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MAKING THE WORLD WORK

This is embarrassing. Many years ago I wrote a book called *Energy and Purpose*. 'Purpose' meant 'what we humans want from energy, and how we try to get it'. A reputable publisher gave me a modest advance. I worked on the book for two years, eventually accumulating about 100,000 words of text. But the longer I worked on it the less I liked it. I finally had to confess to myself that I didn't know what I was talking about. I didn't understand enough about energy and purpose to say anything really useful or persuasive. I gave the publisher back the advance, piled the typescript in a cardboard box and stashed it in the archive, along with the unpublished novel, the unpublished textbook and the unproduced musical.

In the coming pages I am returning to the scene of my failure so long ago, to write again about energy and purpose – what we humans want from energy, whether we can get it and, if so, how. I have an alarming sense of déjà vu, knowing I have been here before, and wondering whether I can do any better this time. Wish me luck.

Why write about energy and purpose? The short answer is that we're making a mess of it. The world isn't working well enough. More than two billion people, one-third of humanity, have no access to the kinds of energy benefits the rest of us take for granted; and the proportion of 'energy have-nots' is increasing, not decreasing. Worse still, the key fuels and energy technologies of the 'energy haves', like us – fossil fuels, large dams, nuclear power – all face problems that look insuperable. Worst of all, doing what we do with energy is disrupting the climate of our only planet. If that doesn't worry you, it should.

What do *you* want from energy? You probably never thought about it. That's as it should be. Almost everything you get from energy you

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get without even noticing. It doesn't involve a meter; you don't get billed for it. You get surroundings whose temperature mostly stays within limits your body can tolerate. You get sunlight processed by green plants, which store up the solar energy in a form you can eventually eat, for your muscles to use. As a by-product from the green plants you get the oxygen you breathe to process the food; and so on. You are immersed in, indeed you are a part of, natural energy systems of astonishing complexity and variety; and you take them all for granted.

You are also, however, immersed in energy processes that you yourself, and other people, initiate and control – what we can call human energy systems. Some you take for granted as completely as you take natural energy systems for granted. You probably can't remember the last time you turned on a light. Some human energy systems you notice, at least some of the time, particularly when they fail. When you turn the key in the ignition, or flip the light switch, and nothing happens, you notice. You also notice when you get a bill. That may be part of the problem. In the past three decades we have come to think of energy as something you get a bill for. That must change.

Using energy

Start with this word 'energy'. When you think of energy, you probably think of oil, coal, natural gas, electricity. You shouldn't. The language we now use to talk about energy is not just wrong – it's actively misleading. If we can't even describe the issues and options correctly we'll never get the policy right. How many times have you heard or read some energy specialist refer to 'energy production' or 'energy consumption'? These people are supposed to be experts. Surely they ought to know one unbreakable law, the First Law of Thermodynamics, the law of conservation of energy. *No one* produces energy. *No one* consumes energy. The amount of energy in *the whole universe* remains the same. That's what makes energy such a valuable and important concept to understand how the world works. We don't have to conserve energy. Nature does it for us.

Why, then, do we talk this way? The answer is simple. When we talk about energy production, energy consumption and energy conservation, we don't mean 'energy'. We mean 'energy carriers' – that is, fuels and electricity. The confusion dates back less than 40 years. Until the

early 1970s governments had 'fuel policy'. They had Ministries of Fuel, or perhaps of Fuel and Power – 'power' meaning electricity. Then, in October 1973, the Organization of Petroleum Exporting Countries (OPEC) suddenly quadrupled the world price of oil, plunging the world into a panic. Governments everywhere launched a frenzied search for a 'substitute' for oil. Within weeks all the different fuels, plus electricity, were swept together and called 'energy', as if they were all potential substitutes for one another, all more or less interchangeable. 'Fuel policy' became 'energy policy'. Governments exhorted their citizens to 'conserve energy'. Ministries of Fuel became Departments of Energy. Oil companies, coal companies, gas companies and electricity companies all became 'energy companies'. In the UK the Institute of Fuel became the Institute of Energy; much the same happened all over the world.

But of course everyone knows that specialists talking about 'energy' really mean 'energy carriers' – oil, coal, natural gas, electricity. Lumping them all together and calling them 'energy' is just a convenient shorthand. Does this quirk of language really matter? Yes, it does. It distorts our understanding of what we are actually doing with energy; that is, 'energy', not 'fuels and electricity'. Worse still, this misleading language obscures crucial options we now have, ways for us to use energy much better.

Note that phrase, 'using' energy. That's what we do with energy. We don't consume it, we use it. Humans have been using energy on purpose since long before the beginning of recorded history. Our human ancestors began using energy by intervening intentionally in natural energy flows, or what we can call 'ambient energy' – energy that is there for us to use, with no meter and no bills to pay. The first 'energy technologies' that our human ancestors hit upon were clothing and shelter. In cold weather, clothing reduces the loss of heat energy from your body; in hot weather, it protects you from too much solar energy. Shelter provides an enclosed space, reducing energy flows and keeping the temperature inside more stable than that outside; inside the shelter you are more comfortable. You may not usually think of clothing and shelter as energy technologies. But if you really want to understand how we humans use energy, clothing and shelter are fundamental. Note, too, that clothing and shelter are physical materials. You don't measure or pay for the energy flows involved. The clothing and the shelter manage the energy flows for you.

Humans were probably manipulating ambient energy in these basic but fundamental ways long before they learned to control fire and use fuel. Fire and the fuel to feed it opened many new possibilities. Nevertheless, intervening in ambient energy remained an important aspect of using energy on purpose. In many parts of the world, for instance, humans developed increasingly subtle and ingenious ways to design the energy technologies we call buildings. They selected materials and erected structures to use the ambient energy of sunlight, of moving air and human bodies to deliver comfort, light and ventilation. They also developed technologies including sails, windmills and watermills, to use the ambient energy of wind and water for human purposes.

Ambient energy is all around us, whether or not we explicitly want to use it. Fuel, by contrast, is a material containing energy that we can release on purpose, when and where we want to use it. The word 'fuel' comes from old French 'fowaille', which comes in turn from low Latin 'focale' and Latin 'focus', meaning 'fireplace'. Etymologically, a fuel is 'material for a fireplace'. Historically, a fuel is a material you can burn, to release its stored energy as heat. This creates a local high temperature, in which you can cook food, fire ceramics and smelt metals. But the real potential of fuel only emerged less than three centuries ago, with the invention of the steam engine.

The steam engine could convert the heat energy from a burning fuel into mechanical energy – a source of controlled force and motion much more powerful than human or animal muscles, and more predictable than wind or water. The steam engine tipped the balance. Since the advent of the steam engine, giving us this potent additional way to use fuel energy, we have gradually forgotten about using ambient energy. Instead we have concentrated our attention on fuel energy – usable energy stored in a form that can be stockpiled, transported, and released in concentrated form, when and where we want to use it.

Note one important corollary. Fuel energy is comparatively easy to measure and quantify – so many tons of firewood or coal, barrels of oil, cubic metres of natural gas. Because it can be stored, it can be possessed – someone can take title to it and own it. It can therefore be bought and sold. Nobody can buy or sell ambient energy, because nobody owns it – not yet, at any rate. Keep the distinction between ambient energy and fuel energy in mind. It's important.

Energy technologies

The steam engine, and all the numberless energy technologies that have come after it, also demonstrate another key point. At its simplest, fuel energy can be released directly from the fuel and used as it comes – say from a bonfire. However, precisely because it is being released intentionally, for a human purpose, fuel energy is usually released in the context of some sort of physical hardware, an energy technology designed to control and direct the conversion of the fuel energy.

For example, my wife and I have a little house on a remote hillside on a Greek island we've been visiting since the 1960s. The house is heavily insulated, roof, walls, windows and floor, in order to take maximum advantage of the ambient energy, whatever the temperature outside, to keep us cool in summer and warm in winter. In northern Greece, however, winters can be cold. Rather than lighting a bonfire on the kitchen floor we have a black potbellied stove. It is essentially a metal canister with a lid, a small front door into which we put the fuel, and a pipe to channel the smoke of the fire out the back of the house. We burn dead heather branches from the hillside, scrap planks from the builders, cardboard packaging, essentially anything combustible. It converts the energy from the fuel into radiant heat energy that saturates the structural material of the house. If it's cold outside, a short burst of heat from the stove fine-tunes the temperature inside, and keeps us cosy for hours. Of course a lot of the heat from the stove escapes out of the chimney, and the emissions would probably get us into trouble in London. As an energy technology our potbellied stove could scarcely be more basic. But we have fallen in love with it.

Our potbellied stove, however, illustrates another significant aspect of human energy use. Precisely because the stove is such basic energy technology, it can use the most basic fuel – whatever we can lay our hands on to burn. The only processing the fuel requires is to break or cut it into pieces small enough to put in the stove. Although we bought and paid for the energy technologies we use, the house itself, and the stove in the kitchen, we don't have to buy the fuel. We can gather and cut it up ourselves. It costs us our own time and effort, but doesn't take any expertise.

In that respect, our stove is no longer a typical energy technology, at least in the richer parts of the world. Over the past three centuries, the interaction between fuels and energy technologies has become ever

more specialized. A particular technology requires a particular fuel, and vice versa. The specifications of both the technology and the fuel have become steadily more stringent. Your car engine probably demands not petroleum, not even plain 'petrol', but unleaded premium petrol. A cooker designed for natural gas will not work safely on bottled propane; and so on.

That's the main reason why looking for a 'substitute for oil' in the 1970s was misconceived. You can't change the fuel without changing the energy technology that uses it. Preparing, delivering and supplying fuels appropriate for their corresponding energy technologies now requires not only high levels of expertise, but elaborate organization of all the necessary skills and competences, with all that that implies. You can't collect the fuel on a hillside. Just as you buy and pay for the energy technology, you also have to buy and pay for the fuel. The companies you buy the fuel from used to be similarly specialized – oil companies, coal companies, gas companies. That, however, is now changing rapidly. Companies that used to be oil companies or gas companies are now both. Companies that used to supply gas or electricity now supply both. Companies that were local or regional are now national and international. Companies that used to deliver gas through pipes and electricity through wires now own and operate both networks, often together, often across national borders. They now call themselves 'energy companies'. But their business is still mainly just fuels and electricity, which they must nevertheless manage distinctly and differently, however much they interact. If and when they become true energy companies, that will be another story, to which we shall return.

Energy systems

Within the past century, the human use of energy in much of the world has come to depend not merely on separate individual fuels and technologies, but on entire intricate human energy systems, complex and interconnected. To fulfil our many purposes these human energy systems use a combination of ambient energy and fuel energy not merely in individual energy technologies but in a vast human energy infrastructure. Enormous aggregations of buildings are expanding into megacities. The buildings are filled with other energy technologies, and linked by roads, pipes, cables and other interacting connections, extend-

ing human energy processes not only across entire continents but even bridging the oceans.

As well as natural energy systems, we now have a human energy infrastructure that also covers the planet. Much of this human energy infrastructure – buildings, appliances and other equipment – delivers the energy services we all want, such as comfort, cooked food, illumination, motive power, refrigeration, information and communication. However, a substantial part of this infrastructure – oilfields, pipelines, power stations and so on – is now devoted to collecting, preparing and delivering fuel energy to run the rest of the infrastructure. Making substantial changes to the delivery infrastructure can take as long as making substantial changes to the energy-service infrastructure, and cost at least as much.

Among the specialized and complex energy systems we have created, perhaps the most specialized are those that function with an energy carrier quite different from fuel: electricity. No matter what you hear from politicians and others, electricity is not a fuel. A fuel is a physical substance. You can store it until you want to use it or sell it. Electricity is not a physical substance. It is a physical process, happening simultaneously throughout an entire interconnected system. It has to be generated more or less exactly as it is being used. Fuels and electricity also differ in another fundamental way. A fuel such as natural gas comes out of a hole in the ground at a particular place. If you want to use it somewhere else you have to carry it there. Electricity, by contrast, you can generate anywhere. Just ask the person with the hissing headphones sitting next to you on the bus.

But electricity by itself is useless. Electricity just carries energy; the energy has to be converted into a useful form by an energy technology such as a lamp, a motor or a computer. When it is being used, the energy technology involved – lamp, motor, computer – becomes a functioning part of the electricity system. The whole system is part of the human energy infrastructure, operating continuously in real time. You can keep a stack of wood, a pile of coal, a tank of oil or even a canister of compressed natural gas on site, ready to use when you wish. But if you want to use electricity, the whole system has to be operating with you, in real time.

In that respect, oddly enough, using electricity has a lot in common with using ambient energy, and the link is going to get steadily closer. Like electricity, ambient energy is delivered continuously. To use

ambient energy on purpose, you need physical assets – a building, a water turbine, a wind turbine, a photovoltaic panel – that is, physical infrastructure. For some purposes – such as comfort, probably the single most important human purpose for using energy – if you make the physical infrastructure good enough, ambient energy may well suffice, with no resort to fuel energy. In much of the world, however, we have accumulated a built infrastructure whose performance with ambient energy all too often seems wilfully poor, making fuel energy essential if we are to get the comfort we want.

When I first arrived in the UK from Winnipeg in Canada more than four decades ago, I could not believe the buildings in the UK. The heat inside barely slowed down before it escaped outdoors. We also settle for poor performance from the energy technologies inside and around the buildings. When first in London I lived in a bedsitter in Bayswater. The bath was in a sort of greenhouse over the front door. The boiler was in the basement. The hot water pipe from the boiler ran up the exterior wall. Not only was it not lagged, it was painted black, the best colour for radiators. The water running into the tub was barely tepid. The arrangement was so futile they need not have bothered.

That may sound like an extreme example, but it's not. Countless reports and analyses have underlined the inadequate performance of lighting, motive power and other energy technologies in many parts of the world, and deplored the missed opportunities for so-called 'energy efficiency'. Many reasons have been suggested. Meticulous and detailed lists of 'barriers to energy efficiency' have been pouring out since the 1970s, and they are all true. But the single underlying reason why our human energy infrastructure does not perform better is that most of us can't be bothered. We have other things to think about. If we are ever going to make the sweeping improvements in human energy use long since readily available, if we are ever going to make the world work better, someone has to want to do it. We have to find ways to make those who can do it want to do it.

Energy and money

What about costs? Energy itself costs nothing. However, if you want to use ambient energy you have to design and fabricate the technology to do so. If you want to use fuel energy you have to produce and process

the fuel, and deliver it to where it is to be used; and you have to design and fabricate the technology to use the fuel. Once you get beyond the mud hut and the bonfire, all these activities become variously part of a financial economy, carried out in transactions mediated by money. The skills, competences, responsibilities and risks involved have been divided up and apportioned out in ways that once appeared to make sense, but now look profoundly unsatisfactory, because of what they have done to human energy infrastructure.

Consider, for instance, the two parts of this infrastructure. One part delivers the energy services we want. The other part delivers the fuels and electricity to run the first part. Both parts represent investments in physical assets. Because the fuels and electricity are to be sold by the unit to users, governments generally treat investment in all of this part of the infrastructure favourably for tax purposes, as business investment. If a company invests, say, in a new power station to sell electricity, the government allows it to claim tax relief. If, however, we all invest, say, in more efficient refrigerators, to make the new power station unnecessary, we get no tax relief on our investments. This one single anomaly, replicated across all the energy infrastructure, skews the pattern severely in favour of more investment to deliver fuels and electricity, and less investment to deliver better energy services. Traditional tax regimes encourage investment in infrastructure that makes money, rather than in infrastructure that delivers the energy services we citizens want.

Using ambient energy does not make money – not at the moment. But fuel energy can be stored and sold, by the unit. What costs money is not the energy, but storing it, carrying it to where it is to be used and converting it. We use fuels and electricity to have energy available where, when and in what form we want; and we pay for the privilege. Policy people call this 'commercial energy', as if paying for it in some form of 'market' makes it better. Commentators scrutinize the prices of fuels and electricity, and analyse their movements minutely. However, in our modern interconnected society the prices of fuels and electricity by the unit have long been essentially artificial, shaped by preferential tax regimes, subsidies and cross-subsidies, cartels and outright monopolies, as in the case of electricity networks. With this in mind the highly respected chairman of Ireland's Electricity Supply Board, Patrick Moriarty, once remarked succinctly, 'The price of electricity is what the government wants it to be.' What with taxation, subsidies and other

interventions, much the same can be said of fuels. Except for short-term advantage, unit price is not a good enough criterion.

'Sustainable energy'?

If we were stuck with these traditional arrangements for using energy on purpose, concentrating on selling fuels and electricity by the unit at more or less arbitrary prices, we would have little chance of making the world work better. But we have another option, as following chapters will describe, an innovative approach to counter the pessimism that says we must use more and more fuels no matter what that does to the planet.

For years we've been talking about 'sustainable energy'. Following the lead of the landmark Brundtland Commission report *Our Common Future*, published in 1987, we could define 'sustainable energy' as 'energy use and supply that meets our needs without jeopardizing the ability of our children to meet theirs'. Unfortunately, we can see all too clearly that the way we now use and supply energy is jeopardizing the future, not only for our children but for the entire ecosystem of our planet. Even on its own terms it looks acutely vulnerable, with long and tenuous supply lines precariously easy to disrupt, for reasons of money, politics or malevolence.

As we scramble for 'energy security' and strive, all too belatedly, to get a grip on climate change, we may at last initiate the energy evolution that will bring us sustainable energy – not just those of us among the 'energy haves', but also the two billion still waiting. If, against the odds, we somehow get this right, in the course of this century we may even manage to make human energy systems work more like natural energy systems, continually delivering the services we want while most of us don't even notice. We now understand a great deal about human energy systems; but natural energy systems still remain in key respects tantalizingly beyond us. The American energy visionary Amory Lovins once offered a vivid illustration. We know, he said, three ways to make a building material out of limestone. We can cut it into blocks. We can calcine it in a furnace to make cement. Or we can feed it to a chicken. Weight for weight, eggshell is one of the strongest materials we know. But we don't know how the chicken does it. What's more, the chicken does it not in a furnace but at its own body temperature. As yet, we

humans manipulate materials and derive other energy services mostly using substantial temperature differences, in processes that use brute force rather than elegance, especially by burning fuel. Can human energy systems converge towards natural energy systems? The vision is appealing and exhilarating.

Energy, to be sure, is only one of the fundamental issues that challenge us. But if we don't get energy right the other issues will be insoluble. To herald the new century, Chatham House published my millennium essay 'Running the Planet', an attempt to reassess the fundamentals of human life on Earth from first principles; you can find it in Annex 1. As the title indicates, whether we like it or not, we humans are now in charge. Our future is up to us. But we cannot long survive as a species, on this interconnected planet we share, unless we can rectify the gaping disparities that divide us: 'The co-existence of opulent luxury and desperate poverty, sometimes within the same urban area, is not a recipe for stability.' Nor can we keep borrowing from our descendants.

If we are to meet this challenge, we have to get energy right. We have to make the world work better, and we can. But it will not be easy. In the closing lines of 'Running the Planet':

> *No one knows all the answers. We may not even be asking the right questions. We are all in this together, and we'll need all the help we can get.*