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How to decarbonize? Look to Sweden

Raymond Pierrehumbert

ABSTRACT

Bringing global warming to a halt requires that worldwide net emissions of carbon dioxide be brought to essentially zero; the sooner this occurs, the less warming our descendants for the next 1000 years and more will need to adapt to. The widespread fear that the actions needed to bring this about conflict with economic growth is a major impediment to efforts to protect the climate. But much of this fear is pointless, and the magnitude of the task – while great – is no greater than the challenges that human ingenuity has surmounted in the past. To light the way forward, we need to examine success stories where nations have greatly reduced their carbon dioxide emissions while simultaneously maintaining vigorous growth in their standard of living; a prime example is Sweden. Through a combination of sensible government infrastructure policies and free-market incentives, Sweden has managed to successfully decarbonize, cutting its per capita emissions by a factor of 3 since the 1970s, while doubling its per capita income and providing a wide range of social benefits. This has all been accomplished within a vigorous capitalistic framework that in many ways better embodies free-market principles than the US economy. Consequently, the Swedish experience shows that solving global warming does not require us to “tear down capitalism.” The world just needs to be a bit more like Sweden.

KEYWORDS

Global warming; climate change; decarbonization; Sweden; carbon budgets; Naomi Klein; capitalism; energy policy

It is surprising and frustrating that, at a time of increasingly overwhelming evidence that human-caused global warming poses a serious problem, public support in the United States for actions of the magnitude required has stubbornly remained tepid for decades. Despite wholehearted denial that there is even a problem – a stance that makes it unique even among the world’s conservative political parties – the Republican Party is able to garner the support of about half of all US voters. While the United States is not alone in failing to meet the challenge of global warming, its status as one of the world’s top emitters of carbon dioxide (chief cause of global warming) makes its recalcitrance especially problematic.

In my experience, inaction on restraining carbon dioxide emissions does not stem from insufficient understanding of the science or insufficient fear of the consequences of warming. Instead, it is more due to excessive fear of the nature of the solutions. On the political right, this takes the form of a fear that it is all a thinly disguised leftist plot to impose socialism. Naomi Klein’s recent book, *This Changes Everything: Capitalism vs the Climate*, plays directly into this fear. Klein’s thesis is that capitalism is structurally unable to meet the challenge of getting fossil fuels out of the economy (Klein 2014; see also the November 2015 interview with Klein on the *Bulletin*’s website: [http://](http://thebulletin.org/naomi-klein-climate-change-makes-hotter-and-meaner-world8910)

thebulletin.org/naomi-klein-climate-change-makes-hotter-and-meaner-world8910). But while Klein is right about many things, including the problem’s urgency and the need for most of the world to take a different course from what is happening right now, she is quite wrong about the root cause of the current inadequate response to global warming.

The problem is not too much capitalism, but rather too little, and even a lack of faith in the power of the ingenuity unleashed by capitalism to solve big problems. As currently practiced, US capitalism, far from being the archetype of a free-market economy, is riddled with fossil-fuel subsidies and hobbled by politically powerful corporate stakeholders who have used their influence to protect the value of their fossil-fuel assets, regardless of how bad this may be for the rest of the economy. And even free markets cannot function properly if burdened by “externalities,” such as polluters not having to pay for the damage they cause. It is a case of privatizing the profits, while shunting the expenses off to the public.

To break the current impasse, the United States needs to look to success stories for reassurance that decarbonization is not mutually exclusive with prosperity and economic growth. We need to look at Sweden.

Sweden is not socialist

If Sweden is to be held up as a model for successful action against global warming in progressive capitalist democracies everywhere, then we must first dispel the notion that Swedes live a grim joyless existence, subsisting on the handouts of an intrusive welfare state. In fact, the very term “welfare state” distorts the Swedes’ conception about the role of their government. The term traditionally used in Sweden is *Folkhemmet* – the people’s home. The term was introduced in 1928 by Social Democrat leader Per Albin Hansson and meant to encapsulate the Swedish vision of a cooperative, capitalist society in which all work together to provide a good life for all.

The principles embodied in *Folkhemmet* amounted to a rejection of the Marxist approach based on class struggle, revolution, and nationalization of the means of production.

The building of *Folkhemmet* is a dynamic process, with the vision evolving over the years. Still, from the standpoint of an outside observer such as myself, having lived in both the United States and Sweden, it looks like the core principles of *Folkhemmet* remain intact. It involves a high level of public services delivered efficiently either directly by the government or via private intermediaries in cases where collective action can deliver essential services better than unguided private enterprise. It recognizes that when it comes to providing essential services such as higher education, public transit, or health care, sometimes the “invisible hand” of the market is not just invisible, but entirely absent. Major Swedish social benefits include universal access to health care under a single-payer system, high-quality day care and pre-schools provided at affordable rates, tuition-free university education, and a full year-and-a-half of paid parental leave. On top of that, every working Swede is entitled to 38 days of paid vacation, plus 18 national holidays – and none of that needs to be used up to provide sick leave or time off to care for sick children, because that is all covered under a separate benefit program.

If this is to be called “socialism,” all I can say is that a lot of countries would benefit from a lot more of it. As economist Paul Krugman puts it:

Every time I read someone talking about the “collapsing welfare states of Europe,” I have this urge to take that person on a forced walking tour of Stockholm. If you believed what the Right says, a country with Sweden’s level of both taxes and social benefits should be a wasteland. Strange to say, that’s not what it looks like, to say the least. (Krugman 2011)

Indeed, a long summer evening spent among Swedish friends winding down after work at Medborgarplatsen

in Stockholm’s now-fashionable Södermalm district is sufficient to dispel any notions of a gloomy Swedish character one might have imagined if one knew Sweden only through Bergman flicks. However, Sweden is emphatically not socialist. In fact, all this has been carried out within a vigorous free-market economy that fosters innovation and entrepreneurship. Sweden consistently ranks in the top 10 in the World Economic Forum competitiveness rankings and has even beaten the United States in many years. The success of Swedish free enterprise is attested by major multinational corporations such as Volvo, Alfa Laval (which provides a variety of solutions for heavy industry), the engineering firm of ASEA Brown Boveri, and the ready-to-assemble furniture maker IKEA, all of which have their roots in Sweden.

More recent examples of Swedish tech innovation include video chat and conference call innovator Skype and the digital music service Spotify. Sweden has become a high-tech start-up paradise not only because of its business-friendly policies, but also because the country’s comprehensive social safety net makes being an entrepreneur less personally risky; financial failure does not put the basic health and well-being of one’s family in jeopardy. And at the same time, Sweden has implemented such typically conservative shibboleths as low corporate income taxes and complete elimination of the inheritance tax. All the traditional post office functions are fulfilled by private providers who compete to provide the best service; the operation of railways and public transit has been largely subcontracted to competitive private enterprise; and there is even substantial involvement by private enterprise in delivering medical care and schooling.

Ironically, the conservative punditry has begun to awaken to the notion that if anything, Sweden represents the opposite of socialism; commentators such as Tim Worstall of *Forbes* have lately been using this realization to counter arguments that socialism can be successful. Worstall’s premise is that countries like Sweden are not really welfare states at all but “economically free, even classically liberal economies” (Worstall 2011). This is in fact a helpful development, since the major impediment to using Sweden as an exemplar of the way forward, particularly in the politics of the United States, is the misperception that Sweden is a socialist welfare state.

Here are the numbers: Sweden’s national budget ran a substantial surplus up to 2008, and was essentially balanced through 2011. Since that time the budget deficit has been allowed to grow to accommodate stimulus spending in response to the global financial crisis, but in 2014, the deficit was still under 2 percent

of gross domestic product (GDP). Despite the recent world economic crisis, Swedish national debt is under 50 percent of its GDP, in contrast to US figures which come in at over 100 percent of GDP. Sweden recognized early that the demographic crisis in its national pension system threatened fiscal stability, and managed to implement pension reforms (largely by turning the national pension system into a defined-contribution plan) that put pensions on a sound financial footing while still guaranteeing a decent standard of living in retirement. This is something that the United States has yet to accomplish. In Sweden, conservative and liberal parties have been able to face reality and work together to solve problems that political leaders in the United States only dream of solving. And so, too, has been the case with the problem of decarbonization.

Sweden's success at decarbonization

The Swedish success story in decarbonization is told in Figure 1. Here, Swedish carbon dioxide emissions are given in terms of metric tons of carbon in the carbon dioxide emitted each year, expressed in per capita terms. One metric ton (called a “tonne” for short) is 1000 kilograms, or about 2200 pounds. Carbon is often used in emissions accounting, because it is the carbon in fossil fuels that is moved to the atmosphere when fuel is burned – the oxygen in carbon dioxide comes from the atmosphere. Carbon dioxide is about 27 percent carbon by weight.

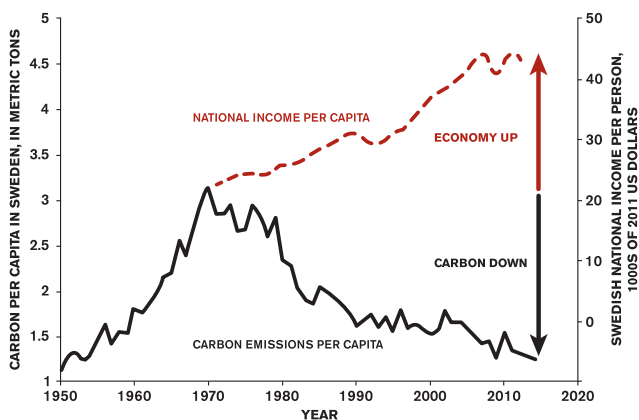


Figure 1. Swedish per-capita gross national income (dashed red line) and annual per-capita CO₂ emissions (expressed as metric tons of carbon) over time. The per-capita income is based on constant United States dollars as of the year 2011, computed on the basis of purchasing power parity. Swedish emissions data is courtesy of the Carbon Dioxide Information Analysis Center (<http://cdiac.ornl.gov>) and the Emission Database for Global Atmospheric Research (<http://edgar.jrc.ec.europa.eu/>). Swedish national income data courtesy of World Macroeconomic Research (<http://macroeconomics.kushnirs.org/>).

Before 1970, carbon emissions were growing exponentially, as is typical for a rapidly industrializing country and is still the case for China and India. Emissions peaked abruptly in the early 1970s, however, when Sweden put into place a number of energy policies in response to the oil shocks of that time. This was initially seen as a matter of national security, and not done primarily for environmental reasons, although environmental considerations could not have been far off the radar screen in the country of Svante Arrhenius – one of the first chemists to win the Nobel Prize, who first clearly drew the connection between fossil fuels and global warming in the early 1900s (Graham 2000). Sweden's emissions have been declining ever since, with precipitous declines in the 1980s when a wave of environmentally motivated decarbonization incentives began to be put into place. For example, the Swedish pulp and paper industry increased its output by 18 percent while reducing its carbon emissions by 80 percent between 1970 and 1990. Currently, Swedish per capita emissions are about as low as they were in 1950. At about 1.25 tonnes annually per person, they are about the same as the global average, and far below the US figure of 4.5 tonnes per capita.

One of the ingredients in the Swedish success story is the early introduction of carbon taxes (Andersson and Lövin 2015). The strong scientific consensus underpinning concern over human-caused global warming is well known, but economists of all political persuasions are almost equally united behind the principle that carbon taxes are the most economically efficient way to bring down carbon dioxide emissions. Sweden introduced one of the world's first carbon taxes in 1991, at a rate of about \$110 per tonne of carbon. The tax was introduced as part of a package of tax reforms that eliminated most other forms of energy tax. These reforms partly offset the carbon tax and provided economic incentives to shift to low-carbon energy sources, without mandating what form that shift would take.

Industrial energy use was taxed at half the standard rate to prevent “leakage,” whereby industrial production would simply move to countries where the cost of emitting carbon is lower. (Later, after the European Union emissions trading scheme was put into place, industries covered by that scheme were exempt from domestic carbon taxes.) In recent years, the Swedish carbon tax increased to over \$500 per tonne of carbon, and some of the special tax breaks for industry have been reduced. To put this in perspective, the price of carbon under the European Union's emission trading scheme has collapsed due to an oversupply of permits, and has recently traded at under \$30 per tonne, while the price in California's own emissions trading scheme

is around \$50 per tonne, and British Columbia's revenue-neutral carbon tax is about \$30 per tonne.

In Sweden, the carbon tax had its biggest effect on the heating of buildings, where the tax has been applied at its full rate. Residential and commercial energy use is now almost entirely carbon-neutral in Sweden, a remarkable achievement for a country with a harsh Northern climate. A key ingredient to this success is the extensive use of district heating – basically like an electricity grid, but for heat – in high-density regions. The district heating grid allows energy to be fed in from a number of different sources. Biofuels make up about 70 percent of the energy in district heating now, but heat is also fed into the grid from non-recyclable garbage combustion, the recovery of waste heat from server farms, and even from the excess body heat of passengers in the central railway station. Where district heating is not practical, there is extensive use of high-efficiency heat pumps powered by renewable electricity. Heat pumps work through a kind of thermodynamic magic whereby it takes less than one watt of power to move heat energy at a rate of one watt from a colder place to a warmer place. But this magic works best when the “uphill” temperature difference is not too large, and so it plays well in conjunction with geothermal heat storage systems (“bergvärme” in Swedish), which tap into the reservoir of nearly constant temperatures some tens of feet down in the bedrock. This technique has been applied extensively in Sweden, and can be used wherever there is rock to drill into, which is basically everywhere.

Public transit is another area of substantial progress in decarbonization. The Arlanda Express is powered by renewable electricity, and whisks you from downtown Stockholm to distant Arlanda Airport in a mere 20 minutes (an amenity not available between Manhattan and JFK). Streets are populated by various kinds of biofuel and plug-in hybrid buses, and there is an excellent high-speed rail network, largely powered by renewable electricity, ready to take you farther afield. Hydropower is still a major source of renewable electricity in Sweden, but wind power has increased from 0.3 percent of the mix to 8.4 percent in 2014, and that is even before Sweden brings Europe's largest wind farm online.

But carbon taxes are not the whole story. Making buildings carbon-neutral required extensive investments in building energy efficiency, such as low-emissivity triple glazing, insulation, and heat-exchanging ventilation, so as to reduce energy needs to the point where they could be fully supplied by carbon-neutral sources. These efforts have been part and parcel of the retrofitting of much of Sweden's existing housing stock,

not just mandated for new construction. An important collateral benefit is that Swedish homes are much more cozy in winter than the drafty, damp Victorian piles many of us inhabit in Oxford (where I currently ply my profession as a professor of physics).

Even with carbon taxes, efficient buildings, and district heating, the necessary infrastructure did not miraculously come into being as a result of the invisible hand of the market, but required encouragement through building codes, judiciously applied regulation, and a certain amount of direct government investment. Likewise, it was important that an increasingly renewable-powered public transit and high-speed rail infrastructure stood ready to take over from automobiles. Even though most of this network is *operated* by private enterprise, substantial forward-looking public investments were required to bring them into being.

Nuclear power also provides low-carbon electricity, and Sweden's nine nuclear power plants produce 40 percent of the electricity used or exported. Nuclear power is not loved by the Green Party in Sweden, but nonetheless the 1980 decision to phase out nuclear power was repealed in 2010, in recognition of the fact that low-carbon replacements would not be available in time. Four of the older plants are scheduled to be closed in 2020, which will take 2.7 gigawatts of base load power off the grid, but this will be easily replaced by the expansion of wind energy in connection with abundant pumped hydropower storage.

Sweden's cautious approach to nuclear power stands in contrast to Germany's foolish decision to abruptly shutter their nuclear power plants, which has resulted in a significant setback to their progress on decarbonization. The retention of nuclear power in Sweden also reflects recognition of the fact that large-scale hydropower, while benign to the climate, is far from environmentally benign generally (Leslie 2006). For example, when the Suorva dam was built in the far north in the 1920s, it shut off Europe's largest waterfall, and subsequent expansions of the reservoir destroyed the diverse aquatic ecosystem that used to exist in the valley flooded by the artificial Akkajärvi lake today, and displaced thousands of indigenous Sami people from their traditional way of life. There is little stomach in Sweden for further expansion of large-scale hydropower, and compared with the environmental disaster of large-scale hydropower (to say nothing of coal), nuclear really does not look too bad.

So, has all this emphasis on decarbonization trashed the economy? Figure 1 tells that story as well. Swedish per capita gross national income (GNI) has doubled in real terms since 1970, with steady growth interrupted only by the same periods of global recession that have

plagued other countries. And GNI, like its close cousin GDP, does not provide a full measure of quality of life, as many of the social amenities that make Sweden such a good place to live are not reflected in such economic statistics. In the absence of a “control Sweden” run without climate-smart policies, it is difficult to say how rapidly the GNI would have grown without such policies, but there is no credible evidence that climate and energy-smart policies have been a significant drag on the economy. On the contrary, it is likely that these policies benefited GNI growth, by reducing the cost of energy imports, providing high-quality employment, and fostering the development of exportable technologies. But regardless of the question of what the Swedish economy would have done in a hypothetical world, the real world demonstrates beyond doubt that a country can grow its economy and provide a very high standard of living for its people while simultaneously reducing its carbon emissions substantially.

Toward net-zero emissions

As remarkable as Sweden’s achievement at decarbonization is, it is not enough. The reason is that the geological processes that ultimately remove excess carbon dioxide from the atmosphere operate exceedingly slowly, over a timescale of tens or even hundreds of thousands of years. That means that as long as there is any net emission of fossil-fuel carbon dioxide remaining, the gas will inexorably continue to accumulate in the atmosphere and the Earth will continue to warm. Reducing the carbon emission rate is an unambiguously good thing, because it reduces the rate of warming, but to halt warming, the world needs to eventually achieve net-zero emissions. The longer it takes to reach net zero, the higher the temperature our descendants will be stuck with into the indefinite future. Sweden is one of very few countries to have undertaken a definite commitment to achieve net-zero emissions, having pledged to reach that goal by 2050. As virtually all remaining Swedish carbon dioxide emissions come from liquid fuels used in transportation (especially private automobiles), getting to net zero will primarily require retooling the passenger car fleet to run on some combination of electricity and biofuels.

Carbon budgets provide the key measuring stick that tells us how fast we need to get to net-zero emissions. The amount by which the world warms is very nearly linearly proportional to the total amount of carbon burned into the atmosphere from the beginning of the Industrial Revolution to the time that net-zero emissions are achieved, at a rate of about 2 degrees C

for each trillion tonnes of carbon burned (see Trillionthtonne.org).

Some commentators who have positioned themselves as opponents of efforts to reduce carbon dioxide emissions – such as former US Undersecretary of Energy Steve Koonin – have tried to use the need to get to net-zero emissions to justify their position. Their argument goes that reducing emissions will not cool the Earth, so there is no point in doing anything other than adapting to the inevitable warming. This argument was put forth in a recent *New York Times* op-ed (Koonin 2015), compounding displays of ignorance about climate in a lengthy *Wall Street Journal* essay by Koonin published last year (Koonin 2014; see response in Pierrehumbert (2014)).

This fallacy rests on a fundamental misunderstanding of the way carbon budgets affect climate. First, although reducing emissions will not significantly reduce temperature below its current level, it will make the *future* a lot less warm than it otherwise would have been – although current temperatures are already irreversibly baked in, there is still a chance to avoid additional warming. Further, if we never achieve net-zero emissions, the Earth will continue to warm indefinitely, until unquestionably fatal conditions prevail for large parts of the Earth’s human population and natural ecosystems. The question is not *whether* we need to achieve net-zero emissions, but how fast we can do it. Reducing the rate of emissions growth is merely the first step toward net zero, and the sooner we make a start the better.

Another fundamental misconception in Koonin’s (2015) *New York Times* op-ed is the claim that keeping a gigatonne of carbon out of the carbon budget has fewer climate benefits when done at a time (such as now) when the cumulative carbon emissions are already large. Here, Koonin is confusing atmospheric concentrations with emissions, in a classic “stock-vs-flow” fallacy – analogous with the confusion between the amount of water in a bucket (the “stock”) and the rate at which the bucket is being filled (the “flow”). It is true enough that increasing the atmospheric concentration of carbon dioxide by one part per million has less warming effect now that concentrations are 400 parts per million than it would have in preindustrial times when concentrations were only 280 parts per million. However, because of chemical limitations on carbon uptake by the oceans, as one adds more and more carbon dioxide into the atmosphere, the proportion that *stays* in the atmosphere (rather than disappearing into the ocean) increases, and this causes the atmospheric concentration to increase faster than

a straight-line prediction as one adds more carbon to the system. This by now well-known effect cancels out the diminishing-returns effect of carbon dioxide concentration on warming, leading to a linear relation between cumulative carbon emissions and warming. A gigatonne of carbon emitted now causes just as much warming as it would have if emitted in preindustrial times.

If the world is to keep warming below 2 degrees C, then net carbon emissions must be kept below a trillion tonnes by the time net-zero emissions are achieved. As we have already emitted 600 gigatonnes, that leaves only 400 gigatonnes in the carbon budget (subject to the usual uncertainties relating to climate sensitivity). Divided equally among a present world population of 7.3 billion souls, that works out to a net emission allocation of 55 tonnes per person, which provides a benchmark against which to measure each country's progress toward net zero. (Note that this 55 tonnes is not an annual or renewable allocation – it is the total net amount of carbon that can be emitted per person alive today over all future time, without breaking the 2-degree limit. That is all there is, and once that allocation is used up, the only choices are to accept greater warming or pray for low climate sensitivity).

Dividing up the remaining carbon budget provides one way of looking at each nation's fair share of emissions, though an argument could be made in favor of taking into account past emissions as well; by that measure, the United States and Europe already used up their fair share of emissions long ago, and by rights owe the developing world compensation for past overuse of the atmosphere as a dumping ground for carbon. But even if we write off past emissions entirely, and just look at the equal allocation of the remaining carbon budget, Sweden could only continue emitting at its current rate for 44 more years before using up its remaining fair share, so it would need to reach net zero by then. If emissions were ramped down linearly to zero, then Sweden would have 88 years to achieve that goal. That makes Sweden's commitment to reach net zero by mid-century seem entirely in line with national responsibility, and indeed generous.

In contrast, at the current rate that the United States is emitting carbon, our fair share would be used up in about a decade, and it would be necessary to attain net-zero emissions in two decades if a linear ramp-down were to begin today. While the United States squandered 40 years dithering and denying the problem (and much of the rest of the developed world at least dithered), Sweden just got down to the nitty-gritty work of decarbonization and did not wait to see what the rest of the world was doing. If more of the rest of the world

had followed Sweden's example, we would have an easy time keeping warming below 2 degrees C. As it is, even if all nations fulfill the commitments they made before and during the COP21 Paris climate negotiations, we will be hard-pressed to keep warming in 2100 under 3 degrees C, without even factoring in the additional time beyond then needed to get to net zero. It is a tragedy that most of the world wasted the last 40 years, but there is no making up for that. The key thing now is to not waste another 40 years, as the consequences for the climate would be so dire as to pose a truly existential threat to human society and natural ecosystems.

But what of China, and indeed the rest of the developing world? Don't they need vast amounts of cheap fossil-fuel energy to lift their people out of poverty? The telling point here is that Chinese per capita carbon emissions, at nearly 2 tonnes per person, are well in excess of Sweden's 1.25 tonnes and even in excess of the European Union average, yet China has a GDP per capita of only \$6807 – not quite a sixth of Sweden's. That means that China could halve its per capita emissions while at the same time becoming as rich as Sweden.

The Chinese economy contains a vast amount of inefficiency waiting to be mined out. Transitioning to a cleaner energy economy would at the same time go far to address the deadly pollution problems that currently plague the Chinese people. Perhaps this is why China has proved willing to make commitments to emission reduction that, in terms of carbon saved, dwarf what the United States has been willing to do – despite the fact that the moral burden of decarbonization by any measures should fall far more on the United States than on China (Pierrehumbert 2013). The lesson for the poorer countries of the developing world, such as India and the African countries, is even clearer: rather than first catching up to China in terms of pollution and then tearing it all down to replace with cleaner technology, wouldn't it be better to skip the intermediate stage and leapfrog directly to a low-carbon clean energy future?

The way forward

The Swedish example demonstrates that a combination of well-crafted public policies and private ingenuity can lead to a future that is both low-carbon and prosperous. This is not to say that every country will be able to duplicate that feat by following the exact mix that was successful in Sweden. Given Sweden's abundant hydro-power and biomass relative to its population, the exact

mix of policies and energy sources needed to solve the problem will differ from country to country. Some will have more wind, solar, and nuclear in the mix than Sweden, and some nations rich in fossil fuels may find it advantageous to employ more natural gas in conjunction with carbon capture and storage.

The point is that this is nothing to be afraid of. It is sometimes made out that revamping global energy systems is a task of monumental proportions, but in fact global energy expenditures are only 10 percent of world GDP and falling, as more and more of the economy becomes based on information rather than energy. This is not a small task, but it is not intrinsically worse than the other major challenges that society has faced and surmounted. And meeting this challenge does not require doing without, or suffering in the cold and dark. It does not require any terrifying revamping of the world economic order. What it does require is a whole lot of boring, unfrightening, and largely routine engineering and construction. It is time to stop quivering in our boots in pointless fear of the future and just roll up our sleeves and build it.

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Notes on contributor

Raymond Pierrehumbert holds the Halley Professorship of Physics at the University of Oxford, and is a frequent visitor to Sweden. During the academic year 2014–2015, he held the

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