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# Development potential for rooftop solar photovoltaic: case studies in commercial and industrial sectors of Hue City

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**Abstract.** A growing interest in solar energy development to ensure national power security and slow the onset of the current climate crisis has spurred the deployment of rooftop solar photovoltaic (PV) in cities in Vietnam. This paper aims to examine the technical and financial potential for rooftop solar PV development of two enterprises in Hue City, namely Truong Tien Plaza Commercial Center and Huetronics Joint Stock Company. The Google Earth Pro, the Roof Pitch Factor, and the on-site survey were employed to determine the rooftop characteristics of the two facilities. The technical potentials of Huetronics Company and Truong Tien Plaza were estimated at 1,256 kWh/day and 1,437 kWh/day, respectively. The financial analysis with Cost-Benefit Analysis reveals that both reference cases proved to be financially viable: the Discounted Payback Period is 5.8 years in the case of Huetronics and five years for Truong Tien Plaza; the Net Present Values are greater than zero, and the Internal Rate of Return is higher than the Cost of Capital. Such results are expected to assist in making informed policy decisions on the commercial and industrial rooftop solar PV development in Hue City.

**Keywords:** commercial facility, development potential, Hue City, industrial facility, rooftop solar PV

## 1 Introduction

Vietnam has transformed into a mixed economy with substantial development activities, which therefore require increasing energy consumption. According to an estimate given by the Vietnam Ministry of Industry and Trade (MOIT), Vietnam's energy demand is poised to go up by over 8% per year in the present decade [1]. The country also faces emerging challenges due to its recent shift from a net energy exporter to a net energy importer since its domestic primary energy sources are swiftly depleted, creating new price volatility and energy security risks. At the same time, it is also necessary to secure Vietnam's commitments to international efforts on climate change mitigation.

Over the past two years, Vietnam has made significant strides in renewable energy as a whole and the solar photovoltaic (PV) development in particular. With an unprecedented

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record number of solar PV plants coming into operation in 2019 and 2020, Vietnam is currently considered the most dynamic and attractive solar PV market in Southeast Asia [2]. This achievement stems from significant changes in national policy to accelerate the deployment of Vietnam's diverse renewable energy sources, such as wind and sunlight.

Situated in a tropical monsoon climate region, Hue City has an abundant radiation regime with a high-temperature background. The annual average temperature is 25.4 °C, with the highest lasting from May to August because of the influence of the hot and dry southwest wind. Therefore, the city possesses a high Global Horizontal Irradiation (GHI) with an average of about 4.36 kWh/m$^2$/day [3]. The technical potential for rooftop solar PV in Hue City is estimated at 1,209.5 MWh/day, corresponding to 441,467 MWh/year [4].

In fact, biomass energy is not commonly used in the commercial and industrial sectors of Hue City. As for wind energy, its development potential is negligible. Therefore, Hue is currently prioritizing the development of solar energy, especially rooftop solar PV. At present, the majority of solar PV deployments in Hue are solar water heaters, while rooftop solar panels are merely in their infancy.

According to WWF-Vietnam, only 107 rooftop solar PV projects had been installed in the city by the end of 2020 [4]. However, most of them are in the residential sector, with a capacity of 1.63 MWp. The installed capacity is accordingly not commensurate with its great potential. Currently, Hue lacks the relevant information and data in the commercial and industrial sectors to make informed policy decisions about the rooftop solar PV development in the city [4]. Therefore, this paper aims to conduct an assessment of rooftop solar PV development potential in selected commercial and industrial facilities of Hue City and sets forward some recommendations to increase its higher economic effectiveness in the study area.

## 2 Material and methods

### 2.1 Interview coupled with on-site survey

To facilitate the interview process and save time, a set of pre-prepared questions was formulated and sent to Huetronics Joint Stock Company and Truong Tien Plaza Commercial Center in advance. These questions include the enterprise's background information, routine operation activities, monthly electricity consumption, etc.

Besides interviews, the on-site surveys of roof conditions and measurement of roof slope were carried out to estimate roof areas suitable for installing solar panels.

### 2.2 Measurement of roof area

A roof footprint is an apparent roof area when looking straight down at it from above. The

actual roof surface area is a result of its roof footprint multiplied by the Roof Pitch Multiplier, which is calculated from the roof pitch.

The measurement of roof footprints was undertaken with Google Earth Pro, one of the most suitable tools for measuring roof footprints. For the roof pitch measurement, the Roof Pitch Factor available on the smartphone's app store was used to calculate the slope. If the roof has several areas with different slopes, such as on a gambrel roof, it is necessary to find more than one slope and use the appropriate Roof Slope Multipliers for different areas.

### 2.3 Technical assessment of rooftop solar PV potential

The technical potential is the total amount of solar PV generated considering GHI and rooftop characteristics, including shaded roof area (hill-shade), roof tilt angle (slope), roof direction, and unsuitable roofs, such as asbestos cement roofs and complex-shaped roofs [5].

In addition to roof characteristics and GHI, the actual potential for rooftop solar PV also depends on solar panel efficiency (also referred to as module efficiency) to convert solar radiation into actual electricity. The remaining potential, after eliminating ineffective and unsuitable rooftop areas, and considering the module efficiency, is called the technical potential (Formula 1) [5].

$$\text{Technical}_T \text{ (kWh/day)} = TRA_{UR} \times GHI \times E_{PV} \quad (1)$$

where $TRA_{UR}$ is the total effective rooftop area of the target region calculated by subtracting the ineffective rooftop area and unsuitable rooftop; $GHI$ is the Global Horizontal Irradiation; $E_{PV}$ is the solar PV panel efficiency, currently ranging from 15 to 22%.

### 2.4 Cost-benefit analysis

There are different types of Cost-benefit analyses to assess the economically beneficial potential of a rooftop solar PV project. In this study, the most common economic metrics for making the decision to proceed with commercial and industrial projects are used, namely Discounted Payback Period (DPP), Internal Rate of Return (IRR), and Net Present Value (NPV).

The DPP is calculated the same as the Simple Payback Period (Formula 2). However, the annual net cash flow is discounted according to Formula (3). The shorter the payback period, the more financially viable the investment. The method of NPV considers the difference between the total discounted benefits and the total discounted costs, which gives the NPV of an investment (Formula 4).

$$\text{Payback Period} = \frac{\text{Project Cost}}{\text{Annual Cash Inflows}} \quad (2)$$

$$\text{Discount Cash Inflow} = \frac{\text{Actual Cash Inflow}}{(1+i)^n} \quad (3)$$

where $i$ is the discount rate; $n$ is the lifespan (year) of a rooftop solar PV system.

$$NPV = \sum_{t=0}^{n} \frac{R_t}{(1+i)^t} \quad (4)$$

where $R_t$ is the annual net cash inflow – outflow; $i$ is the rate or return that could be earned in alternative investments; $t$ is the number of year.

The IRR is defined as the Cost of Capital that makes the present value of the cash inflows equal to the present value of the cash outflows in a capital budgeting analysis. The Cost of Capital represents the minimum desired rate of return, i.e. a weighted average cost of debt and equity capital. The relationships between NPV, IRR, and Cost of Capital are presented in Table 1, along with the decisions based on the cash flow perspective. Here, the Cost of Capital represents the minimum desired rate of return [6].

**Table 1.** Relationships between IRR, NPV, and Cost of Capital

| If | Then | Capital budgeting decision |
|---|---|---|
| NPV < 0 | IRR < Cost of Capital | Rejecting the investment from the cash flow perspective. |
| NPV = 0 | IRR = Cost of Capital | Providing the minimum return. Probably rejecting from the cash flow perspective. |
| NPV > 0 | IRR > Cost of Capital | Screening in the investment because of its economic benefit. |

# 3 Results and discussion

## 3.1 Huetronics Joint Stock Company

**Company's background**

- Location: No. 1 St., Huong So Industrial Cluster, Hue City.
- Production type: design, manufacture, and sales of electrical-electronic products, computer and telecommunication software and products.
- Daily production time: from 7:30 to 17:00 with one shift a day.
- Weekly and yearly production days: from Monday to Saturday and 299 days per year (off-days: 52 Sundays and 14 public holidays).
- The company has no substations, so it purchases grid electricity at the price of below 6 kV voltage for manufacturing facilities (Fig. 1) [7].
- The total electricity demand in 2019 is 266,000 kWh. The monthly demand in 2019 is shown in Fig. 2.

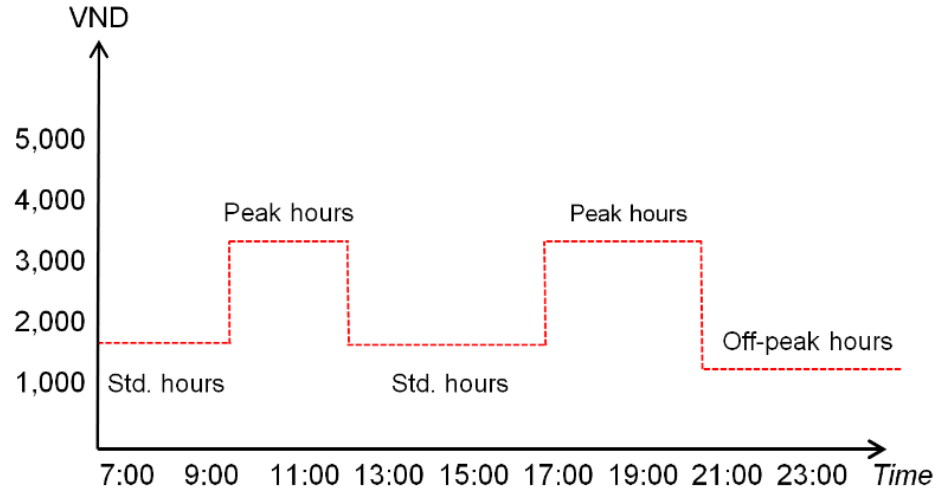


**Fig. 1.** Current production electricity tariff for voltage of below 6 kV

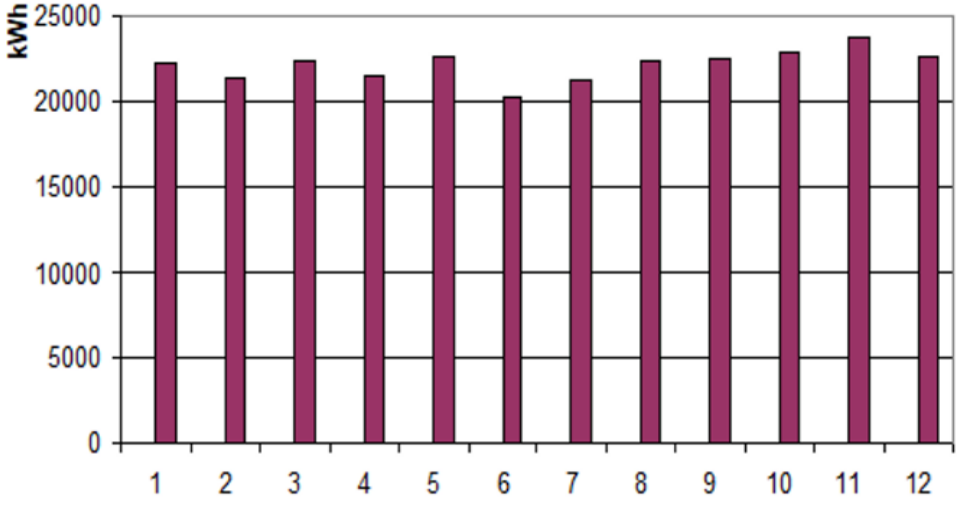


**Fig. 2.** Monthly electricity demand of Huetronics in 2019

**Technical potential**

The on-site survey results, the interpretation of roof status from satellite images, and the technical potential analysis are presented in Fig. 3 and Table 2. The roof slope was mainly directed towards the North-East and South-West. At the same time, the company's roofs are subjected to the hill-shade effect due to high buildings located in the West. Therefore, the company's effective roof area is smaller than its total existing roof area.

The technical potential for rooftop solar PV shown in Table 2 is 1,256 kWh/day, corresponding to 31,965 kWh/month or 388,908 kWh/year. As noted above, the company's electricity demand in 2019 was 266,000 kWh/year. Thus, the total rooftop solar PV potential completely meets the company's requirement.

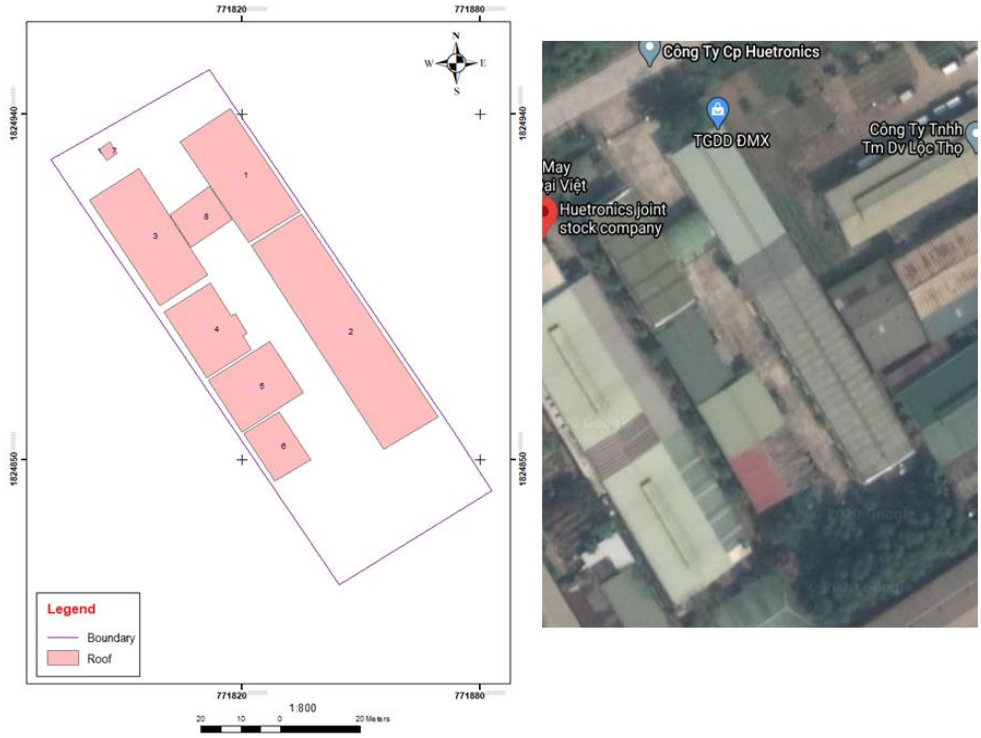


**Fig. 3.** Satellite image and roof map of Huetronics (Zoomed out from 1:1,800 scale map)

**Table 2.** Rooftop characteristics and technical potential of rooftop solar PV

| Block | Existing roof area ($m^2$) | Effective roof area ($m^2$) | Roof type | Technical potential (kWh/d)* |
|---|---|---|---|---|
| 1 | 486.7 | 335.8** | Metal sheet, tilted on both sides | 219.6 |
| 2 | 987.5 | 711** | Metal sheet, tilted on both sides | 465 |
| 3 | 477.6 | 343.8*** | Metal sheet, tilted on both sides | 224.8 |
| 4 | 285.7 | 205.7*** | Metal sheet, tilted on both sides | 134.5 |
| 5 | 296.9 | 213.8*** | Metal sheet, tilted on both sides | 139.8 |
| 6 | 153.5 | 110.5*** | Metal sheet, tilted on both sides | 72.3 |
| 7 | 11.9 | 0**** | Metal sheet, tilted on both sides | 0 |
| 8 | 126.6 | 0**** | Half barrel plastic roof | 0 |
| **Total** | **2,120.4** | **1,640.5** | | **1,256** |

*Notes*: * Calculated with GHI of 4.36/kWh/$m^2$/day in Hue City and the lowest solar PV panel efficiency (15%). ** Accounting for 69% of the existing roof area because of some aged roof areas. *** Accounting for approximately 55% of the existing roof area as a result of the hill-shade effect. **** Ineffective roof area due to either small area or half barrel roof [5].

## Financial potential

Given that the aforementioned effective roof area of Huetronics is 1,640 $m^2$ and that 1 kWp of solar PV generation commonly requires an area of about 7 $m^2$, the installed capacity of a rooftop solar PV system proposed for Huetronics is 200 kWp. Blocks number 1, 2, 3, 4, and 5 (Fig. 3) should, as per the rooftop analysis in Table 2, be used for solar PV deployment. The projected amounts of electricity consumed, sold, and purchased are shown in Table 3, which is based on Hue City's GHI (4.36 kWh/$m^2$/day), daily production time, and annual production days of the company.

**Table 3.** Projected amounts of electricity consumed, sold and purchase

| Description | Estimated amount (kWh) | Percentage (%) |
|---|---|---|
| Solar PV consumed on-site | 211,402 | 69.8 |
| Solar PV sold to Vietnam Electricity (EVN) | 36,798 | 12.2 |
| Power purchased from EVN | 54,598 | 18 |
| **TOTAL** | **302,798** | **100** |

The Cost-benefit analysis results in Table 4 show a summary of economic efficiency for the 200 kWp system if the company gets a loan of 70% of the total investment cost (also known as the equity-debt portfolio of 30:70). The proposed system proves to be financially viable with a positive NPV of 7,398 million VND, IRR of 22,4%, which is greater than the Cost of Capital (9%) and the DPP of 5.8 years.

**Table 4.** Analysis results of financial potential for 200 kWp rooftop solar PV system

| No | Description | Unit | Amount |
|---|---|---|---|
| 1 | Total investment cost (with Jinko solar mono 445W module) | Million VND | 2,300 |
| 2 | Averagely increased rate of power tariff for manufacturing industries from 2009 to 2019 | % | 5.6 |
| 3 | New Feed-in-Tariff for rooftop solar PV (effective from May 22, 2020) | VND | 1,943 |
| 4 | Preferential bank interest rate for renewable energy development | % | 11 |
| 5 | Cost of Capital | % | 9 |
| 6 | DPP | Year | 5.8 |
| 7 | IRR | % | 22.4 |
| 8 | NPV | Million VND | 7,398 |

The above assessment results of financial potential for the rooftop solar PV development are more viable than the previous ones on the same issue in the industrial sector, such as the study of Da Nang Center for Energy Conservation and Technology Consultant on the potential

for solar energy deployment in selected industries of Da Nang, the pre-study assessment of GIZ on rooftop solar application at Kwong Lung Meko factory in Can Tho City and Namyang Song May factory in Dong Nai Province [8-10]. This is simply because previous studies omitted 66 holidays, during which the production was suspended; therefore, most of the solar PV generated on these days is sold to EVN. However, above all, the discrepancy comes primarily from the cost of solar PV panels and the loan interest that has been plummeted recently.

### 3.2 Truong Tien Plaza Commercial Center

**Center's background**

- Location: No. 6, Tran Hung Dao St., Hue City.
- Business type: Shopping and catering business entertainment, and apartments and offices for rent. Of which, Co-opmart activities are the major part of the business.
- Business time: from 8:00 to 22:00, 7 days/week, and 365 days/year.
- The Plaza is currently using a solar hot water system for the restaurants' kitchen area.
- The Plaza owns a private 22/0.4 kV substation, so it is entitled to purchase grid power at the price of 22 kV voltage for the business sector (Fig. 4) [7].
- The monthly electricity demand in 2019 is presented in Fig. 5, with a total of 2,039,600 kWh/year.

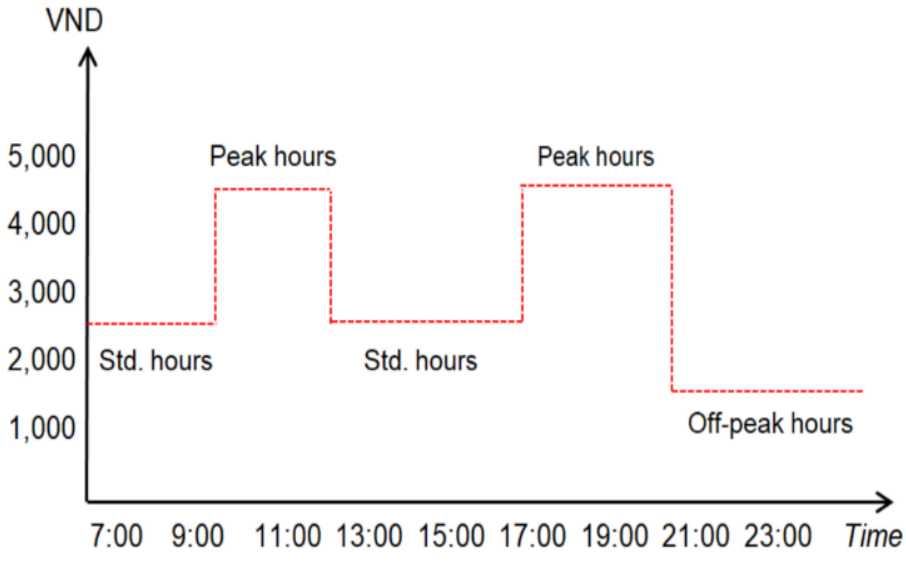


**Fig. 4.** Current business electricity tariff for voltage of 22 kV

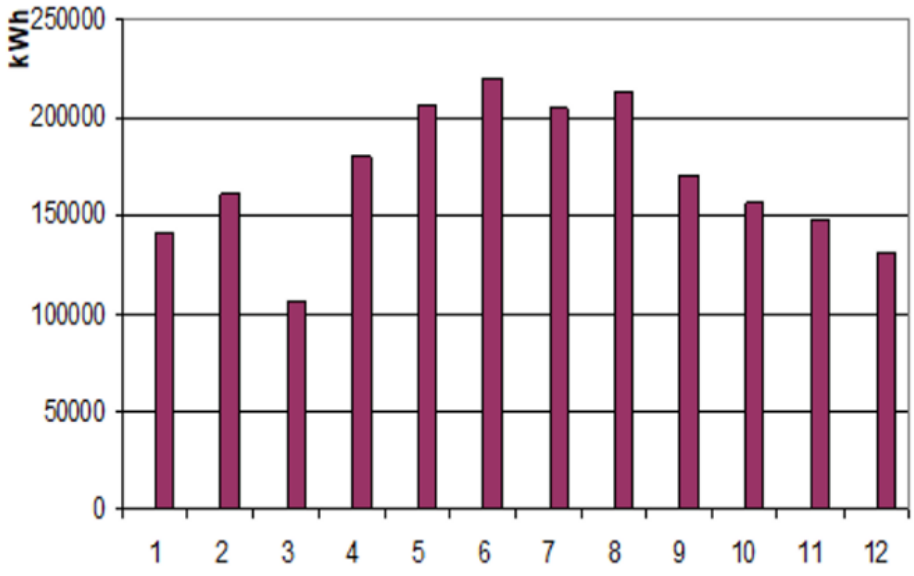


**Fig. 5.** Monthly electricity demand of Truong Tien Plaza in 2019

**Technical potential**

The main roof direction of the Plaza is South-West, and the roof is not shaded by either high buildings or tall trees nearby. Therefore, it may have a high solar PV efficiency if installed with a rooftop solar PV system. The interpretation of roof conditions from satellite images, the roof survey results, and the technical rooftop solar PV potential are shown in Table 5 and Fig. 6

**Table 5.** Rooftop characteristics and technical potential of rooftop solar PV

| Block | Existing roof area ($m^2$) | Effective roof area ($m^2$)* | Roof type | Technical potential (kWh/d)** |
|---|---|---|---|---|
| 1 | 3,329 | 2,197 | Metal sheet, tilted on either one side or both sides | 1,437 |

*Notes*: *Accounting for 66% of the existing roof area because of a solar water heater system and ornamental stuff placed on the rooftop. **Calculated with GHI of 4.36/kWh/$m^2$/day and the lowest solar PV panel efficiency (15%).

The technical potential for rooftop solar PV of Truong Tien Plaza, shown in Table 5, is 1,437 kWh/day, equivalent to 43,110 kWh/month or 524,505 kWh/year. As mentioned above, the Plaza's electricity demand in 2019 was 2,039,600 kWh/year; therefore, the total rooftop solar PV potential meets only 25.7% of its annual requirement.

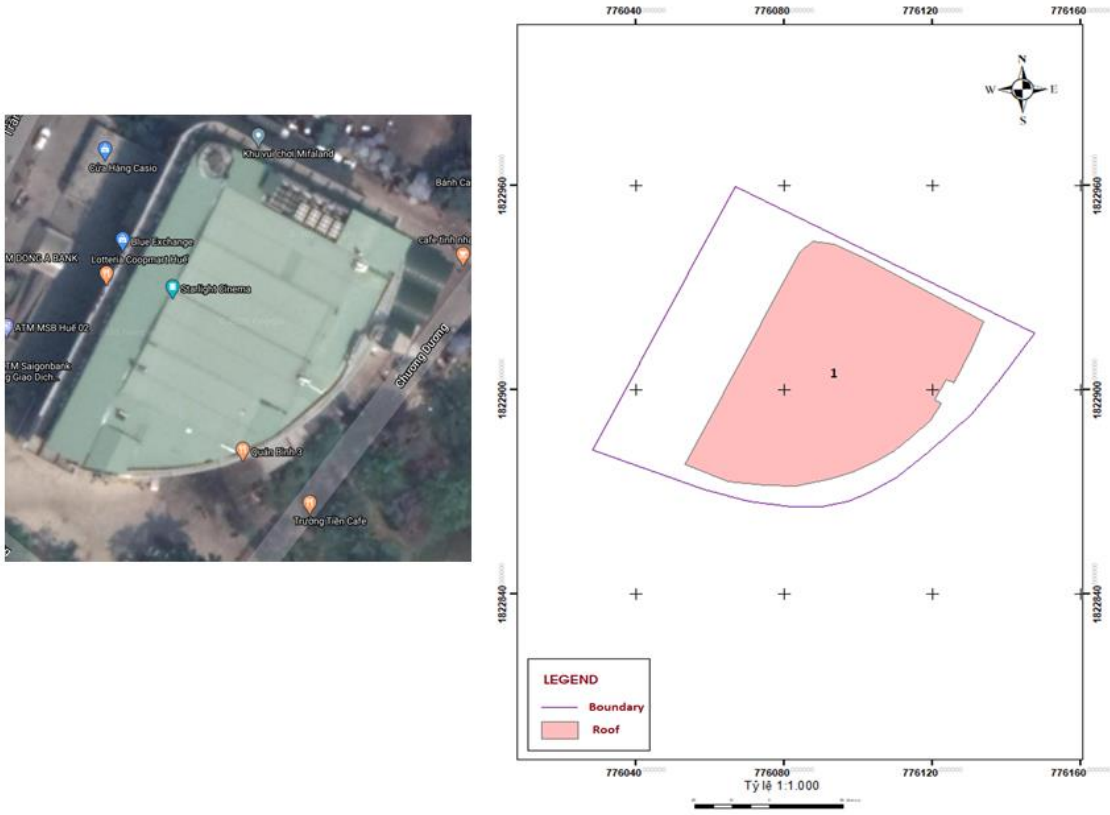


**Fig. 6.** Satellite image and roof map of Truong Tien Plaza (Zoomed out from 1:1,000 scale map)

## Financial potential

Based on the fact that the effective roof area of Truong Tien Plaza is 2,197 $m^2$ and that 1 kWp of solar PV generation commonly requires an area of about 7 $m^2$, the installed capacity of a rooftop solar PV system proposed for the Plaza is 300 kWp. The projected amounts of electricity consumed, sold, and purchased are shown in Table 6. These amounts are calculated on the basis of Hue City's GHI (4.36 kWh/$m^2$/day), daily business time, and annual business days of the Plaza.

**Table 6.** Projected amounts of electricity consumed, sold and purchase

| Description | Estimated amount (kWh) | Percentage (%) |
|---|---|---|
| Solar PV consumed on-site | 372,300 | 9.3 |
| Solar PV sold to EVN | 0 | 0 |
| Power purchased from EVN | 1,667,300 | 90.7 |
| **TOTAL** | **2,039,600** | **100** |

The Cost-Benefit Analysis results presented in Table 7 show a summary of economically beneficial potential for the 300 kWp system in the event the Plaza gets an equity-debt portfolio of 30:70. The proposed system proves to be financially viable with a positive NPV of 6,443 million VND, IRR of 27.6% that is greater than the Cost of Capital (9%) and the DPP of 5 years.

**Table 7.** Analysis results of financial potential for the 300 kWp rooftop solar PV system

| No | Description | Unit | Amount |
|---|---|---|---|
| 1 | Total investment cost (with Jinko solar mono 445W module)* | Million VND | 3,300 |
| 2 | Average annually increased rate of power tariff for manufacturing industries from 2009 to 2019 | % | 4.5 |
| 3 | New Feed-in-Tariff for rooftop solar PV (effective from May 22, 2020) | VND | 1,943 |
| 4 | Preferential bank interest rate for renewable energy development | % | 11 |
| 5 | Cost of Capital | % | 9 |
| 6 | DPP | Year | 5 |
| 7 | IRR | % | 27.6 |
| 8 | NPV | Million VND | 6,443 |

*Note*: *The higher the installed capacity, the lower the cost per 1 kWp of a rooftop solar PV system.

The analysis results in Table 7 reveal that the proposed investment in the 300 kWp system would bring about a higher economic benefit in the case of the commercial sector. This is understandable since commercial facilities usually consume a large amount of electricity, and almost all of them are in business year-round, regardless of weekends or holidays. Hence, the solar PV generated on-site is mostly used up by themselves, which means there is no excessive solar PV sold to EVN at the price of 1,943 VND/kWh, much lower than the electricity tariff purchased from EVN. Therefore, special concern and priority in rooftop solar PV development should be directed to the commercial facility in particular and their nationwide networks, such as Co-Opmart, Big C, etc. in general because they have higher potential for rooftop solar PV development.

Rooftop solar PV systems of a high capacity definitely entail large investment costs; therefore, the simple payback period under these circumstances is completely impractical and insufficient to indicate the actual economic benefit. Accordingly, it is necessary to resort to the Cost of Capital to obtain appropriate and accurate financial metrics, especially the DPP.

## 4 Conclusion

The financial analysis of two facilities in Hue City reveals that both reference cases are financially viable. The NPVs are greater than zero; the IRRs are higher than the Cost of Capital, and the DPP is estimated at 5.8 years and 5 years for industrial and commercial facilities. These results indicate that the financial potential for rooftop solar PV development of the commercial case is greater than the industrial one. However, the technical potential for deploying a rooftop solar PV system in the commercial sector is limited as the roof of this system is usually covered with either ornamental landscapes or items that hamper the installation of solar panels.

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