STRATEGIC INSIGHTS

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Keeping the home fires burning:
Australia's energy security

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Introduction

Like all developed economies, Australia requires reliable and affordable supplies of energy to function smoothly. The Australian Government's definition of 'energy security' is clear and to the point:

> [E]nergy security is defined as the *adequate*, *reliable* and *affordable* supply of energy where:
>
> - *adequacy* is the provision of sufficient energy to support economic and social activity
> - *reliability* is the provision of energy with minimal disruptions
> - *affordability* is the provision of energy at a price which does not adversely impact on the competitiveness of the economy and which supports continued investment in the energy sector.[1]

These criteria are sufficiently robust for discussions about the short to medium term. However, lacking a temporal dimension, they don't collectively capture the longer term dynamics of energy production, distribution and consumption. Political, economic and

Oil pumps at night © Fotosearch.com

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demographic changes in the international environment can all affect Australia's energy security—the right policy settings for today mightn't be right for the future.

Because of the many uncertainties in the international environment, the longevity of current approaches to energy security is hard to assess, but in many ways it's the most important aspect from a policy point of view. To date, Australia has largely adopted a market-based approach that's proven very effective. But, while there's no reason to think that market stability is about to drastically decline in the short term, the longer term prognosis is less clear. There are also challenges on shorter timescales, and mechanisms to damp down short-term volatility such as price spikes can be useful. However, short-term mechanisms aren't generally useful in dealing with longer term problems.

For example, the world oil supply will become increasingly dependent on Middle East suppliers in the next couple of decades. And at some stage—exactly when is a matter of active debate—the worldwide production of oil will begin to decline. That will necessarily result in a shift of global consumption towards other energy sources, most likely a combination of natural gas, coal, nuclear energy and renewable sources. Later still, there's a very real question about the ability of the world to generate energy at the current rate, which will present a very big challenge in a world with a significantly larger human population.

This paper begins with an examination of Australia's current energy security. Here the news is good—we're well served by current arrangements and have robust policy and market settings that allow potential energy vulnerabilities to be managed. Those arrangements will continue to provide the energy required by Australian consumers in the short term (0–5 years).

Of course, it's not just about Australia—part of the energy security we enjoy today is due to multilateral international arrangements. However, some developing economies aren't covered by the mechanisms in place for industrialised economies—and their strategic drivers may be quite different. As is the case in most contemporary security analyses, the growth of China and India looms large in discussions of energy. How extant international energy arrangements could accommodate developing countries so that their energy needs can be met in a way that adds to overall international security is the topic of the next section.

Looking to the medium term (5–25 years), the news is also generally positive for Australia. By virtue of being in possession of very large energy reserves, especially gas and coal, we can manage the risks that might otherwise accrue through the increased concentration of the world's oil supply in the hands of a smaller number of players concentrated in the Middle East.

This paper finishes with a look to the far term (25+ years). ASPI usually concerns itself with policy decisions on shorter timeframes than that, but the energy security policy challenges of the next twenty years are likely to pale into insignificance compared to those that will arise when the availability of fossil fuels declines significantly. Unfortunately, it doesn't look like renewable sources of energy will be able to provide adequate substitutes, at least based on current technology.

Short-term issues (0–5 years)

Because Australia possesses large reserves of coal, gas and uranium and a moderate (but declining) reserve of oil, it's very well placed to meet current domestic demands, while having sufficient stocks to allow for substantial quantities to be exported. In terms of the 'adequate and reliable' rubric, there's little obvious vulnerability—at least in the strategic sense that this paper's concerned with.

Affordability

Affordability requires a little more discussion. In terms of the government's definition of maintaining economic competitiveness, oil prices are neutral; even if they were to rise significantly, that would be a function of the broader world market price. Australian producers and consumers will be in the same boat as everyone else with comparable levels of oil intensivity (the amount of oil consumed per unit of GDP produced), so relative competitiveness shouldn't decline. In any case, the only policy lever available in the short term is the level of taxation applied by governments, which would have to be considered as part of the overall budgetary process. In the medium term there are other options, which will be described below. As far as the generation of electricity is concerned, extensive and economically exploitable coal and gas deposits provide a high level of self-sufficiency and could provide the lion's share of Australian electricity for some time to come.

Overall, the affordability of various methods of energy production will depend on the price of inputs, which will be dictated by purchase and/or exploitation costs and by the prevailing taxation regime. A carbon price, such as recently legislated, will shift the economics of energy production—especially electricity—towards alternatives. Natural gas fired plants are already being built and further projects are likely to follow.

Uranium could also be used for electricity production. The current business case for nuclear generation of electricity in Australia is, at best, marginal[2], but the higher the carbon price, the more competitive nuclear power will become. However, it's unlikely to be developed—especially since Fukushima—unless there's an overwhelming economic case that overrides environmental and political concerns.

For reasons that will be explained below, renewable energy production isn't likely to become the chief source of electricity in Australia in the foreseeable future, although it will have a growing role.

Australia's oil supply chain

The one energy source for which adequacy and reliability *might* be an issue is oil. Oil products play a vital role in Australia's economy and social structure due to their extensive use in transport. For long-haul travel or freight transport, there's no practical substitute for liquid fuels. However, domestic production falls well short of national consumption. In addition, for quality and cost reasons, only around a quarter of the oil products consumed in Australia come from locally produced crude oil. Australia isn't self-sufficient in refinery capacity either: 25% of our demand for refined oil products is satisfied by imports.

The fact that domestic oil production and refining capacity falls short of local demand means that Australia is, at least to some extent, vulnerable to the disruption of supplies of crude and refined petroleum products during times of crisis. There are possible hedges against interruptions to oil supply. One is to replace oil derivatives with liquefied gas products. Another, which many countries have in place, is to maintain strategic oil reserves. But it's important to note that energy security isn't synonymous with self-sufficiency. So before analysing hedging strategies, it's important to first understand whether there's a serious problem. That requires an examination of the robustness of Australia's oil supply chain.

Australian oil production has declined over the past decade or two, which would suggest that oil security might have become more problematic. Instead, when the situation is examined closely, a rather counterintuitive result emerges: the decline of Australian domestic oil stocks has *improved* the resilience of our supply chain. By moving to diversify the sources of oil products so that no one supplier or cartel of suppliers has a stranglehold on Australian imports, and by becoming a frequent and reliable participant in both medium-term and spot oil markets, Australia has reduced its vulnerability to disruption. The soundness of this strategy has been recognised from the beginning of the Western world's dependence on oil. Winston Churchill—who was a strong advocate of the use of oil rather than coal for ship propulsion—told the House of Commons in 1913 that 'On no one quality, on no one process, on no one country, on no one route and on no one field must we be dependent. Safety and certainty in oil lie in variety and variety alone.'

...and by becoming a frequent and reliable participant in both medium-term and spot oil markets, Australia has reduced its vulnerability to disruption.

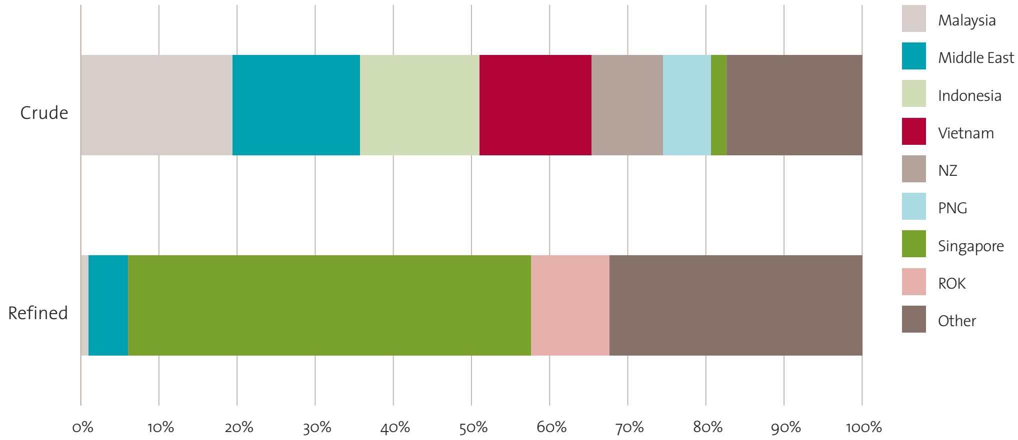
By Churchill's measure, Australia's in a sound position. Figure 1 shows the sources of Australian oil product imports. Australian imports are mainly sourced from sixteen countries, and the Asia–Pacific region provides about 80% of the total imports. The rest originates mainly from the Middle East, with a small supplement from West Africa.[3] By importing refined product from a variety of sources, the Australian economy is shielded from the bottleneck that could result from a heavily subscribed local refinery going offline for any reason.

But Churchill wasn't entirely right—while diversity of suppliers is an important contributor to resilience to disruption in oil markets, there are other factors. They include the relative political stability of suppliers, market liquidity (the size of the local market compared to the global one) and oil share (the proportion of oil in total national energy consumption). Two other factors that currently serve Australia well, especially compared to other Organisation for Economic Co-operation and Development (OECD) countries, are net import dependency and the ratio of domestic reserves to consumption.

It's possible to combine the various factors in a systematic way to produce a quantified measure—an 'oil vulnerability index', as has been done in a recent academic study.[4] The results of such calculations are shown in Figure 2. Australia has the lowest (= best) ranking of the twenty-six developed economies that were included in the study. Two caveats need to be applied to these results. First, any index that involves many disparate factors necessarily involves judgments about the weights of those factors, and is therefore more subjective than might first appear. Second, the data used is for 2004, and some factors have changed in the interim. In particular, Australia's net import dependency has increased and is forecast to grow further in future due to increasing consumption, as it has for most OECD countries.

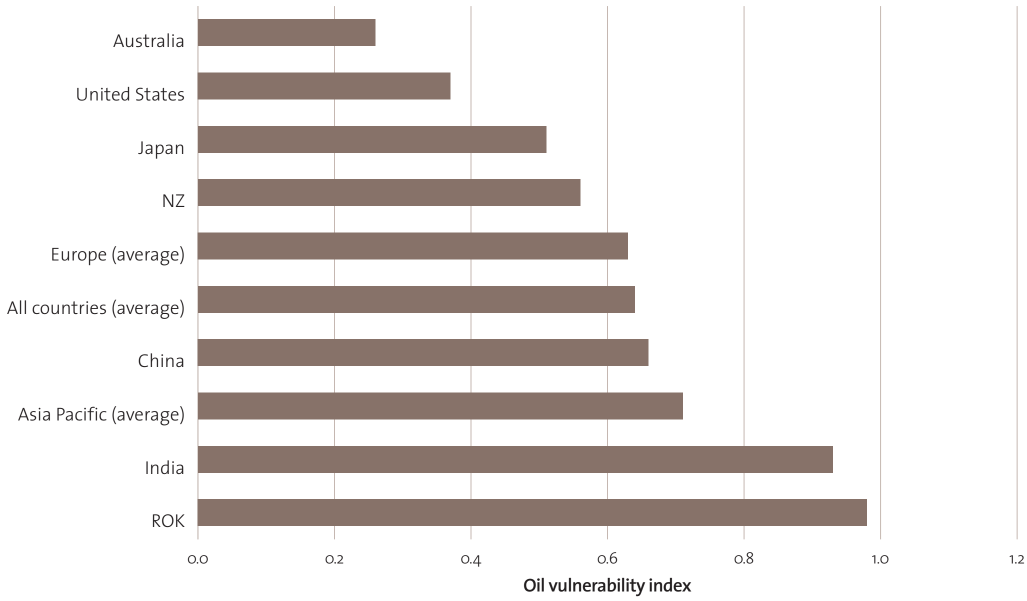
Nonetheless, the overall qualitative result of this analysis is robust; as a result of the market-driven approach of successive governments and the response of industry, Australia currently has low overall vulnerability to oil market disruptions, especially in the zero to five-year timeframe. The next section looks at longer timeframes, over which a steady decline in domestic and regional crude production will result in Australia's oil being sourced further from home. This trend might already be visible—anecdotal reports suggest that suppliers have had to go further afield in 2010–11 than before, due to increased competition for 'regional barrels'.

Figure 1: The diversity of suppliers of Australia's oil needs



Source: Energy in Australia 2011, *Department of Resources, Energy and Tourism, Canberra.*

Figure 2: Oil vulnerability index for selected oil-importing countries (lower scores = lower vulnerability)



Source: E Gupta, 'Oil vulnerability index of oil-importing countries', Energy Policy, *vol. 36, 2008, 1195–1211.*

Strategic reserves

Even low-probability events occur sometimes. Despite being well placed to ride out supply disruptions by virtue of diversity in its sources of oil, Australia could still find it worthwhile to make further investments in hedging strategies, in the same way that a householder can take steps to reduce fire hazards around their home but still buy insurance. Ultimately, the question becomes whether the cost of doing so is commensurate with the benefit.

One approach would be to establish a strategic oil reserve, a repository of crude and/or refined products that could be drawn upon in times of crisis. The International Energy Agency (IEA) was set up under OECD auspices in response to the oil crisis in the 1970s caused by the actions of the Organization of the Petroleum Exporting Countries (OPEC). Its main aims are to provide policy advice and coordinate energy policies between member states. It also encourages greater market transparency throughout the entire energy sector. The IEA sees national emergency stocks as an important tool for managing energy security. It requires member states to 'hold oil stocks equivalent to at least 90 days of net imports and to maintain emergency measures for responding collectively to sudden disruptions in oil supply'.[5]

Nationally controlled stocks are maintained by many of the member states. In some cases there are obvious reasons for doing so. The Republic of Korea has one of the highest calculated oil vulnerability indices, and the desirability of holding reserves is necessarily higher in those circumstances. The US has a government-controlled stockpile in the form of the Strategic Petroleum Reserve (SPR), which makes for an interesting case study.

First set up in the mid-1970s as a response to the OPEC-induced oil shock of 1973–74, the SPR holds a little over two months of total US oil consumption (although oil can't be extracted at that rate and it is more accurately described as a 160-day reserve that can service about a third of total demand).[6] As can be seen from Figure 2, the US has a relatively low oil vulnerability index—higher than Australia but well below the OECD average. That should mean that the US is also well placed to weather disruptions in supply, and SPR usage data supports that inference.

The SPR was called upon in the aftermath of hurricane Katrina in 2005. The hurricane closed down production of almost all oil production in the Gulf of Mexico, which equalled the loss of a quarter of total US oil output. Even more importantly, 40%–50% of US refinery capacity was unavailable for a period after the hurricane. The existence of the SPR meant that there was ample crude oil available, but there were no refineries that could process the oil cost-effectively (that is, at market prices). As a result, quantities drawn from the reserve amounted to only 20 million barrels, half of which was a loan to oil companies, amounting to less than a single day's worth of oil at current US consumption rates.

The SPR was also called upon during the 1991 Gulf War, when thirty million barrels were extracted in response to market uncertainty and subsequent price rises. Again, the total amount was small compared to total usage, amounting to around two days of consumption in total, and that was during a war in a key oil production region. The most recent use of reserve oil stocks occurred in June of this year, when around thirty million barrels was released from the SPR, along with another thirty million barrels from other IEA states. The release was intended to offset disruptions caused by lost production from Libya during the political turmoil there.

This release surprised some in the oil industry because Libyan production accounts for just 2% of the world total. At first glance the impact of the release appears to have been minimal. There was a short-term reduction in oil prices, but the market quickly returned to the pre-release price. However, there were more subtle impacts which changed the differential price of light 'sweet' (low sulphur content) oils and 'sour' (high-sulphur) crude. The net effect was to increase the throughput of sweet oil through refineries, which produced a greater output of petroleum in time for the peak demand expected during the northern summer.[7]

These examples illustrate that a simple stockpile isn't, in itself, a hedge against disruption, although it can be helpful in smoothing out short-term disruptions and is part of a collective strategy. An end-to-end industrial capability and capacity and ready access to world markets are important components of resilience. The ability of the US to ride out the disruption of hurricane Katrina was, in the end, due more to the breadth and depth of the American petroleum industry and its ability to source products from the world market. And the disruptions in Libya could have been ridden out—albeit with likely higher short-time prices. Indeed, the effects of the release have now passed, although it may take over a year for Libyan production to come back on line.

However, avoiding short-term disruption is an important outcome, and there is a *collective* benefit from national reserves held by IEA members. The ability of the United States in the case of hurricane Katrina and Europe in the Libyan case to rapidly source products from the world market was in turn enhanced by the collective release of other members' government-controlled or regulated stockpiles at that time.

Even without government reserves, virtually all developed economies have the capacity to ride out disruptions on a scale of days to weeks. There's an inherent resilience in the petroleum industry, and government-controlled strategic reserves aren't the only holdings of oil products. The normal business of shipping, refining and distributing oil and its refined derivatives means that, at any given time, there's a quantity of oil 'in the system' that would enable economies to function for a while. In fact, private oil companies hold 64% of the total reserve across IEA member countries, with government-controlled holdings making up the rest. In most IEA member states, the remaining 36% of 'public' stocks (either government or agency controlled) make up over half of their IEA-mandated emergency reserve; the balance is held in private stocks.[8]

Until late 2009, Australia met its IEA-required ninety-day net imports stockholding target, equal to about fifty to sixty days of consumption, entirely through industry-controlled stocks. The supply line contains around two weeks of oil en route at sea and three weeks' worth of consumption in refineries and the distribution network.[9] Under the *Liquid Fuel Emergency Act 1984*, the Australian Government can direct the distribution of fuel in emergencies.

However, failing to be in compliance with IEA requirements isn't to be taken lightly. Because compliance is a treaty-level obligation, Australia runs the risk of being seen as 'free riding' on the rest of the IEA and the collective ability to smooth out short-term shocks in energy supply surety and pricing. Recent possible Australian noncompliance with the treaty is currently under review by government, and there are subtleties in reporting mechanisms to be worked through. If noncompliance with IEA requirements were to become a more commonplace circumstance, a national reserve is one possible solution, albeit one that's very expensive compared to the problem it would be setting out to solve.

A more cost-effective approach might be for the Australian Government to buy 'ticketed stock' (options to purchase) on the world market and exercise them should circumstances demand it. That's the approach taken by New Zealand and some other IEA signatory countries. It is a low-cost strategy for Australia to consider. This possibility, coupled with Australia's low overall vulnerability to disruption, leads to the conclusion that there's no compelling reason—at least in terms of treaty compliance or continuity planning—for Australia to establish a government-controlled strategic reserve of oil or refined products.

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Helping out the neighbours

While there's no need for Australia to establish a national oil reserve to ensure supply security, other countries are in a less secure position. Helping regional states via a shared reserve program could form part of Australia's regional stability-building strategy, foreign aid program, or both. As argued above, that course of action couldn't be based on a cost-effectiveness criterion; it would have to be part of a strategy to enhance Australia's broader security by reducing the exposure of already fragile states to external forces well beyond their ability to control. Australia is geographically and politically suited to managing regional energy contingency stocks.

Multilateral approaches to oil security already occur within the IEA framework. For example, IEA member states France, Italy and Germany have signed an oil-sharing agreement that complements their wider IEA obligations, as have South Korea and Japan. But there's no reason to preclude arrangements with non-OECD/IEA states. For reasons of efficiency and security self-interest, it would be most sensible for Australia to develop such relationships with nearby states—Indonesia, Papua New Guinea, East Timor, New Zealand and the South Pacific island states.

One option is to work towards one or more regional agreements via the Asia–Pacific Economic Cooperation (APEC) group or the Association of Southeast Asian Nations (ASEAN). However, it's far from clear that either organisation would have enough political commitment to move into an agreement that's essentially a combination of strategic and commercial interests. As well, any agreement would have to reassure the regional IEA member states Australia, Japan, New Zealand and the US that they were not going to acquire burden-sharing obligations in addition to their existing IEA obligations. As far as the wider Asia–Pacific region's concerned, an approach based on expanded IEA influence is preferable.

There's unlikely to be a sound business case for individual national reserves. Studies have shown that only the US has oil requirements that make having its own national reserve economically feasible[10], even if the effect is strategically marginal for the reasons described above, and no country in Australia's region comes close to the level of US oil consumption. In Indonesia's case, a partnership arrangement should be possible. Smaller, less developed states that are less able to participate in a regional stockpile at a commercial rate could instead be provided with a guarantee of assistance during a crisis.

The principal difficulty with a regional oil reserve is in overcoming perceptions of sovereign risk. Since oil is such a strategic commodity, states may be concerned that the ‘host’ state will fail to honour its obligations by refusing access to the reserves. However, while Australia could increase its access to emergency oil by effectively seizing the share of a participating state, it’s unlikely to need to do so and would defeat the purpose of the initiative if it did.

Given the modest oil requirements of Australia’s immediate neighbours, an initial common reserve that includes Australia, New Zealand, Papua New Guinea and the Pacific island countries should be feasible. Used this way, a strategic reserve would spread the costs of extending Australia’s own emergency stockpile and usefully complement other relationship-building measures in the south-western Pacific. However, given the lack of strategic compulsion, it would come down to a judgment call by the government about whether the largely diplomatic benefits would balance the cost.

Medium-term issues (5–25 years)

As shown above, Australia’s current energy security is based upon a combination of its own energy reserves and sourcing imports from a diverse set of suppliers of oil. The global market has served us well, both as a customer and as a supplier, but the shape of the current market—and hence the energy security that we enjoy—is built upon a foundation established when the current OECD member countries enjoyed the greater proportion of global prosperity.

The world energy market is not especially free. It’s estimated that only 14% of proven reserves of oil and gas are fully available to international oil and gas companies. The rest is controlled to at least some degree by national governments and their national oil companies.[11] Many of those national companies hail from countries with rapidly developing economies, which will necessarily require more extensive energy supplies in the future.

Trends

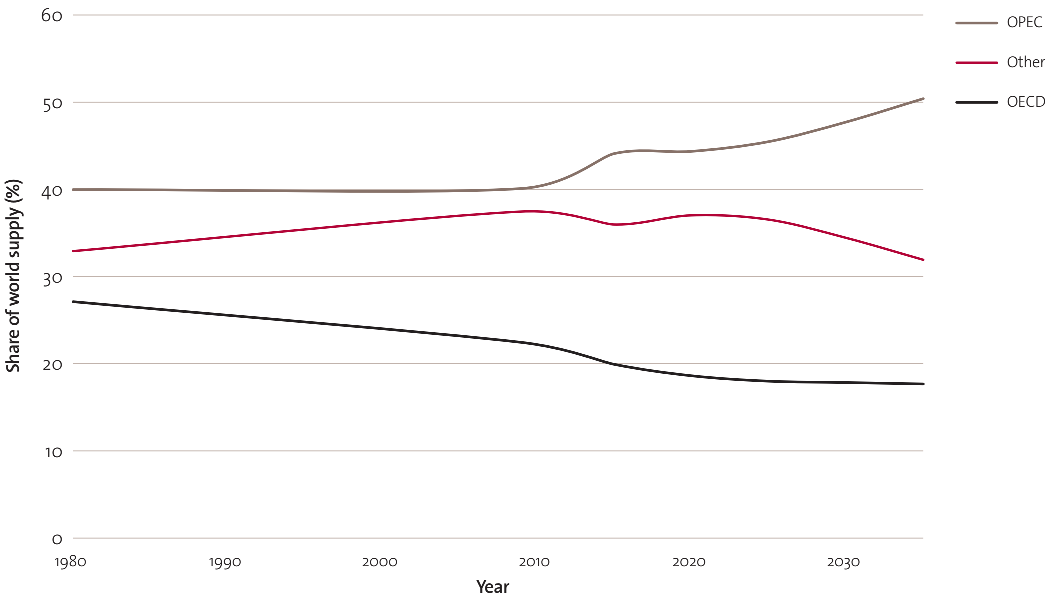
Two trends will be increasingly important over the next couple of decades, and they will reshape the demand and supply sides of the market:

- a shift in the demand for energy towards today’s developing economies
- an increased concentration of global energy production, especially oil, in the hands of fewer suppliers.

First, the BRIC countries (Brazil, Russia, India and China) will have an increasingly significant share of the global economy and a commensurately greater requirement for energy. This will have two important effects: it will increase the competition for energy resources and, perhaps more importantly, it will mean that the multilateral energy-related structures in place will no longer accurately reflect market realities. Between now and 2035, most of the growth in global oil demand will occur in the developing world (see Figure 3).

China and India, which are non-IEA states, are projected to account for 23% of global oil demand by 2035, up from 13% today. In much the same way as the Nuclear Non-Proliferation Treaty ‘locked in’ historical relationships that don’t accurately reflect today’s nuclear landscape, a static IEA membership would increasingly reflect the past rather than the present.

Figure 3: Shares of global oil demand, 1980 to 2035

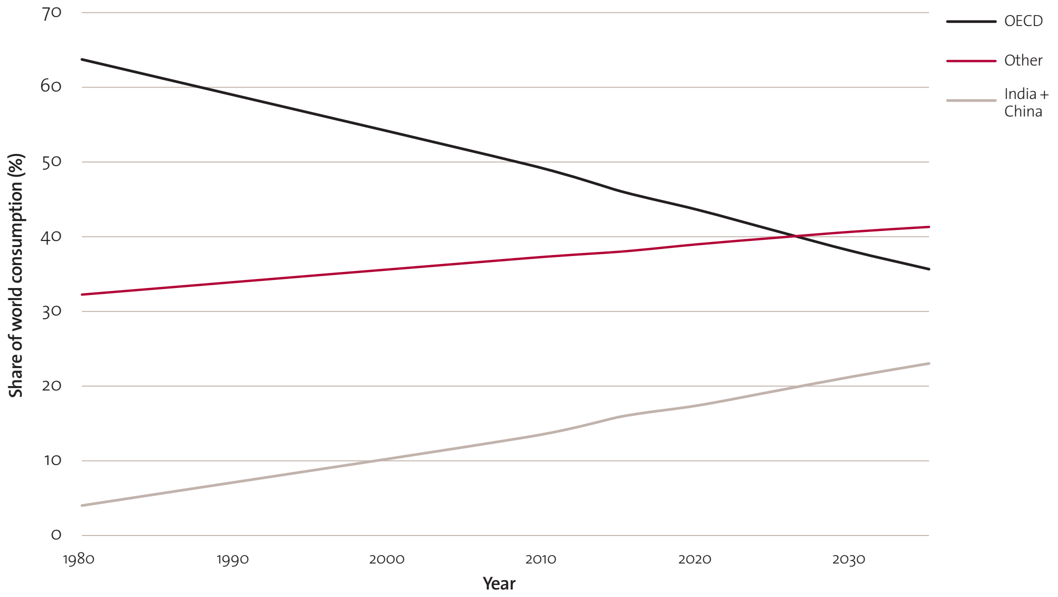


Source: IEA, World energy outlook 2010.

Figure 4 shows the projected global production of oil out to 2035. By the end of that period, non-OECD countries will account for over 80% of global oil production. OPEC countries will have more than 50%, shifting market power further towards the cartel. OPEC, while sometimes acting to stabilise world oil prices and supply, has at other times acted to manipulate the supply of oil to further the economic interests of its member states or, as in the 1973 oil crisis, to make a political point. Because of mechanisms put in place in response—not the least of which is the IEA—OPEC no longer has the sway it had in 1973, although it still controls nearly two-thirds of world oil reserves.

However, the projected increased concentration of oil supply in OPEC countries, combined with increasing oil consumption in non-IEA states, will tend to shift the balance. The IEA's capacity to manage a supply-side oil shock and to dampen price spikes has already diminished markedly since the 1970s and will diminish further. IEA strategic reserves will also carry less weight as a proportion of global consumption. A coordinated IEA response will therefore be less effective in constraining a spike in global oil prices than it would be today, and much less than it would have been thirty years ago.

Figure 4: Shares of global oil production and supply, 1980 to 2035



Source: IEA, World energy outlook 2010.

The effects of both of the identified trends could be magnified by the fact that countries with increased influence on both the demand and supply side are, generally speaking, not as committed to free market principles as are OECD members. This could result in an upswing in practices contrary to the operation of free markets. States could attempt to operate at least partly outside of market mechanisms, such as by 'tying' resources for their own use through state-owned companies. As resources become more sought after, there could also be an increased use of what's termed 'resources diplomacy'—the use of resources (energy, in this instance) as a tool of foreign policy, rather than as simple revenue producers.

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The actions of OPEC in 1973 are one example of what can be done. A good current example of a country using energy supplies as an arm of national policy is Russia, which has threatened or actually restricted supplies of natural gas to downstream customers on several occasions. Sometimes the objective appears to be economic, with supply surety being used as leverage to extract particularly favourable pricing outcomes, but at other times Russian aims seem to be more political.[12]

Large domestic reserves of energy mean that Australia's exposure to such manipulative behaviour is limited—except, again, in the case of oil. While a diversity of suppliers has served us well to date, increased concentration in the hands of fewer suppliers in the future will tend to diminish the effectiveness of our current strategy.

However, the extent to which that's a problem is debatable. Despite the current wave of unrest in the Middle East, including a civil war in one oil-producing state, oil supplies have continued almost uninterrupted. The Iraq War of 2003 didn't have a major impact on oil supplies, despite Iraq being a much more important exporter than Libya. The 1991 Gulf War, in which Kuwait's oil industry was targeted directly by Iraqi forces, saw the IEA implement a 2.5 million barrel a day contingency plan—about 4% of total world consumption at the time. Peak losses were about 4.3 million barrels per day, or a little over 6% of world consumption. Impacts of that scale are manageable using existing mechanisms but, overall, the bottom line appears to be that the cash flow generated from oil exports trumps other concerns, except in extreme circumstances.

Nonetheless, a hedging strategy is often desirable, provided that the cost incurred is proportionate. Given the lack of past experience of major disruptions, it will be necessary to make a judgment about how much hedging is required.

For Australia, possible policy responses to these trends include:

- expanding the membership of existing multilateral international bodies to include important new non-OECD players—especially China and India—thereby better aligning the interests of all parties
- reducing Australia's exposure to OPEC oil through substitution of other fuels produced from natural gas or other feedstocks
- modifying Australia's existing 'market first and foremost' approach to achieve greater energy security for ourselves by quarantining a portion of energy reserves for exclusive Australian use.

Looking beyond our own shores, we also have an interest in our near neighbours achieving greater energy security. Future changes that adversely affect Australia will be even more keenly felt by the already fragile states in the arc that comprises Australia's immediate neighbourhood—described in the 2009 Defence White Paper as Indonesia, Papua New Guinea, East Timor, New Zealand and the South Pacific island states. We therefore can add to Australia's policy options:

- the use of Australia's relatively strong position to increase energy security across the immediate neighbourhood as part of wider efforts to foster stability and cohesion.

The following sections expand upon these four options, which aren't mutually exclusive.

Expanding the IEA?

Expanding IEA membership to include China and India is difficult because changes to IEA membership rules require OECD authorisation. Joining the IEA involves a commitment to an institutional bargain. China and India would be obliged to increase the transparency of their energy sectors—a move that would benefit those countries that obtain energy from global markets, as Australia does in the case of oil, because companies could make more accurate trade and investment decisions. They'd also be obliged to disclose information on the extent of their strategic oil stockpiles, which would have to be built up to ninety days of net imports in accordance with IEA obligations. In the event of a serious crisis, they'd have to implement emergency measures (in practice, that means a stock release as far as the IEA is concerned).

This would add to the total world reserve holding, effectively further spreading the 'insurance' benefit that all member nations enjoy. In return, both China and India would be entitled to emergency assistance should they experience a shortfall in oil supply.

There's been some enthusiasm for reform within the IEA, and the US recently advocated that both China and India be allowed to join as non-OECD members. But China and India are unlike other IEA countries, and will weigh other factors when considering the cost–benefit calculus of IEA membership. As the IEA is closely tied to the OECD, they'll be hesitant to join an organisation that could place them at odds with their commitments to key institutions of the developing world—most notably the Group of 20 developing nations and the G77. So, if the organisation's membership were to include China, India or both, it may need to expand to accommodate other major developing countries.

China's concern over its energy security reinforces those difficulties. China's strategic outlook is very different from Australia's. It's likely that China is more anxious about military actions that would restrict its access to imported oil than about disruptions to the world market that can be managed through IEA mechanisms. So it's no surprise that China has so far been reluctant to subject its stockpiles to international scrutiny or to enter agreements to make some of the oil available to the international market. The benefits that China—and the rest of the world—stand to make from greater transparency and coordination of national stockpiles might be outweighed by China's perception of strategic vulnerability.

However, it's not clear that China's position is immutable. Internal debates indicate that Chinese policymakers have a range of views on how China's interests can be pursued in global energy markets.[13] Deeper cooperation with the IEA is possible even if China doesn't become a full member. Signs of this are already appearing, and the IEA currently engages with China as a 'dialogue partner'. Australia, as a net energy exporter, has a vital interest in building stronger links between the IEA and major developing nations—with a view to long-term accession—in order to enhance the collective resilience to short-term oil crises with the concomitant bonus of building stronger relationships among the countries of the Asia–Pacific region.

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Oils don't need to be oils

Given our natural gas reserves, we have a natural fall-back position if future developments in the Middle East or elsewhere lead to a decline in the reliability of delivery of crude and refined oil products. Liquefied natural gas (LNG) can be used as a fuel in its own right, and industrial processes can transform almost any kind of hydrocarbon into any other, so it's technically feasible to produce liquid fuels for transport and other applications from reserves of natural gas. One such process produces diesel from gas.

Until now, the rate of production and consumer take-up of fuels produced from gas has essentially been an economic question. LNG is produced for ease of transporting large volumes by sea in specialised vessels where pipelines are not feasible—which applies to Australia's exports. As a result, there's been investment in LNG production facilities in Australia, which in turn has allowed a modest take-up of LNG for domestic transport applications.

Left to the market, the use of synthetic fuels derived from gas or coal will be driven by price considerations: if the price of oil increases and looks set to stay high, then there'll be greater take-up of alternatives as price thresholds are passed. For example, it's also possible to use coal as the feedstock for liquid fuel production, but costs tend to be higher still.

However, there are considerable lag times involved, and upfront capital costs are high. The construction of conversion facilities on a big enough scale to meet widespread demand is a five- to ten-year process. Because of that, it's unlikely that much investment will be made until the national policy response to climate change is agreed.

So any sustained instability of oil supplies from the Middle East or elsewhere could be addressed over time, but there's no quick fix. Economics will manage any transition. Given the costs involved, any government market intervention would probably have to be based on a perception of changed strategic circumstances and a marked deterioration in surety of supply—for which there's little evidence at present.

Quarantining supplies

As for most complex subjects, there are many misconceptions about energy security. There are myths concerning the level of security and pricing certainty that can be derived from controlling energy supplies within a nation's borders by quarantining production for local use, or through 'locking down' foreign-sourced supplies.

It might seem attractive to hold at least a proportion of Australian supplies for local use in the event of market volatility, adverse trends or foreign interference in the markets at the cost of Australia's energy security. It's also sometimes argued that local prices could be driven down in this way—an argument that's especially pervasive in the US.

None of those propositions stands up to close scrutiny. Pricing is dictated by the world market price—in a global market for energy, local suppliers would be significantly disadvantaged by being constrained to sell their products at a lower price locally. At best, a small discount could be achieved due to reduced transportation costs, but transport's a small fraction of energy costs, although there are niche exceptions to this rule of thumb. For example, consumers on the east coast of Australia currently pay less for natural gas than their west coast counterparts because there is no east coast LNG production for export. However, that's likely to change. Recent industry moves to establish LNG infrastructure on the east coast mean that local prices are likely to move closer to parity with the export price than is currently the case.

More than the usual level of short-term market volatility can be smoothed out by the IEA mechanisms discussed above, which don't require market quarantining. Australia has large energy reserves that will come into play should trends produce a situation where oil—our main point of energy vulnerability—becomes too difficult or too expensive to obtain in sufficient quantities. That leaves interference in the market by foreign entities, especially government-controlled ones, as the remaining argument for what would amount to interference in the Australian market. Since the biggest player in the regional marketplace is China, it's worth looking at the Chinese approach to energy, and to resources more broadly, which comprises a mix of market and centralised approaches.

Like every other nation, China is keen to diversify its sources of energy to reduce vulnerabilities, but in China's case state-controlled companies are leading the effort. The key question is how significant this development is. One concern is that actions by Chinese companies will 'remove' energy resources from the competitive market, constricting supply and raising world prices (which, incidentally, might be a *good* outcome for Australia as a net energy exporter). This view was articulated by, among others, the US National Security Advisor, who expressed concern in 2006 about China's 'quest to lock up energy supplies, rather than participate in energy markets'.[14]

Concerns about the effects of China removing energy stocks from the market for exclusively Chinese consumption seem misplaced.

Concerns about the effects of China removing energy stocks from the market for exclusively Chinese consumption seem misplaced. First, there's no evidence of that happening. Second, and more importantly, the overall market effect of such a move would be neutral. Around the same time that the National Security Advisor was expressing concerns, the US Department of Energy observed that:

> Even if China's equity oil investments remove assets from the global market, in the sense that they are not subsequently available for resale, these actions merely displace what the Chinese would have otherwise bought on the open market'.[15]

That same assessment would apply to any attempt by Australia or any other country to lock away energy reserves.

The long term (25+ years)—preparing for the post-fossil-fuel era

This paper finishes with a look beyond the medium term. ASPI usually concerns itself with policy decisions twenty years or less ahead, but the energy security policy challenges of the next twenty years are likely to pale into insignificance compared to those that will arise when the availability of fossil fuels declines and their prices rise significantly. This paper therefore finishes with a look beyond the medium term.

There's a spirited debate in industry and academic circles about the timing of 'peak oil'—the point at which global oil production reaches a level that will never be achieved again due to the depletion of readily-exploitable stocks. The IEA surprised many in its *World energy outlook 2010* report by apparently suggesting that peak oil occurred in 2006—although it predicts a plateau of around 68–69 million barrels per day from 2020, down from 70 million in 2006, rather than a precipitous fall. But demand will steadily increase as developing economies increase their per capita energy consumption. In conjunction with that, the global population will continue to increase until around 2050. These factors and the projected amount of fossil fuel (particularly oil) remaining to be exploited mean that there are huge challenges looming around the middle of this century.[16]

Of course, as the price of fossil fuels rises, incentives will increase for further exploration, the opening up of new fields and the exploitation of sources that are currently not cost-effective, such as oil extraction from shale or tar sands. As well, it's likely that gas stocks will be used to produce oil substitutes through gas-to-diesel conversion. The same IEA projection in fact shows that the total oil supply actually *increases* out to the end of its prediction period in 2035.

Over the same time, there will be downward pressure on fossil fuel use due to concerns about climate change, to an extent still to be determined. If a strong international consensus on carbon emission reduction emerges, with an associated taxation or cap and trade regime for carbon emissions, then the demand for fossil fuels will decline markedly and there will be a corresponding increase of demand for renewable energy.

As well, energy production from nuclear fuel (uranium, plutonium and thorium) and renewables will become cost-competitive as various cost thresholds are passed, and the share of energy production from various sources will change over time. However, rather than *micro* issues of percentage energy mixes among fossil fuels and substitutes, the analysis that follows is concerned with a *macro* issue—maintaining the total energy supply.

From the perspective of energy security, the following results strongly suggest that there's little scope—at least at present—for economies to replace a significant fraction of their fossil fuel energy. And developing countries are even less likely to be able to adopt alternative energy sources on a large scale. As a result, any large reduction in fossil fuel usage will most likely be due to scarcity and price rather than choice.

A renewable future?

When considering the role of renewable sources in the future provision of energy, the main factors to take into account are economics and practicality. As with the exotic sources of fossil fuels and nuclear fuels discussed above, the economics of renewables will be dictated by a combination of their intrinsic costs and market interventions such as prices imposed on carbon or restrictions on nuclear energy for other reasons. However, the practicality of renewable energy sources is more amenable to analysis; it depends primarily upon their efficiency, which in turn sets the scale of the effort required.

Almost all renewable energy is generated by an array of some kind or, in the case of biofuels, grown. This necessarily requires areas of land or sea to be available for the purpose. Wind generated electricity produces around 2–3 Watts per square metre (W/m^2) and 20% efficient solar panels—which are the cheapest and most easily mass-produced without requiring exotic materials—about 20–40 W/m^2.[17] Because of its efficiency relative to other forms of renewable energy, and the fact that Australia is literally well placed for solar energy generation, the calculations that follow assume that solar energy is the likely main source of non-fossil fuel generated energy in the future.

With these figures, it's possible to estimate the amount of space that would be required to meet the energy requirements of modern societies. Table 1 shows the results

Solar energy panels © Fotosearch.com

Table 1: Energy consumption of six countries and the area required for solar electricity generation

	Population (million)	Average power consumption per person (W)	Average solar power (W/m^2)	Area required to meet energy demands km^2	Fraction of landmass covered	# Sydneys required
Australia	20.8	7,812	40.0	4,162	0.05%	2.3
China	1,310.6	2,120	33.3	83,358	0.87%	46.3
Germany	82.4	5,343	22.5	19,566	5.48%	10.9
India	1,129.9	702	43.3	18,299	0.62%	10.2
UK	61.2	4,596	21.7	12,981	5.37%	7.2
USA	301.6	9,954	33.3	90,067	0.98%	50.0
World	6,625	2,457	30.0	542,671	0.36%	301.5

Data sources: World Bank (population) and IEA (energy consumption)

of calculations for six countries, based on *current* population sizes and energy consumption levels and assuming that all energy requirements can be met by electricity production.[18] The figure used for Australia is 40 W/m^2—a population-weighted average of the average power generated at the latitudes of Australia's main cities.[19] For other countries a mid-latitude figure is used. For illustrative purposes, the land areas required are also expressed as multiples of Sydney's urban area of around 1,800 square kilometres.

So to generate enough renewable power to meet the demands of today's population, Australia... would have to construct solar panel arrays that occupy over 4,000 square kilometres...

So to generate enough renewable power to meet the demands of today's population, Australia—a country with the relative advantages of high levels of incoming solar energy and a large amount of land for a small population—would have to construct solar panel arrays that occupy over 4,000 square kilometres, corresponding to an area greater than twice the Sydney urban area. The requirement can also be expressed as 200m^2 of panel per person, or about four times the average amount of roof area per person in Australia today. Building on this scale is certainly possible, but this calculation represents a lower bound because it doesn't include the infrastructure required to store and distribute energy that is required at a time and place removed from the point of production—a point returned to below.

Liquid fuels are likely to continue to be required for heavy land transport and aviation. Because of their low overall efficiency of around 0.5 W/m^2, adding biofuels to the mix makes matters significantly worse. About 25% of Australian energy consumption goes towards transport. If that energy were to be produced by biofuels, it would require an *additional* 97,700 square kilometres of crop production—about the area currently devoted to the growing of wheat in Australia.[20]
The current generation of biofuel crops are relatively inefficient, so they require about twenty times more land per unit energy output than wind and eighty times more than solar. So-called second and third generation biofuels are more efficient, but even a factor

of ten improvement would not change the qualitative conclusions.

The United States and China would each require over 80,000 square kilometres of arrays to meet today's needs and future population growth and, in the case of China, further economic development will only increase the demand for energy. India has even more potential to increase its demand for energy into the future—the average Indian today uses one tenth of the energy used by the average Australian.

Bringing today's population in India and China up to the level of energy consumption of Europeans would require almost 250,000 square kilometres of additional arrays—fully 6% of India's area and almost 2.5% of China's. While these unfeasibly large numbers are future projections for developing countries, similar figures already apply for densely populated European countries today. Germany and the United Kingdom would have to cover over 5% of their territories with energy-producing arrays. For the United Kingdom, that corresponds to an area half the size of Wales and corresponds to more than six times the current average roof area per person. So for Australia the numbers are plausible, if large. For countries with one or both of a higher population density and less sunshine than Australia (i.e. most other countries), the prospects are much less promising.

The next step is to look at the cost. The 200m^2 of solar panel per Australian calculated above would cost a little under $100,000 per person at current retail prices, to which would have to be added the opportunity cost of the land.[21] The hardware cost is likely to be a significant overestimate because of the economies of scale that would result from a large-scale rollout. As a rough estimate, if the cost per panel could be halved, the total cost would be around $100 billion in net present value terms—a large but not inconceivable sum.

Unfortunately it's not that simple. The peak power production of solar power is during the middle of the day during the summer. At other times the instantaneous power is less—and is obviously zero during hours of no sunlight. So it's necessary to have mechanisms in place to provide 'baseload' (the level that must always be available) and 'intermediate' (levels that are variable but predictable—such as mornings and evenings) power, with a surge capability for peak loads at other times.

...most serious medium-term strategies to combat climate change... are critically dependent on the development of 'clean coal'...

A recent study found that, in the absence of a carbon price, the only source able to produce baseload power at a similar cost to coal is nuclear fission. Solar thermal storage technologies that store solar energy as heat in repositories of molten salt or other material can provide baseload power, but at more than two and a half times the cost of coal generated power. Equivalently, it would require a carbon price of $150 per tonne of CO_2 to make the technologies equally cost-effective. That's why most serious medium-term strategies to combat climate change, including that put forward by the Australian Government, are critically dependent on the development of 'clean coal'—which is estimated to require a more modest carbon price of around $40 per tonne.[22]

For all of the reasons explained above, most serious energy policy advocates agree that a combination of fossil fuels and renewable sources will be required rather than a 100% move to renewables. For example, the IEA suggests that even an aggressive move away from fossil fuels will leave a 60% reliance on fossil fuels in 2035. The consequences of such developments can be easily calculated from the results above. For example, a 40% contribution to Australia's energy requirements in 2035 would require a little over 1,600 km^2, or a little less than one Sydney area, of solar arrays—an eminently achievable proposition.

Other factors

This problem will only be exacerbated by population growth. Modern food production is energy intensive. The 'green revolution' that staved off the famines that many demographers in the 1960s were projecting has been critically enabled by fossil fuels, directly in the form of mechanisation and indirectly through the production, transport and application of fertilisers. According to United Nations projections, food for an additional 2–3 billion people will be required by 2050. That will require 40% or more area than is under cultivation today, given that the most fertile land is already in production, with a corresponding increase in demand for energy to provide fertiliser and transportation of the extra food.

Already, very modest demands for biofuels, compared to total energy demand, have resulted in upward pressure on food prices. A World Bank study found that:

> ... the most important factor [in the rapid increase in internationally traded food prices since 2002] was the large increase in biofuels production in the US and the EU. Without these increases, global wheat and maize stocks would not have declined appreciably, oilseed prices would not have tripled, and price increases due to other factors, such as droughts, would have been more moderate.[23]

Any further rise in demand for renewable liquid fuels will occur against a backdrop of a growing global population, which will itself require additional crops for food.

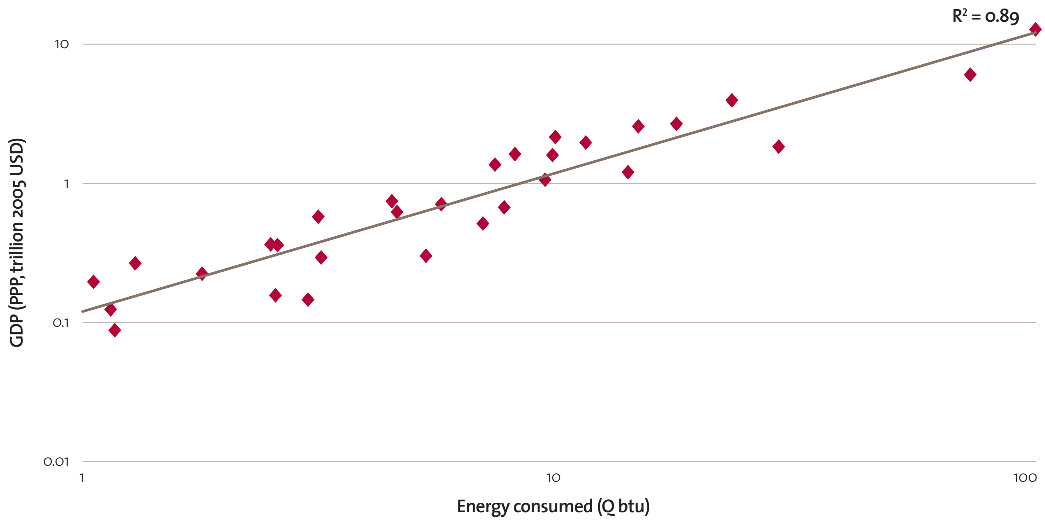
Looking ahead, as fossil liquid fuel depletion becomes an issue and prices rise dramatically, we're left with some uncomfortable conclusions. Any attempt to curb fossil fuel usage to eke out supplies for longer is unlikely to be successful—simply put, continued economic growth in the developing world, coupled with global population growth, is likely to overwhelm any reductions in fossil fuel use from efficiency gains or renewable energy production.

Mitigation

For those reasons, policy settings on energy production and usage today won't make a whole lot of difference in the long run. Barring a technological breakthrough, future societies are going to have less—possibly much less—energy than is the case today, and will be paying more per unit for it. Consequently, in the decades to come there'll have to be some serious structural adjustments to the way societies operate. Even the basics of subsistence, let alone the trappings of modern life such as greatly increased personal mobility, are based upon the ready availability of energy, the bulk of which comes from fossil fuels. Figure 5 shows how strongly the GDP of today's economies depends on energy—the correlation between energy consumption and GDP is around 90%. A marked reduction in energy availability would result in society being poorer in all physical respects.

Barring a technological breakthrough, future societies are going to have less—possibly much less—energy than is the case today...

Figure 5: The relationship between energy consumed and GDP at purchasing power parity



Note: GDP is plotted using purchasing power parity (PPP) because that method most accurately reflects prosperity. (Sources: International Energy Agency and World Bank data 2007)

There are four possible approaches to the problems outlined above, which could be applied separately or in combination:

- reduce the consumption of energy
- increase the efficiency with which energy is used
- find more efficient ways of producing alternative/renewable energy
- limit population growth (with a long-term aim of a smaller global population).

Some energy efficiencies can be harvested without significant economic impact. Indeed, reducing wastage may *increase* the overall efficiency of the economy. And, despite the evidence of Figure 5, economic growth and energy consumption can be decoupled to some degree. This process is well underway in developed countries. For example, the US has decreased the *energy intensity* (the amount of energy consumed per unit of GDP produced) by about 2.1% per year since the oil shock of 1973[24] while maintaining GDP growth of greater than 3% over the same period. At these average rates, the US economy could double in size again with an increase of energy consumption of only 22%.

However, the increased efficiency of energy use has partly come about due to the export of energy-intensive manufacturing to other countries. And it remains to be seen whether efficiencies can continue to be found, or whether they'll 'bottom out' at some point.

Increasing the efficiency of alternative/renewable energy production is obviously desirable, but the gains will have to be substantial. Doubling the power extracted from each square metre will halve the total area required for energy production—but much larger gains will be required before the numbers reflected in Table 1 begin to look manageable. Additional research funding may help, but there's already much work underway on these technologies. Assessing the cost-effectiveness of additional government funding for such projects is beyond the scope of this paper.

Finally, the world should be working hard to make the problem as manageable as possible. Population growth can't be ignored in the calculus of energy. Some developing countries—particularly China—have already recognised the resource consequences of large populations and have worked hard to limit growth. Australia and other developed nations have made good efforts through their aid programs to deliver contraceptive and reproductive health initiatives, but there's no doubt that more could be done. Australia should make every effort in international forums to promote efforts to mitigate population growth.

Australia should make every effort in international forums to promote efforts to mitigate population growth.

Conclusion

Energy security is important to modern economies. The linkage between prosperity and the assured availability of energy is a strong one and will remain so. Australia has managed its energy affairs well and has made good use of commercial markets to both reduce its vulnerability to supply-side shocks and to generate healthy revenue streams from exports.

The rise of new economic powers that are outside the OECD framework and the increasing market share of OPEC cartel energy suppliers mean that adjustments will be required. As is always the case when systems are changed, there'll be threats to be managed and opportunities to be taken, but the challenges should be manageable and current market and multilateral cooperative mechanisms should be able to be modified to accommodate the new major players.

In the longer term, the entire world faces a huge challenge to manage the energy needs of economies and the human populations they support. The timescale is decades rather than years, and the decline of existing fuel stocks will be gradual rather than precipitous, so there's scope for technological advances to come to the rescue—but there are no obvious solutions at the moment.

Notes

1 Department of Resources, Energy and Tourism, definition at http://www.ret.gov.au/energy/energy_security/Pages/EnergySecurity.aspx.

2 The difference is not huge. The US Congressional Research Service estimated in 2007 that the annualised cost of electricity production from a nuclear plant is about 20% higher than from a coal-fired plant, while an Australian study found that the cost-effectiveness of nuclear energy compared with coal-fired energy depends on the assumed discount rate in net present value calculations. As a rule of thumb, nuclear plants are more expensive to build but cheaper to run, so it's the upfront cost that works against them, especially when the future cost of money is high.

3 Australian Institute of Petroleum, *Maintaining supply reliability in Australia*, April 2008.

4 E Gupta, 'Oil vulnerability index of oil-importing countries', *Energy Policy*, vol. 36, 2008, 1195–1211.

5 See the 'Energy Security' section of the IEA website: http://www.iea.org/subjectqueries/keyresult.asp?KEYWORD_ID=4103.

6 Details of the Strategic Petroleum Reserve can be found on the US Department of Energy website: http://www.fe.doe.gov/programs/reserves/spr/index.html.

7 'Views run "sour-sweet" on IEA oil release', *Financial Times*, London, 21 July 2011.

8 International Energy Agency (IEA), *Oil supply security 2007*, pp. 33–36, available from: http://www.iea.org/textbase/nppdf/free/2007/oil_security.pdf.

9 Australian consumption is around 1 million barrels per day. According to IEA figures, total industry holdings amount to 42 million barrels.

10 P Leiby, D Bowman and D Jones, *Improving energy security through an international cooperative approach to emergency oil stockpiling*, 2002, available from: http://www.ornl.gov/~webworks/cppr/y2001/pres/114235.pdf.

11 S Harris and B Naughton, 'Economic dimensions of energy security in the Asia Pacific', in M Wesley (ed.), *Energy security in Asia*, Routledge, London, 2007, p. 180.

12 Cuts in gas supplies during particularly cold weather are apparently intended to constrain the Western-leaning inclinations of the states that form Russia's strategic approaches—Georgia, Ukraine and Belarus. At other times, Russian actions have been directed towards European Union states (especially Poland and Germany) in response to developments in Western Europe that Russia judges to be inimical to its interests.

13 A Kennedy, 'China's new energy-security debate', *Survival*, 2010, 52:3:137–158.

14 *Remarks by National Security Advisor Steve Hadley to the National Bureau of Asian Research Strategic Asia Forum*, Washington, 5 April 2006, available from: http://georgewbush-whitehouse.archives.gov/news/releases/2006/04/20060405-11.html.

15 US Department of Energy, *National security review of international energy requirements*, February 2006, available from: http://www.pi.energy.gov/documents/EPACT1837FINAL.pdf.

16 See also Mark Thomson, *The human tide: an Australian perspective on demographics and security*, ASPI, June 2009, available from: http://www.aspi.org.au/publications/publication_details.aspx?ContentID=218.

17 The wind figure is from http://www.inference.phy.cam.ac.uk/withouthotair/c4/page_32.shtml

Solar panels can produce power at higher levels but only during daylight hours, and the instantaneous power generated varies with factors such as time of the year and day and latitude. The figure 20–40 W/m^2 is a steady-state average for temperate latitudes and assumes 20% efficient solar panels.

18 The calculations in this section were suggested by the work of Professor DJC MacKay of Cambridge University.

19 The figure of 40 W/m^2 was calculated from first principles, starting with NASA's insolation data for Australia, as summarised at: http://www.apricus.com/html/insolation_levels_asiap.htm As an example, Melbourne has an average insolation (over the year) of 4.34 $kW.hr/m^2/day$, or an average energy flux of 181 W/m^2. (The peak value is close to 900 W/m^2 in the middle of the day in January.) The theoretical maximum efficiency for silicon-based photo-voltaic cells is 20%, which gives 36 W/m^2 as the average output of such a panel in Melbourne. Cities nearer the equator do a little better. For example, the figure for Brisbane is 44 W/m^2. Weighting the average outputs by population size, the Australian average is a touch under 40 W/m^2. This corresponds to an annual energy output of 350 $kW.hr/m^2$. This number is between 50% and 100% *greater* than current domestic installations achieve (depending on location), as estimated using the Office of the Renewable Energy Regulator's calculator at www.orer.gov.au It is therefore a conservative estimate that allows for greater future efficiency.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20 The total area of wheat under cultivation in Australia is approximately 10 million hectares, or 100,000 km^2. See http://www.environment.gov.au/soe/2001/publications/theme-reports/atmosphere/atmosphere02-15.html.

21 This corresponds to a price per peak Watt of around $3.20/$m^2$. Again, this number is better than current domestic installations achieve (typically $4–6), but should be within the reach of future systems. The estimate of total cost for a large-scale installation in the following paragraph assumes a price that is half of that per unit area—i.e. around $1.60 per peak Watt/$m^2$.

22 M. Nicholson, T. Biegler and B. Brook, 'How carbon pricing changes the relative competitiveness of low-carbon baseload generating technologies', *Energy*, Vol 36, pp 305–313, January 2011 . Available at http://www.sciencedirect.com/science/article/pii/S036054421000602X

23 D Mitchell, *A note on rising food prices*, policy working paper 4682, World Bank, July 2008, available from: http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2008/07/28/000020439_20080728103002/Rendered/PDF/WP4682.pdf.

24 See the discussion and historical data at http://eco-efficiency-action-project.com/tag/united-states/.

Important disclaimer

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