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Data Article

Data for the project management, life cycle inventory, costings and energy production of a ground-mounted photovoltaic farm in Greece

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ABSTRACT

Data was collected using standard communication equipment and invoices provided by an established civil construction and renewable energy development and operation company. Data referring to the construction, costings, operation and environmental impacts of a photovoltaic farm were recorded into four distinct Excel files namely: i) Project Management Data, ii) Life Cycle Inventory (LCI), iii) Electricity Generation Data and iv) Operational Cost Data.
For the project management, the given quantities of the resources used in each activity could be further combined with the costs from different geographical and time regions to estimate overall project implementation costs for similar projects. The LCI data for the materials and transportation used can set the basis for life cycle assessment modelling of ground-mounted photovoltaic farms of that size and type. The electricity generation data along with meteorological parameters and location coordinates can be further enhanced to predict and manage energy generation and cashflow of expectations installations of this type and size over time. Finally, the data referring to a number of cost

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categories(‘maintenance costs’, ‘operational costs’, ‘insurance costs’ and ‘any other costs’), especially combined with the previously mentioned types of data could support a holistic technoeconomic and environmental assessment of comparable commercial photovoltaic installations.
In addition, these data can be used for a comparative multidisciplinary evaluation between photovoltaics and among various renewable electricity generation alternatives and traditional fossil fuel-based options as well.

Specifications Table

Subject	Renewable Energy, Sustainability, and the Environment
Specific subject area	Life Cycle Assessment (LCA), Renewable Energy Sources (RES), Sustainability, Environmental Sciences, Construction Engineering, Project cost and schedule management and control.
Type of data	Table
How the data were acquired	Electricity generation data were acquired through the communication device which is installed at the photovoltaic farm and which is directly connected to the inverters through UTP cables. The device is the “Smart Communication Box,” model COM100E of Sungrow Power Supply Co., Ltd [1]. The measurements are recorded and are accessible to the owner of the photovoltaic farm through the manufacturer’s portal. Financial, project management and life cycle inventory related data were gathered from the respective project task invoices.
Data format	Raw Analyzed
Description of data collection	No specific conditions were considered for the data collection, nor any normalization or exclusion/inclusion criteria were applied. Data was collected from the civil construction company which developed and is operating the PV park utilizing communication devices and the financial documents.
Data source location	Town/Region: Arnissa/Macedonia Country: Greece Latitude 40.7842643846203 Longitude 21.8619472830377
Data accessibility	Repository name: Mendeley Data Data identification number: 10.17632/7h9mdf5fvt.1 Direct URL to data: ⟨13:italic ⟩https://data.mendeley.com/datasets/7h9mdf5fvt/2⟨/13:italic⟩
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Value of the Data

- The current data set or parts of it can be used between others to estimate the necessary resources to develop, compare, test and evaluate strategies/policies in order to optimise decision-making processes in the fields of Project Management, Environment, Finance, Engineering and Renewables.
- The data are provided using the original units of measurement and are not explicitly expressed in monetary terms, thus avoiding the loss of information. In case they are expressed in monetary terms, a description of the procedure of how the respective costs are calculated is given, so that the data can be adjusted to the specific needs of the users for various spatial and temporal occasions.

- The data can be used by researchers and academics who would like to develop similar life cycle assessments, when a clear and analytical inventory for the works and the supporting infrastructure is required. They can also be used for a multitude of other studies, ranging from the forecasting of a system performance to the evaluation of alternative locations for solar power generation.
- This dataset can be valuable to developers and investors who need to have a clear overview of the time and resources required to develop a ground-mounted photovoltaic installation. In addition, the data can be useful for various comparisons between photovoltaics and other renewable energy sources and electricity production.
- The provided data can be useful to various stakeholders such as policy makers, local authorities, prospectors, and organisations who need to get well-informed decisions about issues related to the development of ground-mounted photovoltaics and renewable energy in general (such as land use and power grid connections).
- The data can be used to provide actual cash flow outcomes on an accrued basis. In particular, they can be used to develop cost and time models, in relation to the construction project performance, as the pertain to their financial viability.

1. Objective

- A dataset of real values for project management, construction, and electricity generation monitoring, which span throughout various disciplines and allow for a representative and holistic technoeconomic and environmental assessment of a commercial photovoltaic installation.
- Comprehensive data which facilitate stakeholder engagement, complex decision-making and strategy development in the specified fields.
- Compared to the original research article, the data provided here additionally includes daily values for electricity generation for approximately 2.75 years, a detailed project analysis (dependencies, durations and resource allocation in tasks), costings, as well as a detailed life cycle inventory per task.

2. Data Description

As energy from photovoltaics have the third largest share of global capacity of renewable energy sources (following that of hydro wind power) [2], the study of ground-mounted photovoltaic farm installations, is receiving more attention the last years. The data collected refer to the construction, costings, operation and environmental impacts of a photovoltaic farm and are provided in four separate Excel files with respect to their type and usage. Each file can be used separately for studying an individual topic or in combination with certain of the others to facilitate the study of more complex concepts. These four Excel files refer to the following dataset types:

1. Project Management Data
2. Life Cycle Inventory (LCI)
3. Electricity Generation Data
4. Operational Cost Data

2.1. Project Management Data

Project Management typically includes the processes of planning, scheduling, organising, executing, monitoring, and controlling the construction of a facility or a complicated product in order to optimize its duration, cost and use of associated resources [3]. Every project is divided in several simpler jobs, called tasks and then dependencies between these tasks are defined so that the plethora of the abovementioned processes can be dealt with in a systematic way. This is also known as work breakdown and presents the tasks in a hierarchy form. As presented in the literature [4], four different types of dependencies between tasks are met, 'Finish to Start' (FS) that is the most common, 'Start to Start' (SS), 'Finish to Finish' (FF) and 'Start to Finish' (SF). A task may have multiple dependencies from other tasks while also a lag is allowed in the above-described dependencies.

The respective dataset, as shown in Table 1 consisting of 6 columns where information for each task and for the elementary subtasks (activities) they comprise of is provided. First column presents the number of each task/subtask while in the second one the project tasks and their subtasks are defined. It must be noted that the first table entry refers to the overall project (task number 1), the bold ones to the tasks the project is broken down to (e.g. entry 3) and finally the rest entries (e.g. 4 and 5) refer to the elementary subtasks (activities) that can be scheduled to optimize overall project cost and duration. The third column contains the tasks/subtasks durations (in days). For each task, divided in a number of subtasks under it, its duration is calculated with respect to the ones of the subtasks and their precedence relationships. The fourth column shows the predecessors of each task (if any) and the fifth column shows the type of the dependencies between them (e.g. 'FS'). Finally, the sixth column describes the types and quantities of the resources that are necessary in order to perform each activity. The number in brackets '[]' denotes the quantity of the specific resource to be used. The defined quantities of the resources used in each activity can be combined with the costs (labour and materials) from different geographical and time regions in order to calculate their specific overall project implementation costs.

2.2. Life Cycle Inventory (LCI)

Life Cycle Assessment is a standardized methodology [5] and it is one of the main tools used for the assessment of the environmental impacts for many products and services including electricity generation [6]. This phased approach consists of four components: goal definition and scoping, inventory analysis, impact assessment, and interpretation [7], with the inventory analysis being the phase where a Life Cycle Inventory is compiled so that a model can be built using a software that utilises databases [8,9] that contain the datasets that can be matched to the collected LCI data. A detailed LCI is crucial so that the life cycle environmental impacts can be estimated better and also because the expected waste from the materials used can be calculated as well. This is particularly important because the waste legacy from renewable energy infrastructure [10] and especially from electronics [11] has become an issue of concern. The LCI dataset presented in this paper constitutes a detailed description of the materials and processes required to develop a 499.95 kW commercial ground-mounted photovoltaic farm with monocrystalline panels.

The respective dataset, as shown in Table 2 consisting of 5 columns following a format similar to the Project Management Table 1 to ensure coherence and facilitate the combination of these two. Therefore, the first two columns present the number of each task/subtask and the second the project tasks/subtasks. The third column describes the material and transport requirements for each subtask and the next columns the measurement unit and the fifth column the quantities used.

For the main tasks denoted in bold font, like 'Earth works', the cells in the last three columns are left blank because there is detailed description provided for their respective subtasks (e.g. site clearing and ground flattening). For some of the subtasks which do not involve any materials inputs like 'concrete hardening' values to measure time from a LCA point of view were not necessary so an indication 'N/A' which stands for 'Not/Applicable' has been used instead. In the third column some of the materials are in italics to denote that they are subcomponent of the material/equipment described above. This mainly refers to the cables, because the data collected only described the type of the cable and its length. The developer and the authors estimated

Table 1
Project management related data table

Project: Construction 499.95 kW ground- mounted photovoltaic farm					
Task/Subtask Number	Tasks/Sub-tasks name	Duration	Predecessors	Dependence type	Resource names and quantities
1	**Overall project**				
2	**Project initiation**	**0 days**			
3	**Earth works**	**5 days**			
4	Site clearing	3 days			Contracted worker [2]; Buldozer
5	Ground flattening	2 days	4	FS	Grader; Contracted worker [2]
6	**Access road construction**	**2 days**			
7	Road opening	1 day	5	FS	Grader; Contracted worker [2]
8	Construction aggregate unloading and flattening	1 day	7	FS	Tipper truck; Grader; contracted worker [2]; GRIT[60 m3]
9	**Positioning**	**1 day**			
10	Land surveyor	1 day	8	FS	Land surveyor
11	**Enclosure construction**	**5 days**			
12	Hole drilling	1 day	10	FS	Excavator; Contracted worker [3]
13	Concrete production	2.5 days	12	FS	Contracted worker; Cement mixer
14	Fence post installation and support with concrete	1 day	13	SS	Contracted worker [3]; Fencing stakes[174 pieces]; Concrete[17.4 m3]
15	Hollow section installation and support with concrete	1 day	14	FS	Mini excavator; Contracted worker [3]; Hollow section[1 piece]; Concrete[1.4 m3]
16	Concrete hardening	1 day	15	FS	
17	Metal fence installation	1 day	16	FS	Contracted worker [5]; Woven metal fence [18 pieces]; Perimeter protection materials[1 pieces]
18	**Panel bases installation**	**9 days**			
19	Allignments and distances	1 day	17	FS	Contracted worker [4]
20	Fence stake transport and distribution	1 day	19	FS	Contracted worker [4]; Loader machine; Mini excavator
21	Fence stake installation	2 days	20	FS	Contracted worker [2]; Ramming machine
22	Bases assembly and installation	5 days	21	FS	Contracted worker [4]; Mini excavator
23	**Construction of bases for substation and shed**	**2 days**			
24	Excavation and flattening	0.5 days	19	FS	Excavator; contracted worker [2]
25	Reinforcement steel placement and shuttering	0.2 days	24	FS	Contracted worker [2]; Reinforcement steel [1528 kg]

(*continued on next page*)

Table 1 (*continued*)

Project: Construction 499.95 kW ground- mounted photovoltaic farm					
Task/Subtask Number	Tasks/Sub-tasks name	Duration	Predecessors	Dependence type	Resource names and quantities
26	Concrete mixing and pouring into molds	1 day	24	SS	Truck concrete mixer; contracted worker; Concrete[1.99 m3]
27	Concrete hardening	1 day	26	FS	
28	**Substation installation and shed construction**	2 days			
29	Substation installation on the base	1 day	27	FS	Crane truck; Driver; Contracted worker PST [2]
30	Construction site shed Production	2 days	27	FS	Construction site shed materials [1 piece]; Contracted worker PST [2]

Table 2
Life cycle inventory related data table.

Project: construction 499.95 κW Ground-mounted photovoltaic farm				
Task/subtask number	Tasks/Sub-tasks name	Materials and transportation requirements	Unit	Quantity
1	**Overall project**			
2	**Project initiation**			
3	**Earth works**			
4	Site clearing	Diesel for buldozer	lt	576.92
5	Ground flattening	Diesel for motor grader	lt	307.69
6	**Access road construction**			
7	Road opening	Diesel for motor grader	lt	153.85
8	Construction aggregate unloading and flattening	Diesel for tipper truck	lt	192.31
		Diesel for motor grader	lt	153.85
		Grit/gravel	m^3	60
		Transport for gravel	tkm	148

N/A' denotes that data values do not apply for this task/subtask.

the weight of their main components, like copper and polymer, and where such an estimation took place an asterisk '*' is used to note it. This can be beneficial for an LCI because in this way the users could either find this specific type of cable or alternatively create their own model based on the estimation provided. The transportation requirements are given in tonne-kilometres (tkm) and the user can choose the type of lorry preferred. There were no electricity uses recorded during the development and most of the energy used was either in the form of fuel for the machines or in the form of transportation. Therefore, the energy requirements are not given separately because they are indirectly provided in the transportation and the quantity of fuel used.

2.3. Electricity Generation Data

The Excel file 'Electricity Generation Data' contains daily electricity generation from the specific photovoltaic installation for a period of 976 days, from 2020-04-10 to 2022-12-11. Table 2 illustrates a part of the dataset. The first column shows the date and the second column shows the electricity generated from the specific ground photovoltaic farm on the specific date in kWh. This ground photovoltaic farm is located in the region of Macedonia in Greece and the installation centre coordinates are (Latitude40.7842643846203,Longitude 21.8619472830377). These data can also be combined with meteorological parameters (such as air temperature, solar irradiance, humidity, wind speed etc.) of the respective area for the time period under study. This in combination with the application of appropriate methods and models could enable predicting future values as also presented in surveys in the literature [12,13].

2.4. Operation and Maintenance (O&M) Cost Data

Four categories of costs are provided per month in this table and in particular: 'maintenance costs', 'operational costs', 'insurance costs' and 'any other costs' as indicated in the first column. Maintenance cost concerns a contract between the owner and a contractor and includes: energy production monitoring, sample check for any mechanical failures or constructional disorders every six months and minor fixes. Operational cost includes telecommunication and power consumption services. The price for the telecommunication services provided under the specific contract and for the given time period is 13.90 €. The rest of the costs refer to power supply from the grid, which range from 13.00 € to 155.25 € monthly which on average corresponds to a consumption of 330 kWh. It is worth mentioning that the lowest cost of 13.00 € refers to the first month for which only 10 days have been accounted for. The monthly consumption cost fluctuations reflect the corresponding variations in the price of the kWh given by the provider for that month. Insurance cost includes insurance which covers mechanical failures and loss of profits. Any other cost may include replacement of any equipment in case of failure or any addition for the upgrade of the installation. In the specific case recorded in our data, a battery was installed, so that the medium voltage substation maintains and prolongs its operation in case of minor power outage/voltage disturbances caused by distribution network issues.

(see Table 3 and Table 4)

It has to be noted that the lag between the apparent electricity generation and the operational cost is explained by the fact that the costs commence with the contractual agreement for the connection of the photovoltaic farm to the grid while the actual electricity generation takes place a month after. The cost values for the last two months of 2022 are due to the fact that the invoices are issued every two months.

3. Experimental Design, Materials and Methods

Data was collected from an established civil construction and renewable energy development and operation company with a track record of projects. The data collected is owned by the co-author – Anastasia Pavlidou who is the President and CEO of P.S.T. S.A company. Standard communication devices, directly connected to the inverters are installed at the photovoltaic (PV) farm and were used for the electricity generation data collection and in particular the "Smart Communication Box," model COM100E of Sungrow Power Supply Co., Ltd [1]. Invoices and the project management schedule were utilised for the compilation of financial, project management and life cycle inventory related data. The project management task decomposition and schedule provided the dependencies, the duration and the sequence among the tasks. The invoices were used to extract the dates, costs, quantities, and description of the resources (materials, energy and labour/services used) that are necessary for the construction, operation and maintenance as well as the compilation of the life cycle inventory for this photovoltaic farm. The data were provided in raw format and no extended filtering or processing (e.g. normalization) was performed.

Table 3
Electricity generation related data table.

Output of 499.95 kW ground-mounted photovoltaic farm	
Date	Electricity generation (kWh)
2020-04-10	157.00
2020-04-11	1,328.70
2020-04-12	1139.70
2020-04-13	1331.00
2020-04-14	923.20
2020-04-15	1287.60
2020-04-16	3287.00
2020-04-17	2452.10
2020-04-18	3437.90
2020-04-19	2070.60
2020-04-20	1804.80
2020-04-21	347.20
2020-04-22	1336.90
2020-04-23	1389.30
2020-04-24	3505.40
2020-04-25	1262.30
2020-04-26	3330.40
2020-04-27	2956.90
2020-04-28	3149.90
2020-04-29	2232.90
2020-04-30	2892.40
2020-05-01	3394.80
2020-05-02	1157.70
2020-05-03	3301.30
2020-05-04	3283.20
2020-05-05	3658.50
2020-05-06	2091.30
2020-05-07	3476.00
2020-05-08	3659.40
2020-05-09	3653.90
2020-05-10	367.90

Table 4
Operation and maintenance cost related data table.

OUTPUT OF 499.95 kW GROUND-MOUNTED PHOTOVOLTAIC FARM				
	Cost type (in '000s euros)			
Year-Month	Maintenance cost	Operational cost	Insurance cost	Any other cost
2020-3	2232.00 €	26.90 €	635.67 €	
2020-4		65.90 €		
2020-5		88.90 €		
2020-6		96.90 €		
2020-7		98.90 €		
2020-8		88.90 €		
2020-9		88.90 €		
2020-10		74.90 €		
2020-11		78.90 €		
2020-12		86.90 €		
2021-1		90.90 €		
2021-2		98.90 €		
2021-3	2232.00 €	86.90 €	715.08 €	
2021-4		90.90 €		
2021-5		96.90 €		
2021-6		88.90 €		998.20 €

Ethics Statement

The authors declare that the present work did not include experiments on human subjects and/or animals.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

The authors declare no conflict of interest except the co-author – Anastasia Pavlidou who is the President and CEO of the company engaged as the Principal Contractor and acted as the contractor's representative for each project.

CRediT Author Statement

George Tsinarakis: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Supervision, Writing – review & editing; **Victor Kouloumpis:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Supervision, Writing – review & editing; **Anastasia Pavlidou:** Conceptualization, Validation, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing; **George Arampatzis:** Conceptualization, Formal analysis, Writing – original draft, Supervision, Writing – review & editing.

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