ADVANTAGES OF COMBINED WIND-BIOGAS ENERGY UTILIZATION FOR DISTRIBUTED POWER GENERATION

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INTRODUCTION

The Kyoto protocol, although not ratified to the extent intended, has become a major issue for governments worldwide. Concern over global warming and the effect of pollution caused by the burning of “brown” fuels cannot be neglected.

Power generation systems using renewable resources — the wind, sun, water, solid biomass, biogas-syngas and geothermal energy do not produce greenhouse gases and emit far less pollution than burning “brown” fuels to generate electricity.

However, renewable energy technologies also have some disadvantages. Solar and wind power are intermittent — they don't produce power if the sun isn't shining or the wind isn't blowing. This can be mitigated through the use of combined, hybrid, systems.

One possible solution for small-distributed power generation systems may be a combination of biogas-syngas fuelled combined cycle gas turbine (CCGT) power plant with a wind turbine-generator (called in this paper “**Hybrid Power Plants**”).

Depending on biogas-syngas production capacity and average available wind power, 10 MW to 15 MW units can be build.

Syngas can be produced from solid biomass in a gasifier, biogas by anaerobic digesting food or animal wastes or from landfills that also generate a methane-rich biogas from the decay of wastes containing biomass.

Small, modular, hybrid power plants, which can be sited close to the end-user load centers, offer advantages that large-scale, centralized power plants can’t provide.

Distributed hybrid power plants avoid transmission and distribution power losses, and provide safe and reliable power source to the end-user.

Hybrid, biogas/syngas – wind, distributed power generation systems produce so little emissions that they can be located immediately adjacent to the consumer where the power is needed.

The excess power can be fed to midi grids that supply power from distributed power generation sources to a localized group of end-users.

Study performed by IMTE shows a great potential for small renewable hybrid distributed power generation plants worldwide.

However, in many countries, the renewable energy generation is not competitive at present market conditions. Therefore, subsidies in the form of guaranteed higher tariffs, soft loans and other technical and commercial support is required.

Worldwide great efforts are made to develop technologies, which can use surplus residual biomass products from agriculture and forestry and also from municipal waste as a fuel at power plants.

Investment in renewable power energy generation is considered as a great challenge for each modern Investor and Project Developer. Topics related to this subject are analyzed and discussed in this paper.

DISTRIBUTED POWER GENERATION

Distributed (decentralized) power generation systems are grid-connected or stand-alone technology systems that can be integrated into small townships, commercial or institutional buildings, industrial facilities and other groups of power consumers.

They strategically apply relatively small electric power generating units (typically 10-15 but usually not more than 30-40 MW) at/or near major power consumer sites to meet their specific needs, to support economic operation of the existing power distribution grid, or both.

Decentralized hybrid power generation systems offer several considerable advantages over conventional grid electricity distribution, mainly higher power reliability, quality and efficiency, lower emissions and greater flexibility to respond to changing energy needs.

The reliability of service and power quality are enhanced by proximity to the power end-user; moreover the power production efficiency may be considerably improved in on-site applications by using waste heat from power generation for process steam generation, heating or cooling purposes.

Decentralized hybrid power plants complement large central power stations by avoiding transmission and distribution capacity upgrades by locating power where it is most needed, providing a relatively low capital cost response to incremental increases in power and providing the flexibility to put surplus power back into the grid at user sites.

Since electricity from decentralized power plants does not need to be transmitted over long distances to end-users, the need for large transmission infrastructure is eliminated or reduced to an absolute minimum; hence the power transmission losses are greatly minimized.

More importantly, on-site power generation allows for the use of technologies, such as small gas, steam and hydro turbines (microturbines), combined heat and power technologies as well as utilization of solar and wind energy or combination of these technologies.

The latter can greatly increase the efficiency with which energy is utilised. As a result, distributed power generation lowers emissions and operating cost through reduced losses and increased efficiency.

To defend against power outages and the threat of cyber-attack against the electrical power grid, steps should be taken to provide a counterbalance to the centralized power generation systems by increasing the number of distributed (decentralized) power generation plants.

Advantages of distributed power generation may be summarized as follows:

- ✓ Enhanced power quality that is required for sensitive information and manufacturing operations.
- ✓ Easy permission/approval procedure; It will be much easier to win governmental and public acceptance for installation of small-scale distributed renewable power plants.
- ✓ Deferral of transmission and distribution costs.
- ✓ Environmental improvement; especially distributed renewable power plants produce ultra-low emissions of air pollutants; they also generally produce lower greenhouse gas emissions than traditional large centralized power plants.
- ✓ There are fewer transmission and distribution line losses with power generation closer to power end-users.
- ✓ The modular, tailor made, nature of distributed power plants allows for perfect load matching, which prevents overbuilding and overspending for excess capacity.

- ✓ There are also advantages in reduced lead times for construction, smaller project capital risk, lower regulatory risk, mobility, lower operating and maintenance costs, and lower fuel escalation risk.
- ✓ Operational safety; risk of terrorist attack on remote located transmission and fuel supply lines is reduced to an absolute minimum.
- ✓ Reduced risk of blackouts in large power consumer centres (townships, airport, underground rail systems, industrial smelters, large shopping centres, etc.).

For example distributed hybrid power plant offers end-user the continuity of safe, reliable and most efficient energy supply, combining wind powered generators with biogas-syngas fuelled CCGT power plant system.

Potential applications of this technology include power supply to end-users located in grid-remote areas, uninterruptible power supplies for computer networks, power supplies for wireless communications and emergency management systems as well as to end-users connected to local area medium voltage minigrids.

Actually, a well-designed hybrid power plant can supply the entire electricity demand to a localized group of customers via minigrids.

By avoiding the cost of transmitting electricity from a distant central power station, or transporting fuel from a distant supply source, a minigrid can significantly improve the distribution safety and the economics of meeting energy needs using decentralized hybrid power plants.

Minigrids typically use the same technologies employed by large electric utilities, but are not always connected to the main, national, HV-grid.

Very often, an electrically isolated minigrid is created with the option for later integration with the main grid if that option becomes attractive.

The essential point is that the hybrid power plants in a minigrid are capable of serving their load independently.

Hybrid power plant technology has the ability to generate designed base load power output during the whole year. It provides a super-reliable power supply capable of operating during disasters even with loss of grid power.

Significant technological advances through decades of intensive worldwide research have yielded major improvements in the economic, operational, and environmental performance of small, modular distributed hybrid power generation options.

HYBRID POWER PLANTS - INTRODUCTION

Hybrid power generation systems offer clean, efficient, reliable, and flexible on-site power generation alternatives.

Fuel flexibility is also afforded by operating on natural gas, propane, or fuel gas derived from any hydrocarbon, including coal, biomass, wastes from refineries, municipalities, forestry, farming and agricultural industries.

Hybrid energy systems combine two or more different power generation applications. When integrated, these systems overcome limitations inhered in either one.

Hybrid energy systems may feature lower fossil fuel emissions as well as continuous power generation for times when intermittent renewable resources are unavailable.

Potential hybrid combinations include fuel-powered (natural gas, coal, oil, etc.) generators that work in conjunction with renewable energy (wind, solar, geothermal, etc.)

The cost and environmental advantages of these advanced power generation technologies can be improved by using renewable fuels such as solid biomass or biogas-syngas to supplement conventional fuels.

While addressing distributed hybrid power generation potential in general, the topics presented in this paper focuses on small and medium size power generation plants consisting of biogas-syngas fuelled combined cycle gas turbine (CCGT) power generation system with a wind turbine-generators.

Combined biogas-syngas fueled CCGT-wind generator hybrid power systems are an increasingly economic alternative especially for rural electrification for the following reasons:

- Biogas-syngas fuelled and wind powered electric power generation technologies are modular;
- Wind and biomass based fuel is locally available;
- Seasonal variations of the biogas-syngas and wind resources are often complementary;
- High power generation efficiency can be achieved;
- Comparing to conventional power plants, the operational costs are low;
- Power plant size can be perfectly matched to local end-user(s) requirements;

- Operational flexibility;
- Very low emissions;
- Simple operation and maintenance requirements.

In general, opportunities to install new hybrid power plants are apparent in all countries worldwide although awareness, installation and operating economies are better in some countries than others.

The future general and common aim of all countries worldwide has to lead to a considerable increase their respective renewable power generating capacities.

Biogas/syngas-wind hybrid power plants are still overshadowed by other options including natural gas fired CCGT power plants as long as the natural gas is sold at relatively low price in many countries worldwide.

However, as worldwide air emissions standards become stricter, the superior environmental performance of renewable hybrid power plants will take on added economic benefits because the technology can achieve greater emissions reductions at lower cost than less advanced technologies.

BIOGAS-SYNGAS FUELLED CCGT POWER PLANTS

Unlike any other energy resource, using biomass to produce energy is often a way to dispose of biomass waste materials that otherwise would create environmental risks.

In this paper the following biomass based fuels are discussed:

- Syngas from forced (mechanical) gasification
- Biogas from anaerobic digestion
- Landfill gas

Very common and most efficient are systems applying one of above listed biomass based gaseous fuel for electrical power generation and co-generation systems.

Such systems can achieve an overall efficiency between 30% (open GT cycle power generation), 45% (CCGT) and 85% (co-generation).

Typical flow diagram of syngas fired CCGT power plant is shown in the following picture (Figure 1).

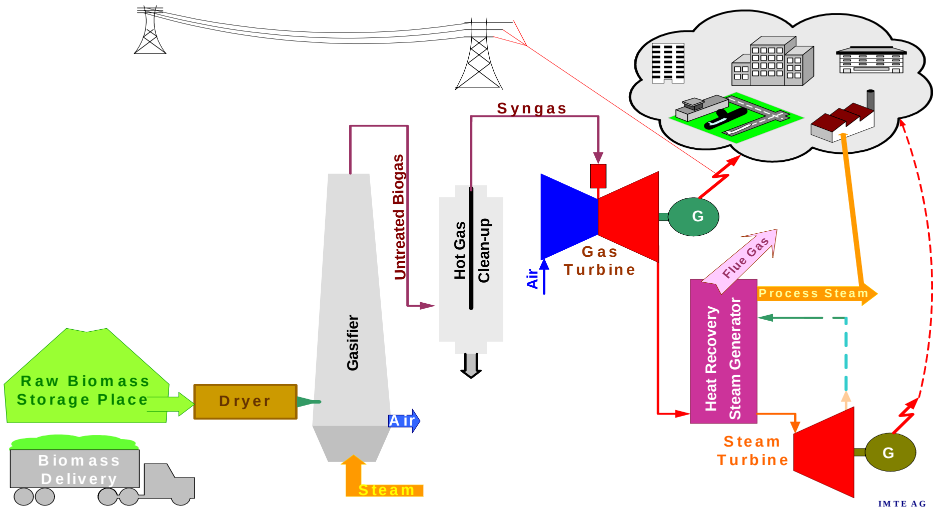


Figure 1
Syngas fuelled CCGT Power Plant

In this case the clean syngas enters the gas turbine (GT) that is producing around 55% of the total cycle output.

The exhaust gas from GT is led to heat recovery steam generator (HRSG). High pressure / high temperature steam from HRSG is then supplied to steam turbine (ST) which complements additional 35% to the total cycle power output.

Steam required for gasification process and also process steam for other purposes may be supplied from the HRSG or can be extracted from the ST.

This CCGT cycle can be directly fed with biogas-syngas either from gasification process, from anaerobic digestion process or from landfill.

The overall cycle efficiency is very much depending on the final design, configuration and end-user requirement. Using today's standard technology, the overall cycle efficiency lies between 40% and 80%.

BIOGAS-SYNGAS PRODUCTION

Direct Gasification

The first commercial gasifier for continuous air-blown gasification of solid fuels was installed in 1839. Later, gas industry producing gas from coal and biomass was established. The first attempt to use producer gas to fire the internal combustion engine was carried out in 1881.

Chemical process of gasification is actually a thermal decomposition of hydrocarbons from biomass in a reducing (oxygen-deficient) atmosphere.

Reducing atmosphere of the gasification stage means that only 20% to 40% of stochiometric amount of oxygen (O_2) related to a complete combustion enters the reaction.

This is enough to cover the heat energy necessary for a complete gasification. Say in other words, the system is autothermic.

The process usually takes place at about 850ºC. Because the injected air prevents the ash from melting, steam injection is not always required. A biomass gasifier can operate under atmospheric pressure or elevated pressure.

If the fuel gas is generated for combustion in the gas turbine (Figure 1) the pressure of gasification is always super-atmospheric.

The resulting gas product, the syngas, contains combustible gases – hydrogen (H_2) and carbon monoxide (CO) as the main constituents.

Direct gasification process is versatile in the feedstock choice as well as the end-product spectrum following from further processing of syngas.

A typical flow diagram of a biomass gasification process combined with power and heat generation was shown in above Figure 1, where the biomass is first dried and than injected in to the gasifier.

Produced raw syngas is purified in hot gas clean-up system from where the treated, clean, syngas is fed into the conventional CCGT cycle, to produce electricity and steam. For more details please refer to [1], [5], [6], [7] and [8].

Anaerobic Digestion

Biogas occurs naturally, hence its name, amongst others in swamps and lakes when conditions are right. Anaerobic digestion can be used to produce valuable energy from waste streams of natural materials or to lower the pollution potential of a waste stream.

The biogas-production will be normally in the range of 0.3 - 0.45 m^3 of biogas per kg of solid substances for a well functioning process with a typical retention time of 20-30 days. The lower heating value of this gas is about 22 MJ/m^3.

Biogas plant has a self-consumption of energy to keep the sludge warm. This is typically 20% of the energy production for a well-designed biogas plant. For example if the biogas is used for power and co-generation, the available electricity will be 30-40% of the energy in the biogas, the heat will be 40-50% and the remaining 20% will be said self-consumption.

Anaerobic digestion is a complex biochemical reaction carried out in a number of steps by several types of microorganisms that require little or no oxygen to live.

During the process a biogas, principally composed of approximately 65% methane (CH_4) and about 30% carbon dioxide (CO_2), is produced.

A mixture of CH_4 with CO_2 is making up more than 90% of the total biogas composition. The remaining gases are usually smaller amounts of H_2S, N, H_2, methylmercaptans and O.

The biogas energy content depends on the amount of CH_4 it contains. Biogas CH_4 content varies from about 55% to 80%.

Typical biogas, with a CH_4 concentration of 65%, contains about 22 MJ/Nm^3 of energy that is equivalent to 0.55 kg of light diesel oil.

The process of biological anaerobic digestion occurs in a sequence of steps involving distinct types of bacteria as illustrated and described in [1] and [4].

Landfill Gas

The same anaerobic digestion process that produces biogas occurs naturally underground in landfills. Most landfill gas results from the decomposition of cellulose contained in municipal and industrial solid waste.

Unlike above motioned anaerobic digesters, which control the anaerobic digestion process, the digestion occurring in landfills is an uncontrolled process of biomass decay. The efficiency of the process depends on the waste composition and moisture content of the landfill, cover material, temperature and other factors.

The biogas released from landfills, commonly called "landfill gas," is typically 50% CH_4 and 45% CO_2. Remaining 5% are usually other gases like H_2S, N, H_2 and O. In theory, the lifetime yield of a good site should lay in the range 150-300 m^3 of gas per tone of wastes. This offers a total energy of 5-6 GJ per tone of waste, but in practice yields are much less. For more details please refer to [1].

WIND POWER PLANTS

Wind energy has come a very long way since the prototypes of just 20 years ago. Today’s wind turbines are state-of-the-art modern technology – modular and very quick to install and commission.

Turbine size ranges from a few kW to over 3.5 MW, with the largest turbines reaching in excess of 100 m in height. State of the art wind farms today can be as small as a single turbine and as large as several hundred MW.

Worldwide, wind energy has grown around 33% annually over the last three years, resulting in an estimated global installed capacity of 31 GW (Figure 3). It is predicted that worldwide wind power industry investment will reach US$ 25 - 30 billion mark in current year (2003).

Only Europe contributed more than 70% of the total global wind power capacity (Figure 4).

In Germany, Denmark and some regions of Spain, more than 15% of the total electric power is coming from wind generation.

The full measure of what it cost to produce a kWh of energy from a power plant consists of three basic elements:

- The capital costs of building the power plant;
- The operating and maintenance costs including also fuel costs;
- Power plant decommissioning costs.

These three major cost components, life cycle cost, range widely among different power generation technologies.

Cost comparison between miscellaneous power generation technologies and various fuels is shown in the following picture (Figure 2).

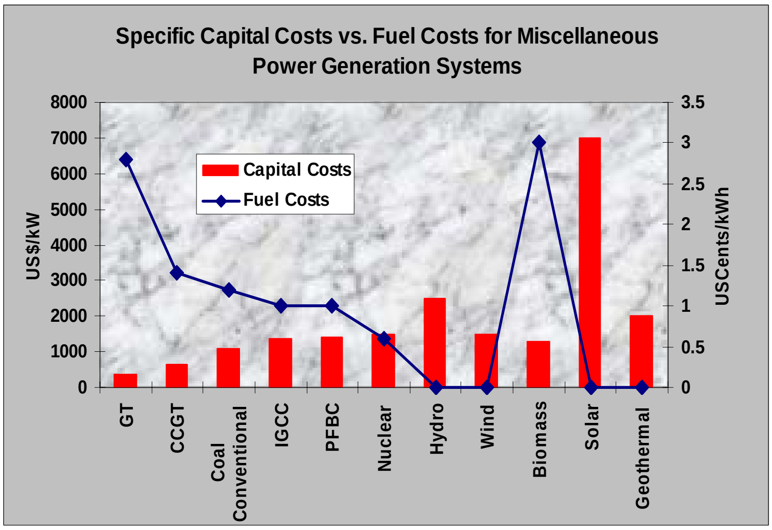


Figure 2

Hydro has very high capital cost but modest, predictable, operating and maintenance costs. Natural gas or coal-fired power plants cost comparatively much less to build, and operating costs are based mostly on fuel prices.

The cost of wind power plants is largely a function of capital costs. But, the wind is a free fuel and operating costs of wind power plants are very low.

Decommissioning costs are difficult to measure as they occur in the future, but are almost certain to be higher for nuclear than other generation technologies due to the high cost of handling, transporting and disposing of spent nuclear fuel and equipment.

And great efforts to identify an acceptable method of nuclear waste disposal have been a dismal failure to date.

Worldwide installed wind energy capacity has increased 9-times, from 2 GW to 18 GW, during the last decade and growth rates in the first two years of this century have been even faster, as shown in the following picture (Figure 3) – 31 GW in year 2002.

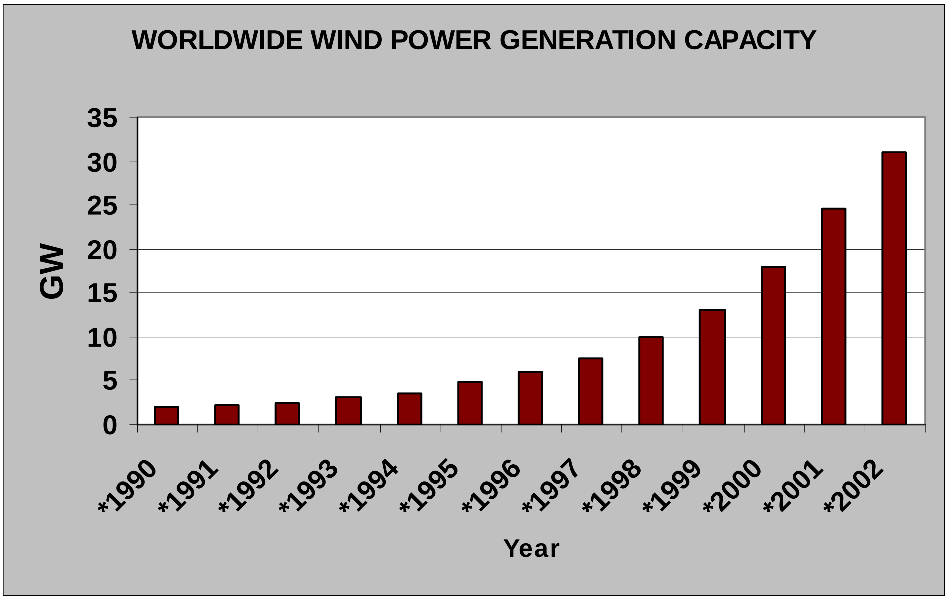


Figure 3

As shown in the following picture (Figure 4) the biggest current wind power producers are Germany, USA and Spain, following by Denmark, India and other countries worldwide.

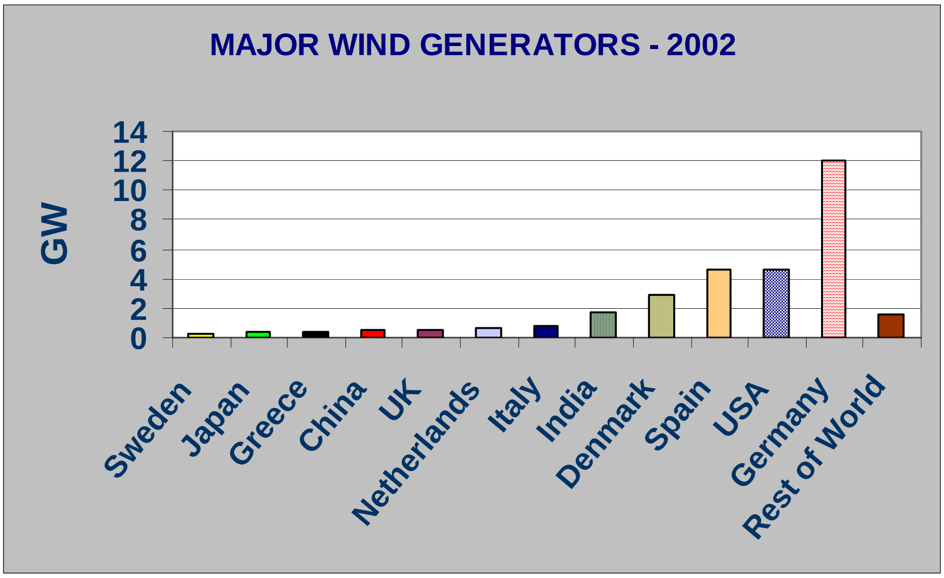


Figure 4

Price per kWh paid in selected countries is shown in the following Figure 5.

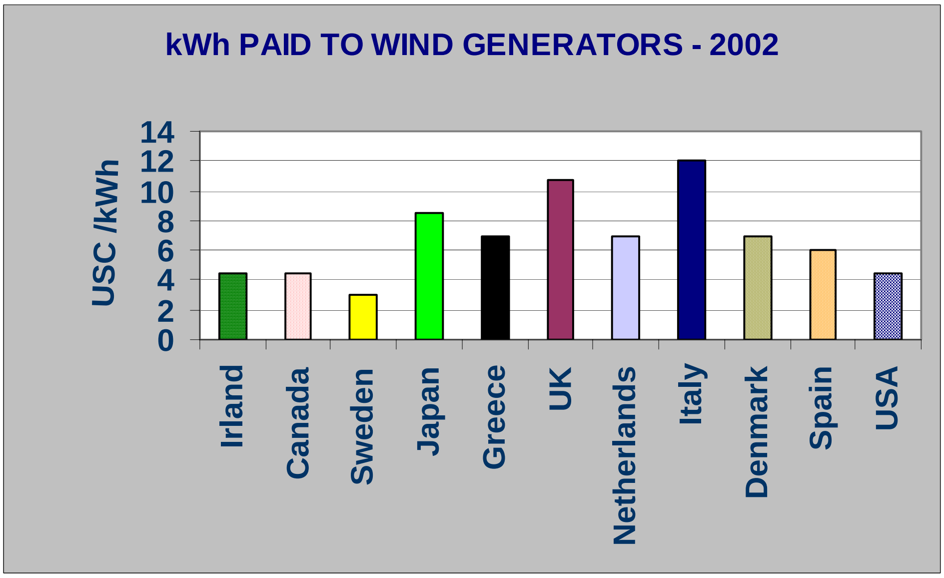


Figure 5

Wind power generators maintenance costs average worldwide around 0.01 US$/kWh, the availability is above 98% and design lifetime over 20 years. The most stressed component like brake pads have to be replaced every 1-3 years, gearbox inner parts every 2-3 years and the parts of yaw system every 5 years.

The attractions of wind power as a source of electricity which does not produce greenhouse gases has led to ambitious targets for wind energy in many countries worldwide.

For example in Europe, there have been several developments of offshore wind installations and many more are planned.

Although offshore wind-generated electricity is generally more expensive than onshore, the resource is very large and there are few environmental impacts.

Dutch agency Novem has carried out a survey of integration of 6'000 MW offshore wind power into the Netherlands national grid by 2020.

Whilst wind energy is generally well developed in the industrialized countries for environmental reasons, it has attractions in the developing world as it can be installed quickly in remote areas where electricity is urgently needed but the access to the power grid is limited.

Wind power generation may be, in many instances, a cost-effective solution if fossil fuel sources are not readily available.

Recent rapid wind power generation capacity growth in Europe shows no sign of slowing and there are plans for further capacity in North and South America as well as Asia.

If the current growth rate continues, there may be about 180 GW by 2010 and 550 GW by 2015 (Figure 6).

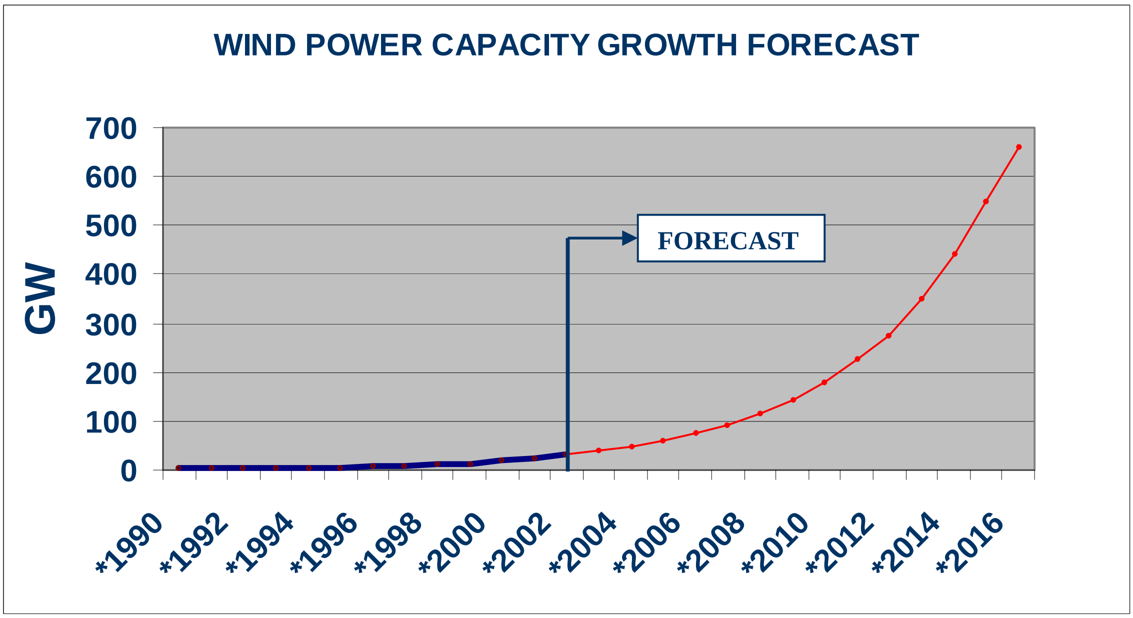


Figure 6

The rate of growth will depend on the level of political support from the national governments and international community.

In many parts of the world, governments are fueling this growth by providing incentives for the development of more environmentally friendly, renewable energy sources.

These subsidies help put the cost of wind-generated power into a competitive range with other traditional generation sources.

In the USA, wind is projected to provide at least 6% of the nation's electricity by 2020 - an estimated 100 GW capacity. Europe has set a goal of 60 GW of wind-generated electricity by 2010.

In other countries and regions, this in turn, depends on the level of commitment to achieving the carbon dioxide reduction targets now internationally agreed.

Although the wind power generation technology has developed rapidly during the past ten years, further improvements can be expected both in performance and cost.

The continuing development of larger and more efficient wind power systems is expected to make the technology an even more cost-competitive power generation option in the years ahead.

MAIN FEATURES OF DISTRIBUTED HYBRID POWER PLANTS

As concern about the global environment grows, governmental authorities and many international utilities are looking ever more seriously at distributed renewable hybrid power generation systems to support remote populations and other prospective decentralized power end-users.

In countries with significant, but not steady, wind power, complementary biomass fuelled renewable power generation systems can be very attractive.

They especially contribute during daily and seasonal declines in wind power, when wind generators cannot generate at base load capacity.

As shown in the following diagram (Figure 7), 35MW *(35MW=design capacity with capacity factor 0.9)* hybrid power plant located in area with productive wind conditions but low biomass production during winter months, consisting of 12x1.66MW (total 20MW) wind generator capacity and 15MW *(15MW=design capacity with capacity factor 0.9)* biomass fuelled CCGT power plant, can efficiently generate maximum electrical energy from wind during winter and maximum power from biomass during summer period.

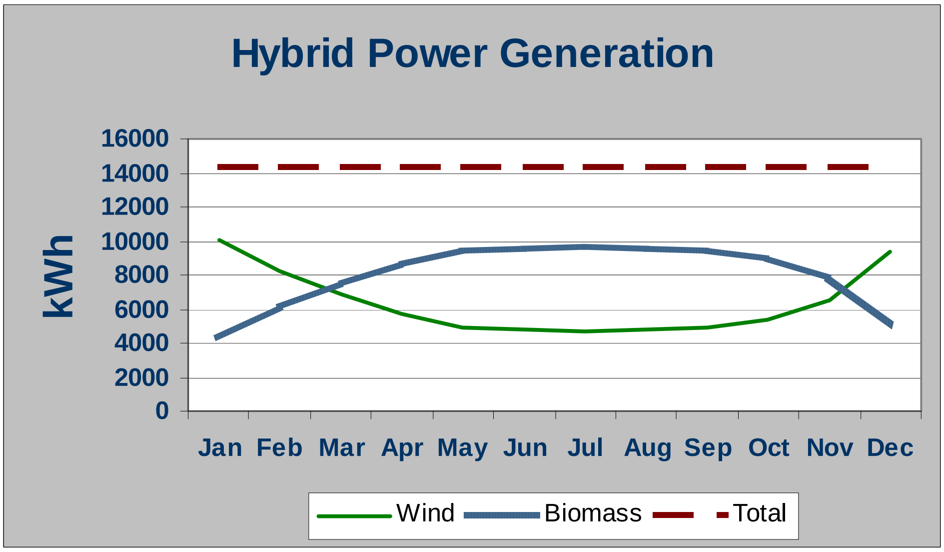


Figure 7

Contrary to popular opinion, wind power energy yields do not increase with the cube of the wind speed, mainly because energy is discarded once the rated wind speed is reached. To illustrate a typical power curve and the concept of rated output, the following diagram (Figure 8) shows a typical performance curve for a 1.66 MW machine. Most machines start to generate at a similar speed - around 3 to 5 m/s - and shut down in very high winds, generally around 20 to 25 m/s.

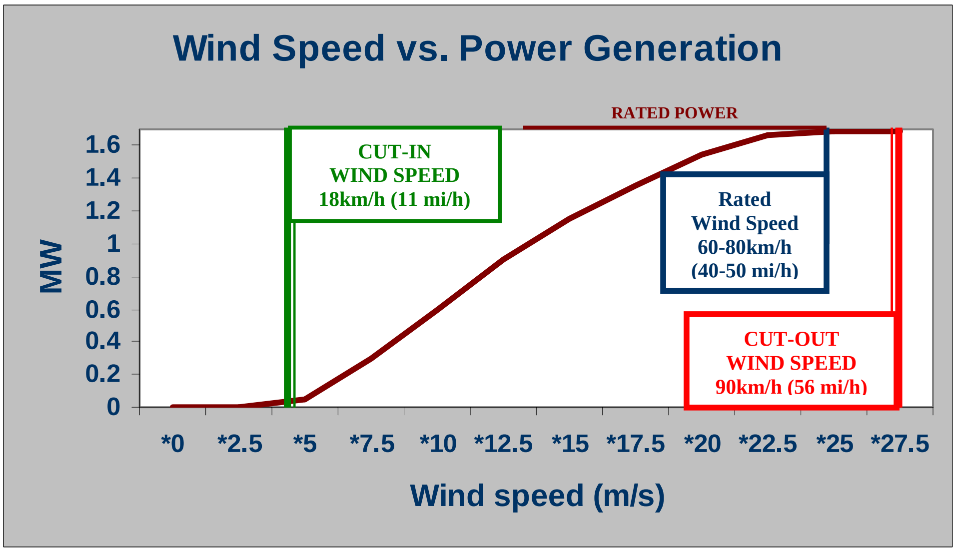


Figure 8

Annual average energy production from the twelve wind generators (with average capacity factor 0.4) whose performance is charted in above diagram (Figure 7) is around 71’424 MWh at a site where the wind speed is between 5 and 25 m/s.

The capacity factor is defined as the actual annual wind power generator energy output, in kWh, divided by the rated base load output, in kW multiplied by 8,760 hours.
However, factors affecting the magnitude of the hybrid power plant capacity factor include wind resource intermittency, the wind farm site's wind speed distribution, biomass fuel availability, power generation equipment design and reliability as well as other not listed factors.
The degree of wind resource intermittency may vary both daily and seasonally. The biomass fuel availability is very much depending on delivery and production reliability of contractual biomass producers.
The annual electricity output for a hybrid power plant increases with average annual wind speed and biomass fuel supply, since more hours of operation at a higher wind speed and continuous biogas/syngas production mean a higher average MW power output from the hybrid power plant.
If the power generator has enough biomass fuel for continuous rated base load operation, the excess energy can be exported via power distribution grid to more remote located power users. The excess energy that may be generated from such hybrid power plant is shown in the following diagram (Figure 9). In this case capacity factor 0.9 was considered for biomass fuelled power plant.

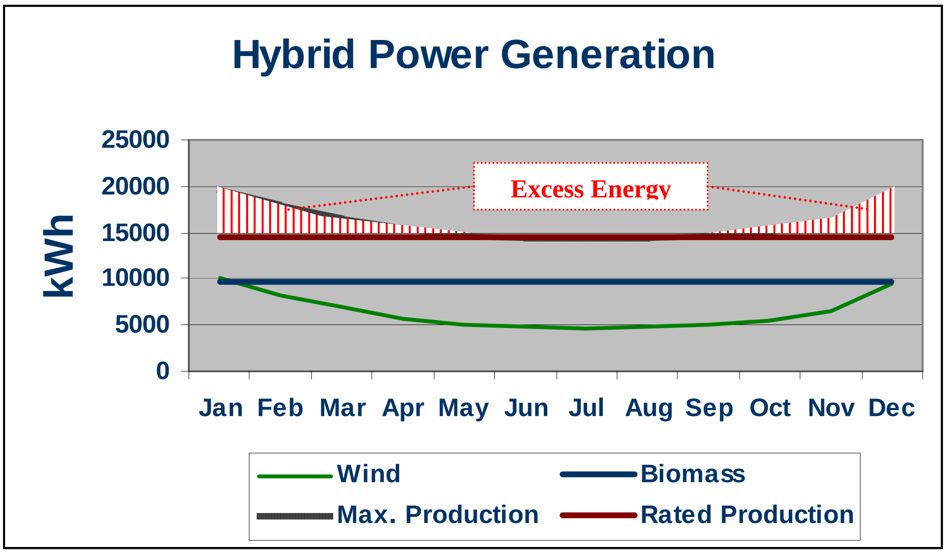


Figure 9

Assuming biogas/syngas low heating value of 22 MJ/m^3, biogas/syngas-production in the range of 0.35 - 0.45 m^3 of biogas per kg of solid substances and CCGT cycle efficiency of 35%, one 15 MW rated CCGT requires between 5’000 and 12’000 tons/month solid biomass waste.

This is very much depending on mode of operation, conceptual design and also on quality of solid biomass waste. The typical consumption of solid biomass waste for miscellaneous modes of operation is shown in the following picture (Figure 10).

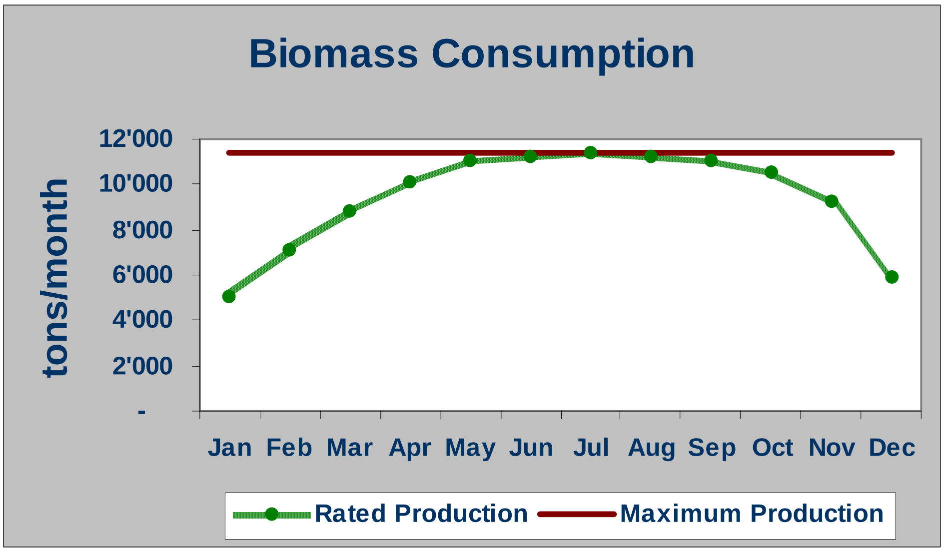


Figure 10

The modular aspect of biomass based renewable power plants also fits the "distributed utility" concept where smaller increments of power are added strategically throughout a utility distribution system to provide power generation closer to where it is needed.

In some world countries, larger-scale demonstrations of biogas and syngas fueled power plants for producing bulk power are under way.

Hybrid wind-GT/ST power generation systems are among the most prospective renewable power generation systems in the future.

This is mainly due to their relatively low capital costs and ability to provide reliable power in the face of intermittent wind power resources. GT/ST generators sets can be quickly started when wind speeds drop below or rise above levels required for safe and reliable wind power generation. GT/ST generators provide a degree of flexibility from a renewable energy perspective.

COMMERCIAL ASPECTS - ECONOMIC VIABILITY

In appropriate locations, distributed hybrid power plants are already economically viable options for the production of electricity.

However, the actual project cost may differ from the present estimates for one or more of the following reasons:

- Changes in interest rates and fees;
- Variation in exchange rates;
- Changes in applicable laws;
- Changes in imposition of any taxes;
- Project delay beyond the control of the Investor;
- Changes in financing draw-down schedule;
- Variations in scope of supply;
- Events or circumstances not within reasonable control of the Investor.

The assumptions detailed in this paper are provided to assist the Investor to undertake its own independent analysis and associated due diligence to determine the viability of the Project. The assumptions have been separated into the following areas, which are detailed below:

- Capital cost;
- Operational cost;
- Revenue;
- Expense;
- Financing;
- Taxation;
- Economics;

Capital cost of the wind/biomass powered hybrid power plants amounts to US$ 53 million (~1500 US$/kW). Total Project Investment Costs breakdown is summarized in the following table (Table 1):

Pos.	Item	Unit	Worst Case
1	Turnkey Price (EPC)	mio US$	44.00
2	Site Preparation	mio US$	0.60
3	O & M Mobilization	mio US$	0.50
4	Contingency	mio US$	1.50
5	Land Costs	mio US$	1.00
8	Reimbursed Development	mio US$	1.80
9	Insurance	mio US$	0.60
10	Consultants' and Advisors' Fees	mio US$	1.00
13	Financing Fees	mio US$	0.50
14	Interest during Construction	mio US$	1.50
15	**TOTAL**	**mio US$**	**53.00**

Table 1
Total Project Investment Costs

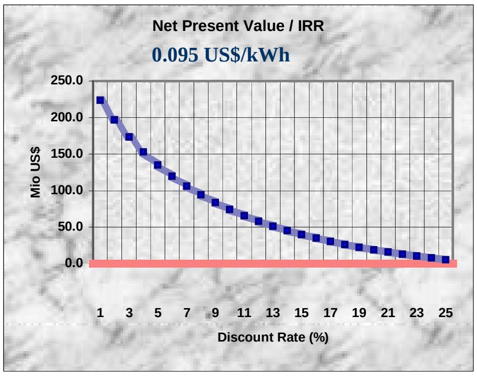
Operational and other main project assumptions are summarized in following Table 2.

Pos	Item	Unit	Worst Case	Best Case
1	Gross Power Output	MW	20	35
2	Degradation factor	%	2	2
3	Power Plant Availability	%	88	92
4	Capacity Factor	%	55	90
5	Expected PPA Tariff	US$/kWh	0.165	0.168
6	Fixed O & M Escalation	%/Year	1.00	0.75
7	Variable O&M Escalation	%/Year	1.50	1.00
8	PPA Tariff & Capacity Escalation	%/Year	0.00	0.25
8	Biomass Price Escalation	%/Year	0.25	0.12
9	Auxiliary Consumption	%	1.8	1.8
10	Hybrid Plant Efficiency	%	45	80
11	Operational Months	No.	12	12
1	Biogas/syngas LHV	MJ/m^3	20	22
2	Biogas/syngas production	m^3/kg SW	0.35	0.45
1	Assumed Solid waste Price	US$/ton	3	2

Table 2
Operational & Other assumptions

Based on above assumptions and other similar projects expected tariff for power generation unit from wind/biomass hybrid power plant will vary between 0.095 – 0.22 US$/kWh.

The lowest tariff, 0.095US$/kWh can be achieved with maximum power output (best scenario, ref. also to Figure 9) as shown in Figure 11. With positive cashflow from year 1, the expected IRR is 23%.



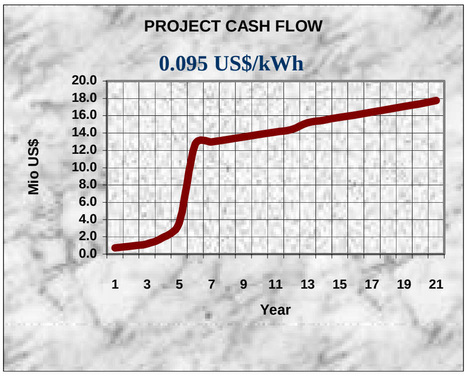
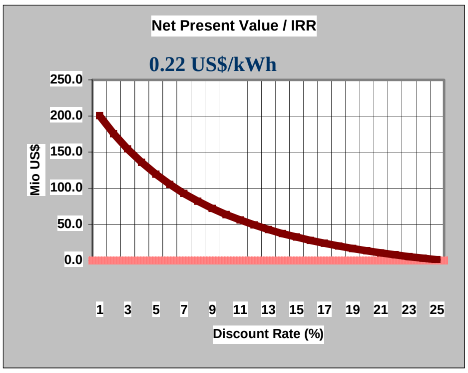


Figure 11

The worst scenario is with combined part load operation (refer also to Figure 7) with expected tariff of 0.22 US$/kWh as shown in Figure 12. The cashflow and IRR remains unchanged.



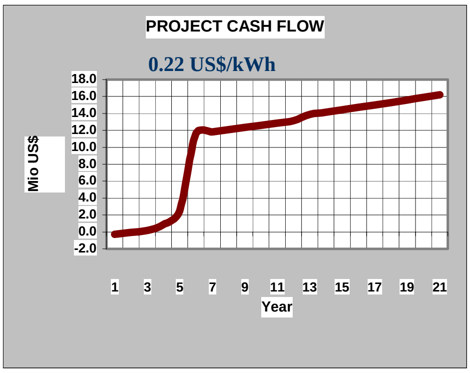


Figure 12

Based on the above figures, it is recommendable to follow similar projects whose assignment is design, construction and operation of 20-40 MW range wind/biomass distributed hybrid power plant.

SUMMARY - CONCLUSIONS

- Fossil fuel derived power causes deaths, illnesses, and contributes to environmental degradation; biomass based fuels and wind don't.
- Disposal of any kind of waste will become ever more constraining, due to environmental regulations and legislations.
- Modern biomass utilization technologies, mainly the gasification and anaerobic digestion, give the advantage of separating the toxious substances and providing clean gas for combustion.
- Additionally, the internal combustion engines fuelled by syngas and biogas have the less emissions compared to petroleum derivates fuelled engines. Sulphur dioxide and NO_x are, normally, absent in syngas and biogas.
- Plantation of electrical energy generation based on gasification and anaerobic digestion technologies is beneficial for world’s environment and its inhabitants.
- In fact, the investment cost for rural electrification based on classical centralized power plants, is related to an erection of long electricity grids to connect the areas to be electrified to the power plants, far away.
- Biomass technologies, such as biomass gasification and anaerobic digestion, that use locally available resources, would enable poor rural areas to access the electricity produced in a decentralized power plants.

- In order to increase the thermal efficiency of small systems, development works with gas/steam cycles aims to downgrade large steam cycle (as already done for GT cycles) to ranges between 1 and 20 MWe.
- In the near future, wind energy will be the most cost effective source of electrical power. In fact good case can be made for saying that it already has achieved this status.
- Renewable wind energy is in constant supply, unlike coal, oil, and gas, which are finite natural resources.
- Unlike fossil fuel prices, which fluctuate due to factors beyond our control, wind power comes with a relatively fixed price, one likely to drop considerably over time.
- Once a site has been selected and permits approved, wind power plant installation can be completed in months (compared to years for a fossil fuel or nuclear power plants).
- The use hybrid power installations as independent systems shall improve access to electric power in regions difficult of access and remote from power grids and thermal power stations in rural and mountain areas.
- Hybrid power systems can improve power quality on weak transmission lines located far from large central power plants.
- The International Energy Outlook 2001 projections indicate a continued growth in worldwide energy demand that is supposed to increase by 59% the present World Energy Consumption by 2020 and, the emissions of CO_2 (one of the GHG that contribute for Global Climate Change) in the same period are almost going to double.

By supporting the development of new hybrid power plants worldwide, we should address the current energy dilemma with a clean, renewable alternative, highlighting the following aspects:

- Worldwide renewable energy portfolio standard that mandates a minimum percentage of renewable energy based power generation in each country should be established by specified date.
- Each government should provide energy tax credits for development of renewable energy projects and should be obliged to provide tax incentives to renewable hybrid power producers that proactively provide biomass waste for power generation.
- Power purchasing and distributing utilities should be encouraged to enter into long-term power purchase agreements with renewable energy power plants at rates that allow the power plants to operate at a profit.

- For modular distributed hybrid power systems to become popular, the public needs to be comfortable with them. The common notion of a noisy and heavily polluting power stations has to be addressed.
- Although modular distributed hybrid power generating systems generally entail a significant first-cost expenditure, a business that suffers an interruption or whose power quality deteriorates to the point that computer-related operations are compromised will likely view that cost as justified.

Modular distributed hybrid power systems are an excellent choice not only for developing countries that have limited central power grids but also for distribution systems in full-developed countries near the rural homes, farms, ranches, or industries likely to produce and use renewable power

Many of the more than 2.5 billion people who live without reliable electricity inhabit areas where huge wind energy and large amounts of biomass are available for fuel production and power generation.

Small and medium size distributed hybrid power plant systems can provide them with power and thermal energy for heating and cooling purposes.

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