The Global Energy Challenge: The Dual Goals of Economic and Environmental Sustainability

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Forecasting 101 – Precision is Folly!

- Long term price projections are rarely accurate, and appear adaptive.
- Too much emphasis on the recent past, can ignore long run fundamentals.
- “The best cure for high (low) prices is high (low) prices”
The past, present and future of energy?
The story is the picture, but the devil is in the details...
Does history repeat itself?

• The early 1980s was a period of robust promise for renewable energy and distributed generation. Why?
  - High oil prices and energy security.
  - Natural gas supply concerns.

• What happened?
  - Incumbent fuel costs fell and efficiency increased.
  - Fixed costs of adoption matter.
  - Coal expanded.

• How is the present different?
  - Costs are lower and coal is encumbered, each aided by policy.
  - Energy and environmental security.
  - Natural gas supply is robust.

• Are recent developments lasting?
This is a *long run* story...

- Economic growth and population drive energy demand. As such, developing nations, not developed nations, will dictate future energy demand growth as well as composition, or the “energy mix”.

- Technology, scale and legacy are each important factors.
  - Technology signals how fuels will ultimately compete. This can work in multiple, sometimes competing, directions by raising the efficiency of use of existing fuels *and* by introducing new competitive energy sources.
  - Scale matters because energy systems must accommodate expanding access.
  - Legacy of infrastructure and fuel delivery systems is the footprint for change.

- Scale and legacy affect the diffusion of new technology.

- Economics matter. The cost-benefit must be favorable for sustainable diffusion of new technologies because, in the long run, fundamentals win.

- Finally, *policy* and *geopolitics* shape, and are shaped, by all of the above.
Long Run Fundamental Drivers of Energy Demand
Global GDP by Country

Data Sources: World Bank, PWT, IMF, BIPP CES
Global Population by Country

Data Sources: World Bank, UN
Total Primary Energy Requirement by Country

Data Sources: IEA, BIPP CES
Note: The reference case assumes EVs are 5% and 15% of all new sales by 2023 and 2030, respectively, up from 1% today → displacement of 2.1 million b/d by 2030.
Natural gas demand growth is driven primarily by growth in power generation and reinforced by shifting market structure → different impact in developing nations vs OECD.

Data Sources: IEA, BIPP CES
Coal use slows in China, rises in India and some ASEAN nations, but declines in the OECD → Economic growth versus new sources.

Data Sources: IEA, BIPP CES
The Global Energy Mix

Charting a new energy future will require unprecedented levels of investment, and it is a global challenge. Firms and governments must figure out the most impactful measures of capital investment given desired energy security and environmental goals. Here is where “legacy” and “scale” are paramount. Moreover, global goals will require significant capital investment in the developing world.
Global TPER by Source

2015 Global Market Share
- Biomass and Other: 8.52%
- Wind/Solar/Geothermal: 1.47%
- Hydro: 2.50%
- Nuclear: 4.88%
- Coal: 31.04%
- Natural Gas: 22.62%
- Crude Oil: 28.98%

Wind/Solar/Geothermal increases by a factor of 10 in 15 years, adding 7.4 quads of delivered energy and over 35 quads of nameplate capacity.

Growth, 2000-2015
- 1.44% pa (Δ 9.22 quads)
- 16.24% pa (Δ 7.38 quads)
- 2.80% pa (Δ 4.75 quads)
- -0.19% pa (Δ 0.78 quads)
- 4.08% pa (Δ 78.59 quads)
- 2.58% pa (Δ 40.36 quads)
- 1.01% pa (Δ 22.66 quads)
Global “Business as Usual” to 2030

2030 Global Market Share
Biomass and Other: 7.40%
Wind/Solar/Geothermal: 3.51%
Hydro: 2.80%
Nuclear: 4.82%
Coal: 30.99%
Natural Gas: 23.88%
Crude Oil: 26.59%

Wind/Solar/Geothermal increases adds almost 17 quads of delivered energy and 60 quads of nameplate capacity.

Growth, 2015-2030
- 0.60% pa (Δ4.79 quads)
- 7.15% pa (Δ16.65 quads)
- 2.22% pa (Δ5.89 quads)
- 1.41% pa (Δ6.86 quads)
- 1.47% pa (Δ45.86 quads)
- 1.83% pa (Δ42.61 quads)
- 0.94% pa (Δ26.18 quads)
Global “Business as Usual” to 2050

Wind/Solar/Geothermal doubles from 2030-2050, adding almost 35 quads of delivered energy and over 100 quads of nameplate capacity.

2050 Global Market Share
- Biomass and Other: 3.50%
- Wind/Solar/Geothermal: 5.52%
- Hydro: 3.94%
- Nuclear: 6.68%
- Coal: 24.94%
- Natural Gas: 27.40%
- Crude Oil: 28.02%

Growth, 2015-2050
- 0.16% pa (Δ 2.81 quads)
- 5.82% pa (Δ 51.47 quads)
- 1.66% pa (Δ 6.23 quads)
- 0.85% pa (Δ 9.43 quads)
- 0.77% pa (Δ 53.60 quads)
- 1.42% pa (Δ 80.67 quads)
- 0.74% pa (Δ 48.09 quads)
Some Key Points

Energy efficiency and new technology will be a major part of any path forward. But, regardless of the view of global energy markets, fossil fuels – especially natural gas – will be a significant proportion of the global energy mix for the next few decades.

Much of the projected demand growth over the next 2-3 decades will be in developing Asia, where there is a paucity of resource. For natural gas, this signals a deepening global market with lower perception of supply risks – which supports natural gas demand growth – which supports entry by new suppliers – which supports natural gas demand growth – etc.

Shale in the US has been paradigm shifting for both natural gas and crude oil markets. But, questions remain regarding shale opportunities (and other frontier resources) outside the US

When examining frontier oil and gas resources, there appears to be an important and expanding role for the Western Hemisphere.
The Crude Oil Market as a Microcosm
US oil and gas production has surged

- The last 10 years has born witness to a dramatic shift in US oil and gas production and stimulated a very different view of the future.
  - Light tight oil production now accounts for about 50% of domestic output, and is Texas heavy – Permian (40%), Eagle Ford (23%), Bakken (23%), Others (14%).
  - Shale gas production now accounts for about 63% of all domestic dry gas production, and is heavily concentrated in the Mid-Atlantic and Gulf Coast regions – Marcellus/Utica (49%), Barnett/Haynesville/Eagle Ford/Permian (35%), Others (16%).
The Global Oil Supply Ramifications are Significant...

- Production declines have been largely in regions with civil strife, sanctions, or sector mismanagement. Less than a third of decline is due to geologic factors.

- Growth in the US offset the declines due to above-ground factors, and high prices encouraged a positive supply response from other regions.

- Production remains robust, exacerbated by efforts for market share by OPEC. Near term market balance hinges largely on global demand.

Source: BP
... and Much Needed for New Demands

- Demand declined in the developed economies of the OECD, while it grew in developing economies in South America, the Middle East, and especially Asia.

- In fact, Asian demand growth accounted for over 80% of the increase in global demand, with China comprising just over three-fifths of that increase.

- However, signs of global demand weakness emerged and set the stage for the price adjustments witnessed over the last few years.

Source: BP
Closing Remarks

• Non-OECD nations comprise over 6.2 billion people compared to about 1.3 billion in the OECD. The non-OECD will dictate the future of energy.

• New technologies will play a critical role, but scale-up can be a challenge.
  - Rapid EV diffusion requires infrastructure overhaul, rapid build-up of vehicle production capacity, and assurances of no supply chain constraints.
  - Renewables will capture market share, but they face supply chain challenges, some of which have yet to be realized.
  - When considering the entry of new technology, one cannot forget that price response is dynamic, so no one extreme change can occur without a reaction that re-establishes competitive margins.

• Energy efficiency play a major role in setting the economic viability of energy sources by establishing the “cost of service” for energy-intensive activities.

• Natural gas enjoys the benefits of being clean and capable of leveraging existing infrastructure and technology.

• “Frontier” resources will have significant bearing on markets for 20+ years.

• And, of course, laying over it all, is the shifting geopolitical landscape.
Bonus Slides
Additional Comments

EVs
The Impact of Electric Vehicles

“After 2020 is when EVs will start to destroy oil demand.” This is a common statement. But, what impact will EVs actually have on global oil demand?

We must first address adoption rates and total vehicle stock growth.

The case depicted assumes EV sales expand to 28x current levels by 2030 and 76x current levels by 2040. Through 2040, this is an annual growth of 19.8%.

The growth rate of EVs will depend on things such as
- battery cost and supply chain rigidities.
- consumer preferences.
- EV infrastructure deployment → charging and assembly.
- EVs mainstream in emerging markets?

Note: The calculations assume 12,000 mpy and 25 mpg vehicle displacement and Gompertz-type adoption with a function max = 100%. Note that this puts the calculations on the high side, particularly if early adopters are displacing more efficient vehicles.
Additional Comments

US Shale
Crude Oil, Price, Cost and Productivity: The Impact of Innovation

- Markets must balance! So, with regard to technology, supply and demand-side innovations are equally important in defining the economic dimensions of fuel choice.

- Bottom line:
  - Shale is a long term phenomenon.
  - Can other frontier resources follow suit?
  - How does public sentiment with regard to fossil fuels effect the competitive landscape?
  - What does this mean for long term affordability and, ultimately, demand?
Consider, US price and cost ($/barrel)

- Fundamentals exert themselves to reveal a long run relationship.
Breaking down US per barrel costs: Cost and productivity per well

Data Sources: EIA, BLS, FRED
Implications for cost and productivity in US shales

• Some key points:
  - Analysis indicates real cost to drill and complete wells is explained by productivity, oil price and the rig utilization rate ($R^2 = 0.946$)
    - For the period Nov 2014-Nov 2016, real well cost declined by 63%. Econometric analysis indicates:
      o Productivity improvement responsible for 67%
      o Cost per well reductions responsible for 33%
  - Assuming the productivity gains are not compromised by drilling less productive targets, any ramp in activity could push costs up to as much as 50% above their current levels.
  - What fraction of the observed productivity gains are transitory, perhaps a result of high-grading?

<table>
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<th>For every 1% increase in</th>
<th>Productivity</th>
<th>Oil Price</th>
<th>Rig Utilization</th>
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<td>we see a change in Real Costs per barrel.</td>
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<td>-0.92%</td>
<td>0.15%</td>
<td>0.61%</td>
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For every 1% increase in productivity, oil price, or rig utilization, we see a change in real costs per barrel of -0.92%, 0.15%, and 0.61%, respectively.
Comments on cost and productivity in US shales

- Productivity is a critical element in understanding the responsiveness of shale production to price increases.
  - Productivity improvements occurred as operators simultaneously (a) high-graded production efforts toward premium acreage in an attempt to maintain profitable operations and (b) employed different completion techniques (longer laterals, more water and sand, etc.).
  - As operators moved into better acreage in an effort to maintain profitable operations, their productivity naturally improved. So, it is unclear to what extent the productivity gains realized over the last two years will persist as drilling ramps up and operators move into more marginal acreage.
  - If productivity gains can be maintained, costs per barrel would only increase slightly, which would convey a relatively minor impact to the profitability of new wells drilled, all else equal.

- Of note... recent data indicates the marginal benefit of new drilling and completion techniques are greater in lower tier acreage. This is currently under investigation.
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The Impact of Innovation

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Additional Comments

What about Crude Oil Price?
Long Term vs. Short Term Fundamentals
Near Term Price

- Unexpected demand lulls result in inventory builds and price collapse. Previously expended capital continues to operate as long as variable costs are covered. But, low price will not incentivize new investment until output decline and demand recovery eliminates the inventory overhang.
Long Term Price and New Investment

- Price must recover to incentivize new investment. But, to what level?
- Cost is dynamic, so understanding the drivers of cost is critical. The graph below is a snapshot... in reality costs change with fundamental drivers.

Source: EIA, Rystad, author calculations
Oil Price versus Cost (Real, $/b vs $/b)

Source: EIA, BEA, BLS, author calculations
Dynamic Costs over the Long Run

- Supply-demand imbalances trigger price and investment cycles.
- Predicting price is an inexact process, but understanding the factors involved provides insight and opportunity. The long run is dynamic!