Engineering Civilisation from the Shadows
6th Brunel International Lecture
The Brunel International Lecture

The Institution of Civil Engineers (ICE) established the Brunel International Lecture in 1999 in memory of Isambard Kingdom Brunel.

The Brunel International Lectures have covered topics ranging from Infrastructure, Technology for the Third Millennium, Sustainable Development, Poverty Alleviation, and Water for the World.

The 2006 Brunel International Lecture – Engineering Civilisation from the Shadows – draws on elements of all of them. Its focus is on the role of engineering in addressing the twin spectres facing the world in the 21st century: climate change and world poverty:

- **Poverty**: Engineering the poor out of the dark shadows cast by world poverty and the misery it generates.
- **Climate change**: Engineering the world away from the equally long shadows thrown by an energy and environmental crisis and with global climate at a tipping point.

The resolutions for these two issues are not unrelated. It was no coincidence they were the central issues at the G8 summit in Gleneagles in July 2005.

The 2006 Brunel International Lecture is launched in London on 6 June 2006, just over 200 years after Brunel was born on 9 April 1806. Over the succeeding 12 months it will be taken around the world to various venues. In particular:

- Where the Institution has members
- Where the content of the lecture is of local relevance
- Where the Institution seeks to influence change

Continual feedback, comment and input will be sought from people around the world. In that sense, it is a living lecture and will be adapted in the process of delivery. This version is just “work in progress.”
Climate change is real. It is now almost universally accepted that global climate change is a reality, and that the activities of the human race – principally through the release of greenhouse gases – are a contributory factor over which we do have some control and which we now need to exercise beneficially.

However unpredictable in terms of their precise spatial and temporal effects, the consequences of climate change – sea level rise, depletion of freshwater resources, changes in the patterns of rainfall, drought and flooding – will have the greatest impact on the most impoverished people of the world. And those least susceptible to the effects will be those most responsible for the bulk of the causative emissions.

In June 2005, National Science Academies of 11 countries – Brazil, Canada, China, France, Germany, India, Italy, Japan, Russia, USA and the UK issued a Joint Statement: 'Global Response to Climate Change'. Its opening line was: “Climate change is real.” It went on to say: “…human activities are now causing atmospheric concentrations of greenhouse gases to rise well above pre-industrial levels. Carbon dioxide levels have increased from 280 parts per million (ppm) in 1750 to over 375 ppm today – higher than any previous levels in the last 420,000 years.”

“…even if greenhouse gas emissions were stabilised instantly at today's levels, the climate would still continue to change as it adapts to the increased emission of recent decades. Further changes in climate are therefore unavoidable. Nations must prepare for them.”

“Developing nations that lack the infrastructure or resources to respond to the impacts of climate change will be particularly affected. It is clear that many of the world's poorest people are likely to suffer the most from climate change.”

“The task of devising and implementing strategies to adapt to the consequences of climate change will require worldwide collaborative inputs from a wide range of experts, including physical and natural scientists, engineers, social scientists, medical scientists, those in the humanities, business leaders and economists.”
A recent paper by Patz et al. reports that the World Health Organization (WHO) has estimated that climate change caused by industrial emissions already accounts for at least five million cases of illness and more than 150,000 deaths per year through illnesses such as diarrhoea, malaria, bacterial contamination of food and malnutrition. This offers further evidence that the issues of global climate change and world poverty are strongly interrelated.

The effects of climate change are not confined to slowly changing and spatially widespread phenomena, but are also manifest in the increased occurrence of short-term episodes of extreme behaviours such as hurricanes and typhoons. There is support for the view that Hurricane Katrina, which devastated New Orleans in late August 2005, was such an event – its power intensified by increased sea temperatures in the Caribbean Ocean. In August 1992 Hurricane Andrew proved to be a near miss for downtown Miami, Miami Beach, Key Biscayne, Fort Lauderdale and New Orleans in particular, but not for some. It resulted in severe damage to the northwestern Bahamas, the southern Florida peninsula and south-central Louisiana. US damage alone amounted to $25 billion, making Andrew the most expensive natural disaster in US history at that time. With Hurricane Katrina in 2005, New Orleans was not so fortunate. The economic damages of Katrina dwarfed those of Andrew – at least $125 billion. The social consequences are even more dramatic – and not countable in dollars...

But perhaps the major lesson to be learned from Katrina and the destruction of New Orleans was how the critical infrastructure of such a major city in the world's richest and technically most advanced nation could so easily be reduced to chaos, and with it the social cohesion of its population. And with urbanisation increasing apace globally (by 2025, the world's population will have increased by about 1.5 billion to a total of approximately 6.6 billion, and the percentage of those living in urban environments will have increased from 40% to 60%) the greatest risks to humanity will be in the lesser developed countries, and where the criticality of urban infrastructure – where it exists – is even more fragile. And where it doesn't, the consequences are even more awful to contemplate.

“Are we the first generation that can look extreme poverty in the eye, and say this and mean it – we have the cash, we have the drugs, we have the science. Do we have the will to make poverty history?” Bono
Poverty is real

Even without the effects of hurricanes, floods, earthquakes and landslides, the immediate prospects for both the urban and rural poor in many parts of the world is bleak, with little or no access to even the most basic of infrastructure, education, and healthcare, and with little, or at best tenuous, legal tenure to land or property.

Six of the eight UN Millennium Development Goals (MDGs) are directly concerned with the human condition – people's physical health, their economic and social well-being and their capacity to play a full and useful role in the world. Two of them relate to the condition we are in and how we deal with it.

In one way or another, all of the UN MDGs depend critically on the delivery – and the processes of delivery – of the underpinning infrastructure upon which civilisation depends. And not just infrastructure, but infrastructure that delivers real, pro-poor outcomes in the process of its planning, construction and operation.

UN Millennium Development Goals:

1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV and AIDS, malaria and other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development

And so, just as addressing climate change will involve engineers, so too will addressing the UN MDGs. This was underlined at a breakfast meeting held in 11 Downing Street on 30 November 2005. The critical role of underpinning infrastructure for development was stated at the outset by Calestous Juma (Chair of the United Nations Science, Technology and Innovation Task Force):

“At least three key factors contributed to the rapid economic transformation of emerging economies. First, they invested heavily in basic infrastructure, which served as a foundation for technological learning. Second, they nurtured the development of small and medium-sized enterprises, which required the development of local operational, repair and maintenance expertise. Third, their governments supported, funded and nurtured higher education institutions, academies of engineering and technological sciences, professional engineering and technological associations, and industrial and trade associations.”

It was reinforced at the same meeting by the UK Government's Chief Scientific Advisor, Sir David King:

“The key to sustainable development in Africa – that is, development that does not rely indefinitely on foreign aid – is the creation of infrastructure. Part of this is a purely physical matter: a question of civil engineering. The business and finance communities in African nations identify the lack of good roads, railways, air and water transport facilities, energy and water supplies, and telecommunications networks as one of the main obstacles to economic growth.”

Of all the UN MDG targets, perhaps those that could have the most impact are those relating to safe water supplies and waste water disposal. Never has there been a truer statement than that which first appeared on a WaterAid poster over 20 years ago: “To judge the health of a nation, count the taps not the hospital beds.”

Two billion people worldwide are currently without access to an adequate water supply. The UN's target is to halve that number by 2015. And that in the face of a world population that is becoming more and more urbanised. Providing safe water for one billion people by 2015 means connecting more than a quarter of a million people per day, every day, for the next 10 years. Can it be done? And if so how?

In another pre-G8 call, and from a very different quarter, Bono, the lead singer of U2, laid down the challenge:

“We are the first generation that can look extreme poverty in the eye, and say this and mean it – we have the cash, we have the drugs, we have the science. Do we have the will to make poverty history?”

(Bono)
Visions of the future—seeing the big picture

It is clear that there are two global issues that affect us all and in which we are all players. There will be no spectators as the future unfolds. But there are particular implications for civil engineers and the Institution of Civil Engineers. And not for the first time.

Brunel

To many engineers—and to many non-engineers too—Isambard Kingdom Brunel was one of the 19th century’s great heroes. Not just an engineering hero. A man of short physical stature but a giant among his peers. The obvious questions arise: How would Brunel respond to the challenges of the 21st century? Would he have been an engineer at all? If he had, would he be motivated by the fascination of machines or by the needs of people? Would he have seen how to use the former to deal with the latter? Just how would he have dealt with the colossal issues of today?

Brunel’s engineering education and training was a combination of the theoretical and practical, of subjects broad and deep, technical and non-technical. When the young Brunel was eight years old, his father, the engineer Marc Isambard Brunel, sent him to a school at Hove on the south coast of England. Here he amused himself by making model boats and surveying and sketching the local buildings. This ‘drawing habit’ (sketching) was something he picked up from his father, who had always insisted that it was as important to the engineer as knowledge of the alphabet. It undoubtedly helped to develop Brunel’s extraordinarily acute powers of observation and visualisation.

His early education ranged from Euclid’s geometry to the Latin poetry of Virgil and Horace. As a 14 year old, Isambard was sent to Caen in France, so that he might have an advanced mathematical education, in preparation for taking the entrance examination to the Ecole Polytechnique. His introduction to engineering practice and project management was rapid. As a young engineer, aged barely 20, he took on heavy responsibilities almost from the start, in the face of great personal and project risks. Few engineers can have paralleled Brunel’s induction to civil engineering—as resident engineer for the Thames Tunnel.

Throughout his life, he was a man of tremendous vision, persuasion and innovation. Always driven, often stubborn, sometimes vainglorious, perhaps occasionally almost reckless with his investors’ money, and it has to be acknowledged, also with the lives of some of his workforce, but always at the forefront. He got things done, sometimes at whatever the cost. Brunel’s engineering was essentially all about that part of the Tredgold definition of civil engineering to do with trade, commerce and opening up markets, and in particular, getting raw materials to the centres of production and finished goods to market—quickly and cheaply. We see it today still in perhaps his greatest legacy—the Great Western Railway. We see Brunel the man in that most famous photograph, wearing his stovepipe hat and with his trademark cigar, standing in front of the launch chains of the largest boat then set to sail the oceans—the Great Eastern. Ironically, simultaneously his greatest success and failure, and which probably contributed to his early death at the age of 53. But what would he have made of today?

Brundtland

In a dictionary of biography, the name of Brundtland would be found pretty close to Brunel.

Gro Harlem Brundtland chaired the World Commission on Environment and Development, which led to the publication of what has become known as the ‘Brundtland Report’ in 1987, and which in turn led to the first Earth Summit in 1992 in Rio de Janeiro. The Brundtland Report also led to the landmark concept of what is now known as sustainable development:

“Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”
and entrepreneurs.

works were funded mainly by the public

itself, rather than directly supporting the

underpinning infrastructure for civilisation

to do with a less explicit part of the

Bazalgette? Again, not too far away

century engineering hero, Joseph

But what about that other 19th

a 19th century engineering hero of whom

a 19th century engineering hero of whom

Joseph Bazalgette's response was to

Authorised that after 18th

Authorised that after 18th

Legislation enacted in the early 1800s

when the stench from the Stygian Thames

Chief Engineer to the Metropolitan Board

No, this wasn't about Africa in 2005.

reformers, campaigners and celebrities

incidence of child mortality. Social

It wasn't Bono and Bob Geldof and Live 8.

reformers, campaigners and celebrities

Their time was yet to come. No, this was

It wasn't Bono and Bob Geldof and Live 8.

As their paddles churned up the sewage

Bazalgette's defining issue (sic) was

the year before construction began).

1,300 miles of brick built sewers, pumping

scheme cost £4.5 million and comprised

1858) empowered the Metropolitan

Board of Works to borrow £3 million,

1858) empowered the Metropolitan

10

10

10

10

10
Determined to challenge orthodoxy in A self-proclaimed movement; inspired characteristics have been interpreted as the Age of Enlightenment, whose defining and temporal scales – was a product of physical behaviour at a range of spatial do they relate to those of today? and Bazalgette operated and how economic conditions in which Brunel What were the technical and and economics Engineering, technology of technological innovation.

Adapted from Joseph Schumpeter's A sighted engineer, who probably did Of the great sewer that runs beneath, their life expectancy: had played an unseen hand in extending the masses were barely aware, but who the Registrar-General could tell them that its existence has added Londoners know, as a rule, nothing, Of the great sewer that runs beneath, "Joseph Bazalgette: That great, far-seeing engineer, who probably did twenty years to their chance of life."

importance of human rights (or accordance with human reason, optimism and faith in human progress, existing ideas but also of institutions) all its forms (not just the orthodoxy of new 'philosophy of science'

"Joseph Bazalgette: That great, far-seeing engineer, who probably did twenty years to their chance of life."
In his ICE Presidential Address in November 2005, Gordon Masterton reflected on the challenge of 'Sustaining our Future':

"In its broadest sense we, as engineers, need to view the 'big picture' in all we do. Brunel addressed the big issues of his time – the growth of trade, and transportation's crucial role in this. If Brunel were alive now, his global vision and genius would be applied to the planet-sized problems of today. Solving these problems will require civil engineers working in partnership, crossing disciplines. We need to use our engineering know-how to help influence and educate decision-makers – including the public stakeholders – to take a global view of sustainability issues."

Society has evolved through various phases of social, economic and technological change. Episodes of technological innovation were followed by their economic exploitation in a series of waves that has taken in the emergence of waterpower/canals/iron/textiles in the late 18th century; steam power/railways/steel in the mid 19th century; and the emergence of electricity/chemicals/the internal combustion engine in the early 20th century. The mid 20th century was characterised by petrochemicals/electronics and aviation. At the start of the 21st century we are in the IT era of digital networks, software and new media, but there is a growing sense that progress isn't the sole province of technology. It is becoming increasingly clear that tomorrow's underpinning drivers are more about environmental issues and social objectives, rather than simply technological and economic development. And that interface between human/social demands and the application of technology is – as it always has been – the domain of the civil engineer.

But the critical infrastructure that benefited the UK, as the foremost engine of the industrial revolution in the 19th and early 20th centuries we now know did not always serve others so well. For example, the initial transport networks in places such as Africa were focused on shifting raw materials to the ports for export rather than to stimulate local industrial development and capacity. And even today, transport costs in countries such as Uganda add the equivalent of an 80% tax to its clothing exports.

At the beginning of the 21st century access to the most basic of infrastructure is still seemingly beyond the reach of millions in the developing world and without it the achievement of the UN Millennium Development Goals will remain a dream. It is time that dream was turned into a reality.

In his introduction to the Brandt Report over 20 years ago, Willy Brandt wrote: "What limits our response to the challenges of the present crisis? It is not primarily the lack of technical solutions, which are already largely familiar, but the lack of a clear and broadly reflected awareness of the current realities and dangers, and an absence of the political will necessary to meet the real problems. Only a new spirit of solidarity, based on a respect for the individual, the national heritage and the common good, can make possible the achievement of the solutions so desperately needed." and later in the report with regard to energy… "Promoting energy research in the third world: …to assist developing countries in negotiating energy contracts and assuring energy supplies; to assist them in the more appropriate use of traditional energy sources, particularly fuel wood, which is now being used at an unsustainable rate with profoundly damaging effects on the environment and agriculture of the world; to examine the feasibility of alternative traditional energy sources, particularly cost effective and low technology means of generating energy; to promote sub-regional and regional co-operation in reducing energy costs and enduring energy supplies for developing countries."
outcomes for those problems of global
not necessarily lead to acceptable decision
opportunities.

money and reflect the sense of future risks
Rate, and with it the notion of net present

In engineering, there is always a tendency
to do so wherever possible.

the world. Engineers and economists alike
have tended to do so wherever possible.

the greatest number” – and with it the
imperative “the greatest good for

the concept that the human tendency is

to maximise economic efficiency – ie ‘the

the equivalent is the Discount

Perhaps for

simplest models available to understand
the nature of capitalism, and the works of people
such as Adam Smith (1723-1790),
Benjamin Dessus (1806-73), and Karl Marx (1818-1883).

Jeremy Bentham (1747-1832),

the other great idea of the time – the

Law to relate stress and strain. Perhaps for

In a pre-echo of Brundtland and

Brandt, it was Bentham who coined

the idea that economics transcend the laws of

thermodynamics and principles of social

affairs. And neither can the ‘laws’ of

results in an equitable, a better, a more

optimal allocation of resources’. It says

to maximise economic efficiency – ie ‘the

human tendency is

occurrence.

have its price. And the planet and some

nothing about whether this optimality

convergence.

Contraction and

Commons Institute

Adapted from Global
This example shows rates of C&C negotiated as regions. This example is for a 450ppmv contraction budget, converging by 2030.

India
China
FSU
OECD less USA
USA
Rest of world

Tonnes Carbon Per Capita

Gigatonnes carbon gross

1800
8GT

6
3
0
4GT

1900 2000 2030 2100 2200

Britain
United States
France
Japan

1880 1920 1960 2000 2040

Oil equivalent in tonnes for $10,000 of GDP

0.4
0.2
0

AB
learning curve as measured by the variation through time of the ratio of energy use per unit of GDP. Typically, as an economy develops, energy dependency grows very quickly with investment in basic infrastructure, heavy industry, transport networks, and urbanisation. Energy use per unit of GDP then falls off as the economy matures. History also shows that newly industrialised countries are successively less energy-dependent during their primary growth period as they learn technologically from their predecessors. This will temper – but only to a limited extent – the impacts of newly emerging economies.

But atmospheric CO2 levels are reaching critical levels and there must be a strategy to stabilise concentrations to a (relatively) safe level, and with the Kyoto process in limbo, some other process or protocol will be required to arrest the asymmetric pattern of ‘Expansion and Convergence’ and which leads to a more equitable and less self-destructive use of the earth’s resources.

The ‘Contraction and Convergence (C&C) Strategy’ proposed by the Global Commons Institute, offers such a process, drawing widespread interest and support, for example from the Indian Government, the Africa Group of Nations and the USA. In December 1997 at the United Nations Framework Convention on Climate Change (UNFCCC) in Kyoto – and shortly before they withdrew from the Kyoto negotiations – the USA stated:

“Contraction and convergence contains elements for the next agreement that we may ultimately all seek to engage in.”

The US Delegation to UN Framework Convention on Climate Change, Kyoto

“The UK should be prepared to accept the contraction and convergence principle as the basis for international agreement on reducing greenhouse gas emissions, and should adopt a long-term strategy for reducing its own emissions.”

The UK Royal Commission on Environmental Pollution

The integrity of the C&C approach was reinforced by the 2000 report of the UK Royal Commission on Environmental Pollution, which concluded:

“Given current knowledge about humanity’s impact on climate and the UN Intergovernmental Panel on Climate Change’s findings, we support 550 ppmv as an upper limit on the carbon dioxide concentration in the atmosphere. Major reductions in global emissions are necessary to prevent that limit being exceeded. The UK should be prepared to accept the contraction and convergence principle as the basis for international agreement on reducing greenhouse gas emissions, and should adopt a long-term strategy for reducing its own emissions.”

The same report also stated:

“There is no foreseeable prospect of some magic source of almost unlimited energy with negligible environmental impact. Nuclear fusion has sometimes been advocated as that, but it is still at the research stage and a commercial scale demonstration plant seems unlikely to be constructed before 2050. Its environmental impact, as well as its economic viability, have yet to be clarified.”
The achievement of a sustainable energy economy requires a participatory, democratic and inclusive policy environment. The pursuit of energy efficiency, including the gradual phase-out of old inefficient power plants, is the key to meeting future energy demands. It is clear that radical changes are needed, and that a knowledge gap exists. There is growing recognition of the need for a long-term strategy for the energy system and society, but also of the complexity of the challenge. It is important that we are all energy consumers, and that we understand our role in the energy system. What changes need to be made to allow us to work or leisure, people are at the centre of the energy equation, there are just three approaches: change our behaviour, change the fuel, change the technology.

There is no magic bullet. There are just three approaches: change our behaviour, change the fuel, change the technology. Whatever the solution, we need to be aware of the potential impact on the environment, the economy, and society. It is important that we are all energy consumers, and that we understand our role in the energy system. What changes need to be made to allow us to work or leisure, people are at the centre of the energy equation, there are just three approaches: change our behaviour, change the fuel, change the technology.

Changing our behaviour involves changing our habits, our preferences, and our values. This can be done through public awareness campaigns, education, and incentives. It is important that we are all energy consumers, and that we understand our role in the energy system. What changes need to be made to allow us to work or leisure, people are at the centre of the energy equation, there are just three approaches: change our behaviour, change the fuel, change the technology.

Changing the fuel involves changing the energy sources we use, from fossil fuels to renewable energy. This can be done through subsidies, taxes, and regulations. It is important that we are all energy consumers, and that we understand our role in the energy system. What changes need to be made to allow us to work or leisure, people are at the centre of the energy equation, there are just three approaches: change our behaviour, change the fuel, change the technology.

Changing the technology involves changing how we use energy, from inefficient to efficient technologies. This can be done through research and development, and innovation. It is important that we are all energy consumers, and that we understand our role in the energy system. What changes need to be made to allow us to work or leisure, people are at the centre of the energy equation, there are just three approaches: change our behaviour, change the fuel, change the technology.
Coal and technology

In the early days of the industrial revolution, coal was the dominant energy source. As technology advanced, other fuels began to supplant coal. In the 20th century, the focus shifted to nuclear power as a viable alternative. However, the nuclear option has faced significant challenges, including safety concerns and public resistance. In recent years, there has been a renewed interest in coal as a source of energy, driven by concerns about climate change and the availability of new technologies for coal conversion.

Changing the technology

Underground coal gasification (UCG) is a process that involves injecting air, steam, or a carbon dioxide/oxygen mixture into coal seams below ground. This process releases methane, which can be collected and used as a fuel. In addition to UCG, there are other technologies being developed to convert coal into a clean fuel. These technologies include clean coal technologies, which involve capturing and sequestering carbon dioxide emissions.

The diagram illustrates the various options for converting coal into a clean fuel. The options include:

- Syngas production
- Underground coal gasification
- CO2 capture and injection
- Methane production
- FLue gases scrubbing

These technologies are being researched to reduce the environmental impact of coal use and to provide a sustainable energy source.

The nuclear debate

The nuclear power industry has faced significant challenges in recent years. The costs of building new nuclear power plants have been high, and there have been concerns about the safety and security of nuclear power plants. Despite these challenges, nuclear power continues to play an important role in the energy mix in many countries. The debate over nuclear power is likely to continue, with proponents arguing for its benefits and opponents arguing for alternatives.
What is certain is that the nuclear option needs to be re-engineered – starting with the issues of nuclear waste management and risk. Otherwise, securing the necessary public acceptance will be difficult. There are already concerns that keeping the nuclear option open will effectively foreclose on other carbon free and renewables opportunities, and on initiatives to change energy demand behaviours.

But nuclear is certainly back on the agenda, as evidenced perhaps most strikingly by the change of heart by the environmental scientist and creator of the Gaia hypothesis, James Lovelock:

"Nuclear power is the only green solution. When, in the 18th century, only one billion people lived on Earth, their impact was small enough for it not to matter what energy source they used. But with six billion, and growing, few options remain; we cannot continue drawing energy from fossil fuels and there is no chance that the renewables, wind, tide and water power can provide enough energy and in time. Every year that we continue burning carbon makes it worse for our descendants and for civilisation."

And if nuclear is the only solution, is it a solution that will be available to all nations – or only to some?

Grid versus non-grid?

By and large the power supplies in the developed economies have evolved from local generation and local distribution into highly interconnected power grids and with generation focused on high capacity power stations of one type or another. Power systems evolved in this way for two principal reasons: to protect against local supply failures by interconnecting consumers to a wider network, and to achieve economies of scale and plant reliability by concentrating generating capacity on larger power plants. The economic price of distribution losses was deemed worth paying.

The combination of large-scale interconnected grids and large-scale generation has become the established paradigm, and which it might now be time to question. Smaller scale generation equipment is no longer so inferior in terms of unit costs or reliability to justify the high rates of energy losses in the grid. And it is increasingly the case that grid failures – not generation failures – are the cause of widespread power blackouts, as evidenced by a number of recent large scale power outages in places such as Italy (September 2003), the north-eastern states of the USA and Ontario, Canada (August 2003) and Auckland, New Zealand (January – February 1998). In all three cases the initial incidents were local and relatively minor, but whose effects cascaded into catastrophic grid failures.

Such effects had been predicted as long ago as the mid 1980s by Amory and Hunter Lovins, who had warned that the structure of the North American electrical network made the system fundamentally vulnerable. When asked recently if things had improved in the past two decades, Amory Lovins is reported to have said, "I'm surprised the lights are still on."
Project in the Moray Firth.

pipelines), for example the Beatrice infrastructure (platforms and subsea interesting examples being developed evokes less opposition, and there are some interconnector access. Offshore wind of demand and with poor grid and problem of being distant from centres the world, and often with the additional be in remote and often beautiful parts of least by its intermittency. By its very nature, might endanger migrating birds, and not aesthetic/noise grounds; or because it who are against it on environmental/without its detractors, including those carbon free energy source, but not Wind has become a well-established, Wind, wave, tidal?

Changing the fuel

of the world.

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Energy Centre58 in Orkney and also in being tested at the European Marine Power Delivery57 in Edinburgh, is now 'Pelamis' device, developed by Ocean A number of devices are now undergoing 2010 and be significant by 202059. pull' for hydrogen is likely to emerge by vehicles. In the transport sector, a 'market combustion gas and as a fuel for road electrolysers could provide a means to reconvert it to electricity. On the demand-side, electrolysers can serve to 'valley fill' greater capability to capture renewable energy, temporarily store it and then balance out these variations and offer a

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The proportion of renewables that can be integrated into the existing electricity be required to operate in even more who still doubt its economics55; those be in remote and often beautiful parts of least by its intermittency. By its very nature, might endanger migrating birds, and not aesthetic/noise grounds; or because it who are against it on environmental/without its detractors, including those carbon free energy source, but not Wind has become a well-established, Wind, wave, tidal?

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The proportion of renewables that can be integrated into the existing electricity be required to operate in even more who still doubt its economics55; those be in remote and often beautiful parts of least by its intermittency. By its very nature, might endanger migrating birds, and not aesthetic/noise grounds; or because it who are against it on environmental/without its detractors, including those carbon free energy source, but not Wind has become a well-established, Wind, wave, tidal?
In the remote village of Ngarambe, on the edge of the Selous National Park in Southern America, bring us back into a cycle of poverty. At the beginning of the 21st century, it is unacceptable for millions of people to live without access to electricity! (Claude Mandil64)

Energy security is a priority for many governments, particularly in recent months as fears of oil supply disruptions dominated the headlines. At the time of the International Energy Agency, we view energy security concerns as closely linked with economic development and international development are central to the issues of world poverty and the alleviation of human tragedies associated with it. Two of the eight UN MDGs, adopted by the UN in September 2000, and to which world governments have committed to meeting by 2015. On current evidence, the chances for achieving these targets are slight. As engineers we are a key profession in helping the world to meet these targets, and we have a role to play… but we must ensure that it is a sound technology whether it be coal or nuclear power, renewable energy. Technology, both large and small, has its role to play.

The engineer's role in energy security concerns is to be addressed at the global level. And the UN Millennium Development Goals programme65 are:

- Providing energy to low-income communities
- Prioritising the productive use of energy
- A strong focus on affordability
- A link between development and energy security concerns
- Delivering the UN Millennium Development Goals
- Engaging with local partners to build skills and know-how
- Providing energy to low-income communities
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Humanity now faces its greatest challenges - addressing issues of climate change and sustainability on the one hand and poverty reduction and governance on the other.

There are certain prerequisites for development, without which attempts to improve livelihoods in the developing world will be unlikely to succeed. Such prerequisites include reasonable governance structures; a functioning civil society; and freedom from persecution, conflict, and corruption.

Thandika Mkandawire, cited and then amplified the comments of Nobel Laureate Amartya Sen: "Development, Amartya Sen has suggested, means the expansion of choice for individuals and societies. It would be the height of irony if aid, which has been used to push for democratic reforms in many countries, were to produce 'choiceless democracies'. To support accountability in the new democracies, there is a pressing need to rethink the institutions that underpin the current management of aid. The message of my remarks is that aid belongs to that category of economic activities in which it is important to proceed by trial and error. This, in turn, requires dialogue and a more deliberative partnership. African politics is changing rapidly."

The impact of global politics, trade and conflicts on development is immense. These include trade rules, tariffs and western subsidies, local and regional conflict, oil diplomacy, governance, and the roles of transnational companies.

The importance of a thriving local private sector (large and small) in poverty alleviation is equally critical. A climate in which individual traders and small businesses can thrive is just as important as the growth of larger industry. A functioning local business sector can also help deliver poverty-reduction outcomes through direct involvement in the development of effective and sustainable infrastructure, which in turn is of critical importance for three reasons:

1. It underpins communities by providing the basic needs and services of shelter, access to safe water/sanitation, energy, transport, education and healthcare
2. It provides an internal demand for local skills and employment through its delivery
3. It provides a vital platform for the growth of the local economy and small and medium sized enterprises through improved access to infrastructure services, local skills, and the stimulation of and better access to both internal/local and external/national markets

But infrastructure delivery also requires investment. Those mired in poverty do not have and cannot afford all the resources necessary to resolve their plight. They will need external investment from business and the international agencies, and assistance from the worldwide engineering community.
The Institution of Civil Engineers, as one of the world's leading professional engineering bodies, has both an opportunity and a duty to play a prominent role in human development and sustainability.

ICE and its members have had a long-standing interest in development work and disaster relief, supporting the establishment of RedR in 1979, establishing the Appropriate Development Panel in 1984, and establishing the Telford Challenge (now Engineers Against Poverty, EAP) with the Institution of Mechanical Engineers in 1998. ICE approved its Sustainability Charter in 2003 and has been actively working to embed sustainability competencies throughout the education and training of the civil engineer.

In November 2003, then ICE President Douglas Oakervee announced in his Presidential Address his intention to establish an ICE Commission – “Engineering without Frontiers” (ICE-EwF) to inquire into society's expectations of the engineer in the 21st century, and in particular to determine the role of the engineer and ICE in achieving the UN MDGs and their contribution to international development.

Momentum was continued during Colin Clinton's year as ICE President, with visits to a number of development and poverty reduction projects in Kenya and Tanzania. These allowed ICE to see what those involved were trying to do, hear of their expectations in terms of international development and poverty reduction and establish ICE's role in this process.

And Gordon Masterton, the current ICE President, in his Presidential Address pointed out the critical role of the civil engineer in terms of building civilisations. A 'Protocol for Engineering a Sustainable Future for the Planet' is ready for signature on 4 July 2006 by the Institution of Civil Engineers, the American Society of Civil Engineers (ASCE) and the Canadian Society of Civil Engineers (CSCE) at their triennial conference in London. This will bring together the work of the ICE-EwF Commission on International Development and Poverty Reduction, with those other key interlinked issues of our times – climate change and energy.

ICE-EwF's prime tasks were to consider:

1. Expectations
   What does society expect of an engineer in the 21st century?

2. Critical activities
   What are the critical activities required to meet the UN MDGs?

3. Partnerships
   How can ICE integrate these ambitions with related organisations already involved?

These have emerged as follows:

Expectations

"The delivery of effective infrastructure services appropriate to international development and poverty reduction."

To provide, maintain, improve and sustain the infrastructure that supports and underpins civilisation: ie equitable access to water supply/wastewater disposal; shelter; transportation systems; waste management and energy.

The same basic requirements apply both in the developed and developing worlds although the starting points are different and so are some of the required solutions and delivery mechanisms. This in turn requires engineering education/training/capacity building in 'development engineering', not only in developing countries themselves, but also important to engineers trained in the UK and similar environments engaged in development work.
Critical activities

Advocacy, influence, and the exercise of the engineering skills to make it happen.

The development and deployment of project management and appropriate engineering skills necessary to fulfil society's expectations of the engineer to deliver the infrastructure to achieve the UN MDGs.

The adoption of appropriate forms of procurement and engineering standards for international development.

Partnerships

The mobilisation of the engineering community in partnership with other sectors to create the high level delivery mechanisms to scale up the response.

An engineering vision for MDG implementation

The MDGs viewed as an engineering project?

If engineering is truly to deliver the best possible outcomes to society, engineers must understand their role in this wider field, and shape their work and their contribution accordingly. So this is our challenge:

As key implementers, how can we produce an action-based plan, to ensure that the MDGs are met while achieving sustainability worldwide?

It raises some key issues.

Engineering activity must be directed towards outcomes – measurable against the MDG targets themselves – not simply the construction of infrastructure artefacts, but infrastructure that delivers.

We need to focus on helping to provide sustainable livelihoods through a 'people centred' approach to poverty reduction. Its starting point should be an analysis of how people survive and thrive, adopting a holistic (systems) view and taking account of the vital role of cross-sectoral partnerships. Capacity building and community involvement is important if development is to be sustainable and not imposed inappropriately by external bodies. Related to this are transaction costs and livelihoods. Problems for the poor are often not to do with supply per se, but to do with the costs and access to supplies and services. This is an important issue in the debate on the benefits of privatisation of utilities and services. It also raises the issue of whether there is a case for a rights-based approach to local governance – especially important in those communities, which are excluded by virtue of illegal/disputed property rights.

Emerging technologies will play a role, perhaps not central but nevertheless important, for example, renewable energy as a means of local access to power, and wireless communications as a means of access to knowledge and services, and indirectly to gender equality. The limiting factors are not a lack of engineering knowledge and technology or knowing what needs to be done, but finding ways of applying that engineering technology, building local capacity to ensure its effective delivery, managing and financing it, and ensuring that its application is maintained.

Whilst engineers must remain experts in their particular fields, they must also understand – and play an active part in – the interactions between infrastructure development, the environment, culture/society/community, the economy and the political/public/private/third sector organisations involved. Just as with the development of energy futures, engineering for international development is not an apolitical activity.

Some key questions need to be answered with regard to:

- Engineering education and professional leadership for development
- Appropriate standards, primary engineering and community involvement
- Procurement, unblocking barriers and finding effective delivery models
- Related high level delivery, political and business issues
- Links with engineering organisations overseas
- Tapping the diaspora, capacity building and institutional learning
- Policy development, advocacy and influence

These issues are addressed over the following pages.
ICE is seeking to develop engineering as a valid route to membership73 and ICE explicitly recognises projects72.

Supporting international development courses, undertaking research and activities range from running training and over 2,000 members, and whose youth represents hope for the future. In international engineering partnership of covering all the world's continents. This national branches in over 50 countries predominantly young engineers, with youth has the energy and motivation to help deliver the world from the shadows of poverty, as amply demonstrated by the enthusiasm of youth and young engineers.

What should civil engineers of the 21st century be like? To what extent does the Institution's values and aspirations reflect those of ICE's routes to professional development? Do we currently have the appropriate structures in industry to enable all this to happen? What changes might be needed to enable industry to support engineers who wish to contribute to development in some way? How can society harness the energy and motivation of youth in the very successful scheme that has been established to reform the procurement system from two points of view – good governance and the use of procurement processes in South Africa government in 1995 to lead a three-man procurement reform task team established to reform the procurement system and how could development infrastructure project financing and procurement issues? Procurement, unblocking barriers and finding effective delivery models for development engineering.

Civil Engineers – SAICE) and his significant experience76, 77, of similar issues in South Africa and internationally. Watermeyer was seconded to the South Africa Department of Water Affairs to develop a model, or multi-sector partnership, project financing and procurement issues? Procurement, unblocking barriers and finding effective delivery models for development engineering.

A piece of action-based research on appropriate procurement, undertaken by EAP on ICE-EwF's behalf, has been particularly encouraging, resulting in a series of Round Table meetings in Kenya, Indonesia, India, London and Nigeria75. One outcome of that work was an article co-authored by EAP and published in the ICE journal of International Development (DfID). This article outlines the route of a joint venture 'pain and gain' programme and was closely involved previously been project manager of Soweto's contractor development programme and was closely involved in community-based job creation for local resource based engineering. How could development infrastructure engineering be improved by development funding be improved by tighter conditionality aspects relating to pro-poor outcomes and poverty engineering? Could the benefit of outcomes from development projects?
have shown. According to Action Aid, financial, as recent reports and events Watermeyer stated:

In his SAICE Presidential Address, A...
professionals across the world, with offices federation of RedRs providing training vision has evolved into an international front-line relief agencies”. Guthrie’s engineering profession, who would be who volunteered from across the work and compiled a register of engineers, need for engineers to help in this sort of people in Malaysia. He “saw the pressing experience working with Oxfam as the by Peter Guthrie in 1980, as a result of his Engineers for Disaster Relief – established of humanitarian crisis has been RedR – engineering and related expertise in times effective – organisations for tapping into disaster risk reduction? How can we work with respect to pro-poor development and support their aspirations and priorities developing countries to better understand with sister engineering organisations in Africa, India, London and New Zealand. Andhra Pradesh. improved sanitation to villages in rural Hyderabad to bring clean water and working with the Byrraju Foundation in Sri Lanka, example of pit latrines. Temporary housing. Post-tsunami Sri Lanka, example of pit latrines. Temporary housing. 

Links with engineering organisations overseas Links with engineering organisations overseas

One of the most successful – and most

infrastructure development offers a

specific reference to infrastructure:

The benefits of this general approach are

also noted by Ridley and Lee89 with

the migration of skilled manpower etc) from developing countries, in

Concerns are often expressed about

Some cases as a result of active

building and institutional learning

the “supply chain” to build a wider

how the skills of RedR and its experience

world. Perhaps it is now time to consider

relieve humanitarian suffering across the

undertake particular RedR missions to

and by the release of personnel to

business community has been prepared

natural and man-made disasters the

building into the curricula extended

for service in local government – in

program of decentralisation. The

in Uganda as part of the government’s

personnel working at the local level) is

rectify (the lack of suitably qualified
Policy development, advocacy and influence

To what extent and how should the Institution make its members more aware of the issues surrounding development and sustainability? Involvement in high-level policy issues will always have the potential to be controversial. But, ICE must be bold. It must:

- Advocate to government, business and the international community the vital importance of effective infrastructure in the fight against poverty
- Argue and demonstrate the need for appropriate procurement processes engaging the international engineering community together with developing technical know-how and the local skills base
- Play a major role in the Anti Corruption Forum to fight corruption in international development projects
- Build and support the international engineering community in creating the partnerships to deliver
- Advocate its view that the UN MDGs will only be met if they are treated as a series of projects, rather than just one grand project, and that civil engineering is best placed to help to deliver
We need to communicate and advocate these positions vigorously— to governments, businesses, our members and other stakeholders. We are doing this already: in a UK Parliamentary debate on international development Tony McWalter stated:

“In the body of evidence is a memorandum from ICE, and if Members are interested in reading only one memorandum, they should read that one, because it contains so much that is relevant to our essential problem.”
Tony McWalter MP
Key messages to G8 leaders and the media

"The ICE-EwF Commission welcomes the outcomes from the G8 summit and the move to write off ODA debt. The door is now open for engineers to work in partnership with other key stakeholders – communities, governments, NGOs, international agencies and financial institutions to start work on the critical infrastructure – in particular water supply and sanitation – needed to achieve the UN MDGs: ‘to measure the health of a nation, count the number of taps, not the number of hospital beds.’"

"ICE will be communicating these views to G8 leaders and the UN, advocating the ICE-EwF ‘Principles for Development and Poverty Reduction’ as a platform for partnership, collaboration and delivery by all parties."

"The world is at a tipping point in terms of international development and the UN MDGs. There is a window of opportunity, opened further by the mood of public opinion, the work of the Africa Commission and the pressure on the G8 leaders at Gleneagles in July, to address poverty reduction and climate change."

"Engineering and engineers have a vital role to play over the next 10 years, making their contribution to development and poverty reduction and the achievement of the UN MDGs."

"The engineering community is ready to unlock the human potential, to create the international partnerships, and build the infrastructure that will reduce world poverty and deliver the UN MDGs – on time, on budget."

"We at the reseach and the engineering community will deliver the ends."

"The engineering community is ready to unlock the human potential, to create the international partnerships, and build the infrastructure that will reduce world poverty and deliver the UN MDGs – on time, on budget."

"Will the means and the engineering community will deliver the ends."
The long march to making poverty history.

Credit: Paul Jowitt

The next steps

International development and poverty reduction is now firmly high up on both the international political agenda and the Institution's. In both cases, this represents a sea change in recent times. Despite scepticism from some quarters, never has the issue of international development been so prominent in the minds of the public (both in the UK and internationally), the international community (governmental, inter-governmental), NGOs, business, and not least, across the generations of ICE's own membership. It is also coupled, through the UN MDGs and the 2005 G8 summit, with the other major global issues of our times – climate change, carbon emissions and energy policy.

As one ICE-EwF Commissioner and former ICE VP has indicated:

"The Institution has a role to represent its individual members on a collective basis, and by doing so, to influence for the public good the direction of government and society. This has the uncomfortable consequence that ICE must have a position on issues that it has historically choked on."

The challenge for ICE – and others – is how to embed and build on what has been achieved so far, transferring momentum to other bodies outside ICE establishing effective interactions and relationships to move the agenda forward and to create multi-dimensional partnerships for delivery within and beyond the engineering community.

"We need to start the process of engineering civilisation out of poverty and away from the threat of climate change – now."

■ Engineering the world away from the equally long shadows thrown by an energy and environmental crisis and with global climate at a tipping point

■ Engineering the poor out of the dark shadows cast by world poverty and the misery it generates

Postscript: paying the price?

Brunel, Bazalgette, Bentham, Brundtland…

At the beginning of the 21st century people such as Bob Geldof and Bono have mobilised international opinion. To reiterate:

"We are the first generation that can look extreme poverty in the eye, and say this and mean it – we have the cash, we have the drugs, we have the science. Do we have the will to make poverty history?"

Be in no doubt: There will be 21st century engineering heroes to parallel Brunel and Bazalgette. The engineering community is ready to unlock the human endeavour, to create the international partnerships and build the infrastructure that will reduce world poverty, ready to deliver the UN MDGs – on time, on budget. Will we the means and the engineering community will deliver the ends.
The engineering community is ready to unlock the human endeavour, to create the international partnerships and build the infrastructure that will reduce world poverty, ready to deliver the UN MDGs – on time, on budget.

Will us the means and the engineering community will deliver the ends.
Acknowledgments
Paul Jowitt is Professor of Civil Engineering Systems and Executive Director of the Scottish Institute of Sustainable Technology at Heriot-Watt University. He is also a Board Member of Scottish Water.

He is a graduate of Imperial College, London and was a Lecturer in the Civil Engineering Department there from 1974, until he took up the Chair of Civil Engineering Systems at Heriot-Watt University in 1987. In 1989 he was appointed Head of the Civil Engineering Department and then Head of the combined Department of Civil and Offshore Engineering from 1991 to 1999. Since 1999 he has been Executive Director of the Scottish Institute of Sustainable Technology (www.sistech.co.uk), a joint venture between the University and Scottish Enterprise, established to put sustainability into practice. Its operational activities are based at Heriot-Watt University (predominantly at its main campus in Edinburgh but with links to the International Centre for Island Technology in Orkney).

Paul Jowitt's major research interests concern the issues of sustainable development, risk, and the development of systems-level solutions within civil engineering, the built environment and environmental management. A recent paper for the Institution of Civil Engineers (ICE) on the educational formation of the civil engineers and their role in terms of sustainable development was awarded the 2005 ICE Trevithick Prize.

Major areas of activity have included water resources systems modelling, asset and resource management and the environmental and engineering applications of systems modelling, optimisation, reliability and risk assessment. This research has been funded mainly by a combination of research grants and water industry research contracts in such areas as water distribution systems, wastewater treatment plant modelling & control, drought management and sustainable water resource management.

Paul Jowitt is Vice-President of the Institution of Civil Engineers, and Chair of the ICE Presidential Commission ("Engineering without Frontiers") to examine society's expectations of the civil engineer in the 21st century and the engineer's contribution to meeting the UN Millennium Development Goals.

He also serves on ICE's Environment and Sustainability Board and was Chair of an ICE Council Task Group to embed sustainable development into civil engineering curricula and professional development. He is a former Chairman of the East of Scotland Region of ICE and the Scottish Hydrological Group.

He is Editor of the international journal 'Civil Engineering and Environmental Systems', a former Editor of ICE's Water, Maritime and Energy Journal (1998-2001). In 1996 he presented a lecture on water resources at the Edinburgh International Science Festival entitled "From the Metamorphosis of Ajax to the Sweet Water of Leith". He is a member of 'The Edge' – an ICE/RIBA/CIBSE Ginger Group created to increase public and political awareness of the role of engineers and architects.

In his private life he enjoys old cars and old houses. He is the co-owner and restorer of one of Edinburgh's last surviving (and B-listed) mews stables properties adjacent to the Water of Leith in Edinburgh's Dean Village. Since 1966 he has been the owner, driver and restorer of a 1937 Morgan Motor Tricycle (a Matchless MX4 990cc V-Twin powered Barrel Back Super Sports). He also enjoys painting and sculpture, and, when given the chance, sailing.

He is a trustee of the charity Engineers Against Poverty, the Forth Bridges Visitor Centre Trust, and The Steamship Sir Walter Scott Trust.
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Bono: http://www.worldvision.org.nz/rampant/MakePovertyHistory

Calestous Juma (Professor of the Practice of International Development, National Oceanic & Atmospheric Administration (NOAA), U.S. Department of...
The Global Commons Institute (GCI) which was founded in 1990 by musician Aubrey Meyer (see/hear http://www.big.jpg). GCI has contributed to the work of the UN Framework Convention on Climate Change (UN FCCC) and the Intergovernmental Panel on Climate Change (IPCC). The London Hydrogen Partnership, http://www.lhp.org.uk; The Global Commons Institute; http://www.gci.org.uk/temp/COP3_Transcript.pdf.

Jeremy Bentham, "Introduction to the Principles of Morals and Legislation", 1789. Plurality should not be posited without necessity. The principle gives precedence to simplicity and states that "Pluralitas non est ponenda sine necessitate" – Plurality should not be posited without necessity.

Economics is often referred to as 'that dismal science', but not for the reasons commonly supposed. The term 'dismal science' was first used by Thomas Carlyle in a criticism of the economist John Stuart Mill for his support of the Smith Institute; 2005; ISBN 1 902488 97 0.

Occam's Razor, also called the law of parsimony, a principle stated by William of Ockham (1285–1347/49). 'Pluralitas non est ponenda sine necessitate' – Plurality should not be posited without necessity.

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