The Shale Gas Shock

Matt Ridley

Foreword by Freeman Dyson

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About the Author

Matt Ridley is one of the world's foremost science writers. His books have sold over 800,000 copies and been translated into 27 languages. His new book 'The Rational Optimist' was published in 2010. He is a member of the GWPF's Academic Advisory Council.

Freeman Dyson

Freeman Dyson FRS, a world-renowned theoretical physicist, is Professor Emeritus of Mathematical Physics and Astrophysics at the Institute of Advanced Study in Princeton where he held a chair for many years. Dyson is the author of numerous widely read science books. He is a member of the GWPF's Academic Advisory Council.

Foreword by Freeman Dyson

I agree emphatically with the conclusions of Matt Ridley's report. This foreword explains why.

Two scenes from my middle-class childhood in England. In my home in Winchester, coming wet and cold into the nursery after the obligatory daily outing, I sit on the rug in front of the red glowing gas-stove and quickly get warm and dry. In the Albert Hall in London, in a posh seat in the front row of the balcony, I listen with my father to a concert and hear majestic music emerging out of yellow nothingness, seeing neither the orchestra nor the conductor, because the hall is filled with London's famous pea-soup fog. The gas-fire was the quick, clean and efficient way to warm our rooms in a damp climate. The fog was the result of a million open-grate coal fires heating rooms in other homes. In those days the gas was coal-gas, with a large fraction of poisonous carbon monoxide, manufactured locally in gas-works situated at the smelly and slummy east end of the town. Since those days, the open-grate coal fire was prohibited by law, and the coal-gas was replaced by cleaner and safer natural gas. London is no longer the place where your shirt-collar is black with soot at the end of each day. But I am left with the indelible impressions of childhood. Coal is a yellow foulness in the air. Gas is the soft purring of the fire in a cozy nursery.

In America when I raised my own children, two more scenes carried the same message. In America homes are centrally heated. Our first home was heated by coal. One night I was stoking the furnace when a rat scuttled out of a dark corner of the filthy coal-cellar, and I killed him with my coal-shovel. Our second home was heated by oil. One happy day, the oil-furnace was replaced by a gas-furnace and the mess of the oil was gone. We were then told that the supply of natural gas would last only thirty years. Now the thirty years are over, but shale gas has extended the supply to a couple of centuries. While the price of oil goes up and up, the price of gas goes down. In America, coal is a bloody fight in the dark. Gas is a clean cellar which became the kids' playroom.

The most important improvements of the human condition caused by new technologies are often unexpected before they happen and quickly forgotten afterwards. My grandmother was born around 1850 in the industrial West Riding of Yorkshire. She said that the really important change in working-class homes when she was young was the change from tallow candles to wax candles. With wax candles you could read comfortably at night. With tallow candles you could not. Compared with that, the later change from wax candles to electric light was not so important. According to my grandmother, wax candles did more than government schools to produce a literate working class.

Shale gas is like wax candles. It is not a perfect solution to our economic and environmental problems, but it is here when it is needed, and it makes an enormous difference to the human condition. Matt Ridley gives us a fair and even-handed account of the environmental costs and benefits of shale gas. The lessons to be learned are clear. The environmental costs of shale gas are much smaller than the environmental costs of coal. Because of shale gas, the air in Beijing will be cleaned up as the air in London was cleaned up sixty years ago. Because of shale gas, clean air will no longer be a luxury that only rich countries can afford. Because of shale gas, wealth and health will be distributed more equitably over the face of our planet.

Freeman Dyson, 22 April 2011

Summary

Shale gas is proving to be an abundant new source of energy in the United States. Because it is globally ubiquitous and can probably be produced both cheaply and close to major markets, it promises to stabilise and lower gas prices relative to oil prices. This could happen even if, in investment terms, a speculative bubble may have formed in the rush to drill for shale gas in North America. Abundant and low-cost shale gas probably will – where politics allows – cause gas to take or defend market share from coal, nuclear and renewables in the electricity generating market, and from oil in the transport market, over coming decades. It will also keep the price of nitrogen fertiliser low and hence keep food prices down, other things being equal.

None the less, shale gas faces a formidable host of enemies in the coal, nuclear, renewable and environmental industries – all keen, it seems, to strangle it at birth, especially in Europe. It undoubtedly carries environmental risks, which may be exploited to generate sufficient public concern to prevent its expansion in much of western Europe and parts of North America, even though the evidence suggests that these hazards are much smaller than in competing industries.

Elsewhere, though, increased production of shale gas looks inevitable. A surge in gas production and use may prove to be both the cheapest and most effective way to hasten the decarbonisation of the world economy, given the cost and land requirements of most renewables.

Introduction

1. The detection and exploitation of shale gas has been described as nothing less than a revolution in the world energy industry, promising to transform not only the prospects of the gas industry, but of world energy trade, geopolitics and climate policy.

> Production of 'unconventional' gas in the U.S. has rocketed in the past few years, going beyond even the most optimistic forecasts. It is no wonder that its success has sparked such international interest… A few years ago the United States was ready to import gas. In 2009 it had become the world's biggest gas producer. This is phenomenal, unbelievable. – Anne-Sophie Corbeau, International Energy Agency[1]

2. The claim made by shale gas's champions is that, in defiance of early scepticism, shale gas is proving to be:

- ubiquitous, with the result that it promises to be developed near to markets rather than in places where it happens to be abundant, like oil;
- cheap, with the result that it promises gradually to take market share from nuclear, coal and renewable energy and to replace oil in some transport and industrial uses;
- environmentally benign, with the result that it promises to reduce pollution and accelerate the decarbonisation of the world economy.

3. This report considers these claims and assesses them against various counter-claims. It finds that although there are considerable uncertainties that make hyperbole unwise, shale gas will undoubtedly prove to be a significant new force in the world energy scene, with far-reaching consequences.

[1] http://www.bbc.co.uk/news/business-12245633

Geological definitions

4. Shale gas is one form of unconventional gas extracted from source rocks such as shale, coal and sandstone.

- **Shale** is a common form of fine-grained sedimentary rock laid down as mud in relatively calm seas or lakes.
- **Black shale** is shale that was laid down in especially anoxic conditions on the floors of stagnant seas and is rich in organic compounds derived from bacterial, plant and animal matter.
- **Conventional gas** is gas that has migrated, usually from shale, to permeable reservoirs, predominantly sandstone.
- **Shale gas** is gas that remains tightly trapped in shale and consists chiefly of methane, but with ethane, propane, butane and other organic compounds mixed in. It forms when black shale has been subjected to heat and pressure over millions of years, usually at depths of 5,000-15,000 feet.
- **Coal-bed methane** is gas trapped in coal seams that can be tapped by similar methods to those used for shale gas.
- **Tight sand gas** is gas held in sandstone reservoirs that are unusually impermeable; it can be extracted by fracturing the rock.

Shale gas drilling

5. The technology of shale gas production is changing all the time, but the basic steps are these:

- **Seismic exploration.** Underground rock formations are mapped using sound waves and 3D reconstruction to identify the depth and thickness of appropriate shales. This may be done from the air, desktop (re-analysing old data) or ground survey.
- **Pad construction.** A platform for the drilling rig is levelled and hard-cored over an area of about 5 acres.
- **Vertical drilling.** A small drilling derrick drills up to 12 holes down to the shale rock, encasing the borehole in five concentric sleeves of steel and concrete near the surface, falling to one sleeve as the depth increases. Suitable shales are typically 4,000-12,000 feet below the surface.
- **Horizontal drilling.** A larger drilling derrick, 150 feet high, is assembled on site and slant-drills each well horizontally into the shale formation for up to 4,000 feet in different directions, using gas sensors to ensure it stays within the seam. The derrick is then removed after about 30-40 days and the wellhead capped.

- **Fracturing or `fracking'.** The concrete casing of the horizontal pipe is perforated with small explosive charges and water mixed with sand is pumped through the holes at 5,000 psi (pounds per square inch) to fracture the rock with hairline cracks up to 1,000 feet from the pipe. The sand is used to prop open the fissures, finer sand being used as the cracks propagate further from the pipe. This takes about 3-10 days. The effectiveness of fracking is rising, as 12-stage fracking replaces 5-stage fracking.
- **Waste disposal.** Tanks collect water that flows back out of the well. The water is generally reused in future fracking, or desalinated and disposed of as waste water through the sewage system.
- **Production.** A 'Christmas tree' valve assembly about the size of a garden shed, and a set of small tanks about the size of a small garage, remains on site to collect gas (and small quantities of oil), which then flows through underground pipes to a large compressor station serving a large number of wellheads and onwards to trunk pipelines.

6. Approximately 25% of a shale gas well's gas production emerges in the first year and 50% within four years. Thereafter the output falls very slowly and wells are expected to continue supplying gas for about 30-50 years. There is considerable disagreement over how rapidly gas production declines during this period.

History

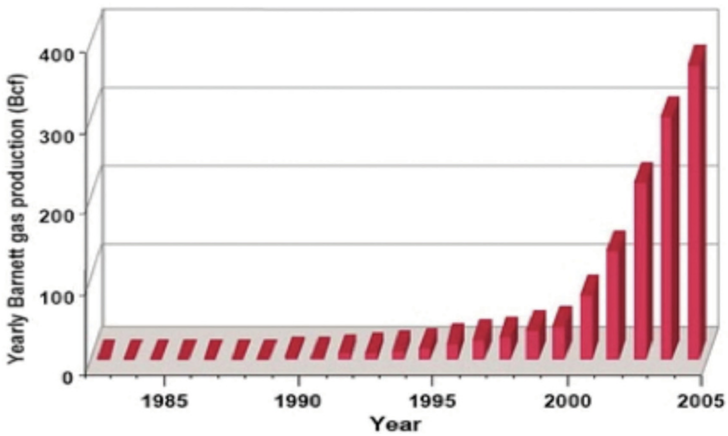
7. Like many technological revolutions, shale gas came about through a timely combination of existing technologies rather than through one new invention:

- The knowledge that shale rock contains gas is old; brief bursts (`shows') of gas would be encountered when drilling through shales to reach oil reservoirs.
- Hydraulic fracking of rock to open pores and allow the extraction of hydrocarbons dates back to the 1940s.
- Horizontal drilling was already in use in the oil industry in the 1970s but improved in the 1990s.
- Seismic exploration was also old, but growing computer power led to the development of sophisticated 3D reconstructions of rock strata in the 2000s.

8. It was George Mitchell's genius to bring these four elements together in the 1990s in Texas and discover that significant quantities of natural gas could be extracted from deep shales that had been subjected over the aeons to heat and pressure, using `slick' (i.e., treated for low-viscosity) water and sand, rather than gel, in just the right mixture to fracture the rock and horizontal drilling to expand the reach of each well.

9. This turned conventional wisdom on its head. Shales had always been thought unprofitable rocks, not because they lacked hydrocarbons – they derive from muds rich in organic matter laid down in ancient seas or lakes – but because they were not permeable enough for the oil or gas to escape. Indeed, shale often forms the `cap' that holds in place the profitable oil and gas reservoirs that have migrated into permeable sandstones beneath.

10. The Barnett Shale in the Fort Worth Basin was the first to be developed and surprised many forecasters by its extent and the productivity of its wells. The Barnett Shale now provides about 5% of US natural gas supply. Mitchell Energy and Development began experimenting with hydraulic fracking in the Barnett Shale in 1981 but it was not until 1999 that it found the right `light sand frac' to release worthwhile amounts of gas[2]. Mitchell was then acquired by Devon Energy, bringing the expertise of horizontal drilling. The success of Mitchell spun off imitators and attracted rivals to learn the new technology. Some of these then began to hunt out other shale basins, including the Fayetteville and Woodford Shales in Arkansas and Oklahoma, first developed in 2004, and the Haynesville Shale in Louisiana, first developed in 2008.



Yearly production of gas from the Barnett Shale in the Fort Worth Basin in BCF(Billion Cubic Feet) Source: geology.com

2 http://www.jsg.utexas.edu/news/feats/2007/barnett/father_of_barnett.html

11. A greater surprise lay in Pennsylvania, where oil drilling had first been invented in 1859 by Edwin Drake and which had long been thought `played out' by the beginning of the 21st century. In 2003 a disappointing $6m series of `dry' wells drilled by Range Resources into a very deep Lockport Dolomite formation had passed through black shale called the Marcellus Formation. Visiting Texas, Range's geologist, Bill Zagorski, suddenly realised the similarity of Marcellus Shale to the Barnett Shale. He suggested the use of hydraulic fracking of the Marcellus Shale.

12. Range Resources returned to Washington County, Pennsylvania, and hydraulically fracked the Renz 1 well in October 2004, to stimulate gas flow[3]. Over the next three years it perfected the formula for stimulating quantities of gas from the Marcellus shale[4]. When Range announced in December 2007 that it had succeeded in producing a flow of 22 million cubic feet of gas per day from seven horizontal wells, geologists led by Terry Engelder of Penn State University realised that the sheer extent of the Marcellus Formation, a black shale laid down in a stagnant sea 385 million years ago, implied a large resource, of perhaps 50 Tcf[5].

13. Yet even this estimate proved conservative. By 2011, some estimates of the gas recoverable from the `beast in the east' had reached 516 Tcf[6], equivalent to 25 years' US consumption and worth potentially $2 trillion. This could prove over-optimistic: the proportion that will be recovered, between 10% and 40%, depends on the price of gas and the evolution of technology. Yet it is possible that the Marcellus shale could be not only the largest gas field ever discovered in North America, but possibly larger than any conventional gas field in Russia, the Middle East or North Africa bar the giant South Pars field shared by Qatar and Iran[7].

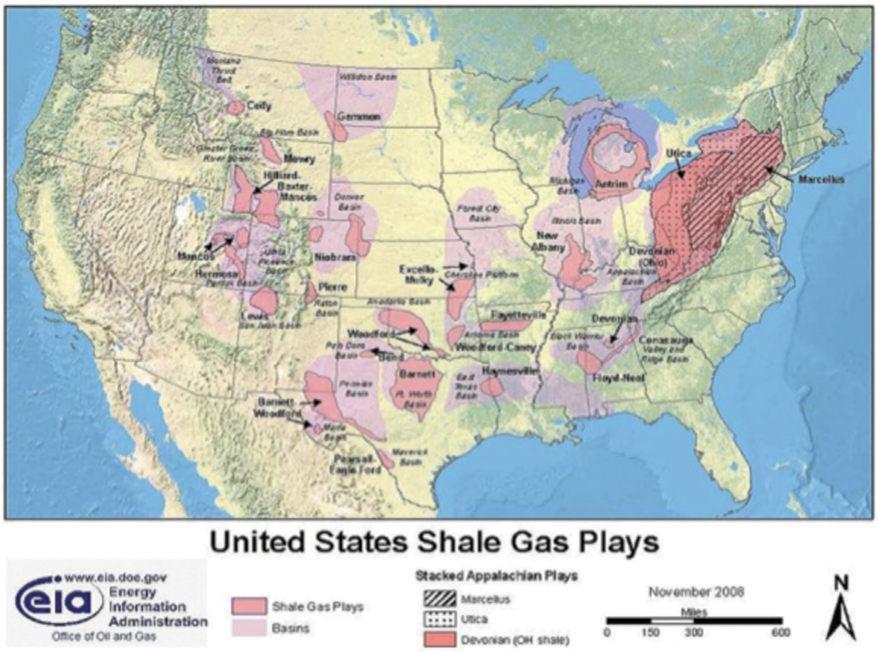
14. In arguing for high recovery rates from Marcellus, shale gas champions maintain that shallow wells (which have been subjected to less gas-creating pressure and heat) in the North-eastern part of the Marcellus shale are among the most productive. And Marcellus is only one of three overlapping shale strata in the Appalachian Basin. The Utica and Devonian shales cover similarly large areas, extending into Quebec and Ohio respectively. Neither is yet fully tested.

15. Shale gas sceptics counter that gas production in the Barnett and Haynesville shales has quickly focussed on a relatively small `core area' or sweet spot, where wells are most productive. They consider it likely that this will also happen in the Marcellus Shale, raising both the risk and cost incurred drilling unproductive wells and lead to lower recovery percentages[8].

[3] http://www.aapg.org/explorer/2010/04apr/marcellus0410.cfm
[4] http://www.post-gazette.com/pg/11079/1133325-503.stm
[5] http://www.geosc.psu.edu/~jte2/references/link150.pdf
[6] Penn State University.
[7] IPC Petroleum Consulting inc
[8] http://www.theoildrum.com/node/7075

16. There is thus considerable uncertainty about how much gas the Marcellus Shale will eventually produce. Combining the probable, possible and speculative quantities in the Marcellus, Haynesville, Barnett, Woodville and other shales, together with conventional fields, the Potential Gas Committee of the Colorado School of Mines (PGC), estimated in 2009 that America holds 2,074 Tcf of gas. In 2010, IHS CERA estimated resources between 2,000 Tcf `discovered' and 3,000 Tcf `expected'[9].

Finding: Shale gas resources are large.



9 IHS Cambridge Energy Research Associates Report `Fuelling North America's Energy Future', 2010.

Peak gas?

17. Until 2008, most experts believed that world natural gas supplies would run out sooner than oil or coal supplies. The exhaustion of natural gas reserves has been regularly predicted. For example, in 1922 President Warren Harding's US Coal Commission, after interviewing 500 experts over 11 months, opined:

> Already the output of [natural] gas has begun to wane. Production of oil cannot long maintain its present rate.
> US Coal Commission, 1922[10]

18. In 1956, M. King Hubbert predicted that gas production in the United States would peak at about 14 trillion cubic feet per year some time around 1970. In 2002, an Exxon executive pointed out that US gas discoveries had peaked before 1980[11].

19. In fact, though oil may yet grow more scarce and costly during this century, there is no realistic prospect of the world `running out' of coal or gas this millennium. As the GBR 2009 Report put it:

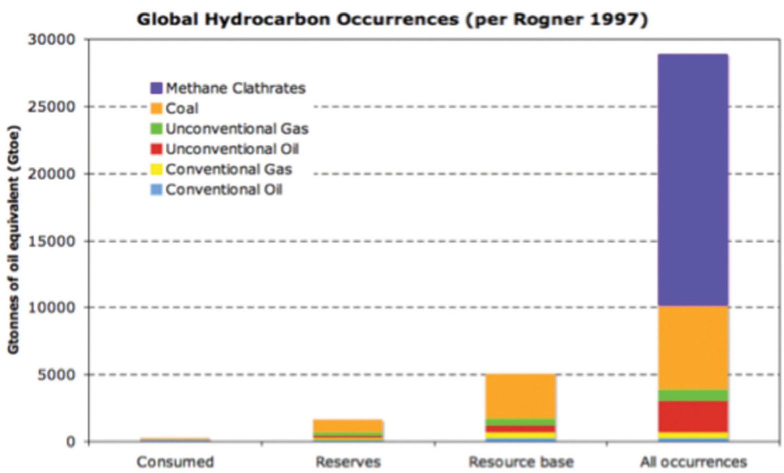
> If one compares the global annual production of all energy resources at the end of 2007 (439 EJ) and the amount of reserves (38 700 EJ) and resources (571 700 EJ), a ratio of approximately 1 : 90 : 1300 results.
> GBR 2009[12]

20. Like the peak-oil theory of the 1970s (when Jimmy Carter, influenced by E.F. Schumacher, argued that oil could be used up within a decade) and the peak-coal debate of 1865 (when W.E. Gladstone, influenced by W.S. Jevons, argued that Britain should retire its national debt before its coal ran out), all these forecasts proved to be far too pessimistic. It is notable that shale gas was first exploited in the most explored part of the world, the United States. Part of the reason for these false predictions was that strict price regulation of gas in the 1970s halted gas exploration in its tracks, producing a peak that some mistook for the beginning of exhaustion of reserves.

[10] Quoted in Bradley, R.L. 2007. Capitalism at Work. Scrivener Press. P 206.
[11] http://www.worldenergysource.com/articles/pdf/longwell_WE_v5n3.pdf
[12] http://www.bgr.bund.de/cln_116/nn_335082/EN/Themen/Energie/Produkte/energyresources__2009.html?__nnn=true

21. Recently, the Congressional Research Service has claimed that America now has the world's largest fossil-fuel resources – greater than Saudi Arabia, Canada and China combined[13] – thanks to shale gas. This is misleading and not just because Canada's 3 trillion barrels of oil sands, one trillion of which are now thought to be economically recoverable, were omitted from the calculation. It is important to realise that the shale gas revolution will not much change estimates of the total hydrocarbon resources existing in the world. Coal, shale oil and oil sands already exist in quantities far greater than can be consumed over the next few centuries. The question has always been one of price: many of these resources are inaccessible at anything less than very high prices. This is especially true of methane hydrates, also known as clathrates, found near the continental margins of the ocean floor. Estimates of the quantities of methane in such reservoirs are that they contain at least twice as much energy, possibly ten times as much, as in all coal, oil and natural gas resources combined: up to 3 million Tcf. To date no practical means to mine this solid fuel, even in shallow permafrost, has been found, and commercial development is probably at least 30 years away. None the less, they serve to remind us that methane is not in any sense likely to `run out'[14].

22. The key question about shale gas is not therefore whether it exists in huge quantities, but whether it can now be exploited on a large scale at a reasonable price. This is what potentially makes it different from shale oil, tar sands and clathrates: its champions claim that it can compete on volume and price, and even undercut conventional gas reserves.



Source: Al Fin Energy blog

13 http://www.energytribune.com/articles.cfm/6933/US-Has-Earths-Largest-Energy-Resources
14 http://fossil.energy.gov/programs/oilgas/publications/methane_hydrates/MHydrate_overview_06-2007.pdf

Sceptical counter-arguments

23. Not everybody agrees with these estimates. Art Berman, a geological consultant, is a well known sceptic, who argues that early experience suggests that only about 10% of each shale gas field will prove to be recoverable. Given that there are large uncertainties about the size of shale gas fields, a careful reading of the PGC report would conclude that US shale gas resources may last for as little as seven years rather than 100[15].

24. Berman also argues that far from continuing to produce gas for 40 years, each well may have a rapid decline rate and cease to be commercial within just a few years; decline rates are so high that, without continuous drilling, overall production would plummet.

> So if you take the position that we're going to get all these great reserves because these wells are going to last 40-plus years, then you need to explain why one-third of wells drilled 4 and 5 and 6 years ago are already dead. – Art Berman, interview with the Energy Bulletin, 19 July 2010[16]

25. Consequently, in the rush to develop shale gas wells and demonstrate high volumes of production to shareholders, most companies are spending 200-400% of cashflow on drilling and are creating only negative shareholder value as they accumulate debt. As volumes depress prices, this becomes a self-fulfilling prophecy, exacerbated by the `use-it-or-lose-it' character of 5-year drilling leases. However great the resource proves to be, companies will go bust trying to develop it. This is a pattern familiar to historians of early railways and dot-com companies. In short, there is a speculative bubble in shale gas[17].

26. This argument has force, but Berman's audience is investors, not consumers. It is quite possible that investment in shale gas firms will indeed prove risky as their very success drives gas prices down. But that will only happen if volumes of gas produced are high; and it does not mean that exploration and drilling will cease, for if they did, prices would rise again and exploitation would resume. After all, this has been the experience of the coal industry, the oil industry, and many other industries throughout history: success drives down prices, leading to business failures, but over the long term this does not prevent continuing expansion of production because low prices stimulate expanding consumption.

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15 http://www.theoildrum.com/node/7075
16 http://energybulletin.net/node/53556
17 http://energybulletin.net/node/53556

27. What makes it possible for prices to fall while production expands in an industry is unit cost reduction through innovation: a farmer, for example, works out how to continue to grow wheat profitably at lower wheat prices. The chief cost of shale gas production is the leasing of drilling and fracking equipment. The cost of this has been falling as companies learn to complete drilling and fracking in shorter and shorter times. With horizontal drilling and hydraulic fracturing being still a fairly new combination of technologies, less than ten years old, unit cost reduction has been dramatic. Some companies are claiming to have halved their costs in approximately two years as they climbed the learning curve[18]. The key question is how far this can continue and when unit costs will flatten out. At present, the overwhelming weight of opinion is that further cost reductions are possible. This means that, even though there is a speculative bubble leading to low prices and some bankruptcies, a large and sustained increase in gas production from shale is none the less likely.

Finding: Low gas prices are a consequence of high production

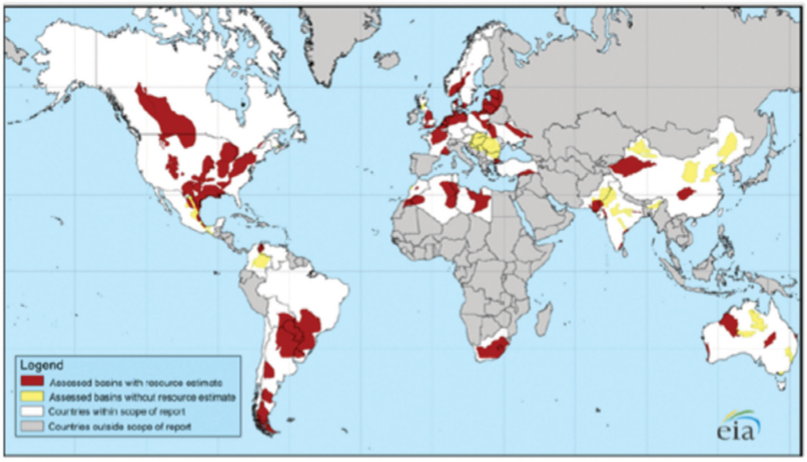
Worldwide interest

28. The Marcellus discovery alerted the world beyond the gas industry to shale gas. Similar shales exist on all continents, wherever ancient seas and lakes have left deposits of mud. By one estimate, there are 688 suitable shale deposits in 142 basins, only a handful of which have yet been explored[19]. Exploration of shale gas basins has begun in Poland, Morocco, South Africa, Australia, New Zealand, China and other places. It is unlikely that Marcellus will turn out to be the richest deposit in the world.

29. No reliable estimate of unconventional gas resources worldwide yet exists[20]. Most observers follow Rogner's 1997 stab in saying that about 16,110 Tcf of in-place shale gas are likely to exist, of which 10-40% would be recoverable[21]. In March 2011, The Energy Information Administration commissioned a report from Advanced Resources International to assess 48 shale basins in 32 countries. The study arrived at an estimate of technically recoverable resources totaling 5,760 Tcf in those basins (plus 862 Tcf in the United States)[22] and total in-place resources of 25,300 Tcf, not counting large parts of the globe that were not covered, which included Russia. These numbers could prove either too optimistic or too pessimistic.

30. World energy consumption is less than 500 exajoules per year, equivalent to approximately 500 Tcf. Thus recoverable shale gas resources of, say, 8,000 Tcf (i.e., 20-30% of in-place resources) would last at least a century if their consumption displaced half of conventional gas use (which is 23% of total energy use). In January 2011 the International Energy Agency raised its estimate of how long world gas reserves will actually last to quarter of a millennium[23]. Given the likelihood of other energy sources coming on line long before then, the energy expert Nick Grealy has said that shale gas may be `essentially eternal'[24].

Finding: Shale gas is likely to occur abundantly worldwide



Map of 48 major shale gas basins in 32 countries
Source: Energy Information Administration: World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States, April 2011

Coal-bed methane and tight gas in sandstone

31. Shale is not the only source of unconventional gas. The same horizontal drilling and hydraulic fracking technology can extract methane from tight sandstones and coal seams. Coal-bed methane is already a major contributor to US gas supplies in the San Juan basin of New Mexico. One estimate of coal-bed methane resources worldwide comes to a range of 3,540 to 7,630 Tcf[25], of which 830 Tcf is recoverable with current technology, or about one-third of shale gas quantities. Total tight gas sands could be similar in quantity but with lower recoverable percentages.

[18] http://www.oxfordenergy.org/pdfs/NG46.pdf
[19] http://www.worldenergy.org/documents/shalegasreport.pdf
[20] http://www.rpsea.org/attachments/articles/239/KuuskraaHandoutPaperExpandedPresentWorldwideGasShalesPresentation.pdf
[21] http://www.worldenergy.org/documents/shalegasreport.pdf
[22] http://www.eia.doe.gov/todayinenergy/detail.cfm?id=811
[23] http://www.bbc.co.uk/news/business-12245633
[24] Grealy, N. 2010. Global Shale Gas: What now? What next? No Hot Air, London.
[25] http://www.rpsea.org/attachments/articles/239/KuuskraaHandoutPaperExpandedPresentWorldwideGasShalesPresentation.pdf

Shale gas exploitation worldwide

32. The rate at which shale gas deposits are exploited worldwide will depend on how fast other countries develop the necessary techniques, and on political will. To take one example, there is little doubt that there will be a shale gas boom in China, for three reasons: China has a policy of encouraging gas use to replace coal; Chinese firms have invested $6 billion in buying into US shale gas firms to learn techniques; and Chinese recoverable resources of shale gas are estimated by EIA/ARI to exceed US ones by 40%[26].

33. In Russia, by contrast, the powerful position of Gazprom, with its control over gas exports and its huge reserves of conventional gas, will be an impediment to shale gas development. In an indication that it does not welcome shale gas as a competitor in export markets, Gazprom's chief executive Alexander Medvedev has suddenly shown a touching and surprising concern for the environmental health of American women:

> Every American housewife is aware of shale gas, but not every housewife is aware of the environmental consequences of the use of shale gas. I don't know who would take the risk of endangering drinking water reservoirs. – Alexander Medvedev, interview with the *Daily Telegraph*, 12 February 2010[27].

Shale gas in Europe

34. There is disagreement as to whether the US experience will prove typical in Europe. Lane Energy and other firms began drilling and fracking in the Silurian shales of Poland in 2010 and are expected to announce imminently that they have found gas. Rich shale gas basins occur in Austria and Hungary. Cuadrilla has drilled a well near Blackpool in England and expects to frack it soon.

35. Chatham House argues that in Europe shale gas may encounter new and special difficulties:

> In Europe the geology is less favourable, there are no tax breaks and the service industry for onshore drilling is far behind that in the United States. – Paul Stevens, Chatham House, September 2010[28].

26 http://www.bloomberg.com/news/2011-04-14/china-may-start-shale-gas-production-by-2015-ministry-says-1-.html
27 http://blogs.telegraph.co.uk/finance/rowenamason/100003741/russian-energy-giant-gazprom-shale-gas-is-really-really-really-rubbish-no-really-it-is/
28 http://www.chathamhouse.org.uk/files/17344_r_0910stevens_es.pdf
29 http://www.oxfordenergy.org/pdfs/NG46.pdf

36. Certainly, there is less experience with entrepreneurial wildcat drilling than in the US; there are fewer firms to compete for contracts; there is higher population density and less tolerance of industrial activity in rural areas (though this has not stopped the wind industry); and planning laws and environmental regulation are tighter and more sluggish. Consequently, Florence Geny argues that the cost of drilling for shale gas in Europe could be double that of America[29]. France has already imposed a moratorium on shale gas drilling.

37. On the other hand, Europe also has advantages. Hydrocarbons are mostly nationalised, so there is no need for gas firms to negotiate with many different landowners (though the owner of the site of the actual drilling pad will surely need compensation); European drillers can benefit from prior American experimentation and can go straight to the newest kind of horizontal drilling and fracking technology with its small footprint and high success rate; many countries in Europe already have well developed gas pipeline infrastructure.

38. None the less, shale gas will encounter formidable opposition from entrenched and powerful interests in the environmental pressure groups, in the coal, nuclear and renewable industries, and from political inertia. Ultimately, it will be a matter of whether overborrowed European governments, businesses and people will be able to resist such a hefty source of new revenue and a clean energy source requiring no subsidy.

Finding: Europe's politics will decide whether shale gas exploitation occurs.

Shale gas exploration sites in Europe

Source: shalegas.com

The predictability of shale gas

39. The shale gas industry argues that, on the whole, dry wells do not now happen because gas occurs throughout the continuous shale stratum, rather than being concentrated in `traps' as conventional gas is. Once the geology is better understood, production is predictable and similar for each well so long as the drilling is accurate and the fracking is successful. The more wells are drilled, the better the properties of the shale become known – effectively `de-risking' the field. This is unlike conventional gas drilling and means that gas companies can choose where to drill based on how close to pipelines and markets the site is, rather than gambling on lucky strikes in remote locations.

40. This is the so-called `manufacturing model', in which shale gas is said to resemble a widget factory more than an oil field. However, this is misleading. Since activity in shale gas fields usually contracts into core areas where productivity is highest, and since the decline rate of production from a shale gas well is still highly uncertain, there will still be great differences between good wells and bad ones.

> The claim of repeatable and uniform results by the shale play promoters cannot be supported by case histories to date. We contend that the factory model is not appropriate because the geology of these plays is more complex than operators claim. – Art Berman, *The Oil Drum*, 28 October 2010[30].

41. None the less, the widespread nature of shale gas, together with the high cost of transporting gas, means that shale gas development will be concentrated in areas close to major markets. Interestingly, this makes shale gas less of a threat to wilderness areas than conventional gas. As Nick Grealy comments:

> A `weak shale' in Northern Germany or Central Britain would be of far higher value than a `strong' shale in central Australia or Alaska. – Nick Grealy, *No Hot Air*, 2010[31].

42. This will damp volatility in price and lead to the viability of longer-term contracts to use gas and longer-term plans to substitute gas for oil and coal in chemical, industrial and transport applications.

Finding: shale gas is not just extra gas, it is potentially predictable, low-risk gas.

[30] http://www.theoildrum.com/node/7075
[31] Global Shale gas: what now? What next? No Hot Air.

Environmental impacts

43. Shale gas was welcomed at first by environmentalists as a lower-carbon alternative to coal. For example, Robert F Kennedy Jr wrote in the *Financial Times*:

> Surprisingly, America has more gas generation capacity – 450 gigawatts – than it does for coal. However, public regulators generally require utilities to dispatch coal-generated power in preference to gas. For that reason, high-efficiency gas plants are in operation only 36 per cent of the time. By changing the dispatch rule nationally to require that whenever coal and gas plants are competing head-to-head, gas generation must be utilised first, we could quickly reduce coal generation and achieve massive emissions reductions. – Robert F. Kennedy, *Financial Times*, 19 July 2009[32].

44. However, as it became apparent that shale gas was a competitive threat to renewable energy as well as to coal, the green movement has turned against shale. Its criticism is fivefold:

- The shale gas industry uses dangerous chemicals in the fracking process that might contaminate groundwater;
- poorly cased wells allow gas to escape into underground aquifers;
- waste water returning to the surface during production, contaminated with salt and radon, may pollute streams;
- the industry's use of water for fracking depletes a scarce resource;
- the exploitation of shale gas damages amenity and landscape value.

Fracking fluid

45. The first problem came about because of the industry's initial refusal to reveal the ingredients of the slick water used in hydraulic fracking. Pressed by regulators, shale gas companies are now becoming more transparent about the chemicals in fracking fluid. Typically, what goes down the well is 94.62% water, 5.24% sand, 0.05% friction reducer, 0.05% antimicrobial, 0.03% hydrochloric acid and 0.01% scale inhibitor[33]. The actual chemicals are used in many industrial and even domestic applications: polyacrylamide as a friction reducer, bromine, methanol and naphthalene as antimicrobials, hydrochloric acid and ethylene glycol as scale inhibitors, and butanol and ethylene glycol monobutyl ether as surfactants[34]. At high dilution these are unlikely to pose a risk to human health in the event they reach groundwater.

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32 http://www.ft.com/cms/s/0/58ec3258-748b-11de-8ad5-00144feabdc0.html#ixzz1H4rIPSjl
33 Range Resources.
34 http://www.waytogoto.com/wiki/index.php/Slickwater

46. But can they even infiltrate groundwater? The aquifers used for well water in states like Pennsylvania lie just a few hundred feet below the surface, whereas the shale gas is several thousand feet below. Seismic studies show that there is approximately one mile of solid rock between the fracking fissures and the aquifer:

> Even in areas with the largest measured vertical fracture growth, such as the Marcellus, the tops of the hydraulic fractures are still thousands of feet below the deepest aquifers suitable for drinking water. – Kevin Fisher, *American Oil* and *Gas Reporter*, July 2010[35]

47. The well pipe running down through the aquifer is encased in alternating layers of concrete and steel and is generally triple-encased down to the depth of aquifers (less than 500 feet). For the well to produce gas it is vital that there are no leaks of either gas or fracking fluids into the aquifer or any other strata, so it is not in the company's interest to allow this. However, on rare occasions wells may fail through the loss of the drilling bit and have to be abandoned. In such cases, the well must be sealed with cement but it is possible that this can be unsuccessful or that contamination can occur before it takes effect.

48. The industry contends that ground water contamination occurs much more frequently as a result of pollution unrelated to the shale-gas industry: agricultural run-off, oil spills from the transport industry, run-off from abandoned coal mines, and so forth. Wherever well water has been tested before and after gas drilling, no evidence has been found of groundwater contamination by fracking fluids.

49. Shale gas operations in the United States are heavily regulated and closely monitored. State regulators from Alaska, Colorado, Indiana, Louisiana, Michigan, Oklahoma, Pennsylvania, South Dakota, Texas and Wyoming have all asserted in writing that there have been no verified or documented cases of groundwater contamination as a result of hydraulic fracking[36]. Here is a typical statement:

> No groundwater pollution or disruption of underground sources of drinking water has been attributed to hydraulic fracturing of deep gas formations. –Joseph J. Lee, Pennsylvania Department of Environmental Protection, 1 June 2009[37].

Finding: groundwater contamination by fracking fluid is possible but unlikely if proper procedures are followed.

35 http://www.bfenvironmental.com/pdfs/inducedfracturingoilreporter.pdf
36 Energy In Depth website
37 Grealy, N. 2010. Global Shale Gas: What now? What next? No Hot Air, London.

Flaming faucets

50. Can gas escape into aquifers? Again, the industry has no interest in allowing this to happen because it would reduce the productivity of a well, so the casing of the well pipe is in everybody's interest. There are cases in Colorado, highlighted by a flaming tap in Fort Lupton in the film Gasland, where gas in domestic drinking water from an aquifer can be ignited. However, testing has shown that in Fort Lupton the water well penetrates several coal seams and the gas is `biogenic' gas (from coal) with a chemical signature different from the `thermogenic' deep shale gas below:

> In most cases, however, the [Colorado Oil and Gas Conservation Commission] has found that contamination is not present or that the methane comes from biogenic sources and is not attributable to oil and gas production. – Colorado Oil and Gas Conservation Commission , 2010[38].

51. Natural gas in well water is a phenomenon that was known for many decades before shale-gas drilling began. (A similar phenomenon allows journalists to film scientists igniting methane that escapes through holes made in ice on Arctic lakes – again this has always happened as a result of organic decay on the lake bed.)

52. In April 2010 Cabot Oil and Gas Corporation paid a fine to the state of Pennsylvania after contamination of the drinking water of 14 homes in Dimock following a water well explosion possibly caused by gas escaping from an incompletely cased well. Cabot maintains that it was not the cause of gas contamination[39].

Finding: gas contamination of aquifers occurs naturally and has not usually been found to result from shale gas production.

Waste water

53. Approximately one-third of the water pumped down the well for fracking returns eventually to the surface together with gas during production. In the Marcellus Shale this water is saline, because the shale rock was formed on the bed of an ancient sea. The water is extracted from the gas, collected in pools doubly lined with heavy-duty polythene, and either re-used for fracking in other wells or desalinated, treated and disposed of as waste. This is no different from the treatment of waste water in any other industrial process. Pollution incidents involving such `produced water' are rare. A gas well operated by EOG Resources blew out in Clearfield County, Pennsylvania, in June 2010, spilling 35,000 gallons of slick water. The water was contained by berms and linings, and there were no injuries or significant damage to the environment.

[38] http://cogcc.state.co.us/library/GASLAND%20DOC.pdf
[39] http://www.cabotog.com/pdfs/Cabot_Release_Statement_9-28-10.pdf

54. The returning water is also slightly more radioactive than surface water because of naturally occurring isotopes within the rocks. However, this radioactivity drops when the salt is removed and before the water is disposed of in the sewage system. In any case many granite rocks have higher natural radioactivity, so exposure to waste water from gas drilling is likely to be no more hazardous than exposure to some other kinds of rock. There is no evidence that either gets close to being hazardous. Indeed the Pennsylvania Department of Environmental Protection has tested the water in seven rivers to which treated waste water from gas wells is discharged and found not only no elevation in radioactivity but:

> All samples were at or below background levels of radioactivity; and all samples showed levels below the federal drinking water standard for Radium 226 and 228. – Pennsylvania Department of Environmental Protection, 7 March 2011[40].

55. All technologies have environmental risks. Press coverage that talks about `toxic', `carcinogenic' and `radioactive' `chemicals' is meaningless. Vitamin A is toxic. A single cup of coffee contains more known carcinogens than the average American ingests from pesticide residues in a whole year[41]. Bananas are radioactive[42]. Dihydrogen monoxide is a chemical[43]. The question that needs to be posed is always: how toxic, how carcinogenic, how radioactive?

Finding: the shale gas industry poses no new or special surface water pollution risks.

Water depletion

56. The shale gas industry uses water: 1-5 million gallons per well. However, its needs are not great in comparison with those of other industries, such as the power generation industry, or even the quantity used in domestic appliances. Gas drilling in Pennsylvania uses less than 60 million gallons per day, compared with 1,550 used in public water systems, 1,680 used in industry and 5,930 used in power generation in the state (US Geological Survey). A single shale gas well uses in total about the same amount of water as a golf course uses in three weeks.

Finding: the shale gas industry does not significantly contribute to depletion of water resources.

40 http://www.portal.state.pa.us/portal/server.pt/community/newsroom/14287?id=%2016532%20&typeid=1

41 There are more rodent carcinogens in a single cup of coffee than potentially carcinogenic pesticide residues in the average American diet in a year, and there are still a thousand chemicals left to test in roasted coffee'' Ames, B.N. and Gold, L.S. (1998) The causes and prevention of cancer: the role of environment. Biotherapy 11:205-20

42 http://chemistry.about.com/b/2008/08/11/bananas-are-radioactive.htm

43 H2O

44 http://www.nytimes.com/2011/02/27/us/27gas.html?pagewanted=3&_r=1&ref=homepage&src=me

Landscape and habitat impact

57. According to some sources, shale gas exploitation has a major impact on the landscape and habitat. For example a *New York Times* article in February 2011 described western Pennsylvania thus:

> Drilling derricks tower over barns, lining rural roads like feed silos. Drilling sites bustle around the clock with workers, some in yellow hazardous material suits, and 18-wheelers haul equipment, water and waste along back roads. – *The New York Times*, 26 February 2011[44].

58. I visited the same area shortly after this article was published and found this picture misleading in the extreme. Drilling derricks were few, hard to spot in the rolling landscape and they 'bustled' for about a month only on each site before being dismantled. The `back roads' had in many cases been extensively improved and paved by the gas drilling companies. Gas production Christmas trees – small, green pieces of plumbing about the size of a garage or a large garden shed – were inaudible and all but invisible among woods, horse pastures, corn fields and houses. Red-tailed hawks soared over drilling sites and a flock of wild turkeys crossed the road nearby. Signs of prosperity stemming from royalties and company spending, in the shape of new fences and barns, new community centres and revitalized town shops, were everywhere.

Shale gas well in production in the Marcellus area. The well head is seen in the midlde of the pad. To the right is shown separation equipment and tanks for storing produced water before being further treated. (photo: Statoil/Chesapeake)

59. Note that new technology further reduces the impact. The old technology of vertical drilling would require a footprint of many wells covering 19% of the surface of the area from which gas was being extracted. Horizontal drilling of several wells from one pad reduces this to less than 1%: a 6-acre drilling pad extracts gas from beneath 1,000 acres of land. And even this is gone after a few weeks, leaving just the `Christmas tree' behind. The concrete, forest clearance and visual impact of more than 50 wind turbines with equivalent energy output is gigantic by comparison (see below).

Finding: shale gas can be extracted from a populated and attractive landscape with far more limited impact than other forms of energy.

Shale gas price

60. Until recently the conventional wisdom held that shale gas would be expensive compared with gas from conventional sources and would be uneconomic at prices below $8.50 per MMBTU[45]. However, according to IHS CERA, shale gas is now being produced more cheaply than most conventional gas[46]. The predictability of shale gas wells combined with the growing experience in how to reduce the time and cost of drilling and fracking wells, means that currently many firms are claiming to be able to produce shale gas at a marginal cost of less than $4 per MMBTU (4.5 cents per kilowatt-hour) – not least because they are close to retail markets. In addition, multi-stage fracking has increased the effectiveness of the fracking process. If this proves sustainable, it effectively makes gas easily competitive with coal, usually the cheapest energy fuel.

61. According to the Institute of Energy Research, the cost of electricity from new plants designed to open in 2016 from different sources will be approximately as follows (in dollars per megawatt-hour):

Solar thermal	312
Offshore Wind	243
Solar photovoltaic	211
Coal with CCS	136
Nuclear	114
Biomass	112
Wind	97
Coal	95
Gas with CCS	89
Hydro	86
Gas, combined cycle	63

Levelized Cost of New Generation Resources

Source: U.S. Energy Information Administration, Annual Energy Outlook 2011

http://www.eia.doe.gov/oiaf/aeo/electricity_generation.html

62. These numbers include costs of capital, fuel, operation and maintenance, and transmission and take into account capacity factor – how much of the time the plant can be on line. Of course, actual costs will vary greatly in practice according to location, design, subsidies and price regulation. None the less, it is clear that gas can, given a level playing field, beat all other technologies on price. As contracts that link gas to oil prices expire, and the price of gas decouples from that of oil, gas's advantage may actually grow.

Finding: shale gas is inexpensive and its price advantage may widen.

Energy efficiency

63. Gas is the most efficient fuel for generating electricity. New combined-cycle gas turbines can achieve almost 60% heat-to-electricity conversion (5,785 btu/kWh), whereas even the newest coal fired turbines cannot yet reach 50% (6,824 btu/kWh)[47]. With waste heat capture for district heating (co-generation), thermal efficiency can approach 80%. Only a perception that gas is expensive, volatile in price, politically unreliable or likely to grow scarce has stood in the way of a global `dash for gas' in power generation. If gas supplies prove to be diversified, domestic, abundant and long-lasting, then these perceptions will fade.

64. Moreover, gas-fired turbines are equally efficient at many different scales down to 50MW, whereas efficient coal or nuclear plants are much larger. And they reach peak efficiency within minutes, so can be powered up and down to meet demand spikes, or to back up intermittent renewable-energy output. This efficiency leads to gas being potentially the cheapest and most flexible fuel for generating electricity.

65. In addition, gas has various advantages over other ways of generating electricity:

66. **Gas versus coal.** Given the higher efficiency of gas turbines and the lower carbon content of gas, burning gas produces only 37% of carbon dioxide as burning coal for the same electricity output[48]. In addition, unlike burnt coal, burnt shale gas includes no sulphur dioxides, no mercury and fewer nitrogen oxides. It requires no surface mining and mountaintop removal, no tunnelling and ground subsidence and results in many fewer human fatalities. Gas is piped to customers rather than transported by congested road or rail. Therefore, while coal is cheap, it has many environmental externalities, not all of which are fully priced in. `Clean coal' with carbon dioxide emissions removed would probably be – at 9 cents per kilowatt hour – roughly twice as costly as gas for electricity generation, yet have only a slim carbon emission advantage. Gas, because it burns cleaner, is also more amenable to carbon capture than coal.

[45] http://www.energybulletin.net/node/49342
[46] IHS Cambridge Energy Research Associates Report `Fuelling North America's Energy Future', 2010.
[47] http://www.npc.org/Study_Topic_Papers/4-DTG-ElectricEfficiency.pdf
[48] http://www.npc.org/Study_Topic_Papers/4-DTG-ElectricEfficiency.pdf

67. **Gas versus oil.** Oil is very useful as a transport fuel but is generally too expensive as a fuel for electricity generation, outside the Middle East. The exhaustion of many onshore oil fields has driven oil exploration into deep offshore waters and towards expensive tar sands and tar shales. In the United States, the effect of shale gas has been to decouple the price of gas from that of oil, with gas prices now much lower per unit of energy, further pricing oil out of the electricity generating industry. The same decoupling will happen in the rest of the world as long term linked oil-and-gas contracts gradually expire. Oil is effectively priced out of baseload electricity generation for the foreseeable future.

68. **Gas versus nuclear.** Gas-fired electricity is cheap to build and costly to fuel; nuclear is the opposite. In practice, thanks to safety requirements, planning delays and design difficulties, nuclear power plants are generally proving far more expensive than expected and the price per kilowatt-hour of nuclear electricity is nearly double that of gas, though of course this may change. Besides, nuclear power, like coal, is most efficient when big. Gas-fired electricity is efficient even at relatively small scales. This means that small units of gas-fired power stations can be added to serve local urban markets, whereas nuclear comes in large units often far from markets.

69. **Gas versus wind.** A gas drilling rig, like a wind turbine, is an intrusion into a rural area. However, it need not be on a hilltop like a windmill and can be hidden in a rolling landscape. With each wellhead capable of producing gas from up to 12 wells, or about 50 billion cubic feet over 25 years, the output of one drilling pad is equivalent to the average output of about 47 giant 2.5MW wind turbines (which also last about 25 years), and is continuous rather than unpredictable and intermittent. Yet the footprint of a shale gas drilling derrick (about 6 acres) is only a little larger than the forest clearance necessary for a single wind turbine (4 acres), requires vastly less concrete per kilowatt-hour, stands one-third as tall and is present for just 30 days instead of 25 years. Additionally, gas drilling rigs have not been known to kill birds of prey or have any other impacts on wildlife, whereas wind farms kill tens of thousands of birds of prey annually[49].

70. **Gas versus solar.** Unlike solar power, shale gas works even at night and on cloudy days. It can be stored cheaply in underground salt caverns, whereas storage of solar electricity is impossibly expensive. It produces electricity at about one-third the cost of solar power and it is found closer to large customer concentrations than the deserts where solar power is most efficient. None the less, abundant gas may prove to be the friend rather than the rival of solar power, because unlike coal and nuclear power it can be powered up and down quickly and efficiently. Using coal or nuclear to back-up intermittent renewable energy results in wasteful production of carbon dioxide, negating virtually all carbon-savings that the renewable resource promises. If the costs of solar power do fall rapidly, it is conceivable that one day an electricity system based on solar power by day and gas by night may well prove economically viable.

[49] http://www.usatoday.com/news/nation/environment/2009-09-21-wind-farms_N.htm?csp=34&loc=interstitialskip; http://www.telegraph.co.uk/comment/columnists/christopherbooker/7437040/Eco-friendly-but-not-to-eagles.html; http://www.abcbirds.org/newsandreports/releases/070430_testimony.html

71. **Gas versus biomass.** Gas requires and attracts no subsidy, whereas the diversion of agricultural products into making fuel for power stations drives up world food prices by taking land away from growing food crops, exacerbating hunger, and does so while using far more water per unit of energy than gas. It also creates ash and has to be transported to power stations by road, neither of which is true of gas.

72. Unlike nuclear and renewable, gas-fired electricity requires no subsidy. As Nick Grealy put it to the House of Commons Energy and Climate Change committee:

> With respect, from what I see of the activities of your Committee, you are used to a large amount of people coming here and saying, "We need a subsidy for CCS, we need a subsidy for wind, we need a subsidy for nuclear" and so on. The shale gas industry wants to give you money. –Nick Grealy, testimony to House of Commons Energy and Climate Change Committee, 2011[50].

Finding: electricity generated using gas is cheaper, cleaner, more environmentally beneficial and more humane than electricity from coal, oil, nuclear, wind, solar and biomass.

New markets for gas in transport

73. Richly productive new shale gas fields like the Marcellus Shale lead to falling gas prices and to gas producers keen to entice new customers to use their product. Hence it is probable – if the optimists are right about supply – that gas will gradually find new markets. Besides partly displacing coal, nuclear and renewables in power generation, it may also expand into transport.

74. There are already nearly 15 million natural gas fuelled vehicles in the world. Natural gas fuelled vehicles are already widely used in some cities such as Washington DC, Kuala Lumpur and New Delhi as a pollution control measure. Now that natural gas tanks for cars have become much smaller, the only obstacle to car drivers also switching to cheap and low-emission gas is a lack of infrastructure in the form of refuelling stations – admittedly a formidable hurdle. Gas-powered vehicles produce almost no particulates, 60% less volatile organics, 50% less nitrogen oxides and 90% less carbon monoxide, which means less smog, ozone and brown haze.

50 http://www.publications.parliament.uk/pa/cm201011/cmselect/cmenergy/uc795-ii/uc79501.htm

75. The fuel cost savings following this conversion could be considerable. At current prices the cost of fuelling a natural gas vehicle is approximately one-third that of diesel or petrol. This gap is likely to increase. Furthermore, hybrid diesel-gas vehicles are under development[51]. Even electric cars may benefit from cheaper gas: electricity generated from natural gas could have about twice the well-to-wheel efficiency of a petrol car. Only the high cost and long charging times of batteries stand in the way.

Finding: gas could begin to take market share from oil in transport.

Feedstock and fertiliser

76. Gas is a common feedstock for the chemical industry; so is ethane, a glut of which is now coming out of shale gas wells as a byproduct. Thus the shale gas revolution has already begun to draw chemical companies back to the Gulf of Mexico from the Persian Gulf, and hand them a competitive advantage[52]. As well as being a fuel, gas and natural-gas liquids such as ethane are used in the manufacture of plastic, specialty chemicals, agrochemicals and pharmaceuticals. Shale gas is therefore revitalising the chemical industry wherever it can be produced.

77. Much environmental criticism of modern high-output farming argues that it is unsustainable because it depends of synthetic nitrogen fertiliser, which is manufactured from air and natural gas. Some have argued that famine will result when the gas, and therefore the fertiliser, runs out. It is now clear that the gas will not run out and will probably remain low-cost, so high-output farming using fertiliser is indeed sustainable and affordable for the foreseeable future. This ensures not only food availability, but less pressure to convert wild lands to agriculture.

Finding: shale gas has reduced the risk of a fertiliser crisis.

51 http://www.publications.parliament.uk/pa/cm201011/cmselect/cmenergy/writev/shale/sg17.htm
52 http://www.businessinsider.com/us-shale-gas-wont-just-revolutionize-energy-it-will-even-make-us-chemical-companies-ultra-cost-competitive-2010-3
53 http://www.federalreserve.gov/BoardDocs/testimony/2003/20030610/default.htm
54 http://www.montrealgazette.com/news/nukes+fade+exports+will+gain/4480633/story.html
55 http://www.reuters.com/article/2010/06/04/cheniere-lng-sabine-idUSN0423301520100604
56 http://online.wsj.com/article/SB10001424052702303491304575187880596301668.html
57 http://www.energytribune.com/articles.cfm/6941/One-Countrys-Disaster-Anothers-Boon

Effect on world trade

78. Unlike oil and coal, gas is not easily transported by sea, so a genuine world market in gas does not exist and prices can vary sharply between regions. Liquefaction of gas for transport is expensive and requires special deep-water facilities and ships. As recently as 2003, it was assumed that America's gas production would decline and it would have to begin importing liquefied natural gas from Qatar and other exporters. No less an authority than Alan Greenspan, then chairman of the Federal Reserve, said so to Congress in 2003:

> Today's tight natural gas markets have been a long time in coming, and futures prices suggest that we are not apt to return to earlier periods of relative abundance and low prices anytime soon… Access to world natural gas supplies will require a major expansion of LNG terminal import capacity. –Alan Greenspan, testimony to Congress, June 2003[53].

79. Sure enough America did invest in natural gas import terminals, but the price of LNG crashed in 2008 because of the recession and the news of shale gas. Most import terminals have now been mothballed.

80. With US gas prices low and easily supplied by domestic production, Canadian gas exports fell sharply. Conventional gas from Alberta (and Alaska) may also now seek export markets. A $4.7 billion LNG export terminal in Kitmat, British Columbia, aims to begin exporting gas in 2015[54]. America may follow suit in gas fields remote from large conurbations. In one case, Sabine Pass in Louisiana, Cheniere has already received approval to convert the terminal to an export facility capable of exporting gas within 5-10 years[55].

81. Loss of US export markets and the threat of Canadian competition in supplying Asian markets will in turn affect the ability of Qatar, Algeria, Venezuela and Russia to sustain LNG and pipeline export prices. Indeed, Qatari exports are now available to Europe and Asia at lower prices because of the loss of American markets. Consequently, an emerging cartel in the gas trade, through the Gas Exporting Countries Forum and run by Vladimir Putin, Hugo Chavez, Mahmoud Ahmadinejad and their ilk, now looks much less likely. Thus the emergence of shale gas, even if it were to happen only in the United States, may tip the geopolitical balance towards energy consumers like China, India, Japan and Europe at the expense of energy producers[56].

82. On the other hand, the crippling of the ageing Fukushima reactors (and some coal-fired plants) by the earthquake and tsunami in Japan in March 2011 is a reminder that demand for LNG imports could also rise. The earthquake reduced Japan's electricity generating capacity by 20%. It also led to the shutdown of Germany's older nuclear plants and promises of a review of nuclear plans in both the United States and China. The immediate effect was a rise in the price of gas, the only fuel that could quickly fill the gap in Japan's electricity market. Japan is already the largest importer of liquefied natural gas and it does not have good shale-gas geology. Its imports could now increase from 3.3 to 4.8 Tcf per year, according to one estimate, or by nearly half of Qatar's LNG output, or more than Australia's current capacity to export[57].

83. Likewise, China's efforts to diversify its energy sector away from coal for environmental reasons are also bound to benefit the gas trade. China aims to get 10% of its power from natural gas by 2020 and, given that shale gas production in China may rise only slowly at first, this could result in demand for imported LNG of up to 9Tcf a year. Australia and Canada may be the beneficiaries[58].

Finding: shale gas may reduce price volatility in gas.

Greenhouse gas emissions

84. As detailed above, burning natural gas produces less than 50% of the carbon dioxide emissions of burning coal for the same energy output. However, Professor Robert Howarth, a biologist at Cornell University, argues that the gas industry generates as much or more greenhouse gas as the coal industry, though only in the short term. This is because methane is a more potent greenhouse gas than carbon dioxide and methane leaks during fracking and production[59].

85. This conclusion requires unrealistic assumptions about: the quantity of methane that leaks during fracking, production and transport; the lack of methane leaks from coal mines; the residence time of methane in the atmosphere; and the greenhouse warming potential of methane compared with carbon dioxide[60]. For example, Howarth assumes that methane has 105 times the global-warming potential of carbon dioxide over 20 years; even the Intergovernmental Panel on Climate Change only uses a factor of 72 over 20 years, but prefers 25 over 100 years, which is the normal period of comparison. And Howarth gets his numbers on high gas leakage from shale gas wells from unreliable sources, his numbers on gas leakage from pipelines from long Russian pipelines, and assumes that `lost and unaccounted for gas' is actual leakage rather than partly an accounting measure[61]. He also fails to take into account the greater generating efficiency of gas than coal. As one critic puts it of Howarth's latest paper:

> Practically every paragraph includes an assumption, simplification or choice by the authors that tends to increase the calculated environmental impact of natural gas. Whether that's the result of bias or merely a series of judgment calls, it undermines confidence in the final conclusions at the same time it amplifies them. – Geoffrey Styles, The Energy Collective, 15 April 2011[62].

86. Absent these unrealistic assumptions, gas is clearly a lower-emission fuel. It is also worth noting that the growth rate of methane concentration in the atmosphere `slowed in the 1990s, and it has had a near-zero growth rate for the last few years' according to NOAA[63]. This is hardly the signature of a growing problem.

58 http://www.energytribune.com/articles.cfm/6941/One-Countrys-Disaster-Anothers-Boon
59 http://www.eeb.cornell.edu/howarth/GHG%20update%20for%20web%20–%20Jan%202011%20%282%29.pdf
60 http://epa.gov/climatechange/emissions/downloads10/US-GHG-Inventory-2010_Chapter3-Energy.pdf
61 http://www.energyindepth.org/2011/04/five-things-to-know-about-the-cornell-shale-study/
62 http://theenergycollective.com/geoffrey-styles/55663/still-not-worse-coal

Conclusion: gas and decarbonisation

87. The dominant fuel in the world fuel mix has gradually shifted from wood to coal to oil over the past 150 years, with gas the latest fuel to grow rapidly. At this rate gas may overtake oil as the dominant fuel by 2020 or 2030. The consequence of this succession is that the carbon-hydrogen ratio in the world fuel mix has been falling steadily, because the ratio of carbon to hydrogen atoms is about 10-to-1 in wood, 2-to-1 in coal, 1-to-2 in oil and 1-to-4 in gas. On its current trajectory, the average ratio would reach 90% hydrogen in 2060, having been 90% carbon in 1850. Jesse Ausubel of Rockefeller University describes this phenomenon as follows:

> When my colleagues Cesare Marchetti, Nebojsa Nakicenovic, Arnulf Grubler and I discovered decarbonisation in the 1980s, we were pleasantly surprised. When we first spoke of decarbonisation, few believed and many ridiculed the word. Everyone 'knew' the opposite to be true. Now prime ministers and presidents speak of decarbonisation. Neither Queen Victoria nor Abraham Lincoln decreed a policy of decarbonisation. Yet, the energy system pursued it. Human societies pursued decarbonisation for 170+ years before anyone noticed. – Jesse Ausubel, *International Journal of Nuclear Governance, Economy and Ecology*, 2007[64].

88. Consequently, although increased energy use means that carbon dioxide emissions are rising all the time, the world is nonetheless slowly decarbonising. A sudden and forced acceleration of this decarbonisation is what environmentalists and many politicians are demanding in the name of climate change policy. The argument is that the cost of waiting for decarbonisation to happen of its own accord is higher than the cost of replacing existing fuels with low-carbon alternatives.

89. However, few of the low-carbon alternatives are ready to take up the challenge on a scale that can make a difference. Nuclear is too slow and costly to build; wind cannot provide sufficient volume of power or reliability; solar is too expensive; biofuel comes at the expense of hunger and high carbon dioxide emissions. All except nuclear (and to a lesser extent solar) require unacceptably vast land grabs. Diverting 5% of the entire world grain crop into the US ethanol program in 2011 will displace just 0.6% of world oil use[65]; getting 10% of Denmark's electricity from wind has saved no net carbon emissions (because of the need for inefficient back-up generation)[66].

90. The world would do well to heed the advice of Voltaire and not make the best the enemy of the good. Rapid decarbonisation using renewables is not just expensive and environmentally damaging, it is impossible. However, switching as much power generation from coal to gas as possible, and as much transport fuel from oil to gas as possible, would produce rapid and dramatic reductions in carbon dioxide emissions.

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63 http://www.esrl.noaa.gov/gmd/obop/mlo/programs/esrl/methane/methane.html
64 http://phe.rockefeller.edu/docs/HeresiesFinal.pdf
65 http://www.energytribune.com//articles.cfm/6681/Biofuels-Driving-Up-Food-Prices-As-Iowa-Primary-Approaches-
66 Bryce, R. 2010. Power Hungry. Public Affairs.

91. Just as genetically modified crops called the bluff of the organic movement, by demonstrating both better crop protection and better environment protection, so abundant gas is calling the bluff of the renewable energy movement by demonstrating both better economic efficiency and better carbon reduction. Yet Europe turned its back on GM crops when they ran into sudden and coordinated environmental opposition based on the precautionary principle that a new technology might be worse than an existing one. Meanwhile GM soya went on to give South America a competitive advantage in the world market in animal feed and GM maize gave North America a competitive advantage in human food. So, likewise, it is entirely possible that Europe may choose to excuse itself from the shale gas revolution and put itself at a competitive disadvantage in the electricity, transport, chemical and fertiliser industry, as well as finding decarbonisation harder.

92. If Europe and the wider world are bent on cutting carbon emissions, they would be foolish to ignore the claims of shale gas, at least until superior versions of nuclear or solar power are developed later in the century[67]. Fortunately, this strategy is also the most affordable.

Finding: Shale gas promises to bring environmental, economic and political benefits.

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Disclosure

The author has no direct financial interest in natural gas. He does have some small shareholdings in oil companies, which comprise less than 10% of his share portfolio. In addition he and his family benefit financially from income related to surface coal mining in Northumberland. Since this report concludes that gas threatens to take market share from both coal and oil, he therefore has the opposite of a vested interest in this conclusion. In the course of writing this report one visit was made to the operations sites of Range Resources in Pennsylvania. No payment or hospitality was offered or asked for.

[67] Bryce, R. 2010. Power Hungry. Public Affairs.

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