CCUS

MONTANA CHAMBER OF COMMERCE

THE CASE FOR

Carbon Capture, Utilization & Sequestration

An analysis from the **Montana Chamber of Commerce**

Introduction

The evidence is clear that our world has been warming, caused in part by man-made carbon emissions. There is also agreement that some mitigation efforts are needed to reduce our emissions in order to address this warming trend. The debate on climate change should not be *whether* it is happening or *if* we should do something about it. The question before us now is: what are the likely future risks associated with climate change and what is the appropriate cost to prevent those risks.

We must also consider that while we're aiming to mitigate carbon emissions, we also need to increase the global energy supply. While growth in energy demand is relatively flat in most developed countries like the United States, it is projected to rapidly increase in the emerging world. **Total world energy consumption is projected to increase by 41% by 2050.**[1]

This dramatic growth in energy demand is driven by increasing populations. The United Nations projects the world population will grow from 7.6 billion people today, to 8.6 billion in 2030 and 11.2 billion in 2100.[2]

In addition to population growth, demand for energy is being driven by the need to eliminate the vast energy poverty that exists throughout the developing world.

IPCC:
"About 1.3 billion people worldwide do not have access to electricity and about 3 billion are dependent on traditional solid fuels for cooking and heating with severe adverse effects on health, ecosystems and development." [3]

Bringing those billions out of energy poverty is every much as pressing a problem as climate change. Energy policy must be designed to lower carbon emissions while at the same time supporting the increasing energy needs of emerging countries.

These dual challenges must be addressed together. We cannot focus solely on climate change or on energy poverty—the solutions we work toward must take both of these challenges into account.

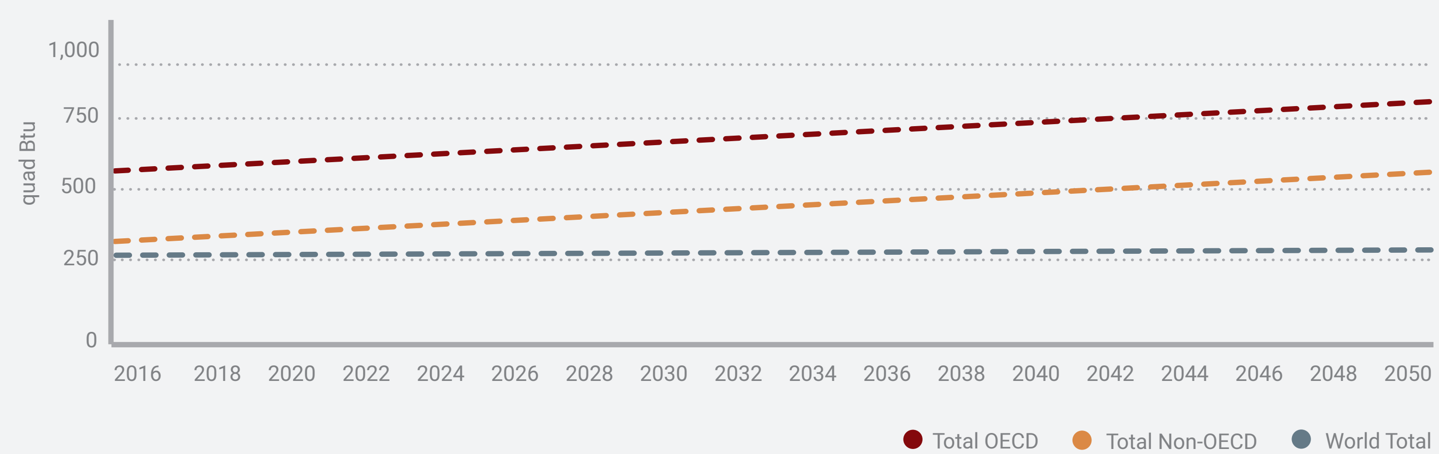
"The scientist is not a person who gives the right answers, he's one who asks the right questions."
—Claude Lévi-Strauss

Deploying renewable energy sources has been one way to increase access to energy while mitigating carbon emissions. But even with the rapid acceleration of renewables around the world, they are projected to meet only a small proportion of our energy needs, even over the long term.

Today, renewables, including hydroelectric, meet 12% of the world's energy needs, according to the United States Energy Information Administration ("EIA"). In 2050, the EIA estimates that renewables will be able to meet 18% of world energy needs.[4]

PROJECTED WORLD ENERGY CONSUMPTION

Data Source: U.S. Energy Information Administration



"Data from the World Bank shows that although 1.7 billion people acquired access to electricity from 1990 to 2010, the gains barely outpaced population growth." [5]

What is energy poverty?

Energy poverty affects almost half the world's population. It ranges from having no access to electricity whatsoever, to being significantly limited in access to power for heating, cooking, lighting, and other activities.

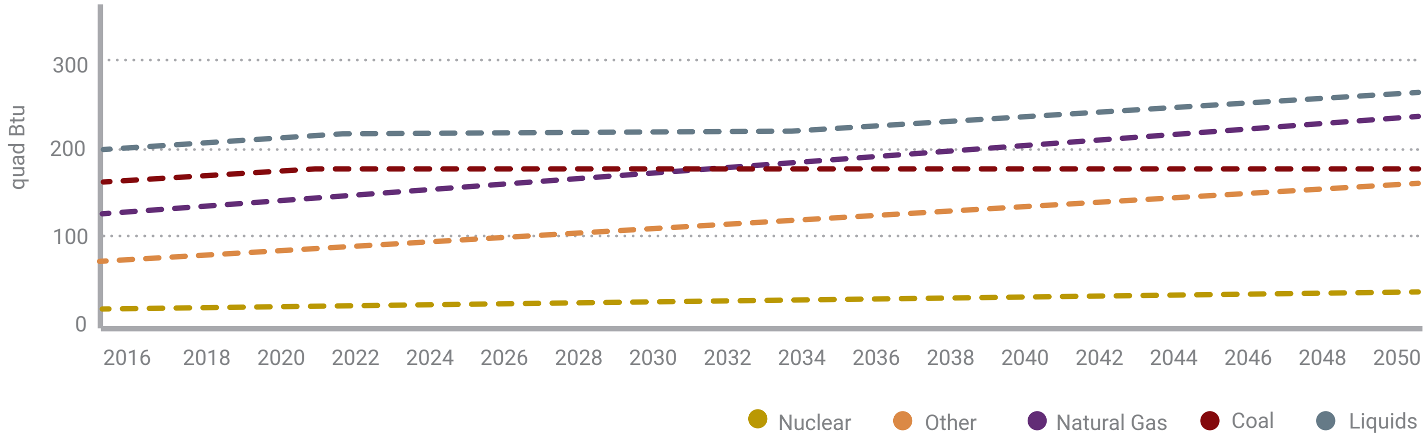
Energy poverty is a root cause of all sorts of undesirable outcomes in the developing world. Cooking indoors over a wood- or dung-fired stove increases chances of lung and heart disease. Lack of refrigeration has consequences for food safety and reduces the likelihood of access to vaccines. Low access to power reduces educational and job opportunities, lowers agricultural output, and decreases mobility.

Most, if not all, of the outcomes that we are trying to improve for the world's population can be tied in some way to energy poverty.

Photo credit: "Ruth Julius" by Trocaire, CC BY.

WORLD ENERGY USE BY FUEL SOURCE

Data Source: U.S. Energy Information Administration



This is not to suggest that renewables should not be a significant portion of our energy mix. But even with the substantial growth in renewable output, it is still not sufficient to replace the large role that fossil fuels play in meeting our current and future energy demands.

But the emphasis by some environmental groups on a renewables-only energy future ignores the realities the scientific community has detailed for us. Other technology, then, will be needed to meet the dual challenges of climate change and energy poverty.

Carbon Capture, Utilization, and Storage ("CCUS") is one of the most promising technologies to dramatically reduce emissions by decarbonizing electrical generation.* The IPCC has identified CCUS as a critical component in reducing emissions by 2100.

Investing further in CCUS technology provides a means through which we can both lower emissions and continue to increase energy production to meet increasing demand.

*For the purposes of this report, the acronyms CCUS and CCS are used interchangeably.

IPCC:

"Reaching atmospheric concentration levels of about 450 to about 650 ppm CO2eq by 2100 will require large-scale changes to global and national energy systems over the coming decades…characterized by a tripling to nearly a quadrupling of the global share of zero- and low carbon energy supply from renewables, nuclear energy, fossil energy with carbon dioxide capture and storage (CCS), and bioenergy with CCS (BECCS), by the year 2050 relative to 2010." [6]

The global push to to develop CCUS technology

"I would rather have questions that can't be answered than answers which can't be questioned." —Richard Feynman

There is broad agreement that decarbonizing electricity generation is the most important factor in addressing climate change, as generation is responsible for around 40% of global carbon emissions. Another 20% of emissions come from industrial processes, like cement and steel production—these emissions can also be mitigated using CCUS. The IPCC emphasizes that decarbonized electricity needs to increase dramatically over the next 30 years.

IPCC:
"Decarbonizing electricity generation is a key component of cost-effective mitigation strategies in achieving low-stabilization levels...In the majority of mitigation scenarios reaching about 450 ppm CO2eq concentrations by 2100, the share of low-carbon electricity supply increases from the current share of around 30% to more than 80% by 2050, and fossil fuel power generation without CCS is phased out almost entirely by 2100."[7] (notations and references to figures omitted)

The IPCC is not alone in focusing on CCUS as a key mitigation factor, other international organizations have also emphasized the importance of CCUS.

U.S. Dept. of Energy:
"The [International Energy Agency] projects that CCS will be required for 14% of the global cumulative CO2 emissions reductions by 2050, for a scenario with less than a 2°C rise in global temperatures. In fact, without a CCS mitigation option, the United Nations Framework Convention on Climate Change projects that the costs of achieving this global goal would increase by 138%."[8] (emphasis added)

During the Obama administration, CCUS topped the list of the U.S. Department of Energy's list of "(R&D) opportunities in clean electric power technologies."[9] DOE emphasized that "CCS has been an especially productive area for international (R&D) cooperation because market drivers for this technology do not exist in most countries, **and CCS may be the most economical approach for dealing with a portion of the CO2 emissions attributable to fossil fuels, which account for 80% of global energy."**[10] (emphasis added)

The U.S. Department of Energy has repeatedly emphasized the importance of CCUS: "*In the long term, to reduce U.S. greenhouse gas (GHG) emissions, significant deployment of carbon capture, utilization, and storage (CCS), coal/biomass to liquids (CBTL) and/or bio-energy with carbon capture and storage (BECCS) will be needed."*[11] (emphasis added)

The International Energy Agency ("IEA") projects that, by 2050, CCUS will be responsible for one-sixth of all emission reductions.[12] The IEA cautions that without investment in CCUS there is little likelihood of developing an effective long term plan for carbon emission mitigation.

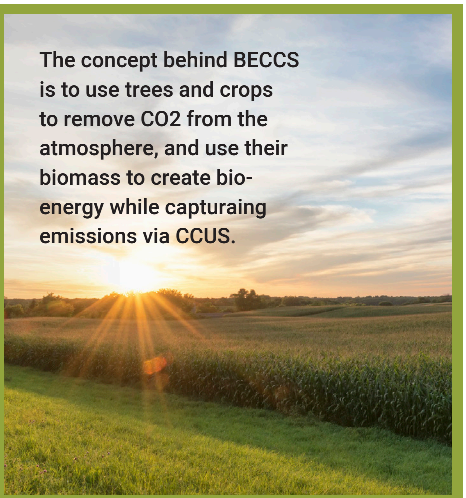
IEA:
"With coal and other fossil fuels remaining dominant in the fuel mix, there is no climate friendly scenario in the long run without CCS. CCS has so far been developing at a slow pace despite some technological progress, and urgent action is now needed to accelerate its deployment…After many years of research, development, and valuable but rather limited practical experience, we now need to shift to a higher gear in developing CCS into a true energy option, to be deployed in large scale."[13] (emphasis added)

While decarbonizing the electricity supply provides the greatest gains in mitigating emissions, it is also necessary to decarbonize industrial processes. Approximately 20 percent of carbon emissions are related to production of steel, cement, and chemicals, and oil refining. CCUS is the most promising technology for mitigating emissions that stem from these sorts of industrial processes.

The focus on CCUS by the scientific community stems from one simple factor: to meet the world population's energy needs in the near- and long-term, fossil fuels must remain a significant part of our energy mix. Even today, with three billion of the world's population living in moderate to extreme energy poverty, we are a long way off from meeting our energy needs.

IEA:
"What is more, CCS is currently the only large-scale mitigation option available to make deep reductions in the emissions from industrial sectors such as cement, iron and steel, chemicals and refining. Today, these emissions represent one-fifth of total global CO2 emissions, and the amount of CO2 they produce is likely to grow over the coming decades. Further energy efficiency improvements in these sectors, while urgently needed, have limited potential to reduce CO2 emissions, partly due to the non-energy-related emissions from many industrial processes. Failure to utilize CCS technology in industrial applications poses a significant threat to the world's capacity to tackle climate change." [14]

BECCUS: Achieving negative emissions depends on developing CCUS first



The concept behind BECCS is to use trees and crops to remove CO2 from the atmosphere, and use their biomass to create bio-energy while capturaing emissions via CCUS.

Over the long run, reducing carbon emissions is just the first step in addressing climate change. Scientists are also working on ways to remove CO2 from the atmosphere, referred to as "negative emissions."

One important negative emissions technology is bio-energy with carbon capture and storage ("BECCS"). The concept behind BECCS is to use trees and crops to remove CO2 from the atmosphere, and then use the biomass to create bio-energy. When that biomass is burned for fuel, the carbon is captured and utilized or stored using CCUS technology.

CCUS, then, is an important precursor to negative emissions technologies like BECCS.

The IPCC notes "combining bio-energy with CCS (BECCS) offers the prospect of energy supply with large-scale net negative emissions." [18]

IEA: *"Bio-energy with carbon capture and storage (BECCS) is an emissions reduction technology offering permanent net removal of CO2 from the atmosphere. BECCS works by using biomass that has removed atmospheric carbon during its growth cycle, and then permanently storing underground the CO2 emissions that result from its combustion or fermentation. A decrease in the amount of CO2 in the atmosphere results from the combination of the benefits of biomass use with the benefits of CCS, with the ultimate aim of storing more CO2 from biomass use than that emitted from fossil fuel use."* [16]

CCUS Fundamentals

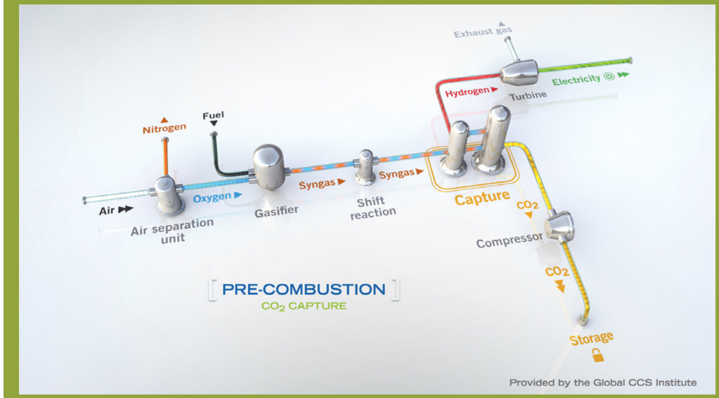
CCUS has been under development for many years, including major research projects in the United States by the Department of Energy. Only recently has CCUS been deployed on a commercial scale.

U.S. Dept. of Energy:
"Four years ago, only a single large-scale CCS demonstration project had begun construction in the United States. As of August 2015, one project is operational and three more are under construction. Globally, the number of large-scale CCS demonstration projects has doubled in this time frame (2011 to 2015), many with U.S. involvement, providing a wealth of data on CO2 capture systems and CO2 storage." [17]

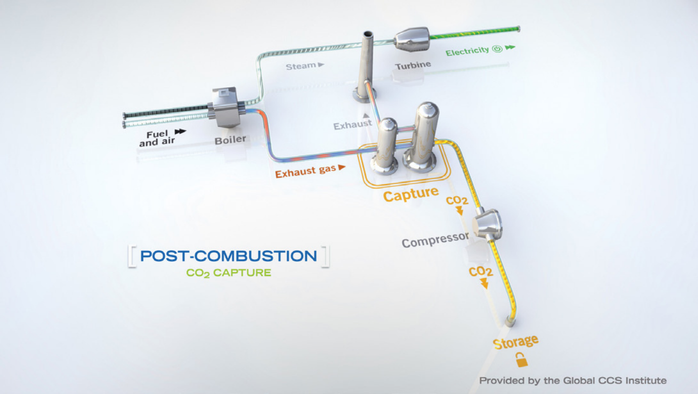
In general, there are three carbon capture technologies: pre-combustion, post-combustion, and oxyfuel combustion. After the CO2 is captured, it can be stored permanently in underground geological formations or used as a value-added commodity. For example, CO2 is being used for enhanced oil recovery, and integrated into concrete, plastics, and biomass manufacturing to create new products.

The IPCC estimates there is the technical potential of "at least about 2 trillion tons of storage capacity (for CO2) in geological formations." [18]

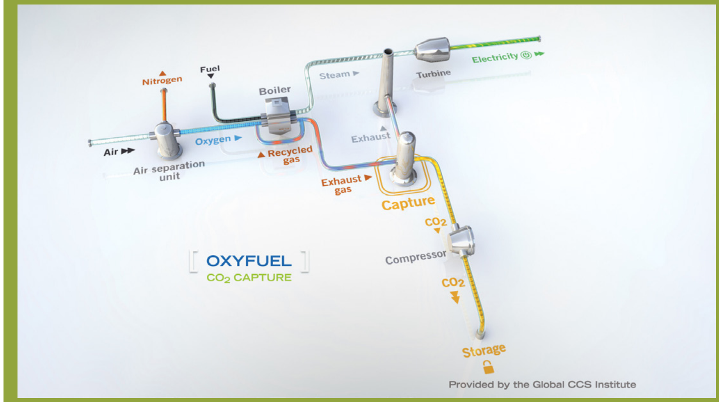
U.S. Dept. of Energy:
"Second-generation CCS technology includes a suite of improvements in capture performance, plant efficiencies, and component cost, and expanded characterization of storage options. These technologies are expected to become commercially available in the mid-2020s. Analyses of coal power with CCS conducted by the National Energy Technology Laboratory (NETL) show a 20% decrease in costs of mature units compared to first generation CCS technology... There are currently twenty-two large-scale CCS projects globally in the 'operate' or 'execute' stages (i.e., between detailed design and commissioning), and thirty-three projects in earlier stages." [19]



***Pre-combustion** processes convert fuel into a gaseous mixture of hydrogen and CO2. The hydrogen is separated and can be burnt without producing any CO2; the CO2 can then be compressed for transport and storage. The fuel conversion steps required for precombustion are more complex than the processes involved in post-combustion, making the technology more difficult to apply to existing power plants. Pre-combustion capture is used in industrial processes (such as natural gas processing) while its application in power generation will be via new build projects.*



***Post-combustion** processes separate CO2 from combustion exhaust gases. CO2 can be captured using a liquid solvent or other separation methods. In an absorption-based approach, once absorbed by the solvent, the CO2 is released by heating to form a high purity CO2 stream.*



*"**Oxyfuel** combustion processes use oxygen rather than air for combustion of fuel. This produces exhaust gas that is mainly water vapor and CO2 that can be easily separated to produce a high purity CO2 stream."*

Descriptions via the Global CCS Institute

TRENDS IN Coal Consumption

Worldwide coal consumption is projected to increase through 2040 by about 10%. In that year, coal will meet about a quarter of world energy consumption.

The increase in coal consumption will run concurrent with increases in all other energy sources, including a 71% increase in renewables, 60% increase in natural gas, and a 60% increase in nuclear. The bottom line is that to meet increasing global energy demand (projected to increase by 37%), we need an increase in production from all fuel sources.[20]

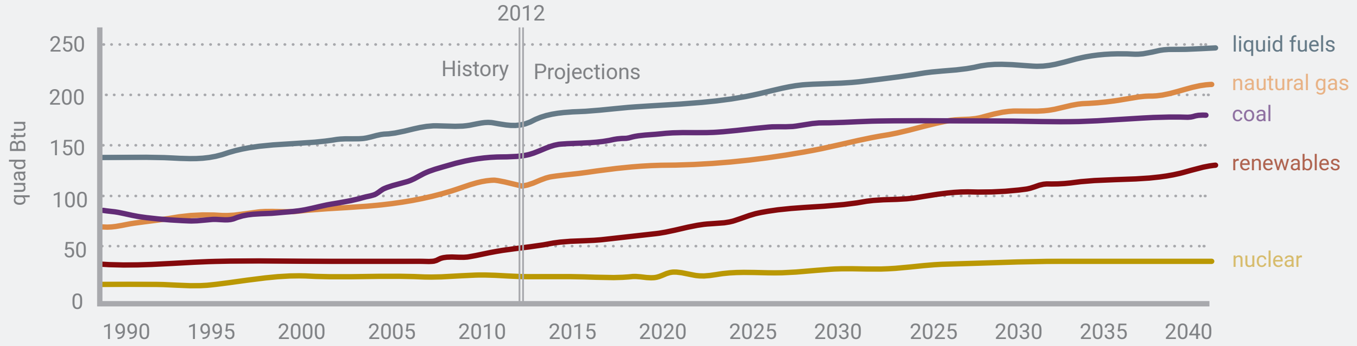
While domestic energy consumption related to coal is projected to see marginal declines, it will continue to remain a significant source of energy.

The reason many scientists continue to encourage investment in CCUS technology is because coal will continue to remain an important part of the energy mix—both domestically and worldwide. Additionally, coal and other fossil fuels provide dispatchable energy at a low cost that is unattainable for most renewables.

Any future energy mix must include some form of reliably dispatchable power in order to prevent down times in power supply that are likely when only renewable power is utilized.

WORLD ENERGY CONSUMPTION BY SOURCE 1990-2040

Data Source: U.S. Energy Information Administration



The Cost of CCUS

There are no solutions, there are only trade offs. - Thomas Sowell

Expanding access to electricity has obvious costs, as do the many emission mitigation strategies that have been proposed. **The IPCC estimates that "the costs of achieving nearly universal access to electricity and clean fuels for cooking and heating are projected to be between 72 and 95 billion USD per year until 2030 with minimal effects on GHG emissions."** [21]

Additionally, the costs of mitigating carbon emissions vary widely. CCUS has received such a great deal of attention because it is projected to be relatively cheaper than other mitigation strategies.

IEA:
"To significantly reduce energy-related CO2 emissions, massive deployment of many different low-carbon energy technologies is required. This includes efforts to increase energy efficiency in power and industrial production, and on the demand side. A broad portfolio of renewable energy, nuclear power and new transport technologies are also critical in reducing the carbon footprints of our societies. While not a 'silver bullet' in itself, CCS must be a key part of this portfolio of technologies." [22]

Similarly, any strategy to mitigate carbon emissions also has a cost. The further we go to reduce emissions, the higher the cost. The appropriate debate for policy makers, then, is not whether climate change is happening—it's to what extent do we need to reduce emissions to prevent catastrophic events related to climate change, and what are the most efficient (cheapest) means of achieving those emissions reductions. **CCUS is considered among the cheapest ways to substantially decrease carbon.**

The IPCC estimates that once CCUS technology has matured, electricity produced by coal-fired generation with CCUS will be cheaper than solar and similar in price to electricity produced by nuclear, natural gas, and onshore wind. [23] The IEA agrees that CCUS is a cost effective option: "CCS is an **integral part of any lowest-cost mitigation scenario** where long-term global average temperature increases are limited to significantly less than 4 °C, particularly for 2 °C scenarios." [24] (emphasis added)

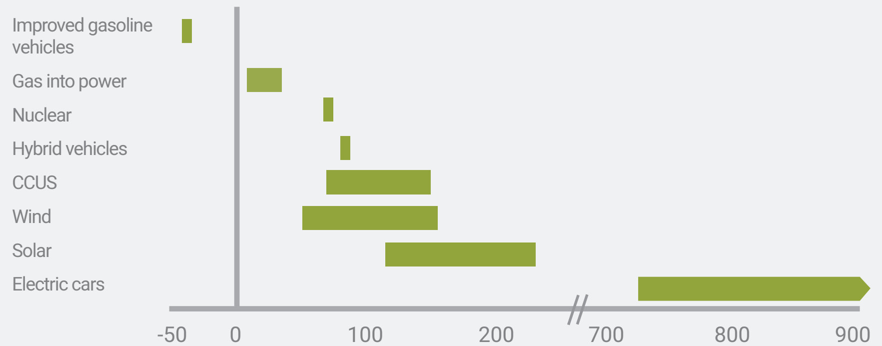
A special advisory group to the British government came to a similar conclusion: "carbon capture and storage is an essential component in delivering lowest cost decarbonization across the whole UK economy." [25]

IEA:
"CCS is also a low-cost emissions reduction option for the electricity sector. If CCS is removed from the list of emissions reduction options in the electricity sector, the capital investment needed to meet the same emissions constraint is increased by 40%. It is clear that CCS is the only technology available today that has the potential to protect the climate while preserving the value of fossil fuel reserves and existing infrastructure (emphasis added, citations in original omitted)." [26]

CCUS has been dismissed by some as being too expensive. Though the technology has been relatively more expensive through the development phase, that soon will not be the case. The U.S. Department of Energy has a goal to "reduce the cost of CCS by 30% by 2025." [27]

In sum, CCS is regarded as a low-cost and less disruptive technology that can mitigate GHG emissions while allowing deployment of new energy to the parts of the world that need it most.

AVERAGE U.S. CO2 ABATEMENT COSTS



Range of 2016 costs to eliminate one tonne of CO_2 (dollars per tonne)

Source: 2017 Outlook for Energy, A View to 2014. ExxonMobile

KEY Takeaways

1. **World energy consumption is projected to increase** by 41% by 2050 as the world's population increases by more than 1 billion, and hundreds of millions more are lifted out of energy poverty.

2. **Renewables are an important part** of addressing the dual challenges of climate change and energy poverty, however, renewables are projected to meet only 18% of world energy needs by 2050.

3. **Coal will remain an important part of the world's energy mix** far into the future. Demand for coal will increase through 2050. A significant effort, then, needs to be made to reduce and eliminate carbon emissions related to burning coal.

4. **CCUS has been identified as one of the most promising technologies** to mitigate carbon emissions. At the same time, CCUS will help the developing world continue to utilize cheap and plentiful coal in order to lift hundreds of millions of souls out of energy poverty.

5. **CCUS is projected to be one of the most cost-effective** $CO2$ mitigation technologies.

6. **CCUS is also the precursor technology** to one of the most promising "negative emissions" technologies: bio-energy with CCS (BECCS). CCS needs to mature as a technology before we can begin working on removing carbon from our atmosphere.

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1 "International Energy Outlook 2017: World total energy consumption by region and fuel." Interactive Table, U.S. Energy Information Administration. www.eia.gov/outlooks/ieo/

2 "World Population Prospects, 2017 Revision: Key findings & advance tables." United Nations. Pg. 1.

3 "Climate Change 2014, Mitigation of Climate Change: Summary for Policymakers and Technical Summary." Intergovernmental Panel on Climate Change, 2015. Pg. 29.

4 "International Energy Outlook 2017: World total energy consumption by region and fuel." Interactive Table, U.S. Energy Information Administration. www.eia.gov/outlooks/ieo/

5 "Power to the Poor," Morgan D. Bazilian. Foreign Affairs. March/April 2015 Issue.

6 "Climate Change 2014 Mitigation of Climate Change: Summary for Policymakers and Technical Summary." Intergovernmental Panel on Climate Change, 2015. Pg. 53.

7 "Climate Change 2014 Mitigation of Climate Change: Summary for Policymakers and Technical Summary." Intergovernmental Panel on Climate Change, 2015. Pg. 69.

8 "Quadrennial Technology Review: An Assessment of Energy Technologies and Research Opportunities." United States Department of Energy. September 2015. Pg. 105. (Footnote in original omitted).

9 "Quadrennial Technology Review: An Assessment of Energy Technologies and Research Opportunities." United States Department of Energy. September 2015. Pg. 418.

10 "Quadrennial Technology Review: An Assessment of Energy Technologies and Research Opportunities." United States Department of Energy. September 2015. Pg. 136.

11 "Quadrennial Technology Review: An Assessment of Energy Technologies and Research Opportunities." United States Department of Energy. September 2015. Pg. 228.

12 "Technology Roadmap: Carbon capture and storage." International Energy Agency. 2013. Pg. 5.

13 "Technology Roadmap: Carbon capture and storage." International Energy Agency. 2013. Pg. 1.

14 Technology Roadmap: Carbon capture and storage." International Energy Agency. 2013. Pg. 8. (citation omitted).

15 "Climate Change 2014 Mitigation of Climate Change: Summary for Policymakers and Technical Summary." Intergovernmental Panel on Climate Change, 2015. Pg 70.

16 "Technology Roadmap: Carbon capture and storage." International Energy Agency. 2013. Pg. 36.

17 "Quadrennial Technology Review: An Assessment of Energy Technologies and Research Opportunities." United States Department of Energy. September 2015. Pg. 101.

18 "IPCC Special Report on Carbon Dioxide Capture and Storage." Intergovernmental Panel on Climate Change. 2005. Pg. 12.

19 "Quadrennial Technology Review: An Assessment of Energy Technologies and Research Opportunities." United States Department of Energy. September 2015. Pg. 106. (Footnote omitted).

20 International Energy Outlook 2016," United States Energy Information Administration. Table: World total energy consumption by region and fuel. goo.gl/gAEU1z

21 "Climate Change 2014 Mitigation of Climate Change: Summary for Policymakers and Technical Summary." Intergovernmental Panel on Climate Change, 2015. Pg. 29. (Footnote omitted).

22 "Technology Roadmap: Carbon capture and storage." International Energy Agency. 2013. Pg. 8.

23 "Climate Change 2014 Mitigation of Climate Change: Summary for Policymakers and Technical Summary." Intergovernmental Panel on Climate Change, 2015. Pg. 71.

24 "Technology Roadmap: Carbon capture and storage." International Energy Agency. 2013. Pg. 22.

25 "Lowest cost decarbonization for the UK: The critical role of CCS," Report to the Secretary of State for Business, Energy, and Industrial Strategy from the Parliamentary Advisory Group on Carbon Capture and Storage (CCS). September 2016. Pg. 4.

26 "Technology Roadmap: Carbon capture and storage." International Energy Agency. 2013. Pg. 8.

27 "Quadrennial Technology Review: An Assessment of Energy Technologies and Research Opportunities." United States Department of Energy. September 2015. Pg. 108.

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