Cost and Benefit Analysis of Household Photovoltaic System Installation in Taiwan

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Institute of Natural Resources Management, National Taipei University
Taiwan

SUMMARY

In recent years, the Taipower (Taiwan’s monopoly electricity industry) always has deficit due to double pressure from both supply and demand sides. In past ten years, even though the Taipower has been implementing many demand side management (DSM) policies in the residential sector, the residential electricity demand is still increasing. In order to abate residential electricity demand, many countries have successfully encouraged household to install distributed electricity generators of renewable energy such as photovoltaic system (PV), solar heating system or wind power system. However, after the government and Taipower have been promoting and subsidizing PV for many years, very few households choose to install PV. This paper aims to empirically estimate the costs and benefits of PV installation that incurred to households.

We first collect data of daily sun radiation and sun hours for different counties, then we estimate the potential maximal electricity amount generated from household PV installation in various counties. Then, the cost-benefit analyses of PV installation for the typical households in different counties are done for both old and new policy scenarios. The empirical results show that in contrast to the old policy, the new policy gives households much weaker economic incentives to install the PV. Since the old policy itself is not very successful to promote PV, thus it is quite plausible to predict the new policy will perform even worse to meet its target to promote household PV installation than the old policy. I truely hope Taiwan’s unsuccessful experience on promoting PV can shed lights on the energy policy of our own and other countries.

KEYWORDS

household photovoltaic system (PV) installation, renewable energy, distributed electricity generators, cost-benefit analysis
I. Introduction

In recent years, the Taipower (Taiwan’s monopoly electricity industry) always has deficit due to double pressure from both supply and demand sides. On the supply side, its electricity costs are rising due to energy prices increases, carbon dioxide reduction pressure and NIBY (not in my backyard) effect of building new power plants. Meanwhile on the demand side, it is seldom able to raise its electricity prices because of political consideration.

In past ten years, even though the Taipower has been implementing many demand side management (DSM) policies in the residential sector, the residential electricity demand is still increasing (refer Figure 1). In order to abate residential electricity demand, many countries have successfully encouraged household to install distributed electricity generators of renewable energy such as photovoltaic system (PV), solar heating system or wind power system. However, after the government and Taipower have been promoting and subsidizing PV for many years, very few households choose to install PV (refer to Figure 1).

![Figure 1. The Electricity Consumed by Sectors during 1995 - 2010](source: [1])

![Figure 2. The PV Capacity Installed in Taiwan during 2001 - 2007](source: [2])

This paper aims to empirically estimate the costs and benefits of household PV installation that incurred to households. I first collect data of daily sun radiation and sun hours, then the potential maximal electricity amount generated from household PV installation in various counties under two separate policy scenarios are estimated. Then, the cost-benefit analysis of PV installation for typical households in various counties is undertaken. The empirical results
are expected to shed lights on the policies related to promoting and subsidizing household PV installation and other types of renewable energy.

II. Potential Maximal electricity form PV system

The potential utility amounts generated from PV in different counties are calculated in Table 1. It is show that the potential for households PV installation on their roof is about 63,559 Gwh annually. This estimate is quite compatible with 65 Twh per year estimated by Chen [3], even though this paper applied different parameters and approach to calculate the potential of household PV.

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<td>1,243</td>
<td>1,574</td>
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<td>95,152</td>
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<td>1,655</td>
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<td>Total</td>
<td>3,048.24</td>
<td>7,902,440</td>
<td>1,122,622</td>
<td>2.25</td>
<td>440,850</td>
<td>947</td>
<td>63,559</td>
</tr>
</tbody>
</table>

Note:
1. average building heights (4)=floor area ratio/ construction coverage ratio ; the floor area ratio is 60–400% for Taipei City, 80–420% for Kaohsiung City, 135% for others ; the onstruction coverage ratio is 30–50% for Taipei, 40–60% for Kaohsiung City, and 60% for others.
2. (6) is collected from the Central Atmosphere Bureau
3. (7)(Gwh-y)= (6)*(5)*solar panel efficiency of electricity generation (15%)* adjust coefficient of construction and surrounding environment (0.75)
### III. Cost-Benefit Analysis

Depending on the researcher’s investigation, there are four kinds of cost-benefit analysis (CBA) that are often used to evaluate the DMS policy such as PV system (refer Table 2). In this paper, only PCT will be undertaken.

<table>
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<th>CBA Tests</th>
<th>Cost and Benefit Items</th>
<th>Performance indicator</th>
<th>Inquiry</th>
</tr>
</thead>
</table>
| Participant test (PCT)      | **Cost:**  
  - installation cost (minus subsidy if three are any)  
  - maintence cost  
  - removal cost (less salvage value)  
  - significant time spent to arrange for PV installation  
**Benefit:**  
  - utility bill saved  
  - selling extra utility to Taipower (with feed-in tariff if there are any)  
  - any tax credit received                                                                                                                                                                                                                       | **net present value for per average participant**  
  **net present value for the total program**  
  **discounted payback year**                                                                                                                                                                                                                           | **Will the household gain benefit from installing the PV system?**  
  **How to design proper incentive schemes for the household?**                                                                                                                                                                                          |
| Program administrator cost test (PACT) | **Cost:**  
  - Expense on subsidizing PV installation  
  - expense on PV feed-in tariff  
  - other miscellaneous cost on promotion  
**Benefit:**  
  - Avoid cost for building new power plant, transmission distribution, capacity cost, and fuel cost                                                                                                                                                  | **net present value**                                                                                                                                                                                                                          | **Is it profitable for the Taipower to promote PV in the residential sector?**                                                                                                                                 |
| Ratepayer impact test (RIM) | **Cost:**  
  - Cost increase due to the Taipower’s incentive payment such as PV feed-in tariff, subsidy for PV  
  - Revenue decrease due to sell less utility  
**Benefit:**  
  - Savings from avoided supply cost of generation, transmission, distribution, capacity cost, and fuel cost                                                                                                                                               | **lifecycle revenue impact per kwh, kw or customer**  
  **net present value**                                                                                                                                                                                                                           | **What happen to consumer bills or rates due to households’ installation of the PV system?**                                                                                                                                 |
| Societal test (ST)          | **Cost:**  
  - cost of PCT and PACT  
**Benefit:**  
  - Avoid cost for building new power plant, transmission, distribution, capacity cost, and fuel cost  
  - Avoid external environmental cost of traditional fossil fuel  
  - Avoid external cost of energy security                                                                                                                                                                                                             | **net present value**  
  **levelized cost**                                                                                                                                                                                                                                   | **Will the society benefit from promote PV system in the residential sector?**                                                                                                                                 |

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Note:1. ST is a variant of Total resource Cost  
Source: [4]
IV. CBA of Photovoltaic System for a Typical Household

In order to encourage households to install PV on their roofs, the government has implemented two different policies. The old policy applies to those households who had finished their PV installation by December 31, 2010—the government subsidizes the purchase of a PV system 120,000 NT$ per peak-kw, and the feed-in tariff (FIT) is 5.9758 NT$ per kwh. The new policy applies to those who installed PV after 2011—no subsidy for purchasing PV but the FIT is 10.3 NT$ per kwh for 20 years. I have analyzed the costs and benefits for a typical household in various counties under these two policies to investigate which policy offers households stronger economic incentives to install PV.

From Table 3, it is found that with the old policy, a typical household in most counties has positive net benefits except Taipei City and Yilan County, but the payback years ranging 13–20 are somewhat too long. Therefore it is not surprising to see very few households have installed the PV system. Further checking the new policy, a typical household in all counties except Yulin County and Chiayi County have negative benefits and payback year are all longer than the PV’s life-cycle year, assumed 20 years in this paper, let alone the households need face much heavier financial pressure to install a PV system without purchasing subsidy. In contrast to the conclusion made in Perez [5], since the new policy gives much weaker economic incentives to households, it is quite plausible to predict that the new policy will be even less effective than the old policy with regards to promoting households to install PV. No matter the potential PV from households is estimated to be up 63,559 Gwh annually, households are not interested in installing PV under current technical and economic situations if the government does not provide properly designed incentive schemes.

Table 3. Cost-Benefit Analysis on PV for A typical Household in Taiwan

<table>
<thead>
<tr>
<th>Counties</th>
<th>Utility generated from PV (1) (kwh/household, year)</th>
<th>Old Policy</th>
<th>New Policy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Levelized annual cost (2) (NT$/per year)</td>
<td>Anual benefts (3) (NT$/per year)</td>
<td>Net benefit (4) (NT$)</td>
</tr>
<tr>
<td>Taipei City</td>
<td>2,224</td>
<td>16,766</td>
<td>13,287</td>
</tr>
<tr>
<td>New Taipei City</td>
<td>5,723</td>
<td>33,833</td>
<td>34,201</td>
</tr>
<tr>
<td>Taichung City</td>
<td>11,436</td>
<td>53,841</td>
<td>68,338</td>
</tr>
<tr>
<td>Tainan City</td>
<td>10,800</td>
<td>50,551</td>
<td>64,538</td>
</tr>
<tr>
<td>Kaohsiung City</td>
<td>5,304</td>
<td>24,782</td>
<td>31,693</td>
</tr>
<tr>
<td>Yilan County</td>
<td>8,425</td>
<td>52,773</td>
<td>50,346</td>
</tr>
<tr>
<td>Taoyuan County</td>
<td>8,969</td>
<td>51,807</td>
<td>53,597</td>
</tr>
<tr>
<td>Hsinchu County</td>
<td>11,770</td>
<td>61,133</td>
<td>70,336</td>
</tr>
<tr>
<td>Miaoli County</td>
<td>11,196</td>
<td>58,254</td>
<td>66,903</td>
</tr>
<tr>
<td>Changhua County</td>
<td>12,305</td>
<td>57,771</td>
<td>73,532</td>
</tr>
<tr>
<td>Nantou County</td>
<td>11,300</td>
<td>58,665</td>
<td>67,528</td>
</tr>
<tr>
<td>Yunlin County</td>
<td>12,844</td>
<td>50,492</td>
<td>76,752</td>
</tr>
<tr>
<td>Chiayi County</td>
<td>9,718</td>
<td>50,807</td>
<td>58,071</td>
</tr>
<tr>
<td>Pingtung County</td>
<td>11,879</td>
<td>53,564</td>
<td>70,984</td>
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<td>Utility generated from PV (1) (kwh/household, year)</td>
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<td>----------------</td>
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<td></td>
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<td>Anual benefits (3) (NT$/per year)</td>
<td>Net benefit (4) (NT$)</td>
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<td>9,099</td>
<td>45,328</td>
<td>54,376</td>
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<tr>
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<td>8,607</td>
<td>48,927</td>
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<td>6,116</td>
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<td>11,079</td>
<td>57,668</td>
<td>66,205</td>
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<tr>
<td>Chiayi City</td>
<td>12,562</td>
<td>49,432</td>
<td>75,070</td>
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Note:
1. Utility generated from PV (1)= Roof area* Annual cumulative amount of insolation * solar panel efficiency of electricity generation (15%)* adjust coefficient of construction and surrounding environment (0.75) / Household no.

2. Levelized annual cost (2) = \[ \frac{\text{installation cost} \times (1 + 0.04)^{20} + \text{annual maintainence cost} \times \left( \frac{1.04 \times (1.04^{20} - 1)}{0.04} \right)}{20} \]

installion cost= per household’s living area /12.5*(NT$200,000-NT$120,000) (install per peak-wh PV system need 10~15m² roof area, installation cost is about NT$200,000 per peak-kw; subsidy for purchasing a PV system is NT$120,000 per peak-kw); annual maintainence cost=1382; discount rate=4%, PV system’s life-cycle=20 years;

3. Annual benefit of utility generated (3) = annual utility amount generated* 5.9758 (feed-in tariff)

4. Net benefit (4)=(3)-(2)*20;

5. payback year (5)=(2)*20/(3); 

6. Levelized annual cost (6)= per household’s living area /12.5*NT$200,000+1,382

7. Annual benefit of utility generated (7) = annual utility amount generated*10.3 

8. Net benefit (8)=(7)-(6)*20;

9. payback year (9)=(6)*20/(7);

V. Conclusion

No matter the potential PV from households is estimated to be up 63,559 Gwh annually, PV installation projects are not economic appealing to general households in the status quo. Even though Taiwan’s government tries hard to subsidize households to install the PV system, without carefully undertaking the participant test of CBA on PV installation and investigating the cash flow and financial pressure faced by households, all the policies implemented may be all in vein. I truly hope Taiwan’s unfruitful experience on promoting PV system can shed lights on the energy policy of our own and other countries.
BIBLIOGRAPHY


Short Bio-data of Main Author
Dr. Yu-Lan Chien is an assistant professor in the Institute of Natural Resource Management. Her major research areas are valuation of non-market goods, cost-benefit analysis, applied econometrics, and energy tariff. She gained PhD. from the Department of Agricultural and Resource Economics in the University of California at Davis.
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V. Conclusion
I. Introduction

Figure 1. The Capacity of Photovoltaic System installed in Taiwan during 2001-2010
Figure 2. The Capacity of Photovoltaic System installed in Taiwan during 2001-2008

Note: the capacity counted here is not restricted to household.
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<td>6,418</td>
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<td><strong>Total</strong></td>
<td><strong>3,048.24</strong></td>
<td><strong>7,902,440</strong></td>
<td><strong>1,122,622</strong></td>
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<td><strong>440,850</strong></td>
<td><strong>947</strong></td>
<td><strong>63,559</strong></td>
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### III. Taxonomy of Cost-Benefit Analysis for Households’ Installing PV

<table>
<thead>
<tr>
<th>CBA Tests</th>
<th>Cost and Benefit Items</th>
<th>Performance indicator</th>
<th>Inquiry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Participant test (PCT)</strong></td>
<td>Cost:</td>
<td>• net present value for per average participant&lt;br&gt;• net present value for the total program&lt;br&gt;• discounted payback year</td>
<td>• Will the household gain benefit from installing the PV system? &lt;br&gt;• How to design proper incentive schemes for the household?</td>
</tr>
<tr>
<td></td>
<td>• installation cost (minus subsidy if there are any)&lt;br&gt;• maintenance cost&lt;br&gt;• removal cost (less salvage value)&lt;br&gt;• significant time spent to arrange for PV installation&lt;br&gt;Benefit:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• utility bill saved&lt;br&gt;• selling extra utility to Taipower (with feed-in tariff if there are any)&lt;br&gt;• any tax credit received</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Program administrator cost test (PACT)</strong></td>
<td>Cost:</td>
<td>• net present value</td>
<td>Is it profitable for the Taipower to promote PV in the residential sector?</td>
</tr>
<tr>
<td></td>
<td>• Expense on subsidizing PV installation&lt;br&gt;• expense on PV feed-in tariff&lt;br&gt;• other miscellaneous cost on promotion&lt;br&gt;Benefit:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Avoid cost for building new power plant, transmission distribution, capacity cost, and fuel cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBA Tests</td>
<td>Cost and Benefit Items</td>
<td>Performance indicator</td>
<td>Inquiry</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>----------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Ratepayer impact test (RIM)</td>
<td>Cost :</td>
<td>• lifecycle revenue impact per kwh, kw or customer</td>
<td>What happen to consumer bills or rates due to households’ installation of the PV system?</td>
</tr>
<tr>
<td></td>
<td>• Cost increase due to the Taipower’s incentive payment such as PV feed-in tariff, subsidy for PV</td>
<td>• net present value</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Revenue decrease due to sell less utility</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Benefit :</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Savings from avoided supply cost of generation, transmission, distribution, capacity cost, and fuel cost</td>
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<tr>
<td>Societal test (ST)¹</td>
<td>Cost :</td>
<td>• net present value</td>
<td>Will the society benefit from promote PV system in the residential sector?</td>
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<tr>
<td></td>
<td>• cost of PCT and PACT</td>
<td>• levelized cost</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Benefit :</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Avoid cost for building new power plant, transmission, distribution, capacity cost, and fuel cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Avoid external environmental cost of traditonal fossil fuel</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Avoid external cost of energy security</td>
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### IV. CBA of PV for a Typical Household

<table>
<thead>
<tr>
<th>Counties</th>
<th>Utility generated from PV (1) (kwh/household/year)</th>
<th>Old Policy</th>
<th>New Policy</th>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Levelized annual cost (2) (NT$/per year)</td>
<td>Annual benefits (3) (NT$/per year)</td>
<td>Net benefit (4) (NT$)</td>
<td>Payback year (5) (year)</td>
<td>Levelized annual cost (6) (NT$/per year)</td>
<td>Annual benefits (7) (NT$/per year)</td>
<td>Net benefit (8) (NT$)</td>
<td>Payback year (9) (year)</td>
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<td>Counties</td>
<td>Utility generated from PV (1) (kwh/household/year)</td>
<td>Old Policy</td>
<td>New Policy</td>
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<td>Levelized annual cost (2) (NT$/per year)</td>
<td>Anual benefits (3) (NT$/per year)</td>
<td>Net benefit (4) (NT$)</td>
<td>Payback year (5) (year)</td>
<td>Levelized annual cost (6) (NT$/per year)</td>
<td>Anual benefits (7) (NT$/per year)</td>
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V. Conclusion

- The potential electricity generated from households’ PV installation on their roofs is estimated to be up to 63,559 Gwh annually.
- PV installation projects are not economic appealing to general households in the status quo.
- Without carefully analyzing the participant test of CBA on PV installation and investigating the cash flow and financial pressure faced by households, all the policies implemented may be all in vein.
- Taiwan’s unfruitful experience on promoting PV can shed lights on the energy policy of our own and other countries.
Thanks for your attention