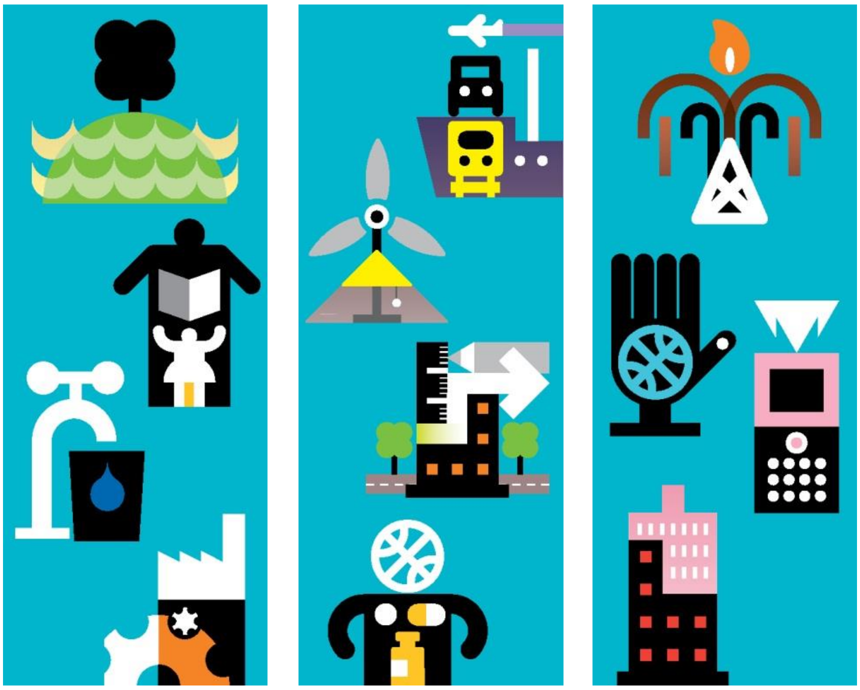

Optimised use of renewable energy through improved system design

A new architecture for a renewable energy system

March 2014

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Mott MacDonald

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The IEA Implementing Agreement for Renewable Energy Technology Deployment (IEA-RETD) is a platform for enhancing international cooperation on policies, measures and market instruments to accelerate the global deployment of renewable energy technologies. IEA-RETD operates under the legal framework of the International Energy Agency.
IEA-RETD aims to empower policy makers and energy market actors to make informed decisions by: (1) providing innovative policy options; (2) disseminating best practices related to policy measures and market instruments to increase deployment of renewable energy, and (3) increasing awareness of the short-, medium- and long-term impacts of renewable energy action and inaction.

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Preface

This position paper - which was commissioned by IEA RETD in 2011 and has had a long gestation - is now offered as thought piece on the challenges and policy framework for moving the world towards a high renewable sustainable energy system. The focus is on the shape of the required energy architecture to deliver and sustain a world with a very high penetration of renewables. It explores this under three aspects, the vision, the challenges and policy requirements.

Acknowledgements

The paper is largely written by Mott MacDonald's chief energy economist, Dr Guy Doyle, but has drawn hugely upon three brainstorming sessions involving four other distinguished experts bringing wider experience across the energy sector:

Dr Mark Barrett, of University College London

Professor Roger Kemp, of Lancaster University

Dr Brian Mark, of Mott MacDonald

Dr Simon Harrison, of Mott MacDonald.

While there was considerable agreement on the vision, there was less of a strong consensus on the relative importance of the challenges and the appropriate policy mix. This has led the author steering his own route, but guided by these various views. In addition, the IEA RETD comments (led by Dr David de Jager) on earlier drafts and other supporting documents, have also shaped this paper.

About IEA-RETD

The International Energy Agency's Implementing Agreement on Renewable Energy Technology Deployment (IEA-RETD) is a policy-focused, cross-cutting platform that brings together the experience and best practices of some of the world's leading countries in renewable energy with the expertise of renowned consulting firms and academia.

The mission of IEA-RETD is to accelerate the large-scale deployment of renewable energies. It is currently comprised of nine countries: Canada, Denmark, France, Germany, Ireland, Japan, Norway, and the United Kingdom. Hans Jørgen Koch, Deputy State Secretary, Ministry of Climate and Energy, Danish Energy Agency, serves as Chair of the RETD.

The IEA-RETD Implementing Agreement is one of a number of Implementing Agreements on renewable energy under the framework of the International Energy Agency (IEA). The creation of the IEA-RETD Implementing Agreement was announced at the International Renewable Energy Conference in Bonn, 2004. For further information please visit: www.iea-retd.org .

Optimised use of renewable energy through improved system design (Optimum)

- *a new architecture for a renewable energy system*

1.1 Introduction

In the absence of a major redirection of energy policy, the industrialised world is unlikely to evolve towards a sustainable, “low carbon” energy system running largely on renewables by 2050. This redirection will involve major challenges and uncertainties.

A sustainable low carbon world would need a policy direction

These uncertainties relate to technology development, economic, social and political changes as well as the inherent complexities of what appears to be an unstoppable movement towards increasingly complex systems.

This short paper summarises the key findings of a series of brain storming sessions by five energy experts on what the energy system of a high renewable energy world might look like in 2050, what are the challenges in achieving this and necessary key policy actions to deliver it. It is structured in three parts; vision, challenges and policies.

1.2 Vision

By 2050 the industrial world could have a new energy architecture based largely on renewable energy supplies, geographically interconnected systems, smart demand and storage solutions. This would offer a sustainable energy system and one that could be achieved at a moderate societal cost - that is, without jeopardising future economic development. This will involve buy-in to the concept of sustainability / decarbonisation and the redirection of energy strategy, but it need not necessarily involve active engagement from consumers: in principle, they need not see any loss of convenience and reliability as their engagement could be via new smart controls. Such smart controls may range from motion/light sensitive lighting controls to internet linked smart thermostats and controls for heating/cooling, vehicle charging, refrigeration etc. Consumer engagement may therefore be as limited as setting overall guidelines on the extent their consumption is auto-managed. Of course, there will also be users who will be keen to actively manage their energy use for sustainability and budgeting purposes.

Technologically achievable but requires political buy-in…..though not necessarily active consumer engagement

Such a renewable energy system would be characterised by a diversity of technologies and a very large number of active participants, across a range of scales and geographies. Managing energy effectively – which implies reducing costs and increasing efficiency while, also, ensuring reliability and security – will require a highly inter-related system in which every piece fits together.

Energy system should be allowed to evolve, subject to an agreed indicative plan

There are six guiding principles for the deployment of this new architecture:

- There must be a societal and political will for action – this means widespread buy-in to the principles of the creation of sustainable energy systems through renewable energy and energy efficiency;
- Policy makers need to adopt a systems approach, which takes into account the interconnections between developments, energy vectors and behaviours and which encourages diversity and flexibility;
- A degree of "prohibition" of unsustainable investment and behaviours, through application of a co-ordinated set of mandatory standards and price/tax incentives;
- A reliance on markets - application of market principles - including appropriate pricing of carbon and other externalities – promises to provide the force for evolution;
- Innovation needs to be fostered. A transition to a sustainable world, will require continuous innovation, not only by technological and system innovations, but also in social and institutional areas;
- A coherent indicative plan in terms of support of common standards, which allows inter-operability, and one that also enhances trading and provides a high degree of optionality.

Needs to integrate variable renewables into system using dispatchable renewables, energy storage, trading opportunities and flexible demand ……..all enabled by smart grid

This vision has no proscribed mix of energy sources and energy carriers. The outcome will be the product of an evolutionary process where the best technologies and practices win out, which means the outcome may differ from region to region. With certain guidelines in place, the structure and arrangements for the new system would be allowed to evolve, driven by commercial incentives and stakeholder interests.

On the supply side, one might expect a major contribution from wind and solar - the two main flow renewables[1] (flow-RES), though in some cases there may be a need to cap their contribution, for wider system benefits (in case the system cannot cope with the level of variability). Other flow renewables like tidal stream and wave are likely to play a minor role on a global level. Hydro, the largest renewable source today, is expected to play a key role, especially reservoir hydro, which can

[1] IEA-RETD is using a different term for these flow renewables, calling them variable renewable energies (VRE).

offer regulated power and so smooth out the variability caused by flow-RES.

Bio-energy promises pivotal role as dispatchable energy source

Even more so than reservoir hydro, bio-energy offers the potential of providing a substantial contribution of truly flexible electrical energy on demand (called dispatchable renewables [Dis-RES]) and is likely to play a key role in bringing electricity supply and demand into balance. This Dis-RES will be part of a portfolio of options for balancing which will include energy trading (via electricity interconnectors), demand flexing (of consumer load), regulated hydro and storage options. The storage options will include bulk electricity storage as well as conversion of surplus electricity to heat in domestic water tanks (and potentially space conditioning) and possibly other conversion options using hydrogen or other energy carriers.

This is likely to be a world where there is a mix of energy carriers, although electricity is expected to become more important in land transport, space heating and industrial applications. Increased electrification of the energy system will reinforce the move towards “just-in-time” energy supply solutions, where there is less fuel stored by consumers (such as gasoline and diesel in vehicles or oil and coal for boilers and stoves). Electric vehicles could partly offset this trend if deployed in sufficient numbers with their charged batteries potentially providing significant energy storage.
Coincidently with these developments, the supply side will become less predictable. This will increase the demand for an overlay of smart controls to allow efficient matching of supply and demand.

Oil use in transport would need to be replaced by a combination of electric motors (for vehicles, trains and ships) driven by power lines, batteries or potentially fuel cells and bio-derived fuels (critical for aviation). This will be made easier if vehicles become much more fuel efficient and if users (can be encouraged to) drive less and at slower speeds.

Industrial users will also need to be switched off fossil fuels. Luckily, most new industrial processes rely on electricity. However, a significant rump may still require carbon based fuels, which may be partially provided via processed biomass.

In this world, bio-energy is expected to play a pivotal role, in transport (especially aviation where it is the only practical renewable solution), in some industrial processes (where carbon is required) and in firing dispatchable generation plant. This will put a huge emphasis on efficient conversion of raw biomass into useful energy carriers in a way that does not compromise use of land (and marine areas) for other uses, notably food production. This will also need to be done in a way that does not seriously erode bio-diversity.

1.3 Challenges

There are many challenges to overcome before the above vision could become a reality. These can be grouped under three broad areas:

- the implementation of such a radically different energy architecture, and the transition to this from the present one;
- whether the system will operate in a stable manner without crashing and jeopardising security of energy supply; and
- whether all this can be achieved at a reasonable societal cost.

3 big challenges are: implementation, security and costs

We explore each in turn.

Challenge 1: Implementation – the critical challenge of making it happen

There are many aspects of the implementation challenge, including the following:

- Can the necessary stakeholder alignment be achieved to allow appropriate incentives and rules to be put in place?
- Can such a major change be evolved or will it need to be planned?
- Can energy efficiency be delivered?
- Can investment in major infrastructure be mobilised?

1.3.1 Getting political buy-in

A clear necessary precedent for implementation of the appropriate regulatory and market framework is a degree of consensus among key stakeholders including political parties in the general aims and direction of change. This is clearly absent at present.

First implementation hurdle is getting political buy-in

Prior to the 2008 financial crisis, the decarbonisation agenda was aligned with the desire of politicians and business to switch the economy away from oil and gas due to the perception of impending severe scarcity – so called “peak oil” threat. However, there is a growing view that oil supply is unlikely to suddenly run short in the foreseeable future, largely as the combination of market economics and new technology developments is expected to bring forth new supply capacity. Much of this is new capacity from unconventional and hard-to-access (offshore and artic) resources. Natural gas has seen an even more marked turnaround and there is now widespread talk of a forthcoming "golden age of gas" in which natural gas displaces coal and oil, bringing both economic and carbon savings.

IEA-RETD on the importance of renewable energy

IEA-RETD says there are clear economic benefits of renewablles

Increased concern about security of energy supply, fluctuating fuel prices, a greater awareness of climate change and the environmental impact of energy production, and rising levels of global energy demand – all these issues highlight the potential benefits of an increased renewable energy deployment. Therefore the Renewable Energy Technology Deployment (IEA-RETD) Implementing Agreement was announced at the first of a series of international renewable energy conferences in Bonn in 2004. It was meant to supplement the technology focussed work of other IEA Implementing Agreements by giving it a technology cross-cutting character and a focus on policies. In this way IEA-RETD was enabled to give renewable energies a strong voice in the global concert of energies and to play an important role in addressing the challenges and opportunities for the deployment of renewable energy.

Need to convince wider public of benefits of vision, versus costs of inaction

The abovementioned concerns were still present at the start of the second term and still are today. The focus of concern may have shifted in the course of years, for instance due to major incidents with geopolitical consequences, but they all reappear in the course of time. With soaring oil prices and a critical socio-political situation in several oil producing countries since the Arab Spring (starting in December 2010), we were reminded that the security of our energy supply and hence our economies could be at risk. With ever increasing greenhouse gas (GHG) emissions the global climate is at risk. Furthermore, the impact of the already occurring climate change is becoming more visible, such as the observed 4.6%/decade decline in the Arctic sea ice extent (as compared to the 1981-2010 average), or the droughts in North America in 2011 and 2012. The incidents at the Deepwater Horizon oil platform (April 2010) and the Fukushima Daiichi nuclear power plant (March 2011) have dramatically shown that the other risks of our conventional energy systems are real and devastating. The need for changing our energy systems becomes more and more clear.

Both energy efficiency and renewable energy technologies will play a major role in shaping our energy future. They can also be an important driver for economic development. However, at current deployment rates, society may *not be able to reap their benefits in time, due to the increased lock-in of dominating 'old' technologies and the temptations of (temporary?) cheap unconventional gas or oil. Decision makers in- and outside government, despite being faced with an economic and financial crisis and limited budgets available for driving this change, should hence take the responsibility to fundamentally improve tomorrow's energy system. The economic benefits of such a strategy can emerge faster than most people think.*

The need and urgency for change have only increased. IEA-RETD will hence continue to focus on one of the important building blocks of the required energy transition, the accelerated deployment of renewable energy, and the role of policies herein.

Source: IEA-RETD Mid-Term Report 2010^{Q4}-2013^{Q1}, April 2013

The current tough economic situation, especially in OECD, which has lowered energy demand and eased the demand-supply balance - and hence prices - has also reduced the urgency and appetite of businesses and policy makers to endorse an ambitious and urgent decarbonisation or renewable energy agenda.

But tough economic times and strong vested interests makes getting buy-in the toughest challenge

There are strong vested interests backing the existing system based primarily on expanding fossil fuel supplies. And there are other vested interests among major energy users including among others mining, metals, chemicals and automakers, who are reluctant to endorse a decarbonisation agenda. Of course, there are some companies in these sectors and even in the oil and gas sectors which are in favour of decarbonisation, however they represent small voice.

In some jurisdictions, most notably the USA, there is a strong lobby opposed to most restrictions on individuals' and businesses' free choice. This "freedom" lobby will need to won over. Almost everywhere, household and businesses tend to view sustainable energy options as being expensive compared with carrying on with the business-as-usual option. The IEA-RETD believes this is one of the key misperceptions that needs to be addressed by policy makers.

1.3.2 Getting to the goal - evolution versus planning

Implementation requires guidelines but delivery can be allowed to evolve….

…with greater or lesser reliance on market depending on jurisdiction

Assuming that there is a consensus on the ambition of large-scale deployment of renewable energy, there is then the question as to how it should be practically implemented. The challenge here is deciding the extent of direction in shaping the outcome. Policy makers choices range from detailed centralised plans at one end of the spectrum to light touch indicative plans which focus on providing the appropriate incentive and regulatory framework. Liberalised North America and Europe tend to lean towards the lighter touch approach.

The lesson of systems theory is that a sustainable energy architecture could evolve through the uncoordinated actions of millions of agents pursuing their own interests, assuming appropriate guidelines and incentives are put in place. In particular there will need to be strong commercial incentives (with carbon and other externalities priced in – through tax or alternative traded allowances/permits) for consumers and businesses to pursue energy efficient and renewable options. This will need to be supported by a set of mandatory standards which effectively prohibit the more unsustainable options. These standards and green pricing measures will need to be part of a stable regulatory framework in order to encourage investment.

Such an evolutionary process does not require a detailed master plan, but it probably requires a at least a looser indicative plan or a set of targets. On the other hand, there is a clearer case for some kind of centralised (or at least co-ordinated) standards in terms of basic interoperability of sub-systems, for instance grid codes, real time balancing, trading arrangements, etc. Without such systems standards it would be more difficult to reap the benefits of interdependency as the parts of the system would not fit properly together.

1.3.3 Delivering energy efficiency

Negawatts are cheaper than Megawatts….

But difficult to deliver

It is widely reported that "NegaWatts are cheaper than MegaWatts". It is more economic to install high efficiency lighting systems than to add new generating capacity. Likewise, improvements in vehicle's fuel efficiency can be won at much lower cost than adding new oil production, processing and distribution capacity.

The challenge is that energy efficiency investments often need to be made by large numbers of small energy users, who through a combination of lack of knowledge, funds and time, and a reluctance to accept disruption or inconvenience associated with the installation or use of energy efficiency, tend to invest well below what economists would deem the rational (optimal) level. There are also constraints arising from the slow turnover of building stock, transport infrastructure and industrial facilities, which reduces the speed at which new technologies can be applied.

The challenge in addressing these "market failures" and legacy infrastructure constraints is the extent to which compulsion can and should be used to direct investment/ behaviour versus providing information and extra carrots to effect the necessary changes. It is likely that a mix of measures would be appropriate, though tailored for each situation.

Rebound effects apply to low cost supply as well…

And only presents a challenge as long as decarbonised energy remains scarce

These measures need to also take account of the so-called rebound effect, whereby low cost energy savings are partly offset by users increasing consumption of final energy services or spending on other energy using services. This is in principle the same as any other income effect, which arises from doing an activity more economically efficiently. New low cost solar PV would provide a similar income effect. This is a product of economic growth, which typically drives energy demand and it will remain a challenge as long as decarbonised energy supplies remain scarce.

1.3.4 Mobilising investment

One feature of a high energy efficiency, high renewable energy supply and smart grid world is the capital intensity of the infrastructures. This is seen as presenting a major challenge in mobilising investment. Compared with historical periods an unprecedented amount of capital needs to be raised. Meanwhile investors are as ever looking for stability, predictability and clarity.

However, if investors have confidence in governments' commitment to maintaining strong incentives and appropriate regulatory guidelines, the focus shifts to the mechanics of raising funds. Given such a framework, the market and industry should evolve a range of financing schemes.

Massive amount of capital needs to be raised

Will require secure cost recovery mechanisms

The development of common carrier infrastructures for electricity, gas, heat and possibly batteries, hydrogen and biofuels will require a shared vision among policy makers and regulators. As today, costs are likely to be recovered through socialised tariffs on infrastructure users. With such a secure cost recovery mechanism there are likely to be many funding options.

Investment in energy efficiency and energy supply is expected to be more risky, unless the market moves to one of long-term capacity services. This could be contracted on a bilateral market basis, especially if there are strong corporations selling energy services, or alternatively, some jurisdictions might move to single buyer models, where a central authority takes the purchasing risk.
There is much uncertainty around how the new market arrangements will evolve, but there can be some confidence that a workable solution will be found.

Consenting is bigger challenge….

Probably requiring compensation of affected parties

Perhaps a bigger challenge for developers and utilities will be the securing of the appropriate consents and planning approvals. Large infrastructure projects (even renewable power stations) are often considered to be visually intrusive, polluting, dangerous or cause disruption and inconvenience during construction and so are frequently seen as unwelcome by local communities and environmental lobby groups. This can make getting permits for their construction lengthy and uncertain. Clearly, in a world where there is a general buy-in to the renewable objective, it would be easier than where support is patchy. Even so, there is likely to be resistance on the basis of "not in by back yard". The challenge is increased if impacted community cannot see direct benefits from the new investments, such as for major electricity transmission lines. This will need to be resolved either through some centralised authority imposing its decision and probably offering compensation, or else through more decentralised and negotiated arrangements within a framework of burden sharing, and again providing some form of compensation to affected parties. Good practice experiences on spatial planning, attained in several regions, should be deployed more widely[2].

Challenge 2: Security – the challenge of ensuring safe and reliable energy systems

Need to balance demand and supply of millions of atomised agents while maintaining stability

Whether such a market based solution would lead to the adequate provision of system redundancy to provide security of supply in energy service provision is unclear, although this can be addressed through various types of administered capacity mechanism, or mandatory reserve and storage requirements.

[2] See the IEA-RETD guidelines 'Overcoming Environmental, Administrative and Socio-economic Barriers to Renewable Energy Technology Deployment' (RENBAR project) at www.iea-retd.org

But unclear at present whether new control architecture will be robust

Almost certainly a bigger challenge is whether an energy system comprising millions of independently acting consumers and suppliers – mainly based on renewable energy - would be stable. Many centralised utilities fret about such a situation, however there are a small number of precedents in which market mechanisms calling upon small users and suppliers are being used for real time balancing of electricity. This does not necessarily mean that the challenges for a new control architecture may soon be resolved. There are complex linkages between energy carriers – electricity, heat and fuels - via conversions, which create new challenges. While logically it could be argued that this diversity should make the system more robust, it is unclear whether this will be the case. All this needs studying and testing in practice. There is a reasonable hope that much of these stability concerns will be resolved during the transition to the eventual renewable based energy economy[3].

It remains to be seen what level of centralised control will be required to provide the markets and regulators confidence that the energy system will be able to respond dynamically to balance demands and supply while maintaining stability.

Challenge 3: Costs – the challenge of ensuring the new energy architecture is affordable

After can it be implemented and seen to operate reliably, the third key challenge the new architecture faces is; can it be done at acceptable cost?

On a societal cost basis leading renewable energies at or close to parity to fossil fuel based energies

Large hydropower, PV and onshore wind in areas with high yields and some biomass waste generation are now competitive when compared with fossil fuel based energies on a societal basis. Most of the remaining RE technologies are relatively new and can be expected to see considerable cost reduction through learning by doing as increased capacity is deployed. Factoring in the expected cost reductions for RE, a significant carbon price and the absence of fuel price risk (for most RE), the economic case for deploying RE is further enhanced.

[3] See the IEA-RETD report 'Next Generation of RES-E Policy Instruments' (RES-E-NEXT project) at www.iea-retd.org

Cost reductions expected from spin-offs from cleantech, nanotech and biotech advances…

And moving to low cost jurisdictions

Some energy technologies may also gain from ongoing hi-tech innovation being driven by large, diverse and apparently sustained R&DD activities of private businesses pursuing “cleantech” opportunities. These are likely to include, on the supply side; solar PV and bio-energy production and conversions, and on the demand/storage side; flexible demand/smart controls, electric vehicles and bulk electricity storage[3,4].

Along with this technical innovation process there may be scope for significant cost reductions through accessing low cost jurisdictions, which can offer lower labour (and other) costs than available in the OECD countries. This has been most noticeable in the solar module manufacturing sector, where China has captured a significant share of the market. In future, other developing countries may offer lower cost manufacturing services.

Taking all these factors into account, the scope for cost reduction and the chances the technologies can achieve, competitive prices will vary. Solar PV, bio-energy conversion and batteries are likely to see greater cost reductions than some of the marine power generation technologies, like wave and tidal generation. Wind is likely to fall somewhere in between these ranges.

Exploiting all bio-energy opportunities in a sustainable way will require innovations in technology, land use management and trading

Perhaps the biggest challenge on the cost side is finding a way to cost-effectively exploit global biomass potential (through cropping, harvesting and using wastes) in a way that is sustainable. This may involve a combination of innovations from new technology breakthroughs in synthetic fuel production, new biota, agricultural techniques, foods and land use management. To truly harness global bio-energy potential will also require harvesting aquatic biota and developing global trade in bio-energy.

Overall there is realistic potential to deliver RE, energy efficiency and smart grid infrastructure at a cost that will not burden the economy, than remaining on a business-as-usual (BAU) path.

1.4 Policy and recommendations

Policy relates primarily to the nature and extent of deliberate

[4] See the IEA-RETD report ‘Cost and Business Comparisons of Renewable vs. Non-renewable Technologies’ (RE-COST project) at www.iea-retd.org

intervention of government and regulatory authorities in individuals' and businesses' activities.

Question of what is appropriate and effective intervention

Within the context of the implementation and operation of the new energy architecture the main policy areas comprise those relating to:

- Encouraging buy-in to the vision and agreeing targets and an implementation plan;
- Providing appropriate incentives for individuals and organisations;
- Setting mandatory standards - ranging from minimum performance standards for appliances and capital equipment to minimum requirements for inter-operability of equipment and systems;
- Setting constraints on what is acceptable behaviour;
- Putting in place arrangements for agreeing and changing rules.

Considerable need for preparatory work to understand consumer and investor behaviours, potential for new techs/practices and practical constraints on implementation

Implementation of any of these policy areas is extremely demanding, not least because of the interpretation of what is appropriate and effective in the different circumstances across the (industrialised) world. There is a substantial amount of preparatory work that needs to be done, not least in terms of understanding consumers and investor behaviour, the potential of new technologies / practices and the practical constraints on implementation. With these caveats in mind, the following provides a brief outline of the five policy areas mentioned above.

Fostering buy-in

Securing buy-in to a sustainable strategy requires acceptance of the "insurance" package….

Easier if burdens are shared

The first prerequisite for moving towards the new energy system outlined above is to get enough support from leaders and other opinion formers, who will then bring along the wider public. In practical terms this involves convincing enough people that it will be better for them (and their offspring) if they follow this path. Most credibly the new path will need to be presented as some kind of necessary insurance strategy – in order to avoid major risks (relating to precipitous climate change, sea level rise, resource wars, mass immigration, price spikes, etc.). If policy makers can present this direction as one where there will be appropriate sharing of burdens and these burdens are not too severe, it will be easier to get buy-in. Policy makers might also make alternative pitches; such as the proposed new direction will anyway provide the least costly option (especially when reaping the co-benefits of renewables, like job creation, avoided air pollution and health care costs), but they will need convincing evidence.

All this will need to be done on an internationally co-ordinated basis [though it need not be unanimous or wholly simultaneous]. There will be a need to set internationally agreed targets which embody rigorous ambition and allocate burden sharing in a fair way. Clearly, this is an immensely challenging task, as the world appears widely split on what is fair in burden sharing, especially on whether legacy impacts (historical emissions) should be taken into account.

Need to agree ambitions – which embody burden sharing – and embed all this within a robust governance mechanism

Ultimately, the chances of getting sufficient body of domestic and international agreement will depend on opinion leaders' views regarding the relative costs of pursuing the new direction versus the risks of not doing so. Over the next decade a combination of falling relative costs of renewable energy and increased fear regarding dangerous climate change and resource scarcities may provide the conditions for a new international accord.

Will be a need for at least an outline implementation plan outlining main policy actions

Once there is endorsement this needs to be formalised in a set of agreed broad ambitions and specific targets (which embody burden sharing). There needs to be agreement on how progress is measured and how and when targets might be revised, in a way that does not undermine the whole project.

As mentioned in the Challenges section, there will be a need for at least an outline implementation plan. This will need to address in broad terms the means by which the vision would be delivered, including the main policy actions in terms of the balance of incentives, guidelines and rules that would be established. It should also include some preliminary thinking on the likely requirements for long life physical infrastructure, especially networks which would have international interfaces.

Incentive structures

Appropriate incentives will be required ….

Removal of support for fossil fuels and carbon pricing – with an international transfer fund mechanism

In terms of appropriate pricing signals for moving to a renewable based low carbon world, there is a clear need for a prompt removal of subsidies, price caps, tax breaks and other measures directed at supporting fossil fuel production, transport and use. A similar retrenchment against support measures could be made against nuclear and unsustainable bio-fuels. At the same time, a significant price for carbon needs to be phased in, either as tax or tradable allowance scheme (with floor price to guarantee a reasonably high minimum level). Ideally, this should be a common international carbon price since greenhouse gas emissions are a global issue. Almost certainly, this would need to be incorporated within a flexible framework that allowed lower income countries to continue to develop, while simultaneously transferring funds from countries which are high per capita emitters to low per capita emitters. One potential approach is that proposed by Cramton and Stoft[5] who have outlined a flexible global carbon pricing mechanism which includes a Green Fund for handling international transfers.

Most other externalities can be addressed on a national or local jurisdiction level, with taxes or other appropriate instruments

In order to encourage the necessary level of investment and consumer demand response, the carbon price will need to set at a high level compared with any so far seen in emission trading schemes or national taxation. Minimum prices will need to be fixed in advance and guaranteed, so as to provide confidence to investors.

In contrast, most other environmental and social externalities can be addressed on a national or local jurisdiction level, with taxes, subsidies and other government interventions set depending on the particular context. A few environmental externalities – such as acid gas (SO_2 and NO_X) and particulates – are best solved through a co-ordinated multi-national - though not global - approach given the transboundary nature of these pollutants.

With these tax or tradable certificates in place, users and producers would face the appropriate price incentives which would influence their investment and consumption decisions.

In practice, however consumers and investors do not behave as idealised rational agents and so there is a need for intervention to get them to take appropriate action. Interventions tend to include combinations of information and publicity campaigns, financial support, encouragement for third party service providers (energy service companies) and mandatory standards.

Pricing signals (including taxes need to reinforced by mandatory standards

Mandatory standards

The above price incentives will need to be reinforced by a set of regulations which would set minimum energy performance standards for new equipment, appliances, vehicles, etc. In an ideal world it would be efficient to have a degree of harmonisation of standards across trading blocs and similar economies, however there would need to be scope for variations to reflect levels of economic development and particular circumstances. Typically, standards for new installations will be set at a moderately demanding level, rather than at state-of-the-art,

[5] Global carbon pricing – a better climate commitment, Peter Cramton and Steven Stoft, Global Energy Policy Center – Research paper No. 09-06. December 6, 2009.

as this provides more flexibility in solutions, but they should increase over time. An example of this is the 'top-runner' approach in Japan, where the most efficient appliances set the standard for the next generation of appliances. Standards may also be applied retroactively after a grace period to existing installations / equipment: although these are likely to be at a less demanding level, though this may be ratcheted up over time. However, applying standards to existing equipment may be considered intrusive where it goes beyond the established areas of industrial and commercial users' process plant, heating and cooling equipment and vehicles (including those owned by private individuals). For instance, setting and then policing standards on domestic heating, cooking and refrigeration appliances already installed, is unlikely to be workable.

Ideally standards should be harmonised, stretching but sensitive to local conditions

There has been a considerable advance in the last decade in applying behavioural economics and experimental approaches (often called the "nudge" theory) to designing effective policy tools to encourage households and businesses to both change behaviour and/or make investments which enhance sustainability.

Nudge theory (behavioural economics) provides new way of increasing effectiveness of interventions

Nudges involve using various combinations of appropriate language and context in messaging, information feedback, peer pressure, goal setting, competitions, rewards, etc. in ways that bring forth the appropriate behaviour. In the energy sector, such techniques have been most widely applied by North American utilities. Notable nudge approaches have been catalogued by Bonneville Power Administration and include BC Hydro's commitment and reward scheme, where customers are given a $75 reward if they use 10% less electricity over a 12 month period and various schemes where customers are sent regular reports showing how their recent consumption versus their cohorts and utility averages, etc, along with energy saving tips. Nudge measures have also been applied outside the utility sector, for instance the so-called "cash for clunkers" programme where by owners of old inefficient vehicles are given cash rewards for surrendering their vehicles.

It is still early stages for application of this approach. We believe that it offers the potential for much more effective policy instruments than has been achieved in the past using traditional interventions.

Standards for interoperability are essential, especially for interconnected infrastructures

Standards will also be required to ensure certain minimum levels of functionality for new installations and network architecture, such as smart meters, electric vehicle charging, data and communications protocols, etc. This is most important to ensure that there is inter-operability of systems, in other words systems can interface with each other, and devices are designed to be compatible with one or more systems. These rules for inter-operability need to be agreed by international industry associations and overseen by regulatory authorities.

Constraints on consumer choices

Interventions on "acceptable" behaviour may be also applied but will depend on particular circumstances

There are already a number of areas where there are constraints on individual behaviour, although these primarily designed to discourage unsafe behaviour, for example, maximum speed limits on public roads. There are others which effectively involve rationing of scarce resources; restrictions on use of hose pipes, or restrictions on using vehicles (with low occupancy) or on certain days (alternating between odds/even licence plates). However, in a liberalised democracy it is difficult to think of examples where similar rules might be applied to consumers in relation to energy use, which are not related to safety or pollution. There is some scope to apply such an approach indirectly through rules on new assets – for instance, newbuild dwellings without off-street parking but with lockable cycle storage - to encourage cycle use and discourage private vehicle ownership and use. Rules on when central heating can be turned on are unlikely to be acceptable in the OECD world. However, policy makers have considerable scope to influence behaviour of consumers and investors through punitive pricing and taxation policy, in what might be called a "heavy nudge". For example, this could be applied to persuade householders to retrofit energy efficiency measures, or trade in their inefficient vehicles.

Governance – arrangements for agreeing and changing rules

Regulatory framework will require robust governance arrangements

It will be a massive challenge to implement a largely renewable based energy system globally by 2050. This will only be possible if households and businesses are confident that the incentives and rules influencing their behaviour are fair and predictable. This means that there is considerable onus on ensuring that the governance arrangements are robust and fair, and that major changes are discouraged, and only allowed where there is a broad consensus that change is for majority's wellbeing. Where manageable and material, any parties impacted detrimentally should have the right to compensation. This is a widely applied principle in regulatory practice in the OECD and is most commonly seen in "grandfathering" any significant support arrangements for investors that were in place when they made their investment decisions.

1.5 Concluding comment

It is technically possible to reshape the energy system to enable high uptake of renewables providing robust supply: the main challenge is gaining political buy-in

There are considerable environmental and sustainability benefits from taking measures to reshape the energy system in the industrialised world so that it can handle a very high share of renewable energy in way that does not jeopardise energy security or affordability. A smart (appropriately designed) energy infrastructure will allow both efficient deployment and integration of RE. Without proper attention to system design issues deployment of renewables will be impeded and integration will be difficult, especially for the variable renewable energies (VRE).

A high renewable energy world will need to rely on VRE for a large share of society's energy needs. In turn, this will require calling upon energy users and others to provide flexibility including demand response measures, storage, trading with other jurisdictions, using storage in energy systems and sourcing a substantial amount of dispatchable renewable energy (most likely bio-energy). All this will need to be done in a way that provides system operators confidence in the system's stability. The main hurdle in delivering this new architecture for the energy system is gaining the necessary buy-in from leaders and opinion formers for such a strategy. The best prospect for convincing them is that a world running largely on renewables will both mitigate impacts of severe climate change and air pollution and increase global security through eliminating reliance on a small group of major fossil fuel exporters.