Global Energy Transitions:
Coming to Terms with Inter-generational Burdens

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Abstract

The need to reduce greenhouse gas emissions to address the challenge of climate change is an issue of intergenerational burdens that requires a cogent national strategy for managing a future liability. We propose a fresh approach to move away from the constraints imposed under the UNFCCC[1] process requiring an enforceable multi- lateral agreement amongst all nations - a treaty with targets and timelines. The two decade UNFCCC process has not delivered meaningful results and in essence become a curse - the T^3 curse. We propose a strategy for Canada to lead by example. The goal is to provide long term policy stability and a coherent framework for action within a national context. Such an approach can be readily adopted by other jurisdictions. The essential components of the plan include:

i) A **'cap and invest'** strategy with a long view: large investments for accelerated deployment of low carbon technologies on a scale that enhances the national scientific, technological and industrial capacity

ii) A **small levy on economy-wide consumption**: one percent of current consumption. This levy would generate a large pool of capital for investments on an on-going basis to de-carbonize the economy. The levy is different from a targeted carbon tax on large emitters. In effect, this levy becomes the basis for an open social contract; an explicit commitment by the present generation to deal with our obligations to future generations by internalizing emission costs that arise from our consumption of goods and services;

iii) **Innovation in Governance:** An "arms-length" independent agency, enacted through an Act of Parliament, would be necessary to inspire trust and political acceptance. A clear mandate for the development and deployment of low-carbon solutions at 'wedge scale'[2] is a critical ingredient of the plan. The levy is the mechanism of accountability for public officials to deliver on the mandate through a governance structure and management of funds commensurate with global standards of best practice (i.e. CPPIB[3])

Re-directing funds from current consumption to investment becomes the foundational basis for a transition of the energy economy to one with lower carbon intensity. The pool of capital would provide the depth and long term stability for investments in low-carbon energy solutions. If the available funds are leveraged with the capacity of industry to access private capital, a larger pool of investment capital, managed over a 30-70 year time frame, has excellent prospects of delivering tangible results.

Keywords: GHG's and climate change, cap and invest, carbon tax, cap and trade, levy on economy-wide consumption, inter-generational liabilities, governance innovation, environmental trust fund, technology road map, low carbon electrified future

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[1] United Nations Framework Convention on Climate Change (UNFCCC)

[2] See Robert Socolow and S. Pacal, Scientifc American, Oct 2006. One wedge equals a reduction of 25 billion tons of carbon emissions reduction over 50 years.

[3] Canada Pension Plan Investment Board (CPPIB)

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Introduction

There is an urgent need for effective action to reduce the world's greenhouse gas emissions. The problem of climate change is an issue of intergenerational burdens and requires a strategy for managing a future liability. Although several factors conspire to undermine progress, the intractable challenge is shaped, on the one hand, by demographics driving the demand for energy, globally, and on the other hand income shifts within the global demographic profile. Eliminating energy poverty remains a powerful driver of change for a better quality of life to address deep social inequities. All these factors lead to forecasts of a near doubling of global energy demand by 2050.

Meaningful actions to decarbonize the global energy system so far have been frustrated because of a dysfunctional negotiation process that produces – at best - ineffectual and paltry commitments, subsequently circumvented by local and regional political considerations. Few are ready to compromise, options to enforce commitments are absent, and target setting has exhausted its relevance. The core of the global effort to cut emissions will not come from a single global treaty; it will have to be built from the bottom up—through ambitious national action focused on specific opportunities to cut emissions (Levi 2009).

We propose a fresh approach to help us move beyond a target-based strategy embedded within the United Nations Framework on Climate Change (UNFCCC) requiring an enforceable multilateral agreement amongst all nations – the T^3 curse. We focus on tackling a global problem but with a suite of credible solutions firmly founded within the ambit of national decision-making broadly aligned with the global goals of reducing the threat to climate change.

We use Canada as an illustration of the steps any one country can take to address the challenge of reducing emissions that impose a burden on future generations.

Although a comprehensive long-term view is necessary, a clear strategy founded upon good governance is a key requirement to advance the dialogue on this complex public policy issue. The need is for early, tangible actions to move beyond arguments around who gains most from subsidies, why one party is more deserving of public largesse than another, which industry is more deserving of allocations and credits, or developing complicated tax mechanisms for preserving "revenue neutrality" designed to pacify vocal interests. In a public process that makes a virtue out of protecting stakeholder and vested interests, we end up denuding our capacity for effective change. A bold measure that embraces a long-term vision is required to set us on a path to deliver meaningful results.

In Section One, we explain the nexus of climate change and the energy system in a global context. We highlight the magnitude and scale of the challenge in meeting energy demand with a low carbon footprint.

Section Two investigates the limitations of current policy instruments, namely, a carbon cap-and-trade regime or a carbon tax. Instead, we propose a levy on economy wide consumption. While a proposed levy on consumption is similar to a carbon tax, it does not link carbon emissions and the burden of their reduction solely to producers of particular products or services. Carbon is embedded in all consumption in one form or another and the supply-chains are so intricately linked that focusing on penalizing the producers, solely, does not address the fundamental issue. It is consumption or final demand for goods and services that drives the production system. Thus we do not seek to identify the "carbon-heavy" or "carbon-light" content of a product or a service for tax purposes.

In Section Three, we focus on the aspects of governance required to establish trust and confidence for managing a large pool of capital that becomes available for investment through a General Environmental Levy (GEL). A small tax on consumption, equivalent to one percentage point increase in the HST[4], would allow the creation of an Environmental Trust Fund (ETF). We then highlight the requirements for governance to ensure how a large and growing pool of investment capital within the ETF can deliver intended results over the long time horizon. We finally review the governance models of the Government Pension Fund-Global of Norway (GPFG) and the Canadian Pension Plan (CPP) and its Investment Board (CPPIB), and draw upon these examples of best practice to illustrate a concept model for the proposed ETF.

Global Context: Why a National Initiative Matters?

Two decades and two treaties on (UNFCC and Kyoto), climate diplomacy as practiced by many governments of the world, has failed to produce any discernible real world reductions in emissions of greenhouse gases.

In 1992, the global community came together in RIO - with much fanfare - and the goal was to cut greenhouse gas emissions to 1990 levels within a decade. Emissions in OECD countries overshot by 12% in 2000 and notwithstanding promises in Kyoto (1997) to reduce emissions by a further 5%, emissions rose by some 20% in OECD countries a decade later. The failure of the world as a whole was even more spectacular with global emissions increasing by an additional 40% from 1990 levels. Global emissions are poised to rise by another 30% in the next 2-3 decades. It has now become abundantly clear that a single minded focus on CO_2 emissions reductions - as the lynchpin for managing the risk of climate change through a negotiated treaty is no longer credible.

The underlying reason for failure is the structural flaw in the UNFCCC-Kyoto model and the framing of the threat to climate as a policy issue. Treaties, targets and timelines, namely the T^3 curse - without any serious consideration of cost and national capacity for effective change – run up against the unsavory calculus of domestic politics. The Hartwell Paper summarily pointed out that the Kyoto model has

[4] Harmonized Sales Tax (HST) is a consumption tax in Canada.

dangerously narrowed our option space for thinking seriously and realistically about energy and environmental policies (Prins et al 2010).

The sorry state of climate diplomacy as practiced over 20 years is clearly evident; it has just about consumed all the political capital and goodwill that any country could afford even amongst those who accept the urgent need for action to mitigate the threat of climate change. Targets are set and targets are not met. There are no consequences and even if non-compliance could be verified, there are no effective mechanisms for enforcement are lacking. The idea that nations could be shamed into compliance or a treaty with legal obligations could achieve significant emission reductions without national pain is, at best, delusional. Effective change will require collaboration and building of regional coalitions where national interests converge, not shame and punishment. Either we declare an end to the UNFCC process, with its primary agenda for a global treaty with targets and timelines, or, completely re-set the frame for achieving meaningful change.

The climate change challenge is, at its core, an energy policy and an energy technology problem. Fossil fuels and its use are deeply embedded in all material flows and goods and services that we consume. There are several reasons why decarbonizing the global energy economy is desirable and significant diplomatic efforts to foster a collaborative international effort would go a long way to breaking the logjam. A positive national initiative, by example, provides a model for wider adoption that is rooted in adoption of best practice rather than treaty obligations.

The locus of basic tensions that animate the debates around energy use and likely impacts on the global climate is energy poverty. Lack of modern energy services makes poverty worse and it makes escaping poverty more difficult. Resolving the problem of energy poverty is an important part of developing an understanding of the underlying forces that will drive demand for energy. The issues of energy access, energy security, energy affordability and impacts of energy use on the environment are all linked. They will shape the texture and the tenor of these debates.

Modern energy systems remain beyond the reach of one-third of the world's population. At least 1.6 billion people have no access to electricity at all. Attainment of a basic quality of life requires energy availability in the range of 800—1,000 kWh per capita per year.[5] If such a goal were to be achieved, we would begin to see a vast improvement in basic human development: substantial reductions in infant mortality, improvements in life expectancy and other indicators of social well-being.

Great increases in consumption of energy will be needed to lift the "bottom two billion" of the world's population out of poverty and squalor if only in accordance with the UN's "Eight Millennium Goals for 2015." For this unfortunate mass of humanity, something much like the catalogue of possible futures described by the International Committee on Climate Change (IPCC) is actually here and now.

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[5] To deliver a minimum individual requirement of 1,000 kWh per year for 2 billion people would cost approximately $2 trillion over a 20-year time frame. (WEC 2003, 2004)

Achieving meaningful reductions in greenhouse gas emission to address global climate change need not be in conflict with our wish to improve the standard of living for all people. By 2030, world population is projected to rise by another 1.4 billion, with an associated increase in world energy consumption of 39% (BP 2011; IEA 2010; IPCC 2007). By 2050, the world population will exceed 9 billion. With no change in the global development profile, another two to three billion would be living in poverty. If we consider a future path, consistent with UN goals to eliminate extreme poverty, and we move from the status quo to a "low poverty" world, implying relatively low energy use, it would still result in a doubling of global primary energy demand by 2050 from 16.5 to 30 terawatts, with greenhouse gas emissions increasing to 15Gt from a current level of approximately half that. A scenario of a more prosperous world means that energy needs will triple by 2050 from current levels[6] (IEA 2008).

Also, existing carbon-based energy infrastructure has a long, useful life, and its replacement will need to be synchronized with the requirements of growing demand, the daunting challenges of energy poverty and the need to limit or reduce emissions (WGSI 2012).

The focus of our efforts, globally, should be to improve the quality of life by ensuring energy access for all and ensuring that the development of the energy system does not undermine the essential functioning of the environmental eco-system. Delivery of non-carbon energy supplies at costs lower than or equivalent to the use of fossil fuels is the technological and policy challenge of the century.

Fresh start to climate policy along these lines may help:

- Develop credible national initiative that serves as a beacon of best practices through accelerated development of options that are cost effective. For example, Energy efficiency in conjunction with a renewed emphasis on non-carbon energy supply resources - such as wind, geothermal power, solar, bio energy and advanced nuclear - to diversify energy supply technologies is a first step to achieve real emissions reductions
- Emphasis on the role of science and technological innovations to spur the transformation of the energy system to a low-carbon energy system recognizing energy transitions are epochal in nature and will take anywhere from 50-70 years.
- Diplomacy with a primary focus on the alignment of national interests around promising technological pathways and to foster international consortia to de-risk the development of specific technology initiatives.

What then can we do to make a significant impact on climate change, and at the same time help shape the directions for change that takes into full account the need for energy? To get at the question,

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[6] If no action is taken, continued expansion and operation of fossil fuel infrastructure would lead to global warming of 2.4C to 4.6C by 2100 due to high levels of atmospheric CO2 concentration. The environmental stress resulting from this will create ripple effects that have the potential to undermine the economic livelihood, food supply and security of millions of people. (IPCC 2007; WGSI 2012)

we first examine the limitations of the prominent instruments now being considered to mitigate the impacts of climate change—a carbon cap-and-trade regime and a carbon tax.

Limitations of a Carbon Cap-and-Trade Regime or a Carbon Tax

Leading approaches to address anthropogenic climate change rely on several economic instruments or a regulatory mechanism. Experience to date with the cap-and-trade regime has revealed important limitations and carbon tax as a policy instrument has also seen mounting challenges from a skeptical public. Neither approach appears capable of delivering coherent international actions that would achieve the long-term stabilization of greenhouse gas (GHG) concentration at a level that would prevent serious interference with the climate system. If we are to rely strictly on those instruments, ability to achieve significant reductions in emissions, from a global perspective, is in doubt.

To help shape a new approach, here we provide a summary critique of the limitations of both cap-and-trade and carbon tax regime directed strictly at a small group of identifiable large emitters. The central message is that under the umbrella of an internationally negotiated climate treaty, neither a 'market-based' cap-and-trade approach nor a 'narrow' carbon tax on producers can begin to break the back of acrimonious target setting and paltry emission-reduction commitments.

Cap-and-trade

Cap-and-trade emerged as the prevailing response to climate change over the last two decades. Currently, twenty-seven European countries have had an emissions trading scheme in place since 2005. Twenty-three US states and four Canadian provinces also participate in regional trading schemes, such as the Regional Greenhouse Gas Initiative (RGGI)—a regional initiative adopted in 2009 by a number of Northeastern US states and Eastern Canadian regions. (IEA 2008; RGGI 2012)In 2012, California's Cap-and-Trade Program took effect, with allowance budget being established out to 2020. (California Environmental Protection Agency 2013) Australia's carbon regime will transition from a flat charge approach to a floating-price market beginning in 2015.[7] In June 2013, China began testing out its own carbon emissions trading scheme in the city of Shenzhen.[8]

In theory, cap-and-trade offers strong appeal to various groups. Environmental groups support an overall cap that provides a high degree of certainty on the environmental benefit resulting from its implementation. To industrial groups, it opens the possibility of a new market in carbon allowances and therefore potential profits, especially when the carbon allowances are "grandfathered". It also makes the costs of cap-and-trade passed to consumers less visible. Some economists are also attracted to it because the scheme minimizes the centrality of government and internalizes the costs of abatement and

[7] http://www.bloomberg.com/news/2013-06-24/australian-factories-meet-carbon-deadline-ahead-of-cap-and-trade.html
[8] http://www.economist.com/blogs/analects/2013/06/carbon-emissions

necessary innovation that would otherwise be subjects of government regulation. By the same token, it appeals to some politicians because it lets them avoid the subject of tax increase, which can be an electoral disincentive to some.

In practice, the benefits and certainties of a 'cap-and-trade' regime have proved to be illusory. A cap-and-trade regime imposes an overall cap on emission. By limiting the quantity of emission permits, it set a price for GHGs. The logic is premised on two factors: the firmness of a cap and the resulting scarcity of emission allowances. Failure to administer the stringency defeats the effectiveness of the cap-and-trade instrument. The political economy of cap-and-trade, on all levels, international, national and subnational, has shown difficulty in maintaining the stringency of these two factors. The lack of a strong and persistent price from a cap-and-trade regime is a serious limitation for investor confidence.

Problem of Leakage: What Actually Happened

Global efforts to enforce an overall cap on GHG emissions, under the Kyoto Protocol, were intended to establish the benchmark for a "cap" at the global level. More than a decade since its adoption, however, the protocol has only produced a low level of emission reductions, falling far short of the levels of emissions reductions necessary to avert the threat catastrophic climate change.

Also under the Kyoto Protocol, countries could exceed their emission quotas by contributing to emission-reducing projects in non-Annex B countries through the Clean Development Mechanism (CDM). The CDM then becomes a part of a broader carbon market, subsequently affecting the overall carbon price levels.

Legitimately, the CDM and associated emission reductions are only admissible as "additional to any that would occur in the absence of the certified project" (Kyoto Protocol Article 12.5). Even with a validation process in place, the counterfactual is impossible to observe, and clearly open to strategic manipulations, since both the buyer and the seller of emission reductions have an incentive to inflate the baseline (Lecocq and Ambrosi 2007).

Entrants into the CDM market poured massive capital to purchasing Certified Emission Reductions (CERs). These included banks and speculators—without the need for CERs for compliance—aiming to trade them on the secondary market, such as the EU Emissions Trading Scheme (ETS).

To date, the CDM has brought forward more than 2,500 registered projects, which are expected to deliver about 1.9 billion tonnes of CO2eq by the end of 2012. However, according to UNEP Risoe calculations only about 1 billion CERs will be available for use in the period 2008-2012. The EU is the single largest demand market for CDM credits (Kossoy and Ambrosi 2010; Vasa and Neuhoff 2011).

The price differences arising from the spot price in the EU-ETS and the price of forward contracts for CERs generated tension on the CDM market (Lecocq and Capoor 2005). It led to hoarding of assets for selling at better terms in the future and an increase in demand for CERs from firms under the ET-ETS and from speculators who saw opportunities for arbitrage, in addition to the increased demand for CERs triggered by the entry into force of the Kyoto Protocol (Lecocq and Ambrosi 2007).

Figure 1 below illustrates how the CDM limits the emissions reduction effort[9]:

EU-27 Reductions in 2020, relative to 2005	…with 20% target	…with 30% target
…with CDM	-7.5%	-12.6%
…without CDM	-13.8%	-23.9%

Figure 1: Emission reduction with and without the CDM. (Vasa and Neuhoff 2011)

In its Directive 2009/29/EC the European Commission recognized that the increased use of CDM credits in the absence of an international agreement could undermine the EU renewables target and the incentives for energy efficiency, innovation, and technological development (den Elzen and Höhne 2008; Vasa and Neuhoff 2011).

In summary, various studies have concluded that a large share of registered CDM projects were not valid[10].

While the CDM exacerbated the misappropriation of emission allowances, the evidence of failure of the First Phase of the ETS has been attributed to an oversupply of permits by the regulatory authorities (J. Andrew, M. A. Kaidonis, and B. Andrew 2010; Tan, M. Kaidonis, and Moerman 2008). National Action Plans and emissions registries were developed late, causing significant confusion in initial permit trading and leading to highly volatile carbon prices (Matisoff 2010). The price of the trading permits collapsed from around **€**30 to **€**0.10 over the three-year term (Andrew et al. 2010).

The complexity of carbon accounting—CDM credits in conjunction with allowance appropriation—for defining eligible tradable credits introduces high transaction costs with uncertain impacts for cap-and-trade which, in reality, neither cap all emission sources nor do they credit all carbon offsets. Biases will be introduced by what is or is not measured as a carbon offset, which can easily lead to counter-productive impacts. European credit trading topped $40 billion in 2007 but emissions grew by 1%, exceeding reduction targets. (Lippke and Perez-Garcia 2008) The EU ETS also failed to achieve any worthwhile reductions in carbon emissions and the 2008 emissions exceeded the 'cap' by 145 million tons (Andrew et al. 2010).

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[9] Based on existing data from the EU Community Independently Transaction Log and the individual National Allocation Plans of EU Member States, the CDM reduces the emission reductions that need to be achieved within the European Union (Vasa and Neuhoff 2011).

[10] Assuming non-additionality of between 20% and 66%, the use of Carbon Emission Reductions in the EU-ETS in the period 2008-2009 increased global emissions between 30 and 106 million tons of CO2eq (Michaelowa and Purohit 2007; Schneider 2009; Vasa and Neuhoff 2011; Wara and Victor 2008).

While purportedly Phase III of the ETS will have auctioned allowances, it is unclear whether the regulatory and administrative arrangements would be robust enough to prevent the issue of leakage. A major shortcoming of the cap-and-trade regime is the ability to induce a high level of confidence and certainty for investment in low-carbon technologies with long-lead times and high capital costs. On April 16th, the European Parliament initially voted to reject "the back-loading" proposal, which aimed to restrict a surplus of carbon allowances that sent carbon prices to below € 5 (euros) a tonne from € 20 (euros) a tonne in 2011 (with the caveat that the allowances would be reintroduced later).[11] After months of negotiation, the EU Parliament voted in support of the plan. According to a study by Sandbag, the EU ETS is now delivering negative tonnes of abatement, setting to cancel out over 700 million tonnes of emissions saves through renewable energy and energy efficiency efforts, a far cry from the 2.8 billion tonnes of emission it was originally expected to reduce. (Sandbag, 2013)

Jurisdictional Difficulties

The cap-and-trade instrument has not only significant regulatory and accounting weaknesses, but the implementation challenges of taxation across jurisdictional boundaries and the need to harmonize overlapping international, national, and subnational programs and distributional conflicts remain unresolved.

In the US for example, a multitude of interactions between any federal climate policy and state and regional programs are largely determined by two factors: the extent to which the state and federal programs cover the same sources and the relative stringency of the federal and state programs in question (McGuinness and Ellerman 2008).

Depending on the division of the two factors between a state or regional program and its federal counterpart, the outcome could be futile or generate additional emissions and costs. Distributional impacts and additional cost burdens and subsequent loss of economic efficiency would be felt at the local level. A nationwide cap-and-trade (without federal preemption to improve a more demanding state program) would impose punitive burdens on a local or regional economy that is less able to adjust to activities requiring deep reductions.

While federal preemption may prevent efficiency losses, it carries a political cost and successful negotiation may require some degree of compensation to states for lost allowance revenues. Implementation challenges under the "carve-out" with linkage approach may render it impracticable, unless states are required to modify their rules to satisfy key policy and design principles, a result which would closely resemble a uniform national program where allowances are allocated to the states (McGuinness 2009).

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[11] http://www.economist.com/news/finance-and-economics/21576388-failure-reform-europes-carbon-market-will-reverberate-round-world-ets; http://www.theguardian.com/environment/2013/jun/25/eu-emissions-trading-scheme-energy

Moreover, in the context of a global cap-and-trade regime, there could be potential arbitrage opportunity, where allowances purchased at one price in one jurisdiction can quickly be sold in another for a higher price. Importing too many cheap foreign emission rights would both depress domestic carbon price and create greater demand for offsets if they exist in the foreign system. Without harmonization across jurisdictions, large imbalances can arise from a trading competition perspective.

Offsets fraud becomes a larger problem in a global setting, where the provision of an offset in one jurisdiction may not follow the same rigorous screening process as in another jurisdiction. Experience with the CDM mechanism also reveals the drawbacks and issues of complexity management when it comes to cross-border CER validation and verification.

Sulfur Dioxide (SO_2) vs. GHGs (CO_s, CH_4 and others)

An often-cited success story for a cap-and-trade mechanism is its application to reducing sulfur dioxide (SO_2) and acid rain in the US. We note that the challenges and complexity of mitigating GHG (CO_2 primarily) at the global level across transnational boundaries are fundamentally different from those posed by SO2 and acid rain.

Briefly described below are the lessons from the SO_2 market in the US as a caution on its relevance for application to the global market.

The Clean Air Act Amendments of 1990 created a cap-and-trade regime for SO_2 that extended to 445 sites in the US. As shown in Figure 2 below, the challenges facing the established regime are simple and straightforward:

Figure 2: A graphical representation of the Acid Rain cap-and-trade challenge. (Breakthrough Institute 2009)

First, SO_2, the principal pollutant under the cap-and-trade regime is relatively local, in that the source of emission in a given region are primarily local coal-fired power plants and subsequently the capped emissions come primarily from them. The discrete and localized nature gave rise to two conditions critical for the success of cap-and-trade. On the one hand, the regulatory signal to the capping part of the problem was clear since emission sources were fixed facilities and identified (as opposed to ambulatory sources such as automobiles). On the other hand, the problem of redistributive justice and equity were largely avoided. In sharp contrast, equity plagues climate negotiation because the responsibility for emission, the cost burden of reductions and the sharing of the benefits remain unclear.

Secondly, availability of technical solutions for mitigating the SO_2 problem made it as simple as adding scrubbers or catalytic converters to smokestacks and tailpipes or burning low-sulfur coal and gasoline with new additives instead of lead (Jenkins 2009). For a typical coal-fired power plant, flue-gas desulfurization (FGD) effectively removes up to 95 percent or more of the SO_2 content. The centralized and localized nature of emission source further simplifies the process, which from the beginning requires neither major innovation nor change of business model.

In comparison, world GHGs present a much more complex set of challenges and issues across various sectors and industries, as illustrated by Figure 3 below:

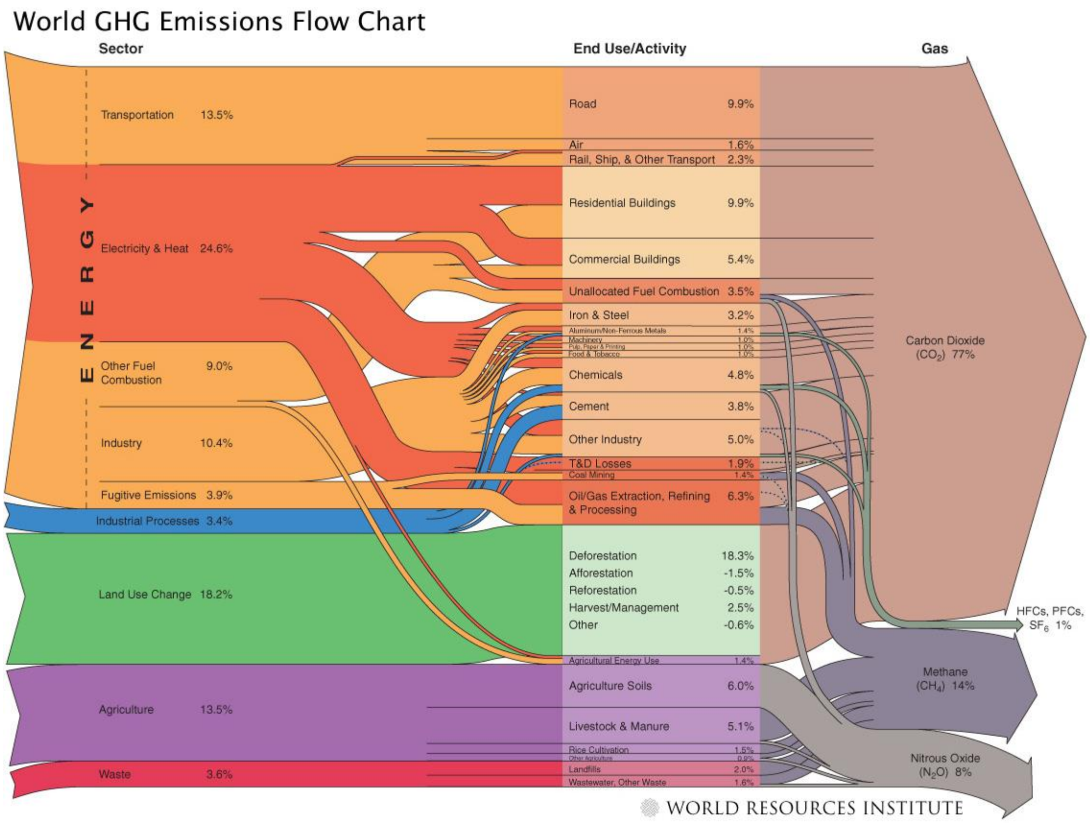

Figure 3: A graphical representation of the global flow of greenhouse gas emissions. (World Resources Institute, 2000)

The figure illustrates the enormous complexity of the energy transformation process from primary energy availability through a long chain of end-users and the embedding of energy into materials and processes with divergent needs of different sectors in the economy. Introducing a cap on some producers at one point in the chain of energy transformation and allowing a pass to another agent invariably leads to a plea for exemption and an unyielding process for settling grievances.

For greenhouse gas mitigation, the magnitude and complexity of the problem requires a transformation of the global energy system, driven by major innovations throughout the multiple chains of supply and linkages to end users and modes of business investments and operational considerations. The SO_2 rationale of a cap-and-trade regime has serious shortcomings with respect to relevance and applicability in this context.

Carbon Tax

Compared to cap-and-trade, a carbon tax is a fairly straightforward instrument. A tax would be imposed at a price per ton of carbon content on the "upstream"—sources of emissions in the economy, such as coal, oil, natural gas and mining entities that are heavy emitters.

In theory, a tax on fossil energy would pass the cost to fossil energy users and propagate to the price of every product and service. As a consequence, as users make decisions to avoid higher costs, emission would decline and the impact would be highest where the emissions impact would be the greatest, producing an efficient outcome. (Lippke and Perez-Garcia 2008)

It can be argued that a carbon tax provides several advantages over a cap-and-trade. As a revenue-generating instrument (as opposed to non-revenue-generating in the form of a free-allowance cap-and-trade), a carbon tax in theory yields a double dividend of economic as well as environmental benefits (Harrison 2010). From an administrative standpoint, a carbon tax is simple to set up because we have extensive experience with economy-wide excise taxes and their enforcement. A carbon tax also ensures cost certainty for business, since the external cost cannot rise above the tax rate. It offers greater transparency with respect to costs and their distribution, which can make it easier to redress impacts on those with low incomes.

However, a carbon tax has clear limitations from the perspective of political acceptability. As with any revenue-raising instruments, the mere act of levying a duty (even if not implying actuarial or budgetary increase) is bound to arouse some electoral opposition. The more direct and visible nature of costs to consumers in the case of a carbon tax may not be politically palatable to the public, due to "a combination of rational ignorance and loss aversion" (Harrison 2010).

Much of the opposition to a carbon tax is likely to come from organized groups that stand to benefit from cap-and-trade (Avi-Yonah and Uhlmann 2009), especially when allowances are grandfathered in or from powerful industry lobby groups disadvantaged because of the carbon intensity of its product. To the extent that industry (energy product and service providers) can adjust to a new cost structure, competition is set to emerge in vying for fiscal privileges, such as exemptions for particular energy-intensive entities, rebates from carbon and energy taxes, reduced tax rates and so on. Business, more aware of their interests and better organized to invest in their appropriation, has time and again won over consumers, as observed in Denmark, Finland and Germany (Harrison 2010).

Along this line, a carbon tax might appear relatively transparent, but discrimination against certain types of emitters (especially in the face of strong anti-carbon taxation lobbying powers), will generate tension over the equity aspect of the taxation.

In terms of international competitiveness, a carbon tax has negative political connotations. Although several academic studies suggest there is "little evidence to support the hypothesis that environmental regulations have had a large adverse effect on competitiveness", politicians remain highly risk averse when confronted with threats of capital mobility (Harrison 2010; Jaffe et al. 1995). The political trade-off is more concessions will be granted to powerful groups that represent large industrial or major emitters. Finally, while segregating the revenue generated from a carbon tax regime can reduce the uncertainty of environmental and social benefits, there remains skepticism that revenues under government management (based on a general perception that government is wasteful) would be effectively channeled to address politically appealing pet projects with high voter satisfaction.

A recent proposal dubbed 40/40, by Alberta's Minister of Environment, Diana McQueen, to reduce intensity-based emissions and raise non-compliance penalty has drawn much national attention. The plan requires large emitters in Alberta to reduce their per-barrel emission by 40 percent and pay $40 per exceeded tonne into a technology fund (thus the 40/40 moniker). This marks a significant jump on both ends compared to the current regulation in effect since 2007 that set emission intensity reduction target at 12% and non-compliance penalty at $15 per tonne. We note that the proposed measure is not technically a carbon tax but a performance regulation. The Pembina Institute pointed out that the $40 carbon price still falls short of keeping Canada's 2020 target agreed to in Copenhagen.[12]

All in all, carbon tax remains a very difficult sell. Where exceptions emerge—such as in the case of British Columbia's adoption of a revenue-neutral carbon tax in 2008, it has been pointed out that there is a uniting feature in the design of diverse policies to clearly state how revenues will be utilized and the possibility of linking potential costs and benefits to bolster public support (Rabe & Borick 2012).

In summary, we have highlighted the important limitations associated with 'cap-and-trade' and 'carbon tax' regimes. Our proposed approach goes beyond reliance on a strict economic instrument. We combine the use of a small levy on economy-wide consumption to create a pool of capital for investments – namely, 'cap and invest' with much greater emphasis on innovations in governance and technology solutions. Broader public acceptance can be obtained but only if there is a clear 'line-of-sight' from a levy ("money out of an individual's pockets") to investment in the infrastructure for the benefit of future generations.

'Cap and Invest' — Levy on Economy-wide Consumption

The need for a bold measure to drive effective actions is clear. We focus on Canada to illustrate how such an approach can be adopted by any country. The three essential components of the approach to promote long term policy stability are:

[12] http://www.pembina.org/blog/707

i) A 'cap and invest' strategy with a long view: large investments for accelerated deployment of low carbon technologies on a scale that enhances the national scientific, technological and industrial capacity

ii) A small levy on economy-wide consumption: **one percent** of current consumption. This levy would generate a large pool of capital for investments on an on-going basis to de-carbonize the economy. The levy is different from a targeted carbon tax on large emitters. In effect, this levy becomes the basis for an open social contract; an explicit commitment by the present generation to deal with our obligations to future generations by internalizing emission costs that arise from our consumption of goods and services;

iii) Innovation in Governance: An "arms-length" independent agency, enacted through an Act of Parliament, would be necessary to inspire trust and political acceptance. A clear mandate for the development and deployment of low-carbon solutions at 'wedge' scale is a critical ingredient of the plan. The levy is the mechanism of accountability for public officials to deliver on the mandate through a governance structure and management of funds commensurate with global standards of best practice (i.e. CPPIB)

What we propose is a measure with teeth that will pull the Canadian economy in the right direction. Large investments, in the order of $10 billion plus per year, will be necessary to develop the solutions to be deployed on a very large scale over relatively long time periods to make any significant impact. A levy on consumption—an increase of one percentage point to the Harmonized Sales Tax (HST) and designated as a General Environmental Levy (GEL)—would result in a pool of investment capital large enough but necessary to reduce carbon emissions on a large scale. The annual revenues from the levy over a 50-year time frame would provide a sufficiently deep pool of liquid capital and certainty for investment purposes to re-shape our collective environmental footprint.

If binding "five year" carbon budgets are set well in advance, say 10-15 years ahead (an approach similar to the U.K), they would provide clarity and policy certainty to businesses. We could aim for at least 1-2 % per year reductions in real terms, net of economic growth, for the next 10-15 years. Achieving a 20-25% reduction by 2030 and a 50% reduction by 2050 from present levels is a tall order—but, if we such a bold measure were to gain broad public acceptance, then the goals can be achieved.

At the outset, we concede one major point: There is little enthusiasm for increased taxes at any time. However, this level of sacrifice to address a compelling global environmental problem does not appear to be particularly onerous, if we view it is an investment in our own future. A levy on consumption spreads the fairness of burden across all individuals and limits large impacts on a narrow group of industries, sectors or communities. Any reduction of emissions arising from reduced consumption—due to the marginal elasticity effect of a tax—is a positive effect but only a small part of the benefit. The larger benefit can only be realized if the revenues from the consumption tax are "ring-fenced" and re-directed for investment in the deployment of solutions. The GEL will be designated and directed towards building the infrastructure with a lower carbon footprint.

In promoting an economy-wide tax on consumption, we draw upon the consent of all citizens to strengthen the base for political discourse to address this important global challenge—how to de-carbonize the economy. The premise of a functioning democracy is the tacit agreement of citizens who willingly pay taxes in exchange for government services. For government, its capacity to tax is its only source of revenues to deliver the service, implied in the social contract. Citizen consent through taxation in essence provides the blinding glue of accountability between public officials and expectations of their constituents. The citizen as taxpayer has a compelling interest in ensuring that the taxes are used for the identified purpose. The impacts on the climate, arising from our actions through current use of fossil fuels, are a case of inter-generational burden that requires a broad-base of consent. The levy is the mechanism of accountability that will dictate the action of public officials.

With respect to administrative implementation, the HST can stand as is but the additional revenues from a one percent increase, explicitly identified as the GEL, and would be dedicated solely to the solutions required for a cleaner environment. The levy thus shifts up an additional one percentage point tax on our consumption to the betterment of the environment.[13] The proposed GEL is somewhat closer to a carbon tax but with a fundamental difference—it does not seek to identify the "carbon-heavy" or "carbon-lite" content of the product or service. It reflects the fact that whatever we consume to support our lifestyle contains an embedded energy component. Thus, collectively, we are part of the problem related to carbon emissions that our consumption engenders.

In our view, there is little merit in devising complicated tax schemes to punish one sector over another or pointing to industry, solely, as the problem. It is just as perverse to punish truckers for bringing our food supplies to our local grocery stores via increased fuel taxes, as it is to blame airlines for flying us to destinations we desire. It may be the easier thing to do to target large industrial emitters or the transport sector or the energy sector, but we must accept that businesses and industry make products and services available because we demand them and consume them, often in prodigious amounts. A small levy, on our gross consumption, no more than one percent of, is reasonably small at the individual level, but at the national level, it frees up a substantial pool of capital to allow investments to be directed to solving the problem of climate change. The next steps involve setting priorities for investments in specific initiatives to ensure they yield the largest return on reduction of greenhouse gases.

One reason that a carbon tax is likely to meet political difficulty is that it entails concentrated costs and diffused benefits. In contrast, cap-and-trade promises concentrated benefits and diffused costs, and is therefore more politically palatable (Harrison 2012). In the approach outlined here, the Green Environmental Levy (GEL) as an integral part of an Environmental Trust Fund (ETF), described in the next section, offers not only the politically palatable feature of concentrated benefits and diffused costs, but also maintains the feature of transparency of a tax-based regime.

[13] For those disadvantaged in our society, there are already several effective compensating measures of tax relief in place (e.g., exemptions on food, textbooks and rebates to low income individuals).

Governance Innovation

The most serious objection to such a bold move is the potential threat of misuse of such a large fund. We accept this concern as being critical to the proposal. Pork barrel politics can derail all good intentions. Temptations to favor some constituencies or industries for political gain are ever present. We believe that a rigorous, transparent and effective management of such a large undertaking would be necessary.

The proceeds would be managed through a national Environmental Trust Fund (ETF) created with a specific mandate by Parliament and at 'arms-length' from overt political influence. Clarity around the goals and vision for use of these funds would be part of the mandate. We also remain optimistic in the level of basic competencies available to us as a society. For example, after much deliberation and fractious political debates (Little, 2009), we have been able to put in place the mechanisms necessary to manage the Canada Pension Plan (CPP). It is in this spirit we note that it is possible to manage the Environmental Trust Fund with the requisite degree of probity. The concern that monies would disappear into some general proverbial "hole-in-the-ground" could be eliminated by introducing necessary legislative requirements for allocations from the ETF.

In the following subsection, we examine the governance model of two exemplar national funds—the Norwegian Government Pension Fund Global and the Canada Pension Plan—the ethics, management, and institutional structure – as role models for national funds. The governance models of these two funds offer several relevant insights as to how the proposed Environmental Trust Fund can be constructed and managed.

Fixing the Future at Arm's Length

The proposed model for directing the revenues from the Green Environmental Levy (GEL) within the governance framework of a national environmental trust fund (ETF) is predicated on an arm's length governance structure—an agency independent from the government tasked with the management of a policy area. We recognize that effective governance needs to be met with de-politicization, which arm's length governance structures have historically worked well in achieving.

The Canada Pension Plan (CPP) and the CPP Investment Board (CPPIB) provide exemplar arm's length governance models from which lessons can be drawn for operational insights. For example, the Economist regards the governance model of the CPP as a "Maple Revolution" towards which many institutional investors aspire (The Economist 2012). There also exist successful examples in other federations of how a more technocratic structure can help remove political obstacles and deliver results.

For instance, the Australian Commonwealth Grants Commission (CGC) is an arm's length body created to administer equalization programs. It comprises respected, non-partisan experts, operates under broad terms of reference set by the Commonwealth government, and makes recommendations for the appropriate redistribution of wealth. The recommendations are highly regarded and generally respected because they come from neutral fiscal expertise. Similar bodies concerning fiscal matters also exist in South Africa and India. The Financial and Fiscal Commission (FCC) and Indian Finance Commissions respectively play a crucial role in the allocation of fiscal resources and evidence-based decision-making (Beland and Lecours 2012).

That being said, there is no guarantee that experience in a foreign political context can be readily applied domestically, nor is there absolutely certainty that agency governing one area of fiscal redistribution can be replicated in other areas. However, as far as de-politicization is concerned, an arm's length structure is a key feature necessary the establishment of GEL-ETF.

A Tale of Two National Funds

The concept of a national fund that draws on current contributions to address a future societal liability is well known. Such funds have been established in several countries. At the core of the concept is a recognition of intergenerational liabilities that spans several decades. We draw upon two successful national funds, such as the Canada Pension Plan (CPP) reserve fund and the Government Pension Fund of Norway in search of insights that may help guide the future development of this proposal. An understanding of the features and the governance architecture is essential for the integrity of the institutional framework. The design of a concept model for the ETF draws upon some of the successful features of the plans. We describe two such designs as illustrations of global best practice.

The Government Pension Fund of Norway

The Government Pension Fund-Global (GPFG) (previously the Norwegian Government Petroleum Fund) was established by an act of the national parliament (Storting) in 1990, as a long-term policy design to offset the curse of resource wealth that may distort the economy and serve as a tool for macroeconomic stabilization against the potential short-term costs of fluctuating revenues (Clark and Monk 2009).

In 2001, the Norwegian parliament adopted a fiscal guideline that non-oil deficit be limited to 4 percent of the Fund to provide predictability in the level of spending. The Fund is formally owned by the Ministry of Finance, as a deposit account with the Norwegian Central Bank. Thus the actual operational management of its assets is administered by the Norges Bank Investment Management (NBIM), which is a special unit created by the Norges Bank that reports to the Bank's Governor and Minister of Finance. While the Ministry has the responsibility for the key long term strategic decisions affecting expected return and risk, the Bank's main responsibility is to maximize expected return relative to the benchmark and variation determined by the former (Vikøren 2008). The focus is on long term policy stability to ensure viability of funding to meet the needs of future generations.

Given its transparent nature, integrity of democratic processes, and commitment to accountability, intergenerational equity and moral complicity, the GPFG is widely acclaimed for its governance model and has high Truman score.

Appendix I explains the working—institutional vision and structure, investment strategy and asset allocation, and ethical guidelines—of the GPFG in greater detail.

The Canada Pension Plan

While in Norway, the Ministry of Finance is at the center of a network of governmental entities that in sum amount to the GPFG, the Canada Pension Plan (CPP) is operated and managed by a private sector entity, the CPP Investment Board (CPPIB), independent of the government.

A large literature discusses the history of the CPP and the political forces at work shaping the fund. Here we describe how the best practice in the Canadian Pension Plan (CPP) can provide some exemplar insights for the management of the Environment Trust Fund (ETF). The CPP has undergone drastic reforms since its establishment almost half a century ago and is presently in good health. Lessons learned and experience of successful governance can be drawn from the framework and management of the CPP to inform the proposed ETF model to address a different problem—reducing the burden of climate change risks on future generations.

In the mid-1960s, the Canadian government and its provincial counterparts began negotiations to set up contributory pension plans as a complementary pension pillar to the general revenue-based plans (Old Age Security (OAS)).

For the first two decades, the CPP contribution rates—financed by a compulsory deduction of a proportion of earnings, and with mandated defined benefits—were largely unchanged. Then a watershed moment transpired in 1983 when for the first time, the plan's (CPP) expenditures exceeded contributions. In the first five-year actuarial review of the CPP, questions revealed the inadequacy of the contribution rate and sustainability of the fund. This prompted the need for revision and eventually a consensus was reached between the provincial and federal government to allow a gradual increase in contribution rates at 0.2 per cent annually. Almost a decade later, in the Fifteenth Actuarial Report produced in 1995, in order to finance a pay-as-you-go system, contribution rate would have to reach 14.2 per cent by 2030, a number feared by both federal and provincial ministries of finance among many other actors as being disruptive of economic growth, especially with respect to job creation (Battle and Tamagno 2007).

The circumstances were such that a flurry of studies, reports, media coverage, public discussions, and political interests quickly incited a nationwide debated on the impending diminishment of the fund and urgently needed measures to fixing it in this light.

The fractious political interests came together in the following years to rescue the CPP (Little 2009). Reforms actions, having undergone iterations of political debates and bargains, resulted in a three-part solution involving the financing of the CPP: 1) a rapid increase in the contribution rates to bring the fund to a better financial standing, consequently bringing it to a steady state in terms of contribution levels in the future and from a pay-as-you-go basis to a partially funded basis; 2) a new investment policy that would create a separate and independent CPP investment fund; and 3) various cuts in benefits and removal of exemptions that would help raise average contribution rates. (Mendelson 2005)

The upshot of the reform was the rise of contribution rate to 9.9 per cent in 2003, which enter a steady-state through 2050 (Mendelson 2005). More importantly, an investment fund, built up for 5 or 6 years of funding, would see to reinvesting earnings from the reserve fund for the indefinite future (Battle 2007).

The 4 per cent annual target of return (to keep at steady-state financing) was too high a threshold for sole investment in provincial bonds that have generally low returns. It could only be achieved by investing in a diversified portfolio in both public and private markets, which the federal Department of Finance could not be expected to manage. (Mendelson 2005)

In December 1997, by an Act of Parliament, the federal government and the nine provinces set up the Canadian Pension Plan Investment Board (CPPIB), a new specialized agency that would operate at arm's length from the governments to assist the CPP in meeting its objectives and sustainability through the maximization of investment return. There is an important point that bears repeating: the amending formula for the CPP is tougher than the general amending formula for the Canadian Constitution. The CPP formula requires seven provinces with 67 per cent of the population; the formula for the Constitution requires seven provinces with only 50 per cent of the population (Little, 2009)[14].

There are several key elements related to CPPIB's governance framework, primarily accountability, independence, and transparency. The Canadian Pension Plan Investment Board was created, in the form of a Crown Corporation, by the Canadian Pension Plan Investment Board Act in December 1997 (Section 5 of the law[15] sets out the objectives of the board, holding the CPPIB accountable to all Canadians). It also prohibits the CPPIB from carrying out any business activities inconsistent with the

[14] There has not been a major overhaul of the Constitution since 1982. The last two attempts failed. Yet the CPP has undergone many small changes since 1966 and three substantial revisions since 1982, the last being a major reform, (Little 2009, p.309).

[15] "a) to assist the Canada Pension Plan in meeting its obligations to contributors and beneficiaries; under the Canada Pension Plan; b) to manage any amounts transferred to it under section 108.1 of the Canada Pension Plan, and its right, title, or interest in any designated securities, in the best interests of the contributors and beneficiaries under that Act; and c) to invest its assets with a view to achieving a maximum rate of return, without undue risk of loss, having regard to the factors that may affect the funding of the Canada Pension Plan and the ability of the Canada Pension Plan to meet its financial obligations on any given business day" –Canadian Pension Plan Investment Board Act, Section 5.

above objectives and any variation would require an amendment to the law[16] (Mendelson 2005; Government of Canada 1997).

The character of independence is reflected in the strong regulatory safeguards (within the CPPIB Act) to protect he CPPIB from political interference.[17] The nomination and appointment process aims to limit ministerial influence on the board so as to maintain professional standards and the primary fiduciary goal of maximizing the rate of return.

The Board is also governed by clear legislations that prescribe a transparent reporting framework. The Board is required to produce quarterly and annual financial statements in accordance with the accounting principles enshrined in the Handbook of the Canadian Institute of Chartered Accountants (Battle and Tamagno 2007).

Along with financial statements, the Board is also required to produce a comprehensive annual report that reviews the governance objectives, changes in investment policies and practices and performance. These documents must also be accessible to the public. Once every two years, the CPPIB is required to hold a public meeting in each province. The guarantee of public deliberation and accessibility to reporting documents is embodied in the Board's disclosure policy.[18]

Appendix II explains the management, performance and sustainability of the CPPIB in detail.

Importance of an 'Arms-Length' Investment Framework

The exemplar governance of the GPFG and the CPPIB lends weight to our view that an arm's- length entity with the right governance structure for managing a large pool of investment capital in a prudent way is possible. A national fund for the purposes of addressing costs and benefits that cut across generations, namely, the intergenerational liability arising from the benefits that accrue to the current generation through use of fossil fuels and costs to future generation s is part of the plan. In light of the broad successful outcomes delivered by these two national funds, we offer a working model for the Environmental Trust Fund.

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[16] Section 6 (2)

[17] A committee of representatives consisting senior public officials from participating provinces and private sector executives, would nominate the board members. The federal minister of finance would review the nominations and after consultation with provincial counterparts, makes a recommendation to the federal cabinet, which would then approve the nominations. In this process the federal minister takes into account "the desirability of having directors who are representative of the various regions of Canada and having on the board of directors a sufficient number of directors with proven financial ability or relevant work experience such that the Board will be able to effectively achieve its objects" (Section 10 (4)) (Government of Canada 1997).

[18] "Canadians have the right to know why, how and where we invest their Canada Pension Plan money, who makes the investment decisions, what assets are owed on their behalf and how the investments are performing" (Canada Pension Plan Investment Board 2005).

A Working Model for the Environmental Trust Fund

Consistent with a desire for strong accountability highlighted earlier through the notion of citizen consent for taxation as the basis for action, the GEL option can be made transparent by ensuring that all receipts are accounted for and deposited to a special Environmental Trust Fund (ETF), kept at "arms-length" from government and managed by an ETF Investment Board (ETFIBoard) accountable directly to Parliament with only one primary goal: de-carbonize the Canadian economy over the next 30-70 year time frame. This concept, in essence, puts the financial burden on each and every citizen to contribute to a pool of capital. The ETFIBoard in turn would establish an investment program to foster development of low-carbon technologies. The pool of investment funds available in the ETF can be further co-invested with business and industry projects that de-risk emerging low-carbon technologies.

Approximately $8 billion per year (corresponding to a 1% increase in HST) becomes available to the ETF, and if these could be leveraged with industry contributions to a value of $15-20 billion, it would provide a firm foundation for reducing carbon intensity of the economy. As the economy grows, the available pool of capital for investments would continue to increase. The policy stability and governance associated with the management of the investment portfolio would provide confidence in our ability to accomplish the major goals of climate reduction targets within a generation or two, about a 30-70 year time frame.

Creating Success: A Drive for Innovation

We can proceed in three ways: By stick, by carrot, or both. But the primary criterion for obtaining access to the Environmental Trust Fund is simple:

"Any project, program or scheme must meet the test of maximum net benefit to Canada."

The maximum net reduction in emissions, on a life-cycle basis, from the established base year would be one metric. The goal is to reduce total national emissions by 50% before 2050 from 2005 levels and 80% by 2100. All solutions subject to a strict test of technical and economic feasibility, with no pre-conceived bias for or against specific technologies, would be eligible for draw from the investment fund. The primary test of efficacy is a net reduction of greenhouse gas emissions at least cost to deliver maximum net benefit. The ETFIBoard would be guided in its investment decision by a number of technical and financial criteria and a due diligence process as part of good management practice.

Commercially available technologies would have the edge in the near term for early deployment. However, what is costly today will become less so over time through innovation and applications at scale. Initiatives new or old, however, would be subject to a simple test for acceptable investment:

"What is the largest, quantifiable and verifiable reduction in greenhouse gas emissions to be delivered when considered on a life cycle basis and at what cost?"

An important criterion for a decision on allocation of funds for investment would require that no preferences be given to any political constituency or regional interests. Expert judgment on deliverability of measurable results, and validation and verification by the ETFIBoard would be a sufficient requirement.

The carrot would be there for ETFIB to invest in clean technologies or the Environmental Trust Fund in co-operation with industry initiatives, could match, dollar for dollar, the implementation costs for effective solutions on a large scale. This provides a powerful incentive for industry to become a willing partner and, thereby, leverage availability of its own financial and technical resources for investments. On a national scale, the availability of capital would grow in the order of $15-20 billion per year if leveraged with industry resources.

The stick is "deep and steep targets" to be met for emissions reductions, but within a stable policy framework predictable over time. As the business environment changes, companies would identify the threat that a competitor would be more creative in achieving profitability in the new carbon-constrained world. The virtue of hypothecation—redirecting investment in cleantech and sectoral innovation—is also pointed out by the Hartwell Paper as a crucial feature of an energy policy instrument to rapidly de-carbonize the global economy (Prins et al 2010).

We have indicated in the design of the GEL the need for a strict "ring-fencing" of the revenues to be allocated to the ETF for investment purposes. The goal is to create a driver for innovation and to create the backbone for a multiplicity of solutions to be deployed at the local, regional and national levels. The key players and actors would over time begin to coalesce around a credible set of solutions that are cost effective and technologically feasible. These can then be integrated with a more coherent long-term system view and implementation on a large scale where national and regional priorities converge.

Tangible Next Steps: Where and How?

The Waterloo Global Science Initiative has spearheaded the vision of a Low-Carbon Electricity Ecosystem in its document "The Equinox Blueprint: Energy 2030" which takes into account the scale of challenge in the energy and climate space and offers one way of thinking through the reality of our existing high-energy civilization and how its transition can be achieved with select transformative technologies (WGSI 2012). The effort goes beyond scenario design to identify feasible technologies and to get at the big question of what future we want and working backwards to identify those technologies that have the potential to bring about transformative change.

As shown in the following Figure 4, the Low-carbon Electricity Ecosystem comprises the four core elements of a technological roadmap for a low-carbon electrified future. Provision of baseload power, technologies for smart urbanization, electrified transport and off-grid electrification all combine different of energy technologies in generation, distribution and storage to tackle a specific domain in the energy system. Within each element, the illustrative technologies include Advanced Nuclear, Enhanced Geothermal System and Large-scale Storage for Renewables for baseload generation, Smart Grid and

Superconductors for smart urbanization and electrified transport, Smart Micro-grid Systems and subsequently Organic Photovoltaics (OPV) for off-grid energy access.

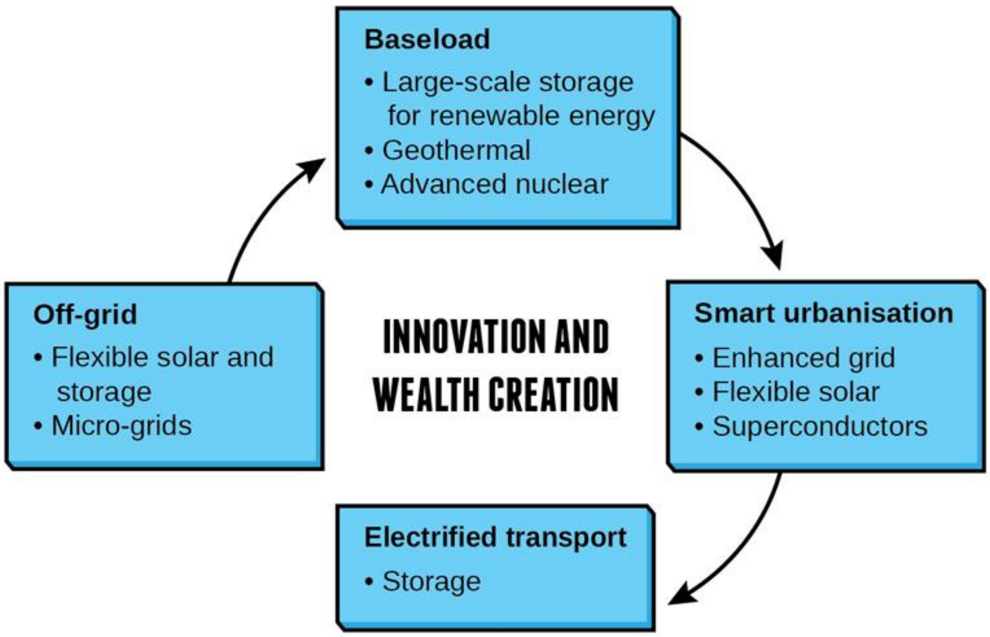

Figure 4: Low-carbon Electricity Ecosystem. (WGSI, 2012)

In Appendix III, we describe further the five technological pillars and select technological innovations in greater detail.

Conclusions

We have outlined, here, a strategy for de-carbonizing a national economy. Although we illustrate this by describing the Canadian context, the approach can be adopted with modifications by any jurisdiction.

Need for a long view - What is necessary is an explicit recognition that energy transitions are an epochal phenomenon and transformation of the existing global energy system will take time—an attribute of societal infrastructure that cannot be ignored. Thus, there is a compelling need for investments that de-risk emerging technologies through deployment at scale. To take the long view of managing uncertainty in the decision processes also requires a predictable flow of revenues on an ongoing basis. This can only be achieved under a stable policy environment and a conscious commitment to reduce the intergenerational burdens associated with current GHG emissions.

Source for a Large Pool of Investment Capital - A small levy, one percent tax on economy-wide consumption—with revenues to be "ring-fenced"—through an Environmental Trust Fund (ETF) is part of the plan.

Public Acceptance through Innovation in Governance - To gain public trust and to allow the development of an orderly political consensus, we have proposed an innovation in governance that would be critical. Creation of an "arms-length" agency through an Act of Parliament would be necessary to manage such a fund with an explicit mandate to support the national goals of a 'cap' on emission and then 'invest' in the development of necessary solutions to effect change at scale.

Technological Pathways - The technological pathways to the development of credible solutions have been identified. Creating the drivers for innovation would not only translate into a competitive national advantage in global markets but it has the potential to become the foundational basis of a contribution to solving the global problem of climate change. It is a constructive approach based on innovation in governance and technological innovations that would enhance the national scientific and industrial capacity. The best practice solutions that emerge within the national context can then become the catalyst for change at the global level if effectively deployed through international consortia and collaborative arrangements.

Appendix I: The Government Pension Fund of Norway

The Government Pension Fund-Global (GPFG) was previously the Norwegian Government Petroleum Fund (GPF), which was established by an act of the national parliament (Storting) in 1990. The reasons for its establishment are twofold. On the one hand, it is a long-term policy design to ameliorate the curse of resource wealth that may distort the economy, discounting the value of agriculture and industry as well as the benefits of education for long-term individual human capital and social development. On the other hand, it is a tool for macroeconomic stabilization against the potential short-term costs of fluctuating revenues based on resource earnings, especially in light of sustained increase in social welfare spending in the 70s and 80s. (Gordon L. Clark and Monk 2009)

The need to seek a solution for addressing intergenerational liabilities with long-term expectation on the sustained decline of resource base and sustained increase in public spending presents an acute challenge for the Norwegian government. As noted in many studies of the spending patterns of western governments, the ageing of the baby boom generation and the increasing longevity of each cohort as they age through retirement implies a growing liability against a likely absolute decline in most European countries' total population (Gordon L. Clark and Monk 2009; Tanzi and Schuknecht 2000).

How the Fund works

The Government Pension Fund – Global (GPFG) absorbs the entire government petroleum revenues and transfers an amount equal to the non-oil budget deficit into the fiscal budget.

Vikøren argues that there are three advantages to this setup: "First, the variability in petroleum revenues is isolated to the growth rate of the Fund. Second, any use of the Fund is integrated into the ordinary budget routine and does not undermine the fiscal budget as a single instrument for assigning priority to different needs. And third, the amount of spending of petroleum revenues, that is the size of the non-oil budget deficit, can be aligned with the needs of fiscal policy as well as with the targeted intergenerational distribution." (Vikøren 2008)

In 2001, the Norwegian parliament adopted a fiscal guideline that non-oil deficit be limited to 4 percent of the Fund to provide predictability in the level of spending. In case of large changes in the value of the fund or national economic performance, the government is allowed to tap into the fund to a higher or lower degree. Yet adherence to the guideline is also closely scrutinized by the public who are owners of the Fund. (Vikøren 2008)

Institutional vision and structure

A distinction should be made between the GPFG and the GPF-Norway, which together constitute the so-called Norwegian Government Pension Fund. Whereas the GPF-Norway holds the assets and liabilities of the Norwegian government's National Insurance Scheme (NIS), the GPFG draws its revenue from the flow of net receipts from the country's petroleum earnings. The objective of the combined sovereign wealth entity is "to support government savings to finance the pension expenditure of the NIS and long-term considerations in the spending of government petroleum revenues" (Ministry of Finance 2009). It is important to note that the GPFG is not ear-marked for future pension expenditure; although it being a significant part of the government budget, the return of the fund should continue to be a general support to the overall public spending (Vikøren 2008).

Although categorized as a sub-entity of a SWF, the GPFG is not a 'pension fund' (besides a mandate that go beyond financing pension expenditures) in the sense that pension fund normally have designated beneficiaries (that are also the contributors, as opposed to drawing from resource earnings), are ruled by the principle of fiduciary duty, and have well-defined horizons over which they must realize their commitments (G.L. Clark 2000; Gordon L. Clark and Monk 2009).

The Fund is formally owned by the Ministry of Finance, as a deposit account with the Norwegian Central Bank. Thus the actual operational management of its assets is administered by the Norges Bank Investment Management (NBIM), which is a special unit created by the Norges Bank that reports to the Bank's Governor and Minister of Finance.

Although the GPFG lacks an independent board of trustees and is subject to the Norges Bank's employment policies and practices, the Bank operates according to a mandate given by the Ministry. Further, the NBIM investment is subject to the Ministry's policies including quantitative rules regarding the allocation of assets as well as mission-led policies regarding ethical investment that derive from the national Parliament (Gordon L. Clark and Monk 2009).

In this way, a clear division of responsibility and accountability is formalized among the agents and institutions that in sum amount to "the Fund": while the Ministry has the responsibility for the key long term strategic decisions affecting expected return and risk, the Bank's main responsibility is to maximize expected return relative to the benchmark and variation determined by the former (Vikøren 2008). The Norwegian parliament receives an annual review (White Paper) of the Fund's performance and management, and then makes decision on changes regarding management strategies such changes on the benchmark portfolio and risk limits and so on.

The Ministry has a secretariat dedicated to the management and regulation of the fund. There are also advisors to the Ministry on matters pertaining to the management of the funding including the Council on Ethics which has 'members'—independent experts with appropriate knowledge of ethics in theory and practice and Norway's international commitments) appointed by the Minister for fixed terms with a mandate to provide "evaluation of whether potential investments in financial instruments issued by specific issuers are inconsistent with the ethical guidelines". (Clark and Monk 2009; Ministry of Finance 2009)

Another key element in this management model is transparency. All investment principles, guidelines, strategies, opinion reports are disclosed to the public. The Norges Bank publishes quarterly reports that list every single investment held at the end of the year and assessments on performance in the corporate governance at the NBIM. (Tranoy 2009; Vikeron 2008)

Investment strategy, allocation of assets and ethical guidelines

The Fund's has a strict portfolio model that aims to achieve moderate risk. This investment position entails a diverse benchmark portfolio that comprises approximately 18,000 different equities and bonds across a large number of overseas jurisdictions. The maximum holding in any given company is limited to 5 percent, while the average ownership stake is approximately 0.5 per cent. The Fund also avoids the holding of large or strategic ownership stakes that have political implications. (Tranøy 2009; Vikøren 2008) See Figure 5 below for a breakdown on asset allocation:

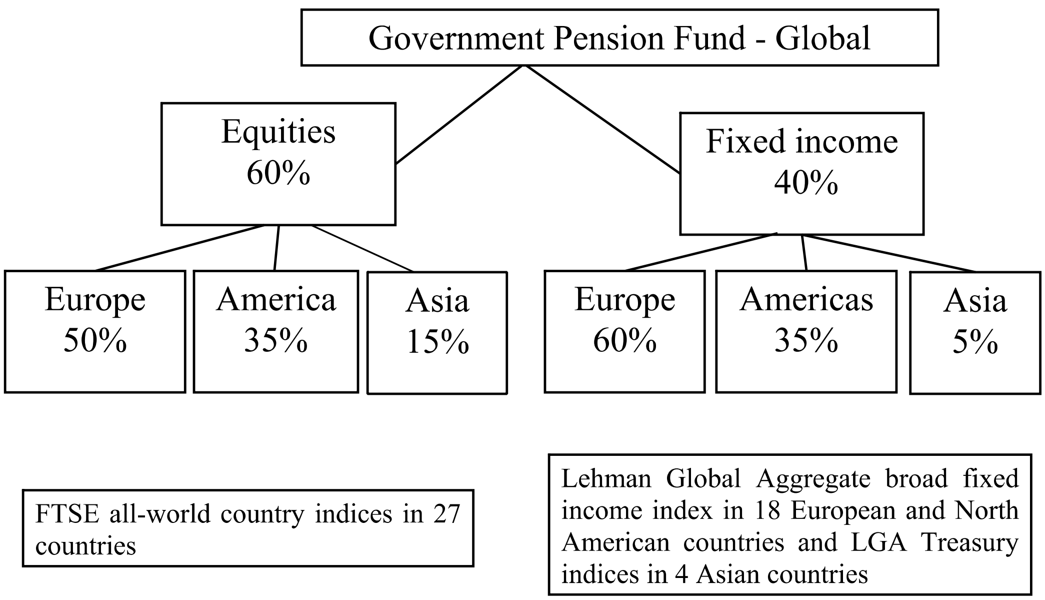

Figure 5: Composition of the benchmark portfolio. (Vikøren 2008)

The Ministry's Guidelines for the Management of the fund sets for the Norges Bank "an important objective for the risk system is that risk attending financial instruments should be calculated in such a way as to ensure that, over time, estimated risk in the Fund does not deviates from actual risk." (Section 4 of the 'Guidelines')

The Guidelines not only regulate the benchmarking of investment portfolios, but also provides governance on ethics. In this regard, section 5 of the Guidelines sets out two principles: 1) "the Fund is an instrument for ensuring that a reasonable portion of the country's petroleum wealth benefits future generations and financial wealth must be managed with a view to generating a sound return in the long term, which is contingent on sustainable development in the economic, environmental and social sense" and 2) "the Fund shall not make investments that entail an unacceptable risk that the Fund is contributing to unethical acts or omissions".

Three mechanisms were established to form a structure for ethical management. Firstly, the Fund exercise ownership rights to promote long-term financial returns based on internationally accepted standards, operationalized as the UN Global Compact and the OECD Guidelines for Multinational Enterprises. It is managed exclusively by a unit set up within the NBIM. The mechanism has to remain consistent with the achievement of long-term financial return—an ethical obligation on par with principles of socially responsible investment (SRI)—because the present generation has an obligation to the future generations in maintaining and increasing the wealth they will inherit. (Tranoy 2009)

The second mechanism is negative screening of companies that produce weapons used towards violation of fundamental humanitarian principles. The third mechanism allows divestment from companies breaching ethical norms in cross or systematic violation of human rights and individual rights in war or conflict situations, severe environmental degradation and gross corruption. These two mechanisms are under the oversight of the Ministry's Council on Ethics.

Tranoy argues that chances are remote that a Norwegian fund with less a percent average point ownership stake can come in and drive any given company towards better social performance (Tranoy 2009). Nonetheless, it is argued that in some cases, the holding of 5 to 10 per cent of a company may provide the GPFG considerable clout over management; therefore, there are concerns that sovereign fund management may be motivated by non-economic considerations, deviating from conventional wealth maximization (Aizenman and Glick 2008). The effect may be magnified by other institutional investors who share the same line of ethical concerns.

To deal with controversial issues, the Council of Ethics applies a strict and thorough review process to assess each case on an individual basis. The process is multi-staged and transparent, involving initial investigation, elicitation of evidence and hearings before the any submission of recommendation for exclusion to the Ministry.

Given its transparent nature, integrity of democratic processes, and commitment to accountability, intergenerational equity and moral complicity, the GPFG is widely acclaimed for its governance model and has high Truman score.[19]

[19] Dowson and Truman constructed a scoreboard for 44 Sovereign Wealth Funds, 34 nonpension funds and 10 representative pension funds on their current practices. (Truman 2008)

Appendix II: Governance of the CPPIB

Management

As with the management of any large fund, the CPPIB's asset allocation strategies are subject to limitations that ensure its portfolio prudence (see Mendelson, 2005 for more details):
"The Board shall not directly or indirectly invest more than 10 per cent of the total book value of the Board's assets in the securities of any one person; two or more associated persons; or two or more affiliated corporations" (Government of Canada 1999: Section 11 (1))

Investment in any single real property or Canadian resource property shall not exceed 5 percent of the board's assets at a book value at the time of investment. The aggregate of all Canadian resource property shall not exceed 15 percent of CPPIB assets, and the aggregate of all real property plus Canadian resource property, 25 percent. (Section 12 (1))

The CPPIB is not permitted to hold more than 30 percent of the voting shares of any corporation (Section (13)).

"The Board shall not directly or indirectly hold or invest in a derivative where the market exposure of the Board under the derivative is not covered by cash or other assets of the Board designated for that purpose. The Board may hold or invest in a derivative if the purpose of the transaction is (a) to offset or reduce the risk associated with an existing investment or group of investments, or (b) to hold or invest in the derivative as an alternative to holding or investing in the underlying asset itself". (Section (14))

Performance and Sustainability

By the end of fiscal 2011, the CPP Fund held $148.2 billion worth of asset, representing a $20.6 billion increase over the previous year. $5.4 billion out of the increase came from excess contributions, while the rest ($15.2 billion) came from investment gains net of expense, with a 12-month investment return at 11.9% (see figure below). The CPPIB reported that the Fund had earned annualized returns of 3.3% and 5.9% for the five- and ten-year periods ended March 31, 2011 (CPPIB 2011).

The Board stated that while the results were significantly impacted by the negative return for fiscal 2009 during the global financial crisis, long-term investment performance of the Fund is consistent with the 4.0% after-inflation return target. One of the long-term strategies of the CPPIB was to increase holdings in private market, particularly private equity, real estate, infrastructure and private debt. In fact, over the past five years, private asset holdings had increased from $7.8 billion to $46.8 billion, and from 8.8% to 31.6% of total Fund assets. (CPPIB 2011)

Appendix III: Core Technological Pillars of the Equinox Blueprint: Energy 2030

Large-scale Storage for Renewables

Renewable energy sources offer a great potential for generating clean energy on a large scale. Despite some practical geographical limitations, the resource base remains enormous in general. The challenges are how to capture these dilute, dispersed, intermittent, and variable resources at reasonable cost.

Large-scale storage is the critical technology required to compensate the variable and intermittent nature of renewable sources, consequently enabling them to 'mimic' the characteristics of baseload generation. With an eye to smart urbanization, increased storage in concert with the development of Smart Grids could also reduce transmission costs and decrease transmission system load.

Within the four main types of energy storage technology for large-scale grid applications—mechanical, electrical, chemical and electrochemical—electrochemical batteries and flow batteries in particular has the potential to address the intermittency and variability characteristics of renewables.

Flow batteries works by storing energy as charged ions in two separate tanks of solutions. To discharge, the electrolyte flows to a redox cell where the electron transfer reactions take place at inert electrodes, producing electric current. The simplicity of the electrode reactions contrast with those of many conventional batteries that involves, for example, phase transformations, electrolyte degradation, or electrode morphology changes.

The most attractive feature of flow batteries is that power and energy are uncoupled, a characteristic that many other electrochemical energy storage approaches do not have. This gives considerable design flexibility for stationary energy storage applications. The capacity can be increased by simply increasing either the size of the reservoirs holding the reactants or increasing the concentration of the electrolyte. In addition, the power of the system can be tuned by simply modifying the numbers of cells in the stacks, using bipolar electrodes, or connecting stacks in parallel or series configurations. The use of solutions to store energy makes recharging relatively easy through replacement of electrolytes—like refilling a fuel tank.

Moreover, flow batteries do not suffer from reactions that can lead to deterioration, which means they could have significantly longer cycle lives than conventional batteries such as lead-acid and lithium.

As with other storage systems, flow batteries have their limitations. They fill the niche of a specific application in electric power utility that integrates scalable renewables generation. Vanadium Redox Battery technology, as described earlier, favours applications with a high energy to power ratio (kWh/KW), namely applications requiring several hours of storage. They are capable of discharging at maximum design power for a period of 4-10 hr. In terms of footprint and space requirements, they scale with system ratings with relatively large footprint. They are generally not suited to applications such as grid angular stability, grid voltage stability, grid frequency excursion suppression, and regulation control.

One possibility of complementing the constraints and limitations of flow batteries is to couple them with Superconducting Magnetic Energy Storage (SMES) systems, which have the characteristics of fast response and high charge-discharge efficiency. Rapid discharge and response capabilities allow potential implementation of SMES in utility applications such as instantaneous load following, stabilization of system oscillations, spinning reserve capacity and so on.

There are number of barriers to full commercialization of flow batteries, particularly in scale-up, capital and cycle-life costs and optimization. An important research and development priority for the expansion of flow battery systems is to produce inexpensive, chemically stable membranes not subject to fouling by impurities in the electrolyte medium.

All in all, the illustrative example of flow batteries shows that large-scale storage provides a well-established time dimension solution, critically strengthening power quality and reliability from renewable generation.

Enhanced Geothermal Power

Geothermal power is an attractive source of clean and abundant Baseload electricity. Deep enough drilling could potentially enable every country in the world to access a large amount of this renewable energy source.

Conventional geothermal systems are already deployed around the world but they are limited to the few areas where suitable hydrothermal resources exist. Enhanced Geothermal Systems (EGS), within the ecosystem of geothermal energy applications and technologies, is one of the more promising options for meeting the requirement of baseload generation without the geologic constraints of conventional geothermal systems. EGS can be implemented over vast areas of the globe where hot dry rocks are found. With established capacity for drilling up to depths of approximately 4 km, every country in the world could have access to this renewable energy resource. Even a landlocked state such as Rwanda, without a rich endowment of natural resources, has prospective areas for geothermal energy exploitation.

Demonstration phase Enhanced Geothermal Systems projects are underway, with one small plant operating in France and another pilot project in Germany. Considerable investment has been made in Enhanced Geothermal Systems exploration and development in Australia in recent years, while the U.S. has revived a national geothermal program for Enhanced Geothermal Systems research, development and demonstration. Geothermal energy has been identified by the Australian Academy of Technological Sciences and Engineering (ATSE) as one of the most important energy resources, and one that is likely to be of strategic interest to Australia over the next few decades. (IPCC 2011; WGSI 2012)

Technical problems or limitations exist for Enhanced Geothermal Systems. But key issues—such as flow short-circuiting, a need for high injection pressures, water losses, geochemical impacts and induced seismicity—can be managed with proper monitoring and operational change. (MIT 2006; WGSI 2012)

A major barrier to the expansion of geothermal has been the large upfront cost of geothermal projects, a result of the need to drill deep wells and construct power plants. Given the high requirements for capital and the current low level of contribution of geothermal energy to the global energy supply mix, a significant policy commitment with the right combination of financial and tax mechanisms will be necessary for it to play an important role to de-carbonize the energy system. Mechanisms such as feed-in tariffs, a carbon price, or other financing and tax incentives, and direct co-investment by government and the oil and gas sector (with its drilling and exploration expertise) will increase the appetite of the private sector. Similar national strategic programs have been recommended by experts groups such as MIT and ATSE in the U.S. and Australia respectively.

All in all, geothermal resources have the potential to play a critical role in the world energy supply mix. For the large-scale commercial deployment of EGS, some economic certainty needs to be established. The barriers to geothermal development are not insurmountable, but there needs to be a basket of risk-diversifying approaches in place, as well as adequate development framework and strategy.

Advanced Nuclear

Nuclear energy has proven capacity to deliver reliable low-cost, low-carbon 'Baseload' power on a large scale. Advanced Nuclear Energy technologies are a promising option for decarbonizing the world's electricity generation profile.

Public concerns about nuclear power potentially stand in the way of its wider use. Concerns tend to focus on the difficulty of dealing with long-lived radioactive waste, the potential for weapons proliferation, safety and cost. It has also been observed by some that global uranium reserves may become a constraint later this century if we rely strictly on current reactor technology with a once-through open fuel cycle and no recycling of the nuclear fuel wastes.

The utilization of a new, much more efficient nuclear fuel cycle—one based on fast-neutron reactors and the recycling of spent fuel through a heat-intensive extractive metallurgical process known as pyrometallurgical processing—would allow vastly more of the energy in the Earth's readily available uranium ore to be used to produce electricity. Such a cycle would greatly reduce the creation of long-lived radioactive waste and could support nuclear power generation indefinitely. Several new nuclear power generation designs, collectively described as 'Generation IV nuclear technology', are currently in development and have the capacity to alleviate some of these concerns. (OECD 2011; WGSI 2012)

Advanced fast-neutron reactor technology permits an alternative recycling strategy that does not involve pure plutonium at any stage. Fast reactors can thus minimize the risk that spent fuel from energy production would be used for weapons production, while providing a unique ability to squeeze the maximum energy out of nuclear fuel.

Integral Fast Reactors in particular are designed such that the fuel reprocessing facility is an integral part of the plant. This closes the entire fuel system, with actinides such as plutonium never leaving the site after arrival. Such a design is proliferation-resistant and ultimately produces only minimal amounts of short- lived waste (lasting hundreds—rather than hundreds of thousands—of years). The need for new uranium mines would also be eliminated for centuries, since currently stockpiled nuclear waste would effectively become significant fuel reserves. Furthermore, enhanced efficiency would vastly increase the ultimately recoverable uranium reserves by improving the energy return on energy invested from currently marginal ores. Fuel supply constraints could then be forestalled for many millennia. (EPRI 2010; WGSI 2012)

While these Generation IV design concepts are an excellent example of the scalability and potential of nuclear energy, they need to be understood within the array of nuclear technologies available. From the perspective of a long-term energy transition, an expansion of the existing base of established Generation III reactor technologies in the near-term provides a credible pathway for a phased transition to the Generation IV technologies.

A good indication of nuclear energy's future, from a policy standpoint, is that emerging powers such as China and India are actively pursuing the nuclear energy path – regions where world energy demand growth is most highly concentrated. However, there remain significant societal and political barriers that will need to be addressed before large-scale implementation of Generation IV nuclear systems can be realized.

Smart Urbanization

Urban densification and a focus on 'smart' planning of the urban environment have significant potential to improve quality of life and to reduce the carbon footprint of cities. Making our cities more energy-smart, through renewal of ageing infrastructure and reinventing the urban landscape by design and good planning, offers a powerful incentive to incorporate innovations in energy efficiency and renewable energy generation. Substantial reduction of energy requirements and greenhouse gas emissions is achievable by adopting strategies that focus on Smart Urbanization and electric transport.

The interrelated opportunities of Smart Grid, Information and Communication Technologies (ICT), electrification of transport, promotion of public transport, and advanced electricity provision technologies such as superconductors have great potential of matching energy supply and demand for cities and sustainable urban transportation with a lower carbon footprint.

A Smart Grid is a modernized electric system that enables two-way flows of electricity and of information; it uses sensors, monitoring, communications, distribution system automation, advanced data analytics and algorithmics for anomaly detection to improve the flexibility, security, reliability, efficiency, and safety of the electricity system. It increases consumer choice by allowing them to better control their electricity use in response to prices or other parameters. A Smart Grid includes diverse and distributed energy resources and accommodates electric vehicle charging. In short, it brings all elements of the electricity system—production, delivery and consumption—closer together to improve overall system operation for the benefit of consumers and the environment. (Doughty et al 2010; Dunn et al 2010; Nguyen et al 2010; WGSI 2012)

Smart Grids can also be the backbone of a larger intelligent energy network that, with ICT, integrates natural gas network, distributed generation, district heating/cooling networks, and hydrogen carriers and so on.

Under a smart energy network construct, a subcomponent that has great potential to reduce dependence on liquid fossil fuels is the electrification of transport. A smarter grid could facilitate the deployment and integration of the charging infrastructure needed to support electric cars. Continued advanced in battery technologies, such as advanced lithium sulfur batteries and flow batteries for heavy-duty vehicles could improve the performance and lowered the cost of electric vehicles. ICT enables real-time tracking of public transportation and thus increases ridership thereof.

All the above innovations would undoubtedly add stress by an order of great magnitude on the existing electricity distribution and supply infrastructure. Conventional infrastructure for existing transmission lines such as poles, towers and cross-arms are limited in their ability to support the weight of the extra wires required to increase capacity. Although Smart Grids can alleviate the need for increased demand to some degree, superconductors offer an opportunity to dramatically increase both the capacity and efficiency of power transmission. They achieve this by allowing much more current to pass through much narrower wires and this feature would be a premium in a highly dense urban environment with severe geographic limitations. Superconductive wiring carries about 10 times as much power as the same volume of conventional copper wiring.

Whereas Smart Grids, ICT and electric mobility are well-established concepts, superconducting technologies fill the niche of providing reliable transmission in dense urban environment with a small physical footprint.

Surely, not all of the above technologies have advanced to commercialization and, for some; the cost of implementation on a commercial scale may prove high. Large-scale pilot projects would be required to de-risk the technologies—such as city-wide electric vehicular infrastructure and deployment of superconductors—and to create confidence in public and private investors, but they would also involve a large amount of financial capital.

Off Grid Electricity Access

Providing an adequate level of energy services to the energy poor is a critical determinant of social and economic development. If the energy needs of this disadvantaged population were to be met over the next few decades with the burning of fossil fuels, however, the impact on the global climate would exacerbate an already precarious situation. Providing low-carbon sources of energy to the world’s billions of energy-poor individuals is an important goal to avoid these consequences.

New technologies, especially those making use of renewable sources of energy, will be key ingredients in providing access to electricity to those distant from the existing grid. For example, portable but durable solar powers, based on thin-film solar technologies (for example, Organic Photovoltaics) hold enormous promise to provide a basic level of energy service for personal power. A smart, self- sustaining micro-grid that delivers an adequate level of power for communities utilizing solar, wind, biomass and hydropower is another example.

As an example, among the thin-film family, Organic Photovoltaics (OPV) are a rapidly emerging solar technology with improving cell efficiency (currently more than 8%), encouraging initial lifetime (more than 5,000 hours unencapsulated), and potential for roll-to-roll manufacturing processes. OPV have several characteristics that offer potential advantages for addressing off-grid energy needs. Their plastic nature makes them easy to transport, use and install. They are light and can be installed into or onto irregular surfaces due to their extreme flexibility. They can be installed in a piece of cloth, rolled up and carried to the installation point, and laid across a roof. Installation requires no specialist equipment or skills. In addition, these photovoltaic cells can be printed with a modified inkjet printer, allowing production facilities to be located anywhere. The technology is therefore very conducive to the creation of a new branch of small-scale, local producers of photovoltaic cells.

The range of photovoltaic technologies in development can, in turn, be viewed as part of a larger energy ecosystem with the potential to be integrated within Smart Micro-Grids (SMG), alongside other local renewable resources that complement and enhance the level of energy access to those who have very little.

In contrast to centralized approaches, SMGs subscribe to a modular system paradigm can provide sensible solutions to off-grid contexts. More specifically, the challenges can be resolved by modular system designs that range anywhere from 5 kW to 10MW and are simple to install and maintain, tailored to community needs, and operated intelligently and effectively through optimized delivery systems. Such designs would use local renewable energy resources for generation. Solar photovoltaics, micro-hydro power plants, wind turbines, biomass, small conventional generators and storage offer credible potential technological solutions to utilize distributed energy resources. SMGs also have the potential to reduce costs, attain a level of reliability comparable to the grid system, manage the variable nature of renewables and promote deployment and integration of energy-efficient and environmentally friendly technologies.

There are still technical challenges in the development of OPVs and SMGs, partly due to the relative high generation cost distributed energy resources, and in particular to SMGs, the difficulty of on-demand fabrication to bring it to a "plug-and-play" status. Another challenge in engineering mass-market appeal of these technologies has to do with financing and business innovation that would effectively connect global producers and remote, energy-poor consumers.

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