Faster and Cleaner

DECARBONIZATION IN THE POWER AND TRANSPORT SECTORS IS SURPASSING PREDICTIONS AND OFFERING HOPE FOR LIMITING WARMING TO 2°C

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Research by ClimateWorks, NewClimate Institute, Ecofys, and Climate Analytics

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EXECUTIVE SUMMARY

The transition from fossil fuels to cleaner, safer energy technologies is under way. To pinpoint where decarbonization is happening most rapidly—and to extract lessons and best practices that can be applied to other areas of the global economy where progress is needed in the fight against climate change—this study by ClimateWorks, NewClimate Institute, Ecofys, and Climate Analytics compares past projections with actual developments in renewable energy, coal consumption, and passenger vehicles.

Key Findings

- **Decarbonization of the power sector is happening faster than predicted.** Reduced coal use in the European Union and the United States, along with peaking of coal consumption in China (now predicted to occur between 2016 and 2020), indicates a continued shift in the world's largest economies to cleaner sources of energy and toward a 2°C-compatible pathway.
- **Wind and solar capacity growth has dwarfed forecasts.** Driven by policy and technology maturation, renewable energy deployment is taking place at significantly higher rates than previously projected. Actual installed capacities of renewable energy have surpassed projections at rates that were not deemed feasible a decade ago.
- **Passenger vehicle fleets are one-sixth less carbon-intense in key economies than they were in 2005.** The U.S. and the E.U. have increased their fuel economy by implementing standards that led to a decrease in emissions per vehicle kilometer of almost 18 percent over the past decade. A global 2°C-compatible rate of improvement for the next decade could be reached if best-practice emissions standards for passenger vehicles were implemented more broadly.
- **Market penetration of electric drive vehicles (EDVs) is exceeding predictions.** EDVs could become a fundamental driver for further lowering light-duty vehicle emission intensities. From January 2012 to September 2015, the total global stock of light-duty electric and plug-in hybrid vehicles grew six fold, from 170,000 to 1,000,000. Continued deployment will support an even larger decrease in transport emission intensities toward a zero-carbon energy future.
- **Despite significant progress, much more needs to be done.** These real-world developments, even coupled with fully implemented pledges from some 160 nations made in advance of the United Nations Climate Change Conference in Paris, would likely only limit warming to just below 3°C—not enough to avoid many of the severe impacts of climate change. Additional collective action on decarbonization is necessary.

Given the urgency to reduce greenhouse gas emissions, it is critical to understand where policymakers, businesses, and the social sector should focus their efforts. Drivers of energy demand and the carbon intensity of producing the energy required to meet that demand can be determined at the sector level. Emissions at this level provide meaningful insight into trends that can be used to identify and design the most effective sets of policies.

By taking a detailed look at projections and real-world progress in the power and transport sectors in China, the E.U., India, and the U.S., this study reveals faster-than-expected decarbonization. Moreover, after demonstrating how projections routinely underestimate the impact of policy and technology, it suggests that supportive policy signals from a transformative coalition of countries can accelerate market uptake and technology development, spur transformation on a scale unachievable by unilateral national action, and catalyze global decarbonization.

INTRODUCTION

Unchecked, climate change could drive 100 million people into extreme poverty by 2030, according to the World Bank (Hallegate et al., 2015). Mitigation action is not yet ambitious enough to limit global warming to two degrees Celsius (2°C) over preindustrial levels—the United Nations-declared threshold for avoiding the most dangerous climate change impacts—increasing the urgency of identifying where rapid decarbonization is occurring and where more action can be taken.[1] Athough economy-wide policies such as prices on carbon and greenhouse gases (GHGs), whether through trading or taxes, are very useful instruments, they are unlikely to be sufficient to achieve the 2°C goal, given market imperfections, monopoly behavior, incumbency problems in major technology sectors and markets, and structural barriers to new entrants in energy-related markets. At least in the short term, sector level approaches will be needed to complement and facilitate measures to enhance the effectiveness of global agreements, and in many instances they may be much more responsive to market realities and more politically feasible than theoretical carbon-price approaches.

In practical terms, sectoral indicators can be used to help increase mitigation ambition in several ways. First, from the perspective of historical trends, they can identify the reasons for emissions-intensive development and the opportunities for low-emissions development. Second, from the perspective of projections versus actual developments, sectoral indicators can help decision makers understand how past technology expectations compare with real world developments. Third, from the perspective of how projections change given new circumstances, sectoral indicators can illuminate broader structural shifts driven by economics, technology and policy.

This study identifies the key sectors in which to evaluate projections of decarbonization and GHG pathways, and it compares current trends with those projections to ascertain the rate of decarbonization. As models show, decarbonization is largely driven by a combination of reductions in overall energy use for services (energy efficiency) and a shift to low- or zero-carbon energy sources, along with changes in demand. Therefore, the analysis focuses on a few key indicators: growth in renewable energy, trends in coal use (especially in China as it transitions from heavy manufacturing to a services-based economy), and trends in transport emissions from fuel-efficient vehicles.

To track how projections have changed, the analysis uses various data sources, the most notable of which are annual projections from the International Energy Agency (IEA) in its World Energy Outlook (WEO) and data developed by Climate Action Tracker (CAT) and ClimateWorks' Carbon Transparency Initiative (CTI), which were used to examine recent trends.

The analysis focuses on those countries and regions with the greatest GHG emissions: China, the E.U., India, and the U.S.

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[1] As of mid-November 2015, nearly 160 countries, representing approximately 91 percent of global GHG emissions, had submitted intended nationally determined contributions (INDCs) in preparation for the United Nations Framework Convention on Climate Change (UNFCCC) 21st Conference of the Parties (COP21), November 30–December 11, 2015. The aggregated effect of the INDCs, as a Climate Action Tracker (CAT) analysis shows, is not yet sufficient to keep global warming within a 2°C limit. If all countries adhere to their INDCs, average temperatures are projected to rise by 2.7°C, with a 90 percent chance of increasing beyond 2°C and a greater than 66 percent probability of remaining below 3°C in 2100 (CAT 2015b). Currently implemented policies, without further action consistent with the INDCs, would result in warming of the planet by 3.6°C and a likely probability of temperatures staying below 3.9°C in 2100 (CAT 2015b). Other studies with different underlying assumptions for the post-2030 time period estimate even higher levels of warming.

METHODOLOGY

To assess global and regional decarbonization trends at the sector level, the authors defined multiple sector-specific indicators and used these indicators to (1) describe historical trends in the power and transport sectors, (2) compare projections with actual developments in those sectors, and (3) identify changes in projections. When possible, the analysis examined decarbonization trends in the context of sector-wide economic and policy developments.

Data for the analysis came from the following sources:

- Carbon Transparency Initiative (CTI)—Under this new project, ClimateWorks developed a bottom-up assessment model that uses a set of leading driver metrics at a sector level to project economy-wide emissions in select regions on the basis of current policies, decarbonization trends, and energy-related investments (ClimateWorks 2015).
- Climate Action Tracker (CAT)—The CAT research team gathered a set of decarbonization indicators by sector for historic trends and future policy trends, where available, in 30 countries (CAT 2015).
- International Energy Agency (IEA)—Using available successive IEA World Energy Outlooks (WEOs) and Energy Technology Perspectives (ETPs), ClimateWorks compared estimates for certain indicators reported in subsequent outlooks, both worldwide and in specific regions.
- Other data sources—ClimateWorks utilized other data sources that provided insight on the decarbonization trend in specific sectors and that showed projections over time, allowing it to examine changes in trends and expectations.

Both the CAT indicators and the CTI model have derived their indicators from calculations based on external sources and projections. Compared with CAT indicators, CTI indicators tend to point to greater decarbonization in the power sector. The reason is that CTI indicators use Bloomberg New Energy Finance (BNEF) data—which tend to be more optimistic about the scale-up of renewable energy—to calculate future projections in the CTI model.

The appendix offers a more detailed description of the methodology of the analysis presented below.

POWER SECTOR

The power sector is responsible for roughly 40 percent of global energy emissions (IEA 2014d, 2015a), making it the largest single sector for emissions. To evaluate changes in projections of power sector emissions, this analysis examined the role of renewables and coal consumption and the total emissions intensity of the sector. In this way, the analysis provides insight into the extent of near- and long-term decarbonization.

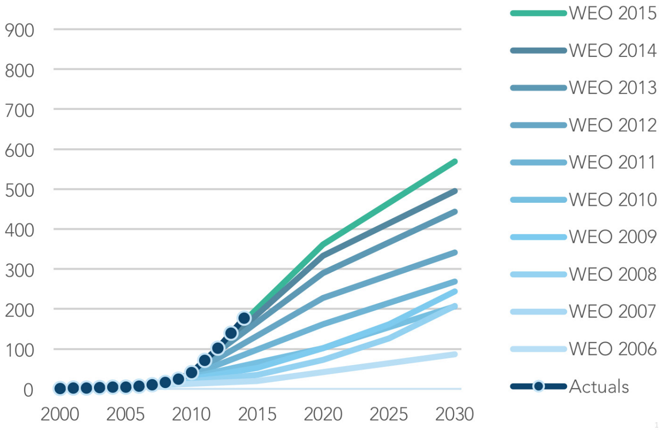
Renewable Power

The power sector provides electricity for every other sector of the economy, making it all the more important to decarbonize. Globally, deployment of renewable energy—for this study, specifically solar photovoltaic (PV) and wind—is occurring at significantly higher rates than projected, likely reflecting both the effectiveness of policies driving such deployment and the maturation of technologies. This success alters future projections and expectations: as renewable energy is deployed at faster rates, future projections of its market penetration become larger, and a market share once viewed as ambitious becomes part of a reference (baseline) scenario representing current or future conditions against which change is measured.

A striking example of faster-than-predicted renewable energy deployment can be found by examining the WEO 2006 projections (IEA 2006b), which present a reference policy scenario of 20 gigawatts (GW) of solar capacity installed globally by 2015 and an alternative policy scenario of 22 GW installed globally. As Figure 1 shows, the more ambitious 22 GW projection was surpassed in 2009; by the end of that year, installed solar capacity had reached 24 GW. By the end of 2014, it had reached 177 GW—eight times the capacity projected in 2006.

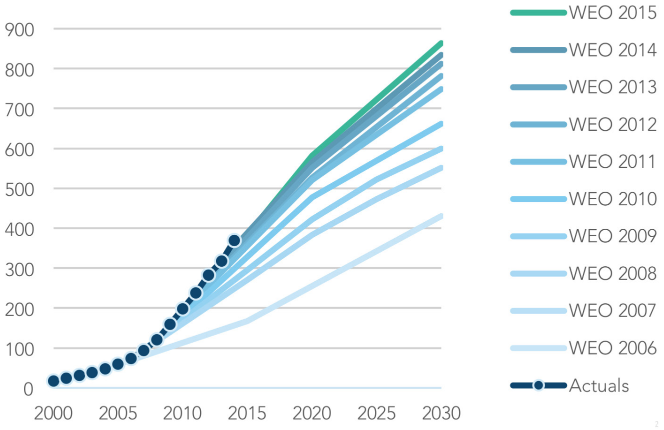
The capacity of wind power installations (both onshore and offshore) has similarly been underestimated. According to WEO 2006 projections for 2015, globally installed wind capacity would reach 168 GW in the reference scenario and 174 GW in the alternative scenario. But it had surpassed these estimates by 2010, and by 2014 it had reached 370 GW. Although WEO 2006 projections reflect an extreme example of underestimation, successive WEO projections indicate a similar pattern, as seen in Figure 2 (IEA 2006c, 2007, 2008b, 2009, 2010b, 2011, 2012b, 2013, 2014c, 2015d).

Figure 1 – WEO Projections of Globally Installed Solar Capacity in Gigawatts



Note: 2006–2009 data reflect the reference scenario; 2010–2015 data reflect the Current Policies Scenario.

Figure 2 – WEO Projections of Globally Installed Wind Capacity in Gigawatts



Note: 2006–2009 data reflect the Reference Scenario; 2010–2015 data reflect the Current Policies Scenario.

This pattern is replicated at the country and regional level. Installed solar and wind capacity in China, the E.U., India, and the U.S. (four of the largest economies and largest emitters) is underestimated in the WEO 2006 projections, albeit at differing levels of magnitude. The largest upward adjustment is for China, where WEO 2014 projected 20 to 25 times more solar PV and 4 to 6 times more wind by 2030 than WEO 2006. In the E.U., solar PV capacity in 2012 already exceeded the 2030 capacity projected in the WEO 2006 alternative scenario.

In the WEO 2014 450 ppm Scenario (hereafter 450 Scenario), which this analysis uses as the benchmark for determining whether renewable energy developments are consistent with the 2°C goal, total solar and wind capacity in China, the E.U., India, and the U.S. must be at 1640 GW by 2030. In the WEO 2015 450 Scenario, the total capacity needs to be at approximately 1730 GW. To assess whether these targets can be met, this analysis used CTI's rates of wind and solar deployment, which builds on data from Bloomberg New Energy Finance, to project diffusion of renewable energy capacity. The analysis finds that by 2030 the four economies' combined solar and wind capacity would be at approximately 2290 GW, exceeding the WEO 2014 450 Scenario projection by 40 percent and the WEO 2015 450 Scenario projection by 32 percent.

To further examine recent renewable energy projections, the analysis looked at the CAT and the CTI projections for a key driver metric: the overall renewable energy share of electricity generation (in this case, including hydropower, biofuels, wind, geothermal, solar PV, concentrated solar, and marine). Figure 3 compares renewable energy shares in electricity generation (output) according to WEO 2014's three main scenarios—Current Policies Scenario, New Policies Scenario, and 450 Scenario—the CTI estimates, and the CAT projections. The shares of RE generation projected in WEO 2015 are quite similar to those in WEO 2014.

In general, CTI projects the highest shares of renewables, and the WEO Current Polices Scenario, which is based on implementation of government policies and measures enacted as of mid-2013, projects the lowest shares. For the U.S., CAT estimates, which are based on U.S. Energy Information Administration (EIA) projections, are lower than WEO Current Policies Scenario estimates. CAT increased its estimate of renewable energy shares in India, relative to the WEO Current Policies Scenario, to reflect renewable energy policies introduced in 2015 to promote achievement of wind and solar PV targets through 2022. It lowered its estimate of those shares after 2022, because no policies are yet in place to promote renewables after that year. Without those policies, CAT projects that India will meet growth in electricity demand with fossil fuel and nuclear power generation. The CTI projections assume that market forces and lowered solar and wind costs will widen diffusion of renewable energy after 2020.

Figure 3 — Projections for Renewable Energy Share of Electricity Generation in Four Major Economies

	CHINA		E.U.		INDIA		U.S.	
	2020	**2030**	**2020**	**2030**	**2020**	**2030**	**2020**	**2030**
WEO 2014 CPS	24%	23%	32%	36%	16%	15%	16%	18%
WEO 2014 NPS	27%	28%	33%	41%	19%	24%	17%	22%
WEO 2014 450	28%	38%	34%	49%	20%	40%	17%	31%
CAT	22%	22%	36%	45%	21%	19%	15%	16%
CTI	26%	36%	35%	52%	26%	35%	20%	26%

Note: CPS = Current Policies Scenario; NPS = New Policies Scenario; 450 = 450 Scenario, which CTI uses as the benchmark for determining whether renewable energy developments are consistent with the 2°C goal.

The public policy of a few countries has accelerated growth of renewables over the past decade. In the 1990s, when wind and solar technologies were in their fledgling stage, Germany, Denmark, and other countries came forward with support schemes and became important renewable energy markets (Beise and Rennings 2005). Their policies made renewable energy technologies competitive in the short term. As these technologies have matured and moved toward or even achieved market parity, it has become easier for other countries to support renewable energy and for the renewable energy industry to develop in those countries.

The CTI and CAT renewable energy generation projections, which are based on current policies and market forces, would, if realized by 2030, greatly reduce overall power sector emissions and allow for relatively low-cost scenarios to achieve emissions reduction targets.

Coal Consumption

The main driver of power generation's carbon intensity—a key metric of power-sector decarbonization—is coal consumption. A decrease in the carbon intensity of electricity generation suggests an increase in low-carbon power sources and an eventual decrease in coal consumption for electricity generation. Looking at coal use—in particular, at when use peaks and at how quickly it declines—can provide insight into progress toward lowering an economy's carbon intensity (as major countries such as China and India are proposing as part of INDCs to a global climate agreement) as well as lowering GHG emissions.

The U.S. and the E.U., along with some other developed economies, have already reached a peak in their overall relative coal use for power generation, and their decreasing percentage of power generation from coal is expected to continue (see Figure 4).

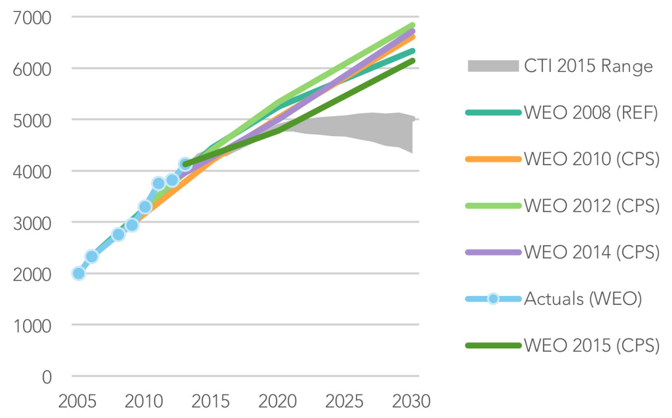
Figure 4 – WEO 2014: Projected Percent of Total Power Generation from Coal in the U.S. & the E.U.

	1990	2012	2020
U.S.	53%	38%	35%
E.U.	41%	29%	23%

Following this trend, China is also likely to peak and ultimately decrease its coal use. The timing of the peak and the subsequent speed of a decline in coal use may indicate possible trends for future timing and rate of decarbonization in other rapidly growing economies, such as India.

Figure 5 shows WEO and CTI projections of coal-generated electricity in China as well as actual data from subsequent WEOs. The WEO Current Policies Scenarios exhibit a fairly linear growth pattern in which the rate of growth in coal-generated electricity barely slows after 2020. By contrast, a range of CTI projections, which are based on varied assumptions about population and GDP growth pulled from the Shared Socioeconomic Pathway scenarios (IIASA n.d.), illustrates uncertainty about the time frame in which China's coal-generated electricity may peak and the rate at which it may plateau or decrease. Although significantly lower than the WEO 2015 CPS projections for 2030, this range is 50–73 percent higher than the WEO 2015 450 Scenario projections for 2030, which reflect a 2°C-compatible pathway.

Figure 5 – China's Power Generation from Coal in Terawatt-Hours as Projected in WEO and CTI Scenarios



Note: REF = Reference Scenario; CPS = Current Policies Scenario; Actuals = actual data.

Forecasters agree that coal will continue to play an important role in electricity generation in China, where in 2012 it made up 52 percent of the country's total coal demand (IEA 2014c). Among the drivers of variability in China's coal-generated electricity are the cyclical variability of hydroelectric power and the "backloading" of non-coal generation capacity in the country's five-year plans (Green and Stern 2015). CTI projections—which build on forecasts from BNEF and CTI's own modeling of electricity demand, structural shifts, and downward pressure on coal—suggest that power generation from coal will peak at or near 2020 and then slowly decline. Those projections appear to be bolstered by 2015 data from the National Bureau of Statistics of China (NBSC) showing that while total energy consumption grew 2.2 percent to 4.26 billion tons of coal equivalent between 2013 and 2014, the consumption of coal declined by 2.9 percent. The growth in total energy consumption mainly came from crude oil, up 5.9 percent; natural gas, up 8.6 percent; and electric power, up 3.8 percent (NBSC).

New data on total coal consumption in China have renewed interest in if and when consumption will peak.[2]

Direct fuel consumption of coal encompasses not only electricity generation but also building heating and demand from fast-growing heavy industries such as iron, steel, and cement. Given the above-noted 2.9 percent decrease in coal consumption from 2013 to 2014, decarbonization in the buildings and industry sectors could also occur more quickly than predicted. That development would increase the likelihood that China will meet or even surpass the carbon intensity goals within its INDC and that other developing countries such as India may be able to meet or surpass their decarbonization expectations.

IEA projects that total final consumption of coal by buildings and industry will reach a peak and gradually decrease between 2020 and 2030 (Figure 6). But more recent projections and forecasts point to broad structural shifts in the Chinese economy—for example, an overall saturation point for steel and cement and a move away from heavy industry to services and higher value-added manufacturing—as evidence that the peak will occur in the next five years (ERI, RMI, LBNL, and EFCSEG forthcoming; Green and Stern 2015). Reflecting these structural shifts, CTI projects that the peak will occur between 2016 and 2020 and that it will be followed by a steep decline.

China recently set a limit for its coal use: 4.2 billion tons of coal by 2020 (CAT 2015a)—meaning that the government has committed to constrain coal use by that date.

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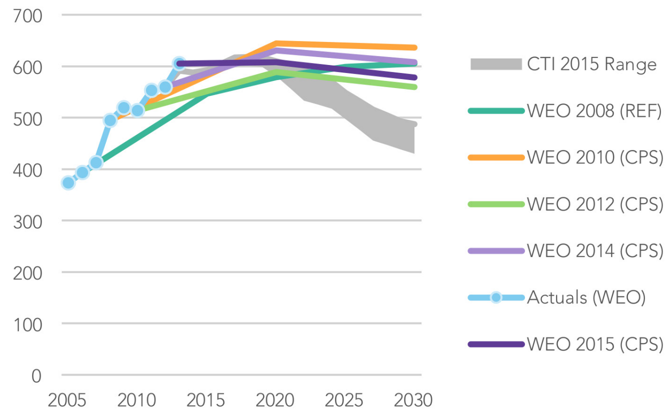
[2] According to the NBSC, energy-content-based coal consumption was 14 percent higher between 2000 and 2013 than previously reported (EIA 2015). Most of the increase in consumption was attributed to industries. However, NBSC estimates indicate that 2014 coal consumption has indeed declined by 2.9 percent. The revised data on energy and coal consumption would result in higher CO_2 emissions for the 2000–2013 period, though likely not for 2014. The present analysis has not revised the data on which its projections are based because it is unclear which industry type has witnessed the increase in coal consumption and how energy intensity rates have been affected.

Figure 6 – China's Total Final Coal Consumption (Buildings and Industry) in Millions of Tons of Oil Equivalent (Mtoe) as Projected in WEO and CTI Scenarios



Note: REF = Reference Scenario; CPS = Current Policies Scenario.

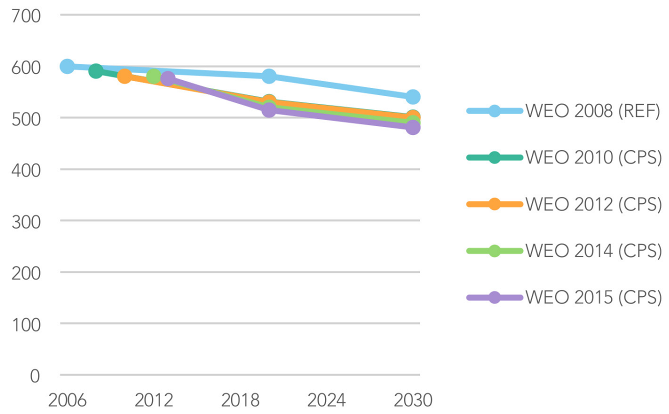
Emissions Intensity

To examine decarbonization of the power sector beyond renewable energy deployment and coal use, this analysis assessed recent changes in projections of the average emissions factor of power generation—that is, the amount of carbon dioxide produced per unit of generation (gCO_2/kWh).

As noted above, increases in the share of renewable energy generation lower this metric, but this phenomenon can also be due to technology switching, such as switching to relatively efficient thermal-generation technologies, or to fuel switching (from coal to gas). The latter will lower emissions factors only so far. Nevertheless, projections of emissions factors are changing and can contribute to optimistic forecasts for decarbonization at both the global and regional levels.

Figure 7 displays global emissions factors projections using WEO 2008, 2010, 2012, 2014 and 2015 projections (WEO projections for other years were omitted for clarity of display but show the same trend). The changes over time evidence a clear decline, meaning that a given amount of energy could be produced with fewer and fewer resulting emissions than previously expected, reflecting projected changes in the generating capacity of various fuels and technologies.

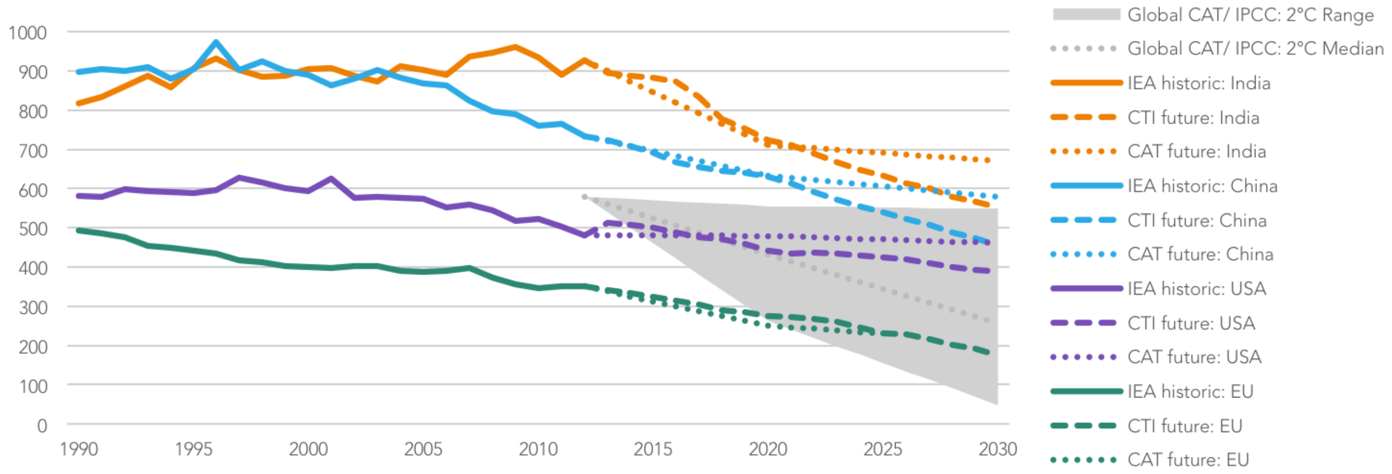
Figure 7 – Projections of Average Global Emissions Factor (gCO_2/kWh) for Electricity Generation Using World Energy Outlooks



Note: REF = Reference Scenario; CPS = Current Policies Scenario.

Figure 8 shows current CAT and CTI projections illustrating generally positive trends for the carbon intensity of power in China, the E.U., India, and the U.S., with regional disparities in emissions factors and an overall range of what would be globally compatible with a 2°C scenario.

Figure 8 – Historic Emissions Factors (gCO_2/kWh) for China, the E.U., India, and the U.S. as Reported by the IEA and Projected by CAT and CTI



Note: IPCC = Intergovernmental Panel on Climate Change.

Comparison of data for the E.U. and India shows the impact of additional renewable energy and technology switching for economies that straddle either side of the global average. Carbon intensities in both economies are on the decline. In India, the decline is more rapid, but emissions factors there have a high starting point; in fact in the CTI model, India's emissions factor is not projected to reach parity with 2013's global average, 576 gCO_2/kWh, until just before 2030.

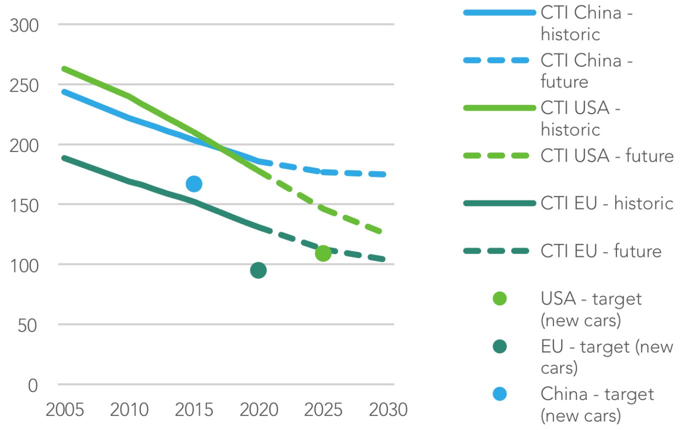
Again, a successive set of projections indicates an evolving understanding of future expectations. In the case of renewables, the rapid increase in capacity in the past few years reveals that the growth previously projected as necessary for a 2°C-compitible pathway by the WEO 2014 and 2015 450 scenarios may be met and even drastically exceeded. Compared with IEA projections, CAT and CTI projections tend to be more optimistic. They anticipate higher renewable energy capacity and lower emissions factors in 2030 and, in the case of China, a faster decline in coal use.

TRANSPORT SECTOR

The transport sector is responsible for approximately one-fourth of global energy-related emissions. If unabated, the sector's emissions will grow more quickly than emissions in other energy-related sectors. In principle, transport emissions can be reduced by avoiding travel, shifting to comparatively efficient modes of travel, reducing the energy intensity of travel, and reducing the emissions intensity of transportation fuels. Much of the emissions reductions will have to be achieved by light-duty vehicles (LDVs), including cars, which account for a large share of emissions in Organisation for Economic Co-operation and Development (OECD) countries and which are projected to play an increasingly important role in non-OECD countries. In total, LDVs account for about half the energy use in the transport sector (Sims et al. 2014).

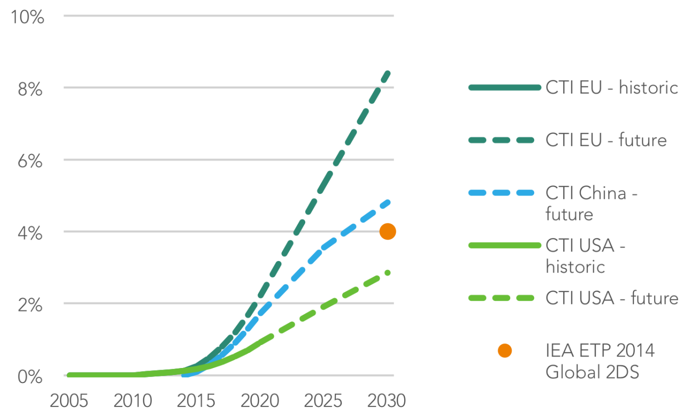
Two major trends can be observed with regard to LDV energy and emissions intensity. First, major economies such as the U.S. and the E.U. have increased their fuel economy by implementing standards that led to a decrease in average emissions per vehicle kilometer of almost 18 percent over the past decade; emissions are expected to decline at even higher rates through 2030. Second, deployment of electric drive vehicles (EDVs) and other vehicles that support an even greater decrease in emissions intensities has picked up with support by U.S. and Chinese policies.[3]

Figure 9 – Historic and Projected Average Intensity (gCO_2/vkm) of LDVs in China, the E.U., and the U.S.



Source: CTI. Note: Additional fuel consumption standards for LDVs in China are expected to take effect in 2016.

Figure 10 – Share of EDVs (% of Total Fleet)



Source: CTI.

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[3] Although EDVs do decrease emissions—even when operated on a grid that includes fossil energy—they can achieve their full emissions reduction potential only when combined with decarbonization of the energy supply sector.

Figure 11 – Development of Expectations for EDVs

2006 IEA ETP	2008 IEA ETP	2010 IEA ETP	2012 IEA ETP	2014 IEA ETP
Baseline 2050 Hybrids: 10%; BEV: 0% CO_2 emissions reduction in more ambitious scenarios reached through biofuels, fuel efficiency, and hydrogen.	Started to predict uptake of EDVs, expected to become fully commercial by 2030 under the EDV variant of BLUE scenarios. Deployment of BEVs projected to begin in 2020; baseline still assumed deployment of only plug-in hybrids.	Predicted that EDVs likely will start to enter market in material numbers in the next few years (IEA 2010, p. 277). BLUE map scenarios predict EDVs and PHEVs will begin to be sold in the U.S. around 2010 and reach significant volumes by 2015 (IEA 2010, p. 445).	Suggested that the adoption of BEVs might be faster than that of HEVs; however, strong policies are needed to overcome remaining shortcomings of BEVs (restricted driving range, cost, charging time).	BEVs projected to reach a penetration rate of <1% in 2030 and 2% in 2050 in the 4DS scenario. In the 2DS scenario this is 4% in 2030 and 17% in 2050

Sources: IEA (2006a, 2008a, 2010a, 2012a, 2014a). Note: BEVs = battery electric vehicles; HEVs = hybrid electric vehicles.

Emissions intensities have decreased as countries have put forward ambitious policy targets. Global fuel efficiency, which is closely linked to emissions intensity, decreased by 2 percent per year on average between 2005 and 2013 (IEA 2014b). In the same period, the CTI projects an average fuel-efficiency increase of 2.4 percent in both the U.S. and the E.U. and of 2 percent in China. Between 2015 and 2030, it projects average annual increases of 3.7 percent in the U.S., 2.7 percent in the E.U., and 1.1 percent in China.[4] These expected increases are largely driven by stringent fuel-consumption targets for new cars between 2015 and 2025.

Improvement in global average annual emissions intensities and fuel economy has recently slowed. In 2013, that improvement was only 1.8 percent—far short of the 2.7 percent improvement that, according to the Intergovernmental Panel on Climate Change, accords with a 2°C-compatible scenario (Fulton 2015; Sims et al. 2014). The 2°C-compatible rate of improvement could be reached if good-practice efficiency standards, such as those in effect in the E.U., were broadly implemented in the transport sector (Fekete et al. 2015).

EDVs could become a key driver for further lowering LDV emissions intensities, but to date they've had little market penetration, as IEA's annual Energy Technology Perspectives (ETP) projections indicate (see Figure 11).

Recently, however, EDV deployment has increased considerably. In 2012 the total stock was at approximately 170,000 (IEA 2015c), but in 2014, global sales were at approximately 300,000. In September 2015 the number of "highway legal, light-duty all-electric cars and plug-in hybrids sold in markets around the globe" passed 1 million (HybridCars.com 2015). This increase is largely attributable to rapidly maturing technology and supportive government policy. EDVs like the Nissan Leaf have become commercially viable options on the market, and though their driving ranges may be limited, consumers have found ways to integrate them into their daily routines. High-end markets offer EDVs with comparatively long-range batteries (the Tesla Model S can achieve a range of 434 kilometers), and these batteries are expected to improve. Furthermore, battery costs are falling at a faster-than-anticipated rate. Although the IEA repeatedly emphasizes cost as a major barrier to EDV offerings, Nykvist and Nilsson (2015) report that costs to

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[4] CTI projections do not as yet include China's phase IV fuel-consumption standards for LDVs, which are expected to take effect in early 2016 and to further increase current projections of fuel efficiency for China.

market leaders are considerably lower than previously reported.

According to Zhou et al. (2014), this development has been spurred by policy interventions:

- In the U.S.—A mix of incentives in national- and state-level policies has promoted EDVs. The most important policies are the California ZEV policy and the national corporate average fuel economy standards, along with national and state income tax credits. In 2010, the number of U.S.-registered plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) was 345; the number increased to approximately 18,000 in 2011 and 53,000 in 2012. In 2014, annual sales hit 123,000, accounting for a 2 percent share of total U.S. car sales (Inside EVs 2015).
- In Europe—The E.U. has no coordinated strategy for EDVs, but some member states, especially the Netherlands, have offered strong incentives, such as exemption from registration fees and road taxes (Zhou et al. 2014). Norway (not an E.U. member state) has reduced its high car-import tax for EDVs, with the result that EDV registration rates were at 12.5 percent of its total sales in 2014 (EV Norway 2015).
- In China—A subsidy was introduced for public electric vehicles in 2009 and then extended to private cars. This subsidy was paired with free license plate distribution in cities such as Shanghai and Beijing (Zhou et al. 2014). Although off to a slow start, EDV sales reached approximately 109,000 as of August 2015. In September 2015, China introduced several new measures to support deployment of EDV-charging infrastructure.

U.S., European, and Chinese governments are well aware that their EDV support is probably not the most cost-efficient way to reduce greenhouse gas emissions in the short term, but they have been motivated by various desires, including independence from fossil fuel imports and reduced local air pollution.

Transport sector forecasts have been corrected both for emissions intensity development and EDV market share. In some regions, if not globally, EDVs could play a major role in achieving 2°C-compatible emissions levels in the transport sector if emissions standards implemented in some countries are adopted by other countries and if promising early-market EDV trends continue.

OVERALL FINDINGS

The most emissions-intensive sectors in the world's four largest emitting economies (China, the E.U., India, and the U.S.) are power generation and transport. Sectoral indicators can help identify where emissions reductions efforts in these sectors could be scaled up and targets could be made more ambitious. In the power generation sector, important indicators are coal consumption, average carbon intensity of power, and growth of renewables. In the transport sector, they are trends in LDV fuel economy and emissions and market penetration of EDVs.

According to the models used in this analysis, decarbonization in the two sectors is proceeding faster than expected through policy support.

- Installed wind and solar capacity—In China, the E.U., India, and the U.S., installed wind and solar capacity has greatly exceeded successive WEO forecasts. CTI projections based on recent trends indicate that by 2030 it will exceed by 32 percent the capacity needed for a 2°C pathway indicated in WEO (2015). Overall, projected renewable energy shares in electricity generation in these economies are generally compatible with a 2°C pathway.
- Coal use and carbon intensity of power—The decrease in coal use in the E.U. and the U.S., along with the faster-than-expected projected decrease in China, is encouraging. CTI projects that total final consumption of coal in the buildings and industry sector in China will peak between 2016 and 2020 and decrease steeply thereafter. Although both CTI and CAT predict lower emissions factors for 2030 than does the IEA, the power sector must do considerably more to move to a 2°C-compatible pathway.
- LDV fuel economy and emissions and market penetration of EDVs—The emissions intensity of LDVs has been decreasing and between 2015 and 2030 is expected to continue that trend, according to CTI projections. EDV sales grew sixfold from 2012 to mid-2015. EDV market penetration could become global as technology costs decrease, much as renewable technologies have done over the past decade.

Nevertheless, some negative developments may counteract these gains.

- The recent discovery of and access to new fossil fuel resources such as shale gas and tar sands could further reduce oil and gas prices and therefore increase consumption.
- Demand for freight and air travel is increasing.
- Economic development could be faster and more dependent on fossil-fuel consumption than expected in some areas.

Together, these trends, some positive and some negative, suggest an overall emissions trajectory incompatible with the 2°C goal. Significantly more action on decarbonization is necessary to meet that goal.

POLICY IMPLICATIONS

Identifying and tracking 2°C-compatible developments, such as the increased use of renewables in power generation and the decreased emissions intensity of transport, suggest that some emissions reductions efforts are ripe for policy intervention or for wider deployment of proven policy supports.

Policy signals from a few countries can change global markets and speed technology development. Renewable energy-supportive policies in a few E.U. countries accelerated global renewables development, lowering prices and spurring adoption. Expansion of policies supportive of EDVs in the U.S., the Netherlands, Norway, and China could open up a global EDV market. Similarly, emissions standards lowered the emissions intensity of transport in the U.S. and E.U. and could do so elsewhere.

These examples suggest that "transformation coalitions" of countries and other players with critical mass could be formed to accelerate market uptake or technology development in areas that complement and support global climate agreements. These coalitions could spur transformation on a scale unachievable by unilateral national action. Members would have to be prepared to provide subsidies, incentives, and an enabling regulatory environment in the initial stages of development and deployment, but these actions would not be contingent on global or even regional carbon pricing schemes.

The coalitions would have to be formed in a way that allows members—while benefitting fellow members—to act in their own interest, as was the case when Denmark and Germany supported renewables in a bid to gain independence from fossil fuel imports and to provide a stimulus for innovation and new jobs. China and Norway supported EDVs to achieve independence from fossil fuel imports and to reduce air pollution. If coalition members are convinced that a transformation is clearly in their interest, "free riding" would be less of an issue for them.

Profitable areas for transformation coalitions include zero-energy buildings, super-efficient electrical appliances, electricity storage, zero-emissions aviation, and zero-emissions cement or steel.

Transformation coalitions could facilitate international cooperation on climate policy in support of a global agreement as well as accelerate urgently needed decarbonization actions.

APPENDIX: METHODOLOGY

Figure 12 – Overview of Indicators, Data Sources, and Data Uses for the Power and Transport Sectors

Sector	Indicator (Unit)	Data Source Used	Use of Data
Power	Cumulative installed capacity of solar and wind (GW)	(a), (b), (c)	(2), (3)
	Power generation from coal and RE (TWh)	(a), (b), (c)	(1), (3)
	Specific emissions per kWh/emission factor (gCO_2/ kWh)	(a), (b), (c)	(1), (3)
	Final coal consumption (Mtoe)	(a), (c)	(1), (3)
Transport	Emissions per kilometer for light-duty vehicles ($kgCO_2e$ /vkm)	(a), (c), (d)	(1), (2), (3) with gaps
	Share of electric vehicles per total vehicle stock (%)	(a), (d)	(2), (3)

Data sources: (a) = bottom-up assessment model developed by ClimateWorks' Carbon Transparency Initiative, (b) = Climate Action Tracker-gathered decarbonization indicators, (c) = ClimateWorks estimates based on the International Energy Agency's world energy outlook and energy technology perspective projections (d) = other sector-specific data indicating successive projections of decarbonisation. Data uses: (1) = description of historical trends, (2) = comparison of projections with actual developments, (3) = identification of changes in projections. Acronyms for units are as follows: GW: Gigawatt, TWh: Terrawatt hour, gCO_2/kWh: grams of CO_2 released per kilowatt hr of energy used, Mtoe: Million tons of oil equivalent, $kgCO_2e$/vkm: Kilograms of CO_2e released per vehicle kilometer travelled.

Power Sector

To determine the overall emissions change in the power sector, we looked at deployment of renewable energy, coal usage (especially in China), and emissions intensity. Whereas the CAT data on the power sector are mainly derived from IEA data, CTI performs its own analysis using chiefly data from Bloomberg New Energy Finance (BNEF). For example, to calculate electricity generation, from which the share of renewables is derived, the CTI method is to multiply the installed capacity of each type of electricity source (coal, oil, solar, etc.) by the appropriate capacity factor and a representative amount of full-load hours. Installed capacities change over time according to projected additions and retirements, all informed by BNEF but adjusted according to CTI's projected demand profile.

CTI indicators tend to point to greater power-sector decarbonization than CAT indicators because the CTI model uses BNEF data—which tend to be comparatively optimistic relative to IEA projections on the scale-up of renewable energy.

To assess coal consumption, the analysis mainly examined the use of coal in China and compared historical projections from the IEA with those of CTI. Coal use was examined in the power sector and in direct use by the buildings and industry sectors. As noted above, the power sector in the CTI is informed by BNEF data, but direct use in buildings and industry is projected separately. Industry sector projections in the CTI rely on a combination of subsector-specific modeling and a wide range of source data, whereas building sector projections are calibrated by the IEA's Energy Technology Perspective model. In all sectors, coal use is sensitive to changes in population and gross domestic product (GDP). CTI uses the Shared Socioeconomic Pathway scenarios to evaluate a range of outputs illustrating how changes in population and GDP might affect changes in energy demand and therefore to provide a range of emissions.

Transport Sector

For all indicators related to vehicle activity and intensity, both CAT and CTI use and modify data from the International Council on Clean Transportation (2014). Therefore, many of their data sets, such as historical data on vehicle activity of LDVs measured in vehicle kilometers, are identical.

The CAT tool calculates emissions intensity by dividing the estimated total amount of emissions from LDVs by overall LDV activity. The CTI model, on the other hand, approximates emissions intensity by a weighted sum of the emissions from each type of LDV (gasoline, diesel, compressed natural gas, fuel cell, or electric); these emissions are obtained by calculating the product of energy emissions intensity (tCO_2e/MWh) and energy intensity of activity (MWh/vehicle kilometer) for each LDV type.

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