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Stranded asset from city level energy transition in Hanoi, Vietnam#

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ABSTRACT

We employed a techno-economic analysis to assess the feasibility and implications of a green energy transition at the city level, focusing on the potential for stranded assets. We explore the integration of rooftop photovoltaics (PV) and electric vehicles (EVs), highlighting a promising future where self-consumption can reach 100% and energy self-sufficiency can rise to 60%, alongside a 52% reduction in CO_2 emissions and cost savings of up to 10%. The transition in Hanoi is estimated to result in $7.4 billion in stranded assets, while also generating 5,000 new jobs in the PV supply chain and achieving a net present value (NPV) of $4.7 billion. Despite the PV+EV system's inability to fully meet the city's electricity demand, our research confirms that it is a cost-effective solution, with the levelized cost of electricity (LCOE) reaching a low of 6.59 cents/kWh. However, considerations regarding stranded assets and grid integration capacities are crucial for a rapid transition.

Keywords: Energy transition, urban decarbonization, rooftop PV, Stranded asset

NONMENCLATURE

Abbreviations	
PV	Photovoltaics
EV	Electrical Vehicles
NPV	Net present value
V2H	Vehicle to Home
BAU	Business As Usual
ET	Energy Transition

1. INTRODUCTION

Vietnam, one of Southeast Asia's fastest-growing economies, faces significant challenges due to its high dependence on fuel-based resources [1]. During last decade, Vietnam has achieved a big step forward the green transition [2,3] but much work remains to achieve the Net Zero target. As the economy and urbanization rapidly expand, major cities like Hanoi and Ho Chi Minh City grapple with critical energy and environmental dilemmas. A key concern is energy security, with Vietnam predicted to face an energy shortfall of up to 12 TWh per year [3]. The country's high potential for renewable energy, particularly solar and wind, has led the government to set ambitious targets for achieving Net Zero and transitioning to 100% renewable energy [4–6]. PV is considered a key solution for energy security and environmental issues. The concept of V2H in the SolarEV model was proposed by Kobashi et al. [7] identified as a promising decarbonization strategy in urban areas, with studies from developed and developing countries underscoring its potential [8–13].

The inevitability of the energy transition in Vietnam is driven by both technological and policy factors, though policy appears to be the preferred catalyst [14,15]. A significant downside of a full transition is the potential early retirement of fossil fuel power plants, creating stranded assets—a concern highlighted by various studies estimating substantial stranded costs globally [16–18]. IRENA estimated that $20 trillion of stranded cost for the fully phase out [19].

This research aims to investigate the feasibility of rooftop PV in Vietnam's urbanized areas, with a focus on Hanoi, using techno-economic analysis to explore the decarbonization potential and the impact of significant stranded assets.

2. METHODOLOGY

2.1 Data

The rooftop area was extracted from the rooftop footprint database [20]. The result was verified through comparison with remote sensing data, showing a minimal discrepancy of 2% [21]. We assumed that 100% of the rooftop area can be used to install the PV systems. The PV capacity was calculated using a standard ratio of $1kw/7m^2$ of rooftop area, as outlined in previous studies [7]. Solar and wind data were sourced from the NASA

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database, with weather files generated by SIREN to compute PV generation. A derating factor of 0.8 was applied to account for weather variability [7,9,22]. The hourly demand was obtained from the dispatch load database from Vietnam Electricity (EVN)[23]. Registration data provided the number of vehicles, crucial for integrating Electric Vehicles (EVs) into our analysis.

2.2 Techno-economic analysis

The research adopted method from Kobashi et al. [7] using System Advisor Model to assess the decarbonization potential of PV and EV systems in Hanoi. The NPV for the project of 25 years lifespan was estimated using the following formular. The we added the effect of stranded assets below to investigate the overall impact in the socio-economy.

$$\mathrm{NPV} = \sum_{t=0}^{T} \frac{\text{Cash flow}}{(1+r)^t} - \text{Installation Cost} \quad (1)$$

The five criteria were employed to assess the decarbonization potentials of PV and EVs system in Hanoi including self-consumption, self-sufficiency, energy efficiency, CO_2 emissions reduction and cost-saving. The calculation was adopted the work from Kobashi et al. [9].

2.3 Scenarios and parameters

We designed two primary scenarios: BAU and ET. BAU is continuation of current situation without additional intervention while ET presents for the green energy transition by implementation comprehensively of PV and EV. Each scenario was analyzed in terms of self-consumption, self-sufficiency, energy efficiency, CO_2 emissions reduction, and cost savings, with the year 2019 serving as the baseline for comparison. Vinfast 8 Eco is the EV model applied in the scenario because of its popularity in the Vietnamese market. The car has big battery capacity of 87.7 kWh.

The electricity demand is assumed to be 9.17% increase following the Power Development Plan 8 [4] while the FIT is forecasted to reduced due to the recent trend. The electricity price is assumed to remain unchanged as price in the year 2024 at 0.12 USD.

Table 1. Technology cost assumption

Scenario	2019	BAU	ET_30	ET_100
PV capacity (GW)	0.10	12.51	25.02	25.02
No. of EV		9%	30%	100%
Demand (TWh)	20.26	42.77	44.37	45.44
Installation cost ($/kwh)	1117.4	558.7	558.7	558.7
Operation cost($/kwh)	24.6	558.7	558.7	558.7

2.4 Stranded assets

Hansen (2022) categorized the stranded assets into 2 broad types: stranded reserves and stranded capital [18]. IRENA [19] mentioned about just transition, a labor-oriented concept explains the social impact of energy transition. In this research, we boarded the definition of the stranded assets as combination of the impact on (1) fuel industry (SP: stranded profit) on the power plant; (2) (SC: stranded capital); and (3) in society (SH: stranded human resource). To measure the stranded asset, we calculated based on the result of 2 scenario BAU and ET to determine the stranded assets of transition in city level when transit to use solar power from rooftop PV system. In the end we will compare the NPV from PV/PV+EV project with SA loss from the transition to see the economic impact.

$$\mathrm{SA} = \mathrm{SP} + \mathrm{SC} + \mathrm{SH}$$

The SP employs the NPV of perpetuity to calculate the future profit of coal if transition doesn’t happen.

$$\mathrm{SP} = \sum_{t=0}^{T} \frac{(Price_i - Production\ cost_i) \times Q_{coal}}{(r-g)^t} \quad (1)$$

We assumed that the life span of all coal power plant will be all 40 years, and the straight method was employed to determine the salvage.

$$\mathrm{SC} = \sum_{t=0}^{T} \frac{SC_{ET} - SC_{BAU}}{(1+r)^t} \quad (2)$$

From the report of IRENA and ILO [24], each GW production of PV will increase 1085- 2020 job in whole supply chain. In the report, we assume that on average 1 GW of PV can create 1552 jobs. In order to calculate the job coal, we gathered the direct employment in coal power plants and the indirect employment in coal companies. observed that the monthly wage rate was 16 mil VND ($630), which is equivalent to the average pay for workers in coal-fired power plants.

$$\mathrm{SH} = \sum_{t=0}^{T} \frac{(\mathrm{Job_{PV}} - \mathrm{Job_{Coal}}) \times Salary\ rate}{(r-g)^t} \quad (3)$$

Where, *r* presented interest rate and *g* was inflation rate.

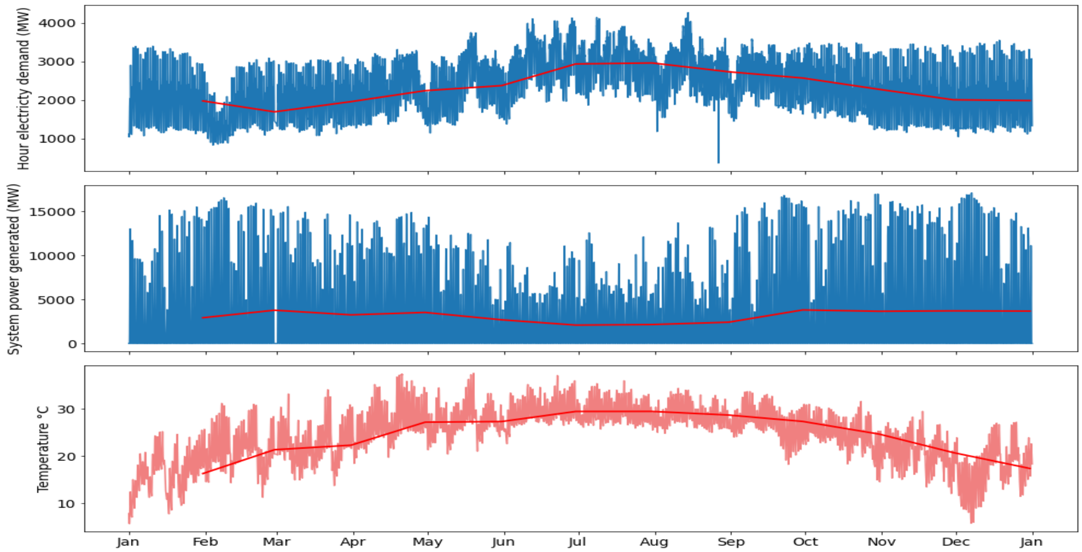

Fig. 1 Hourly Temperature, system generation (25 GW capacity) and electricity demand in hourly (blue) and daily (red).

3. RESULTS

3.1 Decarbonization potential of PV+EV system

Figure 1 illustrates the trendline of electricity load in Hanoi. The peak load occurs between 4:00 PM and 6:00 PM, reaching up to 4.3 GW, with the highest monthly demand from June to August due to increased cooling requirements, resulting in 2203 GWh.

Given the prevailing rate of growth in electricity demand, the full capacity of rooftop installations is insufficient to meet these demands, as demonstrated in Fig 1. However, the system's enhanced self-sufficiency—achieving up to 60% and self-consumption to 100% with the integration of electric vehicles (EVs), as shown in Fig 2—indicates an improved capability to manage outages or blackouts. Notably, during the summer months from June to August, elevated temperatures coincide with decreased solar output, resulting in a significant discrepancy in supply from the system.

CO_2 emissions have significantly decreased, with a notable reduction of up to 52% attributed to the technological contributions from EVs. This reduction is likely due to decreased energy consumption from the grid and the adoption of greener transportation methods. The project's financial viability is confirmed by a positive NPV, with the greatest cost savings, up to 10%, being realized in the Feed-in Tariff (FIT) scenario, as depicted in Figure 3. However, the return on investment from EVs is limited, potentially due to the inadequacy of the PV system. The minimum Levelized Cost of Electricity (LCOE) achieved is 6.59 cents/kWh in the BAU scenario. The results indicate that a complete transition to 100% EV and PV installation yields lower decarbonization potentials when compared to a scenario with 30% EV implementation and BAU conditions

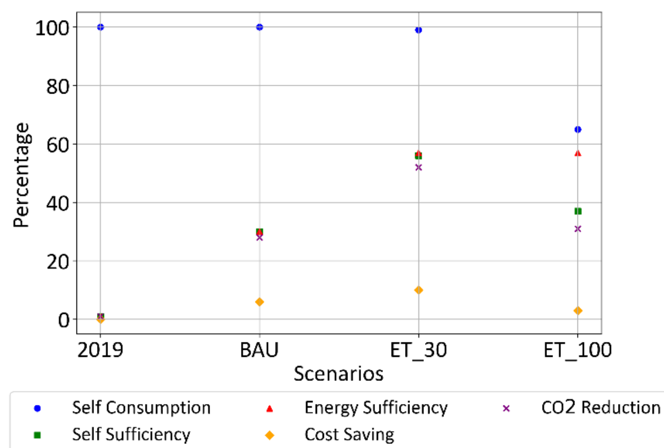

Fig. 2 Techno-economic assessment by scenario

3.2 Stranded assets resulting from the green transition

In the ET_100 scenario, where a maximum of 25 GW of rooftop PV capacity is installed, it is projected that nine coal power plants could be decommissioned by the year 2030. The selection of these particular plants was strategically based on their operational years to minimize the value of stranded assets.

3.2.1 Stranded Profit

Annually, the nine coal power plants consume an average of 14 million tons of coal, potentially generating approximately $279 billion in profits per year. The coal price is assumed to remain at the 2023 level of $136.67 per ton, with a profit margin of 14.4%, based on findings from the Australian Energy Regulator (AER) [25]. Consequently, the Stranded Profit (SP) from the decommissioning of these nine plants is estimated to be around $8 billion.

3.2.2 Stranded Capital

By employing the straight-line method to depreciate the asset value of the coal power plants, we determined that the remaining lifespan of these facilities ranges from 11 to 16 years, with asset values between $5 million and $520 million, as illustrated in Figure 3. The Stranded Capital (SC) for each individual plant was then discounted using the prevailing interest rate to calculate the Net Present Value (NPV) of SC by 2030, which is estimated to be $408 million.

3.2.3 Stranded Human resources.

Upon full transition, the closure of nine coal power plants resulted in 4,700 direct job losses within these facilities. The impact extended beyond the plants themselves to the coal industry, where we estimated that approximately 30% of the workforce, or around 29,000 jobs, would be affected due to a reduction in coal consumption by the same proportion. In contrast, the PV supply chain under the ET_100 scenario is projected to create 38,841 jobs. Furthermore, this transition at the city level is expected to generate an additional 5,000 jobs, resulting in approximately $1 billion in payroll.

In summary, the combined Stranded Assets (SA), consisting of Stranded Profits (SP), Stranded Capital (SC), and Stranded Human resources (SH), amounted to $7.4 billion for Hanoi's city-level transition. After accounting for the profits from the PV+EV system, there remains a deficit of $2662 million that the city must address.

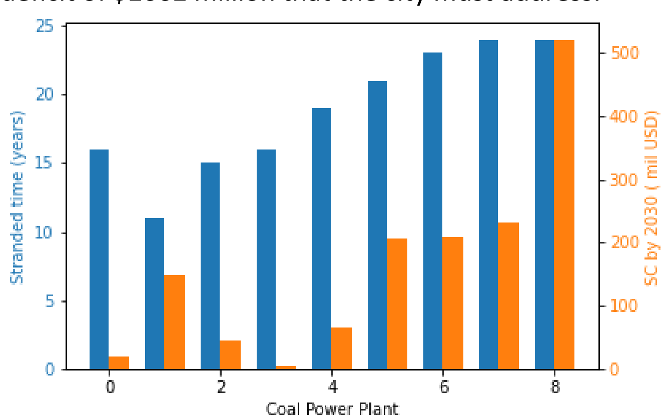

Figure 3. Stranded time and SC of 9 coal power plants.

4. DISCUSSION

This study empirically substantiates the decarbonization potential of the PV+EV system in Hanoi, aligning with prior research [7–13]. The findings reveal significant decarbonization potential as the adoption of the PV system has notably decreased CO_2 emissions, markedly enhancing both self-sufficiency and energy sufficiency. Considering that Vietnam is a developing nation with Hanoi as its economic hub, the demand for electricity is high and expected to continue rising. While the integrated PV and EV system does not meet the city's full electricity demand, it alleviates pressure on the grid and contributes to national energy security. Notably, Vietnam has the lowest renewable energy costs in Southeast Asia [26] and with the deployment of the PV system, the Levelized Cost of Electricity (LCOE) has been reduced to 6.59 cents/kWh, which significantly lowers household electricity expenses.

Furthermore, the introduction of rooftop PV+EV represents a burgeoning solution for the green energy transition, yet it also entails considerable consequences. As the transition unfolds, a substantial volume of assets become stranded [18,19]. Previous studies on the stranded assets of energy transitions have typically focused solely on asset evaluation [17,18] or solely on just transitions [24]. Our research, however, encompasses both the monetary and human impacts. As a result of the transition to the PV+EV system within the context of Hanoi, approximately $7.4 billion in stranded assets are anticipated. Conversely, the project is projected to yield a profit of $4.7 billion and create over 5,000 jobs.

The inevitability of energy transition in the evolution of human societies underscores the shift towards a sustainable future. The presented analyses confirm the technological and economic viability of PV and EV systems in Hanoi, although the risk of stranded assets persists. Moreover, given the limitations of the national grid, the full potential of the FIT scheme at the household level remains a significant challenge.

5. CONCLUSIONS

Vietnam is committed to achieving both industrialization and decarbonization, implementing robust strategies that place energy security and urban environmental challenges at the forefront of socio-economic concerns. In conclusion, given Vietnam's ongoing struggles with energy shortages in urban areas like Hanoi, the rooftop PV+EV system presents a promising solution. This system has demonstrated its efficacy by increasing self-consumption rates to 100%, enhancing self-sufficiency and energy sufficiency to approximately 60%. Furthermore, it has achieved a substantial decarbonization potential, evidenced by a

52% reduction in CO_2 emissions and cost savings of up to 10%.

Despite its emerging status, the transition at the city level is accompanied by significant challenges related to stranded assets, with the transition in Hanoi projected to generate $7.4 billion in stranded assets. Nonetheless, this transition also opens new opportunities, creating approximately 5,000 jobs in the PV sector and its associated supply chain, and generating a net present value (NPV) of $4.7 billion in profits from the project.

While the PV+EV system does not fully meet the city's electricity demands, it remains a cost-effective solution, with the Levelized Cost of Electricity (LCOE) reaching a low of 6.59 cents/kWh and partially covering the electricity load. However, the issues of stranded assets and the capacity for grid integration warrant careful consideration moving forward.

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