COMPARISON OF ENERGY GENERATION ALTERNATIVES

Relative energy densities of various fuels by volume:

Wood:	240,000,000
LNG:	32,500,000
Coal:	24,000,000
Petroleum:	21,500,000
U3O8:	288
ThO2:	1 (naturally occurring without processing)

Comparison of the amount of fuel required to do specific work:

- 2500 MWh of useful work required.
- Efficiency multiple for LWR is 3, for coal 2.5, for LFTR 2. So need 7500 MWh thermal U3O8, 6250 MWh thermal coal, 5000 MWh thermal ThO2.

Required Fuel by Volume (in liters)

Biomass needed:	4,800,000 liters
Coal needed:	480,000 liters
U3O8 needed:	6 liters (soccer ball)
ThO2 needed:	0.02 liter (golf ball)

How much land does a wind farm require? www.renewableenergyworld.com - 18 Feb 11 - Lake Country Wind Energy, LLC and National Wind announced that 25,000 acres of land have been secured for the project. These acres represent over three-quarters of the land needed to develop the 340MW(e) community-owned wind farm. The project's goal is to sign up 30,000 acres.

The other problem with land requirements is illustrated in the Reading, UK example below. One wind turbine performs abysmally (its electrical output worth less than its government subsidy) in peak times just when its power output is needed, while another wind turbine located a few hundred meters away regularly produces electricity worth more than the value of its government subsidy. Careful studies over a protracted time are required to identify locations where wind blows at higher more frequent rates. This means that based on elevation and lines of light, far more land must be held captive by the wind farm than the turbines' footprints in order to optimize each turbine's potential production. Otherwise the improperly located wind turbine installation becomes a wasted investment as in the case of the Reading, UK example.

How much land does a solar farm require? http://www.gizmag.com - 11 June 2010 - The largest concentrated solar power (CSP) plant in the Middle East is to be built in Madinat Zayed, in the UAE. Operational in 2012, the plant features some 768 parabolic trough collectors with an area of 6,300,000 sq. feet, covering 741 acres of desert with a capacity of approximately 100MW(e).

How much land does a nuclear power plant or a coal-fired plant require? International Atomic Energy Agency, answers.com – 20 Nov 2009 – Nuclear power plants require anywhere from 1 to 4 square kilometers of land, or about the same as a fossil fuel facility. [Athlone Power Station, Capetown, South Africa, 180 MW(e) capacity on 89 acres. Wkipedia.] These relatively small land requirements are due to the high energy density of both nuclear and fossil fuel plants.

How much land does a 100 MW(e) LFTR require? Less than one (1) acre.

Build costs and resource requirements.

Deaths from generating electric power: In 2003, the death rate per million tons of coal mined in China was 130 times higher than in the United States, 250 times higher than in Australia (open cast mines) and 10 times higher than the Russian Federation. In 2007 China produced one third of the world's coal but had four fifths of coal fatalities. Many direct deaths happen in coal mining and processing. In 2007, 1,084 out of the 3,770 worker deaths were from gas blasts. – WIKIPEDIA.

Environmental Health, D.W. Moeller – "On average, the mining of sufficient coal to provide fuel for one 1,000 MW(e) power station results in two to four accidental deaths each year."

ENERGY SOURCE DEATH RATE (IN DEATHS PER TERAWATT HOUR)

Coal – world average	161	(26% of world energy, 50% of electricity)
Coal – China	278	
Coal – USA	15	
Oil	36	(36% of world energy)
Natural Gas	4	(21% of world energy)
Biofuel / Biomass	12	
Peat	12	
Solar (rooftop)	0.44	(less than 0.1% of world energy
Wind	0.15	(less than 1% of world energy)
Hydro	0.10	(Europe Death rate, 2.2% of world energy)
Hydro – (world including Banqiao)	1.4	(about 2,500 TWh/yr and 171,000 Banqiao dead)
Nuclear	0.04	(5.9% of world energy)

Based on the data given in the EU ExternE project

How much water is consumed making electricity? According to the California Energy Commission (cited in Paul Gipe's WIND ENERGY COMES OF AGE, John Wiley & Sons, 1995), conventional power plants consume the following amounts of water (through evaporative loss, omitting that water that is recaptured and treated for further use.

TECHNOLOGY	GALLONS PER KW HOUR	LITERS PER KW HOUR
Light Water Nuclear Reactors	0.62	2.30
Coal fired Plants	0.49	1.90
Oil	0.43	1.60
Combined Cycle Gas	0.25	0.95
Concentrated Solar Power (Cleaned w/distilled water)	0.20	0.76

The LFTR does not use water to cool the reactor core, nor to moderate the neutron flux (as with LWRs), nor to drive the electricity turbine (as do conventional coal and nuclear power plants).

How does electricity get from the generator to the user? Giant nuclear and fossil fuel plants are located near the resources (water, coal) that they need: A 1000 MW(e) coal or LWR power plant will require 600,000 gallons per minute of river water, or it will evaporate 20,000 gallons per minute of water to remove dangerous, unwanted waste heat. A 1000 MW(e) coal fired power station requires 230 car-loads of coal every 30 hours. A 1000 MW(e) PWR nuclear power plant requires six 18-wheeler tractor trailers of 30-ft. uranium fuel rods once every 18 months.

By contrast, a 100 MW(e) LFTR will require 100 kg of fissile material (^{235}U) to startup, and 10 kg of Thorium Oxide per year to fuel it.

In South Africa, coal plants must be located up in the north of the country where coal fields are located hundreds of kilometers from their population centers. A 500,000-volt long distance transmission line – the standard infrastructure configuration for electricity long-haul – takes from 5 to 10 years to complete (depending on distance), at a cost of $1.5 million per 1.67 kilometers. Such 500 kV alternating current (AC) transmission lines are limited in how far they can transmit power, typically up to 885 kilometers, and they lose a significant amount of power, about 7% of capacity, in transit. Transmitting at higher voltages (756Kvolts, 1MV) results in lower capacity losses per mile, but requires more HV transformers, as CapEx increases exceed OpEx reductions.

By contrast, the 100 MW(e) LFTR and its Brayton gas turbine will be co-located on less than an acre with its local power grid customer – no long-haul HV transmission lines will be required.

How does the open cycle gas turbine (OCGT) compare as an energy alternative?

The Deir Ali Station is comprised of a group of OCGTs producing 750 MW(e).

An OCGT is a combustion turbine plant fired by liquid fuel to turn a generator rotor that produces electricity. Without a steam cycle OCGTs are installed as peaking capacity. The delicate balance of generation (supply) and load (demand) on an electricity grid continuously fluctuates, on varying timescales as industrial and household demands ebb and flow throughout a day, a week, or a season.

Generation must adapt where and when it is required. A power grid requires load following, peaking power, and base load power. Nuclear and coal plants are typically relied on to meet a grid's continuous energy demand, and they can produce electricity inexpensively at a constant rate. The grid must add additional generation to available base load to meet moment-to-moment demand in the grid – this is known as 'load following' with 'peaker' plants such as the OCGT.

The thermal efficiency of OCGTs is much lower than nuclear or coal base load plants. The high running cost per hour is offset somewhat both by the low capital cost as well as the intention to run such units only a few hundred hours per year.

To illustrate, South Africa's Ankerlig power station, an OCGT, has nine units of 150 MW each, giving a total of 1350 MW. It is a peaking power plant, meaning it is operational for only 6% of the year and uses diesel to produce power.

An Ankerlig OCGT running diesel costs R 3.00 per kWh, 7.5 times more expensive than Eskom's average electricity cost of R 0.40 per kWh. Ankerlig's nine OCGTs use an average of 40-million litres of diesel a year, but this is consumed while they run just 6% of the year.

One can only imagine how much diesel the OCGTs will require when their peaking power becomes the backup to wind farms that generate power only 25% of the time.

By contrast, the 100 MW(e) LFTR will sell electricity at USD 0.09 per kWh into the market of 2015 which is estimated to reach an average of $.15 per kWh plant cost of base-load (peak load will be sold at a premium in 2015). (*OCGT data from Dr. Philip Lloyd, Energy Institute Cape Peninsula University of Technology, RSA*)

Summary

- The LFTR will be co-located with the local power grids it serves in less than a hectare of land.

- The LFTR requires no water in any part of its operation.
- The LFTR requires no giant concrete and steel containment vessels to control high pressure.
- The LFTR is assembly-line manufactured, imported from India and assembled in less than 3 months.
- Thorium, LFTR's fuel, is 4 times more plentiful than uranium globally.
- The LFTR burns up all but a tiny portion of its long-term radioactive transuranic isotope products.
- The LFTR can be started up with spent uranium fuel from other nuclear reactors.
- One pound of thorium can produce as much energy as 3 million pounds of coal.
- One ton of thorium used as fuel in a Liquid Fluoride Thorium Reactor can produce as much energy as about 200 tons of uranium used as fuel in a 3rd Generation Light Water Nuclear Reactor.
- One 3.5" diameter ball of thorium, about the size of an extra large apple, could produce an amount of electricity equivalent to the yearly consumption of one average American for about 8,000 years.

The cost of implementing a LFTR has been provided in the Protocol Agreement. It includes:

In general, SAL currently estimates the cost of each LFTR procurement is as follows:

- $255.75 million for the reactor the sub-systems, and the closed gas generator sub-system
- $6 million for a full operations / maintenance suite of equipment
- $1 million for 100 kg fissile startup load
- $150,000 annually for 10 kg fertile fuel load for first year
- $3.5 million for core / blanket salt compounds and first year operations
- $12.4 million for site preparation per LFTR

Total: SAL Commitment per LFTR at installation: $291.2 million

Operating a single LFTR will cost about $3.5 million on a standalone basis, but installations involving multiple LFTRs the operations cost may achieve 10% to 15% reductions from economies of scale.

Review of Wind Farm Representation in the "Comparison Between (Deir Ali Open Cycle Gas Turbine workstation and a Wind Farm to Generate Electric Power of 750 MW(e)".

The Wind Farm is represented as having a "name plate capacity" of 750 MW. The daily production assumption of 9.5 million kilowatt hours represents a 57.8% availability of the 100% of the "name plate capacity" of 750 MW for a 24-hour period.

This is not possible.

Wind turbines start producing electricity at a wind speed of about 6 mph (10 km-ph), reach their rated capacity at about 32 mph (53.3 km-ph), cut out (to avoid damage) at about 56 mph (93.3 km-ph), and restart about 45 mph (75 km-ph). Much of the time they produce no electricity or only small amounts well below their rated capacity. (G.R. Schleede, True Cost of Wind Electricity)

What is the cost of electricity from Wind? Those asking this question seek a simple way to compare the cost of electricity from wind with the cost of electricity from other sources. The cost of electricity from wind should not be compared with the cost of electricity from reliable generating sources because the VALUE of electricity from wind is much lower.

The VALUE of electricity that is produced by wind turbines is much lower than the value of electricity from reliable generating units because wind turbine output is intermittent, volatile, unreliable, and most likely to be produced when least needed and thus wasted as utility scale electricity cannot be stored effectively except with large hydroelectric dams.

Electricity must be produced as it is required by customers. Demand for electricity by customers varies widely by time of day, day of week, season of the year, prevailing weather and temperature, strength of the economy, among other factors.

Reliable generators must be available or operable and have necessary fuel so that they can produce electricity when their output is needed.

Dispatchable generators must be subject to the grid manager's control so that it can be brought on line into production or taken off line, stopping its production, and for a generator on line, it can be ramped up or down, increasing or decreasing its output of electricity.

A wind turbine's "rated" or "nameplate" capacity is expressed in terms of kW or MW which is a measure of the amount of electricity that could be produced by the unit at an instant in time if the unit was producing at full capacity. Regardless of their "nameplate" capacity, wind turbines cannot be counted on to produce any electricity at the time it is most needed, i.e., when electricity demand reaches peak levels. Therefore, wind turbines really have little or no real "capacity value", as that term is used in the electric industry. **Cases in point**:

(http://www.telegraph.co.uk/journalists/nick-collins/ "The 280 ft. turbine situated in a business park near the M4 in Reading, UK operated at just 15 percent of its capacity year, meaning it generated £100,000 of energy, despite attracting subsidies of £130,000 from the Government. Since 2005, when it began producing energy, the turbine has been subsidized with £600,000 of public money but has run at an average of 17 percent of its capacity…"

"Application 09-12-002 (Dec 3, '09) of Pacific Gas and Electric Co. for Approval of the Manzana Wind Project

"…This decision rejects the application of the PG&E for approval of and issuance of a certificate of public convenience and necessity for the Manzana Wind Project…a unity-owned renewable generation wind farm and to recover the $911 million costs of the project in electricity rates. We reject the application because we find that the Manzana Wind Project is not cost-competitive and poses unacceptable risks to ratepayers. We find the proposed cost of the Manzana Wind Project is significantly higher than other energy resources PG&E can procure to meet its RPS program goal. Moreover, it will subject ratepayers to unacceptable risks due to potential cost increases resulting from project under-performance, less than forecasted project life, and any delays which might occur concerning transmission upgrades…paying a lump sum cost rather than a performance based cost, the ratepayers would be at risk if the project underperforms. ***State of California Public Utilities Commission 21 Dec 10"***

Engineering News Online, Dr. Kelvin Kemm, 17 Sep 10 *– "…There is no technology breakthrough on the horizon for wind that will suddenly reduce its cost by one-half or more. I have a colleague in Germany who lives near some of these large wind turbines and he tells me of houses in the area havin developed large cracks owing to the low-frequency vibrations transmitted through the ground from the wind turbines. My Associate in Germany tells me that the price of coal-fired electricity has gone up in some areas as a result of wind energy – as soon as the wind blows, they remap the coal-fired electricity down to make sure of the wind. When the wind stops, they rapidly bring the coal-fired electricity back on line. This is the most inefficient way to sue coal-fired electricity and so its costs have increased. I believe* *that any future value for wind energy in South Africa will be in standalone systems designed to take the intermittent nature of wind into account. These would typically be small systems in towns or villages that could feed a pumped-storage 'battery' and then use the stored electricity at peak- demand times. I do not see any future for wind power in South Africa that feeds directly into the national grid. I believe that we should scrap this idea right now, before it wastes resources that could be better employed elsewhere…"*

The Scotsman, Jane Bradley, 27 Dec 2010*: "…Scotland's wind farms are unable to cope with the freezing weather conditions – grinding to a halt at a time when electricity demand is at a peak, forcing the country to rely on power generated by French nuclear plants… Output from major wind farms fell to as low as 2.5 percent of their potential generation capacity during the cold snap as power demand rose to close to the highest level yet recorded, new figures have revealed. Meteorologists say extremely cold temperatures can occur only when there is little or no wind and icy pockets of air are trapped close to the ground. The Balancing Mechanism Reporting System website, used by the National Grid to monitor UK power generation, revealed that at times when wind energy was at its lowest, back-up power had to be piped in from France, where the majority of electricity is nuclear-generated."*

Because electricity from wind turbines depends on availability and speed of wind, grid managers must always have immediately available enough reliable, dispatchable generating capacity to keep grids in balance as wind turbines start producing, vary widely in output, or stop producing.

Providing balancing and backup capability for intermittent, volatile, and unreliable wind turbine output involves cost that is properly considered a part of the cost of electricity from wind. Units that are available to bring on line are likely to be running n "spinning reserve" mode – connected to and synchronized with the grid but inputting little or no electricity. Their costs are really a part of the true cost of electricity from wind.

Electricity from wind results in higher costs of transmission. Areas where winds are sometimes strong enough to power wind turbines are often located at considerable distance from areas where electricity is needed – the "load centers". Furthermore, "wind farms" are not welcome near residential areas, even if wind conditions may be adequate, because of the large size of the wind turbines, their noise and other environmental damage – and because of their adverse impacts on property values.

Sufficient transmission capacity must be available to serve the full rated output of a "wind farm". However, because wind turbines product at full rated capacity only wind speeds are about 32 mph (53.3 km-ph) or higher, the full transmission capacity is used only n a minority, part-time basis (that is, usually less than 30% of the time). The effect of this is that the unit cost per kWh is higher because of high transmission cost on fewer kWh. Wind farms are also bing built where there is no transmission capacity – meaning expensive new transmission capacity msut be built just to accommodate the wind farms. This is properly attributed to the cost of the electricity rom wind.

Key factors that cannot be known n advance are:

- Total operating and maintenance (O&M) and replacement costs
- Useful, productive life of the wind turbine
- Amount of electricity (kWh) that will be produced during the useful life, taking into account turbine and equipment out of service time, and deterioration in output as turbines, blades and other equipment age.

Comparison of Energy Generation Alternatives

None of the wind turbines of the type now being installed have operating histories long enough to provide valid, reliable estimates for these factors.

Furthermore, producing electricity with wind energy imposes external costs, including adverse impacts on environmental, ecological, scenic, and property values. These include noise, dead birds, and bats, destruction of vegetation and disruption of ecosystems and wildlife habitate, and nuisance impacts such as shadow flicker.

Comparative Analysis of Cost per KiloWatt Hour

GAS TURBINE @ 750MW nameplate capacity w/ 11K-MWh/day Output:
Cost per kWh for OCGTs at Deir Ali: **.1167 EUROs/kWh** **USD 0.16/kWh**
Plus cooling costs, existing transmission infrastructure charges against electricity produced & transported
Plus Land Costs.

Wind Farm @ 750 MW nameplate capacity
Cost per kWh @ 25% Output + OCGT Backup To reach equivalent OCGT 11K-MWh/Day Output: **.0895 EUROS/kWh** **USD 0.124/kWh**
Plus New Transmission Infrastructure Costs Amortized against 25% utilization @ USD$ 1.5 million per 1.67 kilometers.
Plus diesel or gasoline startup engine fuel. Maintenance cost is understated as no modern wind turbine has sufficient Mean Time Between Failure statistics on system and components.
Plus Land Costs.

LFTRs @ 90% Capacity: **.06 EUROS/kWh** **USD 0.09/kWh**
No cooling costs, No Transmission Costs
Plus Land Costs.

All build costs are amortized over 20 years at 8% per annum financing costs.

Calculations and references available for review.