Meeting energy demand in the post-peak world? The blind spot in The Millennium Project's Challenge 13: A response to the *2009 State of the Future Report*

Joshua Floyd
Strategic Foresight Practitioner
Melbourne, Australia
Steering Committee Member, Australasian Node of the Millennium Project

This is an updated version of a submission made to the Millennium Project's 2010 State of the Future Report, in my capacity as steering committee member for the Australasian Node. The submission responds to the 2009 report's Challenge 13—How can growing energy demands be met safely and efficiently? Information about the 2009 report is available at http://www.millennium-project.org/millennium/sof2009.html#print (the 2009 text for Challenge 13 is no longer available on the Millennium Project website, as this is updated annually).

In the opening paragraph of the 2009 State of the Future summary report on energy, we learn that "World energy demand could nearly double by 2030" and that "Without major policy and technological changes, fossil fuels will meet 80% of primary energy demand."

In the context of this opening, and recognising that the State of the Future Report represents the "cumulative and distilled views from over 2,700 participants" I was particularly struck by the shift between 2008 and 2009 in how the Millennium Project understands the relationship between global human activity and the geophysical limits of fossil fuels. In the 2008 report, we see cursory acknowledgement of both the finitude and current state of exploitation of these remarkable resources—"Some argue that oil production is peaking and will end in 40-70 years"—immediately alongside the International Energy Agency's (IEA) blithe cornucopianism of 40% growth in demand for oil between 2006 and 2030. By 2009, reference to the depletion of fossil fuel resources, let alone the implications of this for the viability of a global industrial civilization, has disappeared altogether from the summary report. In fact, were I not to dig deeper into the detailed material on the accompanying CD, it would be reasonable for me to conclude that in the Millennium Project's view the issue of peaks in production of oil and indeed all non-renewable primary energy resources is irrelevant to addressing its 15 Global Challenges.

What seems to be going on here? I grappled with this question for some time before realising the thoroughness with which my own assumptions about how best to make sense of the human situation and its future prospects in terms of energy transformations had limited my appreciation of the Millennium Project's thinking on these matters. Considering the summary report more closely, the nature and implications of the worldview within which energy is discussed became much clearer. The framing of the question for Challenge 13 provides significant insight into the nature of this worldview, but perhaps more importantly, illustrates how comprehensively such framing can influence what is seen. This more general insight has important implications not just for the State of the Future Report's examination of energy issues, but for all of the 15 Global Challenges.

The framing issue may at first appear subtle, but its implications are far less so. I'll try to make clear here my understanding of what seems to be happening. By asking "*How* can growing energy demands be met safely and efficiently?" the consideration of global energy futures is decoupled from the more fundamental question of *whether* growing demands between now and 2030 *can* be met. To leap immediately to examining *how* this might occur "safely and efficiently" is to reduce the discussion of global energy futures to a merely technical question. Doing so submerges from view the broader historical, social, economic, financial, environmental, geophysical, thermodynamic and above all *epistemological* contexts within which technical considerations must be made. It should be of little surprise then that the summary report amounts to a list of emerging and anticipated technologies for enabling energy conversions deemed by the report's contributors to be necessary, in ways other than through the exploitation of fossil fuel resources. This seems to set the boundary on how "safe and efficient" is understood by the authors. How the nature of the growing demand itself and its relationship with primary energy sources and energy conversion technologies is understood is not clear. Given that our industrial civilization has arisen in the context of cheap, abundant fossil fuels, how it is that a system of global living arrangements of such scale and complexity might fare as these energy resources are depleted would seem to be a matter of some significant concern. It seems reasonable to me that a summary of the nature presented in the State of the Future Report would at least acknowledge this situation.

At this point, some deeper examination of this relationship between energy demand and supply may help to illustrate the consequences of making the technical question—the *how* question—prime in discussing Challenge 13. This will establish important foundations for then thinking about a pervasive and foundational cultural myth that appears to influence much discourse relating to the energetics of civilization. There is much to be gained by considering the linked metaphors of *supply* and *demand* in light of our very human propensity for constructing the situations that interest us in terms of such dualisms. There seems to be a very natural tendency, once such a binary characterisation is established, for our thinking to be shaped in turn by the construct itself. Hence we have a situation where energy supply and energy demand become separate areas of technical speciality, each frequently regarded as enclaves to be understood, overseen and administered by their own cohorts of expert caretakers. As such, questions of demand and supply are very often treated as relatively independent matters. The task is to understand demand—from a futures perspective, typically via socio-economic forecasting of a technical nature—with this in turn forming the basis for supply planning that focuses on presently available and emerging technologies. For the most part, the relationship between energy and society is reduced to questions of how taken-for-granted expectations of human activity will be met through the techno-economic exploitation of a circumscribed set of naturally occurring resources. This typically leaves aside considerations of the ways that expectations are constructed by us—humanity acting together—in the context of historically and geophysically contingent existential circumstances. Appreciation for what energy in fact *is*—a system of conceptual constructs for making sense of regularities in the ways that situations are observed to change—or of *energetics*—the study of such regularities—is so far from most minds as to seem an esoteric irrelevance (perhaps test this in terms of your own immediate response to what you are reading right now).

Alternative framings that give rise to very different understandings of energy and society are readily available. Consider the implications of starting with a view of reality organised in terms of integrated wholes, the boundaries of which are a matter of human perspective-taking—that is, where situations in which we are interested are organised conceptually along lines that are best characterised as *systemic*. With such a framing, the supply-demand duality is subsumed within an integrated system of human “socio-energetics”. In this view, “energy supply” and “energy demand” are simply conceptual tools for making sense of human activity as it arises in our field of perception here and now, and as we reflect on the past history of such activity and anticipate its future unfolding. Moreover, supply and demand can be seen as arising together, each setting the context within which the other is understood. Expectations of energy use emerge in the context of the particular energy sources and supply regimes available to us, while the sources that we exploit and the means employed for this are shaped by the expectations that we hold.

In light of this way of thinking, the concept of demand takes on a very particular character that is often misunderstood. It is not simply a matter of “what people want”, a product of collective wishful thinking. It is better understood as the aggregate energy required to run that portion of the installed base of powered devices that we deem necessary to provide us with work, lighting and heating at any given time. The reference here to the installed device base is crucial to the understanding that I’m hoping to foster. The *nature* of this installed base—the designs of the machines, vehicles, lighting systems and heating equipment upon which contemporary human civilization depends for enabling the activity that we desire—directly reflects the particular forms of energy available to us—especially electrical energy and chemical energy via fuels—and the primary sources of that energy and the infrastructure for transforming it to end-use energy. It also reflects the way that infrastructure is distributed across the different energy forms available to us. The *scale* of the installed base directly reflects past investments that we have made both in infrastructure to power the installed device base, and to produce the installed base itself: our civilizational infrastructure *embodies* vast expenditure of previously-but-no-longer available energy. This hopefully highlights a crucial point: expansion of the installed base—and hence growth in *demand*—is itself dependent on the use of energy, energy that must be provided by *current* sources. There is an absolutely critical insight to take from this. The primary sources upon which *industrial* civilization has depended for the growth of its entire energy supply infrastructure *and* for the installed base of devices that use this energy were from the outset, and continue to be today, fossil fuels. It is cheap, abundant fossil fuels, characterised especially by their high energy density and high energy return on the energy invested in making them available, that provide the energetic context within which industrial civilization has arisen and expanded outwards to encompass most of the globe. In light of this, it is particularly important to understand that, apart from traditional bio-fuels, the use of which continues at significant levels today only in less-industrialised parts of the world, all significant non-fossil energy sources in commercial use and under development today—in other words, nuclear and modern renewables—have arisen in the context of existing fossil-fuelled energy infrastructure. In other words, all non-fossil energy converters receive a general subsidy from fossil fuels. Today, more than 80% of global primary energy supply continues to come from oil, coal and gas: all other industrial energy sources owe their existence to a global system of social, technological and economic arrangements underpinned by this remarkable geophysical windfall.[1]

It is in this context that we must consider the viability of all non-fossil energy sources. In assessing such viability, it is generally well recognised that any end-use energy supply system capable of contributing to what might be considered as a “sustainable energy supply” must provide sufficiently more energy over its operating life than is required to make it available in the first place and maintain and operate it over its life. It is this that is under consideration when we talk about energy return on energy invested or EROI. It is far less well appreciated that conducting this analysis in terms of direct energy use for provision of materials and manufacturing alone is not sufficient: we must also consider the sources of that energy and the means by which it is made available in forms useful to us. Why is this the case? Surely, “energy is energy”. Well, not so. And this is where popular—and in fact, many apparently specialist—understandings of energetics tend to depart from the understandings of those with a more fundamental grounding in thermodynamics, particularly as it applies to the satisfaction of human needs and desires—that is, in an engineering context. Energy resources are unlike other resources in that it is not just the *quantity* of energy available to us that is important, but the proportion of whatever quantity we have that can be made available to us in a useful form. At all stages of the chain of conversions from primary source to end-use, energy must be expended to make *useful* energy available to us. The proportion of energy in the primary source that can be made available depends on a whole raft of considerations. Looking at these comprehensively is well beyond the scope of the present discussion.[2] As a very

---

[1] In fact this situation extends beyond renewable energy and nuclear to include the “minor” fossil fuels, coal and natural gas, themselves. Each of these primary energy sources is similarly dependent for its large scale exploitation on the subsidy that it receives from oil. Crude oil is the raw material for fuel critical to the mining and transport of these resources, and the maintenance of the supply infrastructure. Open cut mining of lignite in the Latrobe Valley (Victoria, Australia) provides an interesting illustration of just how important this is. While the coal is mined using massive bucket dredges powered by electricity from the power stations that they feed, these dredges are entirely reliant for viable operation on comparatively tiny (although the largest available) diesel-fuelled bulldozers that facilitate their movement across the floor of the open cut. Continuous movement of the conveyor belt system for transporting coal to the power stations is also reliant on diesel-fuelled vehicles, as are all maintenance activities and personnel transport (to observe this, one needs only to view the power station workers’ carpark). The open cuts are also subject to fires, as lignite spontaneously combust on exposure to air at sufficiently high ambient temperatures. Diesel-fuelled vehicles are essential for management of these fires and hence for viability of the mining operation.

[2] One additional layer of complexity here that does bear mentioning is that to replace fossil fuels as they are currently used, renewable energy technologies would not only need to have a similar EROI to fossil fuels *under life cycle circumstances in which the invested energy is provided by those same renewable energy technologies*; they would also need to provide that energy return at a similar *rate* to that available from fossil sources. This is often neglected in discussion of EROI from renewable sources such as thin-film photovoltaics, which promise much higher life cycle EROI than renewable energy technologies currently in use (see for instance this story by Bardi, U 2010, ‘Renewables out of the bottle’, The Oil Drum, http://europe.theoildrum.com/node/5573?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+theoildrum+%28The+Oil+Drum%29&utm_content=Google+International, viewed 23 April 2010). The high EROI for renewable energy conversion technologies is typically calculated over life cycles of multiple decades. Therefore, in order to replace the energy supply *rate* of fossil fuels, it is the installed capacity of the renewable energy conversion technology that is important. To achieve this, the installed base—and hence the energy investment upfront—needs to be many times greater than it would be if EROI was the only relevant consideration. This requires suitable production scales and material resource availability, as well as sufficient enabling and connecting infrastructure. The key

general rule of thumb though, the higher the energy density of a source—the higher the concentration of stored energy per unit volume of source material as it occurs naturally—the greater the proportion of the stored energy that can be made available to us in useful form and the greater the EROI. Again in general terms, this is because the scale of the infrastructure required to make the energy stored in the naturally occurring source available to us in some useful form is relatively lower for more concentrated energy sources than it is for less concentrated energy sources. All energy conversions involve the dispersal of energy from where it is more concentrated to where it is more spread out. Consequentially, the higher the initial concentration, the less energy (and other resources) that must be invested in supply and conversion infrastructure in order to provide a given end service. Bear in mind with all of this the emphasis that I place on naturally occurring energy sources: it is the concentration of energy in these original sources that is most important, not the concentration of energy in fuels that have already undergone some series of processing steps: all such steps depend on infrastructure that has associated capital and operating resource costs.

What consequences does this entail for assessing new energy sources and conversion technologies? Perhaps most importantly, it means that it is not acceptable to place the sources of the energy that are used to provide any technology outside the system boundaries for the assessment. For instance, photovoltaic panels, wind turbines and nuclear power plants, to the extent that they are demonstrated in practice to provide positive EROI, do so in the context of a global industrial system that runs on oil, and to a lesser extent, coal and natural gas. Transport activity is almost exclusively fuelled by oil. To the extent that these technologies rely upon a globally—or even regionally—integrated transport infrastructure, they rely not just on a certain number of joules of energy, but on a certain number of joules of energy sourced from crude oil. Any practical experience of an alternative energy source's viability on the basis of a sufficiently positive EROI cannot simply be translated to contexts in which crude oil is less abundant. Changes to the structure of our primary energy sources flow through the whole system and hence the real life-cycle energy use for any particular situation changes. Assessment of the viability of alternative energy sources and technologies in a world in which the fossil fuel subsidy is *not* available on the scale that it is at present—for reasons either of geology or politics—must be made on a theoretical and hence a speculative basis. We do not have any historical basis for assuming that an industrial civilization of the scale and complexity that we live with today could be viable in the absence of today's fossil fuel subsidy. In the absence of an equivalent energy source with the remarkable properties of crude oil[3], we can however assume that the resource requirements for maintaining our current global economic activity, let alone increasing its scale, would increase. Certainly, there is great potential for efficiency improvements to allow for the same activity with lower energy and other resource use, but for a given activity provided in a given way, substituting energy sources of lower density than oil or without oil's ease of material handling requires more infrastructure and more enabling activity.

---

point: in addition to EROI, we also need to look at *power return on energy invested*, when thinking about a transition from fossil-fuelled industrial civilization to civilizational forms using alternate energy sources and conversion technologies.

[3] It is also worth noting that these "remarkable properties" are themselves highly variable—the composition of crude oil changes geospatially, as does the circumstances of its occurrence (deep water versus desert landscapes, for instance). This is worth bearing in mind when considering the way that crude oil's fungibility is conventionally viewed.

Discoveries of new oil fields peaked decades ago and new discoveries lag far behind net global production—that is, we are using oil much faster than we are finding new oil (Homer-Dixon 2007). The EROI for petroleum based fuels in the U.S. has decreased since the 1930s from something in the order of 100:1 down to around 17:1 today (Cleveland 2005 cited in; Homer-Dixon 2007). In light of this and the detailed discussion I've presented of why it matters so much, accepting without more critical consideration the IEA's projection of nearly doubling global energy demand by 2030 restricts the value of the assessment presented in the State of the Future Report to a very narrow range of possible futures indeed.

In the spirit of trying to better understand why such restriction perhaps makes sense within the worldview with which the Millennium Project's assessment arises, I'd like to return to discussion of what I described earlier as a pervasive and foundational cultural myth relating to energetics. The primacy given to the technical question of how growing demand can be met safely and efficiently reflects in important respects what Greer (2008) describes as the *myth of progress*. Within this myth, our present high energy civilization is seen as an inevitable *consequence* of the forward march of human ingenuity. An entailment of this way of understanding the pathways by which we arrived in our current situation is that further progress is primarily a matter of further growth in ingenuity. If we are faced with the limits of our current energy sources, the default assumption becomes one in which those limits will inevitably be transcended by innovations in energy conversion systems. Living within this myth, it is essentially *unthinkable* that our present era of energy abundance might be an historical anomaly and that the energy available to us—along with the industrial civilization that it makes possible—might be headed towards decline. We see this reflected in much conventional economic thinking, in which technological innovation driven by price signals is often regarded as the primary determinant of resource limits: if a resource becomes scarce, the price goes up, and this drives innovation leading to the expansion of the resource base. While for any natural resource this is at best a simplistic view of socio-ecological relations, its failure to serve us well is perhaps most comprehensive in relation to energy resources. The reason for this is closely bound up with the apparently unproblematic use of the very terminology that I've adopted in the last sentence, namely "energy resources". When we reduce our description of a resource to its stored energy alone, we characterise it in the most general way available to us. In talking about oil resources or wind resources as *energy resources*, we abstract from its background context the very most general characteristic of the resource and leave its particular characteristics out of the picture. In doing so, we diminish our ability to recognise the critically important differences between energy sources. As discussed above, these broader contextual characteristics are just as important for understanding the value of these resources as is the quantity of energy that they store, or the rate at which they potentially make energy available to us. This masks the consequences, for instance the capital, maintenance, operating and environmental implications, of accessing energy from one particular source in place of another. It is these consequences that prevent us from simply substituting one energy source for another one of different origin. At the level of abstract economic theory, though, this is all hidden from view: from such an abstract perspective, the history of the past couple of hundred years of civilization can be depicted as a series of evolutionary successions in dominant primary energy sources, enabled by innovation in conversion technologies. If such a view is taken as an inalienable article of faith, and if this past history is taken as *the* model for future change, then it might seem reasonable to proceed on the assumption that as the oil era heads to decline, there must surely be a replacement energy source and conversion technology just over the horizon, waiting only for progress in human innovation to bring it to view.

There's little reason though to privilege this view of history—and futures—over a view in which fortuitous circumstances enabled exploitation of oil as a primary energy source, creating the conditions for global industrial civilization, which in turn provided the circumstances within which increased human endeavour could be directed towards technological development including that necessary for further exploitation of energy resources. The growth in availability of high-density energy, while partly a consequence of that technological development, is for the most part underpinned by the geological occurrence of oil—once an oil field is opened up to production, the marginal cost (in financial and energy terms) of increasing the rate of production initially reduces. A positive feedback effect means that a little initial oil makes more and more oil available. It is the characteristics of oil and the way that it occurs naturally that carries the bulk of the load here though, rather than expanding ingenuity on our part (which is not to deny the significant growth in our instrumental technical know-how and praxis that has accompanied the age of oil). In this view, global industrial civilization is a particular historical phase that is contingent upon the availability of cheap, abundant oil. In the absence—or more realistically, the declining abundance—of this natural subsidy, there is little basis for expecting the current system of global living arrangements to continue with a simple transition to some replacement energy source. This need not mean the loss of everything that is important to us—while oil continues to be available, and on a decadal timeframe at least, there is significant scope for maintaining an acceptable quality of life for a large global population. Smil (2003) presents a wide range of data demonstrating the non-linear relationships between measures of societal wellbeing and energy use. For instance, Japan is rated at essentially the same level as the USA on the human development index while using almost half of the energy per capita of population (Smil 2003, p.102).

Does all of this mean that I would discount altogether the value of the assessment of Challenge 13 presented in the State of the Future Report? Not at all. The transition away from the vast wealth, abundance, comfort and security afforded for a brief historical period by our oil windfall is unlikely to be particularly pleasant by comparison. Having in place as early as possible during such a transition period renewable energy infrastructure that is as large in scale and diverse as we can achieve will help to offset that unpleasantness. This will depend on appropriate investment of our remaining high-density energy resources in general, and oil in particular. As a summary of the opportunities available to us for such investment the State of the Future assessment is certainly useful. Its value would be further enhanced by more critical consideration of the broader circumstances within which those technological opportunities might be pursued.

References

Cleveland, C 2005, 'Net energy from the extraction of oil and gas in the United States', *Energy*, vol. 30, no. 5, April, pp. 769-82.

Greer, J M 2008, *The long descent: A user's guide to the end of the industrial age,* New Society Publishers, Gabriola Island, Canada.
Homer-Dixon, T 2007, *The upside of down: Catastrophy, creativity, and the renewal of civilization,* Text Publishing, Melbourne.
Smil, V 2003, *Energy at the crossroads: Global perspectives and uncertainties,* The MIT Press, Cambridge, Massachusetts.