ECONOMICS

The real cost of energy

All energy production has environmental and societal effects. But calculating them — and pricing energy accordingly — is no easy task.

BY ERICA GIES

Luang Prabang in Laos — a city chock-a-block with gilded Buddhist temples — sits at the confluence of the Nam Khan and Mekong rivers. At all hours of the day, people can be found dotted along the shallows, standing in the water and catching fish with hand-held nets. This type of subsistence fishing supports about 60 million people living along the 4,350 kilometres of the mighty Mekong — but maybe not for long. Laos and other countries — China, Myanmar, Cambodia, Thailand and Vietnam — are on a dam-building spree, which will reduce the water flow in the Mekong and prevent the passage of fish, threatening the livelihoods of these subsistence fishers, diminishing biodiversity and flooding cultural sites.

In the world of economics, these are examples of externalities: costs of doing business borne not by the company, but by the environment and society. Electricity production is rife with externalities. Mining for raw materials often causes water pollution, habitat destruction and socio-economic harm. Burning coal pollutes the air, sickening and killing people, and introduces toxic mercury into the aquatic food chain. Nuclear-power plants require the clean-up and maintenance of radioactive materials after decommissioning. Energy production uses water, sometimes at the expense of agriculture and ecosystems. Centuries of fossil-fuel use have released more than 1 trillion tonnes of carbon dioxide and other greenhouse gases, causing climate change that is already leading to a rise in sea level, extreme storms and droughts. If this continues unchecked, it will amplify the damage it is already causing to infrastructure and businesses, threatening global food security and undermining political stability.

"Economists are the first to admit that these issues are classic market failures," says Adele Morris, policy director for Climate and Energy Economics at the Brookings Institution, a global public-policy think tank in Washington DC. Market failures are inefficient allocations of goods and services, such as when an individual (say, an energy-company chief executive) benefits at the expense of others being made worse off, such as the Laos fishers. Externalities are a type of market failure in which the price of energy does not reflect its real cost to society and the environment. "But," Morris adds, "it's a little easier said than done to know what those damages are and to appropriately account for them."

Despite the challenges, economists are trying to put a price on some of these impacts. Many think that you can achieve a more equitable outcome by assigning an 'accurate' price to a good. Ian Parry, an environmental fiscal policy expert for the International Monetary Fund, wrote in a 2016 article that accurate prices redirect "investment and financial flows towards low-emission technologies", effectively incentivizing technologies with lower externality costs (see go.nature.com/2iovdt5). Getting prices right would reduce global carbon emissions by 25% and reduce premature deaths from fossil-fuel air pollution by 60%, he says. Efforts to correct prices are already beginning to turn humanity's energy ship around. The world's dramatic retreat from coal in recent years is Exhibit A.

Dams threaten the livelihood of fishers on the Mekong River.

SANGKHOM HUNGKHUNTHOD/GETTY IMAGES

ACCOUNTING FOR COAL

On a trip to China in June 2006, I was standing in the broad, empty space of Beijing's Tiananmen Square, but it still felt claustrophobic — there was a dark-grey haze hanging over the city, cutting visibility to about 10 metres. It seemed as if my eyeballs needed windscreen wipers. My lungs burned and my breathing was shallow. The nasty cough I picked up persisted for a couple of months after my return to the United States. It wasn't so long ago that Western cities also suffered obvious air pollution from burning coal: London's infamous Great Smog of 1952 left as many as 12,000 people dead, and a smog on Thanksgiving weekend in

1966 in New York City killed 168 and cut short the lives of several hundred more.

These dire events inspired clean-air legislation, which obliges coal plants to control the emission of particulate matter, sulfur oxides, nitrogen oxides and, more recently, mercury by installing filters. "These devices aren't free," says Frank Ackerman, principal economist at Synapse Energy Economics, a research and consulting firm in Cambridge, Massachusetts. "And once you bolt three or four of them onto a coal power plant, coal-fired electricity isn't cheap any more." By requiring plants to invest in countermeasures to air pollution, the legislation implicitly put a price on some of the human health impacts of coal pollution. And by making coal more expensive, clean-air regulations also reduce pollution, as alternatives to coal become more cost-competitive.

That's not to say coal is now clean, even in power plants that abide by the clean-air regulations, because not all emissions are eliminated. "In the United States, air pollution from burning fossil fuels is still estimated to account for tens of thousands of premature deaths per year," says Daniel Shawhan, who models the economic and environmental effects of electricity policies at Resources for the Future, a think tank in Washington DC that applies economics to environmental policy questions. "In China, which is less regulated, it's more like 1 million deaths per year, primarily from coal."

Under clean-air regulations, companies have no incentive to reduce emissions lower than the required standard, explains Morris. Most economists agree that a tax on all emissions would be more efficient because companies "would have an incentive to control emissions up to the point at which it is cheaper to pay the tax", she says. Some places in the world, such as British Columbia and Norway, have taxed CO_2 to some extent; however, an economy-wide tax has proved to be a difficult political proposition in the United States, a situation that is unlikely to improve under the current administration.

But in rapidly industrializing countries such as China and India, citizens have been increasingly demanding clean-air regulations as air pollution chokes their cities, says Ackerman. Such demands have helped to galvanize China's big investments in solar and wind energy, bringing down prices for these technologies worldwide. As prices have plummeted over the past few years, there's been a marked technology shift, such that many countries, including China, South Africa and India, are cancelling or delaying planned coal plants and dramatically expanding solar and wind development.

COST OF CARBON

Air pollution from coal is a short-term, local externality, meaning that people who live near the coal plant experience the negative impacts almost immediately. Climate change, however, is a long-term, global externality: the impacts are felt farther in the future and around the world. That makes the causal link less obvious, helping people to avoid paying for or even addressing it. Nevertheless, economists have been attempting to measure the costs of climate impacts to put a price on CO_2-equivalent emissions, a measure that calculates the global-warming potential of all greenhouse gases in units of CO_2.

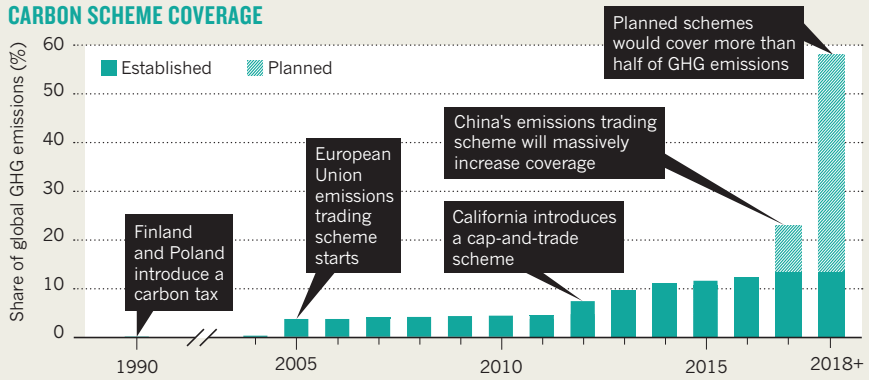
More than 40 countries now have national carbon-pricing schemes, says Parry, yet this covers only about 13% of global greenhouse-gas emissions (see 'Carbon going cheap'). According to the World Bank report *State and Trends of Carbon Pricing 2016*, this could jump to 20–25% if China follows through on its announced national emissions trading scheme. However, 75% of included emissions are valued below US$10 a tonne: too low to limit warming to 2 °C, the target of the Paris agreement. "So far we haven't seen prices at a level that would change behaviour," says Severin Borenstein, an energy economist at the University of California, Berkeley. To hold to Paris targets, the price would need to be $40–80 per tonne by 2020 and $50–100 per tonne by 2030, according to the Carbon Pricing Leadership Coalition, a voluntary partnership of governments, businesses and civil-society organizations. Other analysts place the figure even higher.

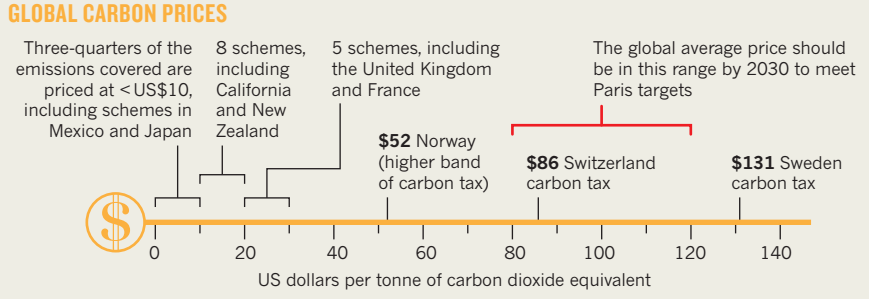
The United States, the world's second-largest emitter of greenhouse gases after China, still notably lacks any sort of carbon-pricing scheme. But, in 2009, then-president Barack Obama assembled an inter-agency working group to calculate a social cost of carbon (SCC). An SCC — used by many countries around the world — estimates future economic loss caused by emitting one tonne of CO_2 today. The United States wanted an SCC to use as a budgetary yardstick to compare against the cost of programmes designed to cut emissions. Externalities weighed in the US SCC calculation included property damage from increased flood risk; declines in agricultural productivity; human health impacts, such as heatwave deaths and increases in mosquito-borne illness; and even the value of ecosystem services, such as coral reefs that protect shoreline infrastructure.

To calculate its figure, the working group used established computer models that analyse growth in population, economies and emissions; probable climate change and impacts; and costs of climate impacts, such as flooding damage in coastal cities caused by sea-level rise. The working group took the models' estimates of a global SCC and added its own assumptions about economic and population growth, the mean global temperature if CO_2 in the atmosphere doubled, and how to convert future damage costs into today's dollars, says Joseph Aldy, a public-policy researcher at Harvard University in Cambridge, Massachusetts, and a member of the group. The most recent figure from August 2016 — $40 per tonne — was used in policies across the Obama administration.

CARBON GOING CHEAP

About 100 of the signatory countries to the 2015 Paris agreement will reduce their greenhouse-gas (GHG) emissions by putting a price on carbon. But the United States, the world's second-biggest GHG emitter, has no plans for a carbon scheme — and schemes that do exist are mostly charging too little.





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Smog killed thousands of people in London in the 1950s.

However, in March this year, US President Donald Trump signed an executive order on energy independence that disbanded the working group and instructed agencies to produce their own SCC estimates. "My guess is that, instead of using a global SCC, they will use a domestic-only measure," says Aldy. One approach to calculating a domestic-only measure is to scale the worldwide figure using the United States' share of global economic activity. Because the United States accounts for about 25% of the global economy, that works out to about one-quarter of the international price. The net result is that the SCC for many agencies is likely to be lower than the working group's — perhaps around $10 a tonne, says Aldy. With that lower price as a yardstick, fewer projects to cut emissions will pass muster — which is the point of the regulation.

"What's the value of not killing someone?"

Ackerman says that even $40 a tonne is too low because it is based on conservative models in which climate changes at a steady rate. "They essentially assume that catastrophic events — that many experts worry about — won't happen," he notes. Such events include the abrupt loss of major ice sheets, ocean acidification passing a certain value, the collapse of the Indian monsoon and rapid dieback of the Amazon rainforest. Such tipping points could suddenly trigger a series of catastrophic changes that weren't accounted for in the gradual models. Aldy defends the process he was involved in: "I'm not going to say $40 is right. But I think it's a credible estimate."

One of the key judgement calls in the SCC calculation is something called the discount rate: "the most important number you've never heard of", says Ackerman. Carbon dioxide emitted today will remain in the atmosphere for hundreds of years causing damage. But instead of paying those future costs in full now, economists employ a discount rate — like compound interest on a savings account, only in reverse — to determine what it is worth to us now to reduce costs in the future. A higher discount rate, say, 5%, generates a lower SCC today, effectively giving ourselves a price break in exchange for future people paying more. For that reason, some people consider higher rates unethical and advocate for a number closer to zero. The working group used a 3% discount rate to arrive at $40 per tonne.

IN THE FLOW

Externalities other than air pollution and climate change have received little attention by comparison. Few models consider the water footprint of various energy sources, for example. It's difficult to create a meaningful economic metric for water use, say economists, because water availability and its price vary so much from place to place. But for energy production, water scarcity can be catastrophic: a low river flow can cut hydropower dramatically, as happened for months in southern Africa following the 2015–16 El Niño drought. Nor can it provide sufficient cooling for coal and nuclear plants, forcing shutdowns — as has happened in India, Europe and the United States in recent years.

Other externalities aren't accounted for at all. Consider Hasankeyf, a charming town on the Tigris River in eastern Turkey, set against sculpted limestone cliffs. It's one of the oldest continuously inhabited towns on Earth: over more than ten millennia it has been claimed by numerous legendary civilizations, including the Romans, Byzantines and Ottomans. Some of the town's homes are caves that have been hollowed out of the limestone. Three carved stone pillars linger in the river, ruins of a twelfth-century bridge, and hundreds of other medieval monuments are still standing. On a visit in 2012, I saw restaurants on the banks of the Tigris with views of that ruin from decks hanging over the water; trucks idled at dusk, waiting for a seemingly endless line of sheep to cross the town's modern bridge.

Hasankeyf will probably be under water within two years, as Turkey proceeds with plans to build the Ilisu dam. As the project has moved along over the past several years, anthropologists, Hasankeyf lovers and local people have protested against the loss of the cultural treasure. In 2009, activists petitioned for Hasankeyf to be declared a World Heritage Site, and international investors pulled their funding for the dam. But Turkey has been riding an economic boom and has been able to use local funding to proceed, ignoring international concerns. It is building homes for people beyond the reservoir line, and a museum to house some of the artefacts that will otherwise be flooded. In May this year, Turkey moved a fifteenth-century tomb, the Zeynel Bey monument, to a new location, and is planning to move others.

Because people have historically lived near rivers, hydropower is prone to cultural externalities like the flooding of archaeological sites. But other energy technologies are not immune to externalities: for example, environmentalists successfully sued to downsize the Panoche Valley Solar Project being built in central California, saying it would harm endangered giant kangaroo rats and San Joaquin kit foxes.

PRICE FOLLIES

One reason decision-makers aren't concerning themselves unduly with water or cultural costs, aside from the difficultly of pricing them, is that increases in premature human deaths caused by air pollution "dominate an economic analysis", says Aldy. For example, for electricity generation from coal, more than 90% of calculated damage costs are for premature human mortality, according to the report *Hidden Costs of Energy* by the US National Research Council.

Human mortality dominates the economic models because that is what society has deemed to be valuable; endangered-species survival, unique habitats and historical sites are deemed lesser concerns, and are valued as such. But just how valuable is a human life? Economists use a variable called the value of a statistical life, which is the amount of money society is willing to spend to save a life. But putting a price on a life raises ethical issues, says Ackerman. "What's the value of not killing someone? And the bonus question is: should it be a larger number in a richer country?" It's also unclear what that figure actually means. "If we've gotten up to $9 million per statistical life in the United States," he says, "that doesn't mean for $10 million you can kill someone with impunity." Also, he adds, the practice of trying to put a price on the priceless can create "misleading theories on how to think about the world". Things such as human lives, irreplaceable species, unique habitats and cultural sites clearly have value. Ackerman sums up this thought by paraphrasing the philosopher Immanuel Kant: "Some things have a price, and other things have a dignity."

Still, if there's any hope of energy companies paying for externalities, it follows that these impacts should be translated into costs — the language that businesses and governments speak. And although more could be done to account for damage to culture, the environment and water resources, global society has won moderate successes in requiring coal to be burned more cleanly and in the pricing of carbon. These are already changing the energy projects we build, helping society to transition away from fossil fuels and towards cleaner energy. ■

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