

Creating a Connected Commons

Why collaborative networks can help solve apparently intractable common good problems

Juan Carlos Castilla-Rubio
Simon Willis

December, 2008



Cisco Internet Business Solutions Group (IBSG)

This paper argues that recent developments in complex network theory, systems dynamics and economics highlight the critical role that information gaps play in obstructing the resolution of some apparently intractable problems¹. As questions of sustainability become questions of survivability, we argue that there is a urgent need to rapidly innovate across sectoral boundaries to address multiple information and knowledge asymmetries and coordination failures. Moving toward pervasive collaborative networks could unlock exciting new opportunities for creative policy-making and new business models addressing significant global challenges. To illustrate this argument, we look at some of its practical implications in the area of climate change.

A number of critical problems threaten our geopolitical, environmental, social and economic stability: uncontrolled mass urbanization; the links between global food and energy markets; and the depletion of natural resources, particularly water². Above all there is a significant need to both reduce carbon emissions to avoid dangerous climate change and to adapt to unavoidable climate change underway.³ The scale and reach of the risks associated with climate change, together with their potentially irreversible nature, make this probably the greatest market failure⁴ and the starkest example of a ‘tragedy of the commons’ the world has ever seen⁵. Yet, despite the fact that urgent action is currently affordable⁶, the incentives and capacity to coordinate a collective response and invest in the necessary low-carbon infrastructures and technologies are undermined by numerous interrelated market failures and information asymmetries.

¹ These issues share a number of characteristics: they are seen as intractable and almost impossible to resolve; they are all fraught with deep uncertainty ; they are global in nature but with local costs/benefits and contexts; they have a number of highly interdependent issues; they all embed systems inertia and are highly resistant to policy influence as they are dynamic, tightly coupled and governed by feedback; they have a myriad stakeholders across sectors with different value and belief systems; they cannot be solved by any individual sector (public, private or NGO) or by any individual disciplines (scientific, engineering, economics & policy, finance); they are all the result of either governance, market and community participation failures or a mixtures of them

² According to CEO of Dow : “Water is the oil of the 21st century”. Goldman Sachs estimates that water consumption is doubling unsustainably every 20 years coupled to a mass deterioration and pollution of fresh water sources - due to climate change and industrial urban pollution - will create the next major crisis. Economist, Aug, 2008.

³ According to Lord Stern in his May 2008 Key Elements of a Global Deal : ‘global emissions must fall by 50% relative to 1990 levels by 2050 in order to minimise the grave risks associated with severe climate change. As a matter of crude arithmetic this will mean global average per capita emissions will need to be around 2T by 2050 (20GT divided by 9bn people) - this figure is so low that there is little scope for any country to depart significantly above or below it. In order to reach this, developed countries must take on immediate emissions reductions targets of [20%-40%] by 2020, and commit to reductions of at least 80% by 2050’

⁴ As described by Lord Stern : “At the heart of economic policy must be the recognition that the emission of greenhouse gases is a market failure. When we emit GHGs as consumers or producers we damage the prospects for others and, unless appropriate policy is in place, we do not bear the costs of the action. Markets then fail in the sense that their main coordinating mechanism – prices – give the wrong signals. That is, prices – of petrol or aluminium produced with dirty energy, for example – do not reflect the true cost to society of producing those goods. In the language of economists, the social cost of production exceeds the private cost, so that markets without policy intervention will lead to too much of such goods being produced and consumed”

⁵ Stern Review on the Economics of Climate Change, UK Government, 2006

⁶ ‘ the costs of action – reducing greenhouse gas emissions to avoid the worst impacts of climate change – can be limited to around 1% of global GDP each year.’ Stern et al, 2006, exec summary, and ‘If market instruments are used, such as the EU ETS, and emission allowances are auctioned rather than given free to the emitters, and the revenues from the auctions are spend on reducing burdensome taxes, then the costs are reduced and may even be converted to benefits.’ Terry Barker, 2005, Evidence to the House of Lords Select Committee on the economics of climate change.

The tragedy of the commons⁷ refers to the claim that any tangible asset class that is freely available to everyone is likely to be over-used and eventually exhausted. If everyone is entitled to graze cattle on a common field, the land is likely to become unfit for purpose due to over-grazing. Intense study in governing the commons⁸ has accelerated over the last few years as this category of problem becomes more critical and pervasive. More generally, common good resource problems share both a public good characteristic – being ‘non-excludable’ as access cannot be restricted easily- and a private good characteristic as they are ‘rivalrous’ in nature, that is to say that common resources are “subtractable” like private property: if one person uses them, another’s access is diminished. This is particularly relevant in the case of global warming as the commons is the whole earth system. But recent financial system events suggests another example in that there may have been a failure to properly understand or regulate the ‘financial commons’⁹

In addition, we appear to face a series of trade-offs that are interrelated: between economic growth and environmental sustainability; between free trade and equity; between urbanisation and rural development¹⁰. There are many others. Sitting behind these apparent tradeoffs are five connected challenges: we do not adequately collaborate across silos to truly understand the problems we face; the information available to various actors and sectors in addressing these problems is insufficient; the distributed and fragmented nature of the opportunities makes the capture of the opportunity very difficult indeed; the complexity of coordination for adequate decision making across all actors is not addressed systematically and the barriers to rapidly scale innovations once identified and tested limit deployments to demonstration projects alone.

In a nutshell the sophistication, scale and complexity of our response capacity thus far does not meet what is required. These of course are not the only challenges faced as one should not underestimate the barriers created for a collective response dependent on an interplay between differing starting points, values, cultural attitudes and intergenerational issues.

7 G Hardin, Tragedy of the Commons, Science 162, 1968

8 Governing the Commons, Elinor Ostrom, Cambridge University Press, 1990

⁹ The financial crisis has shown that what happens deep inside one national financial system (eg subprime lending in the US) can wreck another halfway across the world through the cascade of failing credit, widespread risk aversion and inadequate regulatory supervision, spreading to both developed and developing markets alike. This ‘externality’ imposed by one country on the next has been allowed as nation-states jealously guard the right to oversee their own systems and the tug of war between national and supranational regulation has gradually led to an ad hoc arrangement for the international banking system which leaves multiple systemic risks under-addressed. Individual risk insurance instruments have once again led to delusions of system wide insurance. Furthermore, governance of the Bretton Woods institutions clearly fails to reflect the economic realities and power distributions of the current global economy. Please refer to ‘What G20 Leaders Must Do to Stabilize our Economy and Fix the Financial System’ by Eichengreen et al available at www.voxeu.org

¹⁰ ‘In 2008, the world reaches an invisible but momentous milestone: For the first time in history, more than half its human population, 3.3 billion people, will be living in urban areas.’ UNFPA, 2007, State of World Population 2007, Introduction

There is no magic solution to any of these issues, but one point is striking: all the imperfections we have mentioned have an important informational dimension. In one sense this is not surprising. After all, what has enabled us to move from small group co-ordination to address ever complex transactions to worldwide coordination have been increases in our ability to share information – from the development of language, through to writing, printing, and real-time distance-communication technologies such as the telephone, radio, television, internet, etc. It is our success in building a globally co-ordinated economy, albeit a highly imperfect one, that has led to the most dramatic challenge to our co-ordination mechanisms – the threat of climate change.

This paper argues that we can break through these significant barriers if we address these connected challenges with a new approach:

Dealing with knowledge asymmetries: we need a better conceptual grasp of the problems we face. A theoretical stance that can embrace complexity, systems thinking and ways to deal with uncertainty is required¹¹. We also need to break out of disciplinary and sectoral silos that limit both realistic and holistic understanding. To innovate we need to collaborate across sectors and disciplines, from global to local and back to global.

Dealing with information gaps and asymmetries: we need to deal with a number of critical and interrelated points of failure in the current approach. Public sector governance failures, market failures and community participation failures all create impediments to effectively dealing with common good problems. In this paper, we will explore the idea that information gaps and asymmetries at the intersections of these three sectors can be addressed with emerging approaches to connectivity and collaboration and the use of open multi-party collaborative platforms, approaches that could build a 'connected commons'.

Dealing with aggregation failures: we need to deal with highly fragmented small abatement opportunities distributed globally where mitigation opportunities are small relative to the transaction costs of securing them.

Dealing with the market failures of the low carbon innovation cycle: we need to deal with multiple and interrelated market and information failures associated to the speed and throughput of the low carbon innovation cycle¹² to speed up the

¹¹ Shaping the Next One Hundred Years – New Methods for Long-term Policy Analysis - Robert Lempert, Steven Popper and Steven Banks – The RAND Pardee Centre and Serman, John D, Systems Dynamics – Systems Thinking and Modelling for a Complex World

¹²As discussed by Jaffe, Adam B, Newell, Richard G, Stavins, Robert, N, A tale of two market failures: Technology and environmental policy, Ecological Economic, 54, November 2005

learning-by-using and learning-by-producing cycles and thus reduce the total cost of deployment whilst avoiding high carbon infrastructure investment lock-in.

Dealing with coordination failures : we need to use the power of collaborative, distributed and dynamic decision- making environments to address complex coordination failures that take advantage of insights provided by integrated data sets arising from connected and pervasive sensor networks.

Below we discuss each of these in turn.

1. Dealing with knowledge asymmetries

Despite much excellent recent work, most policymakers and business planners are trapped in intellectual prisons constructed on foundations laid by 19th century economists, mathematicians and physicists¹³. Damaging and unexamined assumptions still prevail. These include: the availability of perfect information; the assumption of rational choice and a lack of bias; the likelihood of unimpeded competition; the inevitability of equilibrium within and across complex systems and the assumed lack of an endogenous mechanisms for innovation. These assumptions have survived because they provide both elegance and simplicity in analysis. They allow some experts to defend and entrench the relevance of both their own and their intellectual silo's work and ideas. But these assumptions do not reflect the complexity of reality and experts have thus repeatedly failed to offer practical and scaleable ways forward in dealing with intractable problems¹⁴.

The general lack of global to local cross-sectoral and cross-disciplinary approaches in the diagnosing and solving of environmental/governance/social problems is especially apparent in the treatment of global 'common good' problems like climate change. We urgently need advisors and analysts able to work contextually, experientially, collaboratively, and across sectors and disciplines.¹⁵ We need individuals who can bridge the gap between global and local understanding. In particular, we need 'public purpose entrepreneurs'¹⁶ who will facilitate and create these new collaborations. Compounding this problem is the fact that the 'people sector' (i.e. communities, NGOs, research institutions, social innovators and individuals) are largely excluded from participation at a high enough level. Let us illustrate the concepts discussed here with three examples.

¹³ The Origin of Wealth from Eric Beinhocker of Santa Fe Institute/ McKinsey Global Institute summarizes the work across multiple disciplines leading to the concept of 'Complexity Economics'

¹⁴ As an example of this refer to Diamond J, 2005, Collapse, Viking Press.

¹⁵ As discussed by Gibbons et al in 'The New Production of Knowledge' discussing two different modes of knowledge creation.

¹⁶ As defined by Nick Mabey, CEO of E3G in a private communication to the authors

- **Value of global to local cross-disciplinary policy-making networks.** Promoting a collective understanding of climate change and achieving a coordinated solution requires approaches that bridge the gap between global and local knowledge of complex issues.¹⁷ This will only be achieved through collaboration between scientists, technologists, economists, policymakers and business networks, as well as ordinary citizens. The global expert climate change RECCS¹⁸ network seeks to update the cross-disciplinary modelling efforts within a globally accepted but locally sensitive framework. It is hoped that this will provide a basis from which to design effective fact-based long-term policy frameworks at the national and regional levels in the lead up to negotiations to a global deal in Copenhagen 2009.

- **Value of collaborative climate science.** Understanding the multiple, interconnected components that may lead to a catastrophic event - such as an accelerated sea level rise, methane permafrost release or Amazon savannization - requires a collaborative, horizontal process. Such a process would improve knowledge in near-real time across diverse disciplines, organizations and geographies. We urgently need simultaneous collaboration between scientists specializing in the atmosphere, biosphere, oceanosphere, geosphere and cryosphere. But current models of endorsement and authentication make collaboration difficult within each of these fields – let alone between them.

The present system of incentives and intellectual property rights means that the 50 or so climate-relevant specialized disciplines operate as silos without any significant sharing of data, models and insights in a timely fashion. Each silo's output is submitted to a mandatory and lengthy peer review before eventual and delayed publication. Together with our scientific and economic partners in this field,¹⁹ we have estimated that the economic value of better-coordinated climate science research to reduce the uncertainty in just one parameter, the climate sensitivity, by half is in excess of US 400 billion²⁰. This is a conservative estimate of the cost of preserving the status quo of today's disjointed global climate science.

- **Value of collaborative risk assessment**

¹⁷ A case in point is dealing with the competitiveness issue. The potential for such pervasive knowledge asymmetries to promote a global governance failure and retard or prevent policy progress cannot be underestimated. Perverse incentives can drive a skewed assessment of the problem prompting parties to wait for others to sign up before taking action and slow down the process of emissions reduction

¹⁸ A global collaborative policy practitioner network of Regional Economics of Climate Change Studies (RECCS) has been set up to do just that. This was initially catalysed by the UK Government after the successful release of the Stern Review. <https://global-recc-network.webexone.com/default.asp>

¹⁹ Cisco IBSG partnership with British Antarctic Survey and NASA exploring prototype scenarios for collaborative digital swarming.

²⁰ The value of better information about the climate sensitivity. Chris Hope & Stephan Alberth, Judge Business School, mimeo, 2007. Cisco IBSG partnership with Cambridge University's Judge Business School to develop the next generation global integrated impact assessment models of climate change.

A recent OECD study²¹ estimates that a total population of 40 million and US 3 trillion of assets (about 5% of global GDP) are currently at risk in the world's ten top coastal cities (6 in developing countries and 4 in developed countries). These numbers will rise to 150 million inhabitants and US 35 trillion or about 9% of global GDP by 2070.

Consider the following scenario: given the increasing frequency and intensity of natural disasters, the global insurance industry – with an ever increasing capital commitment - pools its unique private risk assessment and mitigation expertise together with publicly managed local and global earth observation²² assets, skills, data and insights, to develop joint preventive disaster response plans. But this can only happen if the people sector is engaged by a diverse body of scientists across disciplines and sectors collaborating for this common cause, aggregating their accumulated contextual and experiential knowledge across disciplines. This is an example of a private good response (the insurance industry unique risk expertise) combining with a public good capacity (global and local earth observation capabilities) combining with a network of individual scientists to provide the basis for a new hybrid cross-sectoral response to a major public policy dilemma.

Innovating at intersections like this, would help to prevent potential disasters from occurring that would affect both the richer and poorer part of the world. Perhaps richer cities and regions will create the required protective climate-resilient physical infrastructure. The less developed cities will have a harder time as their current infrastructure planning cannot contemplate the massive funding needed for climate resiliency.

2. Dealing with information gaps and asymmetries

At the heart of global common good problems like climate change, are multiple market, governance and community participation failures. These are driven in part by a number of information gaps and asymmetries that impede a common understanding of interrelated social, environmental and economic problems. They present a formidable obstacle to an efficient, coordinated and collective response. Closing these information asymmetries and gaps will require political, social and technical innovation at the intersections between the public, private and people sectors to create a *connected commons environment* for multi-party collaboration.

21 OECD 2008 study Ranking of Port Cities with high exposure to Climate Change Risk
22 Centre for Strategic & International Studies Space Initiative report by Wigbels, Sabathier et al, July 2008, 'Earth Observations and Global Change – why ?, where are we ?, what next ?'

None of the three sectors can, acting alone, solve common good problems – especially where they stretch across legal, national, jurisdictional or administrative boundaries. As noted above, communities and individuals face problems of standing and participation and thus rely heavily on both the state and markets to address each other's failures.

Where possible, policies must encourage market-based solutions, minimise transactions costs, and stimulate reform of existing distortion mechanisms. With the general exception of public goods, the market –with its ability to capture preferences and choices instantly, compared with the state's less frequent interrogation of the 'will of the people' – often is a more effective and efficient mechanism for capturing expressions of individual choice.

It is vitally important that the market is able to harness the power of individual entrepreneurs and innovators through the price mechanism. For the most part, price does reflect choices in the form of both production possibilities and resource allocation on the supply side and consumer tastes and preferences on the demand side. However, price is not always a complete vehicle for the communication of hyper-complex information underpinning market transactions (and sometimes there is no price for an illiquid asset). It can provide incomplete information. Assuming that it provides all the information at all times fails on several counts relating to numerous market failures in production and consumption. Producer and consumer behaviour may not be responsive to price changes, for example consumers may be driven by habits or rules of thumb. Humans might also behave in ways that analysts may deem not 'rational'. Market practitioners have superstitions and biases – in fact humans can sometimes be 'predictably irrational',²³

Furthermore, as the market does not always have the incentive to correct failures of information, the state has a fundamentally important role to play in addressing market failures that arise from those information gaps/ asymmetries and coordination failures. Poorly designed government intervention risks raising transactions costs, and creating additional market distortions, perverse incentives and sometimes outright collapse. It also risks promoting protectionism and providing incentives for corruption and graft²⁴.

Governments fail as frequently as markets, either actively through interventions that cause a more inefficient allocation of resources than would otherwise occur,

²³ As discussed by Dan Ariely, MIT Professor of Behavioural Economics in 'Predictably Irrational, the hidden forces that shape of decisions', Harper Publishing 2008.

²⁴ See Jain A, 1998, Economics of Corruption, Springer.

or passively through failure to intervene in a market failure in a way that would result in a socially preferable outcome. Government failure can have many causes and may take many forms. As we have observed recently, one of the most dangerous forms is that related to regulatory failure that is compounded by :

- *Rational ignorance* - because there are budgetary constraints and the regulated entities have a better grasp of the total problem and the time costs associated with gathering information and the benefits to doing so are limited, legislators, administrators and voters will not necessarily obtain all of the information necessary to make an informed decision on a subject.
- *Short time horizons* - election cycles can drive a tendency to focus on short term fixes and to ignore long lasting large, complex problems.
- *Unintended consequences* - an unintended consequence comes about when a mechanism that has been installed with the intention of producing one result produces a different (and often conflicting) result. (e.g. mark to market rules)

In addition, the decision-making processes of government (or other public bodies) take more time than market co-ordination and delivers broad rather than finely-tuned solutions. Furthermore, government intervention is only imperfectly oriented towards the common good – whatever decision process is used there is a risk that the self-interest of those closest to the process will have a negative impact on the outcome. Another limitation arises from the geographical limits on governments. We do try to use formal agreements and rules across national boundaries, but lack of trust between governments - and the absence of enforcement mechanisms - make co-ordination uncertain and rarely fully effective. Finally, as with markets, this mechanism does not deliver co-ordination of all our activities – there are some transactions that are too small to be regulated in this way.

The debate, however, has moved on from whether the market, the state or the community is best-placed to address past failures. It is now acknowledged by most well informed observers and policy makers that all three are fundamental to each other's survival.²⁵ Now, the more interesting question is how to identify where and when each sector can intervene to ameliorate the others' failures without unnecessarily impeding the functioning and incentive structures of the

²⁵ Sustainability is a classic euphemism – we are not talking about whether our children will have the same as us which most previous generations would have regarded as a disaster but whether they can survive our decisions.

market. Understanding that all sectors are part of any sustainable and effective solution, the challenge is to identify the intersections that offer the highest impact for multi-party collaboration. In fact, such intersections are not fixed, but permanently contested and moving. This is because they shift in response to new developments, new information, new players and their networks, and resulting behaviour. There are no fixed demarcations between the public, the private and the people sectors; they are in flux precisely because the contexts in which they interact, and the information they use, is similarly in a constant state of change.

To create and implement effective solutions to common good problems at the intersections between the three sectors, we have to think less about unilateral regulation and demarcation and more about sharing and complying against a common vision for joint success. Integral to this collaborative vision is a shared responsibility for dealing effectively with failures. Central to an understanding of where market, governance and participation failures start and stop, is defining or identifying how far short of ‘shared goals, information and knowledge’ any one of the intractable situations described above is. Only then can we start to innovate to deal more effectively with the pervasive information failures and asymmetries²⁶.

So what are these interrelated set of information failures and asymmetries? There are too many to list here, but the following examples will examine some of them. Each example illustrates innovation at the intersections using three different instances of the general concept of ‘*collaborative performance contracting*’: in energy efficiency capture, in energy services delivery and in multi-modal transport and smart work centres applications.

- **Resolving the energy efficiency paradox**

A number of studies have estimated that 35 to 55%²⁷²⁸ of all major global greenhouse gases abatement opportunities are related to energy efficiency, have apparently negative marginal costs and therefore should be rapidly and freely adopted by all players, in for example the building industry²⁹. In reality, however, there is not much adoption of these abatement opportunities. So what explains this curious paradox?

The answer lies in multiple non-price factors, such as information gaps, agency asymmetries and coordination failures between government, investors,

26 The classical information asymmetry occur when two parties to a transaction do not have equal access to relevant information. Such information asymmetries particularly on “lumpy” and non-standardised purchases lead to split incentives and the principle agent problem.

27 The so-called marginal abatement cost curves (MAC) of which there are several variations typically only consider a static supply view of technology deployments and do not consider the non-price related mechanisms at play such as information gaps, asymmetries and coordination failures and a myriad of other demand and behavioural issues

28 The International Energy Agency (2006) has estimated that increased energy efficiency could account for 45 to 55 per cent of global emissions reductions projections to 2050 in International Energy Agency (IEA) (2006) Energy Technology Perspectives: Scenarios and Strategies to 2050

29 Vattenfall Global Climate Impact Abatement Map- 2007

developers, owners and users of the built environment across the investment and use cycle. Many energy efficiency studies are overly optimistic as they do not include potentially unavoidable transaction costs from the uptake of more efficient solutions, such as time spent in information gathering and decision making. A study of energy efficiency investments by Danish companies estimated that transaction costs relating to information gathering and decisions accounted for 3 to 8 per cent of the costs of the investment³⁰. If this cost outweighs the benefits of action then agents are behaving efficiently in failing to undertake it. The trouble is that individual consumers cannot assess this trade-off before having sunk the resources into seeking the information – there is an information gap. Therefore, individuals may choose to remain uninformed even when better information could help them to make decisions that would be more advantageous in the absence of information costs. Incomplete information also underlies the “principal agent asymmetry” problem. The importance of addressing climate change and securing energy supplies has made the issues of market barriers to energy efficiency, and the principal agent problem in particular, receive renewed attention recently³¹.

Principal–agent problems can occur in many spheres of economic activity, when one person (the agent) performs tasks on behalf of another paying person (the principal) but the parties face different incentives and the principal cannot ensure that the agent act in their best interest. The two parties have split incentives and neither acts to maximise the value or efficiency of the good or service being exchanged. In the climate change context, principal–agent problems may entirely insulate some decisions from a carbon price, potentially reducing the adoption of low-emissions options. Principal–agent problems persist when:

- it is hard to monitor a contract due to information asymmetries
- it is difficult to enforce contracts (mandatory disclosure may be an effective way to reduce principal–agent problems e.g. landlords delivering energy rating certificates to tenants).
- the costs of negotiating and establishing a better contract exceed the benefits.

The first noted use of the principal-agent problem idea in the context of energy efficiency was by Jaffe and Stavins³². They were attempting to catalogue

30 Hein, L.G. & Blok, K. 1995, ‘Transaction costs of energy efficiency improvements’, in Proceedings of the 1995 Summer Study: Sustainability and the reinvention of the government—a challenge for energy efficiency (NWS-95056), A. Persson (ed.), The European Council for an Energy Efficient Economy, Stockholm.

31 International Energy Agency (2007), *Mind the Gap: Quantifying principal–agent problems in energy efficiency*, IEA, Paris.

32 Jaffe, A.B., R.G. Newell, and R.N. Stavins (1999), “Energy-Efficient Technologies and Climate Change Policies: Issues and Evidence”, Resources for the Future Climate Issue Brief No. 19 (Resources for the Future, Washington, D.C.); Jaffe, A.B. and Stavins R (1994), “The Energy Paradox and the Diffusion of

market and non-market barriers to energy efficiency adoption. In efficiency terms, a market failure arises when a technology which is both cost-effective and saves energy is not implemented.

To illustrate this point, imagine a builder who bears the costs of investing in the installation of energy efficient appliances and materials in a building project. While the builder invests, it is the buyer who experiences the benefits of the investment in the long run. In a competitive market the increased cost of the efficient building is hard to pass on when the current cost differential is clear and the future energy savings opaque. Consumers are often poorly informed about the savings on offer and, even when they have the time, information and ability to calculate the savings, the transaction costs are high. Some of this could of course be regulated extensively through mandatory standards; some will require multi-party collaboration platforms.

These market failures are at the heart of explaining the “paradox” of low adoption rates of energy efficient solutions that are cost effective in principle. The required *potentially* profitable investments in energy efficiency globally are in the region of \$170 billion a year until 2020—about 2% of today's global annual investment in fixed capital³³. The challenge posed, is how to enable mass adoption of the current technologies by overcoming the information asymmetries/ gaps and the coordination failures, whilst simultaneously reducing the associated transaction costs of acquiring common information and allocating the different risks to the best bearer of the different risk classes. Innovation across the intersections to solve this adoption challenge may require extensive use of ‘*collaborative performance contracting*’ information and financial risk solutions to aggregate the networks of actors across sectors and provide them with end-to-end visibility of costs/ benefits and risks across the build and use lifecycle. This would allow both benefits and costs to be shared and total risks to be understood and managed more predictably and equitably. Scaling up the multi-party collaborative information and financial solutions that close these gaps is needed to fully capture the massive energy efficiency opportunity³⁴.

- **Enabling low carbon energy service business models**

To unlock potentially large opportunities in the power industry, a reinvention of its value chain and how the price mechanism is coordinated across it will be

Conservation Technology”, Resource and Energy Economics 16:91-122 ; Jaffe, AB. and Stavins R, (1994a). “The energy efficiency gap: What does it mean?” Energy Policy 22 (10): 804-810;

33 Energy Efficiency Economist special report in May 2008

34 Lovins, Amory B, Energy End-Use Efficiency, Rocky Mountain Institute, 19 September 2005

required. To put this into context, traditionally most power companies were keen to encourage their customers to consume as much power as possible. In California, regulators have inverted the incentives, making it more profitable for their utilities to encourage efficiency. This could be taken further by devising new ways to create value for all sectors through innovations to ‘save a watt’³⁵ versus creating a watt to sell. With the right pervasive information systems in place it would be possible to create more efficiency in homes or businesses by allowing users more control over their use of energy and offering real time peak energy pricing. Giving householders and small businesses more control over their energy use through the use of wireless home energy controllers³⁶ typically reduces consumption by at least 10%. These intelligent controllers can display carbon production and energy consumption to the consumer and allow the supplier to provide flexible peak pricing. Early discussions with several major utilities suggest that savings in the cost of peak production, together with potential deferral of infrastructure refresh, make the cost of installing the controller attractive to the market. The key requirement for this to work is that the information asymmetries and gaps between all players in the value chain are closed so that real time energy prices at source can trigger automatic use changes at the edges of the power network with low transaction costs. This will require rethinking power industry regulation and incentives.

This example of ‘collaborative performance contracting’ could have a very significant impact on utility companies’ business models as they make the transition to becoming providers in the low carbon economy. The private sector would generate value from ‘demand shaping’ that not only reduces operational costs but also, and perhaps more significantly, reduces the capital that would be required to meet peak loads - most utilities already operate near 80-90%³⁷³⁸ of capacity. Innovating at the intersections between the three sectors enables new forms of multi-party collaboration to create new economic value, placing the real opportunity cost into the hands of people that can do something about it.

- **Enabling low carbon urban transport and workspaces**

As mass urbanization accelerates globally, traffic congestion uses more and more energy and causes increasing delays and environmental damage. Again, the market has not been able to allocate the cost of driving to drivers and their

³⁵ Jim Rogers, CEO of Duke Energy first articulated the proposition that it is cheaper to ‘save a watt than to create a watt’

³⁶ Web based interface allows consumer control through PC, TV with set top box and other devices. Additional bundling opportunities with home health monitoring services for independent living and home security applications are natural future steps.

³⁷ NERC 2007 study of US power industry supply and demand

³⁸ See, for instance, <http://www.eia.doe.gov/cneaf/electricity/epa/epat3p2.html>

employers. The real price - including externalities - of driving in cities needs to be captured to change behaviour and stimulate innovation. Congestion pricing by specific patterns of use (as opposed to a more general levy on fuel or car ownership) offers a more accurate reflection of the true cost in the price paid by the driver³⁹.

A good example of applied thinking in this context is dynamic and intelligent congestion charging that directs the price of continuing to drive into the urban centre directly at the driver. If drivers' costs more accurately reflect the true cost of driving into the city centre, there is a clear incentive for drivers to change their behaviour or innovate. There is potential for these systems to become increasingly more intelligent and flexible through the creation of incentives that influence the intensity of activity rather than just one activity in a bi-polar way. In addition, integrating transport and traffic information to provide individuals with more choice over their travel options could further drive a change in their behaviour. As a bonus the resulting new integrated data sets are potentially a unique source of sustainable urban planning innovation.

This is where 'personal travel assistants' - such as those in San Francisco, Amsterdam and Seoul⁴⁰ - can play a role. By closing the information gaps and asymmetries in scheduling, cost and availability - in real time - between the providers of multiples modes of transport (public or private) and the citizens they are serving, personal travel assistants can reduce search, interaction and transaction costs to reduce carbon footprints in urban transport. They will provide information about travel and work place choices, encompassing information about different modes of transport, traffic conditions, costs and flexible congestion charges, as well as environmental impacts perhaps ultimately linked to personal or corporate carbon accounts. It is possible that innovations like these, and the many small players that are likely to innovate on these open platforms, will help to catalyse gradual urban redesign on the principal that information should go to where it is needed rather than everyone moving to the centre - the site of medieval market places - to get access to information. Sustainable urban development will require increasingly sophisticated innovation at the intersections between the sectors with multi-party collaboration if the carbon footprint of the flow of people, traffic, goods and services and energy is to be optimised in a more distributed way.

39 Button KJ, 1993, Transport Economics 2nd Edition, Edward Elgar Publishing Ltd

40 Cisco IBSG Connected Urban Development program aims to create replicable templates for sustainable urban infrastructure development considering urban planning, built environment, transport and energy solutions to reduce carbon emissions from cities. For more information visit www.connectedurbandevlopment.org

These examples illustrate one of the general principals outlined by this paper: that targeted connectivity and real-time multi-party collaboration will make it feasible to create a near-frictionless reintroduction of externalities - pricing the true environmental cost of economic decisions back in to markets - to incentivise the mass behavioural changes required.

3. Dealing with aggregation failures

A large proportion of the abatement opportunity is highly fragmented (up to 45%⁴¹ of the opportunity below 40 euros/ ton CO₂e spread across the developing world, excluding India and China). In the developed world, challenges like the effective capture of the energy efficiency opportunity are similarly highly fragmented; it does not help that the potential savings, although huge when added up across the world, usually amount to only a small share of the budgets of individual firms, institutions and households.

A market failure is most likely to occur where mitigation opportunities are small relative to the transaction costs of securing them, such as in the areas of:

- energy efficiency, fuel switching and small-scale generation in buildings, industry and
- emissions reductions in agriculture, forestry and waste.

Even when agents can do the sums, the transaction costs are high and it is a time-consuming chore for someone to identify the best energy-saving equipment, buy it and get it installed. Aggregation benefits are a primary reason why governments set standards for white goods, buildings and car emissions often with the full support of consumer bodies.

Today, spending on energy still accounts for a smaller share of the global economy than it did a few decades ago⁴². These highly fragmented and dispersed opportunities co-exist with a few highly concentrated abatement opportunities – such as carbon sequestration and storage which require wholesale approaches in technology development, economies of scale of production and wholesale financing approaches. In contrast, the capture of large but fragmented and dispersed energy efficiency opportunities must rely on minimizing the search, interaction and transaction costs that dominate these low value abatements, further - illustrating how to cope with the energy efficiency paradox explained in the previous section.

⁴¹ Source: McKinsey Vatenfall global marginal cost curve study, 2007

⁴² Source : Economist special report on Energy Efficiency, 2008

To deal with the aggregation requirement to develop a scaleable business model, scale free networks⁴³ can play a unique role in that while there are in average six degrees of separation between any two nodes (people) at random in the world, there are only two degrees of separation between the connector (or hub) and the small nodes (average person)⁴⁴. This network design principle can be exploited to amplify and speed up awareness, understanding and collaboration among peers. In addition, the bottom up self-organizing behaviour of social networks creates what is effectively a people ‘web without a spider’. We need to learn to put much more reliance on these types of behaviour to deal with the ‘long tail’ of small fragmented opportunities as there is a limit to the effectiveness and efficiency of top-down government and private sector initiatives.

As an example of aggregation in this space consider the rapidly evolving markets for Energy Services Companies (ESCO).

- Community wide ESCO model to capture energy efficiency citywide**
 City wide ESCOs⁴⁵ can help to address the many barriers to capturing the massive opportunities behind energy efficiency and distributed micro-generation. This can be done by providing a set of integrated and pervasive sensing & monitoring solutions, funding & risk solutions and design-construction-operation-maintenance solutions under long term agreements that use the key principle of ‘collaborative performance contracting’ discussed above. As the ESCO model progresses in sophistication and value from focusing initially on the mature ‘facilities management’ play to the ‘household model’ where energy suppliers and equipment manufacturers evolve to sell energy efficiency services, the largest potential opportunity arises out of the ‘community wide model’ where aggregation of community of households and large public and private sector entities with distributed facilities in a city can provide an asset base large enough to develop the integral collaborative solutions required. Designing these cross-sectoral ESCO networks will be foundational to maximize the aggregation and coordination required whilst at the same time minimizing the search, interaction, transaction, monitoring and risk costs of this replicable venture approach. Other critical urban resources like water and heating networks can be optimally managed this way.

43 The concept of scale-free networks was developed by the Hungarian mathematician Albert –Laszlo Barabasi in his paper ‘Emergence of Scaling in Complex Networks’⁴³. One way of understanding why most complex networks have a small number of disproportionately connected nodes is to see this as a reflection of growth. As networks grow, new nodes do not attach randomly but are more likely to attach to existing high-value nodes. So the rich nodes get richer and the poor nodes stay poor. The networks are scale-free in the sense that their structure and dynamics are independent of the number of nodes the network has.

44 Source: ‘Small World Problem’ by Stanley Milgram in Physiology Today, 1967

45 Source : Liberating the power of energy services and ESCOs in a liberalized energy market – Bertoldi et al, Oxford University, 2007

4. *Dealing with the market failures of the low carbon innovation cycle*

There are multiple and interrelated market and information failures associated to the speed and throughput of the low carbon innovation cycle⁴⁶, which stretches well beyond simply understanding the damage already caused by activities that emit greenhouse gases – and pricing-in the so-called “externality”. The Stern Review⁴⁷ made clear that technological innovation is a second market failure that can be addressed by actions that mitigate greenhouse gas emissions. What is important is that a choice is made early, before technical and physical investment becomes “locked-in” and the costs of switching to low carbon paths later increase substantially.

To discuss these we break down the problem and the potential solutions in terms of:

- Role of innovators
- Role of adopters
- Role of producers & interoperable network effects

- **Innovators**

Consider, for example, an innovative firm in the climate change solution space that creates benefits for others but incurs all the costs. Polluters profit and others pay the price while innovators pay the development costs while others reap the benefits. The “invisible hand” of the market fails in the face of these pervasive positive and negative externalities.

The positive externality comes from knowledge being a public good and results in the creation of “knowledge spillovers” from innovators to other firms, and then to consumers. The processes of innovation and diffusion of new technology⁴⁸ are characterized by additional market failures that are associated with information gaps and asymmetries. While all investments have some risk profile, investments in innovation have a much higher level of uncertainty regarding payback. Information about the prospect of success of any given innovation is asymmetric in the sense that the innovator is often in a better position than outsiders to assess its potential.

⁴⁶As discussed by Jaffe, Adam B, Newell, Richard G, Stavins, Robert, N, A tale of two market failures: Technology and environmental policy, *Ecological Economic*, 54, November 2005

⁴⁷ Stern Review of the Economics of Climate Change

⁴⁸ Branscomb, L and Auerswald, P, “Taking Technical Risks: How Innovators, Executives, and Investors Manage High-Tech Risks”, Cambridge, MA: MIT Press (2001).

Information associated with the diffusion and adoption of ideas is also subject to its nature as a public good⁴⁹⁵⁰. That is to say, different agents can use the same information simultaneously without reducing its value. Once information is created it will diffuse naturally to the public domain without anyone contributing to sharing the costs. This leads to the under-production of vital new information⁵¹. This can be especially true when dealing with common good problems such as climate change.

- **Adopters**

Early adopters of some low-emissions solutions bear additional costs in gathering information, developing skills for adopting the solution and testing its reliability⁵². Early adopters firms for example are often unable to capture the knowledge and skill spillover benefits that accrue to other firms and other industries.

This acts as a disincentive to early adoption of novel technologies and practices. Most new technologies take time to diffuse. Spillovers and other market failures may extend the time⁵³. This delay in diffusion could increase the cost of mitigation.

On the other hand, there are positive externalities such as the value increasing for a new adopter of an innovation as a function of the number of existing adopters. This applies for example, to communication networks and to operating systems. So addressing the community participation failure is highly synergistic. This increased potential value can sometimes be associated in turn with “learning-by-using” on the demand side. “Learning by using”, a positive externality is generated by making new information about the existence, attributes and benefits of the innovation widely available

Of particular importance are early adopters ‘buying’ a particular innovation and before it can scale, it has to bridge the highly connected hubs in a ‘scale free’ network that will confirm its value and then communicate to the rest of the ‘nodes’ in the network. This reinforces the significant value that social networks can help catalyse in the adoption space. ‘Scale free’ networks have the special property of being able to accelerate the throughput of innovations

49 Once new information has been created, it is almost costless to pass on and difficult to exclude individuals from using it (“non-excludable”), and one person’s use of that information does not prevent others from using it (“non rival”)

50 Romer Paul, Economic Growth, The Concise Encyclopaedia of Economics 2007-09-28

Romer. Paul, Idea gaps and object gaps in economic development, Journal of Monetary Economics, 32, 1993

51 Tirole J, 1988, The Theory of Industrial Organization, MIT press.

52 Jaffe, A.B., Newell, R.G. & Stavins, R.N. (2004), “A Tale of Two Market Failures: Technology and Environment Policy”, Resources for the Future

53 Jaffe, AB. and Stavins R, (1994a). “The energy efficiency gap: What does it mean?” Energy Policy 22 (10): 804-810;

deployed and adopted. Where innovation diffusion is concerned, most innovation processes have a critical threshold below which mass adoption cannot happen. By contrast, networked diffusion processes lack this minimum critical limiting threshold⁵⁴.

- **Producers and interoperable network effects**

“Learning-by-doing” spillovers on the producer side, on the other hand, allows for the widespread availability of new knowledge that allows other members of the private sector to access new information and offers early producers the chance to gain production experience and scale. In turn, this promotes the generation of new economies of scale and scope. However, without the aggregation and coordination of information and markets and better and deeper interoperability between sectors and actors across demand and supply, it is difficult to create the basis for “network effects”. A good example of this is provided by the Carbon Disclosure Project⁵⁵ that can act to accelerate innovation as economic agents learn what are the best levers to deal with their own carbon footprints. Interestingly Wal-Mart, after joining the CDP, found that the refrigerants it used in its grocery stores made up a larger percentage of its footprint than its truck fleet – and thus proceeded to capture the benefit.

5. Dealing with complex coordination failures

To achieve climate change abatement, we need to make the connection between the global problem – global impacts and the response in terms of limiting global emissions – and the local level where the costs and benefits are experienced and where implementation, design and investment solutions need to be carefully applied. Bridging the two requires a complex “middle layer” in which the global institutional architecture needs to be carefully designed to provide a trusted, credible, verifiable and fungible system of global carbon emission reductions⁵⁶. The success of this vital intermediary set of vehicles will rely on the pervasive sensing, monitoring and accrediting of urban and rural emissions at the local level and the broadening and deepening of carbon markets at the global level. The process must draw together a wide array of actors across sectors, institutions and regions to participate in an international system that is effective in managing the risks of extreme events by imposing an absolute limit on emissions and is

54 Source: Granovetter in ‘Threshold Models of Collective Behaviour’ in American Journal of Sociology 83 (1978) and Abrahamson et al in ‘Social Network Effects on the extent of innovation diffusion’ in Organization Science 8, 1997.

55 The Carbon Disclosure Project collates data about the greenhouse gas emissions of many of the world’s largest companies, at the request of their institutional shareholders. CDP has published emissions data for 1,500 + groups, representing \$57 trillion of investor assets under management and accounting for a quarter of the world’s man-made greenhouse gas emissions.

56 UNFCCC MRV principles of measurability, verifiability and reportability at the least transaction costs

efficient in minimizing the costs of action by rewarding abatement where it is cheapest. In the process it will generate large financial flows between buyers and issuers of carbon credits, with as much as \$50-100bn a year flowing to developing countries by 2020⁵⁷.

The carbon markets can be seen as a special form⁵⁸ of directed scale free networks – in which companies, governments, financial institutions and regulators are the ‘nodes’, the ‘links’ are the interactions between these actors, the ‘weight’ of the links are the monetary transactions and the ‘direction’ is determined by who has carbon credits and who needs them. As such, as we integrate and network the different local, regional, national and global carbon market institutions and utilities into a ‘system of systems’ we should on the one hand consider the key design principles of the growth and preferential attachment (cooperative or competitive) of scale free networks⁵⁹. On the other, we need to factor in the reach limitations of directed ‘scale free’ networks, whereby the network topology itself has distinct ‘regions’ which can only be reached through a particular route. A case in point is that even the best search engines today can only reach 50-60% of the total web content.⁶⁰

Little consideration has been given to date as to the practicalities of carbon trading with a global price of carbon mandated internationally and deployed locally. We are a long way from achieving the kind of execution that can pervasively and accurately sense, measure, authenticate, risk profile, certify, monitor and monetise externalities in a number of markets – globally and locally - in close-to-real time, so that a global carbon price signal can:

- Account for the true cost of driving to the centre of London and be priced into choices between car and bus;
- Monitor and time shift energy consumption in a smart home in Amsterdam so that efficiencies can be sold back to a smart grid;
- Capture energy efficiency opportunities in a new real estate development in Guangdong Province unhindered by agency and information asymmetries between developers, investors, construction companies and users of the built space;
- Preserve a hectare of pristine rainforest in Peru because the living carbon is worth more than dead carbon and
- Justify the financing of the rollout of wind farms in Bangalore by a high carbon manufacturing facility in Pittsburgh.

⁵⁷ As per the simulations using the GLOCAF Model described in from <http://www.occ.gov.uk/activities/gcf.htm>

⁵⁸ Directed scale free networks have the special characteristics that flows from one node to the next one has one direction only

⁵⁹ Preferential attachment in scale free networks as discussed in ‘The Structure and Dynamics of Networks’, Newman et al Princeton Press, 2007

⁶⁰ Source: As discussed in Barabasi’s ‘Linked – The New Science of Networks’, Perseus Publishing 2002

The technology to achieve these is all available; but the institutions, the scale free networks and agreements needed are not.

Dealing with the complexity of coordination from global price signals to execution at the household or firm level will remain a key requirement for next-generation carbon market backbones. Materializing large public and private funding flows⁶¹ and changing mass behaviour, requires a set of interconnected carbon market institutions⁶² that sit between the global carbon markets and executing institutions, firms and households. These markets will need to be able to deal with the ‘long tail’ of fragmented abatement opportunities in both developed and developing countries. And they will need to be able to cope with massive flows of projects to roll-out low carbon infrastructure, in contrast with the current low throughput high transaction cost Clean Development Mechanism⁶³. This will most likely require proactively managed carbon prices and green house gas abatement volumes so that large, CO₂-producing infrastructure is not locked in during the USD 21 trillion energy infrastructure investments⁶⁴ planned between now and 2030.

This ‘middle layer’ can be thought of as an essential global utility providing the key Monitoring, Reporting and Verification capabilities required to successfully implement a global deal. This utility is required to provide a massive deployment of trusted and reputable open-standards based capabilities with transparent access, auditability and low transaction costs. These new capabilities would also need to be widely distributed and networked globally with ‘scale-free’ characteristics so as to be able to incorporate in time the large but highly fragmented mitigation opportunities across markets and sectors. Extending this concept further we can envision these urban and rural carbon sensing and monitoring capabilities extended into the critical areas of energy, water, land and food productivity management and integrated risk management to mention just a few – as part of a Planetary Skin^{65,66}.

A Planetary Skin deployment will leverage collaboration environments for dynamic, distributed decision-making⁶⁷. These will provide a common fabric that

61 UK government has estimated that the funding flows from developed to developing countries resulting from global carbon markets are of the order of US 50- 100 billion per annum as estimated by the UK Government’s GLOCAF model, Bali UNFCCC meeting in 2007

62 Integration of the European ETS and multiple other cap and trade capabilities being deployed regionally, nationally and locally will be key
63 Currently there are several regional and national emissions trading schemes in existence. The EU ETS achieved sales of around \$24bn in 2006 (Phase I and II) whereas the CDM sales were around \$6bn. The Clean Development Mechanism (CDM) has about 400 project registrations per year, resulting in new financial flows of perhaps US\$6billion at current carbon prices. Moreover, the project-by-project nature of the CDM, and the measurement of emission reductions against an unobservable, project-specific, baseline impose substantial transaction costs in terms of validation, verification, and independent scrutiny. The CDM regulatory process currently takes about 300 days, on average, from validation to registration. Transaction costs can easily reach US\$ 500,000 (€325,000) per project- Key Elements of a Global Deal, Stern et al , London School of Economics.

64 IEA 2007 study of energy infrastructure planned globally

65 Planetary Skin platform development is partnership between Cisco and NASA

66 The Role for a Planetary Skin in an Era of Increased Uncertainty, forthcoming white paper by JC Castilla-Rubio

67 Connected Decision Spaces paper by JD Stanley, forthcoming

connects people, processes, and knowledge to enable faster, better decision making. It connects all nodes on the network—sensors, data, machines, objects, and people—in an intuitive environment that harnesses the collective intelligence of say carbon management communities to achieve its mission and mandate. It will focus on the distributed capabilities for improving cognitive decision making of those communities through techniques that connect decision-makers to a rich, distributed, complex, immersive and real-time flow of ideas, information, interactions, and feedback to improve the quality of decisions.

As an illustration of this type of complex coordination let us discuss the application of this platform concept into mitigating the accelerating emissions of Tropical Forests.

- **Making rainforests be worth more alive than dead**

Devastation of the world's rainforests is occurring at the rate of one England per year⁶⁸ and is the second largest contributor to global greenhouse gas emissions after the power sector⁶⁹. The destruction of this invaluable planetary resource⁷⁰ is driven by a number of factors: The unexpected links between food, fuel, fibre and forests are contributing to recent catastrophic food price inflation. This has arisen from land competition between food and fuel, a competition artificially created by short-sighted biofuel policies as well as increases in demand for meat caused by increasing wealth in China, India and elsewhere in the developing world. At the same time we face regional economic development challenges for the 1.6 billion poor living off the forests' natural resources⁷¹.

The market and governance failures at play here involve many organisations at many levels, from global companies and public institutions to the forest communities themselves. But all conspire to make forests more valuable dead than alive. Reversing this deadly trend will require mechanisms to manage deforestation hotspots by monetising forest property rights so that carbon sequestration services can be priced and traded. Forest carbon stocks will need to command a predictable price that can compete with food, fibre, fuel and cattle grazing. We have estimated that the economic value of eliminating deforestation is in excess of US 400

68 Global deforestation rate is estimated a total of 13 million Ha of forests is destroyed every year – an area the size of England. FAO (2005) Global Forest Resources Assessment. Food and Agriculture Organisation: United Nations

69 Deforestation related emissions are in the range of 20% of total emissions according to Houghton, R. A. (2003) Revised estimates of the annual net flux of carbon to the atmosphere from changes in land use and land management 1850–2000. Tellus 55B: 378-390. These emissions include around 5.9Gt CO₂, which are approximately equivalent to the total annual CO₂ emissions from the USA

70 77 % of all rainforests are notionally owned by the governments of 20+ countries, not by forest communities or the private sector, Forest Trends (2005)

71 Source : Chomitz, Kenneth, Piet Buys, Giacomo De Luca, Timothy S Thomas and Sheila Wertz-Kanounnikoff (2006) At Loggerheads? Agricultural Expansion, Poverty Reduction and Environment in the Tropical Forests; World Bank

billion per annum⁷². By contrast, the financial flows needed to pay for the associated opportunity costs, the protection and the transaction costs can be estimated to be in range of US 40 billion per annum up to 2050^{73,74}.

This high return opportunity is ripe for innovation at the failing edge of the market through the creation of a ‘rainforest skin’⁷⁵ - an open network platform for real-time, highly distributed mass remote sensing, authentication, risk-profiling, certification and monitoring⁷⁶ of carbon stocks and flows that generates trust and enables collaboration between the actors in all three sectors. This platform would use a ‘mash-up’ of geo-referenced satellite, unmanned aerial vehicle and multiple ground based sensor networks to estimate the forest’s carbon stock and flow dynamics and then allow for trading and risk management of this new commodity. Shifting the calculations of risks and opportunities in this way will remain central to maintaining the world’s capacity to avoid crossing dangerous climate thresholds.

Another important application of complex coordination is the need to avoid and in the limit adapt and be climate resilient to very significant low probability catastrophic events⁷⁷. There are significant risks that certain temperature thresholds will trigger systemic changes in the global ecosystem. These include the melting of the Greenland and/or West Antarctic ice sheets, the release of CO₂ and methane deposits from the tundra, the die-back of the Amazon and the abrupt changes in oceanic currents. When such tipping points will be reached is hard to determine in prospect, but once they are reached, they have the potential to do catastrophic damage and exacerbate the process of global climate change.

As a complementary illustration of this type of complex coordination let us discuss the application of this platform concept dealing with the ‘long tail’ of expected risks in climate change.

- **Coordinating complex current and potential disaster responses**

⁷² Result of the Cisco IBSG and U of Cambridge partnership, the Cambridge Cisco Policy Assessment for Deforestation (CCPAD) integrated assessment model estimated the average NPV value of global economic impacts to be in range of US 12 trillion which equates to an annuity of US 400 billion per year. Hope (2008) Valuing the climate change impacts of tropical deforestation., submitted to Nature as part of Cisco IBSG Planetary Skin program

⁷³ The costs incorporate best knowledge on potential agricultural opportunity costs modelled via CCPAD model described in note 49. A briefing note on the CBA of REDD, Chris Hope and Juan Carlos Castilla-Rubio, published as part of the UK Prime Minister Eliaesch Review of Global Deforestation and Finance - http://www.occ.gov.uk/activities/eliasch/Hope_Castilla-Rubio_cost-benefit_analysis.pdf

⁷⁴ According to CSERGE Working paper ECM 08-01, for 95% reduction of deforestation it is estimated that US 1.1 Billion is required in transaction costs and US 7.6 billion in forest protection costs. The balance are opportunity costs.

⁷⁵ ‘Rainforest Skin’ is the first set of carbon flux and stock monitoring capabilities being developed as part of ‘Planetary Skin’ platform

⁷⁶ NASA and Cisco IBSG partnership to develop a ‘planetary skin’ platform for global mass sensing, certification and monitoring of carbon flows and stocks from forests as a key component of the next generation utility or ‘middle layer’ enabling the provision of ecoservices to the world

⁷⁷ IPCC report on Climate Change 2007, Impacts, Adaptation and Vulnerability, Cambridge University Press

As an example of dealing with a current disaster consider a set of real time mapping capabilities being developed by NASA and partners to combat forest fires⁷⁸. This ‘mashes-up’ all the necessary geo-referenced data of current damage, weather predictions and simulations from multiple siloed sources, - providing past, current and future damage dynamics, and distributes the data to a widely dispersed set of emergency responders and social relief workers on the ground in real time. The information, and the immediacy/efficiency of its distribution, allows emergency relief organisations to quickly identify an emergency, the path to coordinated action and ultimately a platform to collaborate in real time to define how best to deal with it.

On the risk prevention side, ‘scale free’ network topologies and network thinking are key to dealing with long tails of expected risks. They are particularly suited to coping with cascading failures. A case in point is the fact that internet-based communications were kept in operation during and immediately after September 11 attack in New York.⁷⁹ The resilience and robustness of such networks should be a key design principle to face low probability catastrophic health related events or, as importantly, increasing water related stresses, amongst others.

It is well known that climate change is expected to contribute significantly to mass insect migrations and to the significant spread of contagious diseases leading to pandemics⁸⁰. In these cases, exploiting the asymmetric structure of connecting hubs with normal nodes in scale-free networks has the potential to limit the spread of viral replication, disease and infestation with innovations or strategies like targeted vaccination of infected hubs or the destruction of insect reproduction hubs⁸¹.

Or consider another good example of using the resilience and low latency of complex networks in dealing with a troubling potential outcome of climate change which leads to outbreaks of new deadly human viruses born by migrating insects, animals and people. The opportunity is for nurses and clinics in remote locations to rapidly identify tell-tale symptoms of emerging virus strains from other clinicians in the field. And then to be able to communicate warnings of viral outbreaks to regional medical containment and response teams. A global peer to peer network of clinicians constantly treating citizens in their village, kept in constant communication with their peer clinics in neighbouring villages, regions, states would be better able to

78 NASA Ames Disaster Response program was successfully prototyped and scaled in dealing with the California wildfires in 2007.

79 Source: New York Times

80 Source : Climate Change 2007 : Impacts, Adaptation and Vulnerability – IPCC, Cambridge University Press, 2007

81 Putting to good use the ‘Achilles Heel’ of scale free network topologies

statistically identify new viral outbreaks and call in the response team with less delay, increasing the probability of local containment.

Conclusion

The world faces a large number of apparently intractable public problems, all of which reflect the difficulties we have in co-ordinating our actions to achieve the common good.

The kind of breakthroughs we envisage here can only be deployed cost effectively today given recent innovations in pervasive sensing, collaboration and connectivity technologies and applications.

For instance, we can already see how collaboration tools are changing the rules of the game within both the market and the state. For many years increasing global connectivity and communications have catalyzed radical changes in commodity markets, global supply chains, the virtualization of the corporation and increasing customer self-service in many industries. The next wave of innovation currently unfolding is based on mass collaboration and common-based peer production⁸², where a range of Web 2.0 businesses – YouTube, Facebook, Flickr and increasingly major corporations - are creating value through the collaborative power of their customers and partners. They work with a mantra of co-development and co-production that is simply not available to top-down, centralised organisations. Pervasive, distributed information systems are changing the rules inside the market. They are also changing the rules within the state and beyond the traditional boundaries of the state as citizens and community organizations embrace bottom-up collaboration to co-develop and co-produce the public value they seek, independent of hierarchies and controlling elites.⁸³

In addition, ‘scale free’ networks and associated network thinking can play a unique and strategic role in aggregating, coordinating and in accelerating the low carbon innovation cycle. Their potential influence lies in that climate change follows a scale free topology in which both large clusters of opportunities and large risks co-exist with a long tail of small clusters of opportunities and risks. This rather simple mathematical topology has been shown recently⁸⁴ to be the basis for understanding the dynamics and special characteristics of all types of

⁸² Yochai Benkler, Coases's Penguin in Yale Law Journal 2002

⁸³ Connected Republic 2.0 by Paul Johnston and Martin Stewart-Weeks. For more information see www.connectedrepublic.org

⁸⁴ The study of complex dynamic networks concluding that a beautifully simple scale-free topology applies across multiple fields in science, mathematics, social sciences, biology, economics was articulated for the first time by Barabasi in Science. The work then has extended globally with the Santa Fe Institute acting as the world class complexity science hub.

complex real networks. These include social networks, the internet, collaborative networks for the diffusion of innovation, evolutionary cell biology and ecosystems, pandemics, language and communication and, very importantly, markets. We argue that complex network theory design principles and a through understanding of the dynamics and limitations of such systems as applied to the real needs of aggregation, coordination and acceleration of the low carbon innovation cycle are crucial to deal with the twin long tails of climate change.

This is true whether the solutions are market-driven, government-driven or community-driven. Indeed, for any complex problem the solution is likely to involve a contributions from business, from government and from a robust and energetic civil society ; and since the effect of networks is to amplify the power of each type of approach, the potential impact on apparently intractable public problems is huge. Today we have the opportunity to create a Connected Commons – a world where pervasive collaborative networks transforms our ability to co-ordinate our actions .

These points are particularly important, given the fact that today’s networks are generally digital (or at least digitally supported). This means that we can map networks much more easily and more accurately than in the past and can seek to influence their dynamics in real-time. Today we are much better placed to identify well-connected nodes in relation to different networks and to identify sections of the network that will be relatively hard to impact. For example, we can work out who the government should be targeting if it wants to improve innovative energy-saving construction techniques in the UK or what type of consumer it would be best to target for appliances that ensured minimised the energy consumer of electronic goods on standby. Similarly, we can identify firms or households who are least likely to respond to general energy-efficiency campaigns and target them individually with measures to encourage up-take. The world of pervasive connectivity is a data-rich world, and this should enable us to adopt data mining strategies which reflect both a general understanding of complex networks and the topology and dynamics of the specific network that is relevant for the social goal we are trying to achieve.

What we are advocating, that has not yet been deployed at scale, is the careful but proactive mass insertion of emerging sensing, communication and collaboration tools and technologies to address five closely intertwined challenges in solving common good problems.

- Firstly, embracing complexity, systems thinking and ways to deal with uncertainty, to achieve a better conceptualisation of the total problem. In

addition, the adoption of a global to local cross-sectoral and cross-disciplinary collaborative approach and model to diagnosing and problem solving to close multiple and pervasive knowledge asymmetries.

- Secondly, deployment of open platforms for multi-party collaboration that will close the key information gaps and asymmetries with low transaction costs at the intersections of the public, private and people sectors to create new sources of value
- Thirdly, we need to aggregate highly fragmented small abatement opportunities distributed globally where mitigation opportunities are small relative to the transaction costs of securing them
- Fourthly, we need to speed up the learning-by-using and learning-by-producing cycles in low carbon innovation and thus reduce the total cost of deployment whilst avoiding high carbon infrastructure investment lock-in, and
- Finally, we need to use the power of collaborative distributed and dynamic decision-making environments to address complex coordination failures that take advantage of insights provided by integrated data sets arising from connected and pervasive sensor networks.

Call to Action

The challenge of global warming is far-reaching, comprehensive, and global. But it is manageable and if done intelligently can be part of a stimulatory package to restore growth in the world economy. Most importantly we cannot ignore the massive risks that we now understand as there is no bail-out possible when collapse occurs. Only sound, measured and coordinated policy and timely international collaboration can deliver strong and clean economic growth for all driven by the business sector and at a reasonable cost. The activities and technologies necessary to eliminate the bulk of the risks associated with climate change are already available, or can be developed through appropriate policies to support innovation. However, the ability to put the technology into practice hinges crucially on widespread collaboration, sensing and human networks to enhance our understanding of the issues, and to bridge the numerous interrelated global and local knowledge /information asymmetries and aggregation / coordination failures that are currently occurring. At the forefront of this process is the need to harness the human network to help close knowledge gaps and move towards an effective,

efficient and equitable global solution to one of the world's most intractable problems.

In this context, what should we do?

- **What should policymakers focus on?**

They need to invest in next generation joined up climate science to further reduce the current scientific uncertainties globally (eg effects of non linear feedback loops) and critically to be able to predict local impacts and risks of ongoing climate change. They should begin by agreeing on what aggressive global goals to adopt and what regulations are required to ensure that dangerous emission pathways are avoided. They need to provide long term predictable but flexible carbon price signalling to motivate mass behavioural change and the adoption of low carbon infrastructures and solutions. They need to climate-proof their development pathway and plan to adapt to unavoidable climate change. They should then focus on enabling an environment that promotes an open and collaborative approach to systematic cross-sectoral cross-disciplinary problem solving⁸⁵. They should embed network thinking into mainstream policy making to accelerate the low carbon innovation cycle and to deal with the twin long tails of opportunities and risks. They should be key partners in the design and deployment of the critical 'middle layer' to enable the complex aggregation and coordination from global price signals to individual change. They should be a full partner in the deployment of open platforms for innovation through multi-party collaboration⁸⁶⁸⁷. They should promote interoperability across the sectoral intersections to capture network effects enabling rapid scaling⁸⁸. Finally, they need to drive the global and local hybrid institutional architectures⁸⁹ and governance required for rapid experimentation to work out the solutions that can be replicated and scaled globally, whilst taking into account local contexts, benefits and costs.

- **What should leading businesses focus on?**

⁸⁵ With distributed knowledge systems involving many people with different skills and many institutions across all sectors of society in as close to real time as possible to connect the various nerve endings of knowledge globally and locally

⁸⁶ Enabling an open collaborative approach across sectors and disciplines will require Public Private People partnerships for innovation that clearly segment the various risk classes and provide incentives for the natural owner of the risk class to bear it given its benefits and its associated costs.

⁸⁷ To materialize this we may need new intermediary institutions that focus on this type of innovation within 'low carbon economic development zones' as described by Bernice Lee in a recent publication by Chatham House and Nick Mabey of E3G

⁸⁸ To enable "learning-by-using" on the demand side, "learning-by-doing" on the supply side and the orchestration of demand and supply to be accelerated through "network effects" enabled by interoperability frameworks that not only consider the 'mean' but also the long tails of opportunities and risks.

⁸⁹ To enable these new institutions will require an inside grasp of institutional architectures and the governance principles which may guide their redesign to offer incentives for reform.

A good example of what leading businesses can do is reflected in a recent⁹⁰ study on the strategic role of the information and technology industry and climate change where it was estimated that ICTs could deliver approximately 7.8 GtCO₂e of emissions savings in 2020. This represents 15% of emissions in 2020 based on a BAU estimation. It represents a significant proportion of the reductions based on 1990 levels that scientists and economists recommend by 2020 to avoid dangerous climate change.⁹¹ In economic terms, the ICT-enabled energy efficiency opportunity translates into approximately US 1 trillion of potential cost savings (or value at stake). While the sector plans to significantly step up the energy efficiency of its products and services, the ICT sector's largest influence will be by enabling energy efficiencies in the power sector, in logistics and transport, in the built environment, in urban design, and in manufacturing and in dematerializing the economy. This is an opportunity that could deliver carbon savings five times larger than the total emissions from the entire ICT sector in 2020. To capture this large opportunity new business models, innovative cross sectoral partnerships and funding vehicles will be required to prototype and scale these innovations with the speed that is required⁹².

- **What should we do as citizens?**

This new world favours a more collaborative and flexible approach to our action and achievement as citizens, providing a platform for voice, empowerment and choice. Harnessing the “power of us” to change political agendas and drive change from within and bottom up, pulling people together to create public value in new ways to avoid the local and international governance failures associated with climate change will be foundational to make or break our path going forward. The urgency of the threat and the fact that many of the necessary actions are individually of small value mean that we will also need to use informal measures if we are to make rapid progress. This will involve people coming together to encourage and help each other voluntarily contribute to the common good, but it also meaning coming together to put pressure on those who are not doing their bit. This virtual peer pressure can reinforce the other actions we take and can provide additional and effective incentives for governments, companies and individuals to deliver on their commitments

⁹⁰ As described in Climate Group/ GeSi Smart 2020 report, 2008

⁹¹ The Stern Review suggested that reducing 20-40% below the 40 GtCO₂e emitted in 1990 would be a necessary interim target based on IPCC and Hadley Centre analysis. Source: Stern, N (2008), Key Elements of a Global Deal on Climate Change, London School of Economics and Political Science, http://www.lse.ac.uk/collections/climateNetwork/publications/KeyElementsOfAGlobalDeal_30Apr08.pdf

⁹² Scaling Up: Global Technology Deployment to Stabilise Emissions, World Resources Institute, April 2007

and take the many small steps that they might otherwise be under-incentivised to take.

Change, uncertainty and complexity are inevitable facts of life (and this will only increase in time), and successful leaders across all sectors embrace and welcome them. By offering a strong policy framework to provide the requisite economic and behavioural incentives, governments can harness both the power of markets and the power of people to find an effective global and local response to social, environmental and economic challenges. For markets and entrepreneurship to work, that framework must be credible, durable, legal and predictable, while still allowing necessary flexibility. Crucially, this process relies on end-to-end transparency, mutual trust and an unimpeded flow of information across all sectoral and institutional borders – from global to local and back to global. It will have to be on a scale and at a speed that the world has not yet seen.

The tasks we suggest do not lack in ambition; but there are multiple cultural, ethical, political and institutional blockages that threaten the progress required, many fuelled by inadequate or asymmetric information. Climate change is a collective problem requiring collective solutions. No single state, enterprise or institution or group of citizens can resolve this problem alone. It requires coordination among and between scientists, engineers, policymakers, businesses, financiers and citizens. The role of collaboration and networks is arguably unparalleled.

ENDS

Note from the authors: to learn more on the applications of this approach and to contribute further to the thinking please go to www.connectedcommons.org