The Renewable Energy System Equation

A White Paper on behalf of potential purchasers of Renewable Energy Powered electrical generation equipment

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1 Executive Summary

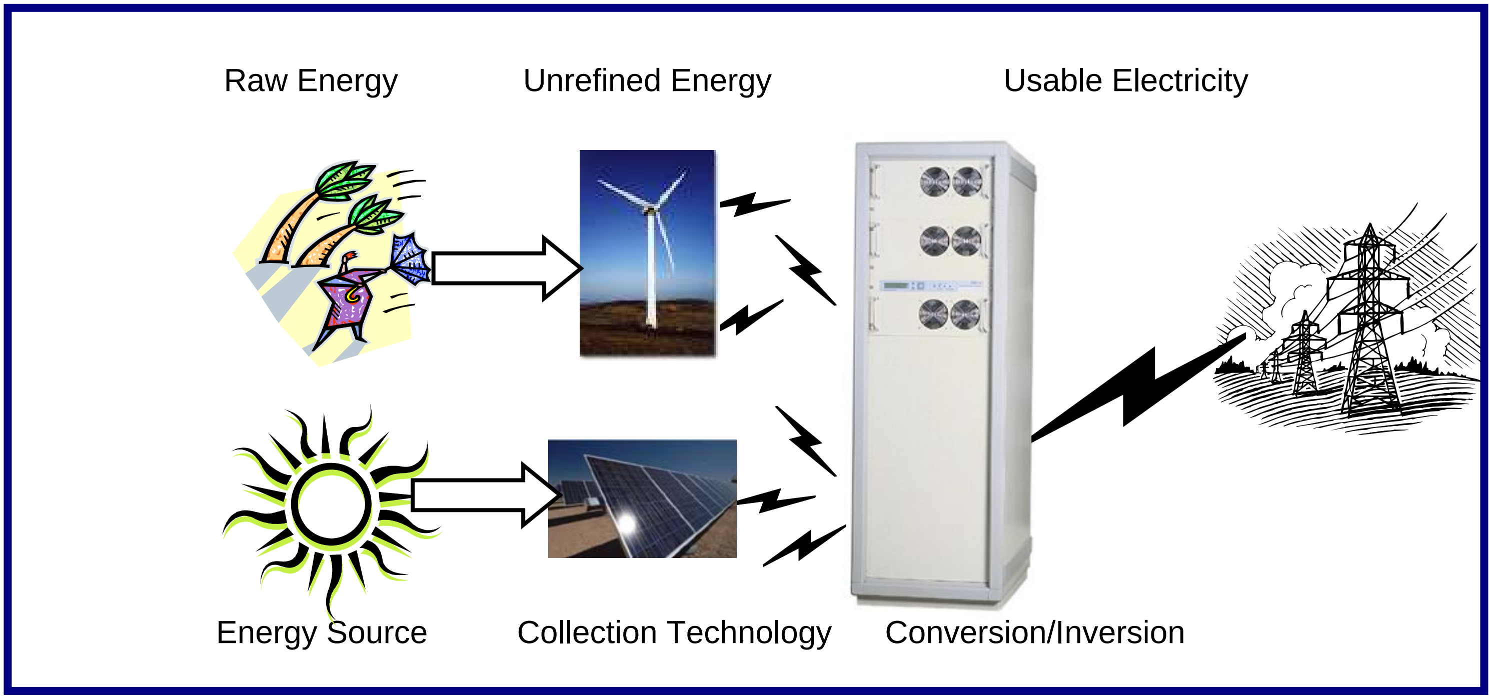
Just as a car is more than just an engine and a house is more than just a furnace, a Renewable Energy system is more than just a wind turbine or solar panel. The Renewable Energy System has a single purpose (to generate electricity) but has many components with many independent functions. To maximize the profit (“ the Yield “) of any Renewable Energy System, one must be cognizant of the *Renewable energy system equation.*

This Equation is a completion of earlier relationships which dealt with only Wind power. With the advent of modern Hybrid systems, the full relationship between all forms of Renewable Energy and the output electricity yield needs to be explored and explained.

2 Some Terminology :

1. **Raw Energy** – the Renewable Energy Resource being captured
    a. the wind speed, intensity, density and duration at the turbine's location
    b. The amount of sunlight reaching a solar panel's location, usually expressed as Insolation - the amount of solar energy received on a given area over time measured in watts or kilowatt-hours per square meter (kWh/m2).
    c. The speed of water moving along a river
    d. Other Renewable sources as available.
2. **Collection Technology** or Collection Device – the mechanical/electrical device which captures 'raw' energy (wind, sun, water movement)
3. **Unrefined Electricity** – the electricity as produced by the Collection Device(s) – normally in a form which cannot be directly sold to the grid or used by consumers
4. **Nameplate Ratin**g – the advertised output of the Collection device under "perfect" conditions. This is usually a measure of Unrefined Electricity
    a. a wind turbine might be advertised as 1 MegaWatt or 5 Kilowatt
    b. a solar panel might be described as 170 Watts peak
    c. a biogas turbine might be rated at 300 Kilowatts peak
5. **Usable Electricity** – electricity converted to a format which can be used (sold)
    a. For an Energy Park©, selling electricity to the grid, this will be defined as 60 Hertz (cycles per second) (in North America) at a particular voltage, say 27,600, or 4800.
    b. For use in a factory or other building, this will be defined again at 50 or 60 Hertz, and at a particular voltage, for example 120/240, 120/208 , 240/380 277/480, 600/347 etc.
6. **Conversion/Inversion** – the process of converting Unrefined Electricity into Usable Electricity
7. Harvest or **Yield** – the number of KiloWattHours (kWh) of electricity generated per year. Since electricity is sold in units of KiloWattHours this is the most critical measurement.
8. Usage Factor – the means of predicting and then measuring how efficiently (or **completely**) the Raw Energy was converted into Usable Electricity.

The Renewable Energy Production Process



3 The Renewable Energy System Equation

$Y_n = R_N * \theta_N * \Sigma_H$

and

$\Sigma_Y = SUM (Y_1 + Y_2 + Y_3 + Y_4 + \ldots)$

Where :

Y_n = the yield of any one Collection Device in KiloWattHours per year
Y = the yield of the Renewable Energy System in KiloWattHours per year
R_N = the Nameplate Rating of each Collection Device
θ_N = the Usage Factor of each Collection Device
Σ_Y = the Total Yield of the System, in KiloWattHours per year
Σ_H = the Total number of hours in the year (365 x 24 = 8760)

3.1 The Goal :

To maximize $\Sigma_{Y,}$ the Yield, under the following constraints :

1. the Raw Energy is not controllable - the wind, water, sunshine do what they will do – while we can statistically "expect" their performance, we cannot alter it.
2. We would prefer not to increase $R_{N,}$ the Nameplate rating of the devices, because that increases the capital cost of the system
3. Σ_H , the operating period of the system is fixed – 24 hours for each of 365 days

Thus, the only factor over which we can (or should) exercise control is θ_N ,the Usage Factor of each Collection Device

3.2 θ_N - Usage factor

The usage (also called "capacity") factor of a Collection Device is expressed as a *percentage or multiplication factor less than 1, to be applied to* R_N *(the Nameplate Rating of the device)* . The factors that come into play to determine this percentage are :

- different for each technology
- all related to the utilization of the resource (wind, solar, etc)
- all related to losses in the system, (magnetic, mechanical, junction, resistance, heat etc.)

Thus, usage factor expresses the expected yield of the device in use, where Nameplate Rating only expresses a theoretical maximum.

It must be made perfectly clear that when purchasing Renewable Energy equipment / system, the wise purchaser will only deal with Usage Factor (effective yield) and will not be misled by claims regarding Nameplate Rating.

3.2.1 Wind Turbines

Many of us have observed conventional Wind Generation installations and seen that often the turbine blade is not rotating, even when the wind is blowing. Shouldn't it be generating power instead of sitting idle ?

Traditional Wind Turbine designs allowed the propeller to rotate only at wind velocities that (after all of their "mechanical and aerodynamic" reductions are applied) were sufficient to spin the alternator (commonly miss-stated as generator) at the correct rotational speed to produce electricity at the 60 Hertz AC required by grid connected applications. Thus the propeller/turbine was idle if the wind velocity was lower than optimum for that device.

Conversely, at high wind velocities, the rotational speed was also outside the nominal range, and turbines would be artificially slowed down using "mechanical and aerodynamic" reductions (even in some cases mechanical brakes or "dump load" resistors) all of which converted the hard-earned electricity to wasted heat.

Thus, conventional wind turbine technology has not been able to effectively, efficiently and economically harness very low (<9km/hr) or high (>150km/hr) velocity wind, because large conventional turbines prefer a constant wind velocity. Developers of 'wind farms' have therefore used the North American and world wide weather system and direct empirical measurement to plot the wind patterns to determine what, until now, have been considered the best locations to install wind generation systems.

Inevitably, this limitation has resulted in developers (individual or corporate land and/or building owners) disregarding areas on the map where they consider the wind velocity too low (too high is rarely a problem). Imagine a technology which would "open up" the rest of the wind resource. Most of North America is well supplied with "moderate" wind which <u>can</u> be effectively harvested by the right technology.

Wind Turbines are rated by the manufacturer in ideal conditions

- steady non-interrupted wind
- maximum wind velocity
- after all internal losses are factored in.

A manufacturer might therefore state that their product's Nameplate Rating (R_N) is 1 MegaWatt, and this is the number upon which they and their customers base their yield data.

However, when this turbine is used in actual (less than ideal) conditions in the field, a Usage Factor must be applied to "de-rate" the turbine to the given application. This rating (usage factor) is used to determine the actual expected Annual Yield. A conventional wind turbine from any of the established manufacturers might have a published usage factor (for specific applications in North America) of .25 - .33. For example, a 1 MegaWatt turbine with a Usage Factor of .3 would deliver a yield of 300 KiloWatts, **<u>on average</u>** all day every day, all year, every year.

3.2.1.1 Wind Usage Factor

Usage Factor (θ_N) , a site-specific multiplier, is derived from:

- average wind velocity at a particular location - not something that can be changed
- prop design - already maximized by manufacturer
- mechanical losses in turbine - dependent on physical design
- swept area formula - rules of physics, unchangable
- **conversion and delivery losses** - something that **can be reduced**

Remembering the Energy Equation, then, the Annual Yield or Energy Harvest of that same 1MegaWatt (nameplate) wind turbine would be calculated as :

$Y_n = R_N * \theta_N * \Sigma_H$

= 1000 * .3 * 8760

= 2,268,000 KiloWattHours per year

However :

Suppose that the Usage Factor (θ_N) could be increased to .6

Under these conditions, the Annual Yield of that same turbine would be :

$Y_n = R_N * \theta_N * \Sigma_H$

= 1000 * .6 * 8760

= 5,256,000 KiloWattHours per year

The Yield and the earnings of this turbine just DOUBLED !

How ? The Patented technology of the Hybridyne CIT is proven to give some wind direct drive turbines greatly increased Usage Factors.

Note

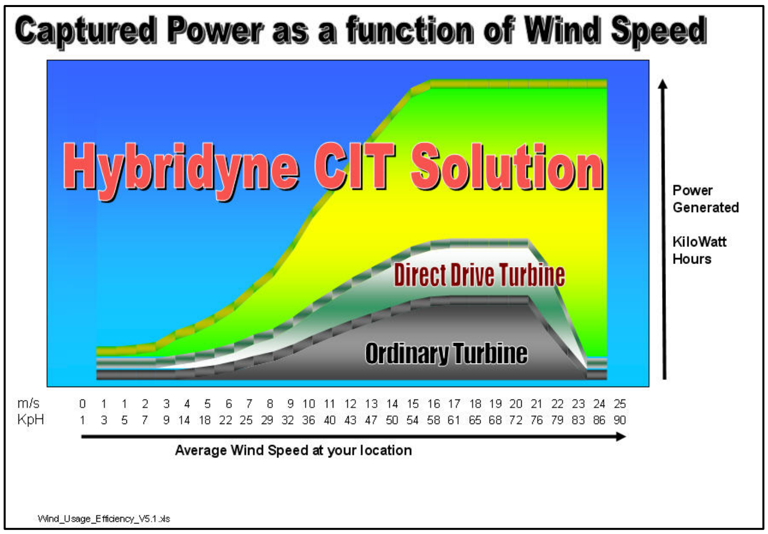
Lets be clear about one thing, however. We are not saying that it is possible to double the yield of a classic “gear reduced” turbine which by its very nature already has significant mechanical losses built in. Our technology was designed to work with gearless direct drive turbines which eliminate the need for transmissions (and their inherent high maintenance and high mechanical loss).

That said, we could in theory still improve the performance of the older-style transmission turbines with our technology - most likely in the vicinity of 8 – 10%, possibly affording the opportunity to retrofit systems in the future.

The Hybridyne Power Electronics Conversion/Inversion Technology (CIT) delivers these dramatic benefits by :

- broadening the input voltage and frequency window
  - increasing how much of the input raw electricity can be used
- increasing efficiency at high and low frequencies and voltages
  - decreasing the amount of energy wasted in conversion
- NOT wasting energy at Low or High wind speeds
  - For utility grade systems , the CIT sends that energy directly to the grid
  - For smaller turbines we use high speed energy to supply the load or charge a storage medium- when other systems are often engaging resistors,brakes, or yaw control out of the wind to slow the turbine down, we are charging and/or selling to the grid.

We call this “utilizing the shoulders of the energy curve”.



The use of the Hybridyne Power Electronics Conversion/Inversion Technology allows us to greatly improve the usage factor and give the investor up to twice as much energy from a system or device, which in turn improves dramatically their return on investment.

Alternatively, the use of the HPE CIT in conjunction with an appropriate direct drive turbine will allow a wind farm developer to develop land where the average annual wind resource is too low for economical installation of more conventional technology. We project that wind developments will begin to be profitable :

- in low density installations (one and two turbines) all over North America (as opposed to exclusively high density farms)
- not only in the few “High Resource” areas which are often prime real estate and already largely occupied or optioned by the standard fare developers (sea and lakeshores , elevated plateaus etc.)
  - but also in the vast areas of “Moderate Resource” which are usually nearer the grid transmission lines necessary to transfer the power, and often nearer to the centers of population where the power will be used.

3.2.2 Solar Photo-Voltaics

It's nice to see Solar Photo-Voltaic panels sitting under the sky, but did you know that most of the time, they simply do not generate electricity ? Or more correctly they are in fact generating electricity at all times when exposed to sunlight, but this often "less than optimal" energy is just being ignored by the balance of system equipment. Solar PV panels are rated in ideal sunlight conditions:

- direct sunlight at noon
- no cloud cover
- 25 degree Celsius ambient temperature
- with the panel properly cooled by proper mounting (allowing convection or radiant cooling)

In the real world, however :

- the illumination and irradiation ramps up gradually throughout the morning, stays at a peak level for a few hours around noon, and then declines throughout the afternoon.
- Low light (less than 80% of optimum) conditions have been considered 'unusable' by the manufacturers of the electronics which converted the output from the solar cells into usable electricity. This mindset is so prevalent that the PV manufacturers often do not have the test data for their modules' performance at less than 80% irradiation, simply because the inverter manufacturers are not asking for it.

Thus PV technology has been made to look artificially expensive because the number of KiloWatt hours (Annual Yield or Net Harvest) can be quite low. Hybridyne prefers not to ignore this opportunity for a bountiful energy harvest.

Based on theoretical, ideal conditions, a manufacturer might state that the Nameplate Rating (R_N) of their product is 170 Watts (.17 KiloWatts), and use this figure to derive their yield numbers.

However, the panel in the field will face less-than-perfect conditions :

- on the average, it's dark 12 hours out of every 24
- some part of the time, the sun may be cloud covered
- high humidity and pollution also reduce the light hitting the panel
- part of every day, the sun is striking the panel obliquely (unless you track the sun's seasonal and daily movement through the sky, which is another story)
    - the further north or south you travel on the globe, the more oblique is the sun angle

3.2.2.1 Solar Usage Factor

Usage Factor can also be related to PV. We are the only organization worldwide thus far to make this correlation which allows us to easily relate wind and solar systems together conversationally and as a system (see Merging Collector Technologies)

Usage Factor (θ_N), a site-specific multiplier, is derived from:

- average solar Insolation at a particular location - not something that can be changed
- illumination at a specific time of day - not changable
- panel efficiency (now in the 20% range) - maximized by manufacturer
- **conversion and delivery losses** - something that **<u>can be reduced</u>**

For most currently available PhotoVoltaic Solar panels now in use, with conventional inverters and no mechanical tracking system, the Usage Factor is usually about .125 - .135 (0.13 seems to be the average). This factor is latitude dependent.

Remembering the Energy Equation, then, the Annual Yield or Energy Harvest of that 170 Watt solar panel would be calculated as :

$Y_n = R_N * \theta_N * \Sigma_H$

= .170 * 0.13 * 8760
= 193.596 KiloWattHours per year

<u>However</u> :

Suppose that the Usage Factor (θ_N) could be increased to 0.1995

Under these conditions, the Annual Yield of that same array would be :

$Y_n = R_N * \theta_N * \Sigma_H$
= .170 * .1995 * 8760
= 297.1 KiloWattHours per year

The Yield and the earnings of this PV panel has jumped by **<u>36%</u>** !

Are we overstating the case ?

Even if we were generous, and said that the normal Usage Factor for a fixed position array with conventional balance of system electronics was 0.14 , the yield would still be :

$Y_n = R_N * \theta_N * \Sigma_H$

= .170 * 0.14 * 8760

= 208.5 KiloWattHours per year

Let's be further generous and reduce the Hybridyne CIT Usage Factor (out of sheer conservatism) to .1895 . The yield would still be :

$Y_n = R_N * \theta_N * \Sigma_H$

= .170 * .1895 * 8760

= 282.2 KiloWattHours per year

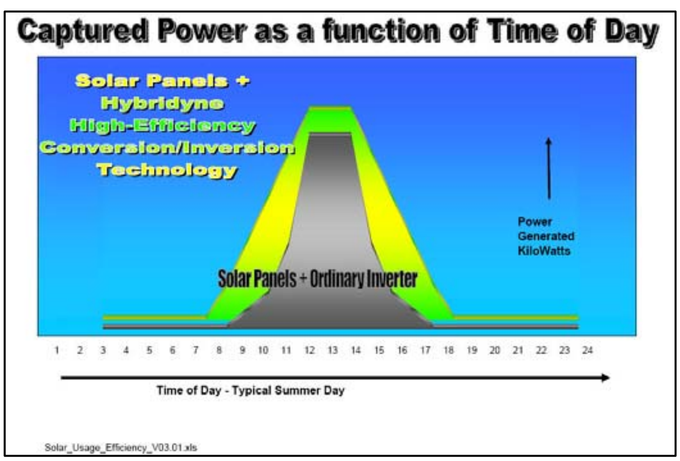
Even under these condtions, the improvement is still an impressive **27%**

This is an even more significant achievement taken in the context of an industry where manufacturers are struggling to improve Sun Energy conversion efficiency by as little as 1% incremental.

The HPE CIT delivers these dramatic benefits by :

- broadening the input voltage window
  - starting earlier in the curve and converting longer
  - increasing how much of the input raw electricity can be used
- increasing efficiency at all applicable conversion voltage levels
  - decreasing the amount of energy wasted in conversion

We call this "utilizing the shoulders of the energy curve ".



The use of the Hybridyne Power Electronics Conversion/Inversion Technology allows us to dramatically improve the Usage Factor and offer the investor a higher return.

3.2.3 Other Collector Technology

The CIT could also be used effectively to gather electricity efficiently from other Collection Technologies :

- Water Turbines (run of river, wave action or tidal)
  - Fluctuations in the velocity of water flow can result in ordinary inverters wasting energy (exactly the same as the case for wind turbines) – the CIT will gather more electricity
  - Lower velocity water flows can become economically viable – the CIT can enable to water turbine to gather electricity even at a lower flow rate.

4 Merging Collector Technologies

One of the key features of the CIT is its ability to effectively and efficiently merge energy from multiple collection technologies.

A typical example is a **Hybrid** solution in a "Behind the Meter" RE system , or an Energy Park© which will consist of BOTH wind turbines and PV solar panels – not with two separate "Balance of System Electronics" arrangements, but with a single, efficient, integrated CIT which gives the owner both a hardened energy supply and also higher annual yield with little increased 'real estate'.

4.1 Hybrid Conversion

Most manufacturers of Renewable energy collection devices labour intensely to increase the efficiency and therefore the overall "performance" of their respective products. However most if not all of this is classified confidential "Intellectual property" and is Patented, copy-written, trademarked, etc. and as such there is very little "sharing" of ideas in this industry, as in many others.

Further, most of these industries are plagued by the vagaries of the raw fuel for their technologies.

- Hydro Electric power is reliant on annual precipitation and snow melt.
- Wind turbines are reliant on the wind, and to some degree the seasons.
- Solar PV relies on the latitude, percentage of sunny days, and to some degree the weather.

Many utilities and Electrical transmission system operators frown on Renewable Energy Generators, as the energy produced is deemed to be intermittent (a "Soft supply").
A soft source of power occurs when the system operator cannot rely on the power offered by the generator being available when required by the customers.

One of the many solutions to this intermittence has been to combine or "hybridize" the renewable with a source more consistent like Hydro, Coal, or Nuclear. This has the effect of "hardening" the combined source by diversity of supply.

We certainly agree that Hybridization is the answer, but we disagree with the approach so far. We believe that it is counterproductive to combine renewables with non-renewable sources for the purpose of ‘hardening’.

Why not Hybridize a Renewable source with other complimentary Renewables instead ?

Early in the Genesis of the Hybridyne Group, we examined this ‘problem’. Since we do not manufacture Collection Technology (turbines, PV panels, etc) we could have an impartial view on generation, and realized that we could improve many types of generators’ Yield with our technology. We realized that we could harden or “firm up” the supply source by combining more than one type of generator, diversifying the energy and fuel mix.

For example, on sunny days there is often little wind, on windy days it is often overcast or cloudy, with less sun.

Seasonally, in Northern latitudes, we have less sun before and after the Winter Solstice, but we tend to have lots of wind during this period.

Similarly in the summer (close to summer Solstice) we tend to have good sun, and little wind.

So it can be generalized by saying that if it’s not sunny, it’s probably windy, and when it’s calm, it’s often sunny. During the sunny times, we can generate a lot of electricity using PhotoVoltaics. On the other hand , when it is cloudy, dark, or winter we can generate good quantities of electricity using Wind Turbines.

If we combine the two, we can generalize by saying that for the most part we will be gathering *some* energy from a hybrid wind and solar system all day, every day.

What remains is to quantify how much energy is being gathered, so that we can predict with a reasonable degree of certainty how much energy will be available.

- We know the statistical probability of annual energy available from a given wind turbine in a given location - its Usage Factor
- we know the statistical probability of energy available from a given PhotoVoltaic panel in a given location - its Usage Factor

If we plot these two probabilities, we will see that the ‘peaks and valleys’ of the two curves are largely ‘out of phase’, with very few times of zero combined output (the few totally windless nights), and some times of very high combined output (sunny days when the wind is also blowing).

The sum of the Usage Factors of all the Collection Technologies is the Usage or Capacity factor of the Hybrid system. Hybridyne have accomplished this combination, both theoretically and practically in commercial applications.