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Transition from Conventional Energy Resources to WWS: An Optimistic Scenario

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***Abstract:** All life on earth is sustained by energy from the sun. Plants and animals can store energy and some of this energy remains with them when they die. It is the remains of these ancient animals and plants that make up fossil fuels. Fossil fuels are non-renewable because they will run out one day and formation new fossil fuels take millions of years. Moreover, burning fossil fuels generates greenhouse gases and relying on them for energy generation is unsustainable. Hence there is a need to find more renewables, sustainable ways of generating energy. Renewable or infinite energy resources are sources of power that quickly replenish themselves and can be used again and again. Non-renewable energy sources have fueled the world's industrial complex for far too long. It has reached a point where the world is facing rapid starvation in this sector. There are also other associated effects like pollution, green house gases etc., too which also need to be carefully looked at just to make sure things are running as intended. However, we must realized that with increased exploitation of these fossil fuels, there are many associated environmental effects which in turn affect both animal and plant life and ultimately our planet. The far-reaching consequences of non-renewable sources are inexplicable and the trend has to be reversed soon before it is too late to do anything.*

The scope for improvement in the energy system is vast. Renewable energy currently makes up a negligible share of total primary commercial energy supply .As per IEA 2014 report, out of World total primary energy supply of 155,505 TWh, 91.7% from fossil fuels and 7.2% from hydro and nuclear resources and 1.1% from renewable..

Ahead of Copenhagen Accord of Clean Development Mechanism of the Kyoto Protocol, which expressed clear a political intent to constrain carbon and respond to climate change, the short and long term, in this paper it is thought of an even larger challenge: to determine how 100% of the world's energy, for all purposes, could be supplied by Wind, Water and Solar resources (WWS), by as early as 2030.

***Keywords:** World Health Organization, Energy Hierarchy, Transition Energy, Clean Technologies, sustainable energy.*

I. INTRODUCTION

Despite past and present administration's hope that the transition from a society dependent on fossil fuels to a world of controlled population growth, sustainable economies and alternative green energies will be forthcoming, the vision seems a bit optimistic. This shift will take strong political and emotional fortitude and decades to accomplish. The transition is not only necessary for the planet's ecological survival; it's critical to the health and well being of every human. World Health Organization reports that in 2012 around 7 million people died - one in eight of total global deaths – as a result of air pollution exposure. Carbon-dioxide emissions are a major culprit in the rapid global warming, which remains a long-range fossil fuel problem.

Virtually everyone agrees that the extraction, distribution, and burning of fossil fuels contribute significantly to many of the planet's environmental problems. This knowledge hasn't yet stopped the ever-increasing consumption of oil and gas by an ever-increasing world population. The fundamental problem is the world's population growth. Currently, the planet's human population is doubling about every 39 years. Not to mention all the environmental and humanitarian losses, this overpopulation problem is causing. With more and more developing countries wanting to offer their growing populations the opportunity to consume fossil fuel products such as gasoline and electricity, it is obvious that the supply will not be sustained by an overpopulated planet. In the near future the world's economic dependence on fossil fuels will continue to grow because we have implemented only few energy alternatives.

Estimates from international organizations suggest that if the world's demand for energy from fossil fuels continues at the present rate that coal, oil and gas reserves may run out within some of our lifetimes. Coal is expected to last longer.

Estimated length of time left for fossil fuels is as below:

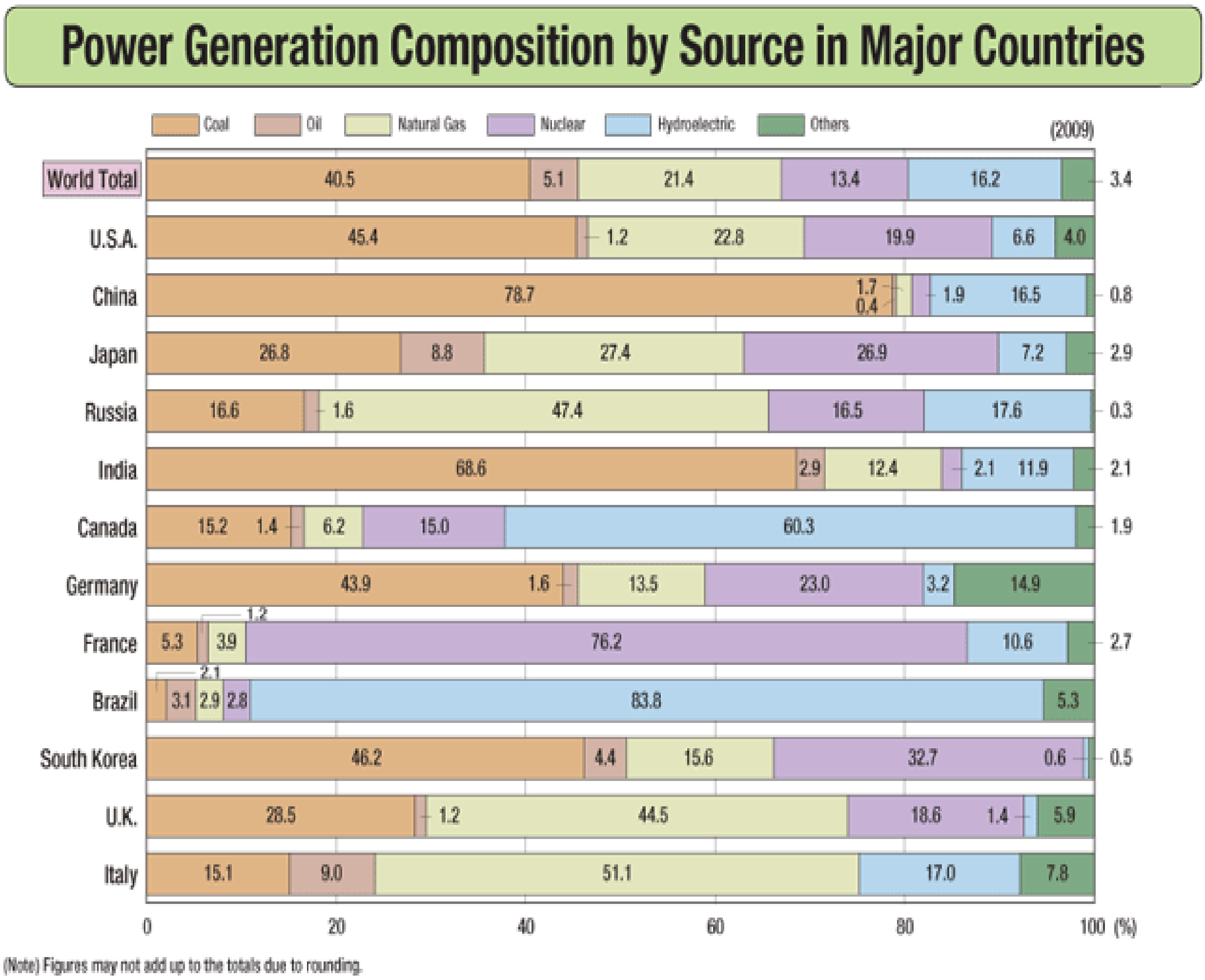
Fossil fuel Time left

Oil 50 years

Natural gas 70 years

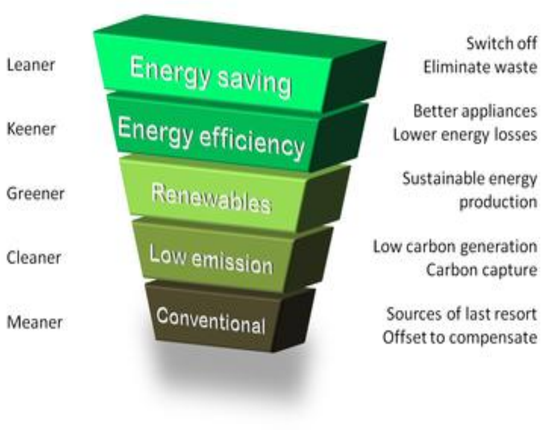
Coal 250 years

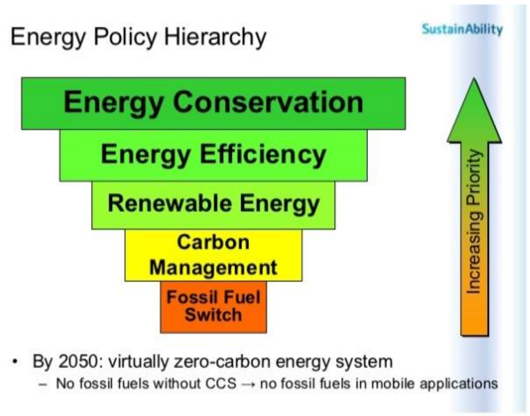
We will be scurrying to find alternative and renewable sources of energy. Mathis Wackernagel and William Rees, in their book, “Our Ecological Footprint: Reducing Human Impact on the Earth” , they state, "With access to global resources, urban populations everywhere are seemingly immune to the consequences of locally unsustainable land and resource management practices at least for a few decades. In effect, modernization alienates us spatially and psychologically from the land. The citizens of the industrial world suffer from collective ecological blindness that reduces their collective sense of 'connectedness' to the ecosystems that sustain them." The present source-wise power generation in major countries is as under:



II. ENERGY HIERARCHY

The Energy Hierarchy is a classification of energy-options, prioritized to assist progress towards a more sustainable energy system. It is a similar approach to the waste hierarchy for minimizing resource depletion, and adopts a parallel sequence. The highest priorities cover the prevention of unnecessary energy usage both through eliminating waste and improving energy efficiency. The sustainable production of energy resources is the next priority. Depletive and waste-producing energy generation options are the lowest priority. For an energy system to be sustainable: the resources applied to producing the energy must be capable of lasting indefinitely; energy conversion should produce no harmful by-products, including net emissions, nor wastes which cannot be fully recycled; and it must be capable of meeting reasonable energy demands.





Under tremendous and increasing pressure we will have to address the fossil fuel and pollution crisis. The alternative energy sources have to be found to replace our present great dependency on fossil fuels. Moreover they should be obtained in significant quantity and widespread around the world and that too at reasonable cost with minimum environmental impacts. Normally it is seen these problems are seen with short-term benefits. A motivation is required to adopt costly, sustainable, long-term energy policies with the aim of preparing for the inevitable energy crisis. The Alliance to Save Energy believes that with just a few adjustments, society will make the jump from unlimited fossil fuel consumption to sustainable economies based on improved energy efficiency. But greater energy efficiency, fuel saving technologies and the installation of minor adjustments in our daily lifestyles will not solve the coming fossil fuel/oil crunch.

Renewable green energy sources can help reduce pollution and dependence on petroleum products. Wind and solar energy do not create dangerous waste products and are indigenous, secure and freely available.

III. TRANSITION ENERGY

Over the last 200 years an ever-increasing proportion of our energy has come from non-renewable sources such as oil and coal. While demand for energy raises these resources are running out and scientists are exploring the potential of renewable sources of energy for the future.

Regardless of whether the process will be easy or extremely difficult, sooner or later we are all going to have to face some major changes to our current way of life. It is not that we lack the knowledge of how to adopt sustainable measures. The challenge is to help developing countries leapfrog to a more decentralized, efficient, renewables-based system. The alternative to this is following the coal or oil-based path; suffering from price volatility, import dependence, mounting pollution and health problems, and expensive retrofits. Ultimately, the question is not *when* the global economy will switch from burning environment-damaging and limited petroleum products to using more earth-friendly alternative energies, but *how* will industry and humanity handle the transition.

IV. Renewable and Non-Renewable Energy Resources

All life on earth is sustained by energy from the sun. Plants and animals can store energy and some of this energy remains with them when they die. It is the remains of these ancient animals and plants that make up fossil fuels. Fossil fuels are non-renewable because they will run out one day. Burning fossil fuels generates greenhouse gases and relying on them for energy generation is unsustainable. Hence we need to find more renewable, sustainable ways of generating energy.

a. Non-renewable energy resources

Type of fuel	Where it is from	Advantages	Disadvantages
Coal (fossil fuel)	Formed from fossilized plants and consisting of carbon with various organic and some inorganic compounds. Mined from seams of coal, found sandwiched between layers of rock in the earth. Burnt to provide heat or electricity.	Ready-made fuel. It is relatively cheap to mine and to convert into energy. Coal supplies will last longer than oil or gas.	When burned coal gives off atmospheric pollutants, including greenhouse gases.
Oil (fossil fuel)	A carbon-based liquid formed from fossilised animals. Lakes of oil are sandwiched between seams of rock in the earth. Pipes are sunk down to the reservoirs to pump the oil out. Widely used in industry and transport.	Oil is a ready-made fuel. Relatively cheap to extract and to convert into energy.	When burned, it gives off atmospheric pollutants, including greenhouse gases. Only a limited supply.
Natural gas (fossil fuel)	Methane and some other gases trapped between seams of rock under the earth's surface. Pipes are sunk into the ground to release the gas. Often used in houses for heating and cooking.	Gas is a ready-made fuel. It is a relatively cheap form of energy. It's a slightly cleaner fuel than coal and oil.	When burned, it gives off atmospheric pollutants, including greenhouse gases. Only limited supply of gas.
Nuclear	Radioactive minerals such as uranium are mined. Electricity is generated from the energy that is released when the atoms of these minerals are split (by nuclear fission) in nuclear reactors.	A small amount of radioactive material produces a lot of energy. Raw materials are relatively cheap and can last quite a long time. It doesn't give off atmospheric pollutants.	Nuclear reactors are expensive to run. Nuclear waste is highly toxic, and needs to be safely stored for hundreds or thousands of years (storage is extremely expensive). Leakage of nuclear materials can have a devastating impact on people and the environment. The worst nuclear reactor accident was at Chernobyl, Ukraine in 1986.

b. Renewable energy sources

Renewable energy sources quickly replenish themselves and can be used again and again. For this reason they are sometimes called **infinite energy resources**.

The advantages and disadvantages of renewable energy sources are as under.

Type of energy	Where it is from	Advantages	Disadvantages
Solar	Energy from sunlight is captured in solar panels and converted into electricity.	Potentially infinite energy supply. Single dwellings can have own electricity supply.	Manufacture and implementation of solar panels can be costly.

Type of energy	Where it is from	Advantages	Disadvantages
Wind	Wind turbines (modern windmills) turn wind energy into electricity.	Can be found singularly, but usually many together in wind farms. Potentially infinite energy supply.	Manufacture and implementation of wind farms can be costly. Some local people object to on-shore wind farms, arguing that it spoils the countryside.
Tidal	The movement of tides drives turbines. A tidal barrage (a kind of dam) is built across estuaries, forcing water through gaps. In future underwater turbines may be possible out at sea and without dams.	Ideal for an island such as the UK. Potential to generate a lot of energy. Tidal barrage can double as a bridge, and help prevent flooding.	Construction of barrage is very costly. Only a few estuaries are suitable. Opposed by some environmental groups as having a negative impact on wildlife. May reduce tidal flow and impede flow of sewage out to sea.
Wave	The movement of seawater in and out of a cavity on the shore compresses trapped air, driving a turbine.	Ideal for an island country. More likely to be small local operations, rather than done on a national scale.	Construction can be costly. May be opposed by local or environmental groups.
Geothermal	In volcanic regions it is possible to use the natural heat of the earth. Cold water is pumped underground and comes out as steam. Steam can be used for heating or to power turbines creating electricity.	Potentially infinite energy supply. Used successfully in some countries, such as New Zealand and Iceland.	Can be expensive to set up and only works in areas of volcanic activity. Geothermal and volcanic activity might calm down, leaving power stations redundant. Dangerous elements found underground must be disposed of carefully.
Hydrological or Hydroelectric Power (HEP)	Energy harnessed from the movement of water through rivers, lakes and dams.	Creates water reserves as well as energy supplies.	Costly to build. Can cause the flooding of surrounding communities and landscapes. Dams have major ecological impacts on local hydrology.

V. How to Achieve Sustainable Energy by 2030

The Copenhagen Climate Change Conference held in Dec’ 2009, raised climate change policy to the highest political level. Close to 115 world leaders attended the high-level segment, making it one of the largest gatherings of world leaders ever outside UN headquarters in New York. It significantly advanced the negotiations on the infrastructure needed for effective global climate change cooperation, including improvements to the Clean Development Mechanism of the Kyoto Protocol. It produced the Copenhagen Accord, which expressed clear a political intent to constrain carbon and respond to climate change, in both the short and long term.

The Copenhagen Accord contained several key elements on which there was strong convergence of the views of governments. This included the long-term goal of limiting the maximum global average temperature increase to no more than 2 degrees Celsius above pre-industrial levels, subject to a review in 2015.

The period of 150 years for coal, 50 years for oil or 70 years for natural gas, is a very meager time period compared to the life of earth and for its creatures surviving. The most effective step to implement that goal would be a massive shift away from fossil fuels to clean, renewable energy sources. If leaders can have confidence that such a transformation is possible, they might commit to an historic agreement. However it needs political commitment. A year ago former vice president Al Gore threw down a gauntlet: to repower America with 100 percent carbon-free electricity within 10 years.

While evaluating the feasibility of such a change, let us thing of an even larger challenge: to determine how 100 percent of the world's energy, for all purposes, could be supplied by Wind, Water and Solar resources (WWS), by as early as 2030. Scientists have been building to this moment for at least a decade, analyzing various pieces of the challenge. Most recently, a 2009 Stanford University study ranked energy systems according to their impacts on global warming, pollution, water supply, land use, wildlife and other concerns. The very best options for renewable i.e. wind, solar, geothermal, tidal and hydroelectric power—all of which are driven by wind, water or sunlight (referred to as WWS). Nuclear power, coal with carbon capture, and ethanol were all poorer options, as were oil and natural gas. The study also found that battery-electric vehicles and hydrogen fuel-cell vehicles recharged by WWS options would largely eliminate pollution from the transportation sector. Our plan calls for millions of wind turbines, water machines and solar installations. The numbers are large, but the scale is not an insurmountable hurdle; society has achieved massive, transformations before. When there is will there is a way. Hence it is feasible to transform the world's energy systems. Can it be accomplished in two decades? It is possible in case right technologies are chosen with availability of critical materials, and economic and political factors.

a. Clean Technologies

In my earlier paper titled "Sustainable Energy Sources with their limitations", the author has quoted that *As per Hinduism's sacred literature, great elements (Mahabhuta / tatva) are fivefold; i.e. space, air, fire, water & earth. All these five Mahabhutas are the basic sources of energy for life on earth. These are Vedic gods & worshipped since ancient time. Today, electric power is generated from all these elements; like power stations based on water (Hydro), Fire (Thermal), Air (Wind) & Space (Solar) and these are in use. The geo-thermal based power stations are in primary stage which is using direct heat inside the earth. Ironically, fossil fuel resources are limited. The fossil fuels – coal, petroleum and natural gas – provide most of our needs of energy and coal used to be major source of energy. If production and consumption of coal continue further, proven and economically recoverable world reserves of coal would last for about 150 years."*

Renewable energy comes from enticing sources: wind, which also produces waves; water, which includes hydroelectric, tidal and geothermal energy (water heated by hot underground rock); and sun, which includes photovoltaics and solar power plants that focus sunlight to heat a fluid that drives a turbine to generate electricity. Our plan includes only technologies that work or are close to working today on a large scale, rather than those that may exist 20 or 30 years from now. To ensure that our system remains clean, we consider only technologies that have near-zero emissions of greenhouse gases and air pollutants over their entire life cycle, including construction, operation and decommissioning. Nuclear power results in up to 25 times more carbon emissions than wind energy, when reactor construction and uranium refining and transport are considered. Carbon capture and sequestration (CCS) technology can reduce carbon dioxide emissions from coal-fired power plants but will increase air pollutants and will extend all the other deleterious effects of coal mining, transport and processing, because more coal must be burned to power the capture and storage steps. Similarly, we consider only technologies that do not present significant waste disposal or terrorism risks. In our plan, WWS will supply electric power for heating and transportation—industries that will have to revamp if the world has any hope of slowing climate change. We have assumed that most fossil-fuel heating (as well as ovens and stoves) can be replaced by electric systems and that most fossil-fuel transportation can be replaced by battery and fuel-cell vehicles. Hydrogen, produced by using WWS electricity to split water (electrolysis), would power fuel cells and be burned in airplanes and by industry.

b. Renewables - The Total Energy source

Today the maximum power consumed worldwide at any given moment is about 12.5 trillion watts (terawatts, or TW), according to the U.S. Energy Information Administration. The agency projects that in 2030 the world will require 16.9 TW of power as global population and living standards rise. The mix of sources is similar to today's, heavily dependent on fossil fuels. If, however, the planet were powered entirely by WWS, with no fossil-fuel or biomass combustion, an intriguing savings would occur. Global power demand would be only 11.5 TW. That decline occurs because, in most cases, electrification is a more efficient way to use energy. For example, only 17 to 20 percent of the energy in gasoline is used to move a vehicle (the rest is wasted as heat), whereas 75 to 86 percent of the electricity delivered to an electric vehicle goes into motion. Even if demand did rise to 16.9 TW, WWS sources could provide far more power. Detailed studies indicate that energy from the wind, worldwide, is about 1,700 TW. Solar, alone, offers 6,500 TW. Of course, wind and sun out in the open seas, over high mountains and across protected regions would not be available. If we subtract these and low-wind areas not likely to be developed, we are still left with 40 to 85 TW for wind and 580 TW for solar, each far beyond future human demand. Yet currently we generate only 0.02 TW of wind power and 0.008 TW of solar. These sources hold an incredible amount of untapped potential. The other WWS technologies will help create a flexible range of options. Although all the sources can expand greatly, for practical reasons, wave power can be extracted only near coastal areas. Many geothermal sources are too deep to be tapped economically. And even though hydroelectric power now exceeds all other WWS sources, most of the suitable large reservoirs are already in use.

No	Sources	TW	% of Supply	Technologies	Units	Size of Unit/Plant
1	Water	1.1	9%	Tidal Turbines	490000	1MW- <1% In Place
				Geothermal Plants	5350	100MW-2% In Place
				Hydroelectric Plants	900	1300MW-70% In Place
2	Wind	5.8	51%	Wind Turbines	3800000	5MW-1% In Place
				Wave Converters	720000	0.75MW-<1% In Place
3	Solar	4.6	40%	Rooftop Photovoltaic Sys.*	1700000000	0.003MW-<1% In Place
				Power Plants Photovoltaic	40000	300MW-<1% In Place
				Centralized Solar Power Plants	49000	300MW-<1% In Place
	Total	11.5	100%		1705905350	

- sized for a modest house; a commercial roof might have dozens of systems

VI. WWS-Power Technology mix

Clearly, enough renewable energy exists. How, then, would we transition to a new infrastructure to provide the world with 11.5 TW? We have chosen a mix of technologies emphasizing wind and solar, with about 9% of demand met by mature water-related methods. (Other combinations of wind and solar could be as successful.) Wind supplies 51% of the demand, provided by 3.8 million large wind turbines (each rated at five megawatts) worldwide. Another 40% of the power comes from photovoltaics and concentrated solar plants, with about 30% of the photovoltaic output from rooftop panels on homes and commercial buildings. About 89,000 photovoltaic and concentrated solar power plants, averaging 300 megawatts a piece, would be needed. Our mix also includes 900 hydroelectric stations worldwide, 70% of which are already in place. Only about 0.8% of the wind base is installed today. The worldwide footprint of the 3.8 million wind turbines would be less than 50 square kilometers (smaller than Manhattan). When the needed spacing between them is figured, they would occupy about 1% of the earth's land, but the empty space among turbines could be used for agriculture or ranching or as open land or ocean. The non-rooftop photovoltaics and concentrated solar plants would occupy about 0.33% of the planet's land. Building such an extensive infrastructure will take time. The building infrastructure for the conventional power plant's network would also take similar time. It is sure that if we stick with fossil fuels, demand by 2030 will rise to 16.9 TW, requiring about 13,000 large new coal plants, which themselves would occupy a lot more land, as would the mining to supply them. The environmental problems with that capacity would be much severe than those of now.

a. Infrastructure for WWS:

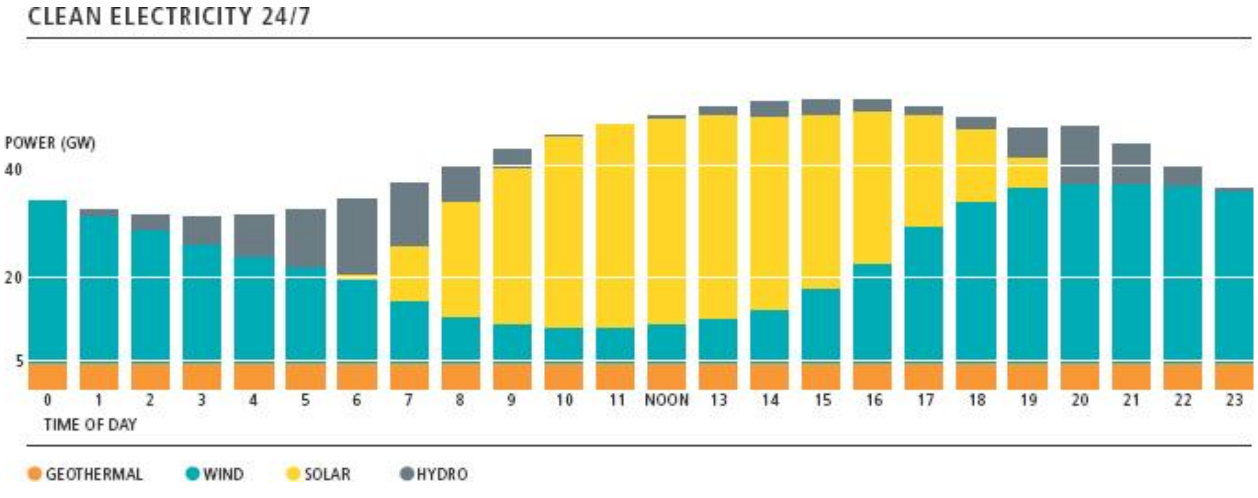
The scale of the WWS infrastructure is not a barrier. But a few materials needed to build it could be scarce or subject to price manipulation. Enough concrete and steel exist for the millions of wind turbines, and both those commodities are fully recyclable. The most problematic materials may be rare-earth metals such as neodymium used in turbine gearboxes. Although the metals are not in short supply, the low-cost sources are concentrated in China, so countries such as the U.S. could be trading dependence on Middle Eastern oil for dependence on Far Eastern metals. Manufacturers are moving toward gearless turbines, however, so that limitation may become moot.

Photovoltaic cells rely on amorphous or crystalline silicon, cadmium telluride, or copper indium solenoid and sulfide. Limited supplies of tellurium and indium could reduce the prospects for some types of thin-film solar cells, though not for all; the other types might be able to take up the slack. Large-scale production could be restricted by the silver that cells require, but finding ways to reduce the silver content could tackle that hurdle. Recycling parts from old cells could ameliorate material difficulties as well.

Three components could pose challenges for building millions of electric vehicles: rare-earth metals for electric motors, lithium for lithiumion batteries and platinum for fuel cells. More than half the world's lithium reserves lie in Bolivia and Chile. That concentration, combined with rapidly growing demand, could raise prices significantly. More problematic is the claim by Meridian International Research that not enough economically recoverable lithium exists to build anywhere near the number of batteries needed in a global electric-vehicle economy. Recycling could change the equation, but the economics of recycling depend in part on whether batteries are made with easy recyclability in mind, an issue the industry is aware of. The long-term use of platinum also depends on recycling; current available reserves would sustain annual production of 20 million fuel-cell vehicles, along with existing industrial uses, for fewer than 100 years.

b. Smart Mix for Reliability

A new infrastructure must provide energy on demand at least as reliably as the existing infrastructure. WWS technologies generally suffer less downtime than traditional sources. Modern wind turbines have a down time of less than 2% on land and less than 5% at sea. Photovoltaic systems are also at less than 2%. Moreover, when an individual wind, solar or wave device is down, only a small fraction of production is affected; when a coal, nuclear or natural gas plant goes offline, a large chunk of generation is lost. The main WWS challenge is that the wind does not always blow and the sun does not always shine in a given location. Intermittency problems can be mitigated by a smart balance of sources, such as generating a base supply from steady geothermal or tidal power, relying on wind at night when it is often plentiful, using solar by day and turning to a reliable source such as hydroelectric that can be turned on and off quickly to smooth out supply or meet peak demand. Interconnecting geographically dispersed sources will be useful so they can back up one another, installing smart electric meters in homes that automatically recharge electric vehicles when demand is low and building facilities that store power for later use. Because the wind often blows during stormy conditions when the sun does not shine and the sun often shines on calm days with little wind, combining wind and solar can go a long way toward meeting demand, especially when geothermal provides a steady base and hydroelectric can be called on to fill in the gaps.



c. Economical WWS Power:

The mix of WWS sources in our plan can reliably supply the residential, commercial, industrial and transportation sectors. The logical next question is whether the power would be affordable. For each technology, we calculated how much it would cost a producer to generate power and transmit it across the grid. We included the annualized cost of capital, land, operations, maintenance, energy storage to help offset intermittent supply, and transmission. Today the cost of wind, geothermal and hydroelectric is all less than 7cents/kilowatt-hour (¢/kWh); wave & solar are higher. But by 2020 and beyond wind, wave and hydro are expected to be 4¢/kWh or less.

For comparison, the current average cost of conventional power generation and transmission was about 7¢/kWh, and it is projected to be 8¢/kWh in 2020. Power from wind turbines, for example, already costs about the same or less than it does from a new coal or natural gas plant, and in the future wind power is expected to be the least costly of all options. The competitive cost of wind has made it the second largest source of new electric power generation in the U.S. for the past three years, behind natural gas and ahead of coal.

Solar power is relatively expensive now but should be competitive as early as 2020. A careful analysis by Vasilis Fthenakis of Brookhaven National Laboratory indicates that within 10 years, photovoltaic system costs could drop to about 10¢/kWh, including long-distance transmission and the cost of compressed-air storage of power for use at night. The same analysis estimates that concentrated solar power systems with enough thermal storage will supply electricity 24 hours a day in spring, summer and fall and at a cost 10¢/kWh or less.

Transportation in a WWS world will be driven by batteries or fuel cells, so we should compare the economics of these electric vehicles with that of internal-combustion-engine vehicles. Detailed analyses by one of us (Delucchi) and Tim Lipman of the University of California, Berkeley, have indicated that mass-produced electric vehicles with advanced lithium-ion or nickel metalhydride batteries could have a full lifetime cost per mile (including battery replacements) that is comparable with that of a gasoline vehicle, when gasoline sells for more than $2 a gallon.

When the so-called externality costs (the monetary value of damages to human health, the environment and climate) of fossil-fuel generation are taken into account, WWS technologies become even more cost-competitive. Overall construction cost for a WWS system might be on the order of $100 trillion worldwide, over 20 years, not including transmission. But this is not money handed out by governments or consumers. It is investment that is paid back through the sale of electricity and energy. And again, relying on traditional sources would raise output from 12.5 to 16.9 TW, requiring thousands more of those plants, costing roughly $10 trillion, not to mention tens of trillions of dollars more in health, environmental and security costs. The WWS plan gives the world a new, clean, efficient energy system rather than an old, dirty, in inefficient one.

VII. Political Will

Our analyses strongly suggest that the costs of WWS will become competitive with traditional sources. In the interim, however, certain forms of WWS power will be significantly more costly than fossil power. Some combination of WWS subsidies and carbon taxes would thus be needed for a time. A feed-in tariff (FIT) program to cover the difference between generation cost and wholesale electricity prices is especially effective at scaling-up new technologies. Combining FITs with a so-called declining clock auction, in which the right to sell power to the grid goes to the lowest bidders, provides continuing incentive for WWS developers to lower costs. Taxing fossil fuels or their use to reflect their environmental damages also makes sense. But at a minimum, existing subsidies for fossil energy, such as tax benefits for exploration and extraction, should be eliminated to level the playing field.

The implementation of WWS Mix needs willingness to invest in a robust, long-distance transmission system that can carry large quantities of power from remote regions where it is often greatest to centers of consumption, typically cities. Reducing consumer demand during peak usage periods also requires a smart grid that gives generators and consumers much more control over electricity usage hour by hour.

VIII. Renewable Energy Technology Program in India

The renewable energy program has been in existence for more than three decades, but a market for renewable energy technologies still does not exist. Though a manufacturing base has been set up and an infrastructure created to support RET design, development, testing and deployment, commercial demand for these technologies still remains low. Some key issues related to faster diffusion of RETs are a strong need to improve reliability of technologies and introduce consumer-desired features (in terms of services and financial commitments) in the design and sales package. Renewable energy strategy needs to be integrated with liberalization of energy markets and withdrawal of direct government interventions in energy sector. Renewable energy deployment could be enhanced from 'energy services' delivery perspective. Incorporation of renewable energy strategy into development programmes will promote its decentralised applications. Renewable energy strategy should form a part of energy sector regulatory framework. Public-private role in renewable energy development needs to be redefined. The government policies should encourage more private participation and industry collaboration in R&D for rapid commercialization of RETs and in market infrastructure development. Most renewables still have a significant way to go before they are competitive with fossil technologies, especially for power generation purposes. This will demand intense further RD&D efforts. However, at present many renewables are in a classic chicken and egg situation - financiers and manufacturers are reluctant to invest the capital needed to reduce costs when demand is low and uncertain, but demand stays low because potential economies of scale cannot be realised at low levels of production. Renewables need to gain the confidence of developers, customers, planners and financiers. This can be done by renewables establishing a strong track record, performing to expectations, and improving their competitive position relative to conventional fuels.

IX. Conclusion

A large-scale wind, water and solar energy system can reliably supply the world’s needs, significantly benefiting climate, air quality, water quality, ecology and energy security. As it is seen that the obstacles are primarily political and not technical. A combination of feed-in tariffs plus incentives for providers to reduce costs, elimination of fossil subsidies and an intelligently expanded grid could be enough to ensure rapid deployment. Of course, changes in the real-world power and transportation industries will have to overcome sunk investments in existing infrastructure. But with sensible policies, nations could set a goal of generating 25 percent of their new energy supply with WWS sources in 10 to 15 years and almost 100 percent of new supply in 20 to 30 years. With extremely aggressive policies, all existing fossil-fuel capacity could theoretically be retired and replaced in the same period, but with more modest and likely policies full replacement may take 40 to 50 years. Either way, clear leadership is needed, or else nations will keep trying technologies promoted by industries rather than vetted by scientists.

It was not clear a decade ago, that a global WWS system would be technically or economically feasible and it looks like as a fantasy. However it is technically possible provided global leaders should show their willingness and commitment to make WWS power feasible. They should start by committing to meaningful climate and renewable energy goals now.

Abbreviations:

WWS-Water Wind Solar, RET- Renewable Energy Technology, FIT-feed-in tariff, ¢/kWh - Cents per kilowatt-hour, TW-terawatts, CCS-Carbon capture and sequestration.

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