WELLINGTON MANAGEMENT®

September 2018

Scott Elliott
Multi-Asset
Portfolio Manager

Scott Elliott manages multi-asset inflation-hedging portfolios for mutual fund sponsors and institutional clients around the world, and researches long-term structural investment themes.

LEARN MORE

For insights on renewables, electric vehicles, and more, watch our video,

The future of energy >>

Lessons from 200+ years of energy evolution: What comes next?

There's no question that we're at the beginning of a major transition in the global energy economy, from a world dominated by fossil fuels to one with a rising share of renewables. But to understand how this transition may play out and to gauge the potential economic and market implications, it's important to look back at previous energy transitions. Among the lessons I think we can draw:

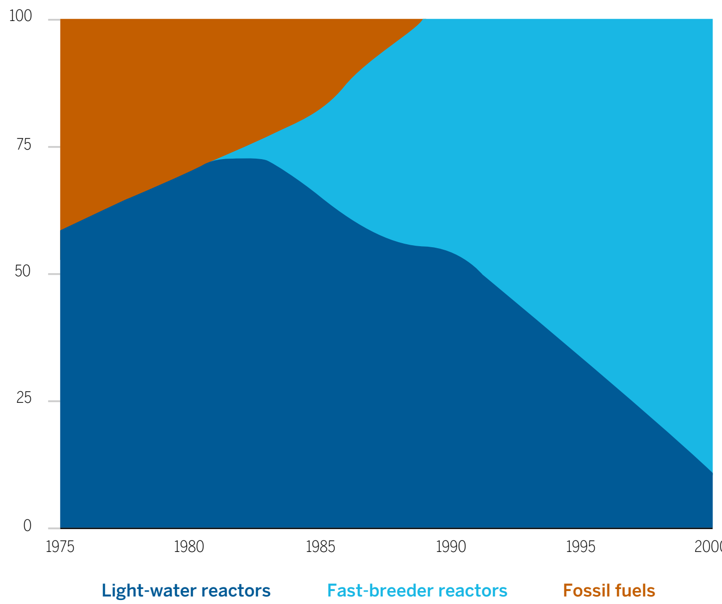
- Transitions in the energy economy take decades, are difficult to forecast, and are best considered in terms of scenarios and probabilities.
- Cyclicality in oil prices should be expected, rather than the structural bear market some fear.
- Climate change and global carbon policy will be the big wild card.

The folly of forecasting

Forecasting in the energy markets has suffered from three common errors. First, there has been overreliance on extrapolation of the past, assuming things will go on as they have. Second, the impact of technological change has at times been overestimated. And third, there has been a tendency to forecast doom — i.e., we're going to run out of fossil fuels.

The reality is that relatively little has changed in the energy markets since about 1940. Certainly things have become massively more efficient and larger in scale, but the basic structure of the system is surprisingly unchanged. In fact, the effectiveness and affordability of the current system has given it quite a bit of inertia, despite regular forecasts of dramatic change. There was, for example, the expected shift to nuclear energy. In 1954, the head of the US Atomic Energy Commission said, "Our children will enjoy in their homes electrical energy that is too cheap to meter." In 1974, General Electric forecast the sources of energy in the electrical sector through the year 2000. As shown in **Figure 1**, they saw a significant increase in the share of nuclear energy and, effectively, the extinction of fossil fuels after about 15 to 20 years. But, of course, nuclear energy never came close to 100% of the US electrical supply, peaking at around 6%.

FIGURE 1
The folly of forecasting
General Electric's forecast for US electricity production
(Nuclear penetration, %)



Source: PM Murphy, "Incentives for the Development of the Fast-Breeder Reactor," 1974, General Electric

Doom forecasts about peak oil production have not panned out.

Or take the example of automobiles, where there have been forecasts of massive change for years. This time may be different, but in the past we've heard about hydrogen cars, solar-powered cars, and, most recently, hybrids, which experienced a brief acceleration period but never really lived up to the optimism.

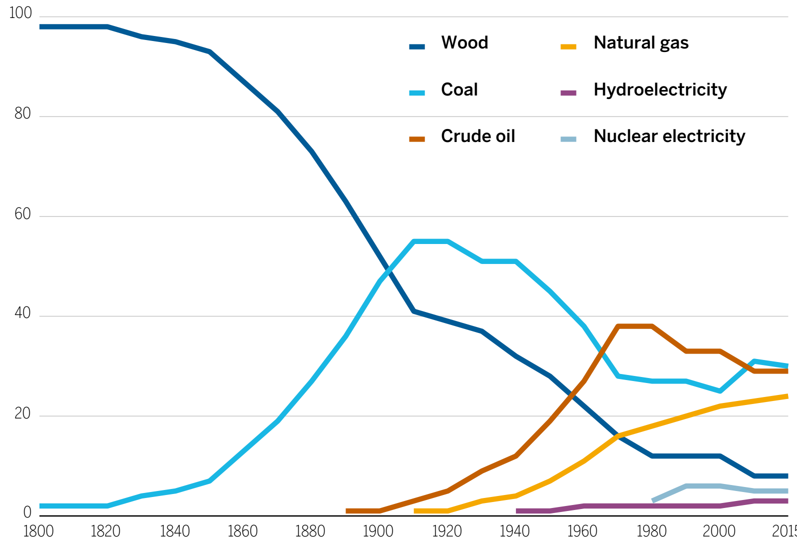
And, of course, doom forecasts about peak oil production have not panned out. We were supposed to reach it in the 1970s, and we did see a brief peak in US oil production, but it was about a third higher than forecasted, and we've reached new peaks since.

All of that said, there is reason to believe change is coming. Fossil fuel consumption has driven the economic growth of the last 200 years to a level previously unknown. And now we may indeed be at a tipping point where future increases in fossil fuel consumption don't contribute to increased economic growth, but instead contribute to destruction of wealth and decreases in economic growth from the effects of climate change.

A quick tour of previous energy transitions

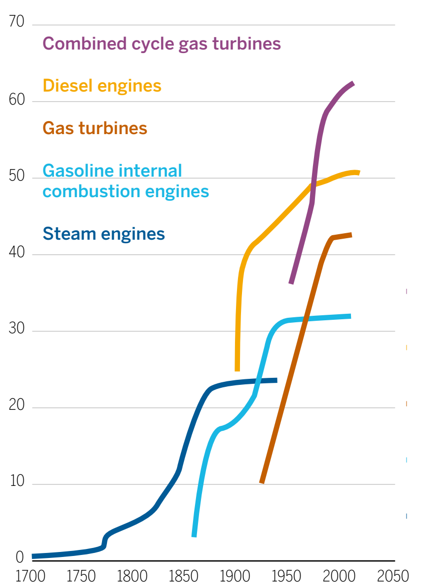
To understand what the coming transition may look like, let's look back at previous transitions, starting with the birth of the fossil fuel era in the early 1800s. At that time, wood was becoming expensive, due to deforestation and increased demands from shipbuilding and iron making. As a result, coal started to become an important source of fuel supply in Europe and the US. Soon after, the steam engine was invented in England to facilitate coal extraction, which points to one of the interesting lessons from the history of energy: It takes an increasing amount of energy to find and extract more energy. **FIGURE 2** shows the global share of energy consumption, with wood (dark blue line) declining from almost 100% to about 40% by 1900 and coal (light blue line) taking off with the Industrial Revolution.

FIGURE 2
Major energy transitions, 1800 – present
Share of global primary energy consumption (%)



Source: Vaclav Smil, *Energy Transitions: History, Requirements, Prospects*, 2017 | Chart data: 1800 – 2015

FIGURE 3
Efficiency drives new possibilities
Maximum efficiency (%)



Source: Vaclav Smil, *Energy Transitions: History, Requirements, Prospects*, 2017

The next major transformation, to crude oil (orange line), was a bit less dramatic, but it was driven by a couple of important changes as the 1800s were coming to an end. The first was the rising price of whale oil, due to overfishing. Crude oil was initially used as a substitute for whale oil in the refinement of kerosene. (This highlights another interesting lesson about the inherent challenge of energy forecasts: The uses of energy evolve.) The second change affecting crude oil was the invention of the internal combustion engine and improvements in its efficiency over time. Electric cars dominated the car market around 1900, but then Henry Ford brought out his Model T in 1908 and it had the power of 20 horses and went 10 times as fast. Crude oil's share of energy consumption began to rise, and it really accelerated after World War II, as the interstate highway system was built, commercial air travel took off, and the use of crude oil in manufacturing grew. Crude oil's share peaked in the 1970s, and since then there's been increasing concern about oil efficiency. Electrification has been the theme of the last several decades, as reflected in the increased share of natural gas, hydroelectric, and nuclear energy in **FIGURE 2**.

Looking across these energy transformations, several big themes emerge. One is the relentless drive toward efficiency. From 1800 to 1900, for example, machines became roughly 30 times more powerful and 10 times more efficient (**FIGURE 3**). This technological innovation ultimately results in lower costs and increased usage. Today the average US consumer uses about 38 pounds of fossil fuels daily at a cost of about $5 — roughly the cost of a latte. This efficiency and affordability has created an incredible amount of inertia and made fossil fuels difficult to displace.

Another theme is the continued growth in demand for different forms of energy, even after their share of total energy consumption has peaked. **FIGURE 4** shows the absolute level of demand for different sources of energy measured in exajoules (one exajoule is equal to 170 million barrels of oil).

Wood's share of global energy consumption has fallen from a peak of 98% in 1800 to about 8% today, yet the amount of wood used for energy has doubled from 20 to 40 exajoules. Coal's share peaked in 1900, but we use roughly eight times more of it today. Oil's share peaked in roughly 1980, but we consume about 50% more today, despite the focus on improving efficiency.

If current projections hold, the global population will rise from about 7.5 billion today to about 10 billion in 2050. That's like adding another China and India to the energy equation.

FIGURE 4

Growing demand for all forms of energy

Exajoules[1]

	Wood	Coal	Oil	Natural gas	Nuclear
1800	20	0.4	0	0	0
1850	26	2	0	0	0
1900	22	21	1	0.2	0
1950	27	45	8	3	0
1980	36	80	110	52	8
2015	40	160	155	125	25

BLUE indicates when share peaked

[1]One exajoule = approximately 170 million barrels of oil | Source: Vaclav Smil, *Energy Transitions: History, Requirements, Prospects*, 2017

What's behind this unrelenting growth in absolute energy consumption? The most obvious explanation is population growth. If current projections hold, the global population will rise from about 7.5 billion today to about 10 billion in 2050. That's like adding another China and India to the energy equation.

A second explanation is that the development of new energy sources and innovations in uses of energy and in efficiency tend to translate into higher energy use, not lower energy use. Also, old sources of energy tend to find new uses over time and they tend to filter from the developed markets to the emerging markets, where absolute levels of demand are higher. Demand for crude oil in developed markets is falling by about a percent a year, but in the emerging markets, it is going up about 3.5% a year.

What conclusions can we draw?

Surveying the historical landscape and the current market, I think there are a few key points to focus on going forward:

1. The pace of the transition

It took about 25 years on average for coal, oil, and natural gas to go from 5% to 15% of the global energy market (FIGURE 5). Currently, renewables are at roughly 3% of the global market, so it's worth asking whether this transition is likely to be a bit slower or a bit faster. I think two factors, at least, argue for a slower transition. The first is the lack of any truly compelling innovations to drive this transition. Certainly there are technology developments in areas like artificial intelligence that are going to drive more electrification, but they aren't at the scale of previous innovations like the automobile or the airplane. The second factor is the size of the energy market today, which is well beyond anything we've seen in previous transitions. The risks to this view that the transition will be slower than others include a change in the nature of fossil fuel pricing, a significant increase in concern about fossil fuel scarcity, and a substantial and effective global carbon policy — all of which I discuss below.

FIGURE 5

Transitions take decades, not years

% of global energy supply	Coal	Oil	Natural gas
5% → 15%	25 yrs	20 yrs	30 yrs
5% → 25%	35 yrs	40 yrs	55 yrs
5% → 40%	55 yrs	60 yrs	

Source: Vaclav Smil, *Energy Transitions: History, Requirements, Prospects*, 2017

> While every transition is unique, I think all of this suggests that the knee-jerk reaction of expecting a bear market in crude oil is too simplistic.

2. Prices and supply

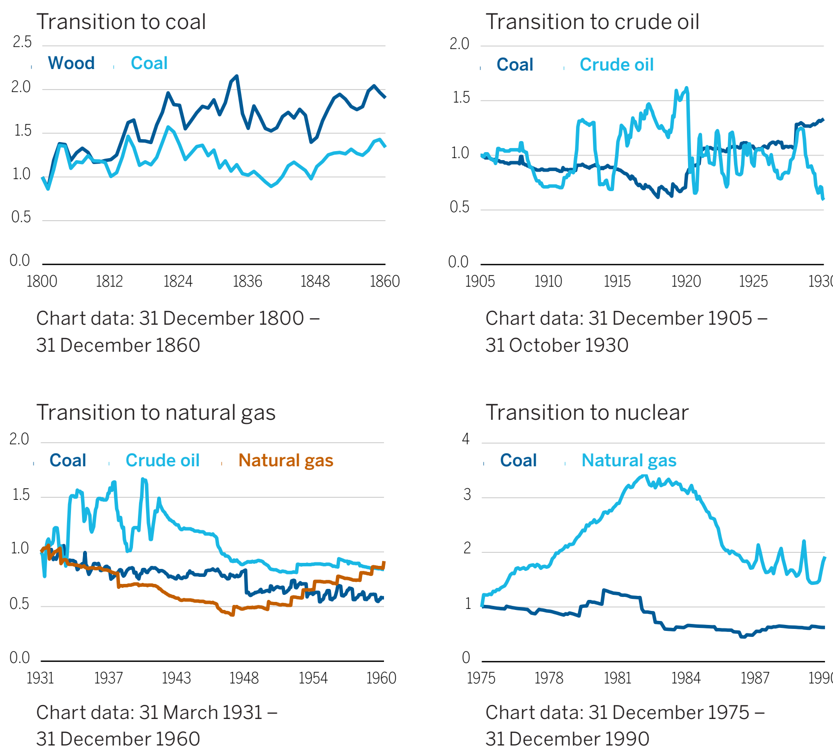
Many assume that with this transition there will be a great bull market for new energy and a great bear market for old energy. But that is not the pattern we've seen historically. **Figure 6** shows what happened to prices of different energy sources during the periods in which they transitioned from 2% to 10% of global energy. During the transition from wood to coal, wood prices didn't collapse and coal prices didn't take off, as one might have expected. The exact opposite happened, as wood prices meaningfully outperformed coal prices. Similarly, during the transition to crude oil in the early 1900s, we didn't see a secular bear market in coal or a secular bull market in crude oil. The two had a very similar price pattern, though crude oil was more volatile. And during the transition to natural gas, price changes in coal, crude oil, and natural gas were more alike than different. Interestingly, natural gas was the worst performing of the energy sources for 25 of the first 30 years of this transition even though it was gaining market share at a rapid clip. With the transition to nuclear energy, the pattern is a little harder to read, but again we did not see a collapse in the price of the old energy.

So while every transition is unique, I think all of this suggests that the knee-jerk reaction of expecting a bear market in crude oil is too simplistic. And in fact, more pessimistic expectations on the part of energy investors will keep capital away from the sector, which will be supportive of crude oil prices if it reduces investment in new supply.

Figure 6

Prices don't tend to plummet as market share declines

Relative index of real commodity prices during transitions from 2% to 10% of Global Energy

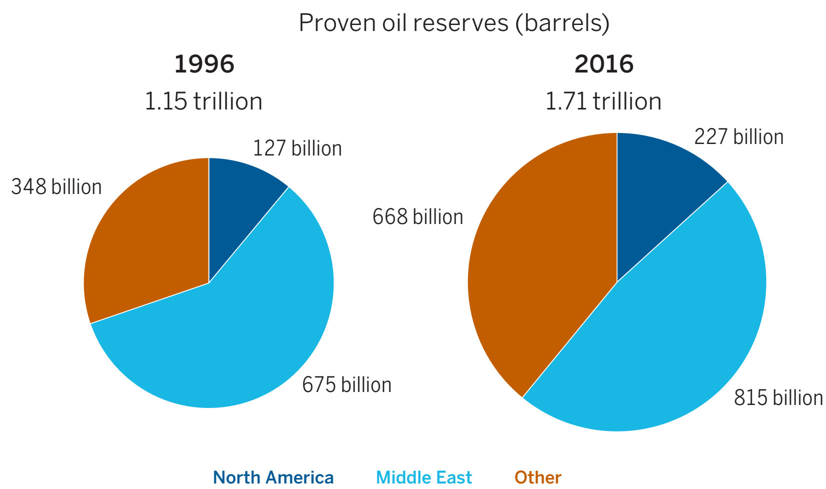


Sources: Global Financial Data and Wellington Management

Turning to supply, I mentioned earlier the challenges of energy forecasts, including supply forecasts. There was, for example, a period of extreme pessimism in energy markets in the late 1990s, driven by concern about an oversupply of oil, with headlines declaring that we were "drowning in oil." That's no longer a concern, of course, as global oil consumption has since grown more than 50%. At the same time, new technology has helped grow global proven reserves from 1.15 trillion barrels to 1.71 trillion barrels (**Figure 7**). In 1996, we had about 45 times more reserves than we had annual production. Since proven reserves have grown even faster than production, that figure now stands at 50. Yet the cost of reserves has changed dramatically. In 1996, the marginal cost of a new barrel of crude oil was about $14. Today, it is about $75. So more oil is findable, at least for the foreseeable future, but it's likely to be findable at ever higher costs.

Figure 7

More resource is available…at a price



1996		2016
45	Proven reserves / Annual production	50
$14	Marginal cost per barrel[1]	$75

[1]Brent oil | Source: BP Statistical Review of World Energy, June 2017

3. Carbon policy

As I mentioned, the big wild card in the energy picture is climate change and carbon policy, including carbon taxation. If there's going to be a secular bear market in fossil fuels, I believe this will be the driver. But there are a number of challenges when it comes to initiating an effective global carbon policy:

- If the scientific consensus is correct, climate change will certainly be growth inhibiting in the future, but carbon policies meant to mitigate climate change will likely be growth inhibiting *immediately*. Consequently, it's difficult for politicians to get behind a policy.

- In the emerging markets, there's a perceived fairness issue. More carbon emissions come from emerging markets than developed markets — 62% vs 38% (**Figure 8**). But high levels of fossil fuel use are viewed as the only viable path to improve income and reduce poverty in emerging markets, and the reality is that on a per capita basis, energy consumption is far lower in emerging markets (far right column).

Figure 8
The next driver of energy transformation: Carbon emissions

	Carbon emissions		
	Global share 2016 (%)	2005 – 2015 annualized growth (%)	Per capita energy consumption (TOE)[1]
Developed World	38	-1	4.6
• US	16	-1	7.0
• Europe	10	-2	3.2
• Japan	4	-1	3.5
Emerging Markets	62	3	1.0
• China	27	4	2.2
• India	7	6	0.6
• Saudi Arabia	2	5	8.4

[1]Tons of oil equivalent | Source: BP Statistical Review of World Energy, June 2017

“ ”

In considering the investment implications, don't focus on one scenario. Think in terms of multiple paths and investment strategies that are robust enough to accommodate them.

There are areas where technology and economic incentives can help limit transition costs, but they are not widespread. The Intergovernmental Panel on Climate Change estimates the cost of a transition to a safe level of carbon at $15 – $20 trillion. That's the size of the US economy. And at the moment at least, I think the physical cost of climate change is just an abstraction to most people, while the largest economic players are incented to retain the status quo. The problem is, in fact, likely to get cheaper to solve the longer we delay, as technology costs will change. So how these incentives ultimately stack up against the rising physical cost of climate change will ultimately be the key question.

Conclusion

I think there are a few key takeaways. First, in considering the investment implications, don't focus on one scenario. Think in terms of multiple paths and investment strategies that are robust enough to accommodate them. Second, remember that these transitions can take an incredibly long time, and that the oil market is probably going to be characterized more by cyclicality than by structural decline over the next decade or two. In addition, the drive toward efficiency and electrification of everything will continue unabated. And finally, carbon policy is the major wildcard to watch.

WELLINGTON MANAGEMENT COMPANY LLP Boston | Chicago | Radnor, PA | San Francisco
WELLINGTON MANAGEMENT AUSTRALIA PTY LTD Sydney
WELLINGTON MANAGEMENT CANADA ULC Toronto
WELLINGTON MANAGEMENT HONG KONG LTD Hong Kong | Beijing Representative Office
WELLINGTON MANAGEMENT INTERNATIONAL LTD London | Frankfurt
WELLINGTON MANAGEMENT JAPAN PTE LTD Tokyo
WELLINGTON MANAGEMENT SINGAPORE PTE LTD Singapore
WELLINGTON MANAGEMENT SWITZERLAND GmbH Zurich
WELLINGTON LUXEMBOURG S.à r.l. Luxembourg

www.wellington.com

488983_3