Global Leadership through Breakthrough SEI (Sustainable Energy Initiatives)
Will India forge a breakthrough like the Cell Phone Revolution?

Probir Ghosh
President & CEO, invVEST
probir.ghosh@invVEST.org
with Dr. Rajan Kapur, Subir Das[i]

"Enabling Global Leadership through Massive Scaling of SEI".

Introduction

Energy is the lifeblood of emerging economies like India, much more so than developed economies. If India manages to find a way to massively scale Sustainable Energy Initiatives (SEI) that harnesses its rich resources to transition to clean, economical & self-reliant energy, India will emerge as one of the global leaders for this century. On the other hand, energy can also become an addictive drug that can ruin global economies, especially for countries like India, if they continue to rely heavily on fossil fuel resources that not only pose exponentially escalating energy security risks but also lead to devastating environmental impacts that may become irreversible. History has shown us time and time again that breakthrough transitions occur only if we dare to shed our conventional thinking and step outside the box.[ii] Conventional thinking points out that India's lack of energy infrastructure poses a gigantic problem, and to many, it may almost seem insurmountable. However, the very lack of traditional energy infrastructure may give India an unfair advantage over other major economies to break away from the mold and create a new path to clean, economical & self-reliant energy. After all, India did just that with the cell phone revolution. The stakes are exponentially higher & urgent for energy transition; our very next generation's future depends on it. *So here are some recommended steps for India to "imagine a handoff, clean sustainable energy, fueling our economy, curing our environment… securing our children's future."*[iii]

The BAU: "Business as Usual" Global Energy Scenario

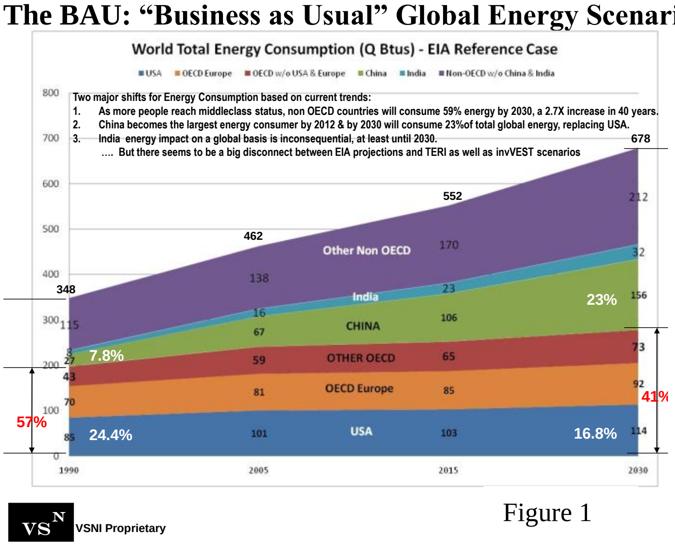


Figure 1

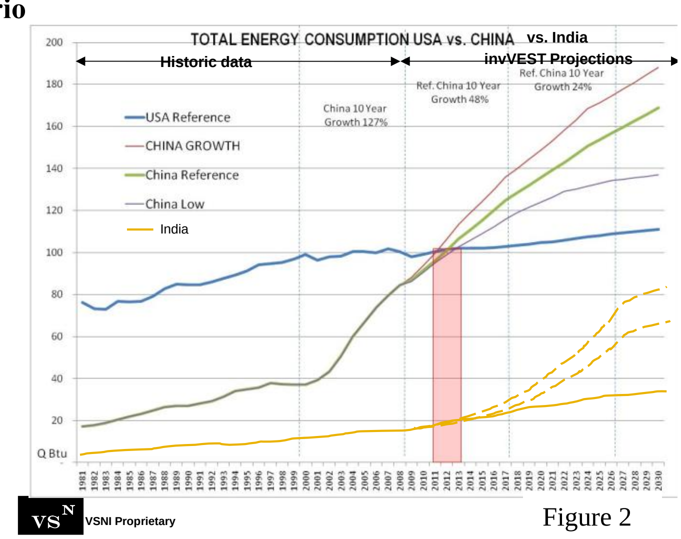


Figure 2

All major institutions such as EIA, IEA, TERI[iv] agree on one thing (Fig 1): energy growth in the future will be coming from emerging economies. While OECD countries are projected to grow from 241 QBtu ((254EJ) in 2005 to 279 Qbtu (294EJ) by 2030, non OECD countries, led by China, will grow from 221QBtu to 400QBtu during the same period. As Fig 2 shows, China's energy growth exploded in the last ten years (1999 -2008). China grew by 127% as they became the Mecca for manufacturing operations when China adopted a controlled capitalist model and introduced its people to consumerism.[v] In 2007 alone, China installed an unprecedented 104GW of power plants, almost all of them coal fired. India's energy consumption growth by comparison has been relatively flat until now. India will install about 35- 40GW of new power plants compared to about 400 GW for China during the 11th plan time frame. **The trillion dollar question for India will be: what will India need to do to emulate similar energy growth, so critically needed for its own sustained economic growth? Does it need to depend on BAU perceived "cheap" fossil fuels, or can India find a way to massively scale SEI to ensure long term economic sustainability?**

While EIA, IEA and TERI have modeled several scenarios, all projections essentially show the world will continue to depend primarily on fossil fuels for the next twenty years. This scenario cannot be sustained and will lead to a "burnout scenario"[vi] in the best case and an unprecedented "collapse" in the worst case, brought on by either exponentially escalating confrontations to try and secure dwindling fossil fuels like oil and/or astronomical costs of adapting to environmental impacts caused by GHG (Green House Gases). Procrastinating on mitigation that needs significant funds upfront will lead to even costlier & futile adaptation exercise. Viewing the unfolding energy saga in a time-warp makes it unnervingly vivid.

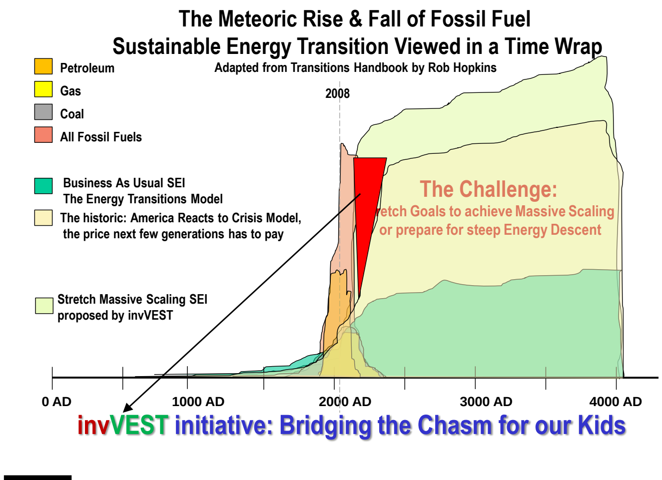


Figure 3

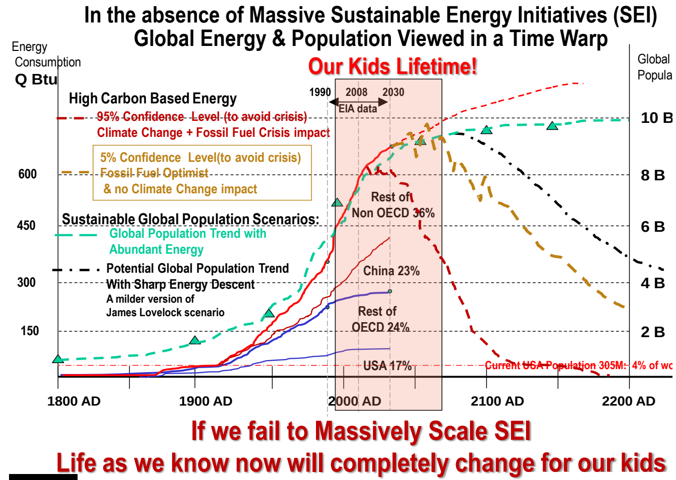


Figure 4

For a world that is obsessed with instant gratification and making a quick buck, it is hard to look beyond a few years (quarters for Wall Street) ahead, but the fact is civilization existed long before 0 AD, the start of time-warp in Fig 3. There is absolutely no question that without the fossil energy provided by oil, coal and natural gas, the world would not have experienced the phenomenal economic progress it has made in the last 150 years or so. However, the exponential consumption of fossil based energy has created two major issues.

First of all, most scientists and world leaders believe that man made emissions in the form of green house gases will lead to irreversible climate change and life changing global impact. While many believe that we may have already crossed the threshold when CO_2 levels crossed 350ppm a few years ago, there is still considerable debate what the threshold levels are and how soon the climate will deteriorate enough to cause grave turmoil globally.[vii]

Secondly, the BAU models and even the alternative scenario models that consider traditional framework and boundaries will exhaust our fossil fuel reserves within the next few generations. Unless energy usage is curbed dramatically or we transition to new energy sources, conventional oil will get exhausted in less than 40 – 60 years and even relatively more abundant gas and coal will get exhausted in about 200 years. If we view these phenomena under the 4,000 year time-warp map as shown in Fig 3, the fossil fuel era looks like a blip. Given that the most disruptive transition to new energy sources will take at least 50 - 60 years, if we do not start the massive transition process now, our very next generation will face a chasm that may make the great economic depression of the early 1900 look like a walk in the park. In fact, there are a growing number of people similar to Rob Hopkin's[viii] transition group who believe that the world will not be able to transition to a new source of energy and they are preparing their communities to live in an energy deprived environment. We believe that nations that promote and accelerate disruptive Sustainable Energy Initiatives (SEI) will be able to avoid the "Chasm". Reversing climate change will require key economies of the world to join forces to transition rapidly to SEI.

Fig 4 zooms into a 400 year time warp to visualize the impact of climate change, fossil based energy resources exhaustion and global population. The actual energy consumption & projection comes from Fig 1 and we are overlaying global population growth to provide different energy scenarios and its impact under business as usual trends. If we need to have a 95% confidence level to avoid a severe global environmental impact and fossil energy scarcity we will have to have completed a significant transition to a sustainable source of energy by 2030, beyond which the environment as well as economic growth may experience unprecedented catastrophe.

The point being made here is even if climate change were not to happen and we figure out ways to extract significantly more fossil based energy by tapping all the nonconventional reserves like Tar-Sands and Shale-Gas, we will have to have completed a significant transition to a sustainable source of energy by 2050 -2070 time frame. The ability to extract more than twice the amount of energy without serious environmental ramifications has less than a 5% confidence level.[ix] Renowned Scientists like James Lovelock are projecting that the world can only sustain 500 million people in the future under these scenarios, a serious reduction from the 10 billion people the world will have by 2050.[x] The bottom line is if we fail to massively scale SEI, life as we know now will completely change for our future generations.[xi]

There are ongoing raging debates, bordering on being futilistic, among developed and developing countries, The Copenhagen Climate Change Conference[xii] being the most recent, on how to agree on a equitable framework and share the burden of this energy transition saga because the perception is clean SEI (Sustainable Energy Initiatives) is added cost to business and countries. But what if clean sustainable energy becomes the more economical energy source through break through innovations and massive scaling? History has shown repetitively that high costs of early implementations are dramatically reduced through relentless innovation and massive scaling. Breakthrough technologies and massive scaling invariably reach a tipping point for large scale adoption.[xiii]

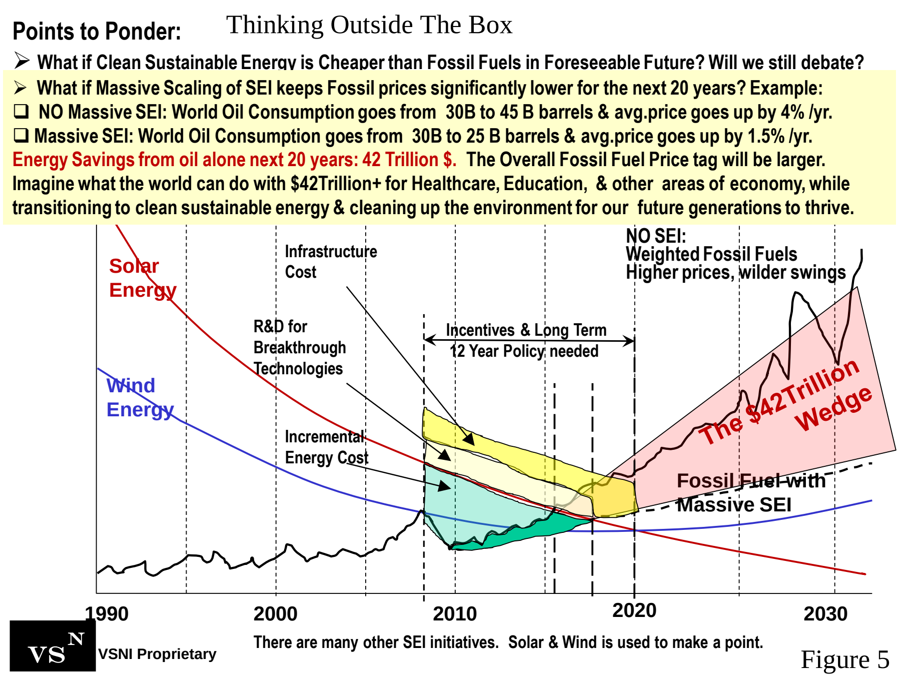


Figure 5

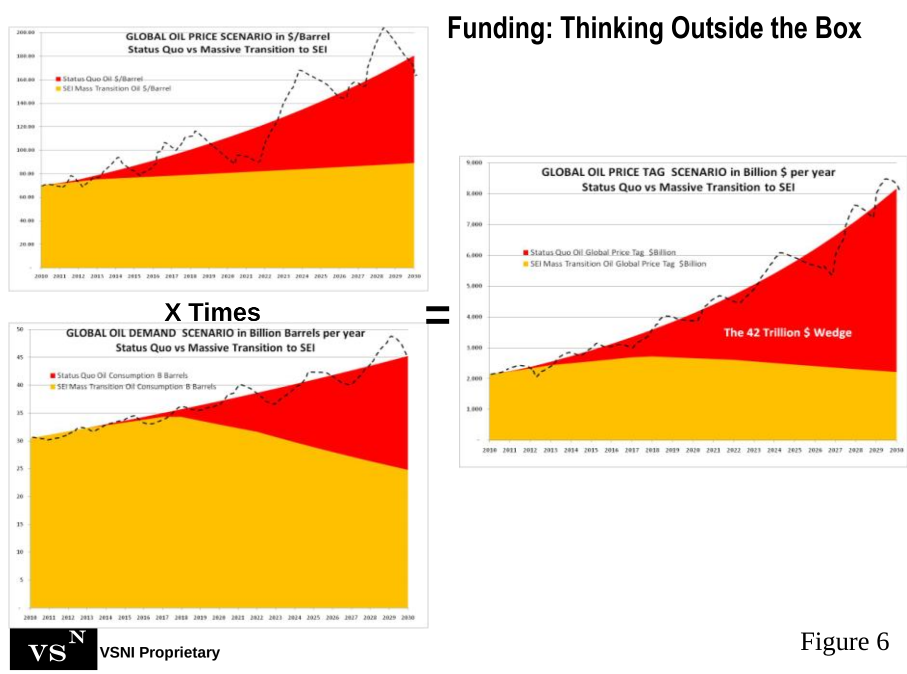


Figure 6

Historically, every time the price of fossil fuel drops, renewable energy initiatives immediately are in jeopardy.

However, if we take a long term view and work on:

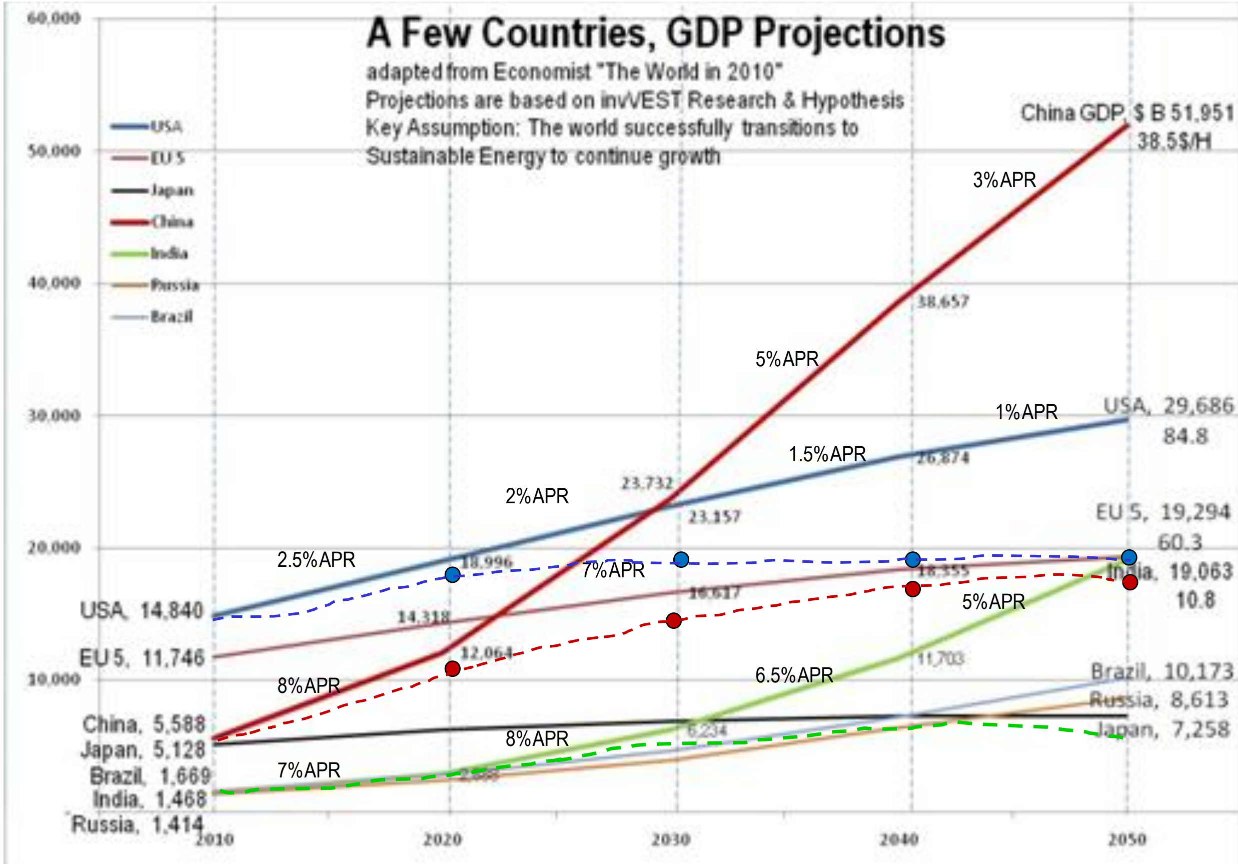
1. Massive scaling with a clear focus to bring down the prices of SEI at or below power parity.
2. Adopt long term policies among major energy consuming countries to entice SEI investments until it meets power parity.

Then fossil fuel demand can be met without supply shortfalls. This should not only bring down price escalation but also stabilize existing wild price fluctuations. See Figure 5 & 6.

The public & private sectors can sit down and figure out how to leverage the 42 trillion $ the world will not spend on oil to pay for the upfront cost required to jumpstart massive scaling of SEI. CDM (Clean Development Mechanism) Carbon Taxes, Cap & Trade may be some of the key mechanisms that need to be adopted to achieve the desired upfront investments.

This scenario can only happen if key stakeholders adopt an aggressive price performance target and launch massive SEI scaling. Mechanisms must be adopted to track clean sustainable energy prices to consistently hit the interim projected price performance targets.[xiv]

The next fundamental question we need to ask ourselves is if we transition to clean sustainable energy, do we need to reduce our energy consumption, or can we find infinite ways to make use of clean sustainable energy that may be abundantly available in the future? While it is imperative that we find more efficient & effective ways to use energy to bring down the cost, we are asking energy companies to produce and sell less energy and energy related products & services, which is counterintuitive to the current private investor owned economic model. There are two key lessons we should have learned from the information technology & telecommunications based business model: 1) convergence of disparate industries exemplified by the landline based telecommunications companies not only faced competition from cell phones that needed relatively minimal infrastructure, but also from the internet, cable and satellite TV based companies & now social networking 2) With the advent of emerging technologies, the cost for communications on per minute basis dramatically reduced and yet the total expenses for communications increased significantly for organizations as well as for families. Similarly, convergence of clean SEI (Sustainable Energy Initiatives) will open doors for new opportunities to use energy in ways we have not even begun to imagine.



VSNI Proprietary

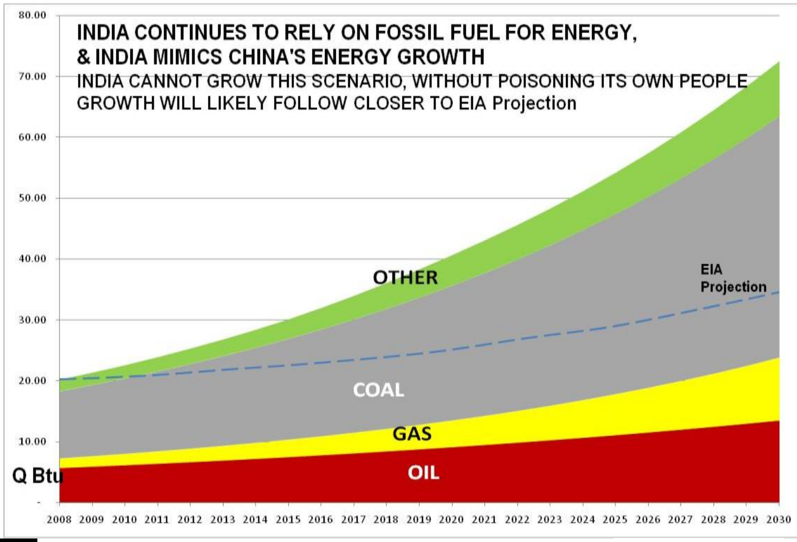
Figure 7

If the major economies of the world can successfully transition to clean sustainable energy, then it is possible to see a robust long term growth for at least the first half of this century. Countries that take the leadership role in breakthrough transition for SEI will be the future global leaders of this century.

According to the data provided in "*The World in 2010*" recently published by The Economist, China's GDP in real dollar valuation will cross Japan's GDP in 2010. From all the reports we see that China is already back on track, growing at 8%+ per annum. We have assumed that in an unconstrained access to resources scenario[xv], China will maintain 8% avg. growth rate per annum from 2010 -2020, 7% per annum from 2021 -2030, 5% per annum from 2031 -2040 and then slow down to 3% per annum from 2041 -2050. Like most analysts are projecting, China will cross GDP of USA around 2030 and may see their GDP north of fifty trillion $ by 2050. Even at that point, their GDP per capita will be $38,500, still significantly below projected USA GDP per capita of $84,800. Among the many constraints China will face while continuing to grow at this rate, transition to clean Sustainable Energy is going to top their list. While China has become the world's largest emitter of GHG overtaking USA in 2007, and they will be the largest energy consumer by 2012, China is moving very aggressively to become the global leader in renewable energy initiatives for not only manufacturing for exports but also for installing multi Gigawatt wind farms and solar farms in their own country. Last year China planted more than two billion trees and they are ramping up their bioenergy initiatives. The reason for this urgency is not at all altruistic, it is for their own survival and sustained growth.[xvi]

As the world's largest democracy, India faces its own set of challenges. If anything, transition to clean, economical & self-reliant energy is one of the gigantic challenges it needs to resolve. While India has significant advantages over China and most nations as a service economy leveraging its low cost intellectual capital, long term growth can be in jeopardy if India cannot provide equitable income for its masses in rural and urban areas. Availability of economically distributed energy can spawn manufacturing based job opportunities and help increase productivity and overall quality of life for its masses. Even if India grows at a more aggressive rate than China as shown in Figure 7 in the next 40 years, India will have a significant advantage in GDP per capita and will still be three to four times lower than China. Availability of clean and reliable energy along with a trained workforce can open the doors for significant manufacturing based opportunities for exports as well as internal consumption for India needed for a long term sustainable growth. On the other hand, if we stick to the BAU model and fail to massively scale SEI we will see stunted growth as represented by dotted lines. And the scary part is this may be representing the best case scenario for the BAU model.[xvii]

India Energy Scenarios: Rational Planning Vs. Disruptive SEI (Sustainable Energy Initiatives)



VSN VSNI Proprietary

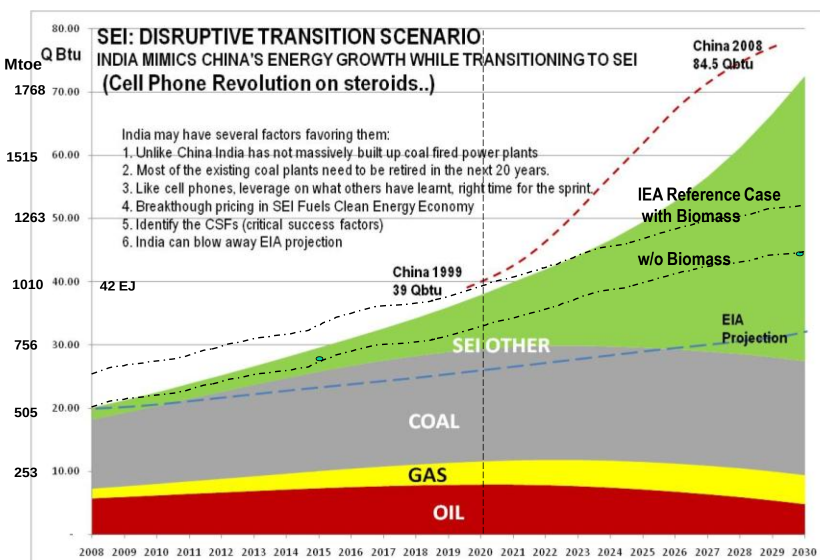
Figure 8

India Energy: Variances for 2030	Qbtu	Peta Joules	B kwh eq.
TERI High Growth	133	140,066	39
TERI BAU	84	88,737	25
TERI Efficiency	61	64,453	18
IEA High Growth	60	63,032	18
IEA Ref. Case	52	54,296	15
IEA Alt.Scenario	43	45,226	13
EIA Ref. Case	32	33,728	9
invVEST SEI	64	67,943	19

Table 1

In all the energy projection models invVEST has reviewed, while there are significant variations in the total energy consumption projections (TERI High Growth Case and the Energy Efficiency Case has a 218% variance & EIA projections seems to be out of whack with everyone else), the fossil fuel resources continue to dominate. Even under the most aggressive alternative policy scenarios considered by IEA and TERI, fossil fuels continue to provide more than 80% of its energy needs and energy imports escalate significantly. India cannot sustain a traditional fossil energy based economic growth and will run into serious energy security and environmental impact issues. See Figure 8 and Table 1.

In the SEI: Disruptive Energy Transition Scenario shown in Fig 9 below, the Central, State, Public Institutions work closely with Private entities to find breakthrough technologies, policies and funding mechanisms to massively scale a portfolio of sustainable energy initiatives. Premier institutions like IITs need to focus not only on fundamental R&D but also focus on applied research that incorporates DFSM (Design for Scaling Manufacturing) at an early stage and work seamlessly with as many world class institutions and organizations to deliver a finished product that can compete globally in quality and price.



VSN VSNI Proprietary

Figure 9

While an in-depth discussion and analysis of the model is beyond the scope for this paper, it is important to note that the next 10 years are critical to set up world class R&D centers in India that will lay the ground for massive scaling in the following 10 years and beyond. To truly understand the strengths and weaknesses of a specific SEI, the team needs to use structured tools like SEIMAT discussed later in this paper.

If India can execute the groundwork in the next 6-10 years, it will provide a framework and infrastructure for SEI breakthrough scaling. It is at that point India can mimic China's exponential growth without its baggage of being excessively dependent on fossil fuels for its energy source. Global benchmarking, especially with China can provide invaluable lessons as India shapes its own destiny for clean SEI breakthrough deployment.

India and USA will have a mutual interest to work together to provide balance of economic power in the not so distant future. Colorado, where invVEST is headquartered, can be one of the leading states to work closely with India especially in the formative years as NREL is headquartered in Colorado, three of its key Public Universities; Colorado University, Boulder, Colorado State University, Fort Collins and Colorado School Of Mines, Golden have significant research work going on with NREL and the industry. Colorado State, PUC, GEO[xviii] has adopted an aggressive policy towards New Energy Initiatives that has enticed several organizations large and small to set up R&D and operations centers in Colorado.[xix]

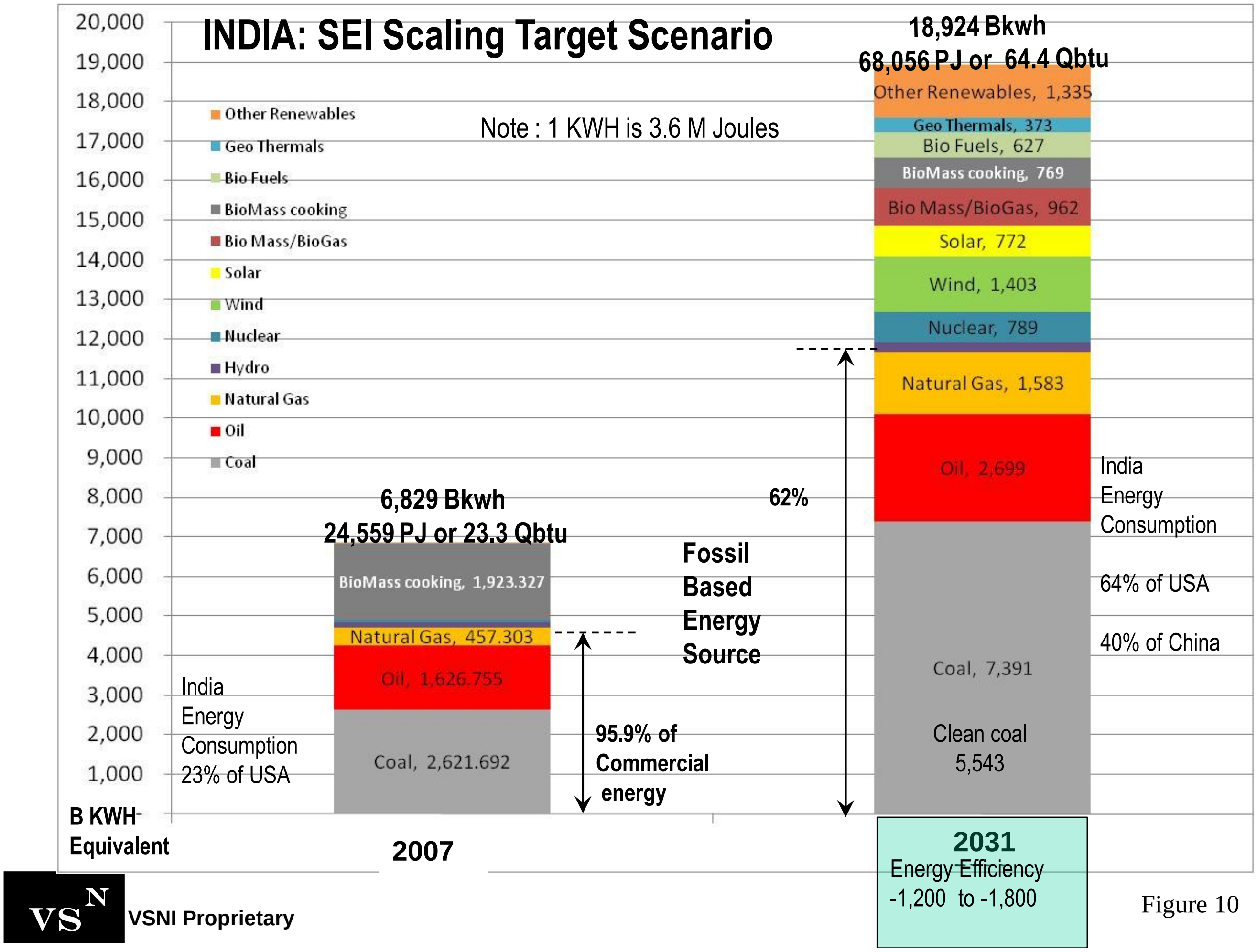


Figure 10

While the commercial energy for India is fairly well defined and up to date at least until 2007-08, the biomass energy data is not so well defined and most available data-points are inferences from assessments made around the year 2000. Both IEA (158Mtoe) and Planning Commission[xx] (150Mtoe) provide noncommercial energy at around 6,300 PetaJoules which is mainly used for cooking and cottage industries, primarily in rural areas of India. The question that is not resolved as yet by invVEST is if this biomass energy, 73% of which is wood and woodchips, can be considered as clean low carbon footprint Sustainable Energy, since it is unclear whether the wood that is being used is being replenished. Without the biomass, which is considered non-commercial energy, 95.9% of the commercial energy is fossil fuel based.

If, as mentioned in the previous section, intensive R&D and pilot scale developments are initiated in the first 6 -10 years to enable commercially viable SEI portfolios, then by 2031 (end of 16th planning session) India can have a diverse portfolio of Sustainable Energy programs that contribute significantly to increase the energy security and reduce the climate impact globally. Despite this disruptive breakthrough scenario, where as much as 38% of energy is provided by SEI program, India will still have an increased fossil fuel consumption simply because energy need is projected to grow by 2.76 times in this period. As more rural based population use more efficient cooking stoves[xxi] and as many of them move to more efficient and/or convenient alternative fuel sources, energy need for biomass based cooking reduces in the traditional form. The excess biomass can then be used for more efficient energy usage such as to generate steam and electric as well as biofuels in an integrated energy environment. India will also need to have a massive tree plantation program in place to replace at the minimum the trees being used to have a zero/low carbon footprint.

The energy efficiency programs[xxii] shown in Fig 10 is incremental over and above what the BAU model is assuming for energy savings through efficiency & conservation programs. In this scenario, India will be consuming 64% of energy USA used in 2007 and will be consuming about 35% - 40% of what China is projected to consume around 2030.

In the invVEST SEI initiative, India generates more energy than all IEA cases to maintain a projected economic growth (but significantly less than the TERI growth case as shown in Table 1) and yet will consume significantly less fossil based energy and have a lower carbon emission rate.

SEI Scaling: Key Statistics expressed in B Kwh Equivalent

Table 2

	2007	2030	2007 Energy %	2030 Energy %	Annualized Growth	Electric	Genration from New Capacity	GW Eq. installed	Cap. Cost B$/GW	Investment Billion $
Coal	2,621.692	7,391	38.4%	39.1%	5.30%	70%	2,432.06	327	2.50	$ 817
Oil	1,626.755	2,699	23.8%	14.3%	2.50%	5%	555.49	67	1.20	$ 80
Natural Gas	457.303	1,583	6.7%	8.4%	6.40%	70%	562.30	68	0.80	$ 54
Hydro	128.878	222	1.9%	1.2%	2.80%	100%	106.46	16	1.00	$ 16
Nuclear	50.993	789	0.7%	4.2%	14.50%	100%	743.33	89	4.00	$ 357
Wind	11.409	1,403	0.2%	7.4%	27.20%	100%	1,392.79	454	1.20	$ 545
Solar	0.004	772	0.0%	4.1%	83.00%	100%	771.68	440	1.00	$ 440
Bio Mass/BioGas	4.001	962	0.1%	5.1%	27.60%	20%	958.06	129	1.50	$ 193
BioMass cooking	1,923.327	769	28.2%	4.1%	-5.50%	0%				$ 14
Bio Fuels	4.448	627	0.1%	3.3%	28.00%	0%				$ 240
Geo Thermals	0.057	373	0.0%	2.0%	66.00%	100%	372.64	50	1.50	$ 75
Other Renewables	0.278	1,335	0.0%	7.1%	53.00%					$ 400
Total Energy B KWH Eq.	6,829	18,924			5.23%					$ 3,232
Fossil Energy ratio			68.9%	61.7%		Other Overheads		25%		$ 808
Fossil Energy ratio w/o Biomass			95.9%	64.3%		Total Energy Expense 2010 -2030				$ 4,040

The big picture framework is meant as a first step to get to the next level of details. There is a significant amount of work that needs to be done to flush out the details for each of the programs, identify the full scope of work involved to get to a more defined roadmap and investment estimates.[xxiii]

As mentioned, while fossil fuel based energy in 2030 is reduced to 62% of the energy needs, there is still a significant growth in each of the three fossil based energy sources as seen in Table 2. Coal Fired Thermal power plants will remain the single largest investments that need to be made to create new energy generation capacity. The actual carbon footprint from the fossil based fuel projects can reduce significantly if breakthrough carbon sequestration or in-situ gas release from coal beds can be commercialized. The cost and energy needs for those programs are not included in these estimates. Costs for coal mining & transportation infrastructure are included in the overheads.

Hydro programs may have been underestimated. India needs to figure out a reliable source for nuclear fuel to increase its PLF factor as well as get a handle on cost per GW before it embarks on aggressively scaling nuclear programs. Given the scarcity of land in India, it is assumed that significant portions of wind projects will need to be installed offshore after cost of offshore programs are brought down.

75% of Solar Capacity installs are backend loaded after 2020 when cost for solar installed is driven down below $1/W from the current $3/W, at which point Solar programs will be at or below power parity. invVEST team has significant expertise for providing feasibility studies, strategy, and deployment programs for breakthrough solar programs.

invVEST needs to verify the current state of Biofuels programs in India for both Generation I to Generation IV and if actually 0.5 Billion litres of biofuels were used and the nature of its carbon footprint. We have assumed that 72 billion litres of biofuel will be produced by 2030 from Generation II (17% cellulosic) and III (80% algal based) programs. Bioreactor cost is assumed at $40K/acre in the model. Yield is assumed to be 5,000 gallons of algal oil/acre by 2020.[xxiv]

invVEST needs to verify any geo thermal base activity in India and can facilitate joint initiatives with US based institutions.

Other renewables are a place holder for nascent technologies like Hydrogen fuel-cell, Tidal based energy, Fossil fuel sequestration/carbon mitigation initiatives.

STEP I: Use SEIMAT to Assess the Strength & Weakness for specific SEI through 6 Traits

SEIMAT: SEI Matrix Assessment Tool . The index of 0 means worst, 10 means best.

Convergence of Energy, IT & Telecom Technologies
The Glue: Smart Grid "Intelligent Energy on Demand"

SEI Traits 0-10 / Vertical Clusters	Sustainable? Massive Scalability in future	Carbon FootPrint	LCOE or PPI slope	Reducing Energy Dependence on one Region or Source	Side Effects	Job Creation
Energy Efficiency & Conservation Cluster						
Solar Energy Cluster						
Wind Energy Cluster						
Geo Thermal Energy Cluster						
Bio Fuels Energy Cluster						
Biomass Energy Cluster						
Nuclear Energy Cluster						
Hydro Energy Cluster						
Other Sustainable Energy Cluster						
Energy Storage Cluster						
Energy Transmission Cluster						
Energy Transportation and infrastructure cluster.						
Coal Energy cluster						
Oil Energy cluster						
Gas Energy Cluster						

If the energy source does not have the potential to satisfy these six criteria, it may not qualify for SEI, but it may still be a renewable energy source, or may qualify as a bridge energy source.

VSNI Proprietary

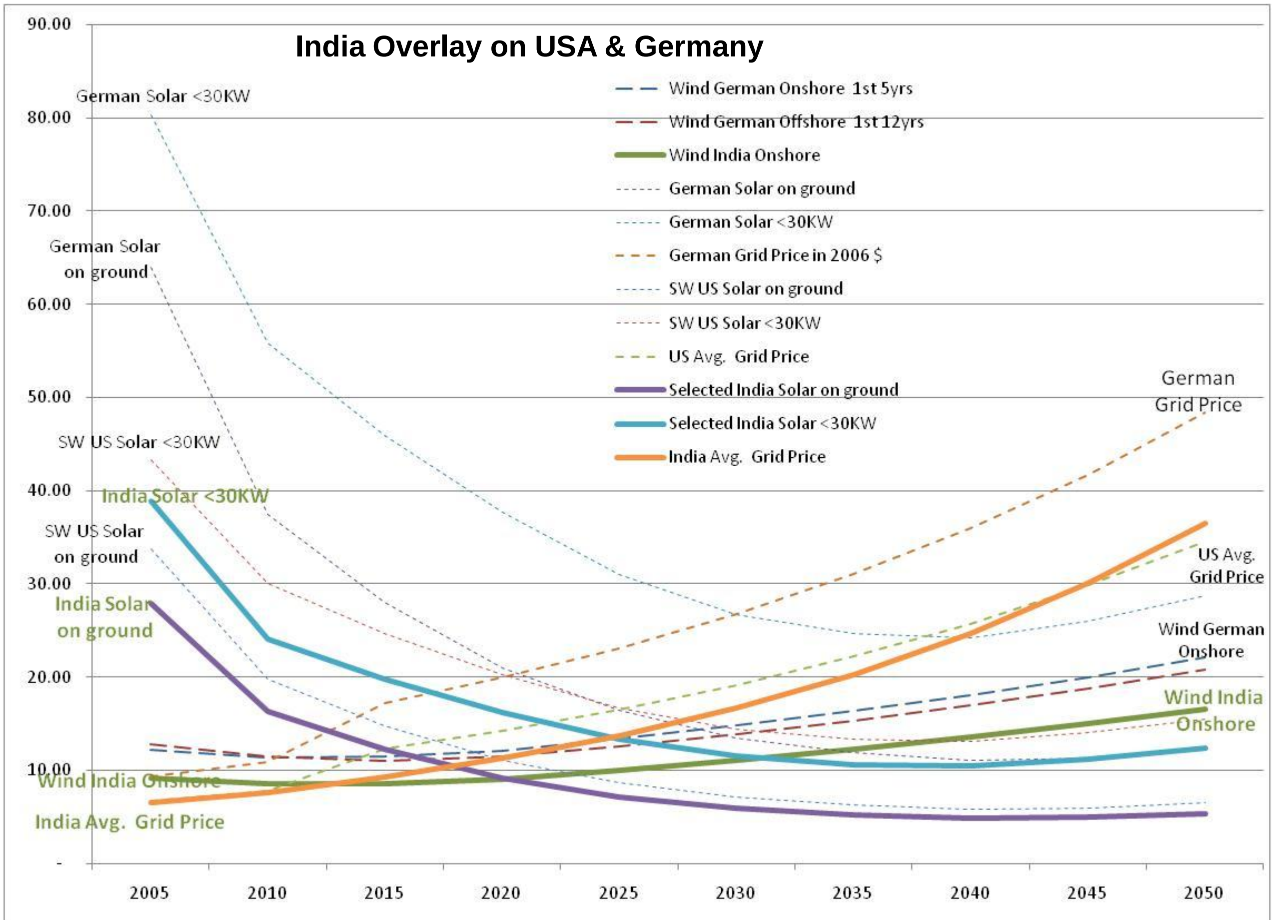
Figure 11

invVEST has a proprietary SEI Matrixed Assessment Tool that provides R&D and development teams with a structured way to identify strengths and weaknesses of each energy initiative. While an in-depth analysis is beyond the scope of the scope of the manuscript, a simple example will provide an idea on to how to use the tool. We will use a simplistic example for Solar Thin Film CdTe based solar panel assessment in the context of installations in India over a period of next 20 years.

Trait I: While the sun can provide almost infinite amount of energy source and it is free, we are looking for 3 specific segments. 1) Material availability for inputs, i.e. raw materials needed for manufacturing. Cadmium availability issues seem to have been resolved but availability of Telluride is still a question mark at TW capacities. Glass is not an issue, but co-locating supply chain clusters should be considered. 2) Materials & inputs needed for manufacturing: needs to be verified for India. 3) Miscellaneous incidentals: some issues. Score 8.
Trait II: Carbon Footprint: While no Carbon footprint is emitted to generate power, manufacturing, installation and recycling takes resources and generates carbon footprint in its lifecycle. Score 9.
Trait III: PPI^{TM} (Power Parity Index) is an indexed version of LCOE that uses 9 steps to project the future price performance curve that involves understanding the technology roadmap, DFSM, constraints, efficiency improvements, scaling index, resource index, convergence index, indirect cost index, etc. Short Term (3-5 Years) Score 10. Long Term (intermittency & energy storage issues need to be addressed). Score 7.
Trait IV: Dependencies: Evaluates 3 aspects. From India perspective, current scores will be low since there is no expertise or new technology manufacturing center in place. Score: 3.
Trait V: Side Effects Cadmium issues taken care of by recycling. Incorporate Cradle to Cradle concept. Score 6.
Trait VI: Job Creation: no expertise in place. Score: 3.

Overall Score: 46.50 out of 60, a good score to pursue the program provided any score below 6 is taken care of. Typically the scoring is conducted by at least 3 persons knowledgeable about the program independently. One can find the variances and address the issues. Convergence opportunities & threats for disparate sources of Energy need to be considered.

A similar analysis for Photobio reactor based Gen III: algal program will provide larger variances and lower scores on several key areas, especially around the fuzziness of definitive roadmaps and PPI.



VSNI Proprietary

Figure 12

Mapping the Price Performance of different energy initiatives provide a clear roadmap. Again using Solar PV (we can be specific on each technology in more detailed analysis & advisory services), here is an overview:

If we track rooftop solar PV for Germany where the typical sun radiance is 700KWH/yr/KW panel, we can see the price curve closely monitored by German FiT programme has dropped significantly since 2005, but will not reach price parity with grid power until about 2030 in Germany. For on-ground Solar, where sun radiance is 950 & price is dropping more sharply, grid parity which is assumed to escalate at an average 3% per year, should be reached by 2020, at which point Germany may not need to provide FIT programs to incent on-ground solar. However on-ground solar will not cross wind program until about 2030.

If we now consider on-ground solar in south western territories of USA like Alamosa Colorado, where avg. Sun radiance is 1800 vs 950 in Germany, the price point will be 47% lower if all other conditions are the same (it is not) and US should see power parity by 2017 or so even though US grid prices are lower. Solar prices will crossover wind around 2020 in USA provided the price curve can be maintained.

If we now overlay India on ground solar and assume the installation point in India has the same sun average radiance as in SW USA, India will enjoy a price point lower by at least 20% compared to USA because of labor costs advantages reflected in BOS (Balance of Systems), again provided all other performance parameters remain the same. The grid power parity cross over should occur around 2018, and solar energy should be cheaper to install compared to wind energy by 2022 or so. However, there are several other parameters that impact performance of solar panels. In many cases, the actual performance is far lower than the projected performance because many parameters were overlooked and/or quality of panel, accessories were not consistently matched with the system. Performance degradation also is a common problem in many places.

If India manages to coordinate all the above parameters systematically, India has a great strategic advantage for manufacturing and installing solar PV over most countries. A similar situation most likely exists for Bioenergy and the invVEST team intends to work closely with P K Sinha Bioenergy Center to leverage each other's network and deliver tangible fundamental research as well as applied research that can be rapidly commercialized.

Competition or Co-opetition? Get Ready for Energy Convergence

The Biofuel-Solar/wind Hybrid Synergy Model will provide longer range, faster demand response to give power back to the grid.

Siloed Narrow Focus: Measuring the Final Ouput for Oil Based Engine: BioFuels have to meet or beat oil prices 2010: 2030

Vital Stats

	Extract		Tranport		Refine		Distribute		ICE Internal Combustion		Wheel	
	Per barrel cost	98.00%		97.00%		92.00%		90.00%		20.25%		16.20%
2010	$ 75.00		2400 litres/acre		17.6 mwh Eq./acre			$0.9/litre	9 KM/Litre		10 cents/KM	
2030	$ 164.33		19,300 litres/acre		146.5 mwh Eq./acre			$1.5/litre	9 KM/Litre		16.67 cents/KM	
							fossil Oil	$2.00/litre	10 KM/Litre		20 cents/KM	

Energy Convergence: Energy from Solar 2010: 2030

Vital Stats

	Harness		Tranport		Central Grid or Ditributed		Distribute		Electric Engine		Wheel	
		CdTe 10%		9.00%	268.8 mwh Eq./acr	8.64%		8.38%		6.70%		5.36%
2010	Free source							$0.39/Kwh	6Km /Litre		6.52 cents/KM	
2030	Free source	CdTe 30%		27.90%	716.7 mwh Eq./acr	26.78%		25.98%		20.78%		16.63%
								$0.13/Kwh	6Km /Litre		2.17 cents/KM	

Recommendations & Conclusions.

India's economic growth cannot be maintained with the existing set of energy initiatives. India cannot stick to the traditional models that view alternatives within a narrow framework. India needs to look at disruptive out of box initiatives that will lead to breakthrough SEI portfolio of programs that in turn can provide India with clean, economical & self-reliant energy.

At the Macro Level:
Before a disruptive SEI initiative can be implemented, a more detailed strategic planning along with relevant feasibility studies needs to be created for identifying breakthrough pathways.

Instead of focusing on reducing absolute carbon footprint or energy intensity, India should focus on setting a stretch goal to generate at least 35% of its energy from clean sustainable self reliant energy by 2030.

India should have added assistance from developed countries over countries like China who has a twenty year headstart of ramping up traditional "dirty" fossil based power infrastructure. Also India's GDP per capita is only 30% of China.

Developed countries need to find a strategic manufacturing alternative for China, and India should leverage that need as an attractive destination. The added advantage is India has a gigantic need to provide energy to its consumers and need for setting up world class manufacturing centers like solar and other renewable energy initiatives is paramount. India has to provide quality power to the industry to attract serious manufacturing based opportunities for exports that can compete on quality and price.

While there are benefits in planning for a vast number of alternatives, India should used a tool like SEIMAT to prioritize SEI programs and establish a roadmap with clear milestones for each year that identifies both long term fundamental R&D needs as well as more focused applied research with pilots and rapid scaling and commercialization in mind.

For India, Energy Security is a far bigger short term threat, although environmental impact may carry far greater and graver impact on its people in the long term.

India's sustained growth will be possible only if it can provide distributed energy for rural and urban poor. Quality of power is not as important as the ability to install as many distributed centers as possible in the near term. As technologies for storage and lower cost distribution becomes more pervasive, India can keep adding features to improve the quality of power to this set of people.

Finally, as a first step to prepare the mindset for transition to sustainable energy, we recommend that we stop representing energy in Mtoe (Million tons of Oil Equivalent) and switch to some other form of energy measure. We recommend Billion Kwh equivalent as it is term commonly used by all countries and anyone who uses energy.

At the Micro Level:
Aggressively pursue joint venture programs with USA and other global based public & private institutions and universities. invVEST can help jumpstart several such initiatives with Colorado based institutions such as PUC, NREL, universities and many private organizations.

References

[i] Dr. Rajan Kapur and Mr. Subir Das are invVEST ambassadors with significant expertise in Solar & Biomass/Bioenergy field respectively. To view invVEST ambassador profiles please visit www.invVEST.org

[ii] Global Leadership through Breakthrough SEI is the result of in-depth research and analysis from hundreds of articles, research papers, and inputs from key thought leaders & industry experts from inside and outside the energy arena. We then used a structured approach to leverage the concepts of key thought-leaders who had focused their works on creating New Emerging Markets and Technologies. In many ways, technology breakthroughs are often more attainable compared to shaping mindsets needed for transition breakthroughs. In particular, invVEST team mindset has been very heavily influenced by:

- Hamel & Prahalad: "*Competing For The Future*".
- *Why Sustainability is now the Key Driver for Innovation;* Ram Nidumolu, C. K. Prahalad & M. R. Rangaswami. HBR Sept 2009.
- Clayton Christensen, "Innovators Dilemma"
- Robert Bergelman's work on Technology and Innovation
- Michael Treacy & Fred Wirsema, "Discipline of Market Leaders"
- Brandenberger & Nalebuff: "*Coopetition*"
- Jim Collins *"How the Mighty Fall"* and a host of other works.

For a more detailed reference list, please visit www.invVEST.org

[iii] invVEST tag-line. invVEST stands for **inv**est in **E**nergy that's **S**ustainable through **V**irtual collaborative **T**eams. For an overview of invVEST vision and purpose, a technology agnostic nonprofit organization, please visit www.invVEST.org

[iv] Three major organizations provide in-depth data and analysis for global energy data & trends:
EIA: Energy Information Administration, data keepers for USA DoE (Department of Energy). http://www.eia.doe.gov/
Specific references leveraged for this report: USA, Global & Country specific Energy Data, Statistics and Analysis
IEA: International Energy Agency, headquartered in Europe. http://www.iea.org/ . Specific references leveraged for this report:
For IEA overview: WORLD ENERGY OUTLOOK 2009 FACTSHEET Why is our current energy pathway unsustainable?
IEA India weo 2007 Special Report
TERI: The Energy Research Institute, headquartered in New Delhi, India. Specific references leveraged:
TEDDY 2009: TERI Energy Data Directory & Yearbook, 2009.
India Technology Vision 2030

[v] *"Hot, Flat & Crowded"* by Tom Friedman gives a great insight into China's relentless growth. Mr. Friedman has coined a term "China for a Day" and wonders what democratic countries like USA and India have to do to keep up with a force like China.

[vi] The Term "Burnout" & "Collapse" are adapted from "Four Energy Scenarios" by Bryn Davidson. For a more in-depth overview, visit www.invVEST.org

[vii] Specific climate change references leveraged for this report:
Is It Too Late to Prevent Catastrophic Climate Change? Presented at Royal Society of the Arts, Sydney, 21 October 2009, by Clive Hamilton.
Carbon Dioxide: What is Earth's Point of No Return? By Dr. Alexander E. McDonald, Director, NOAA ESRL.

[viii] Refer to Transitions HandBook by Rob Hopkins. View Video www.ted.com/talks/rob_hopkins_transition_to_a_world_without_oil.html

[ix] EIA Oil Production Scenarios: http://tonto.eia.doe.gov/FTPROOT/presentations/long_term_supply/sld011.htm

[x] James Lovelock : Gaia Hypothesis: http://www.ecolo.org/lovelock/

[xi] *"Our Choice"* by Al Gore provides a good overview of the technology options and issues involved in an easy to understand narrative.

[xii] You can view The Framework adopted by UNFCC and a summary report by invVEST ambassador Zack Baize who is a US scholar at Oxford studying Environmental Policies.

[xiii] View appendix for Household Penetration of Technology that was included in a presentation by F. M Valocchi VP/Partner Global Energy and Utilities Leader, IBM Global Business Services at the Colorado PUC Commission sponsored conference "COLORADO'S **NEW ENERGY** ECONOMY: THE PATH FORWARD" You can view many of the presentations at www.invVEST.org for New Energy Initiatives presentations by Katrina Johnson, Under Secretary of Energy DoE and Dan Arvizu, Head of NREL.

[xiv] The success of German FIT model is due to the fact that German Advisory Council for Global Change adopted a framework to meet the needs of key stakeholders and yet adopt aggressive price performance improvements with rapid scaling of renewable energy initiatives. The Spanish model ran into problems because policy makers failed to adopt a long term structured mechanism to do the same. invVEST team of ambassadors has deep expertise to advise each State in USA and India for customizing a structured mechanism that takes into account the resources available to the constituents.

[xv] While energy is a key resource, there are several other tangible (water, air, food) and non tangible resources (IP, mindset, etc) that are critical to a sustained growth. In a recent Global Leadership conference in Aspen Institute, Colorado, leaders were told to independently identify the top 10 issues the world needs to resolve and energy was the number one issue. More importantly, most felt if energy issues were resolved, other 6 issues go away.

[xvi] China will become the largest wind installer in the World surpassing Germany and USA (who overtook Germany in terms of installed capacity last year). Also Chinese wind turbine manufacturing companies are rapidly growing and many of them will figure in the top 10, if not the top five in the next few years. The focus of China has been more towards applied research with an eye to rapid commercialization. In areas like carbon sequestration from coal based power plants , large USA based companies like Duke Energy are planning to adopt Chinese technologies.

[xvii] Review *"The Path We Choose for Energy Source will Shape Our Destiny for Our Very Next Generation"* at www.invVEST.org.

[xviii] PUC: Public Utility Commission. GEO: Governor's Energy Office.

[xix] invVEST team has a close working relationship with the Colorado PUC commission, NREL, CU, CSU & CSM as well as hundreds of organizations working in the SEI space.

[xx] Planning Commission 11th Plan Energy Report:
http://planningcommission.gov.in/plans/planrel/fiveyr/11th/11_v3/11v3_ch10.pdf

[xxi] Envirofit is an organization spun out of CSU Engine Conversion Labs who has designed efficient cook stoves and are selling them to the rural and urban poor in India. Visit http://www.envirofit.org/

[xxii] "*Unlocking Energy Efficiency in the U.S. Economy"* by McKinsey Global Energy Group is an excellent report for identifying and prioritizing energy efficiency programs.

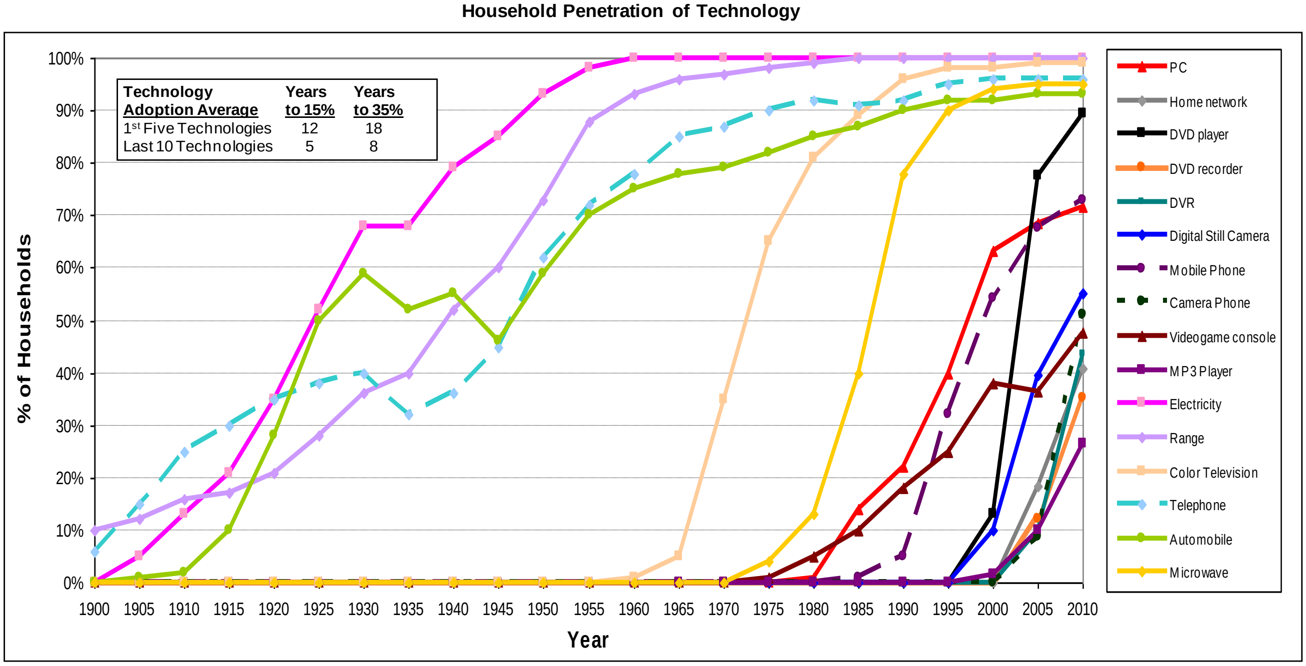
[xxiii] invVEST team has significant expertise in creating strategic frameworks for optimizing resources and SEI feasibility studies.

[xxiv] Specific Biofuels references leveraged for this report:

- *"National Algal Biofuels Technology Roadmaps"* by NREL (draft Version, report not yet published)
- *"Algal Biofuel Technologies*:" CleanTX Forum by Dr. Al Darzins , NREL, Nov 2008
- *"From 1st to 2nd Generation Biofuels Technologies, An Overview of Current Industry and RD&D activities"*, IEA BioEnergy, Nov 2008.
- *"Assessing Biofuels*" A Full Report by UNEP (United Nations Environment Programme) published 2009.

Appendix:

Household Penetration of Technology



Source: Forrester Research – Benchmark 2004, A Better Way, Fed Reserve Dallas Annual Rep 2003, IBM BCS Analysis