Energy from the Vietnamese sun: photovoltaic system at a sewage treatment plant

A flagship project for water management in South-East Asia

A photovoltaic (PV) system combined with sewage plant – a combination which constitutes a novelty in Vietnam. The first plant of its kind is being constructed as a joint project between Tilia GmbH and the German Energy Agency (dena) in the provincial capital of Sóc Trăng.

Starting point

Leipzig-based service provider and consultancy firm Tilia GmbH has been supporting Vietnamese municipal wastewater companies when it comes to optimizing their operations from as early as 2015. As part of the develoPPP project "Good Practices and Development of a Management Partnership for Optimized Wastewater Management in Vietnam", supported by the German Federal Enterprise for International Cooperation (GIZ), the partners have, among other things, improved the technology used in the local sewage treatment plant of the provincial Vietnamese city of Sóc Trăng, which is located in the Mekong Delta, in the south of the country.

The municipal sewage treatment plant on site was designed for a population equivalent of 100,000 and an average dry weather flow of 13,000 m^3/d, whereby the actual utilization rate of the sewage treatment plant in relation to the organic load only amounts to around 50% of the original design. To some extent, the hydraulic load fluctuates considerably due to the change between the dry and wet season. Currently, only the mechanical expansion phase and the plant's sludge treatment have been completed. However, a second (biological) expansion phase is already being planned.

A partial aspect of the develoPPP project was the aim of achieving an increase in efficiency across the entire plant. Therefore, in Sóc Trăng, focus was placed on improving the infrastructures of the plant and in the grid in particular. What's more, alternative methods of treating sludge were also tested.

A solution for energy provision in the future was developed in conjunction with Vietnamese partner and operator of the wastewater infrastructure, the Sóc Trăng Public Works Company (SPWC): the energy needs of Sóc Trăng's sewage treatment plant were, for the most part, to be covered using renewable sources. Upon considering various solutions, it became clear that, under the given framework conditions, using a photovoltaic system to generate electricity was a solution which made sense both ecologically and economically. Sóc Trăng, the capital city of the region which bears the same name, is in the sunny south of Vietnam, an area which receives up to 2,600 hours of sunlight per year. Global irradiation values here amount to 1,825 kWh/m^2*a, or 5 kWh/m^2*d, on average [1]. For comparison: in Germany, the annual average value only amounts to around 1,000 kWh/m^2. Furthermore, the sludge drying beds offer an existing roof with an area comprising 12 x 172 m^2 which is free from shade. Due to its incline (17°), alignment (azimuth 86° SW / 94° SE), and load-bearing capacity, this area is optimally-suited for being filled with photovoltaic modules (see **Figure 1**). Due to the meteorological and structural suitability of the location, an initial conceptual design has already been carried out as part of the develoPPP project. The Vietnamese partners received this with great interest.

For this reason, Tilia GmbH and the SPWC decided to pursue this idea after the develoPPP project had been concluded. Financial support was able to be obtained through dena and their acceptance of the project into their "Renewable Energy Solutions (RES) Programme", which enabled the concept idea to be implemented.

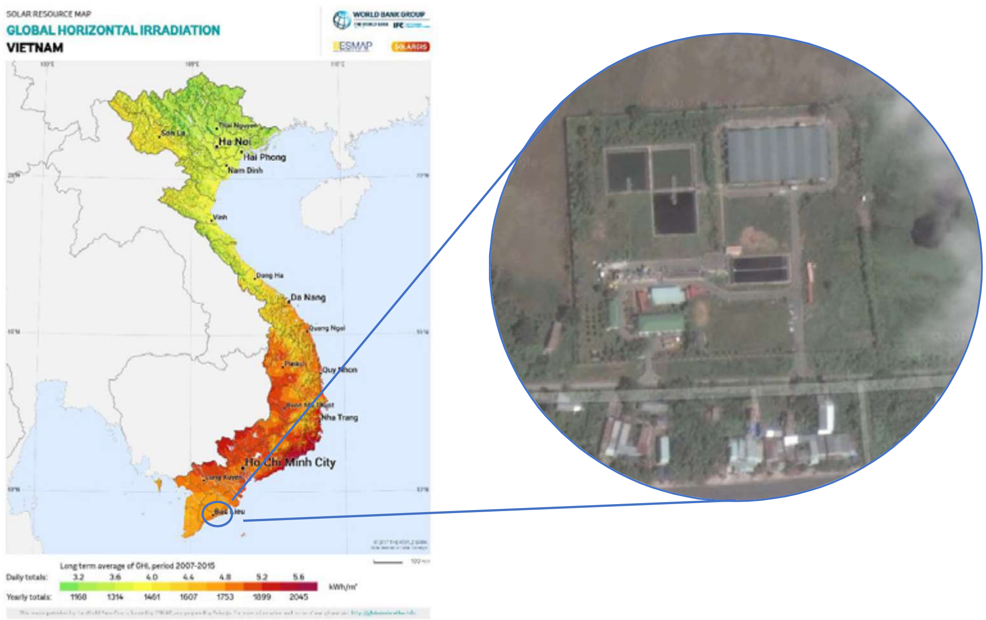

Figure 1: *Map of average annual global irradiation in Vietnam and the location of the sewage treatment plant [2]*

***Table 1:** Vietnam Electricity (EVN) electricity tariffs for consumers with a nominal value of more than 22 kV [3, 4]*

	Time periods	VND/kWh	ct/kWh[1]
Off-peak	10:00 p.m. - 4:00 a.m. (daily)	2,254	8.2
Standard	4:00 a.m. - 09:30 a.m. 11:30 a.m. - 5:00 p.m. 8:00 p.m. - 10:00 p.m. (Mon. – Sat.) 4:00 a.m. - 10:00 p.m. (Sun.)	1,256	4.6
Peak	09:30 a.m. - 11:30 a.m. and 5:00 p.m. - 8:00 p.m. (Mon. – Sat.)	3,923	14

1 Exchange rate as of 21 September 2018 [5]

Planning

When it came to planning the photovoltaic system, maximising the system's output was not the main foundation on which everything else was to be based. Rather, the aim was to minimise electricity purchase costs and maximise the use of electricity produced by the plant itself. In doing so, it must be taken into consideration that the prices of electricity for all groups of consumers are subject to state regulation and subsidy and are dependent on both the nominal voltage (connected load) and the time at which the electricity was purchased. The three different, time-dependent electricity tariffs in the nominal voltage classes to which the sewage treatment plant belongs are presented in Table 1.

When comparing these electricity tariffs, it becomes clear that the extent to which the price of electricity depends on the time has a considerable influence on purchasing costs. Thus, the price of the cheap night tariff amounts to less than half of the standard tariff, while the peak tariff is 74% higher than the standard price. Upon comparing the tariff structure with the daily load profiles for the sewage treatment plant, it becomes clear that large parts of the plant's load are situated within the standard and peak tariff zones. Due to the stark differences in price, it is thus of particular importance that the purchase of electricity be minimised or even avoided during the times of the peak tariff, so that electricity costs can be reduced. Thus, having the plant produce its own electricity through a photovoltaic system can only make the best-possible contribution towards this goal when the times during which the photovoltaic system produces electricity and the times during which the plant consumes electricity overlap as much as possible. As depicted in **Figure 2**a), the peak yields of the photovoltaic system are, as is to be expected, generated around midday, while the peak loads of the sewage treatment plant primarily occur in the morning and during the late afternoon[2]. It is particularly during the evening peak tariff period between 5 p.m. and 8 p.m. that the plant is faced with only a low rate of electricity generation from the photovoltaic system. Based on the fact that we are dealing with a sewage treatment plant with a flow-through system, making demand-side adjustments to the profile is only possible to a very limited extent. Were a marked postponement of the purification process to be carried out in order to have this correspond with the periods of a cheaper electricity tariff, this would most probably have a negative influence on the plant's purification capacity. This was something which was evaluated by the project partners

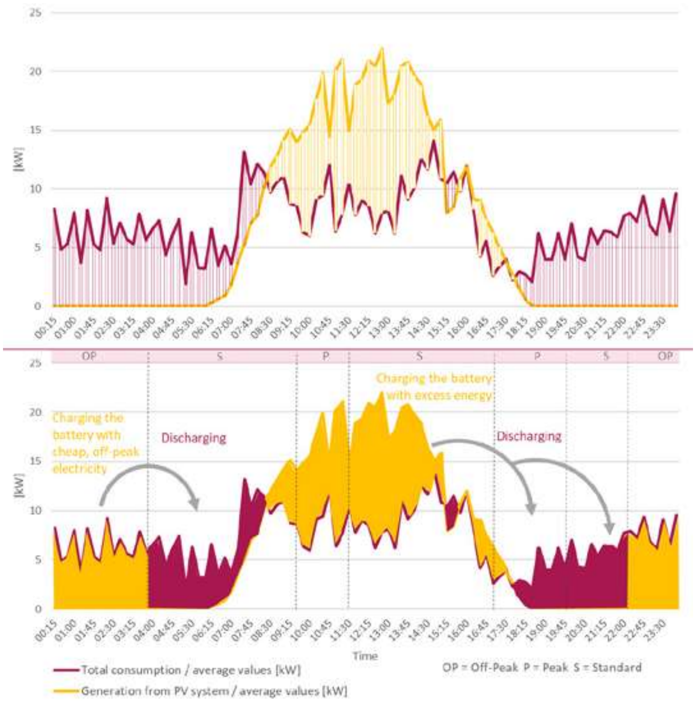

***Figure 2**: a) Comparison of the sewage treatment plant's load profile and the PV system's yield on an example day in August 2018 b) Depiction of intelligent battery charging management to minimise grid purchase*

2 Typically, hydraulic peak loads at municipal sewage treatment plants occur in the morning and in the evening.

in advance. Nor would an increase in the PV system's output prove expedient as, although this would enable the peak loads to be covered to a large extent, it is very difficult to implement the feed-in and compensation of any excess electricity which would be generated as a result in accordance with the current legal framework conditions in Vietnam.

The installation of an energy storage unit poses a solution when faced with increasing the degree to which the plant provides for itself without increasing the output of the installed PV system. With this, the self-generated electricity can either be used as soon as it is produced or used to charge the storage unit during times at which solar irradiation is particularly high but consumption particularly low. Combining the PV system with a battery storage device thus enables the plant to use a higher amount of the electricity generated on site. In doing so, the purchase of electricity from the grid and the costs associated with this can be reduced.

Due to the structure of electricity tariffs in Vietnam described above, the installation of the innovative energy storage unit also provides another special advantage: the cheap night tariffs can be used to charge the storage unit during the night. This enables the morning peak loads to be covered by more economical off-peak electricity. To some extent, cheap, off-peak electricity is thus transformed into electricity which is of a higher quality, achieved through temporarily storage. Here, we are dealing with a type of arbitrage transaction, which is advantageous not only for the operator but also for the system as a whole. This principle is called tariff arbitrage.

With this, a combination of a photovoltaic system and an appropriately-sized energy storage system ensure that a maximum amount of electricity does not need to be purchased from the grid during times with the highest electricity purchase costs (the daily peak load times during the morning and evening). This is an aspect which has a positive effect when it comes to cost savings and efficiency. These positive effects, which come about through bridging the gap between temporal disparities, are depicted in graph form in **Figure 2**b.

Figure 3: *Installing the PV system*

Implementation & results

The first part of the above-mentioned objectives was already able to be implemented with the initial start-up of the photovoltaic plant in July 2018. Two of the twelve existing roof surfaces were covered with 96 modules when it came to the photovoltaic system, which boasts a total output of 28.8 kWp (see **Figure 3**). Here, the opposing alignments of the two selected roof areas offer the advantage of flattening the yield curve, while the placement of modules in the middle contributes towards reducing active wind loads. The system as installed should achieve an annual yield of around 37,700 kWh, thus avoiding CO_2 emissions of 23 tons per year[3]. Thanks to live monitoring, up-to-date yield data can be tracked at any time[4]. The first months of operation have already

3 Basis: CO_2 emission factor 609 g/kWh for the mix of electricity in Germany in 2012

4 Current data can be viewed on our informational website, http://pv-vietnam.com/, at any time.

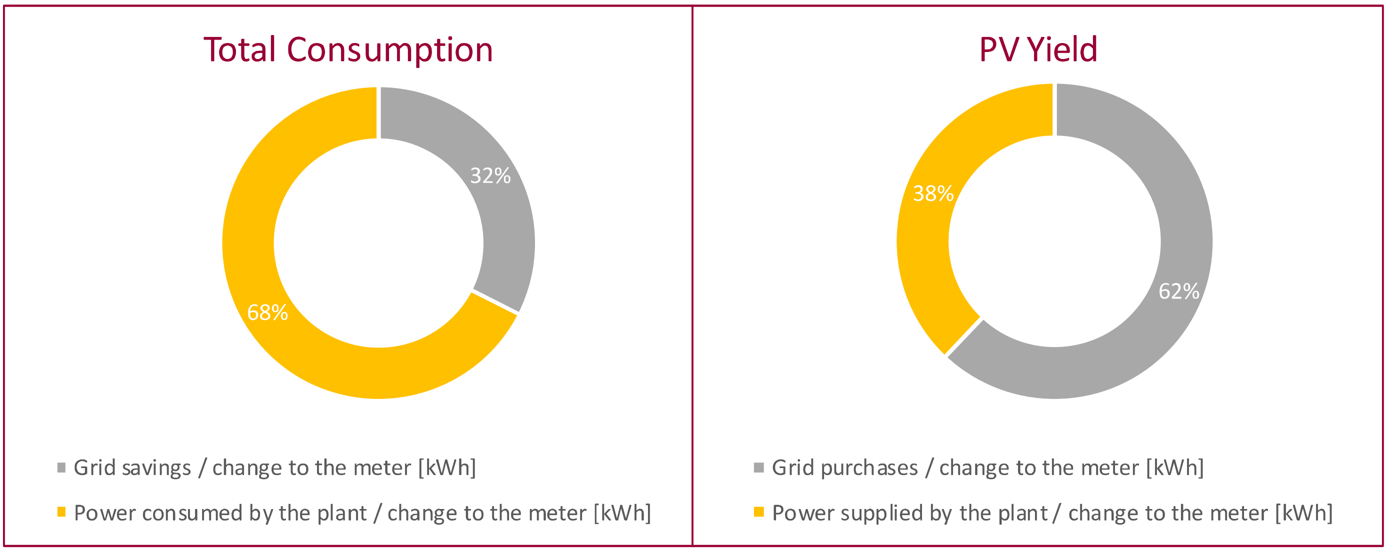

Figure 4: *Energy transferred between the public power grid, PV system and the consumer, shown proportionally*

demonstrated that the actual yields only deviate from the values anticipated in the plans by a few percent.
Modules featuring solar cells made from monocrystalline silicon were selected for filling the area due to their durability and higher levels of efficiency. Specifically, the installed modules reach efficiency levels of up to 18%.
In the first three months, the system is first being operated without storing electricity and with feeding excess amounts of electricity into the Vietnamese grid. The flows of electricity resulting from this are visualised in **Figure 4**. In this period, the plant's own consumption rate – which indicates the proportion of electricity produced by the plant which can be used on site – will reach approximately 68%. By installing the energy storage system, which consists of three batteries, it will be possible to increase this value to up to 90%. The degree of self-sufficiency[5], which, for the time being, is around 38%, will also increase further when the batteries are integrated into the system.
With a usable total capacity of 20.4 kWh, the energy storage system is designed so as to cover the periods of peak prices in the morning and in the late afternoon completely (see **Figure 2**b). In doing so, the smart battery management enables optimal charging and discharging of the storage system while taking into consideration the given tariff phase (see Table 1). Last but not least, the PV energy storage system will be connected to and supported by a solar inverter with a multi-string concept, as well as three battery inverters from the company SMA. With their high levels of efficiency (up to 98.3% and 95.5% respectively), these inverters guarantee that electricity is converted at all grid connection points with as few losses as possible.
As a result, the installation of this PV energy storage system saves the sewage plant operator up to 70% when previous grid purchase costs are compared with current electricity purchase prices and, in doing so, helps considerably increase their independence when it comes to the supplier and increasing electricity prices.
Products from German manufacturers were used to a great extent within the scope of this project. A list of the installed components, as well as of the most important key data surrounding the entire system, can be found in Table 2.

Outlook

Despite the successful start-up, Tilia's work in Vietnam is far from over. The sewage treatment plant operators may be taking over the operation of the photovoltaic system, but Tilia GmbH will continue to work together with the operators of the sewage treatment plant even after the energy storage system has been integrated into the plant in order to guarantee the best battery management possible.
What's more, when the sewage treatment plant's second expansion phase – currently under construction – is completed, the plant's energy consumption will increase even more. Accordingly, there is potential for further expanding the energy concept and, in doing so, adapting it to fit with changing needs.
More projects in Vietnam are to follow. This means that the plant in Sóc Trăng also serves demonstration purposes as a reference for potentially interested parties.

5 The degree of self-sufficiency indicates which proportion of the sewage treatment plant's electricity requirements can be covered with electricity produced by the plant itself.

Table 2: *Overview of the system's most important components and key data*

Key data	
Total output	28.8 kWp
Usable storage capacity	20.4 kWp
Annual yield	Approx. 37,700 kWh/a
Specific yield	1,310 kWh/kWp
Components	
PV modules	96x Q Cells Q. Peak-G5 300 Wp
Battery storage device	3x BMZ ESS 9.0 Li-NCA energy storage systems
Inverter	3x SMA Sunny Island 4.4 M
	1x SMA STP 25000 TL
Expanded energy storage system	1x Enwitec BAT Breaker 200A
	1x SMA Sunny Home Manager 2.0
	1x BMZ Connection Kit/set of 3
Substructure	Schletter system

Check the References:

www.water-solutions.info

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