Energy Consumption in the Developing World in 2030

What would it mean to the world if we were to discover that developing countries may use 57% more energy in 20 years than previously calculated? Or that the world as a whole may use 30% more energy in 2030 than we are planning for now?

Energy issues have periodically been the subject of intense debate, especially following the first oil supply shock in 1974. Questions regarding peak oil, energy independence, climate change, pipelines and fracking have passed from technical discussion to political issues to policy issues for the general public worldwide. Newspaper stories from Djakarta to Washington routinely explore key issues—will there be enough energy for a country or region's energy needs, will it be affordable and will it be environmentally friendly enough to safely use?

The possibility that the world as a whole has been underestimating the amount of energy needed in the medium term future is disturbing. How many extra nuclear power plants, new oil discoveries, wind turbines, dams and solar panels would we have to build to satisfy this unanticipated demand? Will we have to remain addicted to fossil fuels to keep the lights on and the motors running? Will there be additional supply shocks? Will this change political strategies and alliances?

By looking at historical consumption of countries that have already developed at the same rate as those racing towards developed status today, we infer that energy consumption for rapidly developing countries such as India and China will surpass official projections and contribute to a much higher level of energy consumption than estimated by either the U.S. Department of Energy's Energy Information Administration or the International Energy Agency.

Table 1: Various Projection Totals Of Energy Consumption in 2030

	US Dept. of Energy, Energy Information Administration *(Sept. 2011)*	Independent or National Projections	Paired With Countries With Similar Backgrounds
China	162.7	223	246.6
India	30.4	63.6	84.57
Indonesia	8.99	16.8	16.72
Brazil	16.4	22	42.54
Total 4 Countries	**218.49**	**325.4**	**390.43**
Total 125 Countries (including those above)	**438.86**		**676.34**
Total World	**721**		**951**

Background

This world of 7 billion people is in the process of preparing for the next 2 or even 3 billion humans who will join us on this planet over the course of this century. For most of us, that preparation consists of taking care of our families and preparing the next generation to do well in an uncertain environment. For those in public service, the preparation also includes making sure their city, region or country is doing more than just surviving the current crises and perennial problems.

For a very few, this preparation centers on predicting the future—how many of us will there be, how the economic condition of the world will enable or handicap their development, who will be advantaged or disadvantaged by changes in the human population and their effects on this world.

This story is about forecasting energy consumption, which forms the basis for both educated guesses and confident predictions about GDP, development and public health. Energy is one of the base assumptions for what we think will happen. Energy, along with fresh water, are limiting factors—if we have enough of them, we can make other plans. Without adequate supplies, planning will be based on shifting sands.

Despite this, there really aren't that many organizations making careful forecasts of energy consumption in the future, especially compared to the number of organizations that try to estimate economic growth. It is true that there are many companies, think tanks and government departments that are very interested in how much of what type of fuel will be available, where they can find it and how much it will cost. But once it's out of the ground or into the fuel tanks and electricity grids of the world, their interest declines sharply. Supply is very important to these people. Consumption, not so much.

One exception to this is the U.S. Department of Energy's Energy Information Administration. It was formed in 1977 as a response to the oil supply shock of 1973. It is the U.S.'s go-to source for data and information about energy use worldwide, as well as America. About 400 people work for the EIA and it has an annual budget close to $100 million. Perhaps because they are independent of political influence, they have a pretty good track record. They are highly respected and deservedly so.

(The other major provider of statistical information about energy use is the International Energy Agency, an inter-governmental organization set up in 1974 for pretty much the same reason as the EIA—to provide information to better deal with situations like the oil crisis that had just concluded. But because they were formed as a policy tool to deal with oil supply disruptions, their numbers (which are not as easy to access as their American counterpart's) are not always considered impartial and are not as widely used. For this article I focus on the U.S. Department of Energy's Energy Information Administration's figures.)

The end result of what both organizations do is hugely important to planners for the future. Those who are deciding where and how many power plants, dams, roads and wind turbines to build, how many roads, planes, pipelines and ships will be needed and for those estimating how to budget for provision of energy to tomorrow's populations. Two million people download data from the EIA's website every month.

I am one of them. I've been an energy analyst in the past, one of those who write incredibly long reports about things like 'The Global Market for Energy Efficiency 2009-2014' (sadly, an actual title). I now work as a market researcher for a solar power company. And this story is about how I have come to believe that the DOE's EIA may be wrong about something very important—their estimates of how much energy the developing world will consume over the next 20 years.

The Energy Information Administration, an organization I greatly respect and whose numbers I use almost daily, projects that the world will use about 721 quadrillion BTUs in 2030, a staggering amount of energy and a large increase over the 500 'quads' the world consumed in 2010. But I think the world will use closer to 963 quads in 2030, primarily because the developing world will develop faster than estimated by the EIA. I hope to show you why I have come to believe this in this article.

Perspective

Sit in a darkened room and light a wooden match. Watch it burn. You may not feel the heat. The light it emits may not create more than a glow around your hand. You may or may not smell the slight sulphur tang, and the trail of smoke will surely be tiny. When it burns out, you have consumed a unit of energy called a British Thermal Unit, or a BTU.

Technically, a btu is the amount of energy required to heat a pint of water from 39 to 40 degrees Fahrenheit. But a wooden match burning in a darkened room provides a more concrete image. Let's try for another concrete image:

Picture a train car, filled with anthracite coal. Let's be picturesque and go back to the 1970s, when smaller and weaker train cars held about 100 tons of coal. Back then, they typically formed trainsets of 100 cars, each holding 100 tons of coal, for 10,000 tons in total. One of the longest trains in history was on the Sishen-Saldanha Railroad in South Africa, operated in August of 1989. It used 7 diesels and 9 50-kV electrics to move 660 cars, a tank car, and a caboose. It traveled 535 miles in 22 hours and 40 minutes. It took a whopping 4.3 miles to stop the train. The train was over 6 miles long.

Now, picture a longer train. Imagine the longest train ever conceived of—one with 378,000 cars loaded with anthracite coal. Although coal cars vary in length, you can often estimate about 100 cars to a mile. So picture a train 3,780 miles long—the distance from Dublin to Kandahar, or from Albuquerque New Mexico to Anchorage Alaska. It is 1,500 miles longer than the tar sands oil pipeline from Alberta to Texas that is being so vigorously disputed as I write this in November of 2011.

If you burn all the coal in that train—each of the 100 tons in each of the 378,000 cars—you will have consumed 1 quadrillion BTUs. And we give the energy liberated from that incredible quantity of coal a cute little name. We call it a 'quad.'

In 2010, the world consumed energy equivalent to the coal loaded onto 500 of those trains. The world as a whole consumed 500 quads. And despite progress in getting power from nuclear, hydro, wind and solar, in actual fact 143 of those imaginary trains filled with coal were not imaginary—they actually *were* filled with coal.

In this article you will see me casually tossing around descriptions of large quantities of quads, the same way a drunken poker player might throw $5,000 chips around in a casino, as if he has completely forgotten their real value. At the conclusion of this I will try and bring our conversation back to reality, but in the meantime, when you see me writing about a quad here and a quad there, remember that each quad represents a train of 378,000 cars, each filled with 100 tons of anthracite coal. I hope you remember it—I find it somewhat difficult to forget.

Projections of Future Energy Consumption

Both the U.S. EIA and the international IEA project robust growth for energy consumption over the next 20 years. However, their definition of 'robust' pales alongside the real-world growth experienced by developing countries in the wake of globalization. The EIA projects energy consumption in the developing world to grow at 2.2% annually (a figure they raised to 2.3% in September of 2011). What I hope to show is that, although that may be true for parts of the developing world (Central and Eastern Europe, parts of Latin America and some oil-rich countries that are already consuming as much as they ever will), the parts of the developing world that are also growing rapidly will see their energy consumption rise by 5% per year. At which point the conversation transcends energy and even economics. Energy growth at that pace in Asia and Africa then becomes a political issue. Several political issues, actually.

It's unfair, of course. The vast energy consumption by the rich world is now taken for granted in this discussion, simply because it has stabilized. Both the EIA and the IEA believe that energy consumption by rich countries will grow by 0.5% annually over the next 20 years. But that flat line is at the top of a vast quantity of coal, oil, natural gas, nuclear power, hydroelectric power and trace amounts of wind and solar that combine to bring us a life we take for granted, and which we will go to great lengths to protect. We don't want your territory and we're willing to pay for your oil and natural gas—but don't even think about pulling the plug on it. The principal policy question then becomes: now that we've got ours, can the world permit the have-nots to get theirs?

The EIA periodically projects future energy consumption for the world, and splits out OECD and non-OECD countries for detailed reporting. In their report, *International Energy Outlook 2010*, the section *World Energy Demand and Economic Outlook* uses a compound annual growth rate (CAGR) of 1.4% per year for increased consumption of energy worldwide (Remember that in 2011 they increased their projected totals by 5%). Using a variety of different methods and other reported figures for GDP growth and energy consumption, I will try to show that this figure is too low and offer a range of possible values that may be more useful for planners, politicians and other stakeholders making decisions based on future energy consumption.

At the heart of my higher projection of energy use in the developing world is a very simple observation: Development is a path travelled by many countries, and different countries are at different stages of that journey. By comparing future energy consumption for one country in the developing world to energy consumption in countries that have been at a similar stage in the recent past, I hope to offer a new perspective that may serve to anchor estimates to realistic boundaries.

At this point I should point out that others have remarked on the discrepancy between projections and performance as far as energy use is concerned. However, most of the discussion has been about China. This is natural, as China has outperformed everybody's expectations and is very hard to ignore. But the fact is that what is happening in China is also happening in Indonesia, the Philippines, Brazil and India, and many other places as well. China is not the only country using energy faster than expected.

Caveats

Although I think this research is persuasive, the scope of the topic is wide enough for alternative assumptions, calculations and conclusions. Because the EIA's reports are widely used and often cited as among the most credible forecasts, the topic is important enough to take seriously, and if this theory is correct, it would be of some use to find this out now, rather than later.

As discussed below, the choice of 'pair countries' used for comparison is key to the success of this exercise. Interested readers can and probably should come up with alternative lists. It is clear that some of the variation between my findings and EIA projections could be explained by inappropriate pairing of two countries. Should that prove to be the case, I would welcome the opportunity to improve on what s found here and will be pleased to note it in reworked pieces in the future.

I should also note that although I call the figures here EIA projections, I did not find EIA projections at the country level. I used their global CAGR% for non-OECD countries. (I used the 2.2% CAGR from their 2010 report. The EIA raised that to 2.3% in September of 2011, when they also raised their forecast of global energy consumption to 721 quads in 2030.)

Perhaps most importantly, this study is comparing figures and projections from separate databases, something that should give readers pause. Although I think that one of the strengths of this study is that it actually uses fewer data sources and more historical figures than competing estimates, it remains true that differences in data collection procedures and analysis may have contributed to incorrect findings in this study.

As I mention elsewhere, I consider this the start of a conversation, not the conclusion. It is for this reason that I have tried to maintain a casual—conversational—tone while writing this, for which I ask the indulgence of academics more used to a different style of presentation.

Sources

Sources used throughout this report are:

- Projected Population and Growth Rates in Population for Baseline Countries/Regions 2000-2030, Updated: July 20, 2010 based on June 2010 Census Bureau Update, Source: U.S. Census Bureau, International Data Base (http://www.census.gov/ipc/www/idb/) organized into ERS/USDA Baseline countries and regions, curated by USDA ERS
- World Per Capita Energy Consumption 1980-2006, International Energy Annual, 2006, U.S. DOE EIA, Table E.1c found at http://www.eia.gov/iea/wecbtu.html
- Real Projected Gross Domestic Product (GDP) and Growth Rates of GDP for Baseline Countries/Regions (in billions of 2005 dollars) 2000-2030, Updated: 12/22/10 Source: World Bank World Development Indicators, International Financial Statistics of the IMF, HIS Global Insight, and Oxford Economic Forecasting, as well as estimated and projected values developed by the Economic Research Service all converted to a 2005 base year. Curated by USDA ERS
- EIA Total Primary Energy Consumption, 2006, http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=44&pid=44&aid=2
- EIA projected growth rates for primary energy consumption calculated at 2.2% CAGR

The worksheet used is available in Excel format upon request from the author, at thomaswfuller@gmail.com

Research Findings

I looked at projected energy consumption totals for 125 countries that are not part of the OECD and have populations of over 1 million. In 2010, these 122 countries had a combined population of 5.86 billion, and a combined GDP of $21.3 trillion. By 2030, they will account for 7.17 billion people and their combined GDP is projected to be $41.17 trillion.

In 2006, these countries consumed 251.16 quads. The EIA projected (in 2010) that in 2030 these countries will consume 438.86 quads, a CAGR of 2.26%. My methodology indicates that these countries may well consume 672.33 quads, a CAGR of 4.02%.

That would permit the inference that global energy consumption will be closer to 951 quads than the EIA's 2011 projection of 721 quads in 2030. The difference between the EIA's estimate and ours—233.47 quads—is greater than the current energy consumption of the U.S. and China combined. (I get to that total by assuming that EIA projections are accurate for the OECD at 278.7 quads.)

What drives the difference? For 106 of the 125 countries, we paired these countries with other, similar, countries that had preceded them along the development path, and used historical figures of per capita energy consumption and per capita GDP to provide new figures. For the other 19 countries we were unable to find suitable pairings and took the EIA estimates instead.

The EIA calculated a 2.2% CAGR for the developing world in their 2010 report (and increased that to 2.3% for their 2011 update). Our calculations, when including the countries where we accepted the EIA estimates, showed a CAGR of 4.02%. For the countries where we were able to find a paired country as an analogue, the CAGR was higher, at 5.07%.

The countries where we were unable to find an adequate 'paired' country had a 2006 energy consumption total of 33.9 quads and are projected by the 2010 EIA report to consume 58.3 quads. They included major energy producers such as Saudi Arabia, Venezuela and the United Arab Emirates, countries that are already consuming very large amounts of energy per capita. They also included high income states such as Taiwan and Singapore. In both cases we felt that we were unable to determine if further development would result in higher per capita energy consumption.

Thirteen of the countries we paired with examples yielded CAGR figures lower than the EIA. Almost all of those countries were Eastern or Central European states, including Russia. Their energy consumption in 2006 was 41.9 quads, and the EIA projected (in 2010) that their 2030 consumption would be 56.2 quads. Our estimate for 2030 energy consumption for these countries was 50 quads.

The BRIC countries (Brazil, Russia, India and China) explain much, but by no means all of the discrepancy between the EIA's projections and our own. According to our projections, those four countries will account for 405.36 of the 636.2 quads from this set of developing countries. The EIA had projected (we infer, from the CAGR percentages applied to non-OECD nations) 243.2 quads from the BRICs.

It Starts With China…

Again, applying the 2.2% CAGR percentage the EIA assigns to the developing countries, they project that China will consume 162.7 quads in 2030. (Like the U.S., China consumed 100 quads in 2010.) I think that China will consume 246.6 quads in 2030. The difference—83.9 quads—is enough to change everyone's vision of the future, if it is true. China has put forward an incredible plan for growth of its energy infrastructure. If it is based on the highly respected EIA projections, it may not be sufficient for their needs.

China's annual growth in GDP from 2000 to 2010 averaged 9.9%.[1] Their consumption of energy grew over the same period of time at a 9.57% compound annual growth rate (CAGR).[2] If they merely maintain that for the next few years, the EIA's projections are bound to fall short of their projected totals.

The EIA in fact is predicting an astonishing slowdown for China's energy consumption over the next 25 years, something that would be as dramatic and profound as their recent growth. As they assume China's economy will continue to grow at a robust rate, this should be explained. As yet, it has not been.

Evidence that the EIA's underlying assumptions in energy projections should be challenged comes from widely reported statistics regarding China's growth. China's energy consumption grew 11.5% in 2010 alone, and they have marked out a path for growth that has energy consumption double between 2010 and 2020.[3] Even if the EIA were broadly correct in predicting a fall-off in China's energy consumption, missing the start of the decline renders their analysis useless for those charged with preparing the infrastructure needed for Chinese children—and ours.

Clearly, over-reliance on CAGR can be a trap, especially when dramatic change is part of a forecast. But for those charged with making plans for the medium term future, it is probably not nearly as important to precisely delineate the rate of change as it is to show broadly correct totals at various points on a continuum. Is there another way of projecting energy consumption that is more closely tied to reality? I think so.

The EIA also breaks energy consumption out on a per capita basis. This is quite useful, as with a bit of cross checking against future populations and projections for GDP, we can analyze, for example, China's projected energy consumption in the future by comparing it to the energy consumption of a country that is at that level of development today. Energy figures used in this exercise come from Table E.1, World Primary Energy, International Energy Annual 2006, updated August 2009, with projected GDP figures coming from the U.S. Department of Agriculture's Economic Research Service. Population figures come from a variety of sources, including the U.N. Population Division and national census offices. Information about the developing countries used as examples for comparison come from a wide variety of sources—including Wikipedia, the CIA World Factbook and Nationmaster.

[1] Countries with the Highest GDP Growth 2000-2010, Global Finance Magazine,

[2] Energy and Environment in China, Table 1, p. 10, Li Junfeng, China Renewable Energy Industry Association, May 2011

[3] Energy Use to Double by 2020, Report Says, China Daily, Nov. 25, 2004

<u>Because the GDP projections used in this study do not extend beyond 2030, I now change our focus on growth of energy and GDP from 2035 to 2030. As almost all of the media coverage given the EIA's projections use their headline 2035 end-dates, readers should note this.</u>

By combining current data on per capita GDP and per capita energy consumption, we can perform an interesting comparison that may provide more accurate projections. More importantly, we are not obliged to provide a date certain for this growth. It doesn't matter if their per capita GDP or energy consumption happens in 2020 or 2040—we can say that when their level of economic development reaches a certain stage, it is quite likely that their energy consumption will be near a value that we can estimate today.

Table 2: China's Population, Per Capita GDP and Energy Usage, 2010 and 2030

China	2010	2030
Population	1.33 billion (China's Bureau of National Statistics)	1.38 billion (U.N. Population Division)
Per capita GDP	$2,802 (2005 dollars, USDA's Economic Research Service)	$10,708 (2005 dollars, USDA's Economic Research Service)
Energy Consumption	100 quads (EIA)	162.7 quads (EIA)

Let's start with China and see how it works. In 2010 they consumed about 100 quads. The EIA projects that to rise to about 163 quads by 2030 (based on Figure 14 of their report showing China as consuming 23.7% of the 739 quads projected for the world). That's a CAGR percentage of 2.47%, higher than their estimated growth rate for the rest of the world—1.4%. But is it high enough? As mentioned above, China's energy consumption grew in 2010 by over 11%, and they look set to match that in 2011.

On a per capita basis, China's energy consumption rose from 29 million British Thermal Units (mbtus) to 56.2 mbtus between 1996 and 2006, the latest date available for examination at the EIA website.

China's per capita GDP is also set to grow, from its 2010 level of $2,802 (measured in 2005 U.S. dollars) to $10,718 in 2030. And during this period, China's population is also projected to grow from its current 1,341,335,000 to 1,393,076,000.[4]

Choice of Pair Countries is Key

Someone who wished to make a political point would find it very easy to use the same methodology chosen here to do so, simply by picking pair countries that would lead to much higher or much lower re-estimates of a target country's future energy consumption.

Similarly, error can arise from ignorance of salient characteristics of either or both the target and paired countries used for comparison and projections. I would personally be astonished if the choices I made in this study could not be improved upon, and repeat my call for suggestions and improvements to the choices presented here.

I did, however, try to use some quality control measures to avoid errors. For example, the key selection criterion was having a pair country with a 2006 per capita GDP similar to the projected 2030 per capita GDP of the target country. As it happens, the average of projected 2030 GDP per capita of all target countries as $7,312 (in 2005 US dollars) and the average 2006 GDP per capita of paired countries was $5,618, a $1,694 dollar difference. So I'm confident I didn't 'cherry pick' paired countries, either consciously or subconsciously, on the basis of choosing richer pairs for target countries than was warranted.

The average energy consumption of the countries I chose as 'pairs' for comparison was 80.86 mbtus per capita in 2006. The same 2006 figure for the target countries I analyzed was 68.36. Hence I feel fairly confident that I didn't overshoot on this metric by much, either. This is also a good indication that the variation I captured was due as much or more to population growth as to development.

Perhaps more drastically, I excluded some countries from my study sample simply because they were not amenable to my choice of methodology. For example, Taiwan is not a member of the OECD, but from both economic and energy usage standpoints, it certainly should be. As I was not certain my approach would be appropriate, I dropped Taiwan from consideration.

But that leaves open the question of whether or not I relied too heavily on per capita GDP for my choices. The primary sources I used for making this decision included The World Bank's database of World Development Indicators (http://data.worldbank.org/data-catalog/world-development-indicators?cid=GPD_WDI), Wikipedia and the CIA World Factbook. I will use the first test case here to try and show how I dealt with other issues in linking target and pair countries.

Starting With a Bad Example

As it happens, Hungary had a very similar per capita GDP to China in 2006. It's certainly not absurd to conjecture that their energy consumption per capita might be quite close to China's energy consumption when it reaches Hungary's level of economic output per capita, whenever that might be.

[4] Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2010 Revision, http://esa.un.org/unpd/wpp/index.htm

Hungary's per capita energy consumption in 2006 was 114.7 million btus. Applying that to China's projected population yields a total of 159.7 quads—and that's far less than the EIA projects.

However, Hungary has been a well-developed nation for a long time, with a stable population and needing little in the way of fresh housing stock or road building, and its population's needs for appliances and cars are for replacement rather than new acquisitions by people joining the middle class for the first time. Hungary is heavily indebted—China is a very large creditor nation. Hungary has completed the transition to a market economy—China still has a long way to go on that score. Hungary's GDP dropped during the recent recession—China's grew strongly. Hungary uses 20% less energy per capita today than in 1985. China uses almost 300% more.

I don't think Hungary is the right pair country to use for China. The same would hold broadly true for other European countries with similar incomes. Is there a better choice for comparison to China?

Apples and Apples

I offer for consideration Oman—a developing country whose population and GDP has grown quickly in recent decades, if not as quickly as China's, and which had a per capita GDP of $11,528 in 2006. Their per capita GDP doubled between 1980 and 2006, showing that development was vigorous and sustained, much like China's. Their energy use has grown even more rapidly than China. Fertility rates are converging rapidly. Life expectancy is identical.

Although much smaller than China, Oman has many parallels, even to the extent of using 5-year plans to steer their economic development. They have spent the last 40 years taking a development path that may not be radically different from what China will be doing in the next 25. Their population growth rate has been similar to what China expects. They have a long coastline, and maritime developments may be similar between the two. Their neighbors have been as touched and troubled as China's. The CIA World Factbook lists many features in common. So Oman in 2006 seems a very good comparison for China in 2030, and far more appropriate than Hungary, primarily due to China's continuing development of basic infrastructure and the number of people moving into the middle class over the next 20 years.

Oman had per capita energy consumption of 177.2 mbtus in 2006. If China's per capita energy consumption were to reach the same level as Oman's, it would total almost 247 quads. Whether China achieves that level of development in 2020, 2035 or 2050 is not significant here; when their per capita GDP approaches $11,500, their energy consumption may be near 250 quads. And as far more analysts make their living projecting financial trends than energy consumption (and have far more at stake), we would expect to see fairly accurate projections of when China would arrive at that point. If the EIA has their GDP figures right, it will be in 2035. The Price Waterhouse Coopers study mentioned earlier predicts that China's GDP will grow more quickly (at a 6.3% CAGR). If that's correct, it would happen in 2032.

We should look at one more point before expanding our examination to other countries. Is it realistic to think that China actually can provide adequate energy to achieve the increase demanded by their rising GDP? After all, we are talking about a rise from 56 mbtus per person to 177 mbtus in as short a period as 20 years.

It would be nice if history provided some examples of that happening in non-island countries (island countries frequently have wild swings in energy consumption for a variety of reasons, usually stemming from dramatic changes in the primary fuel sources used).

There are several—the states comprising the former Yugoslavia increased per capita energy consumption from 77 mbtus to 174 between 1980 and 2006, and Iceland went from 250 to 348. And a number of countries either doubled (Turkey, Hong Kong) or even tripled (Malaysia) per capita energy consumption during the same period. And, as luck would have it, Oman doubled its energy consumption and per capita GDP between 1980 and 2006. There is also one other country that tripled its energy consumption in that time frame—China went from 17.6 mbtus per capita in 1991 to 56.2 in 2006. So it can be done.

Few people think that China will grow at the same rate it achieved over the past few decades. Indeed, very few developing countries—actually, *no* developing countries—have an unbroken streak of continuous growth at high levels for the fifty year period that we're referring to for China. But then, very few believed that China could maintain this high rate of growth over the past three decades…

Table 3: Various Projections For China's Growth in Energy Consumption

Scenarios for China Energy Consumption as discussed above	**China's projected energy consumption in quads when per capita GDP reaches $11,500**
EIA's current projection for 2030	167
Lawrence Berkeley Laboratory (3.26% CAGR)	223
China matches Oman's per capita energy consumption in 2006 (177 mbtus per person per year)	246.6

…But It Holds True Throughout the Developing World

India

From an energy standpoint, India today can quite accurately be described as being where China was in 1980. In that year, China's per capita energy consumption was 17.6 mbtus. In 2006, India's was 15.9, having tripled from the 5.9 mbtus per capita it consumed in 1980. It desperately needs the same level of infrastructure build-out that China has been engaged in since Deng Xiao Peng declared a new era for China in 1978.

Table 4: India Population, Per Capita GDP and Energy Usage, 2010 and 2030

India	**2010**	**2030**
Population	1.22 billion (UN Pop. Div.)	1.52 billion (UN Pop. Div.)
Per capita GDP	$965 (2005 dollars, USDA's Economic Research Service)	$3,309 (2005 dollars, USDA's Economic Research Service)
Energy Consumption	21 quads (EIA)	37.6 quads (EIA)

Although India faces obstacles to growth, such as red tape, corruption, illiteracy and more, China did too. Although India's per capita GDP doubled between 1998 and 2010, growing by 6.4% annually, the end total--$965 per capita—was a third that of China in the same year.

Projections through 2030 show India's per capita GDP reaching $3,309, which is very close to Thailand's per capita GDP today. And the EIA projects India's energy consumption to reach 37.6 quads by that time, up from 20.5 quads in 2010, a CAGR of 2.39%.

However, a report titled Integrated Energy Policy, Report of Expert Planning Commission[5], predicts an annual increase in demand (not production—they are not certain India can provide for its energy needs) of between 5.2% and 6.1%. And this is an important point. China has the money to import energy. Some of the countries examined below are net exporters of energy and can divert energy supplies to domestic use as demand grows. This may not be as viable an option for India over the next two decades, creating a latent and unmet demand for energy that could surge if the economics of energy changes and leave hundreds of millions in an energy-starved situation.

Once again, GDP projections seem oddly disconnected from projections of energy consumption. In an extremely poor country with very large needs for infrastructure, housing, roads, and tens of millions of people eagerly waiting to buy cars to drive on those roads, while per capita GDP is projected to triple, per capita energy consumption is not even expected to double. The rate of growth is actually expected to slow down. India's per capita energy consumption had a CAGR of 4% between 1980 and 2006. Any slow down in the growth of energy consumption will be happening as India's population grows, overtaking China as the most populous country—in 2030.

To put it in perspective, the EIA projects that India, with a 2030 population of 1.52 billion and a per capita average GDP of $3,309, would use about the same amount of energy as did North Korea in 2007.

Table 5: Various Projections For India's Growth in Energy Consumption

Scenarios for India's Energy Consumption as discussed above	**India's projected energy consumption in quads when per capita GDP reaches $3,309**
EIA's current projection for 2030	37
Integrated Energy Policy, Report of Expert Planning Commission (midrange 5.7%)	63.6
At Thailand's equivalent per capita GDP and energy consumption levels (56.2 mbtus per person per year)	84.57

Indonesia

Like India, Indonesia has grown dramatically in recent decades, and like India it suffers only by comparison to the astonishing performance of China. Indonesia's energy consumption grew 315% between 1980 and 2001 and has continued to grow since then, reaching a total of 5.6 quads in 2010.

[5] Integrated Energy Policy, Report of Expert Committee, Planning Commission, 2008

If it maintained that level of growth through 2030, Indonesia would consume 17.64 quads, far more than the 8.7 quads the EIA projects. And the Indonesian National Energy Council predicts just that—a tripling of demand by 2030.[6]

Table 6: Indonesia Population, Per Capita GDP and Energy Usage, 2010 and 2030		
Indonesia	**2010**	**2030**
Population	243 million (CIA World Factbook)	286 million (World Bank
Per capita GDP	$1,621 (2005 dollars, USDA's Economic Research Service)	$4,104 (2005 dollars, USDA's Economic Research Service)
Energy Consumption	5.6 quads (EIA)	8.7 quads (EIA at 2.2% non-OECD rate)

Indonesia's situation is complicated by its situation as an energy exporter (it is the world's largest exporter of coal, mostly to China), which means that existing stocks of energy supplies can be quickly converted to domestic use if required.

If Indonesia were to consume energy at the same per capita rate that Thailand does today when it reaches the same level of per capita GDP, it would be 16.72 quads, almost 60% more than the EIA projects.

However, if there is a short list of candidates for heroic performance in GDP growth among the developing countries, Indonesia must surely be on it. They are the world's largest exporter of coal. The World Bank predicts growth for 2011 and 2012 at over 6%, and over the past decade the middle class has grown to 56% of the population, normally a sign of intensified energy consumption.

Table 7: Various Projections For Indonesia's Growth in Energy Consumption	
Scenarios for Indonesia's Energy Consumption as discussed above	**Indonesia's projected energy consumption in quads when per capita GDP reaches $4,104**
EIA's current projection for 2030	8.99
Indonesian National Energy Council	16.8
At Thailand's equivalent per capita GDP and energy consumption levels (57.9 mbtus per person per year)	16.72

Brazil

One of the fastest growing countries in the world is Brazil. It has a population of 191 million, and its energy consumption reached 10.6 quads in 2009. In 2006, energy consumption was 51.2 mbtus per capita. Brazil's energy consumption grew at 3% per year between 1990 and 2010.

[6] High Economic Growth and Energy Challenges, Jakarta Post, 1.21.11, http://www.thejakartapost.com/news/2011/01/21/high-economic-growth-and-energy-challenges.html

Table 8: Brazil Population, Per Capita GDP and Energy Usage, 2010 and 2030		
Brazil	**2010**	**2030**
Population	191 million (Brazilian Census)	240 million (UN World Population Prospects)
Per capita GDP	$6,010 (2005 dollars, USDA's Economic Research Service)	$12,681 (2005 dollars, USDA's Economic Research Service)
Energy Consumption	10.6 quads (EIA)	16.4 quads (EIA at 2.2% non-OECD rate)

Brazil's Energy Planning Company EPE predicts that the country's energy consumption will rise 3.7% annually, to 21.2 quads by 2030[7]. This is roughly in line with the Brazilian National Energy Plan, which forecasts a rise to 22 quads by that date.[8] Like Indonesia, Brazil has access to large supplies of energy, ranging from hydroelectric and ethanol at the greener end to vast oil deposits offshore. While India may face constraints on meeting the energy demand of its people, Brazil and Indonesia will not.

Pairing Brazil up with another developing country leads us back to Oman, which had, as noted above, per capita GDP of $11,528 (in 2005 dollars) in the year 2006, close to the per capita GDP projected for Brazil in 2030. Again, their per capita energy consumption that year was 177 mbtus. If Brazil's population in 2030 does indeed reach 240 million and they do follow a pattern of consumption similar to Oman's that would result in the much higher total of 42.54 quads.

Table 9: Various Projections For Brazil's Growth in Energy Consumption	
Scenarios for Brazil's Energy Consumption as discussed above	**Brazil's projected energy consumption in quads when per capita GDP reaches $12,681**
EIA's current projection for 2030	16.4
Brazil's National Energy Plan	22
At Oman's equivalent per capita GDP and energy consumption levels (177.2 mbtus per person per year)	42.54

[7] NUCLEP, Government Plans to Raise Between 4 and 6 Nuclear Plants by 2030, http://www.nuclep.gov.br/en/news/government-plans-raise-between-4-and-6-nuclear-plants-2030

[8] Methodology for Procel Edifica, Terms of Reference, Sept. 2011, https://docs.google.com/viewer?a=v&q=cache:Cmi4groSAscJ:www.ukerc.ac.uk/support/tiki-download_file.php%3FfileId%3D1843+brazil+energy+consumption+2030&hl=en&gl=us&pid=bl&srcid=ADGEESjpcS2XtGdZHtxv0GlPqLpuOfRX_BzzvXimqwzyMgo-9dOum2wKRWFAtqRTQczkP_flMdckwNg6oxSYH0Xtq-KLlp5caR2Uemq6YjtNuQTL_44ags-lc9lzOsDD_PcTb2tmH2qD&sig=AHIEtbRHUTRgh6lAPGNOszFMoliS-AhPvA

For those keeping score, the figures reached for the four countries examined so far are sobering. We show again the table presented on page 1:

Table 10: Various Projection Totals, China, India, Indonesia and Brazil			
Scenarios for Energy Consumption as discussed above	**EIA Projections**	**Independent or National Projections**	**Paired With Development Analogues**
China	162.7	223	246.6
India	30.4	63.6	84.57
Indonesia	8.99	16.8	16.72
Brazil	16.4	22	42.54
Total 4 Countries	**218.49**	**325.4**	**390.43**

The Developing World and Energy Consumption

To the extent that readers agree with the logic driving this argument—that looking at countries a little further ahead on the development path can provide rough analogues to energy consumption for other countries, we should be able to proceed fairly quickly at arriving at an estimate for the part of the developing world most likely to be of interest—those that have significant populations and are developing quickly.

Table 11: Various Projection Totals, non-OECD nations		
Country	**EIA Projections**	**If Energy Tracks Country's Development Pair**
Total 122 Countries (Including BRICs)	**393.22**	**612.29**

Discussion

At the beginning of this (what is this? A paper? Article? Essay?) I asked what it would mean to the world to discover that our energy needs in 20 years had been significantly underestimated. Although I cannot provide a definitive answer, I do feel the responsibility to add my contribution.

I start by saying that it seems eminently feasible to provide this extra energy to the world. If we need to supply 913 quads of primary energy to the world instead of 721, we will. Although localized shortages will certainly occur (mainly to countries too poor to pay for the energy they need), the lights will not go out and the gas tanks will not run dry—not in America, not in China, not in any country with the cash or good credit to buy it. Sufficient reserves of proven fuels exist to provide even this higher supply of energy.

The important question is what mix of fuels will be called on to cover the gap between what was thought to be needed and what actually is. If there is no planning, no acknowledgement of a changed reality, the odds are high that the mix will be dominated by coal. And I consider this to be a tragedy in the making. It's a natural choice for an emergency supply—plentiful, inexpensive and familiar. But the costs carried with it are so high and would be felt so disproportionately by those just emerging from immiseration, that it would call into question the reasons for further development. If purchasing a washing machine comes with black lung for hundreds of thousands as part of the price tag, do we want the washing machine? If the numerous negative externalities associated with coal are an inevitable consequence of future development, what should have been a joy for all mankind becomes just more of the same old, same old.

It is true that coal is getting cleaner—but it isn't clean enough to provide 192 additional quads worth of primary energy in 20 years without real consequences, both in terms of short-term health effects from traditional pollution and from the inevitable addition of greenhouse gases to an atmosphere that seems close to full. Environmentalists are trying to reduce dependence on coal even now—they will certainly not welcome increased reliance upon it due to new estimates of consumption.

It is possible that natural gas may step up to the plate and cover some of the gap—however, there are reasons to expect a more cautious deployment of fracking, at least in the developed world. Supplies of natural gas may be smaller than initially reported and more quickly depleted.

Similar constraints seem to limit the possibilities for other dependable sources of power, such as hydroelectric and nuclear, where siting and environmental fears have so far outweighed the potential benefits of these two workhorses of the energy field. Petroleum seems destined to be earmarked specifically for transportation and industrial uses, and will probably never again be used in bulk for pedestrian uses such as provision of electricity or heating.

Which leaves the field open for the trio of renewable sources of energy—wind, solar and biofuels. And each of them brings their own baggage with it. But each of them also has the potential to make a significant contribution. As volume manufacturing brings prices down and efficiency up, both wind and solar are set to step onto the stage as significant providers. Biofuels has a longer road ahead of it.

At the end of the day, we will be choosing a portfolio that will include each of these fuels. There is no point in excluding coal completely—it's just completely unrealistic. Similarly, there is no point in demanding that wind or solar dominate the fuel mix, unless tremendous progress is made in both storage and transmission technologies.

So my contribution, small consolation and small beer though it is, is that the most important thing we can do now is to recognize the need and configure the portfolio now—to do what is needed to uprate existing hydroelectric dams and improve the efficiency of existing nuclear power plants, to design and site new facilities in both fields, to transfer the technology needed to make new coal plants as clean as possible in the developing world, and to be judicious in the introduction of natural gas, sending it to the places where it will do the most good, rather than the places where it may be easiest to sell. Above all, I recommend that we clear the path for smoother and quicker take-up of renewables, so that they can supply close to 30% of our needs rather than 10%, as would be the case if current trends continue. We've spent a generation getting the pieces of the puzzle in place for rapid deployment of wind and solar, and as we've done so the prices have dropped dramatically. The next wave of price reductions won't come so much from cheaper solar modules or turbines. They will come from one-page permitting and sustained commitments to power purchasing at reasonable levels.

I believe that renewable, or at least sustainable, energy can scale up to 300 quads of available energy by 2030. Electric cars and scooters recharged by solar power could radically reconfigure how energy is used (and stored) in both the developing and developed world. Properly configured and sited wind turbines matched with hydroelectric and pumped storage can provide large-scale regional, not just local, solutions. Combined heat and power plants, which currently provide 9% of the world's primary energy, could be deployed at a far greater scale. Ground source heat pumps, district heating and other uses of cogenerating facilities, all of these are used at scale and are proven sources of power—there is no need to use science fiction solutions, no need for a deus ex machina. And the numbers can add up—and they won't break the bank.

To plan and build the additional nuclear power plants, hydroelectric dams, combined heat and power plants, fully deploy wind, solar and biofuels, the scale of the problem must be acknowledged in the very short term and planning decisions put in the pipeline.

We do have choices. The point is to choose now.

Below is a chart of all 122 non-OECD nations included in this study, including those discussed above. It includes the paired development partner (where applicable), gives EIA projections for energy consumption, projections for per capita GDP and the resulting projection of energy consumption for equivalent level of development in 2030.

Recap of Methodology

1. Select appropriate pair country for target (e.g., row 1 target is China, pair country is Oman). The selection criteria are crude, as noted above. I tried to match on more than one criterion, but the primary factor is the target's 2030 projected GDP per capita being similar to the pair country's 2006 GDP per capita. However, I also looked at size, geographic proximity, assumed cultural affinity and assumed developmental pathway. I recognize that this area is where I could use assistance from interested readers.
2. Multiply the pair country's 2006 per capita energy consumption (in mbtus) by projected 2030 population in target (eg, Oman's per capita energy consumption in 2006 is 177.2 mbtus. Multiply by the 1,391,500,000 people projected for China in 2030, yielding total projected energy consumption of 246.6 quadrillion btus).
3. Take EIA's reported energy consumption for 2006 and multiply by CAGR of 2.2% to reach projected energy consumption in 2030. (Note: the EIA's total energy consumption for 2006 is not shown in this table for reasons of space. It is available upon request, and also at the EIA website noted below.) Remember that in September of 2011 the EIA increased its projections by roughly 5%, and to match their more recent findings, the CAGR should rise to 2.3%.
4. Where no suitable pair country was found, I accepted the EIA projections.

Sources

Sources used in this table (and throughout this report) are:

- Projected Population and Growth Rates in Population for Baseline Countries/Regions 2000-2030, Updated: July 20, 2010 based on June 2010 Census Bureau Update, Source: U.S. Census Bureau, International Data Base (http://www.census.gov/ipc/www/idb/) organized into ERS/USDA Baseline countries and regions, curated by USDA ERS
- World Per Capita Energy Consumption 1980-2006, International Energy Annual, 2006, U.S. DOE EIA, Table E.1c found at http://www.eia.gov/iea/wecbtu.html
- Real Projected Gross Domestic Product (GDP) and Growth Rates of GDP for Baseline Countries/Regions (in billions of 2005 dollars) 2000-2030, Updated: 12/22/10 Source: World Bank World Development Indicators, International Financial Statistics of the IMF, HIS Global Insight, and Oxford Economic Forecasting, as well as estimated and projected values developed by the Economic Research Service all converted to a 2005 base year. Curated by USDA ERS
- EIA Total Primary Energy Consumption, 2006, http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=44&pid=44&aid=2
- EIA projected growth rates for primary energy consumption calculated at 2.2% CAGR
- The worksheet used is available in Excel format upon request from the author, at thomaswfuller@gmail.com

Table 12: Supporting Data and Estimates of 2030 Energy Consumption, 122 Developing Countries

Target Country	**Pop 2030** (millions)	**GDP p.c. 2006** (US $ 2005)	**GDP p.c. 2030** (US $ 2005)	**CAGR %**	**Energy p.c. 2006** (mbtu)	**Energy 2030 EIA projection** (Quadrillion btu)	**Our est. 2030** (Quadrillion btu)	**CAGR %**	**Pair Country**	**Energy 2006 paired ctry p.c. (mbtu)**	**Paired Country GDP 2006 p.c. (US $ 2005)**
China	1,391.5	1,968	10,718	7.01	56.2	162.7	246.6	5	Oman	177.2	11,528
India	1,460.7	751	3,309	6.11	15.9	30.4	84.574	6.46	Thailand	57.9	3,022
Brazil	240.1	5,309	12,681	3.54	51.2	16.4	42.54	6.1	Oman	177.2	11,528
Russia	124.1	6,003	14,235	3.51	213.9	33.7	31.645	0.37	Saudi Arabia	255	13,424
Indonesia	288.7	1,359	3,638	4.02	17.9	8.988	16.715	4.77	Thailand	57.9	3,022
Ukraine	39.5	1,938	5,425	4.2	125.9	10.018	10.018	2.2	none	none	none
Thailand	72.8	3,022	7,233	3.55	57.9	6.411	9.609	3.87	Libya	132	6,857
Iraq	43.8	2,610	6,033	3.41	46.6	2.014	9.369	8.68	Russia	213.9	6,003
South Africa	48.9	4,867	13,551	4.18	117.2	9.116	8.635	1.98	Czech Republic	176.6	13,401
Iran	93.5	2,739	4,762	2.24	118.2	1.321	7.386	7.13	Argentina	79	4,763
Philippines	138.3	1,189	2,283	2.64	14.2	2.257	7.219	7.07	Jordan	52.2	2,385
Saudi Arabia	33.8	13,424	23,683	2.3	255	12	6.916	2.2	none	none	none
Argentina	48.8	4,763	10,495	3.21	79	5.38	5.6	2.37	Hungary	114.7	10,676
Malaysia	36.6	5,403	10,216	2.58	104.8	4.075	5.464	3.41	Slovakia	149.3	9,660
Venezuela	35	5,924	9,322	1.83	124.4	5.458	5.458	2.2	none	none	none
Egypt	111	1,407	2,631	2.54	32.2	4.419	5.173	2.85	Iraq	46.6	2,610
Bangladesh	211.3	390	1,020	3.92	5	1.32	5.11	7.86	Bolivia	24.2	1,043
Vietnam	105.5	662	2,424	5.33	16.6	2.235	4.916	5.47	Iraq	46.6	2,610
United Arab Emirates	7.5	32,790	44,092	1.19	577.6	4.376	4.376	2.2	none	none	none

Table 12: Supporting Data and Estimates of 2030 Energy Consumption, 122 Developing Countries											
Target Country	**Pop 2030** (millions)	**GDP p.c. 2006** (US $ 2005)	**GDP p.c. 2030** (US $ 2005)	**CAGR %**	**Energy p.c. 2006** (mbtu)	**Energy 2030 EIA projection** (Quadrillion btu)	**Our est. 2030** (Quadrillion btu)	**CAGR %**	**Pair Country**	**Energy 2006 paired ctry p.c.** (mbtu)	**Paired Country GDP 2006 p.c.** (US $ 2005)
Pakistan	242.9	702	1,365	2.7	14.2	4.031	4.347	2.51	Indonesia	17.9	1,359
Democratic Republic of the Congo	130.1	842	1,467	2.25	7.6	0.174	4.19	16.07	Egypt	32.2	1,407
Kazakhstan	16	4,194	9,342	3.26	195.3	4.125	4.125	2.2	none	none	none
Uzbekistan	32.9	475	1,140	3.56	80.9	3.837	3.837	2.2	none	none	none
Nigeria	211.8	697	1,382	2.78	7.8	1.792	3.791	5.31	Indonesia	17.9	1,359
Colombia	53	3,045	6,744	3.23	29.8	2.221	3.63	4.23	Mexico	68.5	7,480
Singapore	5.1	28,603	66,689	3.44	476.8	3.584	3.584	2.2	none	none	none
Algeria	41.6	3,083	4,543	1.56	46.6	2.66	3.29	3.1	Argentina	79	4,763
Peru	35.9	2,997	7,909	3.96	21.6	1.137	2.786	5.93	Chile	77.6	7,917
Syria	28.2	1,447	2,318	1.9	42.9	1.411	2.445	4.47	Azerbaijan	86.7	2,333
Romania	20.4	4,982	10,694	3.1	75.2	2.965	2.339	1.23	Hungary	114.7	10,676
Libya	8.9	6,857	12,072	2.29	132	1.268	2.27	4.61	Saudi Arabia	255	13,424
Cuba	11.6	3,407	12,064	5.19	35.1	0.613	2.05	4.95	Czech Republic	176.6	13,401
Czech Republic	9.7	13,401	33,743	3.76	176.6	2.736	1.875	0.67	South Korea	193.4	18,476
Tunisia	12.2	2,893	6,832	3.5	32.9	0.574	1.61	6.51	Libya	132	6,857
Turkmenistan	6	1,910	5,109	4.01	174.1	1.488	1.488	2.2	none	none	none
Angola	19	3,219	8,545	3.98	13.7	0.288	1.47	9.1	Chile	77.6	7,917
Sri Lanka	24.2	1,185	3,913	4.89	10.5	0.372	1.435	7.87	Jamaica	59.3	3,349
Trinidad and Tobago	1.2	10,671	21,509	2.84	769.9	1.415	1.415	2.2	none	none	none
Morocco	37.9	1,843	3,613	2.73	15.2	0.889	1.33	3.86	Cuba	35.1	3,407
Belarus	8.8	4,033	9,384	3.44	117	1.99	1.31	0.52	Slovakia	149.3	9,660
Serbia	6.7	5,768	19,522	5	68.4	1.277	1.296	2.26	South Korea	193.4	18,476
Azerbaijan	9.6	2,333	5,932	3.8	86.7	1.2	1.19	2.2	Venezuela	124.4	5,924
Kuwait	4.6	31,477	39,714	0.93	469.8	1.972	1.145	2.2	none	none	none
Guatemala	18.8	2,686	3,892	1.49	16.3	0.354	1.114	6.98	Jamaica	59.3	3,349
Ecuador	18.7	2,628	3,420	1.06	31	0.764	1.108	3.73	Jamaica	59.3	3,349
Jordan	8.6	2,385	4,137	2.23	52.2	0.531	1.006	4.85	Belarus	117	4,033
Sudan	70	812	1,337	2.01	4.8	0.331	0.994	6.8	Philippines	14.2	1,189
Burma/Myanmar	64.1	790	1,823	3.4	5	0.439	0.974	5.51	Morocco	15.2	1,843
Kenya	54.1	573	1,178	3.24	5.6	0.365	0.936	6.12	Honduras	17.3	1,182
Bulgaria	5.9	3,842	10,170	3.97	121.5	1.61	0.88	0.676	Slovakia	149.3	9,660
Dominican Republic	12.2	3,171	7,005	3.22	28.9	0.484	0.835	4.45	Mexico	68.5	7,480
Oman	4.3	11,528	21,811	2.58	177.2	0.968	0.831	1.58	South Korea	193.4	18,476

Table 12: Supporting Data and Estimates of 2030 Energy Consumption, 122 Developing Countries											
Target Country	**Pop 2030** (millions)	**GDP p.c. 2006** (US $ 2005)	**GDP p.c. 2030** (US $ 2005)	**CAGR %**	**Energy p.c. 2006** (mbtu)	**Energy 2030 EIA projection** (Quadrillion btu)	**Our est. 2030** (Quadrillion btu)	**CAGR %**	**Pair Country**	**Energy 2006 paired ctry p.c.** (mbtu)	**Paired Country GDP 2006 p.c.** (US $ 2005)
Lebanon	4.3	5,490	14,132	3.85	53.3	0.334	0.762	5.62	Oman	177.2	11,528
Panama	4.3	5,239	12,784	3.63	70.8	0.396	0.759	4.89	Czech Republic	176.6	13,401
Bolivia	13.3	1,043	2,083	3.52	24.2	0.384	0.748	4.96	Bosnia and Herzegovina	56.3	2,161
Paraguay	8	1,471	3,022	2.92	65.5	0.732	0.732	2.2	none	none	none
Honduras	10.8	1,182	1,913	1.94	17.3	0.217	0.73	7.28	Armenia	67.6	1,916
Tanzania	56.5	299	881	4.42	2.1	0.162	0.717	8.47	Democratic Republic of the Congo	12.7	842
Croatia	4.3	8,740	20,499	3.47	92.1	0.715	0.692	2.07	Slovenia	160.9	18,030
Uruguay	3.8	5,483	12,824	3.46	38.8	0.257	0.672	6.21	Czech Republic	176.6	13,401
Lithuania	3.3	7,641	16,362	3.09	97	0.608	0.531	1.65	Slovenia	160.9	18,030
Papua New Guinea	8.4	881	1,673	2.6	12.7	0.121	0.524	18.84	Paraguay	65.5	1,471
Bahrain	0.9	19,500	36,364	3.16	695.4	0.86	0.519	0.16	United Arab Emirates	577.6	32,794
Ghana	33	503	1,787	5.2	7.1	0.258	0.501	4.94	Morocco	15.2	1,843
Mozambique	31.3	313	754	3.58	10.6	0.305	0.498	4.22	India	15.9	751
Cameroon	27.5	975	1,486	1.7	5	0.159	0.492	6.94	Indonesia	17.9	1,407
Tajikistan	10.1	379	608	1.91	40.4	0.484	0.484	2.2	none	none	none
Yemen	35.5	214	314	1.55	12.4	0.482	0.482	2.2	none	none	none
Afghanistan	42.7	432	1,395	4.8	0.6	0.31	0.45	17.4	Sri Lanka	10.5	1,185
Costa Rica	5.6	4,775	8,374	2.27	43.6	0.322	0.435	3.43	Chile	77.6	7,917
Zambia	23.5	783	1,389	2.32	11.1	0.219	0.421	4.91	Indonesia	17.9	1,359
Jamaica	3.2	3,349	3,967	0.68	59.3	0.296	0.388	3.31	Bulgaria	121.5	3,842
Armenia	3.1	1,916	3,764	2.74	67.6	0.351	0.377	2.49	Bulgaria	121.5	3,842
Uganda	67.3	324	611	2.57	1.2	0.065	0.377	9.61	Kenya	5.6	573
Kyrgyzstan	7	471	711	1.66	38.1	0.37	0.37	2.2	none	none	none
Albania	3.1	4,212	10,796	3.8	34.3	0.203	0.36	5.6	Hungary	114.7	10,676
Ethiopia	162.5	136	310	3.35	1.4	0.177	0.357	5.1	Madagascar	2.2	308
Niger	31.9	264	322	0.8	1.3	0.029	0.338	12.7	Mozambique	10.6	313
Senegal	19.5	773	1,117	1.48	6.9	0.148	0.337	5.61	Honduras	17.3	1,182
Bosnia and Herzegovina	4.4	2,161	5,980	4.16	56.3	0.488	0.336	0.69	Lithuania	97	7,641
Mali	22.7	477	706	1.58	1.1	0.021	0.336	14.26	Mauritania	14.8	700
Latvia	1.9	7,756	15,020	2.68	80	0.317	0.335	2.43	Czech Republic	176.6	13,401
Côte d'Ivoire	29.7	839	1,175	1.36	6.4	0.196	0.312	4.11	Sri Lanka	10.5	1,185
Macedonia	2.1	2,888	6,330	3.19	55.2	0.208	0.277	3.37	Libya	132	6,857
Cambodia	19	451	1,253	4.17	0.7	0.11	0.27	6.2	Philippines	14.2	1,189
Burundi	17.7	90	118	1.09	0.8	0.01	0.25	5.87	Ethiopia	1.4	136

Table 12: Supporting Data and Estimates of 2030 Energy Consumption, 122 Developing Countries

Target Country	Pop 2030 (millions)	GDP p.c. 2006 (US $ 2005)	GDP p.c. 2030 (US $ 2005)	CAGR %	Energy p.c. 2006 (mbtu)	Energy 2030 EIA projection (Quadrillion btu)	Our est. 2030 (Quadrillion btu)	CAGR %	Pair Country	Energy 2006 paired ctry p.c. (mbtu)	Paired Country GDP 2006 p.c. (US $ 2005)
Mauritius	1.4	4,901	11,271	3.39	44.3	0.013	0.245	16	Estonia	175.2	11,125
El Salvador	6.3	2,947	5,442	2.48	19.2	0.227	0.244	2.49	Uruguay	38.8	5,483
Moldova	4.1	689	2,161	4.68	33.9	0.246	0.231	1.94	Bosnia and Herzegovina	56.3	2,161
Mongolia	3.9	788	3,237	5.81	33	0.148	0.231	4.03	Jamaica	59.3	3,349
Botswana	2.5	4,508	9,391	2.98	33.1	0.134	0.23	5.52	Croatia	92.1	8,740
Nepal	38.9	280	558	2.8	2.4	0.122	0.218	4.59	Kenya	5.6	573
Estonia	1.1	11,125	24,668	3.24	175.2	0.398	0.212	<0.34>	South Korea	193.4	18,476
Georgia	4.2	1,547	3,114	2.84	29.1	0.238	0.195	1.39	Algeria	46.6	3,083
Madagascar	36.8	308	373	0.77	2.2	0.071	0.184	6.19	Bangladesh	5	390
Malawi	25.6	206	474	3.39	1.9	0.05	0.172	7.38	Togo	6.7	412
Benin	15.2	577	796	1.3	4.9	0.075	0.169	2.2	Zambia	11.1	783
Burkina Faso	29.2	412	585	1.41	1.3	0.033	0.163	8.98	Kenya	5.6	573
Gabon	2.3	5,793	7,422	1	29	0.072	0.157	5.42	Mexico	68.5	7,480
Nicaragua	8	873	1,130	1.04	12.8	0.126	0.138	2.58	Honduras	17.3	1,182
Rwanda	18	513	886	2.21	1.4	0.027	0.137	10.23	Democratic Republic of the Congo	7.6	842
Laos	8.5	540	1,805	4.95	3.6	0.064	0.129	5.12	Morocco	15.2	1,843
Namibia	2.3	3,040	5,413	2.33	29.3	0.109	0.123	2.71	Lebanon	53.3	5,490
Mauritania	4.9	700	1,019	1.51	14.8	0.072	0.119	4.25	Bolivia	24.2	1,043
Guinea	17.2	360	416	0.58	2.4	0.04	0.115	4.31	Togo	6.7	412
Sierra Leone	8.5	193	346	2.36	2.8	0.029	0.09	6.89	Mozambique	10.6	313
Lesotho	2	539	1,241	3.39	2.5	0.087	0.087	2.2	none	none	none
Chad	15.1	588	629	0.27	0.3	0.052	0.074	13.68	Benin	4.9	577
Togo	11	412	465	0.49	6.7	0.063	0.063	2.2	none	none	none
Haiti	11.8	513	801	1.8	3.3	0.039	0.056	3.62	Sudan	4.8	812
Central African Republic	7.3	324	508	1.82	1.3	0.01	0.052	17.12	Ghana	7.1	503
Republic of the Congo	6.9	1,293	1,560	0.75	1.6	0.05	0.05	2.2	none	none	none
Swaziland	1.7	2,072	2,921	1.38	15	0.031	0.05	4.17	Namibia	29.3	3,040
Liberia	5.9	277	546	2.75	2.5	0.016	0.033	5.33	Kenya	5.6	573
Eritrea	8.7	180	189	0.2	2.2	0.017	0.019	2.6	Sierra Leone	2.2	193
The Gambia	2.9	202	376	2.52	2.6	0.009	0.009	2.2	none	none	none