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

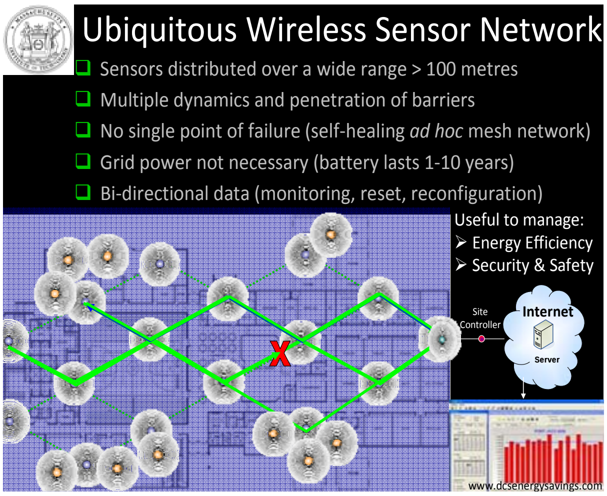
- Execute actions to reduce transaction cost (TCE) of operation
- Offer choices of materials, materials origin, manufacturing process
- Compare dynamic pricing, energy use and carbon status with sector specific practices

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**



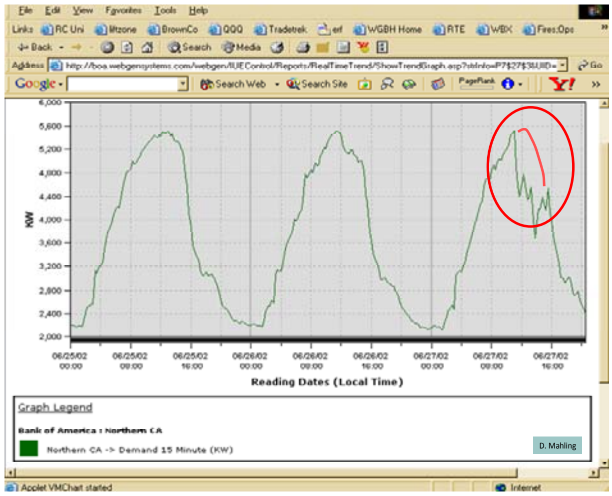


FIGURE 3: Illustrates a generic WSN (L) and energy usage data to predict aggregated consumption (R). In a scenario where the local power regulator issues a request to reduce energy consumption during a peak period, a curtailment decision can be executed using WSN and automated control to reduce consumption 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.

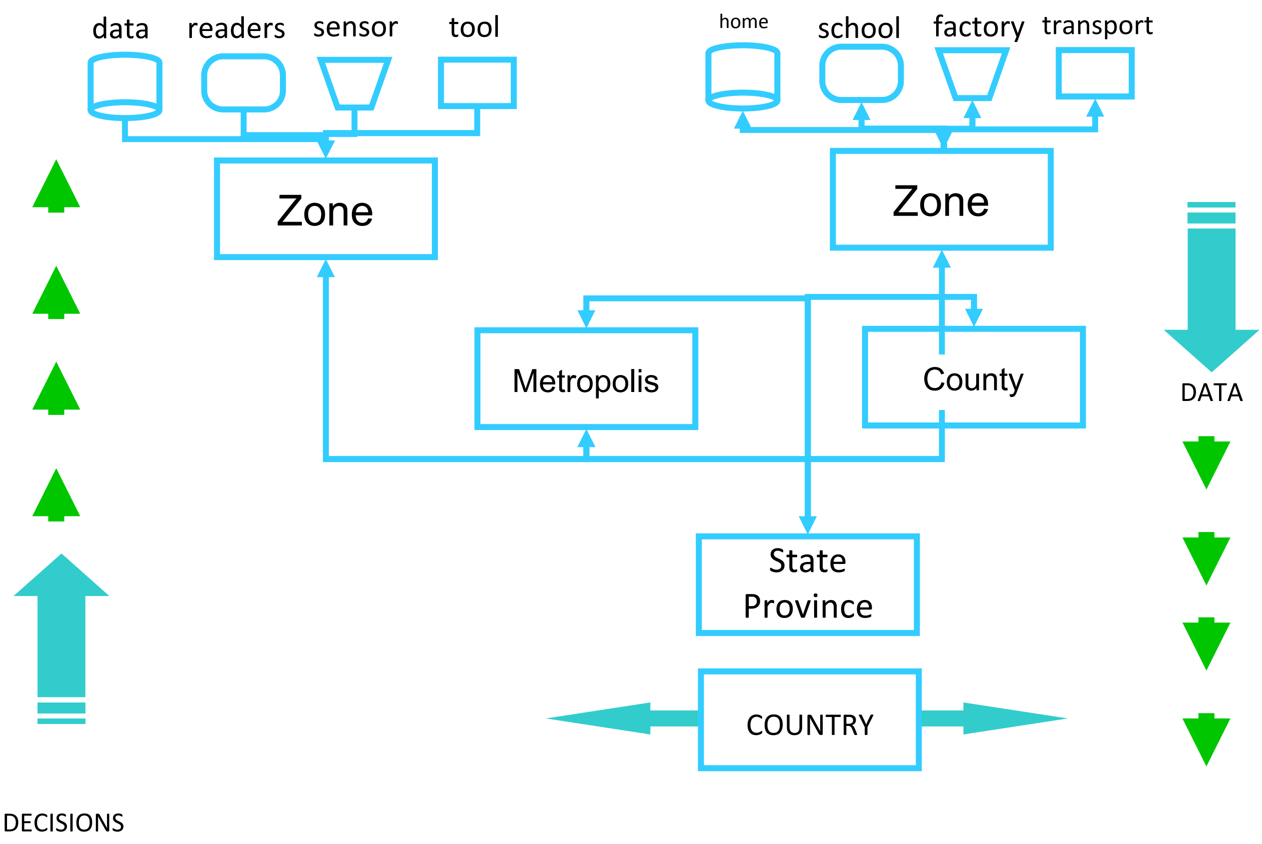


FIGURE 4: Flow of granular data, aggregated by operational level offer accurate parameters for decisions.

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?

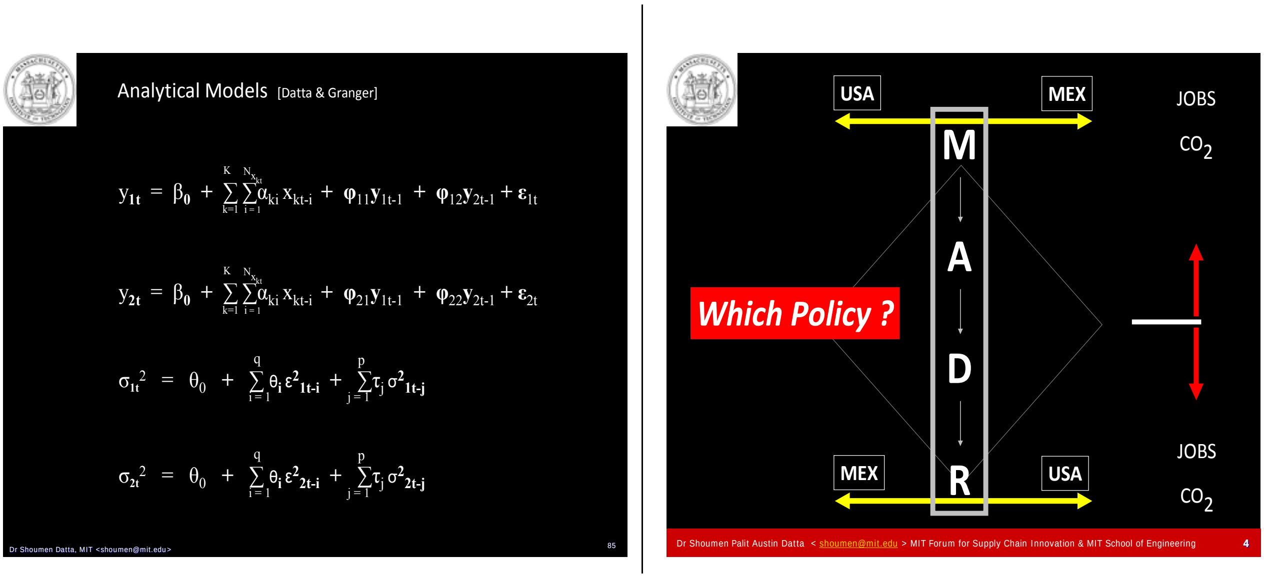


FIGURE 5: Analysis and Policy may reflect the concept of "different strokes for different folks"

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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