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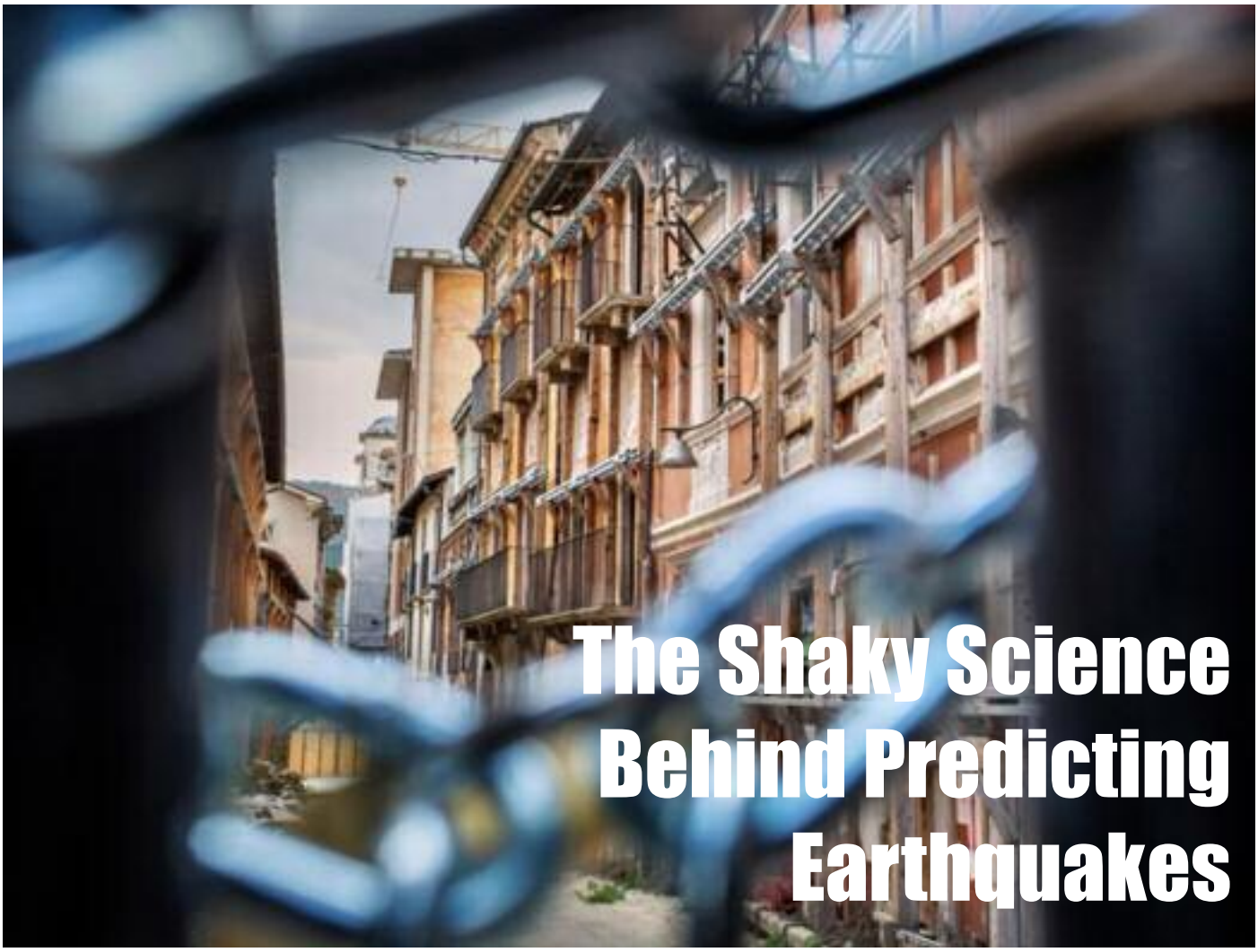

The Shaky Science Behind Predicting Earthquakes

Bringing the age of steam into the information age

Stalling emissions: a temporary blip?

The world's first climate positive data center

The Monsanto Fears

YEAR I - NUMBER 3 - JULY-SEPTEMBER 2015

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Only Natural Energy

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The world's first climate positive data center is built in Sweden

The world's first climate positive data center is now being built in the city of Falun, Sweden. It will be one of the 13 safest in the world, meeting the highest security requirements with world-class performance.

Up to 10 percent of the world's electricity is consumed by the Information and Communications Technology sector alone. ICT is emerging as a new target area in terms of energy efficiency. There are currently over three million data centers globally and the growing cost of powering them is plain to see.

A single data center can easily use more electricity than a mid-sized town. A large part of this energy is never used, but simply released as heat into the atmosphere. According to several reports the combined carbon dioxide emissions from these data-centers are expected to exceed the emissions from the entire airline industry in only five years.

"This development implies an increased need for energy, which also affects the environment to a great extent. It is also a cost-driver, which requires a new way of thinking", says Børge Granli, one of the founders of EcoDC AB.

Sweden has proven to be an excellent and safe location for data centers due to its cold climate, reliable and renewable energy sources, political stability and lack of natural disasters. The Cushman & Wakefield and Hurleypalmerflatt Data Centre Risk Index ranks Sweden as the third safest

location for data centers in the world, after the US and UK. EcoDataCenter is projected to attain the highest level of availability according to Uptime Institute Tier IV™, something only twelve other data centers in the world have managed to attain to date.

Falun Data Center will be connected to the local energy system, which in 2013 was praised by Global District Energy Climate Award 2013 in New York as one of the world's best. The excess heat from the servers and IT equipment will warm the buildings in Falun through the district heating system. In the summer time, excess steam from the local electricity plant will run the machines cooling the data center.

"We are connecting the data center to an already sustainable energy system and can make use of all the energy. Thereby we are building the very first climate positive data center in the world", says Bengt Gustafsson, CEO of Falu Energi & Vatten. The electricity powering Falun data center comes only from solar, wind and water power as well as secondary biofuels. The first building of three will be completed in the first quarter of 2016.

SARDINIA
Technology & Nature

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SOTACARBO

Stalling increase in emissions: a new trend or a temporary blip?

By JEZ ABBOTT

ONE

Spring, the season of new beginnings, also marked the beginning of something new. In March came data from the International Energy Agency (IEA) indicating global emissions of carbon dioxide from the energy sector stalled in 2014. This, according to the IEA, is the first time in 40 years there has been a halt or drop in emissions of greenhouse gas that was not tied to an economic downturn.

"This gives me even more hope that humankind will be able to work together to combat climate change, the most important threat facing us today," IEA chief economist Fatih Birol said in the month of budding blooms and rising temperatures. Birol's global organisation works to ensure reliable, affordable and clean energy, so this latest finding was particularly good news.

Global emissions of carbon dioxide stood at 32.3 billion tonnes in 2014, unchanged from the preceding year. The IEA data suggest efforts to slow climate change may be having a more profound effect on emissions than previously thought. The IEA attributes the halt in emissions growth to changing patterns of energy consumption in countries such as China.

In China, 2014 saw more generation of electricity from renewable sources such as hydropower, solar and wind, and less burning of coal. Meanwhile efforts in countries of the Organisation for Economic Co-operation and Development (OECD) to drive sustainable growth seem to be doing just that - decoupling economic growth from emissions, according to the IEA.

Professor Corinne Le Quere, based at the Tyndall Centre for Climate Change Research at the University of East Anglia in England, added to the IEA debate. "An important factor could be that China's coal consumption fell in 2014, driven by their efforts to fight pollution, use energy more efficiently and deploy renewables," she told the BBC.

Efforts to reduce emissions elsewhere would have played a role, but there were more random factors such as the weather and oil, coal and gas prices, she added. Several factors, therefore, could have led to this welcome news. IEA has collected data on carbon dioxide emissions for 40 years, but there have been only three times when emissions stood still or fell against the previous year. And all were associated with global economic weakness: the early 1980s; 1992 and 2009. In 2014, however, the global economy expanded by 3%. The IEA insists "this is no time for complacency", nor is it a time to "stall further action" on the environment.

The UK government's former energy and climate change secretary Ed Davey, who was replaced after the general election this May, agreed back in March when the figures were first released. They proved green growth

was achievable not just for Britain but for the world, he said.

"However, we cannot be complacent. We need to dramatically cut emissions, not just stop their growth. Getting a new global climate deal is absolutely vital, and the year ahead is going to be of critical importance. The UK must stay the course and continue to show strong, decisive leadership in Europe and globally."

Need for caution becomes even more pronounced following another report, published three months later in June. Writing about this report in the British newspaper *the Guardian* Dr John Abraham, a professor of thermal sciences, drew attention to the recent talk of global warming on cable news and from online bloggers that suggested a hiatus or a halt to global warming.

Not so according Dr Abraham, who insists there is no halt and never has been. He drew attention to the report, called Possible artifacts of data biases in the recent global surface warming hiatus. Lead researcher Dr Thomas Karl and colleagues looked at the near-surface temperature records and asked whether they really suggested a slowdown. The team took into account several factors.

For example they noticed ocean surface temperature measurements from floating buoys differed from those taken by ship-board sensors. The latter are often warmer than temperatures measured by buoys because of the heat generated by the ship engine. They also factored in historical changes to how ships measured surface temperatures and their effectiveness.

"The end result," according to Dr Abraham in the Guardian, "is that temperature trends over the past 17 or so years have continued to increase with no halt. In fact, it has increased at approximately the same rate as it had for the prior five decades." He adds: "What this new paper shows is that the warming in the recent years has not stopped and has not even slowed down."

Dr Karl told the newspaper: "Considering all the short-term factors identified by the scientific community that acted to slow the rate of global warming over the past two decades (volcanoes, ocean heat uptake, solar decreases, predominance of La Niñas, etc) it is likely the temperature increase would have accelerated in comparison to the late 20th century increases. Once these factors play out, and they may have already, global temperatures could rise more rapidly than what we have seen so far."

Even more need for caution on the issue is also due in part to uncertainty on the cause of the alleged pause in emissions. Is it due to national and international policies or economic forces? Back in China, for example, coal forms almost two-thirds of the energy mix. But reduction targets, better technology and a lull in heavy

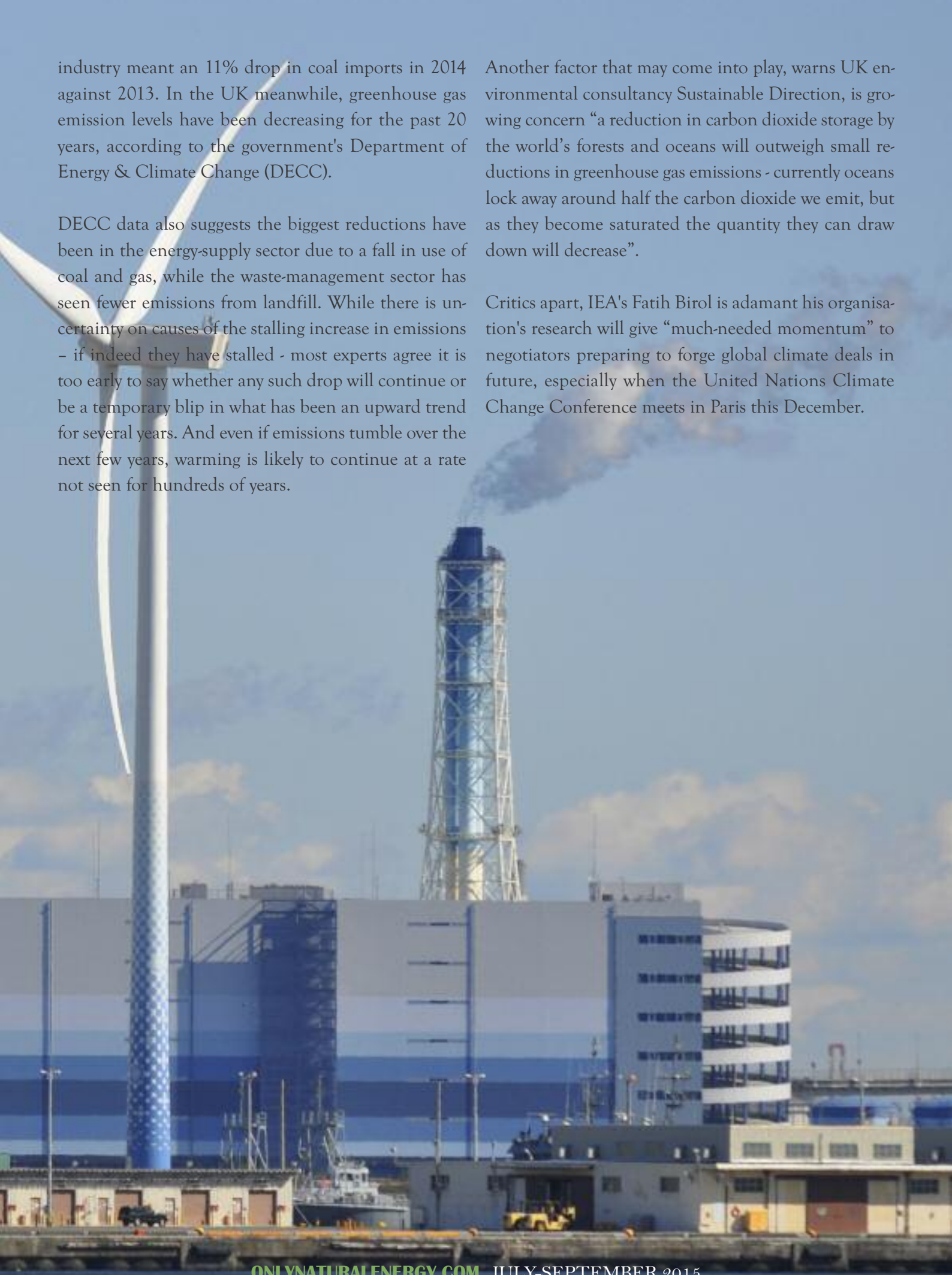
Yokohama Power Station. **Photo credit: ISTOCK**

industry meant an 11% drop in coal imports in 2014 against 2013. In the UK meanwhile, greenhouse gas emission levels have been decreasing for the past 20 years, according to the government's Department of Energy & Climate Change (DECC).

DECC data also suggests the biggest reductions have been in the energy-supply sector due to a fall in use of coal and gas, while the waste-management sector has seen fewer emissions from landfill. While there is uncertainty on causes of the stalling increase in emissions – if indeed they have stalled - most experts agree it is too early to say whether any such drop will continue or be a temporary blip in what has been an upward trend for several years. And even if emissions tumble over the next few years, warming is likely to continue at a rate not seen for hundreds of years.

Another factor that may come into play, warns UK environmental consultancy Sustainable Direction, is growing concern "a reduction in carbon dioxide storage by the world's forests and oceans will outweigh small reductions in greenhouse gas emissions - currently oceans lock away around half the carbon dioxide we emit, but as they become saturated the quantity they can draw down will decrease".

Critics apart, IEA's Fatih Birol is adamant his organisation's research will give "much-needed momentum" to negotiators preparing to forge global climate deals in future, especially when the United Nations Climate Change Conference meets in Paris this December.



Fossil Fuels (emissions) here to stay

By EUSEBIO LORIA

ONE

31 percent of GHG emitted globally on an annual basis comes from 32 global energy companies and the population's use of their products.

Gone are the days of the fossil fuels golden age but we are still in a period of abundance. New supplies added to the world market have sent the price of oil plummeting by 40-60 percent and large amounts of new, cheaper carbon are now in our global energy pipeline. These shifts in global conditions raise important questions about the sources and global impact stemming from an abundance of carbon-intensive energy.

A Thomson Reuters's new research – *Global 500 Greenhouse Gas Report: The Fossil Fuel Energy Sector* – reveals greenhouse gas (GHG) emissions data from 32 global energy companies, a subset of the world's largest publicly traded businesses. Data around consumers' use of a company's products are included to present a fuller view of the business's overall contribution to GHG emissions.

From 2010 to 2013, GHG emissions from the 32 energy companies and use of their products increased by 1.3 percent – a sharp contrast to the United Nations Environmental Program (UNEP), which recommended in 2014 a 4.2 percent reduction of GHG emissions over the same time period to keep global temperatures within manageable limits.

"Since our last report, energy prices have decreased dramatically, economic conditions continue to improve and consumer habits remain unchanged, yet the data suggests that more progress needs to be made in cur-

Credit @Vincent Kessler,Thomson Reuters

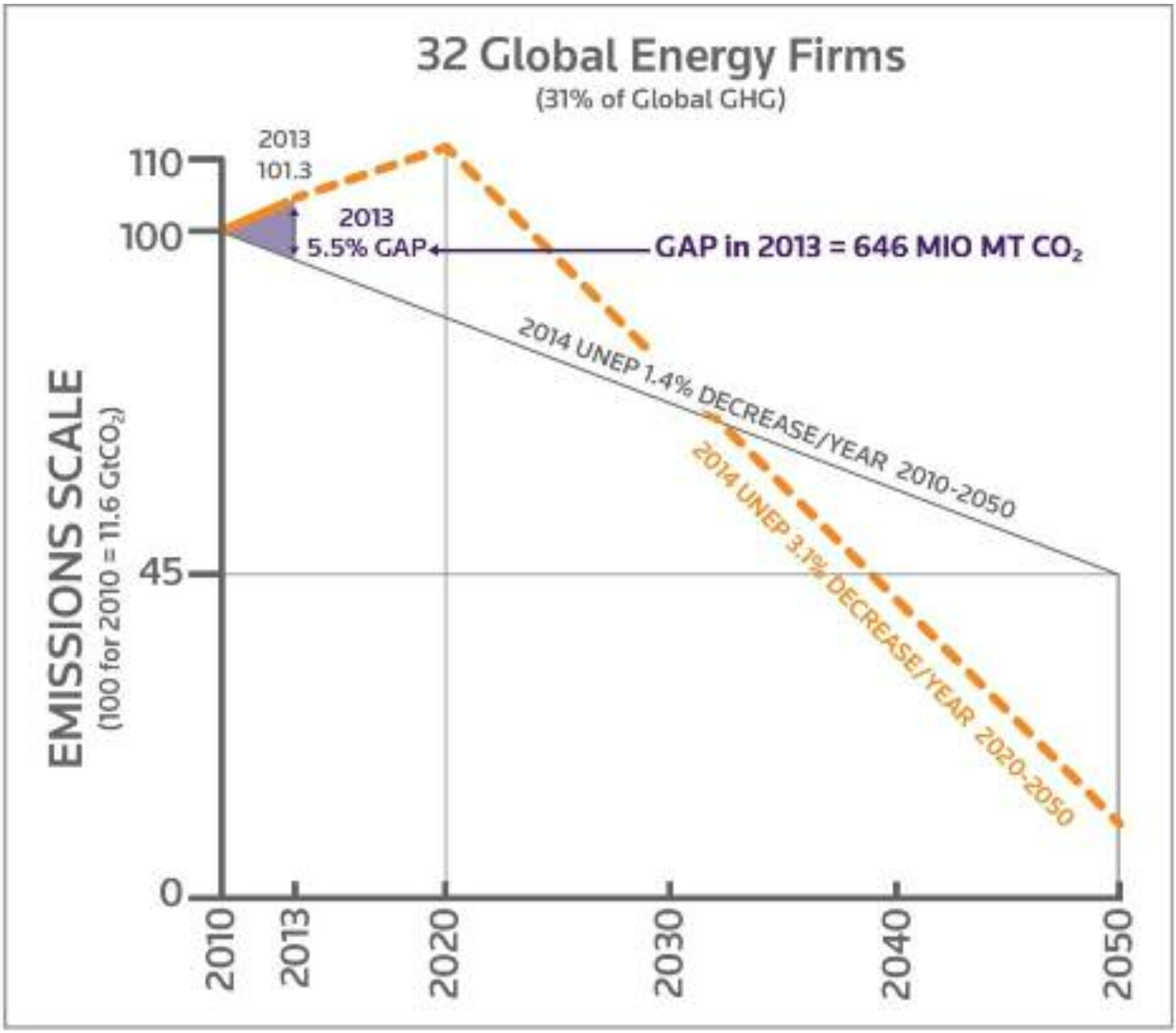


Figure 2. 32 Global Energy Firms

Source: Global 500 GHG report- Fossil fuel energy sector
Energy companies emitting a total of 31% of GHG on an annual basis 2013 and 2010

bing greenhouse gas emissions," said Tim Nixon, director of Sustainability at Thomson Reuters, and a co-author of the report. "While energy companies will need to play a leading role reducing greenhouse gas emissions, consumers and regulators must also play important roles if global greenhouse gas emissions are to be reduced."

In addition to contributions from the Carbon Disclosure Project and the Climate Accountability Institute, self-reported GHG emissions data was gathered from energy sector businesses and combined with estimates pulled from ASSET4 – a TR leading provider of environmental, social and corporate governance (ESG) data. ASSET4 gathers standardized, objective, quantitative and qualitative ESG data on more than 4,800 publicly listed companies.

"The main goal of this new report is to provide for greater transparency into this important sector of the Global 500 from a greenhouse gas perspective," said John Moorhead, executive manager of BSD Consulting, and co-author of the report. "If we are to balance our needs for energy with our harmful effects on our environment and subsequent generations, it is critically important for energy consumers and producers alike to reduce total fossil fuel consumption, particularly in its most carbon intensive forms, and achieve the target of 1.4 percent or greater yearly reduction in GHG emissions." Very distant goal. And we have done very little so far.

Photo: JOE KLAMAR / AFP

The Shaky Science Behind Predicting Earthquakes

By ELIZABETH KOLBERT

Smithsonian Magazine

A powerful earthquake in Italy killed hundreds of people and set in motion a legal battle and scientific debate that has kept seismologists on edge.

It ís a typical day and Italy is shaking.

I am standing in the monitoring room at the National Institute of Geophysics and Volcanology, in Rome, and I watch the earthquakes taking place in real time. At least two people staff the room 24 hours a day, 365 days a year. The quakes—*terremoti*, or earth motions, as they say in Rome—pop up as red, yellow and black dots on a series of screens that cover the front wall. When I arrive, just before noon, there have already been four quakes of a magnitude greater than 2.0 recorded that morning in Italy. There have also been 16 smaller quakes. Most of these have been concentrated in an area northwest of Florence, which is experiencing what's known as an earthquake "swarm." By the time I leave the room, an hour or so later, two more terremoti have jolted the area.

"It's a quiet day," Giulio Selvaggi, a seismologist at the institute, tells me. Selvaggi is a trim man with dark hair, light eyes and a dry wit. "For the moment," he adds.

Thanks to the northward drift of Africa, the "boot" of Italy is gradually being compressed, like a leg being pushed from below. Meanwhile, for reasons no one entirely understands, the country is also expanding laterally, like a thigh growing wider. The net result is that Italy is known, perhaps euphemistically, as "seismically active."

Small earthquakes happen all the time; every decade or so, there's a major one. (Repeated quakes are one of the main reasons ancient Rome now lies in ruins.) A sequence of quakes in Assisi in 1997 killed at least ten people and destroyed a series of world-renowned frescoes in the Basilica of San Francesco. In 2002, twenty-seven schoolchildren died in the southern region of Molise when a quake destroyed the roof of their school.

Today, whenever there's an earthquake in Italy of a magnitude greater than 2.5, one of the technicians in the monitoring room in Rome picks up a red phone and reports it to the country's Department of Civil Protection. This way, the department can explain to nervous citizens why their pictures have dropped from the walls or their dishes have rattled. What would be a lot more useful, of course, would be a system that alerts residents minutes, hours or better still days in advance of a quake. People could then take real precautions. They could secure artworks and other valuables. They could fasten down their furniture and evacuate their homes.

The most recent major earthquake struck in April 2009, in the mountainous region of Abruzzo. More than 300 people were killed, thousands were left homeless and the picturesque center of the region's capital, L'Aquila, was left in ruins. Outside the region, the L'Aquila earthquake is famous not so much for the devastation that it caused as for the legal battle that ensued, one that essentially put the science of earthquake prediction on trial.

The city of L'Aquila sits about an hour and a half northeast of Rome, on a hilltop shadowed by some of the highest peaks of the Apennines. The mountain chain, which runs down the center of Italy's leg, like the seam of a stocking, is among the country's most seismically dangerous areas, and it has a long history of tragedy. In 1461, a quake largely destroyed L'Aquila; this happened again in 1703. A magnitude 6.9 quake centered in the nearby town of Avezzano killed more than 30,000 people in 1915. The L'Aquila quake six years ago had a magnitude of 6.3 and, because its center was close to the surface of the earth, it was unusually destructive.

The drama of the 2009 earthquake began in the fall of 2008, when L'Aquila experienced a seismic swarm. Dozens of tremors shook the city, most too minor to be felt. The swarm continued through the early months of 2009, and some of the tremors were powerful enough to prompt school evacuations. People began to worry that the shaking was a sign that a disaster was imminent. Their anxieties were heightened by an amateur seismologist named Giampaolo Giuliani, who claimed he could predict quakes on the basis of radon levels. (Radon, a colorless, odorless radioactive gas, is present in small quantities in most rock formations.) Giuliani had installed radon detectors around L'Aquila and reported seeing levels rise sharply, which, by his account, represented a dire warning.

To address the mounting sense of panic, Italy's National Commission for Forecasting and Preventing Great Risks held a special meeting in L'Aquila. The seismologists present pointed out what was known: L'Aquila was in a high-risk area. Seismic swarms only rarely precede major quakes. Meanwhile, studies had shown that radon spikes had no forecasting value.

A week after the commission met, on April 6, at 3:32 a.m., the quake struck. It lasted only 20 seconds, but the damage was enormous. Survivors described a roaring sound, a hideous shaking and a cascade of debris. "It was like being in a blender," a L'Aquila resident who lost his wife and daughter in an apartment building collapse would later tell the journal Nature.

Grief turned quickly to outrage. How could the experts have failed so badly? One government official from the National Department of Civil Protection had gone so far as to state before the quake that the seismic swarm in L'Aquila had reduced the danger of a major event, a claim based on a misunderstanding of the underlying science. Some residents said this statement had convinced them to stay inside on the night of the quake and that this, in turn, had cost family members their lives. In 2010, six of the scientists who'd participated in the meeting in L'Aquila were charged with manslaughter, along with the government official. One of the scientists was Giulio Selvaggi, then director of the National Institute of Geophysics and Volcanology. "I couldn't believe it," Selvaggi told me of the indictment. "I thought it was a mistake."

The prosecutors in the case argued that, while there might be no way of reliably predicting earthquakes, the scientists were nevertheless criminally negligent, as they'd failed to adequately assess the risk of a quake. To the defendants, this was a distinction without a difference.

"An earthquake is unpredictable, so the risk is unpredictable," Selvaggi said to me. Scientists all around the world—indeed, scientists across fields—condemned the case as a witch hunt tricked out with statistics.

"The charges against these scientists are both unfair and naive," the head of the American Association for the Advancement of Science, Alan Leshner, wrote in an open letter to the Italian president. The American Geophysical Union warned that the case could have a dangerous rebound effect, discouraging scientists "from

advising their government or even working in the field of seismology" because of the legal risks.

The trial, which was held in L'Aquila, lasted more than a year. All those charged were found guilty. Prosecutors had recommended four-year prison terms; the judge handed down sentences of six years. The defendants' guilt, he explained, was "severe." One of those convicted, Claudio Eva, a seismologist from the University of Genoa, called the decision "very Italian and medieval."

The appeal of the L'Aquila verdict took another two years. At its conclusion, the six scientists were all acquitted, though for the seventh defendant—the government official—the verdict was upheld.

At the time I visited Selvaggi, his conviction had just recently been overturned, and he still seemed deeply shaken by the experience. He felt confident that he'd done nothing wrong, but he found the wrath of the victims' families difficult to bear. Meanwhile, his teenage children had a tough time dealing with the negative publicity surrounding the trial. "It was terrible," he said. Alessandro Amato, one of Selvaggi's colleagues at the institute, told me that the damage to the reputations of the scientists will be hard to undo. "The second verdict stated that the scientists were not responsible legally," he said. (Amato, who was not involved in the case, is now working on a book about it.) "But most people still think they are. So many people think we are hiding from our responsibilities, that earthquakes are somehow predictable, but we just don't want to admit it."

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Not long after I visited the Institute of Geophysics and Volcanology, I took a bus from Rome to L'Aquila. A geologist at the institute named Fabrizio Galadini, who works on archaeoseismology—the study of past earthquakes—had offered to show me around. The first thing I noticed as the city came into view were the many construction cranes poised over it, their long, steely arms outlined against the clouds. I counted 30 before losing track.

When I arrived at an enormous piazza in the city center it was almost completely deserted. The buildings lining the piazza—shops, churches, elegant palazzos—were covered in scaffolding. In the window of a defunct bar, a handwritten sign advertised a soccer game scheduled for April 6, the very date the quake struck.

As we walked, Galadini told me about how the city had been built and rebuilt over the centuries, quake after quake. L'Aquila was founded in the 13th century by Frederick II, Holy Roman Emperor and King of Sicily, to counter the power of the Papal States. According to legend, the residents of 99 surrounding villages abandoned their homes to move there. Records of quakes extend nearly as far back: Medieval documents attest to a major earthquake in 1315 and multiple damaging quakes in 1349. Another strong quake struck in 1456, and the quake in 1703 very nearly destroyed the city.

Many of the city's historical buildings were restored after 1703, Galadini said. "Those suffered damages" in 2009, he told me. "But the most dramatic fact is that the strongest damage was not suffered by historical buildings. It was suffered by modern buildings." In one well-known case, a wing of a dormitory constructed in 1965 collapsed, killing 11 university students.

(Photo: Guilbert Gates)

We turned and wandered down a narrow side street. Here, too, the buildings were covered in scaffolding and held together by steel braces. Most were locked up, but occasionally it was possible to peer inside and see men working among piles of rubble. Galadini said he thought some buildings would never be repaired, but would remain as "seismic fossils." We arrived at Santa Maria di Paganica, an enormous stone cathedral con-

structed in the 14th century, which had been restored after the 1703 earthquake. The walls were still standing, but the roof had collapsed. A temporary roof of plastic sheeting had been constructed to keep out the rain, but this was now in tatters. "It's a sort of symbol of the earthquake," Galadini said.

Finally, we got to a newer building, constructed, Galadini speculated, in the 1960s or '70s. The front wall, which had no central support, had completely given way. It seemed that nothing inside had been touched in the intervening six years. In a ground-floor apartment, I could see a jumble of broken tiles and plumbing, piles of clothes, and, on the walls, someone's collection of coasters.

I asked Galadini what he thought the effect of the L'Aquila trial had been. He said it had pushed scientists in Italy to become latter-day Cassandras, always erring on the side of catastrophe. This was true not just in seismology, but also in unrelated disciplines, like meteorology: "If you say a hurricane is coming here, if the hurricane does not affect this area, OK, nothing has happened," he said. "But if a hurricane occurs here, you can say, 'Ah, I told you!' For geologists, seismologists, the effect is quite simple. If people ask me, 'Can you reassure us about the possibility that an earthquake will occur or not?' I say, 'No. I cannot reassure anybody. An earthquake may occur any minute!'"

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People have been trying to predict earthquakes probably for as long as they've lived in structures that could fall down on top of them. The early theories now sound farfetched. Aristotle, for example, thought that quakes could be foretold by looking at the sky. "A little, light, long-drawn cloud…like a long very straight line" was, he wrote, a sign of danger. Modern seismology is often said to have begun with the man who coined the term, an Irish engineer named Robert Mallet. Mallet became curious about the subject in the 1840s, after reading about earthquakes that had devastated Calabria, in southern Italy.

In order to study earthquakes more effectively, Mallet decided to stage some on his own. Using buried casks of gunpowder, he set off explosions in the sand of Killiney Beach, south of Dublin. Then, in December 1857, there was a major earthquake near Naples, which killed 10,000 people. With the help of Charles Darwin, who had a lifelong interest in geology, Mallet convinced Britain's Royal Society to send him to Italy to view the destruction. He concluded—correctly—that earthquakes send out shock waves that radiate in all directions. (He also coined the word "epicenter.") Mallet wasn't sure what caused earthquakes. He believed they were probably the result of some sort of underground explosions. But he realized what people really wanted to know was not so much the why of earthquakes as the when and where.

"It will occur to many to ask, Can the moment of the occurrence or the degree of intensity of earthquake shock be predicted?" he wrote. "It is neither impossible nor improbable that the time shall arrive when…such forewarnings may be obtainable." In other words: perhaps, someday.

A century after Mallet, an explanation for what causes

earthquakes was finally found with the discovery of plate tectonics. When tectonic plates move—as they're always doing, albeit very slowly—their edges can lock. Stress accumulates until, eventually, the locked blocks of rock abruptly slip past each other and the earth rumbles. (The strength of an earthquake depends on a complicated interplay of factors, including the physical properties of the rock and the distance the fault slips as the plates release from their grip.) Plate tectonics made it seem possible that obtaining "forewarnings" might be imminent.

In 1971, the head of Caltech's seismology laboratory said he thought that, once the necessary research was completed, experts would be able to "forecast a quake in a given area" if not down to the exact day then "within a week." Four years later reports reached the United States that Chinese scientists had successfully predicted a large earthquake in the northeastern province of Liaoning. This was in the middle of the cold war, and there was talk of an "earthquake gap" opening up between the East and West. The reports of a successful prediction in Liaoning would, a few decades later, be revealed to have been greatly exaggerated. But by that point, the U.S. Congress had already budgeted tens of millions of dollars to finance research into a reliable method of quake forecasting. Japan, another seismically active country, poured tens of millions of dollars into a similar program.

Plate tectonics suggest that earthquakes ought to occur

in cycles—a rhythm of building stress and release, building stress and release. In 1988, seismologists tested this logic by observing a section of the San Andreas fault near the town of Parkfield, in central California. The area had produced six earthquakes of a magnitude 6.0 or greater since 1857. Researchers concluded that the next one was due within four years. In fact, it did not take place for 16 years. Similarly, the next major quake in the Tokai region of central Honshu, in Japan, was forecast for 2001, 2004 and 2007, but as of this writing has not happened. In a tragic twist, in mid-April seismologists gathered in Katmandu, Nepal, to discuss the dangers of a major quake. They knew the area was vulnerable to disaster but could not foresee the magnitude 7.8 quake that struck the city one week later, killing thousands of people.

Research has also shown that swarms of small quakes of the sort L'Aquila experienced before the 2009 quake—and that Tuscany was experiencing on the day I visited the institute in Rome—have limited predictive value. If a region experiences a swarm, it becomes more likely to experience a large quake. The problem is that it's even more likely not to experience a large quake. Italian geologists who examined seismic data from three earthquake-prone regions found that if a swarm contained a medium-sized shock, it was followed by a major shock 2 percent of the time. This represents a significantly elevated risk, but it means that if you use a swarm to try to predict a major quake, something like

98 out of 100 times you'll be wrong. Most swarms end not with a bang, but with a whimper.

A report by the International Commission on Earthquake Forecasting for Civil Protection, which was set up in the aftermath of the L'Aquila quake, put it bluntly: "The absence of simple foreshock patterns precludes their use as diagnostic precursors."

Studies of radon spikes and bulges in the earth's surface and changes in electromagnetic emissions and fluctuations in groundwater chemistry have all yielded the same negative results. So has research into weird animal behavior. (One of the signs Chinese officials supposedly used to predict the 1975 Liaoning quake was the unusual behavior of the region's snakes, which were seen slithering around in the middle of winter.) Though it's tough to perform a rigorous analysis of bizarre animal reactions, Susan Hough, a seismologist with the U.S. Geological Survey, reported on the "handful" of controlled experiments that have been done in this area in her book Predicting the Unpredictable: The Tumultuous Science of Earthquake Prediction. One study looked at the number of newspaper ads placed by people looking for lost pets. Another looked at the behavior of rodents in earthquake-prone southern California. The studies "never demonstrated any correlation," Hough wrote.

After more than 40 years of intensive research, seismologists have yet to find a signal that can reliably be used to forecast a major quake. "Earthquake science is a field in which the most fundamental problem—reliable earthquake prediction—remains to be solved," Hough observed.

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Of the many seismically active regions in Italy, none, in a manner of speaking, is more active than Cesano, a suburb of Rome about 15 miles north of downtown. There, on the campus of the Italian National Agency for New Technologies, Energy and Sustainable Economic Development, known as ENEA, researchers routinely stage earthquake disasters in the hope of averting them.

The work takes place in an enormous hangarlike building known around the campus as the seismic hall. The building is a sort of architectural bazaar, filled with models of existing and imagined structures. On the day I visited, the inventory included miniature apartment buildings; a small-scale medieval tower; a model of the cathedral dome of San Nicolò All'Arena, in Sicily; and several statues. The apartment buildings, made of steel and concrete, were about 30 feet tall and big enough to walk around inside. Gerardo De Canio, an ENEA engineer who was showing me around, pointed to a large metal plate, 13.5 feet by 13.5 feet, embedded in the floor. This, he explained, was the "shaking table." The table can be programmed to simulate any sort of quake. It could, for example, be set to mimic one of the recent Tuscan tremors or the quake that destroyed the center of L'Aquila.

The question of whether seismologists will ever be able to predict earthquakes is one that still divides the field. To some, the fact that no reliable signal has yet been found simply means more research is needed. To others, it's an indication that such a signal doesn't exist. "Nothing is hopeless," is how one Italian geologist put it to me. "What I say is, Now we do not know how to predict earthquakes. So we have to face the problem: What to do in this time when we do not predict quakes."

In the seismic hall, De Canio and his colleagues study new methods of construction as well as ways to retrofit old structures to make them more stable. The architectural models, which are so heavy they have to be moved around by crane, are placed on the shaking table, a quake is set in motion, and the engineers watch what happens. De Canio showed me a video of a recent test. As the table shook, a mini-apartment building collapsed in a shower of dust.

We crossed the hangar to look at a pair of replicas of ancient statues. The originals, known as the Bronzes of Riace, were crafted in the fifth century B.C., and they dazzled the art world when they were discovered, in 1972, by a diver in the Mediterranean. Now on exhibit at a museum in Calabria, they depict two naked Greek warriors with rippling muscles and great beards. The Bronzes of Riace are particularly vulnerable because, like actual people, they have no support except their feet. To protect the statues, De Canio and his team designed flexible bases, with shock absorbers, internal

Six years after the quake first struck, the city of L'Aquila is still rebuilding. The recovery is estimated to cost at least $16 billion. (Paolo Verzone)

springs and a series of balls, like oversized marbles, that allow them to roll around instead of snapping off at the ankles.

ENEA is planning to build a similar base for Michelangelo's David, which, after spending centuries outdoors in Piazza della Signoria, a public square in Florence, is displayed at the Galleria dell'Accademia. Like the Bronzes of Riace, the David is unusually vulnerable because its entire weight—some 12,000 pounds—is supported only by the statue's feet and a narrow marble tree stump. Already there are cracks in the stump and along the statue's left ankle.

During the recent swarm of tremors in Tuscany, the Italian government announced that it would allocate €200,000 for a new earthquake-resistant base, but so far, De Canio told me, the funds had not yet been released. In his office above the test floor, De Canio showed me a foot-high model of the David; a larger model would be built next.

"We are ready for the David," De Canio told me. Then he shrugged. When I got home that evening, I checked the website of the National Institute of Geophysics and Volcanology, where interested citizens can get the latest information on terremoti. Over the previous 24 hours, there had been one magnitude 3.1 earthquake, in eastern Sicily; six other earthquakes measuring over 2.0; and doubtless many smaller quakes that were not reported on the website. By Italian standards, at least, it had been a quiet day.

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The rise of electricity storage: Something for everybody

By JOHN P. BANKS

Brookings

The barrage of news about the progress and promise of electricity storage in the last year just got another jolt from two disparate sources: the U.S. Department of Energy (DOE) and Tesla Motors. On April 21, DOE released the first installment of the Quadrennial Energy Review (QER) focusing on improving the nation's energy infrastructure and notably referring to "energy transmission, storage, and distribution," emphasis added. On April 30, Tesla's CEO Elon Musk announced two new business lines: the PowerWall, a re-chargeable lithium ion battery for homes (in either a 10 kWh or 7 kWh size), and the PowerPack, a 100 kWh battery for grid applications.

These are only two items in a dizzying array of projections, market developments, reports, and statistics emerging in the last year, highlighting that storage is arguably THE big story in the electricity industry. The U.S. Energy Information Administration recently indicated that non-hydro storage capacity in the United States has doubled in the last five years, to 350 MW.

A report from Greentech Media and the Electricity Storage Association estimated that the U.S. energy storage market grew 40 percent in 2014 over the previous year, adding 62 MW of storage–and they predict an additional 220 MW will come online in 2015.

The growth in the storage market is not limited to the United States: IHS CERA projects that 40 GW of storage will be connected to the grid globally by 2022.

Electricity storage benefits

Unlike discussions surrounding net metering and rooftop solar PV, storage appears less controversial. It's easy to see why—storage provides many benefits across the entire grid. In research we've conducted at Brookings, a cross-section of stakeholders describe storage as "emissions-free capacity," a source of "time value," and "a great way to make intermittent resources more valuable." Indeed, storage can help the entire electricity system operate more efficiently and offers something for everybody:

1. At the wholesale level it can provide ancillary services such as frequency regulation;
2. In generation, it can help integrate variable renewable supply;
3. In transmission, it can provide congestion relief;
4. In distribution, it can provide volt/VAR and peak capacity support;
5. On the customer side, it can provide back-up power and store excess onsite energy generation.

With the advent of more widespread deployment of rooftop solar PV, there has been particular excitement on the customer side of the meter for combining residential solar PV with storage. SolarCity and Telsa are partnering to offer a rooftop solar PV and battery package,

Storage can help the entire electricity system operate more efficiently

Florida International University's solar thermal collector system.
Photo: © Stefano Paltera/U.S. Department of Energy Solar Decathlon

and Sungevity and Sonnenbatterie have agreed to offer a solar-plus-battery integrated system. Wall Street also recognizes the solar-plus-storage potential. In May 2014, Barclays stated "we believe a confluence of declining cost trends in distributed solar PV and residential scale power storage is likely to disrupt the status quo." And UBS in August 2014 said that "Solar systems and batteries will be disruptive technologies for the electricity system."

A burgeoning storage market

But the enthusiasm for storage also extends to the front of the meter. In a recent Utility Dive survey, utility executives were asked to choose the top three technologies they should invest in, and the majority chose storage. The reasons are clear: Storage could help utilities firm-up renewable generation, integrate customer-sited distributed generation, and manage peak load, among other benefits. Indeed, as Katherine Hamilton, policy director at the Electricity Storage Association recently pointed out at a panel that I moderated on storage at Johns Hopkins University, of total storage capacity deployed in the United States in 2014, 90 percent was in front of the meter, and 10 percent was behind the meter (most of the latter was in the commercial sector).

What's driving the burgeoning storage market are the inter-related factors of policy and cost declines in storage systems, especially batteries. First, we are seeing more supportive policy and regulations at the state and federal level. As Hamilton explained, there are several main policy drivers for storage: the increasing deployment of variable renewable energy generation, the need to address resilience, grid edge innovation, and the EPA's Clean Power Plan (CPP). Regarding the CPP, over the next 15 years, in addition to reducing fossil fuel generation, we are going to need 40 GW of peak capacity, and storage can play a role in meeting those peaks. Examples of leading policy efforts include California's mandate under A.B. 2514 for the three investor-owned utilities in the state to procure 1.3 GW of storage capacity by 2020, and Hawaii, New York, and New Jersey are also actively promoting storage. The Federal Energy Regulatory Commission (FERC)'s Order 755 calls on the ISOs/RTOs to allow storage to partici-

pate in ancillary service markets, specifically to provide frequency regulation.Costs are also declining. One study estimated that the cost of lithium ion battery packs for electric vehicles declined 8 percent annually between 2007 and 2014. EPRI forecasts that lithium ion battery packs will be one-quarter of their 2010 price by 2022. These trends in policy and technology are impacting the market and two big announcements in November 2014 are illustrative. Southern California Edison (SCE) released the results of a procurement—designed to develop a portfolio of resources to replace the retirement of the San Onofre nuclear station and several large natural gas generation units—in which it awarded contracts for 260 MW of storage. Oncor, the largest transmission and distribution company in Texas, announced plans to invest over $5 billion in storage.

Electricity storage challenges

Nevertheless, there are important challenges. First, costs remain high. Lazard's most recent levelized cost of electricity analysis indicates that battery storage costs are still well above other technologies. But cost issues go beyond the battery itself. As Craig Irwin, clean tech analyst at ROTH Capital Partners emphasized at the Johns Hopkins panel, it is critical to reduce costs in supporting infrastructure such as cooling systems—especially for larger MW-scale deployment—and inverters. He added that other improvements are needed in developing a systematic approach to site specification and buyer education beyond the technologies proposed by specific vendors.

Moreover, one of the key lessons of the last 20 years is "that you have to own your supply chain." In this regard, Tesla's partnership with Panasonic in the $2 billion development of its Gigafactory designed to produce enough lithium ion batteries for 500,000 cars annually, could move the needle in reducing battery costs. Irwin suggested that today the 85 kWh battery in Tesla's Model S costs about 25 cents per watt hour, compared to other batteries in the 45 to 50 cents per watt range. With Tesla's goal of knocking costs down to 10 cents per watt hour, this should help drive down lithium ion battery costs worldwide, but it will also affect the competitiveness of other battery chemistries. In addition, there are a number of other unanswered questions about Tesla's business model, especially regarding cost at the residential level.

Second, supportive policy and regulatory frameworks need to be in place to help create markets. The example of PJM is illustrative. Of the 62 MW deployed in the United States last year, two-thirds was deployed in PJM's territory. Indeed, at utility scale, the biggest market is PJM, largely responding to FERC Order 755. The result, according to Scott Baker, senior business solutions analyst at PJM, is that there are currently 100 MW of storage in the PJM market with another 500 MW in the interconnection queue indicating that "clearly this market is not slowing down." But, overall, the wholesale ancillary services market is small, with Baker describing it as a "starting point to prove the capability of storage and allow the wholesale market to evolve."

However, one of the challenges for owners of storage participating in a competitive wholesale market is the unevenness of the revenue stream. For this reason, SCE's recent procurement of 260 MW of storage capacity changes the landscape. For example, Colleen Lueken, director of market analytics at AES Energy Storage noted that the company not only operates as a merchant in PJM, but also now has a competitively procured power purchase agreement (PPA) to provide storage as capacity and as a flexible resource: AES was selected by SCE to provide 100 MW of in-front-of-the-meter battery storage in the West Los Angeles Basin. This is a far more certain revenue stream than bidding ancillary services into PJM.

Third, figuring out the right policy and regulatory framework requires more progress in sorting out how to monetize the value of storage in different applications. The basic challenge is that the flexibility of storage—in terms of services it can provide—makes it difficult to fit into existing regulatory rules. As Lueken of AES noted, "to access the full value of energy storage you need to break up the resource from a revenue perspective and be able to provide benefits for different applications." Arnie Quinn, acting director of energy policy and innovation at FERC echoed this sentiment indicating that "We need to move away from the question of where storage fits, to whether it's the right solution." There is progress in this area: Quinn believes that "who-

US legislation the key driver in the energy storage market

Last April Tesla Motors unveiled its Powerwall and Powerpack lithium ion batteries for homes and utility-scale applications, which could facilitate an increased role for wind and solar energy resources. Both wind and solar have so far been limited by a need for storage options to address the intermittent nature of their generation.

As well synthesized by **Enerkol**, a US based regulatory data cloud software company, in its *"New Storage Technologies Open Doors for Wind and Solar"*, recent studies from GTM Research and ESA project the United States deploy 220 MW of energy storage in 2015, more than three times the 2014 level.

By 2019, energy storage is projected to represent a 861 MW annual market valued at $1.5B, with behind-the-meter storage accounting for 45 percent of overall storage market.

- State legislation and regulations are key drivers in the energy storage market.
- California, New York, Hawaii, and Texas have all introduced policy initiatives designed to facilitate revenue opportunities and reduced costs of storage integration and interconnection. These initiatives have opened opportunities for energy storage companies.
- While the focus of distributed energy resources has primarily occurred through state-level policy initiatives, federal legislation and regulations could re-define the market structures that impact energy storage.
- States would have to consider rates for distributed energy resources in an unbundled manner, enhancing consumers' rights to connect distributed resources to the grid, and ensuring proper compensation for grid owners and operators.
- The US Department of Energy's (DOE) Quadrennial Energy Review (QER) released in April recognizes energy storage as a key functionality to provide grid flexibility, and it signals a continued focus from the Obama Administration on creating a strategy for flexible storage solutions. *(Alice Masili/ONE)*

lesale markets are moving toward attribute based compensation where we define the attribute of the service we want, and then compensate it."

What comes next for electricity storage?

In sum, there is great potential for storage both in front of the meter and on the customer side of the meter. Costs need to come down, but the longer-term trajectory indicates that this will happen, and policies and regulations to incentivize storage need to continue to be implemented to spur the creation of markets. The DOE's QER is a step in the right direction, calling for the establishment "a framework and strategy for storage and flexibility."

In the near-term, it is likely that most of the market development and storage capacity deployed will be at the grid-scale in competitive markets such as PJM, but the SCE procurement certainly highlights the impact of supporting policy and regulation in spurring competitively procured PPA-type arrangements. In addition, California's investor owned utilities have initiated the first round of storage auctions in response to the state's mandate, with final project selection and submission to the California Public Utilities Commission for approval this coming fall.

In the longer-term, solar-plus-storage could become increasingly economic on the customer side. Indeed, as Hamilton of the Electricity Storage Association described, the three biggest storage markets in the residential sector are California, Arizona, and Hawaii and what they all have in common is lots of solar. But beyond selected markets, residential-scale storage systems such as Tesla's PowerPack won't likely lead to mass defection from the grid in the next five to 10 years. The important point, however, is that Tesla's announcement—and all the other recent news—is exciting because it shows the progress and potential of a technology with multiple applications and benefits across the grid, providing something for everybody..

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Four reasons why the transition from fossil fuels to a green energy era is gaining traction

By MICHAEL T. KLARE

Tomdispatch.com

Don't hold your breath, but future historians may look back on 2015 as the year that the renewable energy ascendancy began, the moment when the world started to move decisively away from its reliance on fossil fuels. Those fuels – oil, natural gas, and coal – will, of course, continue to dominate the energy landscape for years to come, adding billions of tons of heat-trapping carbon to the atmosphere. For the first time, however, it appears that a shift to renewable energy sources is gaining momentum. If sustained, it will have momentous implications for the world economy – as profound as the shift from wood to coal or coal to oil in previous cen-

Sunedison fotovoltaica - Chile

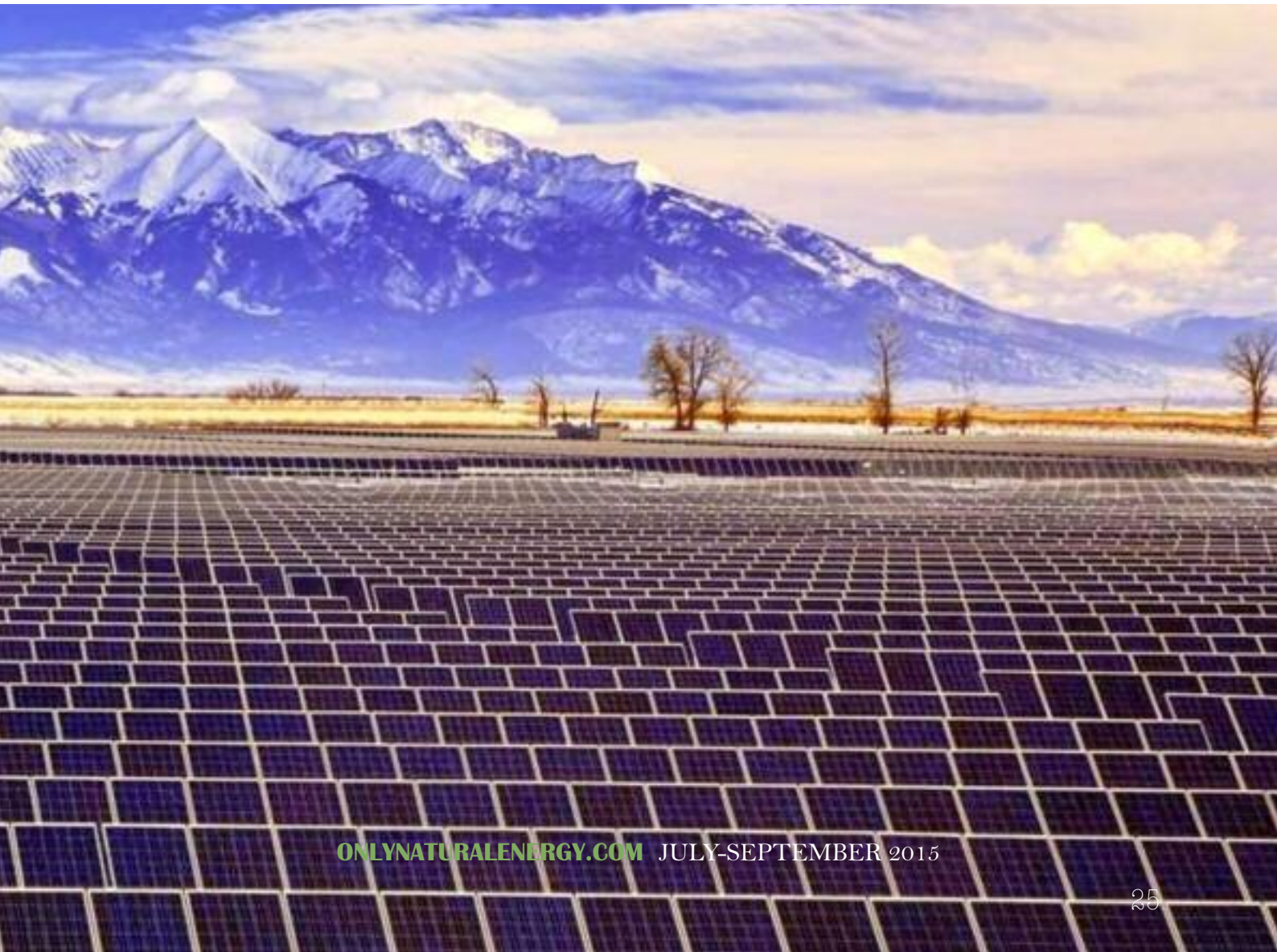
turies. Global economic growth has, of course, long been powered by an increasing supply of fossil fuels, especially petroleum. Beginning with the United States, countries that succeeded in mastering the extraction and utilization of oil gained immense economic and political power, while countries with huge reserves of oil to exploit and sell, like Kuwait and Saudi Arabia, became fabulously wealthy. The giant oil companies that engineered the rise of petroleum made legendary profits, accumulated vast wealth, and grew immensely powerful. Not surprisingly, the oil states and those energy corporations continue to dream of a future in which they will play a dominant role.

"Fossil fuels are our most enduring energy source," said Ali Al-Naimi, Saudi Arabia's minister of petroleum and mineral resources, in April 2013. "They are the driving force of economic development in the U.S., Saudi Arabia, and for much of the developed and developing world [and] they have the capacity to sustain us well into the future."

But new developments, including a surprising surge in wind and solar installations, suggest that oil's dominance may not prove as "enduring" as imagined. "Rapidly spreading solar technology could change everything," energy analyst Nick Butler recently wrote in the Financial Times. "There is growing evidence that some fundamental changes are coming that will over time put a question mark over investments in old energy systems."

Normally, transitions from one energy system to another take many decades. According to Vaclav Smil of the University of Manitoba, the shift from wood to coal and coal to oil each took 50 years. The same length of time, he has argued, will be needed to complete the transition to renewables, which would leave any green energy era in the distant future. "The slow pace of this energy transition is not surprising," he wrote in Scientific American. "In fact, it is expected."

Smil's analysis, however, assumes two things: first, that



a business-as-usual environment in which decisions about energy investments will largely be made within the same profit-seeking outlook as in the past will continue to prevail; and second, that it will take decades for renewables to best fossil fuels in terms of cost and practicality. Both assumptions, however, appear increasingly flawed. Concern over climate change is already altering the political and regulatory landscape, while improvements in wind and solar technology are occurring at an extraordinary rate, rapidly eliminating the price advantage of fossil fuels. "The direction of change is clear," Butler writes. With the cost of renewable installations falling, solar power has moved "from being a niche supplier to being a major regional competitor [to fossil fuels]."

Experts agree that renewables will claim a larger share of the global energy budget in the years ahead. Nevertheless, most mainstream analysts believe fossil fuels will be the dominant form of energy for decades to come.

Experts largely agree that renewables will claim a larger share of the global energy budget in the years ahead. Nevertheless, most mainstream analysts continue to believe that fossil fuels will be the dominant form of energy for decades to come. The U.S. Department of Energy (DoE) typically predicts that the share of world energy provided by renewables, nuclear, and hydro combined will climb from 17% in 2015 to a mere 22% in 2040 – hardly change on a scale that would threaten the predominance of fossil fuels. There are, however, four key trends that could speed the transition to renewables in striking ways: the world's growing determination to put a brake on the advance of climate change; a sea change in China's stance on growth and the environment; the increasing embrace of green energy in the developing world; and the growing affordability of renewable energy.

Taking Climate Change Seriously

Resistance to progress on climate change is widespread and well entrenched. As Naomi Klein documents in her latest book, This Changes Everything, the major fossil fuel companies have mounted well-financed campaigns for years to sow doubt about the reality of climate change, while politicians, often in their pay, have obstructed efforts to place restraints on carbon emissions. At the same time, many ordinary people have been reluctant to acknowledge what's happening and so consider steps to bring it under control (a phenomenon examined by George Marshall in Don't Even Think About It). As the devastating effects of extreme weather, including droughts, floods, and ever more powerful storms, gain greater prominence in everyday life, however, all of this is clearly in flux.

Considerable evidence can be assembled to support this assessment, including recent polling data, but perhaps the most impressive indication of this shift can be found in the carbon-reduction plans major nations are now submitting to U.N. authorities in preparation for a global climate summit to be held this December in Paris. Under a measure adopted by delegates to the most recent summit, held last December in Lima, Peru, all parties to the U.N. Framework Convention on Climate Change (UNFCCC) are obliged to submit detailed action plans known as "intended nationally determined contributions" (INDCs) to the global climate effort. These plans, for the most part, have proven to be impressively tough and ambitious. More important yet, the numbers being offered when it comes to carbon reduction would have been inconceivable only a few years ago.

The U.S. plan, for example, promises that national carbon emissions will drop 26%-28% below 2005 levels by 2025, which represents a substantial reduction. There are, of course, many obstacles to achieving this goal,

most notably the diehard resistance of Republican legislators with strong ties to the fossil fuel industry. The White House insists, however, that many of the measures included in the INDC can be achieved through executive branch action, including curbs on carbon emissions from coal plants and mandated improvements in the fuel efficiency of cars and trucks.

Other countries have submitted similarly ambitious INDCs. Mexico, for example, has pledged to cap its carbon emissions by 2026, and to achieve a 22% reduction in greenhouse gas levels by 2030. Its commitment is considered especially significant, since it's the first such pledge by a major developing nation. "Mexico is setting an example for the rest of the world by submitting an INDC that is timely, clear, ambitious, and supported by robust, unconditional policy commitments," the Obama White House noted in a congratulatory statement.

No one can predict the outcome of the December climate summit, but few observers expect the measures it may endorse to be tough enough to keep future increases in global temperatures below two degrees Celsius, the maximum amount most scientists believe the planet can absorb without incurring climate disasters far beyond anything seen to date. Nevertheless, implementation of the INDCs, or even a significant portion of them, would at least produce a significant reduction in fossil fuel consumption and point the way to a different future.

A Sea Change in Chinese Energy Behavior

Of equal importance is China's evident determination to reduce its reliance on fossil fuels – a critical change in stance, given its projected energy needs in the decades to come. According to the DoE, China's share of world energy consumption is expected to jump from an already impressive 19% in 2010 to 27% in 2040, with most of its added energy coming from fossil fuels. Should this indeed occur, China would consume another 88 quadrillion British thermal units of such energy over the next 30 years, or 43% of all added fossil fuel consumption worldwide. So any significant moves by China to reduce its reliance on those energy sources, as now being promised by senior government officials, would have an outsized impact on the global energy equation.

China has not yet submitted its INDC, but its plan is expected to incorporate the commitments made by President Xi Jinping in a meeting with President Obama in Beijing last November. Xi promised to cap China's carbon emissions by 2030 and increase the share of non-fossil fuels in primary energy consumption to around 20% by that time. He also agreed to work with the U.S. "to make sure international climate change negotiations will reach agreement as scheduled at the Paris conference in 2015."

Although the Chinese plan allows for continued growth in carbon emissions for another 15 years, it substantially reduces the amount of new energy that will be derived from fossil fuels. According to a White House statement, "It will require China to deploy an additional 800-1,000 gigawatts of nuclear, wind, solar, and other zero-emission generation capacity by 2030 – more than all the coal-fired power plants that exist in China today."

It appears, moreover, that Chinese leaders are preparing to move even faster than their pledge would require in transitioning away from fossil fuels. Under pressure from urban residents to reduce punishing levels of smog, the authorities have announced ambitious plans to lessen reliance on coal for electricity generation and rely instead on hydropower, nuclear, wind, and solar power, as well as natural gas. "We will strive for zero-growth in the consumption of coal in key areas of the country," Premier Li Keqiang told the National People's Congress, China's legislature, this March.

As in the United States, the Chinese leadership will face opposition from entrenched fossil fuel interests, as well as local government structures. However, their evident determination to reduce reliance on oil and coal represents a real change of mood and thinking. It's likely to result in a far different energy landscape than the one laid out by the Department of Energy and,

until recently, most other experts. Despite repeated predictions of ever-increasing coal consumption, for instance, China actually burned less coal in 2014 than in the previous year, the first such decline in decades. At the same time, it increased its spending on renewable forms of energy by an impressive 33% in 2014, investing a total of $83.3 billion – the most ever spent by a single country in one year – to a renewable future. If China leads the way globally and such trends continue, the transition from fossil fuels to renewables will occur far sooner than expected.

Green Goes Global

The giant oil companies have long acknowledged that the most advanced countries, led by the U.S., Japan, and Europe, would eventually transition from fossil fuels to renewables, but they continue to insist that developing nations – eager to expand their economies but too poor to invest in alternative energy – will continue to rely on fossil fuels in a big way. This outlook led ExxonMobil and other oil firms to make massive investments in new refineries, pipelines, and other infrastructure aimed at satisfying anticipated demand from the global South. But surprise, surprise: those countries are also showing every sign of turning to renewables in their drive to expand energy output.

The global South's surprisingly enthusiastic embrace of renewables is impressively documented in Global Trends in Renewable Energy Investment 2015, a recent collaboration between the Frankfurt School of Finance and Management and the U.N. Environment Programme. It reports that the developing countries, excluding China, spent $30 billion on renewables in 2014, a substantial rise over the previous year. Together with China, investment in renewables in the developing world totaled nearly as much as that spent by the developed countries that year. Significant increases in spending on renewables were registered by Brazil (for a total of $7.6 billion), India ($7.4 billion), and South Africa ($5.5 billion); investments of $1 billion or more were posted by Chile, Indonesia, Kenya, Mexico, and Turkey. Given how little such countries were devoting to a renewable future just a few years ago, consider this a sign of changing times.

No less striking is the degree to which oil-producing countries are beginning to embrace green energy. In January, for example, the Dubai Electricity and Water Authority awarded a contract to Saudi Arabia's ACWA Power International to build a 200-megawatt, $330 million solar electricity plant. The deal received widespread attention, as ACWA promised to deliver electricity from the plant for $58.50 per megawatt-hour, one-third less than the cost of natural gas-fired generation.

"This is a major breakthrough in the oil-fired Emirates and a clear demonstration of the ongoing global energy transition," suggested Mark Lewis of Kepler Cheuvreux, a European financial services company. "We think this is a landmark deal both in terms of the extremely competitive cost at which the project will generate power and the potential for a much greater take-up of renewables in countries that have so far been slow to embrace them."

The Falling Price of Renewables

As the Dubai deal indicates, price is playing a crucial role in the shift from fossil fuels to renewables. Listen to the apostles of coal and oil and you'd think that poor countries had no choice but to rely on their chosen form of energy because of its low cost compared to other fuels. "There are still hundreds of millions, billions of people living in abject poverty around the world," said Rex Tillerson, the CEO and Chairman of ExxonMobil. "They need electricity they can count on, that they can afford... They'd love to burn fossil fuels because their quality of life would rise immeasurably, and their quality of health and the health of their children and their future would rise immeasurably."

Until recently, this would have been gospel among mainstream energy experts, but the cost of renewables, especially solar power, is dropping so rapidly that, even in a moment when the price of oil has been halved, the news on the horizon couldn't be clearer: fossil fuels are no longer guaranteed a price advantage in delivering energy to developing countries. Among the harbingers of this change: the cost of solar photovoltaic cells (PVs) has plunged by 75% since 2009 and the cost of electricity generated by solar PVs has fallen globally by 50% since 2010. In other words, solar is now becoming com-

petitive with oil and natural gas, even at their currently depressed prices. "Cost is no longer a reason not to proceed with renewables," concluded a report released by the National Bank of Abu Dhabi in March. Says Lewis of Kepler Cheuvreux: "Over time, as renewable-technology costs continue to come down and economies of scale continue to increase, the relative competitiveness of renewables in the global energy mix will only increase further."

Developing nations have a powerful reason to favor renewables over fossil energy that has nothing to do with price and everything to do with costs of another sort

Keep in mind as well that developing nations have a powerful reason to favor renewables over fossil energy that has nothing to do with price and everything to do with costs of another sort. As the most recent reports from the U.N.'s Intergovernmental Panel on Climate Change (IPCC) make clear, poor countries in the global South will suffer more (and sooner) from the ravages of climate change than countries in the global North. This is so because these countries are expected to experience some of the sharpest declines in rainfall and so the most droughts, endangering the food supply for hundreds of millions of people. Combine such concerns with the plunging prices of renewable energy, and it appears that the transition away from fossil fuels will occur faster than predicted in the very regions that the oil companies were counting on for their future profits.

A New World's A-Coming

Add up these factors, all relatively unexpected, and one conclusion seems self-evident: we are witnessing the start of a global energy transition that could turn expectations upside down, politically, environmentally, and economically. This transformation won't happen overnight and it will face fierce opposition from powerful and entrenched fossil fuel interests. Even so, it shows every sign of accelerating, which means that while we may be talking decades, the half-century horizon previously offered by experts like Vaclav Smil is probably no longer in the cards.

Fossil fuels -- and the companies, politicians, and petro-states they have long enriched -- will lose their dominant status and be overtaken by the purveyors of renewable energy far more quickly than that.

Even with the quickening of investment in green technology, the likelihood that world temperatures will be held at a 2 degrees Celsius rise, that all-important threshold for catastrophic damage, is unfortunately vanishingly small. Which means that our children and grandchildren will live in a distinctly less inviting world. But as the destructive effects of climate change become more pronounced and more embedded in daily life across the planet, the impetus to slow the warming phenomenon will only intensify. This means that the urge to impose strict curbs on fossil fuel consumption and the companies that promote it will grow, too.

We're talking, in other words, about the building of genuine momentum for an energy transition which, in turn, means that the majority of people alive on the planet today will experience the ascendancy of renewables. As with previous energy transitions, this shift is going to produce both winners and losers. Countries and companies that assume early leadership in the development and installation of advanced green technologies are likely to prosper in the years ahead, while those committed to the perpetuation of fossil energy will see their wealth and power decline or disappear. For the planet as a whole, such a transition can't come soon enough.

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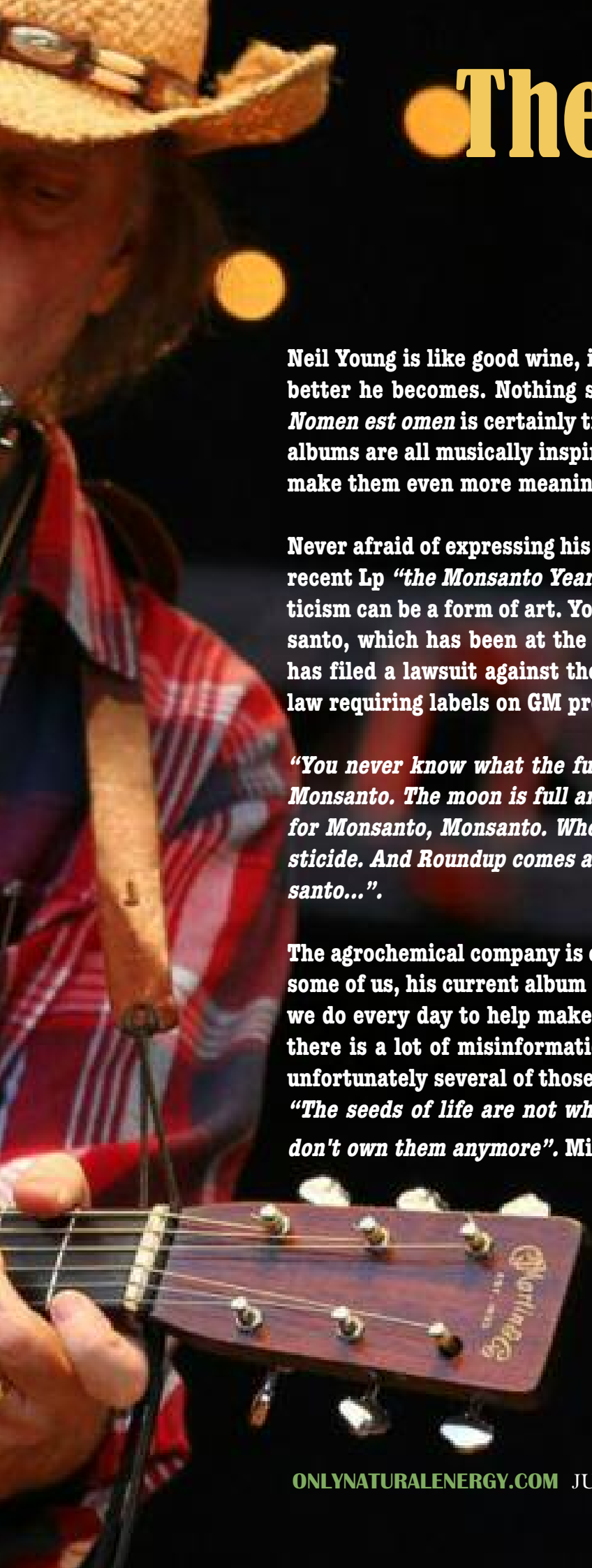
Photo: Kevin Mazur/WireImage)



The Monsanto Fears

Neil Young is like good wine, improving all the time. The older he gets the better he becomes. Nothing sad, nothing pathetic no sign of decadence. *Nomen est omen* is certainly true with Young. The Canadian singer's latest albums are all musically inspired and filled with some vitriol lyrics, which make them even more meaningful and poignant.

Never afraid of expressing his strong opinions, Young confirms in his most recent Lp *"the Monsanto Years"* that when you have talent even angry criticism can be a form of art. Young has taken aim at agricultural giant Monsanto, which has been at the forefront of genetically modified crops and has filed a lawsuit against the state of Vermont, the first state to pass a law requiring labels on GM products.

"You never know what the future holds in the shallow soil of Monsanto, Monsanto. The moon is full and the seeds are sown while the farmer toils for Monsanto, Monsanto. When these seeds rise they're ready for the pesticide. And Roundup comes and brings the poison tide of Monsanto, Monsanto...".

The agrochemical company is certainly less impressed: "Unfortunately, for some of us, his current album may fail to reflect our strong beliefs in what we do every day to help make agriculture more sustainable. We recognize there is a lot of misinformation about who we are and what we do – and unfortunately several of those myths seem to be captured in these lyrics." *"The seeds of life are not what they once were. Mother Nature and God don't own them anymore".* Misinformation, art or plain facts?

Bringing the age of steam into the information age

By TOBY LOCKWOOD
ONE

How cutting edge sensor and control technologies are helping coal plants to clean up their act.

'Greetings from the Stone Age' proclaimed the German newspaper *Süddeutsche Zeitung* upon the opening of a brand new coal power plant near Hamburg this year, reflecting the growing view that coal power is yesterday's technology. However, the mounting pressure faced by coal plants to stay relevant in a cleaner power sector is actually compelling them to make use of increasingly futuristic technologies.

Nowhere is this more the case than in a plant's control system, which acts as its central nervous system and is tasked with finding a 'sweet spot' that satisfies the often conflicting goals of high energy efficiency and cleaner emissions. On top of this, as the use of intermittent wind and solar power expands rapidly in countries like Germany and the USA, coal plants are increasingly obliged to turn their output up and down in a manner

Moorburg (Germany): in late February 2015 regular operation of the first of the two units began. Photo: © Vattenfall.

which makes it even more challenging for their control systems to keep everything running smoothly.

In these demanding conditions, the system needs both more sensory data to work with and more advanced software which is able to make sense of the daunting complexity of a large power plant.

In the past, the furnace of a coal plant was essentially a black box into which coal and air were fed, and from which a mixture of gases and ash emerged on the other side. Relatively little information was available on the exact nature of the flows in and out, and still less on the combustion processes occurring within, making it difficult to accurately adjust the critical ratio between air and coal. Although the coal needs enough air to consume as it burns, too much air represents an energy loss to the plant, as well as encouraging the formation of the strictly regulated pollutant, oxides of nitrogen.

On top of this, with large furnaces feeding coal and air through dozens of separate burners, hitting the best ratio on a global scale is no guarantee that the whole furnace is well mixed and free from areas with too much or too little air.

To help the control system balance out and optimise the combustion process, plants have been making use of newer technologies which give them a much better idea of what's going on inside the furnace.

US-based company Zolo Technologies installs a grid of infrared lasers which criss-cross the furnace and use spectroscopy to map out levels of critical gas components like oxygen, carbon monoxide (a key indicator of poor combustion), and oxides of nitrogen.

An alternative approach for mapping temperature variation across the furnace is provided by Enertechnix, who place sound wave transmitters and receivers around the furnace to measure the temperature-dependent speed of sound through the hot combustion gases. The detailed information generated by these systems is then fed to the control system and used to balance out and optimise the levels of each parameter.

The importance of these sensor technologies has been fully recognised by the United States Department of Energy, to help bring the country's huge fossil fuel fleet into a low carbon age

Even with the extra data being generated by sensors like these, a power plant has such a large number of variables to adjust that it can be difficult for operators to identify exactly which combination will give the best results, particularly when the grid's power demand can change so unpredictably.

Over the last decade, plants have therefore begun to install advanced software known as 'combustion optimisers' which help control systems by generating a complex model of how each combination of control actions will affect the plant. Rather than being based on physical principles, these models use complex mathematical algorithms such as neural networks, which are trained on operational data to mimic the response of the plant to various inputs. With more and more computing power readily available, these models have become increasingly powerful and capable of predicting how the plant will respond even in rapidly changing conditions.

The importance of these sensor and control technologies has been fully recognised by the United States Department of Energy, which is funding a research drive into how they can be developed even further to help bring the country's huge fossil fuel fleet into a low carbon age. This programme is focussing particularly on designing sensors which will be able to survive in the even harsher conditions likely to prevail in coal power plants of the future, whether they are using hotter furnaces to generate higher steam temperatures, or first 'gasifying' the coal for use in more efficient gas turbines.

Many of the sensors being developed are miniaturised, solid state devices which can packaged and deployed in

large numbers to maximise the flow of data from the process. However, traditional silicon-based chips are not able to withstand the temperatures of over 1000°C encountered in coal furnaces, gasifiers, and gas turbines. Novel materials such as high temperature ceramics or silicon alloys are instead being employed for the fabrication of more robust devices, with new gas sensor designs even making use of high surface area 'nanomaterials' to enhance their performance.

In the US and elsewhere, there is growing interest in replacing microelectronic sensors altogether with optical devices which use light instead of electrons as their medium for sensing and transmitting information. Not only can optical fibres be made from high temperature materials like sapphire, they are immune to signal interference from the electromagnetic noise which abounds in power plants. Miniaturised devices are also possible, as sections of individual optical fibres can be engineered to modulate light according to the temperature, pressure, and chemistry of their environment.
One idea being investigated at the University of Massachusetts is to surround the furnace with optical fibres which can both generate and detect sound waves, allowing the temperature profile of the whole space to be mapped out in three dimensions.

This ability of optical fibres to simultaneously report on the environment along their entire length is another property which makes them particularly useful. Whilst many of the basic concepts being explored have already been used in other industries, making them viable at such high temperatures poses a real challenge to researchers.
To better protect these sensors, as well as bring them closer to the processes they're monitoring, researchers are also attempting to actually embed them into power plants components such as steam pipes and turbine blades.

This idea relies on the relatively new and revolutionary technology of additive manufacturing, in which solid objects are made from the bottom up by selectively binding together successive layers of a precursor material. For example, a turbine blade can be fabricated by using a pair of lasers to melt together powdered metal, point by point and layer by layer. Using this technique, researchers at Herriott-Watt University in the UK have placed optical fibre sensors within a blade during the fabrication process, producing a 'smart part' which can report on how it is coping in the demanding physical and chemical environment of a gas turbine. This approach allows the failure of components to be preempted, and equipment to be run closer to its limits with reduced risk. The prospect of plants containing large networks of miniaturised sensors has also prompted a new look at the computational approaches which can make best use of the growing quantities of data.

By combining wireless communication technology with microelectronics which shift processing power to the level of the sensor, there is a possibility of highly interconnected networks of 'smart' sensors which can communicate and make control decisions amongst themselves, without needing higher level supervision. Some of the algorithms best suited to managing this kind of scenario take their inspiration from biological systems such as ant colonies, where complex behaviour emerges from a large number of entities making simple decisions.

This could be an effective means of dealing with control of larger, more complex power plants which defy attempts to create a global model of the system. Such is the size of the coal fleet in the USA, the Department of Energy has calculated that even the incremental improvements to plant efficiency and reliability gained from these technologies could represent yearly savings of 358 million dollars and 14.4 million tons of carbon dioxide. Considering the even greater impact that could be made by applying successfully commercialised technologies to the still larger coal capacity in China, the value of such improvements in mitigating the impact of the power sector cannot be underestimated.

Above all, it demonstrates that this kind of hi-tech laboratory research should not just be limited to making our computers run faster, but to helping clean up the power they consume - even when it comes from 'stone age' sources like coal.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Russia completes design papers for Fukushima tritium removal

By World Nuclear News

Russia's Atomproekt has completed the draft design and working documents for a demonstration unit to separate tritium from contaminated water at the Fukushima Daiichi nuclear power plant in Japan. Construction of the facility is expected to start early next year.

If the demonstration unit is successful, a full-scale facility could be built at the plant to remove tritium from 400 cubic metres of contaminated water per day. An Atomproekt statement yesterday said that talks with Japanese experts on the design of this facility had already started.

Atomproekt said the documents it has completed detail the design, construction, piping, ventilation and electrical systems for the demonstration facility that would verify the performance of tritium separation technology. They also include land resettlement and architectural solutions, the company said.

Saint Petersburg-based Atomproekt was commissioned in February to develop the documents by another Rosatom subsidiary, FSUE Radioactive Waste Management Enterprise (RosRAO).

The Japanese government in August selected RosRAO - and the Khlopin Radium Institute - as one of three overseas companies for the demonstration project.

The other two companies Japan's Ministry of Economy, Trade and Industry (METI) selected to demonstrate their respective technologies are the USA's Kurion and GE-Hitachi Nuclear Energy Canada.

11 March 2011: Fukushima


Fukushima Reactor 4

The aim of the demonstration projects is both to verify the tritium separation technology and also to assess the construction and operating costs for full-scale implementation of the technology at the Fukushima Daiichi plant. The technology must be capable of removing tritium from water with concentrations of 0.6 and 4.2 million bequerels per litre and to be expandable to process more than 400 cubic metres per day.

A fund to subsidise the projects is being managed by the Mitsubishi Research Institute on behalf of the Agency for Natural Resources and Energy, part of METI. The upper limit for subsidies will be JPY 1 billion ($9.4 million) per project. The projects will run until the end of March 2016. While the current decontamination equipment at Fukushima Daiichi is able to remove some 62 nuclides from the contaminated water, it is unable to remove the tritium in it. METI said it has yet to decide whether to introduce tritium removal facilities at the plant.

Tritium is produced during the operation of water-cooled reactors and its usual disposal route is a monitored outflow to a large body of water, but public opinion in Japan will not allow this. Atomproekt noted that, together with the Leningrad District branch of RosRAO, it had worked on the development of a facility for processing liquid waste contaminated with tritium in 2011. This technology, called Triton, "can significantly reduce the volume of radioactive waste to prepare it for safe disposal", Atomproekt said.

RosRAO began operations in 2009 for the management of used nuclear fuel, non-nuclear radioactive waste, and decommissioning services, especially of submarines. Then in 2011, NO RAO was created to consolidate these activities as the national manager of Russia's used nuclear fuel and radioactive waste. RosRAO aims to be a global provider of back-end fuel cycle services.

Atomproekt - the former VNIPIET (All-Russia Science Research and Design Institute of Power Engineering Technology), which since 2013 incorporates Saint Petersburg Atomenergoproekt (SPbAEP) - designs nuclear power projects, radiochemical plants and waste facilities.

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More coal plants are being cancelled than built

By SOPHIE YEO
Carbon Brief

The global coal boom has started to slow, a new report says, as more plans for new power plants are now being shelved than completed.

The number of cancelled coal projects across the world has outstripped those completed at a rate of two to one since 2010, according to Sierra Club and CoalSwarm - two campaign groups that have tracked the progress of 3,900 intended plants since 1 January 2010.
The findings update a 2012 report by the World Resources Institute, which estimated that 1,199 new coal-fired power plants, with a total capacity of 1,401 gigawatts, were in the pipeline for construction.
New figures suggest that, by 2014, this had shrunk by 23% to a proposed 1,083 gigawatts of new coal-fired capacity.

The report puts this down to citizen opposition, competition from renewables, new policy initiatives and political scandals putting a freeze on the highly polluting projects. IEA figures show that in 2012, electrical capacity provided by coal was 1,805 gigawatts. Even adding

the reduced 1,083 gigawatts that the two groups estimate are in the pipeline would go beyond the 1,999 gigawatts of coal capacity that the IEA says can be online in 2020 in order to stay within their two degree scenario.

Between 2010 and 2014, the groups calculated that 356 gigawatts of capacity was added to the world's network of coal-fired power plants, while 493 gigawatts - or 624 individual power plants - were shelved.

These cancelled coal plants would have emitted 88,204 million tonnes of carbon dioxide over their lifetime. The slowdown in coal expansion has been sudden and followed a period of rapid growth in the construction of coal plants.

For around two decades, capacity increased at a stable rate of between 20 to 25 gigawatts every year. Between 2005 and 2012, this tripled. The new report shows that it has now started to slow. This is supported by the IEA's 2014 Medium Term Coal Market report, which said that coal growth in 2013 was substantially lower than the average rate over the last ten years. However, the IEA also stressed that coal continued to be the fastest growing fossil fuel.

Regional distribution

The successes and failures of the coal industry are unevenly distributed between countries and regions. Five Chinese provinces individually added more new coal power capacity than the entire US between 2010 and 2014. Jiangsu, the Chinese province where construction of plants is most intense, has built almost as much new coal capacity as the whole of the US and the EU combined. The highest proportion of coal projects were canned in Europe, where the failure rate was 7:1. The lowest was in east Asia, where only one project failed for every success. And the majority of these were in China, where around 228 gigawatts were added between 2010 and 2014, compared to 119 gigawatts cancelled. However, in terms of tonnes of carbon dioxide avoided, the cancellations in east Asia were more than double that of Europe, due to the sheer scale of projects being proposed in the first place.

In India, the story is of a particularly rapid slowdown in the rate at which proposed coal plants are being con-

structed. From the beginning of 2010 to mid-2012, the ratio of plants halted to plants completed was nearly 2:1. From mid-2012 to mid-2014, this increased to more than 6:1. The report puts this down to a variety of factors, among them the "Coalgate" scandal concerning the corrupt allocation of coal mining rights between 2004-9. The coal industry in the EU and US is already in decline. In the EU, despite the addition of 14,469 megawatts of capacity, a further 17,580 megawatts were retired, leading to a net loss of 3,112 megawatts.

Readiness

Not all proposed coal plants are equally likely to come to fruition. The report differentiates between projects that are already in an advanced state of development and those with less certain futures. Around 635 gigawatts of the total 1,083 gigawatt pipeline appeared likely to progress towards construction, whereas 448 gigawatts was more speculative. In the future, this could shift the geographical balance of where the coal industry has most success. Many of the most advanced projects are distributed across south Asia and Europe/Turkey, which means that these regions are more likely to see their proposed projects go ahead.

This report's conclusions are an improvement on previous projections, but not enough to prevent global warming of more than two degrees Celsius. In 2013, the Intergovernmental Panel on Climate Change announced that the world had a "carbon budget" - an overall limit to the amount of carbon dioxide that can be emitted to prevent global warming exceeding this internationally agreed target. This budget was estimated to be 870-1,240 gigatonnes of carbon dioxide. The combined, cumulative lifetime emissions of 842 gigatonnes emitted by existing infrastructure, as well as coal-fired power plants currently proposed or under construction, would almost be enough to single-handedly blow the lower end of this budget, even if the current cancellation rate of 2:1 continued. This means that even more projects must be canned in order to give the world a good chance of remaining below the two degree target. A recent article published in the science journal Nature suggested that 80% of the world's coal reserves need to stay in the ground to meet this goal. The IEA says that the amount of energy that the world gets from coal needs to fall by around a third by 2040 to aim for a less than two degree future.

Stranded assets

The current rate of coal project cancellations is already causing a headache for investors in the industry, Ted Nace, one of the report's authors, tells Carbon Brief: "The clearest example right now is in coal mining stocks like Peabody, Arch, and Alpha Natural Resources. Arch's stock, for example, hit $75 per share in 2008 and now sells for 88 cents per share. An individual or an institutional investor that invested $75,000 in Arch stock in 2008 would have lost over $74,000 in the past seven years."

The decline in the European and US coal fired capacity growth has been taking place for over a decade, but mining companies had hoped that exports to China and other Pacific Rim nations would help to make up the difference. This has not happened. China's coal consumption fell by 2.9% in 2014, while the use of existing coal plants dropped to 54% - a 35-year low. Meanwhile, new renewable energy capacity exceeded new coal capacity in China for the first time in 2013, and then again in 2014 - although coal remains the dominant source of Chinese electricity. The rate at which projects are being shelved in India has also had an impact on connected projects overseas, explains Nace: "With capacity growth stalling in India, numerous overseas mega-projects such as mines, railroads, and terminals designed to increase imports of coal to India are now on turning into white elephants."

The rate at which coal plants are being cancelled is an improvement upon previous estimates on the future growth of the industry. But with international efforts targeted towards keeping global warming to below two degrees, the news that there is still 1,083 gigawatts of coal capacity in the pipeline is little cause for celebration.

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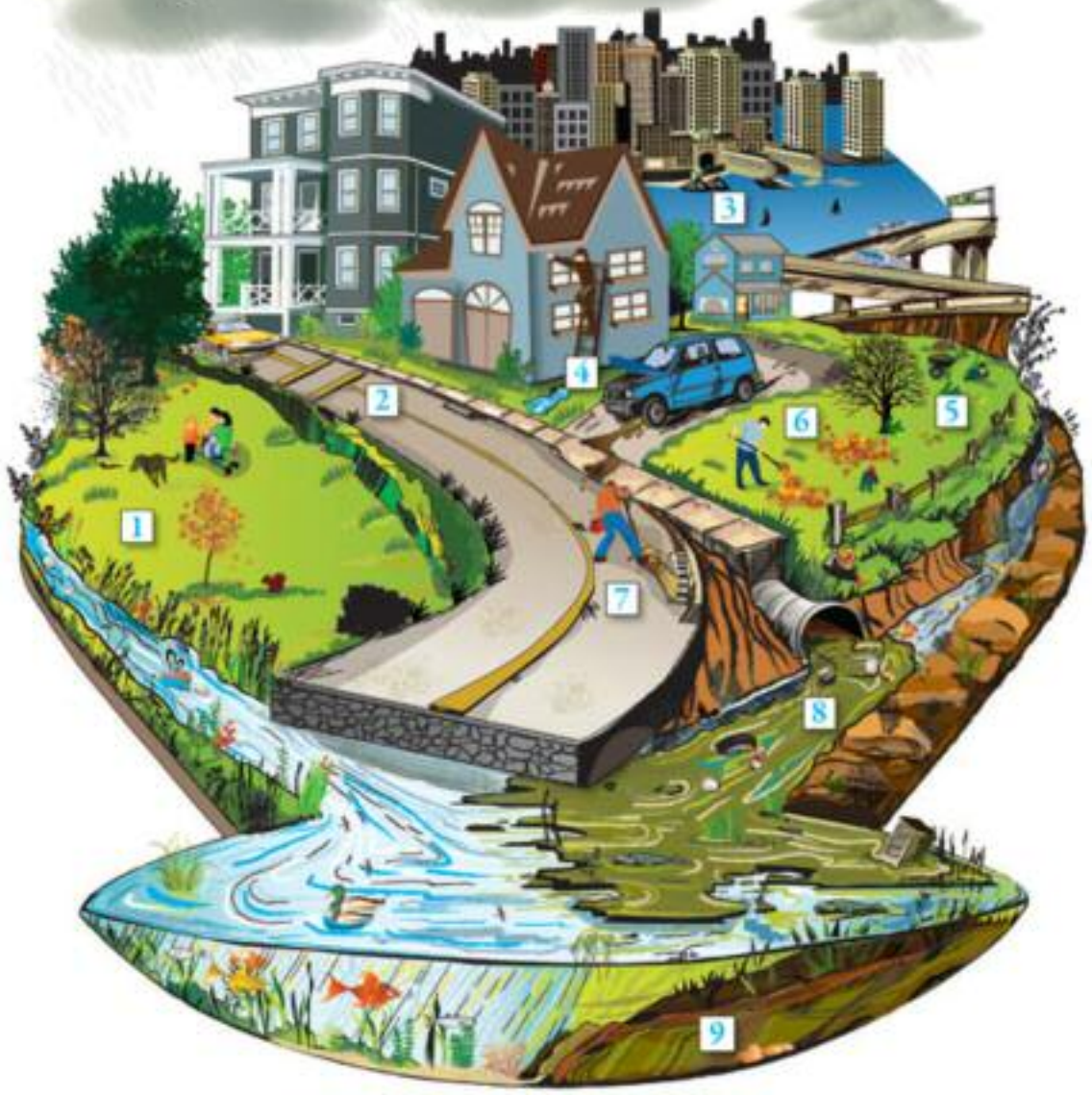
COONAWARRA

The Coonawarra train station used to be one of the stops along the Mount Gambier railway line, which opened in 1887. Hardly you will find a more minimal train station - the design is extremely simple: a box and a cylinder in the middle of nowhere. Since early 2000s even tourist trains have stopped passing there.

POLLUTION

Begins—And Ends—With *You*



Everyday Water Quality Problems

1 Undisturbed areas absorb rainwater and recharge the groundwater supply. Natural vegetation holds soil in place, preventing sedimentation of waterbodies. Pet waste pollutes our water. Scoop, dissible bag, and throw pet waste in the garbage.

2 Paving an area prevents absorption of rainwater, increasing the potential for flooding and erosion of soil into waterbodies. Driveways and walkways can be sources of water pollution. Oil, antifreeze, and other pollutants can collect on your driveway. When spilled during maintenance or are dumped on the ground can be carried by runoff to our streams and bays.

3 Boat and engine maintenance can pollute. Toxic chemicals, oils, cleaners, and paint scrapings from boat maintenance can make their way into the water. While boating, treat and dispose of your sewage properly.

4 If you, from aging pipes, gutters and metal roofs leaches into rainwater and enters the environment, where it may harm aquatic life. Asbestos and copper— both potential pollutants— leach into runoff from car and truck brake linings and worn pipes and linings.

5 Lawn clippings and yard waste in ravines and ponds can become unwanted fertilizer for streams. Lawn and garden fertilizers enter runoff and increase nutrient levels (nitrogen and phosphorus) in waterbodies. Too much plant growth in streams can use up all the oxygen choking water ways and killing fish and aquatic life.

6 Waste from leaf and grass clippings, garbage, animal droppings, and other organic debris pollute runoff. The decaying organics deplete oxygen levels in water and affect fish.

7 Used motor oil, household cleaners and chemicals disposed of outside can end up in our streams and bays. It washes down to local waterways where oil harms fish and wildlife. Potential toxic chemicals can be taken up by animals within ou can food chains. Since most animal foods contain high fish meal and fish oil contents, toxins can be found a few weeks later in commonly consumed food derived from livestock such as meat, eggs, milk and butter.

8 Trash thrown directly into lakes, streams, and wetlands is unsightly, may hurt aquatic life and may pollute the water as it decays.

9 Sediment accumulates in waterbodies from soil erosion and destroys feeding grounds for aquatic life, clogs fish gills, blocks light transmission, and increase water temperatures.

Remember Everything You Do *DOES* Make A Difference!

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