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FINANCIAL EVALUATION OF RES-BASED HYBRID POWER STATIONS IN GREECE INCLUDING ENVIRONMENTAL ASPECTS

Master in Energy Systems

You are asked to undertake a preliminary cost-benefit study, associated with the comparison between the implementation of a hybrid RES based solution and a diesel-oil based one, used to cover the electricity consumption of a remote area with total annual electricity consumption of 4.5 GWhe and peak load demand of 1.1 MW.

The hybrid energy solution is based on two different renewable energy technologies; the first regarding the installation of a small wind park (based exclusively on 0.6 MW wind turbines) at a medium-high wind potential (Table I), and the second concerning a small PV power station (based exclusively on 0.5kWp modern PV panels) to be installed in an appropriate area of high solar potential (Table I). The safe operation of the RES-based hybrid power station includes Li-ion batteries for two days of energy autonomy of the remote consumer (DODmax=90% and total-round trip efficiency equal to 80%) along with the necessary electronics (i.e. AC/DC rectifiers, battery charge controllers, and three 50 Hz 450 kVA inverters).

On the other hand, the alternative solution will be based on the operation of three diesel engine generators (each one of 500 kW nominal power), with average efficiency equal to 32%, including the loss of the asynchronous electrical generators.

For both technologies examined, environmental aspects will also be taken into account, while the status of the local electricity market should also be examined taking into consideration the existing system of subsidy and support for RES applications in the course of time.

Financial evaluation of the available solutions should be based on the estimation of the investments’ (simple and complete) pay-back period, NPV (npv) and IRR value.

However, the final evaluation of the proposed solutions should be based also on the estimation of the levelized (on life cycle basis) total electricity production cost (including externalities). •

Investment cost shall derive from the combination of the initial installation cost and the corresponding maintenance and operation cost, considering the entire economic life of each investment and including the possibility of State subsidy.

Revenues from the operation of the plants should be estimated by using the current selling price of electricity, valid for autonomous island networks, while taxation should also be taken into account. The annual escalation rate of the local market electricity price should also be considered, excluding the case of the simple pay-back method.

Name of the student is Konstantinos Georgiou. As I am doing the assignment alone, I will choose the first surname letter for wind turbine and the first letter of my name for the solar panel. Thus Capacity factor values are the following:

* (G from Georgiou) for the wind turbine is ΘCFWT=27%
* ( K from Konstantinos) for the PV Panels comes as the CFPV=18%

and the Wind Turbines in the selected remote island

1. Estimate the simple and the complete pay-back period of the proposed investment (using selected combinations of wind turbines and PV panels) and compare your findings with the diesel based solution. Note that the estimation of the complete pay-back period must be based on the present values of cash flows. At this point it is important to mention that you should select solutions based on commercial available equipment. Is there any remarkable difference between the simple and the complete pay-back period estimated? What are the limitations of the simple pay-back period as an investment appraisal tool? (15%)

We start our proposal by defining the total requested power by the isolated island. This is given by the assignment as 4.500 MW per year with a requested peak load demand of 1.1 MW. The output power for a panel is 0.5kW, for a wind power is 0.6 MW and for diesel engine is 0.5 MW. We have also the efficiency for each different possibility. The Capacity factor values are CFPV=18%, ΘCFWT=27%, ηdiesel =32%, for a panel, for a wind power and for diesel engine, respectively.

By the afore-mentioned I create three different scenarios. One employing only wind turbines, one employing only solar panels and one with a diesel engine.

For the first scenario, that I only utilize solar panels, with a CFPV=18% . In order to fulfill the isolated island demand, I need a park with 5800 solar panels. This means a total power of 0.522MW in order to fulfill an energy demand of 4.572 MW / year. Assuming that the cost of solar panels in Greece is approximately ~ $3 per watt (Source: Ecowatch), this means an investment of 3.000.000 €/MW. So for my scenario, 1.566 million euros. The revenue comes from the relevant price of electricity in Greece. Nowadays, a rough estimation is about 300 €/MWh, yielding a total revenue of 1.371 million euros per year. Assuming running costs (Maintenance and Operations) m for panels equal to 0.5%., yields an FCO=0.0783 million euros. At first point we car about time zero. We calculate the net value of the investment (investment -VAT). Then subtracting from this the annual revenue and dividing with the cost of the investment, gives a payback period of ~0.92 years.

This is the simple payback period method.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Requested power [MW] | 4500 | price of el | 300 | €/MWh |
| Requested peak load demand [MW] | 1.1 | turnkey price panels | 3000000 | €/MW |
| Power of each panel [MW] | 0.0005 | turnkey price wind | 1300000 | €/MW |
| Power of each wind turbine [MW] | 0.6 | turnkey price diesel | 5000000 | €/MW |
| Power of diesel engine [MW] | 0.5 | M&O cost inflation rate | 3% |  |
| CFw | 27% | loan cost | 5% |  |
| Cfpanels | 18% | electr price escalation rate | 1.50% |  |
| Diesel efficiency | 32% | VAT | 20% |  |
| Panels [pieces] | 5800 | m\_panels= | 0.50% |  |
| Wind turbines [pieces] | 0 | m\_wind= | 2% |  |
| Diesel engines [pieces] | 0 | discount rate | 8% |  |
| P panels [MW] | 0.522 |  |  |  |
| P Wind turbines [MW] | 0 |  |  |  |
| P Diesel engines [MW] | 0 |  |  |  |
| Ptotal [MW] | 0.522 |  |  |  |
| Epanels [MWh/year] | 4572.72 |  |  |  |
| Ewind [MWh/year] | 0 |  |  |  |
| Ediesel [MWh/year] | 0 |  |  |  |
| Etot [MWh/year] | 4572.72 |  |  |  |
| Ro [M€] - Annual revenue | 1.371816 |  |  |  |
| Ico [M€] - Cost of investment | 1.566 |  |  |  |
| Ico [M€] - Cost of investment without VAT | 1.2528 |  |  |  |
| Fco[M€] | 0.00783 |  |  |  |
| Average annual cash flow | 1.363986 |  |  |  |
| Simple payback period[years] | 0.9184845 |  |  |  |

Nevetheless, the simple payback period does not take into account the Time Value of Money. This method does not take into account the fact that a euro today is much more valuable than a dollar promised in the future. For example, €10,000 invested over a 10-year period will become €100,000. However, while €100,000 may seem like a bargain today, it won't have the same value a decade from now. The method also does not take into account the cash inflow after the payback period.

We will proceed with the estimation of the complete pay-back period that must be based on the present values of cash flows.

Running costs have an inflation rate of 3% (maybe not a good guess based on the last years). So I have to calculate the running costs for each year, with the Maintenance and Operations inflation rate. Income revenue has to consider the electricity price escalation rate (which is considered for this assignment 1.5%. Maybe also not a good guess for the current situation. From the discounted maintenance costs and the revenue , we derive the cash flow. Assuming a 20% VAT for tha investment and subtracting the VAT from the cash inflows, we divide by the discount rate (assumed to be 8%) to derive the present value. This gives a payback period of 2 years.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Requested power [MW] | 4500 | price of el | 300 | €/MWh |  |  |  |
| Requested peak load demand [MW] | 1.1 | turnkey price panels | 3000000 | €/MW |  |  |  |
| Power of each panel [MW] | 0.0005 | turnkey price wind | 1300000 | €/MW |  |  |  |
| Power of each wind turbine [MW] | 0.6 | turnkey price diesel | 5000000 | €/MW |  |  |  |
| Power of diesel engine [MW] | 0.5 | M&O cost inflation rate | 3% |  |  |  |  |
| CFw | 27% | loan cost | 5% |  |  |  |  |
| Cfpanels | 18% | electr price escalation rate | 1.50% |  |  |  |  |
| Diesel efficiency | 32% | VAT | 20% |  |  |  |  |
| Panels [pieces] | 5800 | m\_panels= | 0.50% |  |  |  |  |
| Wind turbines [pieces] | 0 | m\_wind= | 2% |  |  |  |  |
| Diesel engines [pieces] | 0 | discount rate | 8% |  |  |  |  |
| P panels [MW] | 0.522 |  |  |  |  |  |  |
| P Wind turbines [MW] | 0 |  |  |  |  |  |  |
| P Diesel engines [MW] | 0 |  |  |  |  |  |  |
| Ptotal [MW] | 0.522 |  |  |  |  |  |  |
| Epanels [MWh/year] | 4572.72 |  |  |  |  |  |  |
| Ewind [MWh/year] | 0 |  |  |  |  |  |  |
| Ediesel [MWh/year] | 0 |  |  |  |  |  |  |
| Etot [MWh/year] | 4572.72 |  |  |  |  |  |  |
| Ro [M€] - Annual revenue | 1.371816 |  |  |  |  |  |  |
| Ico [M€] - Cost of investment | 1.566 |  |  |  |  |  |  |
| Ico [M€] - Cost of investment without VAT | 1.2528 |  |  |  |  |  |  |
| Fco[M€] | 0.00783 |  |  |  |  |  |  |
| Average annual cash flow | 1.363986 |  |  |  |  |  |  |
| Simple payback period[years] | 0.9184845 |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
| Year | FCn | Rn | Cash-Flow | Investment | Tax Payments | C-F after tax in PV | Gn |
| 0 |  |  |  | 1.2528 |  |  | 1.2528 |
| 1 | 0.0080649 | 1.39239324 | 1.3843283 | - | 0.2768657 | 1.0254284 | -0.227372 |
| 2 | 0.0083068 | 1.413279139 | 1.4049723 | - | 0.2809945 | 0.9636298 | 0.7362582 |

Following with the next scenario, for a complete utilization of wind turbines.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Requested power [MW] | 4500 | price of el | 300 | €/MWh |  |  |  |
| Requested peak load demand [MW] | 1.1 | turnkey price panels | 3000000 | €/MW |  |  |  |
| Power of each panel [MW] | 0.0005 | turnkey price wind | 1300000 | €/MW |  |  |  |
| Power of each wind turbine [MW] | 0.6 | turnkey price diesel | 5000000 | €/MW |  |  |  |
| Power of diesel engine [MW] | 0.5 | M&O cost inflation rate | 3% |  |  |  |  |
| CFw | 27% | loan cost | 5% |  |  |  |  |
| Cfpanels | 18% | electr price escalation rate | 1.50% |  |  |  |  |
| Diesel efficiency | 32% | VAT | 20% |  |  |  |  |
| Panels [pieces] | 0 | m\_panels= | 0.50% |  |  |  |  |
| Wind turbines [pieces] | 4 | m\_wind= | 2% |  |  |  |  |
| Diesel engines [pieces] | 0 | discount rate | 8% |  |  |  |  |
| P panels [MW] | 0 |  |  |  |  |  |  |
| P Wind turbines [MW] | 0.648 |  |  |  |  |  |  |
| P Diesel engines [MW] | 0 |  |  |  |  |  |  |
| Ptotal [MW] | 0.648 |  |  |  |  |  |  |
| Epanels [MWh/year] | 0 |  |  |  |  |  |  |
| Ewind [MWh/year] | 5676.48 |  |  |  |  |  |  |
| Ediesel [MWh/year] | 0 |  |  |  |  |  |  |
| Etot [MWh/year] | 5676.48 |  |  |  |  |  |  |
| Ro [M€] - Annual revenue | 1.702944 |  |  |  |  |  |  |
| Ico [M€] - Cost of investment | 0.8424 |  |  |  |  |  |  |
| Ico [M€] - Cost of investment without VAT | 0.67392 |  |  |  |  |  |  |
| Fco[M€] | 0.016848 |  |  |  |  |  |  |
| Average annual cash flow | 1.686096 |  |  |  |  |  |  |
| Simple payback period[years] | 0.3996925 |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
| Year | FCn | Rn | Cash-Flow | Investment | Tax Payments | C-F after tax in PV | Gn |
| 0 |  |  |  | 0.67392 |  |  | 0.67392 |
| 1 | 0.0173534 | 1.72848816 | 1.7111347 | - | 0.3422269 | 1.2675072 | 0.5935872 |
| 2 | 0.017874 | 1.754415482 | 1.7365414 | - | 0.3473083 | 1.1910435 | 1.7846307 |

And for the diesel generator:

Operations and maintenance cost for diesel reciprocating engine-driven generators is $0.005-$0.010 per kWh. (Gas Technology Institute - https://www.facilitiesnet.com/powercommunication/article/Onsite-Options--1679#:~:text=The%20average%20operations%20and%20maintenance,kWh%2C%20according%20to%20the%20GTI.)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Requested power [MW] | 4500 | price of el | 300 |  |  |  |
| Requested peak load demand [MW] | 1.1 | turnkey price panels | 3000000 |  |  |  |
| Power of each panel [MW] | 0.0005 | turnkey price wind | 1300000 |  |  |  |
| Power of each wind turbine [MW] | 0.6 | turnkey price diesel | 5000000 |  |  |  |
| Power of diesel engine [MW] | 0.5 | M&O cost inflation rate | 3% |  |  |  |
| CFw | 27% | loan cost | 5% |  |  |  |
| Cfpanels | 18% | electr price escalation rate | 1.50% |  |  |  |
| Diesel efficiency | 32% | VAT | 20% |  |  |  |
| Panels [pieces] | 0 | m\_panels= | 0.50% |  |  |  |
| Wind turbines [pieces] | 0 | m\_wind= | 2% |  |  |  |
| Diesel engines [pieces] | 4 |  |  |  |  |  |
| P panels [MW] | 0 | discount rate | 8% |  |  |  |
| P Wind turbines [MW] | 0 |  |  |  |  |  |
| P Diesel engines [MW] | 0.64 |  |  |  |  |  |
| Ptotal [MW] | 0.64 |  |  |  |  |  |
| Epanels [MWh/year] | 0 |  |  |  |  |  |
| Ewind [MWh/year] | 0 |  |  |  |  |  |
| Ediesel [MWh/year] | 5606.4 |  |  |  |  |  |
| Etot [MWh/year] | 5606.4 |  |  |  |  |  |
| Ro [M€] - Annual revenue | 1.68192 |  |  |  |  |  |
| Ico [M€] - Cost of investment | 3.2 |  |  |  |  |  |
| Ico [M€] - Cost of investment without VAT | 2.56 |  |  |  |  |  |
| Fco[M€] | 0.056064 |  |  |  |  |  |
| Average annual cash flow | 1.625856 |  |  |  |  |  |
| Simple payback period[years] | 1.5745552 |  |  |  |  |  |
|  |  |  |  |  |  |  |
| Year | FCn | Rn | Cash-Flow | Tax Payments | C-F after tax in PV | Gn |
| 0 |  |  |  |  | -2.56 | -2.56 |
| 1 | 0.0577459 | 1.7071 | 1.6494 | 0.3299 | 1.2218 | -1.3382 |
| 2 | 0.0594783 | 1.7328 | 1.6733 | 0.3347 | 1.1477 | -0.1906 |
| 3 | 0.0612626 | 1.7587 | 1.6975 | 0.3395 | 1.0780 | 0.8874 |

2. Estimate the net present value and the internal rate of return (IRR) value of the potential investments under investigation and evaluate your findings. What is the IRR telling you about an investment? Is the net present value the most reliable financial evaluation criterion? Can you choose the most beneficial investment on the basis of the results of questions (1) and (2) using a multi-criteria analysis, taking also into consideration the initial capital to be invested? Discuss your selection/answer. (20%)

Internal rate of return is a capital budgeting calculation for deciding which projects or investments under consideration are investment-worthy and ranking them. IRR is the discount rate for which the net present value (NPV) equals zero (when time-adjusted future cash flows equal the initial investment). IRR is an annual rate of return metric also used to evaluate actual investment performance.

We will calculate the IRR with the excel IRR function.

For the first scenario where only solar panels are considered.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Year | FCn | Rn | Cash-Flow | Tax Payments | C-F after tax in PV | Gn | IRR |
| 0 |  |  |  |  | -1.2528 | -1.2528 |  |
| 1 | 0.0080649 | 1.39239324 | 1.3843283 | 0.2768657 | 1.0254284 | -0.227372 |  |
| 2 | 0.0083068 | 1.413279139 | 1.4049723 | 0.2809945 | 0.9636298 | 0.7362582 | 38% |

For the wind turbines respectively:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Year | FCn | Rn | Cash-Flow | Tax Payments | C-F after tax in PV | Gn | IRR |
| 0 |  |  |  |  | -0.67392 | -0.67392 |  |
| 1 | 0.0173534 | 1.72848816 | 1.7111347 | 0.3422269 | 1.2675072 | 0.5935872 |  |
| 2 | 0.017874 | 1.754415482 | 1.7365414 | 0.3473083 | 1.1910435 | 1.7846307 | 157% |

For the diesel generator:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Year | FCn | Rn | Cash-Flow | Tax Payments | C-F after tax in PV | Gn | IRR |
| 0 |  |  |  |  | -2.56 | -2.56 |  |
| 1 | 0.0577459 | 1.7071 | 1.6494 | 0.3299 | 1.2218 | -1.3382 |  |
| 2 | 0.0594783 | 1.7328 | 1.6733 | 0.3347 | 1.1477 | -0.1906 |  |
| 3 | 0.0612626 | 1.7587 | 1.6975 | 0.3395 | 1.0780 | 0.8874 | 17% |

A positive IRR mean that the project is beneficial and should be selected. So all of the projects are beneficial. If we would like to choose only one project then we would have to select the highest IRR. Thus the wind turbines scenario.

3. Furthermore, estimate the levelized (on life cycle basis) total electricity production cost of the proposed configurations (excluding the externalities at this point). Rank your proposed solutions on the basis of the LC electricity generation cost and compare your results with the ones of question (2). Comment on your findings.

The levelized (on life cycle basis) LCOE can be calculated by first taking the net present value of the total cost of building and operating the power generating asset. This number is then divided by the total electricity generation over its lifetime.

For the first scenario where only solar panels are considered.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | FCn | Rn | Cash-Flow | Tax Payments | C-F after tax in PV | Gn | IRR | NPV of costs | NPV of electrical energy | LCOE (euro/kWh) |
| 0 |  |  |  |  | -1.2528 | -1.253 |  |  |  |  |
| 1 | 0.0081 | 1.3924 | 1.3843 | 0.277 | 1.025 | -0.227 |  | 0.007 | 4234 |  |
| 2 | 0.00831 | 1.4133 | 1.4050 | 0.281 | 0.964 | 0.736 | 38% | 0.007 | 3920.37 |  |
|  |  |  |  |  |  |  |  | 0.014 | 8154.37 | 0.0017 |

For the wind turbines respectively:

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | FCn | Rn | Cash-Flow | Tax Payments | C-F after tax in PV | Gn | IRR | NPV of costs | NPV of electrical energy | LCOE (euro/kWh) |
| 0 |  |  |  |  | -0.67392 | -0.67392 |  |  |  |  |
| 1 | 0.017 | 1.728 | 1.711 | 0.342 | 1.268 | 0.5936 |  | 0.016 | 5256 |  |
| 2 | 0.018 | 1.754 | 1.737 | 0.347 | 1.191 | 1.7846 | 157% | 0.014 | 4866.67 |  |
|  |  |  |  |  |  |  |  | 0.030 | 10122.67 | 0.0030 |

For the diesel generator:

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | FCn | Rn | Cash-Flow | Tax Payments | C-F after tax in PV | Gn | IRR | NPV of costs | NPV of electrical energy | LCOE (euro/kWh) |
| 0 |  |  |  |  | -2.56 | -2.56 |  |  |  |  |
| 1 | 0.058 | 1.707 | 1.649 | 0.330 | 1.222 | -1.338 |  | 0.0519 | 5191.11 |  |
| 2 | 0.059 | 1.733 | 1.673 | 0.335 | 1.148 | -0.191 |  | 0.0481 | 4806.58 |  |
| 3 | 0.061 | 1.759 | 1.697 | 0.339 | 1.078 | 0.887 | 17% | 0.0445 | 4450.54 |  |
|  |  |  |  |  |  |  |  | 0.1445 | 14448.24 | 0.0100 |