RESEARCH REPORT

Subsidies and External Costs in Electric Power Generation: A comparative review of estimates

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About GSI

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1. Introduction

Over the past twenty years the political and economic landscape for energy has begun to shift in response to environmental, health and natural resource concerns. However, the fuel mix for global electricity generation in 2008 was not dissimilar to that in 1990, with a slight decrease in the share of hydroelectricity and nuclear power being offset by an increase in the share of thermal and, to a lesser extent, renewable generation from non-hydroelectric sources.[1] On an absolute basis, there has been significant growth in generation from non-hydro renewable energy sources, from 124 terawatt-hours in 1990 to 535 terawatt-hours in 2008, but these still accounted for less than 2 per cent of global electricity generation.

The extent to which governments support each of these electricity generation technologies is generally not apparent, though claims abound that each source benefits from subsidies to the detriment of others. While the literature on energy subsidies is considerable and growing, only a fraction of this literature focuses on subsidies to electricity generation, and only a small subset attempts to quantify the level of these subsidies. This report:

- reviews the information currently available for each fuel type,
- describes the principal methods for quantifying subsidies,
- identifies the major gaps in the literature, and
- makes a preliminary comparison of results.

It is in no way a complete assessment of subsidies to electricity generation: this would require an extensive research program, drawing upon expertise on the subject and on the countries examined. Rather, it is an attempt to summarize the state of knowledge, highlighting the information that exists and what this information can tell us.

The analysis aims to cover only the support received by electricity generators and end-users—it does not include subsidies to producers of fossil fuels, nor those to electricity consumers. However, the studies reviewed do not always specify the exact scope of their work, making it difficult to be precise as to what is included and excluded. This lack of transparency characterises the subject in general, and the following should be read with this in mind. See Box 1 for further discussion.

All exchange rates are converted based on average rates for the year(s) under consideration.

This report is one of a pair, the other being ***Subsidies to Liquid Transport Fuels: A comparative review of estimates***.

BOX 1: IDENTIFYING SUBSIDIES FOR ELECTRICITY GENERATION BY ENERGY SOURCE

One of the factors complicating an analysis of subsidies to electricity generation is distinguishing those subsidies that apply to electricity generation from all sources and those that apply to electricity generation from a particular source. Generally, it is easier to draw this distinction for subsidies that support generation than it is for subsidies that support consumption. For example, it is clear that in subsidizing the price at which coal is sold to electricity generators, a government is subsidizing generation from fossil fuels. By contrast, subsidies arising from poor bill-collection rates, excessive losses due to inefficient operations or theft from the networks will apply to all generation. This distinction is not always made in studies that assess subsidy levels, which may inject a source of bias in the estimates presented.

[1] Data from the Energy Information Administration show that the percentages in 1990 (2008) were 63 per cent (67 per cent) conventional thermal, 19 per cent (16 per cent) hydroelectric, 17 per cent (14 per cent) nuclear power and 1 per cent (3 per cent) renewable.

2. *Subsidies to Electricity Generation: Background*

a. Defining Subsidies

Defining subsidies is often considered to be a complicated and controversial issue. In practice, many of the issues revolve around how a subsidy is evaluated—whether it is "good" or "bad"—rather than how it is defined.

This report employs the definition used by the Global Subsidies Initiative (GSI), who define a subsidy as any form of preferred treatment granted to consumers or producers by a government. The definition is based on the World Trade Organization's Agreement on Subsidies and Countervailing Measures, agreed by 153 Member states, and tried and tested through a rigorous negotiating process and legal analysis and jurisprudence by the Dispute Settlement Body and Appellate Body. A full definition, extracted from GSI (2010) is given in Box 2.

This definition of subsidies captures transfers from government. However, other forms of support also exist which involve transfers from either fossil fuel producers or consumers to electricity generators. Notably, this category would include Renewable Portfolio Standards—which require electricity suppliers to source a certain proportion of their electricity from renewable energy sources, with the costs of doing so generally passed onto consumers. Such support measures are included in within the GSI's definition of a subsidy under the "income or price support category," since a government has mandated a course of action which has led to a transfer which would not otherwise have occurred.

Further, the definition does not include the externalities associated with electricity generation—the additional costs to the environment and to society that are not captured in the market price of electricity. Some analysts (e.g. Koplow, 2010) consider that the incomplete capture of these costs does constitute a subsidy. However, the methodological difficulties and uncertainties, particularly in relation to climate-related damages, mean that estimates of externalities range widely. For this reason, among others, we treat estimates of external costs separately. A comprehensive review of the literature on externalities is beyond the scope of the paper, but the results from key studies are highlighted. This paper focuses on outputs of the EU ExternE Project, which assesses external costs based on the full life cycle of generating facilities (ExternE, 2003).

BOX 2: SUBSIDY DEFINITION (ADAPTED FROM (GSI, 2010))

The Global Subsidies Initiative adopts a three-step approach to: *define, measure and evaluate* subsidies (GSI, 2010). This approach starts with a broad definition of "subsidy" with the purpose of identifying all existing subsidies in a sector, whether those subsidies are subsequently considered "good" or "bad." This provides a comprehensive starting point for the analysis to follow. Therefore, it should not be assumed, that because a subsidy is identified at the beginning of a process that it is necessarily in need of reform.

The GSI uses a definition of "subsidy" based on the World Trade Organization's (WTO) Agreement on Subsidies and Countervailing Measures (ASCM). Under Article 1: Definition of a Subsidy, the ASCM determines that four types of subsidies exist, where:

- Government provides direct transfer of funds or potential direct transfer of funds or liabilities,
- Revenue is foregone or not collected,
- Government provides goods or services or purchases goods,
- Government provides income or price support.

The ASCM also requires that a subsidy be specific to an enterprise, industry, or group of enterprises or industries under Article 2. So although in some cases government support is offered to more than one sector, it can still be considered a subsidy—if, for example, it is offered only to the oil, gas and mining sectors, or if one sector disproportionately benefits from the support.

Based on the ACSM list above, GSI has developed subcategories of subsidies that form the framework identifying subsidies. This forms a comprehensive framework for identifying and analysing subsidies in any country. The analysis in this report is based on this framework.

b. Objectives for Subsidies

To assess the relative appropriateness and effectiveness of subsidies to electricity generation, it is important to consider the objectives for the policy. While there are some objectives that are universally cited, they tend to vary by country and by generation source in line with domestic circumstance and the specific characteristics of each generation type. Table 2.1 outlines frequently stated rationale for subsidies.

TABLE 2.1: OBJECTIVES FOR SUBSIDIES BY GENERATION TYPE

Generation Type	Objectives of Subsidies
Renewable	• Environmental improvement (reductions in CO_2 and local pollution) • Boost the national economy and create jobs in high technology and growth industries • Improve energy security through diversification and reduced dependence on imports • Widen access to energy and realize related social benefits, particularly in rural areas • Stimulate cost reductions in renewable energy technologies
Fossil Fuel	• Welfare improvements through lower costs to consumers • Widen access to energy and realize related social benefits, particularly in rural areas • Subsidies for switching across fossil fuels (e.g. from coal to gas) • Development of local fossil-fuel sources (particularly otherwise stranded assets) • Stimulate national economy (or segments thereof) through lower costs to business
Nuclear Energy	• Reduce CO_2 emissions from combustion of fossil-fuel emissions • Support the creation of a strong nuclear industry and viable nuclear fuel cycle • Improve energy security through diversification and reduced dependence on imports
Any or All Types	• Stimulate and support economic growth • Meet growing consumer and industry demand • Generate employment and social benefits

Besides these overall objectives, certain subsidies are targeted at specific characteristics of each generation type. One example is subsidies to maintain or compensate the health of employees exposed to the nuclear fuel cycle (U.S. DOJ, 2011).

c. Subsidy Types

A range of approaches is used for classifying subsidies (GSI, 2010). It is important to bear in mind these differences since a study using one classification will pick up on a different set of measures than a second study using a different classification, making comparison across studies problematic and often inexact.

Table 2.2, based on GSI (2010b), summarizes types of subsidies that are commonly applied to electricity generation: this highlights the main policies but should not be considered exhaustive. Table 2.3 extends the analysis by giving examples of policies that apply to particular generation types and countries that have introduced these policies; again, this is provided by way of illustration and is not exhaustive.

d. Measurement of Subsidies

There are three common approaches to measuring subsidies:

i. The **price gap approach** measures the difference in observed price for electricity versus a free market reference price. It will pick up the combined effect of policies that result in a price change, but will not enable disaggregation of these policies or capture policies that do not change price. In particular, subsidies to generators will only be captured to the extent that these are reflected in the price to consumers. Note also that in the case of electricity the reference price has to be calculated based on assumptions regarding the cost of domestic supply by an efficient producer; this introduces another source of uncertainty and potential inconsistency into estimates. For further discussion of the difficulties associated with the price gap approach see Section 2.2 of IEA, OPEC, OECD, World Bank (2010).

ii. The **transfer measurement approach** relies on a bottom-up assessment to quantify the subsidy associated with a given program, regardless of whether this has an effect on end price. Whilst this enables quantification of any particular measure, the data requirements are substantial and studies tend to focus on a particular intervention. For further information see Koplow (2009) and World Bank (2010).

iii. The **integrated approach**, the main example of which is the Producer Support Estimate and Consumer Support Estimate (PSE-CSE) framework applied in particular by the OECD. This combines direct financial transfers (including those benefiting producers through government assumption of risk) as well as transfers generated between producers and consumers and vice versa as a result of government policies. The Effective Rate of Assistance (ERA) builds on the same information required to construct a PSE, but expresses the resulting transfers (adjusted for policies, such as import tariffs, that raise an industry's input costs), in terms of the industry's value added.

In addition to methodological problems, studies tend to be limited by a lack of data availability, poor quality data and a lack of comparability among data sources (Ellis, 2010). In particular, while point-in-time estimates are more widely available, these are not necessarily representative of subsidies over time. Price support provided to new technologies may initially be set at a high level so as to encourage deployment, but could be expected to fall over the longer term as the technology matures and penetration increases. Alternatively, where subsidy mechanisms are not adjusted in line with changes in the price of energy inputs, price volatility can lead to rises and falls in subsidy spending. Finally, analysts do not always make clear which subsidy types their study captures and which it omits, making assessment and comparison across studies difficult.

TABLE 2.2 TYPES OF SUBSIDIES TO ELECTRICITY GENERATION

	Direct and Indirect Transfer of Funds and Liabilities	Government Revenue Foregone	Provision of Goods or Services	Income or Price Support
R&D	• R&D grants • Government loans and guarantees	• Tax incentives for private R&D	• Information provision • Government provided R&D facilities • Technical Assistance	
Investment	• Government loans and guarantees • Public funding for construction • Capital grants • Export Credit Support • Stranded asset charges • Subsidized liabilities • (Perceived) government backed contracts	• Investment tax credits • Tax exemptions and reductions • Import duty reductions • Accelerated depreciation • Property tax abatements	• Regulatory Support (eg Planning Process) • Royalty Relief	• Lower grid connection charges for generators • Priority access to infrastructure
Generation	• Tolerance of excessive technical losses	• Production tax credits	• Grid investment and provision • Subsidized use of cooling water	• Subsidised inputs to generation • Feed-in tariffs and premiums • Energy Production Payments • Low tariffs on production services
Consumption	• Under-collection of bills • Tolerance of theft	• Tax exemptions (e.g. low rated VAT)		• Reduced charges to end users • Long term favorable PPAs • Consumption Mandates • Renewable Portfolio Standards • Below-cost grid connection charges to consumers
Decommissioning	• Nationalized waste management responsibility • (Perceived) government backed contracts • Decommissioning shortfalls	• Tax breaks	• Use of government owned infrastructure	
Throughout	• Insufficient bonding of environmental costs, cap on accident liability, health payments, worker training support	• Funding of international conventions	• Unfunded regulatory oversight	• Weak security standards

TABLE 2.3 EXAMPLES OF SUBSIDIES TO ELECTRICITY GENERATION

	Direct and Indirect Transfer of Funds and Liabilities	Government Revenue Foregone	Provision of Goods or Services	Income or Price Support
R&D	• Renewable: Grants for Marine R&D (New Zealand) • Renewable: Loan guarantees for new technology research (U.S.) • Fossils: Funding for Clean Coal R&D (Australia) • Nuclear: Funding for R&D (France)	• Renewable: Deduction of expenses for income tax (China) • Renewable: Tax deductions for R&D (Australia)	• Nuclear:funding for national laboratories (U.S.) • Renewable: Promotion of domestic industry (Germany) • Renewable: Funding of research institues (Australia)	
Investment	• Renewable: Reduced rates of interest on loans (Germany, India) • Fossil: Low interest loan for power plant build (Indonesia) • Fossil: Guarantees for raising construction capital (South Africa) • Fossil: Govt funding for new investment (South Africa) • Nuclear: Subsidized liabilities (U.K.)	• Nuclear: Accelerated depreciation (U.S.) • Nuclear: Property tax abatements (U.S.) • Renewable: Invetsment tax credits (U.S.) • Renewable: Reduced rate import duty for solar components (India) • Renewable: Tax credit for Solar PV (Sweden)	• Renewable: Exemption from planning requirements (France)	• Renewable: Priority access to grid (Czech Republic) • Renewable: Obligatory connection to grid (Bulgaria) • Renewable: Refund of grid connection costs (Poland)
Generation	• All: Losses in generation, transmission and distribution (Cuba)	• Nuclear: Production tax credit (U.S.)	• All: Provision of grid infrastructure and service below cost • Renewable: Grid strengthening • Nuclear: underpriced cooling water (USA) • Nuclear: subsidized heavy water (India)	• Fossil: Gas provided to generators below cost (Iran) • Fossil: Income support to gas generation (Australia) • Renewable: Feed in tariffs for production (Germany)
Consumption	• All: Absence of penalties for non-payment of bills • All: Theft from network (Dominican Republic)	• All: VAT reductions for electricity sales • Renewable: Reduced VAT on wind power (China)		• All: Below cost provision to end users (Iran, Bangladesh) • Renewable : Portfolio Standards (U.K., Chile, Italy) • Renewable: Obligatory long term PPAs (France)
Decommissioning	• Nuclear: subsidised waste management facilities (South Korea)	• Nuclear: Decomissioning funds tax exempt (Japan)		
Throughout	• Nuclear: public funds for education (U.K.) • Fossil: subsidies for health programs • Nuclear: cap onaccident liabilities	• Renewable: Payroll subsidy for investors (Greece)	• Fossil: Oversight of new power stations (China)	

3. Subsidies to Renewable Sources of Electricity Generation

a. Subsidy Types and Incidence

Any one country is likely to apply a variety of subsidies during any given period, with the combination varying in line with specific objectives for renewable generation technologies and perceived advantages of each instrument in meeting these objectives. A survey of common policy types by REN21 (2010) shows that, of 85 countries adopting some kind of support measure for renewable energy in 2009, over half offered feed-in tariffs, over half tax incentives, and over half capital subsidies.

b. Quantification of Subsidy Levels

The following section reviews the existing literature that quantifies subsidies to renewable energy based electricity generation, focusing on studies covering more than one country. Table 3.1 summarises results, with estimates presented on the basis of US cents/kilowatt-hour (kWh) of electricity generated. This generally involves manipulating the data reported in the studies, and the basis for these manipulations is described in the notes to the table. The estimates presented are not directly comparable due to a range of factors, including differences in subsidies included, the estimation method used, the geographical scope, and the time period under consideration. The inclusion or otherwise of hydropower in renewable generation has a significant effect on the per unit values—it is often excluded from analyses on the basis that it is a mature technology and support levels are generally likely to be low. The notes to table 3.1 indicate where hydroelectric power is included in estimates.

TABLE 3.1: SUMMARY OF RESULTS FROM STUDIES OF RENEWABLE SUBSIDIES

All currencies are converted based on year under consideration. Generation data are from the EIA

Category	Specific Type	Author	Fuel & Country Scope	Period	$ bn	US c/ kWh	Notes
Financial	Direct Price Support	IEA	Global, non-hydro renewables	2008	26.6	4.7	(1)
	Direct Price Support	CEER	All Renewables, EU (16 states)	2009	26.5	5.2-10.9	(2)
	Direct Price Support	EURElectric	All Renewables, EU 15	2001	3	3.3	(3)
	On and off budget support	EEA	All Renewables, EU	2001	4.8	5.6	(4)
	Direct Price Support & tax incentive	Babcock & Menzen	Wind, Global	1975-2007	65	8.8	(5)
	"Material" Financial Subsidies	Vivid Economics	Japan	2009	0.6-0.7	2.3-2.8	(6)
			South Korea	2009	0.26-0.32	12.3-14.8	(6)
			Australia	2009	0.3-0.5	5.9-8.9	(6)
			China	2009	1.7-2.1	6-7.6	(6)
			U.K.	2009	1.4-1.5	6.9-7.3	(6)
			Germany	2009	7.9-9.9	9.8-12.3	(6)
			U.S.	2009	2.7-3.1	1.7-2.1	(7)
R&D	National Government Expenditure	IEA / BNEF	Global, excluding hydro > 50 MW	2009	c. 2.1	0.1-0.6	(8)
	National Government Expenditure	UNEP / SEFI	Global, excluding large hydro	2010	c. 3.3	0.1-0.4	(9)
	IEA Member Goverment Expenditure	IEA Database	IEA Members	1974-2007	22.8	0-0.5	(10)
	National Government Expenditure	Babcock & Menzen	Global	1974-2007	25.6	0-0.5	(11)
Externalities	Health, envt, & climate change	ExternE	EU-15	2001	3.7-4.0	0.4-0.44	(12)
		EEA	EU-15	2001	1.8-2.4	0.3-0.4	(13)
		Owen	EU-15	2004	3.0	0.5	(14)
		Babcock & Menzen	Global Generation	2007, 2008	1.3-10.4	0.2-3.2	(15)

Notes: 1. Based on 2008 global generation from non-hydro renewable sources; 2. Range reflects inclusion / exclusion of hydro power. Based on 2009 generation; 3. Based on 2001 generation from non-hydro renewables; 4. Based on 2001 generation from non-hydro renewables, will capture some R&D expenditure; 5. Based on wind generation over period; 6. Exact subsidies captured vary across countries. Estimates based on 2009 generation excluding hydro; 7. Only captures material interventions at federal level and California at state level; 8. Based on investment data for 2009 and generation data for 2008. Range reflects inclusion / exclusion of hydro generation from per unit estimates; 9. Based on investment data for 2010 and generation data for 2008. Range reflects inclusion / exclusion of hydro generation from per unit estimates; 10. Based on investment data for and generation data for 1974-2007. Range reflects inclusion / exclusion of hydro generation from per unit estimates; 11. Based on investment data for and generation data for 1974-2007. Range reflects inclusion / exclusion of hydro generation from per unit estimates; 12. Based on estimated ranges for each country, weighted by generation in 2007; 14. Based on lower bound for each technology, weighted by generation in 2007; 15. Based on estimates of 2008 total cost, divided by generation, and calculation of weighted average. Range reflects significant uncertainty in costs for biomass, and to a lesser extent, wind.

Financial transfers: This category covers all forms of financial support to electricity generation. While further disaggregation would be ideal, the structure of studies and their results limit the extent to which this can be achieved on any meaningful basis. Studies generally focus on direct price or income support to generators and, less frequently, on tax and capital incentives. The other subsidies highlighted in Table 2.2 are generally not assessed quantitatively, although some studies at a country level may do so.

On a global basis, the IEA (2010) quantifies the price support for renewable energy by comparing the premium paid to electricity from renewable energy sources to a reference electricity price, and estimates a total subsidy to non-hydroelectric sources of US$27 billion in 2008. This excludes potential sources of subsidies such as funding for R&D, capital grants, lending-based support mechanisms, and tax incentives. Badcock & Lenzen (2010) estimate direct subsidies and favourable tax treatment for each group of renewable technologies over different time periods, highlighting the variations that arise upon using a different study scope.

For the EU, a range of estimates exists for different subsidies and for different time periods. The Council of European Energy Regulators (CEER, 2011) assesses direct price support provided by 16 member countries in 2009 through feed-in tariffs, premium and green certificates, and estimate a total support level of €19 billion (US$27 billion). Using 2001 data, the EEA (2004) assesses on and off budget subsidies in the EU-15, and estimates a minimum total support level of €5.3 billion (US$4.8 billion), although the exact support measures considered are not explicitly stated. Eurelectric (2004) focuses on direct support in the EU-15, estimating a total support level of €3.3 billion (US$3.1 billion).

Studies of individual countries, while not necessarily applicable beyond these countries, can be useful as a supplement to broader studies and also in building up an analysis of the country in question. For example, Marsh & Miers (2011) quantify support provided in the U.K. in the form of direct price support, grants, and exemption from taxes. ECOFYS (2011) review direct price support schemes, investment and production tax incentives and low interest loans in Spain, Germany and the U.K. The Productivity Commission (2011) conducted detailed reviews of subsidy schemes in a number of countries in the year 2009. These surveys attempted to capture all financial subsidies considered material and for which data were available, but they are still likely to exclude some subsidies, particularly at the sub-national level. These analyses suggest a wide range in the level of support provided across countries from a low-end estimate of 1.7 US cents/kWh through to 14.8 US cents/kWh. Results for Germany and the U.K. are broadly similar to those reported by ECOFYS (2011) and Marsh & Miers (2011).

Financial subsidies to renewable energy-based electricity will vary across generation type, with less mature technologies generally receiving higher subsidies per megawatt-hour generated. As an example, the U.K. Renewables Obligation (a renewables portfolio standard) assigns greater value to 1 megawatt-hour of electricity generated by solar PV than to 1 megawatt-hour of electricity generated by onshore wind turbines (Ofgem, 2011).[2] Similarly, tax incentives and other forms of financial support are often differentiated by technology (KPMG, 2010). Box 3 gives further information.

In addition to the funding provided by national governments, international and national development banks are also sources of financing for emerging countries: Bloomberg New Energy Finance (BNEF, 2010) estimates the support provided by these institutions in 2009 to have been US$21.1 billion. At the other end of the scale, many local governments also offer incentives which are not necessarily captured by the studies outlined (REN21, 2011).

[2] The Renewables Obligation is based on awarding certificates to renewable generation, which can then be sold to electricity suppliers who are obligated to source a certain proportion of generation from renewable energy. Solar PV is currently awarded two certificates per megawatt-hour of generation; onshore wind is awarded one certificate.

BOX 3: SUBSIDIES TO DIFFERENT TYPES OF RENEWABLE-ENERGY-BASED ELECTRICITY GENERATION

The term renewable-energy-based electricity generation encompasses a wide range of technologies at different levels of maturity and with different characteristics. The subsidies provided to each of these generation types vary correspondingly. Badcock & Lenzen (2010) estimate direct financial subsidies, tax incentives, R&D expenditure and externalized costs associated with each generation type. For 2007, they estimate a global total subsidy of around 7 US cents/kWh for wind power, 64 US cents/kWh for solar PV power, 2.9 US cents/kWh for concentrated solar power, 1.4/kWh for geothermal power, 6.7-10.7 US cents/kWh for biomass and 0.1 US cents/kWh or hydroelectric power. It is important that the differences in renewable generation types and subsidies are recognised when defining, measuring and evaluating subsidies.

R&D: Using BNEF data, the IEA (2010) estimates global R&D spending on all renewable-energy technologies, excluding biofuels, to have been US$4.7 billion in 2009, of which US$2.1 billion is accounted for by government spending. This is supported by data presented in a UNEP (2011) study. However, neither of these studies allocated R&D by end-use, so not all of these totals were necessarily related to electricity generation. Estimates can be derived from the IEA database on Energy R&D, but country coverage is limited and attribution to end-use is not possible. A rough estimate of subsidies to renewable technologies would be in the region of US$22.8 billion over the period 1974–2007. A similar estimate for the same period is derived by Badcock & Lenzen (2010). Comparing the estimates for a point in time against those for a multi-year period highlights the sensitivity of results to the period in question, and reflects the increase in public R&D for renewable energy over time.[3]

External Costs: The ExternE Project quantified externalized costs for each renewable-electricity generation type in each of the EU-15 member states (ExternE, 2003). Much of the subsequent work on externalities has been based on the data and approach developed by this project. Studies therefore report similar results: examples include Owen (2006) and the EEA (2006) for the EU, and Badcock & Lenzen (2010) on a global basis. Other studies of individual countries and generation types also consider externalized costs, and while exact estimates vary, the general conclusion is that those associated with renewable generation vary from technology to technology, with hydro and biomass typically being associated with higher costs than other technologies.[4]

[3] For further description of R&D policies in OECD countries and Brazil, India and China see IEA (2008)
[4] See ATSE (2009) for Australia, and National Research Council (2009) for the United States

4. Subsidies to Fossil Fuel Electricity Generation

Analyzing subsidies to fossil fuels for electricity generation is complicated by a number of factors. First governments may provide subsidies all along the value chain: to the fuels themselves, to the power plants, and for the consumption of electricity. Second, fossil fuels have a wide variety of end uses, notably for transport and heating, that may attract subsidies; this distinction is not always drawn in the available data. For example, the EEA (2004) estimate that on-budget and off-budget subsidies to fossil fuels in 2001, but do not disaggregate this estimate by end-use[5]. Finally, where subsidies to electricity generation are explicitly assessed, the numbers often refer to all sources of electricity generation and not just fossil fuels (see Box 1).

a. Subsidy Types & Incidence

A distinction can be drawn between those subsidies that support consumption and those that support generation of electricity. It is generally supposed that the former are more common in developing countries and are implemented with the aim of alleviating energy poverty and subsidizing industry (De Moor, 2001). This is reflected in the IEA (2010) review of subsidies to electricity generation from fossil fuels, which presents data on consumer subsidies in 25 countries, stating that "almost all ... were found in non-OECD countries". Beyond this survey, there is a considerable literature on consumer subsidies in the energy sector—see GSI (2010)—but few studies that explicitly consider electricity generation.

b. Quantification of Subsidies

Table 4.1 summarizes results from the studies, presenting estimates on a US cents/kWh of electricity generated basis. This generally involves manipulating the data reported, and the basis for these manipulations is described in the notes to the table.

[5] On-budget defined as transfers that appear on national balance sheets as government expenditure, off-budget defined as transfers which do not appear in the national accounts as government expenditure (EEA, 2004).

TABLE 4.1: SUMMARY OF RESULTS

All currencies are converted based on year under consideration. Generation data are from the EIA

Category	Specific Type	Author	Fuel & Country Scope	Period	$ bn	US c/ kWh	Notes
Financial	All subsidies captured through price gap	IEA	Global Fossil fuel generation	2009	95	0.74	(1)
	Subsidies to electricity end users (EU)	EEA	Electrical power in the EU	2001	5.5	0.3	(2)
	Direct subsidies and tax incentives	Badcock & Menzen	Global Coal Generation	1974-2007	536	0.3	(3)
	Input price, tax incentives	Reidy	Electrical power in Australia	2006	0.5-1	0.3-0.6	(4)
	Direct subsidies, tax, and federal support	EIA	U.S. Fossil Fuel Generation	2007	2.7	0.1	(5)
R&D	National Government Expenditure	Badcock & Menzen	Global Coal Generation	1974-2007	32.6	0.02	(6)
	IEA Member Goverment Expenditure	IEA Database	Fossil Fuel Combustion & network	2007	0.4	0.01	(7)
	IEA Member Goverment Expenditure	IEA Database	Fossil Fuel Combustion & network	1990-2007	16.5	0.02	(8)
	Federal Government Expenditure	EIA	U.S. Fossil Fuel Generation	2007	0.6	0.02	(9)
Externalities	External Costs	ExternE	Weighted Average of Coal, Oil, Gas in EU	2001	33-59	2.2-3.9	(10)
	External Costs	Owen	Weighted Average of Coal, Oil, Gas in EU	2004	48	3.2	(11)
	External Costs	EEA	Solid Fuels in the EU-15	2001	23-42	3.3-5.9	(12)
	External Costs	EEA	Oil and Gas in the EU-15	2001	11-20	1.3-2.4	(13)
	External Costs	Badcock & Menzen	Global Coal	2007	227-1890	2.9-23.8	(14)
	External Costs	ATSE	Brown coal generation in Australia	NA	NA	4.3	(15)
	External Costs	ATSE	Gas Generation in Australia	NA	NA	1.6	(15)
	External Costs	NRC	Coal generation in the U.S.	2005	89-280	4.2-13.2	(16)
	External Costs	NRC	Gas Generation in the U.S.	2005	6-47	0.7-5.2	(16)

Notes: 1. Range reflects low and high estimates for investor and publicly owned utilities; 2. Range reflects low and high estimates for investor and publicly owned utilities; 3. Based on 2001 generation. Captures some element of R&D; 4. Per unit data omitted due to lack of information on generation over this period; 5. Based on global nuclear generation in 2008; 6. Based on global nuclear generation in 2008; 7. Per unit data omitted due to lack of information on generation over this period; 8. Based on U.S. nuclear generation over this period; 9. Based on U.S. nuclear generation in 2007; 10. Based on French nuclear generation in 2009; 11. Based on high and low estimates per unit across the EU, multiplied by generation in 2007; 12. Based on generation in 2007; 13. Based on representative value for efficient technology, multiplied by generation in 2007; 14. Per unit figures based on generation in 2007; 15. Per unit data omitted due to lack of information on generation over this period.

Financial Subsidies: In reviewing studies, it is useful to draw a distinction between those that adopt the price gap approach and those that are based on the transfer measurement approach, since each will capture different types of subsidies.

The IEA (2010) uses the **price gap approach** to assess the level of subsidies to fossil-fuel based electricity generation, estimating the level of support at US$95 billion in 2009. This estimate will pick up any subsidies that are captured in end-user price. Most notable amongst these are the provision of fossil fuels as inputs to electricity generation below actual cost. It does, however, underestimate any subsidies that do not have an effect on final price, such as lending-based support mechanisms, grants and R&D support to generators, and should therefore be considered a lower-end estimate. As discussed above, the IEA survey focuses on non-OECD countries and therefore excludes subsidies to certain sectors of the population and certain industries in OECD countries.

A number of country-level studies use the **transfer measurement** approach to estimate subsidies, but the coverage and currency vary, making comparisons difficult.[6] For example, the EEA (2004) estimates consumption subsidies to electricity generation for the EU–15 in 2001, but this number includes all electricity sources rather than just fossil fuels. The EIA (2008) reviewed subsidies to electricity production from fossil fuels in the United States, estimating that total subsidy in 2007 was in the region of US$2.7 billion, not counting government expenditure on R&D.[7] For Australia, Reidy (2007) estimates the value of input price support and tax incentives to coal-fired generation of up to A$1.3 billion (US$1 billion) and subsidised supply of electricity to aluminium smelters and vulnerable sections of the population of up to A$0.7 billion (US$0.5 billion) in 2006.[8] A number of studies by the IMF also identify specific subsidies in certain countries which give further details for the country in question (for example IMF (2008) on Iran and Tieman (2011) on Macedonia).

R&D: Existing studies suggest that current levels of R&D support for fossil-fuel generation are low, reflecting the maturity of the technologies. Badcock & Lenzen (2010) estimate global R&D for coal-fired generation at US$32.6 billion over the period 1974–2007. Based on IEA data for member countries only, 2007 R&D expenditure equaled US$173 million when including expenditure on fossil fuel combustion only, and approximately US$430 million when conversion, transmission and distribution technologies are included. R&D on so-called clean coal technologies could result in an increase in these levels in the coming years, reflecting the fact that subsidy levels change over time.

External Costs: The results from studies assessing externalities associated with fossil-fuel-based generation vary widely depending on the estimation methodology used and the values assumed. These variations result in widely varying costs, but studies generally conclude that externalities associated with fossil-fuel-based electricity generation are much larger than subsidies (see Boyle, Everett, & Ramage (2003) for an overview of studies and further discussion). The ExternE (2003) project estimated values for externalities associated with a range of fossil-fuel technologies in each EU Member State. When allocated in line with 2007 electricity generation in the EU, this suggests externalized costs, including climate related damages, in the range of €29 billion–€52 billion (US$28 billion–US$47 billion) for fossil-fuel technologies.[9]

External costs associated with each fossil fuel vary considerably, with the level of support to coal-fired generation being up to five times that for gas-fired generation and four times that for coal-fired generation. Different levels of support by fossil fuel source were also highlighted in EEA (2004) where the subsidy to solid fuel electricity generation was estimated at up to three times that liquid and gas fired generation on a per kWh basis. In a subsequent update, a value of €19–€80/tonne CO_2 was estimated for climate-related damages, leading to considerable range in estimated externalities (EEA, 2008). A number of country level studies also consider externalities; these are likely to better reflect local impacts in those countries—see ATSE (2009) for Australia and National Research Council (2009) for the United States.

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[6] The OECD (1997) reports the findings of a series of case studies, but these are generally based on research in the early 1990s.

[7] The study is generally considered to underestimate subsidies due to exclusions and methodology applied (see Koplow, 2009).

[8] In the Reidy study, the subsidised supply of electricity to end users refers to electricity generation in general rather than to coal-fired electricity generation specifically.

[9] Climate related damages are estimated at €19/tonne CO2 equivalent which is generally considered to be a low-end estimate. See EEA (2008).

5. Subsidies to Nuclear Electricity Generation

a. Subsidy types and incidence

Koplow (2011) identifies subsidies at all stages of the nuclear fuel cycle, drawing distinctions between legacy subsidies (subsidies that no longer affect market economics but did so in the past), current subsidies to existing reactors, and subsidies to new reactors, and between subsidies to publicly and privately owned utilities. The most important subsidy types are aimed at reducing the cost of capital. This has been a crucial factor in nuclear-power economics since about 70 per cent of levelized generating costs relate to investment (Linares & Conchado, 2009). In addition, a range of subsidies can be found across the nuclear fuel cycle, adding up to significant governmental support next to construction or output related subsidies.

b. Quantification of subsidy levels

Apart from expenditure on R&D, there is very little information on types and levels of subsidies to nuclear generation. The following table briefly highlights studies that attempt a broad analysis of subsidies across countries, with the results presented in Table 5.1. More detailed analyses are conducted for three countries where information is available, namely the United States, the U.K. and France. In particular, the United States case study indicates that most estimates in larger studies are rather conservative and leave out potentially important support. In most other countries—including those such as Russia, China, South Korea and India which are investing heavily in nuclear energy—reporting of support mechanisms is still minimal (IAEA, 2011).[10]

[10]China has 11.1 gigawatts installed with 27.2 gigawatts underway, Russia has 22.7 gigawatts with 9.2 gigawatts foreseen, the Republic of Korea has 18.7 gigawatts installed with 5.6 gigawatts planned and India currently operates 4.4 gigawatts with 3.6 gigawatts to be added. These four countries account for the majority of forthcoming capacity.

TABLE 5.1: SUMMARY OF RESULTS

All currencies are converted based on year under consideration. Generation data are from the EIA

Category	Specific Type	Author	Fuel & Country Scope	Period	$ bn	US c/ kWh	Notes
Financial	Direct Price Support	Koplow	Existing Reactors, US	NA	NA	0.7-5.7	(1)
	Direct Price Support	Koplow	New Reactors, U.S.	NA	NA	4.2-11.4	(2)
	On and off budget support	EEA	Nuclear, EU-15	2001	2.0	0.2	(3)
	Direct Price Support & tax incentive	Badcock & Menzen	Nuclear, Global	1960-2007	324	NA	(4)
R&D	National Government Expenditure	IEA	Nuclear Fission	2008	5.5	0.2	(5)
	National Government Expenditure	WNA	Nuclear Fission	2005	c. 3	0.1	(6)
	National Government Expenditure	Badcock & Menzen	Global	1960-2007	178	NA	(7)
	US Government Expenditure	EIA	U.S.	1988-2007	13.5	0.1	(8)
	US Government Expenditure	EIA	U.S.	2007	0.9	0.1	(9)
	France Government Expenditure	IEA	France	2009	0.7	0.2	(10)
Externalities	Health, envt, & climate change	ExternE	EU-15	2001	1.5-5.1	0.2-0.6	(11)
		EEA	EU-15	2001	2.5	0.3	(12)
		Owen	EU-15	2001	2.2	0.3	(13)
		Badcock & Menzen	Global Generation	2007	11-31	0.4-1.2	(14)
		Badcock & Menzen	Global Generation	1960-2007	250-741	NA	(15)

Notes: 1. Range reflects low and high estimates for investor and publicly owned utilities; 2. Range reflects low and high estimates for investor and publicly owned utilities; 3. Based on 2001 generation. Captures some element of R&D; 4. Per unit data omitted due to lack of information on generation over this period; 5. Based on global nuclear generation in 2008; 6. Based on global nuclear generation in 2008; 7. Per unit data omitted due to lack of information on generation over this period; 8. Based on U.S. nuclear generation over this period; 9. Based on U.S. nuclear generation in 2007; 10. Based on French nuclear generation in 2009; 11. Based on high and low estimates per unit across the EU, multiplied by generation in 2007; 12. Based on generation in 2007; 13. Based on representative value for efficient technology, multiplied by generation in 2007; 14. Per unit figures based on generation in 2007; 15. Per unit data omitted due to lack of information on generation over this period.

Financial Subsidies: The EEA (2004) estimates both on-budget and off-budget subsidies in 2001 at €2.2 billion (US$2 billion), excluding liability insurance. Of this, €1.2 billion (US$1.1 billion) is classified as on-budget, with R&D accounting for the majority. In a global review, Badcock & Lenzen (2010) estimate that direct financial subsidy and tax incentives over the period 1960-2007 equalled US$324 billion, but note that subsidies were particularly high (in excess of US cent 10/kWh) in the early stages of industry development.

R&D: World Nuclear Association (2011) estimates that globally a little over US$3 billion was spent on fission R&D in 2005. The IEA estimated this number to be about US$5.5 billion in 2008 with US$4.5 billion in selected G-20 countries. Based on IEA data, Badcock & Lenzen (2010) estimate global R&D for nuclear at US$178 billion between 1960 and 2007. Country-level surveys suggest that in the United States, US$13.5 billion was spent on R&D between 1988 and 2007, with US$0.9 billion in 2007 (Energy Information Administration, 2008). In 2009, France spent 56 per cent of its energy R&D funding (or $0.7 billion) on nuclear energy (IEA, 2010).

External Costs: A brief survey of the extensive literature on this topic shows that analysis of externalities to nuclear energy is complicated by the difficulties of estimating potential costs associated with long-term exposure to radiation, and the costs of low probability but high impact events such as nuclear accidents (see EEA, 2005). This means that while costs of an accident can be significant, the low statistical probability of such an accident occurring translates into a lower cost estimate. However, as context, the Japanese Centre for Economic Research estimated the costs associated with liabilities following the Fukushima accident at US$246 billion (Koplow D. , Earthtrack, 2011).

The ExternE project assesses externalities at between 0.3 and 1.1 US cents per kWh in 2001 (ExternE, 2003). Based on these results, the EEA (2004) estimates externalized costs of nuclear generation in the EU–15 at €2.7 billion (US$3.1 billion). Finally, Badcock & Lenzen (2010) estimate external costs of up to US$31 billion in 2007 and US$741 billion over the period 1960–2007, with the range reflecting uncertainty in estimating costs.

c. Case Studies on subsidies to Nuclear Generation

For the United States, quantitative estimates of the majority of subsidies to nuclear generation are available. For France and the United Kingdom, the data are less complete, with only some subsidy types assessed. Therefore, subsidies per unit of nuclear power generation are only given for the United States.

United States: Comprehensive research on the quantification of subsidies in the United States has been conducted by Doug Koplow and the Union of Concerned Scientists (UCS). Their research has identified subsidies to the nuclear fuel cycle in excess of the value of energy produced, provided through a range of support mechanisms (Koplow, 2011). Most subsidies go to factors of production, mainly to reducing the cost of capital for investment owned (IOU) and publicly owned (POU) utilities. Koplow (2011) identifies the main specific subsidies to existing reactors as:

- ***Combined legacy subsidies:*** These reduce the cost of capital goods. They include combined legacy tax subsidies, accelerated depreciation, allowance for funds used during construction and investment tax credits. They are estimated to reach a level of 5.9 US cents/kWh.
- ***Stranded asset charges:*** The costs of uneconomic investments were recovered by adding a surcharge to the electricity bills of ratepayers. These legacy subsidies added up to US$110 billion until 1997 (2007), representing a per unit charge of 1.1 US cents/kWh between 1957 and 1997.
- ***Price-Anderson cap on accident liability:*** Because of high levels of uncertainty, the range estimated is rather large. The value of the cap is estimated at between 0.1 US cents/kWh and 2.5 US cents/kWh, equivalent to up to several billion dollars per year.

The Price-Anderson cap on accident liability is expected to continue and therefore also applies to new reactors. Other main subsidies to new reactors are:

- ***Nuclear production tax credit:*** A 1.8 US cents/kWh production tax credit offers payment support in the form of a tax credit on current output. This subsidy is available to investment owned utilities, reaches a level of between US$6–8.6 billion or from 1.1–1.5 US cents/kWh.
- ***Title XVII loan guarantees:*** Also only available to investment-owned utilities, US$18.5 billion of loan guarantees to nuclear reactors has been authorized, with an additional US$4 billion put away for front-end fuel cycle facilities. The subsidy to new reactors can cover up to 100 per cent of the debt and 80 per cent of the total project costs. The estimated per kWh subsidy is from 2.5–3.7 US cents, making this the most important subsidy to new investment owned reactors.

- ***Reduced cost of borrowing:*** This support is available only to publicly owned utilities. It includes financial benefits such as tax-advantage debt or lower requirements of return on high-risk investments than would have been the case in privatized markets. The Congressional Research Service has estimated that the financial benefit itself reduces levelized cost of nuclear electricity by up to 3.1 US cents/kWh.

These main subsidies are complemented by numerous smaller subsidies at each stage of the fuel cycle.

France[11]: Between 1970 and 2000, France built 58 nuclear reactors under its PWR program. This is often referred to as the most successful story of nuclear industrial growth. No raw data on costs were available until 2000 (Grübler, 2009), and the share of government spending on the program is still unclear, as is the current status of nuclear subsidies. Information on costs and subsidies is available from reports of cost-escalation during the recent construction of Olkiluoto 3 in Finland by the French company Areva for the private Finnish utility TVO. The original contract price was €3 billion (US$4.2 billion), and overrun costs are already close to that amount again (Schneider, Thomas, Froggatt, & Koplow, 2009). Loan guarantees were reportedly granted at a low 2.6 per cent interest rate (Schneider, Froggatt, & Thomas, 2011). The project has supposedly received up to one third of contract value in guarantees, with the share of French loan guarantees unclear. Coface, France's export credit institution, also gave a €610 million (US$850 million) export guarantee to cover Areva's supplies for the construction of the plant (Schneider, Thomas, Froggatt, & Koplow, 2009). Assistance by the French state in covering the costs of disputes regarding international contractual obligations may also be possible.

As in other countries, France has a cap on accident liability. While Faure & Fiore (2009) set this at a low level, the efforts of the industry to retain it would suggest a benefit greater than cited levels (Koplow, 2011). Finally, decommissioning liabilities for EDF (85 per cent publicly owned), Areva (87 per cent public ownership) and CEA (a public research body) are estimated by the French Court of Account to be in the region of €65 billion (US$90 billion).

United Kingdom: Subsidies that have previously applied in the U.K. include support provided through redistribution of a fossil-fuel levy charged on thermal generation to Nuclear Electric between 1990 and 1996, representing support of £1 billion (US$1.6 billion) per year (Schneider, Thomas, Froggatt, & Koplow, 2009).[12] A subsidy to operators was also granted at the time of privatisation when British Energy and its eight reactors were sold for £1.7 billion (US$2.7 billion). The estimated value of these eight reactors was at least £17 billion (US$27 billion). During the process, decommissioning funds were lost as they had never been set apart but stayed assets of the companies that were being privatized and further regulatory benefits were granted for decommissioning.[13] Data from (Schneider, Thomas, Froggatt, & Koplow, 2009) indicates that subsequent support to rescue British Energy from bankruptcy added up to £11.6 billion (US$21 billion), and that re-nationalisation cost at least £3.4 billion (US$6.1 billion). Further re-privatizations excluded £14 billion (US$22 billion) of decommissioning liabilities (Energy Fair, 2011).

The U.K. also has other nuclear subsidies in place, including a cap on accident liability, and underfunding of waste disposal costs (Energy Fair, 2011). Further, it is currently debated whether low carbon measures imply a subsidy to nuclear energy. The U.K.'s floor price on EU Emission Trading System carbon allowances is expected to provide at least a £50 million (US$81 million) per annum benefit to the nuclear industry through 2030 (UK Parliament Environmental Audit Committee, 2011).

[11] All exchange rate conversions for the case study on France based on 2009 average USD–EUR exchange rate.
[12] The European Commission subsequently ruled that this was state aid.
[13] Companies were allowed to fund 50 per cent of the decommissioning funds out of cash flow instead of segregated funds, despite it being dubious that cash flow would cover this. This proved to be the case when British Energy had to be re-nationalized.

6. Assessment of Studies and Results

a. Identifying and filling the gaps in current knowledge

Table 6.1 summarizes the major gaps that have been identified in estimations of subsidy levels. There are few comprehensive studies that assess subsidies to electricity generation either within or across different generation types.

TABLE 6.1: GAPS IN EXISTING STUDIES

Generation Type	Gaps
Renewable Energy	• Some policy interventions are either not captured, or only partially captured by existing studies. These include subsidies to capital formation through grants, subsidized and guaranteed loans, tax incentives, bidding rounds, and mandates • Subsidies relating to infrastructure investment necessitated by increases in intermittent renewable-energy plants are generally not captured • Quantification according to policy intervention is not always clear
Fossil-Fuels	• Few qualitative or quantitative analyses of subsidies to generating companies (OECD or non-OECD) • Analyses of consumer subsidies to electricity are limited to those subsidies with price effects and to non-OECD countries • Studies do not capture capital grants, lending based support mechanisms, tax incentives, mandates in a systematic fashion. • Assessments of international aid and lending for fossil-fuel generation projects generally report the face value of the loans, not their subsidy equivalent values.
Nuclear Energy	• No robust global estimates of subsidies to nuclear energy and few attempts to quantify robust country-level estimates • Inconsistent methodologies for liability subsidy estimation Subsidies to decrease cost of capital under-researched

Extending the analysis to cover the areas identified in Table 6.1 would enable a more complete assessment of subsidy levels. While conducting such analysis on a global level would help identify the overall scale of the subsidies, the methodological problems in completing such an analysis are considerable and a series of consistent bottom-up studies, focusing on specific countries and technologies, may be more realistic and also more relevant at the level of national policy. Some such studies already exist, giving both useful insights into specific policy details, and a starting point for the more detailed analysis necessary to progress understanding.

It is also possible that some of the current data on energy subsidies in general may enable some of the gaps to be filled, if disaggregated on the basis of end use (for studies that look at subsidies to fossil fuels in general), or if disaggregated by source fuel (for subsidies that look at subsidies to electricity in general). It is also the case that existing studies are not always transparent about their estimation methods, or about the uncertainties that apply to the analysis. Further work could help reconcile these studies so that data can be aggregated and studies better compared.

b. Limitations of Current Studies for Comparative Purposes

There are few existing studies that attempt to quantify subsidies to electricity generation on a consistent and comprehensive basis. Whilst studies such as IEA's (2010) provide some high level quantification for some subsidies, they do not give a complete assessment of all subsidies to all types of electricity generation. Generally, the most useful information comes from more detailed country level studies, although often the focus is restricted to one generation type.

A range of factors cautions against comparing the results of studies quantifying subsidies to technologies for electricity generation. Regarding design, each study tends to use different methodologies and to adopt different parameters (technologies under consideration, time periods under consideration, geographies captured, different subsides captured, and stages of life cycle considered). Studies are constrained by data limitations—often data do not exist, are not publically available, or are out of date. It is often the case that both studies and data lack transparency, making interpretation difficult.

More fundamentally, technologies themselves differ. Even within the broad categories of renewable, fossil-fuel and nuclear energy, there are important differences. For example, hydroelectric power, a mature, widely deployed technology with little need of financial support, cannot reasonably be compared with tidal generation. It is therefore important to refer to the specific objectives for subsidies for each generation type and to assess the cost of the subsidy against these objectives.

A more complete assessment would require improvements in the availability of data, and disaggregation of data such that it is possible to attribute subsidies to generation source and end use. This data could then be used in comprehensive country-level surveys, or in global surveys of a particular subsidy type. In addition to assessing subsidies at a point in time, these should also consider subsidies over a time period so as to capture changes. However, given uncertainties and problems of extrapolation, such estimates are still likely to be best captured in terms of ranges rather than as absolute values.

c. Comparison

TABLE 6.2: SUMMARY OF STUDIES REVIEWED

All currencies are converted based on year under consideration.

		US ¢ / kWh	2009 Generation (TWh)	Notes
Fossil Fuels	Financial + R&D External Costs	0.1 - 0.7 0.7 - 23.8	12,900	• Range of estimates reflects different scope and methodologies of studies • Estimates not applicable to all countries and generation technologies • Data from tables 3.1, 4.1 and 5.1
Nuclear	Financial + R&D External Costs	0.5 - 11.6 0.2 - 1.2	2600	
Renewables	Financial + R&D External Costs	1.7 - 15.4 0.2 - 3.2	500 (excl. hydro) 3600 (incl. hydro)	

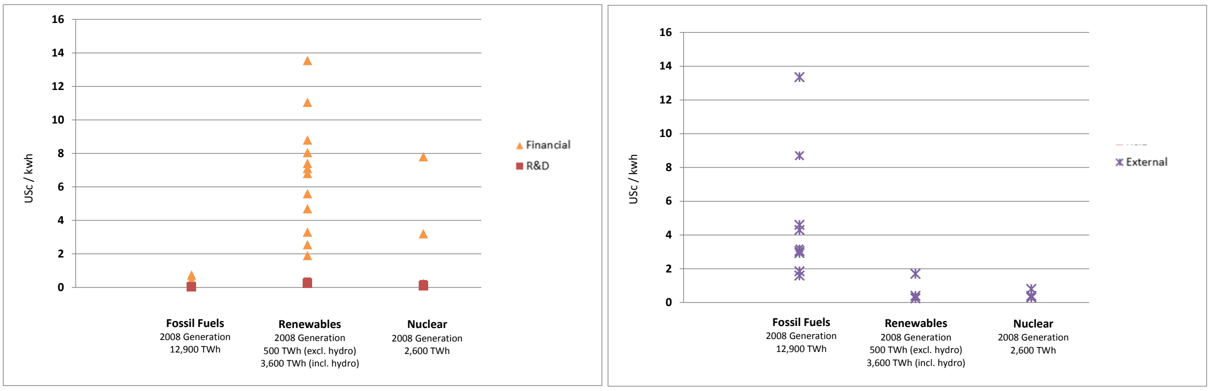
The difficulties associated with comparisons of subsidies are considerable. Table 6.2 and Figure 6.1, which summarize the studies discussed in this paper, show the wide range of estimates. Presenting these estimates shows the importance of careful consideration before accepting and using the results of any one study. Using estimates from any study in either further analysis or policy making requires should be informed by an understanding of the nuances of study scope and estimation method. While acknowledging such caveats, these estimates are the best that are publicly available, and by considering in aggregate, a general impression of the distribution of subsidies for each generation type may be obtained.

FIGURE 6.1: SUBSIDIES AND EXTERNAL COSTS BY GENERATION TYPE

Where studies report ranges, the points on the graph represent the mid-point of this range.

Financial and R&D Subsidies

External Costs
Estimates of externalities are only indicative and are subject to significant uncertainty



Fossil Fuels: A conservative estimate for non-OECD countries, based on estimates by the IEA (2010), and without consideration of producer subsidies in these countries, would be just over 0.7 US cents/kWh. For OECD countries, based on applying EIA (2007) estimates of subsidies in the U.S. to all countries and ignoring potential consumption subsidies, a low-end estimate would be 0.1 US cents/kWh. Adding in R&D expenditure as estimated by the IEA, the estimate would increase only very slightly. By comparison, estimates of externalised costs are as high as 23.8 US cents per kWh.

Nuclear energy: Studies assessing subsidies to nuclear energy show variation in methodologies and estimates. There is no comprehensive global estimate. Koplow (2011) estimates that in the U.S., subsidies to existing reactors range from 0.7 US cents/kWh to 5.7 US cents/kWh, depending on whether the utility is investment owned or publicly owned. For new reactors the range is 4.2US cents/kWh to about 11.4 US cents/kWh. For global generation, (Badcock & Lenzen, 2010) estimate a per unit subsidy for 2007 of between 0.7 and 1.6 US cents/kWh, including direct price support, tax incentives, R&D and external costs.

Renewable energy: While estimates of financial support vary considerably, the IEA estimate of 4.7 US cents/kWh for direct price support appears to be a reasonable low-end estimate. Including other forms of support would increase this further, and individual country analyses suggest that it could be much higher in certain cases. R&D may add a further 0.5 US cents/kWh. Estimates of externalities vary across technologies, but appear to be in the range of 0.5 US cents/kWh.

BOX 4: COMPARING RESULTS TO PREVIOUS GSI STUDIES

A previous study by the GSI—"Relative Subsidies to Energy Sources: GSI Estimates"—attempted a high-level analysis of global subsidies to energy sources. This study was based on an analysis of the readily available data, across all energy sources, rather than a detailed survey of the literature on electricity generation. The differences in subsidies for each generation source are as follows:

Nuclear Power Generation (estimated subsidy = 1.7 US cents/kWh): Estimate based on which reports that subsidies to nuclear generation of at least one third of wholesale electricity price, and on an approximate wholesale price of 5 US cents per kWh. This estimate is at the lower end of the range indicated from this survey.

Non-hydroelectric Renewable Power Generation (estimated subsidy = 5.0 US cents/kWh): Estimate based on the minimum premium provided by feed-in tariffs in Denmark and Spain. This estimate is at the lower end of the range indicated from this survey, reflecting the fact that only feed-in tariffs were considered.

Fossil-fuel Based Power Generation (estimated subsidy = 0.8 US cents/kWh). Estimate is based on consumer subsidies averaged across all end uses (transport, heating and electricity), and is therefore not directly comparable to the estimates summarised in this survey.

7. Conclusions: Lessons for Policy-makers

Based on the foregoing analysis, this brief concludes with a number of suggestions for policy-makers.

a. **Comparing subsidies:** This report has shown that studies that quantify subsidies differ in scope, data, assumptions and estimation method. As a result, great caution has to be used when comparing results across studies. Further, even within studies the limitations of data and differences in technologies mean that comparisons across generating type and countries are not necessarily appropriate.

b. **Validity of global estimates:** While global estimates are useful for illustrative purposes, they are of limited value for policy making on the national level. Even accepting the validity of the numbers, the level of aggregation is such that they can provide little useful guidance. For these purposes, it is necessary to develop robust national estimates for subsidies to each generation type and to assess the effectiveness of these subsidies in meeting policy goals. A useful model could be the GSI series "Fossil Fuels—At What Cost?,"[14] which develops estimates based on detailed analysis of subsidies in specific countries.

c. **Evaluation of Subsidies:** Little can be said about the effectiveness or otherwise of subsidies based on estimates alone. Instead, expenditure should be assessed against the objectives for the subsidies in question, taking into account the maturity of the generation type. The GSI recommends that policy makers adopt a define-measure-evaluate approach to identify, quantify and ultimately assess the effectiveness of subsidies to electricity generation (GSI, 2010). The development of standards for quantification of subsidies, perhaps similar to the WRI Greenhouse Gas Protocol, would help to standardise and improve the transparency of this process.

[14]See **www.globalsubsidies.org** for all GSI publications in the series.

d. **Reforming Subsidies:** Where subsidies are associated with an adverse impact, action should be taken to reform or phase out these subsidies. Governments should be encouraged to take commitments to reform as appropriate, and consider the suitability of existing fora for this purpose (for example the G-20, APEC, OECD, UNFCCC, or WTO). The additional financial resources provided by successful reform efforts would be particularly attractive when governments are looking to reduce debt and finance pensions and other increasing liabilities.

e. **Further Analysis:** The GSI future work program will focus on subsidies to energy, covering fossil fuels, biofuels, other forms of renewable energy, and nuclear power. This will include researching the full cost of subsidies to renewable energy in country case studies similar to those already developed for biofuels and fossil fuels. Further work will focus on identifying the impact that subsidies to fossil-fuel electric power generation could have on renewable-energy based electricity generation. Together, these pieces of research will contribute to a better informed debate on the relative subsidies to different technologies used to generate electricity.

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Tom Moerenhout is an independent consultant with expertise in international trade, energy subsidies and EU external policies. In the past, he has, among other projects, evaluated EU emergency programs on energy and water access in Israel and the occupied Palestinian Territory. Trained as a foreign policy analyst, he now works in the area of sustainable development as a visiting academic at IISD. In this capacity he cooperates with the Global Subsidies Initiative and a wide range of international organizations.

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