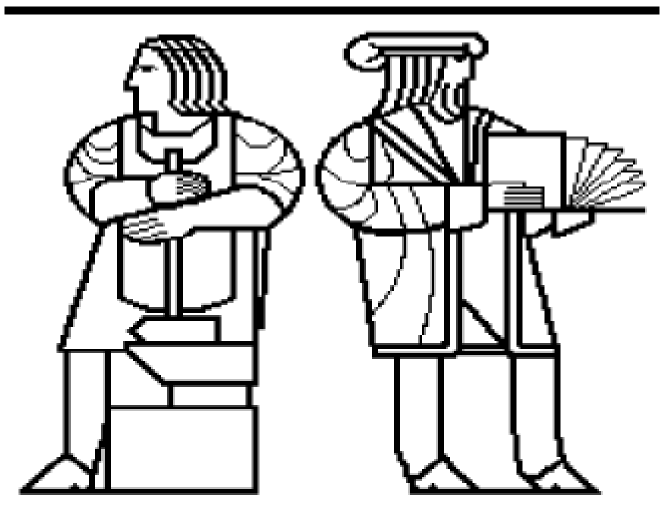

ARM-CHAIR ESSAYS IN ENERGY

Part I	**Green Energy Manufacturing Systems**
Part II	**Carbonomics**
Part III	**INGRID and the Zen of Energy**

Rx GEMS

GREEN ENERGY MANUFACTURING SYSTEM

Prescription for Sustainable Economic Growth

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Summary

A *Prescription for Survival* [00] is not enough! Nations need a robust prescription for sustainable economic growth. Availability of energy at a competitive price must be a priority. The general ignorance of masses and the politicians who serve them, have made it difficult for the solution, at hand, that is energy from nuclear fission, to be used in alleviating global poverty and hunger. The social limitations of physics in energy generation may find some solace through the advances in biology and that of genomic sciences, in particular. The tools of molecular biology and biotechnology are making it possible to engineer metabolic systems in organisms to optimize pathways that can synthesize short chain carbon molecules as alternative liquid fuels, for example, butanol or pentanol, from biomass waste, especially, ligno-cellulose. Promoting metabolic engineering may retain the liquid fuel (petrol) infrastructure but replace fossil fuel with short chain butanol or pentanol type fuels that can be used even for automobile engines, with minimal changes. There is another equally compelling reason to champion the manufacturing of energy to use low-carbon liquid fuel obtained from metabolic engineering of harmless bacteria. Metabolic engineering catalysed GEMS offer the possibility of ***both*** scalable and portable plants. The benefit of a portable plant as a domestic fuel source is valuable if viewed as a power source for fuel cells and electrolyzers. The latter can replenish hydrogen in storage systems, for example, hydrogen fuel cells in automobiles.

Following in the footsteps of Penicillin (chemically synthesized at MIT in 1930's), this article makes the case for bio-engineered alternatives to non-fossil fuel and proposes an immediate exploration to scale manufacturing processes necessary to extract short chain carbon molecules from designer microorganisms. It may reduce our dependency on petroleum as a key source of energy. Metabolic engineering may become synonymous with prosperity and peace.

Solipsistic Bliss or Bluff?

On 13 January 2009, light, sweet crude was down 91 cents at US$36.68 a barrel [1] in electronic trading on the New York Mercantile Exchange (NYMEX). On 11 April 2006, just 3 years ago, forecasters outlined scenarios [2] that could take oil prices up to a terrifying US$262 a barrel. On 6 June 2008 it reached US$147 per barrel, a cost at which nuclear energy from fission is a better bargain! Oil price increase was unaccompanied by any known catastrophe, reduction in resources or loss in capacity. On 11 October 1990, the then highest recorded price was US$40.42 per barrel. It took more than 13 years to 'peak' again at US$42.33 on 1 June 2004 [3]. Is there a rationale for the volatility [4] that took $40 per barrel in 1990 to $147 per barrel in 2008 and dropped it under $40 in 2009? Compared to the actual cost of production of crude oil by OPEC nations, at about only US$5 per barrel [5], the price of crude violates supply and demand rules. It appears to reflect an orchestration of power play or an exhibition of greed. The sinusoidal fluctuation is not novel and is known to recur (Figure 1). It may reflect a reaction from the OPEC cartel to investment in alternative non-fossil fuel that becomes more attractive with high price of oil [6]. By lowering the price of oil, the cartel stokes the global sense of solipsistic bliss and fuels lethargy to do little but prolong the irrational 'trust' in oil with the bleak hope of a return to the halcyon days. Some predict that oil prices may remain around US$35 per barrel through 2012-2013 before the next wave of increases [7]. The latter may strike another destabilizing blow and inflict bold new punctures in the global economy just as the world begins to emerge from the current economic meltdown.

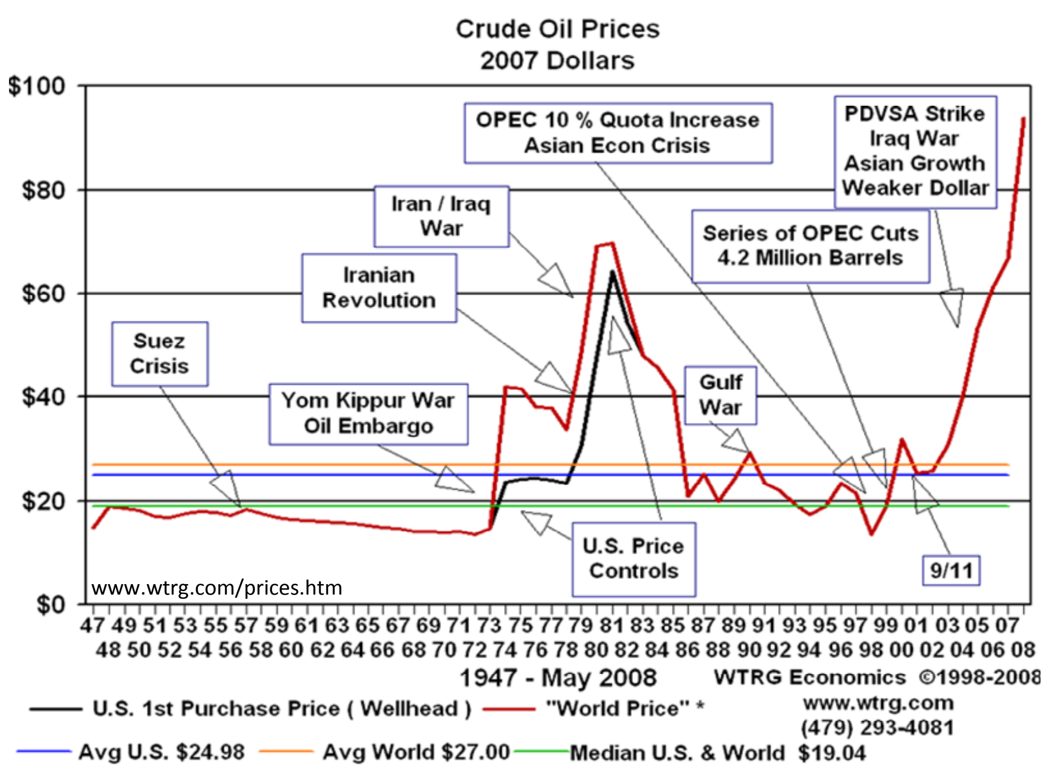


FIGURE 1: PERIODIC (?) VOLATILITY OF OIL PRICE

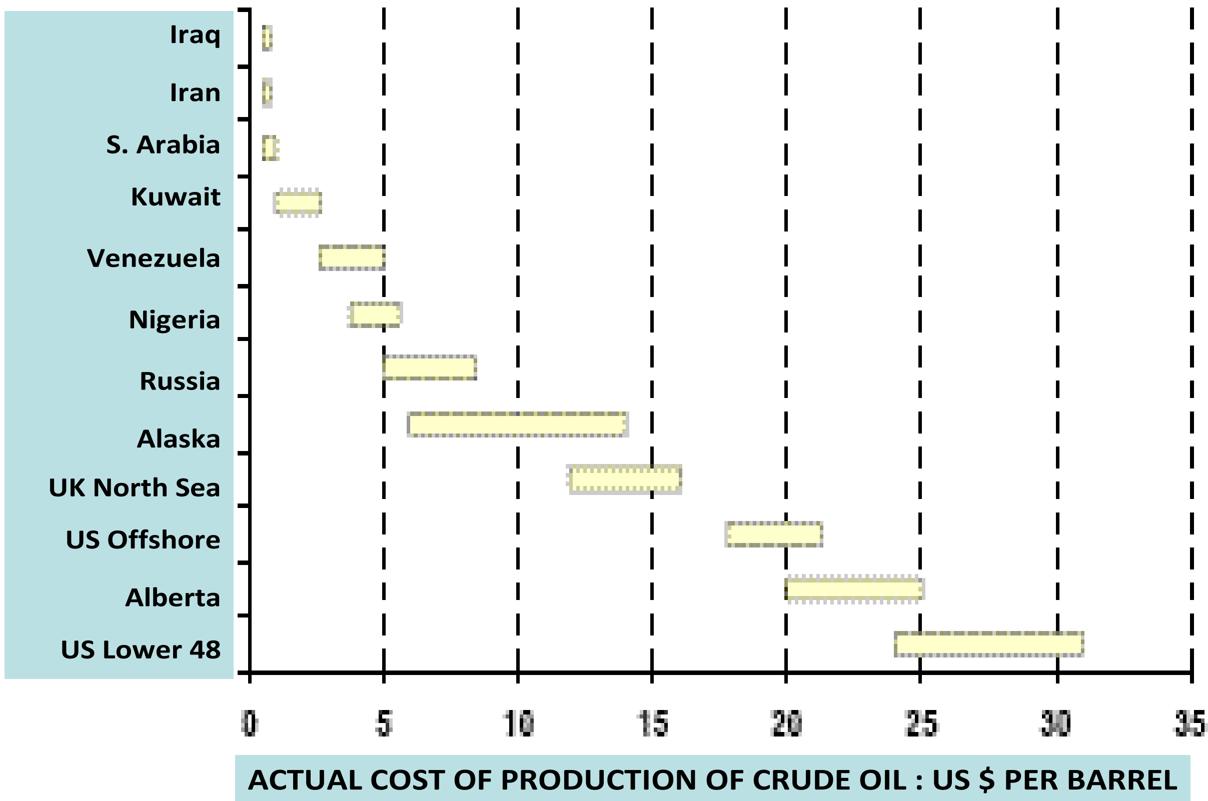


FIGURE 2: COST OF OIL PRODUCTION

FIGURE 3: OPEC REVENUE from OIL EXPORT

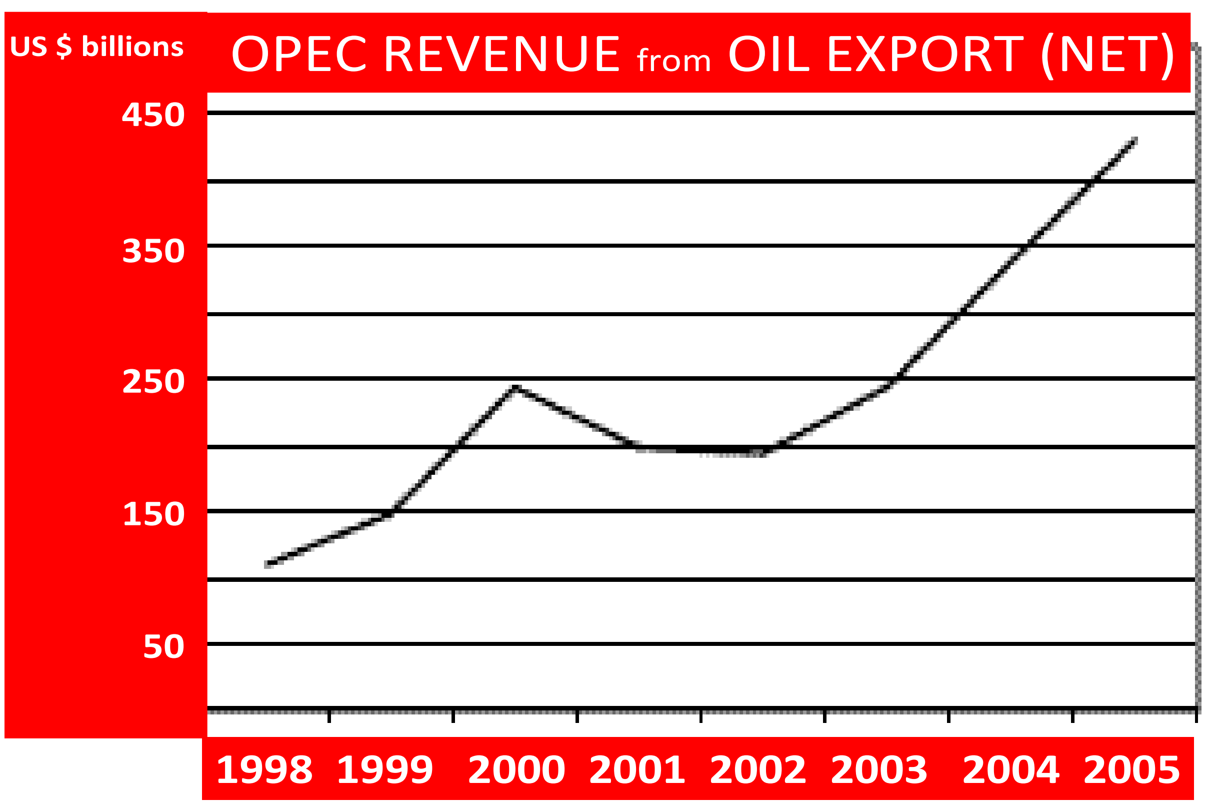
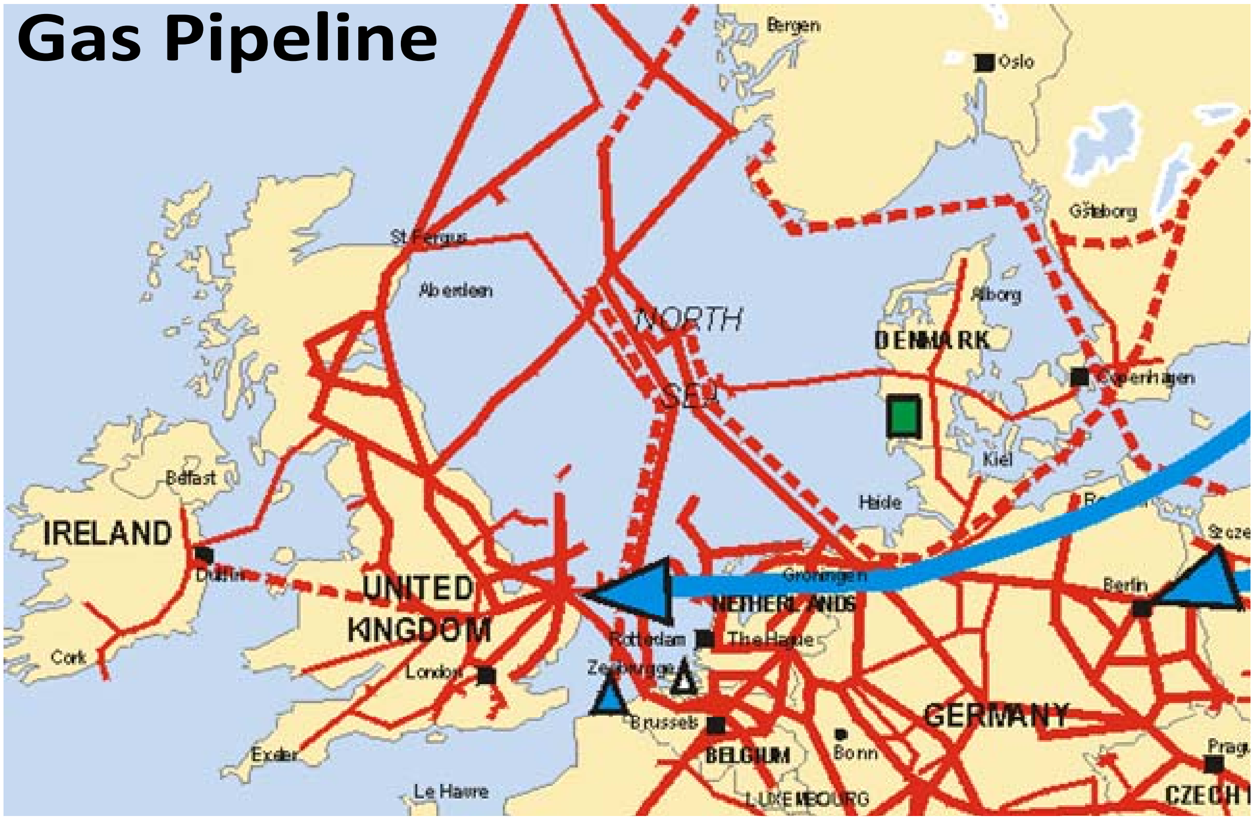
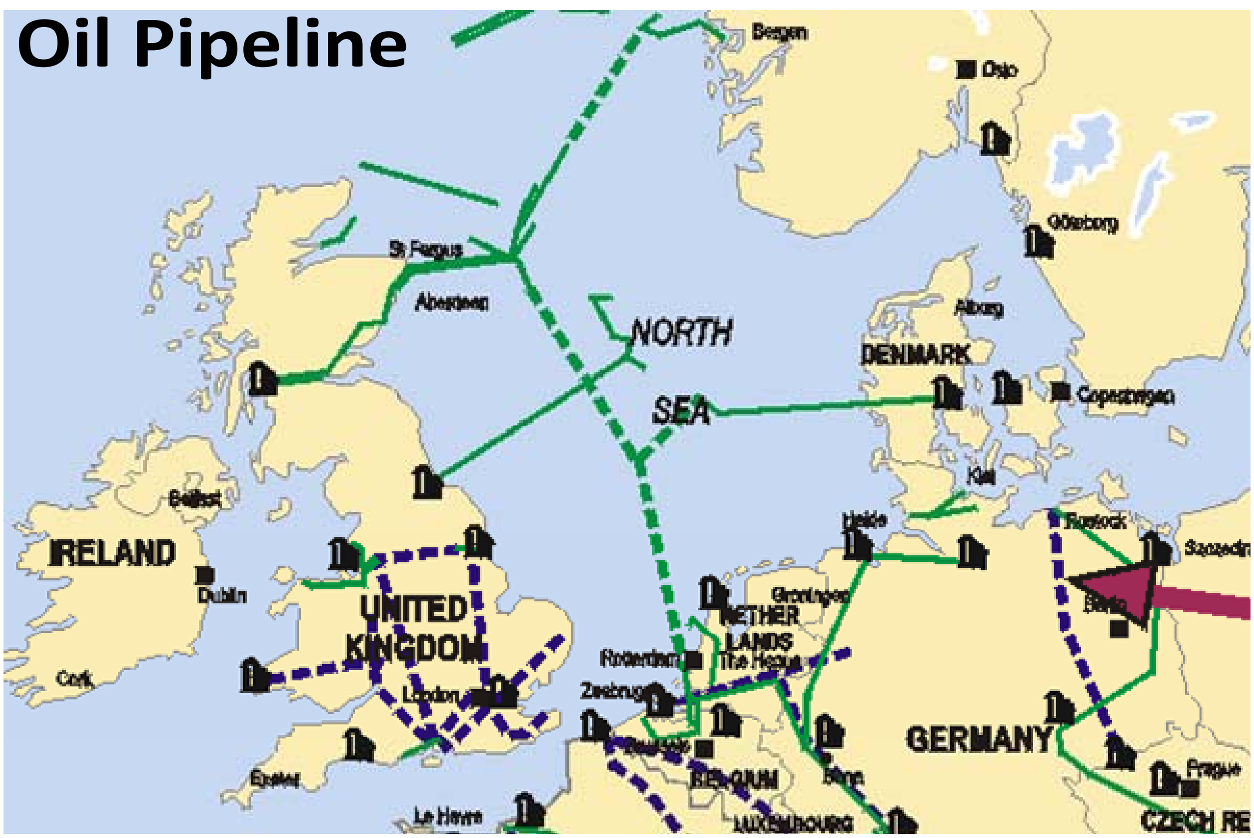


FIGURE 4: Partial Map of GAS PIPELINE **FIGURE 5: Partial Map of OIL PIPELINE**





Economic Recovery and Long Term Sustainable Growth: The Energy Genie

On 20 January 2008, an august Irish academic wrote that "although the 2007 and 2008 budgets have permitted a significant decline in the general government budget balance, the Irish fiscal position is very healthy [8]." The incredible shrinking economy of Ireland (by 4%) with €13 billion in the red in 2008 [9], a banking crisis that could eventually swallow a €40 billion bail-out using tax-payer's money [10] and a near-collapse of the housing industry (prices plummeting by 15% to 30%) are indicative of the forecasting wisdom of Irish pundits or the lack thereof [11].

This series of unfortunate events has triggered a conservationist *modus operandi* in full swing in Ireland. Education and healthcare budgets are bearing the brunt while the salaries of government employees remain unscathed, thus far. Is a healthy way out of this doom and gloom only a hypothetical possibility? Not quite. To the politically naïve and academically optimistic, at least one path for Ireland's recovery is still a brilliant beacon of hope. The suggestion is to embrace innovation and help release the energy genie out of the bottle! Not a panacea to cure all ills but availability of energy is catalytic, now, more than ever before. In figure 4 and figure 5, partial maps of EU gas and oil pipelines, respectively, are illustrated. Figure 6 (below) summarizes the energy mix and dependency of Ireland [12].

Key Figures (2004)

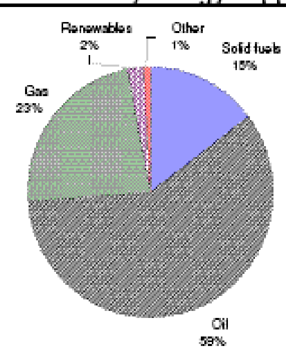
Mtoe	Primary Energy Supply	Domestic Production	Net Imports	Final Energy Consumption	Electricity Generation (TWh)
Solid fuels	2.3	0.9	1.8	0.5	7.7
Oil	9.3		8.8	7.5	3.2
Gas	3.6	0.7	3.0	1.3	12.9
Nuclear					
Electricity			0.1	2.0	
Renewables	0.3	0.3		0.2	1.4
Other	0.1				0.3
Total	**15.7**	**1.9**	**13.7**	**11.5**	**25.6**

The source for all data is the European Commission, unless otherwise stated

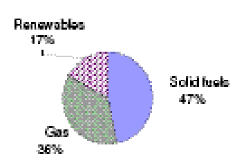
Key Indicators (2004)

	IRELAND	EU-27
Energy per capita (kgoe/cap)	3 870	3 689
Energy intensity (toe/MEUR '00)	122	185
Energy import dependency %	86.5	50.1
CO_2 Emissions (Mt)	43	4 004
CO_2 intensity (tCO_2/toe)	2.7	2.2
CO_2 per capita (kg/cap)	10 589	8 180

2004 Primary Energy Supply



2004 Domestic Production



http://ec.europa.eu/energy/energy_policy/doc/factsheets/mix/mix_ie_en.pdf

FIGURE 6: MIX OF ENERGY AND SOURCES OF ENERGY SUPPLY FOR REPUBLIC OF IRELAND

Renewable Uncertainty

If the sun is shining [13] and if the wind is blowing [14] the additional capacity from renewable energy may be significant in geographies near the equatorial belt or with balmy coast lines. If the problems associated with extracting renewable energy, storage and transportation (grid) were nugatory [15], the countries of Africa with vast deserts, should be quite wealthy nations and net exporters of energy. The arid state of Bihar, India should have a surfeit of renewable solar energy. The crippling poverty in Africa and Bihar are a reminder that forcing a blind eye to the solution of nuclear energy [16] amplifies the morbidity and mortality associated with energy deprivation.

The 'green corporate responsibility' buzz has induced investment from Sun Microsystems co-founder Vinod Khosla of Khosla Ventures and Sapphire Energy in San Diego has raised millions from investors including Bill Gates (Cascade Investments) for algae bio-fuel. Can the next green fuel be the pea-green pond scum? At current production costs upto US$100 per gallon, the answer is largely speculative [17] but metabolic engineering to improve 'lipid triggers' may improve the prospects for algae [18]. It will be remiss not to mention the significant advances in mimicking photosynthesis achieved in the laboratory [19]. Coupled with catalysts, for example, for hydrogen fuel generation [20], the convergence of these developments may spur innovation in the embryonic energy manufacturing industry.

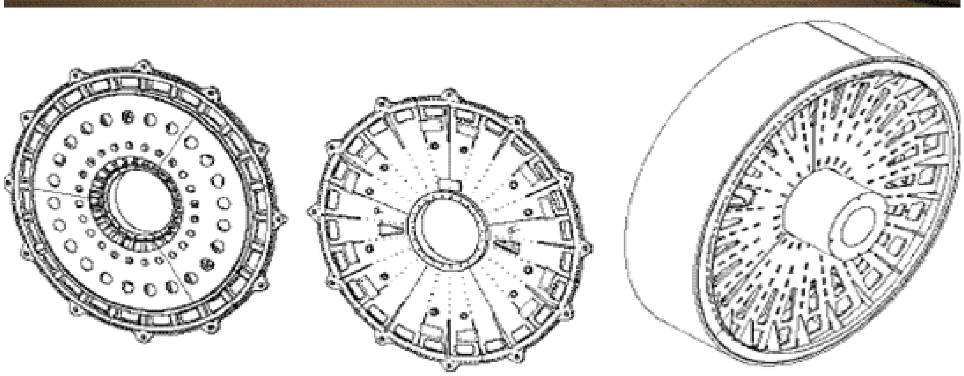


FIGURE 7 (TOP): SOLAR FARM IN SPAIN - Parabolic troughs capture and focus the sun's energy to heat synthetic oil at Acciona's Nevada Solar One. Heated oil will in turn heat water into steam to power a turbine.
FIGURE 7 (BOTTOM): WINDMILL MANUFACTURING - Components manufactured by Rotatek (Finland) for 3.5 MW generator: on the left, two steel shields (diameter 6 metres and weight 9 tons per shield) and on the right, a rotor (diameter 5.25 metres, width 2.5 metres and weight 37 tons). http://www.tukkk.fi/~ohilmola

Manufacturing Energy: Metabolic Engineering of Microorganisms (MEMEM)

The intrinsic biological machinery of the cell produces fatty acids, lipids and natural alcohols, such as ethanol. All carbon containing chains are potential sources of energy. The synthesis of biological molecules specifically for use as fuel, either *in vivo* [21] or through catalytic modifications *in vitro* [22], represents significant opportunities to ***manufacture*** energy. These developments, particularly the *in vivo* engineering of carbon synthesis pathways to render the products (molecules) as efficient sources of fuel, was made possible by developments in molecular biology in the past quarter century and recent advances in genomics. The emergence of metabolic engineering is unleashing the potential to use nature's factories (bacteria) to produce fuel. Credible scientific reviews outline the process [23] and engineered bacteria are increasingly [24] available [25] but still within the academic community. Organisms capable of producing liquid fuel have been tested only in the lab scale. The use of agri-waste (biomass) to feed microorganisms avoids the food-fuel debate (ethanol from sugarcane and corn). The energy that nature captured from sunlight to create cellulose (hemi, ligno) can be hydrolyzed by enzymes inside bacteria, instructed (engineered) to follow a specific system of operation in stages, eventually to produce what we need, liquid fuel that can be extracted from microorganisms (chemical process engineering) in a simple manner that is financially feasible.

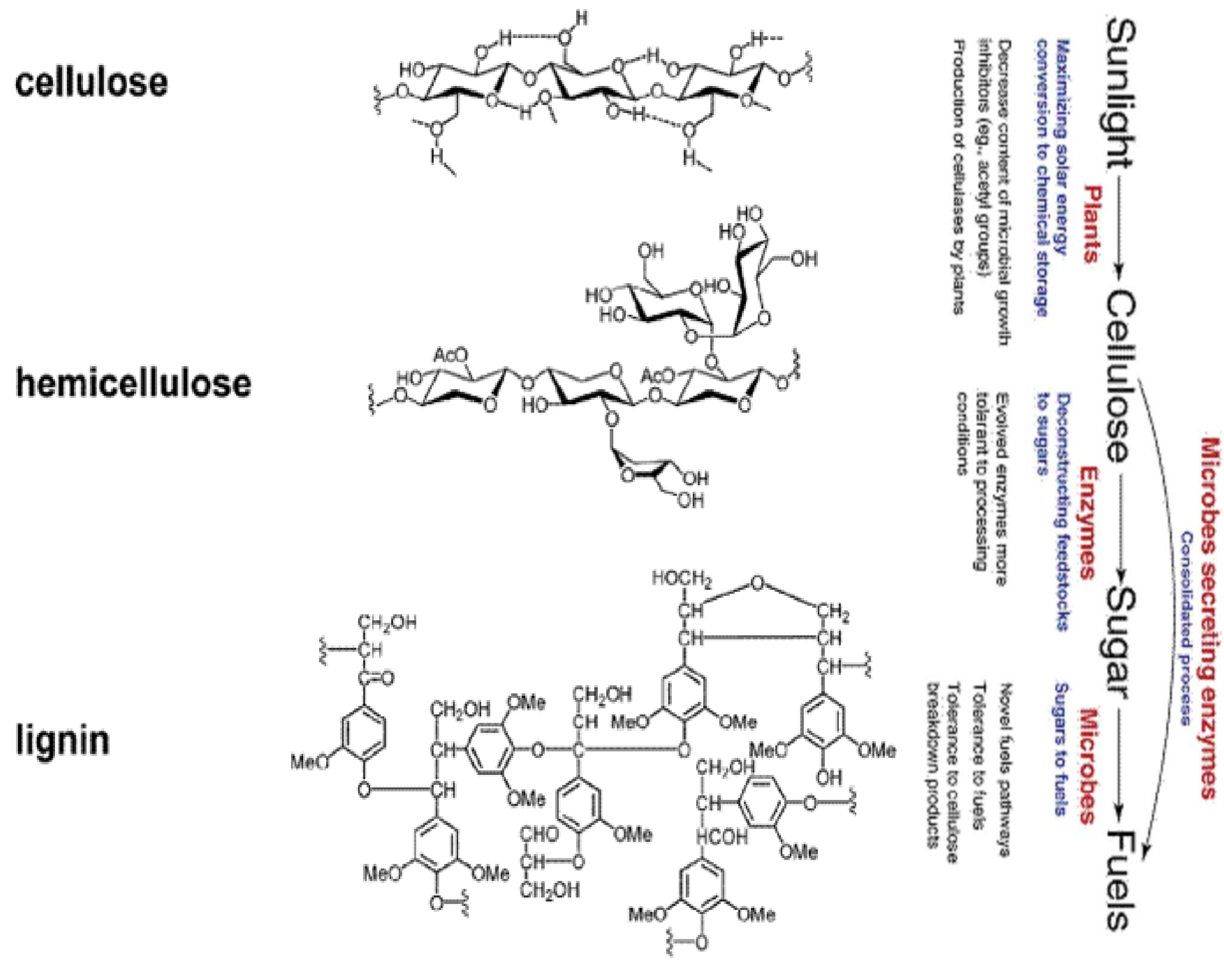


FIGURE 8: THE NEW CURRENCY OF GLOBAL POWER

Scalability: An Opportunity for Innovators in Manufacturing

Nations aspiring to chart new approaches to economic recovery [26] must seek tools that can deliver sustainable growth over the medium term and simultaneously exhibit the ability to take risks and be bold enough to grasp the first-mover advantage, albeit temporary, latent in metabolic engineering to manufacture energy from organisms. The political volatility of traditional oil and gas supplies taken together with the ignorance about the benefits of nuclear energy is a debilitating burden on most nations. Metabolic engineering represents one emerging alternative to partially shed the dependency on foreign oil and gas. The knowledge tools from metabolic engineering can create a new legacy in business services.

Creating the perfect metabolically engineered bacteria or algae to produce commercially useful liquid fuel (butanol, pentanol) may be a worthwhile academic goal but the pragmatism necessary to bolster energy supply in the real world calls for a multi-pronged application-specific research and development. Academic-industry partnerships may explore bio-chemical process engineering optimizations necessary for manufacturing scalability for the alternative liquid fuel products. Lab vs commercial scalability are different dimensions where applied R&D may be required. The ability to scale manufacturing of energy from microorganisms not only leads to commercial production but also represents knowledge as a service and exemplar of knowledge economy [27] for global public goods [28].

Inevitable forces of demographic change due to an aging population in the Western hemisphere, will present new challenges [29] for generating jobs that can sufficiently remunerate in order to support the higher cost of living. The workforce for low cost repetitive manufacturing demands a demography which is rapidly on the decline in the industrialised nations. Those possessing the skills necessary for manufacturing energy may be duly rewarded. The skills are portable since the skilled workforce can act as advisors to develop manufacturing plants, world wide. It offers the potential to create business services that are likely to grow only in a knowledge economy. Hence, energy may evolve as a key driver for the growth of innovation societies.

Conclusion: Invest to Explore Manufacturing Scalability of Metabolic Engineering

From common sense, it stands to reason that an ENERGY PARK approach with complementary R&D endeavours in scalability issues may help migrate the MEMEM lab experience to a commercial dimension in manufacturing energy. Although metabolic engineering has failed to push its 'green' credentials or align itself with environmental lobbyists, to the future innovators, leaders and citizens, GEMS shall slowly but clearly reveal that it is pragmatic, productive and green.

The facts quoted here are supported by evidence or references. The interpretation of the facts and opinions expressed here are solely due to the author. Opinions and interpretations do not represent or reflect the views of MIT or the institutions with which the author may be associated.

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CARBONOMICS

Trinity of Elements 6, 92 and 94 may Re-define the World Economy

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Progress of civilization and ethical gains from global productivity are held hostage by Element 6 [1]. To pay the ransom, the existing world order may need re-engineering to sense and respond with a dynamic and agile economic infrastructure that can sustain higher transaction costs [2]. The international currency of growth shall be forced to adapt and adopt an economic standard where operations may be pegged to the cost of unit energy based on an index of about US$100-US$150 per barrel of oil at 2008 rates [3]. This prediction is not about actual cost of crude but based on estimates that energy from nuclear fission and coal with carbon sequestration will be comfortably competitive if oil price approaches US$150 per barrel [4].

The cartel of oil producing nations may be unaware that they may be fueling a designed dis-incentivization strategy to punctuate the pursuit of alternative non-fossil energy sources by aiding price volatility. The inflation of $35 per barrel price of oil in 2004 to nearly $150 per barrel in July 2008 occurred without any key changes in production. The current price (January 2009) under $50 per barrel does not appear to be associated with any major resource reorganization. Coordinated development and deployment of non-fossil energy sources must be a priority for 21st Century world leaders who may need to inculcate the personal discipline necessary to remain oblivious of the Russian roulette of oil prices and platitudes from actors, such as, OPEC.

The obvious answer to the carbon conundrum is US Patent 2,708,656 and has been staring in our face for half a century: nuclear fission [5]. The political positioning of 'nuclear' catalysed by the well orchestrated 'march of unreason' [6] by effective groups of environmental dissidents are forcing rational thinkers with good intentions to generate short lived, poorly designed, crowd pleasing, semi-scientific, *ad hoc* measures [7]. Carbon pricing, carbon calculators, carbon credits, carbon exchanges, carbon policy compliance and environmental risk management [8] are a part of our current vernacular.

These carbon initiatives are gaining momentum. It may serve as a necessary but perhaps a bit wobbly platform for the climate control debate. In the next quarter century, with the rise of a new generation of thinkers and leaders, the potential for demise of carbon regulatory measures are imminent. One reason is embedded in the flawed principle of its construction. It assumes that enforcing a price on carbon will act as a financial incentive to use non-fossil fuels. The logic is weak because carbon taxation primarily impacts the end-user or the average citizen. But, the investment and ability to manufacture and distribute non-fossil energy is concentrated in the hands of a few behemoths and/or governments. The stimulus for the end-user to use green or renewable or non-fossil fuel is blunted by the lack of adequate non-fossil energy supply. Availability of the latter is not controlled by the consumer but carbon pricing may affect the cost of goods and services, which will be passed on to the end customer, in some form or the other.

Hence, carbon pricing may be viewed by some as a deterrent to productivity and may increase transaction cost, if implemented. Having said that, a pragmatist faced with the present state of global quagmire must reluctantly add that the short-term impact of carbon pricing may merit implementation despite the bleak prediction about its long-term value (beyond 2050). Thus, the current call for carbon pricing is a sign of the times [9]. Perhaps 'doing' something is viewed with sympathy by the public even though citizens may not be scientifically literate to understand that tax and price does not address the science of reducing carbon emissions or the root cause producing the effect (i.e. emissions). In fact, carbon pricing may turn the age-old aphorism on its head: go where the pastures are not so green! Carbon pricing in the 21st Century "systems age" may also ring similar to the cliché of running out of iron ore in the middle of the industrial age.

In other words, carbon pricing may produce the unanticipated effect of industries migrating to zones where carbon regulation is not ratified or sloppy in its execution and enforcement. It may be optimistic to anticipate global harmony on carbon pricing and taxation (carbox) schemes [10]. Governments may ignore carbon regulations to attract businesses. Ireland, an EU member state, has successfully resisted EU calls for uniformity in corporate tax. In order to attract and keep big corporations operating and "cooking" their finances in Ireland, the government has held fast to the low 12.5% corporate tax. Recently, the Irish ignited the wrath of some in the EU by ignoring EU's call for constitutional harmony by voting against the adoption of the Lisbon Treaty.

Technically, carbon pricing initiatives shall be plagued with acrimony stemming from ambiguities about models, standards, metrics and data dependencies. Lack of global accord shall segue to an uneven playing field of carbon haves and have nots. But, viewed from the perspective that the glass is half full, legislating carbon pricing may drive home the awareness that climate change affects all and each one of us has a role to play, no matter how small or insignificant. Perhaps, imbued by a genuine sense of camaraderie to reduce carbon emissions or stimulated by an urgency to shake off the economic burden of carbon taxation or to legally defy the validity of carbon legislation, the energy industry may join forces with other industries, academia and government to educate and inform the masses why investment in nuclear fission energy guarantees sustainable return with long term benefits for the economy and the environment. The prudent solution is to immediately ramp up to generate an abundant supply of non-fossil energy from safe nuclear fission, without aggravating the global carbon footprint.

Hence, it may be good news that the US Nuclear Regulatory Commission (USNRC) has registered applications for licenses to build 25 new reactors, since July 2007. The projection that in 2030 nuclear energy shall provide about 10% of the global energy demand may be short sighted [[3]]. By 2030, China and India's energy demand is expected to be in excess of 4,000 and 1,000 million tones of oil equivalent (MTOE), respectively. The global demand for energy is expected to approach 15,000 MTOE by 2030. It should be met by an abundance of non-fossil energy supply.

The advances in the next few decades should enable reduction of the unit cost of nuclear energy from $150 per barrel oil equivalent, estimated at present. Capital expenses, amortized over time, shall further aid nuclear energy cost reduction and stabilization rather than carbon taxation and the burden of bureaucracy implicit in carbon compliance. It appears that the energy debate is losing its coordinates in the cost versus value argument. The value of non-fossil nuclear energy is far more important that the present or perceived cost. In 1960, DEC produced PDP-1, a desktop computer at $120,000. Today, even Wal-Mart sells super powerful desktop computers and they are priced at $500 or less. In 1956, Ampex pioneered the video recorder market and each VCR unit was priced at $50,000 [11]. If you can find a VCR in 2009 then expect to pay $50 or less. By 2050, the unit cost of clean and safe non-fossil energy from nuclear fission may follow similar trends in addition to competition from emerging energy supply from nuclear fusion plants [12].

The path to global productivity and improvements in standard of living may not be constructed through the tunnel of energy conservation. Availability of energy to fuel progress should be almost a non-issue. An analogy may be found in the cost of computing. It has decreased so much so that applications, irrespective of complexity, may ignore the cost of processing power as an insurmountable transaction cost. The amount of computing power (micro-processors) in a birthday card that sings a tune, when opened, is greater than all the computing power that existed on this earth before 1950. A garden variety chronometer watch bought from a corner convenience store has more computing power than all computers in Silicon Valley before 1975. Can we imagine a world where Nintendo Wii, Sony PSP, Match.com, Facebook, eBay, Amazon and Google users may be required to pay a "computer processing tax" or "MIPS based pricing" for using computing intensive applications? How about an IOU (internet over-user) tax scheme?

Innovation in renewable sources may add to the safety net of grid based electricity powered by nuclear energy. Innovation in hydrogen generation through replication of photosynthesis [13] and hydrogen storage in carbon nanostructure [14] based fuel cell may usher in key changes in the transportation industry [15]. Other forms of entrepreneurial innovation may make it possible for green energy manufacturing systems (GEMS) to produce alternative liquid fuels such as butanol and pentanol, through metabolic genomic engineering of microorganisms [16] feeding on biomass waste, rather than items with food value (corn or sugarcane) as a source of carbon.

Harnessing the power from renewables begs innovation in storage technologies. Wind, wave and solar energy are excellent alternatives as long as the need for affordable storage does not arise. The best batteries, at present, can store only about 300 watt-hours of energy per kilogram (gasoline stores about 13,000 watt-hours per kilogram) and is one of the available solutions for storing solar energy (or any energy) if it is to be used when the sun is not shining. Similarly, the numbers add up poorly if wind energy [13] is used to pump water at an elevation and then (run the water through a turbine to) generate electricity. One kilogram of water raised to 100 metres stores about one kilojoule of energy. One kilogram of gasoline stores 45,000 kilojoules of energy.

If policy and principles are based on scientific evidence, then, one must wonder whether carbon pricing or levying a duty based on emissions can be rationalized as an incentive when non-fossil alternatives are still embryonic in their development or demonized by society (nuclear energy).

But, there is no doubt that 'something' must be done to restrain the unbounded and perhaps irrational growth of the carbon footprint created by human endeavour. Energy conservation through micro-metering and monitoring usage by deploying wireless sensor networks [[17]] to reduce waste are healthy approaches to limit the carbon footprint. Accumulation of carbon credits by demonstrating the reduction of carbon footprint is certainly a goal worth pursuing, at all times. However, the metrics and data stream necessary to determine carbon savings and assignment of carbon credits are still developing [[10]]. This quagmire may offer temporary advantages and innovative opportunities for integrating systems that may meter and monitor usage, document reduction in footprint over time and generate online metrics-based real-time analytics. This integrated system may serve as a platform or a standard operating procedure promoted the by climate control organizations [[18]] or innovators [[19]]. Entrepreneurs [[20]] may have the wisdom to grasp these emerging needs and profit from creating analytics (eg: metrics, carbon calculators) and predictive engines [[21]] that may eventually surface from cloud computing as web services. It may also enable grocery chains to affix carbon footprint numbers to your banana [[7]], depending on its source, production, transport and distribution, or, in other words, the digital carbon supplychain [[20]]. If you pay more for a banana imported from Central America, then, the carbon pricing scheme in effect, masquerades the temporary failure of government incentives and leadership to provide global public goods [[22]], in this case, safe supply of non-fossil energy.

Later in the 21st Century, to provide about 10 billion people in the world an adequate level of energy prosperity, conservatively estimated at a couple of kilowatt-hours per person, the global demand may exceed 60 terawatts or the equivalent of almost a billion barrels of oil per day [[23]]. The largest hydroelectric power station in China (Three Gorges Dam), when completed at a cost in excess of US$22.5 billion, may generate peak power of 22.5 gigawatts, an order of magnitude more energy than what is currently generated by the Hoover Dam or the largest nuclear reactor in operation [[24]]. The sheer construction necessary to build enough power plants to meet the domestic energy demand will be staggering even if the US were capable of reducing its energy craving and consume a mere 10% (only 6 terawatts) of the projected global energy demand.

Climate control and carbon pricing may soon become synonymous but will it address the root cause or aid the terawatt challenge? The implication of taxing the key mediums of global productivity (i.e. energy) is similar to the scenario where one hopes that a race horse will win despite the burden of a carrying a heavy load around its neck. Economic hindrances imposed on mediums of growth (i.e. energy), communication (i.e. internet), human capital (i.e., healthcare) and capacity development (i.e., immigration) may only serve to slow the progress of civilization.

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Carbon Conundrum: INGRID and the Zen of Energy

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ABSTRACT

Policies based on empirical assumptions without a foundation in granular real-time data may be limited in scope. It may sputter ineffectively in its role as the engine of energy economics. For energy efficiency and conservation, it is increasingly necessary to invest in systems, tools and practices that can facilitate bi- or multi-directional flow of energy to control or balance consumption with the goal to reduce carbon footprint. The central dogma of an energy oligopoly and uni-directional distribution through the electricity grid is poised for a radical overhaul. An "internet" of electricity capable of executing differential distribution strategies from capacity generated by a network of micro-suppliers and electricity producers may evolve from the proposed Smart Grid infrastructure. The future Intelligent Grid (INGRID) is a step toward the obvious. Development of methodologies using technologies based on rigorous scientific standards must be coupled with effective dissemination of tools and adopted by consumers to acquire real-time monitoring data for analyses and feedback decision support. Automation driven by intelligent systems is key to the efficacy of INGRID. In this essay, we advocate a convergence of innovation through service science, which may evolve in parallel with INGRID, representing an amorphous nexus of engineering and management with the needs of society, industry and government. Higher levels of decision support, necessary both for strategists (policy makers) and engineers (INGRID operators), may be impotent or without global impact if we fail to promote diffusion of a "grass-roots" approach to seed one or more methodologies necessary to acquire data from a critical mass of users in each environmental category (domestic, industrial, hospital) from each major geographical region.

KEYWORDS

Smart Grid, Intelligent Grid, INGRID, IPv6, Carbon Micro-Credits, Carbon Trading, Carbon Emissions, Carbon Tax, Carbonomics, Internet of Electricity, Service Science, Wireless Sensor Networks, Energy Monitoring, Policy, Carbon Footprint, Green House Gas (GHG) Emissions, Clean Development Mechanism (CDM), Analytics, Dynamic Pricing, Dynamic Programming, Intuitive Software, Carbon Supply Chain, Operations Management, Econometric Techniques

A SENSE OF THE FUTURE

Using data from energy measurements, in addition to other policy and parameters, INGRID [1] may spur economic growth by further catalysing energy efficiency. Among other things, users may pay even less for electricity. Ingrid may accumulate carbon micro-credits for her i-house [2] through an entrepreneurial environmental cooperative for energy eBusiness (which trades in carbon options) and use banked carbon credits to offset the carbon footprint each time she needs to fly. INGRID potentially ushers in an era when Jane or Joe can generate energy from a variety of sources including renewables and profit from auctioning their excess (capacity) electricity on the hypothetical portal power.on.eBay [3] while contributing to the global deal [4] to reduce greenhouse gas (GHG) emissions.

Micro-generation of electricity, micro-sales and distribution via INGRID may have positive economic consequences, immediately, for some rural regions and eventually, for some of the remote parts of the world. Rural economic revitalization commences with the investment to generate energy from rural areas by harvesting unused natural resources (wind, solar) and agri-waste (biofuels). Non-fossil energy may find its way to power the air conditioner in room 8080 of a city-based conglomerate. If waste-land areas can grow oil weeds [5], then biofuel-based near-carbon-neutral electricity may be distributed and sold through INGRID. Today, we continue to hear [6] the question: are you connected to the Internet? In the near future, the question may be: Ingrid, are you connected to the INGRID?

SOLUTION IN CONTEXT

Climate change [7] is a global phenomenon with profound local impact. The relatively slow rate of climate change in combination with the nature of factors responsible for the problem, in part, makes it difficult for managers to invest their limited resources to implement enabling technologies necessary to address environmental responsibility unless the investment can be linked with a financial incentive, for example, savings [8] from energy efficiency. Various forms of legislation [9] are making their way through governments to mandate some elements of efficiency. The impact of regulation will extract a price which will influence the cost of all goods and services [10]. The science and engineering developments necessary to mitigate climate change will usher in a convergence through innovation in service science [11]. A catalyst in the information and communication revolution was the Internet. Although embryonic, evolution in climate control strategy may find part of its solution in the 'internet of electricity' through the emergence of INGRID, the intelligent grid. INGRID is not without its problems and is only one component in the global energy debate. In addition to the staggering cost of infrastructure, issues arising from synchronization and automation of micro-generation, storage with minimal loss, dynamic distribution, differential pricing and auctions, collectively, presents technical challenges for systems engineers and energy e-business [12] entrepreneurs.

PROBLEM SPACE

The science of climate change [13] has fuelled an acrimonious debate from which the principal of "polluter pays" surfaced as an UNFCCC agreement in Kyoto, 1997 [14]. It continues to aggravate the global economic woes and threatens to destabilize the already fragile harmony between nations on either side of the energy chasm. This essay attempts to add yet another perspective, through convergence of data driven analytical tools and a zen approach to the conundrum whether carbon should be viewed as a liability in the portfolio of instruments that impact economic growth. This concept of liability may shake up the fundamental notion that energy is an asset and an indispensable medium to improve quality of life. In an ironic twist, on the other hand, it has triggered a rapid increase in "green" collar consultancy jobs in the area increasingly popularized as sustainability or energy risk management [15]. At the heart of this debate is the financial "carrot and stick" approach to reduce greenhouse gas emissions by ***monetizing*** the assault on the environment, resulting in the concept of a market derivative, commonly referred to as Carbon Credit [16]. This mechanism places an open market cost on every metric tonne (1000 kg) of carbon dioxide (excludes methane and nitrous oxide, the other greenhouse gases) generated from any operation.

The justification of this financial incentive is based on the rationale that operators and end-users, in an effort to stave off transaction cost [[17]], shall turn to energy from carbon-neutral or renewable sources to decrease their carbon footprint. They shall seek rewards for their action in the form of carbon micro-credits, thus, ushering the potential for carbon trading options for those carbon-positive entities that may profit from selling carbon credits to carbon-negative groups. Each carbon credit allows the right to release one metric tonne of carbon dioxide, thus, legalizing the assault on the environment. This strategy drives a wedge between those nations that are capable of stimulating the accumulation of carbon credits by seeking or investing in alternative energy versus the developing world where the zeal to save the environment must be balanced by the pragmatic need to grow the national economies that are already plagued with other problems [[18]].

Due to the magnitude of the energy demand [[19]], the issues germane to GHG shall remain in the forefront of public discourse for at least another quarter century unless we magically encounter a global transformational innovation or acquiesce to immediately profit from an abundance of electricity from nuclear power [[20]]. The latter may not solve all the global energy needs but allows enough time to productize sources of energy that offers a low risk profile with even better GHG emissions control. Before we arrive at the post-2050 fossil fuel free era, at least for the next few decades, therefore, it may be prudent to focus on how to optimize the use of available forms of energy through pro-active measures including (1) conservation or waste reduction and (2) improving efficiency (device, infrastructure, behaviour) in order to decrease energy consumption and reduce GHG emissions. Investment is necessary to adopt some of these measures and the return on investment (ROI) is expected from (a) aggregated micro-savings from decreased use of energy, (b) reward for reduction in carbon footprint enabling accrual of carbon credits, (c) global certifications for environmental responsibility [[21]] and (d) sustainability or ***green*** goodwill. The policies to drive the mechanisms necessary to accomplish the tasks outlined above are proceeding at a frenetic pace in various countries and global organizations. Committees and task forces are framing the structure of infrastructure to be embedded in auditing tools. Carbon calculators are already featured as interactive software on a variety of decision making platforms [[22]]. Tools and simulation [[23]] to model interaction with INGRID are also necessary and expected to evolve.

A closer look at a few determinants, reveal (Figure 1) that frameworks are too often reliant on standard data or assumptions which may exclude local environmental data and introduce general error by aligning the tools with ***averages*** of global data. Of course, in some cases the "science" remains unchanged irrespective whether the action or event occurs in Argentina or Zimbabwe. However, there is need for granular real-time data to forge the basis of key policy constructs. For the task at hand, if we focus on energy efficiency and conservation to reduce emissions and carbon footprint, then it may be necessary to acquire granular data (monitoring usage) using technologies based on rigorous scientific principles. Data must be auditable according to established methodologies to provide a basis for further decision making. The physical and financial facets of the entire energy supply-demand value network must be taken into consideration by assigning proper weights to local and global factors, that may have an impact on the decision, either directly or indirectly. For example, in the post-2050 hypothetical petroleum free era, what options exist for manufacturing of liquid fuel for certain segments of the transportation industry? Will the limitations of liquid biofuel from metabolic engineering necessitate the birth of the nuclear aircraft for commercial flights?

FIGURE 1: Greenhouse Gas Inventory – Training Workshop conducted by the United Nations Framework Convention on Climate Change (UN FCCC) reveals that the systems under development may be mired in uncertainty arising from lack of data. Some of the policies and frameworks under construction by UNFCCC and UN Inter-governmental Panel on Climate Change (UN IPCC) are expected to be globally adopted yet (a) lack data or (b) are based on incomplete data or (c) use averages from IPCC 'standard' default values or (d) use data from Annex I countries (igniting disparity and adding ambiguity). UN-FCCC and UN-IPCC may continue to perpetuate this quagmire unless the UN champions, in addition to other important measures, the global diffusion of the type of tools and technologies (mentioned in this essay and other related articles) to acquire country-specific granular data from a plethora of applications.

Pushing aside the broad questions, for the moment, the use of data to provide a service valuable to the consumer is at the heart of the pragmatic approach. It is feasible, if we use proper tools to monitor and reduce energy usage. Translating the reduction in consumption to monetary savings is the incentive to invest in the tools. The generalized framework for this translational carbon savings is still emerging. *Ad hoc* methods, often proprietary and without verifiable data accuracy, feeding a cobbled framework, may be detrimental to energy efficiency. If it is feasible to acquire a critical mass of accurate granular data, then, the data-driven tools will save money and resulting policy constructs may stand the test of time. Enlightened policies in the national and global framework may offer incisive insight into the (a) magnitude of the crisis, (b) dimensions of the ripple effect and (c) better clues to sustainability.

Dependency on data, in this case, mimics or may be analogous to, at least to some extent, the scenario where the rate limiting factor in the speed of communication as a function of high speed data transmission was and still is, in "the last mile" or FTTH (fiber to the home). Information velocity on the super highway is only as good as the granularity of access in the hands of the end-user. Locally and globally the energy sector is pursuing a plethora of worthy initiatives and decision making software but the granularity of data, in some cases, is still poor or based on default assumptions or standard models. Tools and technologies to acquire granular data and analytics to process or derive meaningful associations for improved decision support in intelligent systems, are necessary. But, systemic methodologies that can accelerate and catalyse the widespread systems integration and dissemination of these tools are not in the hands of users, in the numbers that may be profitable, on several dimensions. In an increasingly volatile and dynamic energy market, some projections place carbon as the largest financial business commodity by 2020 [[24]]. Carbon trading will be driven by auditable data and that requires bonafide systems, tools and analytics.

EMERGING SOLUTIONS FOR THE CARBON SUPPLY CHAIN: INTELLIGENT ENERGY TRANSPARENCY (iET)

Principles of operations management suggests that volatility between operational stages may be due to information asymmetry [[25]]. Volatility may be reduced by improving or increasing transparency through data acquisition and sharing. Applying the same principle in energy dynamics may create the intelligent Energy Transparency (iET) portal. Unlike INGRID and its long term economic impact, the measures and functions in an intelligent Energy Transparency portal must yield value within a short term and profitability will be the primary driver. iET portals may include:

- Savings Optimization
- Carbon Footprint Audit
- Power Saving Automation
- Differential Dynamic Pricing
- Energy Risk Management
- INGRID "Globus Tools"

This may be the information arbitrage based evolutionary pathway suitable for an energy service portal that must serve the pressing call for profitability yet offer the long-term resilience for integrating with INGRID. INGRID may develop an operating system [[26]] for electricity distribution [[27]] which may be analogous to the ICT grid [[28]].

FIGURE 2: Illustration shows Ingrid using a hypothetical INTELLIGENT ENERGY TRANSPARENCY (iET) portal to balance her demand for INGRID delivered electricity vs options to sell back to INGRID her excess capacity. Energy efficiency and ability to meet demand from micro-generation or on-site generation are drivers for optimization. Ingrid enjoys direct monetary benefit from reduced electricity bill for her i-house and the advantage of cash for carbon credits.

The concept of iET originates from the original proposal of Homeostatic Utility Control suggested by scientists at MIT nearly three decades ago [[29]]. HUC type products exist in building and/or energy management systems [[30]]. But, often, these tools are device-specific with local automation and control. The latter may be inadequate for overall energy efficiency in a building, hospital or commercial enterprise. Building on HUC and extending the concept of the Energy Box [[31]], the proposed iET is expected to offer dynamic control using local or device-specific real-time data with the aim to generate "global" optimization, for example, savings across an enterprise through better control. But iET will fall short of its potential unless its architecture allows for future integration with INGRID. Existing products in the market are sophisticated but address limited number of issues. iET calls for architectural design of software components that can respond or adapt to needs of the market when elements of the Smart Grid [[32]] and the future INGRID comes into play. However, to be viable over the long term, iET must also be useful immediately, in the short term, to help generate monetary savings for investors in energy efficiency.

Since savings is price dependent, a key component of iET must be pricing, specifically, dynamic pricing algorithms. Application of the principles of operations research to the practice of supply chain management has demonstrated that volatility of demand is reduced if an EDLP (every day low price) strategy is adopted by retailers [33]. EDLP is in contrast to practices that attract customers using promotions and discounts using variable pricing or price based on inventory, competition, demand variability, seasonal trends or brand marketing, through some form of dynamic pricing scheme. The electricity market uses a constant price per kilowatt-hour that rarely changes. But, the pre-set rate is not reflective of EDLP. Without any incentive to conserve, the usage pattern of consumers are unaffected and that leads to peak periods of consumption for which the energy provider must build capacity. This pre-dominant scenario of peaks and valleys clearly indicates the need to build excess capacity in order to meet peak demand. It also indicates excess electricity generation capacity that is under-utilized for several hours each day. It has been proposed that an electricity quota at a base price in combination with dynamic pricing (higher rate for increasing demand) may offer incentives to users to be more efficient. Aggregated energy efficiency can reduce peak load and providers need not build capacity continuously (pass on the cost to users) in order to meet projected peak demand.

If energy efficiency took effect, it has been estimated that a less variable electricity demand pattern will ensue with projected savings of about US$100 billion and a diminished need to expand capacity over the next quarter century [34]. Enabling technologies can improve energy efficiency by automating the response of the consumers to dynamic pricing to substantiate the savings. Data from wireless sensor network (WSN) monitoring systems [35] integrated with savings optimization and automation portals of the proposed iET can deliver energy efficiency and savings. To maximize savings, the decision support tool cannot be manually controlled nor "fixed" at pre-set levels irrespective of other independent variables, for example, weather. There is a need for an iterative process to perform dynamic optimization and re-sets, perhaps every few minutes, if necessary, depending on an intelligent analysis of factors and fluctuations but without compromising the ***service*** expected of energy, that is, for example, human comfort inside an airport waiting lounge.

To extract sustainable value from the future INGRID, the diffusion of iET tools and its adoption by consumers must be accelerated to create an enabled society [36]. Combination of dynamic pricing with storage and distribution via INGRID will allow Ingrid (Figure 2) to buy and store electricity from providers at a low off-peak cost and sell power during peak demand. Weather permitting, the rooftop solar panel or the wind turbine in the backyard could add to the energy portfolio and decrease demand on the grid [37]. If the grid response time is in hours, then the system may be limited because weather conditions (for example, wind) may not be predicted several hours in advance. The bi-directional control and flow of electricity over INGRID from Jack and Jill (suburban) to specific addresses (urban) will make our current demand profile flatter by dynamic re-routing of electricity. Jack and Jill may get a credit on their electricity bill (***make*** money) and accumulate carbon credits while their urban counterparts choose their supply at a fair price from power.on.eBay or pay spot price to meet an unexpected demand (beyond low-price quota). Dynamic in-grid analytics may use cloud computing [38] to deliver the energy ***ebusiness services*** made possible through iET. Re-routing the flow of electrons (electricity) to specific addresses may mimic DNS used by the internet protocol (IP) and can benefit from the increased number of unique addressing capability made possible by IP version 6 [39].

ENERGY eBUSINESS NOW

Revenue from iET energy ebusiness services (software: portals) and routing activities (hardware: routers) may form a micro-payment stream based on IPS (instructions per second) or CINT units of processing power [[40]] consumed for optimization (sequential decision support). The traditional POTS (plain old telephone service) pay-per-use *modus operandi* may be replaced by the CINT-e-meter (pronounce: *centimeter*). One advantage of a CINT-e-meter is the ***choice*** offered to the user to select the preferred degree of optimisation, hence, introducing service level as a value-add. The rationale is based on principles of operations management and is analogous to service level agreement (SLA) or fill-rate criteria used in supply chain management [[41]]. For example, if a retailer expects customers to find a product on the shelf 95 times out of 100 visits (95% fill rate) then it carries a certain amount of inventory for which it pays an inventory carrying cost. If the retailer demands 97% or 99% on-shelf availability to minimize its lost sales opportunity due to out-of-stock (OOS), then the retailer may secure a higher SLA but probably pay an exponentially higher inventory carrying cost due to increased safety stock requirement to prevent OOS.

Mapping this logic for use of a CINT-e-meter, it works as follows: if a customer was satisfied to save 10% of electricity charges, then the frequency of local and global optimisation routine will consume a certain amount of processing power. However, if the consumer aims for 20% or 40% savings, then the dynamic iterative programming must consider more variables, optimize more frequently and hence consume more processing capacity to seek out and shave off even minor variations to minimize electricity consumption and maximize savings. In a POTS revenue model, the consumer pays a flat rate for using iET service. CINT-e-meter enables SLA reconfiguration which translates to pricing reflective of the optimization necessary to reach the savings target. Because the infrastructure may be agnostic to SLA, the consumer can switch back and forth between SLA's or schedule a portfolio of SLA depending on usage (weekdays, weekends) or special conditions (holidays that are not fixed or falls on a certain weekday).

In a more profitable model, venture funded, hardware-driven platform service providers may create sustainable long-term revenue streams through initial capital investments. Eliminating capital expenditure for tools necessary for energy efficiency reduces the barrier to rapid deployment in the commercial sector. The provider enters into a SLA with the buyer whereby a percentage of the savings from the buyer (over a number of years) is the revenue for the provider. This revenue model must measure the baseline consumption with accuracy and build a general pattern of usage model ***before*** implementing control automation to optimize savings. Continuous monitoring is necessary to audit consumption and remain vigilant about addition of load to baseline metrics (new HVAC, another transformer) that violates the SLA designed to deliver a specific savings target. Because the earnings of the provider are directly related to savings of the buyer, changes (extra load) in baseline metrics may be detrimental to the provider, if it dilutes the savings. Various micro-payment strategies may be profitable for the long term service provider using iET's intelligent systems capability (software as a service). But, the merit of the micro-payment system must be evaluated in context of the principle illustrated below: millions of tons of gold are in the waters of the oceans. Why aren't we extracting gold from the seas? It is the dilution factor. If we can not obtain at least $8 worth of gold from one tonne of water, the costs of extraction will exceed the value of gold.

INTELLIGENT ENERGY TRANSPARENCY: PARTS OF THE ENGINE

Integrating a plethora of independent variables in a repetitive and sequential decision making process may be served by classical stochastic dynamic programming (SDP) for most optimization needs [[42]]. Decisions will take into account the stages, states, transitions, policies and forecasts or conditions prevailing at the time. Approximation or accuracy of SDP will depend on or may be limited by dimensionality or state-space. In simulating or controlling a device, the input value of some of the independent variables may be selected either from a distribution or to simplify matters, certain discrete values may be used. Classical linear regression model may suffice for certain types of time-varying forecasts but other situations may benefit from application of autoregressive moving average or other advanced [[43]] econometric techniques (Figure 5). The value of an iET engine relies on the ability to be modular and host a variety of algorithms that can serve general as well as specific functions which will vary between verticals (industry, hotels, hospitals, domestic, public, commercial). iET may be best served by a conceptual intelligent differential decisioning engine (IDDE). Building intelligence in the tool using learning algorithms based on the principles of artificial neural networks (ANN) will be an important criteria and over time may produce a bonafide 'intelligent' decision support for energy. From a pragmatic data driven energy efficiency and savings perspective, it may be prudent to consider some of the design criteria for stationary assets and apply these criteria in context of mobile assets (transport) and SCM.

Energy Usage: Audit

- Accuracy and types of data
- Data collection, analysis and systems integration
- Efficiency and consistency of carbon footprint algorithm
- Optimisation of process or customer comfort vs best practices for energy efficiency

Carbon Savings: Objectives

- Calculate and compare carbon footprint
- Control through automation for carbon and energy savings
- Optimise carbon credits for non-energy intensive business units
- Reduce carbon emissions and increase carbon trading opportunities
- Value-add over existing technologies [www.carbonetworks.com and www.climatmundi.fr]

Carbon Footprint: Parameters

- Fuel portfolio: fossil, non-renewable, carbon-neutral, renewable
- Energy consumption in kilo-watt-hours (kwh) per unit area
- Location, weather, volatility, uncertainty, unknowns, TCE
- GHG emitted (tonne per kwh) versus energy cost
- Calculate carbon credits (barrels of oil saved)

Decision Automation: Recommendation

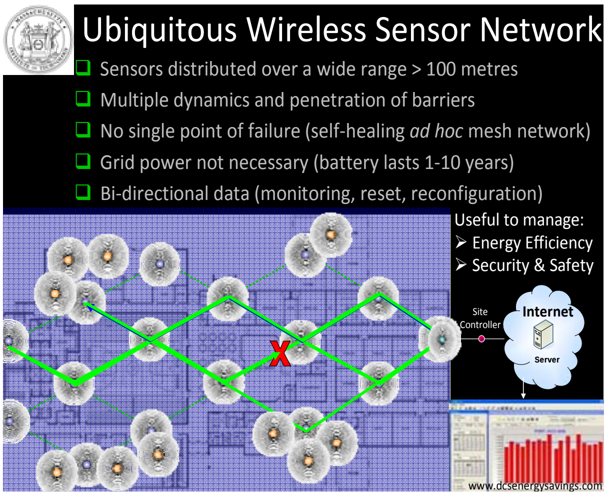
- Execute actions to reduce transaction cost (TCE) of operation
- Offer choices of materials, materials origin, manufacturing process
- Compare dynamic pricing, energy use and carbon status with sector specific practices

APPLICATION OF iET

Diffusion of conceptual iET and INGRID may enable institutional and business leaders to seek solutions appropriate in order to respond to their demand. Almost every CEO and heads of government agencies must get acquainted with demand response, the tools necessary to implement and evaluate energy savings as well as carbon trading options. When functional, iET provides decision makers a mobile dashboard necessary to deal with near real-time carbon reduction, energy savings and carbon trading (as an asset or a liability). Based on the granularity of the data, the hypothetical iET can be used in a hierarchical manner starting with units in businesses, then chamber of commerce, municipality, city, state and country (Figure 4). In some countries, legislation already exists to address the issue of energy risk management. The US Congress legislated the Sarbanes-Oxley Act (SOX) in 2002. SOX 409 [[44]] requires businesses to assess types of risk that may be associated with its operation. This 'risk' may extend to include energy or carbon footprint. One form of clearance that may be required in the future may borrow from the framework of Clean Development Mechanism (CDM) created by United Nations (UNFCCC). The importance of the carbon footprint was magnified by the introduction of the "polluter pays" principal in the form of financial costs for generating carbon dioxide. The need for *carbon footprinting* of business and industry may become mandatory. Since emissions are now a financial liability, CFO's must implement measures or strategies to limit these costs on the balance sheet. Hence, comprehensive energy usage *audit* may enable *carbon liabilities* to be balanced against reduced energy usage by improving energy efficiency.

Rewards for saving energy may be a marketing asset as well as a financial incentive. *Carbon credits* have been trading on the open market for about US$30. Each *carbon credit* allows the owner to release one tonne of carbon dioxide. The value of the *carbon credits* is predicted to soar with the City of London predicting that current sales of £30 billion may even exceed £1 trillion by 2020 [[45]]. Governments are keen to increase revenue and carbon tax is no longer a novel idea but represents a lucrative resource to benefit national treasuries. Carbon tax is an economic baggage, not a solution for reducing GHG. Controlling climate change through appropriate enabling technologies is a better mechanism. Use of wireless sensor networks (WSN) to monitor energy usage (Figure 3) and optimize energy efficiency is only one component in a portfolio of technologies that will drive the functional development of iET. Except for purposes of audit from a supply perspective, the data from monitoring energy usage is almost worthless to improve energy efficiency unless accompanied by automation of controls to reduce consumption without compromising the function for energy usage, for example, human comfort from an optimum temperature in an enclosed space. The granularity of the continuous monitoring approach will not deliver value unless the streaming data is able to fine tune the devices in order to optimize energy efficiency. The visualization of the data and controls must offer different "views" based on the user and factors that are of importance to users [housekeeper, building manager, financial controller, energy authority, power distributor, state regulator]. The ability of the iET software to "learn" preferences of users and characteristics or patterns of energy usage is crucial to intelligent decision support. iET is expected to integrate hardware-associated visualization software with operational logic executing artificial neural network routines which continuously improve performance and prediction using learning algorithms in IDDE.

TOOLS & TECHNOLOGY	**DATA & DECISIONS**



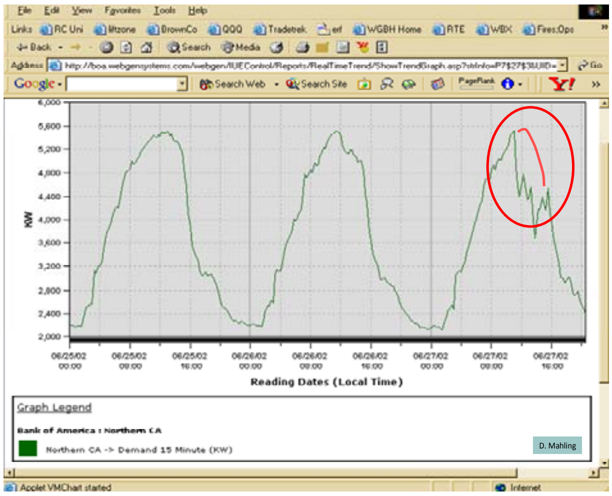


FIGURE 3: Illustrates a generic WSN (L) and energy usage data to predict aggregated consumption (R). In a scenario where the local power regulator issues a request to reduce energy consumption during a peak period, a curtailment decision can be executed using WSN and automated control to reduce consumption optimized at the device level and successive aggregation to decrease demand by specified target amount. The zone within the circle (R) shows the actual reduced consumption after curtailment plan was executed. Bi-directional WSN data communication is key to *'sense & respond'* triggers to execute effective controls. Graphics: MIT Building Technology Program (D. Mahling)

The strength of this granular approach for data acquisition and utilization is exemplified by the ability of a local or state electricity board to issue an online command and effect a reduction in energy consumption in buildings or premises using an iET system integrated with WSN features and controls. In this approach, it is not difficult to envision that systemic commands may be deployed with a short lag time (minutes) at multiple levels or hierarchies of control (Figure 4). The knowledge that this system can re-distribute power and reduce consumption on demand, may be an important tool for planning and designing (1) consumption prediction (2) power supply generation (3) power demand volatility (4) emergency options and (5) security alternatives. Integrating successive layers of data in communal, local, municipal, state and country model is the framework necessary for development of policy and planning for the future. Global organizations (UN) can use this data to better design the tools and instruments to monitor and audit carbon emissions or credits.

In reality, this approach will not materialise simply by pontificating its value. It may require the following: (1) offer transparency of aggregated consumption data through iET (2) for a meaningful contribution, it is essential that granular data acquisition tools are in use (3) investment necessary for adoption of these tools will depend on incentives rather than the goodwill of sustainability (4) adopters seeking return on investment will seek actual monetary savings from reduced energy charges (5) standards of installation for rapid "go live" execution and (6) advanced modeling tools [[46]] and technologies [[47]] to profit from emissions trading schemes [[48]] as they evolve.

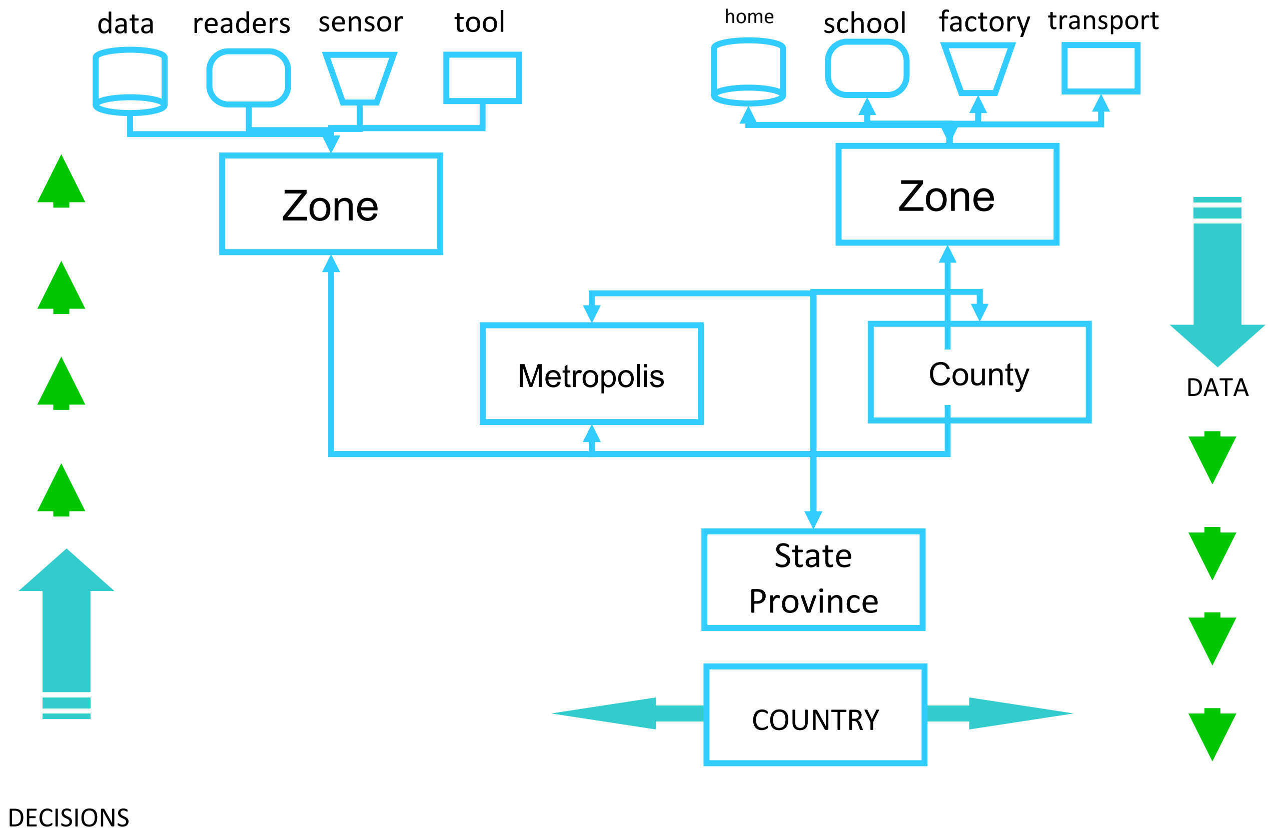


FIGURE 4: Flow of granular data, aggregated by operational level offer accurate parameters for decisions.

THE GOAL

One goal of the author is to forward the concept that better energy policy and effective carbon efficiency related decision support may arise from use of country-specific granular data as a key guiding instrument. This lofty goal is theoretical, at best. It is entirely dependent on adoption of technology to provide the basic layer of the goal, that is, granular data. Hence, the key assumptions here are: (1) market forces will steer manufacturers, suppliers, system integrators and consumers to work together to improve energy efficiency by deploying innovative technology and (2) oversight from non-political organizations (UNFCCC, UNIPCC) may create frameworks to promote methodologies that can be deemed as a 'best practice' convergence of many technologies to improve energy efficiency and savings.

It is easy to see why the goal may be difficult to reach. There is no provision in this mechanism except for complete dependence on others to deploy tools to obtain the critical mass of data to feed the hierarchy (Figure 4) or interface with INGRID (Figure 2). At higher levels of decision, the question of analytics will feature prominently given the emphasis on data. Is it one of the goals to predict or forecast energy consumption? How important is it for a country to use such demand forecasts to design supply? Is there a sufficient volatility pattern in energy consumption to use advanced econometric techniques (Figure 5) for analytics? If data-driven analytics helps to shape rigorous policy, does that imply that such policy will be applicable?

Consider a case (Figure 5) where M, A, D and R are four cities located in the four corners of the diamond. In scenario 1, the city M is in Mexico and manufactures a product that is transported to A, D and R in USA as a part of the physical supply chain. The product is assembled in city A in USA, distributed from city D to retail store in city R, all in USA. In scenario 2, city M is in Massachusetts, USA. The product is transported to locations A, D and R in Mexico for assembly, distribution and retail. Can we expect a single informed policy to choose or re-design the supply chain based on value, job creation/loss [location of plant, logistics, stores], cost of goods, transportation energy risk and overall carbon footprint of the operation?

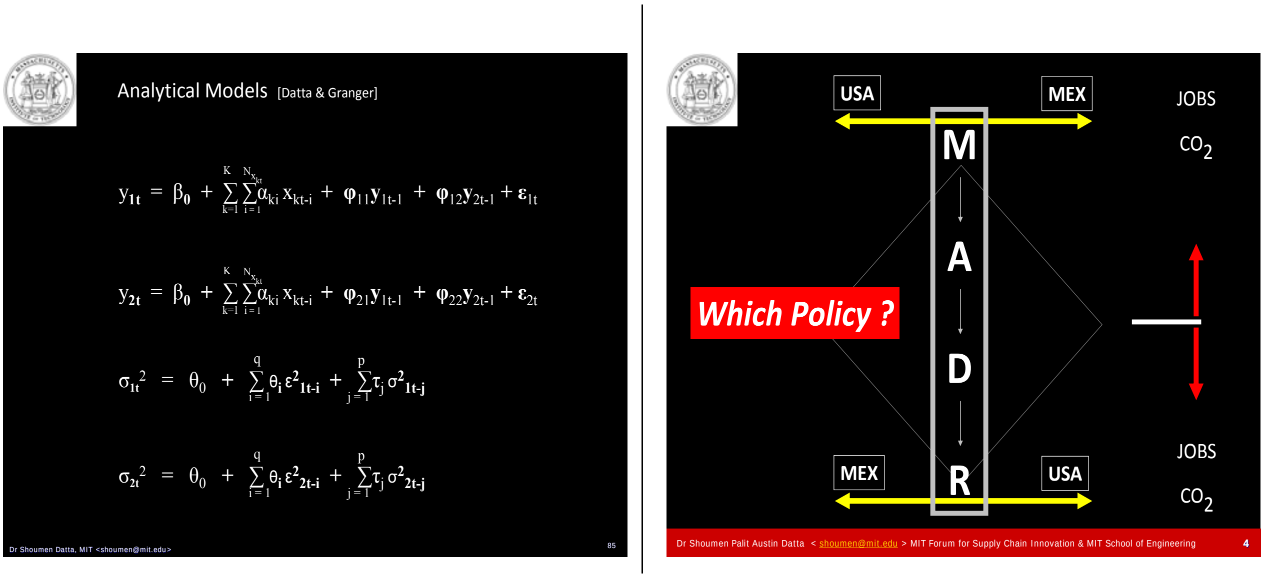


FIGURE 5: Analysis and Policy may reflect the concept of "different strokes for different folks"

SUMMARY: VISION OF THE FUTURE and BUSINESS PRAGMATISM ARE NOT MUTUALLY EXCLUSIVE

Profits from energy efficiency may not materialize if we continue the policy debates without implementing the tools [[49]]. Without quantitative analysis, policy provides poor guidance. With the help of analytics, some policy issues may be formalised. Hence, rigorous analytics and intelligent systems are necessary. But, it demands granular data and development of decision criteria and tools that will interface with the gradual diffusion and evolution of INGRID.

- Implement systems to monitor and record carbon emissions for carbon footprint audit
- Profit from savings and incentives due to energy efficiency or conservation measures
- Install carbon reduction management tool (iET) to balance carbon liabilities or risk
- Innovate on carbon trading options through cooperatives of carbon micro-credits
- Optimize ROI through energy savings, carbon credits and alternative energy use
- Use academic-industry-government-global forums to approve methodologies
- Use academic-industry-government-global forums to better define INGRID
- Bolster proven energy solutions at hand (nuclear, metabolic engineering)
- Manufacture of liquid fuel in the petroleum free era (post-2050)

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[49] *There is a principle which is a bar against all information, which is proof against all arguments and which cannot fail to keep man in everlasting ignorance - that principle is contempt prior to investigation.* (H. Spencer)