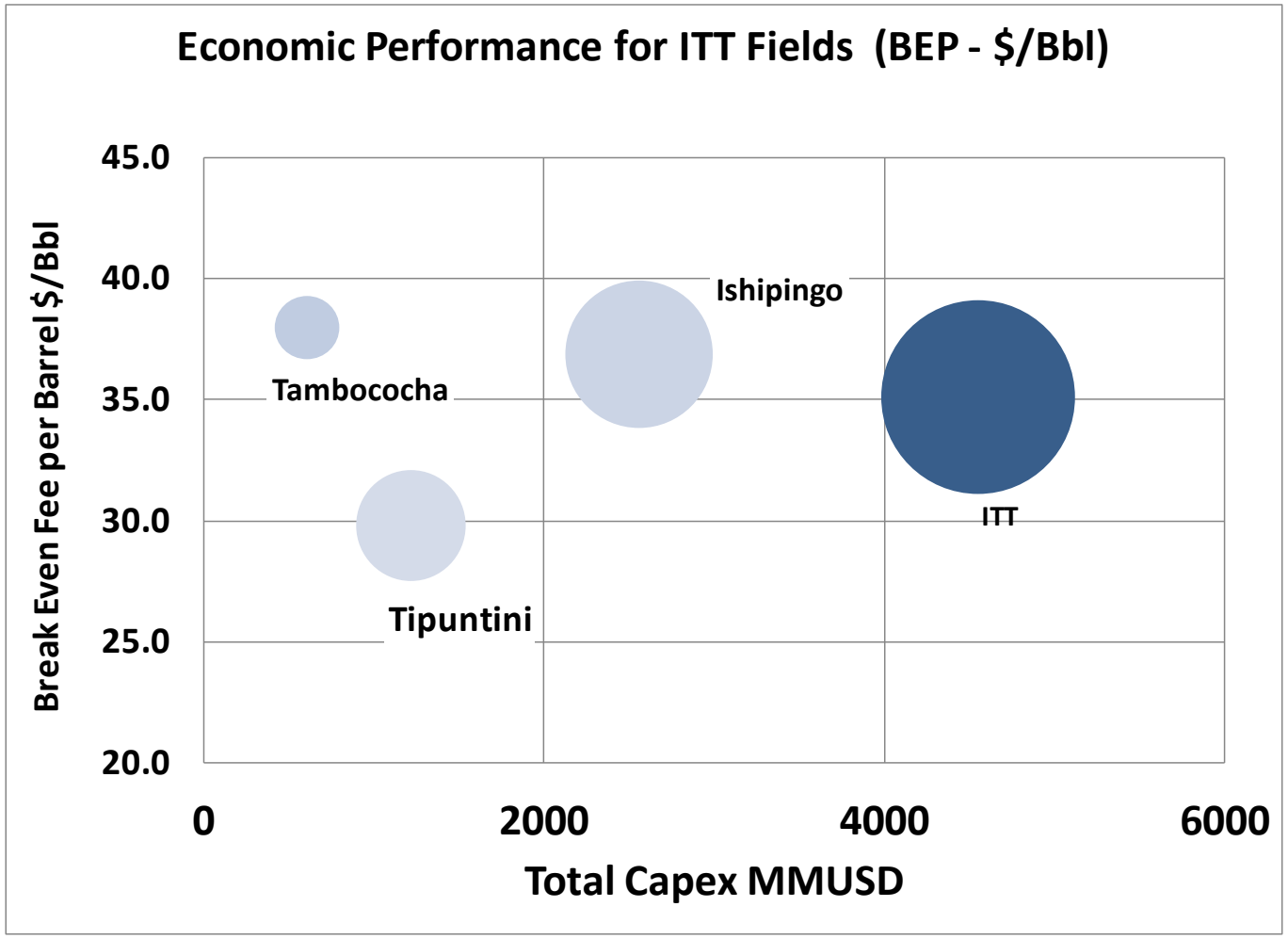
Value Distribution Under Ecuador New Service Contract

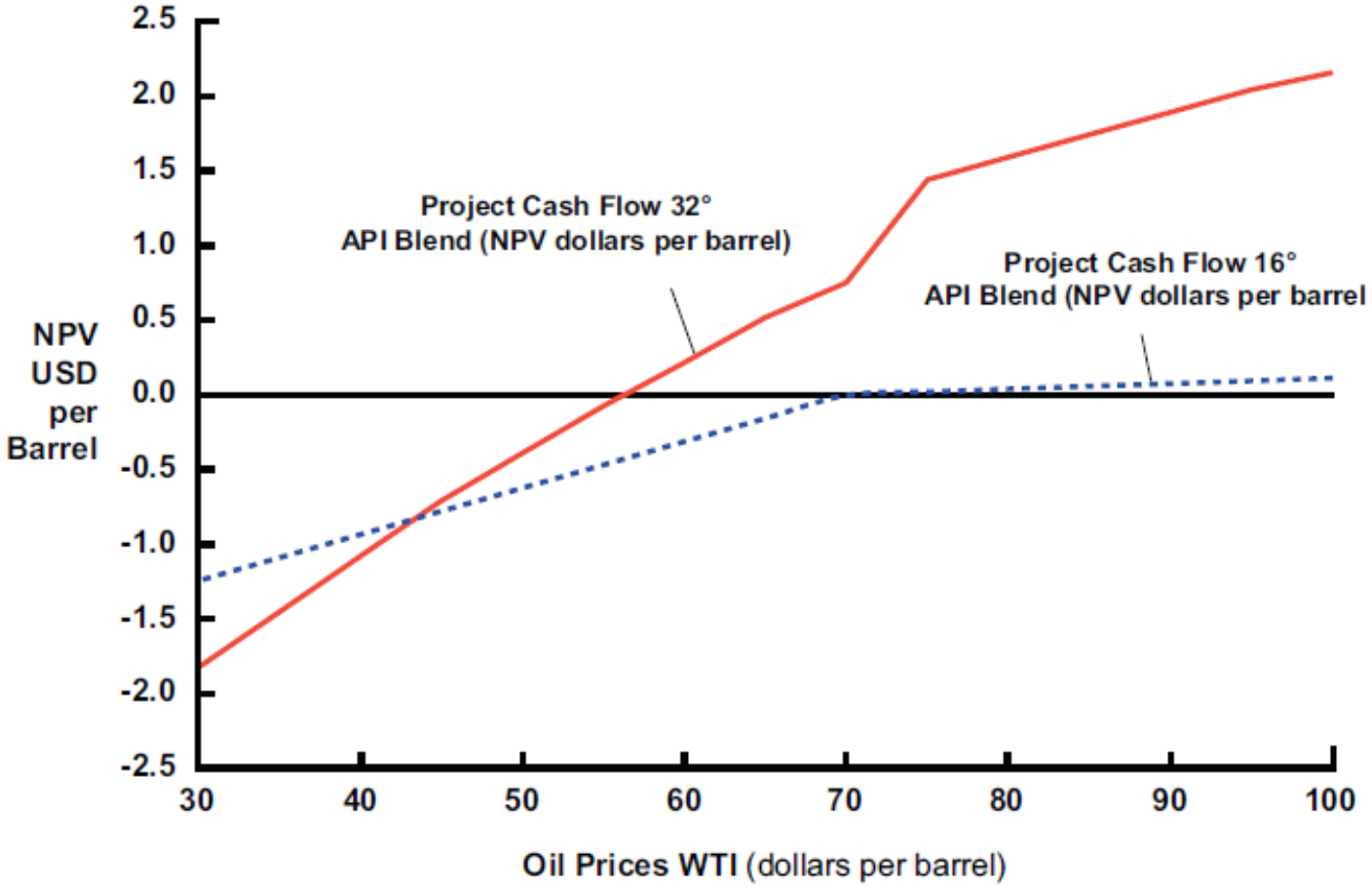


But the Model will hardly favor the development of its largest opportunity



Source: IHS CERA.

EHO Project Value for Different Development Concepts without including any Fiscal Incentives



Source: Cambridge Energy Research Associates.
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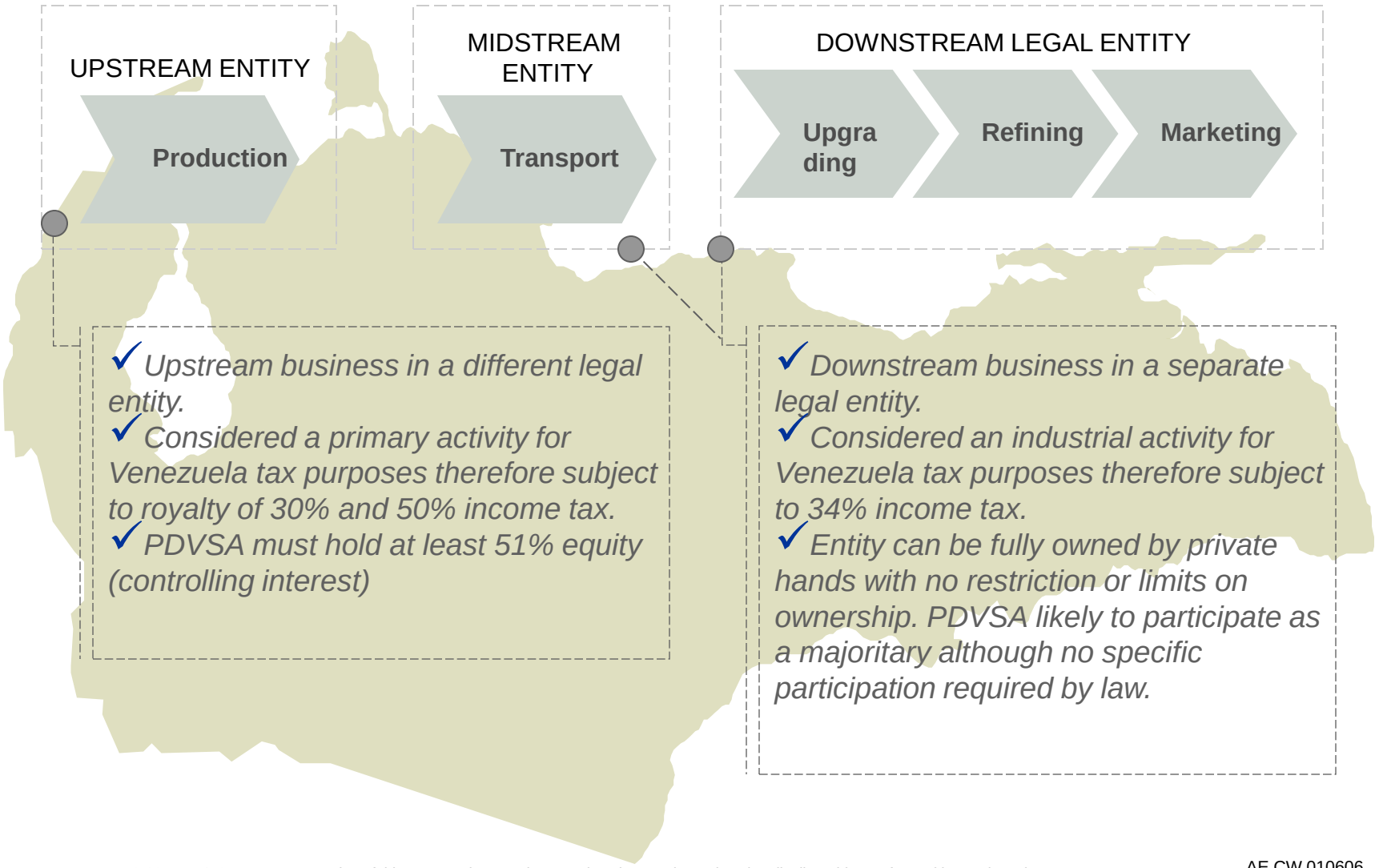
Venezuelan Extra Heavy Oil New Structure - From Vertically Integrated to Value Chain Fragmentation



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...but other challenges will likely reduce potential of heavy oil developments

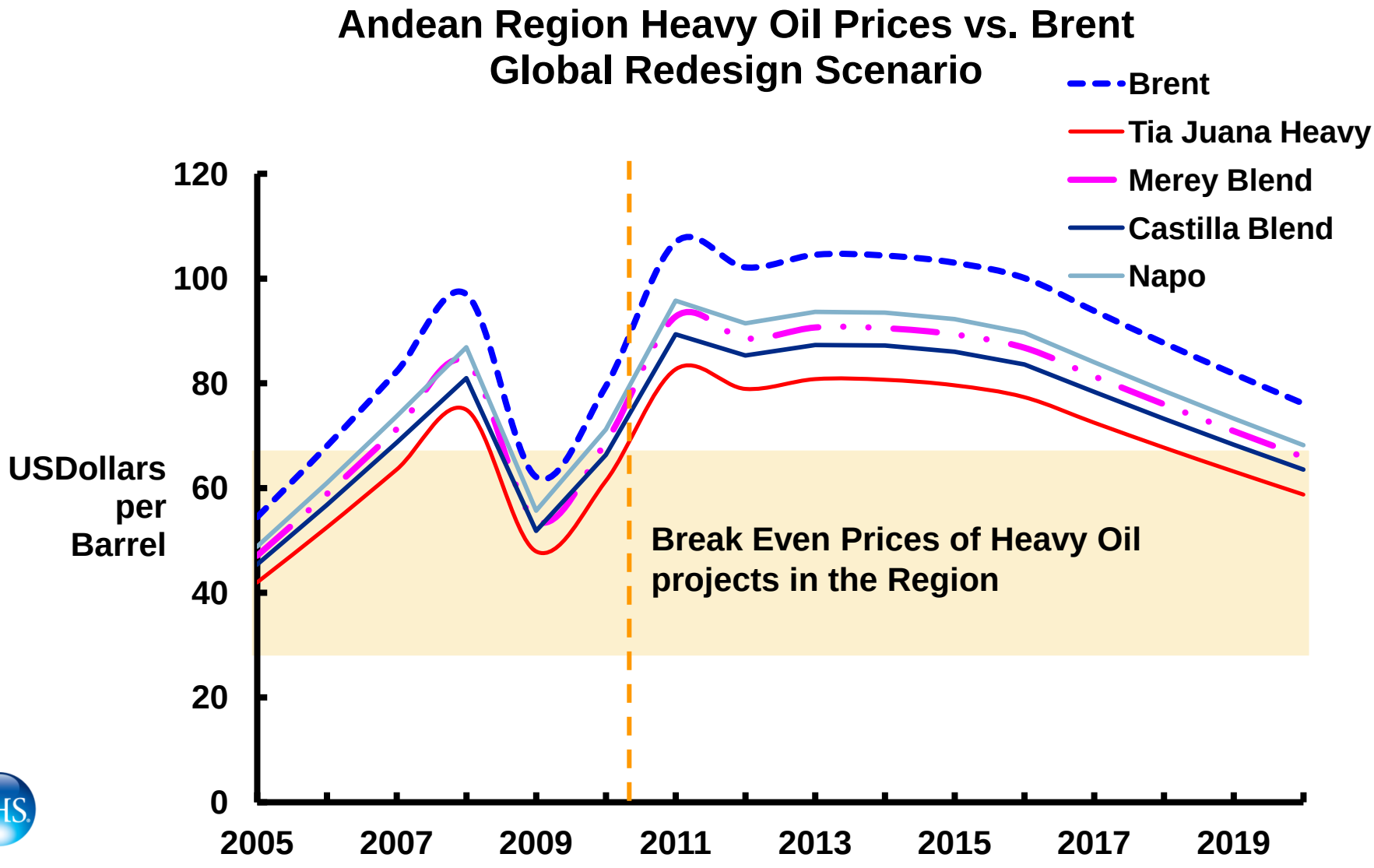
- **Energy Intensive recovery methods combined with lack of fuel options**
  - Minimum 20 % recovery rate of heavy oil projects
  - Steam techniques would be needed and consequently large quantities of natural gas will be required.
  - Where will the gas come from?

- **Effort to build new transport and service infrastructure are beyond the possibilities of PDVSA.**
  - The risk of delays and cost overruns is large.

- **Upgraders will only be available after 2018, at best.**

- **It is a hard to sell blend.**
  - Vertical integration into targeted markets will be needed.

Future Oil Prices might also pose a risk for project developments (I)



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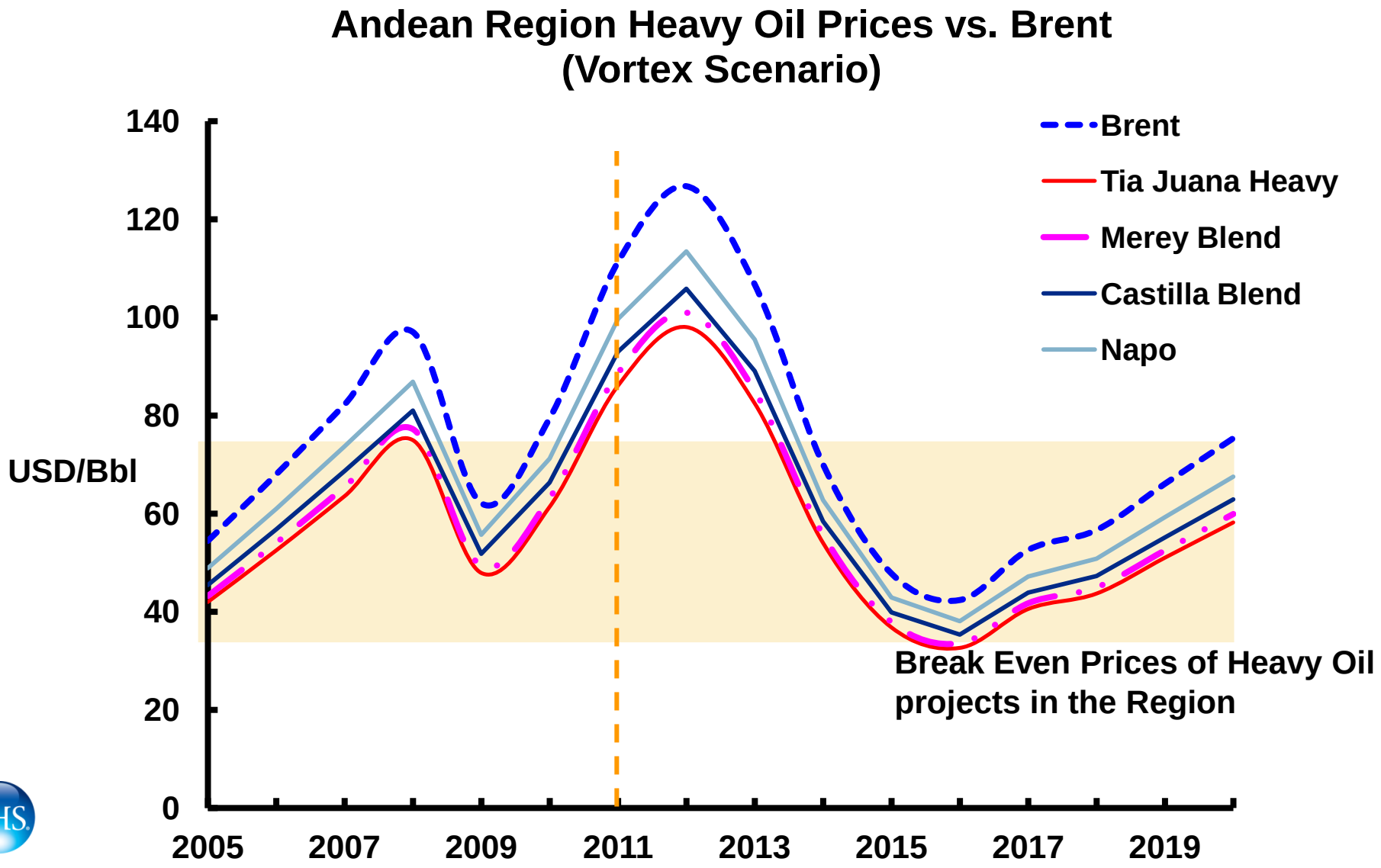
Future Oil Prices might also pose a risk for project developments (I)



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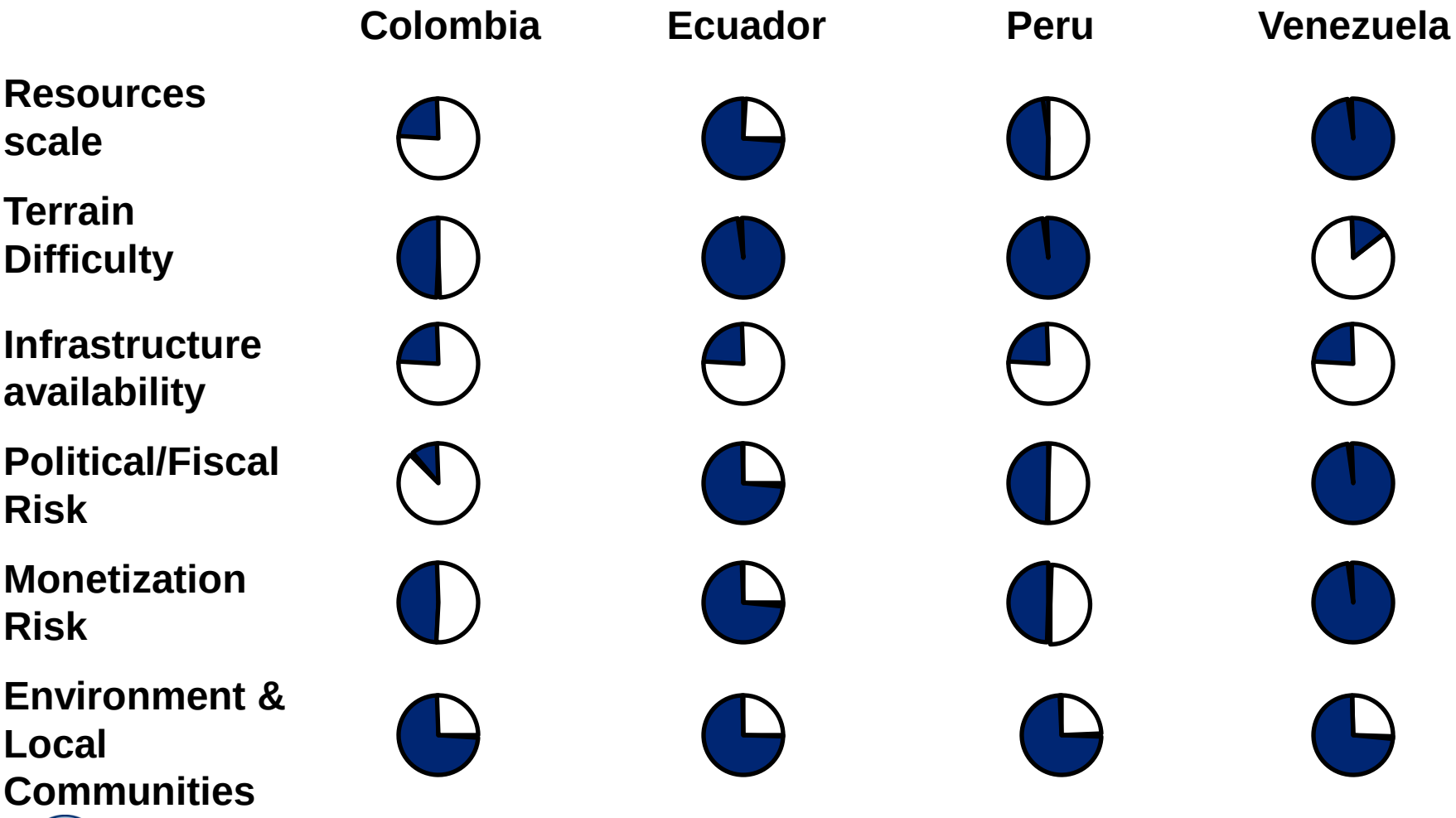
Heavy Oil Attractiveness Screening Matrix



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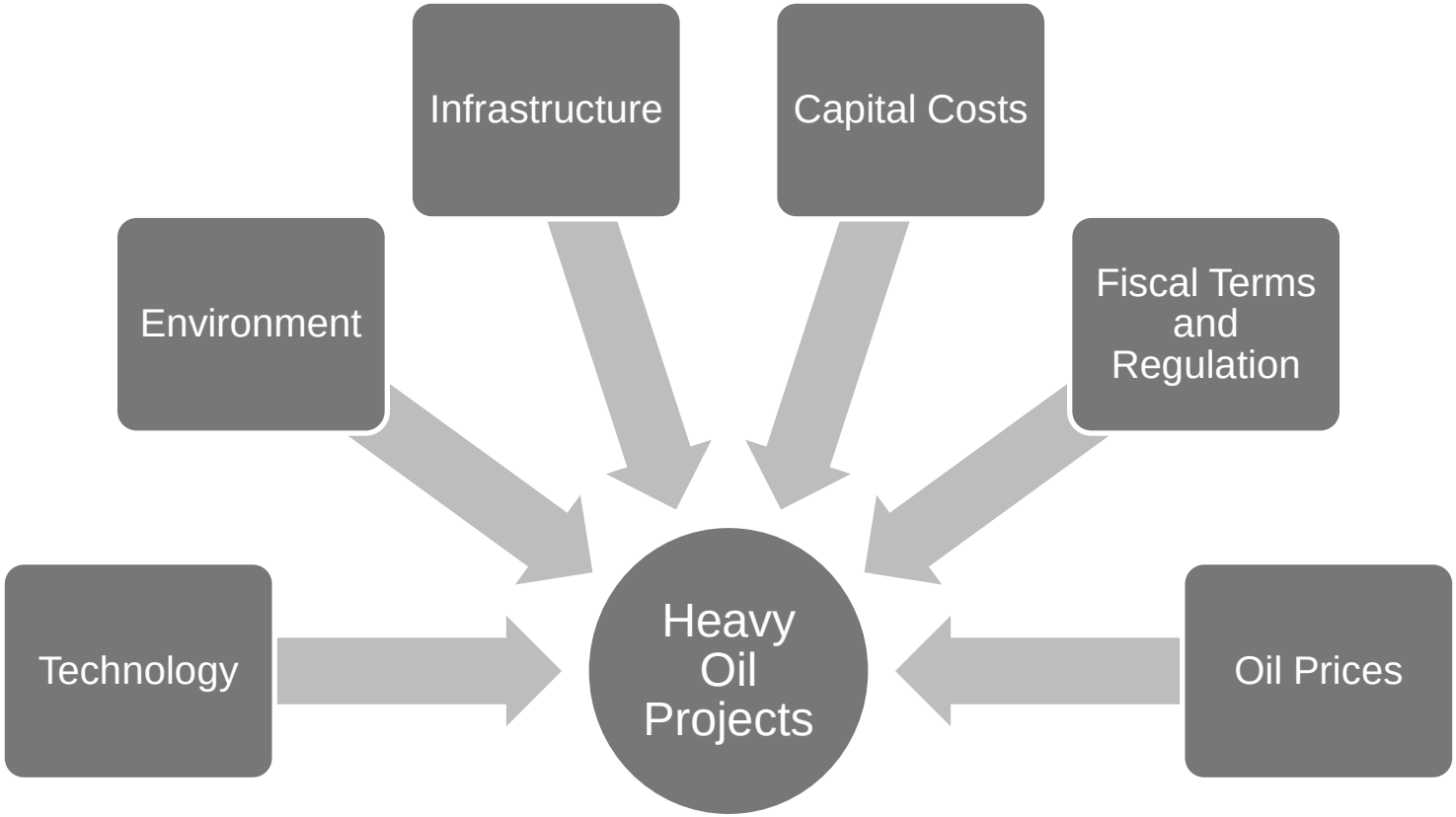
What are the Challenges and How Can They be Best Managed?



Main Takeaways

✓ Main challenges in growing heavy **oil** production capacity in the region continues to be above ground risks

- Venezuela's new business model
- Ecuador new service contract

✓ Full potential for Colombia and Peru is rooted in progressive fiscal terms and relatively stable regulatory regime and will only become a reality if……

- ✓ Transport solution under optimal monetization strategy is implemented
- ✓ EOR to boost reserves and achieve critical mass

✓ Opportunities for accessing and developing HO and EHO reserves in the region still very restricted leading to production outlook well below its potential and leaving substantial amounts of stranded resources underground.

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For more information about this presentation or IHS CERA in general, please contact

Enrique Sira
+1 617 866 5000
Enrique.Sira@ihs.com

55 Cambridge Parkway
Cambridge, Massachusetts 02142, USA
IHSCERA.com

IHS CERA