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Assessment of the Decoupling of GHGs and Electricity Costs Through the Development of Low-Carbon Energy Technology in Taiwan

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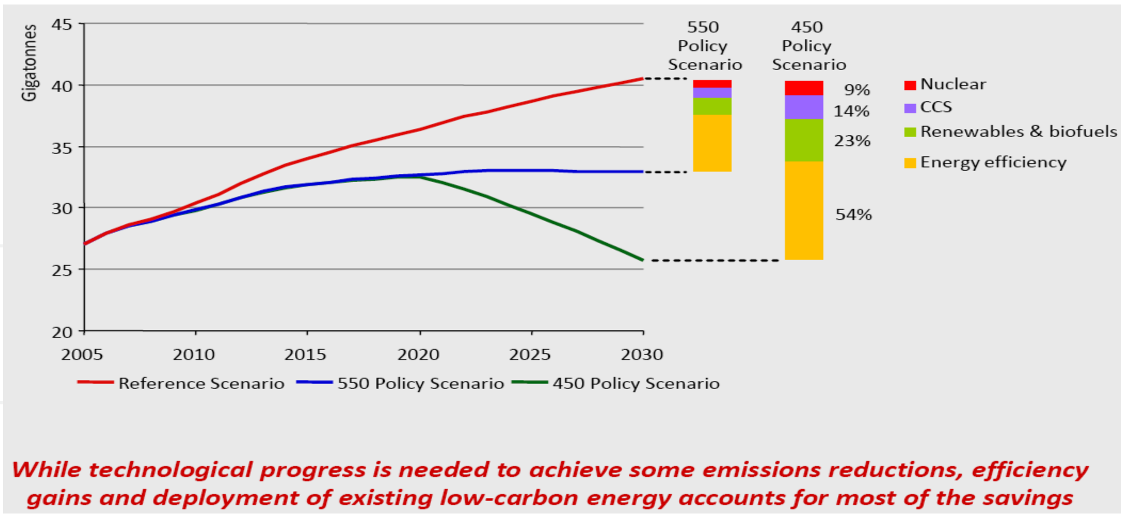
1. Introduction

Since the 1990s, global warming together with the abatement of greenhouse gases (GHG) has emerged as a key issue in the world. Achieving a 450mmp GHG concentration in the atmosphere and a control temperature of less than 20C relative to pre-industrialized conditions in the world in 2100 have been designated as long-term goals. The International Energy Agency (IEA, 2008) indicated that low-carbon energy technologies (including renewable energy and biofuels, nuclear energy, natural gas, et al.) are priority policies and measures to response to global warming and reach GHG mitigation targets, where energy efficiency and renewable energy account for about 78% of the reduction of GHG emissions (see Figure 1).

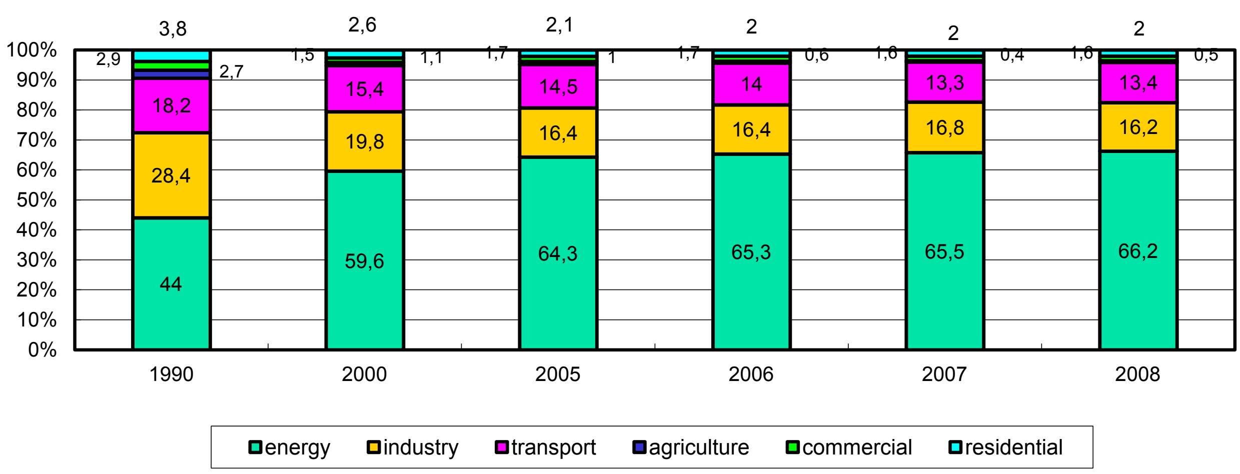
The energy sector accounted for more than 66% of GHG emissions in 2008; it is the biggest GHG emission sector in Taiwan (see Figure 2). Thus, how to reduce CO2 emissions from power generation has become the most important strategy in response to global warming in Taiwan. Therefore, Taiwan's government passed "The Sustainable Energy Policy Guidance "in 2008; it also established a low-carbon energy target in 2020 as well, i.e., it has deployed low-carbon energy , with a goal of up to 55% (renewable energy no less than 8%, natural gas must more than 25%) in power generation in 2025. Figure 3 indicates the 40.6% low-carbon energy rate in 2008; in other words, a huge gap (i.e., a reduction of about 15%) needs to be closed in the coming decade.

In addition, under "The Sustainable Energy Policy Guidance," Taiwan's government has committed itself to reducing CO2 emissions to the 2008 level (about 294 MtCO2) by 2016-2020, and to the 2000 level (about 221 MtCO2) by 2025. However, due to the lack of previous CO2 emission reduction assessments, it is not clear whether the ambitious GHG target can be achieved by 2025.Besides, how will electricity costs be impacted? This is a significant concern of the public. The purpose of this paper is to assess the effect of GDP decoupling with GHG emissions and the impact of the cost of electricity by developing low-carbon energy technology in Taiwan. Implications for the government with respect to policy implications will also be provided.



Source: IEA (2008), World Energy Outlook 2008.

Figure 1. GHG abatement strategy in various climate scenarios



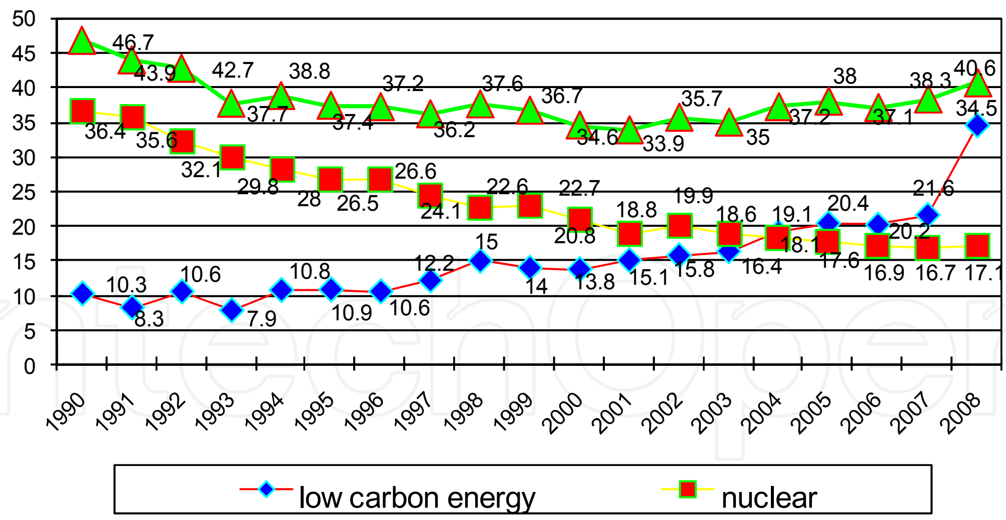
Source: Bureau of Energy (2009), Trend of CO2 emission rates from fuel combustion in various sectors in Taiwan.

Figure 2. Trend of CO2 emission share in various sector in Taiwan

2. Methodology

Equation 1 illustrates CO_2 intensity (CO_2 / GDP) can be broken down into two parts, CO_2 emission per Energy (CO_2 / E) and energy intensity (E / GDP) respectively, where CO_2 / GDP is a decoupling indicator; i.e., if CO_2 / GDP is reduced, this will result in GDP decoupling with CO_2 emissions. CO_2 / E represents a degree of clean energy (or low-carbon energy) in power generation; in other words, CO_2 / E will be reduced if the clean energy share of power generation increases. E / GDP is the inverse of energy efficiency, meaning E / GDP will decrease when energy efficiency increases.

Equation 2 illustrates how CO_2 intensity ($CO_2^{total} / GDP^{total}$) nationwide can be divided into four parts: (1) CO_2 emission per Energy ($CO_2^{energy\ sector} / E^{energy\ sector}$) in the energy sector; (2)



Source: Bureau of Energy (2009), Trend of CO2 emission rates from fuel combustion in various sectors in Taiwan.

Figure 3. Trend of low-carbon energy rates in Taiwan

energy consumption share $(E^{energy\ Sector}/E^{total})$ in the energy sector; (3) inverse CO_2 emission share(CO_2^{total} / $CO_2^{energy\ sector}$) in the energy sector, and (4) energy intensity (E^{total}/GDP^{total}) nationally.

As all of the penal data are time series, "unit root" and "co-integration" tests, these must be engaged in before regression can be run.[1] In addition, this study adopts a mean absolute percentage error (MAPE) criterion to make sure the regression equations can be used to predict a future time path.[2] (See Figure 4)

$$\frac{CO_2^{total}}{GDP^{total}} = \frac{CO_2^{total}}{E^{total}} \times \frac{E^{total}}{GDP^{total}} \quad (1)$$

$$\frac{CO_2^{total}}{GDP^{total}} = \frac{CO_2^{enrergy\ sector}}{E^{energy\ sector}} \times \frac{E^{energy\ sector}}{E^{total}} \times \frac{CO_2^{total}}{CO_2^{emergy\ sector}} \times \frac{E^{total}}{GDP^{total}} \quad (2)$$

[1] This indicates that a stable relationship exists among dependent and independent variables.
[2] A MAPE of less than 10% means it is highly accurate; one greater than 50% is not accurate.(Lewis,1982)

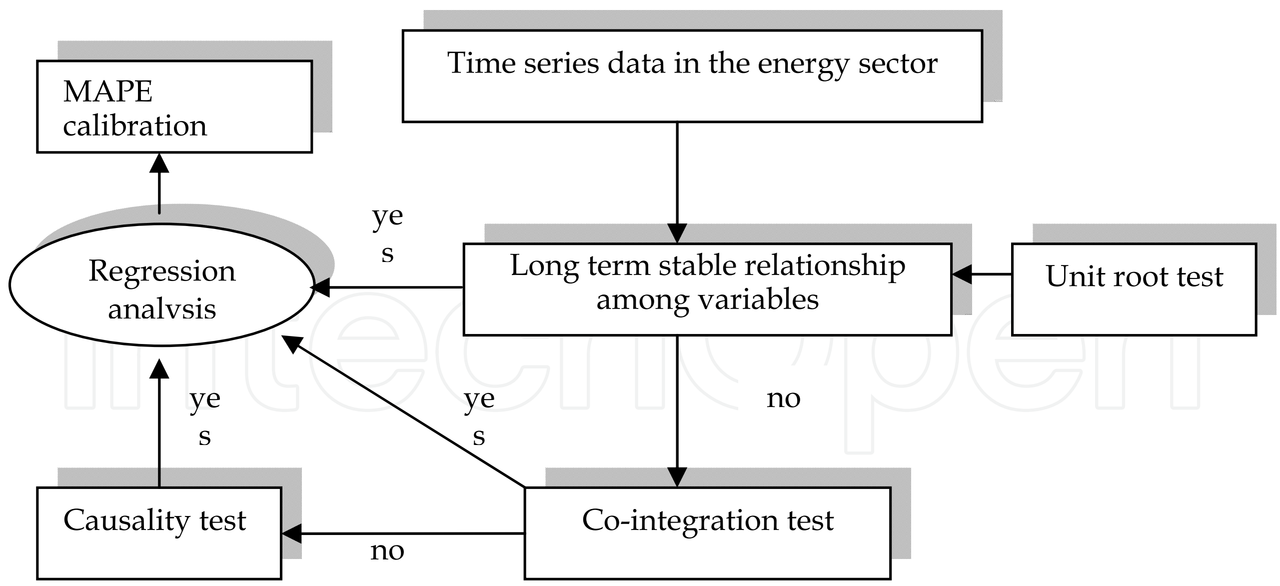


Figure 4. Flowchart illustrating the econometric test process

3. Scenario design and Incorporating the learning effect

To simplify the study, a scenario has been designed as follows:
1 Allow energy efficiency (E/GDP) to increase 2% annually.
2 Set two low-carbon energy power generation rate scenarios at 55%, and 60%, respectively.
Experience studies have demonstrated that there is a correlation between the cost of manufacturing an item and the cumulative quantity of the item produced (Colpier and Cornland, 2002; Hamon, 2000; Neij, 1999).This relationship can be illustrated by an experience curve, which shows that the cost of a product decreases by a certain percentage every time the total quantity manufactured (total experiences) doubles. The experience curve is often expressed as a power function. (See following equation.)

$$C_q = C_0 q^{-b} \tag{3}$$

Where C_q is the cost per unit q, C_0 is the cost for the first unit, q is the cumulative production (experience curve time) and b is a so-call experience index. The value 2^{-b} is called the progress ratio (PR). If an experience curve shows a progress ratio of 85%, it means that cost declines by 15% (learning rate) for each doubling of cumulative production. The reduction of the average cost of power generation is the result of the learning effect (See Appendix). This is derived from the progress ratio estimation of the average cost of power generation average cost in Taiwan (See Table 1).

year	PR (%)	leArning rate (%)
2009	88.2	11.8
2010	86.7	13.3
2015	80.5	19.5
2020	76.2	23.8
2025	72.5	27.5

Table 1. Progress ratio estimation of power generation costs in Taiwan

4. Results

4.1 Assessment of GDP decoupling with CO2 emission

To simplify the study, we let energy efficiency (E/GDP) increase 2% annually and set two scenarios for low-carbon energy power generation rates of 55%, and 60%, respectively. Figure 5 shows a typical business scenario: CO_2 intensity is 22.3 tCO_2/MNT$ by 2025; however CO2 intensity will be sharply reduced to 10.35 tCO_2/MNT$ in the first scenario of a 55% reduction by 2025. This can be further decreased to 9.06 tCO_2/MNT$ in the second scenario of 60% reduction by 2025. From the above results, it can be easily understood that if the Taiwanese government implements low-carbon energy technology, GDP decoupling from CO2 emissions will be achieved in the future.

unit: tCO_2/MNT$

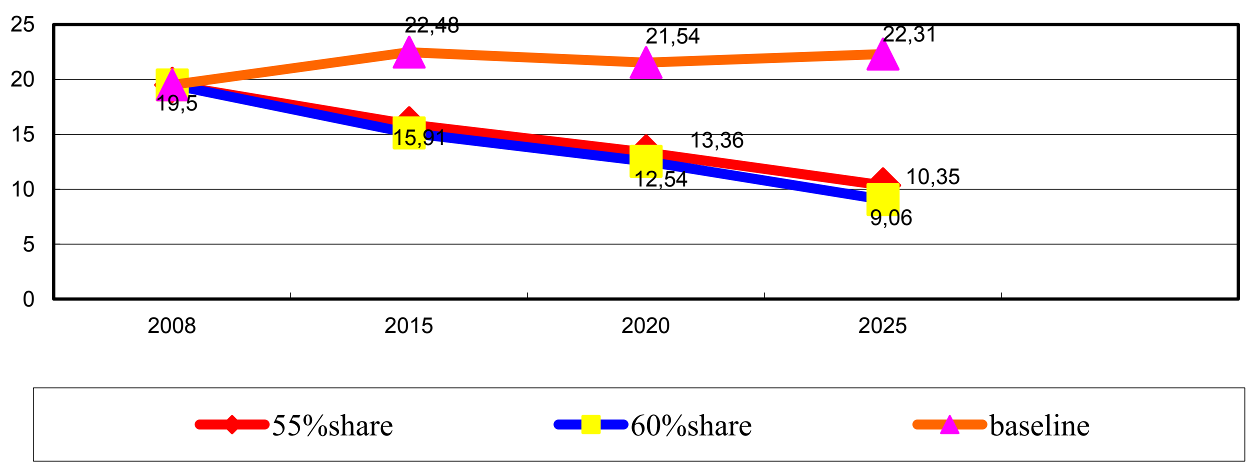


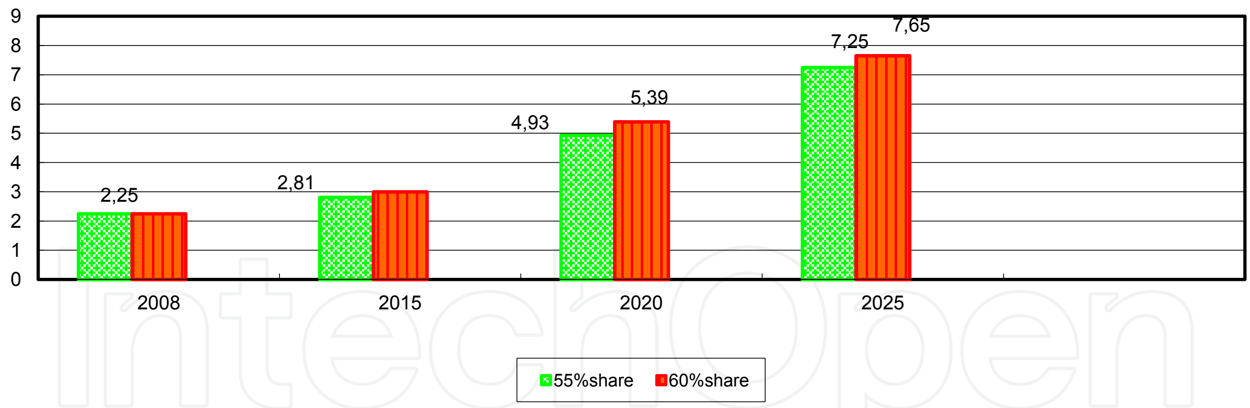
Figure 5. Assessment of GDP decoupling from CO2 at various low-carbon energy rates

4.2 Assessment of electricity costs

Due to the fact that the cost of low-carbon energy is higher than carbon-intense fuels (such as coal), renewable energy sources will increase the share of low-carbon energy sources in power generation. This must then increase electricity costs as well. As indicated in Figure 6, electricity costs will significantly increase to 7.25 NT$/kWh in the 55% scenario, and 7.65 NT$/kWh in the 60% scenario.

5. Conclusion

Under the Framework on Sustainable Energy Development Policies developed by Taiwan's government, the low-carbon technology development target (i.e., not less than 55%) is to be reached as a response to GHG mitigation by 2025. The purpose of this paper is to assess the effect of GHG decoupling and electricity costs by the development of low-carbon energy technology in Taiwan. Results indicate the following: CO_2 is decoupled with economic growth when electricity generation rates of low-carbon energy go up. This can be seen from the following: (1) CO_2 intensity decreases from 22.31 tCO_2/MNT$ (in 2025) to 10.35tCO_2/MNT$ (in 2025) if the electricity generation rate of low-carbon energy reaches



unit: NT$/kWh

Figure 6. Electricity cost in various low carbon energy share assessment

55%; (2) CO_2 intensity decreases from 22.31tCO_2/MNT$ (in 2025) to 9.06 tCO_2/MNT$(in 2025) if the electricity generation rate of low-carbon energy reaches 60%. However, electricity costs also occur as the electricity generation rate of low-carbon energy increases; i.e., (3) the cost of electricity will increase from 2.25 NT$/kWh (in 2008) to 7.25 NT$/kWh (in 2025) if the electricity generation rate of low-carbon energy reaches 55%; (4) the cost of electricity will increase from 2.25 NT$/kWh (in 2008) to 7.65 NT$/kWh (in 2025) if the electricity generation rate of low-carbon energy reaches 60%.

6. References

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7. Appendix

$$\ln \frac{CO_2{}^i}{E^i} = c_0 + c_1 \ln S_1 + c_2; \ln S_2 + c_3 \ln S_3 + c_4 \ln S_4 + c_5 \ln S_5 + c_6 \ln S_6 + c_7 \ln S_7$$

variables	Statistics coefficient	T value
constant	1.2267	0.7805
$\ln(S_1)$	-0.0180	-0.3077
$\ln(S_2)$	0.0843	1.3490
$\ln(S_3)$	0.0179	0.0636
$\ln(S_4)$	0.1939	1.2938
$\ln(S_5)$	-0.0908	-1.1346
$\ln(S_6)$	-0.0040	-0.5035
$\ln(S_7)$	-0.3355	-1.2657
R-squared	0.9775	

Table A1. CO_2 / E regression equation

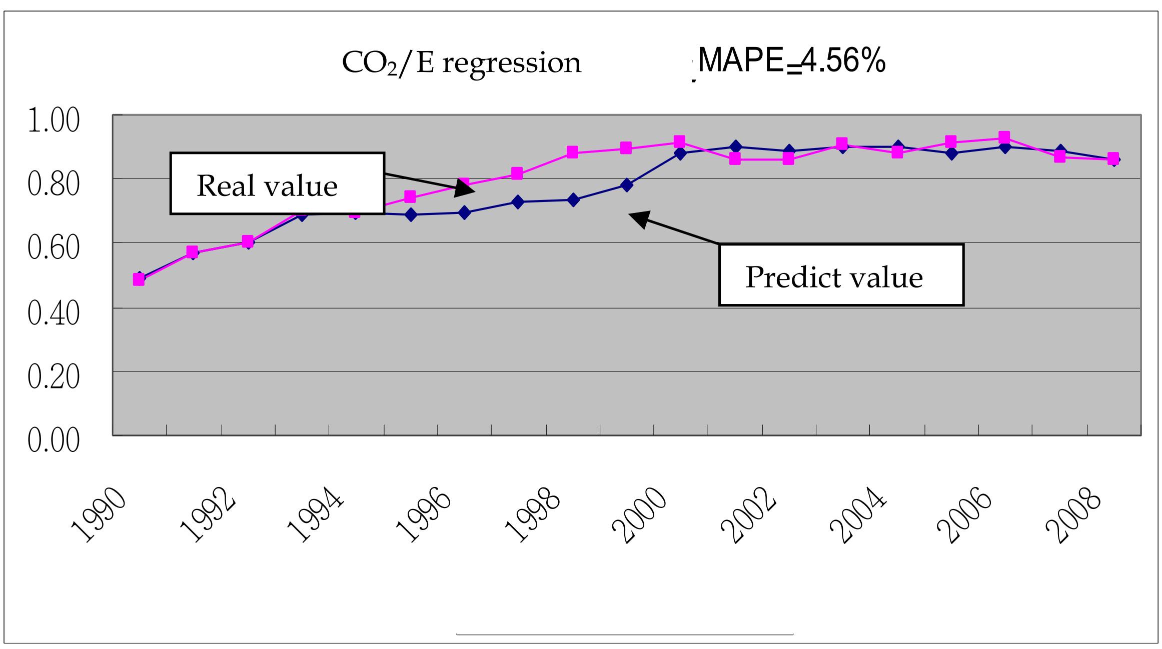

Figure A1. MAPE calibration of CO_2 / E

$AC_{1t}^{e} = c_0 + c_2; S_2 + c_3 S_3 + c_4 S_4$		
variables	Statistics coefficient	T value
Constant	3.436733	5.422285
Oil share(s_2)	-0.0302	-1.65073
Coal share(s_3)	-0.04144	-2.97093
CHP share(s_4)	-0.07528	-3.48088
R-squared	0.87763	
$AC_{2t}^{e} = c_0 + c_1 S_1 + c_5 S_5 + c_6 S_6 + c_7 S_7$		
Constant	1.160219	1.514886
Natural gas share(s_1)	0.031062	1.511986
Hydro share(s_5)	-0.0039	-0.1836
Renewable energy share(s_6)	3.043012	5.705584
Nuclear share(s_7)	0.001841	0.093962
R-squared	0.962363	

Table A2. Average electricity cost (AC) regression equation

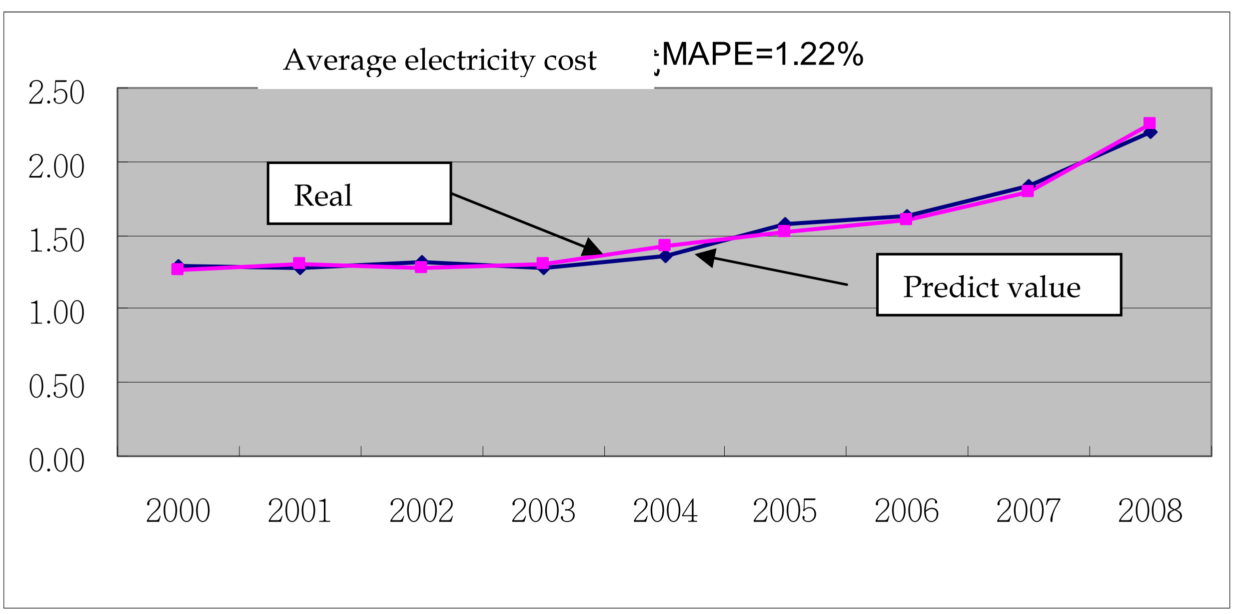

Figure A2. MAPE calibration of average cost

$\ln C_t = \ln C_0 - \zeta \ln Q_t + t + \varepsilon_t$		
variables	Statistics coefficient	T value
constant	14.228	17.538
$\ln Q_t$	-0.178	-2.706
t	0.136	8.335
R-squared	0.980	

Table A3. Learning curve estimation of power generation

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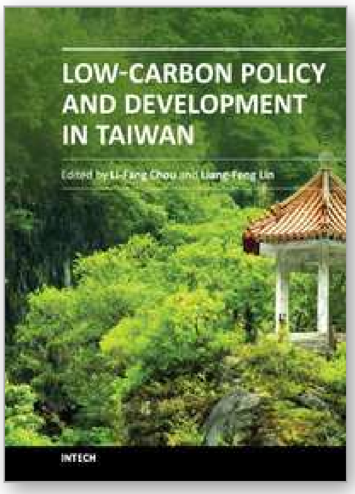

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Taiwan a typical small Asian country with few energy resources is well known for its high-tech industry in the last 20 years. However as a member of the global village Taiwan feels the responsibility to reduce carbon emissions. The book tells you how Taiwan transforms itself from a high-tech island to become a low carbon island. The book address Taiwan's low-carbon developmental policies of the past 10 years, applies an econometric approach to estimate Taiwan's sector department CO2 emissions, shows how environmental change affects the economic growth of Taiwan, and provides two successful examples of low-carbon pilot regions in Taiwan. Stephen Shen, the Minister of the Environment Protection Agency of Taiwan, believes that the book arrives at the right time, because this is the time to educate the people of Taiwan, about the necessary action for achieving a low carbon society.

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