Unlocking Heavy Oil Value Challenges and Technologies

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

Source: IHS CERA.

Recoverable Reserves (billions of barrels)

- Venezuela
- Iran
- Brazil
- Iraq
- Kuwait
- Mexico
- China
- Russia
- Saudi Arabia
- Indonesia
- Ecuador
- Oman
- Azerbaijan
- Colombia
- Nigeria
- Divided Zone
- United Kingdom
- Trinidad and Tobago
- Egypt
- Kazakhstan

Producing
Non-producing
Most Relevant Heavy Oil Producers are Also in Latin America

2 MM BPD

1.2 MM BPD

300 MBPD

400 MBPD

250 MBPD

300 MBPD

630 MBPD

55 MBPD

200 MBPD

180 MBPD

35 MBPD

15 MBPD

250 MBPD
Andean Countries Dominate Heavy Oil Resources in the World

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

- Middle East 48%
- Far East 29%
- Africa 8%
- CIS 7%
- Americas 4%
- Europe 3%
- Australasia 1%

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
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

- **Light**
  - Venezuela: 3%
  - Ecuador: 1%
  - Colombia: 13%
  - Peru: 22%
- **Medium**
  - Venezuela: 24%
  - Ecuador: 58%
  - Colombia: 44%
  - Peru: 48%
- **Heavy**
  - Venezuela: 70%
  - Ecuador: 41%
  - Colombia: 42%
  - Peru: 29%
- **Extra Heavy**
Latin America Oil Resource Base Characteristics (weighted average)

Source: Cambridge Energy Research Associates.
Note: Relative amount of crude oil resources are shown by circle.
EHO Must be Industrially Transformed Before It Can Be Marketed Competitively....

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>High margin feedstock</td>
<td>Expensive conversion capacity required</td>
</tr>
<tr>
<td>Premium low-sulfur feed</td>
<td>Gasoline yield low</td>
</tr>
<tr>
<td>Industry benchmark</td>
<td>Expensive feedstock</td>
</tr>
<tr>
<td>Diminishing supply</td>
<td></td>
</tr>
</tbody>
</table>

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 245 MMBbl), Redondo (OOIP 235 MMBbl) and Sabanero (OOIP 180 MMBbl). The actual recoverable reserves will depend on the production approach used. If they reach 40% recovery rate, 2P recovery could pass 500 MMBbl.

- 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).
IOCs and Other Privately-run Companies

**North America**

<table>
<thead>
<tr>
<th>Country</th>
<th>Company</th>
<th>Sample Activities and Segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>Chevron</td>
<td>EHO E&amp;P and upgrading, LNG train</td>
</tr>
<tr>
<td>USA</td>
<td>Harvest NR</td>
<td>Oil and gas E&amp;P, acquisitions</td>
</tr>
<tr>
<td>USA</td>
<td>Shell</td>
<td>EHO exploration, downstream</td>
</tr>
<tr>
<td>CAN</td>
<td>PetroFalcon</td>
<td>Oil exploration and services</td>
</tr>
</tbody>
</table>

**Europe**

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

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<tr>
<th>Country</th>
<th>Company</th>
<th>Sample Activities and Segments</th>
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<tr>
<td>JAP</td>
<td>Teikoku</td>
<td>Gas E&amp;P</td>
</tr>
<tr>
<td>JAP</td>
<td>Inpex, Mitsui, Mitsubishi</td>
<td>LNG train 1</td>
</tr>
<tr>
<td>KOR</td>
<td>Kogas</td>
<td>Gas E&amp;P</td>
</tr>
</tbody>
</table>

**IOCs Participation in Venezuela’s Orinoco Oil Belt:**

Sample Regional and Local Players with Presence in Venezuela:

<table>
<thead>
<tr>
<th>Country</th>
<th>Company</th>
<th>Sample Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARG</td>
<td>Pluspetrol</td>
<td>E&amp;P</td>
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<tr>
<td>VEN</td>
<td>Petrocumarebo</td>
<td>Oil and gas E&amp;P</td>
</tr>
<tr>
<td>VEN</td>
<td>Ypergas</td>
<td>Gas development</td>
</tr>
<tr>
<td>VEN</td>
<td>Suelopetroil</td>
<td>EHO E&amp;P and upgrading</td>
</tr>
<tr>
<td>VEN</td>
<td>Inelectra</td>
<td>Tech services</td>
</tr>
<tr>
<td>COL</td>
<td>Ecopetroil</td>
<td>E&amp;P</td>
</tr>
</tbody>
</table>

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.*

**Venezuela’s Oil & Gas Competitive Environment**

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

<table>
<thead>
<tr>
<th>Project</th>
<th>Country</th>
<th>PDVSA Partners</th>
<th>Start Date* IPP</th>
<th>Additional Capacity (kbd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carabobo 1</td>
<td>Venezuela</td>
<td>Repsol YPF ONGC Videsh Petronas Indian Oil Oil India Ltd</td>
<td>2015</td>
<td>400</td>
</tr>
<tr>
<td>Carabobo 3</td>
<td>Venezuela</td>
<td>Chevron Mitsubishi Inpex Suelopetrol</td>
<td>2015</td>
<td>400</td>
</tr>
<tr>
<td>Junin 4</td>
<td>Venezuela</td>
<td>CNPC</td>
<td>2016</td>
<td>400</td>
</tr>
<tr>
<td>Junin 6</td>
<td>Venezuela</td>
<td>Surgutneftegas Rosfnet Gazprom BP</td>
<td>2015</td>
<td>450</td>
</tr>
<tr>
<td>Junin 5</td>
<td>Venezuela</td>
<td>ENI</td>
<td>2014</td>
<td>240</td>
</tr>
<tr>
<td>Junin 2</td>
<td>Venezuela</td>
<td>Petrovietnam</td>
<td>2013</td>
<td>200</td>
</tr>
</tbody>
</table>
What are the Challenges and How Can They be Best Managed?

- Infrastructure
- Capital Costs
- Fiscal Terms and Regulation
- Technology
- Environment
- Oil Prices

Heavy Oil Projects
Technologies Driving EHO and HO Development
Technology has a great upside potential in unlocking reserves in the region

- Cold Production
- Cyclic Steam Stimulation
- Steam Flood
- Steam assisted gravity drainage (SAGD)
- Solvent Added Process (SAGD + Solvents)
- In Situ Combustion

Most of Heavy Oil Production in Andean Region

Tests in Venezuela

Tests in Venezuela

Pilot in Colombia

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

- For light oil fields, energy consumed to extract barrels grow over time from typically 2.5 percent of the energy content in the barrel, to some 5–10 percent.

- Complex fields have higher energy needs.

- For heavy oil fields with thermal EOR, energy consumed is in the range of 15–35 percent of the energy content in the barrel.

- 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 Bcf/d of Natural Gas

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= 1.8 Bcf/d

2,000 Cubic feet / Bbl SCO

- 2,000 Cubic feet / Bbl SCO

EHO 8.5Deg API + HOT

Hydrogen Manufacturing

Delayed Coking + MHC
The production of Heavy Oil tends to have higher GHG emissions
EHO Production Technique: Well Productivity Evolution

- **Cold Production Methodology**
- **Vertical Wells**
- **Horizontal Wells of 1000 mts**
- **Multiphasic ESP**
- **Multilateral Wells High Capacity PCP/ESP**
- **Diluent Injection**
- **Horizontal Wells Diluent Injection**

**Expected Future Recovery Factor > 20%**
**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**
- High recovery factors (50-60% OIP)

**Cons**
- high surface facility costs
- requires special safety measures.
Cyclic Steam Stimulation CSS (Huff ‘n’ Puff)
Exxon Cold Lake – Alberta Oil Sands

Attributes
- Wells required
- Well type
- Steam pressure

CSS
- One
- Deviated or horizontal
- 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
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).

**Pros**
- High recovery rates (up to 60% of OIP)
- Widely tested

**Cons**
- Mainly oil sands
- High vertical permeability needed
- Highly energy and water intensive

**History:** First applied in Alberta’s oil sands

**Locations:** Canadian oil sands,
SAGD: Steam Assisted Gravity Drainage
Widely used in Athabasca Sands

12 in projects in full production; 4 in pilot production; High recovery factors: 40-50% routine; 80% potential.
**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 towards combustion and water flooding (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.

**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**

- Growing confidence and proven track record
- Use for a wide range of crudes

**Cons**

- Operational issues – well plugging (oil cracking), sand and wax production, corrosion, emulsions, acidic water
- Not well proven in carbonates
- Environmental issues - gases

**Sources:**

Infrastructure, Costs and Taxation
Infrastructure investments are also critical to the development of heavy oil projects in Colombia.

**Map Details:**
- **Cartagena Expansion**
- **Barrancabermeja Expansion by 2016**
- **Phase 1 of planned Oleoducto Bicentenario (524 miles / 450 Mbbld)**
- **New pipeline Oleoducto de los Llanos Orientales**

**Key Points:**
- **Refineries**
  - Refined products pipelines
  - Crude pipelines
- **Storage**
- **Terminals**

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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)**

**In Peru**

- **La Pampilla**
- **Brazil**
- **Colombia**
- **Ecuador**
- **Bolivia**

**Key Pipelines and Projects**

- **Oleoducto Nor Peruano**
- **Expansion of Talara Refinery (2016)**
- **Block 39 (Raya, Buena Vista)**
- **Block 67 (Dorado, Paisha, Pirana)**

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

Source: EDIN, IHS CERA.
Venezuela: Extra-heavy Oil Upgrading Facilities Outlook*

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

*Announced capacity.

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More Progressive Terms, More Development

Percent of Heavy Oil That Has Been Developed

Progressive

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

State Stake in Different Fiscal Models in The Region*

- Royalty and Tax (2003)
  - Peru: 40%
- ANH 2010
  - Colombia: 56%
- New Heavy Oil Contracts (Carabobo and Junín)
  - Venezuela: 92%
- New Service Contracts (2011)
  - Ecuador: 94%
Adjustments to New Service Contracts Determine Future Growth in Ecuador

- 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

- 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
Value Distribution Under Ecuador New Service Contract

Value Distribution for ITT as Function of Service Fee

Net Present Value (MMUSD)

Service Fee ($/Bbl)

Contractor NPV

Government NPV

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

Source: IHS CERA.

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

Source: Cambridge Energy Research Associates. 90407-2
Venezuelan Extra Heavy Oil New Structure - From Vertically Integrated to Value Chain Fragmentation

**Upstream Entity**
- Production

**Midstream Entity**
- Transport

**Downstream Legal Entity**
- Upgrading
- Refining
- Marketing

- ✔ Upstream business in a different legal entity.
- ✔ Considered a primary activity for Venezuela tax purposes therefore subject to royalty of 30% and 50% income tax.
- ✔ PDVSA must hold at least 51% equity (controlling interest)

- ✔ Downstream business in a separate legal entity.
- ✔ Considered an industrial activity for Venezuela tax purposes therefore subject to 34% income tax.
- ✔ Entity can be fully owned by private hands with no restriction or limits on ownership. PDVSA likely to participate as a majority although no specific participation required by law.
...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)

Andean Region Heavy Oil Prices vs. Brent
Global Redesign Scenario

Break Even Prices of Heavy Oil projects in the Region
Future Oil Prices might also pose a risk for project developments (I)

Andean Region Heavy Oil Prices vs. Brent (Vortex Scenario)

USD/Bbl

Break Even Prices of Heavy Oil projects in the Region
Heavy Oil Attractiveness Screening Matrix

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<tr>
<th></th>
<th>Colombia</th>
<th>Ecuador</th>
<th>Peru</th>
<th>Venezuela</th>
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<tbody>
<tr>
<td>Resources scale</td>
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<tr>
<td>Terrain Difficulty</td>
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<tr>
<td>Infrastructure</td>
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<tr>
<td>availability</td>
<td></td>
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<tr>
<td>Political/Fiscal Risk</td>
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<tr>
<td>Monetization Risk</td>
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<tr>
<td>Environment</td>
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<tr>
<td>&amp; Local Communities</td>
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What are the Challenges and How Can They be Best Managed?

- Infrastructure
- Capital Costs
- Environment
- Fiscal Terms and Regulation
- Technology
- Oil Prices

Heavy Oil Projects
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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