No Fool's Choice
Create Win-Win opportunities for Shale Development in Emerging Countries

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TEXAS Geosciences
Bureau of Economic Geology
Jackson School of Geosciences
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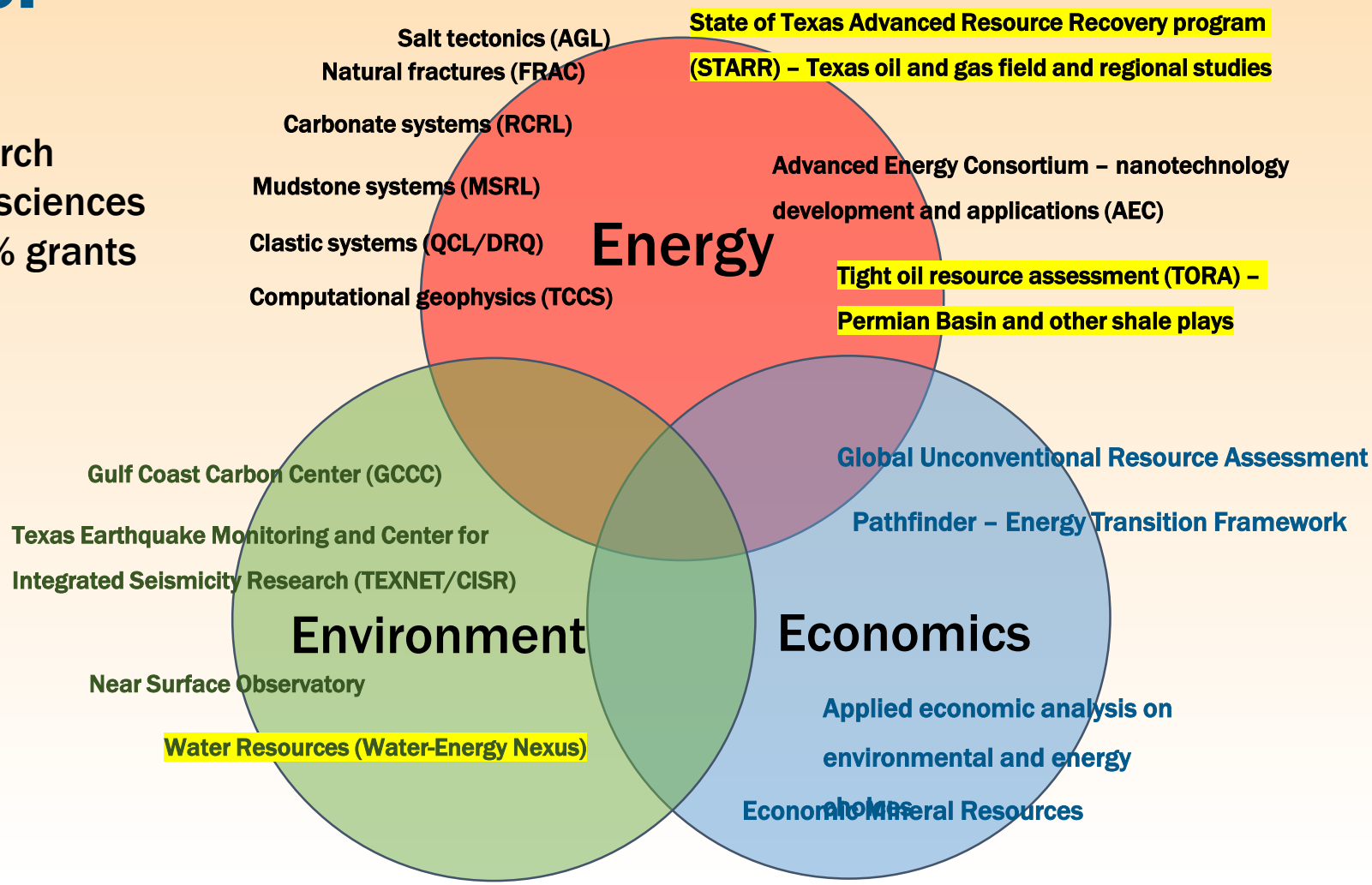
Why and What Doing Economics at Bureau of Economic Geology

- Energy, Environment & Economic Research
  - Unit of the Jackson School of Geosciences
  - $30 - 35 million/year budget, 90% grants & contracts
  - Established in 1909
- Ca. 250 researchers, staff & students



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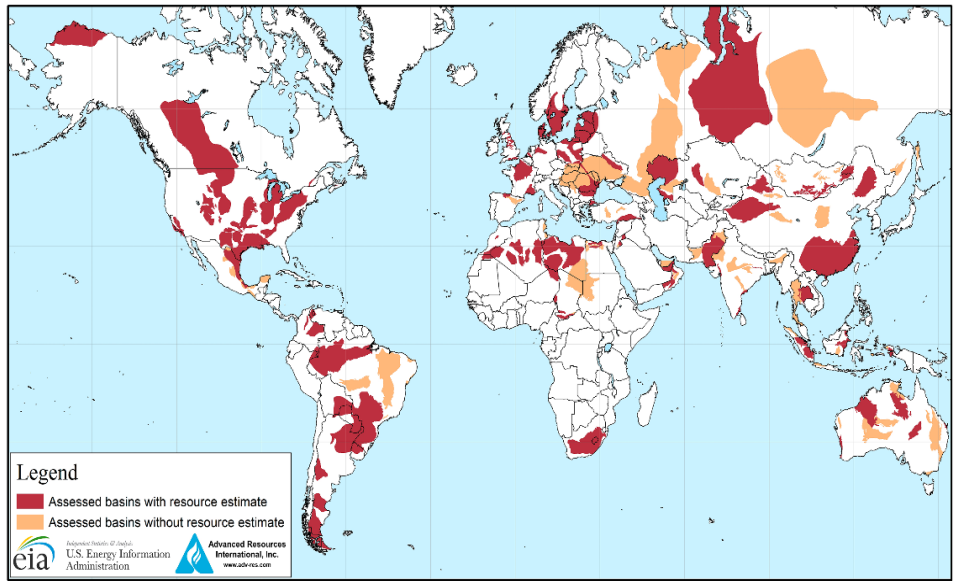
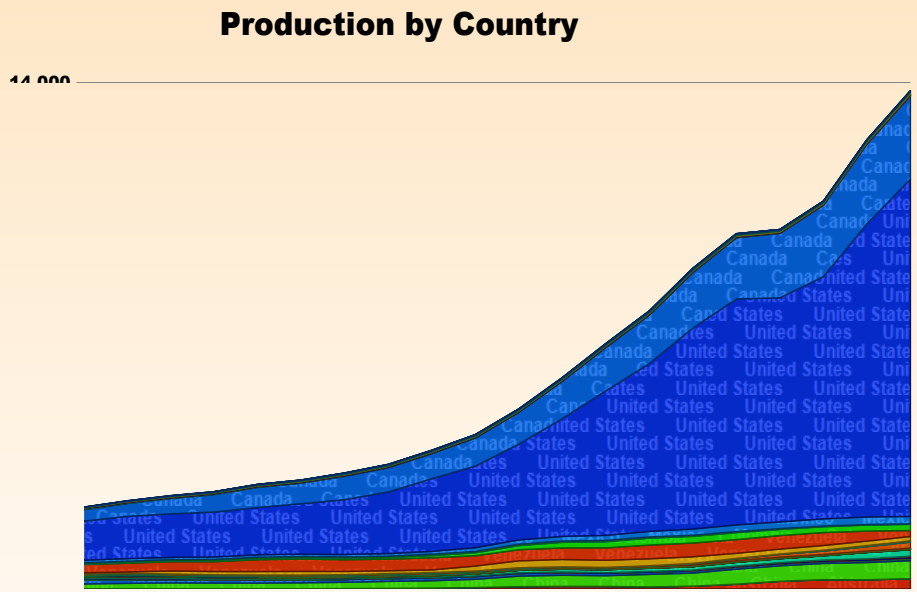
Global Unconventional Resource Development: Great Potential but…

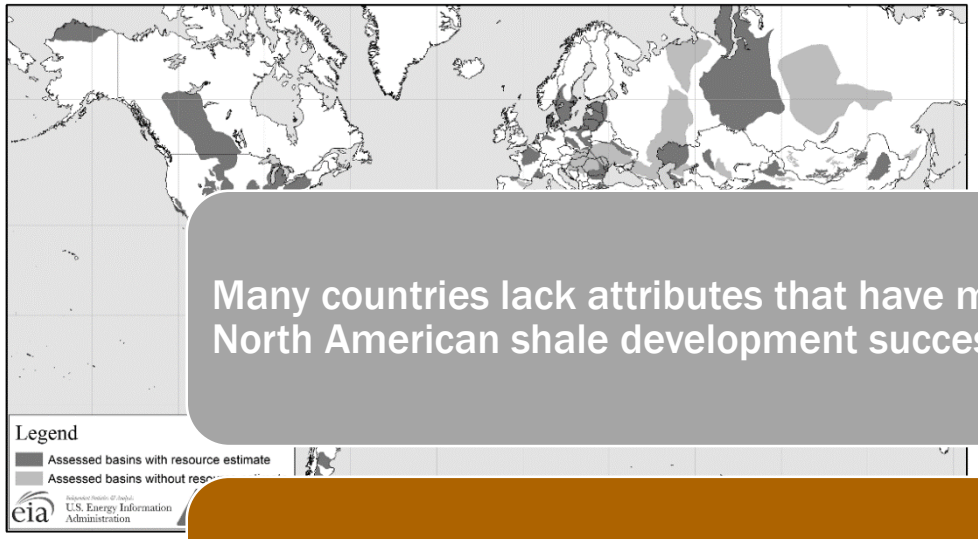


…almost half of the unconventional resources is outside of NA, but only 16% of production is outside of NA currently …
slow progress

Year 2019	Resources (Million bbl)	1P Reserves (Million bbl)	Production (Million bbl)
World Total Volume	1,101,616	157,425	13,780
US and Canada - Volume	**607,148**	**131,841**	**11,625**
% of Total	55%	84%	84%
ROW - Volume	**494,468**	**25,584**	**2,155**
% of Total	45%	16%	16%
No.Of Countries	57	20	10

Why? Here are some challenges we identified





Many countries lack attributes that have made North American shale development successful

Asymmetry of information and perspectives prevents alignment and collaboration.

Limited investment return and lack of optionality to weather in a volatile and competitive price environment

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Project Atlas: A Study of Opportunities and Risks in Global Unconventional Resources

Global Resource Scorecard

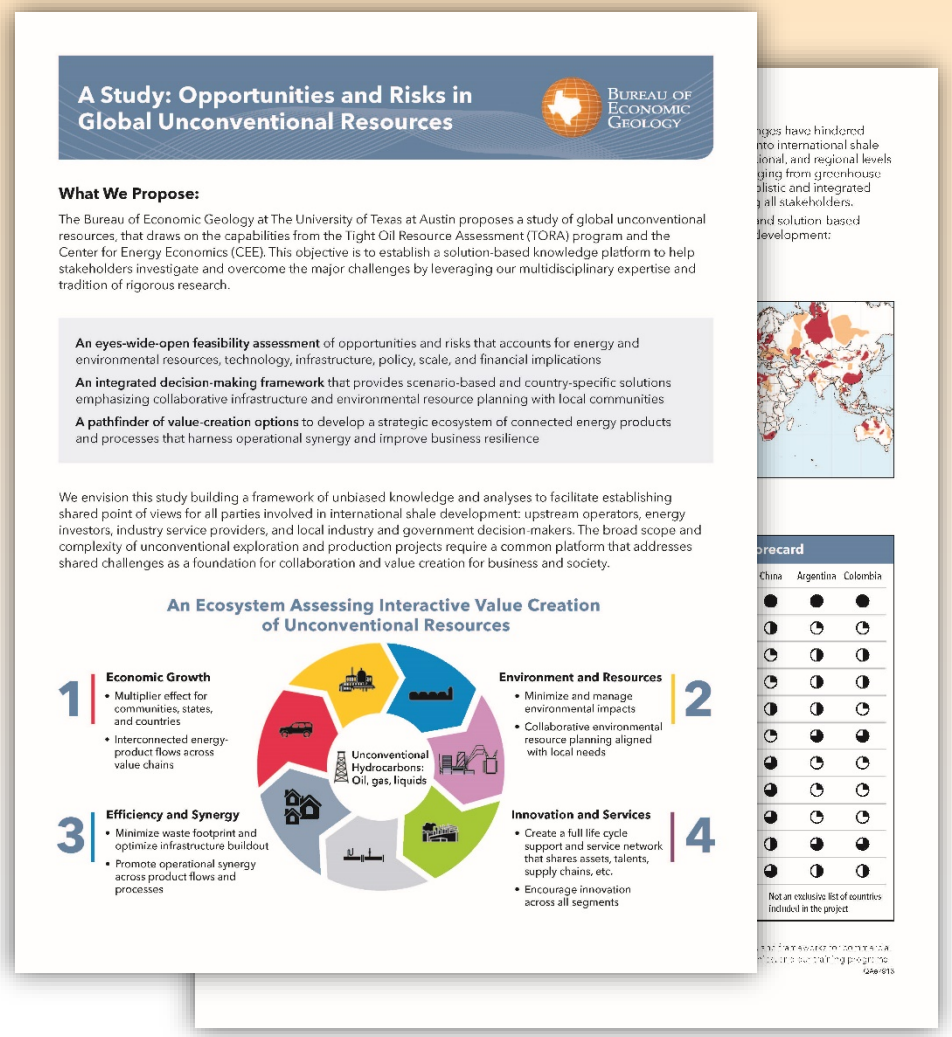
- Country-level assessment from global perspective
- Comparative data analyses

Country-Level Analysis

- Deep-dive assessment of economic, energy, and environmental factors
- Identification of challenges and risks from perspectives of governments, operators, and investors
- Education of necessary structure, industry capacity and expectation of operation process and needs, for local governments or new investors

Pathfinder Scenario Planning

- Pathways and strategies for cross-segment monetization options for unconventional resources
- Market and economic scenarios about development decisions, policy choices, and energy/resource planning



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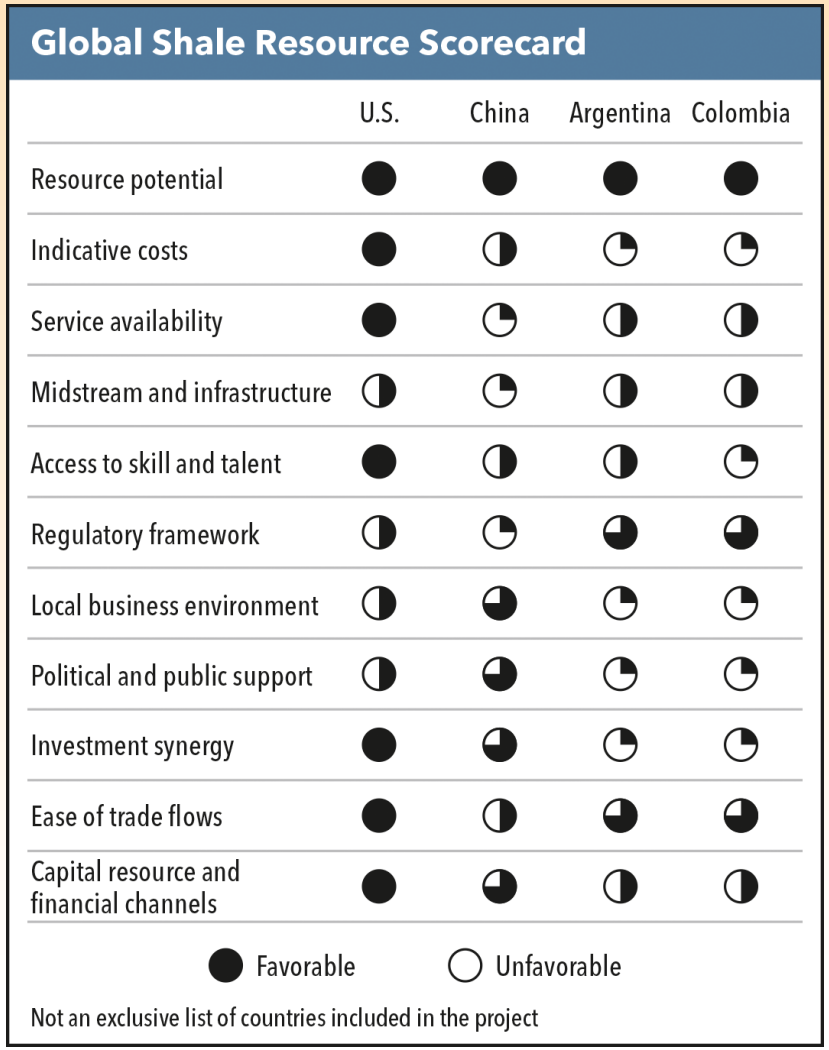
Step 1 - Global Scorecard for Status Quo

- **An eyes-wide-open feasibility assessment** for energy and environmental resources, technology, infrastructure, policy, scale, and financial implications, to set stage for identifying **actionable solutions** to support development decisions



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Step 2: At country level: A system approach to asses the impacts of Shale

Geological and technical conditions

- Economic assessment for technically recoverable reserve
- Estimate costs and phases for EP activities
- Estimate drilling patterns and production migration across basin

Resource and infrastructure requirement

- Land/Water/Air/ Seismic
- Pipeline and processing plants;
- Load profile and transmission needs
- Substitution effect with other fuels for power generation

Opportunities and Risks

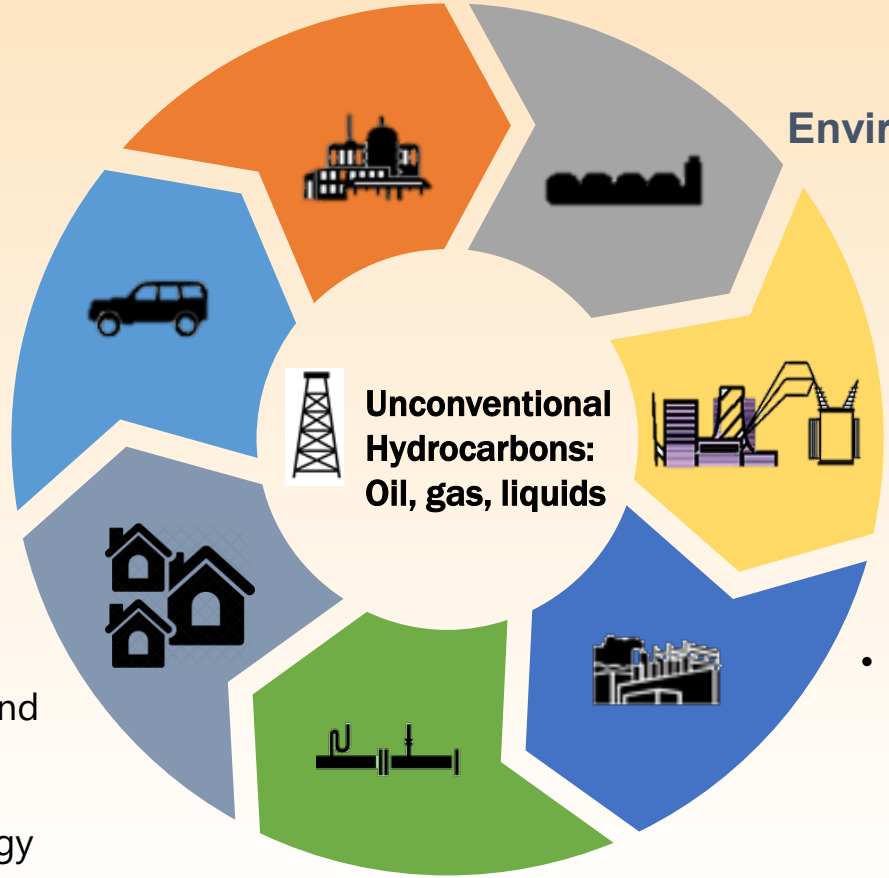
- Routes to market evaluation
- Gaps in current regulation and local policy system
- Sensitivity analysis to prioritize rewards vs risks

Step 3: An ecosystem for value creation of unconventional resources

1

Economic Growth

- Multiplier effect for communities, states, and countries
- Interconnected energy product flows across value chains



2

Environment and Resources

- Minimize and manage environmental impacts
- Collaborative environmental resource planning aligned with local needs

3

Efficiency and Synergy

- Minimize waste footprint and optimize infrastructure buildout
- Promote operational synergy across product flows and processes

4

Innovation and Services

- Create a full life cycle support and service network that shares assets, talents, and supply chains, etc.
- Encourage innovation across all segments.

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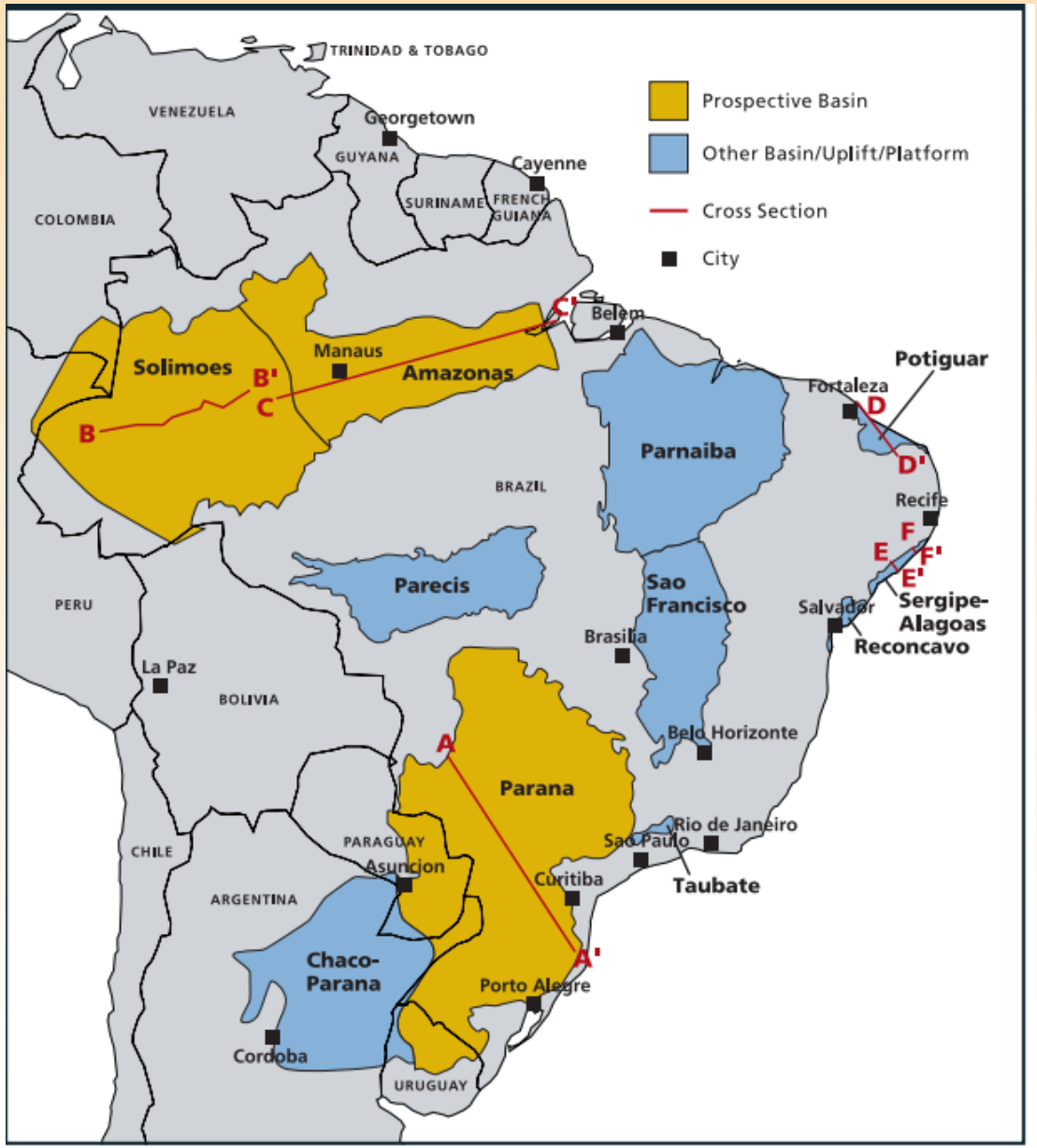
Country Example: Brazil Shale

- Fast growing energy demand and robust GDP although not stable in recent years
- Biggest hurdle is access to capital and stability of investment environment
- Ranked 10th shale gas in the world, while there has been dominating off-shore oil production so far

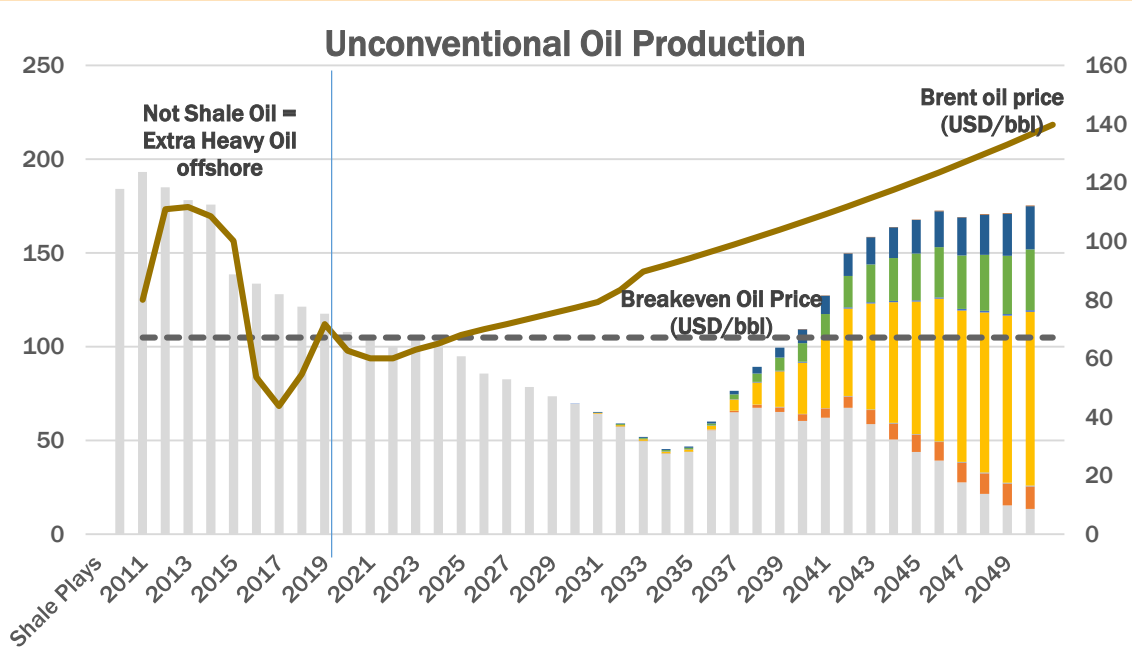
EIA: 244 TCF Wet Shale, 5 BBL Tight Oil

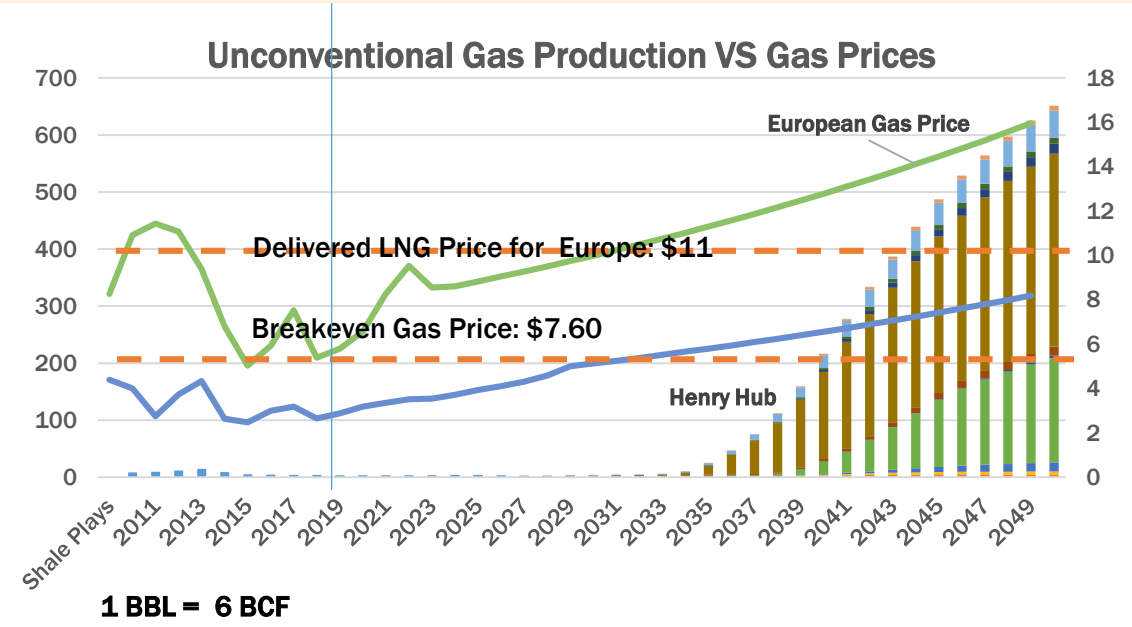
there is more to come for 2020 and beyond for Brazil…



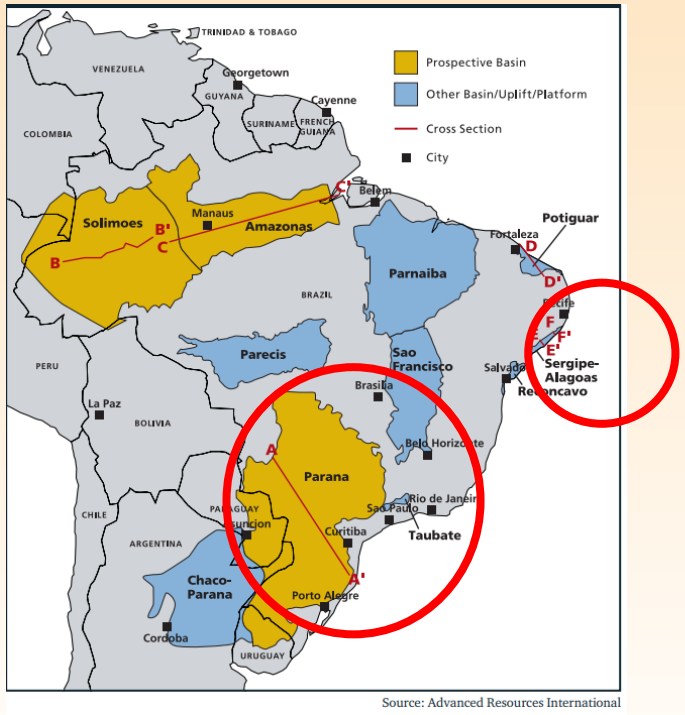
Source: Advanced Resources International

Unconventional Production in Brazil





1 BBL = 6 BCF

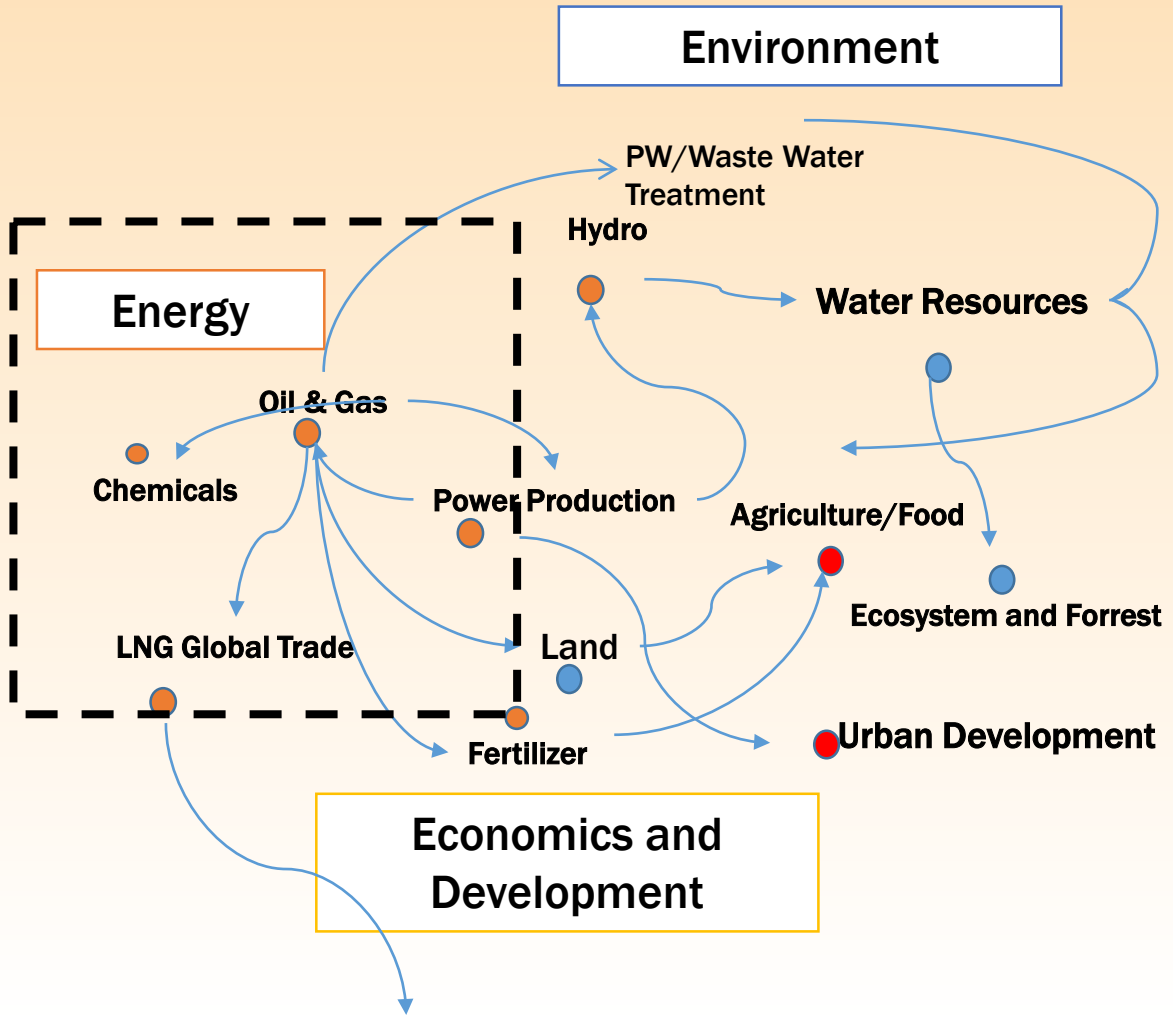


- unconventional oil (mainly offshore pre-salt) continues to grow.
- Shale gas starts to grow after 2030, mainly to substitute for LNG imports needs for domestic demand, as global price for LNG rises higher.

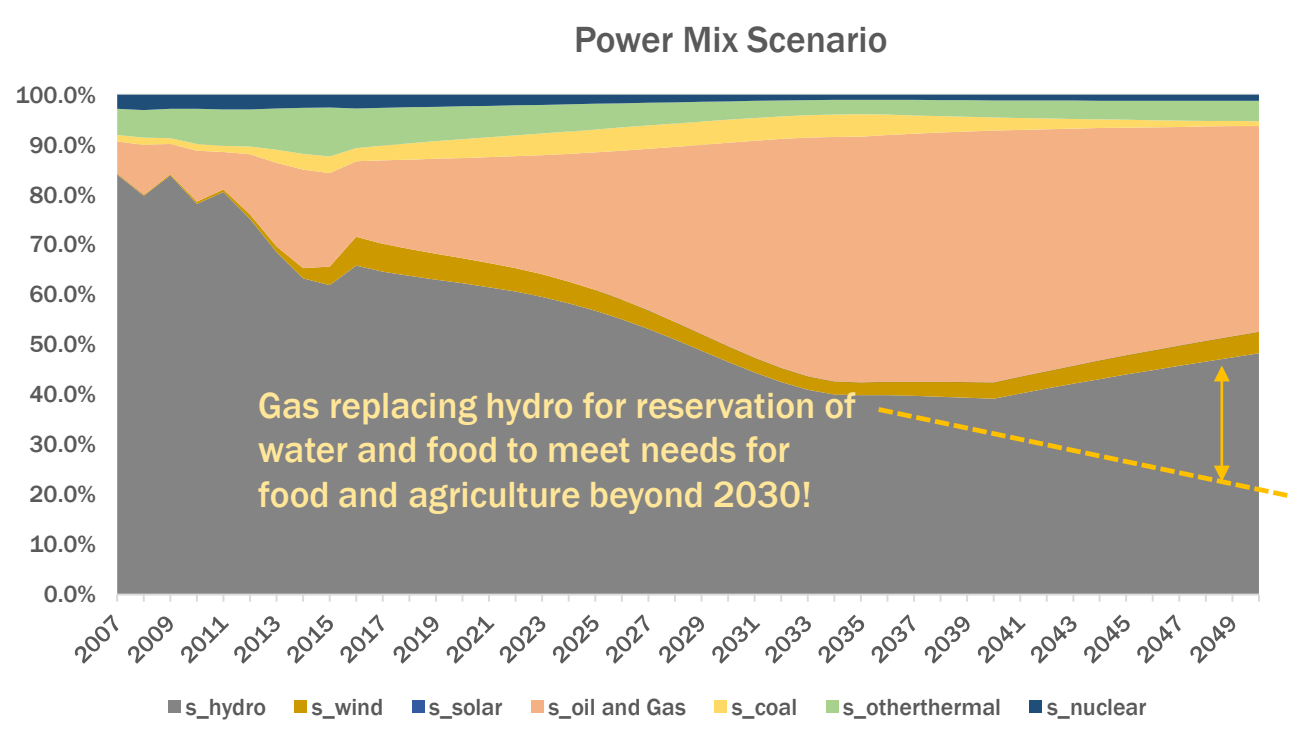
Next… Broaden the scope to look for opportunities and risks

- **LAND and infrastructure for future shale development**
  - Roads and transmission lines
  - Pipeline and processing plants
  - Deregulated midstream promotes private projects on gas/liquid to wire
  - Export incentive – regional competition

- **Food-Water-Energy nexus:**
  - **One of the largest agriculture producer and exporter**
  - **Soybean production and agriculture needs for water**
    - Largest soybean producer surpassing US in 2018, and due to US-CHINA trade war, Brazil becomes largest exporter to China
    - Fertilizer for Agriculture: Brazil is one of largest importers and marginal market for AS and Urea.
  - Between now to 2050, the world needs feed 2.5 billion more people, 35% increase, hence it requires a fundamental shift for development priority (providing sufficient profits to farming) and resource planning.



Strategy 1: Extra value of shale gas for electricity replacing hydro



With increased shale gas production, we estimated through a MNL model, as a function of existing capacity, LCOE, fuel prices and net installed capacity by year, etc.

From 2016 to 2040, **oil and gas share of power generation would be grow from 15% to almost 50% by 2040.**

Beyond 2035, the decrease of gas share reflects in forecasted higher gas price beyond 2035, which also promotes shale production

However, there is shift in higher valuation of food and water rise beyond 2035, which may make gas fired generation more competitive in an alternative case (leading higher shale production) – This would lead to 20% higher market share of gas-fired generation, which would translates to

Strategy 2: Wastewater treatment needs met by integrated water management for shale

- Brazil has a growing challenge for serving almost 50% of populations needs, stated R270 billion investment since 2010.
  - The situation has not get improved due to the unstable economy and investment environment.
  - Needs include water monitoring, waste water treatment and reuse waste water options.
- How would water needs for shale production play a role here?
  - Understand water cycle of major shale plays through multiscale data and modeling with hydrologists.
  - Integrate water management into energy development scenarios.
  - Historical data for water cycle and production in other basins as a training set for projections. Economic evaluation for options in recycle, reuse, disposal and transport.

Strategy 3: Exploring additional usage for wasted methane

- Brazil is the largest fertilizer importer and highest agriculture exporter in the world
- Agriculture areas has been focused in south central region, away from the coast.
- Wasted methane from future shale gas plays (onshore) could be turned into ammonia through innovative technology at small scale close to farm lands.
  - Economic evaluation on new conversion technology of wasted gas (methane) into ammonia
    - Techno-economic analysis (Cost of conversion, CAPEX, OPEX, ROI) to highlight competitive advantage
    - Assessment of necessary market and policy framework for commercialization

Questions?