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Climate change and energy policy in Chile: Up in smoke?

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Abstract

This paper provides an ex-post assessment of the climate and energy policy developments in Chile emerging from a neoliberal economic model, during the period 1971-2007. First, correlation and regression analyses were performed to analyse historical CO₂ emissions as a product of demographic, economic and energy-wide drivers. Then I estimate indicators related to CO₂ emissions, energy use and economic activity. In the light of empirical results, I identify policy instruments and structural issues. Finally, I present a comparative analysis of Chile and other Latin American countries. Statistical tests show that variability of CO₂ emissions is explained mostly by GDP per capita ('affluence') than any other tested variable. Indicators show that the diversification and decarbonisation of the energy mix has been a major policy challenge. With two notable exceptions (hydro and natural gas), the CO₂ intensity of the energy supply mix suggests no effective policies, while energy security crises triggered negative carbon effects and increased prices. No clear policies to promote energy efficiency can be identified until 2005. Explicit policy instruments to promote renewable energy are only recognized after 2004. The results strongly suggest that Chile lacked of policies to effectively decarbonise its energy-economy system.

Keywords: Chile; Climate policy; Energy policy; Neoliberal economic model; Policy instruments.

1. Introduction

Chile's economic model has been widely recognised as success story by international organisations such as the World Bank, the International Monetary Fund and the World Economic Forum. Powered by a neoliberal economic model implemented in the early 1980s, the country has been the fastest-growing, most competitive Latin American economy for many years. In the 1990s, while the rest of the world was coping with the economic crisis in Asia, Chile's economy was growing at 4-5%. The country has enjoyed more than 15 consecutive years of positive growth, and per capita income (measured in purchasing power parity) has doubled. It has been argued (Havro & Santiso 2008) that this high economic growth is due to, among other things, sound macroeconomic management, a strong focus on international free trade, very low public debt and the limited role of the state in commercial activities¹.

However, it has been also argued that Chile's impressive economic success has created significant negative environmental impacts (OECD 2005; Stedman-Edwards 1997; World Bank 1994) and that neoliberal economic policies severely restricted, or undermined environmental policy-making (Silva 1996). An unregulated economy and weak state regulation gave high priority to market forces, free trade and privatisation, and had undesirable environmental and social consequences (Liverman & Vilas 2006; Silva 1996). Social inequities appeared, and environmental problems such as air pollution, soil erosion and deforestation rapidly developed (Beghin et al. 2002; Carruthers 2001; Claude 1997; Stedman-Edwards 1997; Tecklin et al. 2011). Bauer (2009), for example, argues that Chile can be considered a world leader in implementing neoliberal policies in the water and hydropower sector, however, Bauer stresses that water property rights given to the owners of hydropower dams undermined the sustainability and governance of water resources.

Chile's return to democracy in the early 1990s provided an opportunity to reformulate its economic model to include environmental goals. The General Environmental Framework Law (Ley No. 19.300), introduced in 1994, was the first building block for Chile's new-born environmental institution. Since then, although environmental policies have developed rapidly (Reyes 2010; Silva 1996) it can still be argued that neoliberal principles, practices and priorities have triumphed over environmental concerns (Bauer 2009; Carruthers 2001; Reyes 2010).

Unfortunately, judgments on the success or failure of Chile's neoliberal model in the domains of energy and climate policy are limited by a lack of empirical data and ex-post policy evaluation studies. A literature review shows there is a lack of evidence with which to quantitatively assess policy efforts —either implicit or explicit. Studies have focussed on very specific issues and/or examined very recent history. For example, Coria (2009) studied environmental and energy policy and analysed time series (1997-2005) data, but only in relation to fuel prices and natural gas switching. Guzowski and Recalde (2010) looked at energy policy, but focused solely on a discussion of the existing renewable energy situation in Chile's electricity market. Karakosta and Psarras (2009) addressed climate policy but only analysed energy technologies within the context of the Clean Development Mechanism (one of the Kyoto Protocol flexible mechanisms). Yoo and Kwak (2010) focused exclusively on the casual relationship between electricity consumption and economic growth².

¹ The 2008 financial crisis had far less impact on the Chilean economy than expected and the international community focused on what could be learnt from this example. In addition to the implementation of various countercyclical fiscal policies, the country operated an institutional framework that regulated banks and credit markets. This was combined with a tight, effective monetary policy and protected Chile's economy from the global economic downturn.

² In the context of an ex-ante policy evaluation, other studies have addressed climate policy and future scenarios by analysing CO₂ abatement and sequestration potentials for the year 2010 (Mosnaim 2001), or have modelled Chile's electricity system. However, these studies only focused on renewable energy sources and one policy instrument (tradable green certificates) (Gebremedhin et al. 2009).

On the question of climate policy, to my knowledge, no study has yet decomposed and analysed the variability of Chile's CO₂ emissions as a product aggregated drivers such as population growth, gross domestic product (GDP) per capita, energy intensity of GDP, and CO₂ intensity of energy supply. In general, the limited number of studies that have addressed energy, economy and climate-related driving factors and intensities either only discussed global trends (Metz et al. 2007; Raupach et al. 2007), or analysed major economies³. Furthermore, and for the case of Chile, there is international debate and disagreement on what constitutes relevant environmental information⁴. The extent to which economic activity has contributed to CO₂ emissions in Chile is not yet known. Moreover, only recently the international community started to pay attention to energy and climate policy development in the country (see IEA 2009a), which is very much unknown at the international level. This lack of empirical knowledge and systematic analysis motivated the current research, which is critical in countries where ex-post policy evaluation is uncommon and historical documentation of energy and climate policy issues is often lacking or scattered (Levine et al. 2007).

The objective of this paper is to provide a quantitative ex-post assessment of climate and energy policies in Chile. It examines whether neoliberal economic policies have produced effective energy and climate outcomes. To achieve this objective, the analysis is separated into four parts: (a) statistical testing of the empirical bivariate and partial correlations between CO₂ emissions, population, GDP per capita, and emission intensity (b) estimates of indicators related to CO₂ emissions, energy use and GDP, (c) identification of policy instruments (e.g. market-based incentives) and structural issues driving or explaining the empirical findings, and (d) a comparative analysis of Chile and other Latin American countries (methodological details in the next section).

This paper quantitatively unravels the key drivers behind CO₂ emissions, and examines the extent to which energy and climate policy efforts have (or have not) decreased energy-economy-environment (E³) intensity patterns across a very long period of time. In turn, it focuses on the impacts of energy efficiency and renewable energy policy. It should, however, be noted that intrinsic data uncertainties and the exploratory nature of the research mean that the findings presented here are only an initial step in an attempt to quantitatively evaluate energy and climate policy efforts in more detail. Research was guided by the following questions: Historically, what were the most significant drivers of CO₂ emission levels? Which policies had the most impact in diversifying and decarbonising the energy mix? From an aggregated policy impact perspective, what can be said about the effectiveness of the policies that were implemented? What has the country done to reform its energy and climate policy agenda?

The paper is structured as follows. Section 2 describes the methodology and the research approach. It stresses the key aspects that need to be taken into account for data collection and data analysis. Section 3 presents and discusses the main outcomes. Results are divided into findings coming from (a) correlation and regression analyses, (b) estimated indicators, (c) policy instruments and key structural aspects, and (d) the comparative regional analysis. Finally, Section 4 draws some conclusions.

³ Wilhite and Nørgård (2004) address energy use and corresponding GHG emissions in India and China. Liddle (2009) analysed decoupling trends (aggregate and sectoral) but only for IEA/OECD countries. Shorrocks and Utley (2006) examined intensity trends for residential energy use in Great Britain.

⁴ For example in February 2011, the Chilean Minister of the Environment complained to the United States Energy Information Administration for incorrectly estimating Chile's CO₂ emissions for the year 2009: the figures indicated an increase of 74% compared to 2008. The Chilean authorities claimed that in fact CO₂ emission levels were reduced by 3.8% for the same period (ORBE 2011). In addition, in 2010 Chile committed itself to undertake Nationally Appropriate Mitigation Actions (NAMAs) to reduce greenhouse gases to 20% below business-as-usual by 2020. However, the country has been criticised because these pledges refer to 2007 data that is not yet publicly available. See the Climate Action Tracker, <http://www.climateactiontracker.org/country.php?id=2775>

2. Methodology

The methodology was based on a top-down decomposition policy analysis using an empirical quantitative approach. It was framed by both policy-oriented research and policy evaluation. Policy-oriented research aims to solve societal problems through improved public policies (Fischer 1995). Its focus is on actionable factors or variables, either complementing theoretical constructs or taking preference over them (Hakim 2000).

The quantitative part of this study builds upon the 'I=PAT equation' (Ehrlich & Holdren 1971 - details below) and 'Kaya Identity' (Kaya 1990) formulations. The I=PAT equation assesses the contribution of population (P), affluence (A), understood as GDP per capita or level of consumption per person, and technology level (T), understood as environmental impact per unit of GDP to the whole environmental impact (I). The latter can be expressed in terms of resource depletion or other unwanted environmental impacts⁵. The 'Kaya Identity' builds upon the I=PAT equation and is a macro decomposition equation for E³ policy analysis based on a set of energy, economic, and demographic indicators that quantitatively estimate CO₂ emission levels (more details below).

2.1 Correlation and regression analyses

First, bivariate correlation tests were carried out using the best available time series data (1971-2007) for Chile, provided by the International Energy Agency (2009b). These correlation tests assessed the relative degree of association (or 'closeness') between each pair of the following variables (as represented in the Kaya Identity): CO₂ emissions, population (P), GDP_{ppp} per capita⁶, and CO₂ emission intensity of GDP_{ppp} (e_int).

Secondly, partial correlations were computed. This was necessary because more than one variable could convey essentially the same information (i.e. multicollinearity), which prevents any inference from being drawn about the relative contribution of a particular driver. Tests were applied to measure the degree of association between CO₂ and each independent variable included later on in the regression model (details below), while the effect of the remaining variables was controlled. The same time series data (1971-2007) was used.

Thirdly, stepwise regression analyses were performed. The objective of these analyses was twofold: 1) to quantify the impact of various simultaneous drivers upon CO₂ emission and 2) to test the hypothesis that 'Affluence', in this case represented by GDP_{ppp} per capita (as in the I=PAT equation), had the strongest impact on CO₂ emissions. To that end, and based on the Kaya Identity, the following model (cf. Raupach et al. 2007) was applied to the case of Chile:

$$CO_2 = P \left(\frac{GDP_{ppp}}{P} \right) \left(\frac{TPES}{GDP_{ppp}} \right) \left(\frac{CO_2}{TPES} \right) = Pgtc$$

where CO₂ emissions (dependent variable) represents the level of emissions from fuel combustion and industrial processes. CO₂ emissions are the product of four driving factors: P is population, $GDP_{ppp}/P = g$ is the per-capita GDP_{ppp} in Chile, $TPES/GDP_{ppp} = t$ is the energy supply intensity of GDP_{ppp}, and $CO_2/TPES = c$ is the CO₂ intensity of total primary energy supply ($TPES$) mix. Upper- and lower-case characters differentiate extensive and intensive variables, respectively. Merging t and c (i.e. $TPES$ is cancelled out) into the CO₂ intensity of GDP_{ppp} (e_int), the formula can be now written as follows: (Kaya 1990)

$$CO_2 = P \left(\frac{GDP_{ppp}}{P} \right) \left(\frac{CO_2}{GDP_{ppp}} \right) = Pg e_int$$

⁵ For more details see Ehrlich and Holdren (1971) and Holdren and Ehrlich (1974).

⁶ GDP is measured in units of purchasing power parity (ppp), as for the year 2000.

The stepwise multiple regression analysis sequentially assessed the unique value of the independent variables on CO₂ emissions. If adding a variable contributed to the model, then the variable was retained, while all the other variables in the model were re-tested to identify whether they were still significant contributors. In the case that the variables no longer contributed significantly to the model, they were removed. Variance Inflation Factors (VIF) were computed to identify signs of multicollinearity. Unless otherwise stated, all interval estimations used a 95% confidence level.

2.2 Estimated intensity indicators

Fourthly, E³ indicators were taken and estimated from the 'Kaya Identity'. Two index (baseline) years were used: 1971 and 1990. This made it possible to adjust the sensitivity of the results according to the chosen base year. Using the same IEA time series data, the following indicators were calculated:

- Energy intensity of GDP_{ppp} (t) = Total Primary Energy Supply ($TPES$) per unit of GDP_{ppp}
- Carbon dioxide intensity of $TPES$ (c) = CO₂ emissions per unit of $TPES$
- Emission intensity of GDP_{ppp} (e_int) = CO₂ emissions per unit of GDP_{ppp}

Notice that I distance myself from the concept of 'decoupling', which is often used to refer to the situation in which resource impacts decline relative to GDP growth. In our case, this means that CO₂ emissions can still rise but at a lower pace than GDP. The term decoupling has often been used as a key political and transitional element to bridge the contentious debate on continuous economic growth and its negative environmental implications. I would argue that the term 'decoupling' is misleading and it should be understood as *no* coupling (cf. Nørgård 2006), as it is simply impossible to have economic activities without affecting the environment and ultimately to the economic system itself (a 'Steady State Economy' also affects the environment). Thus, I would also argue that the distinction between *relative* and *absolute* decoupling (see Jackson 2009) is artificial.

2.3 Identification of policy instruments

Fifthly, an extensive literature review was carried out to identify explicit policy instruments addressing energy and CO₂ emissions. Documentation from the Chilean National Energy Commission (CNE)⁷, the Chilean Ministry of Environment, and press articles were examined. The study aimed to identify and assess the importance, usefulness and effectiveness of policies driving or explaining the empirical results. The methodology included a limited discourse and text analysis. This addressed the substance of the reviewed material and its contextual organisation related to the issues under investigation.

2.4 Comparative regional analysis

Finally, Chile's estimated indicators, including energy use and CO₂ emissions, were compared to figures from selected Latin American (LATAM) countries. The analysis looked at the period 1990-2007 and provided an international and historical perspective on Chile's climate and energy policies. 1990 was chosen as the baseline year as it is the legally binding reference year of the Kyoto Protocol. It is important to point out here that energy use is extremely heterogeneous across LATAM countries. At the risk of oversimplifying matters, it is neither stagnant nor homogeneous and differences arise from dissimilar income levels, living standards and economic activities —amongst other factors. Therefore, comparisons and related findings must be made with caution. The Climate Analysis Indicators Tool (CAIT) provided the data for this analysis⁸.

⁷ Comisión Nacional de Energía (CNE) in Spanish.

⁸ CAIT was developed by developed the World Resources Institute (WRI). For further information, see WRI (2011).

3. Results and discussion

3.1 Correlation and regression analyses

The initial correlation analysis is shown in the symmetrical matrix in Table 1. A priori, all independent variables have the potential to individually explain the behaviour of CO₂ emissions. Correlations between CO₂ and all variables are statistically significant; all p-values are below 0.05. *g* shows the highest correlation (99%) followed by *P* (94.5%) and *e_int* (33.2%). The strong correlation between CO₂ and *g* is consistent with neoliberal economic policies, which aim to maximise ‘affluence’ via economic growth and give little consideration to environmental protection and regulatory frameworks. However, the fact that independent variables, in particular *g* and *P* were also highly correlated (96.4%) already indicated signs multicollinearity for the regression analysis.

Table 1: Results from bivariate correlation tests

		<i>CO₂</i>	<i>P</i>	<i>g</i>	<i>e_int</i>
<i>CO₂</i>	Correlation	1	0.945**	0.990**	-0.332*
	<i>p</i> -value		0.000	0.000	0.045
	N	37	37	37	37
<i>P</i>	Correlation	0.945**	1	0.964**	-0.593**
	<i>p</i> -value	0.000		0.000	0.000
	N	37	37	37	37
<i>g</i>	Correlation	0.990**	0.964**	1	-0.436**
	<i>p</i> -value	0.000	0.000		0.007
	N	37	37	37	37
<i>e_int</i>	Correlation	-0.332*	-0.593**	-0.436**	1
	<i>p</i> -value	0.045	0.000	0.005	
	N	37	37	37	37

* Correlation is significant at 0.05 level

** Correlation is significant at 0.01 level

Results from partial correlation tests confirmed the initial hypothesis that *g* has the most significantly correlation with CO₂ emissions (see Table 2), although with *P* and *e_int* controlled, the correlation between CO₂ and *g* dropped to 92.8% (compared to 99% from bivariate correlation tests). This suggests that the relationship between CO₂ and *g* is mediated by *P* and/or *e_int*. Partialling out *P* and *g* individually suggested that *e_int* was the principle mediator: *e_int* showed a high correlation with CO₂ (88.8%) when the effects of *P* and *g* were controlled.

Table 2: Results from partial correlations tests

Control variables: <i>g, e_int</i>		<i>CO₂</i>	<i>P</i>
<i>CO₂</i>	Correlation	1.000	0.702
	<i>p</i> -value	-	0.000
	df	0	33
<i>P</i>	Correlation	0.702	1.000
	<i>p</i> -value	0.000	-
	df	33	0
Control variables: <i>e_int, P</i>		<i>CO₂</i>	<i>g</i>
<i>CO₂</i>	Correlation	1.000	0.928
	<i>p</i> -value	-	0.000
	df	0	33
<i>g</i>	Correlation	0.928	1.000
	<i>p</i> -value	0.000	-
	df	33	0
Control variables: <i>g, P</i>		<i>CO₂</i>	<i>e_int</i>
<i>CO₂</i>	Correlation	1.000	0.888
	<i>p</i> -value	-	0.000
	df	0	33
<i>e_int</i>	Correlation	0.888	1.000
	<i>p</i> -value	0.000	-
	df	33	0

Contrary to initial expectations, results showed that *P* was much less significantly correlated with *CO₂* (70%) as shown in bivariate tests (94.5%). One explanation for this may be found in the fact that biomass is not included in the figures associated with *CO₂* emissions (only fossil fuel combustion and industrial processes). Therefore this energy source and its associated demand are not captured in the quantitative analysis. However, we need to keep in mind that biomass represented in reality approximately 50% of energy use in residential and commercial sectors, which together represented nearly 20% of total energy demand in 2006-2007 (CNE 2008). In addition, and given high historical deforestation rates in Chile (e.g. annual temperate forest net loss rate of 4.5% per year, see Echeverria (2006, p.485)), the unsustainable use of biomass is likely to be adding *CO₂* emissions.

Indications from bivariate and partial correlation tests were confirmed when the independent variables were analysed using stepwise multiple regression. Results are shown in Table 3. First, and due to their statistical significance, all the variables were kept in the original model (named 'Model 1'). The Model 1 was significant ($F_{3,33} = 2814.6$; *p*-value < 0.05). The adjusted R^2 was 0.996, indicating that 99.6% of the variability of *CO₂* emissions is explained collectively by *P*, *g* and *e_int*. Secondly, the coefficient of variation of the estimated regression model ($Coef_Var_{reg} = \text{Std. error estimate} (+/-1.16) / \text{mean value of } CO_2 \text{ emissions (35.2 MtCO}_2\text{)}$) yielded a value of 3.29%, which suggests that the estimated stepwise model would be useful in predicting *CO₂* emission interval values (i.e. ratio is lower than 10% threshold). Thirdly, estimated coefficients showed that *g* ($\beta=0.753$) had the strongest impact on *CO₂* emission levels. Fourthly, however, estimated VIF measures revealed signs of multicollinearity, with estimated values for *P* and *g* much higher than the defined 5 maximum threshold value. These values were consistent with the indications given by the bivariate tests, in which *P* and *g* appear highly correlated.

Based on the above, a new simulation round took place and new models were computed. In this case, each of the highly-correlated variable was removed individually and the regression equation that explained the most variance of CO₂ (i.e. highest adjusted R²) and showed no sign of multicollinearity was finally kept. This stepwise approach resulted in the 'Model 2', in which only *g* and *e_int* are significant predictors. Indication for removing *P* already came from its relatively lower contribution ($\beta = 0.333$) compared to *g* ($\beta = 0.753$), and also by revealing the largest reduction from bivariate (94.5%) to partial correlations (70.2%) as compared to other tested variables. In other words, partial correlation test had already suggested that *g* and *e_int* were stronger determinants than *P*.

That said, Model 2 was significant ($F_{3, 33} = 2198.11$; $p\text{-value} < 0.05$). While further investigation is needed to assess how useful the Model 2 is for predictive purposes (e.g. homoscedasticity test), the adjusted R² was still very high, indicating that 99.2% of the variability of CO₂ emissions is explained collectively by *g* and *e_int* (only marginally reduced compared to Model 1). Secondly, although the standard error was slightly higher (+/- 1.60 MtCO₂) compared to Model 1, the coefficient of variation of Model 2 yielded a value of 4.53%, which suggested that Model 2 would also be useful in predicting CO₂ emission interval values (i.e. ratio is lower than 10% threshold). Thirdly, estimated coefficients confirmed that *g* ($\beta = 1.043$) had the strongest impact on CO₂ emission levels. Finally, VIF measures revealed no signs of multicollinearity, with estimated tolerance values for the independent variables equal to 1.23, a value lower than the defined 5 maximum threshold value.

Table 3: Summary output from stepwise regression analyses

REGRESSION STATISTICS						
Model	R	R ²	Adjusted R ²	Std. Error		
Model 1*	0.998	0.996	0.996	1.16		
Model 2**	0.996	0.992	0.992	1.60		
ANOVA						
		Sum of Squares	df	Mean Square	F	p-value
Model 1*	Regression	11422.72	3	3807.57	2814.66	0.000
	Residual	44.64	33	1.35		
	Total	11467.36	36			
Model 2**	Regression	11379.35	2	5689.67	2198.11	0.000
	Residual	88.00	34	2.58		
	Total	11467.36	36			
COEFFICIENTS						
		β (Standardised)	Std. Error	t	p-value	VIF
Model 1*	(Constant)	-68.23	6.51	-10.47	0.000	-
	<i>P</i>	0.333	0.48	5.66	0.000	29.38
	<i>g</i>	0.753	0.37	14.29	0.000	23.52
	<i>e_int</i>	0.193	7.30	11.09	0.000	2.5
Model 2**	(Constant)	-33.81	3.23	-10.45	0.000	-
	<i>g</i>	1.043	0.12	62.50	0.000	1.23
	<i>e_int</i>	0.122	6.99	7.31	0.000	1.23

* Predictors: (Constant), *P*, *g*, *e_int*

**Predictors: (Constant), *g*, *e_int*

In summary, correlation and regression analyses strongly suggest that CO₂ emissions in Chile from 1971-2007 are better explained by *g* ('affluence') than any other tested variable. The results support the initial hypothesis that affluence, in the form of *GDP* per capita, is the most significant determinant of historical CO₂ emissions.

3.2 Estimated indicators

Using 1971 as the baseline year, estimated E³ (environment-energy-economy) indicators show a strong correlation between CO₂ emissions, energy supply, and *GDP* (see Figure 1). Relative to 1971, the estimated trends confirmed the country's strong economic performance: Chile's income level increased by a factor of four. *TPES* increased by a factor of almost 3.5 compared to the early 1970s. CO₂ emissions followed a similar path and increased by a factor of 3.5. Reductions in CO₂ emissions and related intensity indicators revealed the critical importance of natural gas imports and hydropower development (discussed in more detail in Section 3.3).

3.2.1 Energy intensity

Estimated energy intensity of *GDP* ($t = TPES/GDP_{ppp}$) provided a limited indication of the transition from traditional to commercial forms of energy and increased industrialization and motorization. *t* trends depended heavily (and obviously) on the phase of economic activity and resulting *GDP*. The economic recession of the early 1980s generated partial reductions in *t* of about 15%. Historical data also showed temporal *t* reductions later on (e.g. between 1990 and 1995) compared to the base

case. Temporal reductions of around 20% were also identified in the mid-1990s and at the end of 2007. These gains were supported by specific and large efficiency improvements in the mining and residential sectors (CNE 2004). The overall, downward trend was driven by high GDP growth relative to energy use though. Results suggest that Chile had not conclusively reached a sustained and marked long-term reduction in t during the period under analysis.

3.2.2 CO₂ intensity

Relative to 1971, CO₂ intensity of energy supply ($c = CO_2/TPES$) decreased slightly and reached its lowest level in the mid-1980s, when the rapid expansion of hydro power allowed intensity reductions of nearly 18% (as in 1987). This is obviously consistent with the development of the electricity fuel generation mix, which was heavily dominated by hydropower until then (nearly 80% of total production). In addition, the data indicate that this was also driven by other factors including, the belated effects of the 1970s oil crisis, when oil prices increased by a factor of four. After that period, estimated c suggests a fossil fuel path dependence in the evolution of the energy-economy system. Note that c was markedly reduced after 1999. This is because massive amounts of natural gas were imported into the country. This cleaner source of fuel increased its share in the electricity generation mix from 1% in 1995, to nearly 32% in 2004 (CNE 2005) (more details in Section 3.3.3). This was a positive development, as the country had heavily relied on oil, gas and coal to fuel its economic growth, with fossil fuels having a much larger share than renewables (further details in Section 3.3.2 and 3.3.3). By 2007, Chile's c once again approached baseline values and the trend can be explained by import restrictions on natural gas, droughts affecting hydropower, and the use of coal (more details in section 3.3.4). All these factors encouraged the use of fossil fuels for power production. As a whole, results show that the decarbonisation of the energy mix has historically been a major policy challenge for the country.

3.2.3 Emission intensity

The estimated trend for CO₂ emission intensity of GDP ($e_int = CO_2/GDP_{ppp}$) confirmed the country's fossil fuel path dependence. While the data showed an irregular trend, results revealed that in the years 1997-2007 a decrease in emission intensity was more due to reduced t than reduced c . In other words, empirical results show that marginal relative reductions in emission intensity can be attributed mostly to increases in economic activity and not to the decarbonisation of the energy mix.

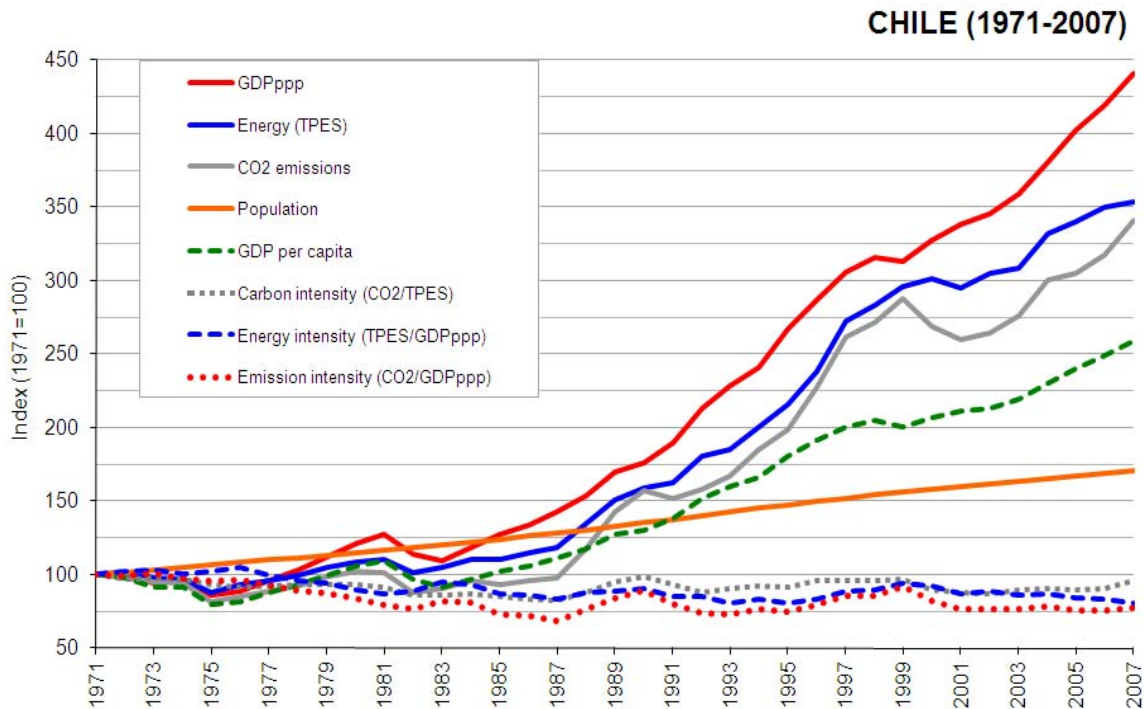


Figure 1: CO2 emissions, related energy use and economic intensities for Chile (1971-2007)

Data source: IEA (2009b)

3.2.4 Baseline year 1990

The same indicators were estimated using 1990 as the base year (see Figure 2). However, some critical aspects emerged which made the analysis look slightly different. First, note that Chile has no legally binding commitments under the Kyoto Protocol, and emissions doubled between 1990 (32.7 MtCO₂) and 2007 (71 MtCO₂). This value (117% increase approx.) is however lower when 1971 is used as baseline (241% increase approx.). Secondly, in the late 1990s (in 1999 more specifically) Chile's energy use and resulting CO₂ emissions grew faster than GDP; a relative increase not seen when using 1971 as baseline. This revealed that more energy supply than before was needed to produce one unit of GDP. This finding suggests that implemented energy efficiency policy instruments (if any) in the last decades were having no or little effectiveness in the late 1990s. In fact, during 1999 all estimated intensity indicators equalled or surpassed baseline values. Thirdly, by 2007 *t* had decreased by nearly 12%, although this was more due to GDP growth, which stresses the role of less intensive technology, than reduced energy supply —in particular after the year 2000. Fourthly, the analysis shows that after 2002-2003 CO₂ emissions once again increased. Again, this suggests that ineffective policy efforts and structural changes had put the country in an uncomfortable climate policy position (e.g. for a post-Kyoto regime).

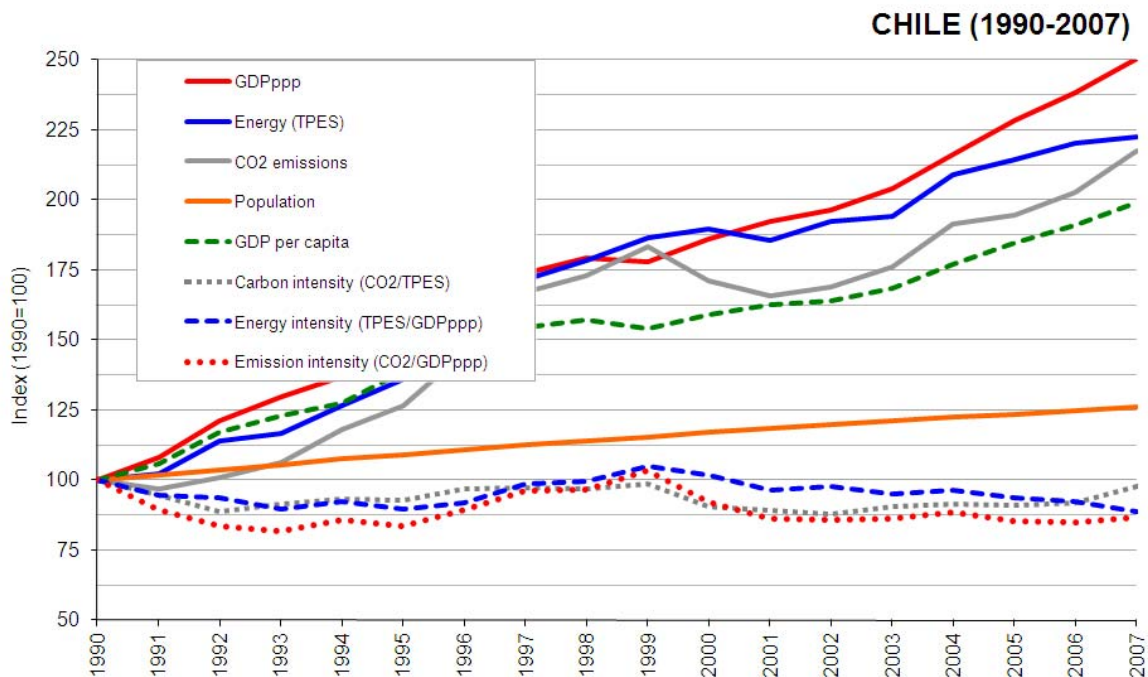


Figure 2: CO₂ emissions, related energy use and economic intensities for Chile (1990-2007)

Data source: IEA (2009b)

In summary, and regardless of the chosen baseline, indicators strongly suggest that the decarbonisation of the energy supply mix has historically been a major policy challenge. While energy crises had negative rebound effects on CO₂ emission levels, energy crises combined with high energy prices (details in Section 3.3) also had positive, but unexpected effects on energy intensity. These findings suggest a “wait-and-see” policy approach to low-carbon technology development. Findings highlight the fact that a technological, efficiency-based policy approach (if pursued) fell short of stabilising or reducing energy use and consequent CO₂ emissions. As a whole, results show that reductions in emission intensity can be attributed more to an increase (or growth) in GDP than a fall in CO₂ intensity.

3.3 Policy instruments and key structural changes

3.3.1 Liberalisation and privatisation

Chile began the liberalisation of its electricity market in 1981, well ahead of many IEA member countries. High inflation in the early-mid 1970s, combined with high fuel prices and price controls resulted in large losses and lack of investment in publicly-owned electricity utilities. These factors provided the foundations for the liberalisation of the sector (Stedman-Edwards 1997) and the Electricity Law was enacted in 1982. The liberalisation and subsequent privatisation of the electricity market, including a successful rural electrification programme provided nationwide access to electricity. In 1982 only 62% of the country had access to the grid, by the late 1980s this had increased to 98% (CNE 2003). This instrument also resulted in increased hydropower capacity which was a key link between electricity and water (details below).

The liberalisation of the electricity market, the expansion in the use of hydropower and the implementation of neoliberal policies were closely connected (Bauer 2009; Stedman-Edwards 1997). In 1981, the military government implemented a Water Code that introduced private property rights for water, promoted the emergence of water markets and greatly reduced the role of the state

(Bauer 1998). Water property rights were created as a fully marketable commodity and given to owners of hydropower dams in the form of ‘non-consumptive’ water permits. Until then, these rights had been held by the state-owned National Electricity Company (ENDESA)⁹. They were transferred to the private sector (via grandfathering) during the privatisation of ENDESA in the mid-late 1980s. However, according to authors such as Bauer (2009), the issue of water permits created three significant problems: the concentration of rights in a handful of owners, the raise of monopoly power and market speculation, and conflict with the agricultural sector.

3.3.2 Hydropower

ENDESA started to build large dams in the 1970s and early 1980s and during this period hydropower dominated electricity generation, providing 80% of capacity (see Figure 3). Besides the economic recession in the early 1980s and the effects of the oil crisis, the rapid expansion of the hydropower sector to some extent explains the relative low level of emissions until the mid-1980s. By the end of the decade the privatisation of the electricity sector, started in the early 1980s, was consolidated (Stedman-Edwards 1997) and hydropower started a new expansion phase as the now-privatised ENDESA and other utility companies built numerous hydro projects (e.g. Rapel 350 MW, El Toro 400 MW, Antuco 300 MW, Colbún 400 MW). Installed capacity almost doubled during the 1990s and reached approximately 5,000 MW (CNE 2008) by the end of this period.

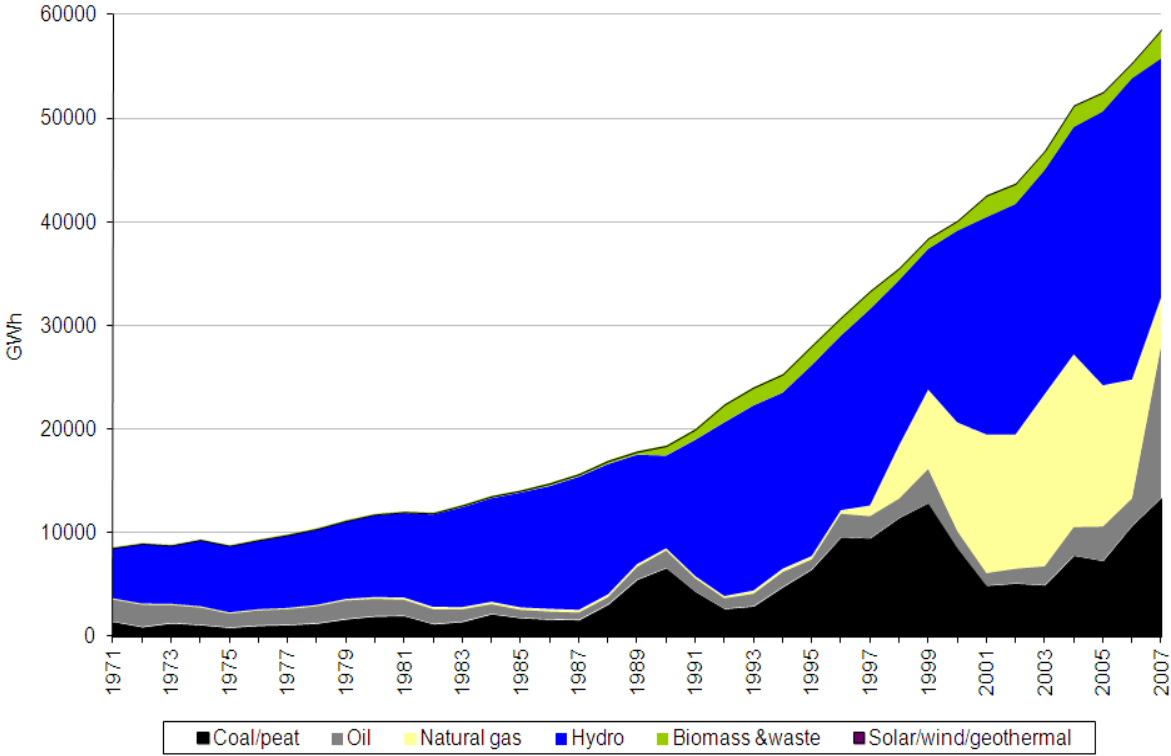


Figure 3: Electricity generation by fuel in Chile (1971-2007)

Data source: IEA (2010)

However, the Chilean authorities faced serious environmental and energy issues. Social and environmental movements strongly opposed the construction of large hydropower infrastructure (e.g. Pangué and Ralco dams in the upper Bío-Bío River). Opposition focussed on its location (on indigenous land) and on the nature and outcome of the environmental impact assessment (EIA). Chile’s General Environmental Framework Law allowed the private sector to select the data it

⁹ Empresa Nacional de Electricidad Sociedad Anónima in Spanish.

deemed relevant to the EIA and the project's objectives; this created opportunities for inconsistency, lack of transparency, and manipulation (Claude 1997; Silva 1996).

Contrary to expectations, the unregulated character of the neoliberal ideology did not materialise in the electricity sector. While the Water Code created an unregulated market, the pro-market Electricity Law was accompanied by an institutional and legal framework (Bauer 1998). Dismantling the state-owned ENDESA resulted in the transfer of duties, the development of enforcement capacities and the creation of important institutions (e.g. the National Energy Commission, and the Electricity and Fuel Regulator). Nevertheless, the privatisation of the electricity market allowed large private electricity companies to appear that wielded great economic power in an otherwise weak regulatory and policy context (Bauer 2009).

3.3.3 Natural gas

Natural gas has also played an important role in Chile's economy and, in the light of the quantitative findings several policy and structural aspects deserve attention.

First, as shown previously, Chile enjoyed strong economic growth for most of the period under analysis. To meet the corresponding energy demand, thermal power (in particular natural gas) expanded rapidly in the 1990s and early 2000 (see Figure 4). In 1995, the electricity supply mix was approximately composed of hydropower (60%), coal-based (30%), and oil and biomass (5%) (CNE 1996). However, Chile started to import huge quantities of natural gas from Argentina: rising from 1.9 bcm¹⁰ in 1996 to 8.9 bcm in 2004 (CNE 2010). This cleaner source of fuel replaced costly and inefficient coal and oil-based power generation and increased its share in the electricity generation mix: from 1% in 1995 to nearly 32% in 2004 (CNE 2005). Consequently, a sharp decrease in CO₂ emissions was seen between the late 1990s and early 2000s¹¹. Increased natural gas capacity also led to a drop in electricity prices (CNE 2011).

¹⁰ bcm = billions of cubic metres

¹¹ Note that Chile does not have national CO₂ emission standards in place.

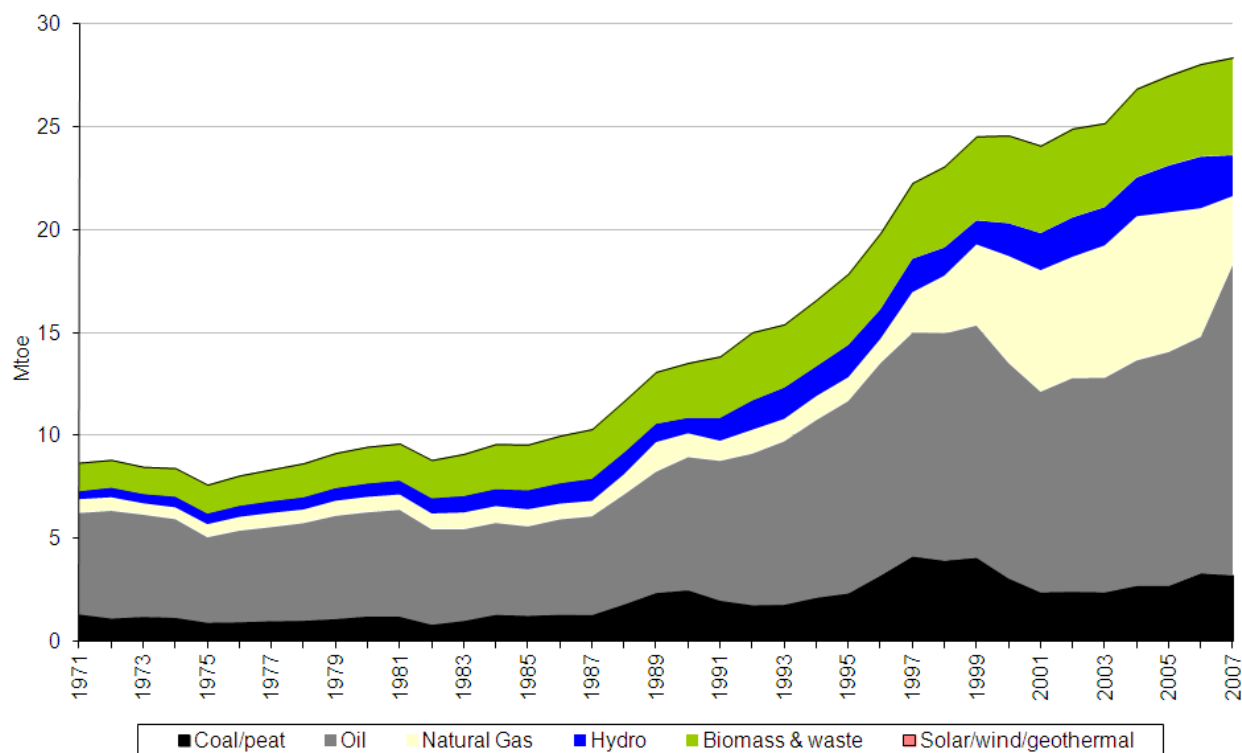


Figure 4: Total primary energy supply in Chile (1971-2007)

Data sources: CNE (2008) and IEA (2010)

Second, the growth in incremental energy use slowed from the early 2000s. This can most likely be attributed to the energy security¹² crises triggered by severe reductions in natural gas imports and droughts (details below). In 2004, the authorities announced that Chile required an additional 350 MW of capacity to meet growing energy demand (Ibarra & Cubillos 2004). At that time, planned natural gas investment projects totalled more than USD 1,500 million (Ibarra 2004a).

Third, the empirical data shows that there was a rapid return to a high growth rate in CO₂ emissions (as shown in Figure 1 and Figure 2). This trend can also be linked to the role of natural gas. In 2004, Argentina, which was experiencing internal political and economic turmoil, restricted the export of natural gas¹³. Supplies were reduced by 30-80% and the situation in Chile became very uncertain for both utility companies and end-users (Olivares & Ibarra 2004). After 2004, natural gas imports fell by more than 90%, as Argentinean suppliers were obliged to meet internal demand before exporting (Ibarra 2005).

Consequently, Chile, which had invested heavily in Argentina as a local and reliable energy supplier, suffered a major energy security crisis. The industrial sector was severely affected and suffered a total cut in supplies (Ibarra 2005; Ibarra & Varas 2005). On average, electricity production costs increased by a factor of three (Ibarra 2004b) and many industries took legal action against the main natural gas distributor in Chile (Metrogas) (Olivares & Ibarra 2004). In parallel, Chilean utility companies demanded financial compensation from Argentinean suppliers and the conflict between the two countries quickly escalated to the highest political level. Natural gas investment projects

¹² Note that in this paper, the term energy security refers to the availability of affordable and reliable energy resources/fuels at all times.

¹³ Note that Chile had already suffered a cut in natural gas supplies from Argentina in 2002 due to labour strikes. Utility companies alerted the Chilean Government to the sudden energy security crisis (English & Rioseco 2002).

were halted and the Chilean government strongly encouraged the non-use of Argentinean natural gas. By 2007, the export of natural gas from Argentina to Chile had almost completely ended. To avoid another 'Argentinean crisis', Chile has embarked on the construction of large-scale liquefied natural gas (LNG) terminals (e.g. USD 940 million to build the Quintero Terminal and USD 500 million for the Mejillones Terminal). Due long-standing border disputes with neighbouring countries that are rich in natural gas (e.g. Bolivia), gas imports are likely to come in the near future from far afield (e.g. Russia and Yemen).

3.3.4 Droughts

In 1998-1999 and 2007-2008 hydroelectric production was affected by droughts. Although the Water Code provided for the preferential supply of water to hydropower installations over irrigation, the severity of the droughts caused several nationwide blackouts. In 2006-2007, a contingency plan to convert combined-cycle natural gas fired plants to open-cycle diesel fired plants was put in place to overcome the double 'hydro-gas' energy crisis. Imports of oil products and coal increased to cover the gap left by natural gas. As a result, CO₂ intensity increased. The government and the private sector promoted the use of coal for electricity production (del Campo 2004). Consequently, installed coal-based capacity grew at a much faster rate than renewable energy capacity. For the future, projections by the CNE already show that coal-based installed capacity will reach 26% in 2020. This needs to be compared with a share of 17% in 2005 (Tokman 2008, p.124). Although absolute emission standards for thermoelectric plants were not identified, one can also argue that these factors greatly affected the increase in CO₂ emissions.

3.3.5 Market price mechanisms

Due to the heavy dependence on imports of fossil fuels, Chile's energy-economy system has been rather vulnerable to international price volatility. To cope with this uncertain scenario and reduce such price volatility, in particular for retail prices and end-users, authorities created the Oil and Fuel Price Stabilisation Funds in 1991 (Law No. 19.030) and 2005 (Law No. 20.493), respectively. In simple terms, these funds work through (a) the charge of a tax when import parity price is lower than the internal price band's lowest limit (set by the CNE), or (b) the payment of a credit when import parity price is higher than the internal price band's highest limit (also set by the CNE)¹⁴. Credits are generated with the taxes. The government often injects funds to maintain a positive balance when credits outweigh the taxes (e.g. in early 2007).

The hydro-gas crises (combined with the rising of oil prices worldwide) had severed effects on marginal electricity costs and resulting prices. For instance, marginal costs increased by 150 USD/MWh in mid 2006 and up to 300 USD/MWh by the end of 2007 (CNE 2011). Within this volatile market scenario, industrial customers switched to back-up diesel power generation to avoid having to pay very high spot market prices of grid-based electricity. Temporal energy intensity reductions correlated with increases in marginal electricity production costs, which suggested that high electricity and natural gas prices had a positive effect on energy intensity. For example, in 2006 electricity tariffs increased by approximately 20% compared to 2004-2005 (CNE 2011). This corresponds with a reduction of 15-20% (depending on chosen baseline year) in energy intensity after 2004.

Despite the fact they do not take full account of the negative social and environmental impacts of energy production and consumption, market price mechanisms were the sole explicit instrument used to foster energy efficiency improvements during the period under analysis.

¹⁴ For further information visit

[Hhttp://www.cne.cl/cnewww/opencms/07_Tarificacion/02_Hidrocarburos/precios_paridad.html](http://www.cne.cl/cnewww/opencms/07_Tarificacion/02_Hidrocarburos/precios_paridad.html)

3.3.6 Energy efficiency and renewable energy

Estimated indicators stress the importance, but lack of energy efficiency policies in end-use sectors; notably industrial, transport and residential. These sectors respectively accounted for 42%, 33% and 20% of total energy use in 2007 (CNE 2008). Until 2005, when the government launched the National Energy Efficiency Programme (NEEP) as the framework for its energy efficiency policies¹⁵ there was no policy instrument designed to foster energy efficiency improvements. This is despite the fact that other studies revealed energy efficiency potentials of around 55% in the mid-1990s (Claude 1997, p.67). Moreover, none of Chile's electricity utility companies were required to encourage energy conservation in its end-use sectors.

Initially, the NEEP focussed on the residential sector and initiatives included the development or implementation of minimum efficiency standards for roofs and insulation, an awareness raising campaign, and labelling schemes for certain appliances (e.g. refrigerators). In 2009, the National Energy Commission announced a target to reduce incremental electricity demand by 20% by 2020. This target could reduce additional power capacity by approximately 10% (ca. 1,600 MW) (APEC 2009, p.10). However, if energy efficiency policies had been implemented in the early 1990s, final energy use could have been reduced by 17% in 2002; together with a reduction in energy intensity of 22% (CNE 2004, p.97).

As has already been discussed, empirical results showed that the decarbonisation of the energy mix has historically been a major policy challenge for Chile. Although the introduction of natural gas from Argentina in the late 1990s diversified the energy mix and reduced CO₂ emissions, the growth of CO₂ intensity was only marginally slowed. In fact Chile, which has rather limited indigenous fossil energy resources, has relied heavily on oil, gas, and coal to support its economic growth (Speiser 2008). In 2007, oil represented nearly 53% of Chile's TPES, coal 11%, natural gas 12%, hydro 7% and biomass 17% (IEA 2010). By the end of period under analysis the country was importing more than 70% of its TPES in the form of fossil fuels (CNE 2010). The historical evidence strongly suggests that government policy (if it existed) had little long-term effective on decarbonising the fuel mix supply.

It is not until 2004-2005 that explicit policies can be identified to promote the use of non-conventional renewable energy (e.g. wind, solar, geothermal, biofuels). The so-called 'Short Law I' (Ley Corta I) and 'Short Law II' (Ley Corta II) introduced tax exemptions (or subsidies) for the use of transmission grid; these included long-term supply contracts between energy generators and distributors. Both policy initiatives were further consolidated when the Senate approved the 'Law for the Development of Non-conventional Renewable Energy' in 2008. The law obliges electricity companies to demonstrate that a given share of electricity is generated from non-conventional renewable energy: 5% between 2010 and 2014, up to 10% by 2024. The government has also implemented specific economic policy instruments: grants for pre-feasibility studies, direct investment support, and guaranteed bank loans, among others¹⁶. A Centre for Renewable Energy was created in 2009¹⁷. These policy developments appear long overdue if one looks at, (i) the vast and diverse potential for renewable energy in the country, and (ii) and the high dependence on imports of fossil fuels noted above. Policy recommendations for the use of wind energy were first proposed in the early 1990s (see CORFO 1993). However, no further action was taken. It was only by the very end of 2007 that the government had implemented a policy that at least 10% of electricity should come from renewable energy (excluding large hydro) by 2020.

¹⁵ The National Energy Efficiency Programme is now under the control of the Chilean Energy Efficiency Agency. In 2006, the programme's budget was about USD 1 million, by 2009, this had increased to nearly USD 35 million. For further information see <http://www.ppee.cl/H>

¹⁶ For further information see <http://www.corfo.cl>

¹⁷ For further information see <http://www.cer.gob.cl>

One explanation for the lack of policy instruments –and consequently investment- to support energy efficiency and renewable energy is the lack of regulatory power of the Chilean government. Both the National Energy Commission and the recently-created Ministry of the Economy¹⁸ have the power to enforce existing policy, but not to modify legislation. This, combined with the prevailing influence of the private sector and a free-market ideology, means that the administration has very limited discretion in directing prices and investments in order to positively affect energy efficiency or renewable energy technology investment (Bauer 2009; Dufey 2010; Speiser 2008). Furthermore, monopoly power and speculation in the water permit market has delayed or stopped hydropower investment projects (Bauer 2009).

3.3.7 Climate change policy

Two climate change policy instruments can be identified. In 2006, a ‘National Strategy on Climate Change’ was announced (see CONAMA 2006). Policies were aimed at mitigation, adaptation and capacity building, although in the case of mitigation, the strategy only focussed on the analysis, definition and implementation of greenhouse gas mitigation and lacked detail. Secondly, at the very end of 2007, a ‘National Action Plan on Climate Change’ was announced. It aimed to support a low-carbon economy that contributed to sustainable development and global efforts to reduce greenhouse gas emissions (Rudnick 2010). However, it is still too early to tell whether this action plan has delivered effective outcomes. At all events, modelling studies already envisage a doubling of GHG emission levels between 2008 and 2025 (POCH Consultores 2009). This may be already casting doubts about the effectiveness of these and other related policy efforts.

3.4 Comparative regional analysis

This section briefly compares energy use, CO₂ emissions and estimated indicators in Chile to other Latin American countries.

3.4.1 Energy use

Results show that energy use grew considerably more in Chile than, for example, Brazil, Argentina, or Mexico (see Figure 5). However, in 2007, Chile’s ranked 46 among 186 countries and its energy use was still lower than Brazil, Argentina and Mexico (but higher than Peru and Colombia) measured in absolute terms (see Table 4). Energy use was similar to some Latin American (LATAM) countries (Argentina, Mexico) on a per capita basis (1.9 toe¹⁹), but above the average for both LATAM (1.3 toe) and MERCOSUR (1.3 toe)²⁰. Note that in absolute terms, the estimated energy intensity for Chile in 2006 was about 0.17 toe/thousand USD_{ppp}. This figure is comparable to the average for OECD countries (0.18 toe/thousand USD_{ppp}), but much higher than some countries in the region (see IEA 2008).

¹⁸ The creation of the ministry in November 2009 was one result of a series of legislative proposals outlined in the ‘Energy Policy: New Guidelines’ developed by the National Energy Commission in 2008 (see Tokman 2008). The policy guidelines aim to re-structure and thus improve energy policy-making, evaluation and implementation.

¹⁹ toe = tonnes of oil equivalent.

²⁰ MERCOSUR (Mercado Común del Sur in Spanish) is a free trade and political agreement between Argentina, Brazil, Paraguay and Uruguay. For further information see <http://www.mercosur.org.uy/H>

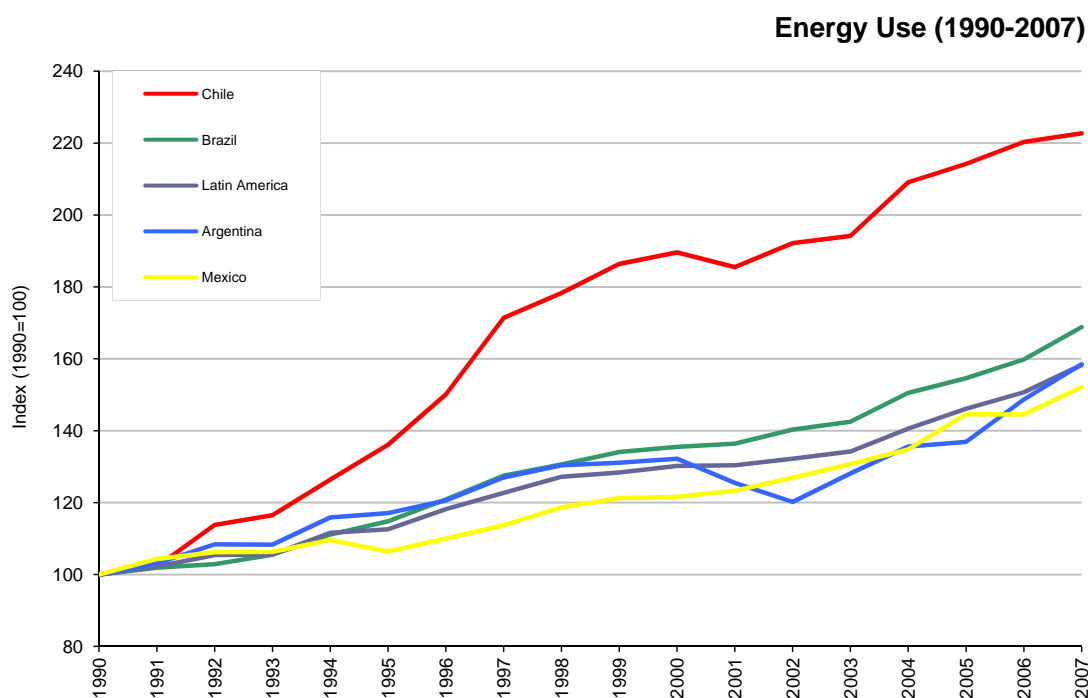


Figure 5: Energy use in Chile compared to selected countries, including Latin America as whole (1990-2007)

Data source: WRI (2011)

Table 4: Energy use in 2007

	Thousands toe	Rank (out of 186)	% of world total	toe per person	Per capita rank
Argentina	73	28	0.63	1.9	61
Brazil	236	10	2.02	1.2	73
Chile	31	46	0.26	1.9	60
Colombia	29	47	0.25	0.7	101
Peru	14	77	0.12	0.5	112
México	184	15	1.58	1.8	64
USA	2,340	1	20.1	7.8	9
EU-27	1,759	-	15.1	3.6	-
LATAM	725	-	1.3	1.3	-
MERCOSUR	316	-	2.7	1.3	-
LDC**	176	-	1.5	0.3	-

* toe: tonnes of oil equivalent ** LDC: Least developed countries

Data source: WRI (2011)

3.4.2 CO₂ emissions

In early 2000, the use of natural gas brought Chile's CO₂ emissions level close to that of Brazil. After that growth in emissions remained clearly above the selected LATAM countries until the end of 2007 (see Figure 6). Table 5 shows the absolute values of cumulative CO₂ emissions from energy use. These figures show that Chile ranks 54 among 186 countries and that its CO₂ emissions were much lower than Argentina, Brazil and Mexico and slightly lower than levels in Colombia or Venezuela (Venezuela is not included in Table 5). However, on a per capita basis, Chile had CO₂ emission levels

that were higher than Brazil, Colombia, Peru, LATAM and MERCOSUR, but lower than Argentina or Mexico.

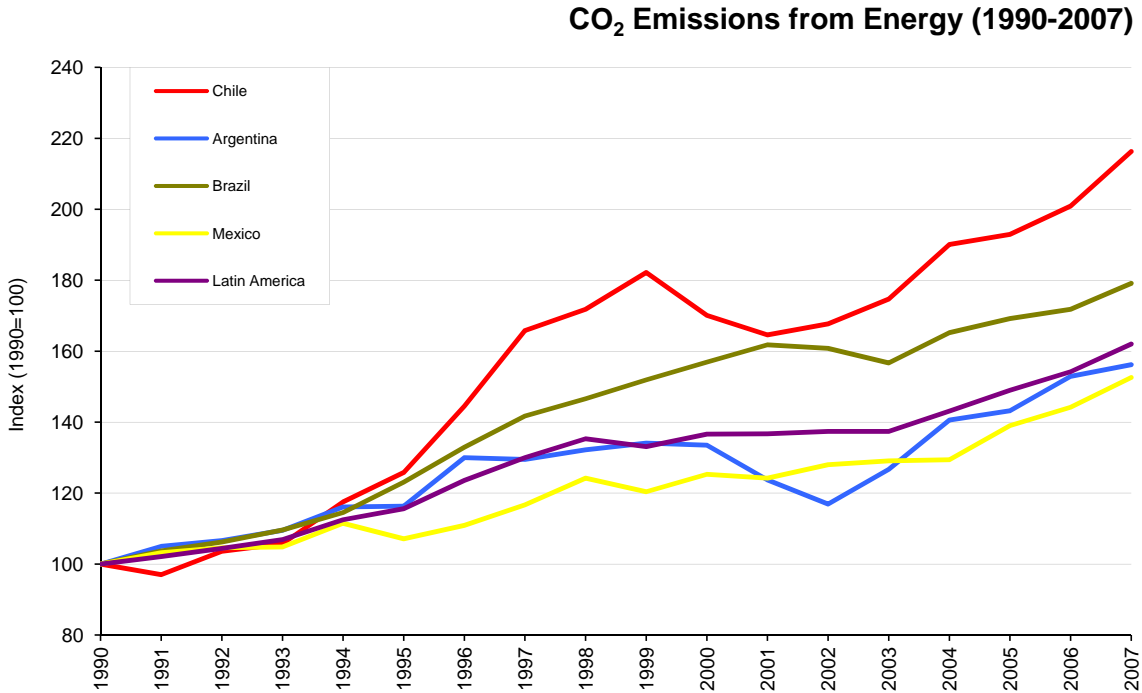


Figure 6: CO₂ emissions from energy use in Chile and selected countries, including Latin America as whole (1990-2007)

Data source: WRI (2011)

Table 5: Cumulative CO₂ emissions from energy use (1990-2007)

	MtCO ₂ -eq	Rank (of 186)	% of world total	tCO ₂ -eq per person	Per capita rank
Argentina	2,443	29	0.57	61.9	77
Brazil	5,302	19	1.23	27.9	104
Chile	951.9	54	0.22	57.2	81
Colombia	1,091	46	0.25	24.6	110
Peru	482.5	70	0.11	16.9	123
México	6,647	14	1.55	63.1	75
USA	98,180	1	22.83	325.9	6
EU-27	72,661	-	16.90	146.9	-
LATAM	22,137	-	5.15	39.4	-
MERCOSUR	7,905	-	1.84	33.1	-
LDC	2,032	-	0.47	2.6	-

Data source: WRI (2011)

3.4.3 Estimated indicators

Figure 7 compares estimated E-3 indicators for Chile with other LATAM countries for the period 1971-2007. There are four main findings. First, regional energy use during this period grew by a factor of three (this is slower than the overall rate of growth of Chile). From the mid-1990s, Chile’s demand for energy was higher than the LATAM average; at the same time Chile’s economic activity grew on average at a higher pace than the rest of the region. This had positive impact on energy intensity. Secondly, Chile’s CO₂ emission levels have been, for the majority of the period under analysis, growing below the LATAM average ratio. At a time when emission levels were becoming

higher than the regional average, the introduction of natural gas in 2001 brought Chile back closer to the regional average. Then, from 2003 (driven by the double 'hydro-gas' energy crisis), emissions once again rose above the LATAM average. Thirdly, Chile's energy intensity trend, albeit irregular, performed better than the LATAM average. While the region showed very little improvement, reductions in Chile's energy intensity were still relatively larger than LATAM as a whole. Fourthly, LATAM had higher CO₂ intensity than Chile for the majority of the period under analysis, although trends were converging by end of 2007.

In summary, Chile had much higher growth in energy supply and CO₂ emissions than LATAM after the mid 1990s. These are worrying trends. However in absolute terms, the country's performance was comparable to (or better than) other countries. Energy intensity patterns confirmed the Chile's economic credentials compare to LATAM's performance. The results also indicate that not only Chile, but the region as a whole, have been facing a major policy challenge in decarbonising its energy mix. This also suggests some infrastructure and capital investments 'locked-in' carbon effects.

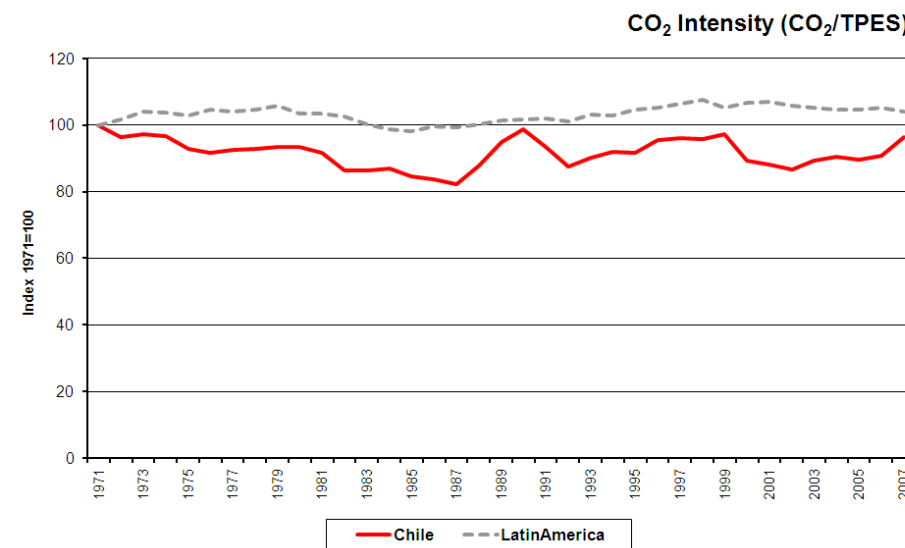
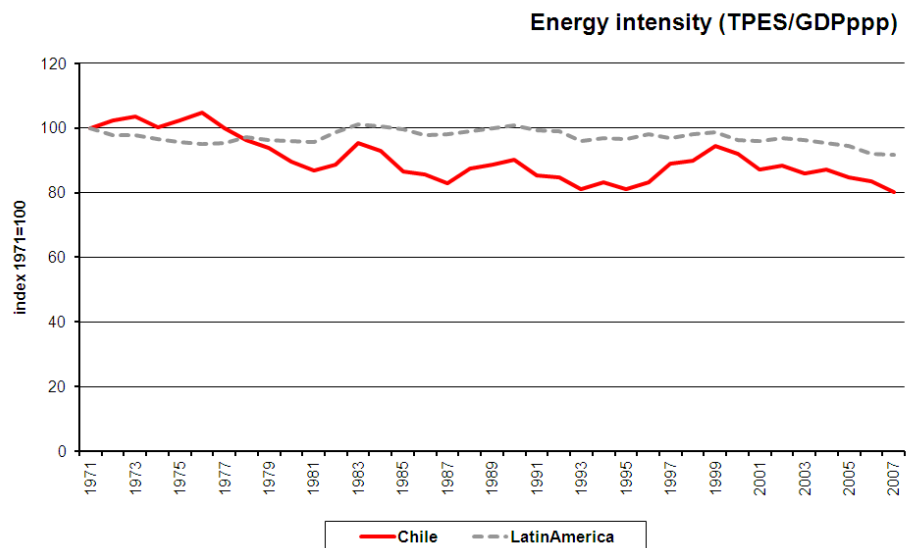
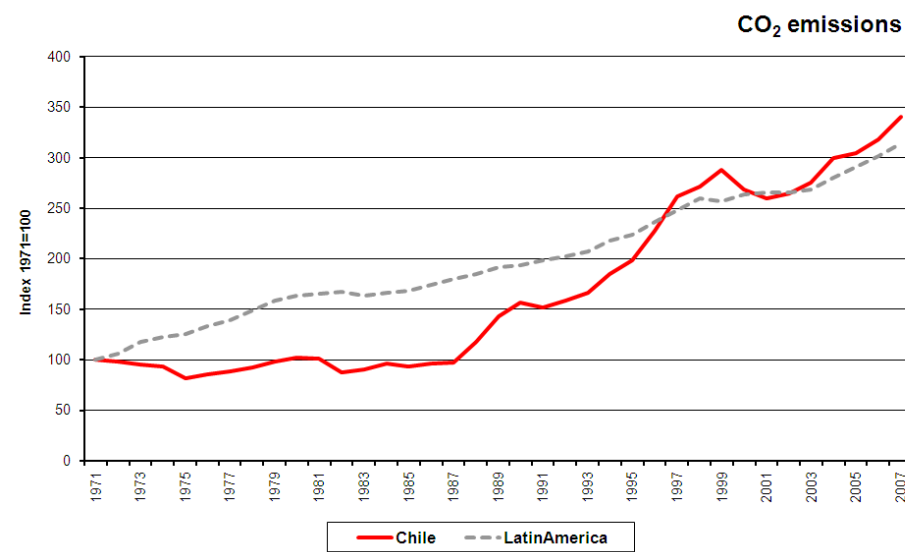
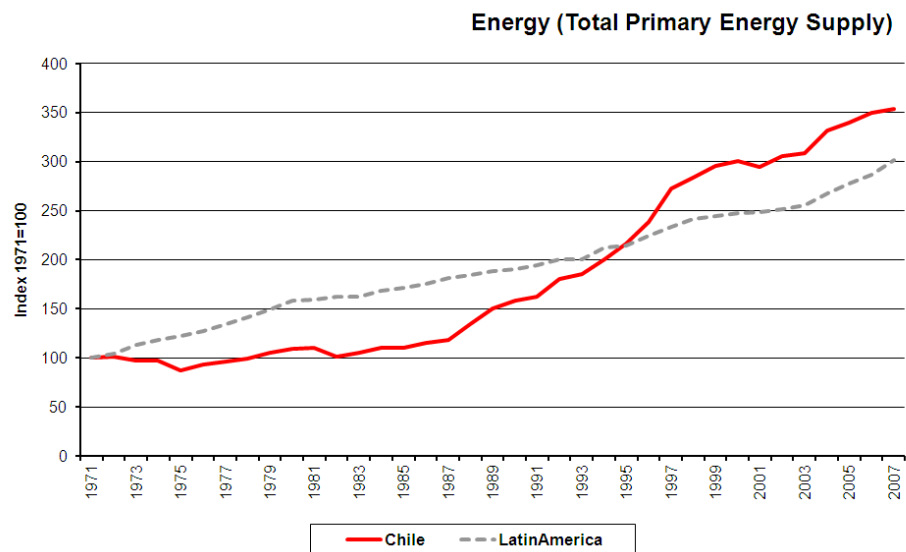


Figure 7: Selected indicators for Chile and Latin America (1971-2007)

Data source: IEA (2009b)

4. Conclusions

The Chilean economy has been portrayed as a model for Latin America, and the nature, development and formulation of its neoliberal economic model holds interesting lessons for international organisations seeking to promote energy and climate policies for sustainable development in the region.

While links between the energy, economy and environmental systems are complex, correlation and regression analyses suggest that CO₂ emissions in Chile over the period under analysis are better explained by GDP per capita than any other tested variable. The results support the initial hypothesis that ‘affluence’, in the form of GDP per capita, is the most significant variable that explains the variability of CO₂ emissions. Results also stress the important role of the energy mix and how energy is used.

Estimated indicators revealed that Chile must find other, low-carbon energy supplies in order to pursue its economic, environmental, social, energy and climate policy goals in much more coherent and sustainable manner than in the past. Consistent with neoliberal strategies, results show that economic activity has taken no account of the environmental costs for ecosystems and future generations. Consequently, CO₂ emissions grew very rapidly despite the steady development of hydro and natural gas power. In turn, empirical results confirmed the political illusion of the term ‘decoupling’. To prevent climate change and other environmental problems, Chile’s CO₂ emissions cannot continue to rise forever, even if they do at lower pace than GDP.

The results strongly suggest that Chile lacked a coherent vision and explicit policy instruments to effectively introduce positive and sustained change in energy generation and use. Government policies related to energy efficiency, (non-conventional) renewable energy, and climate change—explicit or implicit—did not exist or found to be rather modest²¹. Again, this finding is consistent with neoliberal economic practices that deregulate economic activities and reduce the interventionist role of the state (e.g. to protect public goods).

The estimated CO₂ and emission intensity trends suggest that there was no (effective) policy to decarbonise the energy-economy system. The analysis suggests that the neoliberal approach to energy and climate policy has paved the way for a fossil fuel path-dependence of the energy-economy system. Energy infrastructure and capital investments may have created ‘locked-in’ effects, and a continuation of a high-carbon growth policy strategy does not seem sustainable. This path may hamper the successful deployment and commercialisation of low-carbon technologies and accentuate estimated CO₂ emission levels. The analysis strongly suggests that very ambitious policies and targets for renewable energy and energy efficiency are needed to accelerate the transition towards a low-carbon economy. Energy efficiency alone, for instance, can be doubled.

Paradoxically, the untenable political and also policy environment depicted above has prevented the formulation of a clear, long-term message about investments in the private energy sector (a critical actor in the neoliberal context). The energy crises seen in Chile suggest that this approach to policy development has not fully supported economic growth. Ironically, the uncertain policy framework conflicted with free-market priorities, and the industrial sector became overexposed to severe shortages in energy supply. Following Chile’s return to democracy in 1990, reform of this unsustainable policy framework was very slow and serious attempts to implement policy were not seen until nearly 15 years later. Within the context of this research, these aspects suggest that the neoliberal policy model is still deeply rooted in Chile’s political economy. The continuation of this approach to energy and climate policy is likely to bring grave economic risks

To revert the negative trends in relation to CO₂ emission, the research at hand suggests that

²¹ Note that the political science literature acknowledges ‘governmental inaction’ as a policy strategy (Howlett 1991; Vedung 1998)

in the very near term high priority should be given to policy instruments that encourage a much more sustainable 'affluence', or a level of consumption of goods and services much more compatible with climate mitigation. This could lower the total 'Impact' computed as $P \times g$. Likewise, policy priority and high ambition should be given to the decarbonisation of the energy mix. Overall, the current policy situation offers potential to evaluate and implement ambitious policy portfolios, covering the full range of economic, regulatory and informative approaches to low-carbon technologies. Population control (P determinant), often a controversial policy issue to reduce CO₂ emissions, does not seem to be a priority at the moment. In fact, fertility rates in Chile (1.9) have declined during the past years and are already comparable to some European countries. At all events, further research should be done on population as predictor for CO₂ emission, in particular in relation to the use of biomass in the residential sector and associated deforestation rates.

In all Neoliberalism, as a political-economic model under which policy efforts, statistical figures and indicators were analysed, does not seem to be particularly suited to laying the foundations for a sustainable low-carbon economy in Chile. Whether policies that have only very recently been implemented are effective and efficient will be critical to improvements in the country's energy security, supporting a less CO₂ intensive economic growth, and preparing the country for a potential post-Kyoto climate regime.

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