ECONOMIC AND SOCIAL IMPLICATIONS OF POTENTIAL UN PARIS 2015 GLOBAL GHG REDUCTION MANDATES

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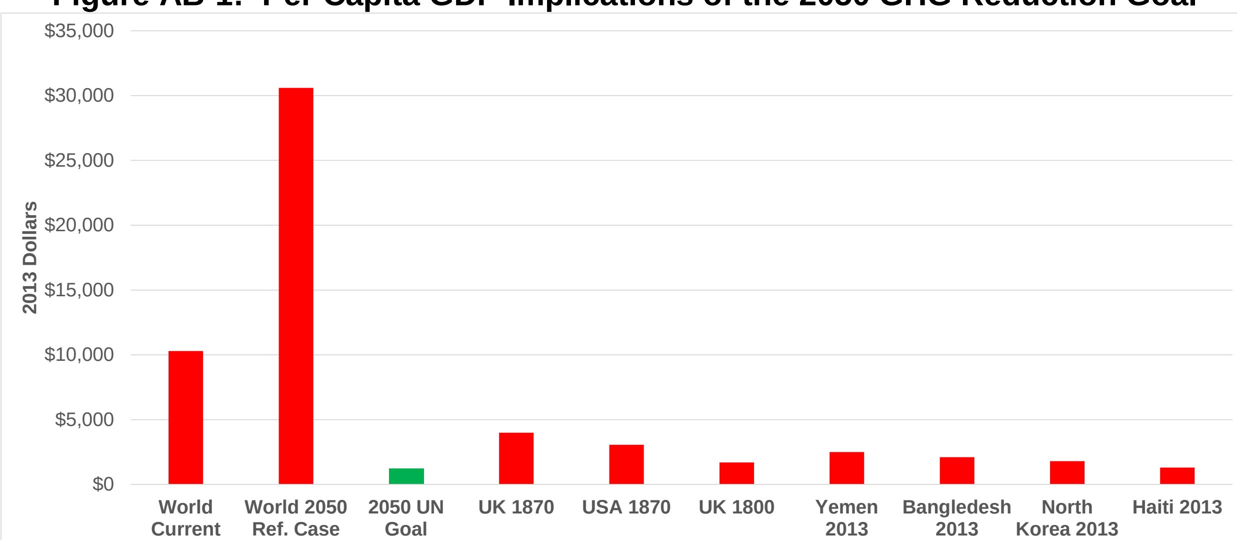
ABSTRACT

The next UN Climate Conference in Paris in December 2015 seeks to achieve a binding universal agreement to reduce GHGs to limit global temperature increase to no more than 2°C above current levels. To achieve this, it is proposed to reduce GHGs to 80-95% below 1990 levels by 2050, with implementation beginning in 2020.

However, without the availability of adequate supplies of accessible, reliable, and affordable fossil fuels none of the economic progress of the past two centuries would have been possible. Fossil fuels powered successive industrial revolutions, created the modern world, created advanced technological society, and permit the high quality of life currently taken for granted. Concurrently, CO_2 emissions increased and atmospheric concentration rose from 320 ppm CO_2 to nearly 400 ppm. Hydrocarbons provide 81% of world energy, and the positive relationship between fossil fuels, economic growth, and CO_2 emissions is strong. All forecasts predict that there will continue to be a close link between energy, the economy, and CO_2 emissions, and that fossil fuels will continue to provide about 80% of world energy.

Two factors are not recognized: 1st, all forecasts *already assume* significant energy efficiency and decarbonization; 2nd, the emissions reductions recommended, when compared to 2050 forecast emissions, are draconian to the point of being ludicrous. **Reducing CO_2 emissions drastically, as is proposed, would within 30 years reduce world per capita GDP to only about 4% of what it is otherwise forecast to be.** It would **reduce 2050 world per capita GDP to less than that of the UK in 1800 or of that currently in the world's poorest nations** – Figure AB-1.

Figure AB-1: Per Capita GDP Implications of the 2050 GHG Reduction Goal



These are the real implications of the UN goals. They are so draconian as to be impossible. Nevertheless, that is what world leaders gathered in Paris in December 2015 will be seriously contemplating. **THIS CANNOT BE ALLOWED TO HAPPEN**.

EXECUTIVE SUMMARY

CO_2 Reduction Goals and Timetables

The next UN Climate Change Conference will be held in Paris in December 2015, and its goal is to achieve a binding universal agreement on climate from all nations to reduce GHGs to limit the global temperature increase to no more than 2° C above current levels. The intention is that by the end of the Paris meeting, all nations will be bound by climate agreement and that implementation will begin in 2020. However, representatives from a number of nations are challenging the climate change policies of the UN and have signed "the Warsaw Declaration," which requested that UN delegates discontinue work on a new treaty until a genuine "scientific consensus is reached on the phenomenon of so-called global warming."

Various goals, milestones, and schedules are being considered and mandated in order "to keep global warming below 2° C." These include:

- The EU is committed to keeping 2030 GHG emissions 40 percent below 1990 levels and to reducing GHGs to 80-95 percent below 1990 levels by 2050.
- The G8 leaders support a 50 percent reduction in GHG emissions by 2050.
- The USA has committed to reducing GHG emissions to 17 percent below 2005 levels by 2020 and to reducing emissions 80 percent below the 1990 level by 2050.
- The UK has pledged to reduce GHG emissions by at least 80 percent (from the 1990 baseline) by 2050.
- Germany has proposed reducing its GHG emissions 95 percent below the 1990 baseline by 2050.
- California has mandated state GHG emissions reductions to 2000 levels by 2010, to 1990 levels by 2020, and to 80 percent below 1990 levels by 2050.

The UN is developing Deep Decarbonization Pathways to determine how individual countries can transition to a low-carbon economy. Such "Deep Decarbonization" will require a radical transformation of economic and energy systems by 2050 through massive declines in carbon intensity in all sectors, and is not about modest or incremental change: It requires major changes to countries' energy and production systems that need to be pursued over the long-term.

All of these emissions reduction goals are ambitious in the extreme; for example, by 2050:

- The USA would have to reduce GHGs from electricity generation by 95 percent from 2010 levels – Figure EX-1.
- In California, there would be no gasoline fueled vehicles, and GHGs from electricity consumption in the residential, commercial, and industrial sectors would be close to zero – Figure EX-2.
- Korea would have to reduce GHGs from industry by 91 percent from 2010 levels.

Figure EX-1: USA Energy-Related CO_2 Emissions Pathway by Sector, 2010-2050

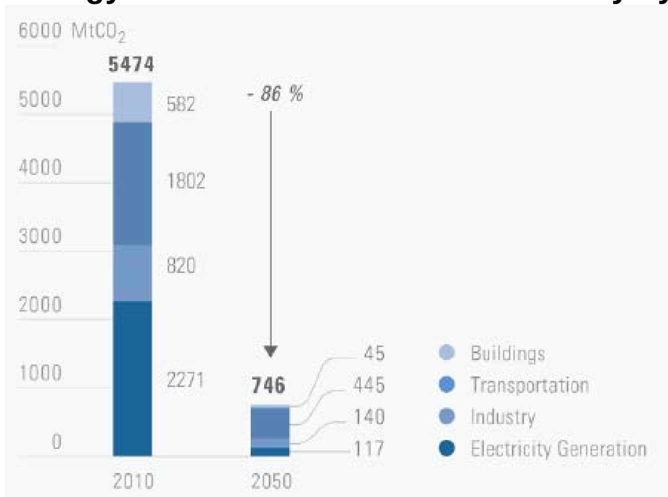
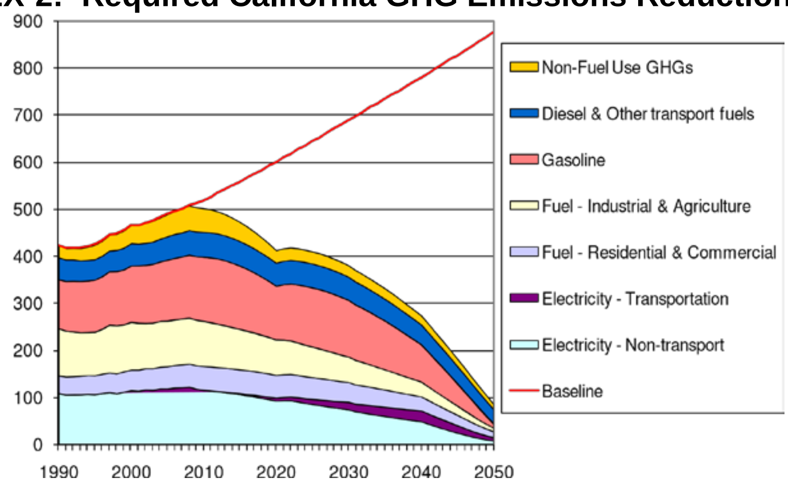


Figure EX-2: Required California GHG Emissions Reductions (MMTCO$_2$e)

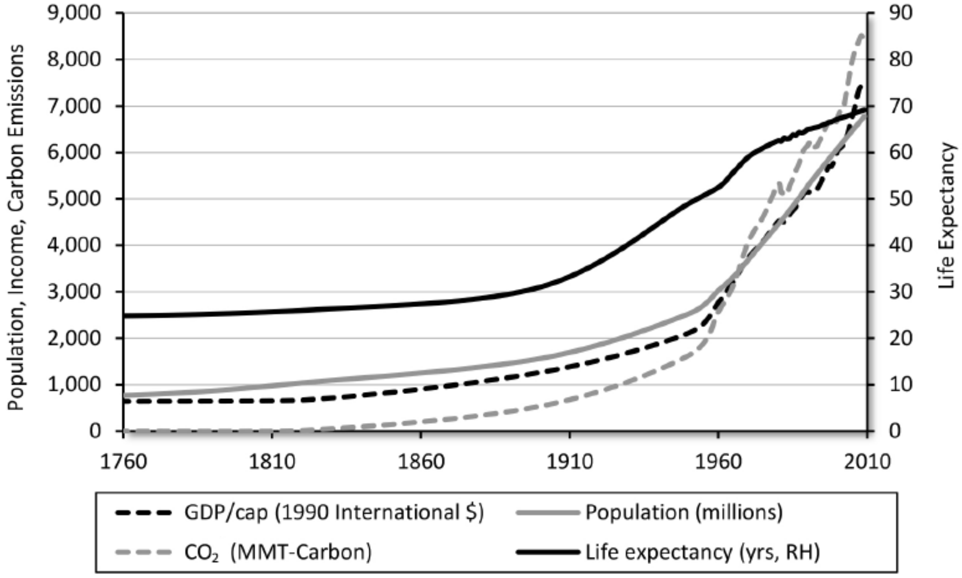


The Essential Historical and Future Necessity of Fossil Fuels

Without the availability of adequate supplies of accessible, reliable, and affordable fossil fuels none of the industrial and economic progress of the past two centuries would have been possible. Fossil fuels facilitated successive industrial revolutions, created the modern world, created advanced technological society, and enabled the high quality of life currently taken for granted. Over the past 200 years, largely because of hydrocarbon energy, human population increased eightfold, average incomes rose 11-fold, and global life expectancy more than doubled. Concurrently, CO_2 emissions increased 2,800-fold, to 8.4 billion tons/year -- and atmospheric concentration rose from 320 ppm CO_2 to nearly 400 ppm – Figure EX-3.

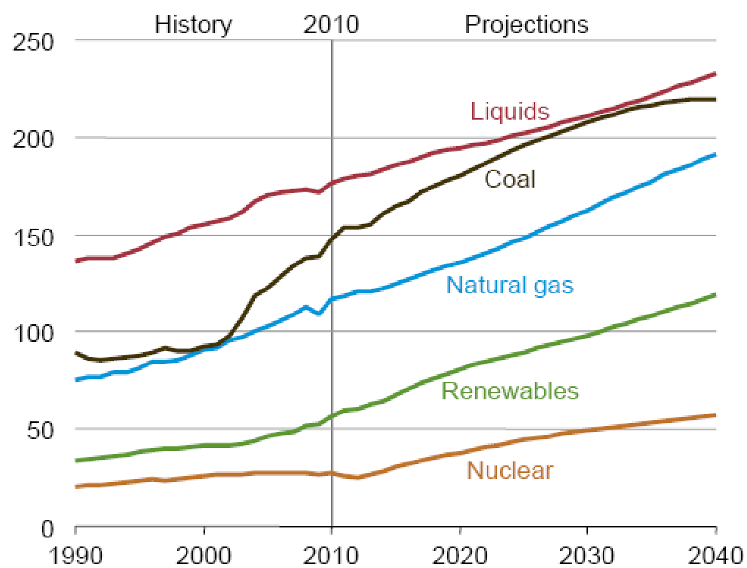
Hydrocarbons provide 81 percent of world energy, and the positive relationship between fossil fuels, economic growth, and CO_2 emissions is strong -- supporting $70 trillion per year in world GDP. Seminal research has concluded that "Ours is a high energy civilization based largely on combustion of fossil fuels," and that "The theoretical and empirical evidence indicates that energy use and output are tightly coupled, with energy availability playing a key role in enabling growth."

Figure EX-3: Global Progress Created by Fossil Fuels, 1760-2009



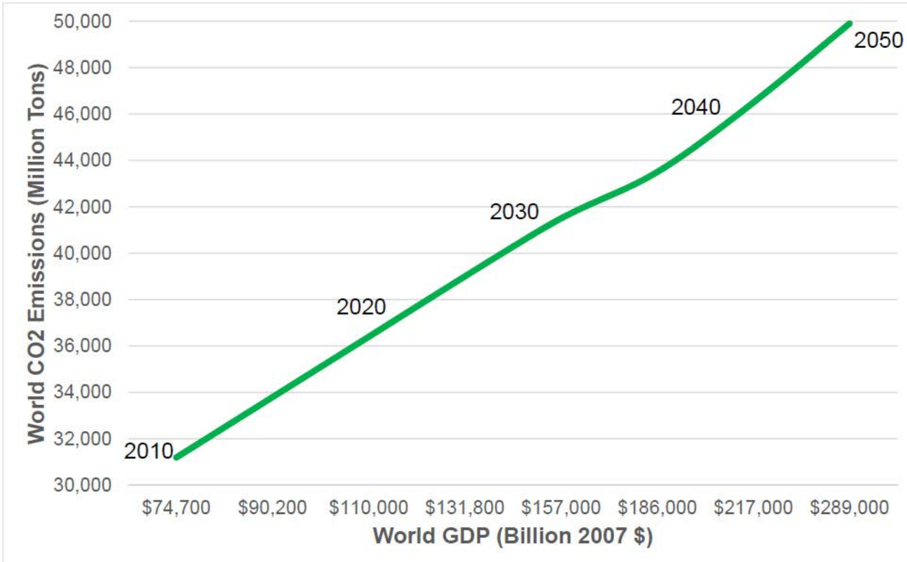
According to all major forecasts, fossil fuels will remain the principal sources of energy worldwide for the foreseeable future and will continue to supply 75 - 80 percent of world energy. Demand for oil, natural gas, and coal will increase substantially in both absolute and percentage terms over the next several decades – Figure EX-4.

Figure EX-4: World Energy Consumption by Fuel Type, 1990-2040 (Quads)



Fossil fuel requirements will increase greatly over the next several decades, and assuring continued world economic growth, increased per capita income, and rising living standards requires this. All major forecasts, including those of the EIA and the IEA predict that, for decades to come, there will continue to be a close link between energy, the economy, and CO_2 emissions, and that fossil fuels will continue to provide about 80 percent of world energy – Figure EX-5.

Figure EX-5: Forecast Relationship Between World GDP and CO_2 Emissions



The Draconian Implications of Drastic GHG Reductions

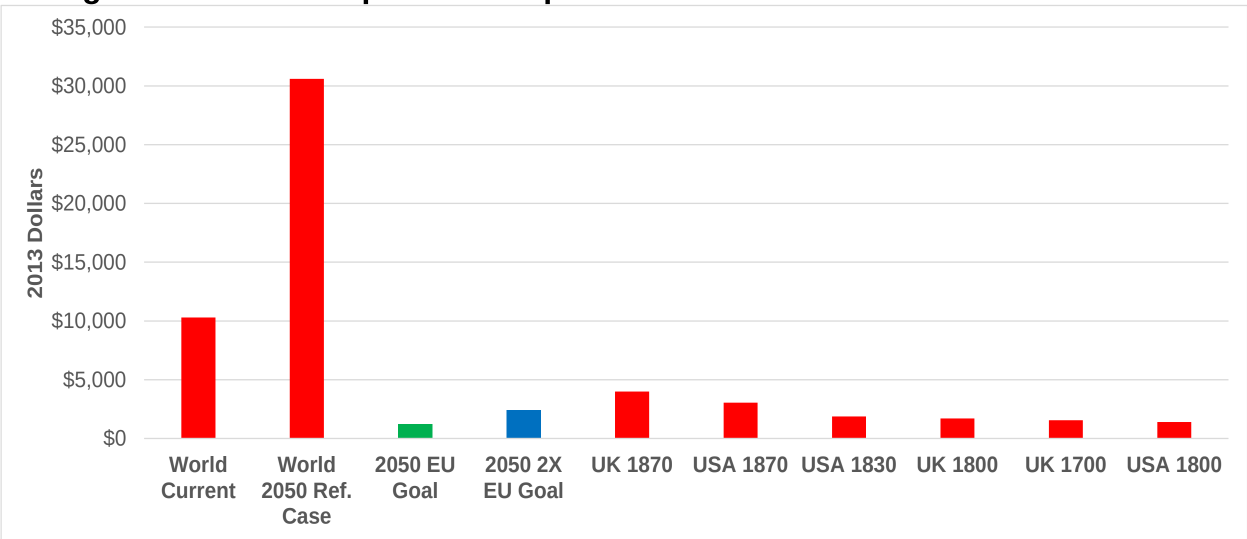
The policy prescriptions for **reducing CO_2 emissions drastically to keep global temperatures from increasing by 2° or 3° C would <u>within 30 years reduce world per capita GDP to only about four percent of what it is otherwise forecast to be</u>**. Attempting to achieve this 2050 GHG reduction goal could reduce 2050 world per capita GDP from its forecast $30,600 to about $1,200 (Figure EX-6):

- This would be only four percent of projected 2050 world per capita GDP.
- It would be only about 1/8th current world per capita GDP.
- It would reduce 2050 world per capita GDP to less than ½ that of the UK or USA in 1870.
- It would reduce 2050 world per capita GDP to less than that of the USA in 1830.
- It would **reduce 2050 world per capita GDP to less than that of the UK in 1800**.
- It would reduce 2050 world per capita GDP to about the level of the USA in 1800.
- It would reduce 2050 world per capita GDP to about the level of the UK in 1700.

Even assuming a two-fold increase in decoupling GDP growth from energy consumption would result in 2050 world per capita GDP to about $2,400:

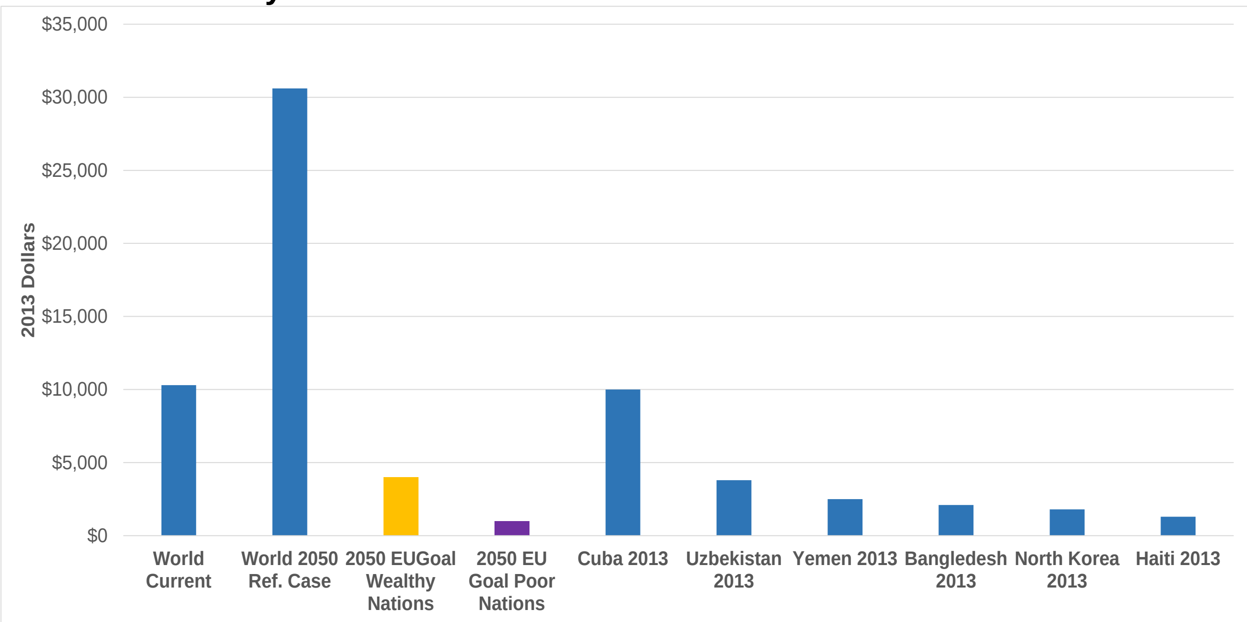
- This would be only about 80 percent of the 1870 USA per capita GDP
- This would be only about 60 percent of the 1870 UK per capita GDP

Figure EX-6: Per Capita GDP Implications of the 2050 GHG Reduction Goal



Reducing global 2050 CO_2 emissions to 90 percent below 1990 levels implies that average **world per capita GDP would be reduced to levels currently below those of the most impoverished nations, such as Yemen, Bangladesh, North Korea, and Haiti** – Figure EX-7. Many of the less developed nations in Asia, Africa, and Latin America would experience per capita GDP levels less than half of the 2013 per capita levels of the these poorest nations.

Figure EX-7: Per Capita GDP Implications of the EU 2050 GHG Reduction Goal For Wealthy Nations and Poor Nations – Relative 2013 Income Levels



The Bottom Line

The proposals to be adopted at the 2015 UN Paris conference for drastically reducing world GHGs by 2050 are fatally flawed, unrealistic, and impossible to achieve without destroying the world economy. There **are two critical caveats that are not recognized**:

- **First, all current forecasts already explicitly assume that there will be significant energy efficiency and decarbonization over the next three decades**; that is, that world GDP will increase at a rate that is much faster than the rate of increase in energy consumption, and that CO_2 emissions will increase at a lower rate than either GDP or energy consumption. Thus, the "Reference" forecasts already have large decarbonization incorporated into them: They are not simple extrapolations of past trends. This implies that **further CO_2 reductions beyond those already incorporated into the forecasts will be increasingly difficult and expensive to achieve**.
- **Second, the emissions reductions being recommended, when <u>compared to the forecast emissions for a given future year</u> are draconian to the point of being ludicrous.** The recommendation to reduce GHG emissions by 80 percent below 1990 levels by 2050 requires that 2050 emissions – and world GDP – has to be reduced more than 95 percent below what they are actually forecast to be in 2050 – forecasts that already incorporate very significant decarbonization. Accordingly, 2050 fossil fuel utilization and world GDP (and hence living standards) would have to be reduced to a very small fraction of what they would otherwise be. **Such an outcome is unacceptable to every country.**

Thus, assuming that the relationship between GDP and CO_2 emissions is relatively fixed – as does EIA and IEA, then to achieve the goal to reduce GHGs to 90 percent below 1990 levels by 2050 will require that world 2050 GDP be reduced to about four percent of what it is projected to be. In other words, **<u>to achieve the implied GHG reduction goal to reduce GHGs to 90 percent below 1990 levels by 2050 implies that world living standards in 2050 would be reduced to a level they were more than two centuries prior</u>**. Virtually all of the economic gains of the industrial revolution and everything that followed would be nullified and **instead of people enjoying the living standards of the 2050's, they would have to endure the living standards of the 1820s**. Average **world per capita GDP would be reduced to levels currently below those of the most impoverished nations**, such as Yemen, Bangladesh, North Korea, and Haiti, and many of the less developed nations in Asia, Africa, and Latin America would experience per capita GDP levels less than half of the 2013 per capita levels of the these poorest nations

These are the real implications of "reducing GHGs to 80-95 percent below 1990 levels by 2050." They are so draconian as to be infeasible and impossible. The idea is truly ludicrous. Nevertheless, that is what world leaders gathered in Paris in December 2015 will be seriously contemplating. **<u>This cannot be allowed to happen</u>**.

I. INTRODUCTION

I.A. From Rio to Paris and Beyond

An important outgrowth of the UN Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil in 1992 (Rio 92) was an agreement on the Climate Change Convention which, in turn, led to the Kyoto Protocol and subsequent agreements, conferences, and proposals. The next UN Climate Change Conference will be held in Paris in December 2015. This will be the 21st annual session of the Conference of the Parties (COP 21) to the 1992 UN Framework Convention on Climate Change (UNFCCC) and the 11th session of the Meeting of the Parties (CMP 11) to the 1997 Kyoto Protocol. The conference objective is to achieve "a binding and universal agreement on climate, from all the nations of the world," and the meeting (with 40,000 attendees expected) will be the largest UN talks since the ill-fated Copenhagen meeting in 2009.[1]

The objective of the Paris conference is to achieve, for the first time in over 20 years of UN negotiations, an agreement on climate from all the nations of the world, including the largest emitters of greenhouse gas emissions (GHGs). The overarching goal of the conference is to reduce GHGs to limit the global temperature increase to no more than 2°C above current levels. By the end of the meeting, all the nations of the world are to be bound by a universal agreement on climate.[2]

The new agreement will be adopted at the Paris conference and implemented from 2020. It will take the form of a protocol and will be applicable to all Parties. Since the contributions are "intended," this implies that, once they are tabled, there will be a period when they could be revised (made more severe) if necessary to ensure that, collectively, the contributions are sufficient to "keep global warming below 2° C."

The Paris meeting will mark a decisive stage in negotiations on the future international agreement on a post-2020 regime, and will, as agreed at the Durban, South Africa climate conference in December 2011, adopt the major outlines of that regime. The intention is that by the end of the Paris meeting, for the first time in over 20 years of UN negotiations, all the nations of the world, including the largest GHG emitters, will be bound by a universal climate agreement. It will replace the Kyoto Protocol as the world's most important treaty on climate change, and will require all countries to radically rethink their economic and energy systems. If the global warming alarmists and UN bureaucrats get their way, the draconian "global-warming" treaty replacing Kyoto would be implemented starting in 2020. All of the "commitments" on CO_2 reductions are supposed to be announced ahead of the Paris conference.

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[1]The EU, a few other European countries and Australia have agreed to join a legally binding second period of the Kyoto Protocol which runs until 2020, while over 70 other countries – both developed and developing -- have made different types of non-binding commitments to reduce, or limit the growth in, their greenhouse gas emissions.
[2]Pilita Clark, "Climate Scientists Spell Out Challenge UN Must Rise to in 2015, *Financial Times*, September 29, 2013.

The new agreement will take the form of a protocol, another legal instrument, or "an agreed outcome with legal force," and will be applicable to all Parties.[3] It is being negotiated through a process known as the Durban Platform for Enhanced Action. The 2015 agreement will have to unite the current patchwork of binding and non-binding arrangements under the UN climate convention into a single comprehensive regime.

In a February 2014 joint press conference, President Obama and French President Francois Hollande stated "Next year's carbon climate conference in France will be an opportunity to forge a strong global agreement that reduces greenhouse gas emissions through concrete actions. The climate summit organized by the U.N. secretary general this September will give us the opportunity to reaffirm our ambitions for the climate conference in Paris."[4] The White House is preparing to bring a new U.S. carbon-reduction pledge to the Paris talks. At least three interagency meetings since September 2013 have debated whether the new goals should have a 2025 or 2030 horizon.[5] According to published reports, "They also have laid out the scientific and economic modeling that must be done in the coming months and discussed whether a new target should assume Congress will eventually enact climate legislation or whether the White House must continue to use existing authority under the Clean Air Act to squeeze out more emissions reductions."[6]

I.B. The Warsaw Declaration

In the fall of 2013 in Warsaw, at the same time as the UN COP19 conference was under way, another conference was held that was hosted by a Polish think tank and co-sponsored by Solidarity, the iconic Polish union.[7] The think tank, Fundacj im Bolestawa Chrobrego, assembled a coalition of experts drawn from the fields of science, labor, government, and public policy to assess the implications of a new international climate treaty for global prosperity and freedom, and it included representatives from the U.S., Italy, Sweden, Hungary, and Poland. They, along with a member of the EU Parliament, joined in strong criticism of climate change alarmism and the troubling climate change policies of the UN.

At the conclusion of the meeting, they formally signed a declaration entitled "Address of Free Nations to Participants of UN Climate Summit (COP 19) – Let Us Revise Global Climate Policy" – or "the Warsaw Declaration." The declaration noted that "media manipulation" and "an international bureaucracy of organizations representing extreme views on environmental protection" have promoted an ideology supporting global warming, and that their agenda has had destructive consequences on "competitive

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[3]"The 2015 International Agreement," European Commission Climate Action, 2014.
[4]**"**Barack Obama and François Hollande, "France and the U.S. Enjoy a Renewed Alliance, *Washington Post*, February 10, 2014.
[5]"Obama Hopes Paris Is No Copenhagen," *National Journal*, February 11, 2014.
[6]Lisa Friedman, "Obama Prepares Plan for Deeper Greenhouse Gas Pollution Cuts," ClimateWire, February 11, 2014.
[7]David Rothbard and Craig Rucker, "Europeans sign Warsaw Declaration: Want no Part of UN Climate Treaty," CFACT, November 11, 2013.

economies" of the world. It then called on delegates attending the UN COP19 conference to discontinue work on a new treaty until a genuine "scientific consensus is reached on the phenomenon of so-called global warming."[8]

I.C. Outline of Report

This study analyzes the GHG reduction goals being advocated, assesses their feasibility in terms of forecast world economic growth and increasing energy consumption in the coming decades, and then discusses the economic and social implications of actually realizing these goals. Specifically:

- Chapter II identifies the GHG reduction goals and timetables being advocated by the UN, EU, G8, and individual nations.
- Chapter III summarizes the economic and energy forecasts for the coming decades.
- Chapter IV identifies the key role that fossil fuels have played in world economic development since the industrial revolution and their role in future economic development.
- Chapter V analyzes the likely economic and social implications of attempting to actually achieve the draconian GHG reductions being advocated.
- Chapter VI presents the findings and conclusions derived here.

[8]Ibid.

II. GHG REDUCTION GOALS, MANDATES, AND TIMETABLES

Various goals, milestones, and schedules are being considered and mandated in order "to keep global warming below 2°C." These include:

- The EU is committed to keeping 2030 GHG emissions 40 percent below 1990 levels and to reducing GHGs to 80-95 percent below 1990 levels by 2050.
- The G8 leaders support a 50 percent reduction in GHG emissions by 2050.
- The USA has committed to reducing GHG emissions to 17 percent below 2005 levels by 2020 and to reducing emissions 80 percent below the 1990 level by 2050.
- The UK has pledged to reduce GHG emissions by at least 80 percent (from the 1990 baseline) by 2050.
- Germany has proposed reducing its GHG emissions 95 percent below the 1990 baseline by 2050.
- The state of California in the USA – which has the world's eighth largest economy -- has mandated state GHG emissions reductions to 2000 levels by 2010, to 1990 levels by 2020, and to 80 percent below 1990 levels by 2050.
- Various environmental groups have recommended "Phasing out fossil fuels by midcentury," which presumably implies drastic GHG reductions.

Below we review some of these proposals.

II.A. The EU Commitment

The EU is committed to "reducing GHGs to 80 - 95 percent below 1990 levels by 2050."[9] In its "Energy Roadmap 2050," the Commission assessed the challenges posed by achieving the EU's decarbonization objective while at the same time ensuring security of energy supply and competitiveness.[10] The EU is committed to these GHG reductions in the context of necessary reductions by developed countries as a group.[11] The Commission analyzed the implications of this[12] and also focused on solutions for the transport sector and on creating a Single European Transport Area.[13] In the Energy Roadmap the Commission explored the challenges posed by delivering the EU's decarbonization objective while at the same time ensuring security of energy supply and competitiveness, responding to a request from the European Council.[14]

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[9]See European Commission, "Energy Roadmap 2050," Luxembourg: Publications Office of the European Union, ISBN 978-92-79-21798-2, 2012, and Altiero Spinelli, "EU Energy Roadmap 2050: EU External Policies For Future Energy Security," presented at the Workshop on Energy Roadmap 2050: EU External Policies for Future Energy Security held on 5 November 2012.

[10]It was responding to a request from the European Council, Extraordinary European Council, February 4, 2011.

[11]European Council, October 2009.

[12]"Roadmap For Moving to a Competitive Low-Carbon Economy in 2050," COM 112, 8 March 8, 2011.

[13] "Roadmap to a Single European Transport Area." 33 COM 144, 28 March 28, 2011.

[14]Extraordinary European Council, February 4, 2011.

The EU policies and measures to achieve the Energy 2020 goals and the Energy 2020 strategy are ambitious: By 2020, at least a 20 percent reduction in GHG emissions compared to 1990 (30 percent if international conditions are right, saving 20 percent of EU energy consumption compared to projections for 2020; A 20 percent share of renewable energies in EU energy consumption, including a 10 percent share in transport.[15] These initiatives will continue to deliver beyond 2020, helping to reduce emissions by about 40 percent by 2050.[16] However, they will still be insufficient to achieve the EU's 2050 decarburization objective, as only less than half of the decarburization goal will be achieved in 2050.[17] This gives an indication of the level of effort and change, both structural and social, which will be required to make the necessary emissions reduction, while keeping a competitive and secure energy sector, and IEA has noted the critical role of governments and emphasized the need for urgent action.[18]

The Energy Roadmap 2050 scenarios examined various approaches for decarbonizing the energy system. All imply major changes in, for example, carbon prices, technology, and networks.[19] The EC analyzed a number of scenarios to achieve an 80 percent reduction in GHGs, which imply an 85 percent decline of energy-related CO_2 emissions, including from transport.[20]

The scenario analysis undertaken was of an illustrative nature, examining the impacts, challenges, and opportunities of possible ways of modernizing the energy system. They were not either/or options, but, rather, focused on the common elements which are emerging and support longer-term approaches to investments. The analysis of the projections conducted by the Commission, Member States and stakeholders illustrated a number of clear trends, challenges, opportunities, and structural changes to design the policy measures needed to provide the appropriate framework for investors. Based on this analysis, the energy roadmap identified key conclusions on “no regrets” options in the European energy system, and a number of structural changes for energy system transformation were identified.

For example, the scenarios showed that decarbonization of the energy system is possible and that and it can be less costly than current policies in the long run. The total energy system cost (including fuel, electricity and capital costs, investment in equipment, energy-efficient products, etc.) could represent slightly less than 14.6 percent of European GDP in 2050 compared to the level of 10.5 percent in 2005. This reflects a significant shift of the role energy plays in society. Exposure to fossil fuel price volatility

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[15]European Council, 8/9 March 2007 and European Council, 10-11 December 2009. See also "Energy 2020 -- A Strategy For Competitive, Sustainable and Secure Energy" COM (2010) 639, November 2010.

[16]‘Energy 2020 -- A strategy for competitive, sustainable and secure energy’ COM (2010) 639 of 10 November 2010.

[17]European Commission, “Energy Roadmap 2050,” op. cit.

[18]International Energy Agency, *World Energy Outlook 2011*.

[19]European Commission, “Energy Roadmap 2050,” op. cit.

[20]Using the Primes energy system model, see National Technical University of Athens,” The Primes Energy System Model: Summary Description,” www.e3mlab.ntua.gr/manuals/PRIMsd.pdf.

would decline in decarburization scenarios as import dependency falls to 35-45 percent in 2050, compared to 58 percent under current policies.[21]

Second, all decarburization scenarios showed a transition from the current system, with high fuel and operational costs, to an energy system based on higher capital expenditure and lower fuel costs. This is also due to the fact that large shares of current energy supply capacities come to the end of their useful life. In all decarburization scenarios, the EU bill for fossil fuel imports in 2050 would be substantially lower than at present. The analysis also shows that cumulative grid investment costs alone could be €1.5 trillion to €2.2 trillion between 2011 and 2050, with the higher range reflecting greater investment in support of renewable energy.[22]

The average capital costs of the energy system will increase significantly -- investments in power plants and grids, in industrial energy equipment, heating and cooling systems, smart meters, insulation material, more efficient and low-carbon vehicles, devices for exploiting local renewable energy sources, durable energy consuming goods, etc. This has a widespread impact on the economy and jobs in manufacturing, services, construction, transport and agricultural sectors. It would create major opportunities for European industry and service providers to satisfy this increasing demand and stresses the importance of research and innovation to develop more cost-competitive technologies.

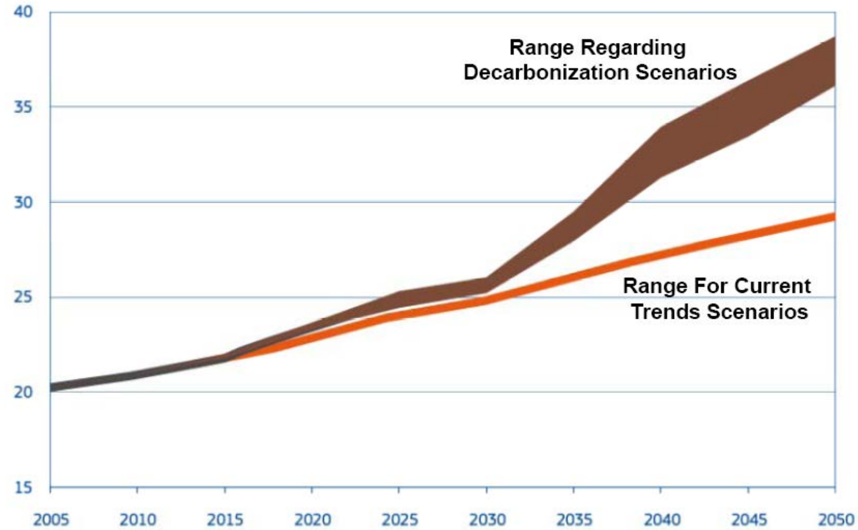
Third, all of the scenarios indicated that electricity will have to play a much greater role than currently (almost doubling its share in final energy demand to 36-39 percent in 2050) and will have to contribute to the decarburization of transport and heating/cooling – Figure II-1. Electricity could provide around 65 percent of energy demand by passenger cars and light duty vehicles, as shown in all decarburization scenarios. Final electricity demand increases even in the high energy efficiency scenario. To achieve this, the power generation system would have to undergo structural change and achieve a significant level of decarburization: In 2030, 57–65 percent, and 96-99 percent in 2050.

Finally, CCS will have to contribute significantly in most scenarios with a particularly strong role of up to 32 percent in power generation in the case of constrained nuclear production and shares between 19-24 percent in other scenarios. Specifically:

- The EU's energy system needs high levels of investment even in the absence of ambitious decarburization efforts.
- The scenarios indicate that modernizing the energy system will bring high levels of investment into the European economy.
- Decarbonization can be an advantage for Europe as an early mover in the growing global market for energy-related goods and services.
- Decarbonization helps in reducing Europe's import dependency and exposure to the volatility of fossil fuel prices.
- Decarbonization brings significant air pollution and health co-benefits.

[21]European Commission, "Energy Roadmap 2050," op. cit.
[22]Ibid.

Figure II-1
Share of EU Electricity in Current Trend and Decarbonization Scenarios
(Percent of final energy demand)



Source: EU Energy Roadmap 2050.

However, the Roadmap noted that, in the course of implementation the EU will need to consider progress and concrete action in other countries. Its policy should not develop in isolation but take account of international developments, for example relating to carbon leakage and adverse effects on competitiveness. A potential trade-off between climate change policies and competitiveness continues to be a risk for some sectors, especially in a perspective of full decarburization if Europe was to act alone. Europe cannot alone achieve global decarburization. The overall cost of investment depends strongly on the policy, regulatory, and socio-economic framework and the economic situation globally. As Europe has a strong industrial base and needs to strengthen it, the energy system transition should avoid industry distortions and losses, especially since energy remains an important cost factor for industry.[23]

II.B. The G8 Proposal

The G8 leaders are on record as supporting a 50 percent reduction in GHG emissions by 2050, but they have not endorsed any specific or binding medium-term targets. "We seek to share with all parties to the UNFCCC the vision of […] the goal of achieving at least 50 percent reduction of global emissions by 2050."[24] EU Commission President José Manuel Barroso hailed the statement as "a new, shared vision by the major economies on the climate challenge. The EU's benchmark for success at this

[23]For example, it is estimated that electricity prices in Europe are more than 20 percent more expensive than in the United States and nearly 200 percent more expensive than in China.
[24]G8 statement released on July 8, 2008.

Summit has been achieved."[25] However, the language reflects the long-standing negotiation impasse between the USA on the one hand and rapidly developing countries like China and India on the other. Developing states say they should not shoulder the same reduction burdens as developed states. But the USA is unwilling to sign up to any global GHG reduction deal without a similar commitment from China and India.[26]

Specifically, the Group of Eight leaders agreed to:[27]

- Reaffirm their commitment to combating climate change and note that enhanced commitments or actions by all major economies are essential to tackle global warming.
- Maintain their determination to achieve stabilization of atmospheric concentrations of GHGs through the common efforts of major economies to slow, stop, and reverse the growth of emissions and move toward a low-carbon society.
- Seek to share the vision of achieving at least a 50 percent reduction in global emissions by 2050.
- Recognize that sectoral approaches can be useful in improving energy efficiency and achieving national emission reduction objectives.
- Recognize the important role of renewable energy in tackling climate change and underscore the importance of sustainable biofuel production and use.
- Recognize that more countries are expressing interest in nuclear power programs.

The G8 nations also agreed to set a midterm emissions-reduction goal for themselves, although no numbers were mentioned in their joint statement on climate change. The G8 leaders did not discuss whether the industrialized nations alone would strive to achieve the goal if any of the major developing countries disagreed on sharing it. Emerging powers, including China, India, and Brazil, have insisted they will not agree to any mid- or long-term goals for reducing greenhouse gas emissions unless developed nations offer bold cuts first.[28]

II.C. The USA Commitment

The USA has committed to reducing GHG emissions by 17 percent below 2005 levels by 2020 and reducing emissions 80 percent below the 1990 level by 2050. When Mr. Obama first ran for President, he pledged to reduce GHGs in the USA 80 percent by 2050, compared with 1990 levels. Mr. Obama's interim goal, for 2020, is a 17 percent reduction in GHG emissions compared with 2005. Specifically, he pledged to:[29]

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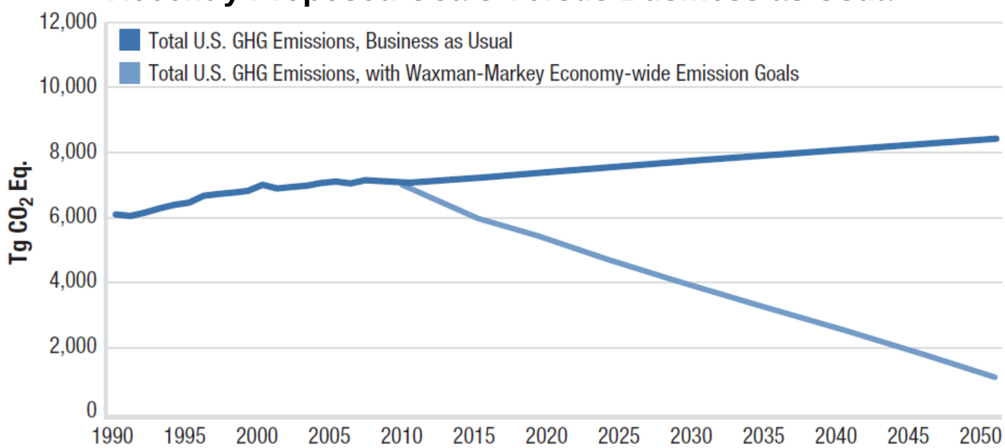
[25]"G8 backs 50 percent CO_2 cut by 2050," EurActiv, July 7, 2008.
[26]Ibid.
[27]Reiji Yoshida and Jun Hongo, "G8 Offers Halving of Emissions by 2050," *Japan Times*, July 9, 2008.
[28]Ibid.
[29]"The Obama-Biden Plan," Change.gov - The Official Web Site of the U.S. Presidential Transition, updated July 14, 2014.

- Implement an economy-wide cap-and-trade program to reduce greenhouse gas emissions 80 percent by 2050.
- Make the U.S. a leader on climate change.

To achieve the GHG reduction goals, the Obama Administration supports the implementation of a market-based cap-and-trade program to stimulate growth in the low-carbon economy and reduce GHG emissions to 83 percent below 2005 levels by 2050 (Figure II-2).[30] Since taking office in January 2009, the Obama Administration has made investments in low carbon and renewable technologies a priority, including through the American Recovery and Reinvestment Act of 2009 (ARRA).[31] The Administration has also worked to reduce GHGs through robust actions by the U.S. Environmental Protection Agency (EPA), the U.S. Department of Energy (DOE), and other executive agencies.

Figure II-2
Projected USA GHG Emissions Meeting Recently Proposed Goals Versus Business as Usual



Source: U.S. EPA 2009. The historical data are derived from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2007*; the baseline scenario is from EPA's ADAGE (Applied Dynamic Analysis of the Global Economy) model; and the decreasing emissions line includes the Waxman-Markey goals for 2012, 2020, 2030, and 2050, with intervening years interpolated.

In 2009, President Obama made a pledge that by 2020, America would reduce its GHGs in the range of 17 percent below 2005 levels if all other major economies agreed to limit their emissions as well. The President remains committed to that goal and to helping place the USA and the world on a sustainable long-term trajectory.[32] In 2012, U.S carbon emissions from the energy sector fell to the lowest level in two decades. The USA's GHG reduction plan, which consists of a wide variety of executive actions, has three key pillars:[33]

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[30]*U.S. Climate Action Report 2010, U.S. Climate Action Report 2010: Fifth National Communication of the United States of America Under the United Nations Framework Convention on Climate Change,* U.S. Department of State, Washington, D.C., June 2010.
[31]See http://frwebgate.access.gpo.gov/ cgi-bin/getdoc.cgi?dbname=111_ congbills&docid=f:h1enr.pdf.
[32]"The President's Climate Action Plan," Executive Office of the President, June 2013.
[33]Ibid.

1. Cut carbon pollution in America: To build on recent progress, the Obama Administration is implementing strict new rules to reduce carbon pollution and move the U.S. economy toward American-made clean energy sources that will create good jobs and lower home energy bills.
2. Prepare the USA for impacts of climate change: The Obama Administration will help state and local governments strengthen roads, bridges, and shorelines to better protect people's homes, businesses, and way of life from severe weather.
3. Lead international efforts to combat global climate change and prepare for its Impacts. No country is immune from the impacts of climate change, and no country can meet this challenge alone. That is why it is imperative for the USA to couple action at home with leadership internationally. The USA will help forge a global solution to this global challenge by galvanizing international action to significantly reduce emissions (particularly among the major emitting countries), prepare for climate impacts, and drive progress through the international negotiations.

Accordingly, the USA is leading efforts to address climate change through international negotiations and has made historic progress in the international climate negotiations. At the Copenhagen Conference of the United Nations Framework Convention on Climate Change (UNFCCC) in 2009, President Obama and other world leaders agreed for the first time that all major countries, whether developed or developing, would implement targets or actions to limit greenhouse emissions, and do so under a new regime of international transparency. In 2011, at the year-end climate meeting in Durban, countries agreed to negotiate a new agreement by the end of 2015 that would have equal legal force and be applicable to all countries in the period after 2020. This was an important step beyond the previous legal agreement, the Kyoto Protocol, whose core obligations applied to developed countries, not to China, India, Brazil or other emerging countries.[34]

The USA anticipates that the 2015 Paris Climate Conference will play a critical role in defining a post-2020 trajectory and will be seeking an agreement that is ambitious, inclusive, and flexible. It needs to be ambitious to meet the scale of the challenge. It needs to be inclusive because there is no way to meet that challenge unless all countries step up and play their part. And it needs to be flexible because there are many differently situated parties with their own needs and imperatives, and those differences will have to be accommodated in smart, practical ways.[35]

According to DOE Secretary Dr. Ernest Moniz, the USA 2020 goal is already half achieved, and achieving the rest will require more rapid fulfillment of new appliance efficiency standards, among other steps. "I think the President's commitment will provide the spur to Office of Management and Budget and the Energy Department to move smartly on these," Dr. Moniz stated.[36] To reach the 80 percent goal may require cutting emissions every year by about 20 percent more than what the President has proposed.

[34]Ibid.
[35]"The Obama-Biden Plan," op. cit.
[36]Matthew L. Wald, "Energy Secretary Optimistic on Obama's Plan to Reduce Emissions," *New York Times*, June 27, 2013.

However, Dr. Moniz stated that the interim goal was compatible with the long-term goal, but reaching the 2050 goal "would require a lot more to happen."[37]

In July 2014, the White House released the report "The Cost of Delaying Action to Stem Climate Change" prepared by its Council of Economic Advisers.[38] The report's main argument is that delaying expensive measures to mitigate climate change will only cost the U.S. more in the long run, and the report is intended to facilitate a series of actions President Obama has proposed (and will propose) to address global warming. The report contended that it is imperative to reduce CO_2 emissions drastically to keep global temperatures from increasing by 2° or 3° Celsius or more above preindustrial levels.[39] To do so would, as discussed below, require drastic reductions in worldwide GHG emissions.

II.D. The UK Pledge

The UK has pledged to reduce GHG emissions by at least 80 percent (from the 1990 baseline) by 2050. The 2008 Climate Change Act established the world's first legally binding climate change target.[40] The goal is to reduce the UK's GHGs by at least 80 percent (from the 1990 baseline) by 2050 through action at home and abroad. Moving to a more energy efficient, low-carbon economy will help meet this target, and it will also help the UK become less reliant on imported fossil fuels and less exposed to higher energy prices in the future.[41]

In December 2011 the Carbon Plan established proposals for achieving the UK emissions reductions committed to in the first four carbon budgets to help achieve the 2050 target.[42] The Climate Change Act 2008 sets out the UK's legally binding targets and its goals are to improve carbon management and help the transition to a low-carbon economy in the UK and demonstrate that the UK is committed to taking its share of responsibility for reducing global GHGs by developing negotiations on a post-2012 international climate change agreement. The Committee on Climate Change (CCC) is an expert, independent, statutory public body created by the Climate Change Act 2008 to assess how the UK can best achieve its emissions reduction targets for 2020 and 2050.[43] It also assesses the UK's progress on meeting the statutory carbon budgets.

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[37]Ibid.
[38]Council of Economic Advisers, "The Cost of Delaying Action to Stem Climate Change," Executive Office of the President of the United States, July 2014.
[39]Ibid., pp. 2-4.
[40]"2008 Climate Change Act," www.legislation.gov.uk/ukpga/2008/27/contents.
[41]"Reducing the UK's greenhouse gas emissions by 80 percent by 2050," Department of Energy and Climate Change, March 6, 2014, GOV.UK.
[42]*The Carbon Plan: Delivering Our Low Carbon Future*, Presented to Parliament pursuant to Sections 12 and 14 of the Climate Change Act 2008, Amended 2nd December 2011 from the version laid before Parliament on 1st December 2011, December 2011.
[43]"Committee on Climate Change," www.theccc.org.uk/.

To ensure that government policies contribute effectively to GHG reduction targets, the UK is:[44]

- Setting carbon budgets to limit the amount of greenhouse gases the UK is allowed to emit over a specified time
- Using statistics on GHGs and further evidence, analysis, and research to inform energy and climate change policy
- Using the EU Emissions Trading Scheme (EU ETS) to deliver a significant proportion of the UK's carbon emission reductions between 2013 and 2020 using a set of values for carbon to make sure project and policy appraisals account for their climate change impacts[45]
- Using the 2050 Calculator to permit policy makers and the public to explore the different options for meeting the 2050 emissions reduction targets[46]
- Reducing the demand for energy and helping people and businesses to use energy more efficiently

The UK believes that significant reductions in GHGs can be achieved if businesses, the public sector, and households reduce their demand for energy. Accordingly, the government is:

- Reducing demand for energy with smart meters and other energy-efficient measures for industry, businesses and the public sector
- Reducing emissions by improving the energy efficiency of properties through the Green Deal[47]
- Providing incentives for public and private sector organizations to implement more energy-efficient technologies and practices through the CRC Energy Efficiency Scheme[48]

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[44]"Reducing the UK's Greenhouse Gas Emissions by 80 percent by 2050," January 22, 2013, GOV.UK.

[45]The EU ETS is a "cap-and-trade" system in that there is a "cap" on the total emissions of GHGs from facilities specified in the ETS Directive. The EU ETS was launched in 2005 and is now in its third phase, running from 2013 to 2020; includes 11,000 power plants and factories -- as well as airlines; covers installations that capture CO_2, transport CO_2 by pipelines, or store CO_2; covers about 45 percent of the total GHG emissions from EU countries. According to the ETS, in 2020, emissions from covered sectors are to be 21 percent less than in 2005. By 2030, the Commission proposes they would be 43 percent lower. However, thus far, the ETS has not worked well and has not reduced emissions. According to the European Environmental Agency "There is little evidence pointing towards a causal link between emissions reductions and the EU ETS." See European Commission, "The EU ETS Trading System," http://ec.europa.eu/clima/policies/ets/ index_ en.htm; Alex Scott, "EU Carbon Emissions Trading Scheme In Freefall," *Chemical & Engineering News*, February 18, 2013; Roger Bezdek, "Carbon Policy Around the Globe: Degrees of Disaster," presented at The Energy Council 2013 Global Energy and Environmental Issues Conference, Lake Louise, Alberta, Canada, December 2013; "The Failure of Global Carbon Policies," *American Coal*, issue 1, 2014, pp. 50-54.

[46]https://www.gov.uk/2050-pathways-analysis

[47]"Green Deal: Helping Households to Cut Their Energy Bills," www.gov.uk/government/policies/helping-households-to-cut-their-energy-bills/supporting-pages/green-deal.

[48]"CRC Energy Efficiency Scheme," www.gov.uk/government/policies/reducing-demand-for-energy-from-industry-businesses-and-the-public-sector--2/supporting-pages/crc-energy-efficiency-scheme

- Reducing greenhouse gases and other emissions from transport and reducing GHGs from agriculture

It is anticipated that low-carbon technologies will make an important contribution to the UK GHG reduction targets. Accordingly, the government is:

- Taking action to increase the use of low-carbon technologies, creating an industry for carbon capture and storage (CCS), and reducing emissions from the power sector
- Encouraging investment in low-carbon technologies by reforming the UK's electricity market and providing over £200 million of funding for innovation in low-carbon technologies from 2011 to 2015
- Publicly reporting carbon emissions from businesses and the public sector

The UK feels that public reporting of carbon emissions helps to encourage organizations to become more energy efficient, and allows assessment of the progress being made. The government is measuring and reporting environmental impacts, providing guidance for businesses, and asking local authorities to measure and report their GHGs.

II.E. The German Proposal

Germany has proposed reducing its GHG emissions 95 percent below the 1990 baseline by 2050, and a study by the Federal Environment Agency contends that such a reduction is feasible and that industrialized countries can achieve a climate-friendly per capita output of greenhouse gases.[49] According to Jochen Flasbarth, President of the Federal Environment Agency (UBA), "It is technically possible to reduce greenhouse gas emissions by nearly 100 per cent compared to 1990 levels – with technologies that are available today. Our current annual per capita emissions of 10 tonnes CO_2 equivalents can be brought down to less than one tonne per capita in 2050. Compared to 1990, that represents a reduction of 95 percent. Germany can become virtually greenhouse gas-neutral by the middle of the century. Energy is the decisive sector to set the right course for climate protection. Electricity, heat, and conventional fuels now account for about 80 per cent of our greenhouse gas emissions. But we can reduce our final energy consumption in 2050 by half compared to 2010, and we can cover our demand entirely with renewable sources of energy. We can already prevent more than three-quarters of emissions, and we do not need nuclear power or underground CO_2 sequestration."[50]

According to the UBA study, reducing GHGs emissions by 95 per cent is only possible if all sectors do their part. In addition to the energy sector (including transport), efforts must be made by industry, waste and wastewater management as well as

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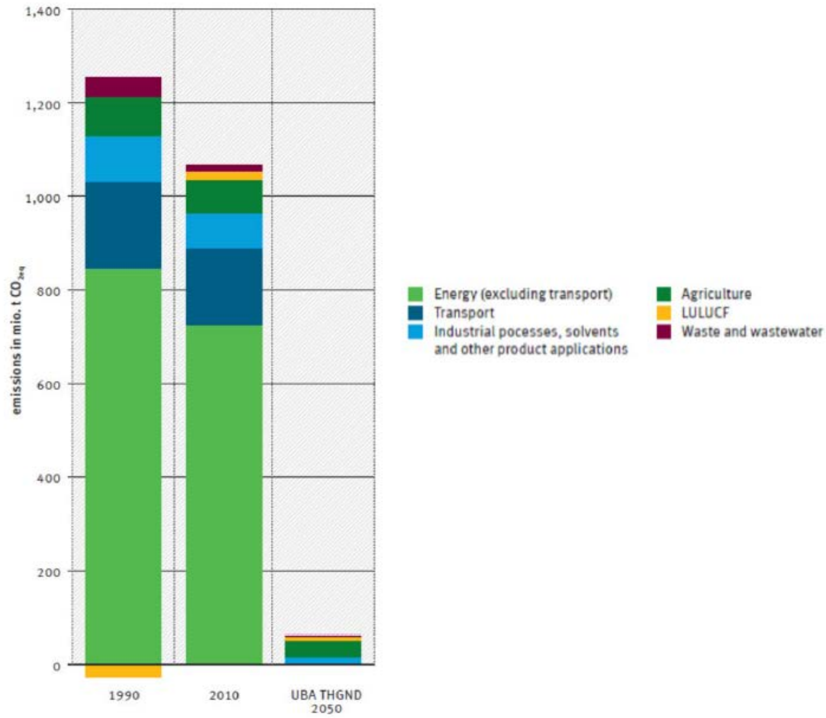
[49]"Germany 2050: A Greenhouse Gas-Neutral Country," background paper, Federal Environment Agency, Umwelt Bundesamt, October 20, 2013

[50]"A Greenhouse Gas-Neutral Germany is (Almost) Possible," October 25, 2013 www.umweltbundesamt.de/en/press/pressinformation/a-greenhouse-gas-neutral-germany-is-almost-possible,.

agriculture and forestry.[51] Figure II-3 shows the decrease in GHGs by 95 percent compared to the baseline year 1990 and illustrates the magnitude of the challenge.

Figure II-3
German GHG Emissions: 1990 and Required 2050 Reductions



Source: Umwelt Bundesamt.

Since emissions from agriculture and certain industrial processes cannot be avoided completely, the essence of the UBA scenario is an energy supply based on renewables only -- and that includes electricity, heating, and fuel supply. The UBA is banking on wind and solar energy in particular for 2050. In contrast, it sees no future in cultivated biomass. Mr. Flasbarth stated "Instead of growing crops like maize and rape for the sole purpose of energy production, we favor the use of biomass from waste and residual wastes as these materials do not compete with food production."[52]

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[51]The UBA based its scenarios on the assumption that Germany will continue to be a leader among industrialized countries in 2050. The study depicts one possible outcome - it is no prognosis of what will happen. The study describes a technically possible scenario for the future. It neither looks at the exact way a transformation from today until 2050 might take, neither does it assess economic costs or welfare gains, It also assumed that the population's consumer behaviour will not undergo fundamental change, although "more climate- and environmentally friendly lifestyles would of course facilitate the achievement of climate protection goals." See "Germany 2050: A Greenhouse Gas-Neutral Country,"
[52]Ibid.

The essential component in the transition to a society that is almost completely GHG-neutral is to convert the power which will be produced entirely from renewables into hydrogen, methane, and long-chain hydrocarbons. Solar and wind power are used in what is known as "power-to-gas" and "power-to-liquid" processes to produce methane or other liquid fuels through the electrolysis of water or other catalytic processes. These fuels can be used to replace natural gas or diesel and petrol in the transport sector, as fuels for heating systems, or as raw materials in the chemical industry. A few pilot projects in Germany have already implemented this technology successfully. However, the process entails energy losses during transfer and is at present still costly. Further research – including other options for the transport and heating sectors – is needed.[53]

The transport sector currently accounts for about 20 per cent of total German GHGs. These emissions can be reduced to zero by 2050 on the key condition that unnecessary transport is avoided. Unavoidable transport must be shifted to environmentally friendly modes of transport such as bicycle, bus, or rail. The technical efficiency of passenger cars and heavy goods vehicles must be further improved. The most important factor, however, is the switch to renewable energy, and in the UBA scenario, passenger cars operate about 60 per cent on electricity in 2050. Airplanes, ships, and heavy goods vehicles will continue to rely mainly on liquid fuels, except that these fuels will be synthetic, climate-friendly, and produced in power-to-liquid processes." [54] Whether and when these electricity-based fuels may be provided for different forms of transport is subject to further research.

Demand for space heating and process heat for industry in 2050 could be met by renewable power and methane generated from renewable sources. This would result in a zero level of energy-related GHGs. Process- and raw material-driven GHGs decrease by 75 per cent, to about 14 million tonnes, but would require the chemical industry to shift from its present petroleum-based raw material supply to hydrocarbons generated from renewable energy. As a result, there would be virtually no emissions from the production of ammonia or other chemical syntheses.

Emissions in the waste and wastewater sectors have been reduced dramatically up to now, and in 2050 levels could potentially be a mere three million tonnes. To achieve this, even more landfill gas must be collected and used in cogeneration plants. In addition, improving the ventilation of biowaste composting plants could more effectively help to prevent the release of climate-damaging methane.

The largest GHG emitter in 2050 might turn out to be agriculture, with emissions that are still 35 million tonnes CO_2 equivalents. Because technical measures alone are inadequate to achieve the targeted reduction, livestock populations in general, and of ruminants in particular, must be lowered.[55]

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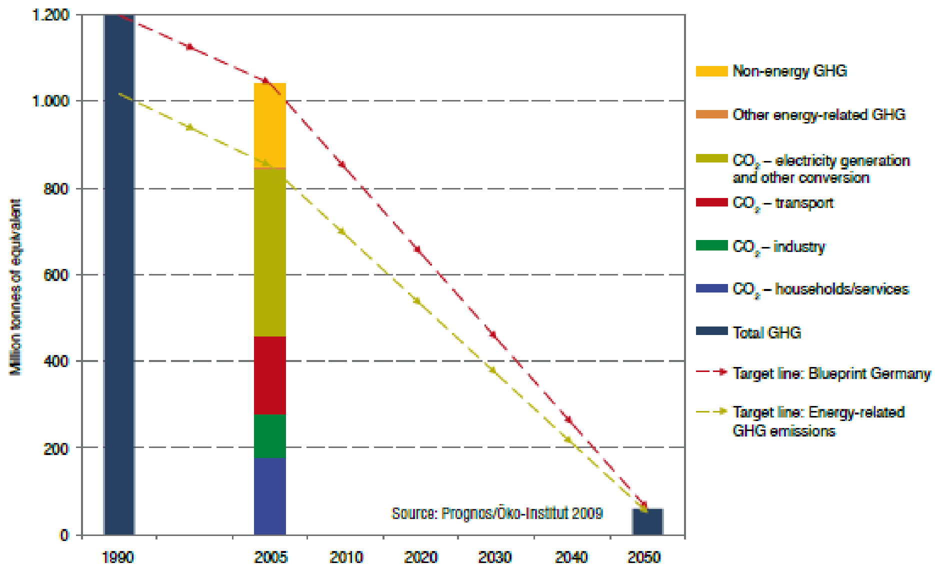
[53]"Germany 2050: A Greenhouse Gas-Neutral Country," op. cit.
[54]Ibid
[55]The UBA scenario is based on the assumption that all energy supplies have been switched to renewables and extensive use of efficiency gains is made. Thus, emissions from the energy sector would fall to near zero and other sectors could substantially reduce their emissions. In the scenario, a key element is the

WWF Germany also found that, for Germany, the 2050 target means a reduction of GHGs by approx. 95 percent compared to 1990 emission levels.[56] That is, less than one tonne of greenhouse gases per capita may be emitted by 2050. An examination of the current situation clearly reveals that there is still a very long way to go before Germany can reach the 95 percent target – Figure II-4. This figure indicates that all sectors will have to make a huge contribution in order to reach this very ambitious goal, that a huge increase in energy efficiency is required to reduce energy demand, and that the exhaustion of renewable energy potentials will be needed.[57]

Figure II-4
German GHG Emissions Reductions Required



Source: WFF Germany.

II.F. The California Mandates

The state of California in the USA – which has the world's eighth largest economy -- has mandated state GHG emissions reductions to 2000 levels by 2010, to 1990 levels by 2020, and to 80 percent below 1990 levels by 2050. California has thus put in place ambitious emission reduction goals: In 2005, California Governor Schwarzenegger's Executive Order S-3-05 committed the state to reduce emissions to 2000 levels by 2010, to 1990 levels by 2020, and to 80 percent below 1990 levels by 2050.[58] One year later,

conversion of renewably generated power to hydrogen, methane and more complex hydrocarbons. This is the only way to meet the demand for fuel and raw materials in the industrial, transport and heating sector. The result is a major increase in power demand, far beyond what could be called excess power.

[56] *Blueprint Germany: A Strategy For a Climate Safe 2050*, prepared by Prognos/Öko-Institut and Dr. Hans-Joachim Ziesing for WWF Germany, October 2009.

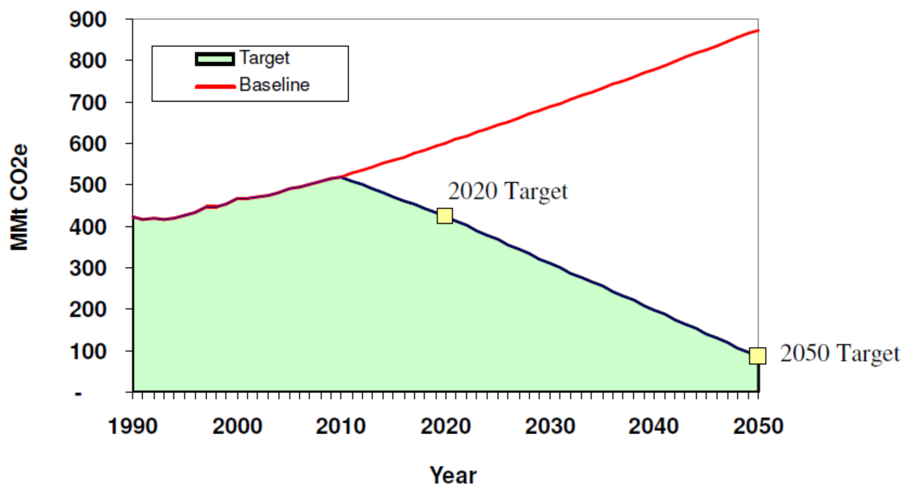
[57] Ibid.

[58] "California Executive Order S-3-05 (June 2005)," www.dot.ca.gov/hq/energy/ExecOrderS-3-05.htm.

the Governor signed the "Global Warming Solutions Act of 2006" (Assembly Bill 32 or AB 32), which legally obligates the state to reduce GHG emissions to 1990 levels by 2020.[59]

The scale of this challenge is illustrated in Figure II-5. California's GHG emissions trajectory under a "Baseline" Case, wherein the state does not undertake efforts to reduce GHG emissions, is shown in red. The state's targeted emissions reduction pathway is shown in black, with the AB 32 target and the Governor's Executive Order 2050 target shown as yellow boxes. The 2020 GHG target represents approximately a 15 percent reduction from current emissions levels, while the 2050 goal implies a 90 percent reduction from 2050 Baseline levels.[60]

Figure II-5
Baseline Trajectory and 2020 and 2050 Emissions Targets (1990 – 2050)
Million Metric Tons CO_2 equivalent ($MMtCO_2e$)



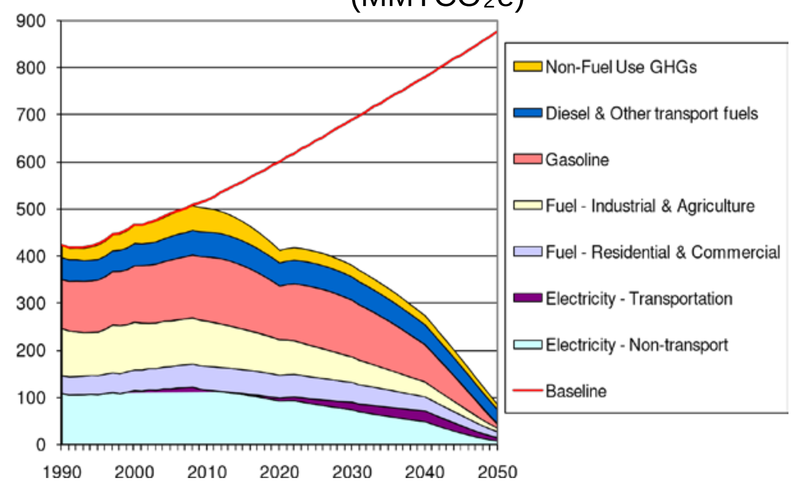
Source: Energy and Environmental Economics, Inc.

California is seeking to achieve these GHG goals even as the state's population continues to increase, and as economic growth continues. The population of California is expected to grow from the current 38 million to nearly 57 million people by 2050.[61] At this level of population growth, Californians will need to reduce their per capita GHG emissions from about 13 metric tons per person per year today to less than two metric tons per person per year by 2050. The goal is to achieve this level of GHG savings while increasing the state's economic output 1.5 times by 2050. Measured against population growth, this represents more than an 85 percent reduction; adjusted for forecast economic growth it represents nearly a 95 percent reduction.

[59]California Environmental Protection Agency, Air Resources Board, "Assembly Bill 32: Global Warming Solutions Act of 2006, www.arb.ca.gov/cc/ab32/ab32.htm,
[60]See Energy and Environmental Economics, Inc., *Meeting California's Long-Term Greenhouse Gas Reduction Goals*, San Francisco, November 2009.
[61]Ibid. More recent population forecasts indicate that the state's 2050 population may be somewhere between 50 million and 57 million; see California Department of Finance, "New Population Projections: California to Surpass 50 Million in 2049," January 31, 2013.

Studies have shown that a required combination of low-carbon electricity, low-carbon fuels, and reduced energy could result in a GHG emissions trajectory in the "2050 Compliant Case" that shows a dramatic reduction in GHG emissions relative to the Baseline.[62] Figure II-6 shows that the 2050 Compliant Case saves nearly 800 MMT CO_2e relative to the Baseline in 2050. This represents a CO_2 reduction of 90 percent relative to the Baseline CO_2 projection. The figure shows in stark terms the dramatic shift that the California economy must undergo within about 35 years if the 2050 GHG target is to be met.

Figure II-6
Compliant Case GHG Emissions Profile (1990 – 2050)
($MMTCO_2e$)



Source: Energy and Environmental Economics, Inc.

II.G. The UN Deep Decarbonization Scenarios

The Deep Decarbonization Pathways Project (DDPP) is a collaborative initiative to determine how individual countries can transition to a low-carbon economy, and was presented to UN Secretary-General Ban Ki-moon in July 2014 in advance of the UN Climate Leaders' Summit that he convened in New York on September 23, 2014.[63] "Deep Decarbonization" will require a profound transformation of energy systems by mid-century through steep declines in carbon intensity in all sectors of the economy.[64] The DDPP

[62]Energy and Environmental Economics, Inc., op. cit.

[63]*Pathways to Deep Decarbonization: Interim 2014 Report*, Sustainable Solutions Development Network and Institute for Sustainable Development and International Relations, July 2014.

[64]The results of the DDPP analyses remain preliminary and incomplete, and in the first half of 2015, the DDPP will issue a more comprehensive report to the French Government, host of the 21st Conference of the Parties (COP-21) of the United Nations Framework Convention on Climate Change (UNFCCC). The 2015 DDPP report will refine the analysis of the technical decarbonization potential, exploring options for even deeper decarbonization, but also better taking into account existing infrastructure stocks. The authors "hope that the findings will be helpful to the Parties of the UN Framework Convention on Climate Change

aims to help countries think through how to pursue their national development priorities while achieving the deep decarbonization of energy systems by mid-century.[65]

Deep decarbonization is not about modest and incremental change or small deviations from BAU. In particular, it requires major changes to countries' energy and production systems that need to be pursued over the long-term. The DDPs developed by the Country Research Teams "backcast" from the global goal of limiting the rise in temperature below 2°C to explore the transformations for deep decarbonization required to reach the goal.[66] The technical DDPs rest on a number of national and global policy assumptions, including:

- All countries take strong, early, and coordinated actions to achieve deep decarbonization.
- All countries adopt adequate nationally appropriate policies, regulations, and incentives.
- Financial flows are re-directed from high-carbon to low-carbon portfolios and projects.
- Financial support is provided to countries that appropriately require financial assistance to implement mitigation policies and finance low-carbon investments.

In aggregate, the initial DDPs achieve deep absolute emissions reductions by 2050. Total CO_2-energy emissions from the 15 preliminary DDPs already developed reach a level of 12.3 Gt by 2050, down from 22.3 Gt in 2010. This represents a 45 percent decrease of total CO_2-energy emissions over the period, and a 56 percent and 88 percent reduction in emissions per capita and the carbon intensity of GDP, respectively. The interim DDPs do not yet achieve the full decarbonization needed to make staying below the 2°C limit "likely," defined as a higher than two-thirds probability of success. The Country Research Teams have identified additional opportunities for deep decarbonization that will be incorporated in the next version of the DDPs to be published in 2015.

The 15 DDPs share three common pillars of deep decarbonization of national energy systems: 1) Energy efficiency and conservation, 2) Low-carbon electricity, and 3) Fuel switching. Successful implementation of national DDPs depends on "directed technological change" -- that is technological change that is propelled through an organized, sustained, and funded effort engaging government, academia, and business with targeted technological outcomes in mind. Based on the best estimates regarding non-CO_2 forcings and excluding the availability of large-scale net negative emissions, the IPCC AR5 WG3 defines a CO_2 budget for the 2011–2050 period of 825 Gt9 and of 950

(UNFCCC) as they craft a strong agreement on climate change mitigation at the COP-21 in Paris in December 2015." See ibid.

[65]The authors did not assess the issue of the costs and benefits of mitigation actions, nor considered the question of who should pay for these costs.

[66]The term "backcasting" describes a process where the future GHG emission target is set, and then the changes needed to achieve that target are determined.

Gt for the period 2011-2100.[67] This implies 125 Gt of CO_2 cumulative net emissions for the period 2051-2100.

Previous studies have frequently assumed the use of large quantities of offsets to minimize costs. The implicit assumption is that large emitters could fund emissions reductions in low-emitting countries in exchange for reducing the need for local reductions. However, the authors felt that this assumption becomes unlikely under global deep decarbonization scenarios in line with the 2°C limit, as all countries will have to make real efforts to come close to the 1.6 tons per capita global average or sectoral performance indicator benchmarks. They did thus not explore global "offsets" in the national scenarios.

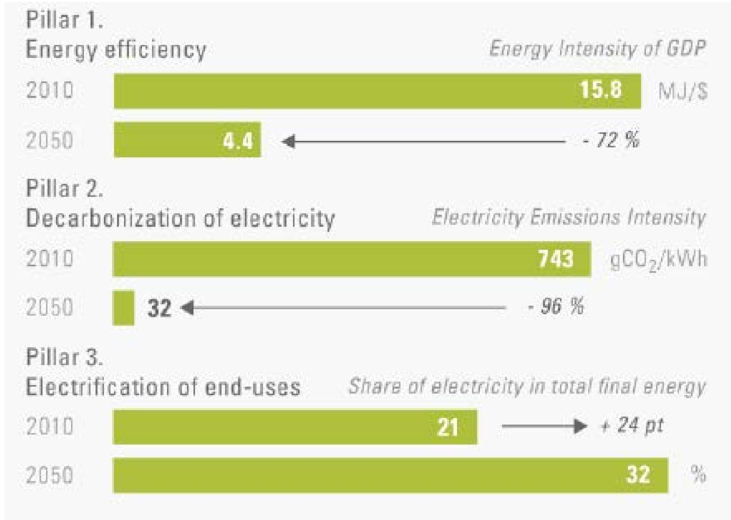
II.G.1. China Deep Decarbonization Pathways

For China, the DDP combines an acceleration of the evolution of economic structural reductions in energy intensity and the promotion of non-fossil fuel energy to control emissions in a context of continued economic growth. GDP per capita is assumed to increase more than six-fold from 2010 to 2050 to satisfy development needs, but energy trends are significantly decoupled from this growth with an increase of primary and final energy of 78 percent (from 93.7 EJ in 2010 to 166.9 EJ in 2050) and 71 percent (from 66.9 EJ in 2010 to 114.4 EJ in 2050) respectively. This increase is mainly triggered by the industrial sector (+28 percent), buildings sector (+141 percent), and transportation sector (+204 percent), along with changes in economic structure, an increase in the urbanization rate, and the completion of the industrialization process. In particular, the share of coal in primary energy consumption declines to 20 percent in 2050, while the use of natural gas and non-fossil fuels increase, contributing 17 percent and 43 percent respectively.

In the DDP, energy-related CO_2 emissions decrease by 34 percent, from 7.25 $GtCO_2$ in 2010 to 4.77 $GtCO_2$ in 2050, essentially due to a decrease of both the primary energy per unit of GDP by 73 percent and of energy-related CO_2 emissions per unit of energy by 61 percent. The former is largely explained by structural change, with a large decrease of the share of energy-intensive sectors of the economy and improvement of economy-wide energy efficiency. The latter comes mainly from decarbonizing the power sector and from the electrification of end-uses (from 21 percent in 2010 to 32 percent 2050), while increasing living standards and modernizing energy use patterns (Figure II-7). The application of CCS technologies in power generation and the industrial sector is also a crucial feature of this illustrative pathway, contributing 1.3 $GtCO_2$ and 0.8 $GtCO_2$ respectively.

[67]See IPCC AR5 Working Group III - Mitigation of Climate Change, Annex II, Table A.II.18 December 2013, www.ipcc.ch/report/ar5/wg3/.

Figure II-7
China's Pillars of Decarbonization



Source: *Pathways to Deep Decarbonization: Interim 2014 Report*.

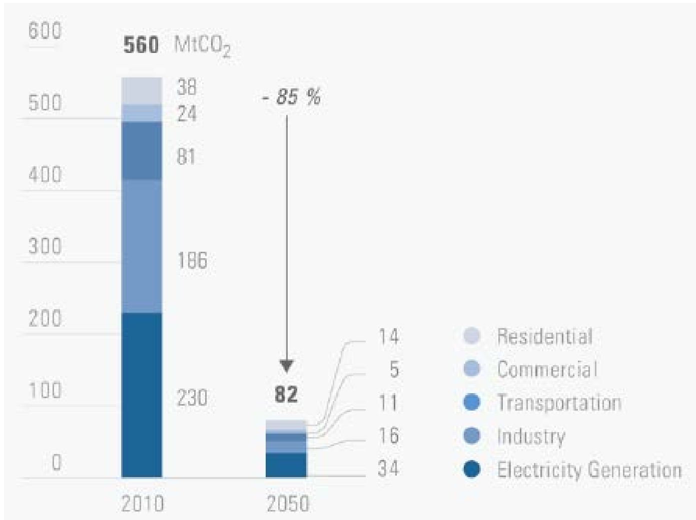
II.G.2. Korea Deep Decarbonization Pathways

The Korean economy is projected to grow at an annualized rate of 2.35 percent on the average through 2050.[68] With the global benchmark of 1.7 tons of CO_2 emissions per person in 2050, the DDP seeks a very ambitious decarbonization path for the Korean economy and reaches an 85.4 percent reduction of CO_2 emissions from fuel combustion.

Emissions are projected to decline from 560 $MtCO_2$ in 2010 to 82 $MtCO_2$ in 2050. This is permitted by a drastic decrease of energy consumption (-37.2 percent in final energy consumption) due to large improvements in energy efficiency. In addition, there are important changes in the fuel mix. In particular, the importance of oil-based fuels, which represent one-half of final consumption in 2010, is significantly reduced, and coal use is almost completely phased-out over the period. In parallel, electricity (and notably renewable sources) develops with an electrification rate of final uses reaching 60.7 percent in 2050 (vs. less than 20 percent in 2010), with significant reductions of the carbon intensity of electricity production, from 531 to 41 gCO2/kWh. All sectors see their emissions decreasing radically over 2010-2050 (Figure II-8).

[68]This pertains exclusively to the Republic of Korea ("South Korea" or "Korea"). A major uncertainty facing Korea is when, if at all, and how, the inter-Korean unification is likely to occur. The DDP ignored this contingency altogether.

Figure II-8
Korean Energy-Related CO_2 Emissions Pathway by Sector, 2010-2050



Source: *Pathways to Deep Decarbonization: Interim 2014 Report*.

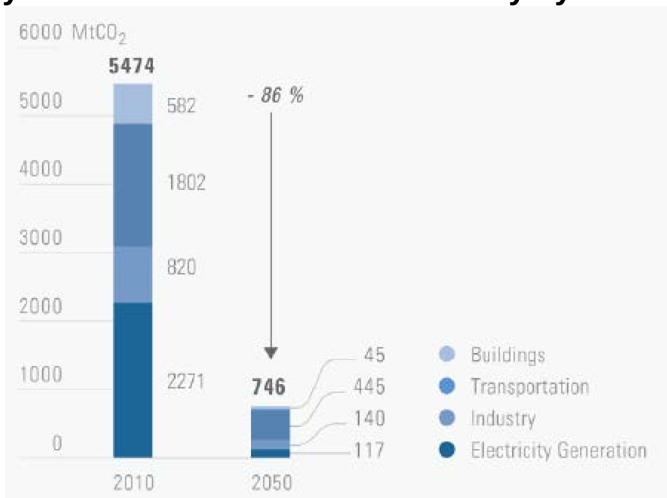
II.G.3. USA Deep Decarbonization Pathways

The USA is the world's second largest emitter of GHGs, and one of the highest per capita consumers and producers of energy and fossil fuels. Deep decarbonization will require a profound transformation of the way energy is produced, delivered, and used, in a transition that is sustained over multiple generations.

The transition to a low-carbon energy system involves three principal strategies: (1) highly efficient end use of energy in buildings, transportation, and industry; (2) decarbonization of electricity and other fuels; and (3) fuel switching of end uses from high-carbon to low-carbon supplies. All three of these strategies must be applied to achieve deep decarbonization, as demonstrated in an illustrative deep decarbonization scenario ("main case").

By sector, electricity generation's share of CO_2 emissions falls from 40 percent in 2010 to 16 percent in 2050 (Figure II-7). The remaining electricity emissions are primarily from residual emissions not captured by CCS for natural gas- and coal-fired generation. Transportation's one-third share of emissions rises to 60 percent of total final emissions by 2050 (excluding electrified transport), as the remaining fossil fuels in the economy are applied to largely to long-distance transport end-uses (including aviation and military use) that are difficult to electrify or convert to pipeline gas. Industrial direct emissions rise from 15 percent to 19 percent of total emissions by 2050, while the residential and commercial sectors are nearly completely electrified, leaving negligible amounts of remaining direct emissions.

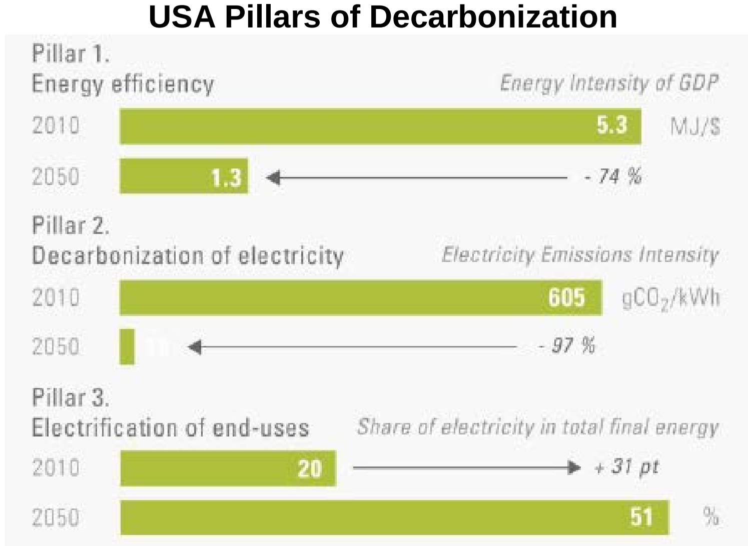
Figure II-9
USA Energy-Related CO_2 Emissions Pathway by Sector, 2010-2050



Source: *Pathways to Deep Decarbonization: Interim 2014 Report*.

Key drivers of changes in CO_2 emissions between 2010 and 2050 -- a growing U.S. population (+42 percent cumulative change between 2010 and 2050) and rising GDP per capita (+87 percent), are more than offset by reductions in the final energy intensity of GDP (-74 percent) and the CO_2 intensity of final energy (-80 percent), resulting in an 86 percent reduction in CO_2 emissions relative to 2010 levels. The three largest contributing factors to CO_2 reductions (Figure II-8) are improvements in end-use energy efficiency, a near-total decarbonization of electricity generation, and extensive electrification of end-uses. Two additional measures contribute to reductions but are not shown in this figure: Fuel switching to partially decarbonized pipeline gas and the use of CCS for some large-scale industrial gas users.

Figure II-10
USA Pillars of Decarbonization



Source: *Pathways to Deep Decarbonization: Interim 2014 Report*.

II.H. Implications of the GHG Reduction Goals

The goals are ambitious in the extreme, and it is highly questionable if they are even feasible. For example, by 2050:

- The USA would have to reduce GHGs from electricity generation by 95 percent from 2010 levels.
- In California, there would be few gasoline fueled vehicles, and GHGs from electricity consumption in the residential, commercial, and industrial sectors would be close to zero.
- Korea would have to reduce GHGs from industry by 91 percent from 2010 levels.
- China would have to decarbonize its electricity generation by 96 percent.
- All nations would have to reduce the carbon intensity of GDP by 90 percent, or more.

These goals are even more problematic when it is realized that, as discussed in the following chapter, the world economy, fossil fuel energy consumption, and GHG emissions are forecast to increase continually and substantially over the next three decades – even as the CO2 intensity of the world economy declines substantially. Simultaneously, all nations anticipate greatly increasing their per capita GDPs and standards of living, and developing nations seek to double or treble per capita incomes. Viewed according to this perspective, the GHG reduction goals become unrealistic to the point of ludicrousness.

III. GDP, ENERGY, AND GHG FORECASTS

According to all major forecasts available, fossil fuels will remain the principal sources of energy worldwide for the foreseeable future and will continue to supply 75 - 80 percent of world energy. Demand for oil, natural gas, and coal will increase substantially in both absolute and percentage terms over the next several decades. Assuring continued world economic growth, increasing per capita income, and rising living standards requires this greatly increased use of fossil fuels.

III.A. The IEA Forecasts

The International Energy Agency (IEA) finds that fossil fuels will continue to meet the vast majority of the world's energy needs over the next two decades. These fuels, which represented 86 percent of the primary fuel mix in 2010, remain the dominant source of energy through 2035 in all of the IEA scenarios, and in 2035 will still comprise over 80 percent of a much expanded energy supply.[69]

Indeed, greater utilization of fossil fuels may be required than is currently forecast. For example, the IEA notes that 1.3 billion people currently lack access to electricity and 2.6 billion people are still without clean cooking facilities.[70]

The New Policies Scenario is the central IEA scenario and analyzes the evolution of energy markets based on continuation of existing policies and measures as well as cautious implementation of policies that have been announced by governments but are yet to be given effect. In addition to incorporating the policies and measures that affect energy markets and that had been adopted as of mid-2013, the New Policies Scenario also takes account of other relevant commitments that have been announced, even when the precise implementation measures have yet to be fully defined. These commitments include programs to support renewable energy and improve energy efficiency, initiatives to promote alternative fuels and vehicles, carbon pricing, and policies related to the expansion or phase-out of nuclear energy, and initiatives taken by G-20 and Asia-Pacific Economic Cooperation (APEC) economies to reform fossil-fuel subsidies.

The IEA Current Policies Scenario takes account only of policies already enacted as of mid-2013. In other words, it describes a future in which governments do not implement any recent commitments that have yet to be backed-up by legislation or introduce other new policies bearing on the energy sector. The scenario is designed to provide a baseline picture of how global energy markets would evolve if established trends in energy demand and supply continue unabated. It both illustrates the consequences of inaction and makes it possible to evaluate the potential effectiveness of recent developments in energy and climate policy.

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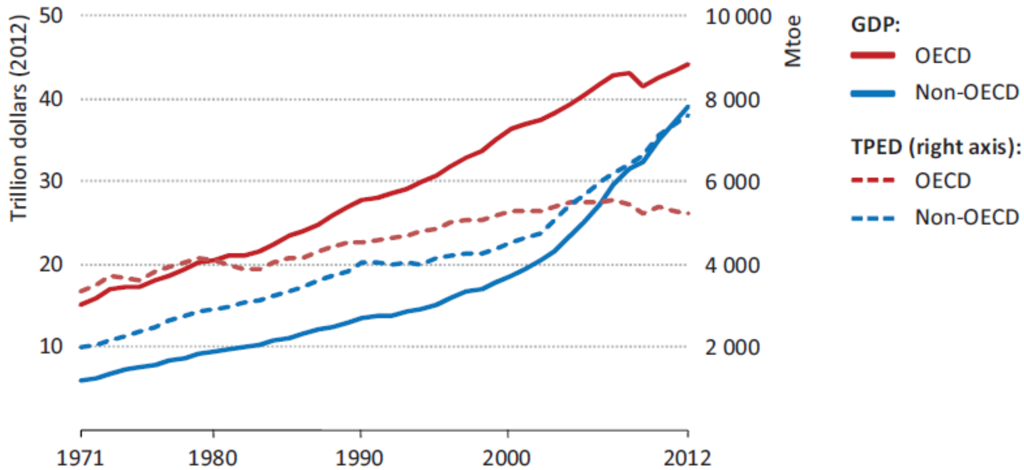
[69]International Energy Agency, *World Energy Outlook*, Paris, 2013.
[70]Ibid.

Over the last several decades, global energy consumption has grown at a much slower rate than GDP, primarily because of structural changes in the economy, energy efficiency improvements, and fuel switching. Global energy intensity – defined as the amount of energy used to produce a unit of GDP at market exchange rates – fell by 32 percent between 1971 and 2012.[71] Despite this partial decoupling of energy demand and economic growth, which has been particularly evident in the OECD, the two still remain closely tied (Figure III-1).

Figure III-1
Primary Energy Demand and GDP



Source: International Energy Agency.

In each of the IEA scenarios, world GDP (expressed in real purchasing power parity – PPP -- terms) is assumed to grow at an average annual rate of 3.6 percent between 2011 and 2035). This means that the global economy more than doubles in size over the period.

In the New Policies Scenario, global energy demand grows by 1.6 percent per year on average to 2020 and then gradually slows to average one percent per year thereafter, reaching around 17,400 Mtoe in 2035 (Figure III-2). Associated with this 33 percent increase in energy demand over the projection period, the global population grows by around one-quarter and the global economy more than doubles. Energy demand growth slows primarily as a result of a gradual slowdown in economic growth in certain countries, particularly the largest rapidly industrializing developing economies, and as recently announced energy policies (targeted at increasing energy security, improving efficiency, and reducing pollution) are implemented and have a greater effect over time.[72]

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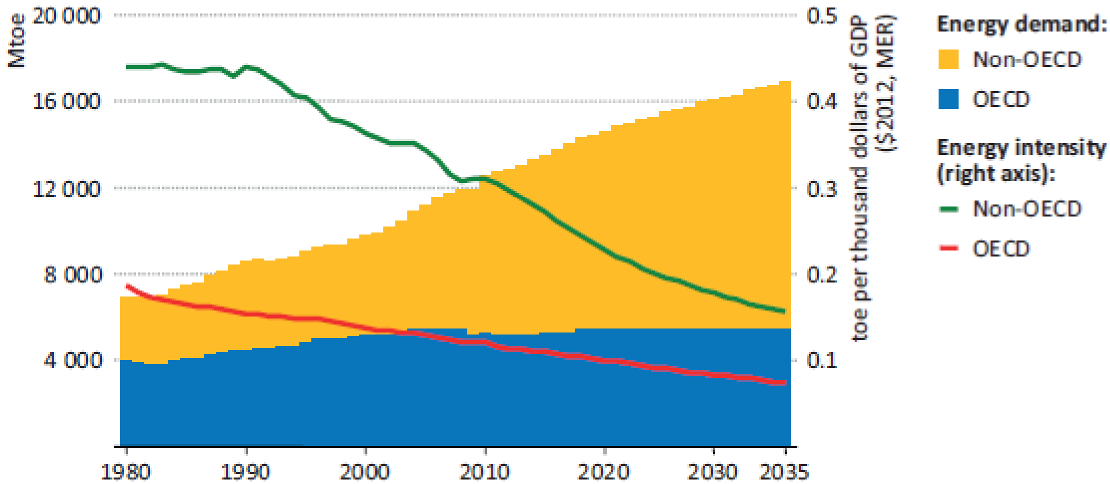
[71]The average rate of improvement, however, was much lower in 2000-2011 than in 1980-2000 (and energy intensity actually increased in 2009 and 2010) due to a shift in the balance of global economic activity to countries in developing Asia which have relatively high energy intensities.
[72]See the *WEO* special report "Redrawing the Energy-Climate Map," International Energy Agency, 2013.

Figure III-2.
Primary Energy Demand and Energy Intensity in the New Policies Scenario



Note: toe = tonne of oil equivalent; MER = market exchange rate.

Source: International Energy Agency.

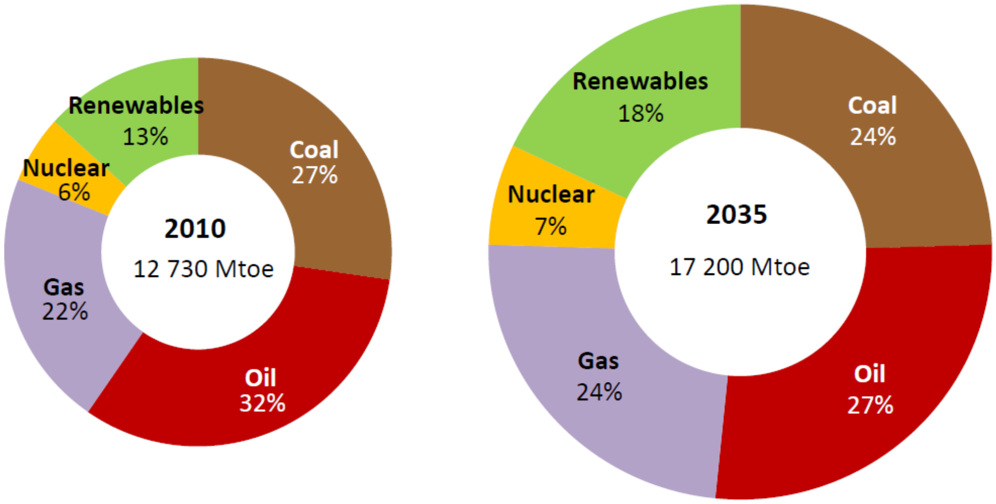
Despite these actions, global energy demand is 190 Mtoe higher in 2035 than IEA's 2013 projection. In the OECD, demand in 2035 is forecast to be slightly lower across all fuels, mainly as a result of the continuing economic woes in many countries. In contrast, non-OECD energy demand is generally higher, the biggest change being higher coal demand in 2035, mainly due to an upward revision of coal used as petrochemical feedstock in China.

A growing global population and expanding economy will continue to push primary energy demand higher, but government policies will play an important role in dictating the pace. In the New Policies Scenario, global primary energy demand increases by one-third between 2011 and 2035, reaching around 17,400 million tonnes of oil equivalent (Mtoe). Global energy demand thus grows by more than one-third over the period to 2035, with China, India and the Middle East accounting for 60 percent of the increase, and fossil fuels continue to supply at least 75 percent of total world energy – Figures III-3 and III-4.[73]

Demand increases more rapidly in the Current Policies Scenario, ending nearly 45 percent higher than 2011, equivalent to adding the combined energy demand of the world's three largest consumers today (China, the United States and India). In both cases, energy demand grows most rapidly in this decade and moderates after 2020. Energy demand grows much more slowly in the 450 Scenario, increasing by only 14 percent over the Outlook period, and just 0.3 percent per year after 2020, which, given historical rates of global energy growth, would represent a massive and extremely challenging change in trajectory.

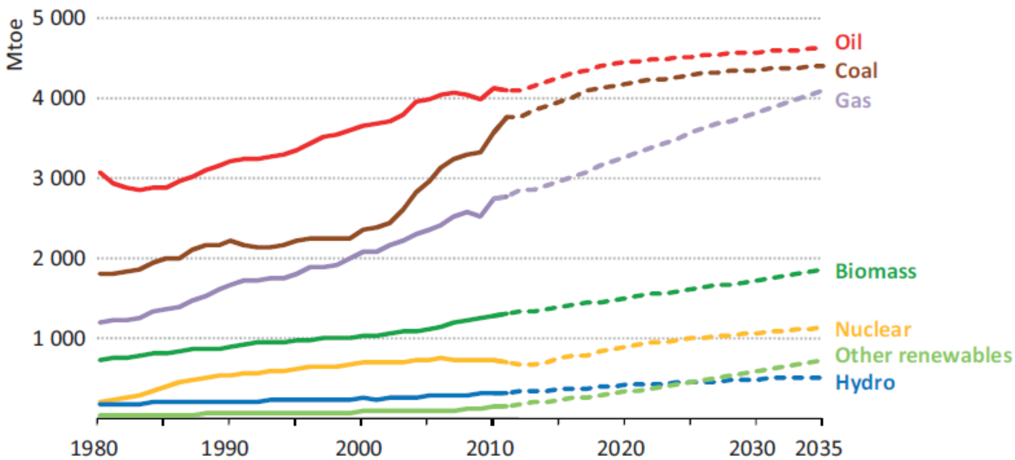
[73]International Energy Agency, op. cit, and Maria van der Hoeven, "Oil and Gas in the Global Energy Mix," presented at the International Oil Summit, Paris, April 4, 2013.

Figure III-3
Energy Demand by Fuel, 2010 and 2035



Source: International Energy Agency.

Figure III-4
World Primary Energy Demand by Fuel in the New Policies Scenario

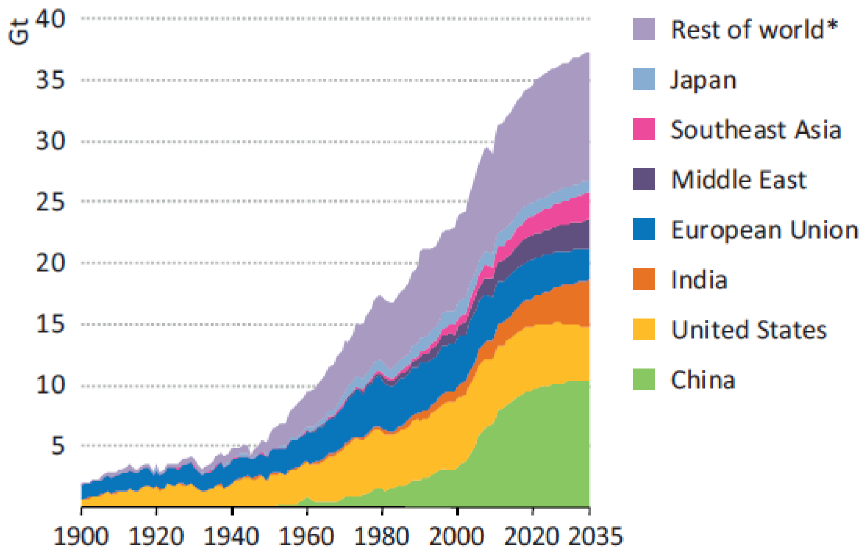


Source: International Energy Agency.

The non-OECD share of global energy demand has increased from 45 percent in 2000 to 57 percent in 2011. This trend continues, reaching around 60 percent in 2020 and around two-thirds in 2035 in each scenario. Compared with *WEO-2012*, global energy demand in 2035 is 0.2 percent lower in the Current Policies Scenario, 1.1 percent higher in the New Policies Scenario, and 0.8 percent higher in the 450 Scenario.

As illustrated in Figure III-5, the geographical distribution of energy-related CO_2 emissions is set to change significantly between now and 2035. All of the growth occurs in developing countries, as emissions across the OECD declines by 16 percent, to 10.2Gt in 2035, due to saturation of energy demand and the effects of policies promoting energy efficiency and decarbonization of the fuel mix. China is expected to remain the largest emitter throughout the projection period. Chinese emissions are 60 percent larger than those of the United States in 2012, but will be more than twice the size of the United States by 2035. Emissions in India are expected to overtake those of the European Union in the mid-2020s and get closer to the levels of the United States in 2035. By the end of the projection period, emissions from both Southeast Asia and the Middle East will be at a similar level to those of the European Union.

Figure III-5
Energy-related CO_2 Emissions by Region in the New Policies Scenario



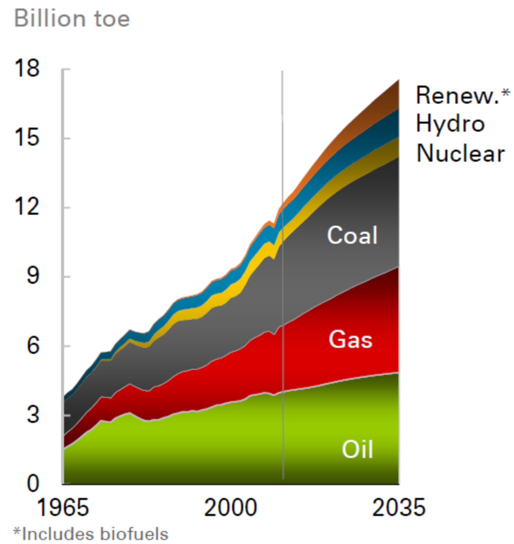
* Rest of world includes international bunkers.
Source: International Energy Agency.

III.B. The BP Forecasts

According to the latest BP forecast, primary energy demand increases by 41 percent between 2012 and 2035, with growth averaging 1.5 percent per annum (p.a.) – Figure III-6. Growth slows, from 2.2 percent p.a. for 2005-15, to 1.7 percent p.a. 2015-25 and just 1.1 percent p.a. in the final decade. Fossil fuels lose share but they are still the dominant form of energy in 2035 with a share of 81 percent, compared to 86 percent in 2012.[74]

[74]*BP Energy Outlook 2035*, BP, January 2014, *bp.com/energyoutlook.*

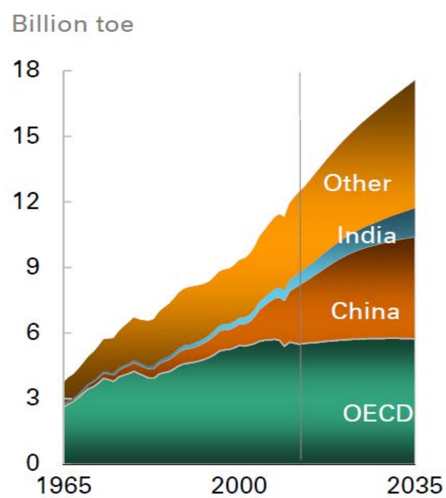
Figure III-6
Global Consumption by Fuel, 1965-2035



Source: *BP Energy Outlook 2035*.

As shown in Figure III-7, there is a clear long-run shift in energy growth from the OECD to the non-OECD. Virtually all (95 percent) of the projected growth is in the non-OECD, with energy consumption growing at 2.3 percent p.a. 2012-35. OECD energy consumption, by contrast, grows at just 0.2 percent p.a. over the whole period and is actually falling from 2030 onwards. China has emerged as the key growth contributor, but by the end of the forecast China's contribution is starting to fade. India's contribution grows, almost matching that of China in the final decade of the forecast.

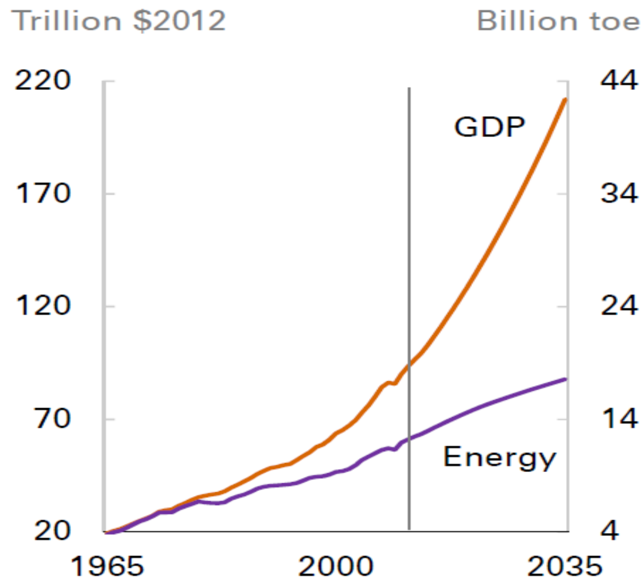
Figure III-7
Global Energy Consumption by Region



Source: *BP Energy Outlook 2035*.

BP forecasts that energy consumption will increase less rapidly than the global economy, with GDP growth averaging 3.5 percent p.a. 2012-35 – Figure III-8. As a result energy intensity, the amount of energy required per unit of GDP, declines by 36 percent (1.9 percent p.a.) between 2012 and 2035. The decline in energy intensity accelerates, and the expected rate of decline post 2020 is more than double the decline rate achieved 2000-2010.

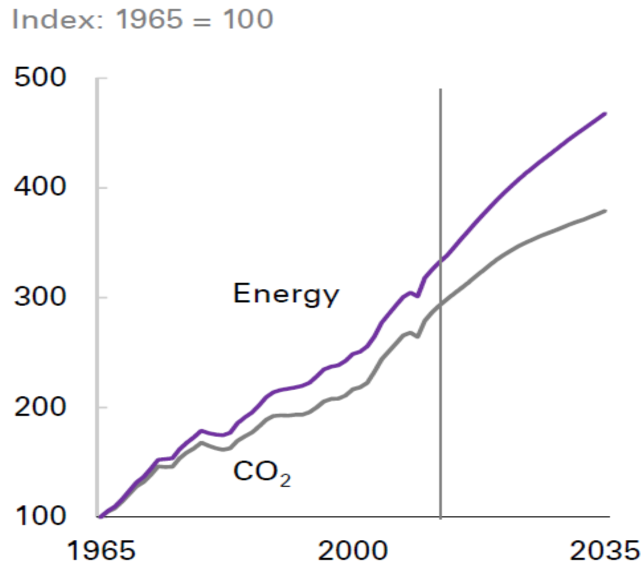
Figure III-8
GDP and Energy



Source: *BP Energy Outlook 2035*.

The biggest challenge in terms of sustainability remains the level of carbon emissions, which continue to grow (1.1 percent p.a.) – slightly slower than energy consumption – Figure III-9.

Figure III-9
Energy and CO_2 Emissions

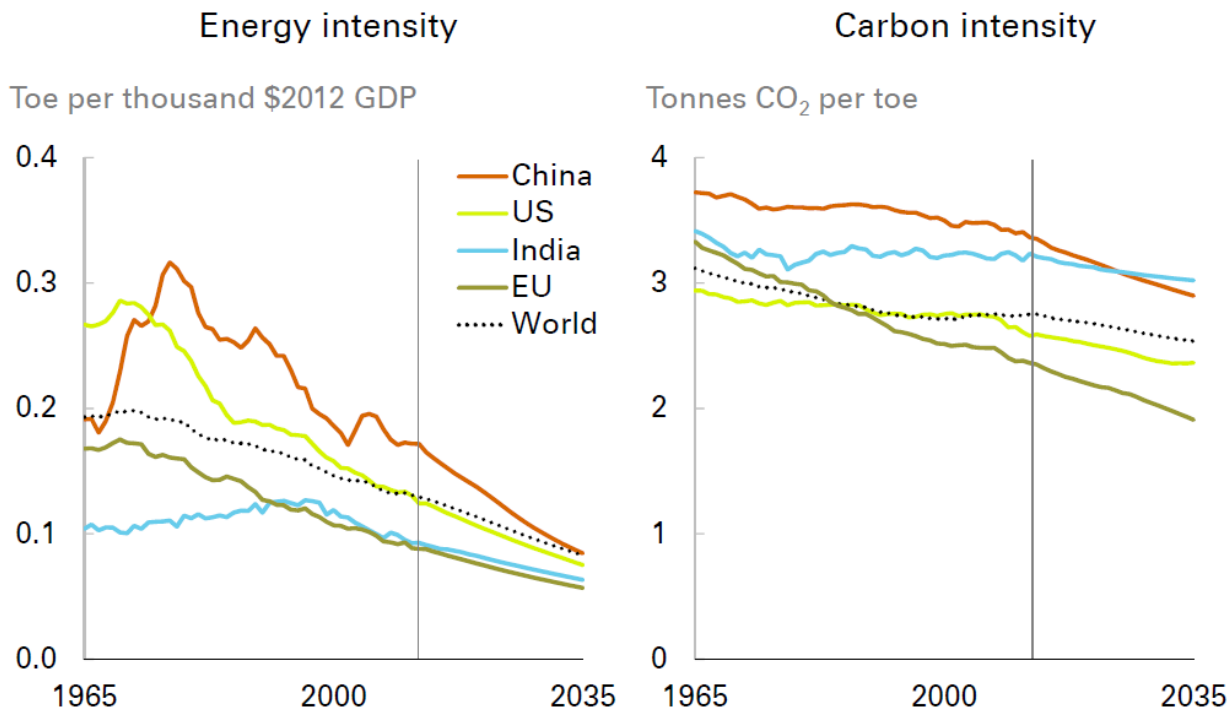


Source: *BP Energy Outlook 2035*.

Given economic growth, CO_2 emissions depend on energy intensity and carbon intensity -- the carbon content of the energy mix (carbon per unit of energy). Global energy intensity is improving rapidly, converging across countries at lower and lower levels. As illustrated in Figure III-10. BP forecasts that it will decline by a further 36 percent by 2035 (-1.9 percent p.a.), with differences across countries the smallest since the Industrial Revolution. Decline and convergence are both the outcome of market forces and global competition, promoting the most efficient use of energy everywhere.

Carbon intensity, in contrast, declines at a slower pace – by eight percent between 2012 and 2035 (-0.3 percent p.a.) – Figure III-10. BP forecasts no apparent convergence, with countries following different, albeit downward trends. Changes in carbon intensity are a function of changes in the fuel mix. In the absence of a price for carbon, the fuel mix is shaped by other factors and the observed decline in carbon intensity, as well as the path followed by individual countries, becomes a by-product of those other factors.

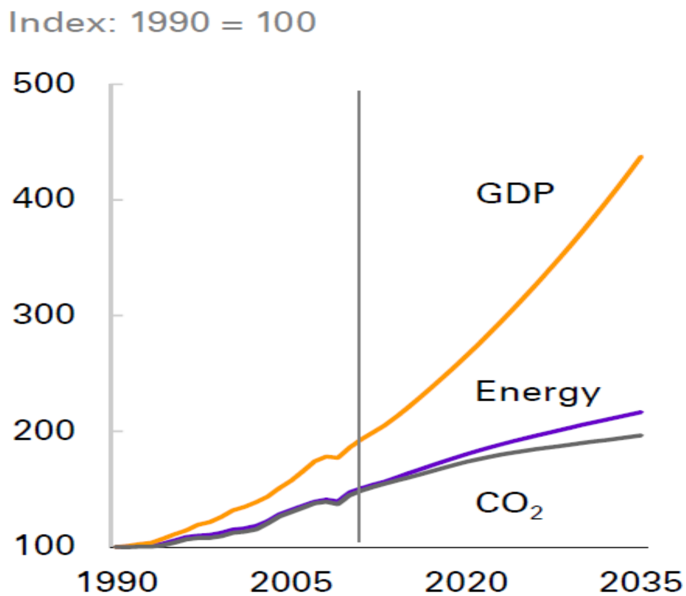
Figure III-10
Energy Intensity of GDP and Carbon Intensity of Energy



Source: *BP Energy Outlook 2035*.

The widening gap between GDP and energy consumption illustrates the impact of declining energy intensity; and the gap between energy and CO_2 emissions reflects changes in carbon intensity, brought about by changes in the fuel mix. Without the projected decline in energy intensity, CO_2 emissions in 2035 would be more than 40 percent higher than BP's forecast, given the projected economic growth. The effect of the expected change in the fuel mix is much smaller – about one fifth as large – though bigger than in the past. More than half of the fuel mix effect comes from the rising share of renewables; most of the remainder comes from changes in the fossil fuel mix, in particular, the substitution of gas for coal. Competition and innovation, guiding the global improvement in energy intensity, are not directing changes in the energy mix toward faster improvements of carbon intensity. The market does not do for carbon intensity what it does for energy intensity because energy is costly, and carbon is not.

Figure III-11
GDP, Energy and Emissions



Source: *BP Energy Outlook 2035*.

III.C. The EIA Forecasts

The latest U.S. Energy Information Administration (EIA) forecast projects that the world's real GDP[75] will increase at an average of 3.5 percent per year from 2010 to 2040 – Table III-1. The most rapid rates of growth are projected for the emerging, non-OECD regions, where combined GDP increases by 4.6 percent per year. In the OECD regions, GDP grows at a much slower rate of 2.1 percent per year over the projection, owing to more mature economies and slow or declining population growth trends. The strong growth in non-OECD GDP drives the fast-paced, large growth in future energy consumption projected for these nations.[76]

[75]Expressed in purchasing power parity (PPP) terms.
[76]U.S. Energy Information Administration, *International Energy Outlook 2013, With Projections to 2040*, July 2013, and U.S. Energy Information Administration, *International Energy Outlook 2014, With Projections to 2040*, September 2014.

Table III-1
World GDP by Region in the EIA Reference Case, 2009-2040
(Purchasing Power Parity, 2005 Dollars)

Region	History 2009	History 2010	Projections 2020	Projections 2025	Projections 2030	Projections 2035	Projections 2040	Average annual percent change, 2010-40
OECD								
OECD Americas	**15,498**	**15,929**	**20,709**	**23,279**	**26,153**	**29,306**	**32,836**	**2.4**
United States[a]	12,758	13,063	16,753	18,769	21,139	23,751	26,670	2.4
Canada	1,165	1,202	1,533	1,716	1,902	2,098	2,303	2.2
Mexico/Chile	1,575	1,664	2,423	2,794	3,113	3,457	3,863	2.8
OECD Europe	**14,262**	**14,618**	**17,681**	**19,752**	**21,775**	**23,972**	**26,304**	**2.0**
OECD Asia	**5,791**	**6,062**	**7,320**	**7,934**	**8,431**	**8,865**	**9,216**	**1.4**
Japan	3,776	3,948	4,448	4,661	4,787	4,858	4,837	0.7
South Korea	1,244	1,323	1,838	2,110	2,345	2,560	2,771	2.5
Australia/NewZealand	771	790	1,034	1,163	1,298	1,448	1,608	2.4
Total OECD	**35,551**	**36,609**	**45,711**	**50,965**	**56,358**	**62,143**	**68,357**	**2.1**
Non-OECD								
Non-OECD Europe and Eurasia	**4,346**	**4,502**	**6,257**	**7,363**	**8,451**	**9,666**	**10,689**	**2.9**
Russia	1,938	2,022	2,741	3,168	3,545	3,954	4,192	2.5
Other	2,408	2,480	3,515	4,196	4,906	5,712	6,496	3.3
Non-OECD Asia	**16,628**	**18,206**	**33,695**	**44,746**	**57,688**	**71,655**	**85,314**	**5.3**
China	8,299	9,167	18,179	24,055	31,431	38,867	44,890	5.4
India	3,364	3,661	6,511	8,919	11,399	14,272	17,580	5.4
Other	4,965	5,379	9,006	11,772	14,858	18,516	22,845	4.9
Middle East	**2,263**	**2,292**	**3,498**	**4,292**	**5,162**	**6,144**	**7,213**	**3.9**
Africa	**3,780**	**3,963**	**6,188**	**7,830**	**9,977**	**12,720**	**16,148**	**4.8**
Central and South America	**4,623**	**4,927**	**6,794**	**8,024**	**9,394**	**10,971**	**12,759**	**3.2**
Brazil	1,833	1,971	2,600	3,069	3,615	4,267	5,015	3.2
Other	2,790	2,955	4,194	4,955	5,779	6,704	7,744	3.3
Total Non-OECD	**31,640**	**33,889**	**56,432**	**72,255**	**90,672**	**111,157**	**132,123**	**4.6**
Total World	**67,192**	**70,498**	**102,142**	**123,220**	**147,030**	**173,300**	**200,479**	**3.5**

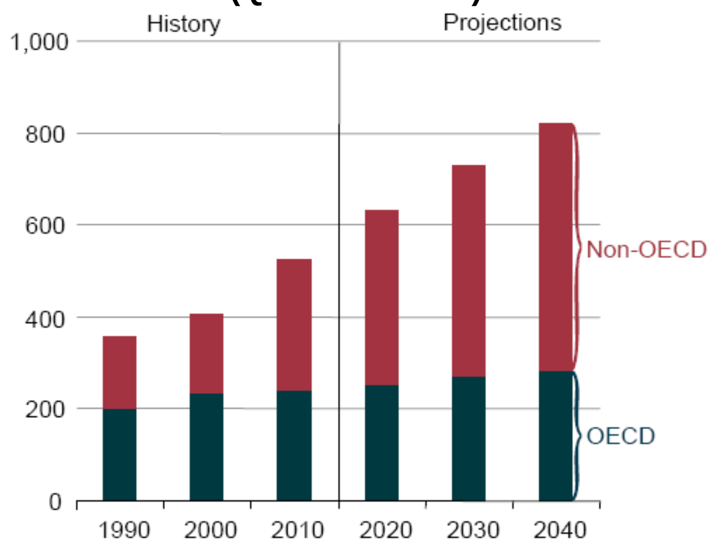
Source: U.S. Energy Information Administration, 2014.

This growth in GDP will be driven by a world energy consumption increase of 56 percent between 2010 and 2040.[77] EIA forecasts that total world energy use will increase from 524 quads in 2010 to 630 quads in 2020, and to 820 quads in 2040 -- Figure III-12.[78] More than 85 percent of the increase in global energy demand from 2010 to 2040 occurs among the developing nations outside the OECD, driven by strong economic growth and expanding populations. In contrast, OECD member countries are, for the most part, already more mature energy consumers, with slower anticipated economic

[77]Ibid.
[78]A quad is a unit of energy equal to 10^{15} (Quadrillion) BTUs.

growth and little or no anticipated population growth. Energy use in non-OECD countries increases by 90 percent; in OECD countries, the increase is 17 percent.[79]

Figure III-12
World Total Energy Consumption, 1990-2040
(Quadrillion Btu)



Source: U.S. Energy Information Administration, *International Energy Outlook 2013*

In the long term, the EIA reference case projects increased world consumption of marketed energy from all fuel sources through 2040 (Figure III-13). EIA forecasts that fossil fuels will continue to supply most of the energy used worldwide. Although liquid fuels -- mostly petroleum-based -- remain the largest source of energy, the liquids share of world marketed energy consumption falls from 34 percent in 2010 to 28 percent in 2040, as projected high world oil prices lead many energy users to switch away from liquid fuels when feasible.[80]

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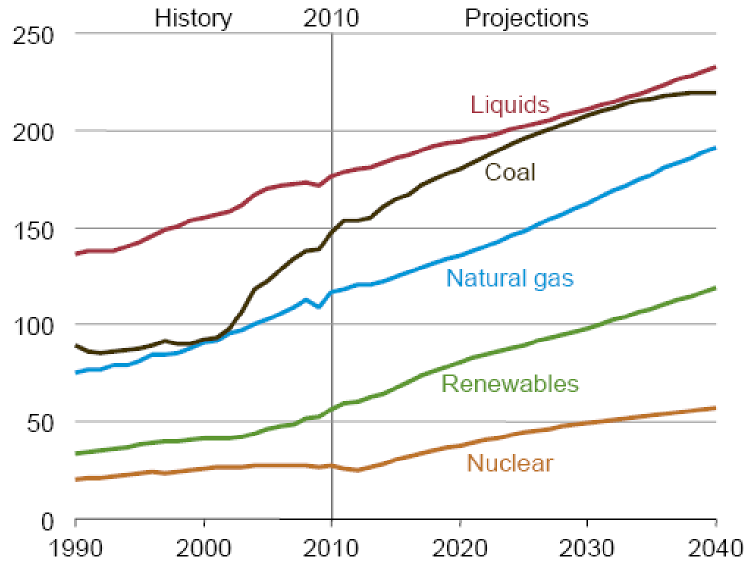
[79]The EIA Reference Case does not incorporate prospective legislation or policies that might affect energy markets.

[80]Also see the discussion in Roger Bezdek, Robert Hirsch and Robert Wendling, *The Impending World Energy Mess*, Toronto, Canada: Apogee Prime Press, 2010.

Figure III-13
World Energy Consumption by Fuel Type, 1990-2040 (Quadrillion Btu)



U.S. Energy Information Administration, 2013.

II.D. Implications of the Forecasts

As illustrated in Figures III-3, III-4, III-6, III-13 and III-14, population and economic growth are the key drivers behind growing demand for energy in all of the forecasts, and fossil fuels continue to supply most of the world's energy in all of the forecasts.[81] In 2040, liquid fuels, natural gas, and coal still supply more than three-fourths of total world energy consumption. World primary energy consumption is forecast to increase by about 40 percent by 2030 and by nearly 60 percent by 2040 – from 524 quads in 2010, to 729 quads in 2030, and to 820 quads in 2040; from about 12 billion tons of oil equivalent (btoe) in 2010, to about 17 btoe in 2030, and about 19 btoe in 2040.[82] Thus, over the next two decades:

- Almost all of the increased energy demand will come from the non-OECD nations.
- Most of the increased demand will be for power generation.
- Fossil fuels will continue to be the world's dominant energy source.
- Non-hydro renewables will continue to supply a very small portion of the world's energy requirements.

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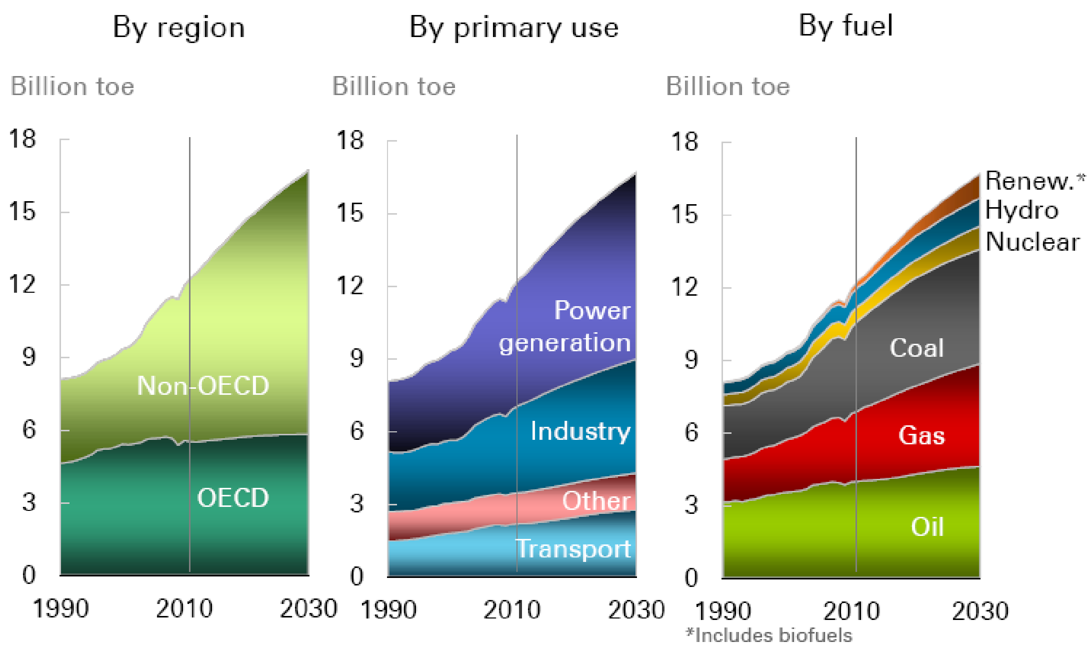
[81]U.S. Energy Information Administration, *International Energy Outlook 2013, With Projections to 2040*, op. cit., and U.S. Energy Information Administration, *International Energy Outlook 2014, With Projections to 2040*, op. cit.
[82]Ibid.

Figure III-14
Growth in Primary Energy Demand



Source: *BP Energy Outlook 2030.*

World primary energy consumption is forecast to increase by 1.6 percent annually, from 2011 to 2030, adding 36 percent to global consumption by 2030. However, the growth rate declines, it is:

- 2.5 percent annually, 2000 – 2010,
- 2.1 percent annually, 2010 – 2020, and
- 1.3 percent annually, 2020 -- 2030.

Almost all (93 percent) of the energy consumption growth is in non-OECD countries. Non-OECD energy consumption in 2030 is 61 percent above the 2011 level, with growth averaging 2.5 percent annually (or 1.5 percent annually per capita), accounting for 65 percent of world consumption -- compared to 53 percent in 2011. OECD energy consumption in 2030 is only six percent higher than in 2011 (0.3 percent annual average growth rate), and will decline in per capita terms to -0.2 percent annually, 2011-2030.[83]

Most of the world's energy growth will be in the power sector: Energy used for power generation increases by 49 percent, 2.1 percent annually, 2011 - 2030, and accounts for 57 percent of global primary energy growth. Primary energy used directly in industry grows by 31 percent (1.4 percent annually), accounting for 25 percent of the

[83]Ibid.

growth of primary energy consumption. World primary energy production growth matches consumption, growing by 1.6 percent annually from 2011 to 2030.

Fossil fuels will dominate world primary energy over the coming decades:

- Oil continues to decline as the world's major energy source, decreasing from nearly 50 percent of world energy in the 1960s to less than 30 percent by 2040.
- Coal overtakes oil as the world's major energy source.
- Natural gas continues to gradually increase its share of the world energy market.
- The share of hydro remains about constant.
- Nuclear power declines slightly in relative importance.
- Non-hydro renewables (including biomass) increase to more than five percent of total world energy by 2040.

In the two years that followed the economic crisis of 2008, global energy demand grew at a faster rate than the global economy. This disrupted the broad trend of delinking global energy intensity over the last several decades.[84] However, preliminary data indicate a 0.6 percent improvement in energy intensity in 2011, indicating that the long-run trend may have been restored. Nevertheless, the main conclusions to be derived from these forecasts are that economic growth will continue to require prodigious amounts of energy and that investment, competition, and innovation are the key to meeting this need.

By 2035 world population is forecast to reach 8.7 billion, and thus an additional 1.7 billion people will require access to energy. World income in 2035 is expected to be more than double the 2012 level in real terms, and low and medium income economies outside the OECD account for over 90 percent of population growth to 2035. Due to their rapid industrialization, urbanization and motorization, they also contribute 70 percent of the global GDP growth and over 90 percent of the global energy demand growth.[85] By 2050 world population is forecast to reach 9.6 billion,[86] and thus an additional 2.7 billion people will require access to energy.

Until recently, it was generally assumed that the world's population would stabilize in mid-century at about 9.5 billion. However, recent research indicates that world population may continue to increase and may reach 12 billion by 2100.[87] Demographers are using new Bayesian probability methods for their projections. These indicate that

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[84]This discontinuity can be attributed to a number of factors: The financial crisis delayed investment in more efficient buildings, vehicles and appliances; emerging economies, where energy intensity is higher, were less affected by the global crisis; energy intensive infrastructure projects were funded by economic stimulus programs; etc. International Energy Agency, op. cit.

[85]*IEA WEO 2013 and BP Energy Outlook 2035*, BP p.l.c., January 2014.

[86]United Nations, *World Population Prospects: The 2012 Revision, Volume I: Comprehensive Tables*, New York, 2013.

[87]Patrick Gerland, et. al., "World Population Stabilization Unlikely This Century," *Science,* published online September 18 2014.

most of the world's anticipated growth is in Africa, where population is projected to quadruple from about 1 billion today to 4 billion by 2100. Demographer Adrian Raftery states that "For the last 20 years, prevailing opinion was that world population would go up to 9 billion and level off in the middle of the century and maybe decline." Population is going to keep growing. We can say that with confidence."[88] He and his colleagues contend that there is a 70 percent probability that world population, now at 7 billion, will not stabilize this century. Countries in sub-Saharan Africa are adding people more rapidly than expected, and according to John Wilmoth, "Fertility levels turn out to be higher today than was expected 10 years ago. There's been a worldwide reduction in fertility, even in sub-Saharan Africa over the last two decades. It's falling, but slower than expected and more slowly than in other countries in Asia and Latin America."[89] The authors conclude that "Contrary to previous literature, world population is unlikely to stop growing this century. There is an 80 percent probability that world population, now 7.2 billion, will increase to between 9.6 and 12.3 billion in 2100. This uncertainty is much smaller than the range from the traditional UN high and low variants. Much of the increase is expected to happen in Africa, in part due to higher fertility and a recent slowdown in the pace of fertility decline."[90]

If world population continues increasing after 2050, even more energy and fossil fuels will be required. This will make it even more difficult than anticipated to reduce CO_2 emissions.

[88]Haya El Nasser, "World Population Growing, Not Slowing," Al Jazeera America, September 18, 2014.
[89]Ibid.
[90]Gerland, et. al., op. cit.

IV. THE PRIMACY OF FOSSIL FUELS

IV.A. Three Industrial Revolutions

The successful development and utilization of fossil fuels facilitated successive industrial revolutions, created the modern world, created our advanced technological society, and enabled the high quality of life currently taken for granted. While this may appear to be a self-obvious truism, the centrality of fossil fuels to everything in society can be appreciated from the recent work of Robert Gordon.[91] Of central importance to our work, Gordon's analysis of past economic growth is anchored by the three industrial revolutions:

- The first (IR #1) centered in 1750-1830 resulted from the inventions of the steam engine and cotton gin through the early railroads and steamships, although much of the impact of railroads on the American economy came later between 1850 and 1900.
- The second industrial revolution (IR #2), 1870-1900, created the inventions that made the biggest difference in the standard of living -- electric light, the internal combustion engine, municipal waterworks and subsidiary and complementary inventions, including elevators, electric machinery and consumer appliances; motor vehicles, and airplane; to highways, suburbs, and supermarkets; sewers, television, air conditioning, and the interstate highway system.
- The third revolution (IR #3) is associated with the invention of the web and Internet around 1995.[92]

Gordon's analysis links periods of slow and rapid growth to the timing of the three IR's that is, IR #1 (steam, railroads) from 1750 to 1830; IR #2 (electricity, internal combustion engine, running water, indoor toilets, communications, entertainment, chemicals, petroleum) from 1870 to 1900; and IR #3 (computers, the web, mobile phones) from 1960 to present. As noted, he finds that IR #2 was more important than the others and was largely responsible for 80 years of relatively rapid productivity growth between 1890 and 1972. Once the spin-off inventions from IR #2 (airplanes, air conditioning, interstate highways) had matured, productivity growth during 1972-96 was much slower than before. In contrast, IR #3 created only a short-lived growth revival between 1996 and 2004. Many of the original and spin-off inventions of IR #2 could happen only once – urbanization, transportation speed, the freedom of females from the drudgery of carrying tons of water per year, and the role of central heating and air conditioning in achieving a year-round constant temperature.[93]

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[91]Robert J. Gordon, "Is U.S. Economic Growth Over? Faltering Innovation Confronts the Six Headwinds," NBER Working Paper No. 18315, August 2012.

[92]However, he notes that electronic mainframe computers began to replace routine and repetitive clerical work as early as 1960. His treatment of IR #3 includes examples of the many electronic labor-saving inventions and convenience services that already were widely available before 1995.

[93]Gordon, op. cit.

A useful organizing principle to understand the pace of growth since 1750 is the sequence of three industrial revolutions.[94] The first (IR #1) with its main inventions between 1750 and 1830 created steam engines, cotton spinning, and railroads. The second (IR #2) was the most important, with its three central inventions of electricity, the internal combustion engine, and running water with indoor plumbing, in the relatively short interval of 1870 to 1900. Both the first two revolutions required about 100 years for their full effects to percolate through the economy. During the two decades 1950-70 the benefits of the IR #2 were still transforming the economy, including air conditioning, home appliances, and the interstate highway system. After 1970 productivity growth slowed markedly, most plausibly because the main ideas of IR #2 had by and large been implemented by then.

Importantly, the computer and Internet revolution (IR #3) began around 1960 and reached its climax in the dot.com era of the late 1990s, but its main impact on productivity has withered away over the past decade. Many of the inventions that replaced tedious and repetitive clerical labor by computers happened a long time ago, in the 1970s and 1980s.[95]

Gordon developed a graph that links together decades of research by economic historians to provide data on real output per capita through the ages.[96] Figure IV-1 displays the record back to the year 1300 and traces the "frontier" of per-capita real GDP for the leading industrial nation – the U.K. or the U.S. The blue line represents the U.K. through 1906 (approximately the year when the U.S. caught up) and the red line the U.S. from then through 2007. British economic historians estimate that the U. K. grew at about 0.2 percent per year for the four centuries through 1700. The graph shows the striking lack of progress; there was almost no economic growth for four centuries and probably for the previous millennium.

Gordon's research, as summarized in this figure, is of potentially profound importance for several reasons. First, it forcefully and poignantly illustrates the critical importance of the industrial revolutions that began in the late 1700s in dramatically improving economic growth rates, productivity, and persons' standards of living and well-being. Second, and much more controversially, it indicates that the trends of the period of 1800 to about 1975 may have been one-time anomalies and that prospects for continued productivity and economic growth may be much less favorable than most analysts anticipate.

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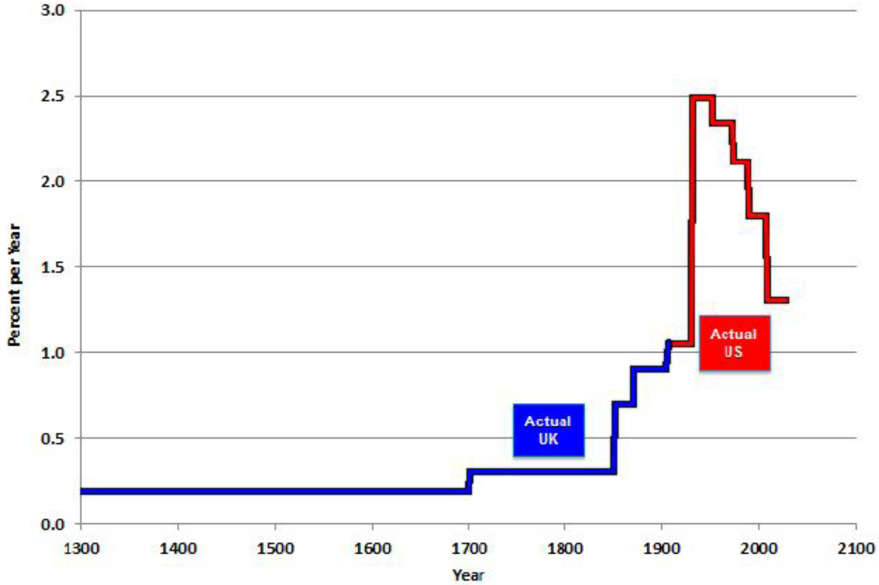
[94] Ibid.

[95] As Gordon notes, "Invention since 2000 has centered on entertainment and communication devices that are smaller, smarter, and more capable, but do not fundamentally change labor productivity or the standard of living in the way that electric light, motor cars, or indoor plumbing changed it."

[96] Gordon, op. cit.

Figure IV-1
Growth in Real Per Capita GDP, 1300 - 2100



Source: Robert J. Gordon, National Bureau of Economic Research, 2012.

IV.B. The Unique, Essential Historical Role of Fossil Fuels

A major implication of Gordon's work is the absolutely essential role in all of the IRs played by fossil fuels – especially coal.[97] Simply stated, without the availability of adequate supplies of accessible, reliable, and affordable fossil fuels none of the industrial and economic progress of the past two centuries would have been possible. This is an indisputable, critical fact that seems to have been insufficiently appreciated by those proposing draconian reductions in CO_2 emissions and fossil fuel utilization.

For example, coal was the essential driving force behind most of the revolutionary technologies Gordon identifies: Steam engines, cotton spinning, railroads, electric light, municipal waterworks and subsidiary and complementary inventions, including elevators, electric machinery and consumer appliances; suburbs and supermarkets; sewers, television, air conditioning, indoor plumbing, etc. Further, coal provides the reliable and inexpensive electricity that powers computers, the web and Internet, social media, mobile devices, high tech manufacturing, and numerous other more recent applications.

It is constructive to compare the growth in per capita GDP shown in Figure IV-1 with the increased use of fossil fuels over roughly the same period. Figure IV-2 shows the enormous increase in world energy consumption that has taken place over the last 200 years. This rise in energy consumption is almost entirely from increased fossil fuel use.[98]

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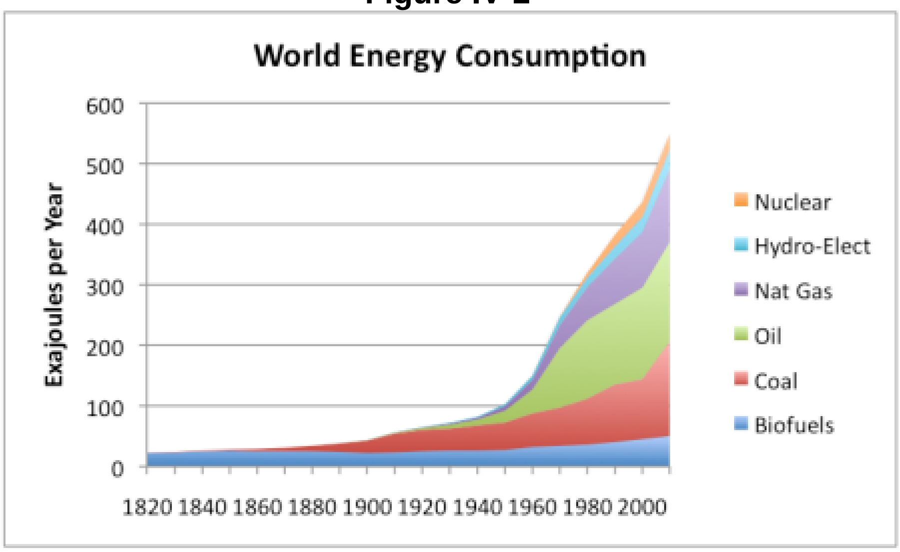
[97]See, for example, Robert U. Ayres and Benjamin Warr, *The Economic Growth Engine: How Energy and Work Drive Material Prosperity*, Northampton, MA: Edward Elgar, 2009.

[98]Gail Tverberg," World Energy Consumption Since 1820," www.ourfiniteworld.com, March 12, 2012.

Figure IV-3 shows the rapid increase in world per capita annual primary energy consumption by fuel over the past two centuries. Once again, it is seen that almost all of the entire increase (90 percent) in per capita primary energy consumption resulted from increased fossil fuel utilization – the increased use of hydro offset the decreased use of wood.[99] Figure IV-4 shows the growth of world population, per capita energy consumption, and total energy use over the past two centuries, compared to 2010 levels. Figures IV-3 and IV-4 illustrate that, over the period 1850-2010:

- World population increased 5.5-fold.
- Total world energy consumption increased nearly 50-fold.
- World per capita energy consumption increased nearly 9-fold.
- Nearly all of the world's increase in energy consumption was comprised of fossil fuels.

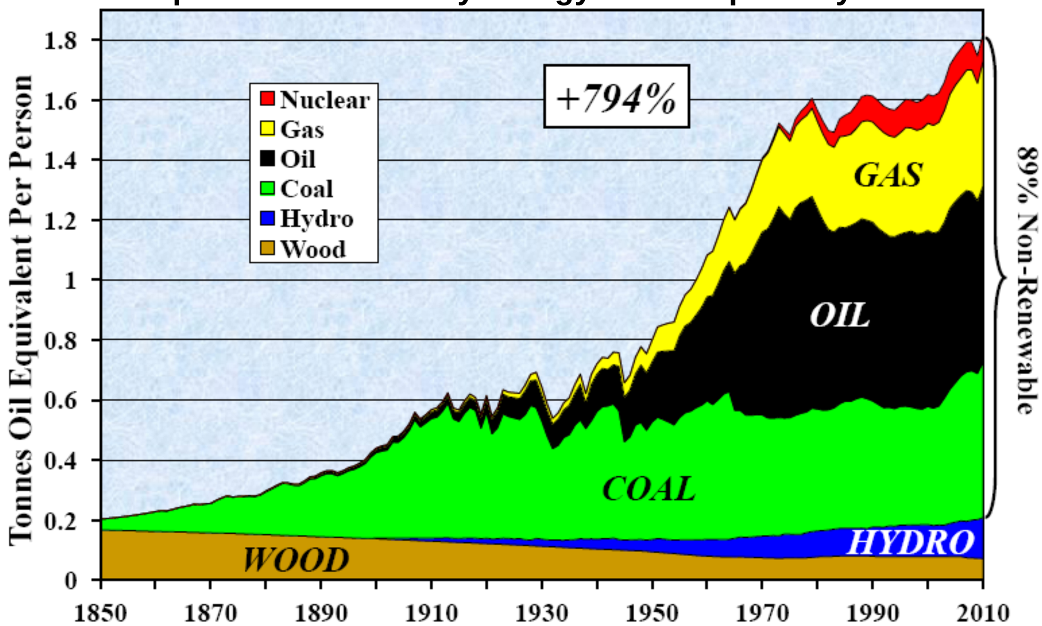
Figure IV-2



Source: Gail Tverberg," World Energy Consumption Since 1820"

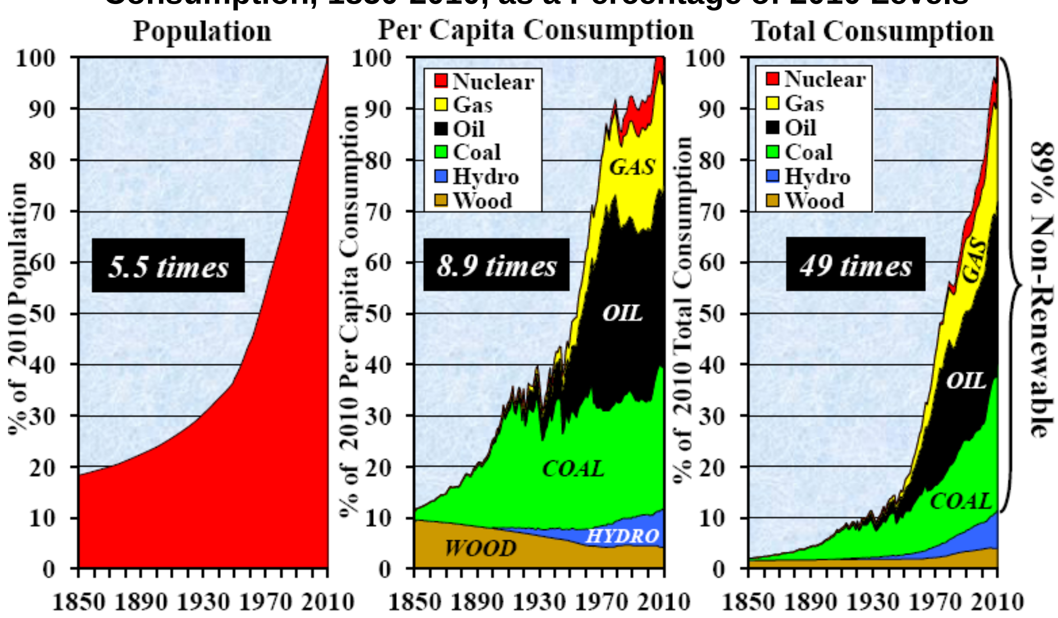
[99]J. David Hughes, "The Energy Sustainability Dilemma: Powering the Future in a Finite World," presented at Cornell University, Ithaca, New York, May 2, 2012.

Figure IV-3
World Per Capita Annual Primary Energy Consumption by Fuel 1850-2010



Source: Hughes, "The Energy Sustainability Dilemma: Powering the Future in a Finite World,"

Figure IV-4
World Population, Per Capita and Total Energy Consumption, 1850-2010, as a Percentage of 2010 Levels



Source: Hughes, "The Energy Sustainability Dilemma: Powering the Future in a Finite World," Comparison of Figure IV-1 with Figures IV-2 through IV-4 forcefully illustrates a central fact: World economic and technological progress over the past two centuries would simply have been impossible without the successful use of vast quantities of fossil fuels. Thus, "For most of its existence, mankind's well-being was dictated by disease, the elements and other natural factors, and the occasional conflict. Virtually everything required -- food, fuel, clothing, medicine, transport, mechanical power -- was the direct or indirect product of living nature."[100] Subsequently, mankind developed technologies to augment or displace these resources, food supplies and nutrition improved, and population, living standards, and human well-being advanced."[101] The IRs discussed above accelerated these trends: Growth became the norm, population increased rapidly, and productivity and living standards improved dramatically. Technologies dependent on cheap, abundant, reliable fossil fuels such as coal enabled these improving trends. Nothing can be made, transported, or used without energy, and fossil fuels provide 80 percent of mankind's energy and 60 percent of its food and clothing.[102]

Key to these developments was that these technologies accelerated the generation of ideas that facilitated even better technologies through, among other things, greater accumulation of human capital (via greater populations, time-expanding illumination, and time-saving machinery) and more rapid exchange of ideas and knowledge (via greater and faster trade and communications). From 1750 to 2009, global life expectancy more than doubled, from 26 years to 69 years; global population increased 8-fold, from 760 million to 6.8 billion; and incomes increased 11-fold, from $640 to $7,300.[103] Living standards advanced rapidly over the past two centuries and, concurrently, as shown in Figure IV-5, carbon dioxide emissions increased 2,800-fold, from about 3 million metric tons to 8.4 billion metric tons.

Figure IV-6 illustrates that in the U.S. from 1900 to 2009 population quadrupled, U.S. life expectancy increased from 47 years to 78 years, and incomes (denoted "affluence") grew 7.5-fold while carbon dioxide emissions increased 8.5-fold. Thanks largely to the extensive utilization of fossil fuels, "Americans currently have more creature comforts, they work fewer hours in their lifetimes, their work is physically less demanding, they devote more time to acquiring a better education, they have more options to select a livelihood and live a more fulfilling life, they have greater economic and social freedom, and they have more leisure time and greater ability to enjoy it."[104] And these trends are evident not just in the United States but, for the most part, elsewhere as well.[105]

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[100]Indur M. Goklany, "Humanity Unbound How Fossil Fuels Saved Humanity from Nature and Nature from Humanity," *Policy Analysis*, No. 715, December 20, 2012, pp. 1-33.

[101]Ibid.

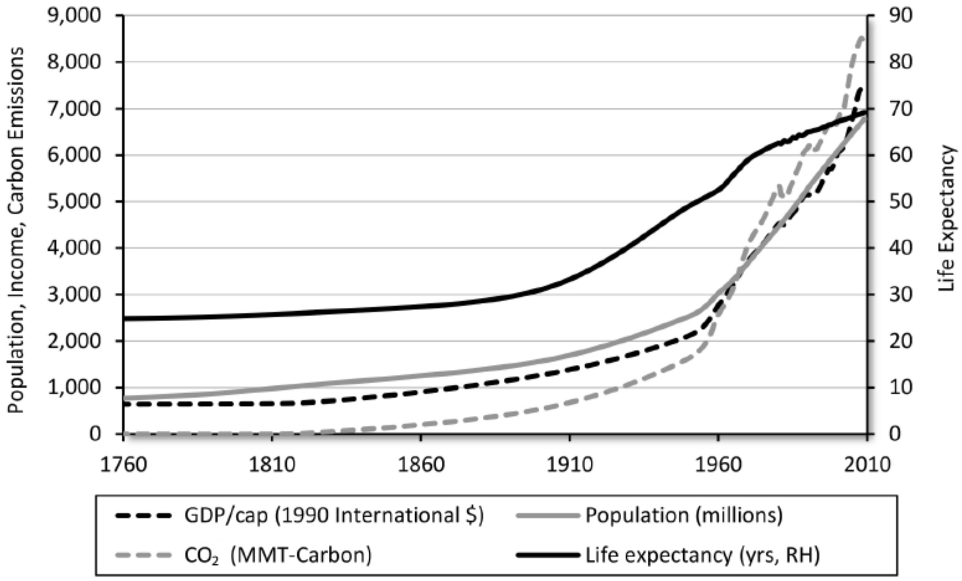
[102]Thus, "Absent fossil fuels, global cropland would have to increase by 150 percent to meet current food demand, but conversion of habitat to cropland is already the greatest threat to biodiversity. By lowering humanity's reliance on living nature, fossil fuels not only saved humanity from nature's whims, but nature from humanity's demands." See Ibid.

[103]Ibid.

[104]Ibid.

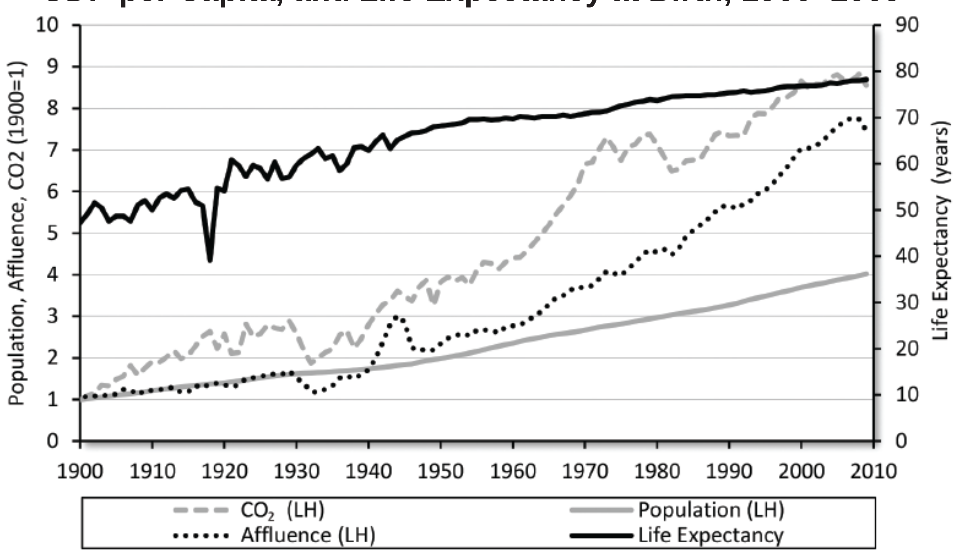
[105]Indur M. Goklany, *The Improving State of the World: Why We're Living Longer, Healthier, More Comfortable Lives on a Cleaner Planet*, Washington, D.C.: Cato Institute, 2007.

Figure IV-5
Global Progress, 1760-2009 -- as Indicated by Trends in World Population, GDP Per Capita, Life Expectancy, and CO_2 Emissions From Fossil Fuels



Source: Goklany, 2012.

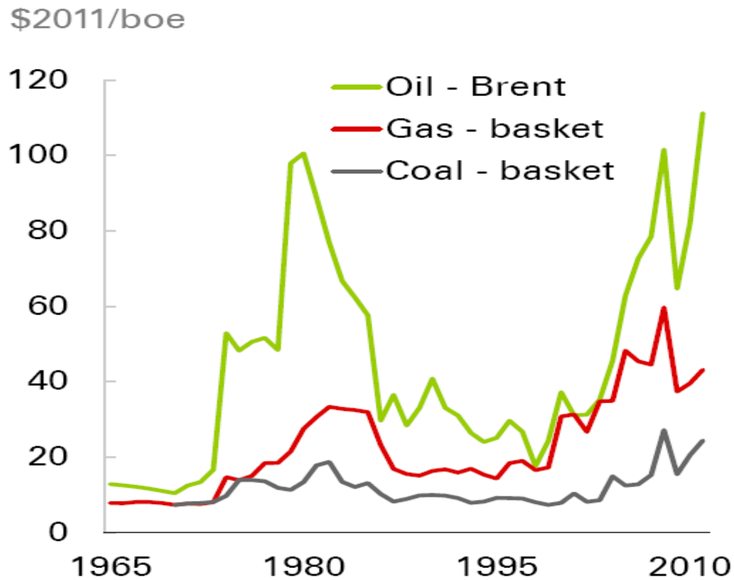
Figure IV-6
U.S. Carbon Dioxide Emissions, Population, GDP per Capita, and Life Expectancy at Birth, 1900–2009



Source: Goklany, 2012.

Figure IV-7 shows fossil fuel prices over the past five decades. It illustrates that oil has been, by far, the most expensive and price-volatile, followed by natural gas. Coal has been the least expensive and least price-volatile.

Figure IV-7
Historical Fossil Fuel Prices



Source: *BP Energy Outlook 2030*

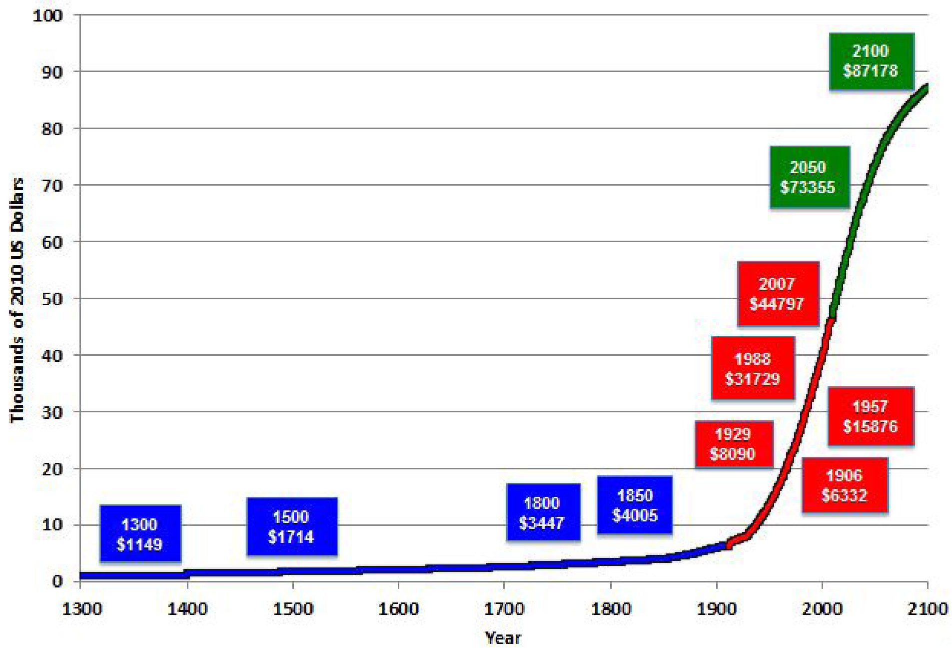
IV.C. The Essential Future Role of Fossil Fuels

Robert Gordon combined the historical U.K./U.S. growth record with a hypothetical, rather pessimistic forecast and overlaid on the historical record a smoothly curved line showing growth steadily increasing to the mid-20th century and then declining back to where it started, 0.2 percent per year by the end of the 21st century. He then translated these growth rates into the corresponding levels of per-capita income in 2005 dollars, which for the U.S. in 2007 was $44,800 – Figure II-8. The implied level for the U.K. in 1300 was about $1,150 in current prices, and it took five centuries for that level to triple to $3,450 in 1800 and more than a century almost to double to $6,350 in 1906, the transition year from the U. K. to the U.S. data. Even with the steady slowdown in the growth rate after 1988, the forecast level implied by the green line in Figure IV-8 for the year 2100 is $87,000, almost double the actual level achieved in 2007.[106]

Notably, even with Gordon's pessimistic assumption that the economic growth rate will decrease to 0.2 percent annually by 2100, the green forecast line in Figure II-8 rises rapidly. Further, under any reasonable assumptions, even modest forecast economic growth will require a very significant increase in energy supplies over the coming century. World economic growth over the past two centuries was powered almost exclusively by fossil fuels. What energy sources are forecast to power future world economic growth? That is, the question is: *What energy sources are required to enable the world to continue to (even modestly) increase income, wealth, productivity, and standards of living?*

[106]Gordon, op. cit.

Figure IV-8
Actual and Hypothetical Levels of GDP Per Capita, 1300 - 2100



Source: Robert J. Gordon, National Bureau of Economic Research, 2012.

According to all major forecasts available, fossil fuels will remain the principal sources of energy worldwide for the foreseeable future and will continue to supply 75 - 80 percent of world energy. Demand for oil, natural gas, and coal will increase substantially in both absolute and percentage terms over the next several decades. Assuring continued world economic growth, increased per capita income, and rising living standards requires this greatly increased use of fossil fuels.

The International Energy Agency (IEA) finds that fossil fuels will continue to meet the vast majority of the world's energy needs over the next two decades. These fuels, which represented 81 percent of the primary fuel mix in 2010, remain the dominant source of energy through 2035 in all of the IEA scenarios.[107]

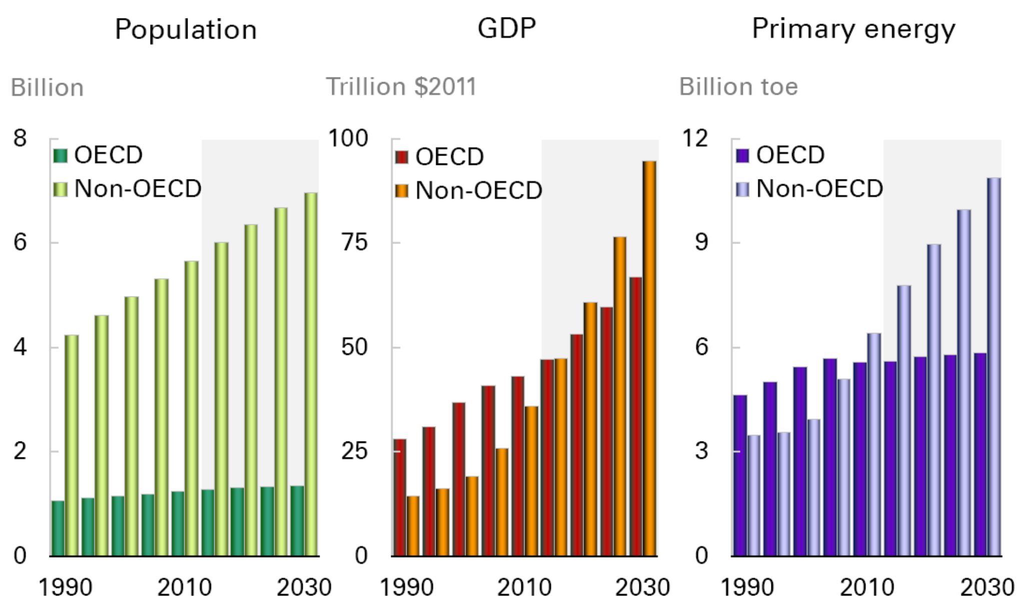
Indeed, greater utilization of fossil fuels may be required than is currently forecast. For example, the IEA notes that, even with the anticipated increase in economic growth and fossil fuel utilization, in 2030 nearly one billion people will be without electricity and 2.6 billion people will still be without clean cooking facilities.[108]

As shown in Figure IV-9, population and income growth are the key drivers behind growing demand for energy. By 2030 world population is forecast to reach 8.3 billion, and thus an additional 1.3 billion people will require access to energy. World income in 2030 is expected to be about double the 2011 level in real terms, and low and medium

[107]International Energy Agency, *World Energy Outlook*, Paris, November 2012.
[108]Ibid.

income economies outside the OECD account for over 90 percent of population growth to 2030. Due to their rapid industrialization, urbanization and motorization, they also contribute 70 percent of the global GDP growth and over 90 percent of the global energy demand growth.[109]

Figure IV-9
Forecast of World Population, GDP, and Energy Growth Through 2030



Source: *BP Energy Outlook 2030*

Similarly, fossil fuels continue to supply most of the world's energy throughout all of BP's forecasts.[110] In 2035, liquid fuels, natural gas, and coal still supply more than three-fourths of total world energy consumption, as was shown in Figure III-6. Further, Fossil fuels will continue to be the world's dominant energy source, and non-hydro renewables will continue to supply a very small portion of the world's energy requirements.

Figure IV-10 shows the forecast of world primary energy shares over the coming decades. It illustrates that:

- Oil continues to decline as the world's major energy source, decreasing from nearly 50 percent of world energy in the 1960s to less than 30 percent by 2030.
- Coal overtakes oil as the world's major energy source.
- Natural gas continues to gradually increase its share of the world energy market.

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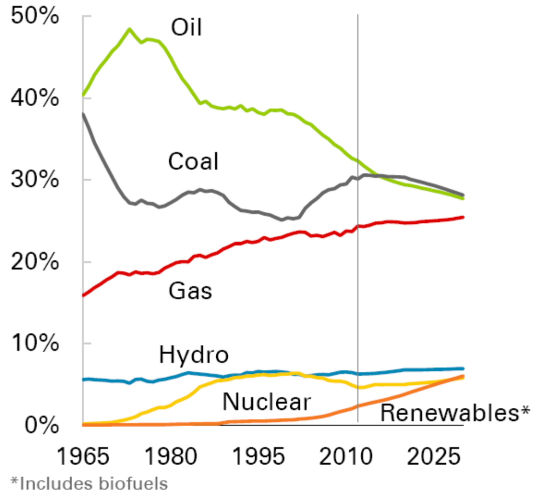
[109] *BP Energy Outlook 2030*, BP p.l.c., January 2013.
[110] *BP Energy Outlook 2035*, BP, January 2014, bp.com/energyoutlook.

- The share of hydro remains about constant.
- Nuclear power declines slightly in relative importance.
- Non-hydro renewables (including biomass) increase to about five percent of total world energy by 2030.

Figure IV-10
Shares of World Primary Energy



Source: *BP Energy Outlook 2030*

As was shown in Figure III-8, energy consumption grows less rapidly than the global economy, and, as a result energy intensity declines by 36 percent between 2012 and 2035. [111] Nevertheless, the main conclusion to be derived from these forecasts are that economic growth will continue to require prodigious amounts of energy.

As was shown in Table III-1, EIA projects that the world's real GDP[112] will increase at an average of 3.6 percent per year from 2010 to 2040. [113] This growth in GDP will be driven by a world energy consumption increase of 56 percent between 2010 and 2040.[114] EIA forecasts that total world energy use will increase from 524 quads in 2010 to 630 quads in 2020, and to 820 quads in 2040 -- Figure III-12.

In the long term, the EIA reference case projects increased world consumption of marketed energy from all fuel sources through 2040 (Figure III-13). EIA forecasts that fossil fuels will continue to supply most of the energy used worldwide. Once again, it must be emphasized that according to all major forecasts available, fossil fuels will remain the principal sources of energy worldwide for the foreseeable future and will continue to

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[111] *BP Energy Outlook 2035*, op. cit.

[112] Expressed in purchasing power parity (PPP) terms.
[113] U.S. Energy Information Administration, *International Energy Outlook 2013, With Projections to 2040*, July 2013.
[114] Ibid.

supply 75 - 80 percent of world energy, and demand for oil, natural gas, and coal will increase substantially in both absolute and percentage terms over the next several decades.

IV.D. Fossil Fuels, CO_2, and World GDP

Fossil fuels have thus played a critical role in the development of the world economy over the past two centuries, and will continue to play a critical role in the future.[115] This was summarized in Figure IV-5, which illustrates the relationship between GDP per capita and the CO_2 emissions resulting from fossil fuel utilization.

There may be an imperfect link between fossil fuel consumption and GDP, marginal benefits may differ from average benefits, and not all energy is fossil-based. Nevertheless:

- As Vaclav Smil states: "The most fundamental attribute of modern society is simply this: Ours is a high energy civilization based largely on combustion of fossil fuels."[116]
- As Robert Ayres concludes: "The rather standard assumption that economic growth is independent of energy availability must be discarded absolutely. It is not tenable. It implies, wrongly, that energy-related emissions (GHGs) can be reduced or eliminated without consequences for growth."[117]
- As James Brown, et al. conclude: "The bottom line is that an enormous increase in energy supply will be required to meet the demands of projected population growth and lift the developing world out of poverty without jeopardizing current standards of living in the most developed countries."[118]
- As David Stern finds, "The theoretical and empirical evidence indicates that energy use and output are tightly coupled, with energy availability playing a key role in enabling growth. Energy is important for growth because production is a function of capital, labor, and energy, not just the former two or just the latter as mainstream growth models or some biophysical production models taken literally would indicate."[119]

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[115]Not all of future world energy will be derived from fossil fuels, but these fuels will continue to provide 75-80 percent of the world's energy for the foreseeable future.

[116]Vaclav Smil, *Energy at the Crossroads: Global Perspectives and Uncertainties*, MIT Press, 2005.

[117]Robert U. Ayres, Jeroen C.J.M. van don Bergh, Dietmar Lindenberger, and Benjamin Warr, "The Underestimated Contribution of Energy to Economic Growth," INSEAD, Fontainebleau, France, 2013.

[118]James H. Brown, William R. Burnside, Ana D. Davidson, John P. DeLong, William C. Dunn, Marcus J. Hamilton, Jeffrey C. Nekola, Jordan G. Okie, Norman Mercado-Silva, William H. Woodruff, and Wenyun Zuo, "Energetic Limits to Economic Growth," *BioScience*, January 2011, Vol. 61, No. 1.

[119]David I. Stern," The Role of Energy in Economic Growth," The United States Association for Energy Economics and the International Association for Energy Economics, USAEE-IAEE WP 10-055, November 2010.

- And Robert Ayres and Benjamin Warr find that economic growth in the past has been driven primarily not by "technological progress" in some general and undefined sense, but specifically by the availability of ever cheaper energy – and useful work – from coal, petroleum, or gas."[120]

Gail Tverberg notes that historical estimates of energy consumption, population, and GDP are available for many years, and she also found a close connection between energy growth, population growth, and economic growth.**[121]** She utilized the population and GDP estimates of Angus Maddison and the energy estimates of Vaclav Smil, BP, EIA, and other sources to estimate average annual growth rates for various historical periods – Figure IV-11. Using these data, she explored the implications of reducing fossil fuel use by 80 percent by 2050 and rapidly ramping up renewables at the same time – an unrealistic, but widely advocated goal.[122] The question she posed is "If we did this, what would such a change mean for GDP, based on historical energy and GDP relationships back to 1820?"[123]

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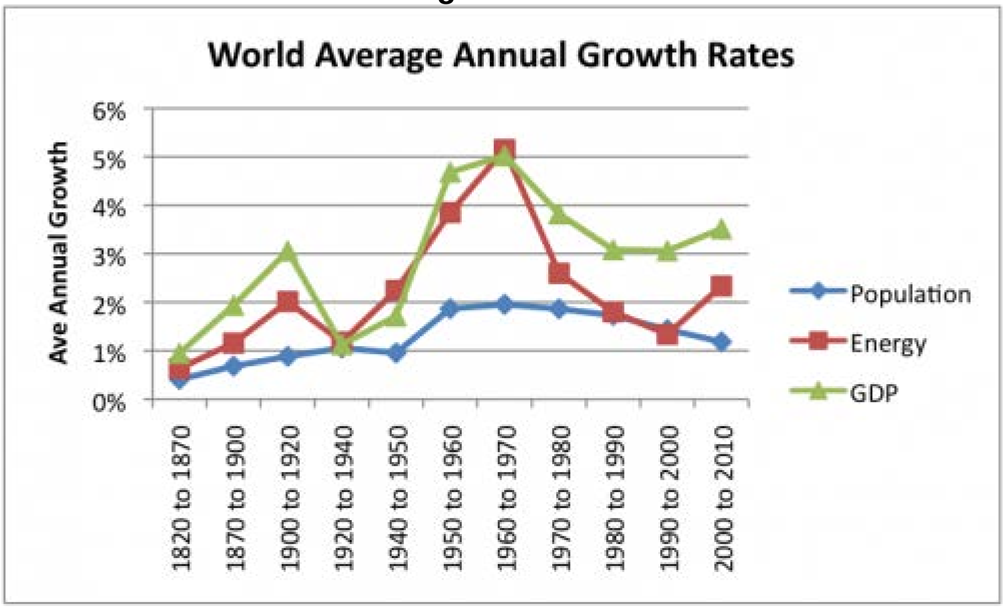
[120]Robert U. Ayres and Benjamin Warr, *The Economic Growth Engine: How Energy and Work Drive Material Prosperity*, Northampton, MA: Edward Elgar. 2009.

[121]Gail Tverberg, "An Energy/GDP Forecast to 2050," http://www.resilience.org/stories/2012-08-14/energygdp-forecast-2050.

[122]The idea of reducing world fossil fuel use 80 percent by 2050 may be unrealistic, but it is a widely advocated goal. See, for example: European Commission, "Roadmap For Moving to a Low-Carbon Economy in 2050," Brussels, March 2011; Jane C. S. Long and Jeffery Greenblatt, "The 80% Solution: Radical Carbon Emission Cuts for California," *Issues in Science and Technology*, September 2012; U.S. National Academies of Science, *Transitions to Alternative Vehicles and Fuels*, Washington, D.C., National Academies Press, 2013; World Energy Council, "Goal of Fossil Fuel Independence by 2050," 2013, www.worldenergy.org/wp-content/uploads/2013/09/ Pack-Leaders-goals-A4.pdf. Also see the discussion here in Section VI.C.

[123]Tverberg, op. cit.

Figure IV-11



Source: Tverberg, 2012

She utilized regression analysis to create what she termed a "best-case" estimate of future GDP if a decrease in energy supply of the magnitude hypothesized were to take place. She considered it a best-case scenario because it assumes that the patterns observed on the up-slope of the trends will continue on the down-slope. For example, it assumes that financial systems will continue to operate as currently, international trade will continue as in the past, and that there will not be major problems with overthrown governments or interruptions to electrical power. It also assumes that the world will continue to transition to a service economy, and that there will be continued growth in energy efficiency. Her results are sobering. Specifically, based on her regression analysis she found that, with the assumptions made:[124]

- World per capita energy consumption in 2050 would be about equal to world per capita energy consumption in 1905.
- World economic growth would average a negative 0.59 percent per year between 2012 and 2050, meaning that the world would be more or less in perpetual recession through 2050. Given past relationships, this would be especially the case for Europe and the U.S.
- Per capita GDP would decline by 42 percent for the world between 2010 and 2050, on average.
- The decrease in per capita GDP would likely be greater in higher income countries, such as the U.S. and Europe, because a more equitable sharing of resources between rich and poor nations would be needed, if the poor nations are to have enough of the basics.

[124] Ibid.

Since, as noted, these are optimistic best case estimates, it is likely that fossil fuel reductions of this magnitude by 2050 would more likely result in decreases in world per capita GDP in the range of 50 – 70 percent, or more – see Section VI-C. As Tverberg notes, "The issue of whether we can really continue transitioning to a *service* economy when much less fuel in total is available is also debatable. If people are poorer, they will cut back on discretionary items. Many *goods* are necessities: Food, clothing, basic transportation. *Services* tend to be more optional -- getting one's hair cut more frequently, attending additional years at a university, or sending grandma to an Assisted Living Center. So the direction for the future may be toward a mix that includes fewer, rather than more, services, and so will be more energy intensive."[125]

Further, she asks "If our per capita energy consumption drops to the level it was in 1905, can we realistically expect to have robust international trade, and will other systems hold together? While it is easy to make estimates that make the transition sound easy, when a person looks at the historical data, making the transition to using less fuel looks quite difficult, even in a best-case scenario." She concludes that such a worldwide reduction in fossil fuels is "very unlikely."[126]

Using similar data, Robert Zubrin analyzed the relationship between global GDP per capita and carbon use from 1800 through 2010.[127] He found that the relationship is generally linear, with GDP per capita and carbon use both increasing by a factor of ten between 1910 and 2010. What is even more important, however, is the fact that the carbon-use benefits identified are enormous. Zubrin notes that just in the past 55 years -- well within living memory -- in line with a fourfold increase in carbon use, the average global GDP per capita has quadrupled. Accordingly, "That is an economic miracle that has lifted billions of people out of hopeless poverty -- and not just in the Third World."[128]

To assess the economic value of fossil fuels in dollar terms, Zubrin compared absolute GDP to carbon utilization -- Figure IV-12. This illustrates that "The relationship between GDP and carbon utilization is not merely linear, but is more nearly quadratic, with total economic output rising as roughly the square of carbon use."[129] For example, Zubrin estimates that since 1975, carbon use has doubled, in conjunction with a quadrupling of global GDP. Further, taking the ratio of current global GDP to carbon use

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[125]Ibid.

[126]Ibid. For an illustration of the difficulties of implementing even minimally restrictive carbon policies, see Roger H. Bezdek, "Carbon Policy Around the Globe: Degrees of Disaster," presented at The Energy Council 2013 Global Energy and Environmental Issues Conference, Lake Louise, Alberta, Canada, December 2013; Roger H. Bezdek, "The Failure of Global Carbon Policies," *American Coal*, issue 1, 2014, pp. 50-54; and Roger H. Bezdek, "Carbon Follies: The EU's ETS Example," *World Oil*, June 2014, p. 23.

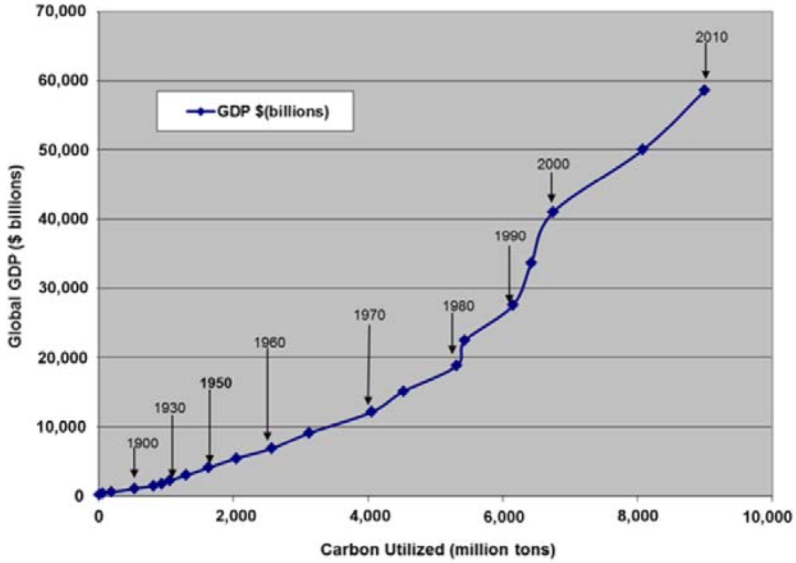
[127]Robert Zubrin, "The Cost of Carbon Denial," *National Review*, July 31, 2013.

[128]Zubrin concludes: "To claim that this came at a comparable "social cost," one would have to show that there has been a climatic catastrophe. Has there? How much better was the weather in the 1950s than it is today? If you don't know, there are plenty of people who were around then whom you can ask. But I'll save you the trouble. The answer is: Not at all. So there was no climatic social cost to the carbon-driven miracle of the 20th century, but there would have been economic cost of genocidal dimensions had carbon deniers been around and able to prevent it." Ibid.

[129]Zubrin, ibid.

and dividing it out indicates that, at present, each ton of carbon used produces about $6,700 of global GDP.[130]

Figure IV-12
Global GDP vs. Carbon Utilization, 1800 - 2010
(2010 Dollars)



Source: Zubrin, 2013.

Zubrin thus estimates that each ton of carbon denied to the world economy destroys about $6,700 worth of wealth, and: "That is the difference between life and death for a Third World family. Seven tons denied corresponds to a loss of $47,000, or a good American job. Since 2007, the combination of high oil prices and a depressed economy has reduced the United States' use of carbon in the form of oil by about 130 million tons per year. At a rate of $6,700 per ton, this corresponds to a GDP loss of $870 billion, equivalent to losing 8.7 million jobs, at $100,000 per year each. Were we to implement the program of the Kyoto treaty, and constrict global carbon use to 1990 levels, we would cut global GDP by $30 trillion per year, destroying an amount of wealth equal to the livelihood of half of the world's population. Such are the costs of carbon denial."[131]

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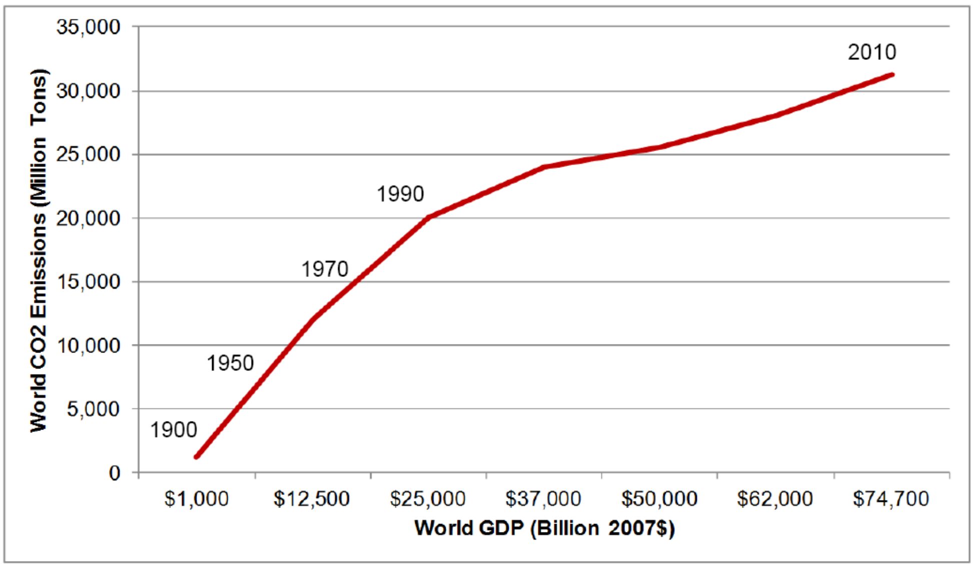
[130]Specifically, Zubrin used the ratio of a recent estimate of global GDP ($60 trillion) to carbon use (9 billion tons) to derive the estimate of about $6,700. Ibid.
[131]Ibid.

Proposals for drastically reducing GHG emissions essentially ignore the critical issue of the relative benefits and costs of CO_2 emissions. Here we assess the estimated costs of CO_2 emissions compared to the benefits derived from the fossil fuels from which these emissions derive. That is, we wish to compare the potential costs of CO_2 emissions with the potential benefits of CO_2 emissions. Estimates of the Social Cost of Carbon (SCC) were derived by the U.S. Government Interagency Working Group (IWG).[132] Accordingly, to conform to IWG conventions we use CO_2 emissions rather than carbon emissions,[133] and we utilize EIA and IEA economic data normalized to 2007 dollars to be consistent with the base year dollars used by the IWG in developing its SCC estimates. The relationship between world GDP and CO_2 emissions over the past century is illustrated in Figure IV-13. This figure shows a similar strong relationship between world GDP and the CO_2 emissions from fossil fuels as indicated in Figures III-8 through III-11.

Figure IV-13
Relationship Between World GDP and CO_2 Emissions



Source: U.S. Energy Information Administration, International Energy Agency, U.S. Bureau of Economic Analysis, and Management Information Services, Inc.

[132]The SCC is an estimate of the monetized damages associated with an incremental increase in carbon (or CO_2) emissions in a given year. That is, it is the increase in aggregate income that would make society just as well off as a one unit decrease in carbon emissions in a particular year. It includes (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change. See Interagency Working Group on Social Cost of Carbon, United States Government, "Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866," May 2013; Interagency Working Group on Social Cost of Carbon, United States Government, "Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866," February 2010; and Charles Griffiths, "The Social Cost of Carbon for Regulatory Impact Analyses, the National Center for Environmental Economics, February 17, 2011.
[133]A ton of CO_2 contains 0.2727 tons of carbon.

Figure IV-13 shows that in 2010, expressed in 2007 dollars, a ton of CO_2 resulting from fossil fuel utilization “created” about $2,400 in world GDP. This is a reasonable and defensible estimate of the indirect benefit of CO_2 – indirect because it is the result of the energy produced by the fossil fuels from which the CO_2 derives. It thus does not include the direct benefits of CO_2 that result from increased plant growth and enhanced agricultural productivity.[134]

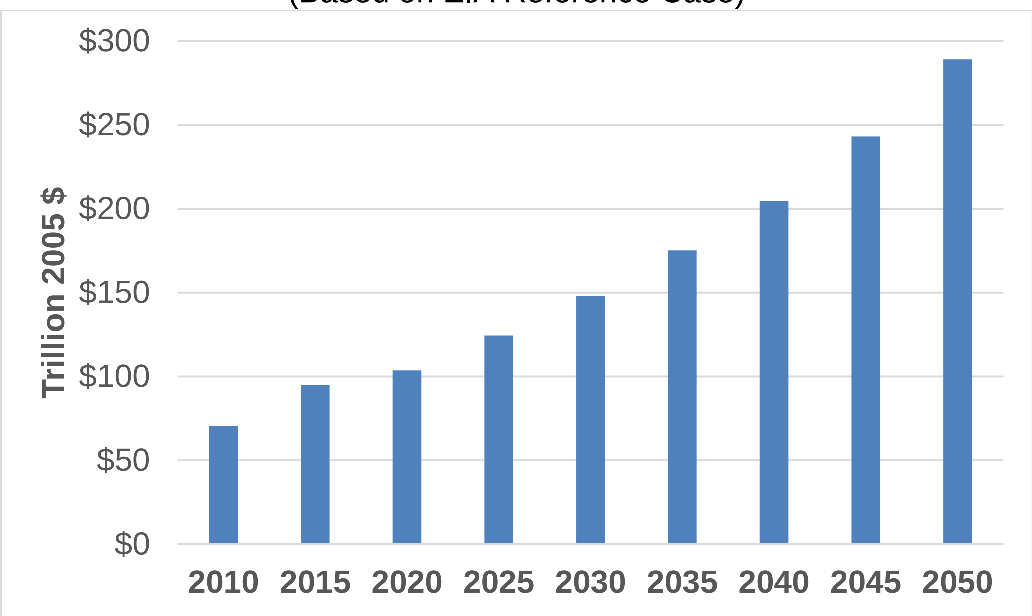
[134]See Craig Idso, “The Positive Externalities of Carbon Dioxide,” Center for the Study of Carbon Dioxide and Global Change, 2013, www.co2science.org.

V. ECONOMIC IMPLICATIONS OF DRACONIAN GHG REDUCTIONS

V.A. Forecasts to 2050

IEO 2013 provides no forecasts beyond 2040. Here we extended the EIA forecasts to 2050 on the basis of the EIA forecast trends 2010-2040. Figure V-1 shows world GDP forecast through 2050 based on the 3.5 percent growth rate that EIA forecasts for 2020 – 2040. It indicates that in 2050, world GDP will total about $290 trillion (2005 dollars).

Figure V-1
World GDP Forecast Through 2050
(Based on EIA Reference Case)



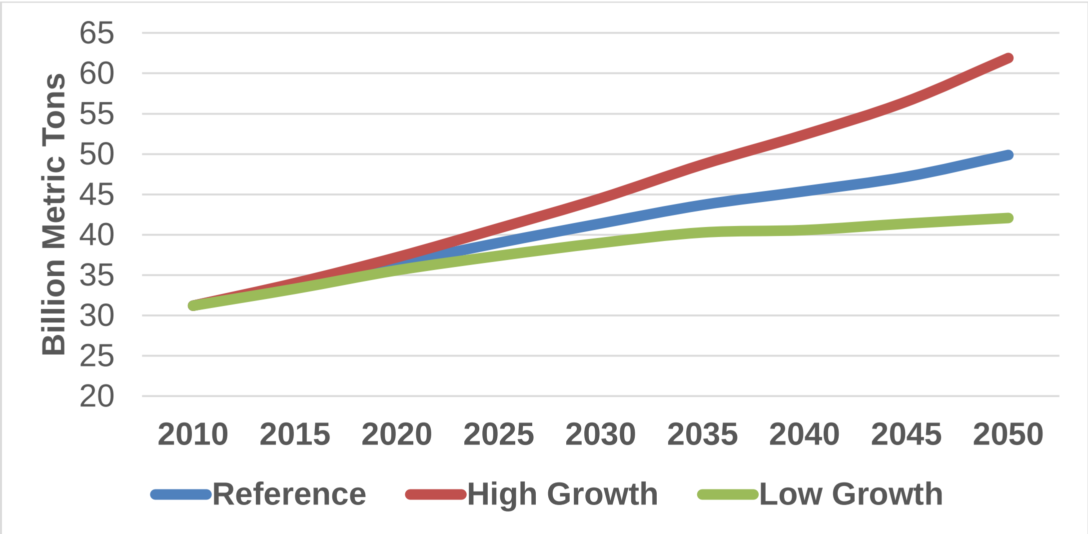
Source: U.S. Energy Information Administration and Management Information Services, Inc.

EIA does not publish alternate CO_2 emissions forecasts corresponding to the high economic growth and low economic growth cases. Here we derived these alternate forecasts by assuming that the relationship between fossil fuel consumption and CO_2 emissions forecast by EIA for the Reference case would be about the same in the high growth and the low growth scenarios. We again extended the EIA forecasts to 2050 on the basis of the EIA forecast trends 2010-2040. Our results are given in Figure V-2, which shows that:

- In 2020, CO_2 emissions total over 37 billion tons in the high growth case and about 35.5 billion tons in the low growth case.

- In 2030, CO_2 emissions total over 44 billion tons in the high growth case and about 39 billion tons in the low growth case.
- In 2040, CO_2 emissions total over 52 billion tons in the high growth case and less than 41 billion tons in the low growth case.
- In 2050, CO_2 emissions total about 62 billion tons in the high growth case and about 42 billion tons in the low growth case.
- Thus, by 2050 the difference in world CO_2 emissions between the high growth and the low growth cases totals about 20 billion tons annually.

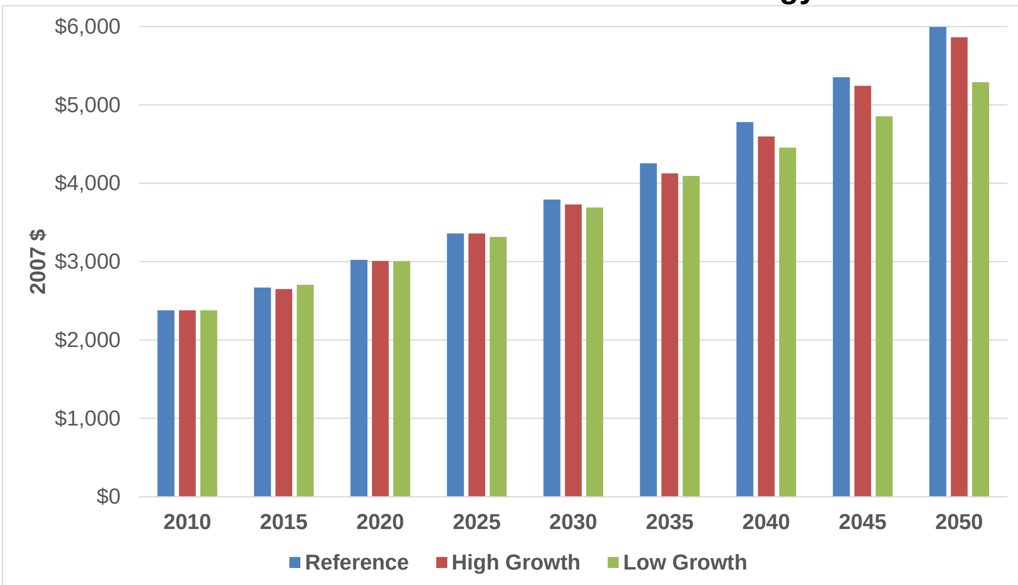
Figure V-2
Alternate Forecasts of World CO_2 Emissions: 2010 - 2050



Source: U.S. Energy Information Administration and Management Information Services, Inc.

The preceding information allows us to forecast world GDP (2007 dollars) per ton of energy-related CO_2 according to each of the three scenarios – Figure V-3. Because both world GDP and world CO_2 emissions are forecast to change over time, this figure indicates that the ratios of GDP to CO_2 emissions do not vary significantly until about 2035. Therefore, in the analyses below we use the forecast Reference case ratios.

Figure V-3
Alternate Forecasts of World GDP Per Ton of Energy-Related CO_2



Source: U.S. Energy Information Administration, U.S. Bureau of Economic Analysis, and Management Information Services, Inc.

Similarly, the Organization for Economic Cooperation and Development (OECD) notes that GHG emissions continue to increase, and in 2010 global energy-related CO_2 emissions reached an all-time high of 30.6 gigatonnes (Gt) despite the recent economic crisis.[135] The OECD Environmental Outlook Baseline scenario envisages that without more ambitious policies than those currently in force, GHG emissions will increase by another 50 percent by 2050, primarily driven by a projected 70 percent growth in CO_2 emissions from energy use. This is primarily due to a projected 80 percent increase in global energy demand, while transport emissions are projected to double due to a strong increase in demand for cars in developing countries and to aviation. Historically, OECD economies have been responsible for most of the emissions; but in the coming decades, increasing emissions will also be caused by high economic growth in some of the major emerging economies.

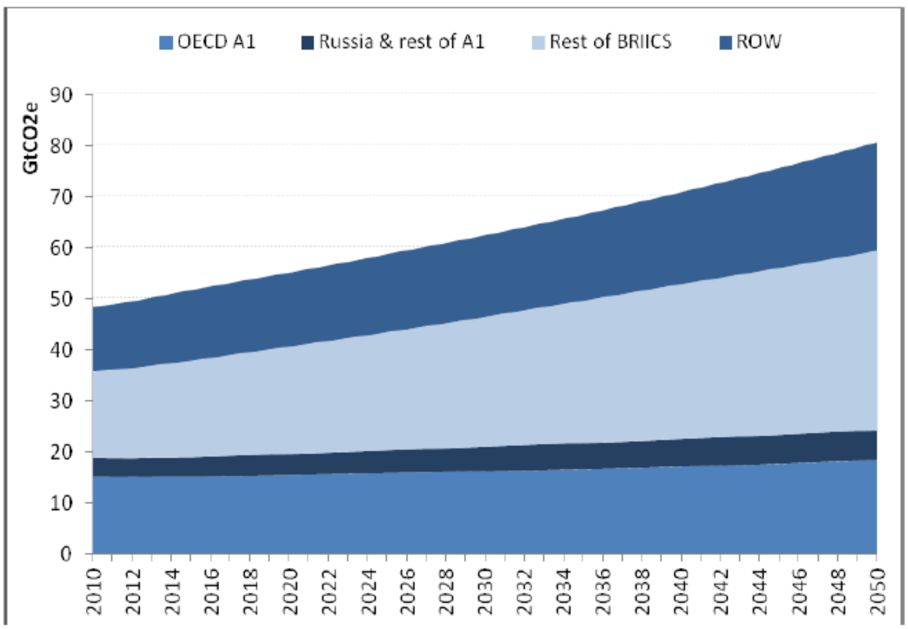
Technological progress and structural shifts in the composition of growth are projected to improve the energy intensity of economies in the coming decades (i.e. achieving a relative decoupling of GHG emissions growth and GDP growth), especially in OECD and the emerging economies of Brazil, Russia, India, Indonesia, China and South Africa (BRIICS). However, under current trends, these regional improvements would be outstripped by the increased energy demand worldwide.

[135] *The OECD Environmental Outlook to 2050: Key Findings on Climate Change*, Organization for Economic Cooperation and Development, Paris, November 2012.

Emissions from land use, land use change, and forestry (LULUCF) are projected to decrease in the course of the next 30 years, while carbon sequestration by forests increases. By 2045, net CO_2 emissions from land use are projected to become negative in OECD countries – i.e. become a net emissions sink. Most emerging economies also show a decreasing trend in emissions from an expected slowing of deforestation. In the rest of the world, land use emissions are projected to increase to 2050, driven by expanding agricultural areas, particularly in Africa.

Nevertheless, the bottom line is that the OECD forecasts that global GHG emissions will increase 50 percent by 2050, mostly driven by energy demand and economic growth in key emerging economies – Figure V-4.

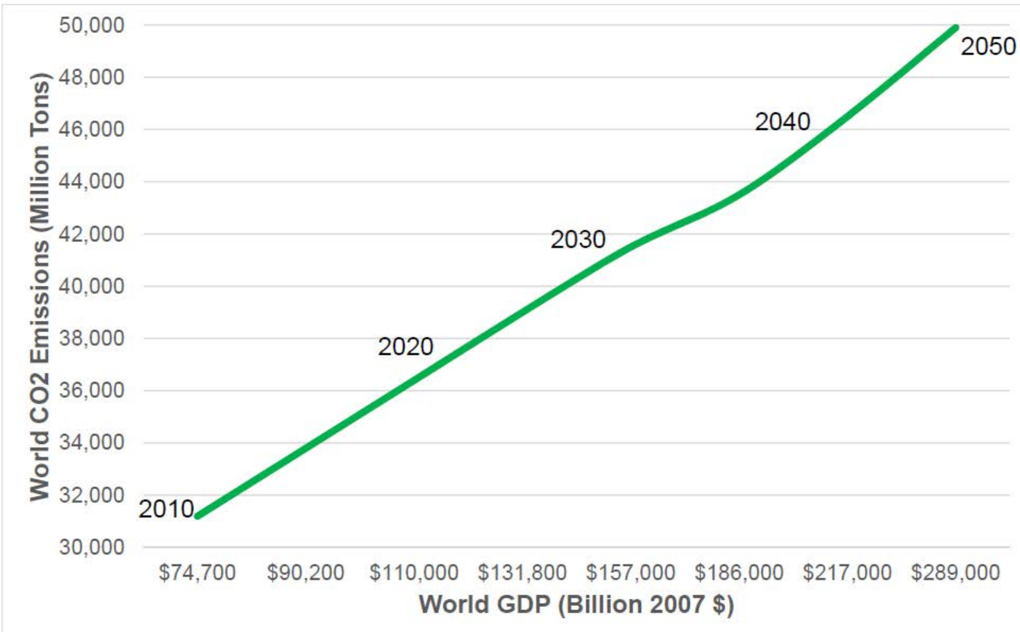
Figure V-4
OECD Forecast of GHG Emissions by Region
(Baseline Scenario, in GtCO2e)



Source: Organization for Economic Cooperation and Development
Note: GtCO2e = Giga tonnes of CO2 equivalent
ROW = Rest of the World

Figure V-5 is analogous to Figure IV-13 and shows the forecast relationship between world GDP and CO_2 emissions in the EIA reference case through 2050. This figure indicates that the relationship is forecast to be roughly linear. Once again, future economic growth – as measured by world GDP – requires fossil fuels which, in turn, generate CO_2 emissions. Figures V-1 and V-2 show that this strong relationship exists across all forecast years in each of the three scenarios. Thus, according to EIA data and forecasts, fossil fuels, which generate CO_2 emissions, are essential for world economic growth, and significant CO_2 emissions reductions will be associated with significant reductions in economic growth.

Figure V-5
Forecast Relationship Between World GDP and CO_2 Emissions
(Based on EIA Reference Case)



Source: U.S. Energy Information Administration, International Energy Agency, U.S. Bureau of Economic Analysis, and Management Information Services, Inc.

V.B. The Real Economic Implications of Draconian GHG Reductions

The UN, EU, the White House, and others contend that it is imperative to reduce CO_2 emissions drastically to keep global temperatures from increasing by 2° or 3° Celsius or more above preindustrial levels.[136] While, it may be debated whether reducing CO_2 emissions would have any discernable impact on long term global temperatures,[137] what sort of economic and social implications are likely from such drastic GHG emissions reductions?

As discussed in Chapter II, various goals, milestones, and schedules are being suggested in order "to keep global warming below 2°C or 3°C." For example, in order to do so:

[136]For example, see Council of Economic Advisors, op. cit., pp. 2-4.
[137]See Management Information Services, Inc., *Analysis of the White House Report "The Cost of Delaying Action to Stem Climate Change,"* September 2014.

- The European Union (EU) is committed to reducing GHGs to 80-95 percent below 1990 levels by 2050.[138]
- The UK's goal is to reduce GHGs by at least 80 percent (from the 1990 baseline) by 2050.[139]
- Germany has proposed reducing its GHG emissions 95 percent below the 1990 baseline by 2050.
- The state of California has mandated state GHG emissions reductions to 2000 levels by 2010, to 1990 levels by 2020, and to 80 percent below 1990 levels by 2050.[140]

What are the energy and economic implications of such drastic reductions?

EIA forecasts that between 2020 and 2040, world GDP will approximately double and world CO_2 emissions will increase by about 25 percent.[141] As discussed, according to EIA the relationship between GDP growth and CO_2 emissions is relatively fixed among the low growth, reference, and high growth scenarios. Extrapolated to 2050, this implies that between 2020 and 2050 world GDP will increase about 260 percent and world CO_2 emissions will increase by about 33 percent, and that the relationship between GDP growth and CO_2 emissions will remain relatively fixed among growth scenarios. Further:[142]

- According to the EIA *IEO 2013* reference case, world primary energy consumption increases 1.5 percent annually, 2010-2040. World primary energy consumption in 2040 is forecast to be 819.6 quads and, assuming 1.5 percent growth annually, indicates to a total of 951 quads in 2050.
- According to the EIA *IEO 2013* reference case, world GDP increases 3.6 percent annually, 2010-2040. World 2040 GDP is forecast to total $204,779 billion (PPT, 2005 $) and, assuming 3.6 percent growth annually, yields GDP of $291,940 billion in 2050.
- According to the AEO *IEO 2013* reference case, world CO_2 emissions increase 1.3 percent annually, 2010-2040. World 2040 CO_2 emissions are forecast to total 45,455 million metric tons in 2040 and, assuming 1.3 percent growth annually, yields 51,722 MMT in 2050.

There are two critical caveats that must be noted. First, it is important to realize that the EIA forecasts already explicitly assume that there will be significant energy efficiency and decarbonization over the next three decades. That is, EIA already

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[138]See European Commission, "Energy Roadmap 2050," Luxembourg: Publications Office of the European Union, ISBN 978-92-79-21798-2, 2012, and Altiero Spinelli, "EU Energy Roadmap 2050: EU External Policies for Future Energy Security," presented at the Workshop on Energy Roadmap 2050: EU External Policies for Future Energy Security held on 5 November 2012.
[139]"2008 Climate Change Act," www.legislation.gov.uk/ukpga/2008/27/contents.
[140]"California Executive Order S-3-05 (June 2005)," www.dot.ca.gov/hq/energy/ExecOrderS-3-05.htm; California Environmental Protection Agency, Air Resources Board, "Assembly Bill 32: Global Warming Solutions Act of 2006, www.arb.ca.gov/cc/ab32/ab32.htm,
[141]U.S. Energy Information Administration, International Energy Outlook, op. cit.
[142]Ibid.

assumes that world GDP will increase at a rate that is much faster than the rate of increase in primary energy consumption, and that CO_2 emissions will increase at a lower rate than either GDP or energy consumption. Specifically, EIA projects that:[143]

- World GDP increases 3.6 percent annually.
- World primary energy consumption increases 1.5 percent annually.
- World CO_2 emissions increase 1.3 percent annually.

In other words, EIA has already incorporated into its forecasts a very significant "decoupling" of GDP, energy, and CO_2 emissions and very significant, continuing "decarbonization" of the world economy. Thus, the EIA "Reference Case" already has large decarbonization incorporated into it: It is not a simple "business as usual" case or an extrapolation of past trends. This implies that further CO_2 reductions beyond those already incorporated into the forecasts will be increasingly difficult and expensive to achieve.

Second, the emissions reductions being recommended "to keep global warming below 2°C or 3°C," when compared to the forecast emissions for a given future year are draconian to the point of being ludicrous. For example, the recommendation to reduce GHG emissions by 80 percent below 1990 levels by 2050 actually implies that 2050 emissions – and world GDP -- would have to be reduced more than 95 percent below what they are actually forecast to be in 2050 – forecasts that already incorporate very significant decarbonization. Accordingly, 2050 fossil fuel utilization and world GDP (and hence living standards) would have to be reduced to a very small fraction of what they would otherwise be. Such an outcome will be unacceptable to any and every country in the world.

What are the economic, social, and political implications of the aggressive reductions in future GHGs below the levels forecast, which are implied by the proposals of the UN, the EU, and others?

As an example, consider the EU GHG reduction goal: The EU is committed to "reducing GHGs to 80-95 percent below 1990 levels by 2050."[144] In its *Energy Roadmap 2050*, the Commission assessed the challenges posed by achieving the EU's decarbonization objective while at the same time ensuring security of energy supply and competitiveness.[145]

[143]Ibid.
[144]The EU is committed to reducing GHGs to 80–95 percent below 1990 levels by 2050 in the context of necessary reductions by developed countries as a group. See European Commission, "Energy Roadmap 2050," Luxembourg: Publications Office of the European Union, ISBN 978-92-79-21798-2, 2012, and Altiero Spinelli, "EU Energy Roadmap 2050: EU External Policies For Future Energy Security," presented at the Workshop on Energy Roadmap 2050: EU External Policies for Future Energy Security held on 5 November 2012.
[145]It was responding to a request from the European Council, Extraordinary European Council, 4 February 2011.

Under the EIA *IEO 2013* reference case, world CO_2 emissions will total 51,722 MMT in 2050. Assume that the goal is a 90 percent reduction below 1990 levels by 2050. Accordingly:

- 1990 world CO_2 totaled 21,223 MMT
- 10 percent of this 1990 level is 2,120 MMT
- 2,120/51,722 = 4.1 percent

Thus, **to reduce GHGs to 90 percent below 1990 levels by 2050 will require that GHGs in 2050 be *96 percent* lower than they are currently projected to be**.

As discussed, according to EIA the relationship between GDP growth and CO_2 emissions is relatively fixed among its low growth, reference, and high growth scenarios. Further:

- EIA's reference case implies that world GDP in 2050 will be $292 trillion (PPY, 2005$).[146]
- The UN "medium" population forecast for world population in 2050 is 9.551 billion.[147]
- Thus, the world per capita GDP in 2050 will be about $30,600.
- Four percent of this is about $1,200.

Assuming that the relationship between GDP growth and CO_2 emissions is relatively fixed – as does EIA, then to achieve the goal to reduce GHGs to 90 percent below 1990 levels by 2050 will require that world 2050 GDP be reduced to about four percent of what it is projected to be in that year. That is, 2050 world GDP would be about $12 trillion instead of $292 trillion, and per capita world GDP will be about $1,200 instead of $30,600.

What does per capita world GDP of $1,200 instead of $30,600 imply?

In purely statistical terms, we can utilize the seminal work of Angus Maddison, who has estimated historical per capita GDP.[148] Using these data, a world per capita GDP of about $1,200, equals about what per capita GDP was in the two wealthiest regions of the world – the USA and Western Europe – in about 1820 or 1830. In other words, to achieve the EU goal of reducing GHGs to 90 percent below 1990 levels by 2050 implies that world living standards in 2050 would be reduced to a level they were more than two centuries prior. That is, virtually all of the economic gains of the industrial revolution and everything that followed would be nullified. Thus, instead of people enjoying the living standards of the 2050's, they would have to endure the living standards of the 1820s.

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[146]Extrapolated by MISI based on EIA forecasts through 2040.
[147]United Nations, *World Population Prospects: The 2012 Revision, Volume I: Comprehensive Tables*, New York, 2013.
[148]Angus Maddison, *Contours of the World Economy, 1–2030 AD: Essays in Macro-Economic History*, Oxford University Press, 2007.

Now, assume that, through massive efforts, it is possible to further decouple GDP, energy consumption, and GHGs – over and above the significant decoupling already incorporated into the EIA reference case forecasts. Assume that this decoupling changes the ratio of GDP to energy/GHGs by a factor of two. This would imply that in 2050, world per capita GDP would be about $2,400 instead of $1,200.

What does per capita world GDP of $2,400 instead of $30,600 imply?

Utilizing Maddison's estimates, a world per capita GDP of about $2,400 equals about what per capita GDP was in the two wealthiest regions of the world – the USA and Western Europe – in about the 1870s. In other words, even with heroic assumptions about decoupling GDP growth from energy consumption and GHG growth, to achieve the goal to reduce GHGs to 90 percent below 1990 levels by 2050 implies that world living standards would be reduced to a level they were nearly two centuries prior. That is, most of the economic gains of the past two centuries would be nullified. Thus, instead of people enjoying the living standards of the 2050's, they would have to endure the living standards of the 1870s.

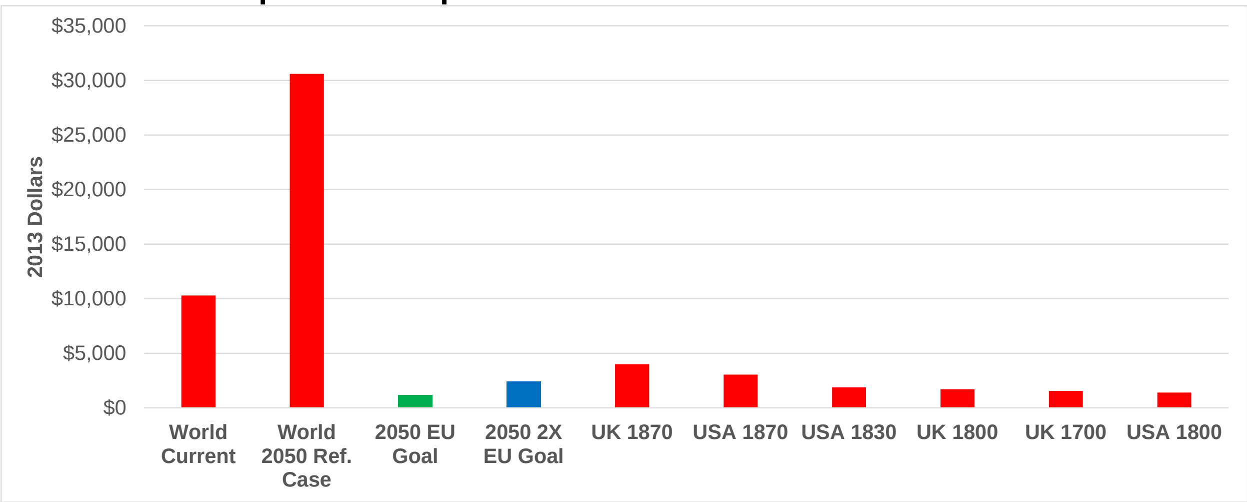
As illustrated in Figure V-6, current world per capita GDP is about $10,300 (2013 dollars), and under the EIA reference case projection, 2050 world GDP will likely be about $30,600. However, attempting to achieve the 2050 GHG reduction goal in order "to keep global warming below 2°C" could reduce 2050 world per capita GDP to about $1,200:

- This would be only four percent of projected 2050 world per capita GDP.
- It would be only about 1/8th current world per capita GDP.
- It would reduce 2050 world per capita GDP to less than ½ that of the UK in 1870.
- It would reduce 2050 world per capita GDP to less than ½ that of the USA in 1870.
- It would reduce 2050 world per capita GDP to less than that of the USA in 1830.
- It would reduce 2050 world per capita GDP to less than that of the UK in 1800.
- It would reduce 2050 world per capita GDP to about the level of the USA in 1800.
- It would reduce 2050 world per capita GDP to about the level of the UK in 1700.

Even assuming a two-fold increase in decoupling GDP growth from energy consumption would result in 2050 world per capita GDP to about $2,400:

- This would be only about 80 percent of the 1870 USA per capita GDP
- This would be only about 60 percent of the 1870 UK per capita GDP

Figure V-6
Per Capita GDP Implications of the 2050 GHG Reduction Goal



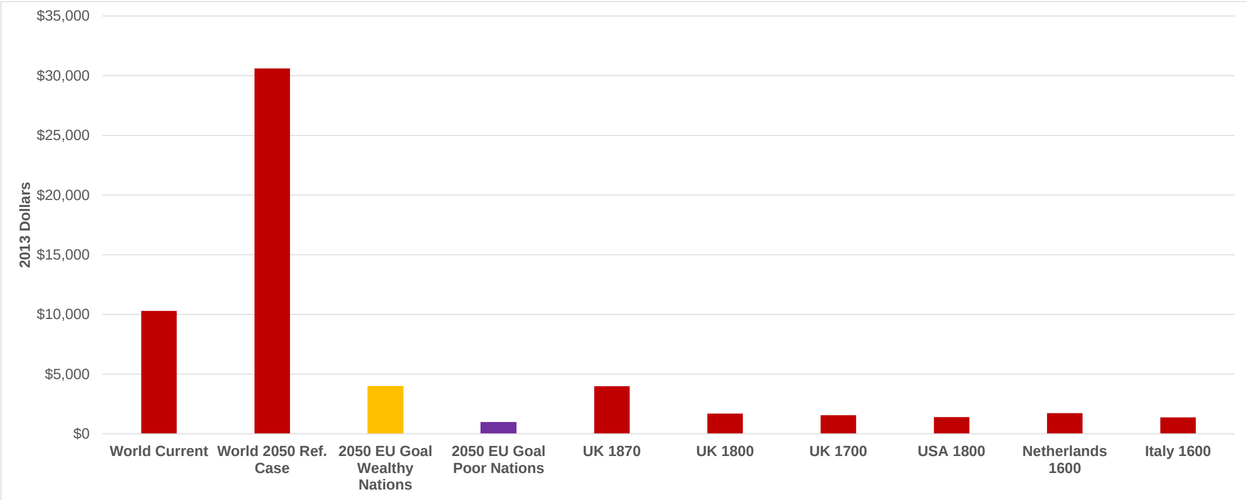
Sources: U.S. Energy Information Administration and Management Information Services, Inc.

But it even worse. The average world GDP estimate obscures the fact that there is wide variation in per capita GDP among nations and regions. At present, per capita GDP in the OECD nations, on the one hand, and most of the developing world on the other hand varies by a factor of five to 20 or more. Even assuming that this diversity decreases in the future, the differences in per capita GDP in 2050 between the wealthy nations and the poor nations will likely be, on average, at least four-fold.

Thus, if 2050 world GDP was, on average, about $1,200, then the less developed nations would likely have a per capita GDP well below this, while the wealthier nations would have per capita GDP higher than $1,200. This implies that in 2050 many of the less developed nations in Asia, Africa, and Latin America would experience per capita GDP levels similar to those in the USA and Western Europe during the 1700s – prior to the industrial revolution – Figure V-7.

If 2050 world GDP was, on average, about $2,400, then the less developed nations would likely have a per capita GDP well below this, while the wealthier nations would have per capita GDP higher than $2,400. This implies that in 2050 many of the less developed nations in Asia, Africa, and Latin America would experience per capita GDP levels similar to those in the USA and Western Europe about 1800 – at the beginning of the industrial revolution – Figure V-7.

Figure V-7
Per Capita GDP Implications of the EU 2050 GHG Reduction Goal
For Wealthy Nations and Poor Nations

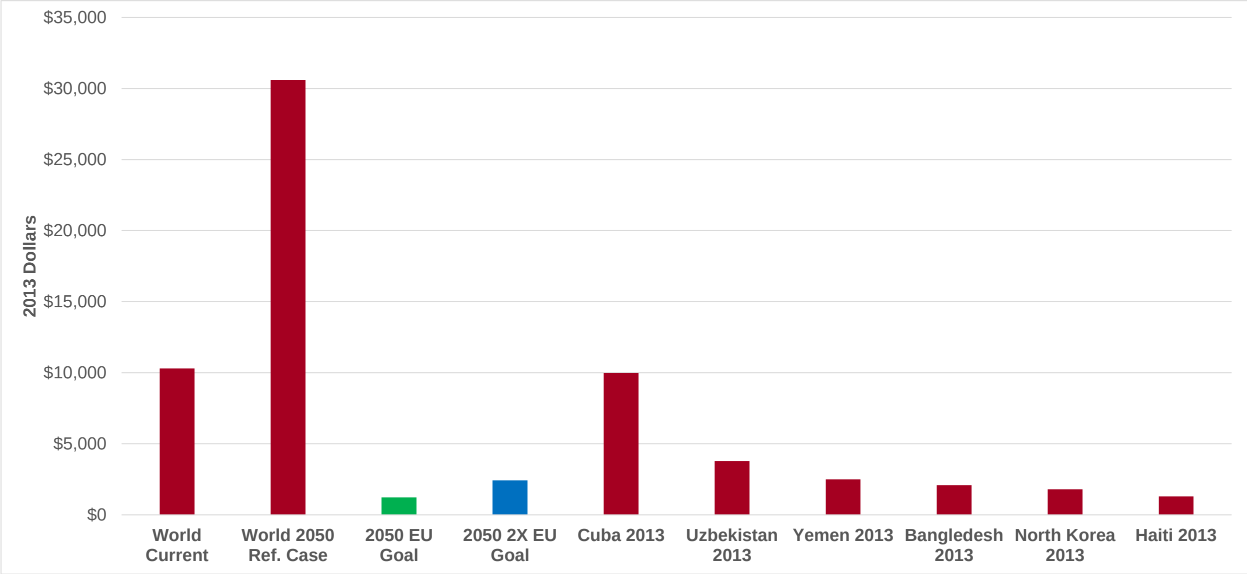


Sources: U.S. Energy Information Administration and Management Information Services, Inc.

This is clearly impossible and absurd. Such comparisons are difficult and nearly meaningless. For example: What is the cost of a computer in 1870? An I-phone in 1820? A sports car in 1700? Penicillin during the 1870s? Central AC in 1850? Etc.

A more meaningful comparison would be of the implied per capita 2050 GDP levels with the current per capita GDPs of different nations. This comparison is illustrated in Figure V-8, which shows the implications of the types of drastic CO_2 emissions reductions implied by the EU goals. Reducing global 2050 CO_2 emissions to 90 percent below 1990 levels implies that average world per capita GDP would be reduced to levels currently below those of the world's most impoverished nations, such as Yemen, Bangladesh, North Korea, and Haiti.

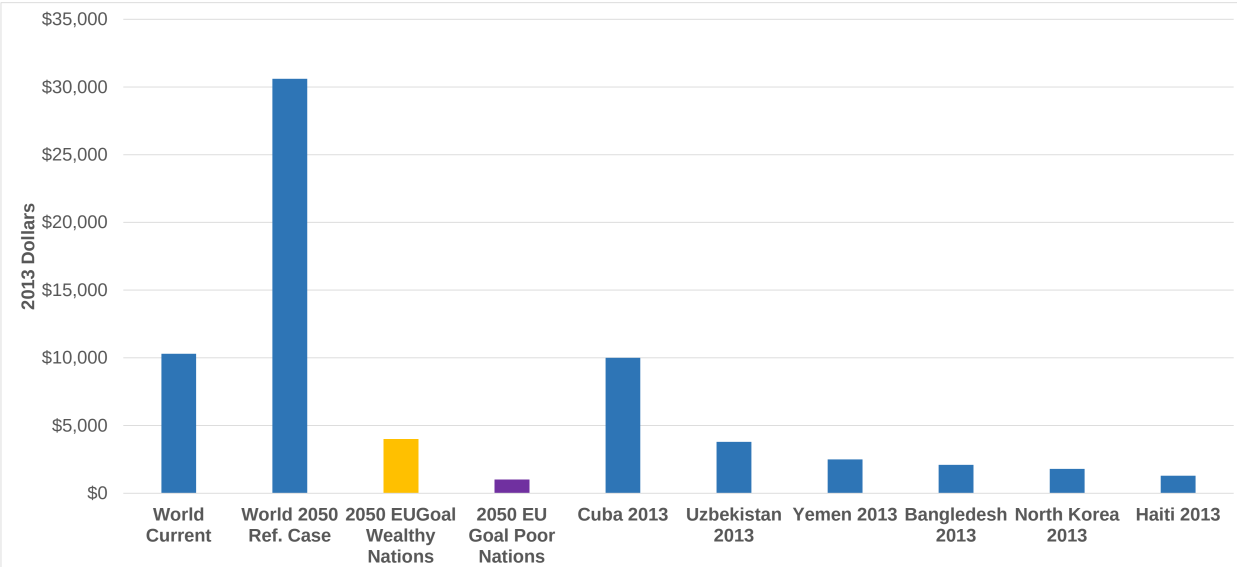
Figure V-8
Relative 2013 Per Capita GDP Implications of the 2050 GHG Reduction Goal



Sources: U.S. Energy Information Administration and Management Information Services, Inc.

Once again, with respect to the wealthy nations and the poor nations, a more meaningful comparison is of the implied per capita 2050 GDP levels with current per capita GDPs of different nations. This comparison is illustrated in Figure V-9, which shows the implications of type of drastic CO_2 emissions reductions implied by the EU goals. Reducing global 2050 CO_2 emissions to 90 percent below 1990 levels implies that in 2050, many of the less developed nations in Asia, Africa, and Latin America would experience per capita GDP levels *less than half* of the 2013 per capita levels of the world's poorest nations, such as Yemen, Bangladesh, North Korea, and Haiti.

Figure V-9
Per Capita GDP Implications of the EU 2050 GHG Reduction Goal
For Wealthy Nations and Poor Nations – Relative 2013 Income Levels



Sources: U.S. Energy Information Administration and Management Information Services, Inc.

We can make a different, perhaps more interesting comparison. The current annual U.S. median household income is about $51,000.[149] On the basis of the EIA forecasts, we estimate that U.S. median household income in 2050 will increase about 80 percent to about $92,000/yr. (2013 dollars).

Four percent of $92,000 is about $3,700. Thus, the U.S. median household income in 2050, instead of being about $92,000 would instead be about $3,700 – Figure V-10. The current U.S. poverty threshold for a family of four is $23,900.[150] This implies that achieving the UN/EU-implied GHG reduction goal in 2050 would be equivalent to reducing the current U.S. median household income to only 15 percent of the poverty level. The relevant comparison is that today, the average U.S. family would have to live on an income of less than $4,000 per year. Programs using poverty income guidelines (or percentage multiples of the guidelines -- for instance, 125 percent or 185 percent of the guidelines) in determining recipient eligibility include Head Start, the Supplemental Nutrition Assistance Program (SNAP), the National School Lunch Program, the Low-Income Home Energy Assistance Program, the Children's Health Insurance Program, and others.[151] If the drastic GHG reduction goals were pursued, the vast majority of U.S. households would qualify for these assistance programs, for which sufficient funds would be lacking.

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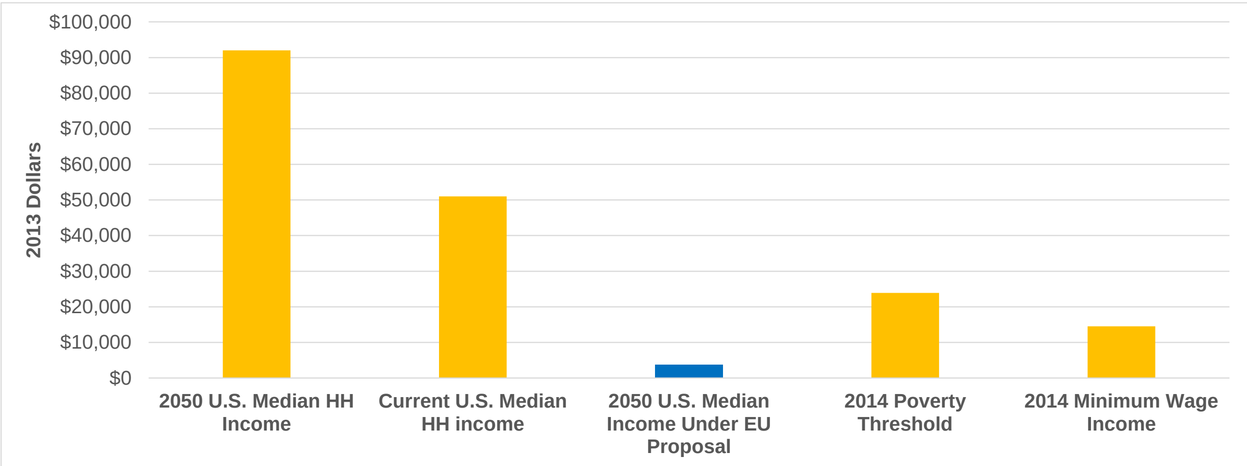
[149]U.S. Census Bureau, "State Median Income," www.census.gov/hhes/www/income/data/statemedian/.
[150]"2014 Poverty Guidelines: One Version of the U.S. Federal Poverty Measure," U.S. Department of Health & Human Services, January 2014.
[151]Ibid.

Figure V-10
Per Capita GDP Implications of the EU 2050 GHG Reduction Goal on U.S. Household Incomes



Sources: U.S. Energy Information Administration and Management Information Services, Inc.

As another example, the Federal minimum wage is currently $7.25/hr., which equates to annual earnings of $14,500.[152] In other words, achieving the GHG reduction goal would imply that a U.S. family of four would have to subsist on an annual income of about ¼ that yielded by current minimum wage – which many contend is already scandalously low.

This illustrates the real costs and implications of "reducing GHGs to 80-95 percent below 1990 levels by 2050." They are so draconian as to be infeasible and impossible. The idea is truly ludicrous. Nevertheless, that is what world leaders gathered in Paris in December 2015 will be seriously contemplating.

[152]"Minimum Wage," U.S. Department of Labor, www.dol.gov/dol/topic/wages/minimumwage.htm.

VI. FINDINGS AND CONCLUSIONS

VI.A. Findings

The UN Climate Change Conference will be held in Paris in December 2015, and its goal is to achieve a binding and universal agreement on climate from all nations to reduce GHGs to limit the global temperature increase to no more than 2°C above current levels. The intention is that by the end of the Paris meeting, all nations will be bound by an agreement on climate and that implementation will begin in 2020. However, representatives from a number of nations are challenging the climate change policies of the UN and have signed "the Warsaw Declaration," which requested that UN delegates discontinue work on a new treaty until a genuine "scientific consensus is reached on the phenomenon of so-called global warming."

Various goals, milestones, and schedules are being considered and mandated in order "to keep global warming below 2°C." These include:

- The EU is committed to keeping 2030 GHG emissions 40 percent below 1990 levels and to reducing GHGs to 80-95 percent below 1990 levels by 2050.
- The G8 leaders support a 50 percent reduction in GHG emissions by 2050.
- The USA has committed to reducing GHG emissions to 17 percent below 2005 levels by 2020 and to reducing emissions 80 percent below the 1990 level by 2050.
- The UK has pledged to reduce GHG emissions by at least 80 percent (from the 1990 baseline) by 2050.
- Germany has proposed reducing its GHG emissions 95 percent below the 1990 baseline by 2050.
- California has mandated state GHG emissions reductions to 2000 levels by 2010, to 1990 levels by 2020, and to 80 percent below 1990 levels by 2050.

In addition, the UN is developing Deep Decarbonization Pathways to determine how individual countries can transition to a low-carbon economy. Such "Deep Decarbonization" will require a profound transformation of energy systems by mid-century through steep declines in carbon intensity in all sectors of the economy, and is not about modest and incremental change: It requires major changes to countries' energy and production systems that need to be pursued over the long-term.

These goals are ambitious in the extreme; for example, by 2050:

- The USA would have to reduce GHGs from electricity generation by 95 percent from 2010 levels.
- In California, there would be no gasoline fueled vehicles, and GHGs from electricity consumption in the residential, commercial, and industrial sectors would be close to zero.
- Korea would have to reduce GHGs from industry by 91 percent from 2010 levels.

According to all major forecasts available, fossil fuels will remain the principal sources of energy worldwide for the foreseeable future and will continue to supply 75 - 80 percent of world energy. Demand for oil, natural gas, and coal will increase substantially in both absolute and percentage terms over the next several decades.

Without the availability of adequate supplies of accessible, reliable, and affordable fossil fuels none of the industrial and economic progress of the past two centuries would have been possible. Fossil fuels facilitated successive industrial revolutions, created the modern world, created advanced technological society, and enabled the high quality of life currently taken for granted. Over the past 200 years, largely because of hydrocarbon energy, human population increased eightfold, average incomes rose 11-fold, and global life expectancy more than doubled. Concurrently, CO_2 emissions increased 2,800-fold, to 8.4 billion tons/year -- and atmospheric concentration rose from 320 ppm CO_2 to nearly 400 ppm.

Hydrocarbons provide 81 percent of world energy, and the positive relationship between fossil fuels, economic growth, and CO_2 emissions is strong -- supporting $70 trillion per year in world GDP. Seminal research has concluded that "Ours is a high energy civilization based largely on combustion of fossil fuels," and that "The theoretical and empirical evidence indicates that energy use and output are tightly coupled, with energy availability playing a key role in enabling growth."

Demand for oil, natural gas, and coal will increase substantially in both absolute and percentage terms over the next several decades. Assuring continued world economic growth, increased per capita income, and rising living standards requires this greatly increased use of fossil fuels. All major forecasts, including those of the EIA and the IEA predict that, for decades to come, there will continue to be a close link between energy and the economy and that fossil fuels will continue to provide about 80 percent of world energy.

The policy prescriptions for reducing CO_2 emissions drastically to keep global temperatures from increasing by 2° or 3° C would within 30 years reduce world per capita GDP to only about four percent of what it is otherwise forecast to be. Attempting to achieve this 2050 GHG reduction goal could reduce 2050 world per capita GDP from its forecast $30,600 to about $1,200:

- This would be only four percent of projected 2050 world per capita GDP.
- It would be only about 1/8th current world per capita GDP.
- It would reduce 2050 world per capita GDP to less than ½ that of the UK in 1870.
- It would reduce 2050 world per capita GDP to less than ½ that of the USA in 1870.
- It would reduce 2050 world per capita GDP to less than that of the USA in 1830.
- It would reduce 2050 world per capita GDP to less than that of the UK in 1800.
- It would reduce 2050 world per capita GDP to about the level of the USA in 1800.
- It would reduce 2050 world per capita GDP to about the level of the UK in 1700.

Even assuming a two-fold increase in decoupling GDP growth from energy consumption would result in 2050 world per capita GDP to about $2,400:

- This would be only about 80 percent of the 1870 USA per capita GDP
- This would be only about 60 percent of the 1870 UK per capita GDP

Reducing global 2050 CO_2 emissions to 90 percent below 1990 levels implies that average world per capita GDP would be reduced to levels currently below those of the world's most impoverished nations, such as Yemen, Bangladesh, North Korea, and Haiti. Many of the less developed nations in Asia, Africa, and Latin America would experience per capita GDP levels less than half of the 2013 per capita levels of the these poorest nations.

VI.B. Conclusions

The proposals likely to be adopted and the 2015 UN Paris conference for drastically reducing world GHGs by 2050 are fatally flawed, unrealistic, and impossible to achieve without destroying the world economy. There are two critical caveats that are not recognized:

- First, all current forecasts already explicitly assume that there will be significant energy efficiency and decarbonization over the next three decades; that is that world GDP will increase at a rate that is much faster than the rate of increase in energy consumption, and that CO_2 emissions will increase at a lower rate than either GDP or energy consumption. Thus, the "Reference" forecasts already have large decarbonization incorporated into them: They are not simple extrapolations of past trends. This implies that further CO_2 reductions beyond those already incorporated into the forecasts will be increasingly difficult and expensive to achieve.
- Second, the emissions reductions being recommended, when compared to the forecast emissions for a given future year are draconian to the point of being ludicrous. Thus, the recommendation to reduce GHG emissions by 80 percent below 1990 levels by 2050 actually implies that 2050 emissions – and world GDP -- would have to be reduced more than 95 percent below what they are actually forecast to be in 2050 – forecasts that already incorporate very significant decarbonization. Accordingly, 2050 fossil fuel utilization and world GDP (and hence living standards) would have to be reduced to a very small fraction of what they would otherwise be. Such an outcome is unacceptable every country.

Thus, assuming that the relationship between GDP and CO_2 emissions is relatively fixed – as does EIA and IEA, then to achieve the goal to reduce GHGs to 90 percent below 1990 levels by 2050 will require that world 2050 GDP be reduced to about four percent of what it is projected to be. In other words, **<u>to achieve the implied GHG reduction goal to reduce GHGs to 90 percent below 1990 levels by 2050 implies that world living standards in 2050 would be reduced to a level they were more than two centuries prior</u>**. Virtually all of the economic gains of the industrial revolution and everything that followed would be nullified and **instead of people enjoying the living standards of the 2050's, they would have to endure the living standards of the**

1820s. Average world per capita GDP would be reduced to levels currently below those of the most impoverished nations, such as Yemen, Bangladesh, North Korea, and Haiti, and many of the less developed nations in Asia, Africa, and Latin America would experience per capita GDP levels less than half of the 2013 per capita levels of the these poorest nations

These are the real implications of “reducing GHGs to 80-95 percent below 1990 levels by 2050.” They are so draconian as to be infeasible and impossible. The idea is truly ludicrous. Nevertheless, that is what world leaders gathered in Paris in December 2015 will be seriously contemplating. **This cannot be allowed to happen.**

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