Socio-technical issues for transition to renewable energies (Revised Nov 2009)

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Socio-technical system of energy is a system that integrates cost, economical, environmental, social, political and technological aspects of electricity power supply and usage. In United States, most average consumers are practically ignored the energy issues because they are happy with their current electric bills and most big businesses found it a great risk to invest in the renewable technology due to the long history of renewable energy companies repeatedly gone out of business.

This paper exploits the major technical and social elements contributing to the impediment use of the renewable technologies. The objective is to observe and recognize these complications and to raise social awareness for people to better evaluate the adoption of different energy-system technologies.

I. Introduction

Current energy systems in the US predominantly are powered by hydro, coal, wind, solar, geothermal, biomass, nuclear and tidal power. Almost 83% of total electricity used in the United States is coming from two sources; coal and hydro. While the rest 17% are coming from five other sources; wind, solar, geothermal, biomass, nuclear and tidal [5]. The primary factors responsible for the impediment use of these renewable technologies are being exploited through careful evaluations of the technical, social/political, environmental and economical issues. These criteria are investigated in the next section.

II. Technological Issues

Technologies applied in renewable energies are relatively more complicated in comparison to those used in fossil energies as they are being challenged by reliabilities of supply. Storage also is becoming a very important issue, for the reason that most renewable energies are fueled from the natural sources, thus it could not be efficiently control and regulate as it could with coal, gas or oil.

Through many years of research and development, new improvements of renewable technology gradually is shifting our interest and making it more feasible to be able to incorporate it into the power grid. However, there exist many factors and issues which hinder its usage:

Wind Energy

Wind power is site dependent that is built upon Wind farm can utilize wind energy; the wind speed is between 2.5m/s and 25m/s. Its generation capability fluctuates in respect to the changing of wind's speed; 16 mph wind could generate 50% more capacity than 14 mph even though the difference is only 2 mph. Also, as the concentration of wind power on the grid rises, the capacity credit percentage drops.

Wind farm is highly reliable, because the total power is being generated by a larger numbers of smaller generators; individual failure of smaller generators does not have very large impacts on the total power grid, thus this referred as resiliency [22].

Wind energy has significant potential and likely to be deployed in increasing amounts, but it is unlikely that it alone can meet the entire demand. The major challenge in using wind as a source of power is that the wind's intermittent nature does not allows us to be continually harvested to meet the timing of electricity demands [17]. In many cases, it has to use other power stations such as coal power plant for back up.

There is also a significant barrier in entering the wind energy industries, particularly as turbine size has grown larger; the technology required to manufacture the giant turbine size is becoming increasingly more complex [30].

Solar Energy

Solar power is the generation of electricity from sunlight. There are two major types of solar power: direct approach photovoltaic (PV) and indirect approach, concentrating solar power (CSP), which concentrate sun light though the use of parabolic reflectors to heat up liquid and extracting the heat to provide power.

The production of electricity from solar sources depends on the amount of light energy that is in a given location, as solar output varies throughout the day and through the seasons, where cloud cover would effect the solar energy production which slows and impairs the process. The capacity factor of Photovoltaic solar in Massachusetts is 12-15%, Photovoltaic solar in Arizona is 19%. Thermal solar parabolic trough is 56% and Thermal solar power tower is 73% [16]. The extent to solar-generated electricity depends to some extent on the generation profile of solar corresponds to its demand.

Like wind power, energy storage is also an important issue for solar because of its intermittent nature. Solar ponds and chemical processes are some of the approaches to convert solar energy into storage power and fuels.

In some cases, excessive electricity from solar energy can be sent to the transmission grid and place with grid-tied systems. Net metering programs give these systems a credit

for the electricity and that is deliver to the grid. This credit offsets electricity provided from the grid when the system cannot meet its demand. The credit effectively uses the grid as a storage mechanism.

Geothermal Energy

Geothermal energy has significant base-load potential, requires no storage, it can complement other renewable energies, such as solar, wind and hydropower.

For a long time, geothermal electric plants were limited to areas on the edges of tectonic plates where high temperature geothermal resources are available closer to the surface. Recent technology enables plants to be built at a much greater geographical range since the development of binary cycle power plants and the improvements in drilling and extraction technologies [29].

A constraint of geothermal is creating a sufficient connectivity within the injection. Well system in the stimulated region of reservoir should be developed in order to allow high per-well production rates without reducing reservoir life by rapid cooling [17]. Also, preventing surface subsidence and landslide is a big technological challenge to geothermal.

Limitation is the geothermal electricity transmission. Geothermal locations are far from the transmission line. It will need further evaluation on routing the transmission line before implementation. Risks and uncertainties are still high, which hinders the support of private investments to the commercial deployment of geothermal.

Biomass

Bio-fuels are divided into three types: corn Ethanol, cellulosic, and bio diesel. They all are derived from different type of plants or animal fats. Pure ethanol is usually blended with gasoline. "E10"—10 percent ethanol—is common today. E85—85 percent ethanol—is the highest practical blend; sometimes it is mixed with other conventional, petroleum-based diesel to help cut down on tailpipe emissions [18].

The current efficiency factor of biomass is about 27.7%. US Department of Agriculture reports that ethanol returns 1.34 times more energy than what was required to grow and to produce ethanol [19].

The production of bio-fuel depends on plants which has overhaul period because of its product life cycle. Another issue is that ethanol cannot be easily transported in the same pipelines as petroleum and natural gas, due to its high water content.

Biomass also has application limitation that they are not compatible with all types of automobiles, airplane, and other leading forms of transportation. Ethanol currently accounts for 2.85% of the fuel supply for gasoline vehicles in the U.S. [20]

Hydropower

Hydropower is power that is derived from the force or energy of moving water. It is available in the areas near shore or rivers, thus geographical availability is one of the key in the decision factor.

It is currently mature in large hydropower plant while the technology in small hydropower plant is emerging. In large scale application, some electricity generators use water dams to store excess energy. In small hydropower projects, a run-of-river project uses only part of the stream flow i.e. the Gorlovhelical turbine.

With an exception for areas of high abundance of large rivers resources, most hydro dam operates on peak load demand. It also provides high-capacity energy storage, known as "pumped storage". Pumped storage plants can respond to load changes within seconds, so that it can maintain the stability of frequency and voltage of electrical generation.

There are some issues in practice, the utilization of stored water in river dams. It is sometimes complicated by demands for irrigation which may occur out of phase with peak electrical demands. Also, as the river flow it put silts in the hydro reservoir thus gradually it loses its capacity to the point of being unable to store enough water to provide water and power in dry weather [21]. Dam failure can be very hazardous.

III. Political/Social Issues

Renewable energies have impact on people's living pattern. And increasing social awareness serves as incentives to the development of renewable energy. Changes in laws and regulations can also shift the trends in renewable energies deployment.

Wind Energy

Wind turbines can be built on farms or ranches. Farmers and ranchers can continue to work the land because of the wind turbines uses only a fraction of the land. Wind power plant owners make rent payments to the farmers or ranchers for the uses of land, which benefits rural areas.

But there are some concerns over the noise produced by the rotor blades and visual impacts. Public opposition to on-shore wind turbines is also strong. Current turbine designs effectively reduce mechanical sound through sound proofing. [30]

Governments support the usage of wind energy in different ways. In the United States, wind power receives a tax credit for each kWh produced. The Energy Improvement and Extension Act of 2008 contain extensions of credits for wind, including micro-turbines. Another tax benefit is accelerated depreciation. Many American states also provide incentives, such as exemption from property tax and mandated purchases. Countries such as Canada and Germany also provide incentives for wind turbine construction, such as tax credits or

minimum purchase prices for wind generation, with assured grid access. These feed-in tariffs are typically set well above average electricity prices. And there the property tax base for rural counties is increasing [31].

Solar Energy

Solar energy is close to people's life. It has a wide range of application. Solar energy farms generate electricity on a large scale while the usage of small scale from solar energy is closely related to daily life. It raises public awareness to renewable energy. Moreover, it makes electricity available to those who live in the rural areas without electricity grid coverage. Solar energy lifts the living standard to them to some extent.

In upstream investment policies, government acts to support the supply of new knowledge in solar energy technologies by investing in R&D and providing seed capital to solar companies. In market creation policies, government acts on to create new customers for solar energy technologies through procurement policies for public properties. It also creates customers for solar technologies, either through subsidies or through mandates/standards. In the interface improvement, government performs the role of installer. It ensures quality installations through decentralized policies like training and certification programs with inspection programs and warranty requirements [24].

Geothermal Energy

Geothermal energy uses land modestly. Geothermal plants require much less land area per MW installed or per MWh delivered. In fact, the required land is not completely occupied by the plant and the wells. Geothermal plants generally have a low profile and are much less conspicuous than other renewable energy. [17]

Noise from geothermal operations is ranging from about 80 to 115 decibels A-weighted (dBA) at the plant fence boundary [27]. The process of opening fractures can occur in a sliding manner by shear failure or in extensional manner by tensile failure [17]. If geothermal fluid production rates are much greater than recharge rates, geothermal fields will be at the risk of surface subsidence and landslide which dangers public.

Compared to other types of renewable energy, the awareness from both government and publics on geothermal is relatively low. Changes in laws and regulations can have large impacts on the sector.

Also Drilling is one of the biggest issues of geothermal plants. Current geothermal systems are in the range of less than couple miles, drilling deeper is available through the petroleum companies but it proves to be very expensive in millions of dollar. Since many of the best drilling companies are owned by the petroleum industries, therefore this raises question on the political favor.

Biomass

Most concern over biomass is whether it has a negative impact on the food supply. Some people think biomass is jacking up world food prices and endangering the hungry. [32] Others suppose that it has little to no effect on food prices and supply. For example, the corn used for ethanol is field corn, not for human consumption, and only a small fraction of the total food fed to animals are field corns.

In some country, biofuel can secure the domestic energy source to some extent because the fuel that comes from agricultural feedstock can be produced domestically.

Consumer behavior will play an increasingly important role in determining demand for biomass [33]. There are incentives and regulations in ethanol fuel mixing requirements. In U.S, Federal and State government policies and regulations of biomass will affect the development of the biomass industry. In addition, the blender's tax credits reduce the cost of biomass, making them more competitive with petroleum fuels. State support for biomass varies, but many States have reduced fuel taxes, and provide grants and loans for distribution of infrastructure. Increasing budgetary impacts may lead to future reconsideration of the subsidy levels.

Hydropower

Hydropower plants provide benefits in addition to clean electricity. Impoundment hydropower creates reservoirs that offer a variety of recreational opportunities, notably fishing, swimming, and boating. Most hydropower installations are required to provide some public access to the reservoir to allow the public to take advantage of these opportunities. Other benefits may include water supply and flood control. Areas with abundant hydroelectric power attract industry.

But there are some critical issues in the hydropower facilities. New hydropower facilities may compete with other uses for the land, which may lose higher opportunity cost for land use. Some older hydropower facilities may have historical value, so renovations of these facilities must also be sensitive to such preservation concerns. Also, Local cultures and historical sites may be impinged upon, due to the construction of reservoirs. It has strong impact in local living pattern.

IV. Environmental Issues

Environmental factors are address in five dominant renewable energy types; wind energy, solar energy, geothermal energy, biomass and hydropower. This section identifies some of the key issues as well as suggestive responses to them.

Wind Energy

Wind power produces no air or water pollution, involves no toxic or hazardous substances and poses no threat to the public safety. However, wind industries are facing public opposition due to its visibility, impacts on wildlife, noise and the threat of depreciation of its nearby properties.

Birds and Bats are among the most susceptible species endangering by the wind farm. Preliminary data shown that newer and larger wind turbines have fewer number of bird and bat fatalities in comparison to the older and smaller wind turbines. However, further comparative investigation must be made to better account for factors such as regional specie's population abundant and behaviors [9].

Also, the biggest misunderstood aspect of wind power is the use of its land. Many regarded wind plant as occupying too much space thus leading to disturbances of the estimation of its land use. In reality, the turbines itself occupy small percentage of the land while the rest can be used for other purposes such as farming or herding cattle. For this reason, wind farming is suitable for farming regions.

Aside from the onshore wind turbines, the land use is not a major factor for offshore wind turbines but the evaluation of its impact to wildlife proved to be the biggest factor. It is predicted that the wind tower's foundation can act as an artificial reef thereby increases the fish population which attracts birds and ultimately lead to more collisions of bird and the turbine's blade. Beside the bird's collision fatalities, the electromagnetic field created by the submersing cables could potentially cause a decrease in benthic communities; altering the natural environment thus affecting many animals migration patterns [8].

Solar Energy

Photovoltaic cells produce no emission during operation but the emission, health and safety issues involving how they are manufactured, installed and disposed. The production of current generation of PV's is rather energy intensive.

During normal operation, PV systems emit no harmful substance or radioactive radiation. However, there is a potential risk of a fire in an array that could release a small amount of chemicals to the environment. This is not significant on a small scale but on a larger scale such as a central plant, a release of these hazardous materials might pose a small risk to public and occupational health [10]. Preparation of an emergency response is needed in case of the accidental event.

Depending on the environmental settings, visual impact of photovoltaic system can be high in natural scenic areas. However, in the urban environment, modern solar cells can be architecturally integrated into buildings to directly supply clean electricity as well as for artistic reason. Photovoltaic panels can only be use to effectively supply low level of power such as for lighting applications. In most case, installing a small Photovoltaic generator is cheaper than to extend the main grid over long distances [10]. Larger commercial scale of PV are installed in arid dessert area which typically have fragile soil and plant communities thus scenic view destruction is not much of an issue.

Another issue with solar energy is due to its intermittent nature, backup batteries are needed to store power thus this raised environmental concern on the type of batteries used, its chemical composition and the batteries disposition processes.

Geothermal Energy

Geothermal energy is extracting heat below the earth's surface. Currently the only type of geothermal plant that is widely used is hydrothermal energy, which extracts trapped hot water or steam. New technologies are being developed to extract heat from hot dry rocks, geo-pressured resources (pressurized brine mixed with methane), and magna. Regardless of the different type of geothermal resources, they all raise a common set of environmental issues; air and water pollution are the two leading concerns.

Earlier versions of geothermal plants utilize an open loop system which was proven in a long term it can dry out the natural reservoir [11]. Observations shown that in some geothermal sites, the ground had sunk more than a few meters; this would cause land tilt, put strain on bores and pipelines, damage building and road, as well as damaging the flood control systems.

Modern geothermal plant utilizes closed loop system which circulates gas and steam up and back to the well, thus it reduces the exposure of toxic gases to the atmosphere. This system is more expensive than the conventional open-loop systems, but in long run it greatly reduces the scrubber and solid waste removal costs, therefore, provide a significant reduction in O&M cost.

Most geothermal power plant will also require large amount of water for cooling, thus in places where water is in short of supply, the issue could become quite dramatic. Also using water for coolant could potentially be harmful to aquatic life since the slight increase in water temperature could potentially be harmful to all temperature sensitive organisms.

Biomass

Biomass power, derived from the burning of organic materials, it produces CO, NOx, and PM (Particulate Matter), thus raises more serious environmental issues than any other renewable resources except hydropower [7].

The amount of pollution emitted varies by technology and the type of burning material. Wood-burning stoves and fireplaces emit the most pollution. Modern technology, enclosed fireplaces pollute much less compare to the conventional open fireplaces. Specialized pollution control devices such as electrostatic precipitators are available but it was never strictly regulated thus it's difficult verify the control its emission.

One advantage of biomass is that soybean and canola oil can be converted into biodiesel, which can be used on car to replace fossil fuel, therefore, reduce our reliance on petroleum product while the plants can be burnt to provide some electric power [12]. Un-burnt wastes will release greenhouse gas through anaerobic decay, thus if it is done in a sustainable fashion, the recycling of CO2 will be neutral or gain negative net emission; this would greatly reduce the emissions of greenhouse gases.

Another important part of biomass is deforestation; clear cutting of trees leading to massive deforestation would result in reverse gain of greenhouse gas since trees absorb CO2 via photosynthesis. Control harvest would benefit the environment if the speed of collection is smaller or equal to the rate of trees' regeneration.

Hydropower

Hydro power is known for its clean energy and emits virtually no emission. However, when dams are built it could cause radical changes in the river ecosystem in both upstream and downstream. Significant amount of methane are produced from decaying of plants in the flooded area. Salmon population declined rapidly as the smolts were forced to make longer and more difficult trips downstream and risking death from turbine blades at each stage. In addition, the longer trip will risk the smolts susceptible to predators [14].

To assist the salmon population, the environmental group demanded that hydro plant must divert water around their turbines at those times of the year during the migration of fish. Smaller hydropower plants can reduce the impacts on fish by installing "ladders" or other devices to allow fish to migrate, screens can also be installed to keep fish away from blades [15].

Despite the effort, hydropower is approaching the limit of its potential in United States. Although newer more efficient turbines can be replaced but speculation shown that the efficiency will not increase more than 10 or 20 percent [7]. The power production will also be offset by the increasing demand of water resources for agriculture and drinking. Declined rainfall and efforts to protect or restore endangered fish species will certainly driving our interest away from the hydro power systems.

V. Economical Issues

Renewable power sources will have social and environmental benefits, but the cost will always remain high. Renewable energy includes biomass, wind, geothermal and solar. Although these sources of energy may provide public benefits, but they have yet to meet the benefits and requirements of power companies since many of those utility sectors focus more on making electricity abundant and cheap. Over time, current society continues to stay with the existing technology because the environmental and social costs doesn't seem to be appealing which makes the environmental issues less noticeable. However, many of the power generations such as nuclear plants and coal generations have provide great benefits since it offers greater amount of power.

Since there has been no distinction between the cost of electricity and environmental benefits, power utilities had rejected many renewable sources. Rather, the focus was more directed toward less efficient and environmental-deadly generators, as long as it promises future profits. Although power utilities may prefer power generators that bring great profit, but as for consumers, homeowners and businesses, they would preferred to be charged at the lowest cost. Renewable power projects cannot meet their desirable rates of return since the price is often higher than traditional power generations. The chart below shows the cost for power utilities and consumers of different power generations.

Table 1: Economic factors of power generation technologies [5]

	Economic Factors				
Type of Power Plants	Cost/kWh (cents)	Cost/MW (dollars)	Initial Capital Investment (dollars)	Plant Life (years)	O&M costs (mills. Dollars/kWh)
Nuclear	12.80	1,857,143	2.6 billion for 14,00MW plant	60	0.49
Coal	5.15	4,000,000	1.2 billion for 300MW plant	30	4.59
Biomass	4.00	23,000,000	2.3 billion for 50MW plant	20	6.71
Wind	5.00	2,400,000	120 million for 50MW plant	15	<0.01
Geothermal	5.00	3,400,000	3,400 per kW	30	<0.01
Hydro	8.20	258,620	82.5 million for 319MW plant	50	2.43
Natural Gas	4.15	4,000,000	2 billion for 500MW plant	30	<0.01

From looking at the table, it is obvious to see which power generations cost the most. Power utilities will often now choose the biomass since the technology requires the largest capital investment based on each megawatt. Factoring in the life of a biomass plant, it is not high compared to other types of power generation, such as nuclear which lasts to 60 years. Other than the costs of power generations presented above, there are other associated costs regarding to the offset cost of emission.

Below is the emission table for each respective technology.

Table 2: Table of emissions vary by different types of power plant [2]

Type of power plant	Non-radioactive life cycle emissions (mg/kWh)			
	$CO_{2\text{-eq}}$	NO_x	SO_2	Particulate matter
Coal/lignite	986,000	2986	16,511	347
Oil	1,131,178	5253	81,590	128
Natural gas turbine	560,000	1477	152	34
Natural gas combined cycle	450,000	756	152	6
Nuclear	21,435	51	27	2
Hydro	22,696	23	33	5
Wind	17,652	32	54	20
Photovoltaic	49,174	178	257	101
Biomass	58,000	1325	76	269

Geothermal	18,913	280	20	0

Below are the estimated costs to remove the major type of air pollutions.

Table 3: Estimated Offset Costs for Emissions [4]

Pollutant	Cost per ton
Sulfur Dioxides (SO2)	$2,600
Nitrogen Oxides (NOx)	$11,255
Particulate Matter (PM)	$63,000
Carbon Dioxide (CO2)	$38

(Offset cost is the cost to remove the pollutants from air to neutralize environmental damage)

Values were calculated from above table 2 and 3 to come up with the cost to remove air emission from each type of generator.

Table 4: Estimation of the Break down cost to offset emission varied by the type of power plant

Type of power plant	Estimated Emission Removal cost (¢/kWh)				
	$CO_{2\text{-eq}}$	NO_x	SO_2	PM	Total $\sum(CO_{2\text{-eq, NOx, SO2, PM}})$
Coal/lignite	3.747	3.361	4.293	2.186	13.587
Oil	4.298	5.912	21.213	0.806	32.231
Natural gas turbine	2.128	1.662	0.040	0.214	4.044
Nat gas comb cycle	1.710	0.851	0.040	0.038	2.638
Nuclear	0.081	0.057	0.007	0.013	0.158
Hydro	0.086	0.026	0.009	0.032	0.152
Wind	0.067	0.036	0.014	0.126	0.243
Photovoltaic	0.187	0.200	0.067	0.636	1.090
Biomass	0.220	1.491	0.020	1.695	3.426
Geothermal	0.072	0.315	0.005	0.000	0.392

Producing power efficiently from a power generation is an issue, but offsetting the emission is another. There are many types of gases that contribute to the greenhouse effect. CO2 is one of which is emitted from the combustion of coal/lignite, oil and natural gas. NO_X is another chemical that is released by the combustion of fossil fuels and biomass. Another harmful gaseous emission is SO_2, which is emitted from coal/lignite, oil and combined cycle natural gas. Lastly, PM is the worst emission for human health, which is mainly released by coal/lignite, oil and biomass (only during their cell construction). New technology can be used to eliminate or reduce the emission of these gases, but the cost varies for each. For power utilities, the offset cost for emissions are considered when selecting the ideal power generation. In the current system, emission offset cost is not calculated in the price for consumers, but if it was, the resulting cost should be as below.

Table 5: Electrical prices after reflected by the environmental offsets cost

Type of Power Plant	Price (¢/kWh)	Price included emission offsets (¢/kWh)
Nuclear	12.80	12.96
Coal	05.15	18.74
Oil	9.00	41.00
Hydro	08.20	08.35
Biomass	04.00	07.43
Wind	05.00	05.24
Geothermal	05.00	05.40
Natural Gas	04.15	06.79

Note this is not the absolute true cost; rather it's a more accurate figures representing the minimum cost for each respective technology

From the values above, the coal and oil power generations cost much more than what consumers are paying. Although these values are good for determining the technology section, but does not reflect which is the best economical technology. It seems people are most drawn to lower prices when offered the same product. But as there is more benefit from the lower price, the environmental concern is often ignored. The incentive that exists for utilities and system operators to change the system and making the earth greener is so little. Therefore, renewable power will continue to face hurdles as long as they deal with the same administrations who seek to retain economical interest rather than concern with environmental issues.

VI. Conclusion

It is seemed like people fundamentally are attracted to low prices; when offers the same product, they would opt for the least expensive one. Although we're benefiting from the low price electric but the fact that ignoring the environmental concern can only last us for short-term. For long term sustainability, environmental cost must be considered.

Despite the ideal minimum cost figures (Table 5), we cannot select the technology as if we are buying a product. Technology adoption is based on its availability, cost, social, economical and political factors. There is no general solution for this thus it must be evaluated base on case per case basis. We must balance and diversifies technologies and recognized that no particular technology is an epic winner. However, we can say that certain technology is better use for their respective region due to its availability and different environmental variations that favors it.

Although the findings suggested that new technologies are needed, we should not pick up one or two models and say this is the future and it's the only way to go. Also, we cannot disregard the problem for the reason that our current electric bill is lower than going renewable; we need to consider the hidden costs. As we raise our awareness, we could input our contribution to the renewable energy transient process by recognizing the beneficial and destructive aspects of the energy system--instead of blindly embrace or reject the technology based on our intuition and its biased images.

Future innovation can shift the favor of technology. For instance, new innovation like introduction of a smart power grid or ultra efficient transmission line could shift the favor of adopting one technology more so than another since certain

technologies are cheaper to produce, but because of its geographic availability; it will costs more for transmission. Whatever the technology we have today, we may shift to another technology in the future if the environment permits and the benefactor outweigh its cost. This conclude that we should keep our mind open and be ready to recognize any possible beneficial changes at the same time don't let ourselves become too obsess with any particular technology.

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