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**Bellona Position Paper:**

# Why $CO_2$ Capture and Storage (CCS) is an Important Strategy to Reduce Global $CO_2$ Emissions

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## Abstract

According to the Intergovernmental Panel on Climate Change (IPCC), global greenhouse gas (GHG) emissions must be reduced by 50 to 80 percent by 2050 to avoid dramatic consequences of global warming. Scenarios from the International Energy Agency (IEA) indicate that the potential for reduced $CO_2$ emissions through enhanced energy efficiency and increased renewable energy production is limited. According to the IPCC, a delay in $CO_2$ emission reductions can lead to dramatic consequences, and a new strategy for reducing $CO_2$ emissions as soon as possible is required. $CO_2$ Capture and Storage (CCS) is a technology with potential for large reductions in $CO_2$-emissions within 10 to 20 years. Therefore, the strategy for reducing global $CO_2$-emission must be a combination of (1) increased energy efficiency, (2) more renewable energy production, and (3) a wide implementation of CCS. By establishing stronger incentives favouring energy efficiency and renewable energy and by ensuring wide deployment of CCS, global $CO_2$ emissions can be reduced by approximately 70 percent by 2050 compared to emissions today.


## 1. Introduction

Emissions of greenhouse gasses (GHG) will increase the average global temperature by 1.1 to 6.4 °C by the end of the 21st century [1], according to the Intergovernmental Panel on Climate Change (IPCC). A global warming of more than 2 °C increase in global average temperature will lead to serious consequences, and IPCC have therefore stated that global GHG emissions should be reduced by 50 to 80 percent by 2050 [2].

The consequences of too high global warming will be melting of glaciers, leading to reduced water and food resources. The sea level will rise, and there will be more extreme weather, more draughts, and more floods. As a consequence more than 200 million humans can become climate refugees. Ecosystems will be disrupted, and 15 to 40 percent of all species can be extinct [3,4,5].

$CO_2$ is the most important greenhouse gas, and anthropogenic $CO_2$ emissions are mainly a consequence of fossil fuels being the most important global energy sources. Enhanced energy efficiency and increased renewable energy production will reduce $CO_2$ emissions, but according to the International Energy Agency (IEA) [6], energy efficiency and renewable energy do not have the potential to reduce global $CO_2$ emissions as much as IPCC's target, *i.e.* 50 to 80 percent by 2050.

The objective of this paper is to discuss different options for reducing global $CO_2$ emissions. Furthermore, a strategy for achieving 50 to 80 percent reductions in

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global $CO_2$ emissions by 2050 will be suggested. The paper starts by presenting scenarios for global energy and $CO_2$ emissions in Section 2. Different options for reducing global $CO_2$ emissions are discussed in Section 3, and a strategy for reducing global $CO_2$ emissions by 50 to 80 percent by 2050 is suggested in Section 4. Conclusions are given in Section 5.

## 2. Scenarios for Global Energy Demand and $CO_2$ Emissions

### *2.1. Global Energy Demand*

Analyzing the future energy demand is a prerequisite for predicting future $CO_2$ emissions. IEA [6] has established two scenarios for future energy demand, a Reference Scenario (*RS*) which is a business-as-usual scenario, and an Alternative Policy Scenario (*APS*). In the *APS* it is assumed that new policies favoring existing environmentally friendly technologies are implemented. Therefore, *APS* assumes more renewable energy production and a larger potential for energy efficiency than *RS*.

Future global energy demand is presented in Figure 1. This figure shows that a large increase in global energy demand is expected and that according to the RS, the global energy demand will increase by 50 percent by 2030.

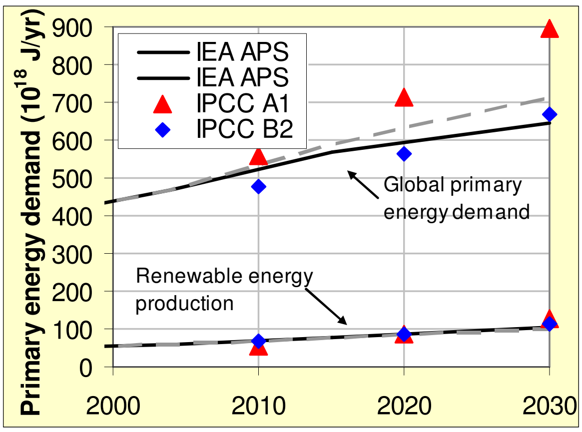


*Figure 1 - IPCC and IEA scenarios for global primary energy demand.*

Renewable energy production is expected to increase, but renewable energy is expected to cover only 13 to 16 percent of the primary global energy demand [6] by 2030, according to the *RS* and the *APS*, respectively. There will be a large gap between renewable energy production and energy demand, and this gap will be filled by fossil fuels. The world will therefore be dependent on fossil fuels as the main energy source for several decades.

The scenarios from IEA have been compared to energy demand scenarios established by the IPCC. As seen in Figure 1, energy demand and renewable energy production show similar trends in the IEA and the IPCC scenarios. IPCC have established several scenarios, but only the *A1* and *B2* scenarios [7] are shown in Figure 1. These are the scenarios predicting the highest and lowest energy demands of the main IPCC scenarios. Both the IEA and the IPCC scenarios illustrate that the renewable energy potential is too low to meet the total energy demand in the next decades. More details on scenarios for global energy demand are presented in Reference 8.

### *2.2. Global $CO_2$ Emissions*

In a business-as-usual scenario, global $CO_2$ emissions will increase by 48 percent by 2030 according to the IEA *RS* scenario. The alternative scenario, *APS*, predicts 26 percent higher $CO_2$ emissions in 2030 than today.

IEA have published a report called "Energy Technology Perspective" [9] where they have analyzed how new technologies can contribute to reductions in global $CO_2$ emissions through 2050. The scenario called *ACT Map* (ACcelerated Technology Map) is based on an ambitious but realistic deployment of new technologies, and according to this scenario, global $CO_2$ emissions in 2050 can be at the same level as today. The main technologies included in the *ACT Map* scenario are energy efficiency in buildings, $CO_2$ Capture and Storage (CCS), bio fuels, and electricity production from nuclear sources, renewables, and natural gas. IEA has also established a more optimistic scenario where new technologies are deployed faster than in the *ACT MAP*. In this scenario, called *TECH Plus* [9], the global $CO_2$ emissions in 2050 is 27 percent lower than in 2007.

Scenarios for global $CO_2$ emissions are presented in Figure 2. This figure shows that the most optimistic scenario, *TECH Plus*, predicts much higher $CO_2$-emissions than IPCC's target of 50 to 80 percent reduction in global $CO_2$ emissions by 2050. Therefore, much stronger incentives than accounted for by the IEA are required to obtain sufficient reduction in $CO_2$ emissions. More details on scenarios for $CO_2$ emissions are given in Reference 8.

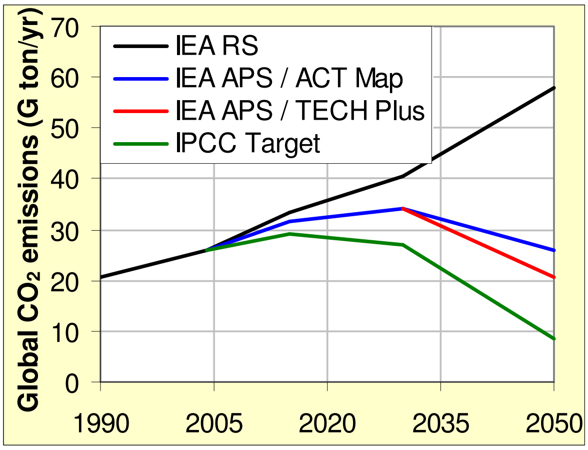


*Figure 2 - Global $CO_2$ emissions based on IEA scenarios. Black line: the Reference Scenario (RS). Blue line: the Alternative Policy Scenario (APS) from 2005 to 2030 and extrapolation to the ACT Map scenario in 2050. Red line: extrapolation from APS in 2030 to the TECH Plus scenario in 2050. Green line indicates $CO_2$ emissions reduced by 2/3 in 2050 compared to emissions today. As such, the green line represents the IPCC target of 50 to 80 percent reduction in global $CO_2$ emissions by 2050.*

# 3. Ways to Reduce Global $CO_2$ Emissions

## 3.1. *Energy efficiency and Renewable Energy*

A sustainable future energy path should be based on renewable energy and enhanced energy efficiency. In the long term, fossil fuels and nuclear energy should be phased out, and all energy production should be based on renewable energy. However, there are considerable barriers to a large increase in renewable energy production in the short term.

### 3.1.1. Barriers

When analyzing the potential for renewable energy it is important to make a clear distinction between the theoretical and the realizable potential for energy production. Even though the theoretical potential for renewable energy is large, the realizable potential is strongly limited by technological and economical barriers, environmental issues and land use conflicts [10]. Four levels of renewable energy potential have been defined by de Noord et al [11]:

- **The Theoretical Potential** is the total physical energy from a given energy source.
- **The Technical Potential** is the energy that can be utilized with existing technology. The *Technical Potential* is lower than the *Theoretical Potential* due to technical barriers.
- **The Realistic Potential** is the energy that can be utilized after addressing barriers like social accept, environmental implications, area conflicts and market mechanisms. As such, the *Realistic Potential* is lower than the *Technical Potential*.
- **The Realizable Potential** is the energy that can be utilized within a given time-scale. This potential is limited by economic barriers and production capacity in the global market. Due to such barriers, the *Realizable Potential* is lower than the *Realistic Potential*.

For most renewable energy sources the *Realizable Potential* is much lower than the *Theoretical Potential*. This can be illustrated by solar energy which has a theoretical potential 15 000 times the global energy demand [12] and a realizable potential today far below the global energy demand.

The main barrier to implementation of large-scale renewable energy production is often high production costs. An improved support framework for renewable energy is required to ensure technological development and thereby reduction of production costs.

The environmental impact of energy production is in most cases not reflected in the energy price. This failure to internalize external costs has created energy markets that are distorted in favor of non-renewable energy sources [13]. Fossil fuels are therefore the cheapest energy source in most cases. New market regulations are necessary to internalize external costs and thereby making renewable energy production more competitive.

The lack of infrastructure and regulatory frameworks are other barriers to the implementation of clean energy production. In addition, government backing of projects requiring incentives to succeed is necessary to ensure that the wider society pays the lowest price possible for renewable energy.

Other barriers include land area conflicts and laws and regulations to ensure the environment and the biodiversity is not negatively affected when large-scale renewable energy production is introduced.

#### 3.1.2. Potential

As seen in Section 2, renewable energy is expected to supply only up to 16 percent of the global energy consumption in 2030, according to IEA [6]. However, it is also clear that the incentives addressed in IEA's scenarios are insufficient to obtain large reductions in $CO_2$ emissions. Stronger incentives are needed.

Greenpeace has performed a study on energy efficiency and renewable energy [14], and its results indicate that global $CO_2$ emissions can be cut by up to 50 percent within 2050 by realizing the full potential for energy efficiency and renewable energy. Greenpeace has phased out nuclear energy and not introduced CCS in its scenario.

Greenpeace is very optimistic in its view on the potential for energy efficiency, and it can be questioned whether Greenpeace is trying to realize the *Technical Potential* and not the *Realizable Potential* for renewable energy. IEA is, on the other hand, conservative in its view on renewable energy. According to IPCC, large reductions in $CO_2$ emissions are required, and stronger incentives than those addressed by the IEA are therefore required to enhance energy efficiency and renewable energy production. Most possible, the true potential for energy efficiency and renewable potential is somewhere between the IEA scenarios and the Greenpeace scenario.

The Greenpeace scenario [14] is a strong indication that energy efficiency and renewable energy, *as the only strategies* to reduce $CO_2$ emissions, might not lead to sufficient emission reductions. The Greenpeace scenario indicates *up to* 50 percent reduction in global $CO_2$-emissions, but according to the IPCC, global $CO_2$ emissions must be reduced by 50-80 percent by 2050 [2].

Other strategies in addition to energy efficiency and renewable energy are therefore required to ensure that $CO_2$ emissions are cut by up to 80 percent by 2050. More details on the potential and barriers for renewable energy are given in Reference 15.

### *3.2. Nuclear Energy*

More nuclear energy has been proposed by several organizations as an option to reduce $CO_2$ emissions. However, the potential for nuclear energy is too small to rely on nuclear energy as the sole strategy to obtain sufficient reduction in global $CO_2$ emissions.

The potential for nuclear energy is limited by technical and economical challenges, security issues, limited Uranium resources, and too few experts with know-how on nuclear energy technology.

The IEA *TECH Plus* scenario assumed a substantial deployment of nuclear energy, but according to this scenario nuclear energy will supply less than ten percent of the total global energy demand in 2050. Even realizing the full potential of nuclear energy will not lead to sufficient reductions in $CO_2$ emissions in order to limit global warming to 2 $^{o}$C.

There are several drawbacks related to nuclear energy production. The nuclear waste is radioactive and will remain deadly for centuries and generations to come. In addition, not one country in the world has deployed a safe method for storing it. Nuclear products from energy production can be used in dirty bombs or processed to nuclear weapons. Furthermore, a terrorist attach on a nuclear energy plant could have catastrophic consequences.

The limited potential for reducing global $CO_2$ emissions and the hazards related to nuclear energy indicates that nuclear energy is a bad strategy for reducing $CO_2$ emissions.

### 3.3. Fusion Energy

Fusion energy production is based on the release of large amounts of energy when hydrogen isotopes react to form helium. Fusion energy has for decades been considered the future energy source that will solve all the global energy problems. However, presently there is no technology available for production of fusion energy.

It is difficult to say when fusion energy will be commercially available, but it will probably take decades. According to the IPCC and the Stern report [5] actions to reduce $CO_2$ emissions must be deployed immediately. Delaying actions to reduce the emissions is not acceptable, and waiting until fusion energy is available is therefore not an option.

### 3.4. $CO_2$ Capture and Storage

$CO_2$ Capture and Storage has the potential to reduce global $CO_2$ emissions considerably. CCS includes the establishment of infrastructure and technology for $CO_2$ capture, transportation and storage in locations where $CO_2$ will be safely isolated from the atmosphere. For practical and economic reasons $CO_2$ capture will be established at large $CO_2$ sources, mainly fossil fuel fired power plants, but also large petrochemical, steal and aluminium plants. The exhaust gas from fossil fuel power plants contains relatively low concentrations of $CO_2$. Therefore $CO_2$ has to be separated from the exhaust gas before transported to a safe storage location. Technologies for $CO_2$ capture from exhaust gas exist today, and $CO_2$ capture plants may be added to existing power plants.

Transportation of $CO_2$ can be done either through pipelines or by ship. $CO_2$ can be stored in geological formations underground, like saline aquifers and depleted oil and gas fields. In the North Sea one million ton $CO_2$ has been stored annually in the underground geological formation called Utsira since 1996. The stored $CO_2$ has been monitored thoroughly, and experiences from the Utsira project shows that $CO_2$ can be stored underground without leaks [16]. More details on CCS technology can be found in Reference 17.

The IEA has already introduced CCS in its scenarios as a way to reduce $CO_2$ emissions. However, it can be questioned if the IEA is too conservative in its view on the potential for CCS. In the last report from the IPCC [18], CCS is suggested as one of the main options for reducing global $CO_2$ emissions, and recent presentations from the IPCC indicate that CCS has a larger potential than addressed by the most optimistic IEA scenario, *i.e.* the *TECH Plus* scenario.

One weakness of the *TECH Plus* scenario is that CCS is not introduced in the transport sector. The EU technology platform on hydrogen and fuel cells concludes that hydrogen can be an important fuel with a marked share of 50 percent in 2050 [19]. If the hydrogen production is combined with CCS, large reduction in $CO_2$ emissions within the transport sector is possible.

In addition, the *TECH Plus* scenario is also too conservative in its view on the CCS potential within the power production and industry sectors. According to the vision of the EU Technology Platform on Zero Emission Fossil Fuel Power Plants (ZEP), CCS has a potential for capturing and storing 240 Giga ton $CO_2$ globally by 2050 [20], thereby reducing global $CO_2$ emissions by 37 %. These numbers are based on a study presented by Bellona [21].

The potential for CCS is illustrated in Figure 3. In this figure the IEA *Tech Plus* scenario is modified with the CCS potential calculated in the Bellona study [21]. From this figure it is seen that global $CO_2$ emissions in 2050 can be cut by about 50 percent compared to emissions today by addressing the full potential for CCS and by addressing energy efficiency and renewable energy as accounted for by the *TECH Plus* scenario.

In order to obtain up to 80 percent reduction in global $CO_2$ emissions, it is not sufficient only to deploy CCS to its full potential. In addition to CCS, enhanced energy efficiency and more renewable energy production must also be addressed.

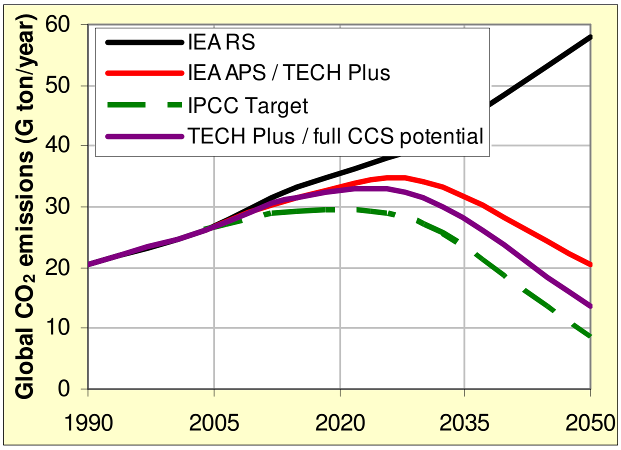


*Figure 3 – Scenarios for global $CO_2$ emissions. Black line: the IEA Reference Scenario (RS). Red line: the Alternative Policy Scenario (APS) from 2005 to 2030 and extrapolation to the TECH Plus scenario in 2050. Purple line: the TECH Plus scenario modified with the full CCS potential calculated in Reference 21. Green line indicates $CO_2$ emissions reduced by 2/3 in 2050 compared to emissions today. As such, the green line represents the IPCC target of 50 to 80 percent reduction.*

## 4. A Strategy for Reducing Global $CO_2$ Emissions by 50 to 80 percent

In the long-term, the best way to reduce GHG emissions is to change the main source of energy production from fossil fuels to renewable sources, and to reduce energy consumption through energy efficiency measures. However, as seen in Section 3, enhanced energy efficient and more renewable energy is not sufficient to reduce global $CO_2$ emission by 50 to 80 percent by 2050.

According to the IPCC, a delay in $CO_2$ emission reductions will have severe consequences. It is necessary to include other options than energy efficiency and renewable energy in the strategy to close the gap between energy demand and renewable energy production. As shown in Section 3.4, CCS has a large potential for reduction in $CO_2$ emissions. The strategy for reducing global $CO_2$ emissions should therefore be a combination of:

- Enhanced energy efficiency
- More renewable energy
- Wide implementation of CCS

The potential for reduction in global $CO_2$ emissions can be calculated as follows:

1. IEA is assumed to be too conservative in their point of view on the potential for energy efficiency and renewable energy. On the other hand, Greenpeace is assumed to be too optimistic.
2. The potential for $CO_2$ emission reduction due to energy efficiency and renewable energy is therefore assumed to be the average of the IEA *TECH Plus* scenario and the Greenpeace scenario.
3. The potential for reduction in $CO_2$ emissions due to CCS is assumed to follow the Bellona calculation in Reference 21.
4. Nuclear energy is phased out.

Calculations based on the assumptions above show that $CO_2$ emissions can be reduced by 71 percent by 2050 compared to emissions today. Figure 4 shows how the combination of enhanced energy efficiency, more renewable energy, and full deployment of CCS can lead to sufficient reduction in global $CO_2$ emissions to achieve the IPCC target of 50 to 80 percent reduction.

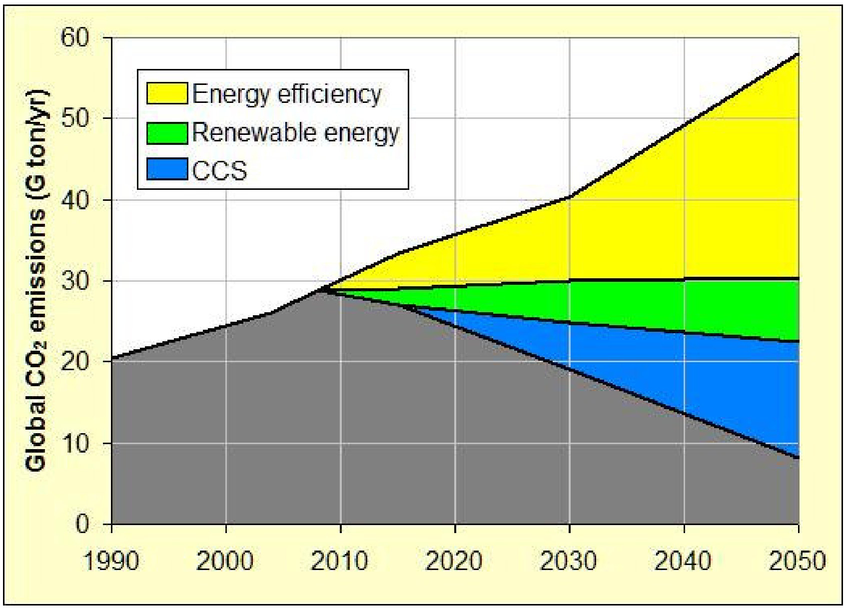


*Figure 4 – The strategy to reduce global $CO_2$ emissions. This figure indicates how global $CO_2$ emissions can be reduced by 71 percent in 2050 compared to emissions today. The upper line is global $CO_2$ emissions according to the IEA Reference Scenario, RS. The yellow, green, and blue areas indicate $CO_2$ emission reduction due to energy efficiency, renewable energy, and CCS, respectively.The grey area indicates the global $CO_2$ emissions when emission reduction through energy efficiency, renewable energy and CCS are addressed.*

## 5. Conclusion

Global $CO_2$ emissions must be reduced by 50 to 80 percent by 2050 according to the IPCC. The potential for reducing $CO_2$ emissions by enhanced energy efficiency and more renewable energy production is limited in this time period. Therefore, other options are required to complement energy efficiency and renewable energy in the strategy to reduce global $CO_2$ emissions.

By addressing the full potential of CCS, it is possible to obtain reductions in global $CO_2$ emissions that will meet the IPPC target. The strategy for reducing global $CO_2$ emissions must therefore be a combination of:

- Increased energy efficiency
- More renewable energy production
- Wide implementation of CCS

It is shown that global $CO_2$ emissions can be reduced by approximately 70 percent by 2050 by addressing an ambitious but realistic potential for energy efficiency, renewable energy and CCS. However, this requires establishment of strong regulatory and economic incentives to realize the full potential for energy efficiency, renewable energy and CCS.

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