Climate Investment Funds

SREP/SC.3/Inf.2
June 8, 2010

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Washington, D.C.
June 22, 2010

Information Note on the Use of Hybrid Systems Under SREP

BACKGROUND

1. In reviewing the document *Elements of Programming Modalities and Operational Guidelines* (SREP/SC.2/3), at its meeting in March 2010, the Sub-Committee requested the Administrative Unit, in collaboration with the MDB Committee, to prepare a background note on the rationale for including or excluding investments in hybrid systems within the scope of activities eligible for SREP financing.

2. The proposed renewable energy technologies covered under SREP include solar thermal and photovoltaic, wind energy, bio-energy (biogas, gasifiers, cogeneration, biofuels), geothermal energy, and hydropower (≤ 10 MW). It has also been proposed that hybrid systems should be eligible for funding under the SREP. This note discusses various issues pertaining to hybrid systems, the rationale for supporting hybrid systems within the scope of the SREP, and recommendations on funding of such systems through the SREP.

HYBRID POWER SYSTEMS

3. While renewable energy is a sustainable energy source, ensuring stability, reliability, affordability and adequacy is equally important for programs that support increasing access to electricity for household use and other income generating and social development activities. Some renewable energy resources such as geothermal, hydropower and bio-energy sources are able to provide stability and reliability in most cases but others such as wind and solar require more innovative ways to optimize their utilization. Renewable energy sources have intermittent (wind), daily cycles (sun) and even seasonal cycles (run-of-river hydro, wind and solar) in terms of resource potential.

4. Hybrid systems provide a high level of energy reliability by using a combination of diverse generation sources, reducing the risk of outages. Hybrid systems, as the name implies, combine two or more energy conversion devices, or two or more fuels, that when integrated overcome limitations inherent in either. These systems can address limitations in terms of fuel flexibility, reliability, emissions reductions, efficiency and economics.

5. In grid-connected renewable energy systems, the grid acts as the energy source/sink for balancing supply and demand. When Renewable Energy (RE) generation is low, other generators on the grid (this could be RE or fossil generators), supply the needed energy. When RE generation is high, then other generation is offloaded. Essentially, grid-tied renewable energy systems make the grid a very large hybrid system, with invariably a high percentage of fossil fuel based systems.

6. In off-grid, mini grid or distributed energy systems, battery storage or a combination of renewable energy sources are used to overcome intermittency and daily cycles, such as wind-battery or wind-PV or even PV-wind-hydro to improve energy availability and to match supply to demand (dispatchability). The most common renewable-only hybrid system uses a combination of solar photovoltaic (PV) and wind turbines, overcoming the intermittency of one renewable energy resource with another, and is most suitable particularly in locations where wind and solar insolation alternate with the seasons.

7. However, on days where both sunlight and wind are limited or not available, the capacity difference needs to be made up in some manner. Such instances call for a combined power plant or hybrid power system that involves both renewable energy and a more reliable and stable source, such as diesel.

8. Further, as systems get larger (i.e. greater use of RE, especially in mini-grids); economic least cost requirements justify inclusion of a diesel generator as back-up. Diesel engines, as a low capital cost technology, is ideal as a backup instead of high capital cost equipment such as batteries or enlarging the wind or PV system. The RE systems can be oversized or a larger battery can be used, but this extra capacity created to enhance supply reliability will lie idle for significant amounts of time when this back up is not needed. For example, in many developing country locations, seasonal variation in solar insolation may be plus or minus 20 percent from the annual average. Without using diesels in a hybrid configuration, the next least cost option might be diesel-only operation in some cases. Figures 1 to 4 in the Annex 1 show energy flows of typical installations for RE hybrids and RE-diesel hybrid systems. The load profiles shown in the annex invariably peak for four-five hours a day starting in the early evening.

9. Moreover, a stand-alone hybrid system will often incorporate at least a small stand-by diesel generating set to supply critical loads in case of emergency. Diesel power plants have been extensively used to complement wind generating systems. Diesel engines have the advantage of a very short start-up time and therefore are available virtually at the press of a button. If bio-energy is used instead of fossil fuels, the plant can also be operated without net carbon dioxide emissions (if biomass is sustainable).

10. RE hybrid retrofits to existing diesel power plants also offer a significant opportunity particularly for remote areas, island grids, mini-grids, off-grid and other similar applications in low income countries.

11. Hybrids, with or without a non-RE component, represent an important market for off-grid power and their total exclusion has the risk of not fulfilling the SREP stated principle of creation of new economic opportunities and increasing energy access through use of RE. Hybrids can be viewed as an enabling technology that allows partial deployment of RE solutions in places where the default choice may be 100 percent fossil. Integration of RE into existing fossil based mini-grids where reliability concerns are high represents a potential to scale up a large market, one which would suffer from a blanket exclusion from SREP support.

12. Hybrid power systems can offer solutions and value to customers that individual technologies cannot match. Also, hybrid projects offer market entry strategies for renewable energy technologies that cannot currently compete with the lowest investment traditional approach.

13. Cost reductions through integration in hybrid systems, in addition to increased reliability, provide additional justification and impetus for large scale deployment of RE. The domino effect of reducing cost, economies of scale and improvements in the technologies and manufacturing processes can help create the enabling environment for scaling up. Stand alone RE systems will then become viable on their own and reduce costs to compare with the grid mix.

14. Advantages and Disadvantages of Hybrid Systems over Stand Alone Systems

System	Advantages	Disadvantages
Stand alone RE	• 100% renewable and clean energy • Mature technologies • Relatively simple	• Seasonal, intermittent, cyclical • Low capacity factor, wind and solar power typically have a capacity factor of less than 40% without storage devices • Dependent on water supply, vulnerable to climate and weather changes • Larger capital cost • Load matching is difficult (solar and wind) • Highly non-dispatchable, especially wind • Site dependent and variable • High cost ancillary equipment such as the battery and the inverter required for a single system must be specified to carry the full system load • Need reliable RE resources
Hybrid systems		
100% Renewable with or without storage	**Advantages**	**Disadvantages**
• Solar PV-wind • Wind-biomass/biofuel • Solar thermal trough technology-biomass combustion steam engines • Solar thermal and biomass-fired • Micro hydro-PV • Solar PV-wind-battery	• 100% renewable and clean energy • Intermittency and seasonality partially addressed; more so with storage or through other complementary renewable resource • Two different energy sources provide a diversity of supply, reducing the risk of power outages • More cost-effective than stand-alone RE systems • A second system is added without increasing the ancillary equipment capacity or adding cost for more of these components • Because of the supply diversity, the capacity of the battery can most likely be reduced • The required generating capacity of the basic solar and wind energy conversion	• More complex than stand alone systems • Without batteries, system has very low capacity during low RE generation • Batteries can be used for short lull periods only unlike diesel back up supply • Waste batteries disposal issues • Not as reliable, affordable and quick-starting compared with non-RE hybrid • Load matching can still be difficult • Vulnerable to changes in weather and climate and to variability and availability of RE resource

	units can be reduced since the total load is shared • Optimizes available RE resources • Mature technologies • Round the clock energy production	
RE and Non-RE with or without storage	**Advantages**	**Disadvantages**
• Solar PV-diesel • Wind-diesel • Solar PV-wind-diesel • Stand alone RE piggybacked on existing fossil-fuel based plant • RE hybrid retrofit to existing diesel power plant	• Supply critical loads in case of an emergency • Require only a very short start-up time and therefore are available virtually at the press of a button • During calm periods, tropical storms or peaks in demand, the engines in the diesel power plant kick in quickly to ensure a constant and reliable supply of power • The optimal dispatch energy mix between renewable and diesel engines also ensures the maximum possible yield from the fuel used. • Sustainable long term energy production • Flexibility of diesel engines to run on biodiesel, enabling a sustainable carbon neutral power supply • Suitable for highly intermittent and variable RE resource • Suitable for limited variety of RE resource to overcome intermittency of stand-alone wind, or lack of insolation for stand- alone solar PV • Medium renewable-share wind-diesel systems are operating in various isolated locations around the world. Instantaneous wind penetration levels exceeding 50% of load are common. • Several high renewable-share systems, with and without energy storage, have been successfully demonstrated • High renewable share systems are capable of prolonged diesel-off operation. • Automatic operation of hybrid systems enhance the power system reliability • Enables load matching	• Not fully renewable • Fossil-fuel capacity needed can be equal to or greater than the RE component to ensure full reliability and load matching

PROPOSED WAY FORWARD

15. Depending on resource availability and load characteristics, combining various technologies in a hybrid system may prove viable where a stand-alone RE system is not. Excluding hybrid systems from SREP might therefore limit the implementation of these types of projects that serve to promote and scale up several RE technologies at once. Retrofitting RE hybrid systems into existing non-RE (e.g. diesel) systems or new RE systems with a small component of non-renewable source offer a significant opportunity for harnessing RE.

16. All 100 percent renewable hybrids should be eligible for SREP support whether off-grid or grid-connected or whether retrofitted or combined into existing RE or non-RE systems. RE resources must be assessed for availability, accessibility and sufficiency to find the right mix of sources for an optimum all RE hybrid configuration. The full 100 percent RE component of the hybrid system should be eligible for SREP funding including ancillary equipment such as batteries, inverters, controllers and similar equipment.

17. For hybrids where non-RE resources are essential, a thorough analysis must be done during project preparation to obtain the optimum hybrid configuration based on local conditions, resource characteristics, relative cost of fuels (including fuel transport to the remote location where the facility operates), energy demand, and financial and economic analyses of the project. The relative costs including fuels costs, specific fuel consumption, variation with load, the variability of the renewable energy resources, and the carbon price[1] for fossil electricity should be taken into consideration in analyzing the optimum configuration

18. Optimization models for hybrid renewable systems developed by various organizations such as RETSCREEN, HOMER may be used to evaluate the design of off-grid or standalone systems. These allow simulation of all possible system equipment with their sizes and a list of many possible configurations may be evaluated and sorted by net present cost to compare the design options.

19. The SREP Sub-Committee may stipulate that hybrid systems, including those that use fossil fuels, may be proposed for financing as a component of a project under a SREP Investment Plan provided justification is made on the GHG emissions reductions achieved as well as cost reductions realized for the RE system. Inclusion of analysis on improved reliability may also be presented as part of the justification.

Recommendation

20. It is proposed that the following systems may be eligible for financing through the SREP:

a. one hundred percent renewable hybrids with or without storage, off-grid or grid-connected
b. one hundred percent RE systems to be combined or retrofitted into an existing RE or non-RE system to form a hybrid whether off-grid or grid-connected

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[1] For the purpose of financial and economic analyses of an investment plan for SREP support, the carbon price can be benchmarked on carbon trading spot prices such as EU allowance spot price.

c. greenfield hybrid systems with a non renewable energy component for off grid and mini-grid applications provided it is a technically and economically optimized design with the percentage of the non-RE component to be determined based on case-specific analysis and bearing in mind the objectives and purpose of the SREP program.[2]

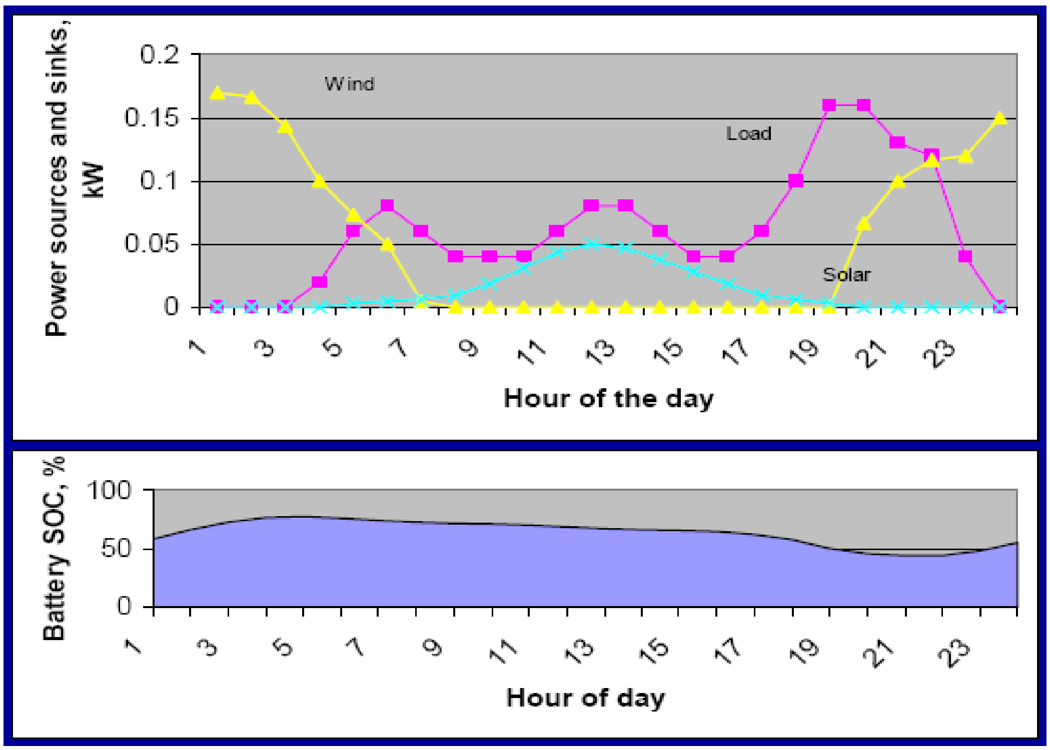
d. replacement of old diesel generators in isolated locations for hybrid systems for off-grid or mini-grid applications provided it is technical optimized viable project and cost-effective solution with a percentage of non-RE component to be determined based on a case-specific considering SREP purpose for RE technology scale-up.

[2] In stand alone or mini-grid configuration, the optimal share of energy from renewables compared to energy from non-RE is a complex function of relative costs including fuel costs, specific fuel consumption variation with load, and the variability of the renewable energy resources. In the simplified analysis presented in Annex 2, an example of a PV-diesel hybrid system is optimized at 20% diesel.

Annex 1 [3]

1. Village hybrid power systems can range in size from small household systems (100 Wh/day) to ones supplying a whole area (10's MWh/day). They combine many technologies to provide reliable power that is tailored to the local resources and community. Potential components include: PV, wind, micro-hydro, river-run hydro, biomass, batteries and conventional generators.

Figure 1 All Renewable Hybrid – Solar-Wind-Battery

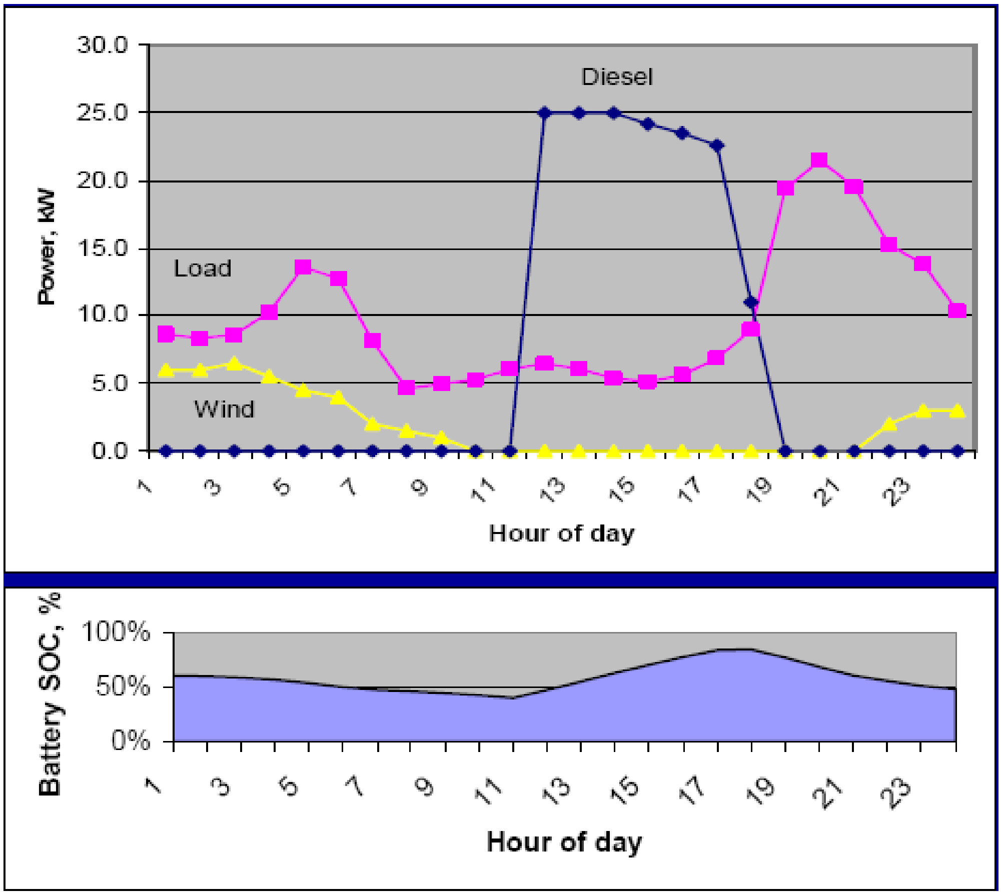


2. Figure 1 shows the energy flow for an all-renewable solar-wind hybrid with storage. The battery is designed to carry the full load and kicks in during low RE generation. Larger, village scale power systems can further be distinguished into two sizes: micro-grids and mini-grids. All have the same feature that they are centrally located and used by the whole community or area through a common distribution system. Micro-grid power systems are small systems with demands up to ~100kWh/day load (15 kW peak load). Equipment include wind turbines, solar PV, batteries and conventional generators. These systems provide AC and potentially DC power. Batteries are used to store renewable energy for use at night or low renewable times. The generator is used as backup power supply only. This is relatively mature technology.

3 (From Hybrid Systems, presentation by Roger Taylor)
Source: *http://files.harc.edu/Documents/EBS/CEDP/HybridPowerSystems.pdf*)

3. Figure 2 shows the energy flow of a small hybrid system with diesel backup. The power system consists of a Whisper 3000 wind turbine, 1.8 kW PV (Siemens), 5.8 kW diesel generator, 25.6 kWh battery bank and 2-SW4048 4kW inverters.

Figure 2 Energy Flow for Small Hybrid – Wind-Diesel



4. Mini-grid power systems are larger systems with demands up to ~700kWh/day load (100 kW peak load). These have the same components used as in micro-grids, just more of them and larger. Batteries are used to store renewable energy for use at times of light loading and the generator is used to supply large loads. The system provide AC power and is mature market although few installations.

5. Figure 3 shows the energy flow of a parallel system with a smaller diesel component. Both the diesel and the inverter are needed to cover the maximum load and both units run together. One such installation is in a remote fishing & tourism community of 400 people in San Juanico, Mexico. The hybrid power system consists of a 17 kW PV, a 70 kW wind, an 80 kW diesel generator, a 100 kW power converter/controller and an advanced monitoring system for optimum performance. Larger systems with demands over ~ 100 kW peak load up to many MW are based on an AC bus configuration. Batteries, if used, store power to cover short lulls in wind

power. Both small and large renewable penetration designs available. There is a large potential for this mature technology but there few examples in the field.

6. On the other hand, Figure 4 shows the switched-system where both the diesel and the inverter are sized to carry the full load and only one runs at a time.

Figure 3 Energy Flow for a parallel system: Wind-Diesel (small)

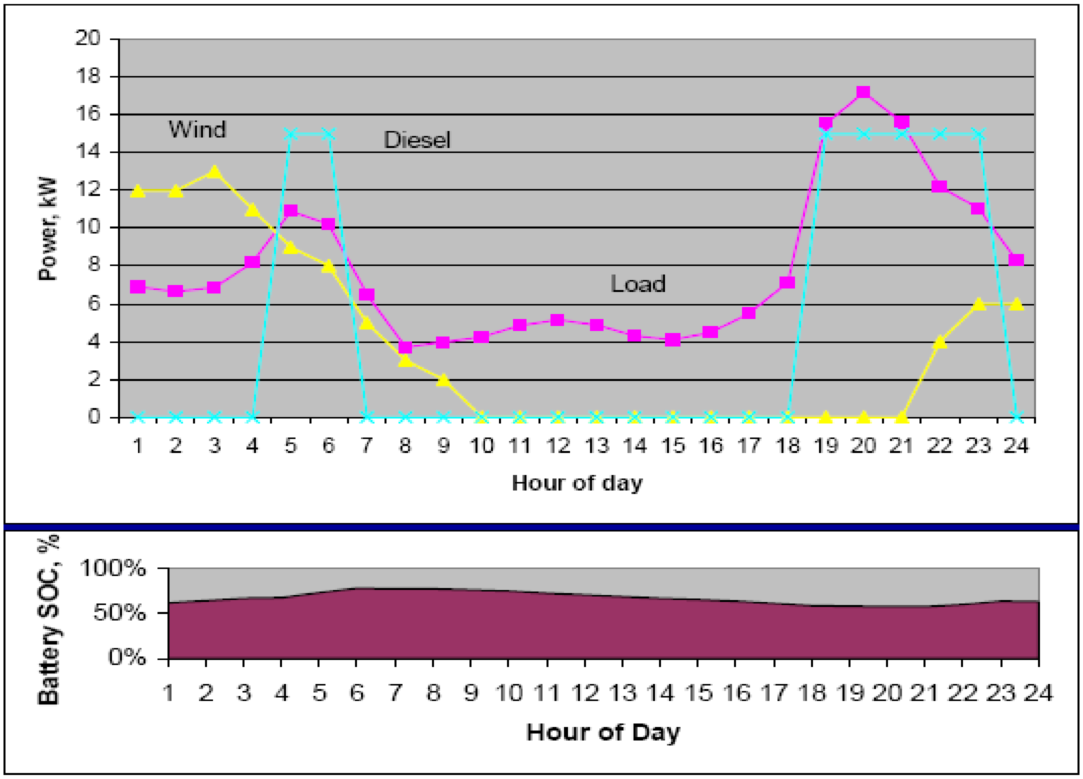
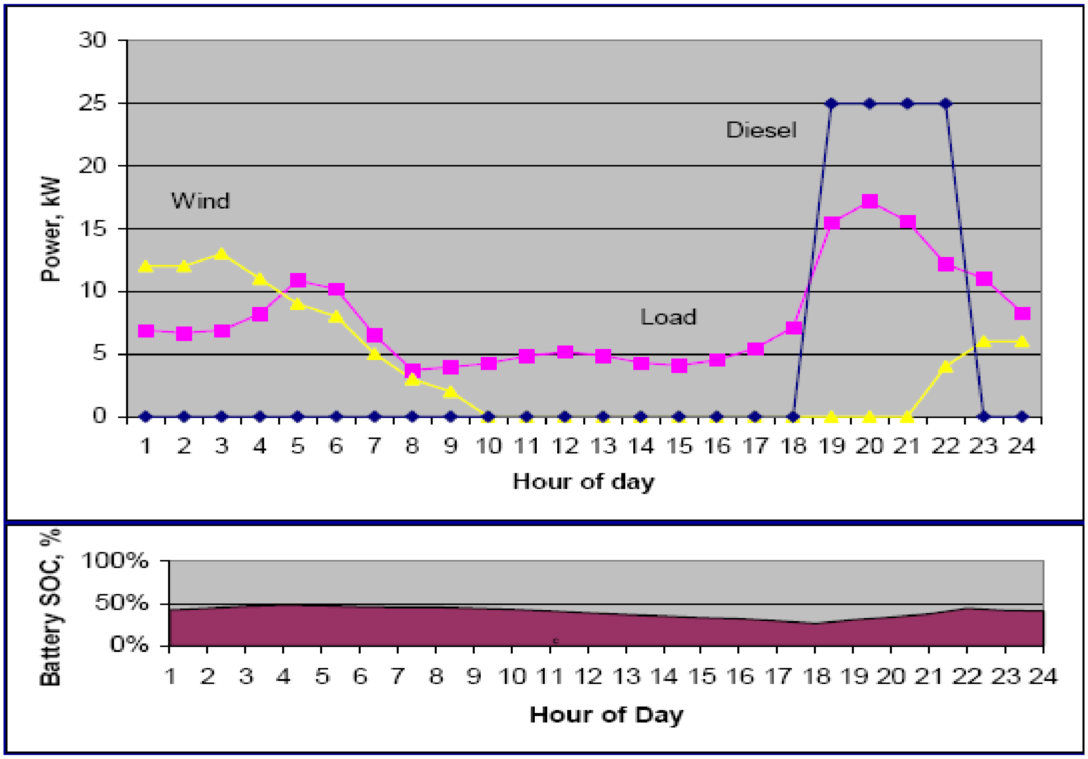


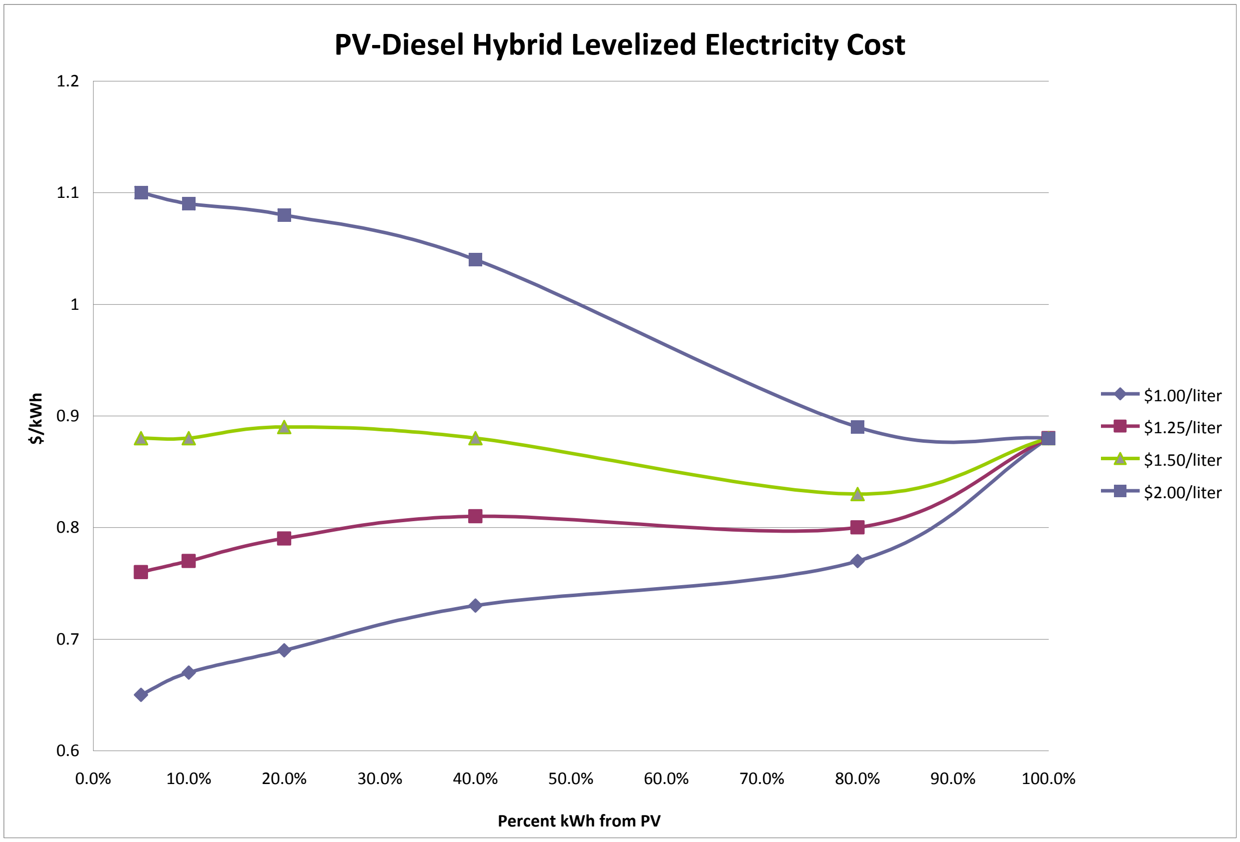
Figure 4 Energy Flow for a switched system: Wind-Diesel (larger)



Annex 2

PV-Diesel Hybrid Levelized Cost

1. As shown in the chart, a rather simplified analysis shows the variation in electricity cost ($/kWh) as the share of PV electricity is increased from 0% to 100% in a PV-diesel hybrid and diesel fuel prices vary form $1 to $2/liter. The fact that the lowest cost of electricity is around 80% PV electricity is merely coincidental - depending on the relative costs, that share would be different. More through analysis of hybrid options and least cost hybrid configuration can be done using a program such as RETSCREEN.



2. It is difficult to come up with the optimal share of energy from renewables compared to energy from non-RE as that depends on various factors. In the example above, PV-Diesel hybrid system is cost optimized at 20% diesel.