Subsidies to Energy Industries[☆]

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Glossary

Consumer subsidy equivalent Integrated metric of aggregate support provided to consumers by varied government policies; policies that act as taxes are incorporated by using the opposite sign.

Cross subsidies Policies that reduce costs to particular types of customers, products, or regions by increasing charges to other groups.

Intermediation value Difference between the break-even costs of debt, insurance, and other programs to large governments and what these same services would cost if a smaller, higher-risk private firm or individual had to buy them directly.

Producer subsidy equivalent Integrated metric of aggregate support provided to producers by varied government policies; policies that act as taxes are incorporated by using the opposite sign.

Renewable portfolio standards Requirements mandating purchase of preset percentages of renewable electricity in particular service regions; the standards normally compete eligible supply sources against each other to minimize the per-unit subsidy.

Subsidies Government-provided goods or services that would otherwise have to be purchased in the market or special exemptions from standard required payments or regulations; subsidies may be in cash but often involve shifting risks from private parties to taxpayers or the public.

[☆] *Change History:* March 2015. Doug Koplow has made minor changes throughout.

 http://dx.doi.org/10.1016/B978-0-12-409548-9.09269-1

Whether by intent or by accident, government interventions affect the relative prices of various energy technologies, the pattern of energy use and investment, and energy-related emissions. Depending on their structure, interventions can act as either taxes or subsidies to particular technologies, producers, or consumers. The lines can blur; some 'taxes' may be insufficient even to cover the cost of related beneficial government services, leaving a residual subsidy to the 'taxed' parties. Available data indicate subsidies to energy industries are extremely large. While data coverage continues to expand, important gaps remain and suggest current estimates likely understate subsidy magnitude.

Introduction

Energy resources vary widely in terms of their capital intensity, reliance on centralized networks, environmental impacts, and energy security profiles. Although the policies of greatest import to a particular energy option may differ, their aggregate impact is significant. Subsidies to conventional fuels can slow research into emerging technologies, thereby delaying their commercialization. Subsidies and exemptions to polluting fuels reduce the incentive to develop and deploy cleaner alternatives. Inadequate tracking and recovery of costs associated with protecting energy security reduce the drive for more diversification. Though estimates remain imperfect, the scale of global subsidies is staggering: more than $800 billion annually in fiscal subsidies alone. Including midpoint estimates for environmental externalities, primarily associated with fossil fuels, brings the annual total above $2 trillion, or roughly 3% of global GDP. Compiled in Koplow (2014) based on IEA (2012), IMF (2013), Kitson, Wooders, and Moerenhout and Wooders (2011), and OECD (2013a).

Justifications for energy subsidies include social welfare, protection and promotion of jobs or industries, rural development, and energy security. Existing policies frequently fail to achieve these aims in practice. Because individual subsidies can be worth millions of dollars and often require sophistication or connections to obtain, policies implemented to help poorer segments of society may end up enhancing the wealth of more powerful groups instead. Often, the objectives of subsidy programs can be achieved in a manner that is more narrowly targeted and efficient than the subsidy policies now in place. For example, decoupling subsidy payments to the poor from resource-depleting activities can greatly reduce the environmental damages associated with the transfers.

This article examines the general issue of subsidy definition and measurement and then presents central issues associated with subsidization at each stage of a generic fuel cycle. Aggregate patterns of subsidization and the challenges of subsidy reform are addressed in the subsequent two sections.

Subsidy Definition and Measurement

Government interventions encompass a wide range of regulatory, fiscal, tax, indemnification, and legal actions. By modifying the rights and responsibilities of various parties involved with the energy sector, these actions decrease (subsidize) or increase (tax) either energy prices or production costs. Differing approaches to subsidy definition and measurement, though not all equally valid, have too often generated disparate subsidy assessments that are difficult to compare or compile.

Common Disagreements in Subsidy Definition

Disagreements over the proper definition of subsidy are common. Conflicts frequently arise over the form and timing of the transfer, the definition of the 'nonsubsidized' baseline, and the boundaries of analysis.

Form and timing of transfer

Energy subsidies are often viewed primarily as cash payments from a government agency to private businesses or individuals. Payments to low-income households to enable them to purchase heating oil and grants to businesses to help them develop particular energy technologies are examples. In reality, subsidies can take many different forms, and a more accurate definition must include any government-provided goods or services, including risk bearing, that would otherwise have to be purchased in the market. Much market activity involves controlling and sharing the risks and rewards of economic activities, and risk-oriented subsidies are quite important. Subsidies can also be in the form of special exemptions from standard required payments such as tax breaks. Although cash payments are easily measured within a single year, more complex subsidies such as loan guarantees are best evaluated over multiple years so that patterns in losses or investment distortion can be seen more clearly.

Defining the baseline

Subsidies must often be measured against a baseline. What would taxes owed have been in the absence of this special tax break? How much would industry have had to pay in interest to build that new facility if the government had not guaranteed the loan? Many disagreements over subsidy definition originate in differing views on the appropriate baseline.

Indirect versus direct transfers

Some argue that interventions 'count' as energy subsidies only if they directly target the energy sector. For example, the US Energy Information Administration (EIA) did not count subsidies to energy facilities provided by tax-exempt general-purpose municipal bonds in its tallies, arguing that the bonds did not constitute an energy subsidy if some hospital and road projects could also use them. Yet bonds it did count were also available for use in multiple sectors (Koplow, 2010). Similarly, fees to use the US inland waterway system have historically been insufficient to reimburse system construction and maintenance costs. Although oil and coal industries are among the largest users of the system, the fee subsidies (which allow a lower delivery cost than would otherwise be possible for these fuels) are often discounted on the grounds that multiple commodities are shipped through the waterways.

Because many subsidies tilt the energy-playing field toward a particular fuel even if there are also nonenergy beneficiaries, such policies should not be ignored. Rather, any policy that has the effect of subsidizing prices or production costs should be assessed. This may include policies targeted at single sectors, multiple sectors, specific geographic areas, or specific factors of production. It is notable that in a recent commitment by the world's largest economies (the 'G20') to eliminate harmful fossil fuel subsidies, many member countries adopted a definition of subsidies that is focused on policy impact rather than its stated intent, addressing this exact problem. See Koplow (2012), and particularly the definition used by the European Union.

Externalities

Although the levels vary by fuel, most energy production and consumption generate wide-ranging externalities such as pollution and damage to human health. Exemptions from appropriate environmental controls (e.g., less stringent air pollution control requirements for certain old power plants in the United States) penalize cleaner energy types and are properly viewed as subsidies. However, externalities do create an analytic challenge because they are difficult to monetize. Koplow and Dernbach (2001) documented that decisions about which externalities to include and how to value them can generate very large variation in reported subsidy estimates, on the order of hundreds of billions of dollars per year. A literature review by the Global Subsidies Initiative found midpoint estimates of environmental externalities from energy of $1.5 trillion per year, significantly larger than currently documented fiscal subsidies. Almost all was linked to fossil fuels, with estimates spanning a range of $90 billion to more than $3 trillion per year (Kitson, Wooders, and Moerenhout, 2011). Segregating externality-related subsidies from fiscal subsidies can help to improve data comparability and transparency across studies, as well as highlight leverage points for policy reforms.

Intermediation value and leverage

Subsidy recipients often incorrectly claim that risk-based subsidies such as loan guarantees have no value unless there are defaults. It is certainly true that both defaults and loan program administration can trigger significant subsidies. However, even if loans are repaid in full, important subsidies arise. Leverage is one source: debt finance is less expensive than equity, and loan guarantees enable even risky projects to use much larger amounts of debt than would be possible in the open market. Because the government's cost of debt is lower than what could be attained by the recipient on its own, using government programs to intermediate credit markets generates subsidies as well. High-risk endeavors – sales of large energy assets to politically unstable countries or building nuclear reactors, for example – can generate particularly high intermediation subsidies, even though the nominal interest rate may be set at or slightly more than the government's cost of borrowing.

Since some energy resources have much greater access to these government programs than do others, distortions in relative energy prices can result. Historical lending for energy infrastructure by development banks and export credit agencies, for example, has heavily favored fossil fuel projects over renewables (Koplow, 1993; Rojas, Aylward and Donge, 2000). Though the mix has improved in recent years, some bias remains. A review of data for the 2008–13 period by Washington, DC-based Oil Change International (2014) indicated fossil funding continued at a rate nearly double the commitments to clean energy and energy efficiency.

Boundaries of analysis

Energy is a primary material, an input to refined energy products (e.g., gasoline and electricity), and an input to nonenergy materials (e.g., metals and consumer goods). To provide an accurate picture of energy subsidies, analytic boundaries with respect to three areas must be addressed: calculation of net values, level of government, and subsidies to complements.

Calculation of net values

Because interventions can act as taxes or subsidies, interventions should be treated holistically so that end values represent net, rather than gross, subsidies to energy. Policies that affect multiple sectors need to be prorated so that only the portion applicable to energy is counted. Although proration is not always possible to do precisely (some policies have joint effects), allocations based on intensity of use, share of production, or similar metrics often provide reasonable proxies. Similarly, non-standard taxes or fees levied on fuels should be counted against the gross subsidy to generate the value net of offsets.

Level of government

Interventions occur at multiple levels of government, and all levels can affect energy costs to some degree. Analysis of these policies should be internally consistent: if tax offsets at the state level are deducted from energy subsidy values, state-level subsidies should be included as well.

Subsidies to complements

Energy subsidies have many second-order effects as they flow through other activities in the economy. Although detailed assessment is beyond the scope of this article, these policies can influence basic aspects of economic structure such as materials production, recycling, and energy demand. Subsidized electricity to primary aluminum is endemic worldwide and inhibits adoption of less energy-intensive materials, for example. Similarly, subsidies for converting wastepaper, animal waste, and landfill gas into energy reduce the viability of recycling and composting alternatives. Widespread subsidies to roads and driving spur increased road use and demand for gasoline; and subsidies to housing underwrite larger building footprints with an associated increase in energy demand.

Methods of Transferring Value

Table 1 provides an overview of intervention types. Depending on the policy specifics, many interventions can generate either a net subsidy or a net tax. Cash transfers from government to private industry may originate from a handful of the intervention types, including direct spending, government ownership, and research and development (R&D) support. However, subsidies resulting from avoided expenditures by private firms are also quite common. These include government provision of market-related information; access to below-market credit, insurance, or government-provided goods and services; tax breaks; and exemptions from prudent regulation on health-, environment-, or safety-related aspects of an enterprise. Particularly in emerging economies, subsidies to keep energy prices below world levels are common. Though some benefits do flow to the poor, empirical analyses by the World Bank (2010), the International Energy Agency (2011), and the International Monetary Fund (del Grenado, Coady, and Gillingham, 2010) all indicate that strategic energy-intensive industries and mid- to upper-income quintiles capture the majority of the support.

Market controls, including general regulations, provisions governing access to resources, restrictions on energy-related imports or exports, and purchase requirements, can act as either a tax or a subsidy depending on one's market position. For example, past restrictions on oil exports from Alaska acted as a *de facto* tax on Alaskan producers because they could not sell output to the highest bidder. However, the very same policy provided oil subsidies to consumers on the West Coast of the United States. Although driven by government policy and having important effects on energy market structure, these policies often involve transfers between various producers and consumers rather than transfers from taxpayers. Cross subsidies follow a similar pattern, with some users paying less than they should and others paying more than they should. Cross subsidies commonly occur when rate structures must be approved by governments or in markets protected from competition.

Special energy taxes, as their name suggests, are levied uniquely on energy activities. They tend to act as taxes rather than as subsidies. However, a tax should be classified as 'special' only if it is above and beyond appropriate baseline recovery of revenue. The baseline taxation of energy should (1) compensate public sector owners for the sale of valuable energy resources, (2) recover public sector costs associated with the public provision of energy-related services, (3) equal the baseline tax on other goods and services, and (4) charge an appropriate levy for negative externalities associated with production and use of the resource. Many

Table 1 Common forms of government interventions in energy markets

Intervention type	*Description*
Access[a]	Policies governing the terms of access to domestic onshore and offshore resources (e.g., leasing)
Cross subsidy[a,b]	Policies that reduce costs to particular types of customers or regions by increasing charges to other customers or regions
Direct spending[b]	Direct budgetary outlays for an energy-related purpose
Government ownership[b]	Government ownership of all or a significant part of an energy enterprise or a supporting service organization
Import/export restriction[a]	Restrictions on the free market flow of energy products and services between countries
Information[b]	Provision of market-related information that would otherwise have to be purchased by private market participants
Lending[b]	Below-market provision of loans or loan guarantees for energy-related activities
Price controls[a]	Direct regulation of wholesale or retail energy prices
Purchase requirements[a]	Required purchase of particular energy commodities, such as domestic coal, regardless of whether other choices are more economically attractive
Research and development[b]	Partial or full government funding for energy-related research and development
Regulation[a]	Government regulatory efforts that substantially alter the rights and responsibilities of various parties in energy markets or that exempt certain parties from those changes
Risk[b]	Government-provided insurance or indemnification at below-market prices
Tax[a,b]	Special tax levies or exemptions for energy-related activities

[a]Can act as either a subsidy or a tax depending on program specifics and one's position in the marketplace.
[b]Interventions included within the realm of fiscal subsidies.
Source: Koplow, D. (1998). *Quantifying impediments to fossil fuel trade: an overview of major producing and consuming nations*. Paper prepared for the OECD Trade Directorate.

assessments of energy taxation fail to incorporate appropriate measures for baseline levels, improperly classifying as an 'energy tax' or an 'environmental tax' policies that in fact recover only a portion of public costs and leave residual subsidies.

Government ownership of energy-related enterprises, including power generation and transmission, oil production and refining, coal mines, and road and pipeline networks, is common around the world. Many of these activities generate large subsidies to consumers as well as depleting fiscal resources. Subsidies are multilayered. The enterprise is often fairly high risk, attains access to low-cost tax-exempt government debt, pays no taxes on net income, and is not expected to earn a return on capital no matter how large the taxpayer investment. Operating losses may ensue above and beyond these cost structure subsidies due to poor controls or politicization of the rate structure. These enterprises can be complex and difficult to analyze but often contribute to significant energy market distortions.

Methods of Measuring Subsidy Magnitude

Efforts to assess subsidy magnitude have generally focused either on measuring the value transferred to market participants from particular programs (program-specific or inventory approach) or on measuring the variance between the observed and the 'free market' price for an energy commodity (price gap approach). One set of methods that captures both pricing distortions (net market transfers) and transfers that do not affect end-market prices (net budgetary transfers) is the producer subsidy equivalent (PSE) and consumer subsidy equivalent (CSE) metrics commonly employed in the agricultural sector. In recent years, the Organisation for Economic Co-operation and Development has expanded the use of the PSE and CSE into the energy sector as well, gradually building an inventory of many subsidies to fossil fuels within its member countries (OECD, 2013a).

These approaches differ in the amount of data required to calculate them and in the degree to which they successfully measure budget transfers plus market transfers. Program-specific transfer assessments capture the value of government programs benefiting (or taxing) a particular sector, whether these benefits end up with consumers (as lower prices), producers (through higher revenues), or resource owners (through higher rents). Unless integrated into a macroeconomic model, this information tells little about the ultimate incidence of the subsidy programs and their effect on market prices. By definition, the price gap metric highlights observed price distortions, although it misses the often substantial fiscal supports that do not affect consumer energy prices but do affect the structure of supply. The combination of PSE and CSE data provides insights into both. Table 2 briefly summarizes the main approaches that have been used in both domestic and international subsidy assessments as well as their respective strengths and limitations.

Subsidies Through the Fuel Cycle

Because no two fuel cycles are exactly the same, examining subsidies through the context of a generic fuel cycle is instructive in providing an overall framework from which to understand how common subsidization policies work. Subsidies are grouped into preproduction (e.g., R&D and resource location), production (e.g., extraction, conversion/generation, distribution, and accident risks), consumption, postproduction (e.g., decommissioning and reclamation), and externalities (e.g., energy security, environmental, health, and safety).

Table 2 Overview of subsidy measurement approaches

Approach/description	*Strengths*	*Limitations*
Program-specific: quantifies' value of specific government programs to particular industries; aggregates programs into overall level of support	Captures transfers whether or not they affect end-market prices Can capture intermediation value (which is higher than the direct cost of government lending and insurance)	Does not address questions of ultimate incidence or pricing distortions Sensitive to decisions on what programs to include and requires program-level data
Price gap: evaluates positive or negative 'gaps' between the domestic price of energy and the delivered price of comparable products from abroad	Can be estimated with more limited data; very useful for multicountry studies Good indicator of pricing and trade distortions	Sensitive to assumptions regarding 'free market' and transport prices Understates full value of supports because it ignores transfers that do not affect end-market prices
PSE/CSE: systematic method to aggregate transfers plus market supports to particular industries	Integrates transfers with market supports into holistic measurement of support Separates effects on producer and consumer markets	Data-intensive Empirical PSE/CSE data for fossil fuel markets remains limited

Source: Koplow, D. and Dernbach, J. (2001). Federal fossil fuel subsidies and greenhouse gas emissions: A case study of increasing transparency for fiscal policy. *Annual Review of Energy and the Environment* **26**, 361–389.

Preproduction

Preproduction activities include research into new technologies, improving existing technologies, and market assessments to identify the location and quality of energy resources.

Research and development

R&D subsidies to energy are common worldwide, generally through government-funded research or tax breaks. Proponents of R&D subsidies argue that because a portion of the financial returns from successful innovations cannot be captured by the innovator, the private sector will spend less than what is appropriate given the aggregate returns to society.

However, the general concept masks several potential concerns regarding energy R&D. First, an innovation near commercialization has much lower spillover than does basic research, making subsidies harder to justify. Second, politics is often an important factor in R&D choices, especially regarding how the research plans are structured and the support for follow-on funding to existing projects.

Allocation bias is also a concern. Historical data on energy R&D (Table 3) demonstrate that R&D spending has heavily favored nuclear and fossil energy across many countries. Between 1948 and 1992, for example, 85% of US energy R&D went to these two sectors. Although efficiency, renewables, and conservation have captured a growing share of public funds more recently, historical patterns have not disappeared. Across the IEA member countries, nuclear research has continued to capture a larger share of public money than all renewables and efficiency combined even during the past ten years. The average annual public investment across the IEA appears to have declined in the more recent time period, though spending patterns across energy types during all periods have been sufficiently skewed such that they may have influenced the relative competitiveness of energy technologies.

Resource location

Governments frequently conduct surveys to identify the location and composition of energy resources. Although the surveys have addressed wind or geothermal resources on occasion, they most often involve oil and gas. Plant siting is another area where public funds are used, primarily to assess risks from natural disasters such as earthquakes for large hydroelectric or nuclear installations. Survey information can be important to evaluate energy security risks and to support mineral leasing auctions, especially when bidders do not operate competitively. However, costs should be offset from lease sale revenues when evaluating the public return on these sales. Similarly, the costs of siting studies should be recovered from the beneficiary industries.

Production

Energy production includes all stages from the point of resource location through distribution to the final consumers. Specific items examined here include resource extraction, resource conversion (including electricity), the various distribution links to bring the energy resource to the point of final use, and accident risks.

Table 3 Federal Research and Development Support has favored conventional fuels over many decades

Region[b,c]	*Nuclear*	*Fossil energy*	*Others*[a]	*Renewables*	*Efficiency/ conservation*	*Total*
Post-WWII through second energy shock (1948–77) heavily favored nuclear and fossil						
United States[b]	73%	24%	0%	2%	0%	100%
Energy shock through 1992 Energy Policy Act in the United States (1978–92) shows some shift to alternatives						
United States[b]	47%	26%	3%	16%	9%	100%
IEA member states[c]	59%	15%	11%	9%	6%	100%
Most recent period (1993–2012) shows growing support for alternatives, though most to nuclear and fossil						
United States[b]	27%	24%	11%	17%	21%	100%
IEA member states[c]	34%	14%	20%	15%	16%	100%
Overall public investments in energy R&D have heavily favored conventional energy						
United States, 1948–2012[b]	49%	25%	4%	12%	10%	100%
IEA, 1974–2012[c]	51%	13%	15%	10%	10%	100%
Public investments in energy R&D per year have declined over time (IEA member countries, millions of 2012 USD)						
Total spending, 1978–2012	256 662	70 877	81 233	56 035	57 878	522 685
Average spending/year, 1978–92	9761	2439	1736	1444	1057	16 437
Average spending/year, 1993–2013	5512	1714	2760	1719	2101	13 807

[a]Includes electrical conversion and distribution, energy storage, and unclassified spending.
[b]US data compiled by Fred Sissine, US Congressional Research Service (2013), based on historical budget and reporting data published by the US Department of Energy.
[c]International Energy Agency (2013). Research and Development database, accessed 1 October 2013. http://wds.iea.org/WDS/TableViewer/tableView.aspx.

Extraction of energy resources

General procedures for leasing access to energy minerals on public lands and more general subsidies for promoting energy extraction both are important areas to evaluate. Extraction-related subsidies are most common for oil and gas production, although they also support nuclear fission (due to uranium mining), geothermal, and coal.

Accessing publicly owned energy resources

Terms of access for energy minerals on public lands can be a source of enormous subsidies. In countries where leases or concessions are granted through graft rather than competitive bidding, wealth transfers worth billions of dollars can occur. Although there are not good statistics on the losses (obtaining even basic information on how much is being paid for extractive rights can be difficult), the problem appears to be large. Oxfam America finds that countries most dependent on oil tend to have very low Human Development Index (HDI) rankings. Developed by the United Nations Development Programme, the HDI ranks countries according to a combined measure of income, health, and education. Strong linkages between large mining and petroleum sectors and elevated levels of bribery and corruption have also been found (Ross, 2011). Low-cost access to energy minerals mutes the incentive for careful management because profits can be had even with inefficient operation (Ross, 2001, Ross, 2011). This problem is compounded by rules that frequently exempt field losses or extraction-related consumption from royalty payments. Lease operation can also generate subsidies: when self-reported royalties are calculated improperly, for example. In the United States, this has been a problem both on federal leases and increasingly with fracking operations on private land (Dharssi and Renders, 2014; Lustgarten, 2014).

Promoting extraction activities

Policies to reduce the cost of extraction are widespread and often take the form of tax or loan subsidies or royalty concessions. They are found at both the national and the state or provincial levels. Particular market niches may be targeted, from geographic (e.g., deep-sea recovery of oil and timbering in a particular forest), to technological (e.g., tax breaks for more advanced oil drilling or coal gasification), to life cycle-related (e.g., lower royalties on idle wells that are restarted). In some cases, baseline tax policy may be applied by firms in creative ways to generate large subsidies. The United States-based multinationals receive a tax credit for foreign taxes paid to avoid double taxation of foreign income. Yet in some oil-producing regions with low or no corporate income taxes, foreign governments have reclassified royalty payments into corporate taxes, generating tax revenue losses estimated by the US Treasury at nearly $1.1 billion annually (US Treasury, 2013).

However, many subsidies to extraction are not restricted to particular market niches. Percentage depletion allowances in the United States allow most mining firms, including those in the oil, gas, uranium, or coal sectors, to deduct more costs from their taxable income than they have actually incurred. Accelerated write-offs of extraction-related investments are also common. For example, many multiyear costs in the US oil and gas industry may be deducted immediately (expensed) rather than over the useful lives of the investments. All of these special provisions tend to reduce the effective tax rate on benefiting energy industries. Historical data collected by the EIA (1997) suggest that the major US energy firms paid federal taxes that were one-quarter to one-half the prevailing nominal rates between 1977 and 1995. In a multicountry review of corporate tax rates for the 2005–09 period, Markle and Shackelford (2012) found that the effective tax rate in mining sector (which includes fossil fuel extraction) was only 11%, with even lower levels in Canada (9%), Australia (8%), and the United States (6%). This sector was by far the lowest of the 10 industry categories evaluated. Excise tax substitution for corporate income taxes was one possible explanatory factor noted. However, countries often use excise tax revenues to support related government services (e.g., fuel taxes to pay for roads or fees to fund oversight of well operations), in which case the two tax types are not interchangeable.

Conversion

Raw energy materials normally go through some conversion prior to consumption. Crude oil is refined into a wide range of specialized products such as gasoline and heating oil. Coal may be pulverized or cleaned prior to use. A combination of heat, water, and machinery converts raw fuels (including wind and solar) into electricity. Common government supports to the conversion stage include capital subsidies, production tax credits or purchase requirements, and exemptions from appropriate protections for environmental quality, worker health, and accident risks. Because this third category affects multiple phases of the fuel cycle, it is addressed in a separate section.

Capital subsidies

Subsidies to capital formation, usually through accelerated depreciation, investment tax credits, or subsidized borrowing, are common. Although often applicable to multiple economic sectors, these subsidies are frequently of particular benefit to energy producers. This results in part from the relative capital intensity of the sector and in part to provisions in the tax code that grant special accelerated depreciation schedules for energy-related assets. For example, in the United States, three sectors of relevance to energy – electric light and power, gas facilities, and mining, shafts, and wells – have allowable depreciation schedules that are 28%, 45%, and 44% faster, respectively, than the actual economic depreciation of their assets according to data compiled by the US Treasury (2000). Capital subsidies are of greatest benefit to large-scale generation assets with long construction times (nuclear, hydro, and coal) and are of greatest detriment to energy resources that conserve capital (most prominently energy conservation).

Tax credits/purchase mandates

A second class of subsidies to the conversion stage is tax credits or purchase mandates for certain types of energy. These subsidies occur at multiple levels of governance (federal, state or province, and utility district), a process sometimes referred to as 'subsidy stacking.' They most often support emerging power sources such as solar, wind, and biomass-based electricity, as well as liquid biofuels for transport. Whereas many of the subsidies to conventional power sources are expensive regardless of whether the energy investments ultimately succeed, production tax credits and purchase mandates have the potential to be more efficient. For example, production tax credits for wind energy in the United States cost taxpayers nothing unless a private investor is successful in getting a wind plant operating. If the plant goes off-line, so too do the credits. Renewable portfolio standards, requiring purchase of a preset *quantity* of power or fuel, and feed-in tariffs, guaranteeing a predetermined *price* for compliant power sources, are common forms of purchase mandates. Though policy specifics vary both within and across the mandate types, both provide subsidies as bounties only if a facility is successfully completed. Project risks remain in the private sector.

Despite their benefits, these approaches have not been free of political problems. As the subsidies have grown, so too has lobbying pressure to expand the range of eligible sources. The US federal tax credits now include poultry waste, for example, a great benefit to the handful of very large chicken processors. At the state level, unsustainable biomass sources are sometimes included, as are waste-to-energy and landfill gas systems. In at least one US state (Pennsylvania), waste coal made the list as well. Energy diversity may increase, but portions of this new supply are not necessarily renewable or particularly clean. Industry lobbying to loosen restrictions on the quantity of power eligible for support and to reduce competition among eligible resources by having separate 'carve outs' for their particular energy resource has driven up the fiscal cost of the policies. Similarly, countries such as Spain and Germany have been perhaps too successful with feed-in tariffs for solar, with so many compliant producers that the cost of the subsidy became fiscally unsustainable.

Transportation and distribution

Fuel cycles may involve multiple transportation steps, including movement of raw fuels to the point of refining, refined fuels to the point of consumption, and movement of wastes to disposal sites. Relevant modes of transport include road, rail, water, pipelines, and transmission lines.

Although specific energy resources vary widely in their transport intensity and in the modes of transportation and distribution on which they rely (Table 4), there are some common themes. Government construction, maintenance, and operation of transportation infrastructure frequently give rise to subsidies when user fees do not cover costs. Underestimates are common: too often, municipalities do not properly cost the resources being consumed. For example, tax exemptions on transportation bonds used to finance roads are routinely ignored, as are the free grants of rights-of-ways for rail, road, pipeline, and transmission links. So too is the opportunity cost of land covered by roadways. Although roads and parking facilities occupy 1.7%, 2.1%, and 3.5% of

Table 4 Impact of transport subsidies on the energy sector

Transport mode	*Issues*	*Energy sector impacts*
Water: inland	Waterway maintenance often provided by governments; user fees may not recover costs	Reduces delivered price of bulk oil and coal
Water: coastal and international	Coastal ports, harbors, and shipping oversight subsidized by federal and other government entities; user fees might not recover costs	Reduces delivered price of bulk oil and coal
	Fuel consumed during shipment in international waters generally tax-free	
Road	Most roadways are municipally owned and operated; user fees (primarily from fuel taxes) often insufficient to cover costs	Primarily benefits refined petroleum products
	Large trucks often pay proportionately less in taxes than the damage they cause roadways	Waste products from coal combustion or waste-to-energy plants may sometimes move by truck as well
Rail	Many rail lines do not recover their full costs	Largest beneficiary is coal, with some benefits to oil
Pipeline	Rights of way, safety and security, and environmental cleanup contribute to reduced costs of pipeline ownership and operation	Primarily benefits oil and natural gas
	Property tax reductions or exemptions are also common	
	Depending on circumstances, government ownership may generate large subsidies to users or use government monopoly to levy high taxes on users	
Electrical transmission grid	Rights of way, tax breaks for municipal ownership or capital investment, and government research and development can generate subsidies to electrical distribution	Benefits all sources of centralized electricity in proportion to their share as a prime mover in generating stations; coal, nuclear, natural gas, hydroelectricity, and oil are the main beneficiaries
	Inaccurate pricing of distance can generate cross subsidies to rural users	

Source: Earth Track Inc., Cambridge, MA.

the total land area in the United States, Germany, and Japan, respectively, Todd Litman of the Victoria Transport Policy Institute noted that no property tax is paid on land used for roads Litman (2013). In contrast, most national parks and forests in the United States make some payments to states in lieu of property taxes, recognizing the opportunity cost of the current land use (US Department of the Interior, 2014). The absence of such fees for roads understates the direct costs of the infrastructure and the rights to use it.

Cross subsidies between user groups may further distort relative prices. Large trucks pay less in highway fees than the damage they cause, generating an incremental subsidy to deliveries of gasoline and other refined fuels (US Department of Transportation, 1997; efforts to update this assessment are often blocked due to its political sensitivity). Government-owned vehicles are routinely exempted from fuel taxes, though these fees are used to share the cost of road construction and maintenance among all users. Deep-berth ships such as large oil tankers may be the primary impetus for channel- or port-deepening projects, yet they often contribute to costs based only on volume of shipments. In the electricity sector, transmission tariffs may represent broad averages of the cost of service rather than rising as the distance traveled and density of users decline. By delivering subsidized electricity to remote users, transmission cross subsidies mask the cost of line maintenance and new construction. This can destroy niche markets in which off-grid technologies (often renewable) or minigrids would otherwise have been able to compete. Cross subsidies between peak pricing and low-demand periods are also common in retail electricity markets and can dampen retail investments in demand-side management.

Power sources such as wind and solar require no shipment of input fuels or waste. Improved energy efficiency and some off-grid technologies require no transmission grid either. As a result, subsidies to energy transport can increase the barriers to renewable energy and efficiency. A major US study conducted by Cone and colleagues in 1978 found that an estimated $19.2 billion (2012$) in federal money subsidized transport of US oil stocks between 1950 and 1977. The policies generating these subsidies have mostly continued to the present day.

Accident risks

While many energy-related activities are dangerous, a handful has the potential to cause catastrophic harm. This includes large oil spills, dam failures, and nuclear accidents. Many governments cap, shift, or ignore the potential liabilities from these activities. Functioning insurance markets and litigation would normally help to drive up prices for the more dangerous energy sources or particularly negligent operators. Government policies that mask these signals impede substitution to safer alternatives.

Large oil spills

Within the United States, the Oil Pollution Act of 1990 stipulates the use of commercial insurance for a first tier of coverage. Liability for damages is capped at only $75 million per incident for offshore facilities and $350 million for onshore, though charges for cleanup costs can go higher (BP waived this limit, though likely was under political pressure to do so). A public trust fund financed by per-barrel levied on most oil (tar sands are exempt) provides supplemental coverage in the United States, although payments out of the fund are capped at $1 billion per incident. Based on empirical assessments of spill cleanup costs by Anderson and Talley (1995), at least five historical spills would have exceeded the $1 billion cap, although most spills will be adequately covered. Compensation for tanker spills in most other parts of the world is governed by a series of liability conventions established under the auspices of the International Maritime Organization. The most recent provides coverage levels of up to $1.15 billion per incident, though only 29 countries have signed on to date. The prior version remains dominant (110 countries participating), though with maximum payments of only $310 million (International Oil Pollution Compensation Funds, 2013). The subsidy value of these caps is not known.

Dam failures

Many activities that would pose a very large potential risk if accident scenarios materialized rely on a system of strict liability. Strict liability focuses only on the magnitude of the potential damages rather than on the intent, negligence, or degree of care of the operator. The failure of a large dam near a populated area can cause catastrophic loss of life: the 1975 failure of the Banqiao Dam in China and its aftereffects, for example, killed more than 150 000 people. It is therefore surprising that the financial assurance for such potential liabilities is poorly characterized, as an absence of clear liability rules and coverage reduces the incentives for dam operators to make sufficient investments in safety monitoring and improvement. Although loss of life from a dam failure will likely trigger widespread litigation, at least in the United States, the rules of that litigation are predominantly set at the subnational level. Historically, a slight majority of states rejected strict liability in dam failures (Binder, 2002). Furthermore, the piecemeal approach to coverage within the United States makes it difficult to evaluate whether existing liability policies are adequate. Poor characterization of the risks extends to the international arena as well. To the extent that liability insurance is not in place or is too low, subsidies to hydroelectricity would result.

Nuclear accidents

Nuclear accidents can expose large populations to dangerous levels of radioactivity, triggering enormous liabilities for the firm responsible. Caps on nuclear liability are common throughout the world. The United States, under the Price–Anderson Act, has a two-tier system of indemnification: a first tier of commercial insurance ($375 million per reactor) plus a second pooled tier (maximum of $121 million per reactor) funded by retroactive assessments on all reactors in case any reactor has an accident. Aggregate coverage under the US system is estimated at roughly $12.6 billion per accident, although most of this is paid out gradually by reactor owners over more than 6 years (US Nuclear Regulatory Commission, 2014). This reduces the insurance pool on a present value basis. It also increases the counterparty risk of nonpayment, particularly since the economics for all reactors normally worsen after a major accident anywhere. Inadequate postaccident funding is even more likely in other countries than in the United States. Ukraine, the site of the 1986 Chernobyl accident, requires only $230 million in private coverage. In Canada, required private insurance for reactors is even less, $75 million, and in China, a mere $45 million (Office of the Auditor General of Canada, 2012; Jing and Faure, 2012).

Japanese nuclear operators must provide financial security of $1.4 billion (World Nuclear Association, 2013). Further, the operators technically face unlimited liability subsequent to an accident. However, the government can waive all required private coverage in the case of some natural disasters. Following the Fukushima accident in March 2011 (estimated liability and cleanup costs run as high as $500 billion) (Saito, Takenaka, and Topham, 2013), much of the money for dealing with the problem has come from taxpayers. Allocating that cost across every kWh of Japanese nuclear power generated to date would likely have rendered the energy resource uncompetitive.

International efforts to standardize liability are ongoing under the Convention on Supplementary Compensation for Nuclear Damage. The convention would establish minimum liability coverage worldwide, although for many countries this would also constitute the maximum. Under the convention, operators would directly face a first tier of liability. A country fund would provide secondary coverage. Because country payments rely on a sovereign guaranty rather than a prefunded instrument such as a trust fund, there are some counterparty risks of nonpayment.

Liability levels established under the prior conventions still in force require private insurance cover of less than $500 million per accident. The not-yet-ratified update boosts this to about $950 million per accident, a level that would still be inadequate. Loss statistics compiled by the Insurance Information Institute (2013) provide some context on appropriate coverage requirements. In 2012 alone, there were 10 natural disasters with insured damages (themselves but a portion of the total losses) in excess of the CSC cap; 19 of the top 20 exceeded the liability caps of the conventions currently in effect. All 10 of the worst insurance losses since 1970 exceeded even the Price–Anderson cap – often by a large margin (International Insurance Institute, 2013).

Subsidies arise when government caps fall below expected damages from an incident and caps under both the Price–Anderson and the convention are likely to do so. Damages above that level are, in effect, shifted to the state or to the affected population. Rising real estate values and growing populations around reactors (a fourfold increase since 1980 in the United States according to analysis by the Associated Press) can drive up accident damages substantially (Donn, 2011). Heyes (2002) estimated that the subsidy to reactors under Price–Anderson ranges between 2 and 3 c/kWh, a value that would roughly double the operating costs of nuclear plants. In addition, there are incremental subsidies associated with indemnification for nuclear contractors and large government-owned enrichment and waste management facilities. Because other countries have lower liability caps and weaker inspection regimes, they likely have higher liability subsidies as well.

Consumption

Government support for energy consumption falls into three main categories: poverty alleviation, economy-wide below-market pricing, and targeted subsidies for certain classes of consumers. The categories are somewhat interrelated.

Poverty alleviation

Subsidies to heat and power for poorer citizens are common, frequently in the form of a lump sum grant or reduced cost access to municipal resources. Often consumption-oriented, these subsidies may miss opportunities to implement conservation measures among the target populations. Targeting can be a problem as well, with funds not reaching the groups most in need. The poorest citizens often rely on traditional biomass fuels (fuels such as dung, wood, and charcoal still comprise nearly 70% of the fuel used for cooking across Africa and more than one-third worldwide) or live outside the reach of the subsidized electrical grid (IEA, 2012).

General subsidies

Nations with large domestic energy industries sometimes institute policies that keep local prices well below world levels. These subsidies may protect antiquated energy-consuming industries that otherwise would be unable to compete, or they may serve as ‘rewards’ to the electorate for supporting a particular official or political party. Price gap data for Venezuela and Iran compiled by the IEA are illustrative, indicating that these large oil producers heavily subsidize both industrial use and residential use of petroleum. Subsidies are also common in many service areas close to large municipal hydroelectric generating stations. For example, rates to customers of the Power Marketing Administration dams in the United States were long heavily subsidized. Although the quantities of power or oil flowing through these regions make the price subsidies seem costless, they are not. Domestic sales at subsidized rates trigger a range of impacts including lost energy export revenues, increased local pollution, reduced incentives to invest in energy conservation, and development of an industrial production base that may be increasingly noncompetitive with that deployed elsewhere in the world.

Many US states exempt fuels from sales and use taxes levied on most other goods and services and sometimes offer favored rates to in-state industries. In addition to significant losses to state treasuries, these exemptions also reduce incentives for conservation and shifting to renewable systems such as wind, geothermal, and solar.

Targeted exemptions

Targeted exemptions direct benefits to particular fuels or industrial sectors. Within the European Union, for example, fuel tax rates on coal used in the industrial or power sector are often lower than those on much cleaner natural gas and on a tax per unit energy output basis are lower than the levies on renewable power as well. Even when viewed in terms of taxes per unit carbon emitted, levies on coal used for heating and industrial processes remain less than half those on natural gas (OECD, 2013b). These differences reduce the market incentives to select cleaner fuels at the margin.

Postproduction Activities

Energy production and conversion require large facilities, often located in remote or pristine environments. Postoperational cleanup can be complex. Decommissioning addresses removal of physical infrastructure, whereas remediation and reclamation address problems with land and water. For markets to make accurate decisions about the relative cost of energy resources, the cost of these postproduction activities must be included in energy prices during the operating life of the facility in much the same way that the cost of an employee pension would be. Indeed, failure to accrue funds for postclosure costs during operations would make public subsidy likely given that revenues often drop to zero on plant closure.

Decommissioning

Decommissioning subsidies arise when infrastructure removal costs are ignored or underestimated or when accrued funds are mismanaged. Costs can be significant at large-scale energy installations such as hydroelectric dams and oil refineries. Where installations are remote (e.g., offshore oil rigs), radioactive (e.g., nuclear plants), or widely dispersed (e.g., gathering pipelines), costs of decommissioning can rise sharply. Requirements for long-term environmental or safety monitoring (e.g., nuclear plants and some mines) can drive costs up further.

Although there are regulations for proper abandonment of pipelines, for example, these can vary by political jurisdiction. Advance funding of closures is infrequently required, creating liabilities for landowners or taxpayers. With respect to dams, the US Federal Energy Regulatory Commission indicated in a 1994 policy statement that it will 'not generically impose decommissioning funding requirements on licensees' but rather will stipulate them on a case-by-case basis at the time of relicensing. According to Andrew Fahlund of Stanford University, this policy has been implemented such that if a 'dam owner is too poor, it is too burdensome to require them to maintain a fund, and if they are rich, they will have plenty of money available for such an eventuality'.

Decommissioning nuclear plants and fuel-cycle facilities is also a concern. Discounted cash flow analysis of nuclear costs tends to include decommissioning as a rounding error given that reactor licenses last 40–60 years, and plants can be left idle after closure for decades more. Yet, cost estimation remains dicey and under accrual during the plant's operating life can result in large public liabilities at closure with no new revenues to lessen the shortfall. The United Kingdom's National Decommissioning Authority, for example, estimated the taxpayer liability to clean up 17 predominantly civilian nuclear facilities at £59 billion (£104 billion undiscounted) (Nuclear Decommissioning Authority, 2013). Further, some countries such as the United States subsidize the provision of private decommissioning funds on an ongoing basis through tax breaks. Koplow (2011) estimated these are worth as much as $1.1 billion per year to US reactors.

Inadequate provision for closure is also apparent in the oil and gas sector. A detailed review of well bonding requirements by Dutzik et al. (2013) found coverage requirements well below reasonable liability levels in many US states. Davis (2012) noted that the rise of fracking operations, often run by small- and mid-size companies, creates particularly high risks of inadequate funding for site closure and management due to relatively low financial strength.

Public bailouts can also be required if accrued funds for postclosure activities are lost through negligence, bankruptcy, or theft. If funds are retained within the firm, bankruptcy is a significant risk, especially given the 40- to 60-year time frame between fund collection and use. Increased segregation of each energy asset into its own limited liability company (now becoming the norm in the US nuclear industry) greatly increases this risk since tapping into assets of a better-capitalized parent company can be difficult. Loss through negligence is less likely where regulations preclude speculative investing. Nuclear decommissioning trusts within the United States are held outside the firm and are subject to conservative investment requirements to reduce the likelihood of loss.

Reclamation and remediation

Small subsidies to site reclamation and remediation may arise through government-sponsored research into remediation technologies or through regulatory oversight of extraction activities that are not recovered via user fees. Much larger subsidies are associated with remediation of government-owned energy-related installations or where reclamation bonding has been insufficient to pay for the damage caused by private operators. Boyd (2001) pointed to widespread inadequacy of reclamation bonding levels historically. Estimated liability for high priority (public health and safety concerns) coal mine remediation in the United States exceeds $3 billion at present, according to the US Office of Surface Mining Reclamation and Enforcement (Office of Surface Mining reclamation and Enforcement, 2013). A recent OECD review of environmental liability regimes in eastern Europe, the Caucasus, and central Asia found the statutory basis weak and implementation poor even where a statutory framework existed (OECD, 2012b). Many mining regions around the world have unreliable, incomplete, or nonexistent data on abandoned mines and their associated costs. These shortfalls may be made up by general tax revenues. However, more often, resource damage is not mitigated and continuing environmental releases are not controlled.

Energy Externalities

External costs of energy production and consumption can include pollution, land degradation, health impairments, congestion, and energy security. This article differentiates between two types of subsidies. The first involves existing government spending to address recognized problems associated with particular energy resources. Included here would be public funding to protect energy supplies and assets, public absorption of energy worker health care costs, and/or public subsidies to pollution control or abatement. Because this spending involves actual outlays, it is counted as a fiscal subsidy. A second class of policies involves loopholes in regulatory controls that allow additional damages to human health or the environment to continue without compensation. This second group is often difficult to quantify and is segregated as an externality.

Energy security

Energy plays a central role in industrialized economies, and supply disruptions can trigger widespread economic dislocations. Geopolitical problems, accidents, and terrorism all are potential triggers. Lovins and Lovins (1982) identified a handful of factors that drive security concerns. These include long distribution channels, geographically concentrated delivery or production systems, interconnected systems that can spread failures, specialized labor and control systems to operate capital-intensive facilities that are very difficult to replace, and dangerous materials that can elevate the severity of any breach.

Energy security strategies include protection of energy-related assets and supply routes, stockpiling of vulnerable resources, and supply diversification. Where costs of these responses are borne by the general public rather than by the appropriate energy producers and/or consumers, the market incentive to build a more resilient, decentralized, and diversified supply system is reduced. Security subsidies tend to provide the greatest benefit to oil, with particularly high transfers to imported oil from unstable regions such as the Persian Gulf. Additional beneficiaries are centralized electricity and natural gas. Off-grid power and conservation are the sources most disadvantaged. Subsidies to protecting energy installations and stockpiling are explored in detail in the following subsections.

Protection of assets and supply links

Defending energy-related assets is an increasing concern of governments around the world. The larger the energy installation, the greater the target and the bigger the dislocation were there to be an attack or accident. Pipelines have long been a target of physical attacks around the world and face significant risk of cyber-attack as well. The US Transportation Security Administration has a separate pipeline division, and the US military has in the past funded protection of energy assets in the countries of Georgia and Colombia (Kashi, 2013). Within the United States, core assets include the Trans-Alaska Pipeline System (TAPS), through which roughly 10% of total US crude production flows, and nuclear plants (Parfomak, 2013). The US military has historically conducted training and planning exercises around TAPS. In the nuclear sector, deployment of state-level security or National Guard troops around plants during periods of high terrorist alerts has been common. Although these anecdotes indicate that public expenditures in the area of protecting energy-related assets are likely large, data to quantify the subsidies are generally unavailable.

The cost to defend oil shipments moving through the Persian Gulf is an exception. As one of the core missions for the US military in the region, there have been multiple efforts to value the subsidy to oil. Koplow and Martin (1998) reviewed eight historical studies of these costs and found general agreement that this presence is of great benefit to oil supply security. Disagreements centered on cost attribution, with a wide dispersion in approaches that ranged from nearly zero (short-run marginal cost approach with almost no costs considered incremental to support the oil mission) to attribution of all regional military costs only to the oil mission. Koplow and Martin concluded the short-run marginal cost approach was unpersuasive, as equivalent arguments could be made for each mission area given that the common costs of the vessels and personnel comprise the largest expenses. They argued instead for treating the military presence through the lens of joint costs and allocating a reasonable portion (in this case, one-third, or $12–27 billion (2012$)) to the oil sector.

While large in comparison with tax breaks to oil, more recent work by Stern (2010) better incorporates long-term trends in defense spending as well as ex-region support costs for the Persian Gulf force projection. Using detailed budget information and an activity-based costing approach, Stern estimated the average annual cost of the Persian Gulf mission at more than $200 billion. Though he did not attribute a specific portion to oil, the base is so much higher that any reasonable allocation to oil would generate substantially larger values than past estimates. The Persian Gulf oil security costs are funded by US taxpayers; however, the benefits accrue to oil consumers in Europe and Japan as well. Recovering this cost via an excise fee on shipments would help to encourage increased supply diversification.

Stockpiling petroleum

Under the terms of the IEA, oil-importing member states are required to hold stocks equal to 90 days of the previous year's net oil imports as a buffer against short-term supply disruptions and to improve military readiness. Subsidies arise if the costs of stockpiling are borne by taxpayers rather than by oil consumers. Relevant expenses include constructing and operating the stockpiles, interest costs on oil inventories and infrastructure, and any payments to third parties for nongovernmental stockpiling (two-thirds of IEA-mandated stocks are held commercially).

Buffer stocks for oil within the United States are held within the publicly owned Strategic Petroleum Reserve (SPR). The SPR has incomplete cost accounting, most prominently ignoring the interest costs associated with more than $20 billion it has spent to purchase its oil inventory since the reserve's inception (US Department of Energy, 2013). Private firms must finance all working capital, including inventory, in their operations; cost savings from reducing inventory levels can be large. Public oil stockpiles are no different. Capital tied up in the enterprise must be borrowed through treasury bond markets and incurs interest charges. Analysis by Koplow and Martin for 1995 estimated annual subsidies to the SPR at between $2.3 billion and $7.6 billion (has been scaled to 2012$) depending on whether unpaid interest on oil inventories is compounded. Because carrying costs are sensitive to the cost of capital, declining interest rates during recent years mean that current SPR subsidies are lower (about $800 million) without compounding. With compounding, annual interest costs would continue to grow, though at a slower rate.

Many countries recover part or all of the costs of stockpiling from oil markets rather than shifting costs to taxpayers. This includes key members of the IEA such as France, Germany, Korea, Japan, and the United Kingdom (IEA, 2007). Subsidies to stockpiling slow transition to less vulnerable, more diversified supplies. Formal tracking of stockpile finance by the IEA, as well as the formalization of accounting rules for calculating costs, would leverage market forces for improved supply security.

Environmental, health, and safety externalities

Externalities involve damages associated with energy production or use that are imposed on surrounding populations or ecosystems without compensation. These may include environmental damage, materials damage, human health effects, and nuisance factors such as bad smells and loud noises. Worker health is sometimes not counted as an externality under the argument that workers are compensated for the added risks of their jobs through higher wages. Such a conclusion requires that workers have some degree of choice in whether or not to accept jobs and that employers can be taken to task retroactively for gross negligence. This is not the case in many countries around the world. As a result, it is reasonable to consider as subsidies high levels of occupational illness, particularly when the costs of maintaining those workers fall on the general taxpayers.

Governments are routinely involved with efforts to make certain energy-related activities safer for workers and surrounding populations. This is most prominent regarding coal and nuclear fuel cycles, where in some countries dedicated government agencies exist to inspect mines and production sites, as well as to provide education and support for improvements. If these costs are not paid entirely by the producers or consumers of the affected energy type, subsidies ensue. Public responsibility for workers' health care or pension costs also constitutes subsidies. This has been quite common in the area of coal: government payments to the US coal miners afflicted with black lung have approached $30 billion, for example (Hurt et al., 2012). Black lung levels are now rising (or are being better documented) in other countries such as Russia, Ukraine, and China. Coal mine fatalities continue at extremely high levels in many of these countries as well.

Although difficult to quantify and normalize, external costs arise in many different ways through the fuel cycle. **Table 5** summarizes the results two literature reviews (one by the Resources for the Future and the other by the Global Subsidies Initiative) to compile quantified historical estimates of energy-related externalities.

External costs are highest for coal and oil both on a per kWh basis and in terms of global totals (of which fossil fuels comprise more than 90%). Were the high-end external cost estimates to be incorporated into end user power prices for coal and biomass, prices would rise so much that the resources would likely be uncompetitive. The environmental costs of nuclear power appear low, though are quite sensitive to assumptions regarding accidents at plants. The data also indicate that renewable energy sources would become far more competitive if the market were forced to account for external costs.

Also striking about these estimates is the persistent uncertainty about their values. Estimates for the same fuel, though evaluated in different studies, are widely dispersed: the high-end estimate is more than a hundred times the low-end estimate for coal, oil, gas, and wind fuel cycles and more than 50 times higher for nuclear. Even within specific studies (where methodological approaches and coverage would ostensibly be consistent), significant imprecision remains, with high estimates for coal as much as 63 times the low estimate; and for natural gas, more than 600 times.

This uncertainty matters in terms of how usable the externality figures are within a context of global policymaking. Consider that on a global basis, the *spread* between high and low estimates for fossil fuel external costs exceeds *total* estimated fiscal subsidies to the fuels. While external costs are both large and important to include when evaluating long-term energy option, mixing them with more precise fiscal subsidy estimates risks shifting the political debate from subsidy reform to attacking the accuracy of the externality numbers.

Patterns of Subsidization

Developing an aggregate picture of energy subsidization is extremely difficult due to the scope of policies affecting the sector and to tremendous fragmentation of the data across thousands of government ministries worldwide. The most extensive tabulations of global subsidies to date have been compiled by the IEA (consumer subsidies), the IMF (consumer subsidies plus some imputed externality adders), and the OECD (primarily producer subsidies in OECD member countries, with some consumer subsidies as well). In recent years, the World Bank has done detailed reviews of pricing mechanisms for fossil fuel markets in many countries and evaluated pricing distortions in electric power as well. These assessments indicate a massive scale of energy subsidization – on the order of $800 billion annually, even excluding externalities.

Table 5 External costs of electric power are both large and uncertain[a]

Fuel	Range across studies: Low-end (c/kWh)	Range across studies: High-end (c/kWh)	High estimate as multiple of low: Across studies	High estimate as multiple of low: Within study
Per unit of electricity[b]				
Coal	0.14	21.00	155×	63×
Oil	0.03	15.38	463×	7×
Gas	0.001	5.59	5380×	578×
Nuclear	0.02	0.98	52×	3×
Biomass	0.00	6.96	n/a	n/a
Hydro	0.00	1.35	n/a	n/a
PV	0.84	0.84	n/a	n/a
Wind	0.002	0.353	170×	n/a
Fuel	*Range across studies: Low-end (bil USD/year)*	*Range across studies: High-end (bil USD/year)*	*High estimate as multiple of low: Across studies*	*High estimate as multiple of low: Within study*
Global total[c]				
All fossil electric	90	3070	34×	
Nuclear	5	31	6×	
Renewable electric	1	16	16×	

[a]Composition of literature reviews differs, and global total estimates will not necessarily align with scaling the per kWh values by global energy production. Data have been scaled to 2012 USD.
[b]Burtraw et al. (2012).
[c]Kitson et al. (2011).

Beyond the international agencies, scores of studies addressing particular fuels and regions continue to be released by governments, industry, and NGOs. In theory, integrating these more localized assessments with multicountry data could provide a better picture of both aggregate subsidies and relative subsidies by fuel. In practice, differences in methodology, policies evaluated, and time periods analyzed make data consolidation quite difficult to do.

Of the published global subsidy totals, most come via consumer subsidies to fossil fuels, though support to renewables (primarily wind, solar, and liquid biofuels) has been growing sharply in recent years. As there has never been a full global inventory of energy subsidies, these existing estimates likely underestimate the true magnitude of energy subsidies by a substantial margin.

Nuclear power, for example, is subsidized throughout the world via shifting of liability, capital subsidies, nationalization of responsibility for radioactive waste, and a variety of subsidies to mining, enrichment, and decommissioning. But a small portion of this shows up in global data sets. More systemically, producer subsidies in non-OECD countries, credit and insurance subsidies worldwide, and all types of subsidies provided by state, provincial, and municipal governments are not well characterized. Cross subsidies in bulk fuel transport and power grids are often overlooked as well though can tip energy markets to centralized power or bulk conventional fuels such as oil and coal.

The types of instruments included or excluded in a subsidy review also vary across assessments, with significant effect on which energy resources appear to be most subsidized. For example, assessments that do not include liability caps for accidents and capital subsidies will systematically understate subsidies to nuclear and newer coal technologies. Those that exclude subsidies to energy security understate subsidization of oil and nuclear. Failure to internalize pollution or health externalities generates subsidies primarily to coal and oil. Exclusion of tax breaks entirely is common in reviews of developing countries. Because tax breaks most often benefit more powerful incumbent industries, these gaps likely understate support to conventional fuels. Similarly, assessments that provide no data on historical levels of support will capture more recent shifts in subsidies to renewable technologies, but will also overstate the degree to which these resources have benefitted from public support over time.

Subsidy Reform

Subsidy reform is likely to generate environmental gains. A recent assessment by the IMF suggests that removing subsidies and adjusting energy taxes to levels commensurate with other goods and services would cut energy-related global greenhouse gas emissions by 15%, as well as generating significant reductions in the emissions of SO2 and pollutants (IMF, 2013). OECD modeling of reform suggests that removing fiscal subsidies to fossil fuels in 37 mostly non-OECD countries could reduce world greenhouse gas emissions by 6–10% in 2050 (and higher in Russia and the Middle East/North Africa countries). This would comprise about one-seventh of the reductions needed to keep global warming below 2 °C (Burniaux and Chateau, 2011; OECD, 2012a). Given the hundreds of billions of dollars involved with current subsidies, reforms would also reduce fiscal expenditures in many countries throughout the world, though achieving these savings can be politically challenging.

In recent years, energy subsidies and subsidy reform have attracted increasing attention from many international governmental and nongovernmental organizations. An IMF review of reform efforts does identify a number of them that have succeeded (IMF, 2013). Yet, the continuing massive scale of global energy subsidies underscores the fact that far more would need to be done if interventions in energy markets are to be better aligned with fiscal and environmental goals.

The limited traction of subsidy reform over many decades reflects the role of political economy in subsidy creation, continuation, and reform. Who gets public resources is often an intensely political decision. Powerful groups in society are best positioned to institute policies that generate transfers to themselves. Furthermore, the theory of rent seeking indicates that groups that have received subsidies in the past will invest at least a portion of those gains to ensure that the subsidies keep coming. Where subsidy reform has been attempted, fiscal distress of the central government has often been the trigger. Yet, rapid changes in prices have too often triggered riots and subsequently the partial or full rollback of the reforms.

Fossil, nuclear, and hydro energy sources all have been around for a long time, involve large companies and/or large government ministries, and have sufficient scale to dedicate staff to political lobbying. In addition, because the cost of many subsidies rises as the installed base eligible for them grows, the large installed base of fossil also contributes to these resources capturing the lion's share of subsidies.

Given the strong political opposition to subsidy reform, a transitional process to precede policy change with much increased transparency makes sense. Initial steps to qualitatively identify and describe subsidies seem simple but can greatly change the political dynamics of subsidization by making recipients more visible to their competitors and the taxpayers. Quantifying the value of these transfers is the next step and helps policymakers to prioritize which subsidies are most important to address first. Quantification also increases the political costs to wealthier subsidy recipients of lobbying against reform. Past efforts to establish broad reporting of fiscal subsidies have included the Agreement on Subsidies and Countervailing Measures via the World Trade Organization and a 2009 commitment by the G20 countries to phase out many fossil fuel subsidies. These initiatives lack a viable enforcement mechanism for inadequate, inaccurate, or late subsidy reporting and as a result have not been successful to date.

Just as is required in corporate financial reporting, data gathering and reporting on energy subsidies must utilize consistent and transparent valuation approaches. In this way, subsidy estimates done for different countries, or prepared by different researchers, can be more easily compared and aggregated into a larger data set or time series. Reaching consensus on subsidy definition and valuation has been challenging, at least in part due to political benefits to some groups from delay. Independent oversight organizations, such as the International Accounting Standards Board, have proved of great value in establishing standardized rules and a transparent process for financial accounting, and a similar structure could be quite useful to address energy subsidy accounting as well. Separating externalities from fiscal subsidies in data reporting, as well as applying consistent rules on subsidy offsets (e.g., fees from users), are two fairly simple additional steps that could enhance data comparability across analyses.

Modeling the impacts of these transfers on human, environmental, and fiscal health is an important complement to subsidy measurement. Demonstrating policy winners and losers can highlight the need for transitional policies; quantifying the fiscal and social cost of status quo can mobilize pressure to overcome resistance from current subsidy beneficiaries. Transitional approaches that decouple payments from practices that harm human health or the environment may be one path forward. Making eligibility for continued receipt of existing subsidies contingent on acceptable environmental practices is another. Finally, new or replacement subsidies should be structured to leverage competitive markets (as do the RPSs) rather than providing support whether or not there is a successful outcome.

Conclusion

Subsidies remain a large, though increasingly recognized, presence in energy markets throughout the world. The scope, complexity, and politics of these policies help to explain why there is not yet global subsidy data set. However, all indications are that these subsidies cost hundreds of billions of dollars per year, impede market penetration of cleaner and more efficient methods of providing energy services, and increase damages to human health and the environment. Efforts to overcome the inherent political resistance to subsidy reform are needed, if only to greatly improve the ability to identify, describe, and quantify subsidies to particular fuels throughout the world.

Acknowledgments

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