CMI CENTRE FOR ENERGY SECURITY
COMMENTS TO THE DTI ENERGY REVIEW

In 2005, the CAMBRIDGE-MIT INSTITUTE (CMI) inaugurated a dialogue with UK energy stakeholders focused on the topic of "energy security and UK competitiveness" (workshop summaries attached).

As a result of these meetings, the CMI is in the process of establishing the CENTRE FOR ENERGY SECURITY, jointly housed at *Cambridge University* and the *Massachusetts Institute of Technology*, to serve as a focal point for research, dialogue and outreach in the area of energy security. The Centre will bring together diverse representatives from industry, government and academia to address national, regional and global responses to energy security and other long-term energy related challenges.

This submission to the DTI's Energy Review is intended to highlight some of the energy network-infrastructure-market topics that may not have been addressed in sufficient detail through parallel, more technology or economic policy focused responses to the DTI's Consultation Document. We hope you find it useful.

Sincerely,[1]

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DTI Goals

The Department of Trade and Industry's goals are well stated in the January 2006 Consultation Document. They can be quickly summarized as:

- ✓ *Protect the Environment*
  Primarily, but not exclusively, from a global climate change perspective.
- ✓ *Protect the Economy*
  Primarily via affordable, reliable energy supplies, relying on market mechanisms where possible, which allow continued improvement in overall UK competitiveness.
- ✓ *Protect the Poor*
  Primarily via affordable, less volatile energy prices, and lower energy consumption in the provision of basic energy services.

The Domestic Energy Security Challenge

This document focuses on prospective solutions to the domestic "Energy Security" challenges facing the UK energy sector. It focuses primarily on the balance and distribution of energy resources, the structure and performance of energy infrastructures (networks), the markets through which they operate, as well as the demand for energy services. For the purposes of this discussion, by "energy security" we *do not mean* "energy and security" (principally the tracking and protection of nuclear materials, and the protection of energy facilities from attack), *nor* "security of energy supplies" from an international and geopolitical perspective. These are both

[1] The views expressed in this document are those of the CMI-CES Planning Team and do not represent the opinions of the Cambridge-MIT Institute, Cambridge University or the Massachusetts Institute of Technology. Due to the complexity of the topic the authors may have varying views on specific aspects of the recommendations put forth in this communication.

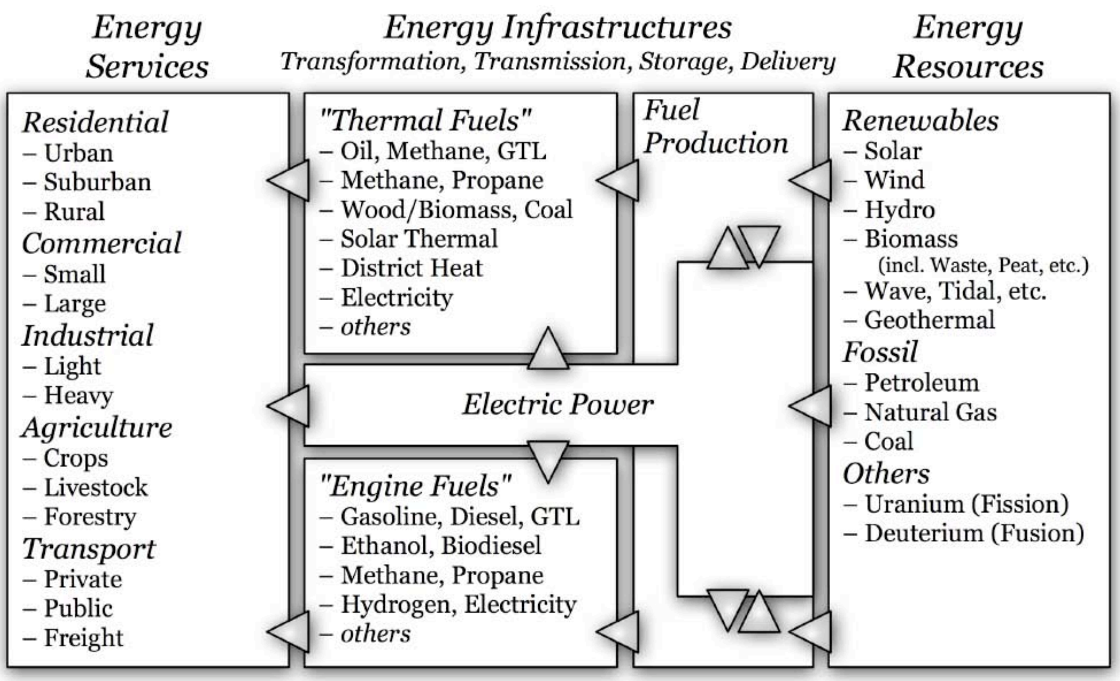
very important topics. In this document however, we focus on domestic energy sector considerations, under the banner of increased energy security which *simultaneously* reduces the economy's exposure to the dynamics of international fuel supply-chains, and helps the nation achieve its long-term social and environmental goals. In this respect, our comments address the issue of "energy reliability" as presented in the 2003 DTI Energy White Paper, but with a longer-term, integrated energy infrastructure focus.

Energy Security and the Structure of the UK Energy Sector

Figure CES.One illustrates the basic components of the UK energy sector. On the left side of the illustration are the basic categories of energy demands or *"energy services"* needed by society. On the right side are the range of possible *energy resources* society might tap to meet these needs. Bridging energy resources and services are the energy infrastructures and networks that tap, transform, and transport those resources to end-users.

For simplicity's sake, "energy supplies"—the forms in which energy is delivered to end-users—have been grouped into three categories: *thermal fuels*, *transport or engine fuels*, and *electric power*. The distinction between energy resources and supplies is made since electricity and numerous fuels (hydrogen, ethanol, biodiesel) can be made from a broad range of energy resources.

Figure CES.One: Basic components of the energy sector



Energy security then can be defined as the ability to meet UK energy service needs, in a robust and reliable fashion, in the near-, medium-, and long-terms. However, it is recognized that this will be more difficult in the future than it has been in the past, with the reduced output of North Sea oil and gas, tightening European gas and electricity markets, and rapid growth in world oil consumption. Expanded or alternative energy supplies/resources will need to be tapped, and the energy infrastructures/networks developed which will deliver these new energy supplies to consumers.

For some of these new options, novel or refined technologies will not only need to be developed, but rapidly deployed, and put into use. Government policies—at the national and European levels—will play an important role in this process, especially in the development and demonstration of new energy technologies. Rapid and broad-based deployment of new technologies however will be quicker with policies which open up new market niches for these innovative technologies and energy services. However, given the challenges of energy infrastructure transformations in response to climate change and global competition for energy resources, how *should* the UK's energy sector evolve?

Energy Security and the Future Evolution of the UK Energy Sector

The above figure highlights three aspects of long-term energy policy, essential to radically improve the energy security in the United Kingdom.[2] With this domestic definition of energy security and overview of the energy sector, three key components of a UK energy strategy become readily apparent. These are:

- *First*, move aggressively to improve the efficiency of UK energy services. An aggressive end-use efficiency strategy reduces the demand for energy and extends the usefulness of the energy delivery infrastructure.
- *Second*, greatly diversify the energy resources tapped by the UK energy sector to meet its domestic energy needs. A large component of this diversification is a shift away from reliance on global fuel markets/supply-chains, to domestic energy resources.
- *Third*, modernise the United Kingdom's energy infrastructures by which those energy resources/supplies are transformed and delivered to consumers. This has near-, medium-, and long-term dimensions when we look at anticipated retirements in coal and nuclear generation, increased imports of oil and gas, and the challenges of meeting Kyoto and post-Kyoto greenhouse gas reduction targets.

Aggressive Energy Efficiency

Strategies which radically reduce the UK economy's energy use and intensity go a long way to meeting the nation's combined energy security and environmental goals. If it can be crafted to reduce imported and/or high carbon content fuels first, then a strategy with an aggressive energy efficiency component can make substantial, early gains in increasing energy security and reducing greenhouse gas emissions.

Reduced energy consumption has both technology investment and utilisation dynamics. For example, fossil fuel use can be reduced in personal transportation by promoting more fuel efficient vehicles, by "diluting" fossil fuel consumption with ethanol or biodiesel, by reducing distances commonly traveled from home to work, by reducing traffic congestion, and by improving the quality and frequency of public transportation.

Such a strategy is much more than just the replacement of older energy consuming devices, with newer, more efficient lamps, heating systems, vehicles, etc. It also requires a *detailed understanding of energy use patterns*, and how those consumption patterns can be modified, or met with advanced technologies—including information technologies.

The technological responses will be a combination of improved energy *conversion/ consumption* efficiency (more efficient lamps, motors, insulation, etc.), energy *utilisation*

[2] All of Figure CES.One can be considered an inter-related set of energy *markets* by which society's energy service needs are met. "Market opportunities" exist within each box, as well as between boxes.

efficiency (smart buildings that turn lights off and temperatures down, hybrid vehicles where engines turn off at signals, etc.), and *integrated* energy efficiency (such as combined heat and power, including microgeneration).

Some of these opportunities have substantial retrofit applications (sensoring and control technologies), while others may require policies which encourage the turnover of various fleets (old autos for new hybrid vehicles, post-war apartment buildings for twenty-first century energy efficient flats). Perhaps most importantly, a strong end-use efficiency component can avoid some of the "not in my backyard" (NIMBY) implementation challenges that even the cleanest of renewable energy projects are facing.

Well designed and targeted policies can create new "market niches" for these end-use technologies, but ultimately these will need to be coordinated with changes in local land-use planning and zoning, as well as the development of the requisite skill sets in the labour force so that prospective employers can deliver such advanced energy services.

Diversify Domestically

Diversifying the UK's energy mix (electric power, thermal *and* transportation fuels), through the increased and responsible use of domestic energy resources, further reduces the nation's exposure to tightening global markets for petroleum and natural gas. While some of these energy options are large centralised facilities (nuclear generation, coal generation with carbon capture), many on both the supply and demand side are more geographically distributed, with significant daily, seasonal and inter-annual variability in both space and time (renewable resources by example). To what degree can the United Kingdom utilise its domestic energy resources?

Tapping a much greater proportion of renewable resources, whether for power generation, or as a feedstock for alternative fuels (ethanol, biodiesel, hydrogen), requires a *detailed understanding of the size, temporal and spatial variability, as well as quality of each renewable resource*. Such dynamics may compensate or compound when different portfolios of renewables are examined. For example, a portfolio reliant on hydropower and bioenergy (fuel crops) will be vulnerable to droughts. Are wind-hydro, or solar-hydro portfolios equally vulnerable? These dynamics need to be well understood, and then factored into the design of energy policies.

Domestic nuclear (new-build), and especially clean coal with carbon capture—if they are to be done well—will also require understanding the details. Fortunately for nuclear, many of the institutions such as CoRWM and others already exist to manage the fuel cycle. Opportunities for advanced nuclear and coal use may increase markedly in the medium- and long-term as technologies advance, which could include the co-production of hydrogen and electricity from coal, or large-scale hydrogen production with nuclear (e.g. "fusion island").

Modernise the Network

The third component connects the first two, and focuses on upgrading the energy delivery network, on both an energy delivery and information basis, to handle the combined dynamics of efficient and responsive energy demands, and diverse and changeable supplies of energy. The degree to which the energy infrastructure requires modernisation is directly linked to our understanding of the quantity, quality and location of domestic energy supplies, and opportunities presented by making energy services, including microgeneration, more responsive to "system state" and "market conditions".

The transformation of the energy sector to one more reliant on local energy resources will require an upgrading of energy delivery systems to handle the regionalisation of renewable energy resources, inter-regional transfer of centralised nuclear generation and remote and/or offshore wind to load centers, and the collection and transportation of diverse, voluminous biomass energy feedstocks to "biorefineries". Intelligent expansion of energy networks should enhance, not degrade, the overall operational reliability and robustness of fuel and power networks.

In electric power these dynamics are well understood. The power network must be extended so that diverse and often remote generation (wind, ocean, etc.) can serve local and regional populations. Power and fuel distribution networks must be upgraded if the benefits of microgeneration, whether local combined-heat-and-power, or power distribution network support, are to be realised. These enhancements need not happen everywhere at once. In fact, staged deployments, where past experiences and technology improvements can be incorporated into successive phases of deployment, constitutes a wise strategy.

The current energy transformation/delivery network has evolved over time to deliver essentially bulk, uniform energy supplies (electricity, natural gas, petroleum fuels) to relatively non-price-responsive customers. Is this topology sufficient to deliver the more diverse, more domestic, and lower greenhouse gas energy supplies that we think we will need? Probably not, especially as we look at more dispersed/ decentralized, and intermittent/ variable renewable energy resources.

Transformation of the UK Energy Sector

To what degree do we allow the national, regional, and global energy markets to choose this new portfolio/architecture of the UK energy sector? Or, do we need a "visioning process" through which the basic characteristics of the future energy infrastructure are determined, and policies are designed which—through market and other incentives—the future energy system is implemented and refined, thereby incorporating detailed local requirements for energy services, and opportunities for targeted efficiency improvements and use of local energy resources.

Clearly, the 2003 Energy White Paper and the current Energy Review represent such a visioning process at the national level, with similar dialogues and policy debates occurring in Wales, Scotland and elsewhere. Historically, the UK as an island nation has had unique energy supply and demand constraints, and so a uniquely UK response to the energy security and low-carbon challenges is consistent with past efforts.

Informational Challenges to the Transformation

Figure CES.One grossly oversimplifies the relationships within and among energy resources/ supplies, infrastructures/ networks and end-uses. The three interrelated strategic energy policy themes —aggressive efficiency, domestic diversification, and network modernisation— have some common challenges. Foremost, they all require a detailed understanding of how energy is used, sourced, and supplied, from short-term dynamics and how they interact, to long-term potentials and how quickly they might be tapped and brought "to market". The DTI's Energy Consultation Document includes long-term baseline forecasts for both energy supply and demand. What we call for here is a similar, but much more detailed assessment of the UK's energy use patterns and domestic supplies.

Energy services in the UK vary region-by-region, season-by-season, and hour-by-hour. This includes both stationary and transport-related energy needs. Similarly, energy resources vary by region, season, and time-of-day, especially as we look to utilise more domestic and/or renewable resources. Developing the requisite information, knowledge and insights to tap renewable resources responsibly will require the participation of additional government assets. For example, the MetOffice's data collection activities could be extended to include direct and diffuse solar insolation measurements to help promote the integration of solar energy. Higher resolution collection of wind speed data, especially at prospective wind turbine "hub-heights" will help both wind farm developers and grid operators understand —and design for— the daily, seasonal and inter-annual variability of wind energy production. DEFRA's agricultural bureaus can conduct similarly focused research on the potential—and risks—to farmers, soils, and watersheds of increased fuel crop production. And finally, agencies such as the British Geological Survey will need to conduct the long-term characterization, viability, and safety analyses of potential carbon storage locations.

Investment Challenges to the Transformation

The three components for increased domestic energy security outlined above identify a need for strong governmental action encouraging investments in the fuel and power delivery networks, as well as increased innovation in energy markets for the development, deployment, and use of novel energy services, on both the demand and supply side.

The DTI's low-carbon, Supergen and other research initiatives, along with the activities of the UKERC, the Climate Trust and others, place the United Kingdom as one of the world's leaders in the development and application of new energy *technologies*. Coupled with robust research initiatives on the dynamics of energy resources and demands, these activities will help expedite the development and deployment of advanced energy *systems*.

Such investments in new technologies and their potential application are a necessary, but not necessarily sufficient, prerequisite to the transformation to a secure, low-carbon energy economy. These advances will need to be backed up by policies which give confidence to both the energy *and* financial sectors, to move forward with the sizeable outlays necessary to transform the energy sector over the coming decades. Fortunately, there are no "low investment" energy strategies. *All* energy infrastructure investments are large, it is just that some like end-use efficiency improvements, non-fuel renewable facility development, and energy network investments tend to have greater up-front costs. This is a fact of life. Governmental policies will need to be developed which encourage, rather than discourage, these types of projects.

The word "infrastructure" implies a degree of over-capacity, as developmental lead times are long, and the need to physically deliver energy in difficult but foreseeable situations requires some amount of "surplus" capacity. As the energy sector transitions to more domestic, but geographically dispersed, intermittent, and perhaps variable energy resources, ensuring some degree of "minimum excess capacity" in the network is beneficial. Already there are news reports warning of potential blackouts during the 2012 Summer Olympics in London, due to the perceived lack of investment in replacement generation capacity, not to mention additional supplies. For industrialised economies, it has been shown that the costs of interruptions are very large, and easily comparable to the "insurance cost" of investing in adequate energy supplies. This is another component of a "vision for a secure and environmentally responsible energy future" for which policies can then be designed and implemented.

Governmental policies which reward network companies to upgrade their systems to handle a more diverse and dynamic set of supplies and loads are a likely component of this "vision". Similarly, local, regional and national policies which recognize the broader benefits of a diverse energy mix must develop and put into place market and other incentives which encourage the deployment of new, domestically sourced, low-carbon energy supplies. This includes streamlined, but locally responsive, siting of new facilities, be it large nuclear power, distributed wind and biomass renewables, or fuel processing, storage or distribution facilities.

Since the 9/11 and subsequent terrorist attacks, the physical security of energy facilities and networks has become a greater concern. Are "optimised" integrated energy networks more or less vulnerable? Are cascading, or catastrophic, failures more or less likely? These questions surrounding the energy system reliability, resiliency, and robustness debate are also important, and should be part of the dialogue regarding the organisation and structure of the future energy infrastructure.

Summary

In order to offer prescriptive recommendations towards the goal of achieving "clean and affordable energy", the DTI's long-term goals will need to be operationalised. By necessity, this includes how to "manage and guide the transformation of the nation's energy infrastructures" on a decade-by-decade basis. We have identified three themes of a long-term energy strategy whereby a balanced energy sector can achieve its environmental, economic, energy security, and other goals.

In this brief communication we have focused on the need for a higher resolution, balanced approach that looks equally at the detailed characteristics of energy demand, the dynamics of a more diverse portfolio of innovative renewable and conventional energy resources, and the requirements of a modernised energy infrastructure connecting the two. It should be recognized that such an approach is not about "picking winners", but developing a broad range of opportunities on both the supply and demand side, and understanding how they, individually and collectively, can help the United Kingdom's long-term goals. In this regard, turnover and transformation of the building stock and vehicle fleets is of equal importance to changes in the fleet of power plants, the diversity of energy resources, and the energy networks over which electric power and fuels (gaseous, liquid and solid) flow.

Market mechanisms in the development and deployment of these opportunities will be very important, as will developing a shared vision of the key aspects of the UK's energy future that are essential. The transformation to this clean, affordable, reliable, and secure energy future will not be "business as usual". The concurrent goals of "substantial and sustained" reductions in greenhouse gases, "secure, reliable and affordable" energy services, are nothing if not complex, and will require concerted, focused actions in both the public and private sector if they are to be achieved.