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Some issues arising from unconventional gas development

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Outline of talk

- How real is the unconventional gas boom?
- What are the prospects for US and Canadian exports of LNG?
- What are some of the implications of unconventional gas development?
- Can the US and Canadian experience be replicated elsewhere, especially Australia?
- What is the problem with restricting natural gas exports?
- What is the relationship between natural gas development and renewables?

Unconventional oil and gas

- In unconventional plays, measures are needed to get hydrocarbons to flow to the well bore, while in conventional reservoirs flow occurs without assistance
  - "Easy to find, hard to produce" versus "Hard to find, easy to produce"
  - Another difference is the aerial extent and usually also the depth of the plays
- Fracturing the rock and propping open the cracks increases permeability
- First hydraulic fracturing job was in 1949 in Duncan OK and since then more than 1 million wells have been hydraulically fractured in the US alone
- "New" development combines multistage fracs with horizontal in-layer drilling
- Fluid used is approximately 95% water, 5% sand with less than 1% chemicals
- With coal seam gas, water is pumped *out* of the coal seam, not *into* it
  - This leads to desorption of the gas
  - Permeability is high enough that fracturing is usually not needed
  - Produced water has only naturally dissolved substances and can be quite high quality
- In both NSW and Qld, conventional gas has been found in same areas as CSG

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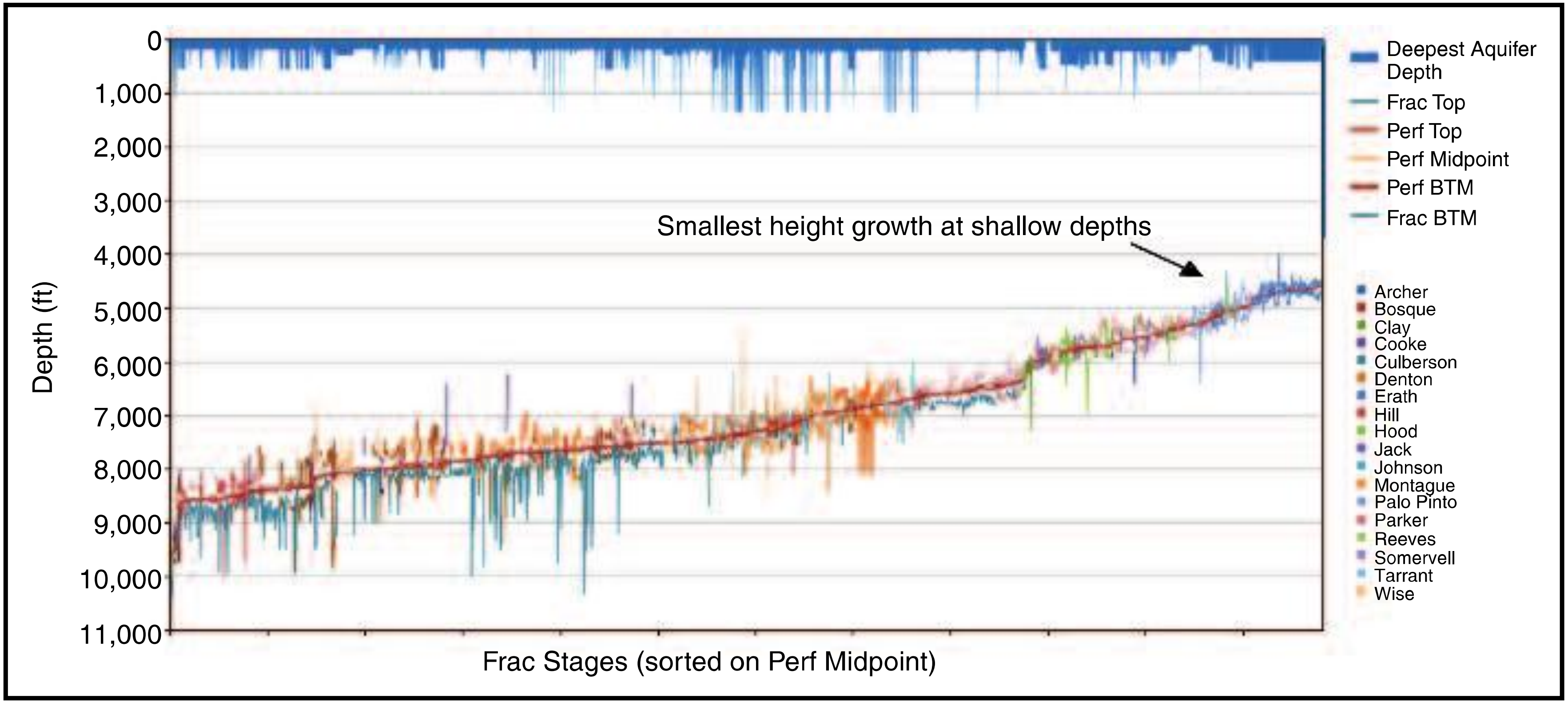
Hydraulic fracturing and water

Frac Heights versus Aquifer Depths (More than 2,000 Barnett Mapped Frac Treatments)



Source: **SPE 145949**

Explaining changes in shale well production over time

- There has been debate in the US about the production profile from shale wells
- Traditional hyperbolic decline curves appear to be unstable, leading some to question how productive shale wells may be
- Researchers at UT BEG have derived a new mathematical model of fluid flow in horizontal and fractured wells
- After the initial surge following clean up, output in year *t* should be inversely proportional to $\sqrt{t}$
- Model tested using longitudinal monthly production data for over 16,500 wells drilled in the Barnett shale covering 1990 through 2011
  - After allowing for lagged production, decline profile matches $K/\sqrt{t}$
- Constant of proportionality (K) depends on the geological characteristics of the shale (thickness, porosity, pressure, depth, thermal maturity, total organic carbon etc), operator size, year of first production and futures price
- Some wells are profitable at \$2.65/mcf, others need \$8.10… median is \$4.85

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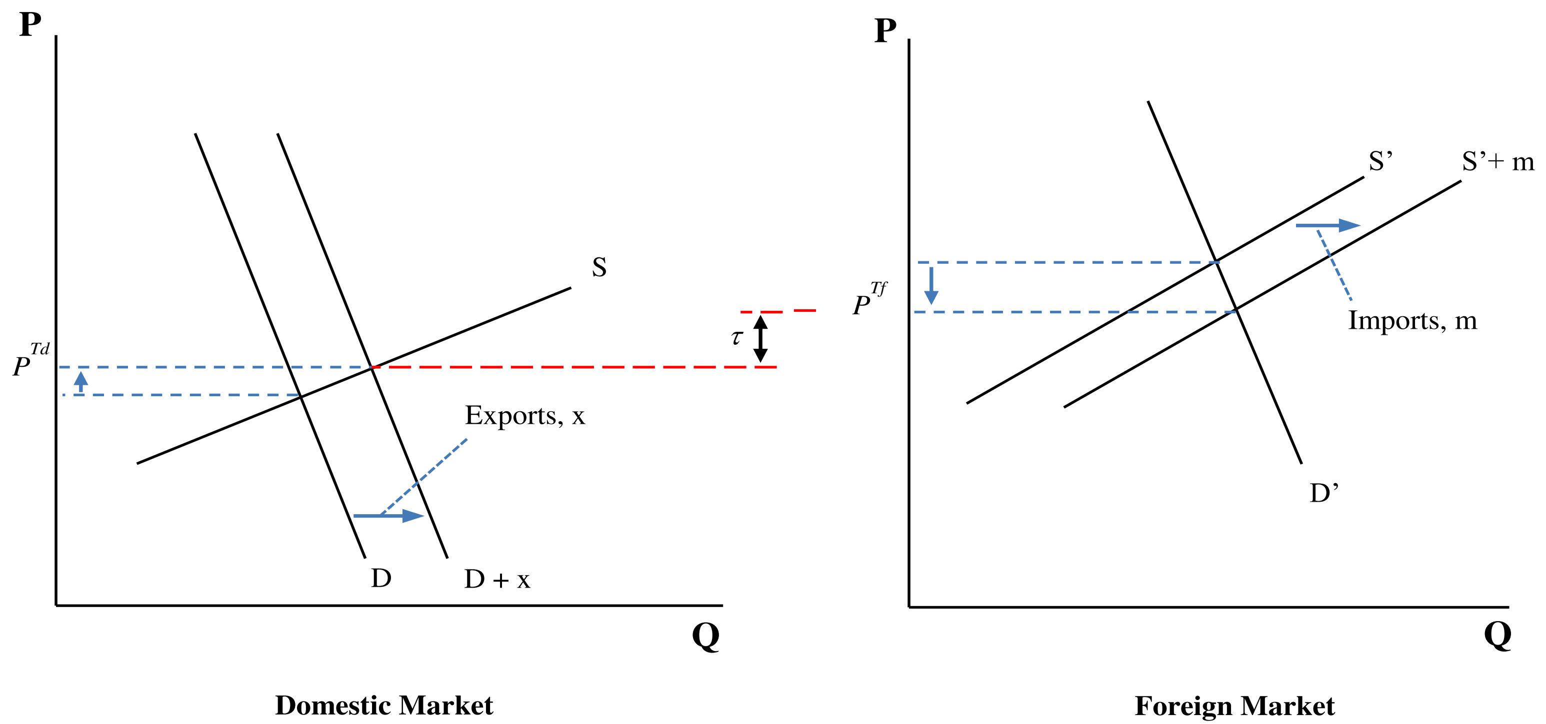
Determinants of US export volume and price

- Price effects will depend on the relative elasticities of supply and demand
- Using the RWGTM, US supply elasticity is 1.52 with shale, 0.29 without it
- *Export* elasticity depends on US supply *net of* domestic demands (industrial, power, transportation and heating)



Other relevant issues

- Short term capacity constraints and the “spot” price of LNG in Asia following Fukushima
- The value of the US dollar and the ratio of natural gas to oil prices
- Current filings for US LNG export capacity exceed 30 bcfd, while 2011 total LNG trade was only about 32 bcfd
  - Exports of the proposed magnitude would reduce prices and ultimately limit the amount of export capacity
- Will widening of the Panama canal reduce transport costs to Asia?
- Exports from Canada may make more long term sense than exports from the US

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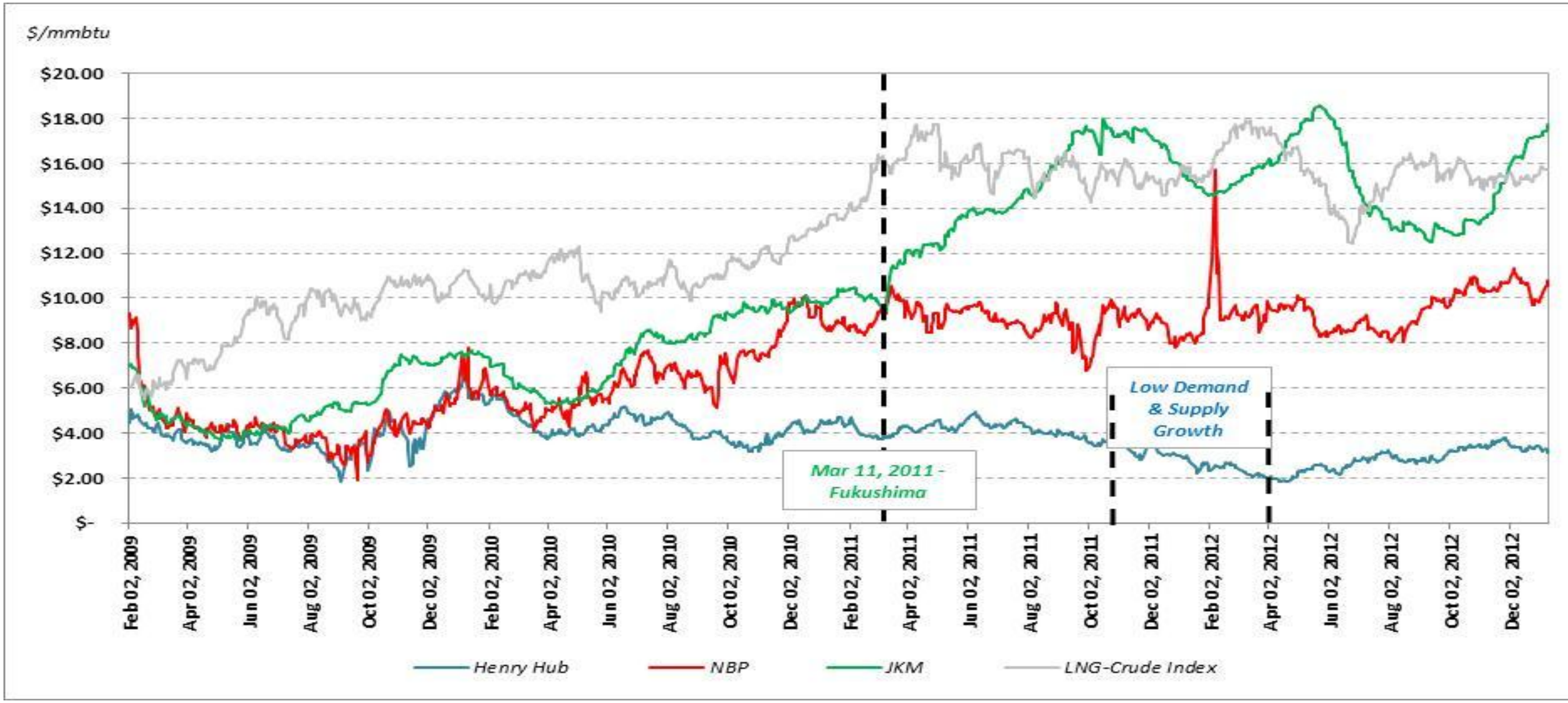
Recent international prices



Price data from Platts; LNG Oil-Index author's calculation

Other recent developments

- LNG swaps are increasingly used to exploit arbitrage opportunities
- Many regasification terminals are adding storage capacity to support arbitrage
- Expiration of some early long-term contracts has left spare capacity and without a need to finance large investments
  - Many have entered the short-term and spot market, not signed long-term contracts
- Much greater volume flexibility, and less than 100% off-take commitments by buyers
- Following the EU restructuring directive of 1998 (promoting competition in EU gas markets), the EU Commission found destination clauses to be anti-competitive in 2001
  - Stimulated re-export of cargoes from Europe and increased destination flexibility
- Growth of “branded LNG,” where non-consuming buyers purchase LNG from multiple projects and sell to buyers under their own names
  - Example: BG, which has signed contracts with several suppliers

Effects of US developments on LNG trade

- US terminals are proposing exports under a tolling arrangement
  - Cheniere signed a 20-year contract with Kogas that priced the feed gas at 115% of Henry Hub and paid Cheniere a $3/mmbtu liquefaction fee
  - They have a similar agreement with the Indian state transmission operator
  - Developers of the Freeport terminal also have signed a tolling agreement with BP, who will add the LNG to their global portfolio
- Many proposed facilities are smaller and more modular than traditional trains
  - For example, the Elba Island liquefaction terminal has modular liquefaction units with lower capacity and capital costs and output assigned to Shell's global portfolio
  - Australian firm LNG Ltd has proposed a terminal in Lake Charles, LA, using a more energy efficient and less capital intensive process for producing LNG
- Future co-location of regasification and liquefaction facilities in the US with pipeline connections to a deep market will facilitate short-term arbitrage
- US exports will likely increase spot and short-term trading, but long-term contracts likely will endure, albeit with more destination and pricing flexibility

Some geopolitical effects of shale gas

- Allow developments predicted worldwide by the RWGTM *versus* keep shale gas production at the 2005 level
- We found that projected shale gas developments virtually eliminate U.S. LNG imports for at least two decades
  - Europe and Asia access LNG formerly destined for US
- World gas supply from Russia, Iran, and Venezuela fall from 33% of global gas supply in 2040 without shale gas to 24% with it
  - Russia's market share in Europe falls from 27% in 2009 to 13% by 2040
  - Reduces the opportunity for Venezuela to become a major LNG exporter
  - Limits Iran's ability to use energy diplomacy for other ends
- Reduces U.S. and Chinese competition for Middle East energy
- Reduced prices spur greater use of natural gas in all countries

Some critical features of the US market

- Stable and conducive regulatory and institutional frameworks
  - **Resource Access** – mineral rights ownership; acreage acquisition; geological knowledge and operating experience; environmental opposition; etc.
  - **Market Structure** – transportation regulation (unbundled access vs. incumbent monopolies) and bilateral take-or-pay obligations vs. marketable rights; existence of infrastructure; pricing paradigms; etc.
- Many other issues face shale development.
  - **Water** – used in production, but declining; water rights and management; treatment and disposal of flowback; concerns about watershed protection from casing failures
  - **Other issues** – earthquakes related to injection of produced and treated water; long term effects of methane escape; ecological concerns over land use and reclamation

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Why was shale in the Cooper Basin next?

- Commercial production from shale gas commenced in the Cooper Basin in Central Australia in September, 2012
- The Cooper Basin resources have access to existing major domestic and, after completion of the Gladstone liquefaction terminals, international markets
- Cooper shales are very similar to the Haynesville and Barnett shales in the US
- There is an extensive subsurface data set as a result of more than 50 years of operation, including over 940 km^2 of 3D seismic
- Almost 300 wells have been drilled through the Roseneath, Epsilon, and Murteree (REM) shales, resulting in more than 1,200 meters of cores
- More than 700 wells have been fracture stimulated in the Cooper Basin to date
- Rigs to drill horizontally are in place and working in the Basin
- Water is available from the Great Artesian Basin, separated from the target zone by impermeable layers
- Other land use in the Basin is non-competitive with oil & gas production, while companies already have working relationships with pastoral leaseholders and traditional land owners
- Traditionally, gas flowed from Moomba to Wallumbilla, was reversed as CBM was developed for LNG export, and may reverse again to support Gladstone LNG export

Comments on restricting gas exports

- A long-standing proposition in economics, known as the Little-Mirrlees rule, implies that any good that can be exported should be valued at its netback price
  - If the good is used as an input into some other downstream process, it will be used until its marginal value in that process equals its price
  - Using the good domestically precludes its export
  - Pricing below the netback price encourages domestic uses that are less valuable than what could be obtained through export
- A related fundamental conclusion in economics is that export taxes (or restrictions) are equivalent to import tariffs (or quotas)
  - Holding monetary policy and capital flows fixed, reducing a country's exports also reduces its imports and vice versa
  - In either case, the imposts or restrictions amount to a tax on trading
- Reducing a country's ability to exploit its comparative advantage through trade makes the country worse off
  - The argument as it applies to restrictions on imports is now widely accepted in Australia and New Zealand, but the same argument applies to export restrictions

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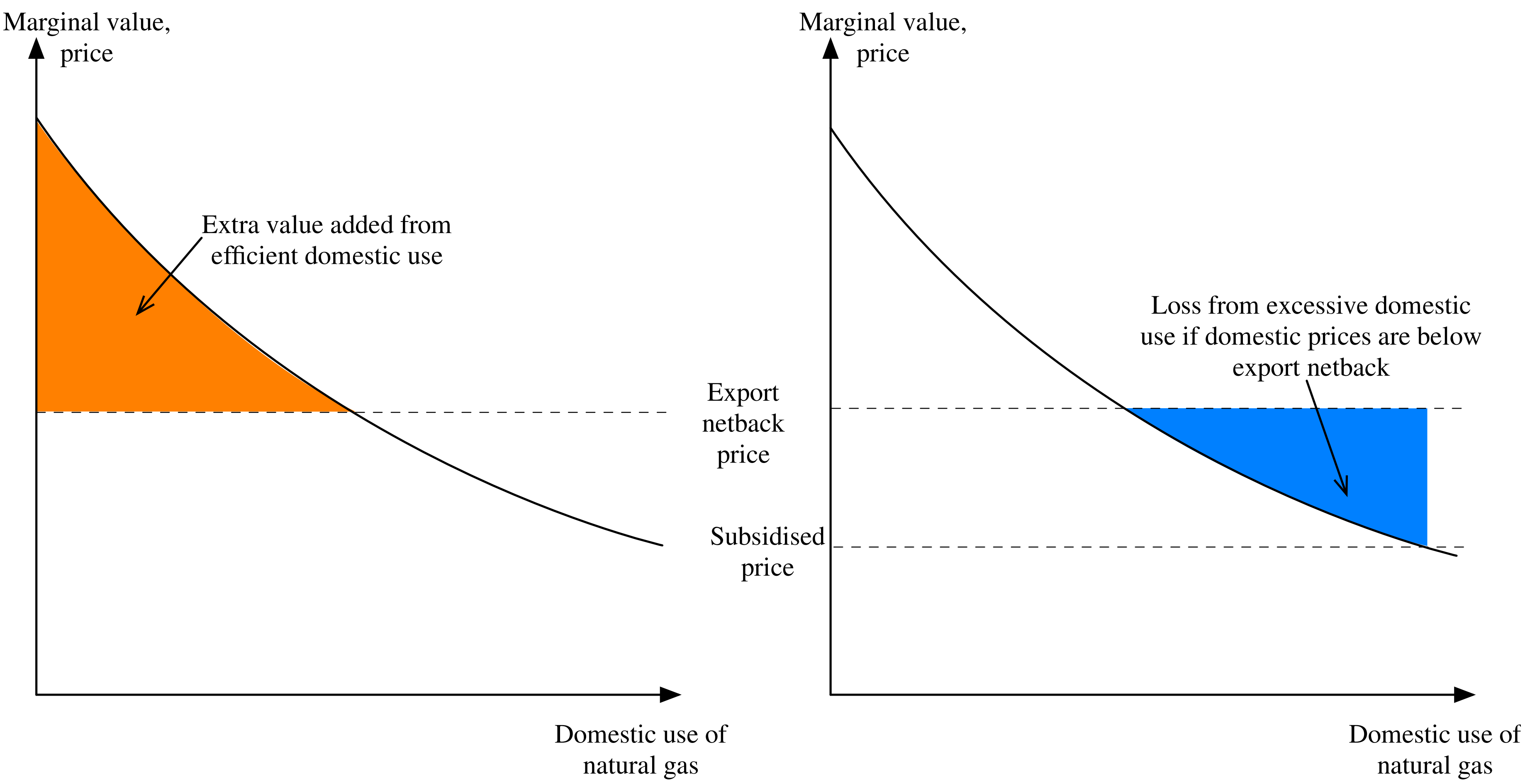
"But domestic uses have higher value added"



Natural gas and renewables

- Some opposition to natural gas may because low gas prices make renewables less attractive
- But current renewable technologies are very expensive for a number of reasons
  - They have a low capacity factor, which raises capital costs
  - The best sites are often remote from markets, which requires expensive transmission line upgrades that then also are used at a low capacity factor
  - Peak generation often occurs when demand is at a minimum, and generation at the demand peak times is much lower than average, so more peaking plant is needed
  - Output fluctuations are extreme – for wind, until maximum allowable wind speed is reached, output at varies with the cube of wind speed
  - Backup plant is not used when the wind blows lowering its capacity factor and raising its cost; also running it less than full output reduces efficiency and raises pollution
  - The imperative to provide backup for renewables favours gas turbines over CCGT, but the latter are much more efficient
  - Expensive upgrades are needed to make networks more robust