

# THE CLIMATE EMERGENCY:

## Two time scales

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## Introduction

### Why is climate change an emergency?

Quick change is needed to save the long-term future.

The central problem which the world faces in its attempts to avoid catastrophic climate change is a contrast of time scales. In order to save human civilization and the biosphere from the most catastrophic effects of climate change we need to act immediately, Fossil fuels must be left in the ground. Forests must be saved from destruction by beef or palm oil production.

These vitally necessary actions are opposed by powerful economic interests, by powerful fossil fuel corporations desperate to monetize their underground “assets”, and by corrupt politicians receiving money from the beef or palm oil industries.

However, although some disastrous effects climate change are already visible, the worst of these calamities lie in the distant future. Therefore it is difficult to mobilize the political will for quick action. We need to act immediately, because of the danger of passing tipping points beyond which climate change will become irreversible despite human efforts to control it.

Tipping points are associated with feedback loops, such as the albedo effect and the methane hydrate feedback loop. The albedo effect is important in connection with whether the sunlight falling on polar seas is reflected or absorbed. While ice remains, most of the sunlight is reflected, but as areas of sea surface become ice-free, more sunlight is absorbed, leading to rising temperatures and further melting of sea ice, and so on, in a loop.

The methane hydrate feedback loop involves vast quantities of the powerful greenhouse gas methane,  $\text{CH}_4$ , frozen in a crystalline form surrounded by water molecules. 10,000 gigatons of methane hydrates are at present locked in Arctic tundra or the continental shelves of the world's oceans. Although oceans warm very slowly because of thermal inertia, the long-term dangers from the initiation of a methane-hydrate feedback loop are very great. There is a danger that a very large-scale anthropogenic extinction event could be initiated unless immediate steps are taken to drastically reduce the release of greenhouse gases.

## Scientists have long been aware of the dangers

Scientists have long been aware that CO<sub>2</sub> and other greenhouse gases released into the earth's atmosphere through human activities can cause dangerous climate change. László Szombatfalvy's important book, "The Greatest Challenges of Our Time", (Ekerlids, 2010), gives the following history of our knowledge of the link between greenhouse gases and climate change:

"As far back as 100 years ago, Swedish scientists observed that human activities could affect the climate. Arvid Högbom, professor of geology in Stockholm, warned in 1895 that anthracite burning would increase carbon dioxide content in the air. The following year, Svante Arrhenius, professor of physics and Nobel Prize Laureate, estimated that doubling of the content of carbon dioxide in the atmosphere would lead to an increase of the earth's average temperature by 5-6 degrees C. However, with the low emissions at that time, the process would take several thousand years.

"In 1938, measurements by Guy S. Callendar, an English researcher, confirmed theories that the amount of carbon dioxide in the atmosphere had actually increased since the previous century. His report made little impact since attention at that time was focused on the outbreak of World War II.

"During the 1950s and 1960s, several research reports were published supporting Svante Arrhenius's calculation of carbon dioxide emissions' warming effects. But the time perspective in these reports has been reduced considerably.

"In the 1970s, it was discovered that emissions of several other greenhouse gases from human activities heightened carbon dioxide's effects.

"In 1988, the International Panel on Climate Control, IPCC, was organized. Every fourth or fifth year since 1990, the IPCC has published climate change reports that are increasingly more extensive and ominous.

"In December 1997, the first international agreement to limit emissions of greenhouse gases was signed in Japan. Known as the Kyoto Protocol, the agreement's goal is that industrialized nations reduce emissions of greenhouse gases by 5.2 percent by 2012, compared with 1990 levels. The Protocol has been hitherto ratified by 176 countries, but unfortunately not by the most important country in this matter: USA."

More recently, on December 12, 2015, the Paris Agreement was adopted by consensus by the 196 parties of the United Nations Framework Convention on Climate Change. As of June, 2017, 195 UNFCCC members have signed the Agreement, and 153 nations have ratified it.

The Paris Agreement aims at “Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change.”

## Outline of the book

In writing this book, I have tried to gather facts from as many sources as possible to throw light on issues connected with climate change. In his autobiography, Charles Darwin says, “Science consists in arranging facts in such a way that general conclusions may be drawn from them.” I have tried to work in this spirit, the Baconian method. The conclusion to which I believe the facts point is reflected in the title of the book: **The Climate Emergency**.

As is discussed in Chapter 1, the transition to 100% renewable must take place in about a century because by that time fossil fuels will become too rare and expensive to burn. They will be used instead as starting points for chemical synthesis.

Chapter 1 also points out that although a very quick transition to renewable energy is needed, there is reason for optimism<sup>1</sup>, because an economic tipping point has been passed. Both solar and wind energy are cheaper than energy from fossil fuels, especially if the enormous governmental subsidies to the fossil fuel industries are discounted.

Chapter 2 reviews current renewable energy technologies. A special section is devoted to Elon Musk’s innovative work.

In Chapter 3, we discuss the fact that although the extraction of fossil fuels urgently needs to stop, coal, oil and natural gas are being produced today, almost as if the climate emergency did not exist.

Some of the frightening consequences of a business-as-usual economic trajectory are discussed in Chapter 4. We are in danger of passing tipping points, after which human efforts to prevent catastrophic climate change will become useless because of feedback loops. There is a danger that a human-produced sixth major extinction event will be initiated. It could be comparable to the Permian-Triassic extinction, during 96% of marine species and 76% of terrestrial vertebrates vanished forever. <sup>2</sup>

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<sup>1</sup>See Al Gore: The Case for Optimism on Climate Change  
<https://www.youtube.com/watch?v=u7E1v24DlIk>

<sup>2</sup>See Last Hours



The thermal inertia of the oceans contribute to the contrasting timescales mentioned above. One of the reasons why the worst effects of climate change lie in the long-term future is that the oceans warm very slowly, as is discussed in Chapter 5. As the oceans slowly warm there will be sea level rise due to thermal expansion of water, and to this will be added the effects of melting ice at the poles. Rising ocean levels have already affected island nations such as the Maldives, and coral reefs are already dying.

Deforestation is one of the main causes of climate change, as is discussed in Chapter 6. It is second only to the emission of CO<sub>2</sub>. In Indonesia, rainforests are deliberately burned, with the cooperation of corrupt politicians, to clear land for palm oil plantations. Rainforests of South America are also illegally burned, in this case for the sake of soy bean plantations and cattle ranches. In both cases, loss of habitat accelerates the extinction of threatened species.

<sup>3</sup>

In Chapter 7, we look at the effects of climate change and the end of the fossil fuel era on the world's ability to feed its rapidly growing population. One can predict that these factors will combine to produce an extremely large-scale famine by the middle of the 21st century if steps are not taken to prevent it. We are already experiencing a crisis from refugees fleeing from famine, rising temperatures, drought and conflicts, as is discussed in Chapter 8.

From the facts presented in these chapters, we must conclude that the world is facing a serious emergency, just as though a universally deadly disease pandemic had broken out. We need to recognize the emergency and act accordingly.<sup>4</sup>

Unchanged life-styles are not an option. Business as usual is not an option. Inaction is not an option. Public education is needed. Votes for environmentally friendly politicians are needed. A carbon tax is needed. Subsidies to fossil fuel giants must stop. Extraction of fossil fuels must stop. Renewable energy infrastructure must quickly be constructed.

Renewable energy infrastructure represents an unprecedented investment opportunity, and new renewable energy jobs far outnumber those that will be lost in the fossil fuel sector.

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<https://www.youtube.com/watch?v=2bRrg96UtMc>

<sup>3</sup>See Before the Flood

<https://archive.org/details/youtube-90CkXVF-Q8M>

<sup>4</sup>Time to Choose

<http://www.timetochoose.com/>

There is reason for optimism because of the economic tipping point mentioned in Chapter 1. Renewables are now cheaper than fossil fuels. With the help of renewable-friendly governmental policies, the transition that we so urgently need can be driven by economic forces alone.

We give loving care to our children and grandchildren, but it makes no sense to do so unless we leave them a world in which they and all future generations will be able to survive.

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# Chapter 1

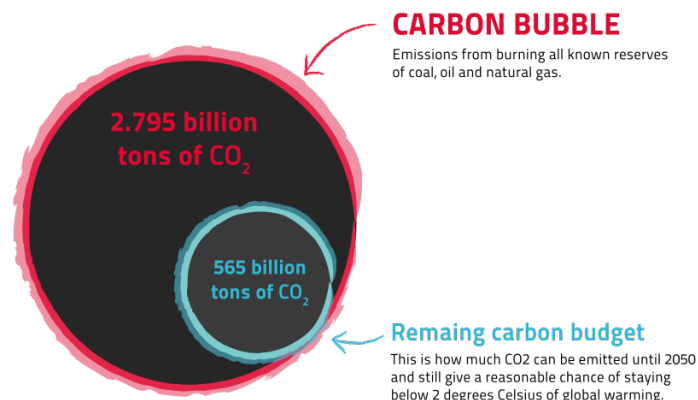
## THE TRANSITION TO 100% RENEWABLE ENERGY

### 1.1 Quick action is needed to save the long-term future

The worst effects of catastrophic climate change lie in the distant future, a century or even many centuries from the present; but disaster can only be avoided if quick action is taken. The nations of the world must act immediately to reduce and eventually stop the use of fossil fuels and the destruction of forests. If decisive action is not taken within the next few decades, feedback loops will make human intervention useless. These feedback loops include the albedo effect, the methane hydrate feedback loop, and the fact as tropical forests become drier, they become vulnerable to fires ignited by lightning. These fires accelerate the drying, and thus a feed-back loop is formed.

As time passes, and as the disastrous consequences of climate change become more apparent, the political will required for action will increase; but by that time it may be too late. We are rapidly approaching several crucial tipping points.

At present, the average global rate of use of primary energy is roughly  $2 \text{ kW}_t$  per person. In North America, the rate is  $12 \text{ kW}_t$  per capita, while in Europe, the figure is  $6 \text{ kW}_t$ . In Bangladesh, it is only  $0.2 \text{ kW}_t$ . This wide variation implies that considerable energy savings are possible, through changes in lifestyle, and through energy efficiency.



Source: Carbon Tracker Initiative 2013 / PIK Potsdam Institut für Klimafolgenforschung Illustration: Felix Müller ([www.zukunft-selbermachen.de/](http://www.zukunft-selbermachen.de/)) Licence CC-BY-SA 4.0

Figure 1.1: *The Carbon Bubble according to data by the Carbon Tracker Initiative 2013. Uploaded by Mueller Felix. [CC BY-SA 3.0], Wikimedia Commons.* **In order to avoid tipping points that will make human attempts to avoid catastrophic climate change useless, we must leave most of the known fossil fuel reserves in the ground!**

## 1.2 Is the transition to 100% renewable energy possible?

If we ask whether the transition to 100% renewable energy is possible, the answer is very simple: It is not only possible; it is inevitable! This is because the supply of fossil fuels is finite, and at the present rate of use they will be exhausted in less than a century. While the transition to 100% renewables is inevitable, the vitally important point to remember is that if we are to avoid disaster, the transition must come quickly.

In this book, we will use kilowatts (kW), megawatts (MW) and terawatts (TW) as the units in which we discuss the rate of use of energy. A megawatt is equal to a thousand kilowatts or a million watts. A terawatt is equal to a thousand megawatts, or a million kilowatts or a billion (1,000,000,000) watts. A citizen of the European Union uses energy at the rate of about 6 kilowatts, while in North America, the rate of energy use is double that amount. The global average rate of energy use is a little over 2 kilowatts. Since there are now 7.5 billion people in the world, our present rate of energy use is roughly 15 terawatts,

The total available energy from fossil fuels can be measured in terawatt.years



## 1.2. IS THE TRANSITION TO 100% RENEWABLE ENERGY POSSIBLE?13

(TWy). Rough estimates of global coal reserves of coal, oil and natural gas are given by the table shown below.

The present rate of use of fossil fuels is greater than the 2005 rate shown in the table, and the remaining reserves are smaller than those shown. It is assumed that as oil becomes exhausted, coal will be converted into liquid fuels, as was done in Germany during World War II.

A second table, shown below, illustrates the historical and projected total global energy demand as a function of time between 1980 and 2030. In this slightly out-of-date table, the last year using historical data is 2003, later years being estimates based on projections.

### Remaining reserves and rates of use of fossil fuels

	Reserves	2005 rate of use	Years remaining
Coal	780 TWy	3.5 TW	217 years
Oil	250 TWy	6.0 TW	42 years
Natural gas	250 TWy	3.7 TW	68 years
Total	1260 TWy	13.2 TW	(95 years)

Year	Demand	Population	Per Capita
1980	9.48 TW	4.45 bil.	2.13 kW
1985	10.3 TW	4.84 bil.	2.11 kW
1990	11.6 TW	5.99 bil.	2.20 kW
1995	12.3 TW	5.68 bil.	2.16 kW
2003	14.1 TW	6.30 bil.	2.23 kW
2010	17.1 TW	6.84 bil.	2.50 kW
2015	18.9 TW	7.23 bil.	2.58 kW
2020	20.5 TW	7.61 bil.	2.70 kW
2025	22.3 TW	7.91 bil.	2.82 kW
2030	24.2 TW	8.30 bil.	2.93 kW

Notice that the per capita energy use is almost constant. Our rapidly growing demand for energy is primarily the result of the world's rapidly growing population of humans. It would be wise to stabilize human populations because of the threat of human-caused ecological catastrophes and the danger of an extremely large-scale famine, involving billions of people rather than millions. Such a famine is threatened because growing populations require a growing food supply, climate changes threaten agriculture through droughts,

## 1.2. IS THE TRANSITION TO 100% RENEWABLE ENERGY POSSIBLE?<sup>15</sup>

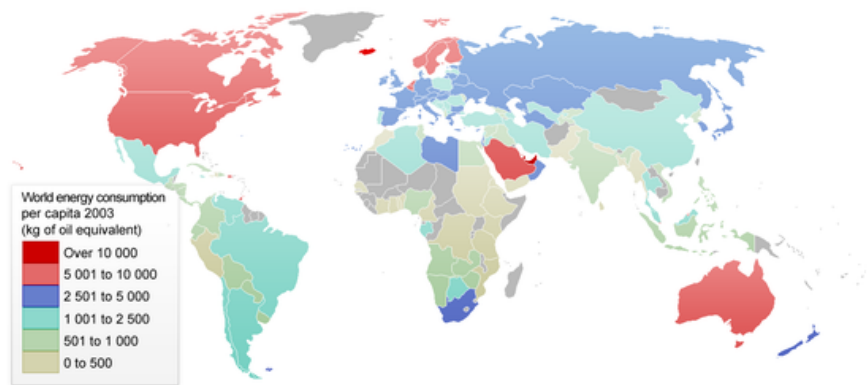


Figure 1.2: *A map of the world showing per capita rates of energy use.*

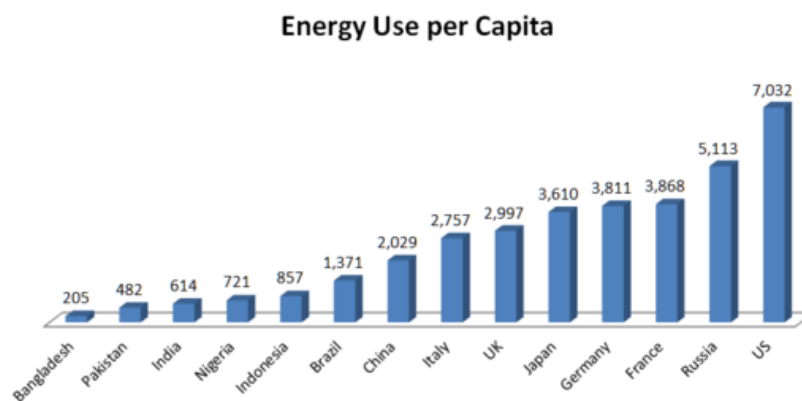


Figure 1.3: *Energy use per capita by country (World Bank data)*

melting glaciers and loss of agricultural land. The end of the fossil fuel era will also mean the end of high-yield petroleum-based agriculture.

### The rate of growth of renewable energy

There is reason for hope that even the high energy demands show in the second table can be met by renewables. The basis of this hope can be found in the extremely high present rate of growth of renewable energy, and in the remarkable properties of exponential growth. According to figures recently released by the Earth Policy Institute, the global installed photovoltaic capacity is currently able to deliver 242,000 megawatts, and it is increasing at the rate of 27.8% per year. Wind energy can now deliver 370,000 megawatts, and it is increasing at the rate of roughly 20% per year.

Because of the astonishing properties of exponential growth, we can calculate that if these growth rates are maintained, renewable energy can give us 24.8 terawatts within only 15 years! This is far more than the world's present use of all forms of energy.

### 1.3 Renewables are now much cheaper than fossil fuels!

According to an article written by Megan Darby and published in *The Guardian* on 26 January, 2016, "Solar power costs are tumbling so fast the technology is likely to fast outstrip mainstream energy forecasts.

"That is the conclusion of Oxford University researchers, based on a new forecasting model published in Research Policy<sup>1</sup>.

"Commercial prices have fallen by 58% since 2012 and by 16

"Since the 1980s, panels to generate electricity from sunshine have got 10% cheaper each year. That is likely to continue, the study said, putting solar on course to meet 20% of global energy needs by 2027.' "

#### Solar energy

Unlike the burning of fossil fuels, renewables like solar energy do not release pollutants into the atmosphere. In China, public opinion has shifted in favor of renewables because of air pollution in cities.

#### Photovoltaic cells

The price of solar photovoltaic panels has declined 99 percent over the last four decades, from \$74 a watt in 1972 to less than 70 cents a watt in 2014.

Between 2009 and 2014, solar panel prices dropped by three fourths, helping global PV installations grow 50 percent per year.

Deutsche Bank notes that as of early 2014, solar PV was already competitive with average residential, commercial or industrial electricity rates in 14 countries, and in California - even without subsidies. By late 2014 there were nearly 600,000 individual PV systems in the United States, almost twice as many as in 2012. This number may well pass 1 million in 2016.

In 2013, just 12 percent of U.S. homebuilders offered solar panels as an option for new single-family homes. More than half of them anticipate doing so by 2016. Four of the top five U.S. home construction firms - DR Horton,

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<sup>1</sup><http://www.sciencedirect.com/science/article/pii/S0048733315001699>

### 1.3. RENEWABLES ARE NOW MUCH CHEAPER THAN FOSSIL FUELS!17

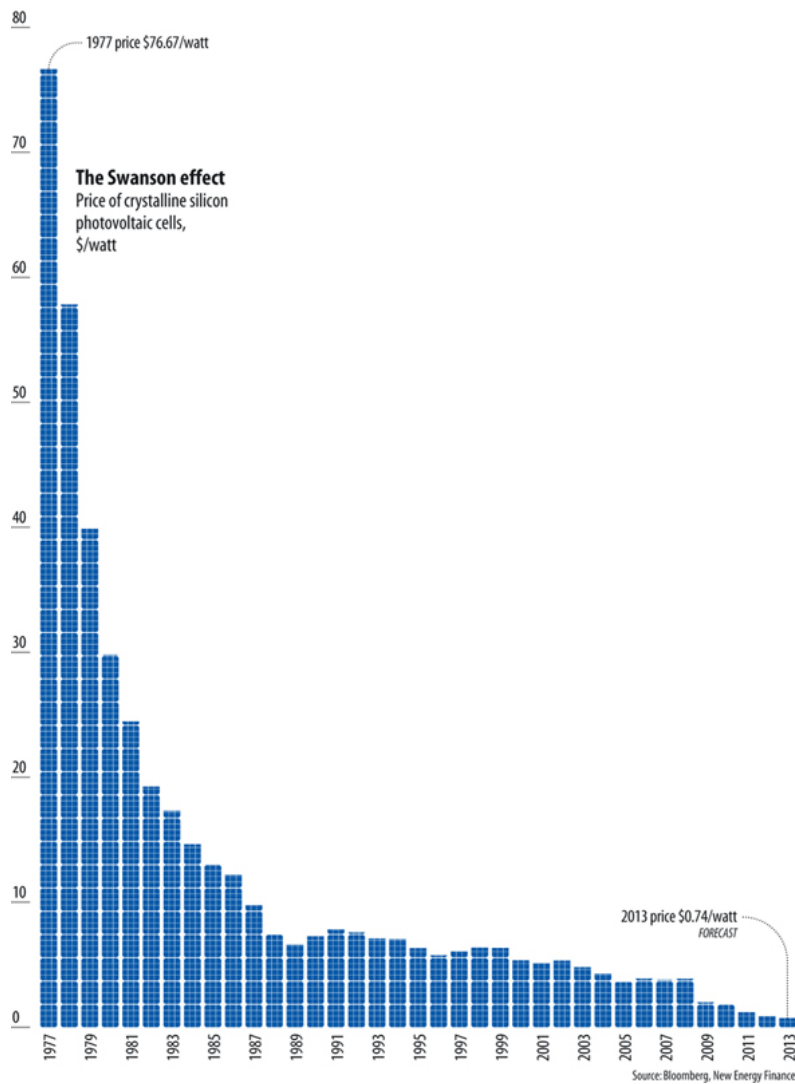


Figure 1.4: *The cost of photovoltaic cell panels is falling rapidly*

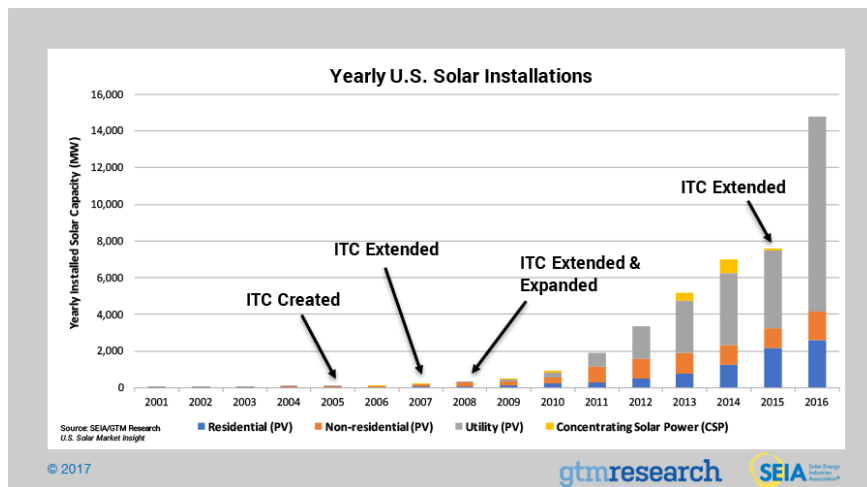


Figure 1.5: *Driven by falling prices, new solar installations in the United States are increasing rapidly. The acronym ITC stands for Solar Investment Tax Credit. Commercial prices have fallen by 58% since 2012 and by 16% in the last year*



Figure 1.6: *Air pollution from the burning of coal has become a serious problem in China. This problem has helped to shift Chinese public opinion away from the burning of coal and towards renewables. China has now become a major manufacturer of photovoltaic cells.*

### *1.3. RENEWABLES ARE NOW MUCH CHEAPER THAN FOSSIL FUELS!19*

Lennar Corp, PulteGroup and KB Home - now automatically include solar panels on every new house in certain markets.

In 2007 there were only 8,000 rooftop solar installations in coal-heavy Australia; now there are over a million.

Saudi Arabia has 41,000 megawatts of solar PV operating, under construction and planned - enough to generate up to two thirds of the country's electricity.

For the roughly 1.3 billion people without access to electricity, it is now often cheaper and more efficient simply to install solar panels rooftop-by-rooftop than to build a central power plant and transmission infrastructure.

## **Wind energy**

Over the past decade, world wind power capacity grew more than 20 percent a year, its increase driven by its many attractive features, by public policies supporting its expansion, and by falling costs.

By the end of 2014, global wind generating capacity totaled 369,000 megawatts, enough to power more than 90 million U.S. homes. Wind currently has a big lead on solar PV, which has enough worldwide capacity to power roughly 30 million U.S. homes.

China is now generating more electricity from wind farms than from nuclear plants, and should have little trouble meeting its official 2020 wind power goal of 200,000 megawatts. For perspective, that would be enough to satisfy the annual electricity needs of Brazil.

In nine U.S. states, wind provides at least 12 percent of electricity. Iowa and South Dakota are each generating more than one quarter of their electricity from wind.

In the Midwestern United States, contracts for wind power are being signed at a price of 2.5 cents per kilowatt-hour (kWh), which compares with the nationwide average grid price of 10-12 cents per kWh.

Although a wind farm can cover many square miles, turbines occupy little land. Coupled with access roads and other permanent features, a wind farm's footprint typically comes to just over 1 percent of the total land area covered by the project.

Wind energy yield per acre is off the charts. For example, a farmer in northern Iowa could plant an acre in corn that would yield enough grain to produce roughly \$1,000 worth of fuel-grade ethanol per year, or the farmer could put on that same acre a turbine that generates \$300,000 worth of electricity per year. Farmers typically receive \$3,000 to \$10,000 per turbine each year in royalties. As wind farms spread across the U.S. Great Plains, wind royalties for many ranchers will exceed their earnings from cattle sales.

## **The problem of intermittency**

Many forms of renewable energy encounter the problem of intermittency. For example, on windy days, Denmark's windmills generate more than enough electricity to meet the needs of the country, but on days when the wind is less strong, the electrical energy generated is insufficient. Denmark solves this problem by selling surplus electrical power to Germany on windy days, and buying power from hydroelectric-rich Norway on less windy days.

The problem of intermittency can alternatively be solved by pumping water to uphill reservoirs when the wind is strong, and letting the stored water drive turbines when the wind is weak. The problem of intermittency can also be solved with lithium ion storage batteries, by splitting water into hydrogen and oxygen, or by using other types of fuel cells.

## **Developing countries: No need for grids**

When cell phones came into general use, developing countries with no telephone networks were able to use the new technology through satellites, thus jumping over the need for country-wide telephone lines. Similarly, village solar or wind installations in the developing countries can supply power locally, bypassing the need for a grid.

## **1.4 An economic tipping point**

### **Renewables are now cheaper than fossil fuels**

Solar energy and wind energy have recently become cheaper than fossil fuels. Thus a tipping point has been passed. From now on, despite frantic efforts of giant fossil fuel corporations to prevent it from happening, the transition to 100% renewable energy will be driven by economic forces alone.

### **Subsidies to the fossil fuel industry**

<http://www.imf.org/en/News/Articles/2015/09/28/04/53/sonew070215a>

<http://priceofoil.org/fossil-fuel-subsidies/>



## 1.5 An unprecedented investment opportunity

### Investment in electric vehicles

On July 5, 2017, the Volvo Car Group made the following announcement: <sup>2</sup>

“Volvo Cars, the premium car maker, has announced that every Volvo it launches from 2019 will have an electric motor, marking the historic end of cars that only have an internal combustion engine (ICE) and placing electrification at the core of its future business.

“The announcement represents one of the most significant moves by any car maker to embrace electrification and highlights how over a century after the invention of the internal combustion engine electrification is paving the way for a new chapter in automotive history.

“‘This is about the customer,’ said Håkan Samuelsson, president and chief executive. ‘People increasingly demand electrified cars and we want to respond to our customers’ current and future needs. You can now pick and choose whichever electrified Volvo you wish.’

“Volvo Cars will introduce a portfolio of electrified cars across its model range, embracing fully electric cars, plug in hybrid cars and mild hybrid cars.

“It will launch five fully electric cars between 2019 and 2021, three of which will be Volvo models and two of which will be high performance electrified cars from Polestar, Volvo Cars’ performance car arm. Full details of these models will be announced at a later date.”

The electric vehicle investment opportunity was also illustrated by the 2017 vote of Germany’s Bundesrat to ban the manufacture of internal combustion engines after 2030 <sup>3</sup>.

The article announcing the vote adds that “It’s a strong statement in a nation where the auto industry is one of the largest sectors of the economy; Germany produces more automobiles than any other country in Europe and is the third largest in the world. The resolution passed by the Bundesrat calls on the European Commission (the executive arm of the European Union) to ‘evaluate the recent tax and contribution practices of Member States on their effectiveness in promoting zero-emission mobility,’ which many are taking to mean an end to the lower levels of tax currently levied on diesel fuel across Europe.”

France plans to end the sale of vehicles powered by gasoline and diesel by 2040, environment minister Nicolas Hulot announced recently.

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<sup>2</sup><https://www.media.volvocars.com/global/en-gb/media/pressreleases/210058/volvo-cars-to-go-all-electric>

<sup>3</sup><https://arstechnica.com/cars/2016/10/germanys-bundesrat-votes-to-ban-the-internal-combustion-engine-by-2030/>

Hulot made the announcement on Thursday, June 13, 2017, in Paris as he launched the country's new Climate Plan to accelerate the transition to clean energy and to meet its targets under the Paris climate agreement.

To ease the transition, Hulot said the French government will offer tax incentives to replace fossil-fuel burning cars with clean alternatives.

Furthermore, the government of India has recently announced its intention to only have electric vehicles by 2030<sup>4</sup>. This hugely ambitious plan was announced during the 2017 Confederation of Indian Industry Annual Session. Besides the avoidance of climate change, which might make many regions of India uninhabitable, the motive for replacing 28 million combustion engine vehicles by electric ones was the severe air pollution from which India suffers. Severe air pollution also motivates efforts by the government of China to promote the transition to electric vehicles.

The governments of Norway and the Netherlands have taken steps towards banning the internal combustion engine<sup>5</sup>. Both the upper and lower houses of the Netherlands' government voted to ban cars driven by internal combustion engines by 2025, the same year in which Norway plans to sell nothing but zero-emission vehicles.

In a report commissioned by the investment bankers Cowan & Co, managing director and senior research analyst Jeffrey Osborne, predicted that electric vehicles will cost less than gasoline-powered cars by the early- to mid-2020s due to falling battery prices as well as the costs that traditional carmakers will incur as they comply to new fuel-efficiency standards. Osbourne pointed out that a number of major car brands are hopping onto the electric bandwagon to compete in a space carved out by industry disrupter, Tesla.

"We see the competitive tides shifting in 2019 and beyond as European [car makers] roiled by the diesel scandal and loss of share to Tesla in the high margin luxury segment step on the gas and accelerate the pace of EV introductions", he wrote.

Bloomberg New Energy Finance reported similar predictions: "Falling battery costs will mean electric vehicles will also be cheaper to buy in the U.S. and Europe as soon as 2025," the report said. "Batteries currently account for about half the cost of EVs, and their prices will fall by about 77 percent between 2016 and 2030."

In October, 2017, General Motors unveiled plans to roll out 20 new entirely electric car models by 2023, with two of the new EVs coming out in the next 18 months. Meanwhile, Ford announced the creation of "Team Edison," intended

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<sup>4</sup><https://www.greentechmedia.com/articles/read/what-country-will-become-the-first-to-ban-internal-combustion-cars>

<sup>5</sup><http://www.prnewswire.com/news-releases/the-dutch-revolution-in-smart-charging-of-electric-vehicles-597268791.html>

to accelerate the company's EV development and partnership work. The name, is "seemingly in direct response to Elon Musk's Tesla, which recently surpassed Ford's market capitalization."

Tesla's Chairman, highly successful inventor and entrepreneur Elon Musk, has made massive investments in factories manufacturing electric vehicles, improved lithium ion storage cells, and photovoltaic panels, as will be discussed in Chapter 2.

## Investment in wind turbine energy

In Denmark, the wind turbine industry contributes substantially to the country's positive balance of payments. According to Wikipedia, "The Danish wind turbine industry is the world's largest. Around 90% of the national output is exported, and Danish companies accounted for 38% of the world turbine market in 2003, when the industry employed some 20,000 people and had a turnover of around 3 billion euro."

Denmark's two largest wind turbine manufacturers are Vestas and Simiens Wind Power. Vestas employs more than 21,000 people globally. In February 2016, Vestas got its largest order of 1,000 MW (278 x 3.6 MW) for the Fosen project near Trondheim in Norway. It costs DKK 11 billion, and should deliver 3.4 TWh per year.

In 2015 Siemens Wind had a combined market share of 63% of European offshore wind turbines (nearly 75% in 2009 by capacity and number). In 2011, Siemens Wind Power had 6.3% share of the world wind turbine market, and was the second largest in 2014.

In many countries, including Australia, Canada, Denmark, Germany, India, The Netherlands, United Kingdom, and United States, wind turbine cooperatives have sprung up. In these cooperatives, communities share the costs and profits of wind turbine projects. For example, the Hepburn Wind Project in Victoria, Australia, owns two 2MW wind turbines which produce enough power for 2,300 households.

## Investment in solar energy

Global revenues from solar photovoltaic installations are expected to reach \$1.2 trillion between the present and 2024 according to a recent article<sup>6</sup>

Another article<sup>7</sup> states that "The global electric power industry is evolving

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<sup>6</sup><https://cleantechnica.com/2016/01/25/global-revenue-solar-pv-installations-expected-reach-1-2-trillion/>

<sup>7</sup><http://www.navigantresearch.com/newsroom/global-revenue-from-solar-pv-installations-is-expected-to-total-more-than-1-2-trillion-from-2015-to-2024>

into a model that offers more diversity, both in terms of generation and in the ownership of generation assets, and solar PV is one technology at the head of this change. Following years of unsustainable pricing and oversupply, demand for solar PV systems has finally caught up, with 2015 expected to be the year when the global solar PV market shifts and starts to compete with other technologies. According to a recent report from Navigant Research, global revenue from solar PV installations is expected to total more than \$1.2 trillion from 2015 to 2024.”

## 1.6 For creating jobs, renewables beat fossil fuels

Here are some excerpts from a 2016 report issued by the Solar Foundation:

- One out of every 50 new jobs added in the United States in 2016 was created by the solar industry, representing 2 percent of all new jobs.
- Solar jobs in the United States have increased at least 20 percent per year for the past four years, and jobs have nearly tripled since the first Solar Jobs Census was released in 2010.
- Over the next 12 months, employers surveyed expect one out of every 50 new jobs added in the United States in 2016 was created by the solar industry, representing 2 percent of all new jobs.
- In 2016, the five states with the most solar jobs were California, Massachusetts, Texas, Nevada, and Florida.
- The solar industry added \$84 billion to the US GDP in 2016 to see total solar industry employment increase by 10 percent to 286,335 solar workers.
- The solar industry added \$84 billion to the US GDP in 2016.

## 1.7 The Stern Review

### Background of the Stern Review

*The Stern Review on the Economics of Climate Change* is a 700 page document commissioned by the government of the United Kingdom and released on 30 October, 2006. The research behind this report was conducted by a team led

by Nicolas Stern (Baron Stern of Brentford), chair of the Grantham Research Institute on Climate Change and the Environment.

The Stern Review discusses the catastrophic climate change which will result if prompt action is not taken, and it proposes that 1% of global GDP be used annually to prevent such disasters. In 2014, the global GDP was estimated to be 77.9 trillion dollars, so that the 1% investment in renewable energy recommended by Lord Stern and his research team would have amounted to nearly a trillion dollars.

Excerpts from the Stern Review Executive Summary are given in Appendix B

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## Chapter 2

# RENEWABLE ENERGY TECHNOLOGY

### 2.1 Beyond the fossil fuel era

After the end of the fossil fuel era, our industrial civilization will have to rely on renewable sources to supply our energy needs. These sources include hydropower, wind and tidal power, biomass, geothermal energy and solar energy. Let us try to survey how much energy these sources can be expected to produce.

According to REN21. (Renewable Energy Policy Institute for the 21st Century), “Newly installed renewable power capacity set new records in 2016, with 161 gigawatts (GW) added, increasing the global total by almost 9% relative to 2015. Solar PV was the star performer in 2016, accounting for around 47% of the total additions, followed by wind power at 34% and hydropower at 15.5%. For the fifth consecutive year, investment in new renewable power capacity (including all hydropower) was roughly double the investment in fossil fuel generating capacity, reaching USD 249.8 billion. The world now adds more renewable power capacity annually

“2016 was the third year in a row where global energy- related CO<sub>2</sub> emissions from fossil fuels and industry remained stable despite a 3% growth in the global economy and an increased demand for energy. This can be attributed primarily to the decline in coal consumption, but also to the growth in renewable energy capacity and to improvements in energy efficiency. The decoupling of economic growth and CO<sub>2</sub> emissions is an important first step towards achieving the steep decline in emissions necessary for holding global temperature rise well below 2 degrees Celsius.”

Before the start of the industrial era, human society relied exclusively on renewable energy sources - but can we do so again, with our greatly increased

population and greatly increased demands? Will we ultimately be forced to reduce the global population or our per capita use of energy, or both? Let us now try to examine these questions.

## 2.2 Solar energy

Biomass, wind energy, hydropower and wave power derive their energy indirectly from the sun, but in addition, various methods are available for utilizing the power of sunlight directly. These include photovoltaic panels, solar designs in architecture, solar systems for heating water and cooking, concentrating photovoltaic systems, and solar thermal power plants.

### Photovoltaic cells and concentrating photovoltaic systems

Solar power was the fastest-growing source of new energy in 2016, surpassing the net growth of all other energy sources including coal, according to a new report from the International Energy Agency (IEA).

The IEA report found new solar capacity increased by 50 percent in 2016, and IEA executive director Fatih Birol hailed solar's rapid growth. "What we are witnessing is the birth of a new era in solar photovoltaics [PV]. We expect that solar PV capacity growth will be higher than any other renewable technology up to 2022."<sup>1</sup>

The report also shows renewables as a whole accounted for two-thirds of all new energy capacity in 2016. "We see renewables growing by about 1,000 GW (gigawatts) by 2022, which equals about half of the current global capacity in coal power, which took 80 years to build," Birol said in a statement accompanying the report.<sup>2</sup>

Solar photovoltaic cells<sup>3</sup> are thin coated wafers of a semiconducting material (usually silicon). The coatings on the two sides are respectively charge donors and charge acceptors. Cells of this type are capable of trapping solar energy and converting it into direct-current electricity. The electricity generated in this way can be used directly (as it is, for example, in pocket calculators) or it can be fed into a general power grid. Alternatively it can be used to split water into hydrogen and oxygen. The gases can then be compressed and stored, or exported for later use in fuel cells. In the future, we may see solar photovoltaic

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<sup>1</sup><https://www.theguardian.com/environment/2017/oct/04/solar-power-renewables-international-energy-agency>

<sup>2</sup><https://www.iea.org/newsroom/news/2017/october/solar-pv-grew-faster-than-any-other-fuel-in-2016-opening-a-new-era-for-solar-pow.html>

<sup>3</sup><https://www.iea.org/renewables/>

arrays in sun-rich desert areas producing hydrogen as an export product. As their petroleum reserves become exhausted, the countries of the Middle East and Africa may be able to shift to this new technology and still remain energy exporters.

It is interesting to notice that the primary process of photosynthesis in plants is closely similar to the mechanism by which solar cells separate charges and prevent the back-reaction. We can see why a back-reaction must be prevented if we consider the excitation of a single atom. An absorbed photon lifts an electron from a filled atomic orbital to an empty one, leaving a positively-charged hole in the orbital from which the electron came. However, a back-reaction occurs almost immediately: The excited electron falls back into the orbital from which it came, and the absorbed energy is re-emitted. One can say that the electron and hole have recombined.

In higher plants, the back reaction is prevented because the photon is absorbed in a membrane which has a sandwich-like structure. Dye molecules (usually chlorophyll molecules) are sandwiched between a layer of charge donor molecules on one side of the membrane, and a layer of charge acceptor molecule on the other side. The electron quickly migrates to the acceptors, which are molecules with low-lying unfilled orbitals. Meanwhile the hole has quickly moved to the opposite side of the membrane, where it combines with an electron from a donor molecule. A donor molecule is a molecule whose highest filled orbital is high in energy. In this process, the back-reaction is prevented. The electron and hole are on opposite sides of the membrane, and they can only recombine after they have driven the metabolism of the plant.

In a photovoltaic solar cell, the mechanism by which the back-reaction is prevented is exactly similar. It too has a sandwich-like structure, with charge donors on one side, charge-acceptors on the other, and photon absorbers in the middle. Here too, the electron and hole quickly migrate to opposite sides. They can only recombine by traveling through the external circuit, which is analogous to a plant's metabolism, and performing useful work.

The cost of manufacturing photovoltaics continues to fall rapidly. In 2017, a homeowner paid approximately \$3,360 per kilowatt to have rooftop solar panels installed. Usually photovoltaic panels are warranted for a life of 20 years, but they are commonly still operational after 30 years or more. Using the fact that there are 8760 hours in a year, and thus 175200 hours in 20 years, we can calculate that the cost of electricity to a solar-using homeowner today is about 1.92 cents per kilowatt hour. This can be compared with electricity generated from coal, which in 2011 cost 3.23 cents per kilowatt hour, while electricity generated from natural gas cost 4.51 cents per kilowatt hour. We must also remember that photovoltaics are falling rapidly in price, and that the fossil fuel costs do not include externalities, such as their contribution to climate

change.

Concentrating photovoltaic systems are able to lower costs still further by combining silicon solar cells with reflectors that concentrate the sun's rays. The most inexpensive type of concentrating reflector consists of a flat piece of aluminum-covered plastic material bent into a curved shape along one of its dimensions, forming a trough-shaped surface. (Something like this shape results when we hold a piece of paper at the top and bottom with our two hands, allowing the center to sag.) The axis of the reflector can be oriented so that it points towards the North Star. A photovoltaic array placed along the focal line will then receive concentrated sunlight throughout the day.

Photovoltaic efficiency is defined as the ratio of the electrical power produced by a cell to the solar power striking its surface. For commercially available cells today, this ratio is between 9% and 14%. If we assume 5 hours of bright sunlight per day, this means that a photo cell in a desert area near to the equator (where  $1 \text{ kW/m}^2$  of peak solar power reaches the earth's surface) can produce electrical energy at the average rate of  $20\text{--}30 \text{ W}_e/\text{m}^2$ , the average being taken over an entire day and night. The potential power per unit area for photovoltaic systems is far greater than for biomass. However, the mix of renewable energy sources most suitable for a particular country depends on many factors. We will see below that biomass is a promising future source of energy for Sweden, because of Sweden's low population density and high rainfall. By contrast, despite the high initial investment required, photovoltaics are undoubtedly a more promising future energy source for southerly countries with clear skies.

In comparing photovoltaics with biomass, we should be aware of the difference between electrical energy and energy contained in the chemical bonds of a primary fuel such as wood or rapeseed oil. If Sweden (for example) were to supply all its energy needs from biomass, part of the biomass would have to be burned to generate electricity. The efficiency of energy conversion in electricity generation from fuel is 20%–35%. Of course, in dual use power plants, part of the left-over heat from electrical power generation can be used to heat homes or greenhouses. However, hydropower, wind power and photovoltaics have an advantage in generating electrical power, since they do so directly and without loss, whereas generation of electricity from biomass involves a loss from the inefficiency of the conversion from fuel energy to electrical energy. Thus a rational renewable energy program for Sweden should involve a mixture of biomass for heating and direct fuel use, with hydropower and wind power for generation of electricity. Perhaps photovoltaics will also play a role in Sweden's future electricity generation, despite the country's northerly location and frequently cloudy skies.

The global market for photovoltaics is expanding at the rate of 30% per





Figure 2.1: *A rooftop array of photovoltaic cells.*

year. This development is driven by rising energy prices, subsidies to photovoltaics by governments, and the realization of the risks associated with global warming and consequent international commitments to reduce carbon emissions. The rapidly expanding markets have resulted in lowered photovoltaic production costs, and hence further expansion, still lower costs, etc. - a virtuous feedback loop.

### Solar thermal power plants

Solar Parabolic Troughs can be used to heat a fluid, typically oil, in a pipe running along the focal axis. The heated fluid can then be used to generate electrical power. The liquid that is heated in this way need not be oil. In a solar thermal power plant in California, reflectors move in a manner that follows the sun's position and they concentrate solar energy onto a tower, where molten salt is heated to a temperature of 1050 degrees F (566 °C). The molten salt stores the heat, so that electricity can be generated even when the sun is not shining. The California plant generates 10 MW<sub>e</sub>.

### Solar designs in architecture

At present, the average global rate of use of primary energy is roughly 2 kW<sub>t</sub> per person. In North America, the rate is 12 kW<sub>t</sub> per capita, while in Europe, the figure is 6 kW<sub>t</sub>. In Bangladesh, it is only 0.2 kW<sub>t</sub>. This wide variation im-



Figure 2.2: *A solar thermal power plant. Arrays of heliostatic reflectors concentrate the sun's rays onto molten salt in the tower. The plant produces electricity at night because the salt remains hot..*



Figure 2.3: *A solar cooker.*



Figure 2.4: *A rooftop solar thermal array for domestic water heating.*

plies that considerable energy savings are possible, through changes in lifestyle, and through energy efficiency.

Important energy savings can be achieved through solar design in architecture. For example, insulation can be improved in walls, and insulating shutters can be closed at night.

In double envelope construction, a weatherproof shell surrounds the inner house. Between the outer shell and the house, sun-heated air circulates. A less extreme example of this principle is the construction of south-facing conservatories. The sun-heated air in the conservatories acts as a thermal buffer, and reduces heat loss from the house.

Solar design aims at making houses cool in the summer and warm in the winter. Awnings can be spread out in the summer to shade windows, and rolled together in the winter to allow sunshine to enter the house. Alternatively, deciduous trees can be planted in front of south-facing windows. During the summer, the leaves of the trees shade the windows, while in the winter, the leaves fall, allowing the sun to enter.

During daylight hours, houses can be illuminated by fiber optic light pipes, connected to a parabolic collector on the roof. The roof can also contain arrays of solar photovoltaic cells and solar water heaters.

Houses can be heated in the winter by heat pumps connected to a deeply buried network of pipes. Heat pumps function in much the same way as refrigerators or air conditioners. When they are used to warm houses in the winter, a volatile liquid such as ammonia is evaporated underground, where the

temperature is relatively constant, not changing much between summer and winter. In the evaporation process, heat is absorbed from the ground. The gas is then compressed and re-liquefied within the house, and in this process, it releases the heat that was absorbed underground. Electricity is of course required to drive a heat pump, but far less electrical power is needed to do this than would be required to heat the house directly.

In general, solar design of houses and other buildings requires an initial investment, but over time, the investment is amply repaid through energy savings.

## Solar systems for heating water and cooking

Solar heat collectors are already in common use to supply hot water for families or to heat swimming pools. A common form of the solar heat collector consists of a flat, blackened heat-collecting plate to which tubes containing the fluid to be heated are connected. The plate is insulated from the atmosphere by a layer of air (in some cases a partial vacuum) above which there is a sheet of glass. Water flowing through the tubes is collected in a tank whenever it is hotter than the water already there. In cases where there is a danger of freezing, the heated fluid may contain antifreeze, and it may then exchange heat with water in the collection tank. Systems of this kind can function even in climates as unfavorable as that of Northern Europe, although during winter months they must be supplemented by conventional water-heaters.

In the developing countries, wood is often used for cooking, and the result is sometimes deforestation, soil erosion and desertification. In order to supply an alternative, many designs for solar cooking have been developed. Often the designs are very simple, and many are both easy and inexpensive to build, the starting materials being aluminum foil and cardboard boxes.

## 2.3 Wind energy

Wind parks in favorable locations, using modern wind turbines, are able to generate  $10 \text{ MW}_e/\text{km}^2$  or  $10 \text{ W}_e/\text{m}^2$ . Often wind farms are placed in offshore locations. When they are on land, the area between the turbines can be utilized for other purposes, for example for pasturage. For a country like Denmark, with good wind potential but cloudy skies, wind turbines can be expected to play a more important future role than photovoltaics. Denmark is already a world leader both in manufacturing and in using wind turbines. Today, on windy days, 100% of all electricity used in Denmark is generated by wind power, and the export of wind turbines makes a major contribution to the



Figure 2.5: *Rows of wind turbines.*

Danish economy. The use of wind power is currently growing at the rate of 38% per year. In the United States, it is the fastest-growing form of electricity generation.

The location of wind parks is important, since the energy obtainable from wind is proportional to the cube of the wind velocity. We can understand this cubic relationship by remembering that the kinetic energy of a moving object is proportional to the square of its velocity multiplied by the mass. Since the mass of air moving past a wind turbine is proportional to the wind velocity, the result is the cubic relationship just mentioned.

Before the decision is made to locate a wind park in a particular place, the wind velocity is usually carefully measured and recorded over an entire year. For locations on land, mountain passes are often very favorable locations, since wind velocities increase with altitude, and since the wind is concentrated in the passes by the mountain barrier. Other favorable locations include shorelines and offshore locations on sand bars. This is because onshore winds result when warm air rising from land heated by the sun is replaced by cool marine air. Depending on the season, the situation may be reversed at night, and an offshore wind may be produced if the water is warmer than the land.

The cost of wind-generated electrical power is currently lower than the cost of electricity generated by burning fossil fuels.

The “energy payback ratio” of a power installation is defined as the ratio of





Figure 2.6: *Vertical axis wind turbines.*

the energy produced by the installation over its lifetime, divided by the energy required to manufacture, construct, operate and decommission the installation. For wind turbines, this ratio is 17-39, compared with 11 for coal-burning plants. The construction energy of a wind turbine is usually paid back within three months.

Besides the propeller-like design for wind turbines there are also designs where the rotors turn about a vertical shaft. One such design was patented in 1927 by the French aeronautical engineer Georges Jean Marie Darrieus. The blades of a Darrieus wind turbine are airfoils similar to the wings of an aircraft. As the rotor turns in the wind, the stream of air striking the airfoils produces a force similar to the “lift” of an airplane wing. This force pushes the rotor in the direction that it is already moving. The Darrieus design has some advantages over conventional wind turbine design, since the generator can be placed at the bottom of the vertical shaft, where it may be more easily serviced. Furthermore, the vertical shaft can be lighter than the shaft needed to support a conventional wind turbine.

One problem with wind power is that it comes intermittently, and demand for electrical power does not necessarily come at times when the wind is blowing most strongly. To deal with the problem of intermittency, wind power can be combined with other electrical power sources in a grid. Alternatively, the energy generated can be stored, for example by pumped hydroelectric storage



Figure 2.7: *Wind turbines on the Danish island of Samsø. The island was the first in the world to achieve 100% renewable energy.*

or by using hydrogen technology, as will be discussed below.

Bird lovers complain that birds are sometimes killed by rotor blades. This is true, but the number killed is small. For example, in the United States, about 70,000 birds per year are killed by turbines, but this must be compared with 57 million birds killed by automobiles and 97.5 million killed by collisions with plate glass.

The aesthetic aspects of wind turbines also come into the debate. Perhaps in the future, as wind power becomes more and more a necessity and less a matter of choice, this will be seen as a “luxury argument”.

### **A Danish island reaches 100% renewable energy**

The Danish island of Samsø is only 112 square kilometers in size, and its population numbers only 4,300. Nevertheless, it has a unique distinction. Samsø was the first closed land area to declare its intention of relying entirely on renewable energy, and it has now achieved this aim, provided that one stretches the definitions slightly.

In 1997, the Danish Ministry of Environment and Energy decided to sponsor a renewable-energy contest. In order to enter, communities had to submit plans for how they could make a transition from fossil fuels to renewable energy. An engineer (who didn’t live there) thought he knew how Samsø could do this, and together with the island’s mayor he submitted a plan which won

the contest. As a result, the islanders became interested in renewable energy. They switched from furnaces to heat pumps, and formed cooperatives for the construction of windmill parks in the sea near to the island. By 2005, Samsø was producing, from renewable sources, more energy than it was using. The islanders still had gasoline-driven automobiles, but they exported from their windmill parks an amount of electrical energy that balanced the fossil fuel energy that they imported. This is a story that can give us hope for the future, although a farming community like Samsø cannot serve as a model for the world.

## 2.4 Hydroelectric power

In 2015, hydroelectric power supplied 16.6% of all electrical power, and 70% of the electrical power generated from renewable energy. In the developed countries, the potential for increasing this percentage is small, because most of the suitable sites for dams are already in use. Mountainous regions of course have the greatest potential for hydroelectric power, and this correlates well with the fact that virtually all of the electricity generated in Norway comes from hydro, while in Iceland and Austria the figures are respectively 83% and 67%. Among the large hydroelectric power stations now in use are the La Grande complex in Canada (16 GW<sub>e</sub>) and the Itapú station on the border between Brazil and Paraguay (14 GW<sub>e</sub>). The Three Gorges Dam in China produces 18.2 GW<sub>e</sub>.

Even in regions where the percentage of hydro in electricity generation is not so high, it plays an important role because hydropower can be used selectively at moments of peak demand. Pumping of water into reservoirs can also be used to store energy.

The creation of lakes behind new dams in developing countries often involves problems, for example relocation of people living on land that will be covered by water, and loss of the land for other purposes<sup>4</sup>. However the energy gain per unit area of lake can be very large - over 100 W<sub>e</sub>/m<sup>2</sup>. Fish ladders can be used to enable fish to reach their spawning grounds above dams. In addition to generating electrical power, dams often play useful roles in flood control and irrigation.

At present, hydroelectric power is used in energy-intensive industrial processes, such as the production of aluminum. However, as the global energy crisis becomes more severe, we can expect that metals derived from electrolysis, such as aluminum and magnesium, will be very largely replaced by other

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<sup>4</sup>Over a million people were displaced by the construction of the Three Gorges Dam in China, and many sites of cultural value were lost



Table 2.1: Technical potential and utilization of hydropower. (Data from World Energy Council, 2003.)

Region	Technical potential	Annual output	Percent used
Asia	0.5814 TW <sub>e</sub>	0.0653 TW <sub>e</sub>	11%
S. America	0.3187 TW <sub>e</sub>	0.0579 TW <sub>e</sub>	18%
Europe	0.3089 TW <sub>e</sub>	0.0832 TW <sub>e</sub>	27%
Africa	0.2155 TW <sub>e</sub>	0.0091 TW <sub>e</sub>	4%
N. America	0.1904 TW <sub>e</sub>	0.0759 TW <sub>e</sub>	40%
Oceania	0.0265 TW <sub>e</sub>	0.0046 TW <sub>e</sub>	17%
World	1.6414 TW <sub>e</sub>	0.2960 TW <sub>e</sub>	18%



Figure 2.8: *Hydroelectric power does not suffer from the problem of intermittency, but may sometimes produce undesirable social and ecological impacts.*

materials, because the world will no longer be able to afford the energy needed to produce them.

## 2.5 Energy from the ocean

### Tidal power

The twice-daily flow of the tides can be harnessed to produce electrical power. Ultimately tidal energy comes from the rotation of the earth and its interaction with the moon's gravitational field. The earth's rotation is very gradually slowing because of tidal friction, and the moon is gradually receding from the earth, but this process will take such an extremely long time that tidal energy can be thought of as renewable.

There are two basic methods for harnessing tidal power. One can build barriers that create level differences between two bodies of water, and derive hydroelectric power from the head of water thus created. Alternatively it is possible to place the blades of turbines in a tidal stream. The blades are then turned by the tidal current in much the same way that the blades of a wind turbine are turned by currents of air.

There are plans for using the second method on an extremely large scale

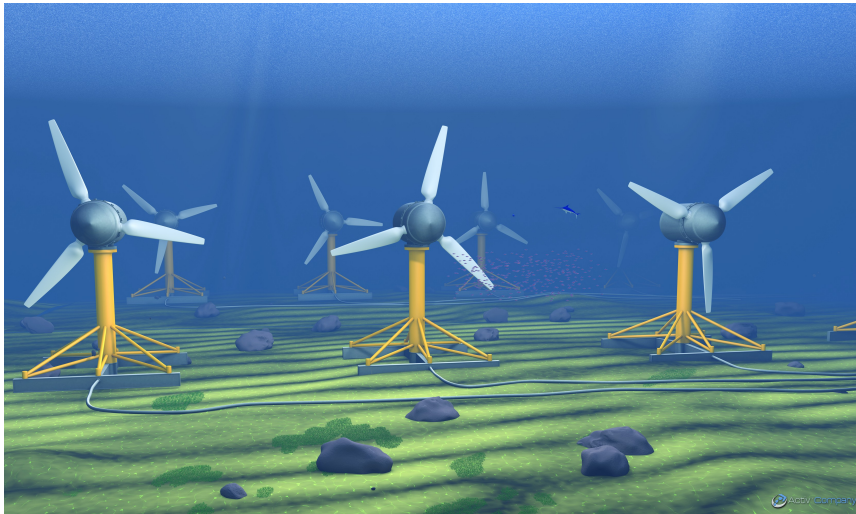


Figure 2.9: *Underwater turbines can make use of the energy of ocean currents.*

in Cook Strait, near New Zealand. A company founded by David Beach and Chris Bathurst plans to anchor 7,000 turbines to the sea floor of Cook Strait in such a way that they will float 40 meters below the surface. Beach and Bathurst say that in this position, the turbines will be safe from the effects of earthquakes and storms. The tidal flow through Cook Strait is so great that the scheme could supply all of New Zealand's electricity if the project is completed on the scale visualized by its founders.

Choosing the proper location for tidal power stations is important, since the height of tides depends on the configuration of the land. For example, tides of 17 meters occur in the Bay of Fundy, at the upper end of the Gulf of Maine, between New Brunswick and Nova Scotia. Here tidal waves are funneled into the bay, creating a resonance that results in the world's greatest level difference between high and low tides. An 18 MW<sub>e</sub> dam-type tidal power generation station already exists at Annapolis River, Nova Scotia, and there are proposals to increase the use of tidal power in the Bay of Fundy. Some proposals involve turbines in the tidal stream, similar to those proposed for use in the Cook Strait.

In the future, favorable locations for tidal power may be exploited to their full potentialities, even though the output of electrical energy exceeds local needs. The excess energy can be stored in the form of hydrogen (see below) and exported to regions deficient in renewable energy resources.

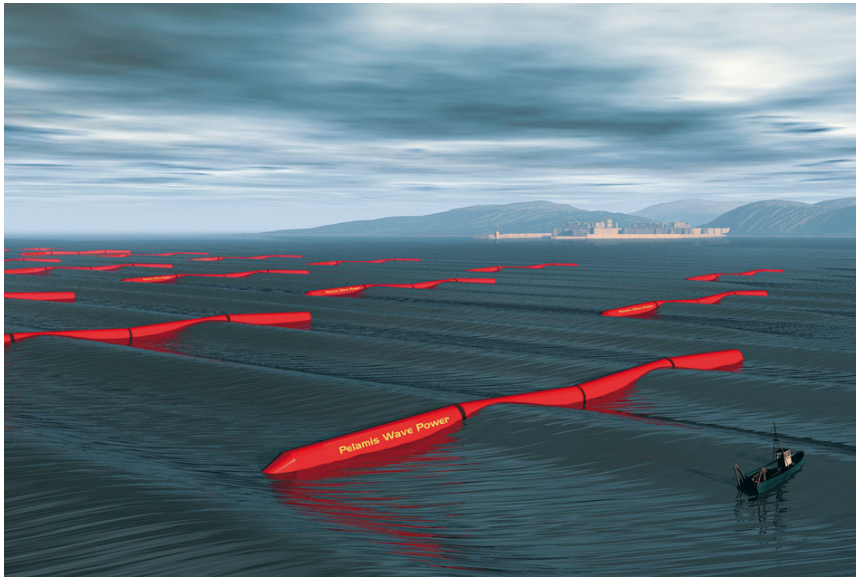


Figure 2.10: *The Pelamis wave energy transformer floats on the ocean like a giant sea snake. It consists of several segments which move against each other and build up hydraulic pressure. This in turn drives a turbine. A new Pelamis generation is currently under construction.*

## Wave energy

At present, the utilization of wave energy is in an experimental stage. In Portugal, there are plans for a wave farm using the Pelamis Wave Energy Converter. The Pelamis is a long floating tube with two or more rigid sections joined by hinges. The tube is tethered with its axis in the direction of wave propagation. The bending between sections resulting from passing waves is utilized to drive high pressure oil through hydraulic motors coupled to electrical generators. Each wave farm in the Portuguese project is planned to use three Pelamis converters, each capable of producing  $750 \text{ kW}_e$ . Thus the total output of each wave farm will be  $2.25 \text{ MW}_e$ .

Another experimental wave energy converter is Salter's Duck, invented in the 1970's by Prof. Stephen Salter of the University of Edinburgh, but still being developed and improved. Like the Pelamis, the Duck is also cylindrical in shape, but the axis of the cylinder is parallel to the wave front, i.e. perpendicular to the direction of wave motion. A floating cam, attached to the cylinder, rises and falls as a wave passes, driving hydraulic motors within the cylinder. Salter's Duck is capable of using as much as 65% of the wave's energy.

The energy potentially available from waves is very large, amounting to as much as 100 kilowatts per meter of wave front in the best locations.

### Ocean thermal energy conversion

In tropical regions, the temperature of water at the ocean floor is much colder than water at the surface. In ocean thermal energy conversion, cold water is brought to the surface from depths as great as 1 km, and a heat engine is run between deep sea water at a very low temperature and surface water at a much higher temperature.

According to thermodynamics, the maximum efficiency of a heat engine operating between a cold reservoir at the absolute temperature  $T_C$  and a hot reservoir at the absolute temperature  $T_H$  is given by  $1 - T_C/T_H$ . In order to convert temperature on the centigrade scale to absolute temperature (degrees Kelvin) one must add 273 degrees. Thus the maximum efficiency of a heat engine operating between water at the temperature of 25 °C and water at 5 °C is  $1 - (5 + 273)/(25 + 273) = 0.067 = 6.7\%$ . The efficiency of heat engines is always less than the theoretical maximum because of various losses, such as the loss due to friction. The actual overall efficiencies of existing ocean thermal energy conversion (OTEC) stations are typically 1-3%. On the other hand, the amount of energy potentially available from differences between surface and bottom ocean temperatures is extremely large.

Since 1974, OTEC research has been conducted by the United States at the Natural Energy Laboratory of Hawaii. The Japanese government also supports OTEC research, and India has established a 1 MW<sub>e</sub> OTEC power station floating in the ocean near to Tamil Nadu.

### Renewable energy from evaporation

A September 26, 2017 article by Ahmet-Hamdi Cavusoglu et al. in *Nature Communications* points to evaporation as a future source of renewable energy. Here are some excerpts from the article:

“About 50% of the solar energy absorbed at the Earth’s surface drives evaporation, fueling the water cycle that affects various renewable energy resources, such as wind and hydropower. Recent advances demonstrate our nascent ability to convert evaporation energy into work, yet there is little understanding about the potential of this resource.

“Here we study the energy available from natural evaporation to predict the potential of this ubiquitous resource. We find that natural evaporation from open water surfaces could provide power densities comparable to current wind and solar technologies while cutting evaporative water losses by nearly half. We

estimate up to 325 GW of power is potentially available in the United States. Strikingly, water's large heat capacity is sufficient to control power output by storing excess energy when demand is low, thus reducing intermittency and improving reliability. Our findings motivate the improvement of materials and devices that convert energy from evaporation...

"Recent advances in water responsive materials and devices demonstrate the ability to convert energy from evaporation into work. These materials perform work through a cycle of absorbing and rejecting water via evaporation. These water-responsive materials can be incorporated into evaporation-driven engines that harness energy when placed above a body of evaporating water. With improvements in energy conversion efficiency, such devices could become an avenue to harvest energy via natural evaporation from water reservoirs."

Ozgur Sahin, a biophysicist at Columbia, has developed technology that uses spores from the harmless soil-dwelling bacterium *B. subtilis* to absorb and release water when the relative humidity of the surrounding air changes. At high humidity, the spores take in water and expand, and at low humidity they release water and contract, acting like a muscle.

## 2.6 Biomass

Biomass is defined as any energy source based on biological materials produced by photosynthesis - for example wood, sugar beets, rapeseed oil, crop wastes, dung, urban organic wastes, processed sewage, etc. Using biomass for energy does not result in the net emission of CO<sub>2</sub>, since the CO<sub>2</sub> released by burning the material had previously been absorbed from the atmosphere during photosynthesis. If the biological material had decayed instead of being burned, it would release the same amount of CO<sub>2</sub> as in the burning process.

The solar constant has the value 1.4 kilowatts/m<sup>2</sup>. It represents the amount of solar energy per unit area<sup>5</sup> that reaches the earth, before the sunlight has entered the atmosphere. Because the atmosphere reflects 6% and absorbs 16%, the peak power at sea level is reduced to 1.0 kW/m<sup>2</sup>. Clouds also absorb and reflect sunlight. Average cloud cover reduces the energy of sunlight a further 36%. Also, we must take into account the fact that the sun's rays do not fall perpendicularly onto the earth's surface. The angle that they make with the surface depends on the time of day, the season and the latitude.

In Sweden, which lies at a northerly latitude, the solar energy per unit of horizontal area is less than for countries nearer the equator. Nevertheless, Göran Persson, during his term as Prime Minister of Sweden, announced that

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<sup>5</sup>The area is assumed to be perpendicular to the sun's rays.





Figure 2.11: *Rapeseed is grown in several countries, including Denmark and the UK. Experimental Danish buses are already running on rapeseed oil.*

his government intends to make the country independent of imported oil by 2020 through a program that includes energy from biomass.

In his thesis, *Biomass in a Sustainable Energy System*, the Swedish researcher Pål Börjesson states that of various crops grown as biomass, the largest energy yields come from short-rotation forests (*Salix viminalis*, a species of willow) and sugar beet plantations. These have an energy yield of from 160 to 170 GJ<sub>t</sub> per hectare-year. (The subscript *t* means “thermal”. Energy in the form of electricity is denoted by the subscript *e*). One can calculate that this is equivalent to about 0.5 MW<sub>t</sub>/km<sup>2</sup>, or 0.5 W<sub>t</sub>/m<sup>2</sup>. Thus, although 1.0 kW/m<sup>2</sup> of solar energy reaches the earth at noon at the equator, the trees growing in northerly Sweden can harvest a day-and-night and seasonal average of only 0.5 Watts of thermal energy per horizontal square meter<sup>6</sup>. Since Sweden’s present primary energy use is approximately 0.04 TW<sub>t</sub>, it follows that if no other sources of energy were used, a square area of *Salix* forest 290 kilometers on each side would supply Sweden’s present energy needs. This corresponds to an area of 84,000 km<sup>2</sup>, about 19% of Sweden’s total area<sup>7</sup>. Of course, Sweden’s renewable energy program will not rely exclusively on energy crops, but on a mixture of sources, including biomass from municipal and agricultural wastes, hydropower, wind energy and solar energy.

At present, both Sweden and Finland derive about 30% of their electricity

<sup>6</sup>In tropical regions, the rate of biomass production can be more than double this amount.

<sup>7</sup>Additional land area would be needed to supply the energy required for planting, harvesting, transportation and utilization of the wood.

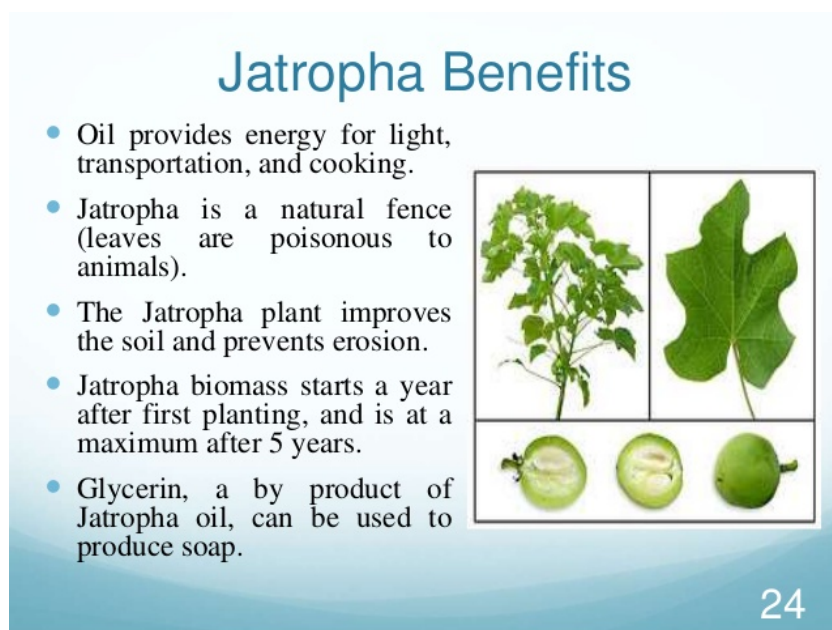


Figure 2.12: *In some countries, Jatropha is a promising source of biomass..*

from biomass, which is largely in the form of waste from the forestry and paper industries of these two countries.

Despite their northerly location, the countries of Scandinavia have good potentialities for developing biomass as an energy source, since they have small population densities and adequate rainfall. In Denmark, biodiesel oil derived from rapeseed has been used as fuel for experimental buses. Rapeseed fields produce oil at the rate of between 1,000 and 1,300 liters per hectare-crop. The energy yield is 3.2 units of fuel product energy for every unit of fuel energy used to plant the rapeseed, and to harvest and process the oil. After the oil has been pressed from rapeseed, two-thirds of the seed remains as a protein-rich residue which can be fed to cattle.

Miscanthus is a grassy plant found in Asia and Africa. Some forms will also grow in Northern Europe, and it is being considered as an energy crop in the United Kingdom. Miscanthus can produce up to 18 dry tonnes per hectare-year, and it has the great advantage that it can be cultivated using ordinary farm machinery. The woody stems are very suitable for burning, since their water content is low (20-30%).

For some southerly countries, honge oil, derived from the plant *Pongamia pinnata* may prove to be a promising source of biomass energy. Studies conducted by Dr. Udishi Shrinivasa at the Indian Institute of Sciences in Bangalore indicate that honge oil can be produced at the cost of \$150 per ton. This



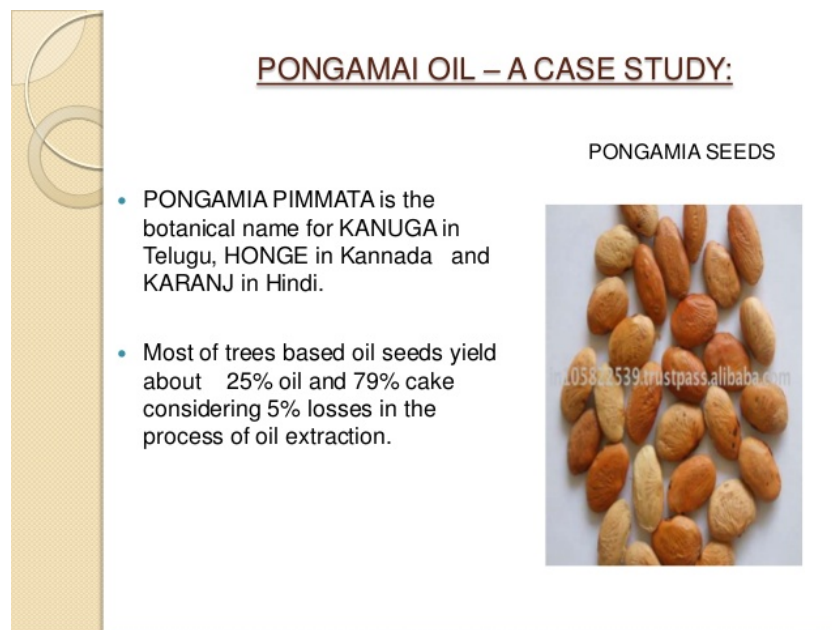


Figure 2.13: *The price of honge oil is quite competitive with other forms of oil.*

price is quite competitive when compared with other potential fuel oils.

Recent studies have also focused on a species of algae that has an oil content of up to 50%. Algae can be grown in desert areas, where cloud cover is minimal. Farm waste and excess CO<sub>2</sub> from factories can be used to speed the growth of the algae.

It is possible that in the future, scientists will be able to create new species of algae that use the sun's energy to generate hydrogen gas. If this proves to be possible, the hydrogen gas may then be used to generate electricity in fuel cells, as will be discussed below in the section on hydrogen technology. Promising research along this line is already in progress at the University of California, Berkeley.

Biogas is defined as the mixture of gases produced by the anaerobic digestion of organic matter. This gas, which is rich in methane (CH<sub>4</sub>), is produced in swamps and landfills, and in the treatment of organic wastes from farms and cities. The use of biogas as a fuel is important not only because it is a valuable energy source, but also because methane is a potent greenhouse gas, which should not be allowed to reach the atmosphere. Biogas produced from farm wastes can be used locally on the farm, for cooking and heating, etc. When biogas has been sufficiently cleaned so that it can be distributed in a pipeline, it is known as "renewable natural gas". It may then be distributed

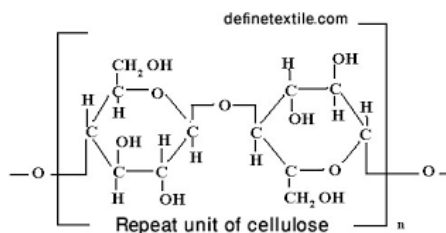


Figure 2.14: *Cellulose is a polysaccharide. In other words, it is a long polymer whose subunits are sugars. The links between the sugar subunits in the chain can be broken, for example by the action of enzymes or acids. After this has been done, the resulting sugars can be fermented into alcohols, and these can be used to fuel motor vehicles or aircraft.*

in the natural gas grid, or it can be compressed and used in internal combustion engines. Renewable natural gas can also be used in fuel cells, as will be discussed below in the section on Hydrogen Technology.

## Cellulostic ethanol

The fact that alcohols such as ethanol can be produced from cellulose has long been known.<sup>8</sup> In 1819, the French chemist Henri Braconnot demonstrated that cellulose could be broken down into sugars by treating it with sulfuric acid. The sugars thus produced could then be fermented into alcohols which could be used as liquid fuels.

In 1898, Germany built factories to commercialize this process, and shortly afterwards the same was done in the United States using a slightly different technique. These plants producing cellulostic ethanol operated during World War I, but the plants closed after the end of the war because of the cheapness and easy availability of fossil fuels. The production of cellulostic ethanol was revived during World War II.

During the last two decades, development of enzymatic techniques has supplied a better method of breaking the long cellulose polymer chain into sugars. In fact, it has recently become possible to use microbial enzymes both for this step and for the fermentation step.

In a September 9, 2008 article in the *MIT Technology Review*. Prachi Patal wrote: “New genetically modified bacteria could slash the costs of producing ethanol from cellulostic biomass, such as corn cobs and leaves, switchgrass, and paper pulp. The microbes produce ethanol at higher temperatures than are possible using yeast, which is currently employed to ferment sugar into the

<sup>8</sup>See the Wikipedia article on *Cellulostic Ethanol*

biofuel. The higher temperature more than halves the quantity of the costly enzymes needed to split cellulose into the sugars that the microbes can ferment. What's more, while yeast can only ferment glucose, 'this microorganism is good at using all the different sugars in biomass and can use them simultaneously and rapidly,' says Lee Lynd, an engineering professor at Dartmouth College, who led the microbe's development...

"Lynd wants to create microbes that would do it all: efficiently break down the cellulose and hemicellulose, and then ferment all the resulting sugars. Lynd, a cofounder of Mascoma, is working with colleagues at the startup, based in Cambridge, MA, to develop a simple one-step process for making cellulosic ethanol. In the combined process, a mixture of biomass and the microbes would go into a tank, and ethanol would come out."

Cellulosic ethanol has several advantages over alcohol derived from grain;

- Cellulosic ethanol avoids the food-fuel competition.
- The net greenhouse-gas-reducing effect of ethanol derived from grain is questionable.
- Cellulosic ethanol can use cardboard and paper waste as starting substances, thus reducing the quantity of trash in waste dumps.

## 2.7 Geothermal energy

The ultimate source of geothermal energy is the decay of radioactive nuclei in the interior of the earth. Because of the heat produced by this radioactive decay, the temperature of the earth's core is 4300 °C. The inner core is composed of solid iron, while the outer core consists of molten iron and sulfur compounds. Above the core is the mantle, which consists of a viscous liquid containing compounds of magnesium, iron, aluminum, silicon and oxygen. The temperature of the mantle gradually decreases from 3700 °C near the core to 1000 °C near the crust. The crust of the earth consists of relatively light solid rocks and it varies in thickness from 5 to 70 km.

The outward flow of heat from radioactive decay produces convection currents in the interior of the earth. These convection currents, interacting with the earth's rotation, produce patterns of flow similar to the trade winds of the atmosphere. One result of the currents of molten conducting material in the interior of the earth is the earth's magnetic field. The crust is divided into large sections called "tectonic plates", and the currents of molten material in the interior of the earth also drag the plates into collision with each other. At the boundaries, where the plates collide or split apart, volcanic activity

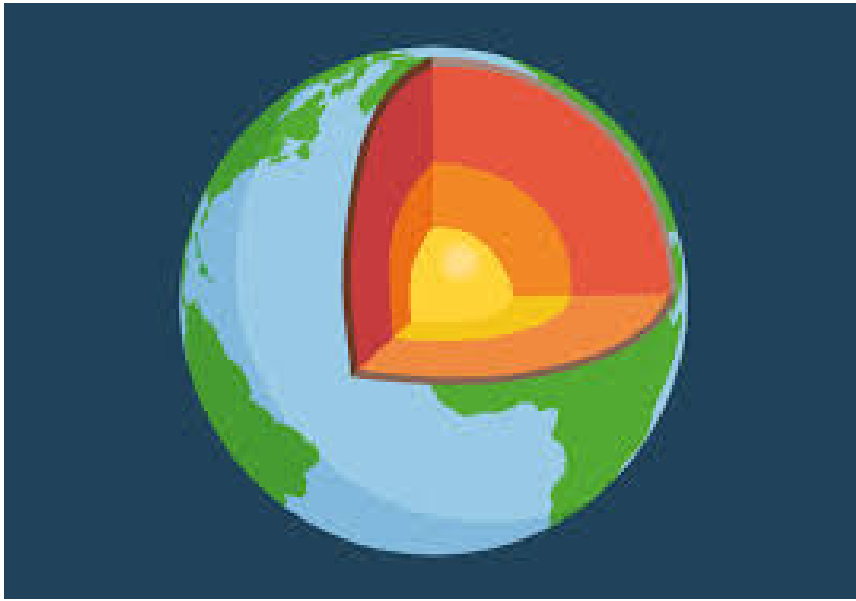


Figure 2.15: *The source of geothermal energy is the radioactive decay of elements deep within the earth.*

occurs. Volcanic regions near the tectonic plate boundaries are the best sites for collection of geothermal energy.

The entire Pacific Ocean is ringed by regions of volcanic and earthquake activity, the so-called Ring of Fire. This ring extends from Tierra del Fuego at the southernmost tip of South America, northward along the western coasts of both South America and North America to Alaska. The ring then crosses the Pacific at the line formed by the Aleutian Islands, and it reaches the Kamchatka Peninsula in Russia. From there it extends southward along the Kurile Island chain and across Japan to the Philippine Islands, Indonesia and New Zealand. Many of the islands of the Pacific are volcanic in nature. Another important region of volcanic activity extends northward along the Rift Valley of Africa to Turkey, Greece and Italy. In the Central Atlantic region, two tectonic plates are splitting apart, thus producing the volcanic activity of Iceland. All of these regions are very favorable for the collection of geothermal power.

The average rate at which the energy created by radioactive decay in the interior of the earth is transported to the surface is  $0.06 \text{ W}_t/\text{m}^2$ . However, in volcanic regions near the boundaries of tectonic plates, the rate at which the energy is conducted to the surface is much higher - typically  $0.3 \text{ W}_t/\text{m}^2$ . If we insert these figures into the thermal conductivity law

$$q = K_T \frac{\Delta T}{z}$$

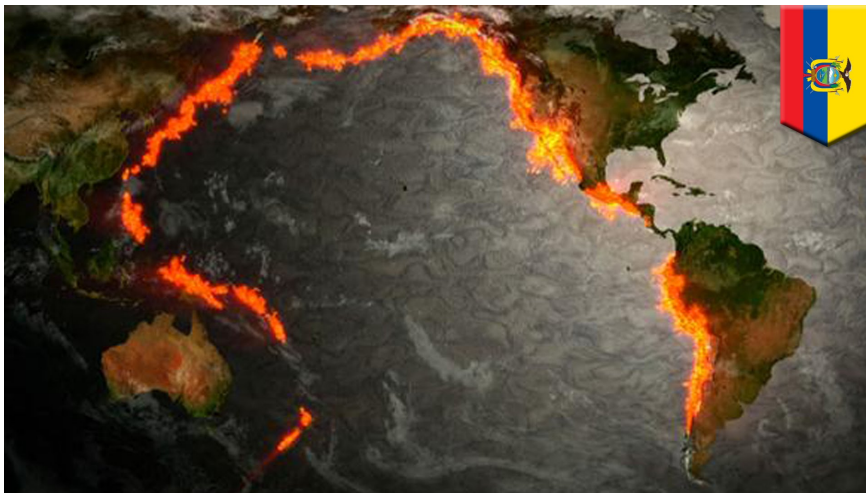


Figure 2.16: *The “ring of fire” is especially favorable for geothermal energy installations. The ring follows the western coasts of South America and North America to Alaska, After crossing the Bering Sea, it runs southward past Japan and Indonesia to New Zealand. Earthquakes and volcanic activity along this ring are produced by the collision of tectonic plates. Another strip-like region very favorable for geothermal installations follows Africa’s Rift Valley northward through Turkey and Greece to Italy, while a third pass through Iceland.*

we can obtain an understanding of the types of geothermal resources available throughout the world. In the thermal conductivity equation,  $q$  is the power conducted per unit area, while  $K_T$  is the thermal conductivity of the material through the energy is passing. For sandstones, limestones and most crystalline rocks, thermal conductivities are in the range  $2.5\text{--}3.5 \text{ W}_t/(\text{m } ^\circ\text{C})$ . Inserting these values into the thermal conductivity equation, we find that in regions near tectonic plate boundaries we can reach temperatures of  $200^\circ\text{C}$  by drilling only 2 kilometers into rocks of the types named above. If the strata at that depth contain water, it will be in the form of highly-compressed steam. Such a geothermal resource is called a *high-enthalpy* resource<sup>9</sup>.

In addition to high-enthalpy geothermal resources there are *low-enthalpy* resources in nonvolcanic regions of the world, especially in basins covered by sedimentary rocks. Clays and shales have a low thermal conductivity, typically  $1\text{--}2 \text{ W}_t/(\text{m } ^\circ\text{C})$ . When we combine these figures with the global average geothermal power transmission,  $q = 0.06 \text{ W}_t/\text{m}^2$ , the thermal conduction equation tells us that  $\Delta T/z = 0.04^\circ\text{C}/\text{m}$ . In such a region the geothermal resources may not be suitable for the generation of electrical power, but nevertheless adequate for heating buildings. The Creil district heating scheme north of Paris is an example of a project where geothermal energy from a low enthalpy resource is used for heating buildings.

The total quantity of geothermal electrical power produced in the world today is  $8 \text{ GW}_e$ , with an additional  $16 \text{ GW}_t$  used for heating houses and buildings. In the United States alone,  $2.7 \text{ GW}_e$  are derived from geothermal sources. In some countries, for example Iceland and Canada, geothermal energy is used both for electrical power generation and for heating houses.

There are three methods for obtaining geothermal power in common use today: Deep wells may yield dry steam, which can be used directly to drive turbines. Alternatively water so hot that it boils when brought to the surface may be pumped from deep wells in volcanic regions. The steam is then used to drive turbines. Finally, if the water from geothermal wells is less hot, it may be used in binary plants, where its heat is exchanged with an organic fluid which then boils. In this last method, the organic vapor drives the turbines. In all three methods, water is pumped back into the wells to be reheated. The largest dry steam field in the world is The Geysers, 145 kilometers north of San Francisco, which produces  $1,000 \text{ MW}_e$ .

There is a fourth method of obtaining geothermal energy, in which water is pumped down from the surface and is heated by hot dry rocks. In order to obtain a sufficiently large area for heat exchange the fissure systems in the rocks

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<sup>9</sup>Enthalpy  $\equiv H \equiv U + PV$  is a thermodynamic quantity that takes into account not only the internal energy  $U$  of a gas, but also energy  $PV$  that may be obtained by allowing it to expand.

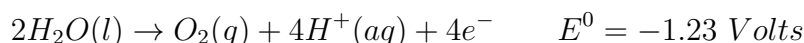
must be augmented, for example by pumping water down at high pressures several hundred meters away from the collection well. The European Union has established an experimental station at Soultz-sous-Forêts in the Upper Rhine to explore this technique. The experiments performed at Soultz will determine whether the “hot dry rock” method can be made economically viable. If so, it can potentially offer the world a very important source of renewable energy.

The molten lava of volcanoes also offers a potential source of geothermal energy that may become available in the future, but at present, no technology has been developed that is capable of using it.

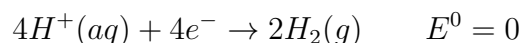
## 2.8 Hydrogen technologies

### Electrolysis of water

When water containing a little acid is placed in a container with two electrodes and subjected to an external direct current voltage greater than 1.23 Volts, bubbles of hydrogen gas form at one electrode (the cathode), while bubbles of oxygen gas form at the other electrode (the anode). At the cathode, the half-reaction

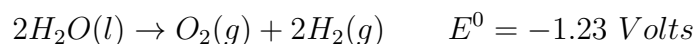


takes place, while at the anode, the half-reaction



occurs.

Half-reactions differ from ordinary chemical reactions in containing electrons either as reactants or as products. In electrochemical reactions, such as the electrolysis of water, these electrons are either supplied or removed by the external circuit. When the two half-reactions are added together, we obtain the total reaction:



Notice that  $4H^+$  and  $4e^-$  cancel out when the two half-reactions are added. The total reaction does not occur spontaneously, but it can be driven by an external potential  $E$ , provided that the magnitude of  $E$  is greater than 1.23 volts.

When this experiment is performed in the laboratory, platinum is often used for the electrodes, but electrolysis of water can also be performed using electrodes made of graphite.

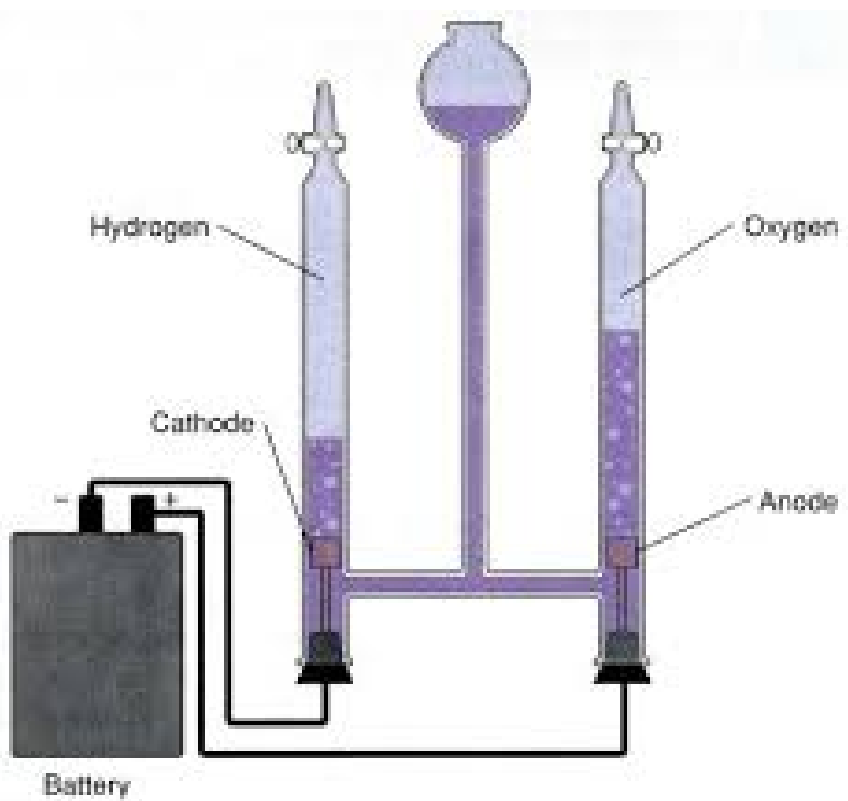


Figure 2.17: *Electrolysis of water.*

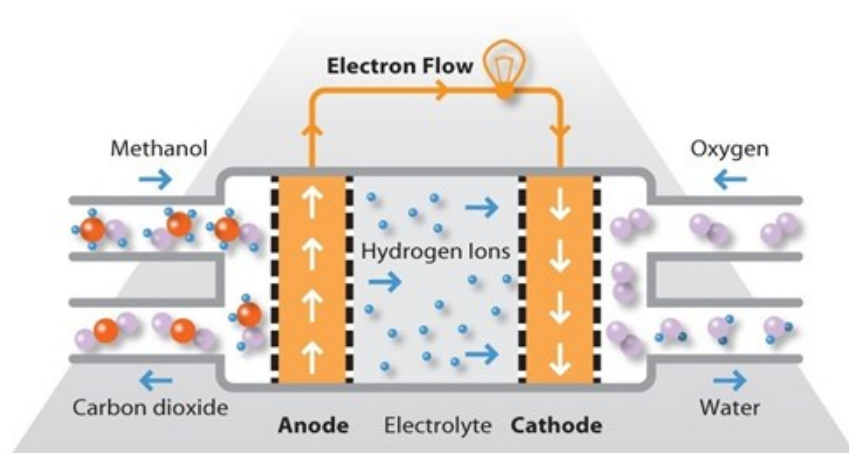


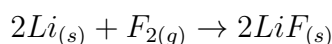
Figure 2.18: *A methanol fuel cell.*



Electrolysis of water to produce hydrogen gas has been proposed as a method for energy storage in a future renewable energy system. For example, it might be used to store energy generated by photovoltaics in desert areas of the world. Compressed hydrogen gas could then be transported to other regions and used in fuel cells. Electrolysis of water and storage of hydrogen could also be used to solve the problem of intermittency associated with wind energy or solar energy.

## Half reactions

Chemical reactions in which one or more electrons are transferred are called *oxidation-reduction reactions*. Any reaction of this type can be used in a fuel cell. As an example, we can consider the oxidation-reduction reaction in which solid lithium metal reacts with fluorine gas;



This reaction can be split into two half-reactions,



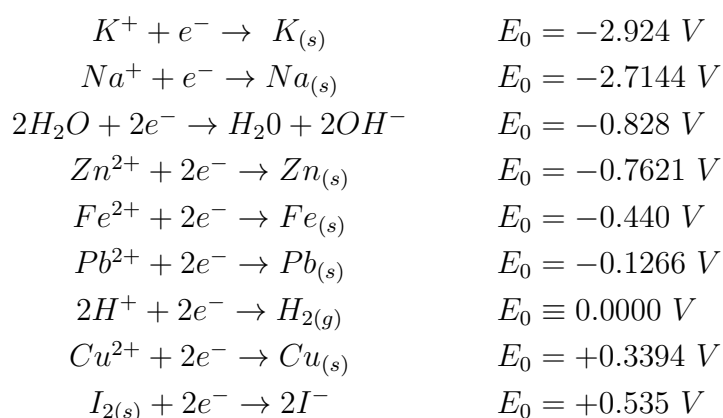
and

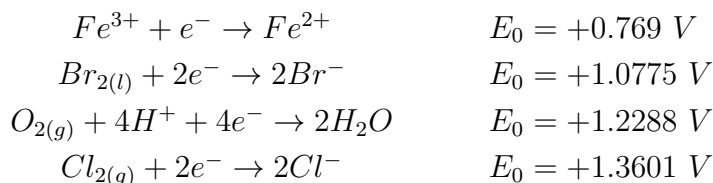


The quantity  $E_0$  which characterizes these half-reactions is called *standard potential* of the half-reaction, and it is measured in Volts. If the oxidation-reduction reaction is used as the basis of a fuel cell, the voltage of the cell is the difference between the two standard potentials. In the lithium fluoride example, it is

$$2.87 \text{ V} - (-3.040 \text{ V}) = 5.91 \text{ V}$$

Here are a few more half-reactions and their standard potentials:





Fuel cells are closely related to storage batteries. Essentially, when we recharge a storage battery we are just running a fuel cell backwards, applying an electrical potential which is sufficient to make a chemical reaction run in a direction opposite to the way that it would run spontaneously. When the charged battery is afterwards used to drive a vehicle or to power an electronic device, the reaction runs in the spontaneous direction, but the energy of the reaction, instead of being dissipated as heat, drives electrons through an external circuit and performs useful work.

The next section is devoted to the renewable energy contributions of Elon Musk, and, as we shall see, he has done much to develop the technology of rechargeable batteries.

## 2.9 Elon Musk and renewable energy technology

Elon Reve Musk was born in 1971 in South Africa. At the age of 10, he developed an interest in computer programming, and by 12 he had invented a computer game which he sold for \$500. Just before his 18th birthday, Musk moved to Canada, obtaining citizenship through his Canadian-born mother. After studying for two years at Queens University in Kingston Ontario, Musk moved to the University of Pennsylvania, where where he obtained degrees in both science and economics.

At the age of 24, Elon Musk started Ph.D. studies in applied physics and material science at Stanford University, but he left the program (after 2 days!) to pursue his interests in the Internet-based businesses, renewable energy and outer space. He became a US citizen in 2002. In the meantime, Musk's business ventures and his inventions have made him the 80th wealthiest person in the world. In 2016 he was ranked as 21st on the Forbes list of the world's most powerful people. He has been called the new Thomas Edison.

Luckily, the transition to 100% renewable energy holds a high place in Musk's priorities, and he has applied his genius both as an inventor and as a businessman to achieving this goal. Two of the corporations led by Musk, Tesla and Solar City, are devoted to solving the problem of intermittency through improved storage batteries, replacing petroleum-driven automobiles by attractive and affordable electric cars, and harnessing solar energy.



Figure 2.19: *Elon Musk in 2015 (Wikipedia)*



Figure 2.20: *Tesla's Gigafactory 1 in Nevada produces improved lithium ion batteries. Energy for the factory is supplied by solar panels on the roof.*



Figure 2.21: *Gigafactory 2. SolarCity's factory in Buffalo New York produces high-efficiency solar modules. Elon Musk estimates that only 100 gigafactories would be enough to achieve a worldwide transition to 100% renewable energy.*

SolarCity leases rooftop solar to customers who pay no upfront costs. In exchange, customers pay for 20 years for power generated by those panels.

Wikipedia states that “In June 2014, SolarCity announced plans to build a new manufacturing facility in Buffalo, New York, in coordination with the SUNY Polytechnic Institute after acquiring Silevo, a maker of high-efficiency solar modules. The initial manufacturing complex will be a 1.2-million-square-foot (110,000 m<sup>2</sup>) facility that will cost \$900 million and employ 1,500 workers in Buffalo and 5,000 statewide.”

Speaking at the University of Paris during the recent climate talks, Elon Musk said “The important thing to appreciate is if let’s say the only thing we had was solar energy, that that was the only power source, if you just took a small section of Spain, you could power all of Europe. It’s a very small amount of area that’s actually needed to generate the electricity we need to power civilization, or in the case of the US, a little corner of Nevada or Utah, power the entire United States.”

Musk has also predicted that by 2031, solar energy will be the world’s largest energy source.

## 2.10 Concluding remarks

At the start of this chapter we asked whether we will ultimately be forced by energy shortages to reduce our global population, or our per capita energy consumption, or both. In this chapter we have seen that renewable energy alternatives to fossil fuels are growing extremely rapidly, and that they offer great hope for the future.

On the other hand, the global population of humans is now increasing so rapidly that almost a billion people are added every decade. Economists continue to insist that industrial growth is necessary for “economic health”. But never-ending growth on a finite planet is a logical absurdity. Neither global population nor resource-using, pollution-producing industries can continue to grow forever. In fact, we have already exceeded the limits of sustainability.

Thus, despite the rapid growth renewable energy technology, we will be forced in the very near future to change our lifestyles, and to give culture a higher place than material goods. We will also need to devote more attention and more resources to the problem of stabilizing and ultimately reducing global population.

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## Chapter 3

# CONTINUED EXTRACTION OF FOSSIL FUELS

### 3.1 The Middle East

According to current estimates, 81.5% of the world's proven crude oil reserves are located in OPEC Member Countries, with the bulk of OPEC oil reserves in the Middle East, amounting to 65.5% of the OPEC total.

### 3.2 China

China's large reserves of coal lie near to the surface, and are thus very easily accessible. Mining of coal has driven the country's rapid industrial growth, but it has also produced a severe public health problem because of air pollution.

In April, 2017, China's rate of economic growth was 6.9%<sup>1</sup>. This rate of growth, if continued, would mean that China's economy would double every ten years. and increase by a factor of 1024 every century. Obviously this is impossible. Never-ending economic growth on a finite planet is a logical absurdity. China's high economic growth rate, is driven by its use of coal, and this must quickly stop if ecological disaster is to be avoided.

### 3.3 India

The MIT Technology Review recently published an important article entitled *India's Energy Crisis*<sup>2</sup>.

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<sup>1</sup><https://tradingeconomics.com/china/gdp-growth-annual>

<sup>2</sup><http://www.technologyreview.com/featuredstory/542091/indias-energy-crisis/>

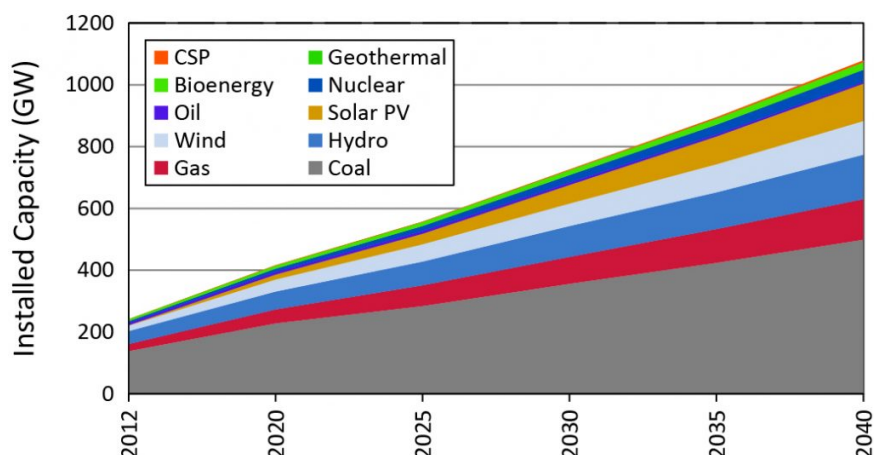


Figure 3.1: *India's installed and future energy mix, as visualized by the World Coal Association*

The article makes alarming reading in view of the world's urgent need to make a very rapid transition from fossil fuels to 100% renewable energy. We must make this change quickly in order to avoid a tipping point beyond which catastrophic climate change will be unavoidable.

The MIT article states that "Since he took power in May, 2014, Prime Minister Narendra Modi has made universal access to electricity a key part of his administration's ambitions. At the same time, he has pledged to help lead international efforts to limit climate change. Among other plans, he has promised to increase India's total power generating capacity to 175 gigawatts, including 100 gigawatts of solar, by 2022. (That's about the total power generation of Germany.)"

However India plans to expand its industrial economy, and to do this, it is planning to very much increase its domestic production and use of coal. The MIT article continues, pointing out that

However India plans to expand its industrial economy, and to do this, it is planning to very much increase its domestic production and use of coal. The MIT article continues, pointing out that "Such growth would easily swamp efforts elsewhere in the world to curtail carbon emissions, dooming any chance to head off the dire effects of global climate change. (Overall, the world will need to reduce its current annual emissions of 40 billion tons by 40 to 70 percent between now and 2050.) By 2050, India will have roughly 20 percent of the world's population. If those people rely heavily on fossil fuels such as coal to expand the economy and raise their living standards to the level people in the rich world have enjoyed for the last 50 years, the result will be a climate catastrophe regardless of anything the United States or even China

does to decrease its emissions. Reversing these trends will require radical transformations in two main areas: how India produces electricity, and how it distributes it.”

The Indian Minister of Power, Piyush Goyal, is an enthusiastic supporter of renewable energy expansion, but he also supports, with equal enthusiasm, the large-scale expansion of domestic coal production in India.

Meanwhile, the consequences of global warming are being felt by the people of India. For example, last May, a heat wave killed over 1,400 people and melted asphalt streets.<sup>3</sup>

Have India’s economic planners really thought about the long-term future? Have they considered the fact that drastic climate change could make India completely uninhabitable?

## 3.4 Russia

According to Wikipedia, “The petroleum industry in Russia is one of the largest in the world. Russia has the largest reserves, and is the largest exporter, of natural gas. It has the second largest coal reserves, the eighth largest oil reserves, and is one of the largest producer of oil. It is the third largest energy user.”

One of the difficulties of reducing Russia’s fossil fuel production is that the Russian economy depends so heavily on its oil and gas industries. Many European countries also depend on natural gas from Russia for winter heating of homes and workplaces.

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<sup>3</sup><https://www.rt.com/news/262641-india-heat-wave-killed/>



Figure 3.2: *Oil production on the shelf in the Russian Arctic.*

## 3.5 North America

### Canadian oil sands

Canada's oil-sands deposits contain an amount of carbon comparable to the world's total reserves of conventional oil. Oil is currently being extracted by methods that release four times as much carbon into the atmosphere as is contained in the refined oil from the deposits. Nevertheless, the government of Canada wholeheartedly supports extraction of oil from the tar sands.

The position of the Canadian government has been strongly criticized by leading climate scientist Professor James Hansen. A recent article in *The Guardian*<sup>4</sup>, reported him as saying; "To leave our children with a manageable situation, we need to leave the unconventional fuel in the ground. Canada's ministers are acting as salesmen for those people who will gain from the profits of that industry. But I don't think they are looking after the rights and wellbeing of the population as a whole.

"The thing we are facing overall is that the fossil fuel industry has so much money that they are buying off governments. Our democracies are seriously handicapped by the money that is driving decisions in Washington and other capitals."

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<sup>4</sup><https://www.theguardian.com/environment/2013/may/19/tar-sands-exploitation-climate-scientist>



Figure 3.3: *Get rich quick at the oil sands.*

## Fracking in the United States

According to the US Department of Energy (DOE), in 2013 at least two million oil and gas wells in the US have been hydraulically fractured, and that of new wells being drilled, up to 95% are hydraulically fractured. The output from these wells makes up 43% of the oil production and 67% of the natural gas production in the United States.

Because of earthquakes and poisoning of water supplies caused by fracking, this practice has been banned by several states in the US, and nine countries or regions in Europe: France, Bulgaria, Roumania, Germany, The Czech Republic, Luxembourg, Northern Ireland, Spain and Switzerland,



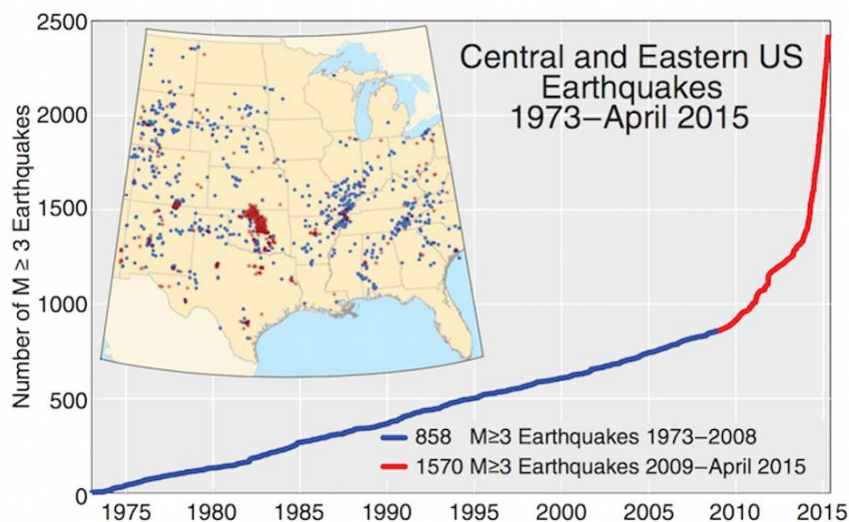


Figure 3.4: *The sharply increased number of earthquakes in the United States has been linked to fracking. The use of fracking has also caused poisoning of water supplies.*

## 3.6 Latin America

### Venezuela's Belt of Tar

The Orinoco River Basin in Venezuela contains the world's largest deposit of extra-heavy oil and tar. The amount of carbon contained in this deposit is comparable to the carbon content of all the world's known reserves of conventional oil, and also larger than the carbon contained in Canada's oil sands.

The Belt of Tar follows the line of the Orinoco river. It is approximately 600 kilometers (370 mi) from east to west, and 70 kilometers (43 mi) from north to south, with an area about 55,314 square kilometers (21,357 sq mi). The Orinoco deposit is estimated to contain 1.2 trillion barrels of extra-heavy oil.

The government of Venezuela has no plans for halting extraction from the Belt of Tar. On the contrary, detailed plans have been made for expanded exploitation of the deposit<sup>5</sup>.

<sup>5</sup><https://en.wikipedia.org/wiki/PDVSA>





Figure 3.5: *Venezuela's Belt of Tar under the Orinoco River Basin is the world's largest deposit of extra-heavy oil and tar.*

## Extraction of oil in Brazil

According to a recent article in *The Guardian*<sup>6</sup> “The discovery of tens of billions of barrels of oil in fields far off the coast of Rio de Janeiro was billed as one of the biggest finds of this century when it was announced in 2006.

“Many hoped it would deliver a bonanza for education and health and make Brazil one of world’s major economies.

“But with the country’s biggest energy company, Petrobras, mired in debt and scandal, the low price of oil and the dangers of a second Deepwater Horizon, the viability of this massive undertaking has never been under more scrutiny.”

The Brazilian offshore deposits are called “presalt oil”, since they lie under a thick layer of salt deposits.

According to the article in *The Guardian*, “Suggestions by climate campaigners that this reservoir of fossil fuel is a ‘carbon bomb’ that should be left in the ground, are dismissed as hypocrisy.”

The article quotes the geologist who discovered the off-shore fields as saying “The big countries of the world today developed without any concern for the environment. The base of US development was the oil in the Gulf of Mexico. The base of the UK’s industrial revolution was coal. How can they now say we can’t use our own pre-salt?”

## 3.7 The European Union

### Coal in Germany and Poland

In 2016, Germany produced 176,100,000 tonnes of coal while Poland produced 131,100,000 tonnes. In the past, Poland experienced severe ecological effects from acid rain due to the burning of coal. Polish forests were destroyed by the effects of acid rain, and the facades of statues and buildings in Krakow and elsewhere were dissolved by the acid. Today the situation is improving, but the two countries are still heavily dependant on coal.

### North Sea oil

According to Wikipedia, “The British and Norwegian sections hold most of the remainder of the large oil reserves. It is estimated that the Norwegian section alone contains 54% of the sea’s oil reserves and 45% of its gas reserves- More than half of the North Sea oil reserves have been extracted, according to official

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<sup>6</sup><https://www.theguardian.com/environment/ng-interactive/2015/jun/25/brazils-gamble-on-deep-water-oil-guanabara-bay>

sources in both Norway and the UK. For Norway, the Norwegian Petroleum Directorate [28] gives a figure of 4,601 million cubic meters of oil (corresponding to 29 billion barrels) for the Norwegian North Sea alone (excluding smaller reserves in Norwegian Sea and Barents Sea) of which 2,778 million cubic meters (60%) has already been produced prior to January 2007. UK sources give a range of estimates of reserves, but even using the most optimistic 'maximum' estimate of ultimate recovery, 76% had been recovered at end 2010.[citation needed] Note the UK figure includes fields which are not in the North Sea (onshore, West of Shetland).

## 3.8 Major producers of fossil fuels

### The top 20 oil-producing nations in 2016

Wikipedia's article entitles *List of countries by oil production* gives information shown in the table below. In the table, which is based on data from the International Energy Agency, production is measured in barrels of oil per day

1	Russia	10,551,497
2	Saudi Arabia	10,460,710
3	United States	8,875,817
4	Iraq	4,451,516
5	Iran	3,990,956
6	China	3,980,650
7	Canada	3,662,694
8	United Arab Emirates	3,106,077
9	Kuwait	2,923,825
10	Brazil	2,515,459
11	Venezuela	2,276,967
12	Mexico	2,186,877
13	Nigeria	1,999,885
14	Angola	1,769,615
15	Norway	1,647,975
16	Kazakhstan	1,595,199
17	Qatar	1,522,902
18	Algeria	1,348,361
19	Oman	1,006,841
20	United Kingdom	939,760

## The top 10 coal producing nations in 2016

Wikipedia gives a similar list of coal producing nations. Only the top 10 are shown here, since these countries completely dominate global coal production. In the table, production is measured in millions of tonnes per year.

1	China	3411.0
2	India	692.4
3	United States	660.6
4	Australia	492.8
5	Indonesia	434.0
6	Russia	385.4
7	South Africa	251.3
8	Germany	176.1
9	Poland	131.1
10	Kazakhstan	102.4
	World	7,460.4

The world production of coal is falling. In 2014 it was 8,164.9 tonnes, in 2015, 7,861.1 tonnes, and in 2016 7,460.4 tonnes. Nevertheless, global production of coal remains worryingly high. If catastrophic climate change is to be avoided, it must stop altogether within one or two decades. At the moment the world is still producing roughly 1 tonne of coal per capita each year.

## List of countries by natural gas production

Here is a similar table for natural gas. Production is measured in m<sup>3</sup> per year. The final column indicates the date of the data.

1	United States	728,200,000,000	2014
2	Russia	578,700,000,000	2014
3	Iran	438,000,000,000	2017
4	Canada	143,100,000,000	2012
5	Qatar	133,200,000,000	2011
6	Norway	114,700,000,000	2012
7	China	107,200,000,000	2012
8	Saudi Arabia	103,200,000,000	2012
9	Algeria	82,760,000,000	2011
10	Netherlands	80,780,000,000	2012
	World	4,359,000,000,000	2010

## 3.9 Blood for oil

There is a close relationship between petroleum and war. James A. Paul, Executive Director of the Global Policy Forum, has described this relationship very clearly in the following words:

“Modern warfare particularly depends on oil, because virtually all weapons systems rely on oil-based fuel - tanks, trucks, armored vehicles, self-propelled artillery pieces, airplanes, and naval ships. For this reason, the governments and general staffs of powerful nations seek to ensure a steady supply of oil during wartime, to fuel oil-hungry military forces in far-flung operational theaters.”

“Just as governments like the US and UK need oil companies to secure fuel for their global war-making capacity, so the oil companies need their governments to secure control over global oilfields and transportation routes. It is no accident, then, that the world’s largest oil companies are located in the world’s most powerful countries.”

“Almost all of the world’s oil-producing countries have suffered abusive, corrupt and undemocratic governments and an absence of durable development. Indonesia, Saudi Arabia, Libya, Iraq, Iran, Angola, Colombia, Venezuela, Kuwait, Mexico, Algeria - these and many other oil producers have a sad record, which includes dictatorships installed from abroad, bloody coups engineered by foreign intelligence services, militarization of government and intolerant right-wing nationalism.”

### The resource curse

The way in which the industrialized countries maintain their control over less developed nations can be illustrated by the “resource curse”, i.e. the fact that resource-rich developing countries are no better off economically than those that lack resources, but are cursed with corrupt and undemocratic governments. This is because foreign corporations extracting local resources under unfair agreements exist in a symbiotic relationship with corrupt local officials.

One might think that taxation of foreign resource-extracting firms would provide developing countries with large incomes. However, there is at present no international law governing multinational tax arrangements. These are usually agreed to on a bilateral basis, and the industrialized countries have stronger bargaining powers in arranging the bilateral agreements.

### 3.10 Fossil fuel extraction must stop!

“Leave the oil in the soil! Leave the coal in the hole! Leave the gas under the grass!” That was message of protesters at the 2017 G20 meeting. But from the facts shown in this chapter, we can see that on the whole, fossil fuels are not being left in the ground, where they have to remain if an ecological disaster is to be avoided. On the contrary, the extraction of coal, oil and gas continues almost as though the climate emergency did not exist. Most politicians, with their eyes focused on the present, seem blind to future dangers. They think primarily about the jobs and living standards of their constituents, and about the next election. Meanwhile, the future of human civilization is neglected and remains in peril.<sup>7</sup>

The fact that historically, the highly industrialized nations were primarily responsible for atmospheric CO<sub>2</sub> increases does not excuse the developing countries from their responsibility for saving the future. Today China’s coal, India’s coal, Venezuela’s tar sands and Brazil’s pre-salt oil are among the greatest threats, and in these countries as elsewhere, extraction must stop.

We have to wake up! Business as usual cannot continue!

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<sup>7</sup>See <https://www.theguardian.com/commentisfree/2017/sep/18/enough-tiptoeing-around-lets-make-this-clear-coal-kills-people>

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Figure 3.6: A view of oil refineries from the Galveston Channel in Texas (Photo: Roy Luck/flick/CC)

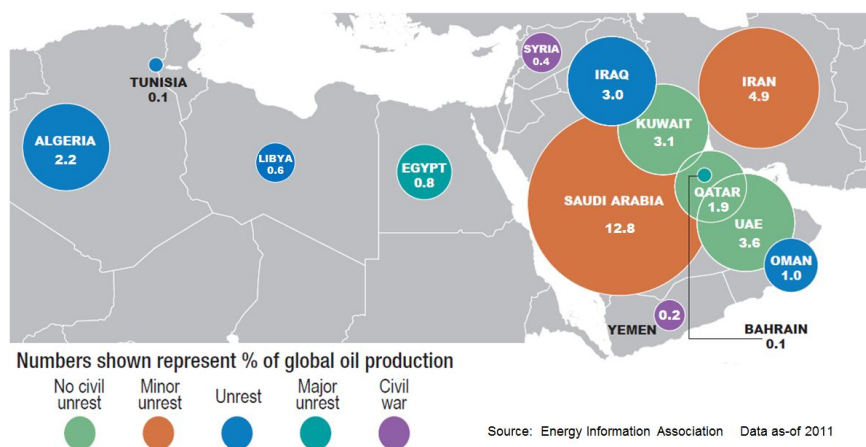


Figure 3.7: A map showing the major oil-producing countries of the Middle East and North Africa. The percent of global oil production is indicated. Many of the countries shown have some degree of civil unrest or civil war.



Figure 3.8: *Burning of coal in China has contributed to rapid industrial growth, but besides being a major factor in the threat of catastrophic climate change, it has produced hundreds of thousands of deaths each year through air pollution (an estimated 366,000 in 2013).*



Figure 3.9: *Protests against the Keystone XL and Dakota Access pipelines which, if completed, would carry oil from the Canadian oil sands to refineries in Texas.*





Figure 3.10: *Protesters at the 2017 G20 meeting in Hamburg Germany.*



## Chapter 4

# EXTINCTION EVENTS AND FEEDBACK LOOPS

### Introduction

Scientists warn that if the transition to renewable energy does not happen within very few decades, there is a danger that we will reach a tipping point beyond which feedback loops, such as the albedo effect and the methane hydrate feedback loop, will take over and produce an out-of-control and fatal increase in global temperature.

In 2012, the World Bank issued a report warning that without quick action to curb CO<sub>2</sub> emissions, global warming is likely to reach 4 °C during the 21st century. This is dangerously close to the temperature which initiated the Permian-Triassic extinction event: 6 °C above normal. During the Permian-Triassic extinction event, which occurred 252 million years ago, 96% of all marine species were wiped out, as well as 70% of all terrestrial vertebrates.<sup>1</sup>

### 4.1 A warning from the World Bank

In 2012, the World Bank issued a report warning that without quick action to curb CO<sub>2</sub> emissions, global warming is likely to reach 4 °C during the 21st century. This is dangerously close to the temperature which initiated the Permian-Triassic extinction event: 6 °C above normal. During the Permian-Triassic extinction event, which occurred 252 million years ago, 96% of all

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<sup>1</sup><http://science.nationalgeographic.com/science/prehistoric-world/permian-extinction/>  
<http://www.worldbank.org/en/news/feature/2012/11/18/Climate-change-report-warns-dramatically-warmer-world-this-century>

marine species were wiped out, as well as 70% of all terrestrial vertebrates.<sup>2</sup>

The 4°C scenarios are devastating: the inundation of coastal cities; increasing risks for food production potentially leading to higher malnutrition rates; many dry regions becoming dryer, wet regions wetter; unprecedented heat waves in many regions, especially in the tropics; substantially exacerbated water scarcity in many regions; increased frequency of high-intensity tropical cyclones; and irreversible loss of biodiversity, including coral reef systems.

And most importantly, a 4°C world is so different from the current one that it comes with high uncertainty and new risks that threaten our ability to anticipate and plan for future adaptation needs. The lack of action on climate change not only risks putting prosperity out of reach of millions of people in the developing world, it threatens to roll back decades of sustainable development. It is clear that we already know a great deal about the threat before us. The science is unequivocal that humans are the cause of global warming, and major changes are already being observed: global mean warming is 0.8°C above pre industrial levels; oceans have warmed by 0.09°C since the 1950s and are acidifying; sea levels rose by about 20 cm since pre-industrial times and are now rising at 3.2 cm per decade; an exceptional number of extreme heat waves occurred in the last decade; major food crop growing areas are increasingly affected by drought.

Despite the global community's best intentions to keep global warming below a 2°C increase above pre-industrial climate, higher levels of warming are increasingly likely. Scientists agree that countries' current United Nations Framework Convention on Climate Change emission pledges and commitments would most likely result in 3.5 to 4°C warming. And the longer those pledges remain unmet, the more likely a 4°C world becomes.

Data and evidence drive the work of the World Bank Group. Science reports, including those produced by the Intergovernmental Panel on Climate Change, informed our decision to ramp up work on these issues, leading to, a World Development Report on climate change designed to improve our understanding of the implications of a warming planet; a Strategic Framework on Development and Climate Change, and a report on Inclusive Green Growth. The World Bank is a leading advocate for ambitious action on climate change, not only because it is a moral imperative, but because it makes good economic sense.

But what if we fail to ramp up efforts on mitigation? What are the implications of a 4°C world? We commissioned this report from the Potsdam Institute for Climate Impact Research and Climate Analytics to help us understand the

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<sup>2</sup><http://science.nationalgeographic.com/science/prehistoric-world/permian-extinction/>  
<http://www.worldbank.org/en/news/feature/2012/11/18/Climate-change-report-warns-dramatically-warmer-world-this-century>

state of the science and the potential impact on development in such a world.

It would be so dramatically different from today's world that it is hard to describe accurately; much relies on complex projections and interpretations. We are well aware of the uncertainty that surrounds these scenarios and we know that different scholars and studies sometimes disagree on the degree of risk. But the fact that such scenarios cannot be discarded is sufficient to justify strengthening current climate change policies. Finding ways to avoid that scenario is vital for the health and welfare of communities around the world. While every region of the world will be affected, the poor and most vulnerable would be hit hardest. A 4°C world can, and must, be avoided.

The World Bank Group will continue to be a strong advocate for international and regional agreements and increasing climate financing. We will redouble our efforts to support fast growing national initiatives to mitigate carbon emissions and build adaptive capacity as well as support inclusive green growth and climate smart development. Our work on inclusive green growth has shown that, through more efficiency and smarter use of energy and natural resources, many opportunities exist to drastically reduce the climate impact of development, without slowing down poverty alleviation and economic growth.

This report is a stark reminder that climate change affects everything. The solutions don't lie only in climate finance or climate projects. The solutions lie in effective risk management and ensuring all our work, all our thinking, is designed with the threat of a 4°C degree world in mind. The World Bank Group will step up to the challenge.

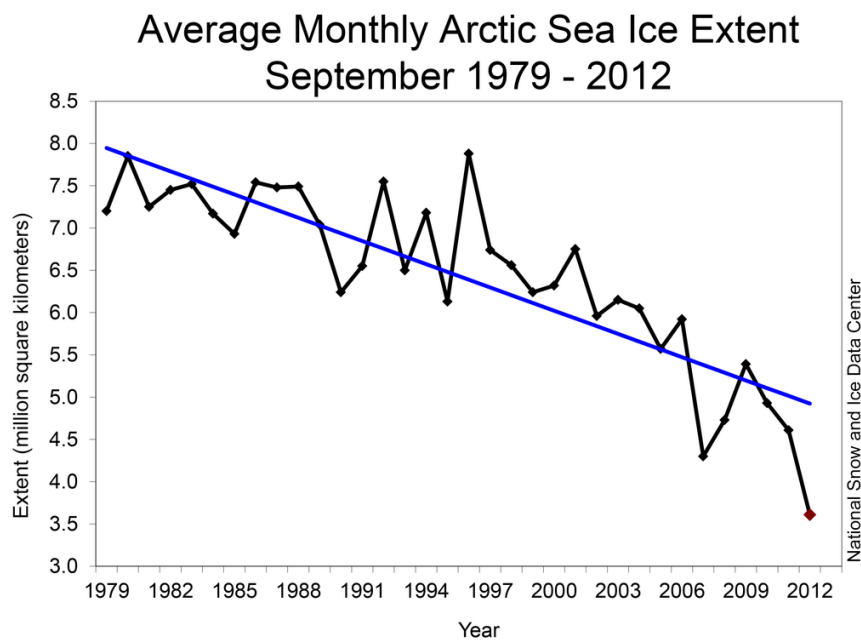


Figure 4.1: *Monthly September ice extent for 1979 to 2012 shows a decline of 13.0% per decade. One can also see that the straight line does not really fit the data, which more nearly resemble a downward curve will that reach zero in the period 2016-2019. Source: National Snow and Ice Data Center. Wikimedia Commons*

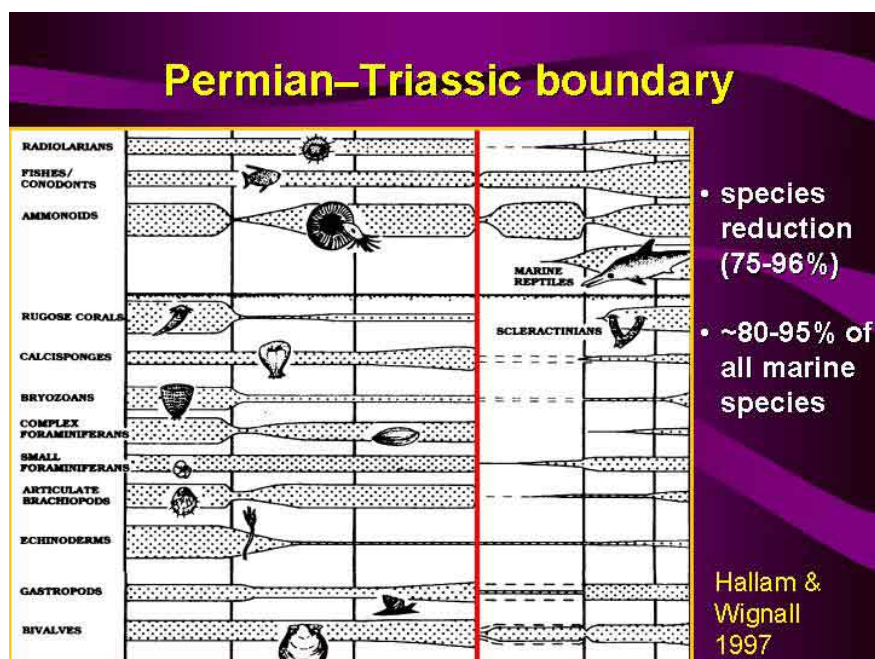


Figure 4.2: *Loss of species caused by the Permian-Triassic extinction event. Unless quick steps are taken to lower our greenhouse gas emissions, we may cause a similar extinction event, which will threaten the survival of our own species. Source: Australian Frontiers of Science, [www.sciencearchive.org.au](http://www.sciencearchive.org.au)*

## 4.2 Permian-Triassic extinction event

The geological record shows five major extinction events.

- Ordovician-Silurian Extinction. around 439 million years ago.
- Late Devonian Extinction. 375-360 million years ago.
- Permian-Triassic extinction. 352 million years ago.
- Triassic-Jurassic extinction, 201 million years ago.
- Cretaceous-Paleogene extinction, 66 million years ago.

The most devastating of these was the Permian-Triassic extinction, which occurred 252 million years ago.<sup>3</sup> In the Permian-Triassic extinction, 96% of all marine species and 76% of all terrestrial vertebrates disappeared forever. The cause of this extremely severe event is disputed, but according to one of the most plausible theories it was triggered by a massive volcanic eruption in Siberia, which released enormous amounts of CO<sub>2</sub> into the earth's atmosphere.

The region where massive volcanic eruptions are known to have occurred 252 million years ago called the "Siberian Traps". (The "Traps" part of the name comes from the fact that many of the volcanic rock formations in the region resemble staircases. The Swedish word for staircase is "trappe".) The eruptions continued for about a million years.

Today the area covered is about 2 million square kilometers, roughly equal to western Europe in land area. Estimates of the original coverage are as high as 7 million square kilometers. The original volume of lava is estimated to range from 1 to 4 million cubic kilometers.

The CO<sub>2</sub> released by the Siberian Traps eruption is believed to have caused a global temperature increase of 6°C, and this was enough to trigger the methane-hydrate feedback loop, which will be discussed below. The earth's temperature is thought to have continued to rise for 85,000 years, finally reaching 15° above normal.

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<sup>3</sup> <https://www.thomhartmann.com/bigpicture/last-hours-climate-change>  
*The Last Hours of Humanity: Warming the World To Extinction* (book), by Thom Hartmann  
<https://www.amazon.com/Last-Hours-Humanity-Warming-Extinction/dp/1629213640>  
<http://www.mediaite.com/online/leonardo-dicaprio-boosts-thom-hartmann-apocalyptic-global-warming-film-last-hours/>



### 4.3 The Holocene (Anthropocene) extinction

We are now living in the midst of a sixth, human-caused, mass extinction. How severe it becomes is up to us.

Recently a group of scientists stated that the scope of human impact on planet Earth is so great that the *Anthropocene* warrants a formal place in the Geological Time Scale.

In a statement issued by University of Leicester Press Office on 2 October 2017, professor Jan Zalasiewicz from the University of Leicester's School of Geography, Geology, and the Environment said: "Our findings suggest that the Anthropocene should follow on from the Holocene Epoch that has seen 11.7 thousand years of relative environmental stability, since the retreat of the last Ice Age, as we enter a more unstable and rapidly evolving phase of our planet's history,"<sup>4</sup>

"We conclude that human impact has now grown to the point that it has changed the course of Earth history by at least many millennia, in terms of the anticipated long-term climate effects (e.g. postponement of the next glacial maximum: see Ganopolski et al., 2016; Clark et al., 2016), and in terms of the extensive and ongoing transformation of the biota, including a geologically unprecedented phase of human-mediated species invasions, and by species extinctions which are accelerating (Williams et al., 2015, 2016)."

The report stated that defining characteristics of the period include "marked acceleration of rates of erosion and sedimentation; large-scale chemical perturbations to the cycles of carbon, nitrogen, phosphorus and other elements; the inception of significant change in global climate and sea level; and biotic changes including unprecedented levels of species invasions across the Earth. Many of these changes are geologically long-lasting, and some are effectively irreversible."

#### Loss of biodiversity

Tropical rain forests are the most biologically diverse places in the world. This is because they have not been affected by the periods of glaciation that have periodically destroyed the forests of temperate and boreal regions. The destruction of species-rich tropical rain forests is one of the mechanisms driving the present high rate of species loss.

According to a recent article published in *The Guardian*<sup>5</sup> "Conservation experts have already signalled that the world is in the grip of the "sixth great

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<sup>4</sup><http://www2.le.ac.uk/offices/press/press-releases/2017/october/significant-scale-of-human-impact-on-planet-has-changed-course-of-earth2019s-history-scientists-suggest>

<sup>5</sup><https://www.theguardian.com/environment/2010/mar/07/extinction-species-evolve>

extinction” of species, driven by the destruction of natural habitats, hunting, the spread of alien predators and disease, and climate change.

“The IUCN<sup>6</sup> created shock waves with its major assessment of the world’s biodiversity in 2004, which calculated that the rate of extinction had reached 100-1,000 times that suggested by the fossil records before humans.

“No formal calculations have been published since, but conservationists agree the rate of loss has increased since then, and Stuart said it was possible that the dramatic predictions of experts like the renowned Harvard biologist E O Wilson, that the rate of loss could reach 10,000 times the background rate in two decades, could be correct.”

A recent article by Profs. Gerardo Ceballos, Paul R. Ehrlich and Rodolfo Dirzo in the *Proceedings of the National Academy of Sciences* was entitled “Biological Annihilation via the Ongoing Sixth Mass Extinction Signaled by Vertebrate Population Losses and Declines”.

The Abstract of the paper reads as follows: “The population extinction pulse we describe here shows, from a quantitative viewpoint, that Earth’s sixth mass extinction is more severe than perceived when looking exclusively at species extinctions. Therefore, humanity needs to address anthropogenic population extirpation and decimation immediately. That conclusion is based on analyses of the numbers and degrees of range contraction (indicative of population shrinkage and/or population extinctions according to the International Union for Conservation of Nature) using a sample of 27,600 vertebrate species, and on a more detailed analysis documenting the population extinctions between 1900 and 2015 in 177 mammal species. We find that the rate of population loss in terrestrial vertebrates is extremely high, even in ‘species of low concern.’ In our sample, comprising nearly half of known vertebrate species, 32% (8,851/27,600) are decreasing; that is, they have decreased in population size and range. In the 177 mammals for which we have detailed data, all have lost 30% or more of their geographic ranges and more than 40% of the species have experienced severe population declines (>80% range shrinkage). Our data indicate that beyond global species extinctions Earth is experiencing a huge episode of population declines and extirpations, which will have negative cascading consequences on ecosystem functioning and services vital to sustaining civilization. We describe this as a ‘biological annihilation’ to highlight the current magnitude of Earth’s ongoing sixth major extinction event.”

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<sup>6</sup>International Union for the Conservation of Nature

## 4.4 Global warming and atmospheric water vapor

A feedback loop is a self-re-enforcing trend. One of the main positive feedback loops in global warming is the tendency of warming to increase the atmospheric saturation pressure for water vapor, and hence amount of water vapor in the atmosphere, which in turn leads to further warming, since water vapor is a greenhouse gas.

Wikipedia's article on greenhouse gases states that, "Water vapor accounts for the largest percentage of the greenhouse effect, between 36% and 66% for clear sky conditions and between 66% and 85% when including clouds."

## 4.5 The albedo effect

Albedo is defined to be the fraction of solar energy (shortwave radiation) reflected from the Earth back into space. It is a measure of the reflectivity of the earth's surface. Ice, especially with snow on top of it, has a high albedo: most sunlight hitting the surface bounces back towards space.

### Loss of sea ice

Especially in the Arctic and Antarctic regions, there exists a dangerous feedback loop involving the albedo of ice and snow. As is shown in Figure 4.1, Arctic sea ice is rapidly disappearing. It is predicted that during the summers, the ice covering arctic seas may disappear entirely during the summers. As a consequence, incoming sunlight will encounter dark light-absorbing water surfaces rather than light-reflecting ice and snow.

This effect is self-re-enforcing. In other words, it is a feedback loop. The rising temperatures caused by the absorption of more solar radiation cause the melting of more ice, and hence even more absorption of radiation rather than reflection, still higher temperatures, more melting, and so on.

The feedback loop is further strengthened by the fact that water vapor acts like a greenhouse gas. As polar oceans become exposed, more water vapor enters the atmosphere, where it contributes to the greenhouse effect and rising temperatures.

### Darkened snow on Greenland's icecap

Greenland's icecap is melting, and as it melts, the surface becomes darker and less reflective because particles of soot previously trapped in the snow and ice

become exposed. This darkened surface absorbs an increased amount of solar radiation, and the result is accelerated melting.

## 4.6 The methane hydrate feedback loop

If we look at the distant future, by far the most dangerous feedback loop involves methane hydrates or methane clathrates. When organic matter is carried into the oceans by rivers, it decays to form methane. The methane then combines with water to form hydrate crystals, which are stable at the temperatures and pressures which currently exist on ocean floors. However, if the temperature rises, the crystals become unstable, and methane gas bubbles up to the surface. Methane is a greenhouse gas which is 70 times as potent as CO<sub>2</sub>.

The worrying thing about the methane hydrate deposits on ocean floors is the enormous amount of carbon involved: roughly 10,000 gigatons. To put this huge amount into perspective, we can remember that the total amount of carbon in world CO<sub>2</sub> emissions since 1751 has only been 337 gigatons.

A runaway, exponentially increasing, feedback loop involving methane hydrates could lead to one of the great geological extinction events that have periodically wiped out most of the animals and plants then living. This must be avoided at all costs.

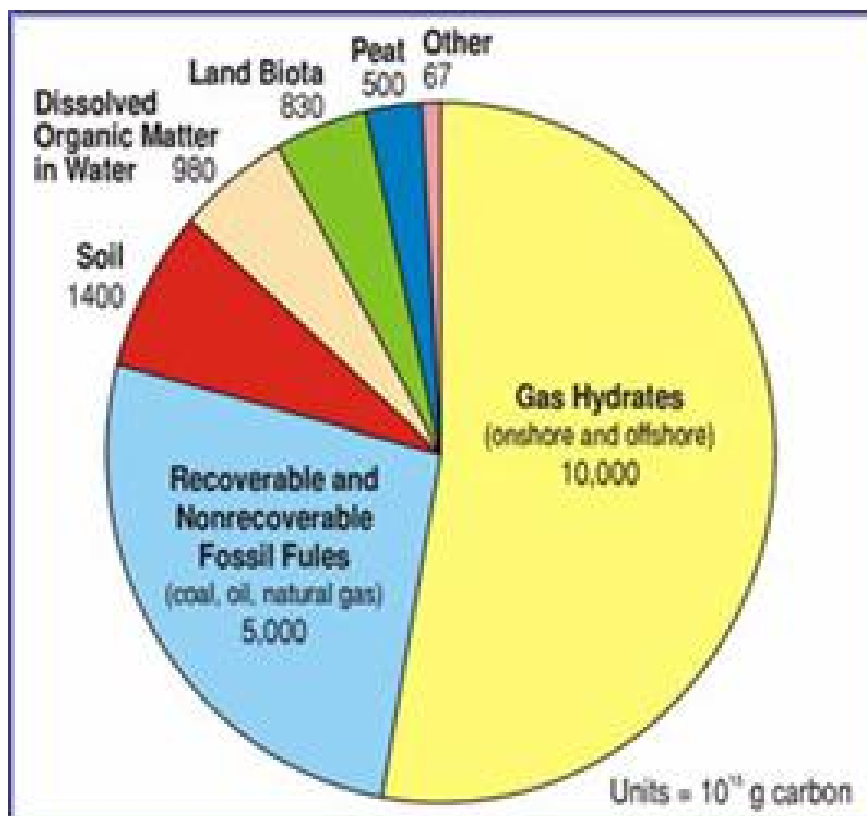


Figure 4.3: *The worrying thing about the methane/hydrate feedback loop is the enormous amount of carbon in the form of hydrate crystals, 10,000 gigatons most of it on the continental shelves of oceans. This greater than the amount of carbon in all other forms that might potentially enter the earth's atmosphere.*



Figure 4.4: *When ocean temperatures rise, methane hydrate crystals become unstable, and methane gas bubbles up to ocean surfaces.*

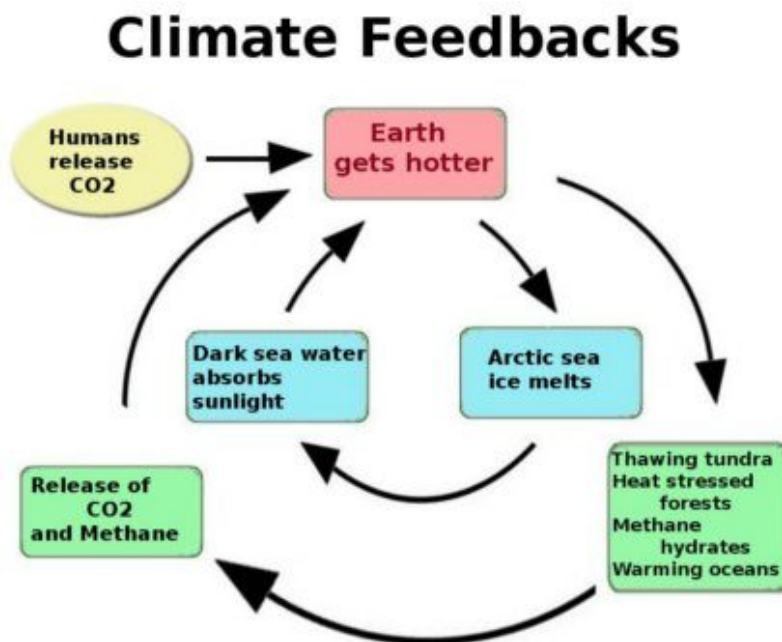


Figure 4.5: This diagram shows two important feedback loops, one involving the albedo effect, and the other involving methane hydrates.

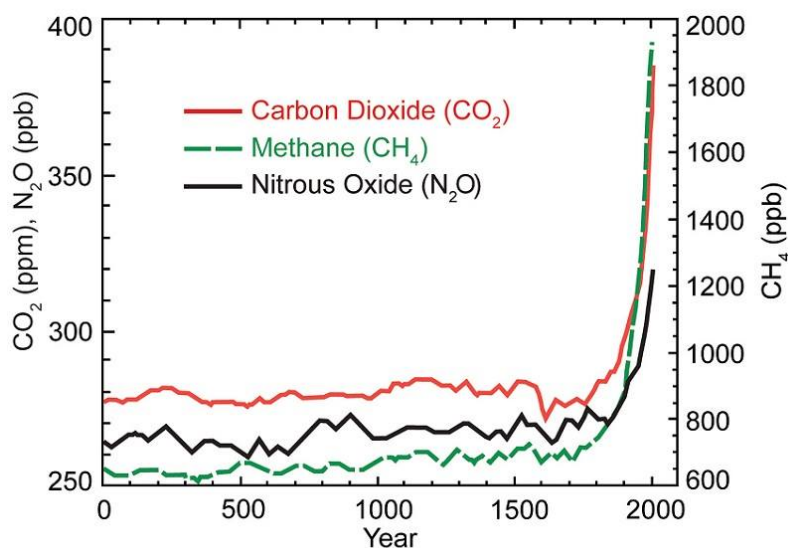


Figure 4.6: A “hockey stick” graph showing atmospheric concentrations of three important greenhouse gasses during the last 2,000 years. The most dramatically increasing of these is methane.

## 4.7 A feedback loop from warming of soils

On October 6, 2017, the journal *Science* published an article entitled *Long-term pattern and magnitude of soil carbon feedback to the climate system in a warming world*<sup>7</sup>. The lead author, Jerry Melillo, is an ecologist working at the Marine Biological Laboratory, Woods Hole Massachusetts. In an interview with *Newsweek*, he said: “This self-reinforcing feedback is potentially a global phenomenon with soils, and once it starts it may be very difficult to turn off. It’s that part of the problem that I think is sobering... We think that one of the things that may be happening is both a reorganization of the microbial community structure and its functional capacity,”

The study reported on three decades of observations of heated sections of a forest owned by Harvard University. The heated sections were 5°C warmer than control sections.

## 4.8 Drying of forests and forest fires

According to a recent article in *Nature*<sup>8</sup>, “Across the American west, the area burned each year has increased significantly over the past several decades, a trend that scientists attribute both to warming and drying and to a century of wildfire suppression and other human activities. Allen suggests that the intertwined forces of fire and climate change will take ecosystems into new territory, not only in the American west but also elsewhere around the world. In the Jemez, for example, it could transform much of the ponderosa pine (*Pinus ponderosa*) forest into shrub land. ‘We’re losing forests as we’ve known them for a very long time,’ says Allen. ‘We’re on a different trajectory, and we’re not yet sure where we’re going.’

“All around the American west, scientists are seeing signs that fire and climate change are combining to create a ‘new normal’. Ten years after Colorado’s largest recorded fire burned 56,000 hectares southwest of Denver, the forest still has not rebounded in a 20,000-hectare patch in the middle, which was devastated by an intense crown fire. Only a few thousand hectares, which the US Forest Service replanted, look anything like the ponderosa-pine stands that previously dominated the landscape.”

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<sup>7</sup>J.M. Melillo et al., *Long-term pattern and magnitude of soil carbon feedback to the climate system in a warming world*, *Science*, Vol. 358, pp. 101-105, (2017).

<sup>8</sup><http://www.nature.com/news/forest-fires-burn-out-1.11424>



## 4.9 Tipping points and feedback loops

A tipping point is usually defined as the threshold for an abrupt and irreversible change<sup>9</sup>. To illustrate this idea, we can think of a book lying on a table. If we gradually push the book towards the edge of the table, we will finally reach a point after which more than half of the weight of the book will not be supported by the table. When this “tipping point” is passed the situation will suddenly become unstable, and the book will fall to the floor. Analogously, as the earth’s climate gradually changes, we may reach tipping points. If we pass these points, sudden instabilities and abrupt climatic changes will occur.

Greenland ice cores supply a record of temperatures in the past, and through geological evidence we have evidence of sea levels in past epochs. These historical records show that abrupt climatic changes have occurred in the past.

Timothy Michael Lenton, FRS, Professor of Climate Change and Earth System Science at the University of Exeter, lists the following examples of climatic tipping points:

- Boreal forest dieback
- Amazon rainforest dieback
- Loss of Arctic and Antarctic sea ice (Polar ice packs) and melting of Greenland and Antarctic ice sheets
- Disruption to Indian and West African monsoon
- Formation of Atlantic deep water near the Arctic ocean, which is a component process of the thermohaline circulation.
- Loss of permafrost, leading to potential Arctic methane release and clathrate gun effect

It can be seen from this list that climate tipping points are associated with feedback loops. For example, the boreal forest dieback and the Amazon rainforest dieback tipping points are associated with the feedback loop involving the drying of forests and forest fires, while the tipping point involving loss of Arctic and Antarctic sea ice is associated with the Albedo effect feedback loop. The tipping point involving loss of permafrost is associated with the methane hydrate feedback loop.

Once a positive feedback loop starts to operate in earnest, change may be abrupt.

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<sup>9</sup>Other definitions of tipping points are possible. A few authors define these as points beyond which change is inevitable, emphasizing that while inevitable, the change may be slow.

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# Chapter 5

## THE OCEANS

### 5.1 Thermal inertia of the oceans

#### Calories required to warm a gram of water

We all know that saucepan full of water on the kitchen stove does not start to boil immediately when the heat under it is turned on. In fact, for every gram of water in the saucepan, one calorie is needed for every degree C in temperature rise. If the pan contains a kilogram of water, a kilocalorie is needed to make it warm by 1°C.

The same principle, vastly scaled up in size, holds for the earth's oceans. When humans "turn on the heat" by releasing greenhouse gases into the atmosphere, the oceans respond very slowly because of the vast amount of energy needed to warm them. The total volume of the oceans is estimated to be  $1.35 \times 10^9 \text{ km}^3$  or  $1.35 \times 10^{24} \text{ cm}^3$ . Thus to warm the earth's oceans by 1°C requires  $1.35 \times 10^{24}$  calories, and the current imbalance between incoming and outgoing radiation supplies only a small fraction of this amount each year.

This means that even if the CO<sub>2</sub> and other greenhouse gases in our atmosphere were stabilized at their current levels, the oceans would continue to warm for many decades. This does not mean that our efforts to reduce greenhouse gas emissions are futile. We must certainly experience some very unpleasant effects of sea level rise, ocean life destruction and global warming during the next few decades, but how bad these become is up to us.

#### Cultural and institutional inertia

Physical systems are slow to respond to forcing, as we have just seen in our discussion of the thermal inertia of the oceans. Human social and economic systems are also slow to respond, even when quick action is urgently needed.

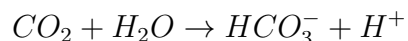


Figure 5.1: *How bad sea level rise becomes is up to us.*

Technology develops with lightning-like speed. Population and industrial production grow with astonishing rapidity. But our habits and attitudes, our political, economic and social institutions, our systems of laws, our educational systems - all these are very slow to change, slow to respond to the climate emergency that we face today. This contrast between rapidly changing circumstances and slowly changing institutions is discussed more thoroughly in Chapter 10.

## 5.2 Carbon dioxide content and acidity

Roughly 30-40% of the  $\text{CO}_2$  released into the atmosphere by human activities is absorbed by oceans and lakes. Much of the dissolved  $\text{CO}_2$  undergoes a reaction with water which converts it into carbonic acid:



Between 1751 and 1995 the amount of  $\text{H}^+$  ion in ocean surface water is estimated to have increased by 35%. Living organisms are very sensitive to



acidity, and today we can observe the alarming death of many forms of marine life, for example the death of coral in the Great Barrier Reef and other coral reef systems. Over a billion people depend on fish from coral reef habitats for protein in their diets.

## 5.3 Pollution with plastic waste

Our oceans are now massively polluted with carelessly discarded plastic waste. Plastic waste is found in huge quantities on the beaches of the remotest islands and in the blocked digestive systems of dead whales. A recent study <sup>1</sup> found that in 2010, 8 million tonnes of plastic went into our oceans,

The problem of plastic waste in our oceans is connected with the climate emergency, but in an indirect way. Today, most plastics are synthesized from starting chemicals extracted from fossil fuels. But the use of fossil fuels must stop if catastrophic climate change is to be avoided. However, there are new methods for synthesizing biodegradable plastics starting with chemicals extracted from plants.

According to the polymer chemist Professor Andrew Holmes,<sup>2</sup> the world may have to move to fully biodegradable plastics, made out of plants. But these have drawbacks. “The challenge is, is there enough arable land to produce the building blocks of plastic when we also need to produce food?”

In the meantime, he said, we must recycle anything we can.

“Ideally all plastics should be recyclable, but at present that is not the case.”

Professor Holmes said plastics that cannot be recycled - such as those used in plastic bags, or expanded polystyrene foam used in coffee cups and packaging around electronic goods - must be responsibly disposed into landfill or by burning.

“The plastic waste in the oceans is disastrous for marine and bird life, and the human race has to avoid disposal of this waste in a way that enables it to enter drains, rivers, and eventually the ocean,” he said.”

## 5.4 Overfishing

Like the massive pollution of our oceans with plastic waste, overfishing is only indirectly related to climate change. However, all three phenomena are part

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<sup>1</sup><http://www.abc.net.au/science/articles/2015/02/13/4178113.htm>

<sup>2</sup>University of Melbourne

<http://www.abc.net.au/news/science/2017-02-27/plastic-and-plastic-waste-explained/8301316>

of the ecological megacatastrophe that may result if humans continue to over-exploit and degrade the earth's ecological systems.

Wikipedia's article on overfishing states that "As much as 85% of the world's fisheries may be over-exploited, depleted, fully exploited or in recovery from exploitation....

"With present and forecast world population levels it is not possible to solve the over fishing issue; however, there are mitigation measures that can save selected fisheries and forestall the collapse of others...

"The United Nations Convention on the Law of the Sea treaty deals with aspects of over fishing in articles 61, 62, and 65:

- Article 61 requires all coastal states to ensure that the maintenance of living resources in their exclusive economic zones is not endangered by over-exploitation. The same article addresses the maintenance or restoration of populations of species above levels at which their reproduction may become seriously threatened.
- Article 62 provides that coastal states: "shall promote the objective of optimum utilization of the living resources in the exclusive economic zone without prejudice to Article 61"
- Article 65 provides generally for the rights of, inter alia, coastal states to prohibit, limit, or regulate the exploitation of marine mammals.

"Several scientists have called for an end to subsidies paid to deep sea fisheries. In international waters beyond the 200 nautical mile exclusive economic zones of coastal countries, many fisheries are unregulated, and fishing fleets plunder the depths with state-of-the-art technology. In a few hours, massive nets weighing up to 15 tons, dragged along the bottom by deep-water trawlers, can destroy deep-sea corals and sponge beds that have taken centuries or millennia to grow. The trawlers can target orange roughy, grenadiers, or sharks. These fish are usually long-lived and late maturing, and their populations take decades, even centuries to recover."

## 5.5 Rate of melting of Arctic ice

### Loss of Arctic sea ice

The melting of Arctic sea ice is taking place far more rapidly than was predicted by IPCC reports. David Wasdell, Director of the Apollo-Gaia Project, points out that the observed melting has been so rapid that within less than five years, the Arctic may be free of sea ice at the end of each summer. It will, of

course continue to re-freeze during the winters, but the thickness and extent of the winter ice will diminish.

For January 2016, the satellite based data showed the lowest overall Arctic sea ice extent of any January since records begun in 1979. Bob Henson from *Wundergrund* commented: “Hand in hand with the skimpy ice cover, temperatures across the Arctic have been extraordinarily warm for midwinter. Just before New Year’s, a slug of mild air pushed temperatures above freezing to within 200 miles of the North Pole. That warm pulse quickly dissipated, but it was followed by a series of intense North Atlantic cyclones that sent very mild air poleward, in tandem with a strongly negative Arctic Oscillation during the first three weeks of the month.”

During some periods, Arctic temperatures have been 50°C above normal for the time of year. Equally alarming is the fact that plumes of methane several km<sup>2</sup> in area have been observed bubbling up from the sea floor in the shallow ice-free seas north of Russia.<sup>3</sup>

## 5.6 Temperature and CO<sub>2</sub> in ice cores

Ice cores from the Greenland and Antarctic ice sheets and from glaciers have yielded valuable data on climate changes as far back as 800,000 years in the past. The ice cores show that there is a close correlation between global temperatures and the CO<sub>2</sub> content of the atmosphere. The cores also show that climatic changes can take place with great rapidity.

An article by Richard B. Alley in the Proceedings of the National Academy of Science (US) <sup>4</sup> Here is an excerpt from the article:

“Ice-core records show that climate changes in the past have been large, rapid, and synchronous over broad areas extending into low latitudes, with less variability over historical times. These ice-core records come from high mountain glaciers and the polar regions, including small ice caps and the large ice sheets of Greenland and Antarctica.

“As the world slid into and out of the last ice age, the general cooling and warming trends were punctuated by abrupt changes. Climate shifts up to half as large as the entire difference between ice age and modern conditions occurred over hemispheric or broader regions in mere years to decades. Such abrupt changes have been absent during the few key millennia when agriculture and industry have arisen. The speed, size, and extent of these abrupt changes required a reappraisal of climate stability. Records of these changes

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<sup>3</sup>N. Shakhova et al., *Methane release on the Arctic East Siberian shelf*, Geophysical Research Abstracts, Vol.9, 01071, 2007

<sup>4</sup>Proc Natl Acad Sci U S A. 2000 Feb 15; 97(4): 1331-1334. PMCID: PMC34297

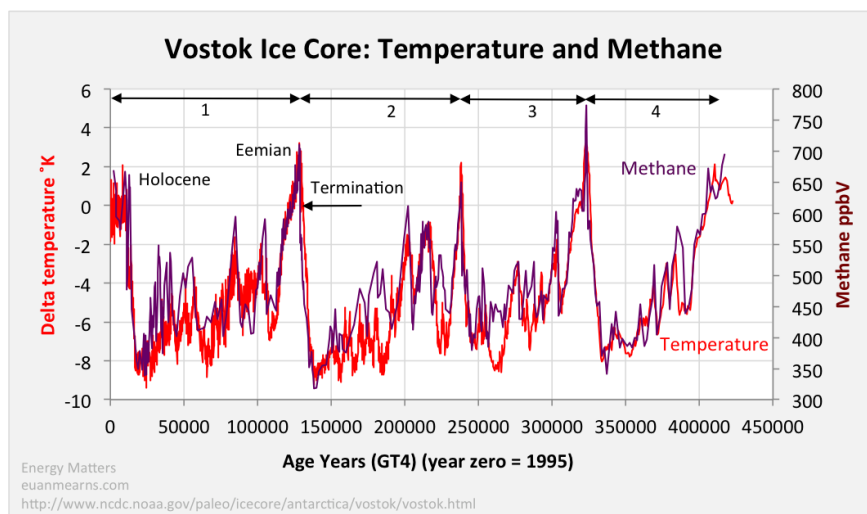


Figure 5.2: *In ice core data, we see a close correlation between temperature and atmospheric CO<sub>2</sub>. There is also a close correlation between temperature and atmospheric methane.*

are especially clear in high-resolution ice cores. Ice cores can preserve histories of local climate (snowfall, temperature), regional (wind-blown dust, sea salt, etc.), and broader (trace gases in the air) conditions, on a common time scale, demonstrating synchrony of climate changes over broad regions.”

## 5.7 Short-term sea level rise

### Flooding of coastal cities in the United States

The *National Geographic* recently published an article by Laura Parker entitled “Sea Level Rise Will Flood Hundreds of Cities in the Near Future+.”<sup>5</sup> Here are a few excerpts from the article:

“Sea level rise caused by global warming is usually cast as a doomsday scenario that will play out so far into the future, it’s easy to ignore. Just ask anyone in South Florida, where new construction proceeds apace. Yet already, more than 90 coastal communities in the United States are battling chronic flooding, meaning the kind of flooding that’s so unmanageable it prompts people to move away.

“That number is expected to roughly double to more than 170 communities in less than 20 years.

<sup>5</sup><http://news.nationalgeographic.com/2017/07/sea-level-rise-flood-global-warming-science/>

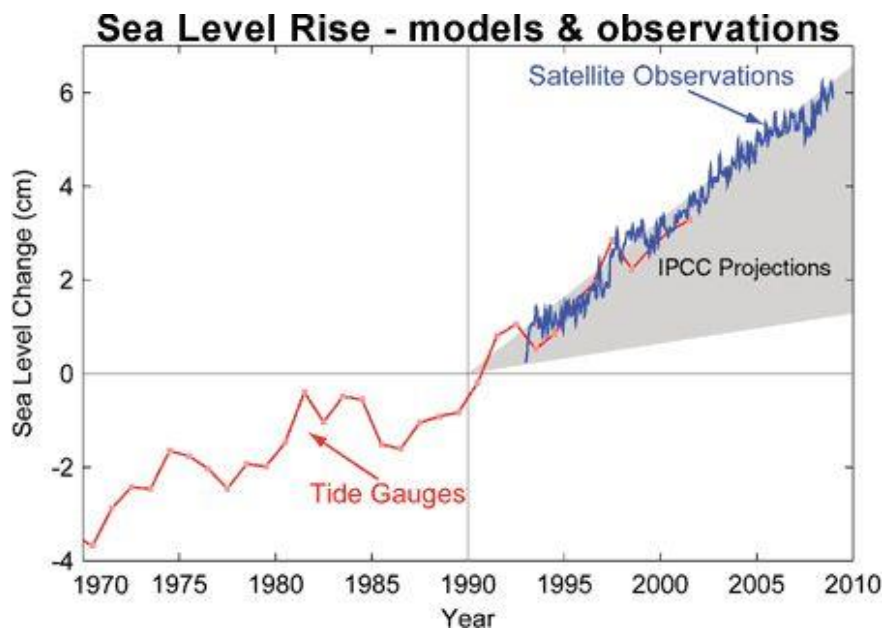


Figure 5.3: *Observed sea-level rise, 1970-2010.*

“Those new statistics, compiled in the first comprehensive mapping of the entire coastline of the Lower 48 states, paint a troubling picture, especially for the East and Gulf coasts, which are home to some of the nation’s most populated areas.

“By the end of the century, chronic flooding will be occurring from Maine to Texas and along parts of the West Coast. It will affect as many as 670 coastal communities, including Cambridge, Massachusetts; Oakland, California; Miami and St. Petersburg, Florida; and four of the five boroughs of New York City. The magnitude of the coming calamity is so great, the ripple effects will reach far into the interior.”

Just as an iceberg the size of Delaware broke away from an ice shelf in Antarctica Wednesday, July 12, 2017, scientists released findings that up to 668 U.S. communities could face chronic flooding from rising sea levels by the end of the century.

The Union of Concerned Scientists recently published a report entitled “When Rising Seas Hit Home: Hard Choices Ahead for Hundreds of US Coastal Communities”<sup>6</sup> The report states that “Chronic inundation will dramatically alter the landscape and the livability rise of just three feet would submerge the Maldives and make them uninhabitable of many coastal communities.” rise of

<sup>6</sup><http://www.ucsusa.org/sites/default/files/attach/2017/07/when-rising-seas-hit-home-full-report.pdf>

just three feet would submerge the Maldives and make them uninhabitable

### **Island nations threatened by rising oceans**

The US National Academy of Sciences predictions from 2009 suggest that by 2100, sea level could increase by anywhere from 16 inches to 56 inches, depending how the Earth responds to changing climate.

The Maldives, consisting of over 1,100 islands to the west of India, is the world's lowest-lying nation. On average the islands are only 1.3 meters above sea level. The 325,000 (plus 100,000 expatriate workers who are not counted in the census) residents of the islands are threatened by rising sea levels. A rise of just three feet would submerge the Maldives and make them uninhabitable. Many island nations in the Pacific are also severely threatened by sea level rise.

### **Displacement of populations in Southeast Asia**

A World Bank press release has stated that "Bangladesh will be among the most affected countries in South Asia by an expected 2°C rise in the world's average temperatures in the next decades, with rising sea levels and more extreme heat and more intense cyclones threatening food production, livelihoods, and infrastructure as well as slowing the reduction on poverty, according to a new scientific report released today by the World Bank Group.

" 'Bangladesh faces particularly severe challenges with climate change threatening its impressive progress in overcoming poverty,' said Johannes Zutt, World Bank Country Director for Bangladesh and Nepal. 'Bangladesh has demonstrated itself as a leader in moving the climate change agenda forward' -

"In Bangladesh, 40% of productive land is projected to be lost in the southern region of Bangladesh for a 65cm sea level rise by the 2080s. About 20 million people in the coastal areas of Bangladesh are already affected by salinity in drinking water. Rising sea levels and more intense cyclones and storm surges could intensify the contamination of groundwater and surface water causing more diarrhea outbreak."

Important rice-growing river delta regions of Viet Nam will also be lost during the present century.

### **Effects on the Netherlands, Danish islands, and Venice**

Although the Netherlands, the Danish islands and Venice have had many years of experience in coping with floods due to high sea levels and storm surges, these European areas may have difficulties during the present century.

Greenland's icecap is melting much faster than was predicted by the IPCC, and sea level rise may exceed 100 cm. before 2100. Hurricanes are also becoming more severe, as has already been shown by Katrina and Sandy. Future hurricanes hitting Europe's Atlantic coasts will produce dangerous storm surges. In Venice, the danger from hurricanes is less severe, but Venice already experiences severe flooding and the rise of sea levels during the present century may endanger the priceless cultural monuments of the famous ancient city.

## 5.8 Long-term sea level rise

A 2012 article by Jevrejeva, S., Moore, J. C. and Grinsted, A. in the *Journal of Global and Planetary Change*<sup>7</sup> deals with sea level rise until 2500. Of course, the long-term future runs over hundreds of millennia, but nevertheless, the article, entitled "Sea level projections to AD2500 with a new generation of climate change scenarios" is of interest.

The article states that "Sea level rise over the coming centuries is perhaps the most damaging side of rising temperature. The economic costs and social consequences of coastal flooding and forced migration will probably be one of the dominant impacts of global warming. To date, however, few studies on infrastructure and socio-economic planning include provision for multi-century and multi-meter rises in mean sea level...

"We estimate sea level rise of 0.57 - 1.10 m by 2100 with four new RCP scenarios. Sea level will continue to rise for several centuries reaching 1.84 - 5.49 m by 2500. Due to long response time most rise is expected after stabilization of forcing. 200-400 years will require dropping the rate to the 1.8 mm/yr- 20th century average."

According to an article published by the Potsdam Institute for Climate Impact Research<sup>8</sup> "The Greenland ice sheet is likely to be more vulnerable to global warming than previously thought. The temperature threshold for melting the ice sheet completely is in the range of 0.8 to 3.2 degrees Celsius global warming, with a best estimate of 1.6 degrees above pre-industrial levels, shows a new study by scientists from the Potsdam Institute for Climate Impact Research (PIK) and the Universidad Complutense de Madrid. Today, already 0.8 degrees global warming has been observed. Substantial melting of land ice could contribute to long-term sea-level rise of several meters and therefore it potentially affects the lives of many millions of people.

"The time it takes before most of the ice in Greenland is lost strongly

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<sup>7</sup>Volumes 80-81, January 2012, Pages 14-20

<sup>8</sup><https://www.pik-potsdam.de/news/press-releases/archive/2012/gronlands-eismassen-konnten-komplett-schmelzen-bei-1-6-grad-globaler-erwarmung>

depends on the level of warming. 'The more we exceed the threshold, the faster it melts,' says Alexander Robinson, lead-author of the study now published in *Nature Climate Change*. In a business-as-usual scenario of greenhouse-gas emissions, in the long run humanity might be aiming at 8 degrees Celsius of global warming. This would result in one fifth of the ice sheet melting within 500 years and a complete loss in 2000 years, according to the study. 'This is not what one would call a rapid collapse,' says Robinson. 'However, compared to what has happened in our planet's history, it is fast. And we might already be approaching the critical threshold.'

"In contrast, if global warming would be limited to 2 degrees Celsius, complete melting would happen on a timescale of 50.000 years. Still, even within this temperature range often considered a global guardrail, the Greenland ice sheet is not secure. Previous research suggested a threshold in global temperature increase for melting the Greenland ice sheet of a best estimate of 3.1 degrees, with a range of 1.9 to 5.1 degrees. The new study's best estimate indicates about half as much.

"Our study shows that under certain conditions the melting of the Greenland ice sheet becomes irreversible. This supports the notion that the ice sheet is a tipping element in the Earth system,' says team-leader Andrey Ganopolski of PIK. 'If the global temperature significantly overshoots the threshold for a long time, the ice will continue melting and not re-grow - even if the climate would, after many thousand years, return to its preindustrial state- This is related to feedbacks between the climate and the ice sheet: The ice sheet is over 3000 meters thick and thus elevated into cooler altitudes. When it melts its surface comes down to lower altitudes with higher temperatures, which accelerates the melting. Also, the ice reflects a large part of solar radiation back into space. 'Our study shows that under certain conditions the melting of the Greenland ice sheet becomes irreversible. This supports the notion that the ice sheet is a tipping element in the Earth system,' says team-leader Andrey Ganopolski of PIK. 'If the global temperature significantly overshoots the threshold for a long time, the ice will continue melting and not re-grow - even if the climate would, after many thousand years, return to its preindustrial state.' This is related to feedbacks between the climate and the ice sheet: The ice sheet is over 3000 meters thick and thus elevated into cooler altitudes. When it melts its surface comes down to lower altitudes with higher temperatures, which accelerates the melting. Also, the ice reflects a large part of solar radiation back into space. When the area covered by ice decreases, more radiation is absorbed and this adds to regional warming.space. When the area covered by ice decreases, more radiation is absorbed and this adds to regional warming."



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## Chapter 6

# DESTRUCTION OF FORESTS

### 6.1 Illegal burning for palm oil plantations

According to a recent article published by the Union of Concerned Scientists, “One huge source of global warming emissions associated with palm oil is the draining and burning of the carbon-rich swamps known as peatlands. Peatlands can hold up to 18 to 28 times as much carbon as the forests above them; when they are drained and burned, both carbon and methane are released into the atmosphere - and unless the water table is restored, peatlands continue to decay and release global warming emissions for decades.

“As if that wasn’t bad enough, the burning of peatlands releases a dangerous haze into the air, resulting in severe health impacts and significant economic losses. Each year, more than 100,000 deaths in Southeast Asia can be attributed to particulate matter exposure from landscape fires, many of which are peat fires.

“Beyond its global warming and human health impacts, palm oil production also takes a toll on biodiversity and human rights. Only about 15 percent of native animal species can survive the transition from primary forest to plantation. Among the species vulnerable to palm oil expansion are orangutans, tigers, rhinoceros, and elephants. Furthermore, palm oil growers have also been accused of using forced labor, seizing land from local populations, and other human rights abuses.”

Licences to burn forests for palm oil plantations are often granted by corrupt government officials. Fortunately, through the efforts of NGO’s the public has become increasingly aware of the problem, and supermarkets are being urged to purchase products containing deforestation-free palm oil.

Another recent article<sup>1</sup> states that “Indonesia is being deforested faster

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<sup>1</sup><https://news.vice.com/article/indonesia-is-killing-the-planet-for-palm-oil>

Palm Oil's Rapid Growth

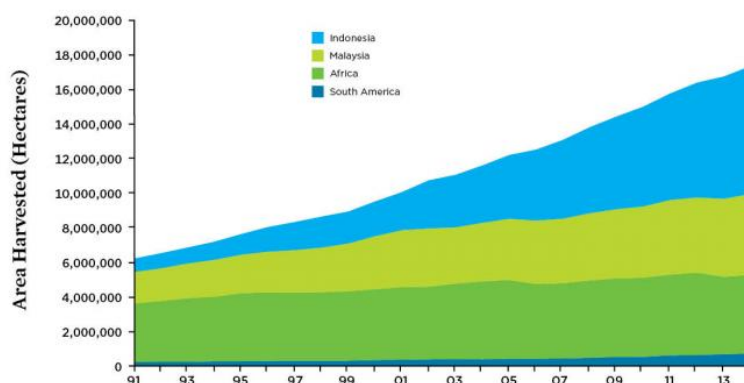


Figure 6.1: *The growth of palm oil cultivation between 1993 and 2013. The dark area at the top of the graph indicates the dramatic growth of palm oil production in Southeast Asia, especially Indonesia.*

than any other country in the world, and it has everything to do with one product: palm oil.

“According to a new study in the journal *Nature Climate Change*, deforestation in the Southeast Asian archipelago is nearly double the rate in the Amazon. Indonesia is said to have lost 840,000 hectares (3,250 square miles) of forest in 2012 while Brazil - which has four times Indonesia’s rainforest - lost a still-massive 460,000 hectares.

“The report’s authors found that government figures underestimated the true toll of forest clearing by as much as half. In the last 12 years, it’s possible that the destruction of one million hectares of ‘primary forest’ went unreported.

“The tree-killing spree is largely due to slashing and burning vegetation for the expansion of palm oil plantations to feed growing demand in countries like China and India. Americans and Europeans are still far and away the top consumers per capita - it’s estimated that palm oil can be found in roughly half the manufactured goods in any supermarket or drug store. Everything from peanut butter to soap to cosmetics contains the oil in its various forms.

“In Indonesia, where much of the land consists of carbon-rich soil known as peat, the problem is acute. Water-logged peat is commonly found in the jungles of Sumatra and Borneo, and merely exposing it to the air releases carbon dioxide into the atmosphere.”

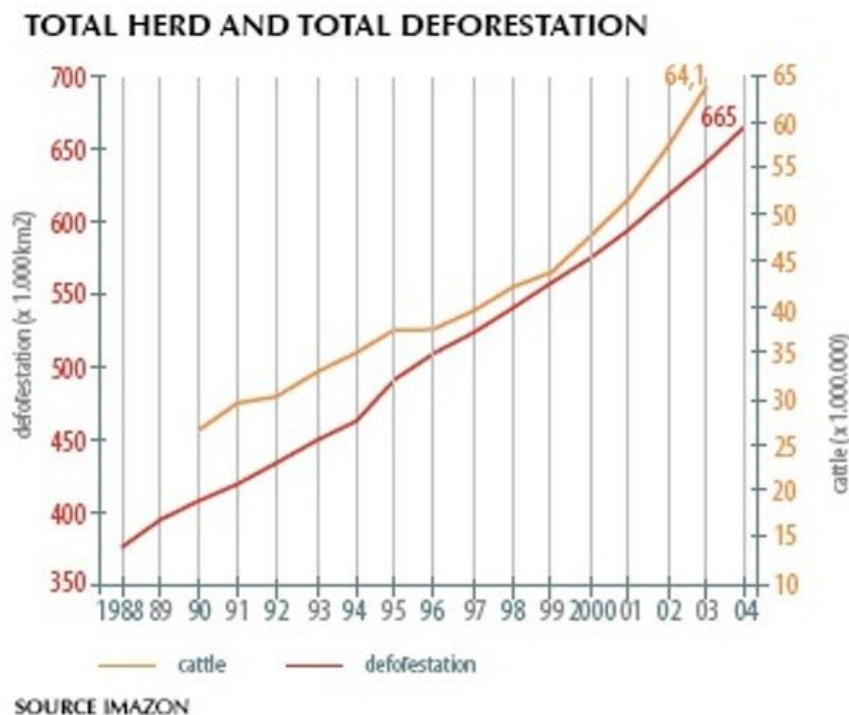


Figure 6.2: *Total cattle herds and total deforestation in Amazonia between 1988 and 2004. Deforestation is measured in thousands of square kilometers, while herd size is measured in millions.*

## 6.2 The beef industry in South America

### Beef is killing the rainforest

*Beef Production is Killing the Amazon Rainforest.* That is the title of an article published by [onegreenplanet.org](http://www.onegreenplanet.org)<sup>2</sup>. Here are some excerpts from the article

“The Amazon rainforest has been facing severe deforestation problems for several decades - it has lost about a fifth of its forest in the past three. While there are many causes, one of the main causes is cattle ranching, particularly in Brazil. Trees are cut and the land is converted into a pasture for cattle grazing. According to one report, an estimated 70 percent of deforestation in the Amazon basin can be attributed to cattle ranching. Using these numbers, cattle ranching in the Amazon has resulted in the loss of an area larger than the state of Washington.

“The government of Brazil offers loans of billions of dollars to support the

<sup>2</sup><http://www.onegreenplanet.org/animalsandnature/beef-production-is-killing-the-amazon-rainforest/>

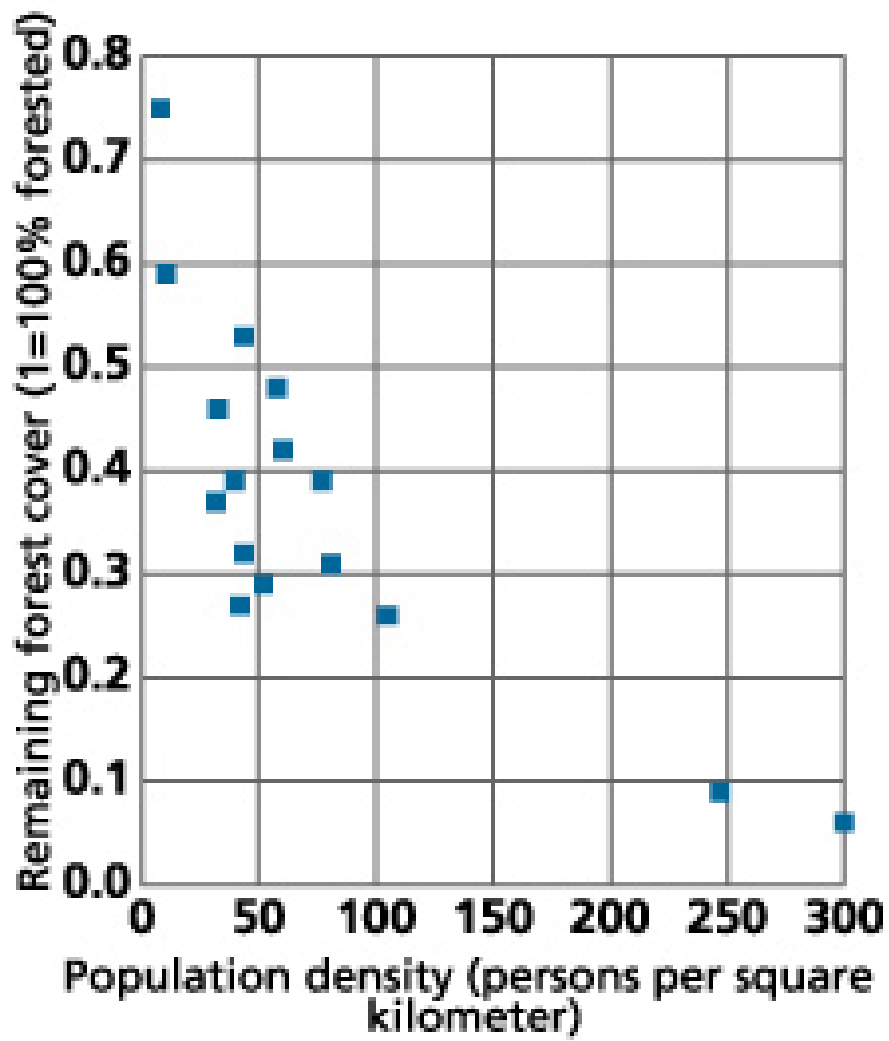


Figure 6.3: *Population density and forest size.*

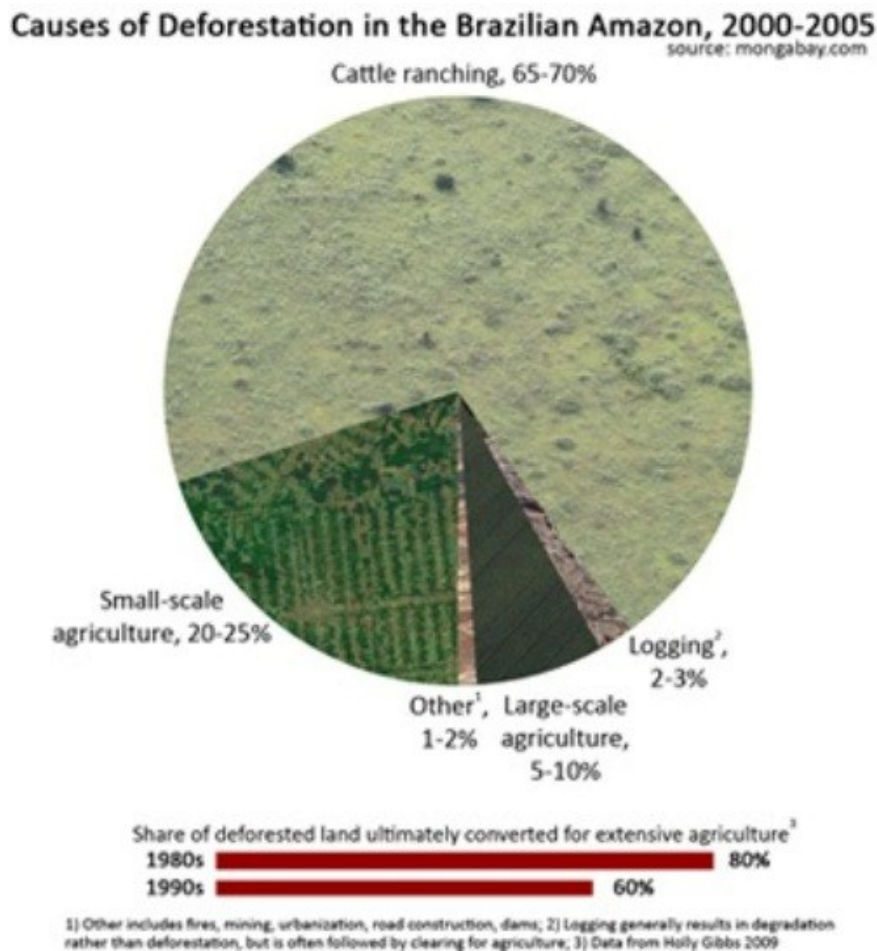


Figure 6.4: *This figure shows the causes of Amazonian deforestation. The largest is beef production.*

expansion of its beef industry. Approximately 200 million pounds of beef is imported by the United States from Central America every year. While the chief importers of Brazilian beef were previously Europe and North America, nowadays Asian countries such as China and Russia consume more Brazilian beef than the European market. So, the demand is increasing day by day.

“With increasing population and increased per capita meat consumption, the rate of deforestation is increasing every day as well. It is expected that by 2018, the beef export will increase 93 percent, thereby increasing Brazil’s beef market share of world exports to 61 percent. Beef is the most carbon-intensive form of meat production on the planet. The United Nations Food and Agriculture Organization finds that beef production gives rise to more greenhouse gases than the transportation industry.”

## Beef production and methane

A cow (or a bull) releases between 70 and 120 kg of methane per year. Methane is a greenhouse gas like carbon dioxide, but the negative effect on the climate of methane ( $\text{CH}_4$ ) is 23 times higher than the effect of  $\text{CO}_2$ . Therefore the release of about 100 kg methane per year for each cow is equivalent to about 2,300 kg  $\text{CO}_2$  per year.

World-wide, there are about 1.5 billion cows and bulls. All ruminants (animals which regurgitates food and re-chews it) on the world emit about two billion metric tons of  $\text{CO}_2$ , equivalents per year. In addition, clearing of tropical forests and rain forests to get more grazing land and farm land is responsible for an extra 2.8 billion metric tons of  $\text{CO}_2$  emission per year!

According to the Food and Agriculture Organization of the United Nations (FAO) agriculture is responsible for 18% of the total release of greenhouse gases world-wide (this is more than the whole transportation sector). Cattle-breeding is taking a major factor for these greenhouse gas emissions according to FAO. Says Henning Steinfeld, Chief of FAO's Livestock Information and Policy Branch and senior author of the report: "Livestock are one of the most significant contributors to today's most serious environmental problems. Urgent action is required to remedy the situation."

Livestock now use 30 percent of the earth's entire land surface, mostly permanent pasture but also including 33 percent of the global arable land used to producing feed for livestock, the report notes. As forests are cleared to create new pastures, it is a major driver of deforestation, especially in Latin America where, for example, some 70 percent of former forests in the Amazon have been turned over to grazing.

## Dietary changes can help

You and I can help to save our common future by changing our diets, especially by cutting out beef. Not only does beef production produce methane and destroy rainforests, it also requires much more land per calorie than other forms of agriculture. By switching from beef to other protein-rich foods, we not only substantially reduce greenhouse gas emissions, but we also shorten the food chain, so that more grain will be available to feed the world's growing population. Furthermore a changed diet with less meat would improve our health, since animal fats have been linked with heart disease, circulatory problems and strokes.



## 6.3 Growing populations and forest loss

Deforestation is occurring at alarming rates, especially in countries that have high levels of population growth.<sup>3</sup> The following table shows the forest loss in some countries where it is particularly high, together with their present and projected populations<sup>4</sup>. In the table, the annual rate of forest loss in the period 2000-2010, measured both in thousands of hectares and in percent. Populations in millions in 2010 are shown, together with projected populations in 2050.

country	forest loss	percent	pop. 2010	pop. 2050
Brazil	-2642	-0.49	194.9	222.8
Australia	-562	-0.37	22.3	31.4
Indonesia	-498	-0.51	239.9	293.5
Nigeria	-410	-3.67	158.4	389.6
Tanzania	-403	-1.13	44.8	138.3
Zimbabwe	-327	-1.88	12.6	20.6
Dem. Rep. Congo	.311	-0.20	66.0	148.5
Myanmar	-310	-0.93	47.9	55.3
Bolivia	-290	-0.49	9.9	16.8
Venezuela	-288	-0.60	28.0	41.8

The main mechanism through which rapid population growth is linked to forest loss is felling forests for the sake of agriculture.

Notice that Nigeria is losing 3.67% of its forests each year. The population of Nigeria is projected to more than double by 2050, but rising death rates from heat, famine and conflicts may prevent this. In general, rising death rates from these causes may ultimately lead populations in the tropics to decrease rather than increase.

Population Action International points out that “Deforestation threatens the well-being and livelihoods of millions of people who heavily depend on forest resources. It is particularly devastating for women and children in poor rural communities.” The organization recommends that information and materials for family planning be made available to all through universal provision

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<sup>3</sup><http://www.prb.org/Publications/Articles/2004/PopulationGrowthandDeforestationACriticalandComplexRelationship.aspx>

<sup>4</sup>Population Action International, *Why Population Matters to Forests*

of primary health care.

## 6.4 Desertification and soil erosion

The Princeton University Dictionary defines *desertification* as “the process of fertile land transforming into desert typically as a result of deforestation, drought or improper/inappropriate agriculture”. It is estimated that approximately a billion people are under threat from further expansions of deserts.

### Southward expansion of the Gobi desert

The Gobi desert is the fastest moving desert on earth. The rapid southward expansion of the Gobi is mainly due to human activities, such as overgrazing, deforestation and overuse of water. Dust storms from the Gobi desert are becoming more and more frequent. Sand dunes are reportedly forming only 70 km north of Beijing.

### The Sahel

Another region in which the threat of desertification is extremely acute is the Sahel, which is the boundary between Africa’s Sahara desert to the north and a region of savanna to the south. The Sahel stretches between the Atlantic Ocean and the Red Sea. During the last 50 years, the Sahel has lost approximately 650,000 km<sup>2</sup> of fertile land to the desert, and the boundary of the Sahara has moved 250 km southward.

The southward expansion of the Sahara has been caused partly by climate change, and partly by human activities. Growing human populations have put pressure on the fragile arid environment by overgrazing, tree-cutting for firewood and inappropriate agriculture.

## 6.5 Forest drying and wildfires: a feedback loop

When climate change produces aridity in a forested region, wildfires produced by lightning, stray sparks from falling stones, or human carelessness become increasingly likely. Forest fires contribute to global warming by releasing CO<sub>2</sub> into the atmosphere and by destroying climate-friendly tree-covered areas. Thus a dangerous feedback loop can be formed, and as was discussed in Chapter 4, with every feedback loop there is an associated tipping point. In the

case of forest drying and wildfires, passing the tipping point means that forest cover will be lost irrevocably. We must avoid passing wildfire tipping points through human activities, such as the deliberate burning of rainforests for the sake of oil palm plantations.

## 6.6 Degraded forests are carbon emitters

According to an article published in the journal *Science* on 28 September, 2017<sup>5</sup>, degraded tropical forest throughout the world have stopped being carbon absorbers, and are now carbon emitters.

Reporting on the study, *The Guardian*,<sup>6</sup> noted that “Researchers found that forest areas in South America, Africa and Asia - which have until recently played a key role in absorbing greenhouse gases - are now releasing 425 teragrams of carbon annually, which is more than all the traffic in the United States.

“The study went further than any of its predecessors in measuring the impact of disturbance and degradation - the thinning of tree density and the culling of biodiversity below an apparently protected canopy - usually as a result of selective logging, fire, drought and hunting.

“Overall, more carbon was lost to degradation and disturbance than deforestation. The researchers stressed this was an opportunity as well as a concern because it was now possible to identify which areas are being affected and to restore forests before they disappeared completely.”

## 6.7 Replanting forests

Around the world, people interested in replanting forests can take inspiration from the Green Belt Movement, which was founded in 1977 by Wangari Maathai.

The Green Belt Movement organizes women in rural Africa to combat deforestation by planting trees. In this way they restore their main source of fuel for cooking, generate income and stop soil erosion. Since its foundation in 1977, the movement has planted 51 million trees. Over 30,000 women have been trained in forestry, food processing, bee-keeping, and other trades. The movement emphasizes economic justice and empowerment of women. This

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<sup>5</sup>A. Baccini et al., *Tropical forests are a net carbon source based on aboveground measurements of gain and loss*, DOI: 10.1126/science.aam5962

<sup>6</sup><https://www.theguardian.com/environment/2017/sep/28/alarm-as-study-reveals-worlds-tropical-forests-are-huge-carbon-emission-source>



Figure 6.5: *Nobel Laureate Wangari Maathai (1940-2011).*

work is particularly valuable in regions of water scarcity, because besides preventing soil erosion, forests prevent the rapid run-off of water.

In order to combat climate change and to prevent southward expansion of the Sahara, the African Union has initiated a project called the Great Green Wall. The project aims at creating a mosaic of green and productive landscapes stretching across Africa, the Sahel region to the Horn of Africa, a strip of forested land 15 km wide and 7,500 km long, stretching from Dakar to Djibouti.

In China, the Green Great Wall project aims at preventing the expansion of the Gobi desert by planting a 4,500-kilometer-long windbreaking line of forests. The project is expected to be completed by 2050.

Reforestation initiatives also exist in other countries, for example in India, Lebanon, Philippines, Japan, Germany, Canada and the United States.

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## Chapter 7

# CLIMATE CHANGE AND AGRICULTURE

### 7.1 Lester Brown's lecture in Copenhagen

After a lecture at the University of Copenhagen in the 1980's, Lester R. Brown of the Earth Policy Institute was asked which resource would be the first to become critically scarce. Everyone in the audience expected him to say "oil", but instead he said "fresh water". He went on to explain that falling water tables in China would soon make China unable to feed its population. This would not cause famine in China itself because of the strength of the Chinese economy, which would allow the Chinese to purchase grain on the world market. However, shortages of fresh water in China would indeed cause famine, for example in Africa, because Chinese demand for grain would raise prices on the world market beyond the ability of poor countries to pay.



Figure 7.1: *Lester R. Brown*

## 7.2 Predictions of drought in the Stern Review

According to a report presented to the Oxford Institute of Economic Policy by Sir Nicholas Stern on 31 January, 2006, areas likely to lose up to 30% of their rainfall by the 2050's because of climate change include much of the United States, Brazil, the Mediterranean region, Eastern Russia and Belarus, the Middle East, Southern Africa and Southern Australia. Meanwhile rainfall is predicted to increase up to 30% in Central Africa, Pakistan, India, Bangladesh, Siberia, and much of China.

Stern and his team point out that “We can... expect to see changes in the Indian monsoon, which could have a huge impact on the lives of hundreds of millions of people in India, Pakistan and Bangladesh. Most climate models suggest that the monsoon will change, although there is still uncertainty about exactly how. Nevertheless, small changes in the monsoon could have a huge impact. Today, a fluctuation of just 10% in either direction from average monsoon rainfall is known to cause either severe flooding or drought. A weak summer monsoon, for example, can lead to poor harvests and food shortages among the rural population - two-thirds of India's almost 1.1 billion people. Heavier-than-usual monsoon downpours can also have devastating consequences...”

In some regions, melting of glaciers can be serious from the standpoint of dry-season water supplies. For example, melts from glaciers in the Hindu Kush and the Himalayas now supply much of Asia, including China and India, with a dry-season water supply. Complete melting of these glacial systems would cause an exaggerated runoff for a few decades, after which there would be a drying out of some of the most densely populated regions of the world.

## 7.3 Ocean current changes and failure of monsoons

It is expected that climate change will affect ocean currents, and hence also affect monsoon rainfall. We are already experiencing a diversion of the Gulf Stream due to southward currents of cold water from melting ice in the Arctic. This has caused what is known as the *North Atlantic Anomaly*. While most regions of the world are experiencing rising temperatures, the North Atlantic and several northern European countries are exceptions to this rule, and have cooled. Complete failure of the Gulf Stream would lead to much colder temperatures in Europe.



Changes in ocean currents have already lead to the failure of the West African Monsoon, and this has already produced severe food insecurity in West Africa.

In the future, climate-changed ocean currents may lead to failures of monsoons in South-east Asia, and thus damage the food supply of almost two billion people.

## 7.4 Falling water tables around the world

Under many desert areas of the world are deeply buried water tables formed during glacial periods when the climate of these regions was wetter. These regions include the Middle East and large parts of Africa. Water can be withdrawn from such ancient reservoirs by deep wells and pumping, but only for a limited amount of time.

In oil-rich Saudi Arabia, petroenergy is used to drill wells for ancient water and to bring it to the surface. Much of this water is used to irrigate wheat fields, and this is done to such an extent that Saudi Arabia exports wheat. The country is, in effect, exporting its ancient heritage of water, a policy that it may, in time, regret. A similarly short-sighted project is Muammar Qaddafi's enormous pipeline, which will bring water from ancient sub-desert reservoirs to coastal cities.

In the United States, the great Ogallala aquifer is being overdrawn. This aquifer is an enormous stratum of water-saturated sand and gravel under-lying parts of northern Texas, Oklahoma, New Mexico, Kansas, Colorado, Nebraska, Wyoming and South Dakota. The average thickness of the aquifer is about 70 meters. The rate of water withdrawal from the aquifer exceeds the rate of recharge by a factor of eight.

Thus we can see that in many regions, the earth's present population is living on its inheritance of water, rather than its income. This fact, coupled with rapidly increasing populations and climate change, may contribute to a very serious food crisis partway through the 21st century.

## 7.5 Glacial melting and summer water supplies

The summer water supplies of both China and India are threatened by the melting of glaciers. The Gangotri glacier, which is the principle glacier feeding India's great Ganges River, is reported to be melting at an accelerating rate,

and it could disappear within a few decades. If this happens, the Ganges could become seasonal, flowing only during the monsoon season. Chinese agriculture is also threatened by disappearing Himalayan glaciers, in this case those on the Tibet-Qinghai Plateau. The respected Chinese glaciologist Yao Tandong estimates that the glaciers feeding the Yangtze and Yellow Rivers are disappearing at the rate of 7% per year.<sup>1</sup>

## 7.6 Advances in desalinization technology

Scientists at the Massachusetts Institute of Technology have developed a new desalinization process, called shock electrodialysis. In this process, water flows through a porous material - in this case, made of tiny glass particles, called a frit - with membranes or electrodes sandwiching the porous material on each side. When an electric current flows through the system, the salty water divides into regions where the salt concentration is either depleted or enriched. When that current is increased to a certain point, it generates a shockwave between these two zones, sharply dividing the streams and allowing the fresh and salty regions to be separated by a simple physical barrier at the center of the flow.

“It generates a very strong gradient,” says Martin Bazant, a researcher involved with the project<sup>2</sup>.

Even though the system can use membranes on each side of the porous material, Bazant explains, the water flows across those membranes, not through them. That means they are not as vulnerable to fouling - a buildup of filtered material - or to degradation due to water pressure, as happens with conventional membrane-based desalination, including conventional electrodialysis. “The salt doesn’t have to push through something,” Bazant says. “The charged salt particles, or ions, just move to one side”.

## 7.7 The Green Revolution

In 1944 the Norwegian-American plant geneticist Norman Borlaug was sent to Mexico by the Rockefeller Foundation to try to produce new wheat varieties that might increase Mexico’s agricultural output. Borlaug’s dedicated work on this project was spectacularly successful. He remained with the project for 16 years, and his group made 6,000 individual crossings of wheat varieties to produce high-yield disease-resistant strains.

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<sup>1</sup><http://www.commondreams.org/news/2015/08/04/global-glaciers-melting-three-times-rate-20th-century>

<sup>2</sup> He was quoted in an article published in *MIT News*, November 12, 2015



Figure 7.2: *Norman Borlaug's work on developing high-yield disease-resistant plant varieties won him a Nobel Peace Prize in 1970.*

In 1963, Borlaug visited India, bringing with him 100 kg. of seeds from each of his most promising wheat strains. After testing these strains in Asia, he imported 450 tons of the Lerma Rojo and Sonora 64 varieties - 250 tons for Pakistan and 200 for India. By 1968, the success of these varieties was so great that school buildings had to be commandeered to store the output. Borlaug's work began to be called a "Green Revolution". In India, the research on high-yield crops was continued and expanded by Prof. M.S. Swaminathan and his coworkers. The work of Green Revolution scientists, such Norman Borlaug and M.S. Swaminathan, has been credited with saving the lives of as many as a billion people.

Despite these successes, Borlaug believes that the problem of population growth is still a serious one. "Africa and the former Soviet republics", Borlaug states, "and the Cerrado<sup>3</sup>, are the last frontiers. After they are in use, the world will have no additional sizable blocks of arable land left to put into production, unless you are willing to level whole forests, which you should not do. So, future food-production increases will have to come from higher yields. And though I have no doubt that yields will keep going up, whether they can go up enough to feed the population monster is another matter. Unless progress with agricultural yields remains very strong, the next century will

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<sup>3</sup> The Cerrado is a large savanna region of Brazil.

experience human misery that, on a sheer numerical scale, will exceed the worst of everything that has come before.”

A very serious problem with Green Revolution plant varieties is that they require heavy inputs of pesticides, fertilizers and irrigation. Because of this, the use of high-yield varieties contributes to social inequality, since only rich farmers can afford the necessary inputs. Monocultures, such as the Green Revolution varieties may also prove to be vulnerable to future epidemics of plant diseases, such as the epidemic that caused the Irish Potato Famine in 1845. Even more importantly, pesticides, fertilizers and irrigation all depend on the use of fossil fuels. One must therefore ask whether high agricultural yields can be maintained in the future, when fossil fuels are expected to become prohibitively scarce and expensive.

## 7.8 Energy inputs of agriculture

Modern agriculture has become highly dependent on fossil fuels, especially on petroleum and natural gas. This is especially true of production of the high-yield grain varieties introduced in the Green Revolution, since these require especially large inputs of fertilizers, pesticides and irrigation. Today, fertilizers are produced using oil and natural gas, while pesticides are synthesized from petroleum feedstocks, and irrigation is driven by fossil fuel energy. Thus agriculture in the developed countries has become a process where inputs of fossil fuel energy are converted into food calories. If one focuses only on the farming operations, the fossil fuel energy inputs are distributed as follows:

1. Manufacture of inorganic fertilizer, 31%
2. Operation of field machinery, 19%
3. Transportation, 16%
4. Irrigation, 13%
5. Raising livestock (not including livestock feed), 8%
6. Crop drying, 5%
7. Pesticide production, 5%
8. Miscellaneous, 8%

The ratio of the fossil fuel energy inputs to the food calorie outputs depends on how many energy-using elements of food production are included in

the accounting. David Pimentel and Mario Giampietro of Cornell University estimated in 1994 that U.S. agriculture required 0.7 kcal of fossil fuel energy inputs to produce 1.0 kcal of food energy. However, this figure was based on U.N. statistics that did not include fertilizer feedstocks, pesticide feedstocks, energy and machinery for drying crops, or electricity, construction and maintenance of farm buildings. A more accurate calculation, including these inputs, gives an input/output ratio of approximately 1.0. Finally, if the energy expended on transportation, packaging and retailing of food is included, Pimentel and Giampietro found that the input/output ratio for the U.S. food system was approximately 10, and this figure did not include energy used for cooking.

## 7.9 Sustainable future populations

In an important and detailed study entitled *Will Limited Land, Water, and Energy Control Human Population Numbers in the Future?*, David Pimentel et al.<sup>4</sup> discuss the problem of agriculture and global population in the post fossil fuel era. Here are some quotations from the article:

“Nearly 60% of the world’s human population is malnourished and the numbers are growing. Shortages of basic foods related to decreases in per capita cropland, water, and fossil energy resources contribute to spreading malnutrition and other diseases. The suggestion is that in the future only a smaller number of people will have access to adequate nourishment. In about 100 years, when it is reported that the planet will run out of fossil energy, we suggest that a world population of about two billion might be sustainable if it relies on renewable energy technologies and also reduces per capita use of the earth’s natural resources.

“Developed and developing nations need to provide a good quality life for their people while coping with rapid population growth, but ‘Population is the issue no one wants to touch’ (Meadows 2000). The current world population is about 6.8 billion. Based on the present growth rate of 1.2% per year, the population is projected to double in approximately 58 years (Chiras 2006; PRB 2008). Because population growth cannot continue indefinitely, society can either voluntarily control its numbers or let natural forces such as disease, malnutrition, and other disasters limit human numbers (Bartlett 1997-98; Pimentel et al. 1999). Increasing human numbers especially in urban areas, and increasing pollution of food, water, air, and soil by pathogenic disease organisms and chemicals, are causing a rapid increase in the prevalence of disease and human mortality (Murray and Lopez 1996; Pimentel et al. 2007). Currently, more than 3.7 billion humans are malnourished worldwide - the largest

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<sup>4</sup>D. Pimentel et al., *Human Ecology* DOI 10.1007/s10745-010-9346-y, (2010)

number ever (WHO 2005a, b).

“The planet’s numerous environmental problems highlight the urgent need to evaluate available land, water, and energy resources and how they relate to the requirements of a rapidly growing human population (Pimentel and Pimentel 2008). In this article we assess the carrying capacity of the Earth’s natural resources, and suggest that humans should voluntarily limit their population growth, rather than letting natural forces control their numbers (Ferguson 1998; Pimentel et al. 1999). In addition, we suggest appropriate policies and technologies that would improve standards of living and quality of life worldwide...

“In 1960, when the world population numbered about 3 billion, approximately 0.5 ha of cropland was available per capita worldwide. This half a hectare is needed to provide a diverse, healthy, nutritious diet of plant and animal products...”

Pimentel et al. state that worldwide, the average cropland per capita has now fallen to 0.22 hectares. This number will continue to fall because global population is increasing at the rate of almost one billion people per decade, while the global area available for cropland is not increasing. On the contrary, it is decreasing because of desertification, erosion, salination and urban sprawl. Pimentel et al. state that cropland is being degraded and lost at a rate of more than 20 million hectares per year-

The current cropland per capita in the United States is 0.56 hectares, and thus still quite large, but in China, the figure is dangerously low: only 0.1 hectares. China will soon be unable to feed its population and will have to buy grain on the world market. As Lester Brown pointed out in his Copenhagen lecture, China will be able to import grain because of its strong economy, but this will raise food prices and will cause widespread famine in other parts of the world.

Added to the agricultural and environmental problems, are problems of finance and distribution. Famines can occur even when grain is available somewhere in the world, because those who are threatened with starvation may not be able to pay for the grain, or for its transportation. The economic laws of supply and demand are not able to solve this type of problem. One says that there is no “demand” for the food (meaning demand in the economic sense), even though people are in fact starving.

What is the optimum population of the world? It is certainly not the maximum number that can be squeezed onto the globe by eradicating every species of plant and animal that cannot be eaten. The optimum global population is one that can be supported in comfort, equality and dignity - and with respect for the environment.

In 1848 (when there were just over one billion people in the world), John

Stuart Mill described the optimal global population in the following words:

“The density of population necessary to enable mankind to obtain, in the greatest degree, all the advantages of cooperation and social intercourse, has, in the most populous countries, been attained. A population may be too crowded, although all be amply supplied with food and raiment.”

“... Nor is there much satisfaction in contemplating the world with nothing left to the spontaneous activity of nature; with every rood of land brought into cultivation, which is capable of growing food for human beings; every flowery waste or natural pasture plowed up, all quadrupeds or birds which are not domesticated for man’s use exterminated as his rivals for food, every hedgerow or superfluous tree rooted out, and scarcely a place left where a wild shrub or flower could grow without being eradicated as a weed in the name of improved agriculture. If the earth must lose that great portion of its pleasantness which it owes to things that the unlimited increase of wealth and population would extirpate from it, for the mere purpose of enabling it to support a larger, but not better or happier population, I sincerely hope, for the sake of posterity, that they will be content to be stationary, long before necessity compels them to it.”<sup>5</sup>

Dennis Meadows, one of the authors of *Limits to Growth*, stated recently that the optimum human population in the distant future may be about 2 billion people.

But what about the near future? Will the global population of humans crash catastrophically after having exceeded the carrying capacity of the environment? There is certainly a danger that this will happen - a danger that the 21st century will bring very large scale famines to vulnerable parts of the world, because modern energy-intensive agriculture will be dealt a severe blow by prohibitively high petroleum prices. At present, there are only a few major food-exporting countries, notably the United States, Canada, Australia and Argentina. There is a danger that within a few decades, the United States will no longer be able to export food because of falling production and because of the demands of a growing population. We should be aware of these serious future problems if we are to have a chance of avoiding them.

## 7.10 The demographic transition

The developed industrial nations of the modern world have gone through a process known as the “demographic transition” - a shift from an equilibrium where population growth is held in check by the grim Malthusian forces of

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<sup>5</sup>John Stuart Mill, *Principles of Political Economy, With Some of Their Applications to Social Philosophy*, (1848).

disease, starvation and war, to one where it is held in check by birth control and late marriage.

The transition begins with a fall in the death rate, caused by various factors, among which the most important is the application of scientific knowledge to the prevention of disease. Malthus gives the following list of some of the causes of high death rates: "...unwholesome occupations, severe labour and exposure to the seasons, extreme poverty, bad nursing of children, great towns, excesses of all kinds, the whole train of common diseases and epidemics, wars, plague and famine." The demographic transition begins when some of the causes of high death rates are removed.

Cultural patterns require some time to adjust to the lowered death rate, and so the birth rate continues to be high. Families continue to have six or seven children, just as they did when most of the children died before having children of their own. Therefore, at the start of the demographic transition, the population increases sharply. After a certain amount of time, however, cultural patterns usually adjust to the lowered death rate, and a new equilibrium is established, where both the birth rate and the death rate are low.

In Europe, this period of adjustment required about two hundred years. In 1750, the death rate began to fall sharply: By 1800, it had been cut in half, from 35 deaths per thousand people in 1750 to 18 in 1800; and it continued to fall. Meanwhile, the birth rate did not fall, but even increased to 40 births per thousand per year in 1800. Thus the number of children born every year was more than twice the number needed to compensate for the deaths!

By 1800, the population was increasing by more than two percent every year. In 1750, the population of Europe was 150 million; by 1800, it was roughly 220 million; by 1950 it had exceeded 540 million, and in 1970 it was 646 million.

Meanwhile the achievements of medical science and the reduction of the effects of famine and warfare had been affecting the rest of the world: In 1750, the non-European population of the world was only 585 million. By 1850 it had reached 877 million. During the century between 1850 and 1950, the population of Asia, Africa and Latin America more than doubled, reaching 1.8 billion in 1950. In the twenty years between 1950 and 1970, the population of Asia, Africa and Latin America increased still more sharply, and in 1970, this segment of the world's population reached 2.6 billion, bringing the world total to 3.6 billion. The fastest increase was in Latin America, where population almost doubled during the twenty years between 1950 and 1970.

The latest figures show that population has stabilized or in some cases is even decreasing in Europe, Russia, Canada, Japan, Cuba and New Zealand. In Argentina, the United States, China, Myanmar, Thailand and Australia, the rates of population increase are moderate - 0.6%-1.0%; but even this moderate



### The Stages of the Demographic Transition.

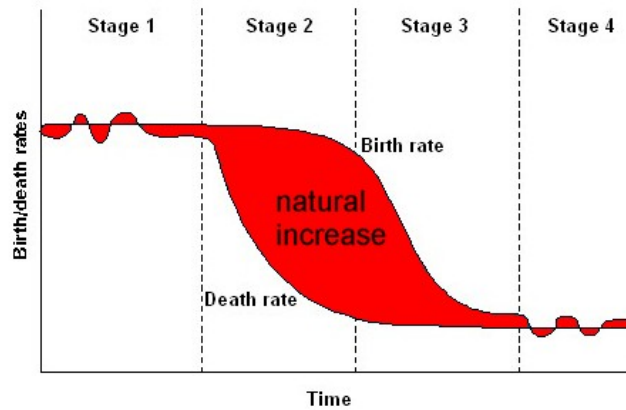


Figure 7.3: *The demographic transition.*

rate of increase will have a heavy ecological impact, particularly in the United States, with its high rates of consumption.

The population of the remainder of the world is increasing at breakneck speed - 2%-4% per year - and it cannot continue to expand at this rate for very much longer without producing widespread famines, since modern intensive agriculture cannot be sustained beyond the end of the fossil fuel era. The threat of catastrophic future famines makes it vital that all countries that have not completed the demographic transition should do so as rapidly as possible.

## 7.11 Urbanization

The global rate of population growth has slowed from 2.0 percent per year in 1972 to 1.7 percent per year in 1987; and one can hope that it will continue to fall. However, it is still very high in most developing countries. For example, in Kenya, the population growth rate is 4.0 percent per year, which means that the population of Kenya will double in seventeen years.

During the 60 years between 1920 and 1980 the urban population of the developing countries increased by a factor of 10, from 100 million to almost a billion. In 1950, the population of Sao Paulo in Brazil was 2.7 million. By 1980, it had grown to 12.6 million; and it is expected to reach 24.0 million by the year 2000. Mexico City too has grown explosively to an unmanageable size. In 1950, the population of Mexico City was 3.05 million; in 1982 it was



Figure 7.4: *Because of the threat of widespread famine, it is vital that all countries should complete the demographic transition as quickly as possible.*

16.0 million; and the population in 2000 was 17.8 million.

A similar explosive growth of cities can be seen in Africa and in Asia. In 1968, Lusaka, the capital of Zambia, and Lagos, the capital of Nigeria, were both growing at the rate of 14 percent per year, doubling in size every 5 years. In 1950, Nairobi, the capital of Kenya, had a population of 0.14 million. In a 1999 census, it was estimated to be between 3 and 4 million, having increased by a factor of 25.

In 1972, the population of Calcutta was 7.5 million. By the turn of the century in 2000, it had almost doubled in size. This rapid growth produced an increase in the poverty and pollution from which Calcutta already suffered in the 1970's. The Hooghly estuary near Calcutta is choked with untreated industrial waste and sewage, and a large percentage of Calcutta's citizens suffer from respiratory diseases related to air pollution.

Governments in the third world, struggling to provide clean water, sanitation, roads, schools, medical help and jobs for all their citizens, are defeated by rapidly growing urban populations. Often the makeshift shantytowns inhabited by new arrivals have no piped water; or when water systems exist, the pressures may be so low that sewage seeps into the system.

Many homeless children, left to fend for themselves, sleep and forage in the streets of third world cities. These conditions have tended to become worse with time rather than better. Whatever gains governments can make are immediately canceled by growing populations.



Figure 7.5: *Sir Partha Dasgupta of Cambridge University has pointed out that all the changes needed for population stabilization are desirable in themselves. These include education for women, higher status for women, state provision of old-age help for the poor, universal health care, and making safe drinking water available near to dwellings.*

## 7.12 Achieving economic equality

Today's world is characterized by intolerable economic inequalities, both between nations and within nations. A group of countries including (among others) Japan, Germany, France, the United Kingdom and the United States, has only 13% of the world's population, but receives 45% of the global PPP<sup>6</sup> income. By contrast, a second group, including 2.1 Billion people (45% of the world's population) receives only 9% of the global PPP income. Another indicator of inequality is the fact that the 50 million richest people in the world receive as much as the 2,700 million poorest.

18 million of our fellow humans die each year from poverty-related causes. Each year, 11 million children die before reaching their fifth birthday. 1.1 billion people live on less than \$1 per day; 2.7 billion live on less than \$2.

At the United Nations Conference on Population and Development, held in Cairo in September, 1994, a theme which emerged very clearly was that one of the most important keys to controlling the global population explosion is giving women better education and equal rights. These goals are desirable for their own sake, and for the sake of the uniquely life-oriented point of view which women can give us; but in addition, education and improved status for women have shown themselves to be closely connected with lowered birth rates. When women lack education and independent careers outside the home, they can be forced into the role of baby-producing machines by men who do not share in the drudgery of cooking, washing and cleaning; but when women have educational, legal, economic, social and political equality with men, experience has shown that they choose to limit their families to a moderate size.

As glaciers melt in the Himalayas, depriving India and China of summer water supplies; as sea levels rise, drowning the fertile rice fields of Viet Nam and Bangladesh; as drought threatens the productivity of grain-producing regions of North America; and as the end of the fossil fuel era impacts modern high-yield agriculture, there is a threat of wide-spread famine. There is a danger that the 1.5 billion people who are undernourished today will not survive an even more food-scarce future.

People threatened with famine will become refugees, desperately seeking entry into countries where food shortages are less acute. Wars, such as those currently waged in the Middle East, will add to the problem.

What can we do to avoid this crisis, or at least to reduce its severity? We must urgently address the problem of climate change; and we must shift money from military expenditure to the support of birth control programs and agricultural research. We must also replace the institution of war by a system of effective global governance and enforceable international laws.

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<sup>6</sup>Purchasing Power Parity



Figure 7.6: *Education of women and higher status for women are vitally important measures, not only for their own sake, but also because these social reforms have proved to be the key to lower birth rates.*

## 7.13 Achieving a steady-state economic system

Endless economic growth on a finite planet is a logical impossibility. Just as population growth is limited by ecological constraints, so too is the growth of resource-using and pollution-producing industrial production. Culture, of course, can and should continue to grow,

A number of economists have studied this problem, and in particular, outstanding contributions have been made by Frederick Soddy, Nickolas Georgescu-Roegan and Herman Daly. These authors have taken into account the role which entropy plays in economics.

## 7.14 Harmful effects of industrialized farming

### Pharming

A major global public health crisis may soon be produced by the wholesale use of antibiotics in the food of healthy farm animals. The resistance factors produced by shovelling antibiotics into animal food produces resistance factors (plasmids) which can easily be transferred to human pathogens. A re-

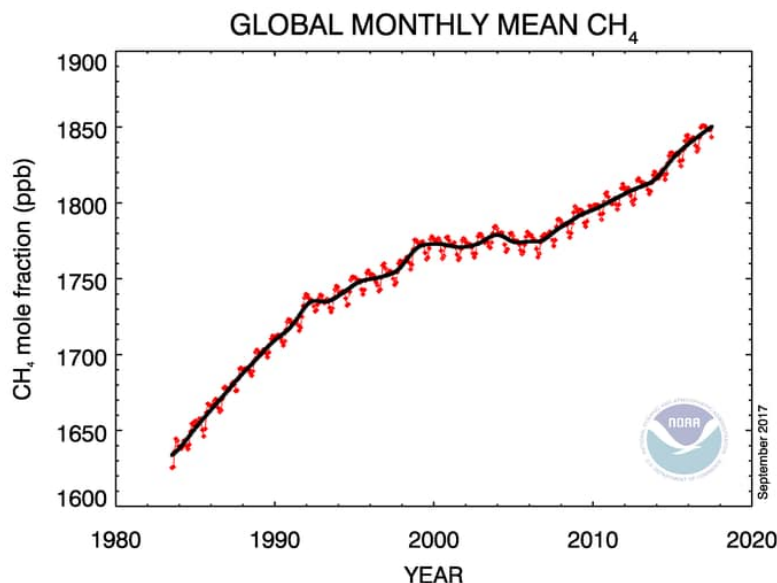


Figure 7.7: *Methane emissions are steadily increasing. A new report has shown ruminants are largely responsible for increases in rates of emission.*

lated problem is the excessive use of pesticides and artificial fossil-fuel-derived fertilizers in agriculture. Pharming is not a joke. It is a serious threat.<sup>7</sup>

## Meat and methane

Methane is an extremely powerful greenhouse gas. and it is emitted in large quantities by ruminants, such as cattle produced for beef. A new report<sup>8</sup> finds that cattle are not the biggest contributor to the annual methane budget in the atmosphere, but they may be the biggest contributor to increases in methane

<sup>7</sup><http://ecowatch.com/2014/03/06/misuse-antibiotics-fatal-superbug-crisis/>  
<http://ecowatch.com/2013/12/06/8-scary-facts-about-antibiotic-resistance/>  
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<sup>8</sup>J. Wolf et al., *Revised methane emissions factors and spatially distributed annual carbon fluxes for global livestock*, Carbon Balance and Management 2017, 12:16

emissions over recent years.

One must also remember that by eating less meat, and in particular less beef, we can shorten the food chain and thus help famine-threatened populations.

### **Pesticides, artificial fertilizers and topsoil**

A closely analogous danger results from the overuse of pesticides and petroleum-derived fertilizers in agriculture. A very serious problem with Green Revolution plant varieties is that they require heavy inputs of pesticides, fertilizers and irrigation. Because of this, the use of high-yield varieties contributes to social inequality, since only rich farmers can afford the necessary inputs. Monocultures, such as the Green Revolution varieties may also prove to be vulnerable to future plant diseases, such as the epidemic that caused the Irish Potato Famine in 1845. Even more importantly, pesticides, fertilizers and irrigation all depend on the use of fossil fuels. One must ask, therefore, whether high-yield agriculture can be maintained in the post-fossil-fuel era.

Topsoil is degraded by excessive use of pesticides and artificial fertilizers. Natural topsoil is rich in organic material, which contains sequestered carbon that would otherwise be present in our atmosphere in the form of greenhouse gases. In addition, natural topsoil contains an extraordinarily rich diversity of bacteria and worms that act to convert agricultural wastes from one year's harvest into nutrients for the growth of next year's crop. Pesticides kill these vital organisms, and make the use of artificial fertilizers necessary.

Finally, many small individual farmers, whose methods are sustainable, are being eliminated by secret land-grabs or put out of business because they cannot compete with unsustainable high-yield agriculture. Traditional agriculture contains a wealth of knowledge and biodiversity, which it would be wise for the world to preserve.

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## Chapter 8

# REFUGEES FROM CLIMATE CHANGE

### 8.1 Climate change as genocide

Climate change does not affect all parts of the world equally. The harshest effects of the extreme weather that we are already experiencing are disproportionately felt by the poorest people of the world.

In March, 2017, the Security Council was informed <sup>1</sup> that 20 million people in four countries, Nigeria, Somalia, South Sudan and Yemen, were in danger of dying unless provided with immediate help. The cost of the necessary aid was estimated to be \$4.4 billion. The developed world's response has been a shrug of indifference. By the midsummer, 2017 only a tenth of the amount needed had been raised.

Conflicts and famine are interlinked. The struggle for food produces conflicts; and famine is often used as an instrument of war. Food aid, when available, is often deliberately blocked or destroyed by warring factions. Boko Haram in Nigeria, al-Shabaab in Somalia, assorted militias and the government in South Sudan, and Saudi-backed forces in Yemen all interfered with the delivery of aid supplies.

In the future, the effects of rising temperatures and reduced rainfall will disproportionately affect poor farmers of Africa, the Middle East, South Asia, and Latin America. If the more affluent parts of the world continue to produce greenhouse gasses in a business-as-usual scenario, and if they continue to ignore calls for help from starving people, these actions will amount to genocide.

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<sup>1</sup>by Stephen O'Brian, UN Under Secretary General for Humanitarian Affairs



Figure 8.1: *A starving child in Somalia.*

## 8.2 The United Nations High Commission on Refugees

In an article on *Climate Change and Disasters* the United Nations High Commission on Refugees makes the following statement:

“The Earth’s climate is changing at a rate that has exceeded most scientific forecasts. Some families and communities have already started to suffer from disasters and the consequences of climate change, forced to leave their homes in search of a new beginning.

“For UNHCR, the consequences of climate change are enormous. Scarce natural resources such as drinking water are likely to become even more limited. Many crops and some livestock are unlikely to survive in certain locations if conditions become too hot and dry, or too cold and wet. Food security, already a concern, will become even more challenging.

“People try to adapt to this situation, but for many this will mean a conscious move to another place to survive. Such moves, or the effects of climate change on natural resources, may spark conflict with other communities, as an increasing number of people compete for a decreasing amount of resources.

“Since 2009, an estimated one person every second has been displaced by a disaster, with an average of 22.5 million people displaced by climate- or



weather-related events since 2008 (IDMC 2015). Disasters and slow onsets, such as droughts in Somalia in 2011 and 2012, floods in Pakistan between 2010 and 2012, and the earthquake in Nepal in 2015, can leave huge numbers of people traumatized without shelter, clean water and basic supplies.”

### 8.3 Populations displaced by sea level rise

In a recent article<sup>2</sup> discussed the long-term effects of sea level rise and the massive refugee crisis that it might create. By 2060, about 1.4 billion people could be climate change refugees, according to the paper, and that number could reach 2 billion by 2100.

The lead author, Prof. Emeritus Charles Geisler of Cornell University says: “The colliding forces of human fertility, submerging coastal zones, residential retreat, and impediments to inland resettlement is a huge problem. We offer preliminary estimates of the lands unlikely to support new waves of climate refugees due to the residues of war, exhausted natural resources, declining net primary productivity, desertification, urban sprawl, land concentration, ‘paving the planet’ with roads and greenhouse gas storage zones offsetting permafrost melt.”

We should notice that Prof. Geisler’s estimate of 2 billion climate refugees by 2100 includes all causes, not merely sea level rise. However, the number of refugees from sea level rise alone will be very large, since all the world’s coastal cities, and many river deltas will be at risk.

### 8.4 Populations displaced by drought and famine

Climate change could produce a refugee crisis that is “unprecedented in human history”, Barack Obama has warned as he stressed global warming was the most pressing issue of the age.

Speaking at an international food conference in Milan, the former US President said rising temperatures were already making it more difficult to grow crops and rising food prices were “leading to political instability”.

If world leaders put aside “parochial interests” and took action to reduce greenhouse gas emissions by enough to restrict the rise to one or two degrees Celsius, then humanity would probably be able to cope.

Failing to do this, Mr Obama warned, increased the risk of “catastrophic” effects in the future, “not only real threats to food security, but also increases

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<sup>2</sup>Geisler C. et al., *Impediments to inland resettlement under conditions of accelerated sea level rise*, Land Use Policy, Vol 55, July 2017, Pages 322-330

in conflict as a consequence of scarcity and greater refugee and migration patterns”.

“If you think about monsoon patterns in the Indian subcontinent, maybe half a billion people rely on traditional rain patterns in those areas,”

## 8.5 Populations displaced by rising temperatures

A new study published in *Nature: Climate Change* has warned that up to 75% of the world’s population could face deadly heat waves by 2100 unless greenhouse gas emissions are rapidly controlled.<sup>3</sup> The following is an excerpt from the article:

“Here we conducted a global analysis of documented lethal heat events to identify the climatic conditions associated with human death and then quantified the current and projected occurrence of such deadly climatic conditions worldwide. We reviewed papers published between 1980 and 2014, and found 783 cases of excess human mortality associated with heat from 164 cities in 36 countries.

“Based on the climatic conditions of those lethal heat events, we identified a global threshold beyond which daily mean surface air temperature and relative humidity become deadly. Around 30% of the world’s population is currently exposed to climatic conditions exceeding this deadly threshold for at least 20 days a year.

“By 2100, this percentage is projected to increase to 48% under a scenario with drastic reductions of greenhouse gas emissions and 74% under a scenario of growing emissions. An increasing threat to human life from excess heat now seems almost inevitable, but will be greatly aggravated if greenhouse gases are not considerably reduced.”<sup>4</sup>

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<sup>3</sup>Mora, C. et al., *Global risk of deadly heat*, *Nature: Climate Change*, 19 June 2017

<sup>4</sup>See also <https://phys.org/news/2017-08-deadly-south-asia-century.html> and <https://cleantechnica.com/2017/09/28/extreme-heatwaves-like-recent-lucifer-heatwave-become-normal-europe-2050s/>

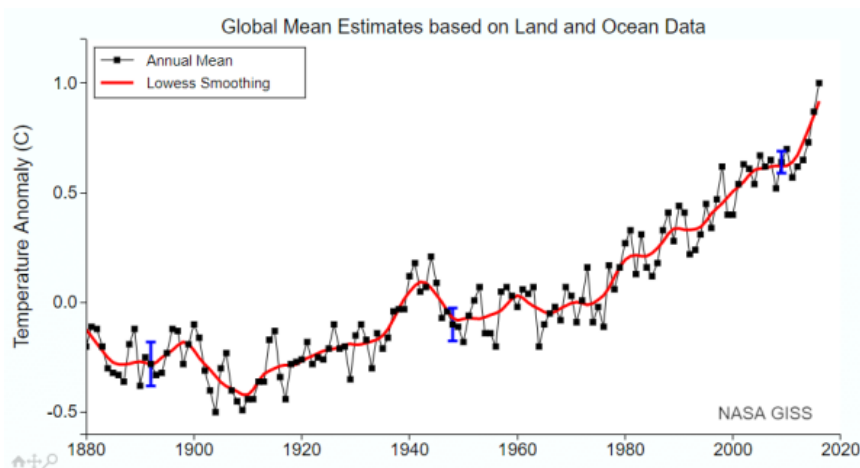


Figure 8.2: *This figure shows an alarming upward turn in the average global temperature*

## 8.6 Populations displaced by war

A recent article in *The Guardian*<sup>5</sup> discusses the relationship between climate change and war. Here are some excerpts from the article:

“Climate change is set to cause a refugee crisis of ‘unimaginable scale’, according to senior military figures, who warn that global warming is the greatest security threat of the 21st century and that mass migration will become the ‘new normal’.

“The generals said the impacts of climate change were already factors in the conflicts driving a current crisis of migration into Europe, having been linked to the Arab Spring, the war in Syria and the Boko Haram terrorist insurgency.

“Military leaders have long warned that global warming could multiply and accelerate security threats around the world by provoking conflicts and migration. They are now warning that immediate action is required.

“‘Climate change is the greatest security threat of the 21st century,’ said Maj Gen Muniruzzaman.

“Muniruzzaman, chairman of the Global Military Advisory Council on climate change and a former military adviser to the president of Bangladesh. He said one meter of sea level rise will flood 20% of his nation. ‘We’re going to see refugee problems on an unimaginable scale, potentially above 30 million people.’

“Previously, Bangladesh’s finance minister, Abul Maal Abdul Muhith, called

<sup>5</sup>Thursday, 1 December, 2016

on Britain and other wealthy countries to accept millions of displaced people.

“Brig Gen Stephen Cheney, a member of the US Department of State’s foreign affairs policy board and CEO of the American Security Project, said: ‘Climate change could lead to a humanitarian crisis of epic proportions. We’re already seeing migration of large numbers of people around the world because of food scarcity, water insecurity and extreme weather, and this is set to become the new normal’.

## 8.7 Political reactions to migration

### Brexit

Across the developed world, the reaction to threatened migration of refugees from climate change has been less than generous, to say the least. The recent decision of Britain to leave the European Union was motivated largely by the fear of British workers that EU laws would force their country to accept large numbers of refugees.

### Swings to the right in Europe

In Germany, Angela Merkel’s generous policies towards refugees have cost her votes, while an openly racist party, the Alternative for Germany (AfD) party, has gained in strength. Frauke Petry, 40, the party’s leader, has said border guards might need to turn guns on anyone crossing a frontier illegally. The party’s policy platform says “Islam does not belong in Germany” and calls for a ban on the construction of mosques.

In September, 2017, eight people from the neo-Nazi Freital Group were put on trial in Dresden for bomb attacks on homes for asylum applicants. Hundreds of similar assaults occur in Germany every year, but they had never before been tried as terrorism in a federal court.

In the German election, which took place on Sunday, October 1, 2017, Angela Merkel won a fourth term as Chancellor, but her party won only 33% of the votes, a percentage much reduced from the 41% won in the election of 2013. Angela Merkel was paying a high price for her refugee-friendly policies.

Meanwhile the far right anti-immigration AfD party made a historic breakthrough, winning 13.5% of the vote, thus becoming the first overtly nationalist party to sit in the Bundestag in 60 years. The Greens have already complained that “Nazis have returned to parliament”. In fact, members of the AfD party have begun to say that Germans should stop being ashamed of their country’s Nazi past.

In France, the National Front is a nationalist party that uses populist rhetoric to promote its anti-immigration and anti-European Union positions. The party favors protectionist economic policies and would clamp down on government benefits for immigrants.

Similarly, in the Netherlands, the anti-European Union, anti-Islam Party for Freedom has called for closing all Islamic schools and recording the ethnicity of all Dutch citizens. In early November, the party was leading in polls ahead of next year's parliamentary elections.

Other far-right anti-immigrant parties in Europe include Golden Dawn (Greece), Jobbic (Hungary), Sweden Democrats (Sweden), Freedom Party (Austria), and People's Party - Our Slovakia (Slovakia). All of these parties have gained in strength because of the widespread fear of immigration.

## Populism in the United States

The election of Donald Trump, who ran for President in 2016 on an openly racist and anti-immigrant platform, can also be seen as the result of fear of immigration, especially on the part of industrial workers.

## 8.8 A more humane response to the refugee crisis

In the long-term future, climate change will make the refugee crisis much more severe. Heat and drought will make large regions of the world uninhabitable, and will threaten many populations with famine. The severity of the refugee crisis will depend on how quickly we reduce greenhouse gas emissions.

While making many parts of the world uninhabitable, long-term climate change will make other regions more suitable for human habitation and agriculture. For example, farming will become more possible in Siberia, Greenland, the Canadian Arctic, Alaska and Patagonia. A humane response to the refugee crisis could include the generous opening of these regions to refugees.

The global population of humans is currently increasing by almost a billion people every decade. Global population must be stabilized, and in the long run, gradually reduced. Money currently wasted (or worse than wasted) on armaments could be used instead to promote universal primary health care, and with it, universal access to the knowledge and materials needed for family planning.

Finally, reduced consumption of meat, particularly beef, would shorten the food chain thus make more food available for famine relief.

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# Chapter 9

## THE ROLE OF THE MEDIA

### 9.1 Introduction

Throughout history, art was commissioned by rulers to communicate, and exaggerate, their power, glory, absolute rightness etc, to the populace. The pyramids gave visual support to the power of the Pharaoh; portraits of rulers are a traditional form of propaganda supporting monarchies; and palaces were built as symbols of power.

Modern powerholders are also aware of the importance of propaganda. Thus the media are a battleground where reformers struggle for attention, but are defeated with great regularity by the wealth and power of the establishment. This is a tragedy because today there is an urgent need to make public opinion aware of the serious problems facing civilization, and the steps that are needed to solve these problems. The mass media could potentially be a great force for public education, but often their role is not only unhelpful - it is negative.

It is certainly possible to find a few television programs and newspaper articles that present the facts about climate change in a realistic way. For example *The Guardian* gives outstanding climate change coverage. However, the mass media could do very much more. One has to conclude that the media are neglecting their great responsibilities at a time of acute crisis for human civilization and the biosphere. The same can be said of our educational systems at both both the primary and advanced levels. We urgently need much more public education about the severe dangers that we face today.

## 9.2 Television as a part of our educational system

In the mid-1950's, television became cheap enough so that ordinary people in the industrialized countries could afford to own sets. During the infancy of television, its power was underestimated. The great power of television is due to the fact that it grips two senses simultaneously, both vision and hearing. The viewer becomes an almost-hypnotized captive of the broadcast.

In the 1950's, this enormous power, which can be used both for good and for ill, was not yet fully apparent. Thus insufficient attention was given to the role of television in education, in setting norms, and in establishing values. Television was not seen as an integral part of the total educational system. It is interesting to compare the educational systems of traditional cultures with those of modern industrial societies.

In traditional societies, multigenerational families often live together in the same dwelling. In general, there is a great deal of contact between grandparents and grandchildren, with much transmission of values and norms between generations. Old people are regarded with great respect, since they are considered to be repositories of wisdom, knowledge, and culture.

By contrast, modern societies usually favor nuclear families, consisting of only parents and children. Old people are marginalized. They live by themselves in communities or homes especially for the old. Their cultural education knowledge and norms are not valued because they are "out of date". In fact, during the life of a young person in one of the rapidly-changing industrial societies of the modern world, there is often a period when they rebel against the authority of their parents and are acutely embarrassed by their parents, who are "so old-fashioned that they don't understand anything".

Although the intergenerational transmission of values, norms, and culture is much less important in industrial societies than it is in traditional ones, modern young people of the West and North are by no means at a loss over where to find their values, fashions and role models. With every breath, they inhale the values and norms of the mass media. Totally surrounded by a world of television and film images, they accept this world as their own.

## 9.3 Neglect of climate change in the mass media

The predicament of humanity today has been called "a race between education and catastrophe": How do the media fulfil this life-or-death responsibility? Do they give us insight? No, they give us pop music. Do they give us an

understanding of the sweep of evolution and history? No, they give us sport. Do they give us an understanding of the ecological catastrophes that threaten our planet because of unrestricted growth of population and industries? No, they give us sit-coms and soap operas. Do they give us unbiased news? No, they give us news that has been edited to conform with the interests of powerful lobbys. Do they present us with the urgent need to leave fossil fuels in the ground? No, they do not, because this would offend the powerholders. Do they tell of the danger of passing tipping points after which human efforts to prevent catastrophic climate change will be useless? No, they give us programs about gardening and making food.

A consumer who subscribes to the “package” of broadcasts sold by a cable company can often search through all 95 channels without finding a single program that offers insight into the various problems that are facing the world today. What the viewer finds instead is a mixture of pro-establishment propaganda and entertainment. Meanwhile the neglected global problems are becoming progressively more severe.

In general, the mass media behave as though their role is to prevent the peoples of the world from joining hands and working to change the world and to save it from thermonuclear war, environmental catastrophes and threatened global famine. The television viewer sits slumped in a chair, passive, isolated, disempowered and stupefied. The future of the world hangs in the balance, the fate of children and grandchildren hangs in the balance, but the television viewer feels no impulse to work actively to change the world or to save it. The Roman emperors gave their people bread and circuses to numb them into political inactivity. The modern mass media seem to be playing a similar role.

## 9.4 Climate change denial in mass media

The Wikipedia article on climate change denial describes it with the following words: “Although scientific opinion on climate change is that human activity is extremely likely to be the primary driver of climate change, the politics of global warming have been affected by climate change denial, hindering efforts to prevent climate change and adapt to the warming climate. Those promoting denial commonly use rhetorical tactics to give the appearance of a scientific controversy where there is none.”

It is not surprising that the fossil fuel industry supports, on a vast scale, politicians and mass media that deny the reality of climate change. The amounts of money at stake are vast. If catastrophic climate change is to be avoided, coal, oil and natural gas “assets” worth trillions of dollars must be

left in the ground. Giant fossil fuel corporations are desperately attempting to turn these “assets” into cash.

## 9.5 Showing unsustainable lifestyles in mass media

Television and other mass media contribute indirectly to climate change denial by showing unsustainable lifestyles. Television dramas show the ubiquitous use of gasoline-powered automobiles and highways crowded with them. just as though there did not exist an urgent need to transform our transportation systems. Motor racing is shown. A program called “Top Gear” tells viewers about the desirability of various automobiles. In general, cyclists are not shown. In television dramas, the protagonists fly to various parts of the world. The need for small local self-sustaining communities is not shown.

Advertisements in the mass media urge us to consume more, to fly, to purchase large houses, and to buy gasoline-driven automobiles, just as though such behavior ought to be the norm. Such norms are leading us towards environmental disaster.

## 9.6 Alternative media

Luckily, the mass media do not have a complete monopoly on public information. With a little effort, citizens who are concerned about the future can find alternative media. These include a large number of independent on-line news services that are supported by subscriber donations rather than by corporate sponsors. *YouTube* videos also represent an extremely important source of public information. Below we discuss a few outstanding people who have made extremely important *YouTube* videos on climate change.

## 9.7 Al Gore

Albert Arnold Gore Jr. served as the 45th Vice President of the United States from January 1985 to January 1993. He then ran for the office of President, but was defeated by George W. Bush in a controversial election whose outcome was finally decided by the US Supreme Court<sup>1</sup>.

Al Gore is the founder and current Chairman of the Alliance for Climate Protection. He was one of the first important political figures to call atten-

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<sup>1</sup>Many people believe that Al Gore won the election.





Figure 9.1: *Al Gore. 45th Vice President of the United States (Wikipedia).*

tion to the problem of steadily increasing CO<sub>2</sub> levels in the atmosphere and the threat of catastrophic climate change. He produced the highly influential documentary film *An Inconvenient Truth*<sup>2</sup>. Because of his important efforts to save the global environment, Al Gore shared the 2007 Nobel Peace Prize with the International Panel on Climate Change.

### **Al Gore's TED talk: The Case for Optimism on Climate Change**

In 2016, Al Gore gave an important talk to a TED audience<sup>3</sup>. in which he pointed out the an economic tipping point has just been passed. Solar energy and wind energy are now cheaper than energy form fossil fuels. This means that economic forces alone can drive a rapid transition to 100% renewable energy. Investors will realize that renewables represent an unparalleled investment opportunity.

## **9.8 Sir David Attenborough**

In a 2011 interview in The Guardian, Sir David Attenborough was asked: "What will it take to wake people up about climate change?". He replied "Disaster. It's a terrible thing to say, isn't it? And even disaster doesn't always do it. I mean, goodness me, there have been disasters in North America, with hurricanes, and one thing and another, and floods; and still a lot of people would deny it, and say it's nothing to do with climate change. Well it visibly has to do with climate change!"

Sir David Attenborough's almost unbelievably enormous and impressive opus of television programs about the natural world have helped to raise public awareness of the importance of the natural environment. He also has made a number of television programs specifically related to questions such as saving threatened species, the dangers of exploding global populations, and the destruction of forests for the sake of palm oil plantations.

Let us return to The Guardian's 2011 interview with Sir David. Had it been made in the autumn of 2017, the interview would certainly have included a discussion of recent hurricanes of unprecedented power and destructiveness, such as Harvey, Irma and Maria, as well as 2017's wildfires and Asian floods. It is possible that such events, which will certainly become more frequent and severe during the next few years, will provide the political will needed to

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<sup>2</sup><https://www.youtube.com/watch?v=I-SV13UQXdk>

<sup>3</sup><https://www.youtube.com/watch?v=I-SV13UQXdk>



Figure 9.2: *Sir David Attenborough: “Disaster. It’s a terrible thing to say, isn’t it?”*

silence climate change denial, to stop fossil fuel extraction, and to promote governmental policies favoring renewable energy.

Although the mass media almost have entirely neglected the link between climate change and recent disastrous hurricanes, floods droughts and wildfires, many individuals and organizations emphasized the cause and effect relationship. For example, UK airline billionaire Sir Richard Branson, whose Caribbean summer residence was destroyed by Hurricane Irma said:

“Look, you can never be 100 percent sure about links, But scientists have said the storms are going to get more and more and more intense and more and more often. We’ve had four storms within a month, all far greater than that have ever, ever, ever happened in history, Sadly, I think this is the start of things to come. Climate change is real. Ninety-nine percent of scientists know it’s real. The whole world knows it’s real except for maybe one person in the White House.”

May Boeve, executive director of the NGO 350.org, said “With a few exceptions, the major TV networks completely failed to cover the scientifically proven ways that climate change is intensifying extreme weather events like hurricanes Harvey and Irma. That’s not just disappointing, it’s dangerous. We won’t be able to turn this crisis around if our media is asleep at the wheel.”

Commenting on the destruction of Puerto Rico by Hurricane Maria, historian Juan Cole wrote: “When you vote for denialist politicians, you are selecting people who make policy. The policy they make will be clueless and will actively endanger the public. Climate change is real. We are causing it

by our emissions. If you don't believe that, you are not a responsible steward of our infrastructure and of our lives."

When interviewed by Amy Goodman of *Democracy Now*, musician Stevie Wonder said: "... we should begin to love and value our planet, and anyone who believes that there is no such thing as global warming must be blind or unintelligent."

Another well-known musician, Beyoncé, added: "The effects of climate change are playing out around the world every day. Just this past week, we've seen devastation from the monsoon in India...and multiple catastrophic hurricanes. Irma alone has left a trail of death and destruction from the Caribbean to Florida to Southern United States. We have to be prepared for what comes next..."

In her September 2017 publication *Season of Smoke*<sup>4</sup>, prizewinning author Naomi Klein wrote:

"We hear about the record-setting amounts of water that Hurricane Harvey dumped on Houston and other Gulf cities and towns, mixing with petrochemicals to pollute and poison on an unfathomable scale. We hear too about the epic floods that have displaced hundreds of thousands of people from Bangladesh to Nigeria (though we don't hear enough). And we are witnessing, yet again, the fearsome force of water and wind as Hurricane Irma, one of the most powerful storms ever recorded, leaves devastation behind in the Caribbean, with Florida now in its sights.

"Yet for large parts of North America, Europe, and Africa, this summer has not been about water at all. In fact it has been about its absence; it's been about land so dry and heat so oppressive that forested mountains exploded into smoke like volcanoes. It's been about fires fierce enough to jump the Columbia River; fast enough to light up the outskirts of Los Angeles like an invading army; and pervasive enough to threaten natural treasures, like the tallest and most ancient sequoia trees and Glacier National Park.

"For millions of people from California to Greenland, Oregon to Portugal, British Columbia to Montana, Siberia to South Africa, the summer of 2017 has been the summer of fire. And more than anything else, it's been the summer of ubiquitous, inescapable smoke.

"For years, climate scientists have warned us that a warming world is an extreme world, in which humanity is buffeted by both brutalizing excesses and stifling absences of the core elements that have kept fragile life in equilibrium for millennia. At the end of the summer of 2017, with major cities submerged in water and others licked by flames, we are currently living through Exhibit A of this extreme world, one in which natural extremes come head-to-head with

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<sup>4</sup><https://theintercept.com/2017/09/09/in-a-summer-of-wildfires-and-hurricanes-my-son-asks-why-is-everything-going-wrong/>

social, racial, and economic ones.”

It seems likely that the climate-linked disasters of 2018 and 2019 will be even more severe than those that we have witnessed during 2017. But will such disasters be enough to wake us up?

The BBC has recently announced that Sir David Attenborough is currently producing a new series, *Blue Planet II*, which will focus on environmental issues.<sup>5</sup>

“My hope is that the world is coming to its senses ... I’m so old I remember a time when ... we didn’t talk about climate change, we talked about animals and species extermination,” Sir David told Greenpeace in an interview, “For the first time I’m beginning to think there is actually a groundswell, there is a change in the public view. I feel many more people are concerned and more aware of what the problems are. Young people - people who’ve got 50 years of their life ahead of them - they are thinking they ought to be doing something about this. That’s a huge change.”

## 9.9 Leonardo DiCaprio

Leonardo DiCaprio has won many awards for his work as an actor, writer and producer in both television and films. These include 50 awards from 167 nominations. DiCaprio has been nominated for six Academy Awards, four British Academy Film Awards and nine Screen Actors Guild Awards, winning one award each from them and three Golden Globe Awards from eleven nominations.

In accepting his Best Actor award at the 2016 Oscars ceremony, DiCaprio said:

“Climate change is real, it is happening right now. It is the most urgent threat facing our entire species, and we need to work collectively together and stop procrastinating. We need to support leaders around the world who do not speak for the big polluters, but who speak for all of humanity, for the indigenous people of the world, for the billions and billions of underprivileged people out there who would be most affected by this. For our children’s children, and for those people out there whose voices have been drowned out by the politics of greed.”

Leonardo DiCaprio has used his great success as an actor in the service of environmental causes. In 1997, following the box office success of *Titanic*, he set up the Leonardo DiCaprio Foundation, which is devoted to environmental causes. He chaired the national Earth Day celebrations in 2000 during which he interviewed US President Bill Clinton, with whom he discussed the actions

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<sup>5</sup><http://www.bbcearth.com/blueplanet2/>



Figure 9.3: *Leonardo DiCaprio as a young actor.*

needed to avoid catastrophic climate change. In 2007 he had a major role in *The 11th Hour*, a documentary about people's relationship to nature and global warming. He also co-produced and co-wrote the film.

DiCaprio's most influential film on climate change is *Before the Flood*<sup>6</sup>. This film, released in 2016, is a 1 hour and 36 minute documentary in which Leonardo DiCaprio travels to many countries to let viewers observe the already visible effects of global warming. He also talks with many of the world's leaders, including Pope Francis I, US Presidents Bill Clinton and Barack Obama, and UN Secretary General Ban Ki-moon.

## 9.10 Thom Hartmann

Thom Hartmann was born in 1951 in Lansing Michigan. He worked as a disk jockey during his teens, and, after a highly successful business career, he sold his businesses and devoted his energies to writing, humanitarian projects and public education. His influential book, *Last Hours of Ancient Sunlight* was published by Three Rivers Press in 1997 and republished in a revised edition in 2004. In 2013, Hartmann published another extremely important book on the same theme: *The Last Hours of Humanity: Warming the World To Extinction*<sup>7</sup>.

Hartmann has hosted a nationally syndicated radio show, The Thom Hartmann Program, since 2003 and a nightly television show, The Big Picture, since 2008.

Concerning Hartmann's radio show, Wikipedia states that "As of March 2016, the show was carried on 80 terrestrial radio stations in 37 states as well as on Sirius and XM satellite radio. A community radio station in Africa, Radio Builsa in Ghana, also broadcasts the show. Various local cable TV networks simulcast the program. In addition to Westwood One, the show is now also offered via Pacifica Audioport to non-profit stations in a non-profit compliant format and is simulcast on Dish Network channel 9415 and DirecTV channel 348 via Free Speech TV. The program is carried on Radio Sputnik in London, England."

"Sen. Bernie Sanders (I-VT) appears every Friday during the first hour of the show titled 'Brunch with Bernie'. Ellen Ratner of the Talk Radio News Service provides Washington commentary daily. Victoria Jones who is the White House correspondent for Talk Radio News Service appears occasionally as does Dr. Ravi Batra an economics professor at SMU."

Together with Leonardo DiCaprio, Thom Hartman recently produced and

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<sup>6</sup><http://www.get.filmovie.us/play.php?movie=tt5929776t>

<sup>7</sup><https://www.amazon.com/Last-Hours-Humanity-Warming-Extinction/dp/1629213640>



Figure 9.4: *Thom Hartmann speaks to the 2010 Chicago Green Festival (Wikipedia).*

narrated an extremely important short film entitled *Last Hours*<sup>8</sup>. This film, draws a parallel between the Permian-Triassic mass extinction, and the danger of a human-induced 6th mass extinction. Various experts who appear in the film confirm that our release of CO<sub>2</sub> into the atmosphere is similar to the greenhouse gasses produced by volcanic eruptions prior to the Permian event. The methane hydrate feedback loop is also discussed. The film should be seen by everyone concerned with the future of human civilization and the biosphere. Concerned citizens should also urgently see Hartman and DiCaprio's short films *Carbon*, *Green World Rising* and *Reforestation*, also available on YouTube .

## 9.11 James Hansen

James Hansen was born in 1941 in Denison, Iowa. He was educated in physics, mathematics and astronomy at the University of Iowa in the space sciences program initiated James Van Allen. He graduated with great distinction. The studies of the atmosphere and temperature of Venus which Hansen made under Van Allen's supervision lead him to become extremely concerned about similar effects in the earth's atmosphere.

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<sup>8</sup><https://www.youtube.com/watch?v=2bRrg96UtMc>





Figure 9.5: *Prof. James Hansen*

From 1962 to 1966, James Hansen participated in the National Aeronautical and Space Administration graduate traineeship and, at the same time, between 1965 and 1966, he was a visiting student at the Institute of Astrophysics at the University of Kyoto and in the Department of Astronomy at the University of Tokyo. Hansen then began work at the Goddard Institute for Space Studies in 1967. He began to work for the Goddard Institute for Space Studies in 1967. Between 1981 and 2013, he was head of the Goddard Institute of Space Studies in New York, and since 2014, he has been the director of the Program on Climate Science, Awareness and Solutions at Columbia University's Earth Institute.

Hansen continued his work with radiative transfer models, attempting to understand the Venusian atmosphere. Later he applied and refined these models to understand the Earth's atmosphere, in particular, the effects that aerosols and trace gases have on Earth's climate. Hansen's development and use of global climate models has contributed to the further understanding of the Earth's climate. In 2009 his first book, *Storms of My Grandchildren*, was published.

James Hansen has refined climate change models, focusing on the balance between aerosols and greenhouse gases. He believes that there is a danger that climate change will become much more rapid if the balance shifts towards the greenhouse gases.

## **Hansen's Congressional testimony leads to broad public awareness of the dangers**

In 1988, Prof. Hansen was asked to testify before the US Congress on the danger of uncontrolled climate change. The testimony marked the start of broad public awareness of the seriousness of the danger, and it was reported in a front page article by the New York Times. However, Hansen believes that governmental energy policies still favor fossil fuels. Therefore he has participated in public demonstrations and he was even arrested in 2011 together with more than a thousand other activists for protesting outside the White House.

## **James Hansen's TED talk and book**

In 2012 he presented a TED Talk: *Why I Must Speak Out About Climate Change*. This talk is easily available on the Internet, and it should be required viewing for everyone who is concerned with the earth's future.

Hansen's book, *Storms of My Grandchildren: The Truth About The Coming Climate Catastrophe, and Our Last Chance To Save Humanity* was published in New York by Bloomsbury Publishing in 2009.

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# Chapter 10

## POPULAR CONCERN VERSUS INSTITUTIONAL INERTIA

### 10.1 Introduction

Citizens throughout the world want to save the future for their children and grandchildren, and indeed for all future generations. Therefore they advocate the steps that are necessary to avoid catastrophic climate change. But popular concern and action are opposed by powerful corporations that control both governments and mass media. This situation has produced violent conflicts between powerholders and climate activists.

Furthermore, the entire economic system of industrialized countries is currently based on fossil fuels. It could be based on renewable energy, and hopefully the transition to renewables will happen soon. However, our institutions have considerable inertia, as will be discussed below, and this must be overcome if we are to save our world for future generations.

In an extremely important 28-page report entitled *What Lies Beneath: The Scientific Understatement of Climate Risks*<sup>1</sup>, David Spratt and Ian Dunlop emphasize the fact that institutions such as the IPCC, constrained by the requirement of consensus, and decision makers, constrained by short-term expediency, completely underestimate the need for emergency action to prevent catastrophic climate change. Here are some excerpts from the introduction to the report:

“Three decades ago, when serious debate on human-induced climate change began at the global level, a great deal of statesmanship was on display. There

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<sup>1</sup><https://www.breakthroughonline.org.au/whatliesbeneath>

was a preparedness to recognize that this was an issue transcending nation states, ideologies and political parties, which had to be addressed proactively in the long-term interests of humanity as a whole, even if the existential nature of the risks involved was far less clear than it is today.

“As global institutions were established to take up this challenge, such as the UN Framework Convention on Climate Change (UNFCCC) at the Rio Summit in 1992, and the extent of change this would demand of the fossil-fuel dominated world order became clearer, the forces of resistance began to mobilize. Today, as a consequence, and despite the diplomatic triumph of the 2015 Paris Agreement, the debate around climate change policy has never been more dysfunctional, indeed Orwellian...

“Orwell could have been writing about climate change and policymaking. International agreements talk of limiting global warming to 1.5-2°C, but in reality they set the world on a path of 3-5°C. Goals are reaffirmed, only to be abandoned. Coal is ‘clean’. Just 1°C of warming is dangerous, but this cannot be said. The planetary future is hostage to myopic national self-interest. Action is delayed on the assumption that as yet unproven technologies will save the day, decades hence. The risks are existential, but it is ‘alarmist’ to say so. A one-in-two chance of missing the goal is normalized as reasonable.

“Climate policymaking for years has been cognitatively dissonant, ‘a flagrant violation of reality’. So it is unsurprising that there is a lack of understanding amongst... the elites of the full measure of the climate challenge”

## 10.2 Demonstrations in Copenhagen

During the Copenhagen Climate conference of 2009, large metal cages were brought to the city by the police force because it was thought that the jails would not be large enough to hold all the demonstrators who would be arrested. During the conference, government helicopters flew continually back and forth over the city, apparently to give people the impression that their actions were being watched.

According to an article published in *The Guardian* on December 13, 2009,

“More than 900 campaigners were arrested in Copenhagen last night as police were accused of overreacting to sporadic street violence. The arrests came the day before an appeal in the Danish capital by the archbishop of Canterbury, Dr Rowan Williams, for people to start loving and caring for their world.

“Williams will address a congregation including Queen Margrethe of Denmark and senior international politicians. He will call for a scaling down of the extravagant use of energy and the amount of waste across the planet. ‘These

things will only happen if we learn to love the world we live in', he will say.

"Williams, a passionate believer in the need for control of the causes of climate change, has had strong words for those who deny that man's activities are not responsible for the current phase of global warming. 'Don't please listen to those who say that there is some kind of choice to be made between looking after human beings and looking after the planet. It is one of the most foolish errors around these days,' he said.

"But last night violence broke out when tens of thousands of people - some dressed as penguins and polar bears, carrying signs saying: 'Save the humans' - took to the streets. The march had been organized to urge conference delegates to work out a binding deal to tackle climate change but was marred when a group of protesters threw bricks at police.

"Hundreds were arrested and police 'kettled'<sup>2</sup> several hundred more before sending coaches into the pen, filling them up and driving away.

"Henri Purje, who was in Copenhagen with Attac, a group opposed to international free trade, was standing in front of the group that was penned in and taken away by police. 'I was in the last line of people before the police suddenly moved in for no obvious reason. It seemed as if they just wanted to take out a bunch of random people. No one was being violent, I didn't see anyone doing anything apart from singing and chanting and marching. Everything had been really peaceful', Purje said."

## 10.3 The United Nations Climate Summit

UN Secretary General Ban Ki-moon has invited heads of state and governments to a 2014 Climate Summit, which will take place in New York on 23 September, 2014. Many thousands of ordinary people plan to march in New York on that day, to show their concern for the future of our planet, and to demonstrate how much they desire to give future generations of humans, animals and plants a world in which survival will be possible.

In order to prevent a tipping point, after which human efforts to prevent drastic temperature increases will become ineffective, it may be necessary for ordinary people to replace their oligarchic governments with true democracies.

On Tuesday, the 23rd of September, 2014, Leonardo DiCaprio made a really excellent speech to the United Nations Climate Summit in New York. Despite the extremely high quality and genuine conviction of his speech, DiCaprio failed to mention the terrible long-term threat which the world faces from the

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<sup>2</sup>i.e. completely prevented from leaving, with the effect of denying the protesters access to food, water and toilet facilities for an arbitrary period determined by the police forces.



Figure 10.1: *UN Secretary General Ban Ki-moon invited heads of state and governments to a 2014 Climate Summit, which took place in New York on 23 September, 2014.*

methane-hydrate feedback loop, which threatens to produce a human-induced 6th geological extinction event comparable to the Permian-Triassic thermal maximum. Here is a link to a video describing the threat: <sup>3</sup> Leonardo DiCaprio's failure to mention it in his otherwise excellent UN speech is surprising, since he and his family were closely involved with the production of the video.

Delegates at the United Nations Climate Summit were shown images of the inspiring and heartfelt People's Climate March, which took place on Sunday, September 21st. The organizers of the march had expected 100,000 participants. In fact, more than 400,000 people came, and the march was unique in its artistic brilliance and its ethnic diversity. It was one of 2,600 events in 170 nations. The slogan of the march in New York was "To change everything, we need everyone", and in fact everyone came!<sup>4</sup>

The United Nations Climate Summit was certainly a success. Much was achieved: <sup>5</sup> And yet, much was missing from the results: <sup>6</sup>

<sup>3</sup><https://www.youtube.com/watch?v=sRGVTK-AAvw>

<sup>4</sup><https://www.youtube.com/watch?v=h5YaqcPEUNc>

<sup>5</sup><http://mashable.com/2014/09/24/united-nations-climate-summit-takeaways/>  
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<sup>6</sup><http://www.breitbart.com/Big-Peace/2014/09/23/UN-Demands-Stricter-CO2-Enforcement-But-Exempts-China>

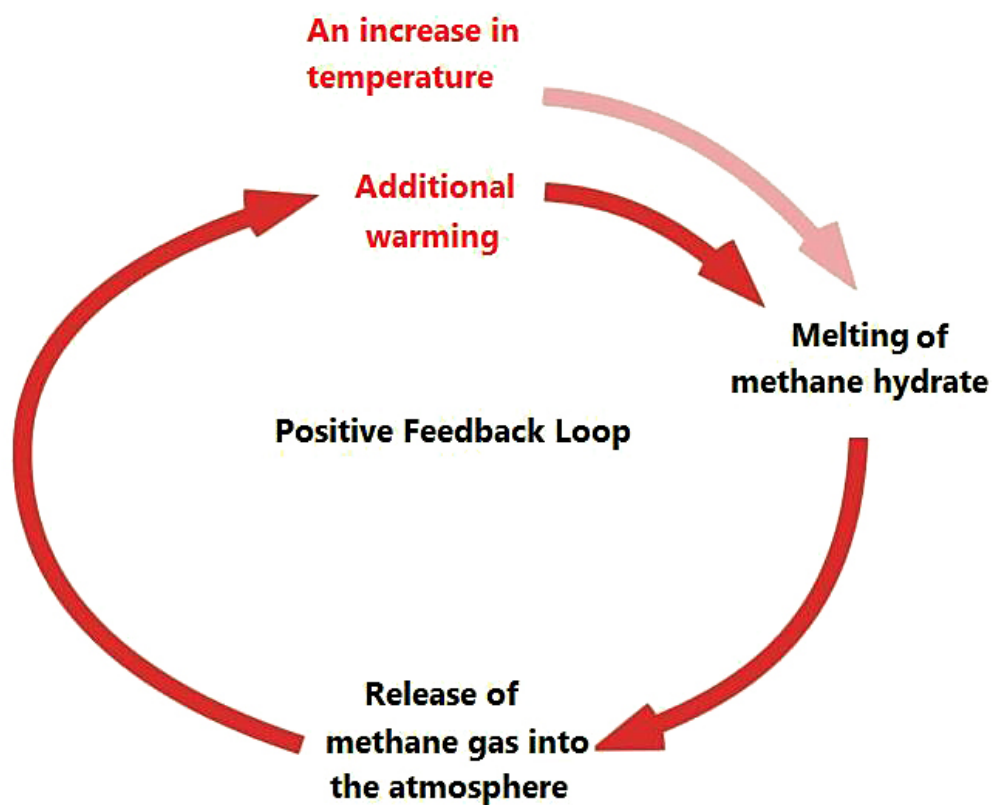


Figure 10.2: *The danger of an out-of-control methane hydrate feedback loop comes from the enormous amount of carbon involved - about 10,000 gigatons. To put this huge figure into perspective, we can remember that the amount of carbon humans have added to the atmosphere since the start of the Industrial Revolution is only 337 gigatons.*



Figure 10.3: *More than 400,000 people participated in New York's People's Climate March, and the march was unique in its artistic brilliance and its ethnic diversity. It was one of 2,600 events in 170 nations.*

China and India are now the world's two largest emitters of CO<sub>2</sub>, but they did not make firm commitments to abandon the burning of coal. In fact, these two countries will suffer greatly from climate change, perhaps already in the near future. The present floods in Kashmir are a warning of what is to come. Summer temperatures in India may soon become so high that people without air conditioning will be unable to survive. In both China and India, summer water supplies will be threatened by the melting of Himalayan glaciers.

Throughout the world, people of all countries need to act with urgency to switch to an economy that aims at sustainability rather than endless consumption and growth, an economy based on renewable energy rather than fossil fuels, an economy devoted to life rather than to profits.

## 10.4 Tear gas at the Paris Conference

WE NEED SYSTEM CHANGE, NOT CLIMATE CHANGE! Civil society, excluded from the COP21 conference by the French government, carried banners with this slogan on the streets of Paris. They did so in defiance of tear-gas-using black-clad police. System change has been the motto for climate marches throughout the world. Our entire system is leading us towards disaster, and this includes both economic and governmental establishments. To save human civilization, the biosphere and the future, the people of the world must take

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<http://www.asianews.it/news-en/>



matters into their own hands and change the system.<sup>7</sup>

We need a new economic system, a new society, a new social contract, a new way of life. Here are the great tasks that history has given to our generation: We must achieve a steady-state economic system. We must restore democracy. We must decrease economic inequality. We must break the power of corporate greed. We must leave fossil fuels in the ground. We must stabilize and ultimately reduce the global population. We must eliminate the institution of war. And finally, we must develop a more mature ethical system to match our new technology.

There are reasons for hope. Both solar energy and wind energy are growing at a phenomenal rate, and the transition to 100% renewable energy could be achieved within a very few decades if this growth is maintained. But a level playing field is needed. At present fossil fuel corporations receive half a trillion dollars each year in subsidies. Nuclear power generation is also highly subsidized (and also closely linked to the danger of nuclear war). If these subsidies were abolished, or better yet, used to encourage renewable energy

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<sup>7</sup><http://www.commondreams.org/views/2015/12/11/we-are-out-time-we-need-leap>  
<http://www.thenation.com/article/naomi-klein-sane-climate-policies-are-being-undermined-by-corporate-friendly-trade-deals/>  
<http://www.commondreams.org/news/2015/12/08/liberte-not-just-word-klein-corbyn-call-mass-protest-cop21>  
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<http://www.truth-out.org/news/item/33961-climate-change-justice>  
<http://www.countercurrents.org/avery280914.htm>



Figure 10.4: *Calling for 'system change,' civil society members hold a sit-in at the Paris climate talks.*

development, the renewables could win simply by being cheaper <sup>8</sup>

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<sup>8</sup><http://eruditio.worldacademy.org/issue-5/article/urgent-need-renewable-energy>  
<http://www.worldbank.org/en/news/feature/2012/11/18/Climate-change-report-warns-dramatically-warmer-world-this-century>  
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<http://therightsofnature.org/universal-declaration/>



## 10.5 Killing environmental leaders

Through 2015 a worldwide total of 185 murders of environmental leaders were documented by the nongovernmental organization Global Witness. A detailed report on these deaths is published this week.

As the study points out, 2015 had the highest conservation-related mortality rates since 2010, with 185 confirmed cases (143 were reported for 2012 and 130 for 2011). In a previous study with data from 2014 Global Witness had counted 116 deaths, which implies a significant growth from one year to the next. Many of these killings took place in Latin America, with an especially high number in Brazil.

## 10.6 Polls reflect concern about climate change

Despite the climate change denial of the current US government, a new poll shows that in the United States, 68% of the citizens believe that global warming is driven by human activities.

A Pew Poll conducted in 40 countries prior to the Paris conference, showed that in all the countries polled, the majority believed that climate change is a serious problem and a mean of 78% supported the idea of their country limiting greenhouse gas emissions as part of an international agreement in Paris.

## 10.7 Institutional and cultural inertia

### Why do we not respond to the crisis?

Today we are faced with multiple interrelated crises, for example the threat of catastrophic climate change or equally catastrophic thermonuclear war, and the threat of widespread famine. These threats to human existence and to the biosphere demand a prompt and rational response; but because because of institutional and cultural inertia, we are failing to take the steps that are necessary to avoid disaster.

### Institutional inertia

Our collective failure to respond adequately to the current crisis is very largely due to institutional inertia. For example, international relations are still based based on the concept of absolutely sovereign nation states, even though this concept has become a dangerous anachronism in an era of instantaneous global communication and economic interdependence. Within nations, systems of

law and education change very slowly, although present dangers demand rapid revolutions in outlook and lifestyle. Our financial system is deeply embedded and resistant to change. Our entire industrial infrastructure is based on fossil fuels; but if the future is to be saved, the use of fossil fuels must stop.

The failure of the recent COP20 climate conference in Lima to produce a strong final document can be attributed to the fact that the nations attending the conference felt themselves to be in competition with each other, when in fact they ought to have cooperated in response to a common danger. The heavy hand of the fossil fuel industry also made itself felt at the conference.

Until the development of coal-driven steam engines in the 19th century humans lived more or less in harmony with their environment. Then, fossil fuels, representing many millions of years of stored sunlight, were extracted and burned in two centuries, driving a frenzy of growth of population and industry that has lasted until the present. But today, the party is over. Coal, oil and gas are nearly exhausted, and what remains of them must be left in the ground to avoid existential threats to humans and the biosphere. Big coal and oil corporations base the value of their stocks on ownership of the remaining resources that are still buried, and they can be counted on to use every trick, fair or unfair, turn those resources into money.

In general corporations represent a strong force resisting change. By law, the directors of corporations are obliged to put the profits of stockholders above every other consideration. No room whatever is left for an ecological or social conscience. Increasingly, corporations have taken control of our mass media and our political system. They intervene in such a way as to make themselves richer, and thus to increase their control of the system.

## **Polite conversation and cultural inertia**

Each day, the conventions of polite conversation contribute to our sense that everything is as it always was. Politeness requires that we do not talk about issues that might be contrary to another person's beliefs. Thus polite conversation is dominated by trivia, entertainment, sports, the weather, gossip, food, and so on. Worries about the distant future, the danger of nuclear war, the danger of uncontrollable climate change, or the danger of widespread famine seldom appear in conversations at the dinner table, over coffee or at the pub. In conversations between polite people, the situation is exactly the same as in the mass media. We obtain the false impression that all is well with the world. But in fact, all is not well. We have to act promptly and adequately to save the future.

## Shooting Santa Claus

No one wants to shoot Santa Claus. That goes without saying! Who would want to harm that jolly old man, with his reindeer and sleigh, and his workshop at the North Pole? Who would want to prevent him from bringing happiness to everyone? Who would want to stop him from making the children's eyes light up like stars? Surely no one!

But the sad truth today is that we have to get rid of Santa somehow, before he kills us, and before he kills most of the plants and animals with which we share our world. Perhaps shooting is too harsh. Perhaps we should just forget Santa and all that he stands for, with his red suit, invented by the advertising department of Coca-Cola.

This is what Santa stands for: The customer is always right. Your wish is our command. You have a right to whatever you desire. If you feel like taking a vacation on the other side of the world, don't hesitate, just do it. If you feel like buying a SUV, just do it. Self-fulfillment is your birthright. Spending makes the economy grow, and growth is good. Isn't that right?

But sadly that isn't right. We have to face the fact that endless economic growth on a finite planet is a logical impossibility, and that we have reached or passed the sustainable limits to growth.

In today's world, we are pressing against the absolute limits of the earth's carrying capacity, and further growth carries with it the danger of future collapse. In the long run, neither the growth of industry nor that of population is sustainable; and we have now reached or exceeded the sustainable limits.

The size of the human economy is, of course, the product of two factors: the total number of humans, and the consumption per capita. Let us first consider the problem of reducing the per-capita consumption in the industrialized countries. The whole structure of western society seems designed to push its citizens in the opposite direction, towards ever-increasing levels of consumption. The mass media hold before us continually the ideal of a personal utopia, filled with material goods.

Every young man in a modern industrial society feels that he is a failure unless he fights his way to the "top"; and in recent years, women too have been drawn into the competition. Of course, not everyone can reach the top; there would not be room for everyone; but society urges us all to try, and we feel a sense of failure if we do not reach the goal. Thus, modern life has become a competition of all against all for power and possessions.

When possessions are used for the purpose of social competition, demand has no natural upper limit; it is then limited only by the size of the human ego, which, as we know, is boundless. This would be all to the good if unlimited



Figure 10.5: *The mass media hold before us continually the ideal of a personal utopia, filled with material goods. Self-fulfillment is your birthright. Spending makes the economy grow, and growth is good. Isn't that right?*

industrial growth were desirable; but today, when further industrial growth implies future collapse, western society urgently needs to find new values to replace our worship of power, our restless chase after excitement, and our admiration of excessive consumption.

If you turn on your television set, the vast majority of the programs that you will be offered give no hint at all of the true state of the world or of the dangers which we will face in the future. Part of the reason for this willful blindness is that no one wants to damage consumer confidence. No one wants to bring on a recession. No one wants to shoot Santa Claus.

But sooner or later a severe recession will come, despite our unwillingness to recognize this fact. Perhaps we should prepare for it by reordering the world's economy and infrastructure to achieve long-term sustainability, i.e. steady-state economics, population stabilization, and renewable energy.

## **Our responsibility to future generations and to the biosphere**

All of the technology needed for the replacement of fossil fuels by renewable energy is already in place. Although renewable sources currently supply only

19 percent of the world's energy requirements, they are growing rapidly. For example, wind energy is growing at the rate of 30 percent per year. Because of the remarkable properties of exponential growth, this will mean that wind will soon become a major supplier of the world's energy requirements, despite bitter opposition from the fossil fuel industry.

Both wind and solar energy have can now compete economically with fossil fuels, and this situation will become even more pronounced if more countries put a tax on carbon emissions, as Finland, the Netherlands, Norway, Costa Rica, the United Kingdom and Ireland already have done.

Much research and thought have also been devoted to the concept of a steady-state economy. The only thing that is lacking is political will. It is up to the people of the world to make their collective will felt.

History has given to our generation an enormous responsibility towards future generations. We must act with dedication and fearlessness to save the future of the earth for human civilization and for the plants and animals with which we share the gift of life.

### Suggestions for further reading

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# Chapter 11

## ETHICS FOR THE FUTURE

### 11.1 The Encyclical of Pope Francis

Despite the worrying nature of the threats that we are facing, there are reasons for hope. One of the greatest of these is the beautiful, profound and powerful encyclical that has just been released by Pope Francis.

When he accepted the responsibility for leading the world's 1.2-billion-strong Catholic Church, Cardinal Bergoglio of Argentina adopted the name Francis, after the universally loved Saint Francis of Assisi, whose life of simplicity, love for the poor, and love of nature he chose as the model for his Papacy. The Pope's inspiring encyclical letter "Laudato Si' " takes its name from a canticle of Saint Francis, that begins with the words "Praise be to you, my Lord, through our sister, mother Earth, who sustains and governs us..."

We can remember that Saint Francis regarded birds and animals as his brothers and sisters. He even thought of the sun, moon, clouds, rain and water as brothers and sisters. Like his chosen namesake, Pope Francis stresses the unity of all of nature, and our kinship with all of creation. Francis appeals to love. We can be saved through love.

His encyclical is addressed not only to Catholics, but also to all men and women of good will, and almost all of its 102 pages appeal to moral sensibilities and rational arguments that can be shared by all of us. Pope Francis stresses that the natural world that sustains us is in grave danger from our ruthless exploitation and greed-driven destruction of all the beauty and life that it contains: animals, forests, soil, and air.

Pope Francis tells us that the dictates of today's economists are not sacred: In the future, if we are to survive, economics must be given both a social conscience and an ecological conscience. Nor are private property and profits sacred. They must be subordinated to the common good, and the preservation of our global commons.

Less focus on material goods need not make us less happy. The quality of our lives can be increased, not decreased, if we give up our restless chase after power and wealth, and derive more of our pleasures from art, music and literature, and from conversations with our families and friends. Please read this great encyclical in its entirety. It can give us hope and courage as we strive to make the changes that are needed to avert an ecological mega-catastrophe.

Don Joao Mamede Filho is the Bishop of the Diocese of Umuarama, commented: “ ‘Laudato Si’, considered by environmentalists all around the world as the Green Encyclical, has become a work read by Christians and non-Christians alike in all corners of the world. In it, Pope Francis calls on us all to take care of our ‘Common Home’ and all that exists in it.

“In his call, the Pope reaffirms that the planet is a common good that must be preserved and guarded. Therefore, it is our duty to refrain from any human activity that may degrade, pollute or pose any kind of threat or risk to our planet and those who inhabit it.

“‘Laudato Si’ also presents a strong and persisting plea for a shift towards a new energy and development model, leaving fossil fuels behind. Since these energy sources are responsible for the highest emissions of greenhouse gases, they pollute, render climate changes more intense, bring on diseases, and kill.

“It is important to remember that, at the beginning of Creation, an organic relationship between all living beings was established. All that exists is connected and coexists in a sustainable and wholesome manner. However, by choosing dirty energy sources such as fossil fuels, which leave trails of destruction behind them, we disconnect ourselves from our surroundings and ignore the harm they may cause us and to our fellow creatures.”

## 11.2 The message of Henry David Thoreau

In the distant future (and perhaps even in the not-so-distant future) industrial civilization will need to abandon its relentless pursuit of unnecessary material goods and economic growth. Modern society will need to re-establish a balanced and harmonious relationship with nature. In preindustrial societies harmony with nature is usually a part of the cultural tradition. In our own time, the same principle has become central to the ecological counter-culture while the main-stream culture thunders blindly ahead, addicted to wealth, power and growth.

In the 19th century the American writer, Henry David Thoreau (1817-1862), pioneered the concept of a simple life, in harmony with nature. Today, his classic book, *Walden*, has become a symbol for the principles of ecology, simplicity, and respect for nature.



Thoreau was born in Concord Massachusetts, and he attended Harvard from 1833 to 1837. After graduation, he returned home, worked in his family's pencil factory, did odd jobs, and for three years taught in a progressive school founded by himself and his older brother, John. When John died of lockjaw in 1842, Henry David was so saddened that he felt unable to continue the school alone.

### **Nonviolent civil disobedience**

Thoreau refused to pay his poll tax because of his opposition to the Mexican War and to the institution of slavery. Because of his refusal to pay the tax (which was in fact a very small amount) he spent a night in prison. To Thoreau's irritation, his family paid the poll tax for him and he was released. He then wrote down his ideas on the subject in an essay entitled *The Duty of Civil Disobedience*, where he maintains that each person has a duty to follow his own individual conscience even when it conflicts with the orders of his government.

In his essay, Thoreau said: "A common and natural result of an undue respect for law is that you may see a file of soldiers, colonel, captain, corporal, privates, powder-monkeys, and all marching in admirable order over hill and dale to the wars, against their wills, ay, against their common sense and consciences, which makes it very steep marching indeed, and produces a palpitation of the heart. They have no doubt that it is a damnable business in which they are concerned; they are all peaceably inclined. Now, what are they? Men at all? or small movable forts and magazines, at the service of some unscrupulous man in power?"

"Under a government that which imprisons any unjustly", Thoreau wrote, "the true place for a just man is in prison." Civil Disobedience influenced Tolstoy, Gandhi and Martin Luther King, and it anticipated the Nuremberg Principles.

### **Harmony with nature**

Thoreau became the friend and companion of the transcendentalist writer Ralph Waldo Emerson (1803 1882), who introduced him to a circle of New England writers and thinkers that included Ellery Channing, Margaret Fuller and Nathaniel Hawthorne.

Nathaniel Hawthorne described Thoreau in the following words: "Mr. Thorow [sic] is a keen and delicate observer of nature, a genuine observer, which, I suspect, is almost as rare a character as even an original poet; and Nature, in return for his love, seems to adopt him as her especial child, and



Figure 11.1: *Henry David Thoreau (1817-1862). Public domain, Wikimedia Commons*

shows him secrets which few others are allowed to witness. He is familiar with beast, fish, fowl, and reptile, and has strange stories to tell of adventures, and friendly passages with these lower brethren of mortality. Herb and flower, likewise, wherever they grow, whether in garden, or wild wood, are his familiar friends. He is also on intimate terms with the clouds and can tell the portents of storms. It is a characteristic trait, that he has a great regard for the memory of the Indian tribes, whose wild life would have suited him so well; and strange to say, he seldom walks over a plowed field without picking up an arrow-point, a spear-head, or other relic of the red men, as if their spirits willed him to be the inheritor of their simple wealth."

### **Walden, an experiment in simple living**

At Emerson's suggestion, Thoreau opened a journal, in which he recorded his observations concerning nature and his other thoughts. Ultimately the journal contained more than 2 million words. Thoreau drew on his journal when writing his books and essays, and in recent years, many previously unpublished parts of his journal have been printed.

From 1845 until 1847, Thoreau lived in a tiny cabin that he built with his own hands. The cabin was in a second-growth forest beside Walden Pond in Concord, on land that belonged to Emerson. Thoreau regarded his life there as an experiment in simple living. He described his life in the forest and his reasons for being there in his book *Walden*,

"Most of the luxuries", Thoreau wrote, "and many of the so-called comforts of life, are not only not indispensable, but positive hindrances to the elevation of mankind. With respect to luxuries, the wisest have ever lived a more simple and meager life than the poor. The ancient philosophers, Chinese, Hindoo, Persian, and Greek, were a class than which none has been poorer in outward riches, none so rich in inward."

Elsewhere in *Walden*, Thoreau remarks, "It is never too late to give up your prejudices", and he also says, "Why should we be in such desperate haste to succeed, and in such desperate enterprises? If a man does not keep pace with his companions, perhaps it is because he hears a different drummer." Other favorite quotations from Thoreau include "Rather than love, than money, than fame, give me truth", "Beware of all enterprises that require new clothes", "Most men lead lives of quiet desperation" and "Men have become tools of their tools."

Thoreau's closeness to nature can be seen from the following passage, written by his friend Frederick Willis, who visited him at Walden Pond in 1847, together with the Alcott family: "He was talking to Mr. Alcott of the wild flowers in Walden woods when, suddenly stopping, he said: 'Keep very still

and I will show you my family.’ Stepping quickly outside the cabin door, he gave a low and curious whistle; immediately a woodchuck came running towards him from a nearby burrow. With varying note, yet still low and strange, a pair of gray squirrels were summoned and approached him fearlessly. With still another note several birds, including two crows flew towards him, one of the crows nestling upon his shoulder. I remember that it was the crow resting close to his head that made the most vivid impression on me, knowing how fearful of man this bird is. He fed them all from his hand, taking food from his pocket, and petted them gently before our delighted gaze; and then dismissed them by different whistling, always strange and low and short, each wild thing departing instantly at hearing his special signal.”

### Thoreau’s views on religion

Towards the end of his life, when he was very ill, someone asked Thoreau whether he had made his peace with God. “We never quarreled”, he answered.

In an essay published by the Atlantic Monthly in 1853, Thoreau described a pine tree in Maine with the words: “It is as immortal as I am, and perchance will go to as high a heaven, there to tower above me still.” However, the editor (James Russell Lowell) considered the sentence to be blasphemous, and removed it from Thoreau’s essay.

In one of his essays, Thoreau wrote: “If a man walk in the woods for love of them half of each day, he is in danger of being regarded as a loafer; but if he spends his whole day as a speculator, shearing off those woods and making the earth bald before her time, he is esteemed an industrious and enterprising citizen.”

### A few more things that Thoreau said

*It is the beauty within us that makes it possible for us to recognize the beauty around us. The question is not what you look at, but what you see.*

*Simplify your life. Don’t waste the years struggling for things that are unimportant. Don’t burden yourself with possessions. Keep your needs and wants simple and enjoy what you have. Don’t destroy your peace of mind by looking back, worrying about the past. Live in the present. Simplify!*

*Go confidently in the direction of your dreams. Live the life you’ve imagined.*

*Happiness is like a butterfly; the more you chase it, the more it will elude you, but if you turn your attention to other things, it will come and sit softly on your shoulder.*

*Rather than love, than money, than fame, give me truth.*

*The mass of men lead lives of quiet desperation.*

*You must live in the present, launch yourself on every wave, find your eternity in each moment. Fools stand on their island of opportunities and look toward another land. There is no other land; there is no other life but this*

*Be not simply good, be good for something,*

*Books are the treasured wealth of the world and the fit inheritance of generations and nations.*

*If you have built castles in the air, your work need not be lost; that is where they should be. Now put the foundations under them.*

*If a man does not keep pace with his companions, perhaps it is because he hears a different drummer. Let him step to the music he hears, however measured or far away.*

*The greatest compliment that was ever paid me was when one asked me what I thought, and attended to my answer.*

*We need the tonic of wildness...At the same time that we are earnest to explore and learn all things, we require that all things be mysterious and unexplorable, that land and sea be indefinitely wild, unsurveyed and unfathomed by us because unfathomable. We can never have enough of nature.*

## 11.3 Gandhian economics

In his autobiography, Mahatma Gandhi says: “Three moderns have left a deep impression on my life and captivated me: Raychandbhai (the Indian philosopher and poet) by his living contact; Tolstoy by his book ‘The Kingdom of God is Within You’; and Ruskin by his book ‘Unto This Last’.” Ruskin’s book, “Unto This Last”, which Gandhi read in 1904, is a criticism of modern

industrial society. Ruskin believed that friendships and warm interpersonal relationships are a form of wealth that economists have failed to consider. He felt that warm human contacts are most easily achieved in small agricultural communities, and that therefore the modern tendency towards centralization and industrialization may be a step backward in terms of human happiness. While still in South Africa, Gandhi founded two religious Utopian communities based on the ideas of Tolstoy and Ruskin, Phoenix Farm (1904) and Tolstoy Farm (1910).

Because of his growing fame as the leader of the Indian civil rights movement in South Africa, Gandhi was persuaded to return to India in 1914 and to take up the cause of Indian home rule. In order to reacquaint himself with conditions in India, he travelled tirelessly, now always going third class as a matter of principle.

During the next few years, Gandhi worked to reshape the Congress Party into an organization which represented not only India's Anglicized upper middle class but also the millions of uneducated villagers who were suffering under an almost intolerable burden of poverty and disease. In order to identify himself with the poorest of India's people, Gandhi began to wear only a white loincloth made of rough homespun cotton. He traveled to the remotest villages, recruiting new members for the Congress Party, preaching non-violence and "firmness in the truth", and becoming known for his voluntary poverty and humility. The villagers who flocked to see him began to call him "Mahatma" (Great Soul).

Disturbed by the spectacle of unemployment and poverty in the villages, Gandhi urged the people of India to stop buying imported goods, especially cloth, and to make their own. He advocated the reintroduction of the spinning wheel into village life, and he often spent some hours spinning himself. The spinning wheel became a symbol of the Indian independence movement, and was later incorporated into the Indian flag.

The movement for boycotting British goods was called the "Swadeshi movement". The word Swadeshi derives from two Sanskrit roots: Swa, meaning self, and Desh, meaning country. Gandhi described Swadeshi as "a call to the consumer to be aware of the violence he is causing by supporting those industries that result in poverty, harm to the workers and to humans or other creatures."

Gandhi tried to reconstruct the crafts and self-reliance of village life that he felt had been destroyed by the colonial system. "I would say that if the village perishes, India will perish too", he wrote, "India will be no more India. Her own mission in the world will get lost. The revival of the village is only possible when it is no more exploited. Industrialization on a mass scale will necessarily lead to passive or active exploitation of the villagers as problems of competition and marketing come in. Therefore we have to concentrate on

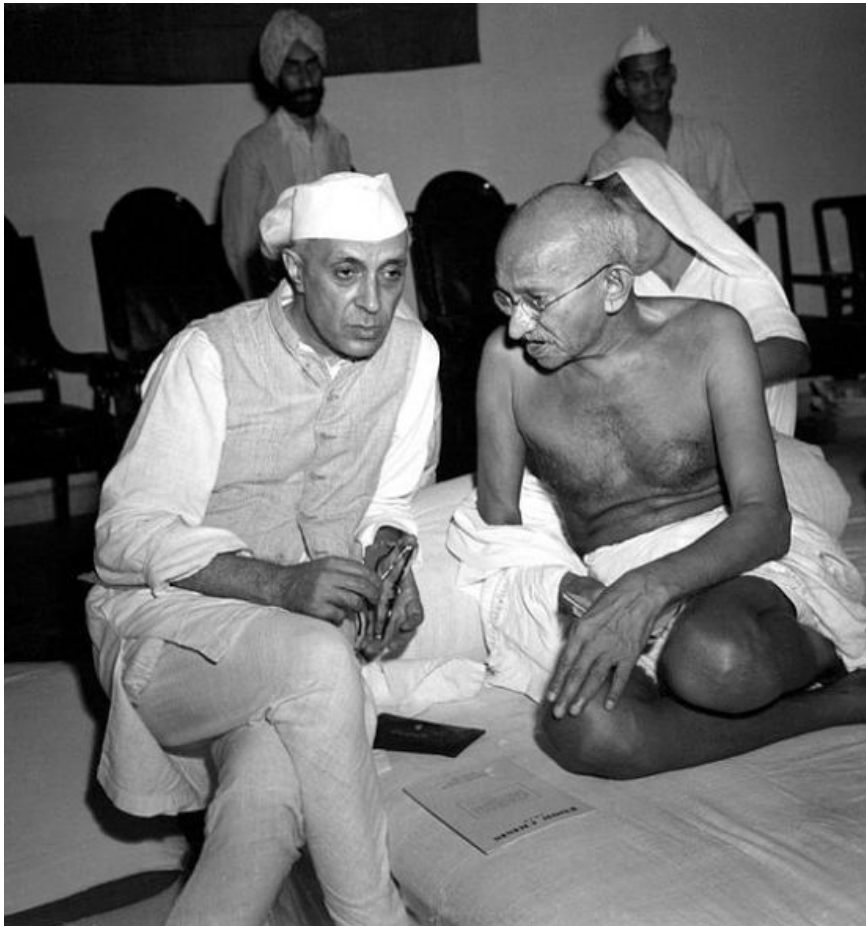


Figure 11.2: *Gandhi with Rashtrapati Jawaharlal Nehru, during a meeting of the All India Congress, Bombay, India. Today, it is Nehru's economic policy of industrialization and urbanization rather than Gandhi's that dominates India, but it is Gandhi's model that is sustainable. Author: Credited to Dave Davis, Acme Newspictures Inc., correspondent. Photo taken by Max Desfor, who gave it to Dave Davis. Wikimedia Commons*

the village being self-contained, manufacturing mainly for use. Provided this character of the village industry is maintained, there would be no objection to villagers using even the modern machines that they can make and can afford to use. Only they should not be used as a means of exploitation by others.”

“You cannot build nonviolence on a factory civilization, but it can be built on self-contained villages... Rural economy as I have conceived it, eschews exploitation altogether, and exploitation is the essence of violence... We have to make a choice between India of the villages that are as ancient as herself and India of the cities which are a creation of foreign domination...”

“Machinery has its place; it has come to stay. But it must not be allowed to displace necessary human labour. An improved plow is a good thing. But if by some chances, one man could plow up, by some mechanical invention of his, the whole of the land of India, and control all the agricultural produce, and if the millions had no other occupation, they would starve, and being idle, they would become dunces, as many have already become. There is hourly danger of many being reduced to that unenviable state.”

In these passages we see Gandhi not merely as a pioneer of nonviolence; we see him also as an economist. Faced with misery and unemployment produced by machines, Gandhi tells us that social goals must take precedence over blind market mechanisms. If machines are causing unemployment, we can, if we wish, and use labor-intensive methods instead. With Gandhi, the free market is not sacred; we can do as we wish, and maximize human happiness, rather than maximizing production and profits.

Mahatma Gandhi was assassinated by a Hindu extremist on January 30, 1948. After his death, someone collected and photographed all his worldly goods. These consisted of a pair of glasses, a pair of sandals, a pocket watch and a white homespun loincloth. Here, as in the Swadeshi movement, we see Gandhi as a pioneer of economics. He deliberately reduced his possessions to an absolute minimum in order to demonstrate that there is no connection between personal merit and material goods. Like Veblen, Mahatma Gandhi told us that we must stop using material goods as a means of social competition. We must start to judge people not by what they have, but by what they are.<sup>1</sup>

Gandhi’s vision of an “India of villages” rather than an “India of cities” has much in common with the Transition Town movement, which we will discuss next.

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<sup>1</sup>[https://en.wikipedia.org/wiki/Gandhian\\_economics](https://en.wikipedia.org/wiki/Gandhian_economics)  
<http://bollier.org/blog/gandhian-economics-and-commons>  
<http://caravan.squat.net/ICC-en/Krrs-en/ghandi-econ-en.htm>  
<http://www.mkgandhi.org/ebks/untothislast.pdf>  
[https://en.wikipedia.org/wiki/Unto\\_This\\_Last](https://en.wikipedia.org/wiki/Unto_This_Last)  
<http://www.efm.bris.ac.uk/het/ruskin/ruskin>





Figure 11.3: *Totnes, Devon, England: a transition town.* Author: Manfred Heyde, Wikimedia Commons

## Transition Towns

The Transition Town Movement of today is a response to the end of the fossil fuel era and the threat of economic collapse. It can be thought of as a modern branch of the Cooperative Movement. In 2006, the Transition Town of Totnes in Devon, England was the first to use this name, which implied a transition from globalism, consumerism and growth to a sustainable, local and self-sufficient economy. The ideal was to produce locally all the necessary food for the town, and as much of other necessities as possible. In this way, the energy expenditures involved in transportation could be avoided.

Today there are more than a thousand Transition Towns and they are located in 43 countries. Many of them have local currencies which are legal tender within the town. If the pioneers of this movement are right in saying that this is the only sustainable model for the future, we may wonder whether mega-cities will be able to survive in the long-term future.<sup>2</sup>

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<sup>2</sup><https://en.wikipedia.org/wiki/Degrowth>  
<http://commondreams.org/views/2015/07/31/we-are-all-greece>  
<http://www.localfutures.org/>  
<http://www.powells.com/biblio/7-9780871566430-2>

## 11.4 We must not use possessions for social competition!

There is something ethically wrong with using material goods for the purpose of social competition at a time when excessive consumption is destroying our planet. Also, in our century, the world's resources are nearing exhaustion, and roughly 40,000 children die every day from starvation or from poverty-related diseases..

The whole structure of western society seems designed to push its citizens towards ever-increasing levels of consumption. The mass media hold before us continually the ideal of a personal utopia filled with material goods. Every young man in a modern industrial society feels that he is a failure unless he fights his way to the "top"; and in recent years, women too have been drawn into this competition.

Of course not everyone can reach the top; there would not be room for everyone; but society urges all us to try, and we feel a sense of failure if we do not reach the goal. Thus, modern life has become a struggle of all against all for power and possessions.

One of the central problems in reducing consumption is that in our present economic and social theory, consumption has no upper bound; there is no definition of what is enough; there is no concept of a state where all of the real needs of a person have been satisfied. In our growth-oriented present-day economics, it is assumed that, no matter how much a person earns, he or she is always driven by a desire for more.

The phrase "conspicuous consumption" was invented by the Norwegian-American economist Thorstein Veblen (1857-1929) in order to describe the way in which our society uses economic waste as a symbol of social status. In "The Theory of the Leisure Class", first published in 1899, Veblen pointed out that it wrong to believe that human economic behavior is rational, or that it can be understood in terms of classical economic theory. To understand it, Veblen maintained, one might better make use of insights gained from anthropology, psychology, sociology, and history.

The sensation caused by the publication of Veblen's book, and the fact that his phrase, "conspicuous consumption", has become part of our language, indicate that his theory did not completely miss its mark. In fact, modern advertisers seem to be following Veblen's advice: Realizing that much of the output of our economy will be used for the purpose of establishing the social status of consumers, advertising agencies hire psychologists to appeal to the consumer's longing for a higher social position.

When possessions are used for the purpose of social competition, demand has no natural upper limit; it is then limited only by the size of the human ego,

which, as we know, is boundless. This would be all to the good if unlimited economic growth were desirable. But today, when further industrial growth implies future collapse, western society urgently needs to find new values to replace our worship of power, our restless chase after excitement, and our admiration of excessive consumption.

The voice of Henry David Thoreau is also a useful and wise one. “Most of the luxuries”, Thoreau wrote, “and many of the so-called comforts of life, are not only not indispensable, but positive hindrances to the elevation of mankind. With respect to luxuries, the wisest have ever lived a more simple and meager life than the poor. The ancient philosophers, Chinese, Hindoo, Persian, and Greek, were a class than which none has been poorer in outward riches, none so rich in inward.”

## 11.5 Benefits of equality

The Industrial Revolution opened up an enormous gap in military strength between the industrialized nations and the rest of the world. Taking advantage of their superior weaponry, Europe, the United States and Japan rapidly carved up the remainder of the world into colonies, which acted as sources of raw materials and food, and as markets for manufactured goods. Between 1800 and 1914, the percentage of the earth under the domination of colonial powers increased to 85 percent, if former colonies are included.

The English economist and Fabian, John Atkinson Hobson (1858-1940), offered a famous explanation of the colonial era in his book “Imperialism: A Study” (1902). According to Hobson, the basic problem that led to colonial expansion was an excessively unequal distribution of incomes in the industrialized countries. The result of this unequal distribution was that neither the rich nor the poor could buy back the total output of their society. The incomes of the poor were insufficient, and rich were too few in number. The rich had finite needs, and tended to reinvest their money. As Hobson pointed out, reinvestment in new factories only made the situation worse by increasing output.

Hobson had been sent as a reporter by the Manchester Guardian to cover the Second Boer War. His experiences had convinced him that colonial wars have an economic motive. Such wars are fought, he believed, to facilitate investment of the excess money of the rich in African or Asian plantations and mines, and to make possible the overseas sale of excess manufactured goods. Hobson believed imperialism to be immoral, since it entails suffering both among colonial peoples and among the poor of the industrial nations. The cure that he recommended was a more equal distribution of incomes in

the manufacturing countries.

Interestingly, TED Talks (ideas worth spreading) was recently under fire from many progressive groups for censoring a short talk by the adventure capitalist, Nick Hanauer, entitled “Income Inequality”. In this talk, Hanauer says exactly the same thing as John Hobson, but he applies the ideas, not to colonialism, but to current unemployment in the United States. Hanauer says that the rich are unable to consume the products of society because they are too few in number. To make an economy work, demand must be increased, and for this to happen, the distribution of incomes must become much more equal than it is today in the United States.

TED has now posted Hanauer’s talk, and the interested reader can find another wonderful TED talk dealing with the same issues from the standpoint of health and social problems. In a splendid lecture entitled “How economic inequality harms societies”, Richard Wilkinson demonstrates that there is almost no correlation between gross national product and a number of indicators of the quality of life, such as physical health, mental health, drug abuse, education, imprisonment, obesity, social mobility, trust, violence, teenage pregnancies and child well-being. On the other hand he offers comprehensive statistical evidence that these indicators are strongly correlated with the degree of inequality within countries, the outcomes being uniformly much better in nations where income is more equally distributed.

Warren Buffet famously remarked, “There’s class warfare, all right. But it’s my class, the rich class, that’s making war, and we’re winning.” However, the evidence presented by Hobson, Hanauer and Wilkinson shows conclusively that no one wins in a society where inequality is too great, and everyone wins when incomes are more evenly distributed.

## **We must decrease economic inequality**

In his Apostolic Exhortation, “*Evangelii Gaudium*”, Pope Francis said:

“In our time humanity is experiencing a turning-point in its history, as we can see from the advances being made in so many fields. We can only praise the steps being taken to improve people’s welfare in areas such as health care, education and communications. At the same time we have to remember that the majority of our contemporaries are barely living from day to day, with dire consequences. A number of diseases are spreading. The hearts of many people are gripped by fear and desperation, even in the so-called rich countries. The joy of living frequently fades, lack of respect for others and violence are on the rise, and inequality is increasingly evident. It is a struggle to live and, often, to live with precious little dignity.”

“This epochal change has been set in motion by the enormous qualitative,

quantitative, rapid and cumulative advances occurring in the sciences and in technology, and by their instant application in different areas of nature and of life. We are in an age of knowledge and information, which has led to new and often anonymous kinds of power.”

“Just as the commandment ‘Thou shalt not kill’ sets a clear limit in order to safeguard the value of human life, today we also have to say ‘thou shalt not’ to an economy of exclusion and inequality. Such an economy kills. How can it be that it is not a news item when an elderly homeless person dies of exposure, but it is news when the stock market loses two points? This is a case of exclusion. Can we continue to stand by when food is thrown away while people are starving? This is a case of inequality. Today everything comes under the laws of competition and the survival of the fittest, where the powerful feed upon the powerless. As a consequence, masses of people find themselves excluded and marginalized: without work, without possibilities, without any means of escape.”

“In this context, some people continue to defend trickle-down theories which assume that economic growth, encouraged by a free market, will inevitably succeed in bringing about greater justice and inclusiveness in the world. This opinion, which has never been confirmed by the facts, expresses a crude and naive trust in the goodness of those wielding economic power and in the sacralized workings of the prevailing economic system. Meanwhile, the excluded are still waiting.”

In a recent speech, Senator Bernie Sanders quoted Pope Francis extensively and added: “We have a situation today, Mr. President, incredible as it may sound, where the wealthiest 85 people in the world own more wealth than the bottom half of the world’s population.”<sup>3</sup>

The social epidemiologist Prof. Richard Wilkinson, has documented the ways in which societies with less economic inequality do better than more unequal societies in a number of areas, including increased rates of life expectancy, mathematical performance, literacy, trust, social mobility, together with decreased rates of infant mortality, homicides, imprisonment, teenage births, obesity and mental illness, including drug and alcohol addiction.<sup>4</sup> We must also remember that according to the economist John A. Hobson, the basic problem that led to imperialism was an excessively unequal distribution of incomes in the industrialized countries. The result of this unequal distribution

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<sup>3</sup>[https://www.youtube.com/watch?v=9\\_LJpN893Vg](https://www.youtube.com/watch?v=9_LJpN893Vg)  
<https://www.oxfam.org/en/tags/inequality>  
[https://www.oxfam.org/sites/www.oxfam.org/files/file\\_attachments/cr-even-it-up-extreme-inequality-291014-en.pdf](https://www.oxfam.org/sites/www.oxfam.org/files/file_attachments/cr-even-it-up-extreme-inequality-291014-en.pdf)

<sup>4</sup><https://www.youtube.com/watch?v=cZ7LzE3u7Bw>  
[https://en.wikipedia.org/wiki/Richard\\_G.\\_Wilkinson](https://en.wikipedia.org/wiki/Richard_G._Wilkinson)

was that neither the rich nor the poor could buy back the total output of their society. The incomes of the poor were insufficient, and rich were too few in number.

## 11.6 Culture and internationalism

Cultural and educational activities have a small ecological footprint, and therefore are more sustainable than pollution-producing, fossil-fuel-using jobs in industry. Furthermore, since culture and knowledge are shared among all nations, work in culture and education leads societies naturally towards internationalism and peace.

Economies based on a high level of consumption of material goods are unsustainable and will have to be abandoned by a future world that renounces the use of fossil fuels in order to avoid catastrophic climate change, a world where non-renewable resources such as metals will become increasingly rare and expensive. How then can full employment be maintained?

The creation of renewable energy infrastructure will provide work for a large number of people; but in addition, sustainable economies of the future will need to shift many workers from jobs in industry to jobs in the service sector. Within the service sector, jobs in culture and education are particularly valuable because they will help to avoid the disastrous wars that are currently producing enormous human suffering and millions of refugees, wars that threaten to escalate into an all-destroying global thermonuclear war.<sup>5</sup>

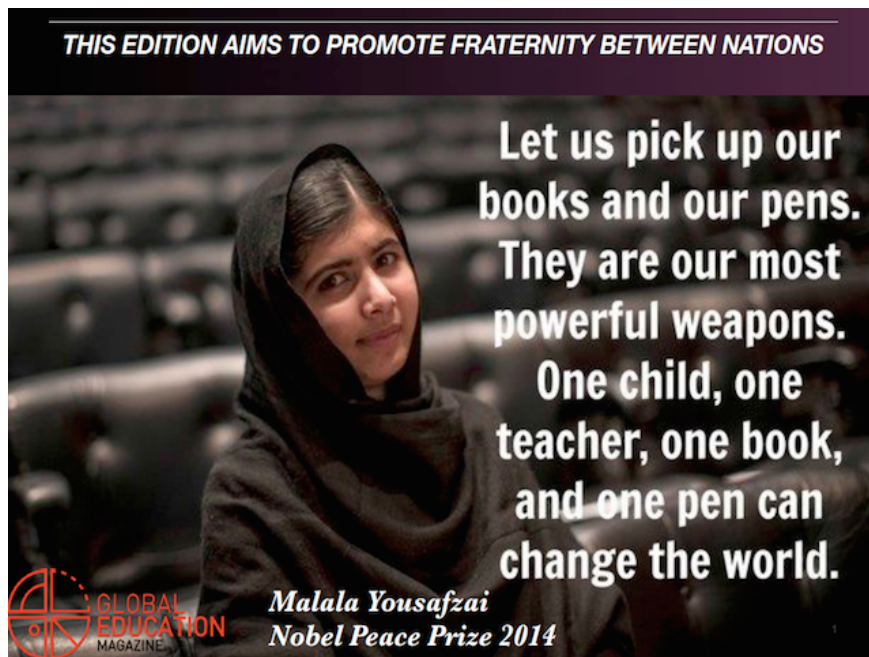
Human nature has two sides: It has a dark side, to which nationalism and militarism appeal; but our species also has a genius for cooperation, which we can see in the growth of culture. Our modern civilization has been built up by means of a worldwide exchange of ideas and inventions. It is built on the achievements of many ancient cultures. China, Japan, India, Mesopotamia, Egypt, Greece, the Islamic world, Christian Europe, and the Jewish intellectual traditions all have contributed. Potatoes, corn, squash, vanilla, chocolate, chilli peppers, and quinine are gifts from the American Indians.<sup>6</sup>

We need to reform our educational systems, particularly the teaching of history. As it is taught today, history is a chronicle of power struggles and war, told from a biased national standpoint. We are taught that our own country is always heroic and in the right. We urgently need to replace this indoctrination in chauvinism by a reformed view of history, where the slow development of human culture is described, giving credit to all who have contributed. When

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<sup>5</sup><http://www.fredsakademiet.dk/library/need.pdf>  
<http://eruditio.worldacademy.org/issue-5/article/urgent-need-renewable-energy>

<sup>6</sup><http://eruditio.worldacademy.org/article/evolution-cooperation>



we teach history, it should not be about power struggles. It should be about how human culture was gradually built up over thousands of years by the patient work of millions of hands and minds. Our common global culture, the music, science, literature and art that all of us share, should be presented as a precious heritage - far too precious to be risked in a thermonuclear war.

We have to extend our loyalty to the whole of the human race, and to work for a world not only free from nuclear weapons, but free from war. A war-free world is not utopian but very practical, and not only practical but necessary.



It is something that we can achieve and must achieve. Today there are large regions, such as the European Union, where war would be inconceivable. What is needed is to extend these.

Nor is a truly sustainable economic system utopian or impossible. To achieve it, we should begin by shifting jobs to the creation of renewable energy infrastructure, and to the fields of culture and education. By so doing we will support human solidarity and avoid the twin disasters of catastrophic war and climate change.

## 11.7 Caring for our children

We give our children loving care, but it makes no sense to do so and at the same time to neglect to do all that is within our power to ensure that they and their descendants will inherit an earth in which they can survive. We also have a responsibility to all the other living organisms with which we share the gift of life.

Inaction is not an option. We have to act with courage and dedication, even if the odds are against success, because the stakes are so high. The mass media could mobilize us to action, but they have failed in their duty. Our educational system could also wake us up and make us act, but it too has failed us. The battle to save the earth from human greed and folly has to be fought in the alternative media. Hence this book, printed by a small peace-oriented Swedish publisher, and hence urgent the tone of this final chapter.

We need a new economic system, a new society, a new social contract, a new way of life. Here are the great tasks that history has given to our generation: We must achieve a steady-state economic system. We must restore democracy. We must decrease economic inequality. We must break the power of corporate greed. We must leave fossil fuels in the ground. We must stabilize and ultimately reduce the global population. We must eliminate the institution of war. And finally, we must develop a more mature ethical system to match our new technology.

## 11.8 Our duty to the biosphere

### We need to learn from long-established cultures

The era of colonialism has left the industrialized countries with a rather arrogant attitude towards other cultures. Although formal political colonialism



has almost entirely vanished, many of the assumptions of the colonial era persist and are strongly supported by the mainstream mass media. It is assumed by many people in the industrialized North that if the developing countries would only learn mass production, modern farming techniques and a modern lifestyle, all would be well. However, a sustainable global future may require a transfer of knowledge, techniques and attitudes in precisely the opposite direction - from pre-industrial societies to highly industrialized ones. The reason for this is that the older societies have cultures that allow them to live in harmony with nature, and this is exactly what the highly industrial North must learn to do.

Industrialism and the rapid development of science and technology have given some parts of the world a 200-year period of unbroken expansion and growth, but today this growth is headed for a collision with a wall-like barrier - limits set by the carrying capacity of the global environment and by the exhaustion of non-renewable resources. Encountering these limits is a new experience for the the industrialized countries. By contrast, pre-industrial societies have always experienced limits. The industrialized world must soon replace the economics of growth with equilibrium economics. Pre-industrial societies have already learned to live in equilibrium - in harmony with nature.

Like biodiversity, cultural diversity is an extremely valuable resource, and for similar reasons. A large genetic pool gives living organisms the flexibility needed to adapt to changes in the environment. Similarly, cultural diversity can give humans the flexibility needed to cope with change. In the changed world of today (changed by the invention of thermonuclear weapons and by the extraordinary growth of global population and commerce) we urgently need to learn to live in harmony, in harmony with ourselves, in harmony with nature, and in harmony with other members of our species. We can do this if we draw on the full human heritage of cultural diversity. We can draw not only on the knowledge and wisdom of presently existing societies, but also on the experiences and ideas of societies of the past.

- **The Pythagorean concept of harmony:** In the ancient world, the concept of harmony was developed to a high level by the Pythagoreans. The Pythagoreans used the idea of harmony to understand medicine, music, mathematics and ethics. A description of Pythagorean ideals can be found on this website in Chapter 2 of *Science and Society*.
- **The concept of harmony in Chinese civilization:** Chinese civilization is very ancient, and it has made many extremely important contributions to the cultural heritage of the world - for example, the invention of paper, ink, printing and the magnetic compass. Agriculture began in

China as early as 6,000 B.C. The art of working in bronze was developed in China during the Shang dynasty (1,500 B.C. - 1,100 B.C.) and it reached a high pitch of excellence in the Chou dynasty (1,100 B.C. - 250 B.C.).

In the Chou period, many of the cultural characteristics which we recognize as particularly Chinese were developed. During this period, the Chinese evolved a code of behavior based on politeness and ethics. Much of this code of behavior is derived from the teachings of K'ung Fu-tzu (Confucius), a philosopher and government official who lived between 551 B.C. and 479 B.C.. The "Golden Rule" was known to K'ung Fu-tzu, but was formulated in a negative way: "Do not do to others anything that you would not like them do to you".

The rational teachings of K'ung Fu-tzu were complemented by the more mystical and intuitive doctrines of Lao-tzu and his followers. Lao-tzu lived at about the same time as K'ung Fu-tzu, and he founded the Taoist religion. The Taoists believed that unity with nature could be achieved by passively blending oneself with the forces of nature.

On the whole, politicians and scholars followed the practical teachings of K'ung Fu-tzu, while poets and artists became Taoists. The intuitive sensitivity to nature inspired by Taoist beliefs allowed these artists and poets to achieve literature and art of unusual vividness and force with great economy of means. The Taoist religion has much in common with Buddhism, and its existence in China paved the way for the spread of Buddhism from India to China and Japan.

Taoist and Confucian teachings each emphasized a particular aspect of harmony. Taoism emphasized harmony with nature, while Confucianism taught harmonious relationships between humans. Thus in China, harmony became an ideal advocated by both traditions. The Chinese respect for harmony as an ideal can be seen, for example, in the beautiful Temple of Divine Harmony in Beijing.

- **India:** Evidence of a very early river-valley civilization in India has been found at a site called Mohenjo-Daro. However, in about 2,500 B.C., this early civilization was destroyed by some great disaster, perhaps a series of floods; and for the next thousand years, little is known about the history of India. During this dark period between 2,500 B.C. and 1,500 B.C., India was invaded by the Indo-Aryans, who spoke Sanskrit, a language related to Greek. The Indo-Aryans partly drove out and partly enslaved the native Dravidians. However, there was much intermarriage between

the groups, and to prevent further intermarriage, the Indo-Aryans introduced a caste system sanctioned by religion.

According to Hindu religious belief, the soul of a person who has died is reborn in another body. If, throughout his life, the person has faithfully performed the duties of his caste, then his or her soul may be reborn into a higher caste. Finally, after existing as a Brahman, the soul may be so purified that it can be released from the cycle of death and rebirth.

In the 6th century B.C., Gautama Buddha founded a new religion in India. Gautama Buddha was convinced that all the troubles of humankind spring from an excessive attachment to earthly things. He felt that the only escape from sorrow is through the renunciation of earthly desires. He also urged his disciples to follow a high ethical code, the Eightfold Way. Among the sayings of Buddha are the following:

“Hatred does not cease by hatred at any time; hatred ceases by love.”

“Let a man overcome anger by love; let him overcome evil by good.”

“All men tremble at punishment. All men love life. Remember that you are like them, and do not cause slaughter.”

Both Hindu and Buddhist traditions emphasize the unity of all life on earth. Hindus regard killing an animal as a sin, and many try to avoid accidentally stepping on insects as they walk. (The Hindu and Buddhist picture of the relatedness of all life on earth has been confirmed by modern biological science. We now know that all living organisms have the same fundamental biochemistry, based on DNA, RNA, proteins and polysaccharides, and we know that our own human genomes are more similar to than different from the genomes of our close relations in the animal world.)

The peoples of the industrialized nations urgently need to acquire a non-anthropocentric element in their ethics, similar to reverence for all life found in the Hindu and Buddhist traditions, as well as in the teachings of Saint Francis of Assisi and Albert Schweitzer. We need to learn to value other species for their own sakes, and not because we expect to use them for our own economic goals.

The Buddhist concept of karma has great value in human relations. The word “karma” means simply “action”. In Buddhism, one believes that actions return to the actor. Good actions will be returned, and bad actions will also be returned. This is obviously true in social relationships. If we behave with kindness and generosity to our neighbors, they will return our kindness. Conversely, a harmful act may lead to a vicious circle

of revenge and counter-revenge which can only be broken by returning good for evil. However the concept of karma has a broader and more abstract validity beyond the direct return of actions to the actor.

When we perform a good action, we increase the total amount of good karma in the world. If all people similarly behave well, the world as a whole will become more pleasant and more safe. Human nature seems to have a built-in recognition of this fact, and we are rewarded by inner happiness when we perform good and kind actions. In his wonderful book, “Ancient Wisdom, Modern World”, the Dalai Lama says that good actions lead to happiness and bad actions to unhappiness even if our neighbors do not return these actions. Inner peace, he tells us, is incompatible with bad karma and can be achieved only through good karma, i.e. good actions.

There is a great deal of similarity between the Buddhist concept of karma and some of the ethical principles of Christianity, particularly principles that appear in the Sermon on the Mount. Also Buddha’s saying “Hatred does not cease by hatred at any time; hatred ceases by love” echoes the Christian principle of returning good for evil. Both are aimed at stopping vicious circles of revenge and counter-revenge, such as those that can now be observed in the Middle East.

More details about the Chinese and Indian civilizations can be found in Chapter 4 of *Science and Society*

- **Bhutan** Before the doors of Bhutan were cautiously opened to visitors in 1974, the country remained aloof from the modern world. One of the most striking characteristics of the ancient Bhutanese culture was that most of the actions of its citizens were done from a sense of duty and tradition, rather than for economic reasons. The citizens of Bhutan derived great happiness from these actions. For example, caring for the elderly was to them not only a duty but also a great source of pleasure. It is doubtful whether modernization will increase the happiness of the Bhutanese.
- **Harmony with nature in the Native American culture:** The attitude towards nature of the Sioux can be seen from the following quotations from *Land of the Spotted Eagle* by the Lakota (Western Sioux) chief, Standing Bear (ca. 1834 - 1908):

“The Lakota was a true lover of Nature. He loved the earth and all things of the earth... From Waken Tanka (the Great Spirit) there came a great unifying life force that flowered in and through all things – the flowers

of the plains, blowing winds, rocks, trees, birds, animals – and was the same force that had been breathed into the first man. Thus all things were kindred and were brought together by the same Great Mystery.”

“Kinship with all creatures of the earth, sky, and water was a real and active principle. For the animal and bird world there existed a brotherly feeling that kept the Lakota safe among them. And so close did some of the Lakota come to their feathered and furred friends that in true brotherhood they spoke a common tongue.”

“The animal had rights – the right of man’s protection, the right to live, the right to multiply, the right to freedom, and the right to man’s indebtedness – and in recognition of these rights the Lakota never enslaved the animal, and spared all life that was not needed for food and clothing.”

“This concept of life was humanizing and gave to the Lakota an abiding love. It filled his being with the joy and mystery of things; it gave him reverence for all life; it made a place for all things in the scheme of existence with equal importance to all. The Lakota could despise no creature, for all were one blood, made by the same hand, and filled with the essence of the Great Mystery.”

A similar attitude towards nature can be found in traditional Inuit cultures.

- **St. Francis of Assisi (1181-1226) and Mahatma Gandhi (1869-1948):** There are similarities between the doctrines of these two great ethical teachers. Both came from wealthy families, but during the course of their lives they acquired strong sympathy with the poor and rejected excessive attachment to worldly goods. Both dressed in the simplest possible rough homespun clothes. (Gandhi said, “Live simply that others may simply live.”) Both taught peace between humans and kindness to all life. St. Francis is said to have preached sermons to the birds; Gandhi personally took care of sick animals in his ashram.
- **Respect for nature in African cultures:** In some parts of Africa, a man who plans to cut down a tree offers a prayer of apology, telling the tree why necessity has forced him to harm it. This pre-industrial attitude is something from which the industrialized North could learn. In industrial societies, land “belongs” to some one, and the owner has the “right” to ruin the land or to kill the communities of creatures living on it if this happens to give some economic advantage, in much the same way that a Roman slaveowner was thought to have the “right” to kill his slaves. Pre-industrial societies have a much less rapacious and much

more custodial attitude towards the land and towards its non-human inhabitants.

- **Preservation of the land for future generations:** Many traditional agricultural societies have an ethical code that requires them to preserve the fertility of the land for future generations. This recognition of a duty towards the distant future is in strong contrast to the shortsightedness of modern economists. For example, John Maynard Keynes has been quoted as saying “In the long run, we will all be dead”, meaning that we need not look that far ahead. By contrast, members of traditional agricultural societies recognize that their duties extend far into the distant future, since their descendants will still be alive.

The pre-industrial societies and ethical teachers mentioned above have much to tell us about how to achieve harmony with ourselves, harmony with nature, and harmony with other members of our own species. Of course it is necessary to learn from the best aspects of each culture and not the worst. Also we must remember that the population of the world is now so large that a complete return to a pre-industrial way of life would not be possible. However, some of the values and attitudes of pre-industrial cultures can help us to an awareness of what it will take to achieve a truly sustainable global society.

The advertising-driven orgies of consumerism that characterize modern market economies cannot be extended into the distant future because of limitations that will be imposed by exhaustion of non-renewable resources and by the limited carrying capacity of the global environment. Therefore we need to stop using material goods as a measure of merit. Gandhi deliberately reduced his possessions to a minimum in order to demonstrate that merit and goods are not synonymous. St. Francis did the same. We can learn from them, and from the values of pre-industrial societies, to stop worshipping the false ideals, *Power*, *Dominance*, *Growth*, and *Profit*. Instead we must learn to live in *Harmony*.

## Education for a harmonious future

Our educational system must reflect the kind of world that we want for the future. What kind of world do we want? We want a world where war is abolished as an institution, and where the enormous resources now wasted on war are used constructively. We want a world where a stable population of moderate size lives in comfort and security, free from fear of hunger or unemployment. We want a world where peoples of all countries have equal access to resources, and an equal quality of life. We want a world with a new economic system, not designed to produce unlimited growth, but aiming instead at meeting the

real needs of the human community in equilibrium with the global environment. We want a world of changed values, where extravagance and waste are regarded as morally wrong; where kindness, wisdom and beauty are admired; and where the survival of other species than our own is regarded as an end in itself, not just a means to our own ends.

In our reverence for the intricate beauty and majesty of nature, and our respect for the dignity and rights of other humans, we can feel united with the great religious and philosophical traditions of mankind, and with the traditional wisdom of our ancestors.

Pictures sent back by the astronauts show the earth as it really is - a small, fragile, beautiful planet, drifting on through the dark immensity of space - our home, where we must learn to live in harmony with nature and with each other.

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## Appendix A

# THE CASE AGAINST NUCLEAR POWER GENERATION

### A.1 The Chernobyl disaster

The dangers of nuclear power generation are exemplified by the Chernobyl disaster: On the 26th of April, 1986, during the small hours of the morning, the staff of the Chernobyl nuclear reactor in Ukraine turned off several safety systems in order to perform a test. The result was a core meltdown in Reactor 4, causing a chemical explosion that blew off the reactor's 1,000-ton steel and concrete lid. 190 tons of highly radioactive uranium and graphite were hurled into the atmosphere. The resulting radioactive fallout was 200 times greater than that caused by the nuclear bombs that destroyed Hiroshima and Nagasaki. The radioactive cloud spread over Belarus, Ukraine, Russia, Finland, Sweden and Eastern Europe, exposing the populations of these regions to levels of radiation 100 times the normal background. Ultimately, the radioactive cloud reached as far as Greenland and parts of Asia.

The exact number of casualties resulting from the Chernobyl meltdown is a matter of controversy, but according to a United Nations report, as many as 9 million people have been adversely affected by the disaster. Since 1986, the rate of thyroid cancer in affected areas has increased ten-fold. An area of 155,000 square kilometers (almost half the size of Italy) in Belarus, Ukraine and Russia is still severely contaminated. Even as far away as Wales, hundreds of farms are still under restrictions because of sheep eating radioactive grass.

Public opinion turned against nuclear power generation as a result of the Chernobyl disaster. Had the disaster taken place in Western Europe or North America, its effect on public opinion would have been still greater. Neverthe-

less, because of the current energy crisis, and because of worries about global warming, a number of people are arguing that nuclear energy should be given a second chance. The counter-argument is that a large increase in the share of nuclear power in the total spectrum of energy production would have little effect on climate change but it would involve unacceptable dangers, not only dangers of accidents and dangers associated with radioactive waste disposal, but above all, dangers of proliferation of nuclear weapons.

Of the two bombs that destroyed Hiroshima and Nagasaki, one made use of the rare isotope of uranium, U-235, while the other used plutonium. Both of these materials can be made by a nation with a nuclear power generation program.

## A.2 Reactors and nuclear weapons

Uranium has atomic number 92, i.e., a neutral uranium atom has a nucleus containing 92 positively-charged protons, around which 92 negatively-charged electrons circle. All of the isotopes of uranium have the same number of protons and electrons, and hence the same chemical properties, but they differ in the number of neutrons in their nuclei. For example, the nucleus of U-235 has 143 neutrons, while that of U-238 has 146. Notice that  $92+143=235$ , while  $92+146=238$ . The number written after the name of an element to specify a particular isotope is the number of neutrons plus the number of protons. This is called the "nucleon number", and the weight of an isotope is roughly proportional to it. This means that U-238 is slightly heavier than U-235. If the two isotopes are to be separated, difficult physical methods dependent on mass must be used, since their chemical properties are identical. In natural uranium, the amount of the rare isotope U-235 is only 0.7 percent.

A paper published in 1939 by Niels Bohr and John A. Wheeler indicated that it was the rare isotope of uranium, U-235, that undergoes fission. A bomb could be constructed, they pointed out, if enough highly enriched U-235 could be isolated from the more common isotope, U-238. Calculations later performed in England by Otto Frisch and Rudolf Peierls showed that the "critical mass" of highly enriched uranium needed is quite small: only a few kilograms.

The Bohr-Wheeler theory also predicted that an isotope of plutonium, Pu-239, should be just as fissionable as U-235<sup>1</sup>. Instead of trying to separate the

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<sup>1</sup>Both U-235 and Pu-239 have odd nucleon numbers. When U-235 absorbs a neutron, it becomes U-236, while when Pu-239 absorbs a neutron it becomes Pu-240. In other words, absorption of a neutron converts both these species to nuclei with even nucleon numbers. According to the Bohr-Wheeler theory, nuclei with even nucleon numbers are especially tightly-bound. Thus absorption of a neutron converts U-235 to a highly-excited state of U-236, while Pu-239 is similarly converted to a highly excited state of Pu-240. The excitation

rare isotope, U-235, from the common isotope, U-238, physicists could just operate a nuclear reactor until a sufficient amount of Pu-239 accumulated, and then separate it out by ordinary chemical means.

Thus in 1942, when Enrico Fermi and his coworkers at the University of Chicago produced the world's first controlled chain reaction within a pile of cans containing ordinary (nonenriched) uranium powder, separated by blocks of very pure graphite, the chain-reacting pile had a double significance: It represented a new source of energy for mankind, but it also had a sinister meaning. It represented an easy path to nuclear weapons, since one of the by-products of the reaction was a fissionable isotope of plutonium, Pu-239. The bomb dropped on Hiroshima in 1945 used U-235, while the Nagasaki bomb used Pu-239.

By reprocessing spent nuclear fuel rods, using ordinary chemical means, a nation with a power reactor can obtain weapons-usable Pu-239. Even when such reprocessing is performed under international control, the uncertainty as to the amount of Pu-239 obtained is large enough so that the operation might superficially seem to conform to regulations while still supplying enough Pu-239 to make many bombs.

The enrichment of uranium<sup>2</sup> is also linked to reactor use. Many reactors of modern design make use of low enriched uranium (LEU) as a fuel. Nations operating such a reactor may claim that they need a program for uranium enrichment in order to produce LEU for fuel rods. However, by operating their ultracentrifuges a little longer, they can easily produce highly enriched uranium (HEU), i.e., uranium containing a high percentage of the rare isotope U-235, and therefore usable in weapons.

Known reserves of uranium are only sufficient for the generation of  $8 \times 10^{20}$  joules of electrical energy<sup>3</sup>, i.e., about 25 TWy. It is sometimes argued that a larger amount of electricity could be obtained from the same amount of uranium through the use of fast breeder reactors, but this would involve totally unacceptable proliferation risks. In fast breeder reactors, the fuel rods consist of highly enriched uranium. Around the core, is an envelope of natural uranium. The flux of fast neutrons from the core is sufficient to convert a part of the U-238 in the envelope into Pu-239, a fissionable isotope of plutonium.

Fast breeder reactors are prohibitively dangerous from the standpoint of nuclear proliferation because both the highly enriched uranium from the fuel rods and the Pu-239 from the envelope are directly weapons-usable. It would

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energy distorts the nuclei to such an extent that fission becomes possible.

<sup>2</sup>i.e. production of uranium with a higher percentage of U-235 than is found in natural uranium

<sup>3</sup>Craig, J.R., Vagn, D.J. and Skinner, B.J., *Resources of the Earth: Origin, Use and Environmental Impact, Third Edition*, page 210.

be impossible, from the standpoint of equity, to maintain that some nations have the right to use fast breeder reactors, while others do not. If all nations used fast breeder reactors, the number of nuclear weapons states would increase drastically.

It is interesting to review the way in which Israel, South Africa, Pakistan, India and North Korea<sup>4</sup> obtained their nuclear weapons, since in all these cases the weapons were constructed under the guise of “atoms for peace”, a phrase that future generations may someday regard as being tragically self-contradictory.

Israel began producing nuclear weapons in the late 1960’s (with the help of a “peaceful” nuclear reactor provided by France, and with the tacit approval of the United States) and the country is now believed to possess 100-150 of them, including neutron bombs. Israel’s policy is one of visibly possessing nuclear weapons while denying their existence.

South Africa, with the help of Israel and France, also weaponized its civil nuclear program, and it tested nuclear weapons in the Indian Ocean in 1979. In 1991 however, South Africa destroyed its nuclear weapons and signed the NPT.

India produced what it described as a “peaceful nuclear explosion” in 1974. By 1989 Indian scientists were making efforts to purify the lithium-6 isotope, a key component of the much more powerful thermonuclear bombs. In 1998, India conducted underground tests of nuclear weapons, and is now believed to have roughly 60 warheads, constructed from Pu-239 produced in “peaceful” reactors.

Pakistan’s efforts to obtain nuclear weapons were spurred by India’s 1974 “peaceful nuclear explosion”. As early as 1970, the laboratory of Dr. Abdul Qadeer Khan, (a metallurgist who was to become Pakistan’s leading nuclear bomb maker) had been able to obtain from a Dutch firm the high-speed ultracentrifuges needed for uranium enrichment. With unlimited financial support and freedom from auditing requirements, Dr. Khan purchased restricted items needed for nuclear weapon construction from companies in Europe and the United States. In the process, Dr. Khan became an extremely wealthy man. With additional help from China, Pakistan was ready to test five nuclear weapons in 1998. The Indian and Pakistani nuclear bomb tests, conducted in rapid succession, presented the world with the danger that these devastating weapons would be used in the conflict over Kashmir. Indeed, Pakistan announced that if a war broke out using conventional weapons, Pakistan’s nuclear weapons would be used “at an early stage”.

In Pakistan, Dr. A.Q. Khan became a great national hero. He was pre-

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<sup>4</sup>Israel, India and Pakistan have refused to sign the Nuclear Non-Proliferation Treaty, and North Korea, after signing the NPT, withdrew from it in 2003.

sented as the person who had saved Pakistan from attack by India by creating Pakistan's own nuclear weapons. In a Washington Post article<sup>5</sup> Pervez Hoodbhoy wrote: "Nuclear nationalism was the order of the day as governments vigorously promoted the bomb as the symbol of Pakistan's high scientific achievement and self-respect..." Similar manifestations of nuclear nationalism could also be seen in India after India's 1998 bomb tests.

Early in 2004, it was revealed that Dr. Khan had for years been selling nuclear secrets and equipment to Libya, Iran and North Korea, and that he had contacts with Al-Qaeda. However, observers considered that it was unlikely that Khan would be tried, since a trial might implicate Pakistan's army as well as two of its former prime ministers.

Recent assassination attempts directed at Pakistan's President, Pervez Musharraf, emphasize the precariousness of Pakistan's government. There a danger that it may be overthrown, and that the revolutionists would give Pakistan's nuclear weapons to a subnational organization. This type of danger is a general one associated with nuclear proliferation. As more and more countries obtain nuclear weapons, it becomes increasingly likely that one of them will undergo a revolution, during the course of which nuclear weapons will fall into the hands of criminals or terrorists.

If nuclear reactors become the standard means for electricity generation as the result of a future energy crisis, the number of nations possessing nuclear weapons might ultimately be as high as 40. If this should happen, then over a long period of time the chance that one or another of these nations would undergo a revolution during which the weapons would fall into the hands of a subnational group would gradually grow into a certainty.

There is also a possibility that poorly-guarded fissionable material could fall into the hands of subnational groups, who would then succeed in constructing their own nuclear weapons. Given a critical mass of highly-enriched uranium, a terrorist group, or an organized criminal (Mafia) group, could easily construct a crude gun-type nuclear explosive device. Pu-239 is more difficult to use since it is highly radioactive, but the physicist Frank Barnaby believes that a subnational group could nevertheless construct a crude nuclear bomb (of the Nagasaki type) from this material.

We must remember the remark of U.N. Secretary General Kofi Annan after the 9/11/2001 attacks on the World Trade Center. He said, "*This time* it was not a nuclear explosion". The meaning of his remark is clear: If the world does not take strong steps to eliminate fissionable materials and nuclear weapons, it will only be a matter of time before they will be used in terrorist attacks on major cities, or by organized criminals for the purpose of extortion. Neither

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<sup>5</sup>1 February, 2004

terrorists nor organized criminals can be deterred by the threat of nuclear retaliation, since they have no territory against which such retaliation could be directed. They blend invisibly into the general population. Nor can a “missile defense system” prevent criminals or terrorists from using nuclear weapons, since the weapons can be brought into a port in any one of the hundreds of thousands of containers that enter on ships each year, a number far too large to be checked exhaustively.

Finally we must remember that if the number of nations possessing nuclear weapons becomes very large, there will be a greatly increased chance that these weapons will be used in conflicts between nations, either by accident or through irresponsible political decisions.

On November 3, 2003, Mohamed ElBaradei, Director General of the International Atomic Energy Agency, made a speech to the United Nations in which he called for “limiting the processing of weapons-usable material (separated plutonium and high enriched uranium) in civilian nuclear programs - as well as the production of new material through reprocessing and enrichment - by agreeing to restrict these operations to facilities exclusively under international control.” It is almost incredible, considering the dangers of nuclear proliferation and nuclear terrorism, that such restrictions were not imposed long ago.

From the facts that we have been reviewing, we can conclude that if nuclear power generation becomes widespread during a future energy crisis, and if equally widespread proliferation of nuclear weapons is to be avoided, the powers and budget of the IAEA will have to be greatly increased. All enrichment of uranium and reprocessing of fuel rods throughout the world will have to be placed under direct international control, as has been emphasized by Mohamed ElBaradei. Because this will need to be done with fairness, such regulations will have to hold both in countries that at present have nuclear weapons and in countries that do not. It has been proposed that there should be an international fuel rod bank, to supply new fuel rods and reprocess spent ones. In addition to this excellent proposal, one might also consider a system where all power generation reactors and all research reactors would be staffed by the IAEA.

Nuclear reactors used for “peaceful” purposes unfortunately also generate fissionable isotopes of not only of plutonium, but also of neptunium and americium. Thus all nuclear reactors must be regarded as ambiguous in function, and all must be put under strict international control. One must ask whether globally widespread use of nuclear energy is worth the danger that it entails.

Let us now examine the question of whether nuclear power generation would appreciably help to prevent global warming. The fraction of nuclear power in the present energy generation spectrum is at present approximately 1/16.



Nuclear energy is used primarily for electricity generation. Thus increasing the nuclear fraction would not affect the consumption of fossil fuels used directly in industry, transportation, in commerce, and in the residential sector. Coal is still a very inexpensive fuel, and an increase in nuclear power generation would do little to prevent it from being burned. Thus besides being prohibitively dangerous, and besides being unsustainable in the long run (because of finite stocks of uranium and thorium), the large-scale use of nuclear power cannot be considered to be a solution to the problem of anthropogenic climate change.

Optimists point to the possibility of using fusion of light elements, such as hydrogen, to generate power. However, although this can be done on a very small scale (and at great expense) in laboratory experiments, the practical generation of energy by means of thermonuclear reactions remains a mirage rather than a realistic prospect on which planners can rely. The reason for this is the enormous temperature required to produce thermonuclear reactions. This temperature is comparable to that existing in the interior of the sun, and it is sufficient to melt any ordinary container. Elaborate “magnetic bottles” have been constructed to contain thermonuclear reactions, and these have been used in successful very small scale experiments. However, despite 50 years of heavily-financed research, there has been absolutely no success in producing thermonuclear energy on a large scale, or at anything remotely approaching commercially competitive prices.



## Appendix B

# EXCERPTS FROM THE STERN REVIEW

### Excerpts from the Stern Review Executive Summary

*The scientific evidence is now overwhelming: climate change presents very serious global risks, and it demands an urgent global response.*

*This independent Review was commissioned by the Chancellor of the Exchequer, reporting to both the Chancellor and to the Prime Minister, as a contribution to assessing the evidence and building understanding of the economics of climate change.*

*The Review first examines the evidence on the economic impacts of climate change itself, and explores the economics of stabilizing greenhouse gases in the atmosphere. The second half of the Review considers the complex policy challenges involved in managing the transition to a low-carbon economy and in ensuring that societies can adapt to the consequences of climate change that can no longer be avoided.*

*The Review takes an international perspective. Climate change is global in its causes and consequences, and international collective action will be critical in driving an effective, efficient and equitable response on the scale required.*

*This response will require deeper international co-operation in many areas - most notably in creating price signals and markets for carbon, spurring technology research, development and deployment, and promoting adaptation, particularly for developing countries. Climate change presents a unique challenge for economics: it is the greatest and widest-ranging market failure ever seen. The economic analysis must therefore be global, deal with long time horizons, have the economics of risk and uncertainty at centre stage, and examine the possibility of major, non-marginal change. To meet these requirements, the Review draws on ideas and techniques from most of the important areas of*

*economics, including many recent advances.*

*The benefits of strong, early action on climate change outweigh the costs. The effects of our actions now on future changes in the climate have long lead times. What we do now can have only a limited effect on the climate over the next 40 or 50 years. On the other hand what we do in the next 10 or 20 years can have a profound effect on the climate in the second half of this century and in the next. No-one can predict the consequences of climate change with complete certainty; but we now know enough to understand the risks. Mitigation - taking strong action to reduce emissions - must be viewed as an investment, a cost incurred now and in the coming few decades to avoid the risks of very severe consequences in the future. If these investments are made wisely, the costs will be manageable, and there will be a wide range of opportunities for growth and development along the way. For this to work well, policy must promote sound market signals, overcome market failures and have equity and risk mitigation at its core. That essentially is the conceptual framework of this Review.*

*The Review considers the economic costs of the impacts of climate change, and the costs and benefits of action to reduce the emissions of greenhouse gases (GHGs) that cause it, in three different ways:*

*Using disaggregated techniques, in other words considering the physical impacts of climate change on the economy, on human life and on the environment, and examining the resource costs of different technologies and strategies to reduce greenhouse gas emissions;*

- *Using economic models, including integrated assessment models that estimate the economic impacts of climate change, and macro-economic models that represent the costs and effects of the transition to low-carbon energy systems for the economy as a whole;*
- *Using comparisons of the current level and future trajectories of the 'social cost of carbon' (the cost of impacts associated with an additional unit of greenhouse gas emissions) with the marginal abatement cost (the costs associated with incremental reductions in units of emissions).*

*From all of these perspectives, the evidence gathered by the Review leads to a simple conclusion: the benefits of strong, early action considerably outweigh the costs.*

*The evidence shows that ignoring climate change will eventually damage economic growth. Our actions over the coming few decades could create risks of major disruption to economic and social activity, later in this century and in the next, on a scale similar to those associated with the great wars and the economic depression of the first half of the 20th century. And it will be*

*difficult or impossible to reverse these changes. Tackling climate change is the pro-growth strategy for the longer term, and it can be done in a way that does not cap the aspirations for growth of rich or poor countries. The earlier effective action is taken, the less costly it will be.*

*At the same time, given that climate change is happening, measures to help people adapt to it are essential. And the less mitigation we do now, the greater the difficulty of continuing to adapt in future*

*The first half of the Review considers how the evidence on the economic impacts of climate change, and on the costs and benefits of action to reduce greenhouse gas emissions, relates to the conceptual framework described above. The scientific evidence points to increasing risks of serious, irreversible impacts from climate change associated with business-as-usual (BAU) paths for emissions.*

*The scientific evidence on the causes and future paths of climate change is strengthening all the time. In particular, scientists are now able to attach probabilities to the temperature outcomes and impacts on the natural environment associated with different levels of stabilization of greenhouse gases in the atmosphere. Scientists also now understand much more about the potential for dynamic feedbacks that have, in previous times of climate change, strongly amplified the underlying physical processes.*

*The stocks of greenhouse gases in the atmosphere (including carbon dioxide, methane, nitrous oxides and a number of gases that arise from industrial processes) are rising, as a result of human activity. The sources are summarized in Figure 1 below.*

*The current level or stock of greenhouse gases in the atmosphere is equivalent to around 430 parts per million (ppm) CO<sub>2</sub>, compared with only 280ppm before the Industrial Revolution. These concentrations have already caused the world to warm by more than half a degree Celsius and will lead to at least a further half degree warming over the next few decades, because of the inertia in the climate system. Even if the annual flow of emissions did not increase beyond today's rate, the stock of greenhouse gases in the atmosphere would reach double pre-industrial levels by 2050 - that is 550ppm CO<sub>2</sub>e - and would continue growing thereafter. But the annual flow of emissions is accelerating, as fast-growing economies invest in high-carbon infrastructure and as demand for energy and transport increases around the world. The level of 550ppm CO<sub>2</sub>e could be reached as early as 2035. At this level there is at least a 77% chance - and perhaps up to a 99% chance, depending on the climate model used - of a global average temperature rise exceeding 2°C.*

*Under a BAU scenario, the stock of greenhouse gases could more than treble by the end of the century, giving at least a 50% risk of exceeding 5 degree C global average temperature change during the following decades. This would*

take humans into unknown territory. An illustration of the scale of such an increase is that we are now only around 5 degree C warmer than in the last ice age.

Such changes would transform the physical geography of the world. A radical change in the physical geography of the world must have powerful implications for the human geography - where people live, and how they live their lives.

Climate change threatens the basic elements of life for people around the world: access to water, food production, health, and use of land and the environment.

Estimating the economic costs of climate change is challenging, but there is a range of methods or approaches that enable us to assess the likely magnitude of the risks and compare them with the costs. This Review considers three of these approaches.

This Review has first considered in detail the physical impacts on economic activity, on human life and on the environment. On current trends, average global temperatures will rise by 2 - 3°C within the next fifty years or so. 5 The Earth will be committed to several degrees more warming if emissions continue to grow.

Warming will have many severe impacts, often mediated through water:

- Declining crop yields, especially in Africa, could leave hundreds of millions without the ability to produce or purchase sufficient food. At mid to high latitudes, crop yields may increase for moderate temperature rises (2 - 3°C), but then decline with greater amounts of warming. At 4°C and above, global food production is likely to be seriously affected.
- In higher latitudes, cold-related deaths will decrease. But climate change will increase worldwide deaths from malnutrition and heat stress. Vector-borne diseases such as malaria and dengue fever could become more widespread if effective control measures are not in place.
- Rising sea levels will result in tens to hundreds of millions more people flooded each year with warming of 3 or 4°C. There will be serious risks and increasing pressures for coastal protection in South East Asia (Bangladesh and Vietnam), small islands in the Caribbean and the Pacific, and large coastal cities, such as Tokyo, New York, Cairo and London. According to one estimate, by the middle of the century, 200 million people may become permanently displaced due to rising sea levels, heavier floods, and more intense droughts.
- Melting glaciers will initially increase flood risk and then strongly reduce water supplies, eventually threatening one-sixth of the world's population,

*predominantly in the Indian sub-continent, parts of China, and the Andes in South America.*

- *Ecosystems will be particularly vulnerable to climate change, with around 15 - 40% of species potentially facing extinction after only 2 degrees C of warming. And ocean acidification, a direct result of rising carbon dioxide levels, will have major effects on marine ecosystems, with possible adverse consequences on fish stocks.*

*The damages from climate change will accelerate as the world gets warmer. Higher temperatures will increase the chance of triggering abrupt and large-scale changes.*

- *Warming may induce sudden shifts in regional weather patterns such as the monsoon rains in South Asia or the El Nino phenomenon - changes that would have severe consequences for water availability and flooding in tropical regions and threaten the livelihoods of millions of people.*
- *A number of studies suggest that the Amazon rainforest could be vulnerable to climate change, with models projecting significant drying in this region. One model, for example, finds that the Amazon rainforest could be significantly, and possibly irrevocably, damaged by a warming of 2 - 3 degrees C.*
- *The melting or collapse of ice sheets would eventually threaten land which today is home to 1 in every 20 people.*

*While there is much to learn about these risks, the temperatures that may result from unabated climate change will take the world outside the range of human experience. This points to the possibility of very damaging consequences. The impacts of climate change are not evenly distributed - the poorest countries and people will suffer earliest and most. And if and when the damages appear it will be too late to reverse the process. Thus we are forced to look a long way ahead.*

*Climate change is a grave threat to the developing world and a major obstacle to continued poverty reduction across its many dimensions. First, developing regions are at a geographic disadvantage: they are already warmer, on average, than developed regions, and they also suffer from high rainfall variability. As a result, further warming will bring poor countries high costs and few benefits. Second, developing countries - in particular the poorest - are heavily dependent on agriculture, the most climate-sensitive of all economic*

sectors, and suffer from inadequate health provision and low-quality public services. Third, their low incomes and vulnerabilities make adaptation to climate change particularly difficult.

Because of these vulnerabilities, climate change is likely to reduce further already low incomes and increase illness and death rates in developing countries. Falling farm incomes will increase poverty and reduce the ability of households to invest in a better future, forcing them to use up meager savings just to survive. At a national level, climate change will cut revenues and raise spending needs, worsening public finances.

Many developing countries are already struggling to cope with their current climate. Climatic shocks cause setbacks to economic and social development in developing countries today even with temperature increases of less than 1°C. The impacts of unabated climate change, - that is, increases of 3 or 4°C and upwards - will be to increase the risks and costs of these events very powerfully.

Impacts on this scale could spill over national borders, exacerbating the damage further. Rising sea levels and other climate-driven changes could drive millions of people to migrate: more than a fifth of Bangladesh could be under water with a 1m rise in sea levels, which is a possibility by the end of the century. Climate-related.

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## Appendix C

# THE LOFOTEN DECLARATION (SEPTEMBER, 2017)

### Climate Leadership Requires a Managed Decline of Fossil Fuel Production

*Global climate change is a crisis of unprecedented scale, and it will take unprecedented action to avoid the worst consequences of our dependence on oil, coal, and gas. Equally as critical as reducing demand and emissions is the need for immediate and ambitious action to stop exploration and expansion of fossil fuel projects and manage the decline of existing production in line with what is necessary to achieve the Paris climate goals.*

*Clean, safe, and renewable fuels are already redefining how we see energy and it is time for nations to fully embrace 21st century energy and phase out fossil fuels.*

*The Lofoten Declaration affirms that it is the urgent responsibility and moral obligation of wealthy fossil fuel producers to lead in putting an end to fossil fuel development and to manage the decline of existing production.*

*We stand in solidarity with, and offer our full support for, the growing wave of impacted communities around the world who are taking action to defend and protect their lives and livelihoods in the face of fossil fuel extraction and climate change. It is a priority to elevate these efforts. Frontline communities are the leaders we must look to as we all work together for a safer future.*

*A global transition to a low carbon future is already well underway. Continued expansion of oil, coal, and gas is only serving to hinder the inevitable transition while at the same time exacerbating conflicts, fuelling corruption, threatening biodiversity, clean water and air, and infringing on the rights of*

*Indigenous Peoples and vulnerable communities.*

*Energy access and demand are and must now be met fully through the clean energies of the 21st century. Assertions that new fossil fuels are needed for this transformation are not only inaccurate; they also undermine the speed and penetration of clean energy.*

*We recognize that a full transition away from fossil fuels will take decades, but also, that this shift is an opportunity more than a burden. We are in a deep hole with climate. We must begin by not digging ourselves any deeper.*

*Research shows that the carbon embedded in existing fossil fuel production will take us far beyond safe climate limits. Thus, not only are new exploration and new production incompatible with limiting global warming to well below 2°C (and as close to 1.5°C as possible), but many existing projects will need to be phased-out faster than their natural decline.*

*This task should be first addressed by countries, regions, and corporate actors who are best positioned in terms of wealth and capacity to undergo an ambitious just transition away from fossil fuel production. In particular, leadership must come from countries that are high-income, have benefitted from fossil fuel extraction, and that are historically responsible for significant emissions.*

*We call on these governments and companies to recognize that continued fossil fuel exploration and production without a managed decline and a just transition is irreconcilable with meaningful climate action. We also note that there are tremendous leadership opportunities for these countries to demonstrate that moving beyond oil, coal, and gas, both demand and production, is not only possible, but can be done while protecting workers, communities, and economies.*

## **Signatories**

1. ACT Alliance EU, Europe
2. Action Paysanne Contre la Faim, Democratic Republic of the Congo
3. African Coalition For Sustainable Energy and Access, Cameroon
4. Alliance Sud, Switzerland
5. Alofa Tuvalu, France / Tuvalu
6. Alternative Information and Development Centre, South Africa
7. Alternative Technology Association, Australia
8. Amazon Watch, United States



9. Arab Youth Climate Muster , Lebanon
10. As You Sow, United States
11. Ashden, United Kingdom
12. The Ashden Trust, United Kingdom
13. Asia Pacific Forum on Women, Law and Development, Asia-Pacific
14. Asian Peoples Movement on Debt and Development, Asia
15. Association Nigã©rienne des Scouts de l'Environnement, Niger
16. Athens County Fracking Action Network, United States
17. The Australia Institute, Australia
18. Australian Marine Conservation Society, Australia
19. The Bellona Foundation, Norway
20. Bicitekas, Mexico
21. Bioroot Energy, Inc., United States
22. Bold Alliance, United States
23. Both ENDS, The Netherlands
24. BSF, Canada
25. Bund für Umwelt und Naturschutz Deutschlands (Friends of the Earth Germany), Germany
26. Campaign for a Just Energy Future, South Africa
27. Canadian Interfaith Fast for the Climate, Canada
28. Caravan of Non-violence, CÅ´te d'Ivoire
29. Catholic Earthcare Australia, Australia
30. CatholicNetwork.us, United States
31. Centar za zivotnu sredinu (Friends of the Earth Bosnia and Herzegovina), Bosnia and Herzegovina
32. Center for Biological Diversity, United States

33. Center for International Environmental Law, United States
34. Center for Justice, Governance, and Environmental Action, Kenya
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36. Centre for Environmental Rights, South Africa
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