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| ✠ |  | *Climate*  *Change —* |
| *the Science * |
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CLIMATE CHANGE: THE SCIENCE AND THE ECONOMICS

A BACKGROUND TO POPE FRANCIS’S ENCYCLICAL *LAUDATO SI*´

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# Introduction

On June 18th, Pope Francis released his second encyclical, *Laudato si*’: *On Care for Our Common Home*. Its subject is climate change. As Francis notes, “this Encyclical Letter . . . is now added to the body of the Church’s social teaching” (§ 15—throughout, “§” refers to sections of *Laudato si*’). The encyclical will have to be taken into consideration by all Catholics when they consider questions of social justice. But the encyclical is important to humanity as a whole. After all, climate change affects all of us: “the first truly planetary question we’ve ever faced [is] the rapid heating of the earth from the consumption of fossil fuels.” (McKibben)

In this paper I propose, not to discuss the encyclical *per se*, but to present background which may be helpful in understanding the Pope’s assertions. After some introductory remarks, I will present that background in two sections: the science and the economics.

# OVERVIEW OF THE ENCYCLICAL

“**Encyclical**”

An encyclical is a papal document intended as a “circular letter” (compare “encyclopedia”: the root is Greek ἐν κύκλῳ, *en kyklō*, “encircling”). Normally addressed to Catholic bishops, encyclicals can also be addressed to all humanity, as Pope Francis does in *Laudato si*’ (§ 3).

How authoritative is an encyclical? Pope John Paul II once said that “Theologians [should] assent to Catholic doctrine according to the degree of authority with which it is taught.” (Pope John Paul II) But the remark is applicable to all Catholics. Though estimates differ a bit, all agree that the encyclical is among the most authoritative types of papal document.

The following list ranks in decreasing order of formal authority: apostolic constitutions, encyclical letters, encyclical epistles, apostolic exhortations, apostolic letters, letters, and messages. (Miller 9 n. 1)

. . . the most authoritative are “apostolic constitutions,” “apostolic letters,” “encyclical letters,” and “apostolic exhortations.” (Sullivan 21)

**Preparations for *Laudato si***’

Pope Francis went to considerable trouble to consult scientists, economists, and theologians in constructing *Laudato si*’. Some awareness of that effort helps one appreciate that the encyclical is not just personal opinion.

The Vatican consulted, of course, its own scientific bodies, the Pontifical Academy of Sciences and the Pontifical Academy of Social Sciences. These “contain academics from around the world, who are handpicked as life members, regardless of their religion. . . . Their job is to produce reports [for] the Vatican . . .” (Yeo “In-Depth”) The Pontifical Academy of Sciences consists of 73 academicians, including atheist Stephen Hawking, physicist (and guest on *The Simpsons*!), and evangelical Francis Collins, leader of the Human Genome Project and now director of the US National Institutes of Health. The Pontifical Academy of Social Sciences has 29 academicians, including Partha Dasgupta, Muslim economist at Cambridge and author of *Human Well-Being and the Natural Environment* (2004), and Joseph Stiglitz, Jewish Nobel-Prize-winning economist and author of *The Great Divide*: *Unequal Societies and What We Can Do about Them* (2015). These two bodies were “involved more than any other in constructing the encyclical.” (Yeo “In-Depth”) (For a detailed look at the preparations—scientific, economic, and theological—see Appendix 1.)

**Organization of *Laudato si***’

*Laudato si*’ has six chapters.

1 “What Is Happening to Our Common Home”

2 “The Gospel of Creation”

3 “The Human Roots of the Ecological Crisis”

4 “Integral Ecology”

5 “Lines of Approach and Action”

6 “Ecological Education and Spirituality”

Generally speaking, chapters 1, 3, 4, and 5 are more scientific and economical, whereas chapters 2 and 6 are more theological. (For some reason *Laudato si*’ lacks a table of contents; for an in-depth one, see Appendix 3.)

The Pope himself notes that there are “a number of themes which will reappear as the Encyclical unfolds.” He lists:

the intimate relationship between the poor and the fragility of the planet,

the conviction that everything in the world is connected,

the critique of new paradigms and forms of power derived from technology,

the call to seek other ways of understanding the economy and progress,

the value proper to each creature,

the human meaning of ecology,

the need for forthright and honest debate,

the serious responsibility of international and local policy,

the throwaway culture [a phrase used 5 times in *Laudato si*’]

and the proposal of a new lifestyle. (§ 16)

In my opinion, interweaving these themes, rather than treating each in its own unit, is one reason the encyclical is rather difficult to read. (Another is its carefully vague style, typical of Church documents. When one’s audience is the world, I suppose one must be diplomatic.)

——————————

As mentioned, it is my intention to present the background to *Laudato si*’ in two sections, the science and the economics. Is climate change happening? How do we know? The “Science” section that follows has two initial subsections, based on climate’s causes: natural climate change and anthropogenic (human-generated) climate change. In addition, a third subsection will consider the arguments of those who deny climate change.

# The Science

Pope Francis makes assertions that he does not back up. He says, for instance, “A very solid scientific consensus indicates that we are presently witnessing a disturbing warming of the climatic system.” And he says: “a number of scientific studies indicate that most [recent] global warming . . . [is] a result of human activity.” (§ 23)

I suppose it would be inappropriate to delve into proofs of climate change in an encyclical, whose primary purpose is to provide direction on an issue from a faith perspective. But I suspect a majority of readers will be unfamiliar with the details of climate change. What is the basis for the “scientific consensus”? Which “scientific studies” does Francis refer to? To provide a scientific foundation for the Pope’s assertions is the purpose of the present section.

## natural climate change

There’s no question that the majority of climate change, in the present as in the past, is attributable to natural rather than human causes. Significant natural factors of climate are: the Milankovich cycles, plate tectonics, solar radiation, volcanoes, and impactors such as asteroids—all of which have contributed to the ice ages.

### Milankovich Cycles

Named after their discoverer (the Croatian Milutin Milanković, 1879-1958), the three Milankovitch cycles are the three ways that the Earth changes in relation to the Sun. (Tudge 71)

*Orbit*: the Earth’s path around the Sun each year is sometimes almost a circle, sometimes an ellipse. The orbit goes from circle to ellipse and back every 95,800 years. With the orbit at its most circular, the Sun’s radiation on the Earth is about the same all year. With the orbit at its most elliptical, the difference in solar radiation from perihelion (Earth at the Sun’s end of the ellipse) and aphelion (Earth at the far end of the ellipse) is 30%. (Tudge 72)

*Tilt*: the angle of the Earth’s axis, relative to the Sun, goes from 21.39° off true vertical to 24.36° (a difference of 2.97°). It does so every 41,000 years. The more tilt, the more contrast between the poles and the tropics, and the more contrast between winter and summer at the poles. (Tudge 72)

*Precession*: the Earth “wobbles” as it rotates: its axis “draws” a cone around the poles. But it’s a slow wobble: a complete cone takes 21,700 years. (Tudge 72)

How do the Milankovich cycles affect climate? They seem to play a large part in the ice ages. The orbital cycle (circle to ellipse and back) of 95,800 years corresponds roughly to the average ice-age cycle of 100,000 years. Also, since 130,000 bc, the oscillation in tilt of 41,000 years corresponds roughly with intra-ice-age fluctuations. (Tudge 74) We now believe the Milankovitch cycles are “The main factor at work in climate cycling . . .” (“Pleistocene”)

### Plate Tectonics

The continents ride on plates of Earth crust; as they slowly drift, they merge or split. Thus, in addition to the present continents, there were also paleocontinents. (For a quick history of pal­eocontinents, see Appendix 4.)

Plate tectonics affect climate by altering, among other things, landmass altitudes and ocean currents. For example, 50 million years ago, as India (a huge island at the time) pushed into the southern edge of Asia, it thrust the Himalayas skyward. By blocking precipitation, the Himalayas created a “rain shadow desert” behind them: the Gobi Desert, third largest in the world (after the Sahara and the Arabian). (“Gobi Desert”)

### Solar Radiation

Variation in the Sun’s energy output can be long-term or short-term.

Short-term, sunspot cycles vary the amount of solar energy reaching Earth. Sunspots can vary from virtually none in the 1690s to over 250 in the 1960s. (“Maunder Minimum”)

Long-term, the sun’s output increases about 10% every billion years. A billion years from now, that 10% increase in solar energy will create a “runaway greenhouse effect”: rising temperatures will produce water vapor (a greenhouse gas much stronger than CO2), which will raise temperatures, which will produce water vapor, etc. (“Runaway Greenhouse Effect”)

As for the effects of solar energy on climate: sunspot cycles *can* explain some temperature variation. For example, a particular sunspot cycle from 1645-1715 (the Maunder minimum) may have contributed to the coldest part of the Little Ice Age (1650-1850). But sunspot cycles are too weak and too common to explain the start or end of an ice age.

### Volcanoes

In the last 500 million years, at least 20 eruptions have been large enough to spew more than 2000 km3 (cubic kilometers) of ejecta (lava, rock, ash, gases) into the atmosphere. Eight of the 20 occurred around 132 million, in east central South America and west central Africa (the bulge of the former and the indentation of the latter were joined at the time). They included the largest eruption ever known, 3600 km3. Five of the 20 occurred at 32-28 million, in the Great Basin of Nevada and Colorado. At 2.6 million, Yellowstone had its largest eruption to date, 2450 km3. (“List”)

Among the 20 largest eruptions are super-eruptions: they spew more than 1015 kg. But they only average 1 every million years. 75,000 years ago, Toba, in Sumatra, ejected 7004 kg. (“Volcanic Winter”) More recent volcanoes have been tame by comparison. (For a list of some recent volcanoes, see Appendix 5.)

Volcanic ash and sulfuric-acid drops in the atmosphere affect climate in three ways. They cool the Earth by blocking sunlight and increasing albedo (reflection of sunlight), sending heat back into space. They warm the Earth—especially the stratosphere (the atmosphere above 6.2 miles [10 km])—by absorbing terrestrial radiation (radioactive heat from inside the Earth). (“Vol­canic Winter”)

### Meteors, Asteroids, and Comets

Meteors and asteroids are mostly rock; comets are mostly ice. A big and bright meteor, asteroid, or comet is called a “bolide,” and some bolides survive atmospheric friction to hit Earth. The three largest impact craters are the Vredefort (South Africa: 300 km, 2.023 billion years ago), the Sudbury (Canada: 250 km, 1.85 billion), and the Chicxulub (half on the Yucatan Peninsula and half off it: 180 km, 66 million). The latter is the famous one: an asteroid at least 9 miles wide (Walkden and Parker) slammed into Earth; the dinosaurs sighed and died.

This raises the question of extinction events. Of the 30 or so largest extinction events in Earth history, some are attributable to bolides. But others are attributable to volcanoes, ice ages, the Great Oxygenation Event (which killed off most anaerobic bacteria), etc. The worst extinction event—the Permian-Triassic, 251 million years ago—likely had multiple causes; 99% of all life died. (“Extinction Event”)

### Ice Ages

The ice ages seem primarily due to the Milankovich cycles. But the other factors we have considered—plate tectonics, solar radiation, volcanoes, bolides—have not been without influence. And there are other factors as well. For example, the Great Oxygenation Event just mentioned (2.3 billion) occurred because cyanobacteria began to do photosynthesis; a by-product was oxygen. Oxygen in the atmosphere reacted with methane, greatly reducing that powerful greenhouse gas. The result was global cooling. (“Great Oxygenation Event”) (For a table of the ice ages, see Appendix 6.)

In the Huronian glaciation (the oldest known, 2.4-2.1 billion) and in the Sturtian and Marinoan glaciations (720-660 and 650-635 million, respectively), Earth’s mean annual temperature reached –40º F (–40º C). It may be that the entire Earth froze over (the “Snowball Earth” hypothesis). (Klotz)

In the quaternary ice age (2.588 million to the present), a cap of glaciers reached down at places to latitude 40º north (the Nebraska/Kansas border), and a permafrost zone of a few hundred miles stretched further still. At the maximum, 30% of the Earth was covered. “The mean annual temperature at the edge of the ice was −6° C (21° F); at the edge of the permafrost, 0° C (32° F).” (“Pleistocene”)

The last glacial maximum of the quaternary ice age was 18,000 bc. We entered our present interglacial (warming) period about 11,700 bc—shortly after which, not coincidentally, we figured out how to farm (by domesticating plants and animals). Note that we are merely in an interglacial: we are still in the quaternary ice age and can look forward—after an episode of anthropogenic (human-caused) climate change—to the next glacial (colder period).

## anthropogenic climate change

Though climate change primarily has natural causes, it also has human causes. That humans affect the climate is easy to demonstrate. If I take a wooden match from its box and strike it, the burning wood releases CO2 into the atmosphere. *Eh voilà*: I have contributed to global warming!

Almost no one disputes that global warming is occurring, and few dispute that humans contribute to it. The issue is the degree to which humans contribute. Several considerations must be taken into account: greenhouse gases; deforestation; world population; global warming; and the effects of global warming (extreme weather, wildfires, thawing ice and permafrost, rising sea level, ocean acidification, decreased biodiversity, and scarce food and water supplies).

### Greenhouse Gases

We have all heard of the “greenhouse effect.” Some gases in the atmosphere—especially water vapor, carbon dioxide, and methane—are almost *transparent* to solar radiation as it enters; they let almost all of the Sun’s energy reach Earth. However, when the Earth converts that energy into heat and radiates it back up, these gases are mostly *opaque* to it. (Why? Because incoming solar radiation is in the vis­ible-light and ultraviolet wavelengths of the electromagnetic spectrum, whereas heat is in the infrared wavelengths.) The now-opaque gases refract the heat energy in all directions, so some returns again to Earth. (The main gases in the atmosphere, nitrogen and oxygen, are almost transparent to visible light, ultraviolet energy, *and* infrared energy; since they let heat back out, they are not greenhouse gases.) (Walsh 798)

Here are the principal greenhouse gases, along with their emissions by economic sector, CO2 emissions by nation, and public opinion about climate change in various regions.

|  |  |  |  |
| --- | --- | --- | --- |
| *2011 emissions by gas* | *2011 emissions*  *by economic sector* | *2008 CO2 emissions*  *by nation* | “*very concerned*”  *about climate change* |
|  |  |  |  |
| carbon dioxide (CO2) 84% | electricity 33% | China 23% | Latin America 61% |
| methane (CH4) 9% | transportation 28% | US 19% | Africa 59% |
| nitrous oxide (N2O) 5% | industry 20% | European Union \* 13% | US 42% |
| f-gases 2% | residential/com­-  mercial buildings 11% | India 6%  Russian Federation 6% | Europe 42%  Asia and Pacific 41% |
|  | agriculture 8% | Japan 4% | Middle East 35% |
|  |  | Canada 2% | (The Middle East has more |
|  |  | all others 28% | immediate concerns.) |
|  |  |  |  |
| \* Excluding Estonia, Latvia, and Lithuania. (Sources: columns 1-2, Obama Administration; column 3: EPA “Global”; column 4: Carle [Pew Research Center].) | | | |

Some explanatory comments:

F-gases (fluorinated gases) include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6). From 2013 to 2030, HFC emissions in the US are expected to almost triple. Potent HFCs are in vehicle air-conditioning systems. (Obama Administration) PFCs are emitted in, for example, aluminum manufacture. (Barrett)

There are other greenhouse factors that are not listed in the chart. Water vapor is missing; it is in fact “the primary greenhouse gas,” two to three times stronger than CO2. However, water vapor on average precipitates back to Earth 10 days after evaporation. In addition, the other greenhouse gases support the suspension of water vapor in the atmosphere. So water vapor is not treated as a greenhouse gas. (IPCC “Physical”)

Another greenhouse factor not in the chart is black carbon (BC). It contributes to global warming, but it is not a gas (it is a particulate, soot). A particulate “embeds deeply in the lungs and is linked to serious heart and lung problems, including an increased risk of lung cancer.” (Gardner) In 2010, particulates caused 3.22 million deaths worldwide. (“Particulates,” citing Lim) Compared to CO2, black carbon and methane are short-lived. Reducing them now would reduce warming in the next couple of decades. (USGCRP)

Concerning electricity: in the US, power plants account for 40% of greenhouse-gas emissions. The Department of Defense is the largest consumer of energy in the US. (Obama Administration)

Concerning transportation: automakers sometimes exceed legal greenhouse-gas levels (Mercedes-Benz in 2006, Hyundai and Kia in 2014). But Volkswagen, the world’s largest auto maker, has committed the most egregious crime. On September 18th, the EPA alleged that Volkswagen violated the Clean Air Act. According to the EPA, from 2009-2015, VW installed software “defeat devices” in about 482,000 vehicles. The software “detected if the vehicle was undergoing emissions testing and modified operation of the emission control system” to give a false reading within the legal limit. The vehicles actually emitted 10-40 times more nitrous oxide than allowed by law. VW has admitted installing the devices; it faces a $20-billion penalty. Researchers estimate that the excess emissions from 2009-2015 caused 59 early deaths in the US and had social costs of $450 million. Noncompliance to the end of 2016 would have caused an additional 130 early deaths and additional social costs of $840 million. (Barrett)

Concerning industry: cement, a component of concrete, creates 5% of global CO2 emissions. About half of the CO2 is from burning fuel to power the chemical process that creates cement, and about half is from the chemical process itself (heating calcium carbonate produces lime and CO2). (“Environmental Impact of Concrete”)

### Carbon Dioxide

French scientist Joseph Fourier (1768-1830) first proposed the greenhouse effect in 1824. Carbon dioxide’s major role in the effect was discovered soon afterward; hence “it has been known for almost two centuries that . . . carbon dioxide traps heat.” (USGCRP)

All greenhouse gases in the atmosphere have increased dramatically in modern times: “carbon dioxide, methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years.” (IPCC “Headline”) The big driver of global warming is CO2. (IPCC “IPCC Fifth”)

* From 1750-2010, CO2 in the atmosphere increased 40%. (IPCC “IPCC Headline”; USGCRP)
* From 1900-2008, CO2 emissions increased 16 times. (EPA “Global”)
* From 1958-2014, CO2 in the atmosphere went from 280 parts per million (ppm) to 400 ppm—for the first time in human history. (EPA “Global”)

In short, “CO2 is the main anthropogenic control knob on climate . . .” (IPCC “Physical”)

A special problem with CO2 is its longevity. Unlike, say, water vapor or methane, CO2 stays in the atmosphere a *very* long time. Of the CO2 we’ve emitted since 1750 (the Industrial Revolution, when we began burning fossil fuels in earnest), 70% will still be there in a hundred years; 40% will still be there in a thousand years. (Weitzman)

### Deforestation

“Tropical deforestation accounts for about 10 percent of the world’s heat-trapping emissions—equivalent to the annual tailpipe emissions of 600 million average U.S. cars. Reducing tropical deforestation can significantly lower global warming emissions . . .” (Union of Concerned Scientists “Global”)

Worse yet: plants absorb CO2—that’s why the Amazon and Congo rain forests have been called “the lungs of the world.” The destruction of forests means that CO2 that might have been absorbed remains in the atmosphere.

“A substantial body of evidence suggests that action to prevent further deforestation would be relatively cheap compared with other types of mitigation . . .” (Stern xiii)

### World Population

The population of the world has grown exponentially. Note the decreasing intervals between the dates in the top row (m = million, b = billion).

world population, 7000 bc-ad 2050 (Cipolla; Kanazawa; US Census Bureau)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 7000 | ad 1 | 1650 | 1750 | 1804 | 1927 | 1959 | 1974 | 1987 | 1999 | 2011 | c. 2030 | c. 2050 |
| 2-20 m | 200 m | 500 m | 750 m | 1 b | 2 b | 3 b | 4 b | 5 b | 6 b | 7 b | 8 b | 9 b |

In 1798, Thomas Malthus in *An Essay on the Principle of Population* predicted that humans, like all species, will outstrip their resources and crash. That has not happened globally yet, largely because of the Green Revolution (1930s-60s: developments in high-yield grains, fertilizers, pesticides, irrigation, and land management). But world population is continuing to climb its parabola. Will there be another Green Revolution, or will we crash into the wall? The US Global Change Research Program expects that “Climate change will . . . alter the stability of food supplies and create new food security challenges . . . as the world seeks to feed nine billion people by 2050.” (USGCRP)

Some see population growth as a major cause of climate change.

The biggest impact a US citizen can have on global environment problems, such as climate change, is having fewer children. Every American child born will add almost 10,000 metric tons of CO2 to the atmosphere . . . 160 times more than a Bangladeshi baby. [Solution: move everyone to Bangladesh!] According to researchers at Oregon State University, having one fewer child reduces a US family’s greenhouse gas impact 20 times more than driving a Toyota Prius . . . (Biello)

Pope Francis, however, places the blame elsewhere.

To blame population growth instead of extreme and selective consumerism on the part of some, is one way of refusing to face the issues. It is an attempt to legitimize the present model of distribution, where a minority believes that it has the right to consume in a way which can never be universalized, since the planet could not even contain the waste products of such consumption. Besides, we know that approximately a third of all food produced is discarded . . . (§ 50)

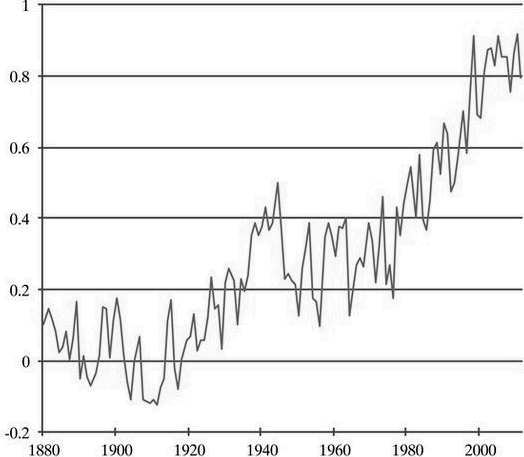
### Global Warming

How do we know the world is warming? Here are some indicators, as well as some data sources that measure the indicators (↑ means “increased,” ↓ means “decreased”).

|  |  |  |
| --- | --- | --- |
| *indicators of global warming* | *some sources of data* |  |
| ↓ glaciers and ice sheets | satellites |  |
| ↓ sea ice | weather balloons |  |
| ↑ sea level | weather stations |  |
| ↑ sea surface temperature | thermometers |  |
| ↑ temperature above oceans | ocean buoys |  |
| ↑ freshwater surface temperature | tide gauges |  |
| ↑ water vapor | ice cores |  |
| ↑ precipitation | soil boreholes |  |
| ↑ temperature over land | tree rings (USGCRP) |  |
| ↓ frost-free days |  |  |
| ↓ snow cover |  |  |
| ↑ extreme weather events |  |  |

“All the indicators expected to increase in a warming world are increasing, and all those expected to decrease in a warming world are decreasing.” (USGCRP)

Direct measures of temperature for more than a century show that the Earth is warming. Here are global mean temperatures (º C) from 1880-2010. (Nordhaus “Why”)



From 1895 to the present, in the US the average temperature has gone from 1.3° F to 1.9° F; and most of the increase has been since 1970. (USGCRP)

Most of the warming is being stored in the oceans. Ocean warming accounts for “more than 90% of the energy accumulated between 1971 and 2010.” Nor is that all: “during the 21st century . . . Heat will penetrate from the surface to the deep ocean and affect ocean circulation.” (IPCC “Headline”) Not to mention marine life.

To contain global warming, it will not be enough to bring our emissions to a standstill; we must bring atmospheric CO2 to a standstill.

To reduce the changes occurring in climate, we would need to stabilize atmospheric levels of carbon dioxide, not simply stabilize current emission levels of carbon dioxide. Just stabilizing emissions still leads to increasing amounts of carbon dioxide in the atmosphere, because emissions are greater than the sinks that remove it. To stabilize levels of atmospheric carbon dioxide, emissions would need to be reduced significantly, on the order of 80% or more . . . (Walsh 817 figure 28)

What target temperature should we aim for? The 2009 *Copenhagen Accord* says the “scientific view” is less than 2º C (3.6º F). Barrett says “Support for the 2° C goal is universal.” (261) Schell­nhuber thinks of 2° C as a “guardrail.” (4)

2º C, however, was chosen because it is still attainable, not because it is a safe amount of change. (Kolbert) It may be too little. We are heading toward twice the 2º C goal. Our present trajectory will bring us to an

average temperature change of 4.5 C (8.2 F) . . . The world has not seen this level of CO2 concentrations for some 50 million years, when crocodiles and palm trees thrived in the Arctic Circle, Greenland and Antarctica were ice-free, and sea levels were hundreds of feet higher than today. (Weitzman)

### Effects of Global Warming

There are many effects of global warming. Some are direct effects, such as extreme weather events. Others are indirect, add-on effects.

#### Extreme Weather Events

##### Extreme Heat

One type of extreme weather event is heat spells. According to the USGCRP, “the human influence on climate has already roughly doubled the probability of extreme heat events such as the record-breaking summer heat experienced in 2011 in Texas and Oklahoma.” A few months ago, a heatwave in India killed more than 2,300 people, and researchers say future heat waves could be “significantly more severe.” (Worland “These”) Not just humans will be affected: “livestock . . . and wildlife get no respite from the heat.” (USGCRP)

In “wet temperature” (high heat plus high humidity), the threshold of survivability is only 95° F (35° C)—and that’s for a fit and well-ventilated person (for most of us, it is lower). Even for a fit person, 6 hours of such exposure results in hyperthermia. (Pal and Eltahir)

If nothing changes by 2100, some cities in the Persian Gulf—Doha, Abu Dhabi, Bandar Abbas—will have ordinary summer temperatures above 140º F (60º C, about the highest temperature ever recorded on Earth). Such heat will not only kill people, it will disrupt the annual pilgrimage of millions to Mecca, and it will disrupt the oil industry on which the region depends. (Worland “These”)

High heat will also affect the objects we make. Rail lines have already been known to buckle in a “dry temperature” of only 104° F (40° C). At 140° F (60° C), “aircraft may not operate properly during takeoff and landing . . .” (Pal and Eltahir)

Curbing emissions will help. Extreme heat “will likely not occur [if] the world holds temperature increase to somewhere between 2° F (1.1° C) to 4.68° F (2.6° C) by 2100 rather than the expected 7.2° F (4° C) increase without any action.” (Worland “These”)

##### Extreme Storms: Heavy Rains

Precipitation is becoming concentrated in heavy rainfalls. In other words, more rain is coming down in heavy downpours and less in lighter, more frequent showers. Here are the increases in the amount of precipitation that has fallen in the heaviest 1% of rainfalls in the US from 1958-2012 (USGCRP).

Northeast 71% south Central and West 16%

eastern Midwest 37% Northwest 12%

Southeast 27% Southwest 5%

##### Extreme Storms: Storm Surge

When Hurricane Katrina hit New Orleans in 2005, it was only a category 2 hurricane. Yet it killed over 1,800 people and caused over $100 billion in damage. Why? Storm surge. (Worland “Why Climate”)

Storm surge occurs when waters rise above their normal level during a storm and wind and weather conditions push that water onto shore. . . . climate change will increase the devastation caused by hurricanes as sea levels rise . . . sea levels are estimated to rise 1 to 3 feet by 2100 due to climate change, and researchers say that in places like New Orleans 1 foot of sea level rise may lead to a 3 or 4 foot storm surge rise. (Worland “Why Climate”)

##### Extreme Storms: Flooding

Heavier downpours and storm surges will create too much runoff for storm drains and levees to handle, causing flooding and accelerated erosion.

Residents of some coastal cities [already] see their streets flood more regularly during storms and high tides. Inland cities near large rivers also experience more flooding . . . Insurance rates are rising in some vulnerable locations, and insurance is no longer available in others. (USGCRP)

##### Extreme Storms: Hurricanes

Though global warming is affecting hurricanes, the effects require further study.

Many peer-reviewed studies suggest that warmer weather in tropical oceans has increased the frequency of tropical storm activity, though not necessarily the intensity. Others suggest that climate change has made storms more intense. Still other research has suggested that future storms will be both more frequent and more intense. (Worland “Why Climate”)

#### Wildfires

Because weather is becoming hotter and drier, and because snow melts earlier, wildfires in the western US “start earlier in the spring, last later into the fall, and burn more acreage.” High temperatures cause droughts that “lead to larger wildfires and longer fire seasons.” (USGCRP)

Moreover, there is an add-on effect here: smoke from wildfires releases particulates into the air; the particulates change atmospheric properties that affect weather patterns and, of course, cause cancer. (USG­CRP)

#### Thawing Ice and Permafrost

In the Arctic, sea ice now disappears in the summer. The loss of ice cover is already “roughly equal to half the area of the continental United States . . .” (USGCRP)

Here, too, there are add-on effects. Summer sea ice used to protect Alaska’s coasts, but “autumn storms now cause more erosion, threatening many communities with relocation.” In addition, the “decline of summer sea ice . . . exacerbates global warming by reducing the reflectivity of Earth’s surface [its albedo] and increasing the amount of heat absorbed.” (USGCRP)

Not just ice, but also permafrost is disappearing. In Alaska, “rapid thawing of permafrost . . . is causing extensive damage to infrastructure . . .” (USGCRP)

Now we come to a truly frightening add-on effect: exposure of the long-buried soils under ice and permafrost may release large amounts of methane.

Recent observations in the Siberian arctic show increased rates of methane release from the Arctic seabed. Land-based permafrost, also in the Siberian arctic, was estimated in 2013 to release 17 million tons of methane per year . . . Shakhova et al. (2008) estimate that not less than [1.5 trillion tons] of carbon are presently locked up as methane and methane hydrates under the Arctic submarine permafrost . . . They conclude that “release of up to [55 billion tons is] highly possible for abrupt release at any time.” That would increase the methane content of the planet’s atmosphere by a factor of twelve. (“Arctic Methane Release”)

What about the truly stupendous amounts of methane trapped inside the offshore continental shelves by low temperatures—might they start to become unstuck by higher ocean temperatures, thereby triggering a vicious global warming circle? (Weitzman)

#### Rising Sea Level

A higher sea level intensifies some extreme-weather effects: storm surges, flooding, hurricanes, erosion.

There are two principal reasons why sea level is rising. Yes, ice is melting around both poles. But also, water expands when heated. Of the global rise in sea level observed over the last 35 years, about 60% is from melting glaciers and ice sheets, and about 40% from heating the water. (Walsh 808)

In the last 100 years, the worldwide sea level has risen around 8 inches. But the rise is quickening. The rate of increase since 1992 is twice what it was from 1890-1991. Between now and 2100, sea level is expected to rise 1-4 feet. (USGCRP; Walsh 808) That much rise endangers “Coastal infrastructure, including roads, rail lines, energy infrastructure, airports, port facilities, and military bases . . . nearly five million Americans and hundreds of billions of dollars of property are located in areas that are less than four feet above the local high-tide level.” (USGCRP)

The long-range outlook for sea-level rise is even more pessimistic. “. . . disintegration of the West Antarctic and Greenland ice sheets [is] associated with about 3.3 [11 feet] and 7 meters [23 feet] of sea-level rise, respectively.” (Schellnhuber 5)

#### Ocean Acidification

Oceans have always absorbed CO2 from the atmosphere. Oceanic CO2 interacts with water to form carbonic acid. Increased carbon emissions mean increased atmospheric CO2, which means increased oceanic CO2, which means increased carbonic acid. Hence, the oceans are becoming more acidic.

In the last 250 years (since the Industrial Revolution), the oceans have absorbed about 30% of the carbon dioxide we have emitted. (IPCC “Headline”) Not coincidentally, the acidity of the oceans has also increased about 30%. At our present rate of emissions, by 2100 the oceans will be 150% more acidic. The oceans have not experienced that level of acidity for over 20 million years. (Walsh 809)

Ocean acidity “makes water more corrosive, reducing the capacity of marine organisms with shells or skeletons made of calcium carbonate (such as corals, krill, oysters, clams, and crabs) to survive . . .” Loss of those organisms will, of course, affect marine life further up the food chain. (USGCRP)

#### Decreased Biodiversity

Five great extinctions are often grouped as the major “extinction events.” A sixth, human-induced event is now underway. “. . . the average rate of vertebrate species loss over the last century is up to 100 times higher than the background rate.” (Ceballos) Species are disappearing at the rate of 140,000 a year. (Pimm)

Ecosystems provide a rich array of benefits and services to humanity, including habitat for fish and wildlife, drinking water storage and filtration, fertile soils for growing crops, buffering against a range of stressors including climate change impacts, and aesthetic and cultural values. . . . salt marshes, reefs, mangrove forests, and barrier islands defend coastal ecosystems and infrastructure, such as roads and buildings, against storm surges. The loss of these natural buffers due to coastal development, erosion, and sea level rise increases the risk of catastrophic damage . . . Extreme weather events that produce sudden increases in water flow, often carrying debris and pollutants, can decrease the natural capacity of ecosystems to cleanse contaminants. (USGCRP)

Coral reefs are an example of decreased biodiversity. High temperatures force coral to

expel the algae [that] help nourish them and give them their vibrant color. This is known as coral bleaching. If the high temperatures persist, the coral die. [808] . . . Both the increased acidity and higher temperature of the oceans . . . negatively affect corals . . . (Walsh 808-09)

On the other hand, not everything can be saved. The Earth has limited space. It’s hard to imagine how the various planetary systems that replaced each other every 400 million years or so could cohabit. Had the dominance of dinosaurs in the age of reptiles (280-66 million) been preserved, we mammals would not have come into our own. Or again, perhaps hunting to extinction large mammals (woolly mammoths, cave bears, aurochs) in the last 20,000 years was an acceptable trade-off for our ancestors’ high-protein diet. Biodiversity policy “involves tradeoffs—we simply cannot . . . save everything.” (Kanazawa)

#### Scarce Food and Water

Food: scientists working for Bank of America Merrill Lynch think that a 40% drop in wheat and corn production in Africa and a 30% drop in rice yields in Asia may result in mass starvation.

Water: the Himalayan glaciers may be “significantly reduced by 2050, putting the water source of billions of people at risk.” Already, 20 cities—a third of a billion people—use 40% or more of water from their watersheds. (BofAML)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Tokyo 37.8 million | São Paulo 20.8 m | Istanbul 13.9 m | Moscow 12.0 m | Lima 9.7 m |
| Delhi 24.9 m | Beijing 19.5 m | Chongqing 12.9 m | Tianjin 10.8 m | Bangalore 9.7 m |
| Shanghai 22.8 m | Karachi 16.1 m | Rio de Janeiro 12.8 m | Shenzhen 10.6 m | Chennai 9.6 m |
| Mexico City 20.8 m | Kolkata 14.7 m | Los Angeles 12.3 m | London 10.1 m | Hyderabad 8.6 m |

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I hope that, given the evidence above, you can see why Pope Francis accepted the consensus opinion of the scientific community. That consensus affirms that: climate change is occurring; it has both natural and anthropogenic causes; its negative effects are serious indeed; we should do something about it.

## climate-change deniers

Yet not everyone is willing to accept the evidence. Unwilling individuals are generally known as “climate-change deniers.” (For some reason “denialists” is gaining ground.) Deniers include many ordinary people who find climate-change arguments difficult to assess. But they also include a number of reputable and authoritative scientists. Before concluding this overview of the science upon which Pope Francis has based his encyclical, we should consider the arguments typically put forward by deniers.

In January 2012, *The Wall Street Journal* published an opinion piece entitled “No Need to Panic about Global Warming.” Though no author is given, the piece is signed by sixteen scientists. The deniers made the mistake of citing research by William D. Nordhaus, Yale economist specializing in climate change, in a way that he felt misrepresented him; so Nordhaus wrote a rebuttal. It was published in February 2012 in the *New York Times* (presumably the *WSJ* refused it): “Why the Global Warming Skeptics Are Wrong.”

Nordhaus begins by complimenting the *WSJ* article for its usefulness “because it contains many of the standard criticisms [of climate change] in a succinct statement.” (Nordhaus “Why”) Let us, then, follow Nordhaus’ lead and use the *WSJ* article as a summary of deniers’ arguments. We will give, first a quotation or claim from the deniers, then a rebuttal.

(1) Deniers say: “Perhaps the most inconvenient fact is the lack of global warming for well over 10 years now.” (“No Need”)

It’s true that warming slowed from 2000-2010. Nevertheless, on average temperatures rose from 1880-1980 by 0.0042° C per year, and they rose from 1981-2010 by 0.0177º C per year—0.0135° C more rapidly. (Nordhaus “Why” n. 3) Also, “Each of the last three decades [1983-2013] has been successively warmer,” and all three were warmer “than any preceding decade since 1850.” (IPCC “Headline”) As a result, 9 of the 10 warmest years ever recorded have been since 2000. (Worland “2014”)

Noting the deniers’ small sample size (“well over 10 years”), Nordhaus gives an analogy: “Suppose an analyst says that because real stock prices have declined over the last decade (which is true), it follows that there is no upward trend.” (Stocks have gained an average of 10% annually for the last 100 years.) (Nordhaus “Why”)

(2) Deniers say: “CO2 is not a pollutant.” (“No Need”)

Presumably they mean that CO2 is not toxic (we breathe it in with every inhalation). But CO2 can have indirectly deleterious effects without being directly toxic. We have seen above the effects of increased atmospheric CO2.

(3) Deniers say: “Alarmism over climate is of great benefit to many, providing government funding for academic research and a reason for government bureaucracies to grow.” (“No Need”)

As an academic, Nordhaus seems to find this charge personally offensive:

[This suggests] that standard theories about global warming have been put together . . . to raise funds from government agencies . . . Academic advancement occurs primarily from . . . contributions to the advancement of knowledge, not from supporting “popular” views. (Nordhaus “Why”)

Most of the 360 scientists who participated in the US Global Change Research Program’s *National Climate Assessment 2014* received no compensation. And all of the 831 scientists who helped compile the UN’s *Climate Change 2013* received none.

(4) Deniers say: “Scientists are divided about climate change.” (“No Need”)

That is technically true but very misleading: “97 percent of working climate scientists accept that global warming is happening . . .” (Gillis) According to the Pew Research Center: (Carle)

* 97% of climate scientists say the earth is warming.
* 97% of climate scientists say humans contribute to global warming.
* 94% of non-climate scientists (physicists, chemists, biologists) say the earth is warming.
* 92% of non-climate scientists say humans contribute to global warming.

(Public opinions, by the way, are quite different:

* Less than 67% of Americans believe the earth is warming.
* Only 40% of Americans say humans contribute to global warming.
* 62% of Democrats are “very concerned” about climate change.
* 20% of Republicans are “very concerned” about climate change.)

The United Nations’ Intergovernmental Panel on Climate Change (IPCC) is composed of consensus scientists. For its report *Climate Change 2013*, it used

* the 831 scientists already mentioned (from “meteorology, physics, oceanography, statistics, engineering, ecology, social sciences and economics” [IPCC “IPCC Fifth”])
* “Over 2 million gigabytes of numerical data from climate model simulations” (IPCC “Working”)
* “Over 9200 scientific publications cited” (IPCC “Working”)

(5) Deniers say: current climate change may be entirely natural. (“No Need”)

Nope: natural causes are not sufficient to explain current change. Milankovich cycles, for example, are millennia long: they cannot explain the present rate of change.

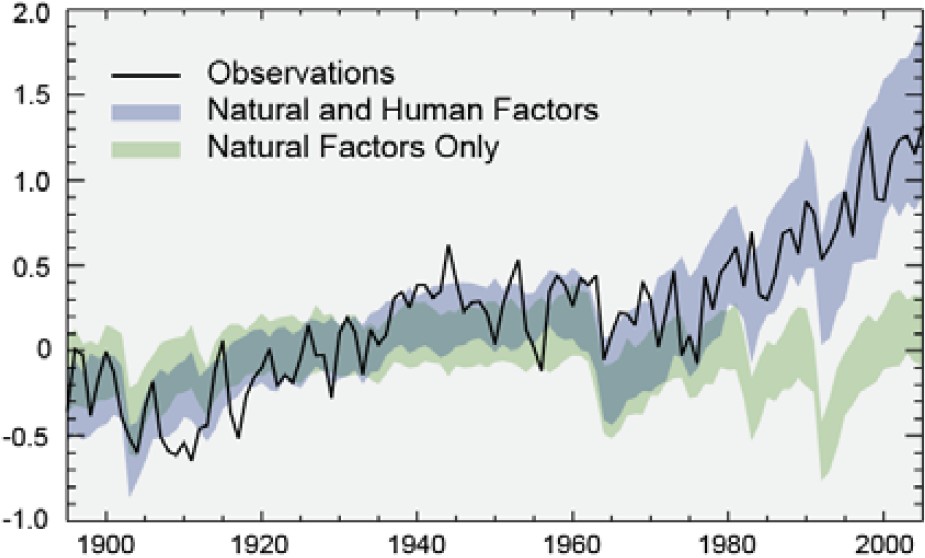
After a glacial maximum, the Earth typically warms by about 7° F to 13° F over thousands of years . . . The observed rate of warming over the last 50 years is about eight times faster than the average rate of warming from a glacial maximum to a warm interglacial period. (Walsh 795)

As for solar radiation and volcanoes, they cannot be the cause.

Sensors on satellites have measured the sun’s output with great accuracy and found no overall increase during the past half century. Large volcanic eruptions during this period, such as Mount Pinatubo in 1991, have exerted a short-term cooling influence. (USGCRP)

Since accurate satellite-based measurements of solar output began in 1978, the amount of the sun’s energy reaching Earth has slightly decreased, . . . but the Earth’s temperature has continued to rise. The sun can explain less than 10% of the increase in temperature since 1750, and none of the increase in temperature since 1960. (Walsh 800)

Let us compare how climate would have changed had only natural causes been in play and how climate did in fact change with both natural and anthropogenic causes in play.



The black line shows actual recorded global average temperatures (º F) from 1895-2005. The green band shows climate models’ projected warming when only natural causes are in play. The blue band shows climate models’ projected warming when both natural and anthropogenic causes are in play. (The green and blue bands are thick because each represents many climate models, whose results differ somewhat because of different starting assumptions. Note, however, that all models predict relatively flat warming for natural-only causes and increasing warming for natural-plus-anthropogenic causes.) (Walsh 803 figure 15; see also 807 figure 19) The *Third National Climate Assessment 2014* concludes: “The match up of the blue band and the black line illustrate that only the inclusion of human factors can explain the recent warming.” (Walsh 803 figure 15)

(6) The deniers say: climate change is actually advantageous. (“No Need”)

The US Global Change Research Program also has a good answer for this one: some “changes can be beneficial over the short run, such as a longer growing season in some regions and a longer shipping season on the Great Lakes. . . . But many more are detrimental . . .” (USG­CRP)

(7) Deniers say: technology will save us.

Some have criticized *Laudato si*’ for downplaying “technology and market mechanisms” and playing up the importance of spiritual transformation. Eduardo Porter belongs to this camp:

[The encyclical] condemned technology and market mechanisms like carbon trading. The pope sees in climate change an opportunity to reform humanity’s ways. So he called on the world to address the challenge by tempering overconsumption. In so doing, however, his encyclical deprived people of the tools humanity will need to prevent climatic upheaval. “We need to look at it as a program of carbon management, not of reforming society,” said Armond Cohen, executive director of the Clean Air Task Force, a nonprofit research and advocacy group. (Porter)

Similarly, Holman W. Jenkins, columnist for the *Wall Street Journal*, chides “this anti-economic pope” for his “moral hectoring.” Francis “expresses a general disdain for technology [which is] confounded with his hope that people in the future will be less materialistic . . .” Spiritual transformation will not work; only technology will save us.

. . . it’s not inconceivable that nano batteries might emerge in the coming decades that will render the whole [climate] debate moot . . . the biggest influence on the climate puzzle over the next 100 years . . . will come from technological change and a competitive economy’s search for efficiency . . . (Jenkins)

Deniers’ characterization of Francis as practically a Luddite is unfair. Francis admires technology. “Technology has remedied countless evils . . .” (§ 102) “Who can deny the beauty of an aircraft or a skyscraper?” (§ 103) “. . . innovative forms of production which impact less on the environment can prove very profitable. It is a matter of openness to different possibilities which do not involve stifling human creativity and its ideals of progress . . .” (§ 191)

But they read Francis correctly when they say that he does not believe new technology alone will solve climate change.

At one extreme, we find those who doggedly uphold the myth of progress and tell us that ecological problems will solve themselves simply with the application of new technology and without any need for ethical considerations or deep change. At the other extreme are those who [say] human beings on the planet should be reduced and all forms of intervention [by humans in nature] prohibited. Viable future scenarios will have to be generated between these extremes . . . (§ 60)

Francis is not opposed to the use of technology to help solve climate change. He is only opposed to the focus on technological change as the sole solution, “without any need for ethical considerations or deep change.”

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If global warming is occurring, then climate-change deniers are actually dangerous. Their danger increases when they hold power in Washington. Senator Ted Cruz (R-TX), chair of the subcommittee that oversees science, says, “The last 15 years, there has been no recorded warming. Contrary to all the theories that they are expounding . . .” (Qtd. in Kluger) Senator James Inhofe (R-OK), chair of the committee that oversees the environment, says climate change is “the greatest hoax ever perpetrated on the American people . . .” (Qtd. in Kluger) Jeb Bush, presidential candidate, said about *Laudato si*’, “I think religion ought to be about making us better as people.” (Qtd. in McKibben) In Congress, “by straight party-line votes, both the House and Senate appropriations committees have passed bills that would make it impossible for President Obama to limit carbon dioxide emissions from coal-fired power plants . . .” (Editorial Board) Obama will of course continue to veto such bills; the next president may not.

Why do climate-change deniers deny climate change? No doubt some of them—even scientists among them—genuinely find the evidence unpersuasive. It is possible, however, that some deniers receive donations from or are in the employ of the fossil-fuel industries (coal, oil, and natural gas). Earlier this year it was revealed that a scientist at the Harvard-Smithsonian Center for Astrophysics (Wei-Hock Soon, who blames global warming on sunspots) received $1.2 million in the last ten years to deny anthropogenic climate change. About half a million came from coal-firm Southern Company Services, and about a fourth of a million came from the Koch brothers’ conservative political foundation. “. . . in correspondence with his corporate funders, [Soon] described many of his scientific papers [not to mention his testimony before Congress] as “deliverables” that he completed in exchange for their money.” (Gillis and Schwartz)

It is typical of deniers to insist on fossil fuels’ glorious past.

This global warming theory relies on a satanic gas, carbon dioxide. This gas is a byproduct of our very breathing and our use of fossil fuel, one of the greatest contributors to human life and flourishing. The theory, however, treats fossil fuel as an evil that must be restricted and eventually abandoned. (Briggs)

Poverty has probably decreased more in the past two centuries than in the preceding three millennia because of industrialization powered by fossil fuels. Only economic growth has ever produced broad amelioration of poverty, and since growth began in the late 18th century, it has depended on such fuels. (Will)

It’s true that industrial growth since about 1750 lifted many out of poverty; it’s also true that it depended on fossil fuels. But does it follow that fossil fuels cannot now have become a problem? We dare not diminish our reliance on them, lest growth diminish? We need not develop renewables?

For several decades now, the Union of Concerned Scientists has documented attempts by the fossil-fuel industries to misguide public opinion about climate change. The Union has compiled the instances into a file they call the “Climate Deception Dossiers.” Here is an example.

. . . a 1995 internal memo written by a team headed by a Mobil Corporation scientist [was] distributed to many major fossil fuel companies. The internal report warned unequivocally that burning the companies’ products was causing climate change and that the relevant science “is well established and cannot be denied.” How did fossil fuel companies respond? They embarked on a series of campaigns to deliberately deceive the public about the reality of climate change and block any actions that might curb carbon emissions. The result? More than half of all industrial carbon emissions have been released since 1988 . . . (Union of Concerned Scientists “Climate”)

On 4 Nov. 2015, the New York State Attorney General began an investigation “into whether Exxon Mobil had lied to the public about climate change,” and the inquiry may expand to other companies. The Attorney General has also been investigating Peabody Energy, the nation’s largest coal producer, for two years. A law professor at the University of Virginia notes:

This could open up years of litigation and settlements in the same way that tobacco litigation did, also spearheaded by attorneys general. In some ways, the theory is similar—that the public was misled about something dangerous to health. Whether the same smoking guns will emerge, we don’t know yet. (Qtd. in Gillis and Krauss) (I hope the professor intended that pun.)

In 2006, tobacco companies were found guilty of “a massive 50-year scheme to defraud the public” (Gillis and Krauss) and forced to pay $206 billion. (“Tobacco”)

The Heartland Institute, a climate-denial group, has received hundreds of thousands of dollars from Big Oil. At a Philadelphia press conference Sept. 17 (a week before Pope Francis was to arrive there), a Heartland official asked, “What is environmentalism but nature worship? . . . pagan forms are returning to [the Catholic] church.” (“Heartland”)

Why have the voices of deniers and affirmers alike become more strident? Because billions, even trillions, of dollars are at stake here.

. . . restricting the use of the atmosphere as a carbon dump . . . will devalue the assets and the property titles of today’s owners of coal, oil and gas. Almost 80% of coal has to remain underground in a [2º C] climate-change mitigation scenario . . . [Perhaps] the upcoming devaluation of fossil resources [will be] an act of ‘creative destruction,’ instigating a new integral industrial revolution that would bring enormous economic opportunities . . . (Schell­nhuber 6, 8)

We have a choice, then: accept the findings of the 97% or accept the denials of the 3%. Harvard economist Martin L. Weitzman, in calculating “The Odds of Disaster,” asks: “can we afford the luxury of assuming that a small minority of climate skeptics are more correct than the vast majority of mainstream climate scientists? What is the probability of that?” (Weitzman)

# ECONOMICS

## The Burden of Climate Change

Already climate and weather disasters are costing us. In 2012, they cost the American economy almost $110 billion. (Obama Administration) Destruction of the coral reefs, mentioned before, will by itself result in a loss of about “$375 billion per year in goods and services.” (“Climate Change Impacts”)

One critical period in which temperatures are a major factor is the pollination stage . . . Exposure to high temperatures during this period can greatly reduce crop yields . . . With the number of nights with hot temperatures projected to increase as much as 30%, yield reductions will become more prevalent. (USGCRP “National”)

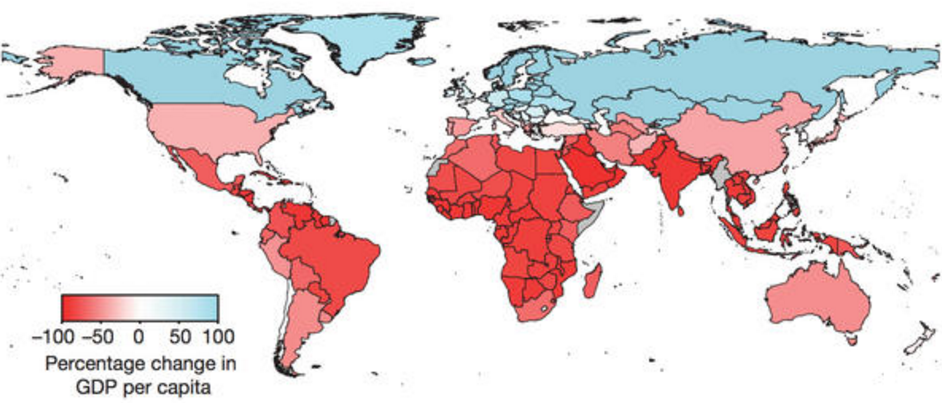
Around the world, climate change could lead to a 5% decline in crop yields by 2030 and 30% by 2080. Disease spread during extreme weather events also threaten to exacerbate global poverty . . . poor households are more vulnerable to increases in food prices . . . (Worland “Climate Change Could Drive”)

In 2006 the British government commissioned a leading economist, Nicholas Stern of the London School of Economics, to assess the costs of climate change. The result was the 700-page *Stern Review on the Economics of Climate Change*. Stern demonstrates that “delaying emissions cuts . . . means that emissions must be reduced more rapidly to achieve the same stabilisation goal.” (Stern xii, xv figure 4) Lessening the effects of climate change *now* will cost 1% of annual global GDP by 2050; lessening them once the temperature is 5-6° C will cost 5-10% of annual GDP, “with poor countries suffering costs in excess of 10% of GDP.” (Stern ix)

In a *Nature* article last month, three economists from Berkeley and Stanford (Burke, Hsiang, and Miguel) estimated that, by 2100, climate change will reduce average global incomes by 23%. While labor productivity and crop yields peak around an annual average temperature of 55º F (13º C), they drop off sharply thereafter. (Hiltzik) Plants and animals, including humans, are adapted to the world they’ve had for 13.7 thousand years (the Holocene).

## The Gap between Rich and Poor

Climate change will widen the gap between rich and poor countries. That is because presently-warm countries will become too hot, while presently-temperate countries will only become warm. In the map below (from Burke, Hsiang, Miguel), “The redder the color, the more severe the impact.” (Hiltzik)



The most severe effects will be felt by countries in the already-warm zones destined to become warmer [red]. . . . Regions now in the temperate zone [will] get warmer and therefore less economically productive [pink] . . . Regions that may remain relatively cool and may experience an increase in productivity, or at least a relative advantage over other regions, include Canada, much of the rest of Europe, and Russia [blue] . . . (Hiltzick)

Note also that Burke, Hsiang, and Miguel only measure the cost of *rising temperature* on the economy; they do not include the *effects* of global warming. “This means the study does not account for the economic impact of sea level rise, storms or any of the other expected effects of climate change beyond simple warming.” (Worland “Climate Change Could Wreck”) Add in the effects, and the difference between action and inaction stretches. A Citi­group report “has found that minimizing temperature rises to 2.7º F (1.5º C) could minimize global GDP loss by $50 trillion compared to a rise of 8.1º F (4.5º C) in the coming decades.” (Worland “Why Big”)

As the map shows, global warming is going to be felt disproportionately by developing countries. Add-on effects will increase their misery.

Since most of the Earth’s ice—inherited from many ice ages over countless millennia—is located near the poles on Greenland and the Antarctic continent, its loss by melting . . . sets the water free to float more towards the Equator [due to gravitational pull]. This is the region on the globe where most of [the poorest] are living . . . (Schellnhuber 4)

Pope Francis is right to note the inextricably linked fates of the Earth and the poor. (§ 10)

Something, it seems, should be done.

## Successes

There have been some successes in addressing climate change.

* 1963: the Clean Air Act of 1963. Rachel Carson’s *Silent Spring*, generally credited with launching the environmental movement, had only been published the previous year. The Act, however, was not motivated by the book but by increasing alarm over smog in Los Angeles.
* 1970: the Clean Air Act of 1970 required catalytic converters. Thanks in large part to them, “Ozone levels in Los Angeles are just 40 percent of what they were in the mid-1970s, and that’s with more than twice the number of cars.” (Gardner) 1970 also saw the creation of the Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA).
* 1988: the UN’s Intergovernmental Panel on Climate Change
* 1990: the US Global Change Research Program

The Obama Administration, too, can boast some recent successes.

. . . we set the highest fuel economy standards in American history that will double the efficiency of our cars and trucks by 2025. (Obama Administration)

. . . we doubled renewable energy generation from wind and solar resources. . . . Renewable energy accounts for about half of all new generation capacity installed in 2012. (Obama Administration)

. . . in 2012, US energy sector carbon pollution fell to the lowest level in nearly 20 years. (Obama Administration) CO2 emissions from energy use [in the US] . . . declined by around 9% between 2008 and 2012, largely due to a shift from coal [to] natural gas for electricity production. (USGCRP)

[In 2014] President Obama set a goal of reducing carbon emissions by as much as 28 percent from 2005 levels by 2025, only 10 years from now. (Porter)

Another success: more and more corporations are coming on board. Microsoft now only uses renewable energy; it even buys carbon offsets to counteract emissions due to travel. On Sept. 23, “nine Fortune 500 companies announced plans to switch to sourcing 100% renewable energy . . .” The companies include Walmart, Procter & Gamble, Johnson & Johnson, Starbucks, Nike, Goldman Sachs, Salesforce, and Steelcase. (Worland “Why Big”)

## Renewables

For decades now, scientists have been working on the greatest renewable resource of all: nuclear fusion. (Whereas present-day nuclear reactors split atoms [fission], future reactors will fuse them [fusion].) Fusion should provide virtually unlimited, clean energy at relatively small expense. Fusion is the big prize, a prize even bigger than oil. (Yergin) “Fusion would mean the end of fossil fuels. It would be the greatest antidote to climate change . . .” (Grossman 32) But fusion is not here yet. Michl Binderbauer of Tri Alpha Energy expects commercial fusion “within a decade”; Stewart Prager of Princeton Plasma Physics Lab, “by the 2040s.” (Grossman 38)

In the meantime, there are current renewables to develop, such as solar and wind.

. . . we are already blessed with [a fusion reactor] that works perfectly well and is free to all of us: the Sun. Photovoltaics [solar panels], wind and energy from biomass are ultimately all powered by sunlight. These new technologies could unfold potential in poor countries where no grid exists to distribute electricity produced by centralized power plants and where settlements may be too distantly located from one another to make such a system feasible. Just like the evolving use of mobile phones without the previous establishment of landlines, developing countries could leapfrog the fossil episode and enter the age of decentralized renewable energy . . . (Schellnhuber 8)

Present renewables are woefully underdeveloped: “Solar power accounted for less than 1% of US electricity generation in 2014 . . .” Nevertheless, the International Energy Agency suggests that “solar power could generate more than a quarter of the world’s energy supply by 2050.” (Worland “SolarCity”)

## Pollution as an Externality

The single greatest hurdle to climate-change mitigation is one that economists have recognized for a century: pollution is an externality.

An externality is a side effect of an economic activity; it is “external” to the direct activity on which the participants are focused. The “activity causes incidental benefits or damages to others not directly involved in the activity . . .” (Baumol and Blinder 356)

Here are examples of both positive and negative externalities.

*Positive Externalities*:

* . . . homeowners who plant beautiful gardens in front of their homes incidentally and unintentionally provide pleasure to neighbors . . . (Baumol and Blinder 310)
* A factory that [trains unskilled laborers] . . . pro­vides the external benefit of better workers to future employers. (Baumol and Blinder 312)
* [Research and development] provide beneficial externalities to persons who [do not] invest in innovation . . . (Baumol and Blinder 356)

*Negative Externalities*:

* . . . the owners of a motorcycle repair shop create a lot of noise for which they pay no compensation to their deafened neighbors. (Baumol and Blinder 310)
* . . . pollution of the air and waterways is . . . contributed by factories and motor vehicles as an incidental by-product of their activities that damages other members of society. (Baumol and Blinder 356)
* [Global warming is] the most threatening damaging externality of them all. (Baumol and Blinder 313)

“Because those who create harmful externalities do not pay for the damage done to others, they have little incentive to desist.” (Baumol and Blinder 357) How, then, have economists proposed that we deal with the most damaging externality, global warming? They have suggested five ways.

The first solution is voluntarism: polluters should voluntarily reduce their polluting. That would be lovely. But competition prevents even well-intentioned firms from cutting back. Rivals will under­price a business that spends on remediation when rivals don’t. (Baumol and Blinder 363)

A second solution is carbon offsets. Such a program determines how much carbon your car or power plant emits, then charges you “to take that carbon out of the atmosphere” by planting trees (reforestation). The first such program was in 1987. AES Corporation was building a coal plant; it determined how much carbon the plant would emit over its 40-year lifetime, estimated the number of trees it would take to offset the carbon, then paid $2 million to have 52 million trees planted in Guatemala.

Hanna Whitman of the University of British Columbia is skeptical of carbon offsets. They don’t force companies or people to change bad behavior; besides, the trees may not get planted, and they die. According to Whitman, “It’s putting a Band-Aid on a gunshot wound.” (Qtd. in Vanek-Smith)

The remaining three options for dealing with global warming are instances of “free-market environmentalism.” (Stroup)

Solution three is government regulation (called “direct controls”). For example, “direct controls may prohibit backyard garbage incinerators or high-sulfur coal burning or require smokestack “scrubbers” to capture the emissions of power plants.” (Baumol and Blinder 363) Regulation is the most commonly used solution in America: the EPA sets emissions standards, and companies must comply. Of course, companies try to sidestep regulations. The Volkswagen defeat-devices mentioned earlier are an example, as are oil companies’ current attempts to pass state laws that take away municipalities’ right to ban their activities. Another problem is that

Direct controls rely on the criminal justice system for enforcement. But a polluter who violates the rules must first be caught. Then the regulatory agency must decide whether it has enough evidence to prosecute. Next, the agency must win its case in court. Finally, the court must impose a penalty strong enough to matter. If any one of these steps does not occur, the polluter gets away with the environmentally damaging activities. . . . [And] in many cases the resources devoted to enforcement are piti­fully small. (Baumol and Blinder 364-65)

These problems explain the present interest in solution four: pollution taxes. With taxes, “polluters pay for the costs they impose on society . . .” (Baumol and Blinder 313)

Most economists agree that relying exclusively on direct controls is a mistake and that, in most cases, financial penalties, or pollution charges, on polluters can do the same job more dependably, effectively, and economically. (Baumol and Blinder 364)

British economist Arthur C. Pigou, the first to explain environmental degradation as an externality (*The Economics of Welfare*, 1911), was also the first to propose charges on pollution to control it. Pollution taxes are “still favored by most economists today . . .” (Baumol and Blinder 356) David Malin Roodman of the Worldwatch Institute thinks “Environmental taxes are perhaps the most powerful tool societies have [to] protect human and environmental health.” (Qtd. in Baumol and Blinder 355)

But this approach too is not without problems.

Social costs are rarely easy to estimate, partly because they are so widely diffused throughout the community (everyone is affected by pollution) and partly because it is dif­ficult to assess many of the costs and benefits (effects on health, unpleasantness of living in smog) in monetary terms. (Baumol and Blinder 314)

Hence the present interest in the fifth solution: cap-and-trade. Cap-and-trade refers to two moments in a process: the government caps emissions, then it sells tradeable emissions permits. “Firms that own the permits can use them or sell them on carbon markets, while firms who need them can purchase permits.” (Nordhaus “Pope”)

. . . the environmental agency decides what quantity of emissions per unit of time (say, per year) is tolerable and then issues a batch of permits authorizing (altogether) just that amount of pollution. The permits are sold to the highest bidders, with the price determined by demand and supply. . . . When the U.S. EPA first introduced tradeable emissions permits in 1995, many people were outraged by the notion of such “licenses to pollute.” Nowadays, one hears few complaints, because tradeable permit programs have turned out to be such a huge success. (Baumol and Blinder 314)

From China to Norway, Kazakhstan to the Northeastern United States, governments are requiring industries to buy permits allowing them to emit set levels of greenhouse gases. Under these plans, the allowable levels of pollution are steadily reduced and the cost of permits rises, creating an economic incentive for companies to cut emissions. (Gillismay)

Cap-and-trade has a significant advantage over carbon taxes: “it reduces *uncertainty* about the *quantity* of pollution that will be emitted. Under a tax, we cannot be sure about this quantity in advance, because it depends on polluters’ future response to a given tax rate.” (Baumol and Blinder 367) But some prefer carbon taxes. “Such a tax is simpler and avoids any of the potential corruption, market volatility, and distributional issues that might arise with cap-and-trade systems.” (Nordhaus “Pope”)

A disadvantage to both taxes and permits is that politics may interfere. The Bush administration attempted to weaken both the Clean Air Act’s regulation of aging power plants and the EPA’s capping of greenhouse gases. Fortunately, the Supreme Court (2 Apr. 2007) struck down both attempts. But the decisions could have gone the other way; environmental solutions are vulnerable to politics. (Baumol and Blinder 367)

Nevertheless, cap-and-trade has been a success. “. . . the number of people living in places that have such a system [is] nearing one billion, or 14 percent of the world’s population, including about 80 million Americans.” (When Congress killed the Obama Administration’s national cap-and-trade plan, 10 states implemented their own.) (Gillismay)

## Solutions and Church teaching

How do these solutions—carbon taxes and cap-and-trade in particular—square with Church teaching? Pope Benedict XVI seems to have approved them: “all economic activity that uses natural resources should also include the costs of safeguarding the environment into the calculations of the overall costs of its activity.” (Pope Benedict XVI) Pope Francis, at first glance, seems to disapprove.

The strategy of buying and selling “carbon credits” can lead to a new form of speculation which would not help reduce the emission of polluting gases worldwide. This system seems to provide a quick and easy solution under the guise of a certain commitment to the environment, but in no way does it allow for the radical change which present circumstances require. Rather, it may simply become a ploy which permits maintaining the excessive consumption of some countries and sectors. (§ 171)

. . . “environmental protection cannot be assured solely on the basis of financial calculations of costs and benefits. The environment is one of those goods that cannot be adequately safeguarded or promoted by market forces.” [Qtd. from *Compendium of the Social Doctrine of the Church* 470] Once more, we need to reject a magical conception of the market, which would suggest that problems can be solved simply by an increase in the profits of companies or individuals. (§ 190)

Here we come to the most serious criticism that has been aimed at the encyclical. While economists are virtually unanimous in praising carbon taxes and especially cap-and-trade, Francis seems to condemn them. The criticisms have been not been muted.

For climate change, the major need is to raise the price of CO2 emissions sufficiently high that they are reduced sharply. This can be done either by taxing emissions or by a system of cap-and-trade. Unfortunately, *Laudato Si*’ does not recognize the fact . . . Given the successes of cap-and-trade and other market mechanisms to improve the environment, it is unfortunate that they are the target of Pope Francis’s criticism. . . . It is unfortunate that he does not endorse a market-based solution, particularly carbon pricing, as the only practical policy tool we have to bend down the dangerous curves of climate change and the damages they cause. (Nordhaus “Pope”)

. . . his skepticism about market-based solutions to climate change is rooted in a misunderstanding. A market-based approach to controlling greenhouse-gas emissions—through carbon taxes or tradable emissions permits—[puts] a price on carbon, so that all businesses and consumers are held accountable and charged for the environmental consequences of their actions. It’s a moral idea that Francis himself endorses elsewhere . . . (Heath, quoting § 195)

Others, however, interpret Francis differently. Anthony Annett, formerly with the International Monetary Fund and a climate-change advisor to Columbia’s Earth Institute, was involved in the preparations of *Laudato si*’. According to Annett, “the pope is criticizing the potential abuse of carbon credits, not ruling them out completely. . . . that business must bear the full social cost of its activity . . . implies putting a price on carbon.” (Qtd. in Romm) This may be the correct interpretation of Francis. He does speak positively of “the obligation of those who cause pollution to assume its costs . . .” (§ 167)

. . . as long as the clearing of a forest increases production, no one calculates the losses entailed in the desertification of the land, the harm done to biodiversity or the increased pollution. In a word, businesses profit by calculating and paying only a fraction of the costs involved. Yet only when “the economic and social costs of using up shared environmental resources are recognized with transparency and fully borne by those who incur them, not by other peoples or future generations,” can those actions be considered ethical. (§ 195, quoting Benedict XVI *Caritas* 50)

Part of the problem is that “carbon credits” (“*crediti di emissione*” in the original Italian) is ambiguous. It is not a term used in economics. Romm calls for clarification:

Without further clarification from the Vatican itself, I can understand why people took that paragraph [§ 171] as critical of carbon trading—although I still don’t understand how one can read the encyclical and think the pope opposes carbon pricing. I’d urge the Vatican to issue a formal statement clarifying the matter . . . (Romm)

I agree that a clarification would be helpful. But I suspect that the misunderstanding is ultimately not so much terminological as ideological. The Pope’s criticism of “carbon credits” should be seen in the context of his broader critique of pure capitalism.

## Critique of Pure Capitalism

Being diplomatic, Francis does not use “capitalism” in *Laudato si*’. Instead, he uses euphemisms like “consumerism” (“consume” and related forms appear 63 times) and “technocratic paradigm” (“technology” and related forms appear 77 times). These euphemisms, however, do not refer to all forms of capitalism, but to capitalism shorn of all other considerations. Hence my adjective, “pure.”

When capitalism in its purer forms is criticized, those toward the right on the free-market spectrum are quick to point out that pure capitalism nowhere exists. (Rush Limbaugh: “Unfettered capitalism? That doesn’t exist anywhere. Unfettered capitalism is just a liberal socialist phrase to describe the United States.” [Qtd. in Tornielli and Galeazzi]) Some forms of capitalism, however, do give selfishness freer rein than others.

And make no mistake: capitalism *is* based on selfishness. Here’s Adam Smith (*Wealth of Nations*, 1776):

man has almost constant occasion for the help of his brethren, and it is in vain for him to expect it from their benevolence only. He will be more likely to prevail if he can interest their self-love in his favour, and shew them that it is for their own advantage to do for him what he requires of them. Whoever offers to another a bargain of any kind, proposes to do this. Give me that which I want, and you shall have this which you want, is the meaning of every such offer; and it is in this manner that we obtain from one another the far greater part of those good offices which we [118] stand in need of. It is not from the benevolence of the butcher, the brewer, or the baker that we expect our dinner, but from their regard to their own interest. We address ourselves, not to their humanity, but to their self-love, and never talk to them of our own necessities, but of their advantages. (Smith 118-19)

This mighty principle—bending individual selfishness to mutual benefit—has served us well.

We are the beneficiaries of two centuries of enormous waves of change: steam engines, railways, the telegraph, electricity, automobiles, aeroplanes, chemical industries, modern medicine, information technology and, more recently, the digital revolution, robotics, biotechnologies and nanotechnologies. It is right to rejoice in these advances . . . (§ 102)

The driving force of capitalism, then, is selfishness. But immediately above that root is *mutual benefit*. Economists do not analyze the capitalist mechanism in various circumstances merely to maximize the selfishness of the individual. Their ultimate goal is the enhancement of mutual benefit. Hence capitalism in all but its purest form is inherently communitarian. Smith acknowledges this: in saying that we appeal “not to [others’] humanity, but to their self-love,” Smith recognizes that there exists, above the root of “self-love,” “humanity” as well. (Notice that Smith presents self-love and humanity as mutually exclusive: self-love alone is inhumane.)

Francis’ criticism is not of all capitalism, but of *pure* capitalism, capitalism shorn of its humanity. Is mutual selfishness to be all there is? Is there nothing more to life? Is the sum of our interactions with one another, or the totality of our existence, to be “*quid pro quo*,” “One hand washes the other,” “You scratch my back, I’ll scratch yours”? The statement by the character Gordon Gekko in the 1987 film *Wall Street* has become famous because it exposes the pure root of capitalism shorn of humanity: “Greed . . . is good.” (“Gordon Gekko”)

What of that other great drive that motivates us, love of others? Jesus commends love of others in the good Samaritan (Luke 10:25-37), the father’s good gifts (Matt 7:9-11//Luke 11:11-13), and the prodigal son (Luke 15:11-32). He castigates its absence in the rich fool (Luke 12:16-21), the rich man and Lazarus (Luke 16:19-31), and the rich young man (Luke 18:18-23). (See Appendix 7 for texts.)

Pope Francis, I think, is looking farther ahead than his critics. What will happen when our mutual selfishness finally ensures full bellies, adequate clothing, and roofs for all? What will life consist of then? Will our selfishness remain uncurbed? If so, then “Life gradually becomes a surrender to situations conditioned by technology, itself viewed as the principal key to the meaning of existence.” (§ 110)

We fail to see the deepest roots of our present failures, which have to do with the direction, goals, meaning and social implications of technological and economic growth. [§ 109] . . . There is a growing awareness that scientific and technological progress cannot be equated with the progress of humanity and history, a growing sense that the way to a better future lies elsewhere. . . . a constant flood of new products coexists with a tedious monotony. Let us refuse to resign ourselves to this, and continue to wonder about the purpose and meaning of everything. Otherwise we would simply legitimate the present situation and need new forms of escapism to help us endure the emptiness. [§ 113] [We need] a bold cultural revolution. [§ 114]

I have said that the Pope’s comments on “carbon credits” should be seen in the context of his analysis of pure capitalism. On the one hand you have pure capitalists who want to rely solely on market-based solutions (carbon taxes or emissions permits).

. . . few of us will be willing to endure present pain so that our grandchildren won’t have to endure an unlivable climate. We’re likely better off tailoring solutions that work with our selfishness and brief attention span, rather than hoping we suddenly become better, more farsighted people. (Walsh)

On the other hand you have the Pope, critical of economic solutions based *solely* on selfishness.

Caring for ecosystems demands far-sightedness, since no one looking for quick and easy profit is truly interested in their preservation. But the cost of the damage caused by such selfish lack of concern is much greater than the economic benefits to be obtained. [§ 36] . . . When people become self-centred and self-enclosed, their greed increases. The emptier a person’s heart is, the more he or she needs things to buy . . . a genuine sense of the common good also disappears. As these attitudes become more widespread, social norms are respected only to the extent that they do not clash with personal needs. So our concern cannot be limited merely to the threat of extreme weather events . . . [§ 204]

Those toward the right on the free-market spectrum have accused the Pope of Marxism. They typically use “Marxism” as a synonym for socialism, “a centrally planned economy in which the government controls all means of production.” (Heilbroner) Rush Limbaugh: “This is just pure Marxism coming out of the mouth of the Pope . . .” Glenn Beck: the Pope has “Marxist tendencies.” (Burke) But Francis is clear: “Marxist ideology is wrong.” (Qtd. in McKenna) Commentator Mark Shields, himself a Catholic, reads the Pope more accurately.

. . . the pope has confronted us with a fundamental question: What are we first? Are we a free market system, that we have confidence that, untrammeled and unfettered, it will eventually provide good for more people? Or are we a community, a community of human beings of equal dignity . . . it’s an optimistic, upbeat, and passionate pope that we are seeing right now who drives a Ford Focus. (PBS)

## Insurance

Some have argued that we should not inflict upon ourselves the massive disruption and expense of combating climate change when the data for its occurrence are not 100% certain. On the contrary: uncertainties are all the more reason to act.

Policies implemented today serve as a hedge against unsuspected future dangers that suddenly emerge to threaten our economies or environment. So, if anything, the uncertainties would point to a more rather than less forceful policy . . . (Nord­haus “Why”)

Many have made the analogy between combating climate change and buying an insurance policy.

. . . abating CO2 emissions is like buying insurance against a catastrophe. We should cut back on CO2 emissions not only to lower the average damages, but, perhaps more importantly, to lower the probability of catastrophic damages. That could imply a lot more CO2 emissions abatement than if we were concerned only about the most likely or average damages. . . . If we don’t start buying into this insurance policy soon, the human race could end up being very sorry . . . (Weitzman)

Martin Rees, Cambridge astrophysicist and a member of the Pontifical Council of Sciences, concurs: “There are a lot of uncertainties and . . . we need to pay an insurance premium against a worst case.” (Qtd. in Yeo “In-Depth”)

Buying this insurance sooner is smarter than buying it later: “the longer we wait to reduce our emissions, the more expensive it will become.” (IPCC “IPCC Fifth”) In fact, we should already have bought it. If we had started in 2010, bringing CO2 emissions down to 265 gigatons by 2050 would have required a 4% reduction in emissions per year. If we start in 2020, it will require double that rate, 8% a year. (Walsh 816 figure 27) If we start in 2065, the cost will be $4.1 trillion. (Nordhaus “Why”)

## Global Governance

Both Benedict XVI and Francis agree on the need for international governance when dealing with climate change.

The twenty-first century, while maintaining systems of governance inherited from the past, is witnessing a weakening of the power of nation states, chiefly because the economic and financial sectors, being transnational, tends to prevail over the political. Given this situation, it is essential to devise stronger and more efficiently organized international institutions, . . . empowered to impose sanctions. (Pope Benedict XVI *Caritas*)

Collaboration, by means of worldwide agreements, backed up by international law, is necessary to protect the environment. Responsibility toward the environment needs to be implemented . . . [by] laws . . . (Pope Benedict XVI “Ten”)

What is needed, in effect, is an agreement on systems of governance for the whole range of so-called “global commons.” (Pope Francis § 174)

The United Nations Framework Convention on Climate Change has already established the Green Climate Fund to distribute monies to developing countries to cope with climate change. Headquartered in Incheon, South Korea, it hopes to raise $100 billion a year by 2020. So far $34.7 billion have been pledged ($5.7 from the US), $16.8 billion have been deposited, and $2.5 billion have been disbursed. (Climate Fund Update)

# CONCLUSION

## Paris 2015

The release of *Laudato si*’ on June 18th was no doubt timed to enhance its impact on the Paris climate change conference that will meet Nov. 30-Dec. 11. (It’s technically called “the 21st Conference of Parties to the United Nations Framework Convention on Climate Change”—“COP21” for short.) Previous efforts to reach an international agreement (the 1997 Kyoto Protocol, the 2009 Copenhagen Accord) failed miserably. The Paris conference will be the most significant attempt yet to negotiate “a new UN treaty aimed at regulating greenhouse gas emissions and dealing with the impacts of climate change.” (Yeo “In-Depth”) President Obama “has pledged to reduce America’s greenhouse gas emissions by 26 percent below 2005 levels by 2025.” (Editorial Board) The date of implementation is to be 2020.

Pope Francis hopes his encyclical will prod consciences at the Conference, but at the same time he does not intend to dictate to the Conference. Two members of the Pontifical Academy of Sciences who were involved in preparing *Laudato si*’ have emphasized this.

It is not a document which wants to prescribe the international negotiations. The Pope wants to highlight, focus and emphasise fundamental ethical principles . . . Like the protection of the poor. Like the global commons. Like the universal destination of goods. And like intergenerational justice. (Ottmar Edenhofer, qtd. in Yeo “In-Depth”)

*Laudato si*’ does not provide technical guidance on how to allocate user rights for the atmosphere. [But] Francis highlights the ethical dimension of the climate problem and provides fundamental principles to be applied for solutions: the preferential option for the poor, inter- and intragenerational justice, common but differentiated responsibility, orientation to the common good. (Schellnhuber 7)

A number of proposals have been made for how the nations of the world should craft an international agreement. Elizabeth Kolbert compares two possibilities.

A simple way to start cutting global emissions would be for all nations to reduce their CO2 output by the same proportion—say, by half. The obvious downside to this strategy is that it would, in effect, reward those countries that have contributed the most to the problem, while punishing those that have contributed the least.

A more equitable approach would be to ask historically high emitters [Europe and especially the US] to cut their emissions more deeply. . . . [Most agree] that if there’s to be any hope at all of hewing to 2 degrees [Centigrade], the EU and the US will have to cut their emissions drastically—by 80 percent or more over the coming decades. (Kolbert)

——————————

The solutions to the problem of global warming should give us hope. And hope is a theme throughout *Laudato si*’.

Hope would have us recognize that there is always a way out, that we can always redirect our steps, that we can always do something to solve our problems. (§ 61)

The God who created the universe out of nothing can also intervene in this world and overcome every form of evil. Injustice is not invincible. (§ 74)

To sense each creature singing the hymn of its existence is to live joyfully in God’s love and hope. (§ 85, quoting the Catholic Bishops’ Conference of Japan)

May our struggles and our concern for this planet never take away the joy of our hope. (§ 244)

The encyclical is especially hopeful concerning you and me—by which I mean, teachers and students.

Concerning teachers, it says, “Environmental education . . . needs educators capable of developing an ethics of ecology, and helping people, through effective pedagogy, to grow in solidarity, responsibility and compassionate care.” (§ 210)

Concerning students, it says, “young people . . . have grown up in a milieu of extreme consumerism and affluence which makes it difficult to develop other habits.” (§ 209) (For “Ways to Reduce Your Carbon Emissions,” see Appendix 8.) But Francis has faith in you:

Young people demand change. [§ 13] . . . In those countries which should be making the greatest changes in consumer habits, young people have a new ecological sensitivity and a generous spirit, and some of them are making admirable efforts to protect the environment. [§ 209]

He is right to have faith in you. You are the future, you are our hope. And the Earth’s.

# Appendices

## APPENDIX 1:

## SOME PREPARATIONS LEADING UP TO *LAODATO SI*’

|  |  |
| --- | --- |
| 2005 | Pope Benedict XVI (2005-2013) has the Pontifical Council for Justice and Peace release the “Ten Commandments of the Environment.” Ten years beforehand, it reads like a summary of *Laudato si*’ (see Appendix 2). |
| 2005-2013 | For his exhortations to protect the environment, Benedict XVI earns the nickname “the green pope.” Through the installation of solar panels and the purchase of carbon credits, the Vatican becomes “the first fully carbon neutral country.” (Yeo “In-Depth”) |
| 2010-2012 | Scientists come to the Vatican three times to meet with the Pope. Among them is Ottmar Edenhofer, chief economist at the Potsdam Institute for Climate Impact Research, who provides input from the Intergovernmental Panel on Climate Change. (Yeo “In-Depth”)  Edenhofer says, “We had, since 2010, three meetings in the Vatican City . . . We had been asked to provide inputs and those inputs have been used by the advisors of the Pope. . . . I provided the input coming from the [UN’s] IPCC and they have used this input in a way that you can now find in the encyclical. This [input] has been used by the writers of the encyclical.” (Qtd. in Yeo “In-Depth”)  Scientists of the Pontifical Academy of Sciences met with Francis to “present their reports to him . . .” (Yeo “In-Depth”) |
| 2012 | The inputs by Edenhofer and the others result in a book “linking climate change, justice and sustainability.” (Edenhofer, Ottmar, et al., eds. *Climate Change*, *Justice and Sustainability*: *Linking Climate and Development Policy*. New York: Springer, 2012.) (Yeo “In-Depth”) |
| 2011 | A meeting results in an article: Working Group of the Pontifical Academy of Sciences. “Fate of Mountain Glaciers in the Anthropocene.” 2011. |
| 2014 | 2-6 May: the Pontifical Academy of Sciences and the Pontifical Academy of Social Sciences hold “a workshop covering a spectrum of climate change-related topics, from food production and the ocean to megacities and tropical forests.” This too resulted in a publication: Pontifical Academy of Sciences and Pontifical Academy of Social Sciences. *Sustainable Humanity*, *Sustainable Nature*: *Our Responsibility*. Vatican: 2014. The book report calls for “near-zero carbon emissions by around 2070 . . . which would mean rapidly replacing fossil fuels with renewable energy, as the Pope recommends” (§ 165). (Yeo “In-Depth”) |
|  | The May discussions were what prompted the writing of the encyclical “in earnest.” (Yeo “In-Depth”) |
| 2014 | Cardinal Turkson of Ghana, president of the Pontifical Council for Peace and Justice, writes the first draft of the encyclical. (Yeo “In-Depth”) |
| 2015 | March: Francis steers the encyclical “into its final shape, taking a week in March to finesse the final edition.” (Yeo “In-Depth”) |
| 2015 | 28 April: the Pontifical Academy of Sciences holds a conference entitled, “Protect the Earth, Dignify Humanity: The Moral Dimensions of Climate Change and Sustainable Humanity.” Resulting publications:  Pontifical Academy of Sciences. “Declaration of Religious Leaders, Political Leaders, Business Leaders, Scientists and Development Practitioners.” Vatican: 2015.  Dasgupta, Partha, et al. “Climate Change and the Common Good: A Statement of the Problem and the Demand for Transformative Solutions.” Vatican: 2015. |
| 2015 | June 18: official publication of *Laudato si*’. |

## APPENDIX 2:

## Benedict XVI’s *TEN COMMANDMENTS FOR THE ENVIRONMENT*

(published through the Pontifical Council for Justice and Peace, 2005)

Commandment One: Use, Don’t Abuse

The Bible lays out the fundamental moral principles of how to confront the ecological question, The Human Person, made in God’s Image, is superior to all other earthly creatures, which should in turn be used responsibly. Christ’s incarnation and his teachings testify to the value of nature: nothing that exists in this world is outside the divine plan of Creation and Redemption.

Commandment Two: Little Less than a God

The social teaching of the Church recalls two fundamental points. We should not reduce nature to a mere instrument to be manipulated and exploited. Nor should we make nature an absolute value, or put it above the dignity of the human person.

Commandment Three: One for All, All for One

The Question of the environment entails the whole planet, as it is a collective good. Our responsibility toward ecology extends to future generations.

Commandment Four: It’s Not a Brave New World

It is necessary to confirm both the primacy of ethics and the rights of man over technology, thus preserving human dignity. The central point of reference for all scientific and technical applications must be respect for the human person, who in turn should treat the other created beings with respect.

Commandment Five: Gaia Isn’t God

Nature must not be regarded as a reality that is divine in itself, removed from human action. It is, rather, a gift offered by our Creator to the Human Community, given to human intelligence and moral responsibility. It follows, then, that it is not illicit to modify the ecosystem, so long as this is done within the context of a respect for its order and beauty, and taking into consideration the utility of every creature.

Commandment Six: What Price Progress?

Ecological questions highlight the need to achieve a greater harmony both between measures designed to promote economic development and those directed to preserving the ecology, and between national and international policies. Economic development, moreover, needs to take into consideration the integrity and rhythm of nature, because natural resources are limited. And all economic activity that uses natural resources should also include the costs of safeguarding the environment into the calculations of the overall costs of its activity.

Commandment Seven: Flowing like a River

Concern for the environment means that we should actively work for the integral development of the poorest regions. The goods of this world have been created by God to be wisely used by all. These goods should be shared, in a just and charitable manner. The principle of the universal destiny of goods offers a fundamental orientation to deal with the complex relationship between ecology and poverty.

Commandment Eight: We’re All in the Same Boat

Collaboration, by means of worldwide agreements, backed up by international law, is necessary to protect the environment. Responsibility toward the environment needs to be implemented in an adequate way at the juridical level. These laws and agreements should be guided by the demands of the common good.

Commandment Nine: Discipline Is Not A Four-Letter Word

Lifestyles should be oriented according to the principles of sobriety, temperance, and self-discipline, both at the personal and social levels. People need to escape from the consumer mentality and promote methods of production that respect the created order, as well as satisfying the basic needs of all. This change of lifestyle would be helped by a greater awareness of the interdependence that ties together all the inhabitants of the earth.

Commandment Ten: It’s All Gift

A spiritual response must be given to environmental questions, inspired by the conviction that creation is a gift that God has placed in the hands of mankind, to be used responsibly and with loving care. People’s fundamental orientation toward the created world should be one of gratitude and thankfulness. The world, in fact, leads people back to the mystery of God who has created it and continues to sustain it. If God is forgotten, nature is emptied of its deepest meaning and left impoverished.

## APPENDIX 3:

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## APPENDIX 4:

## A BRIEF HISTORY OF PALEOCONTINENTS

(based on Scotese)

|  |  |
| --- | --- |
| past plate-tectonic movements | |
|  | |
| 1.1 billion | supercontinent Rodinia |
| 514 million | supercontinent Gondwana; island continents Laurentia, Avalonia, Baltica, etc. |
| 390 million | supercontinent Gondwana; Laurentia, Avalonia, and Baltica collide to form Eur­america |
| 350 million | Gondwana and Euramerica press together, forming the Appalachian Mountains |
| 306 million | Gondwana and Euramerica fully merge |
| 237 million | Pangea (“all Earth”): most land is one supercontinent |
| 152 million | Western and Eastern Gondwana begin to separate |
| 94 million | modern continents separate (North America and Europe still join, as do Australia and Antarctica) |
| 50 million | India pushes into Asia, forming the Himalayas; Australia moves north |
|  | |
| future plate-tectonic movements | |
|  | |
| +50 million | Africa will join Europe (the Mediterranean will be upthrust as mountains); Australia will join Southeast Asia; California will slide up to join Alaska |
| +150 million | Antarctica will join Australia-Southeast Asia |
| +250 million | Pangea Ultima: North and South America, Africa, and Eurasia; Antarctica-Australia remains separate |

## APPENDIX 5:

## SOME RECENT VOLCANIC EXPLOSIONS

(based on Tudge 27-28)

|  |  |  |  |
| --- | --- | --- | --- |
| *date* | *eruption* | *location* | *notes* |
| 1470 bc | San­torini | island of Thera, north of Crete | about 10 km3 (cubic kilometers) of ejecta (lava, rock, ash, gases). The ash and acid rain wiped out Minoan (Cretan) civilization, making way for “the mainland Mycenaeans and hence the rise of Greece.” (Tudge 27) |
| ad 79 | Vesuvius | southern Italy | about 10 km3; obliterated the city of Pompeii |
| 1783 | Laki | Iceland | about 10 km3 |
| 1815 | Tambora | island of Sumbawa, east of Java | about 160 km3  1816: “Crops failed across the whole northern hemisphere . . . [which] in­flamed political unrest all over Europe . . .” (Tudge 28)  1816-19: typhus spread, leading to a European epidemic |
| 1883 | Krakatoa | Indonesia | about 10 km3 |
| 1980 | St. Helens | Washington State | about 1 km3 |
| 1991 | Pinatubo | Philippines | about 10 km3 |

## APPENDIX 6:

## THE ICE AGES

Note: because sites of human habitation build up layers over generations, newer atop older, archaeologists present their data in the same way; and other scientists are adopting this bottom-up approach. So the newest ice age—the quaternary—is top left; the oldest ice age is bottom right.

|  |  |  |  |
| --- | --- | --- | --- |
| *quaternary ice age* (*2*.*588 million*-*present*) | | *major older ice ages* | |
|  | | | |
| 11,700-present | interglacial (warmer) | 360-260 million | Karoo ice age |
| 71,000-12,000 | glacial (colder) | 460-430 million | Andean-Saharan ice age |
| 130,000-115,000 | interglacial | 582-580 million | Gaskiers ice age |
| 200,000-130,000 | glacial | 650-635 million | Marinoan ice age |
| 424,000-374,000 | interglacial | 720-660 million | Sturtian ice age |
| 478,000-424,000 | glacial | 750 million | Kaigas ice age |
| 563,000-478,000 | interglacial | 2.4-2.1 billion | Huronian ice age |
| 676,000-621,000 | glacial |  | |
| 800,000-621,000 | interglacial | (sources: Gibbard and van Kolfschoten; | |
| 1.3 million-800,000 | glacial | “Pleistocene”) | |
| 1.55-1.3 million | interglacial |  | |
| 2.588 million | glacial |  | |

## APPENDIX 7:

## PARABLES EXEMPLIFYING

## THE PRESENCE OR ABSENCE OF LOVE OF OTHERS

**Parables Commending the Presence of Love**

The good Samaritan (Luke 10:25-37): “A man was going down from Jerusalem to Jericho, and fell into the hands of robbers, who stripped him, beat him, and went away, leaving him half dead. 31 Now by chance a priest was going down that road; and when he saw him, he passed by on the other side. 32 So likewise a Levite, when he came to the place and saw him, passed by on the other side. 33 But a Samaritan while traveling came near him; and when he saw him, he was moved with pity. 34 He went to him and bandaged his wounds, having poured oil and wine on them. Then he put him on his own animal, brought him to an inn, and took care of him. 35 The next day he took out two denarii, gave them to the innkeeper, and said, ‘Take care of him; and when I come back, I will repay you whatever more you spend.’ 36 Which of these three, do you think, was a neighbor to the man who fell into the hands of the robbers?” 37 He said, “The one who showed him mercy.” Jesus said to him, “Go and do likewise.”

The prodigal son (Luke 15:11-32): “There was a man who had two sons. 12 The younger of them said to his father, ‘Father, give me the share of the property that will belong to me.’ So he divided his property between them. 13 A few days later the younger son gathered all he had and traveled to a distant country, and there he squandered his property in dissolute living. 14 When he had spent everything, a severe famine took place throughout that country, and he began to be in need. 15 So he went and hired himself out to one of the citizens of that country, who sent him to his fields to feed the pigs. 16 He would gladly have filled himself with the pods that the pigs were eating; and no one gave him anything. 17 But when he came to himself he said, ‘How many of my father’s hired hands have bread enough and to spare, but here I am dying of hunger! 18 I will get up and go to my father, and I will say to him, “Father, I have sinned against heaven and before you; 19 I am no longer worthy to be called your son; treat me like one of your hired hands.”‘ 20 So he set off and went to his father. But while he was still far off, his father saw him and was filled with compassion; he ran and put his arms around him and kissed him. 21 Then the son said to him, ‘Father, I have sinned against heaven and before you; I am no longer worthy to be called your son.’ 22 But the father said to his slaves, ‘Quickly, bring out a robe-- the best one-- and put it on him; put a ring on his finger and sandals on his feet. 23 And get the fatted calf and kill it, and let us eat and celebrate; 24 for this son of mine was dead and is alive again; he was lost and is found!’ And they began to celebrate. 25 “Now his elder son was in the field; and when he came and approached the house, he heard music and dancing. 26 He called one of the slaves and asked what was going on. 27 He replied, ‘Your brother has come, and your father has killed the fatted calf, because he has got him back safe and sound.’ 28 Then he became angry and refused to go in. His father came out and began to plead with him. 29 But he answered his father, ‘Listen! For all these years I have been working like a slave for you, and I have never disobeyed your command; yet you have never given me even a young goat so that I might celebrate with my friends. 30 But when this son of yours came back, who has devoured your property with prostitutes, you killed the fatted calf for him!’ 31 Then the father said to him, ‘Son, you are always with me, and all that is mine is yours. 32 But we had to celebrate and rejoice, because this brother of yours was dead and has come to life; he was lost and has been found.’”

The father’s good gifts (Matt 7:9-11//Luke 11:11-13): “Is there anyone among you who, if your child asks for bread, will give a stone? 10 Or if the child asks for a fish, will give a snake? 11 If you then, who are evil, know how to give good gifts to your children, how much more will your Father in heaven give good things to those who ask him!”

**Parables Castigating the Absence of Love**

The rich fool (Luke 12:16-21): “The land of a rich man produced abundantly. 17 And he thought to himself, ‘What should I do, for I have no place to store my crops?’ 18 Then he said, ‘I will do this: I will pull down my barns and build larger ones, and there I will store all my grain and my goods. 19 And I will say to my soul, ‘Soul, you have ample goods laid up for many years; relax, eat, drink, be merry.’ 20 But God said to him, ‘You fool! This very night your life is being demanded of you. And the things you have prepared, whose will they be?’ 21 So it is with those who store up treasures for themselves but are not rich toward God.”

The rich man and Lazarus (Luke 16:19-31): “There was a rich man who was dressed in purple and fine linen and who feasted sumptuously every day. 20 And at his gate lay a poor man named Lazarus, covered with sores, 21 who longed to satisfy his hunger with what fell from the rich man’s table; even the dogs would come and lick his sores. 22 The poor man died and was carried away by the angels to be with Abraham. The rich man also died and was buried. 23 In Hades, where he was being tormented, he looked up and saw Abraham far away with Lazarus by his side. 24 He called out, ‘Father Abraham, have mercy on me, and send Lazarus to dip the tip of his finger in water and cool my tongue; for I am in agony in these flames.’ 25 But Abraham said, ‘Child, remember that during your lifetime you received your good things, and Lazarus in like manner evil things; but now he is comforted here, and you are in agony.”

The rich young man (Luke 18:18-23): “A certain ruler asked him, “Good Teacher, what must I do to inherit eternal life?” 19 Jesus said to him, “Why do you call me good? No one is good but God alone. 20 You know the commandments: ‘You shall not commit adultery; You shall not murder; You shall not steal; You shall not bear false witness; Honor your father and mother.’” 21 He replied, “I have kept all these since my youth.” 22 When Jesus heard this, he said to him, “There is still one thing lacking. Sell all that you own and distribute the money to the poor, and you will have treasure in heaven; then come, follow me.” 23 But when he heard this, he became sad; for he was very rich.

## APPENDIX 8:

## 10 WAYS TO REDUCE YOUR CARBON EMISSIONS

(Union of Concerned Scientists “Top Ten”)

From *Cooler Smarter*: *Practical Steps for Low-Carbon Living*; *Expert Advice from the Union of Concerned Scientists*.

1. Switch to a car with better fuel economy. Upgrading from a 20 mpg car to a 40 mpg car can save you 4,500 gallons of gasoline over the car’s life span. At today’s gas prices, that’s a total savings of more than $18,000.

2. Make your house more air tight. Even in reasonably tight homes, air leaks may account for 15 to 25 percent of the heat our furnaces generate in winter or that our homes gain in summer. If you pay $1,100 a year to heat and cool your home, you might be wasting as much as $275 annually.

3. Buy and *use* a programmable thermostat for a 15 percent reduction in your heating and cooling emissions and save $180 a year. During the summer, a setting of 78 degrees Fahrenheit is optimal during the hours you are at home, and 85 degrees when you are away during the day.

4. Eat less meat, especially beef. An average family of four that cuts its meat intake in half will avoid roughly three tons of emissions annually.

5. Use power strips in your home office and home entertainment center to curb “phantom loads” and save a surprising amount on your electric bill. Keeping your laser printer turned on when not in use could be costing you as much as $130 annually.

6. Upgrade your refrigerator and air conditioner, especially if they are more than five years old. New ones are twice as efficient or more. For fridges: if they’re old an upgrade can pay for itself in as little as three years in energy savings alone.

7. Get an electricity monitor from your local hardware store or even borrow one from many local libraries to see where the energy hogs are in your home. This can help you save hundreds of dollars annually.

8. Change those light bulbs. New LED light bulbs can give the same light for 15 percent the electricity. That adds up to more than $100 in savings for most families each year.

9. Wash clothes in cold water. They get just as clean with today’s detergents. But hot water washes use five times the energy—and create five times the emissions. This could save you nearly $100 a year.

10. Buy less stuff. Reduce, re-use, and recycle—it’s not just about pollution, but the strategy will lower your emissions too and help combat global warming.

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