The Design of De-Centralized, Renewable Energy Plants.

The fundamental requirement for this design is that it be able to produce an uninterrupted supply of high quality power under all conditions whatsoever. For this reason it includes diverse sources of renewable energy.

These are:

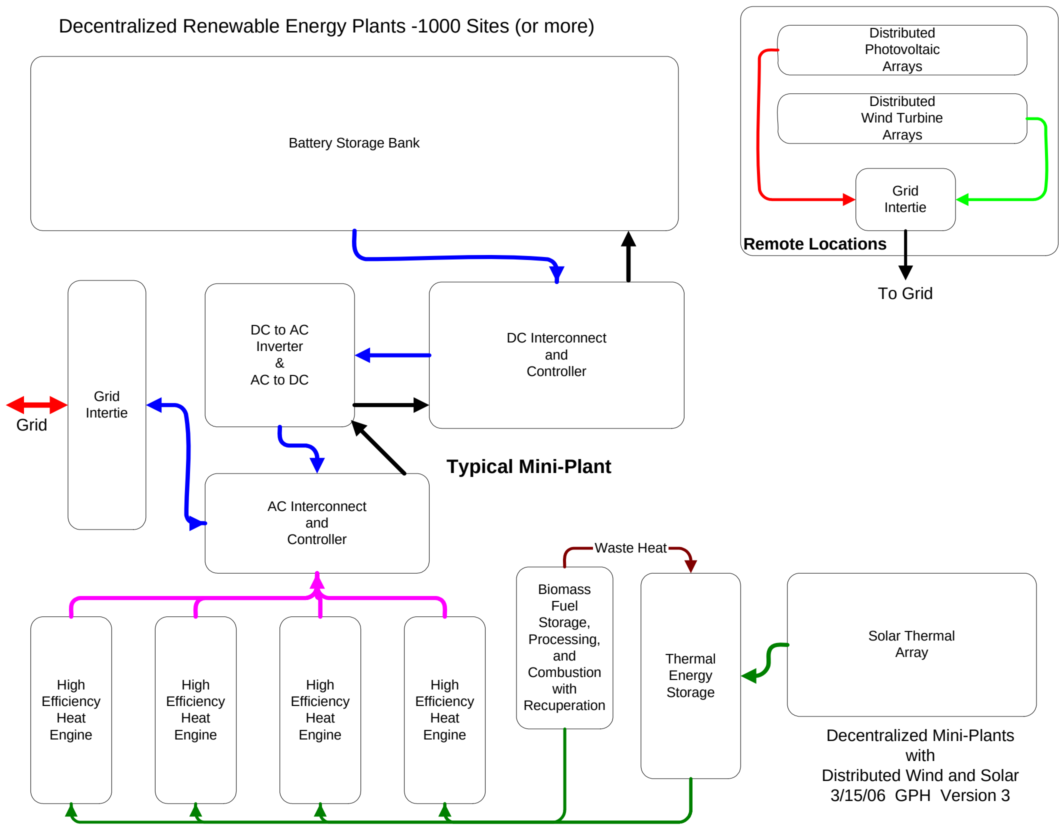
Solar Photovoltaic

Wind Turbines

High Efficiency Heat Engines fueled with either Biomass or Solar Thermal Energy.

Each of these sources would be sized appropriately to be able to supply the full rated output of the plants.

Below is a schematic of the typical decentralized energy plant.



In addition, large banks of storage batteries would be provided. These would be used to smooth out moment to moment fluctuations in the power output of the plant. Such fluctuations would occur during a wind gust for example, or during a period when a cloud drifts in front of the sun, momentarily reducing the output of the solar array.

These batteries would also provide the needed output during the period needed to start up the Heat Engines, following the setting of the sun, or a sudden drop in the wind, or the like. They would be sized to provide full plant output for an hour, which is more than sufficient time for this purpose.

Under favorable conditions, when both sun and wind are available, even higher levels of power would be available than the rated output of the plants. Besides recharging the batteries, this means that very large amounts of power would be available for export via the grid to other areas. In this way, by sharing power between plants, it is expected that use of the Heat Engines may be kept to an absolute minimum.

The Heat Engines, when burning biomass as their fuel, are still carbon neutral, and thus do not contribute any harmful carbon dioxide gas to worsen global warming. They also provide a guaranteed market for our Nation's farmers to sell excess biomass products at a good price.

The rated power of the plants, and the total number of plants, will be designed such that several times the present day energy needs of the country for all purposes combined, are available. This allows for a very large growth in energy consumption in the country, without any need to redesign the system. In this way, the design will be seen to be adequate for the needs of several generations without replacement or redesign. Only periodic maintenance and repair will be needed.

Since only minimal amounts of biomass fuel are needed, and since solar and wind power are free, this means that the combined costs of operation, once the plants are built and paid for will be very minimal. This in turn means that power will be extremely inexpensive, and essentially unlimited in its availability.

It is estimated that the present rate of US energy consumption – for ALL purposes – is about 3.345 Terawatts. We would design for several times this need. Then divide the resulting total by the total number of plants desired. This would give us the needed output capability for each plant. Then each plant would be conservatively designed to easily generate its assigned output.

For example, suppose we design for 10 times the need. This would be about 33.45 Terawatts. Then divide this among 1000 plants. This would yield a requirement of 33.45 Gigawatts per power plant. If a larger number of plants are built, each can be smaller. This is just an illustrative figure.

With this as a target goal, then we will develop below the details of how much solar and wind energy, heat engine capacity, battery storage, and so forth will be required in each plant.

The basic requirement for capacity will be driven as follows. Each of the two primary resources, that is wind and solar, will each by itself be able to supply the entire required output. The reason for this is obvious, as the Sun never shines at night, nor does the wind always blow when desired. Thus we will often have one source but not the other.

The third source, the Heat Engines, must likewise be able to carry an appropriate load when necessary. However, it may not require the same degree of over design as the solar and wind resources. This is because we will attempt first in all cases to avoid the burning of fuel in favor of using free power, shipped in via the grid from other plants. Thus perhaps instead of being over designed by a factor of 10, as given above for the other two sources, a factor of two may suffice. This allows much long term growth, as well as ample downtime for maintenance, while still meeting the needs.

Thus, in summary, each of the power sources is to have a rated power generation capability as follows:

> 33.45 Gigawatts of Solar Photovoltaic per PV site.
>
> 33.45 Gigawatts of Wind per wind Site.
>
> 6.690 Gigawatts of Heat Engine Generation from Biomass and Solar Thermal Collectors.

Several high efficiency heat engines will be provided at each engine location. Together they will combine to produce their needed total output.

It is expected that some use of the Heat Engines will be made on a daily basis. It is too much to hope that there will always be enough wind or sun at every moment. On the other hand, the full output of all Heat Engines combined will seldom be needed. This means that these engines can be operated flexibly as required, with only one or two operating, and more brought on line if and when needed. All engines will be used on a rotating basis, to equalize wear, and assure that all are exercised and known to be in good operating order at all times.

It is clear that not all of these resources will be co-located. That is, although our example cites 1000 plants, each plant would be further split up by resource.

That is, wind power generation would be done at sites best suited for that purpose. That is, sites which are endowed with an excellent wind resource. They must also be spaced sufficiently from other development to avoid concerns about noise, safety, and the like.

PV sites have more flexibility by far. Much of the PV resource can be located on existing and future buildings. Every building has a rooftop for instance, and can have some of the resource distributed there. Other good locations are covered parking areas, as well as actual field installations. More focus can be placed on PV installations where the resource is better, while wind can be emphasized at other sites.

The other components, such as batteries and thermal engines, tend to need more professional attention on a regular basis. As such they should be located on small mini-sites where fuel can be stored for them, and maintenance and upgrades can be easily made. This also provides many sites from which the total resource on line can be monitored and controlled. The engines can thus be brought on-line as needed, in a timely way. And battery capacity can be added to at sites where experience shows it to be inadequate.

Solar Photovoltaic Power.

Solar Photovoltaic power is the most reliable source of power we have in our power mix. That is because the Sun shines every day without fail. Naturally, on some days the sky is overcast. But even on those days, modern solar cells are quite capable of providing a very useful amount of output. The obvious design procedure is to design for the overcast days, and then have a surplus on other days.

In line with this design philosophy, we assume that there are only 300 watts per square yard of solar energy available. We further assume that the cells used are only 15 % efficient. This gives us a solar yield of 45 watts per square yard. This value is extremely conservative.

There are 3,097,600 square yards in a square mile. This means we can expect a yield of 139,392,000 watts per square mile. This is 0.139392 Gigawatts. So each of the 1000 sites must have a distributed covered area of 239 square miles. This is a space of about 15 x 15 miles, located mostly on building facades and roofs.

To continue our example of 1000 sites nationwide, this means that each solar site must have a total capacity of 33.45 Gigawatts. This capacity can be located all over the place, on existing buildings, on new buildings, in fields, and so forth. So while we are calling this a PV “plant” it will actually be totally distributed over a large space per site. In the 1000 such spaces nationwide, the entire required amount of PV power needed for the nation will be produced – for all forms of power, not just the electric power, but power for heating, transportation, and so forth.

Where possible, the solar cells will be mounted on Sun tracking mounts, that track the passage of the sun in two dimensions. This will maximize the output of the panels at every point in the day, and at all seasons. In addition, maximum power point tracking solar inverters/controllers will be used, which will ensure that the maximum possible amount of energy is extracted from the cells at every point during the day. The mounting of the cells well above the ground will ensure abundant cooling for the cells, which minimizes their operating temperature and thus maximizes their output.

On most days, the output of the solar arrays will exceed their design ratings. This excess power will be available for export to adjacent areas via the grid.

Wind Power.

On 1000 sites nationwide, we will locate wind turbines which are capable of providing an output of 33.45 gigawatts of energy per site. Since the wind resource at each site will not necessarily be perfectly optimum for wind generation, in general it will be essential to use Turbines whose design has been optimized for low wind speed power generation.

This means that sufficiently tall towers must be used, to keep the hub height of the turbine well above ground level. In addition, longer blades will be used, giving a greater swept area per turbine. And finally, the blades will be shaped optimally for the wind speeds expected.

Modern turbines, rated at 4 megawatts each will be used. To achieve 33.45 gigawatts of output, we will employ 8,612 turbines at each site. They will be spaced appropriately, which will minimize any interactions.

On most days and nights, given the height of the towers, and the optimization of the designs for low wind speeds, the wind array will be able to produce a very large percentage of its rated output. To ensure that an even greater percentage of rated output is available, we will employ a surplus of turbines above that required to just meet the rated output. A starting point for this would be to employ 10,000 turbines at each site.

On favorable days and nights, the array will thus be capable of producing a surplus of power, above its rated value. Since this surplus will be unneeded locally, it will be available for export to the grid, to make up for any shortfalls at adjacent plants.

Again, even though we imagine 10,000 turbines to be associated with each of the 1000 plants, these can be further distributed throughout the area served by the plant. This means that they will likely be divided up into several smaller wind farms, each located in an optimum wind location to the extent possible. Many will be located offshore, out of sight of land.

Energy Storage in the Batteries.

Obviously, the power provided by each facility has to be absolutely stable and reliable. The frequency and voltage must be held constant, and sufficient wattage must be available at all times.

There will be both short term and long term fluctuations in the availability of wind and Sun of course. Long term shortages, such as calm winds for a whole day, and of course, lack of sun at night, will be accounted for by the Heat Engines. The short term fluctuations, such as wind gusts (both up and down) or clouds drifting in front of the Sun, will be handled by the battery storage system.

Sufficient energy must be stored in the batteries to accommodate any conceivable short term fluctuation, as well as to provide backup power while the heat engines are started at the beginning of a long term fluctuation.

Since the rated TOTAL output of each plant is only 33.45 gigawatts, then to provide two hours of backup power, we need at total battery storage of 66.9 gigawatt hours of energy.

This is no problem. There are 1000 amp hour batteries, with 48 volt outputs, readily available for this use. Thus each single battery provides 48,000 watt hours of storage. We thus need 1,393,750 batteries per site.

This is no big deal. Stacked 4 high, this is an array of about 590 x 590 batteries. Since each battery needs just over a square foot of space, we need about 350,000 square feet of storage space, which is simply the equivalent of a large shipping warehouse.

Obviously, additional batteries will be provided to ensure that drawing the rated total amount of energy from the battery reserve will not totally discharge the battery bank, thus damaging it or shortening its life. The real total battery bank size thus will be about 1,500,000 batteries.
Since the total energy draw will not in fact be 33.45 gigawatts, given the over design of the system, this means that battery power alone will be able to sustain power output for many hours in a typical scenario. In fact, some modest amount of power will even be available from the batteries for export to the grid to

adjacent areas, for a modest period of time. This will ensure rock solid stability of the grid in the face of extremely adverse circumstances.

As mentioned previously, the batteries will be located at the mini-sites, where centralized management and maintenance is available for them.

Backup Power from High Efficiency Heat Engines.

The heat engines will of course be used at those times when the other sources are just not available in sufficient quantity. This may happen regularly, but the total capacity of all the available heat engines will almost never be needed. Rather there will generally be a need to use only one or two of them, which can be done on a rotating basis to equalize wear and assure maximum availability.

Energy for the Heat Engines will either come from burning of Biomass, or from the Solar Thermal Collectors. Both of these sources will be able to recharge the heat storage tank, so that Biomass will only have to be used when the heat storage is depleted. This will further reduce the amount of Biomass that will actually be used.

Biomass is an excellent source of energy. It can be produced in any quantity needed at reasonable prices by our nation's farmers. It is renewable, with an essentially infinite supply thus available over time. It is carbon neutral. And, there is little or no release of other pollutants, such as sulfur, since biomass is free of these impurities.

The Solar Thermal collectors may be of the Solar Trough design or the Parabolic Dish design, depending on the temperatures needed by the heat engines. Once heat is collected, it will be either sent directly to the heat engines, if they are running at the time, or it will be stored in the heat storage tanks.

To use the various heat sources effectively, we will require a high efficiency Heat Engine.

The basic heat engine design will consist of the following elements:

A Universal, External Combustor.

This will be designed to accept a very wide range of biomass fuels and burn them efficiently and cleanly. There will be a fuel feed system that will grind up the biomass and feed it into the combustion chamber at the proper controlled rate.

A Heat Recuperator will be used to vastly increase the thermal efficiency of the system. This will pick up waste heat from the exhaust of the combustor, and recycle it back to the input of the combustor, preheating the incoming combustion air.

Stack scrubbers and catalytic converters will be use to totally clean the exhaust.

Solar Thermal Collectors and A Heat Transfer System.

This will collect the heat from the combustor or the solar collectors, and transfer it to the heat engine.

The Heat Engine Itself.

These basic components will be used to build an array of several Heat Engines at each site. Together they will add up to the required capacity of 6.690 gigawatts. One or two extra engines will be provided, to allow for maintenance or other unexpected downtime.

Using an array of smaller engines allows them to be brought online one at a time, as their capacity is needed. They can likewise be disconnected sequentially, as the need is reduced. This is much more efficient that using one or two huge engines to meet the load.

Redundancy of this sort keeps the system reliability extremely high. The failure or unavailability of one or two engines will not imperil the overall system.

Note that heat engines are very fast to start up and shut down. This greatly facilitates load management.

As mentioned previously, these engines will also be located at the mini-sites, where they can be maintained, fueled, and operated properly.

The Power Grid.

Obviously, with 1000 major power generation sites nationwide, the power grid will have to be significantly enhanced, to enable efficient distribution of the power.
It is very clear that new transmission lines will have to be built. They will have to interconnect the 1000 sites directly or indirectly, to facilitate power sharing. And sufficient grid capacity must be provided to allow for redundancy. The blackout scenarios seen recently in the Nation must be avoided in the future.

Fortunately, in this country we already posses a very large and well developed power grid. Much of the required expansion can be accomplished by improving the existing grid.

There are three extremely effective strategies for improving the existing grid by a factor of many times over. These are:

Moving to Higher Voltage Lines.

Most of the existing lines, particularly in local and regional grid segments, operate at far less than the optimum voltages. These lines can easily operate at two, three or four times their present voltage levels, with the proper modifications of course.

At the same time, the intent would be to avoid the use of the controversial Super High Voltage lines. They will not be necessary with this scheme.

Paralleling more Lines Together.

In the existing grid, for every one run of wire, or line, add two or three additional wires in parallel. This can be done in the same space, with suitable modifications to the support structures and insulators.

Upgrade all Transformers.

Essentially all the large transformers on the grid would be replaced. In their place, new transformers designed for the higher voltages and wattages would be used. These would also be more reliable modern designs, that would be far less likely to fail. They would also permit modern, remote control strategies to be used, further improving the grid.

Obviously, by making an average 3 fold increase in voltage, and using an average of 3 lines in parallel, the capacity of the grid would be increased by 9 fold. By adding new transmission lines in addition, the required capacity can be realized. This grid will also be more stable, reliable, and controllable.

Using the Power Effectively – for All Power Needs.

Electrical Energy is the highest quality energy type, and the most flexible in its use. It can also be readily converted to other forms as needed. Since an essentially infinite supply of Inexpensive electrical energy will be available, some level of inefficiency in power conversion is acceptable, although proper design will minimize this.

The following notes illustrate briefly how electrical energy will be used effectively to meet the various kinds of energy needs.

Heating

Electrical heat would be the heating system of choice. This is because electric resistance heating is 100 % efficient. All energy delivered to the heaters is converted into useful heat.

In addition, with a power factor of 1, there is no waste circulating energy in the power grid. This reduces transmission losses and the need for excess generation and transmission capacity.

Since in this scenario, electricity would be cheap and plentiful, the present premium paid by users of electric heat (compared to say, gas heat) would be eliminated as well.

Lighting.

Compact fluorescent bulbs would be the lighting source of choice. Plentiful supplies of electricity would make these a very economical and energy efficient source of light.

Fluorescent bulbs also generate less waste heat energy. This would limit cooling loads in buildings.

Modern, natural color fluorescent bulbs give a more natural light than the older lamps they replace.

Finally, these lamps have extremely long useful life spans.

Business.

The greatest benefit to business would be the stable, predictable, financial conditions. Businesses thrive best under such conditions.

By eliminating pricing uncertainty from energy costs, the ability of businesses to grow and to raise capital would be greatly enhanced.

The low cost of energy would translate to higher profits. Lower costs also mean better international competitiveness.

Investors would also benefit, as the value of their investments appreciates over time.

The present negative effects of energy speculators would be eliminated as well.

Manufacturing.

Plentiful, cheap electricity would especially benefit manufacturing, by greatly reducing a major cost component of US manufactured goods. This would lead to a competitive advantage. This is turn would lead to the creation of more jobs and to greater profits.

The security of supply would also be a major benefit. Lenders will be more likely to finance long term investments in plants and capital goods if a long term advantage in the marketplace is assured.

Transportation.

For transportation needs, a portable energy source is obviously needed. It is clear that direct connection to the grid is useless for this need. Some forms of transport, such as automobiles, can run effectively directly on electricity, which they may obtain initially from the grid, and then store on board in batteries. Other forms of transport cannot employ this approach.

It is in these latter cases that hydrogen fuels may play a productive role. Hydrogen is not an energy source. Rather, it requires the use of energy to produce useful forms of hydrogen.

To produce hydrogen renewably, the plentiful grid supplied electric energy from wind and sun will be used to run hydrogen electrolysis plants. Thus no fuel source is involved. The hydrogen is broken down from sea water. The low cost of the electricity used, and the complete absence of the use of any carbon based fuel make this approach extremely attractive.

This hydrogen can then be used to power autos, trucks, trains and the like. This leaves only a small number of cases where higher energy storage density is essential, such as in the case of aircraft, where fossil fuels may still have to be used. Such a small usage of fossil fuels is considered acceptable. One could also consider using carbon neutral fuels such as Ethanol or BioDiesel in these cases.

Note that it has already been demonstrated elsewhere that neither Ethanol or BioDiesel can be used as the primary transportation fuel, in place of hydrogen, since it is manifestly impossible to produce enough such fuel with the available farmland and other resources.