



“Peak Oil”: The Global Crisis of Diminishing Petroleum Supply, and Its Implications for the Philippines

KELVIN S. RODOLFO

Abstract

Peak Oil refers to the time when half of all the petroleum stored in the Earth has been used up. That time is the present, when the world’s rapidly shrinking petroleum reserves are causing rapidly rising fuel prices wars and diplomatic tension over oil. Such tensions have arisen over the Spratly Islands in the South China Sea because oil may be discovered there—a possibility, not a certainty. Among all nations, the Philippines is one of the most modest oil consumers, but it is already suffering from the global warming caused by humankind’s excessive use of fossil fuel since the 19th century. Sea-level rise threatens two thirds of the Philippine population living on coastal plains. The oceans are being acidified by increased solution of carbon dioxide, harming coral reefs. Shifting climatic prevalence from La Niña to El Niño may cause decreased rainfall, droughts, and fewer but more powerful typhoons crossing the Philippines. The average Filipino uses less than 1.5 barrels of oil annually, but that oil fuels virtually all transportation, 11 percent of electricity, a huge array of plastics and other petrochemical products, road asphalt, cement manufacture, and more than two million tons of chemical fertilizers used annually. In the long run, the Philippine economy, work force and populace will benefit greatly by weaning agriculture away from petroleum. The nation urgently needs to develop alternate sources of energy, not only to free itself from

steeply rising oil prices, but also to decrease its own contribution to atmospheric carbon dioxide and global warming. It can learn from Cuba, which underwent Peak Oil in the 1990's when the Soviet Union, its only source of oil, collapsed, but has achieved a healthy, sustainable, organic agriculture without fossil fuels and inorganic fertilizers and pesticides. The Philippines is already initiating projects that reduce greenhouse gas emissions with financial and technologic help from developed countries, which in return would earn credits toward meeting its own emission reduction targets. Spain is helping to electrify remote Mindanao *barangays* with solar power, and Denmark is subsidizing the Bangui wind farm in Ilocos Norte. To generate electricity, petroleum is being substituted with natural gas and coal, but coal pollutes the air with toxic substances in addition to carbon dioxide. Nuclear power is another energy source that should be avoided, because it is particularly hazardous in a volcanic and earthquake-prone area. Some of the alternate energy sources already used in the Philippines can be relied on more strongly and efficiently. These include geothermal power, draft animals, biofuels; mini-hydro, wind, and solar energy. Ocean waves are the one marine source of power that can be tapped by relatively inexpensive, small-scale projects.

Introduction

The world is beginning to awaken to the fundamental reason behind the inexorably increasing prices of oil-based fuels. As is often the case, the Philippines and its government are slow to join this realization. In November 2006, Prof. Floro Quibuyen and I lectured on Peak Oil at the University of the Philippines - Manila. An attending student reported that one of his professors says Peak Oil is a problem only in developed countries like the U.S. that depend much more heavily on fossil fuels.

The good professor must be in a very small minority. Perhaps he lives within walking distance of his work, shopping, and entertainment, and thus does not share the ever-increasing financial pinch experienced by anyone who drives, or rides a jeepney, bus or taxi. The average Filipino

indeed uses far less oil than the average American does, but is also deeply dependent on oil in ways that we may not realize. All transport of people and goods, all petrochemical products, and virtually all agriculture rely heavily on petroleum. In this impoverished country, increasing petroleum prices will inevitably continue to worsen the economy, quality of life, and social unrest.

This article explores the meaning of Peak Oil for the Philippines. It cannot be properly grasped without a look at the geologic time involved in the formation of petroleum. No discussion of Peak Oil is complete without a brief discussion of the convergent problems of human-induced global warming and its consequences. The petroleum crisis involves far more than fuel scarcity; petrochemicals are so pervasive in our daily lives, so taken for granted, that we virtually ignore them. We will examine agriculture, the most important use of petroleum aside from transportation. Finally, we will examine present energy use in the Philippines and evaluate a large menu of proposed and potential alternative energy sources.

What "Peak Oil" means

The modern oil age began in the later half of the 19th Century, accelerated through the 20th, and has arrived at its climax early in the 21st. Usage of any finite resource like oil inevitably must reach a maximum, or peak, and then decline. Peak Oil refers to the time when that happens, which is now. Every oil well, oil field, oil-producing country—and the entire world itself—must experience such a peak. Petroleum geologist M. King Hubbert initially applied the idea to the contiguous 48 United States. In 1956 he realized that oil discoveries there had climaxed in 1930, and predicted that U.S. peak oil production would occur in the early 1970s (Fig.1). He was derided by many until 1973, when industry statistics demonstrated that the peak had occurred three years before.

The reasoning behind Hubbert's successful prediction of peak oil for the United States, and for more recent estimates of the global peak, is simple. First, the supply of petroleum is finite. At first, there is so much

oil, and it is so easy to find and extract, that its use accelerates rapidly. Naturally, the half of the oil that is most easily found and extracted is used first. Its use, however, unavoidably has to decrease the amount in the Earth's crust. When this half of all the oil is gone, accelerating use has reached its inevitable limit. After this time of Peak Oil, the remaining oil gets harder and harder to find and extract. Even if new fields are found, the time of global Peak Oil is not delayed very much. The oil that is hardest to extract cannot be used because to extract it would expend more energy than it can yield.

It is important to note that in the United States the peak time for discovery preceded the production peak by 40 years (Fig. 1). That much time after an oil field is discovered is required to develop it to its full capacity. If four decades is the typical lag period, the global discovery peak in 1965 should be followed by global peak production in 2005, give or take a few years.

C. J. Campbell and J. Laherrère (1998), among others, have refined Hubbert's approach and applied it to the entire globe. Laherrère (2000) has also written a thoughtful, but somewhat technical analysis of the concept. By far the most lucid and authoritative introduction to the concept is Kenneth S. Deffeyes' 2001 book, *Hubbert's Peak*. Deffeyes also explored the ramifications of peak oil and the search for alternative energy sources in his 2005 book, *Beyond Oil*. Early in 2004, Deffeyes facetiously pronounced on his webpage that global Peak Oil would occur in 2005, on the American Thanksgiving holiday, November 24. Two years later, after the statistics for world oil production for 2005 had been released, he revised that date to December 16, 2005. Strong believers in Peak Oil include Matthew Simmons, the Houston banker who advises George W. Bush. As one of the world's largest financiers of petroleum R&D, he is exceptionally self-taught in all aspects of oil, including its geology and extraction. His book *Twilight in the Desert* (2005) argues convincingly with a wealth of documentation that Peak Oil will arrive sooner rather than later, because the reserves in Saudi Arabia have been badly exploited and misrepresented.

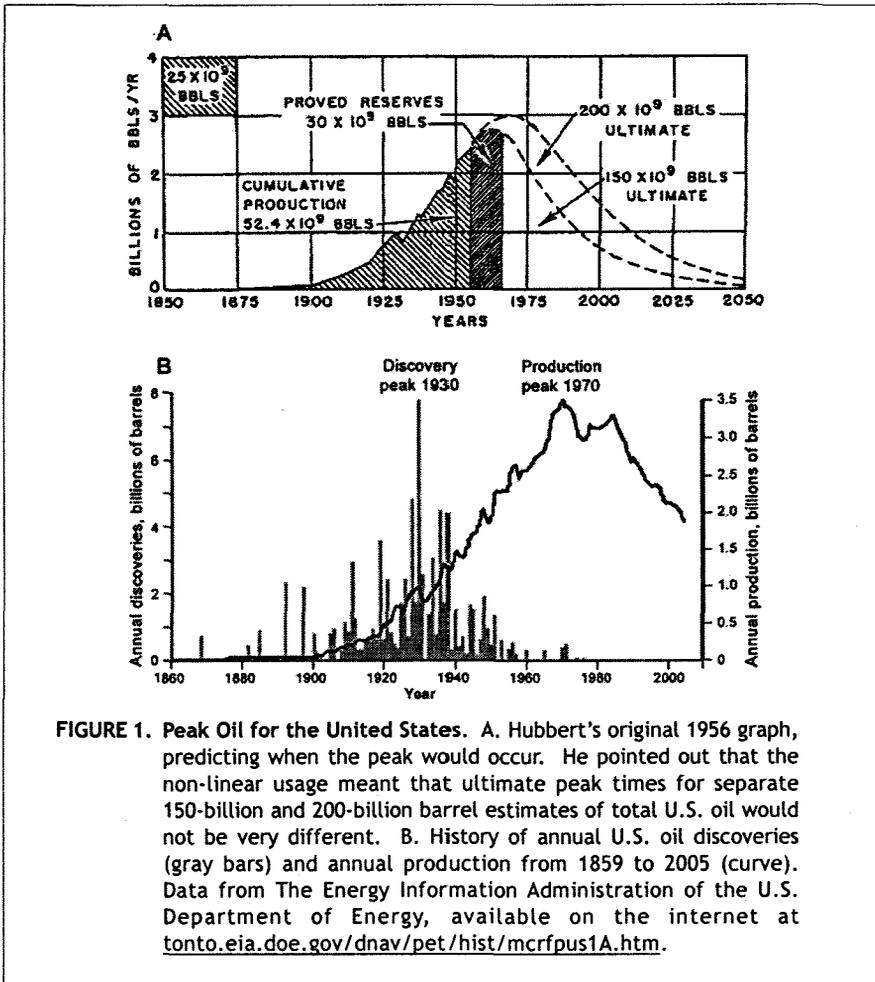


FIGURE 1. Peak Oil for the United States. A. Hubbert's original 1956 graph, predicting when the peak would occur. He pointed out that the non-linear usage meant that ultimate peak times for separate 150-billion and 200-billion barrel estimates of total U.S. oil would not be very different. B. History of annual U.S. oil discoveries (gray bars) and annual production from 1859 to 2005 (curve). Data from The Energy Information Administration of the U.S. Department of Energy, available on the internet at tonto.eia.doe.gov/dnav/pet/hist/mcrfps1A.htm.

Figure 2A should be enough to convince any logical thinker of the reality of Peak Oil. Until about 1950, the sequence of discoveries was very sporadic, because the science of petroleum geology was still very crude. Large fields were still being discovered by chance and accident. Notably, the largest oil field in the contiguous United States was discovered in 1930 when, purely on a whim, an oilman with no geologic training

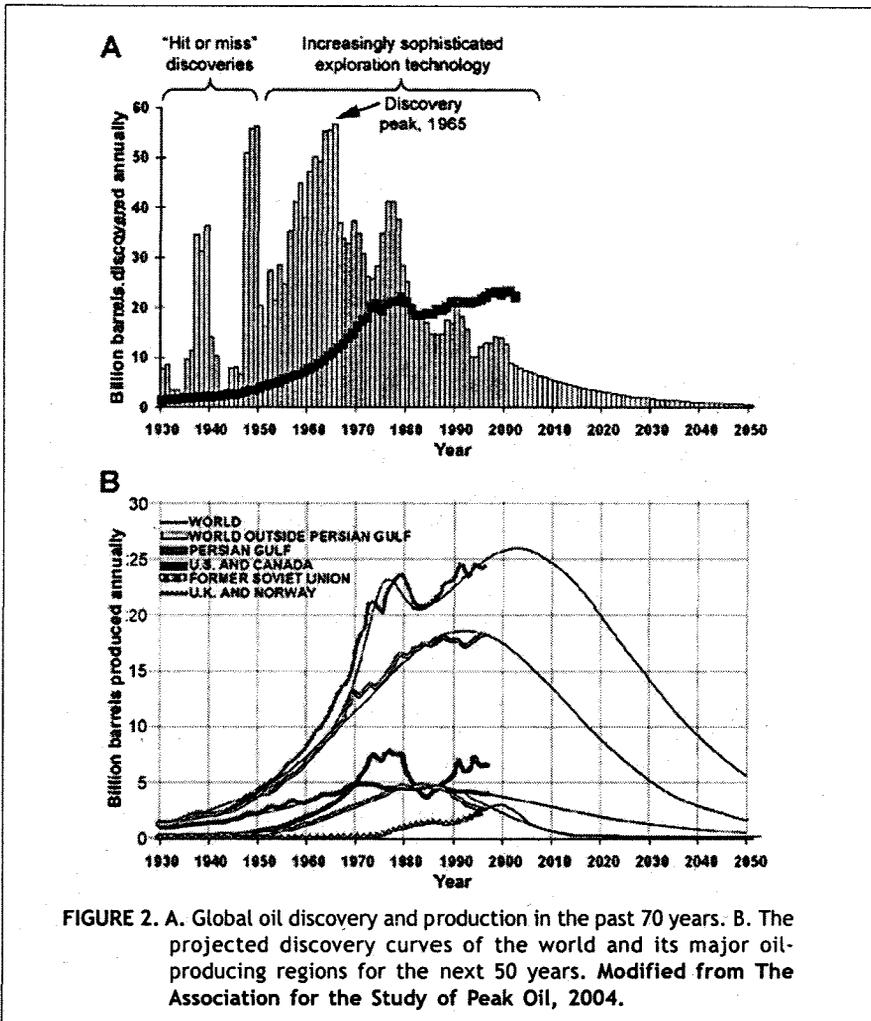
drilled several wildcat holes in east Texas (Deffeyes, 2001). After World War II, military technology adapted to exploration greatly improved its efficiency. Seismic reflection surveys penetrate kilometers into the crust beneath land and sea, providing detailed images of possible oil traps. "Bright spots" in the seismic records may even indicate the presence of natural gas associated with oil. Satellites generate useful images and detailed maps and charts of gravity and magnetism. Given all this continually evolving high technology, why have discoveries fallen off? The global discovery peak occurred in mid 1963, over four decades ago.

It is important to realize that the modern exploration technology not only identifies areas with potential; it also eliminates vast areas without such potential. Clearly, the world has discovered most of the oil; certainly, all the largest oil-producing regions have been found.

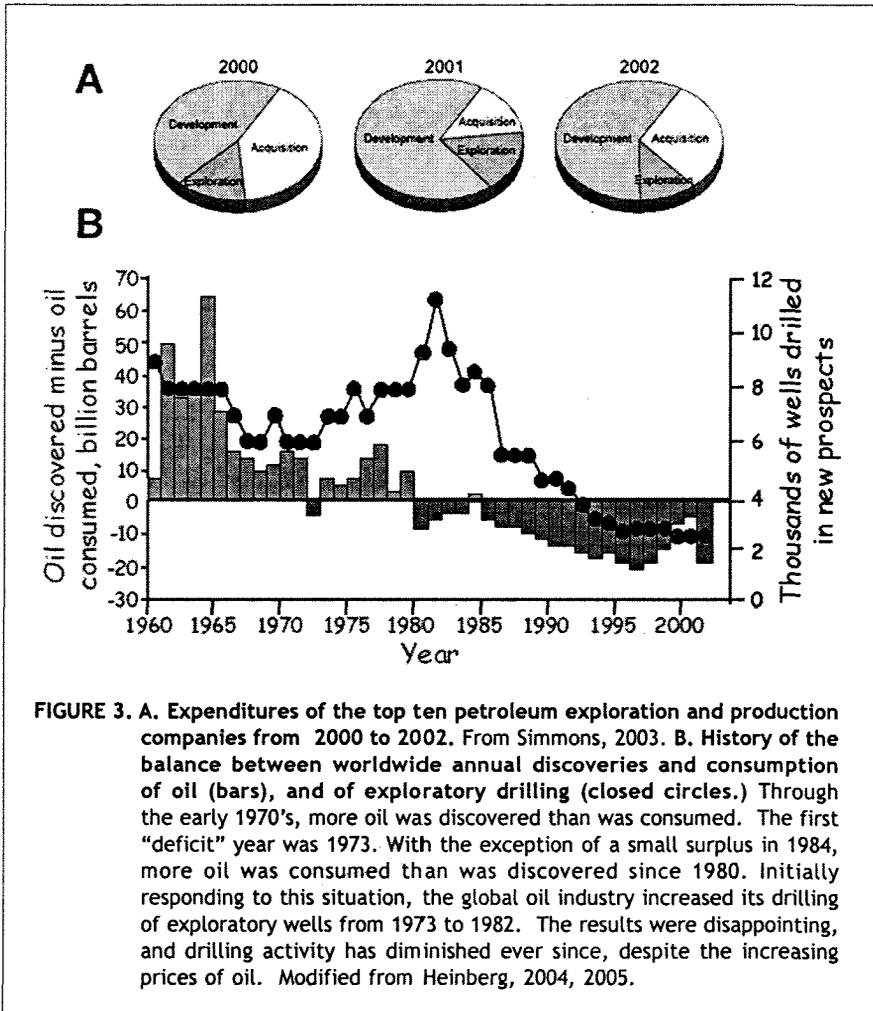
Figure 2B shows that Peak Oil has already arrived in all oil-producing regions of the world with the possible exception of the Middle East. Even that assessment may be too optimistic, given that the oil reserves in Saudi Arabia, officially the world's biggest, may be much smaller than reported (Simmons, 2005).

Another important measure of the arrival or imminent arrival of peak oil is the behavior of the petroleum industry. Despite the escalating price of oil, the largest ten companies spent only 14, 16 and 11 percent of their resources in 2000, 2001 and 2002 on exploration. They limited most of their expenditures to developing existing oil fields and acquiring properties from one another (Fig. 3A). No wonder; in 2003, oil companies spent \$8 billion on exploration, but discovered only \$4 billion of commercially useful oil (Homer-Dixon and Friedmann, 2005). Oil exploration is no longer a profitable enterprise.

Figure 3B illustrates the problem very well. After 1965, the surplus of oil discovered annually after subtracting what was consumed decreased steadily. In 1972, for the first time in the Age of Petroleum, the world discovered less oil than it used. In the following years, the global oil industry responded to this crisis by drilling more exploratory wells, but



the deficit continued to grow. After 1982, when more than 11,000 exploratory wells were drilled with disappointing discoveries, exploratory drilling dropped off precipitously. It was never again to approach the level of 1982. Only smaller fields in places difficult to access remain undiscovered



Contrary to common belief, global "peak oil" does not mean that the world is running out of oil. It means that fully half of the two trillion barrels of petroleum stored in the Earth's crust before humankind started using it has been consumed. Realizing this may tempt one to swing from alarm to undeserved complacency. True, a trillion barrels remain, but the

half that is now gone was the easiest to find and the easiest to pull out of the ground. What is left is harder and more expensive to locate and to extract.

The problem is compounded by the accelerating global usage of oil. Not only does the United States, by far the biggest consumer, continue to use ever-larger quantities; the emerging economic powerhouses of China and India have only begun to indulge in their thirsts for oil. The increasingly fierce competition for oil is reflected not only in the increasing prices at the wellhead and the gasoline pump, but in international politics and warfare as well.

The Spratly Islands

The Philippines has a major interest in the Spratly group of islands in the South China Sea (Fig. 4), perhaps the last region in the world that holds any possibility of large untapped petroleum deposits. Ownership of the Spratlys is contested by China, Malaysia, the Philippines, Taiwan and Vietnam, which by 1996 respectively have established military presence on ten, four, eight, one, and twenty-two of the islands. From 1974 to 1999, the contesting countries have been involved in 23 military incidents, most seriously between China and Vietnam at Johnson Island in March of 1988 (Energy Information Administration, 2003). The Vietnamese reported 74 sailors killed, the Chinese a large number wounded (Swanström, 1999). It is quite possible that those casualties were in vain, because the area may actually contain little or no oil. China is the most optimistic nation regarding the Spratly oil potential. Its most moderate estimate is that potential oil resources of the Spratly Islands and the Paracel Islands to the north could be as high as 105 billion barrels of oil, implying that potential production levels for the Spratly Islands could be 1.4-1.9 million barrels per day. The U.S. Geological Survey, although often extremely optimistic (Deffeyes, 2001), estimates only a tenth as much potential for the Spratlys, only 137,000-183,000 barrels per day (Energy Information Administration, 2006).

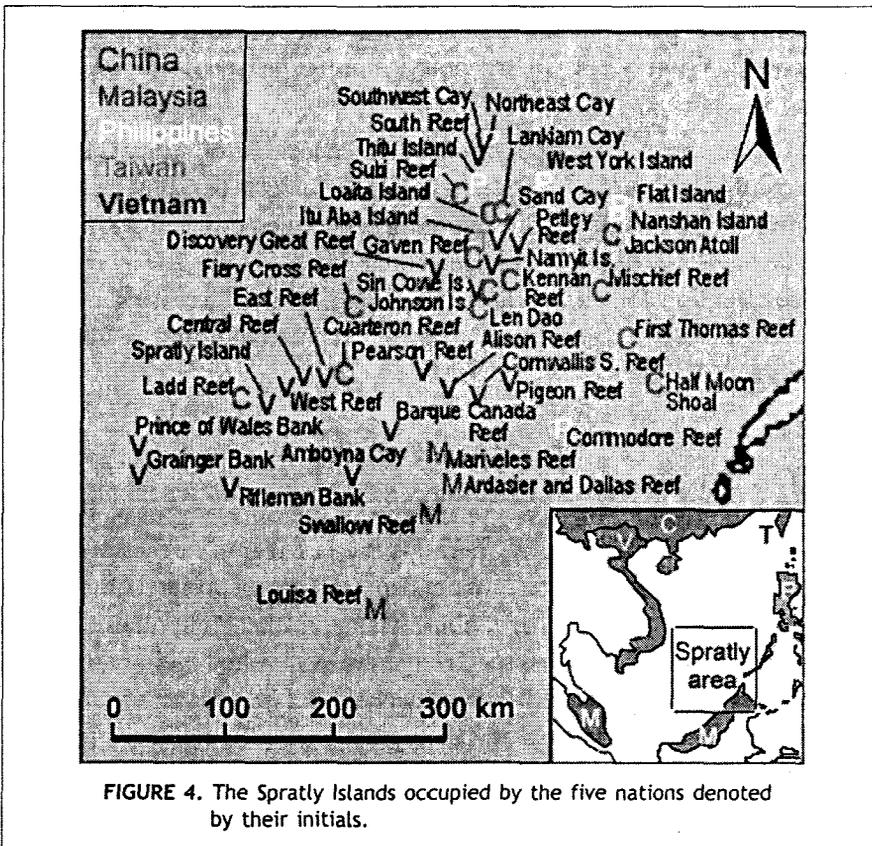
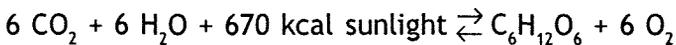


FIGURE 4. The Spratly Islands occupied by the five nations denoted by their initials.

Thus, all the nations concerned should evaluate the petroleum potential of the Spratlys collaboratively. A large step was taken in that direction in March, 2005, when China, the Philippines and Vietnam agreed to conduct a joint, three-year seismic exploration of the area (Central Intelligence Agency, 2006). If sizeable discoveries are made, all nations involved in extraction would have to be held collectively responsible for protecting the island environment and its plant and animal inhabitants from pollution associated with exploration, production and transport of oil. Entire flora and fauna of islets and reefs like the Spratlys could be wiped out by relatively small oil spills.

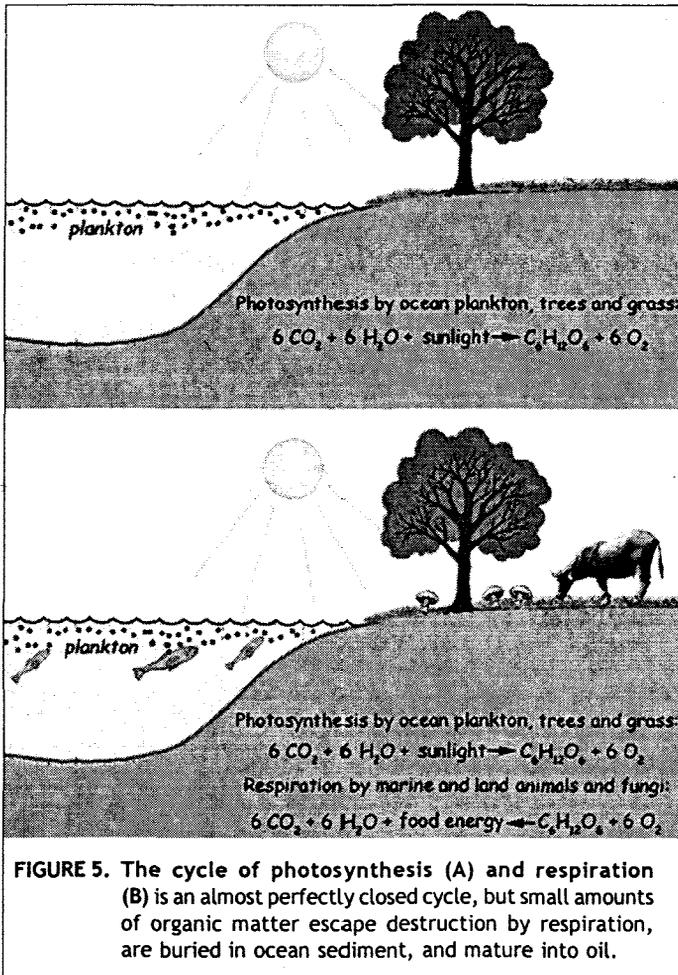
Petroleum and Geologic Time

Peak oil cannot be properly understood without a grasp of the geologic time involved in petroleum generation – a grasp lacked by most people, including many economists who dismiss the concept. Petroleum has accumulated in the Earth’s crust at exceedingly slow rates, by slowly escaping out of the biological cycle of *photosynthesis* and the opposite process called *consumption* or *respiration* (Fig. 5). We can summarize that cycle in an equation:



In non-chemists’ language, plants and more primitive photosynthesizers such as oceanic algae use sunlight to combine 264 grams of carbon dioxide with 108 grams of water, producing 180 grams of carbohydrate, represented in the equation by the sugar glucose, containing stored chemical energy in the form of 670 kilocalories (equal to 683 nutritionist’s calories), and release “waste” products of 192 grams of free oxygen (Fig. 5A). Respiration, represented in the equation by the leftward arrow, is the exactly opposite process: Animals and fungi power their existence with the chemical energy stored in the sugar, releasing it by combusting it with 192 grams of oxygen (Fig. 5B). Their “waste” products are 264 grams of carbon dioxide and 108 grams of water, so Nature’s grand recycling scheme comes full circle.

The photosynthesis-respiration loop is almost, but not quite, perfect. Small amounts of organic matter produced at the sunlit surface waters of the ocean rain down to the sea floor. There, most of this matter is consumed by bacteria, worms and other organisms, but minute quantities avoid this final consumption and are buried in the mud. As the sediment and its organic content accumulate, they are slowly buried ever more deeply. On average, temperatures within the Earth increase by 25 degrees Celsius with every kilometer of depth. From about 2.3 to 4.6 kilometers below the surface, the respective temperatures are 82 to 148°C, the range within which the buried organic matter can become liquid petroleum (Deffeyes,



2001). Above 2.3 kilometers the temperature is too low for this to happen. Below 4.6 kilometers the temperatures are so high that petroleum molecules are torn apart, and only simple molecules of methane gas (CH_4) can survive (Fig. 6A).

Geological processes operating over many millions of years can bury oil so deeply that it is entirely destroyed by heat. Alternatively, the petroleum-

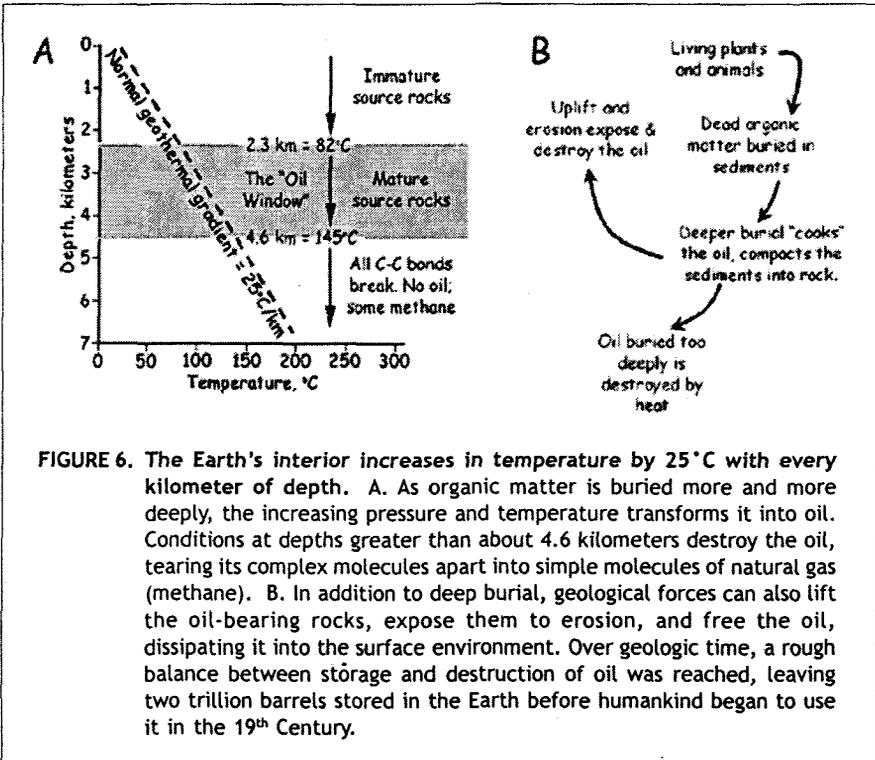


FIGURE 6. The Earth's interior increases in temperature by 25°C with every kilometer of depth. A. As organic matter is buried more and more deeply, the increasing pressure and temperature transforms it into oil. Conditions at depths greater than about 4.6 kilometers destroy the oil, tearing its complex molecules apart into simple molecules of natural gas (methane). B. In addition to deep burial, geological forces can also lift the oil-bearing rocks, expose them to erosion, and free the oil, dissipating it into the surface environment. Over geologic time, a rough balance between storage and destruction of oil was reached, leaving two trillion barrels stored in the Earth before humankind began to use it in the 19th Century.

bearing rocks can be uplifted by mountain-building, and erosion releases the oil back into the surface environment, where it decomposes. Over billions of years, a rough natural balance was reached. Petroleum destroyed by heat or erosion was eventually replaced by the small quantities continually stored in the crust (Fig. 6B). At any time during the eons before humanity began to use oil, about two trillion barrels were in storage.

We can estimate how fast the oil accumulated in several ways. Only about 0.2 percent was older than about 570 million years (Klemme and Ulmishek, 1991). The oldest petroleum of any real abundance, about 9 percent of the total, is of Silurian age, 408 to 438 million years old. If the two trillion barrels accumulated over the last 438 million years, the average yearly accumulation was 4,570 barrels. An alternative estimate:

about 72 percent of all the world's oil, including all in the Middle East, was deposited from late Jurassic time about 169 million years ago until 5.3 million years ago during the Cenozoic. This indicates an average accumulation rate of about 11,800 barrels per year. Even at this faster rate, oil accumulates so slowly that it must be regarded as a non-renewable resource.

Specifically, in 2003 the 84 million Filipinos consumed about 123 million barrels of oil (CIA, 2006). This equates to less than one and a half barrels per Filipino. Thus, even the faster rate of 11,800 barrels per year stores only enough oil for the needs of only about 8,000 Filipinos. According to the CIA statistics, per capita annual use in America is much more: 27 barrels per year, so the yearly storage of 11,800 can serve the needs of only 437 Americans. Beyond demonstrating that oil is virtually non-renewable, these statistics indicate that the Philippines should be able to wean itself from petroleum much more easily than the United States can, given the foresight and political will.

Global Warming and Its Consequences

The use of fossil fuels since the Industrial Revolution of the 19th Century is largely responsible for warming Earth's surface environments to levels and at rates unprecedented over the past two millennia. At present, all the people on Earth use 80 million barrels a day, or about 29 billion barrels annually. That means that humanity in one year consumes what earth stored in nine million years since the Silurian period. In one century—the blink of an eye in geological terms—humanity has burned and returned to the atmosphere the carbon dioxide that Earth had buried in a trillion barrels of oil. The resulting greenhouse warming is one of the greatest traumas ever inflicted on the living environment of our planet. Its accelerating consequences include rising sea level, acidification of the ocean and the destruction of corals, fewer but stronger typhoons, and redistribution of rainfall, all of which will be increasingly felt in the Philippines as well as the rest of the world.

During the 20th century, sea level has been rising at rates estimated at 1-2 millimeters per year (Cazenave, 2004), partly from expansion of the warmed surface waters, partly from glacial meltwater returning to the sea. The rise is accelerating. From 1993 to 1998, it was 3.2 ± 0.2 millimeters per year, measured precisely by the Topex/Poseidon satellite (Cabanes et al., 2001). Complete melting of the Greenland and Antarctic ice sheets could raise sea level as much as 70 meters (Alley et al., 2005). Melting of the Greenland ice, measured by gravity-sensing satellites, was 2.5 times higher from 2004 to 2006 than in the previous two years (Murray, 2006).

Implications for the Philippines

Sea-level rise has serious consequences for any archipelagic nation such as the Philippines, where coastal plains are occupied by the fastest-growing 63 percent of the population. To make matters much worse, excessive use of well waters around Manila Bay is causing the plains to subside at rates ten or more times faster than the rise in sea level, greatly aggravating the flooding from storms and high tides (Rodolfo and Siringan, 2006).

One result of global warming appears to be a shift in Pacific Ocean climate from La Niña to El Niño prevalence (National Oceanic and Atmospheric Administration, 2006). During El Niño events, fewer typhoons form in the west Pacific, but these would tend to form closer to the Equator (Landsea et al., 1993; Landsea, 2005) and thus may tend to follow paths leading across the Philippines. Furthermore, it is believed that global warming is resulting in fewer but stronger and more destructive storms (Emanuel, 2005; Webster et al., 2005). It is uncertain how annual rainfall will be affected, but in the Philippines from 1968 to 1992 the overall trend has been to decrease slightly (Jose et al., 1996). Increasingly more carbon dioxide from the atmosphere is being absorbed by the surface waters of the ocean. The resulting acidity is posing a serious threat to Philippine corals.

The Varied Uses of Petroleum

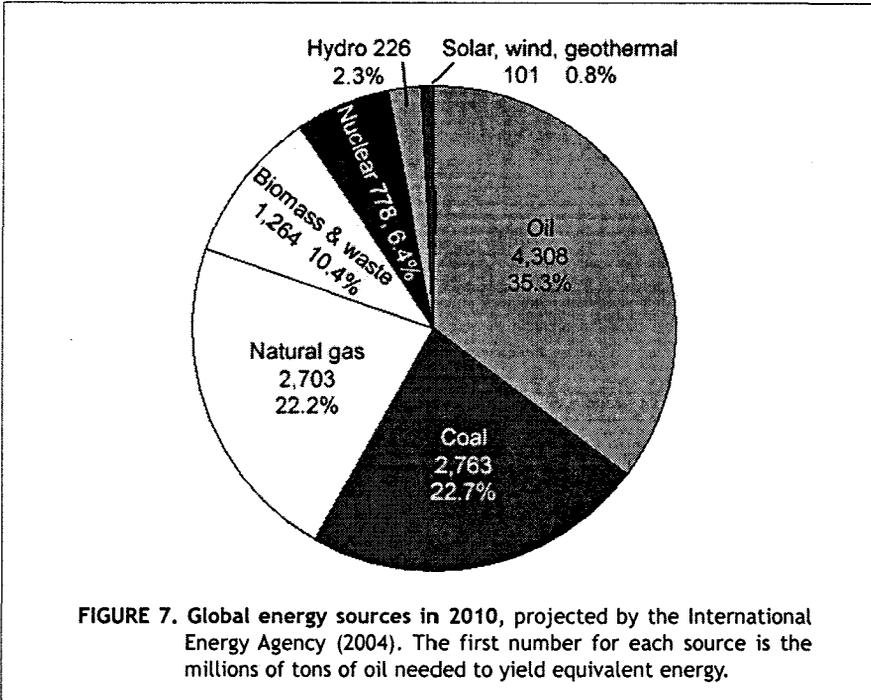
Petroleum is the world's most widely used energy source. The Organization for Economic Development (2004) estimated that 4.3 billion barrels of oil will provide about 35 percent of the world's energy by 2010 (Fig. 7).

The prominent role of petroleum in transportation tends to mask its other critical roles in modern life. As Figure 8 shows, oil provides more than 95 percent of the energy for all transportation, but this accounts for only a little more than half of the petroleum used (International Energy Agency, 2004). Oil is also needed to generate electricity, empower industry and agriculture, and heat homes.

Figure 9 displays the considerable variation in products obtained from oil coming from different regions and processed to satisfy regional needs, and the yield from an average barrel. Almost half is gasoline, between a fourth and a fifth is diesel and heating oil, and 10 percent, jet fuel. Liquefied petroleum gas, so heavily used in Philippine kitchens, accounts for 4.6 percent.

Given that about 92 percent of the average barrel of oil is made into various products that are burned, it is easy to overlook the critical uses of the remaining 8 percent. The 3 percent consisting of asphalt is also critical for transportation. About 3 percent is feedstock for the chemical manufacture of plastics and other useful compounds.

This small percentage of oil-derived material is far outweighed by the crucial role it plays in modern life, as this bewildering array of products listed alphabetically shows: Ammonia; anesthetics; antihistamines; antiseptics; awnings; balloons; ballpoint pens; bandages; boats; cameras; candles; candy wrappers; car battery cases; carpeting; car sound insulation; cassettes; caulking; clotheslines; cold cream; combs; contact lenses; cortisone; crayons; credit cards; curtains; deodorant; detergents; dishwashing liquids; dice; disposable diapers; dresses; drinking cups; dyes; electrician's tape; dolls; eyeglasses; fan belts; false teeth; faucet washers; fertilizers; fishing boots; fishing lures; fishing rods; floor wax; food preservatives; ink; garden hoses; glue; golf



bags; golf balls; guitar strings; hair curlers; hair dyes; hand lotion; heart valves; house paint; ice buckets; ice chests; ice cube trays; identification cards; insecticides; insect repellent; life jackets; linoleum; loudspeakers; luggage; model cars; mops; motorcycle helmets; movie film; nail polish; nylon stockings; oil filters; paint brushes; paint rollers; pajamas; panty hose; perfume; permanent press clothes; petroleum jelly; photograph film; pillows; plastic wood; plywood adhesive; purses; putty; refrigerator linings; roller-skate wheels; roofing; rubber cement; rubbing alcohol; safety glass; salad bowls; shampoo; shoe polish; shoes; shopping bags; shower curtains; shower doors; slacks; soap dishes; spandex tights; sports car bodies; sun glasses; sweaters; synthetic rubber; telephones; tennis rackets; tents; tires; toilet seats; tool racks; toothbrushes; toothpaste; toys; transparent tape; trash bags; TV cabinets; umbrellas; unbreakable dishes; upholstery; VCR tapes; vitamin capsules; water pipes; wire insulation; X-ray film; yarn.

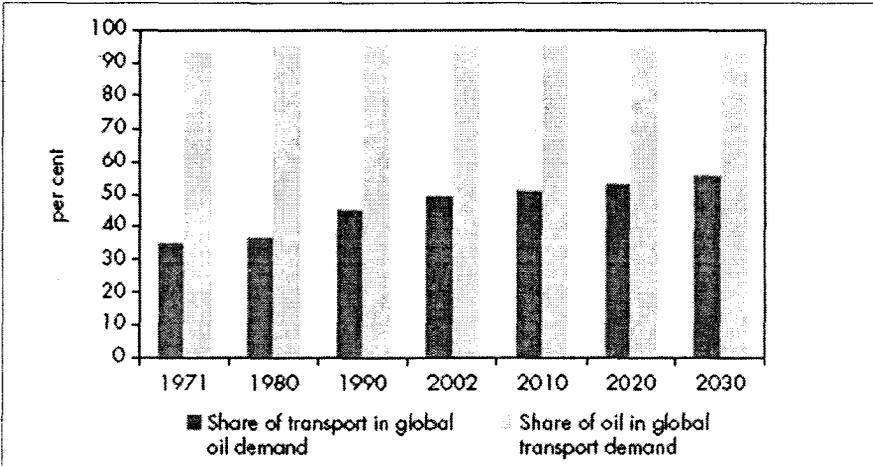


FIGURE 8. Oil and transportation. Virtually all transportation is fuelled by oil, but transportation consumes only half of the world's oil at present. From International Energy Agency, 2004.

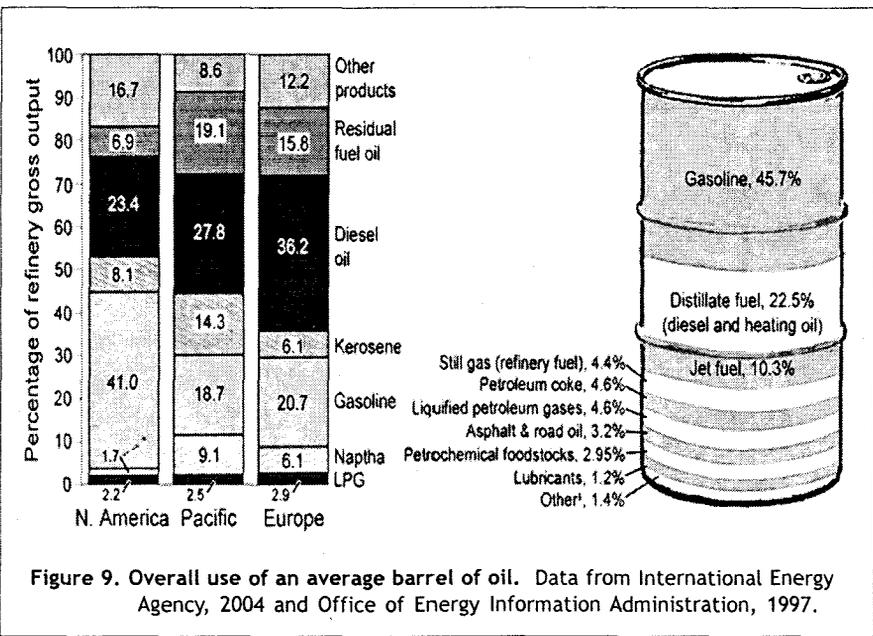


Figure 9. Overall use of an average barrel of oil. Data from International Energy Agency, 2004 and Office of Energy Information Administration, 1997.

TABLE 1. Some modern materials derived from petroleum.

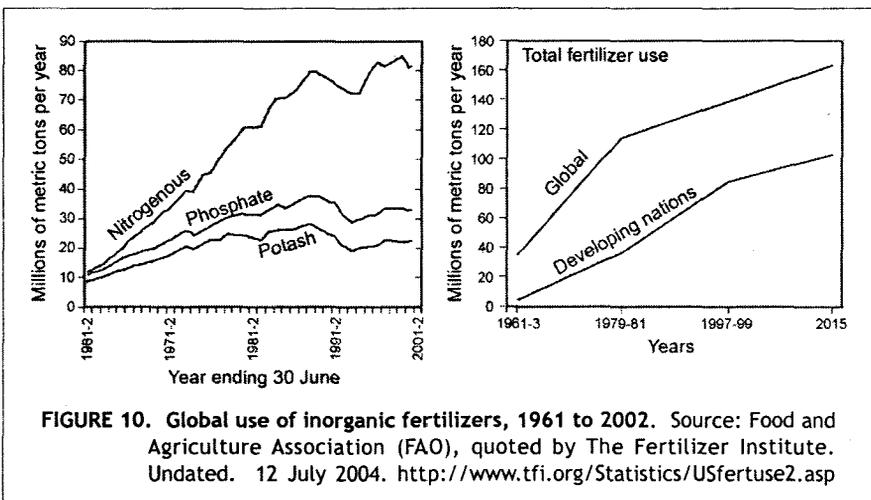
ACETYL
Acetic Acid: food sauces, pharmaceuticals, electroplating, textiles.
Acetic anhydride: photographic, cinematographic, x-ray film, microfilm, graphic film. Ingredient in aspirin.
Ethyl acetate: solvent for high-resolution printing inks, laminating adhesives, flexible packaging and plastic films. Solvent in paints, resin coatings, varnishes, pharmaceuticals.
Vinyl acetate monomer: latex paints, adhesives, flexible packaging, and hot melt adhesives.
Acetone: manufacturing of pharmaceutical ingredients, printing inks, paints, cosmetics, CD's, DVD's, adhesives.
AROMATIC
Polyesters, plastics, cosmetics
NAPHTHALATES
Used to expand the thermal, and mechanical properties of polyesters.
OLEFINS
Packaging, automobile parts, carpet backing, synthetic rubber, nylon fibers.
POLYMERS
Wires, cables, packaging materials, film, piping.
POLYSTYRENE
Plastics, packaging, insulation.
POLYESTER INTERMEDIATES (Dimethylterephthalate).
Polyester and other textiles.
SOLVENTS
Alcohols: Ethanol, isopropanol, n-butanol, isobutanol and 2-ethyl hexanol.
Glycol ethers: Coatings, printing inks, paints, cleaning applications, polishes, resins, brake fluids, cosmetics, textile printing and dyeing, anti-icing agents, and pharmaceuticals.

Table 1 segregates many of these items according to their petrochemistry. Sadly, the most visible products of petroleum in the Philippines are the throwaway plastic bags and containers that litter the landscape.

Oil and Agriculture

One of the most critical, but hardly acknowledged roles of petroleum in modern life is its use in agriculture, especially in agrarian nations like the Philippines. From 1950 to 1984, the “Green Revolution”, best known for hybrid crops such as the rice developed by the International Rice Research Institute at Los Baños, increased world grain production by 250 percent (Kindell and Pimentel, 1994). To a great extent, this increase was accomplished with fossil fuels to manufacture pesticides and fertilizers (Fig. 10), and to power irrigation. Oil-based agriculture typically uses about 50 times more energy than traditional farming, and in extreme cases 100 times or more (Pimentel and Pimentel, 1979; Giampetro and Pimentel, 1993).

The arable surface of the Philippines, like all of Earth’s (Buringh, 1989), is now fully utilized by agriculture and aquaculture, leaving only areas that are too steep, too dry, or with barren soils. As the population and its need for food inexorably grow, the only response can be to increase the productivity of the land, using oil-derived fertilizers and pesticides. Since the early 1980’s, the global increase in fertilizer use was largely in



developing nations (Fig. 9). This does not improve the well-being of their farmers; it can only partially prevent starvation (Giampetro and Pimentel, 1993). The following quote from Smil (1991, p. 593) also applies to the Philippines:

The image is counterintuitive but true: survival of the peasants in the ricefields of Hunan or Guangdong - with their timeless clod-breaking hoes, docile buffaloes, and rice-cutting sickles - is now much more dependent on fossil fuels and modern chemical synthesis than the physical well-being of the American city dwellers sustained by Iowa and Nebraska farmers cultivating sprawling grainfields with giant tractors. These farmers inject ammonia into soil to maximize operating profits and to grow enough feed for extraordinarily meaty diets; but half of all peasants in Southern China are alive because of the urea cast or ladled onto tiny fields - and very few of their children could be born and survive without spreading more of it in the years and decades ahead.

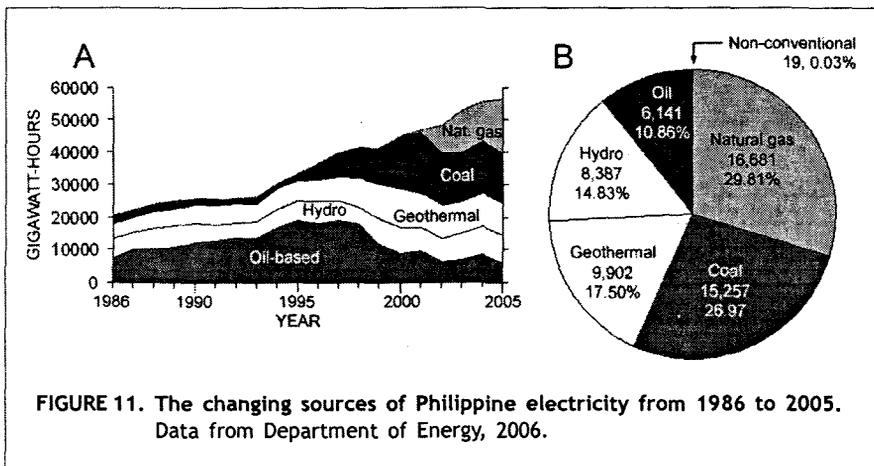
In 1991, the Philippines used 1,944,892 tons of inorganic fertilizer, primarily nitrogenous (Philippine Fertilizer and Pesticide authority, 2002). Few people realize that the production of each kilo of nitrogen fertilizer uses as much energy from fossil fuels as that in 1.4 to 1.8 liters of diesel (McLaughlin et al., 2000; Pfeiffer, 2003). Thus, to manufacture the Philippine fertilizer used in 1991 expended the energy equivalent of more than 2.7 billion liters of diesel. Furthermore, to provide the necessary hydrogen for the ammonia needed, substantial amounts of natural gas are also used, at times exceeding 90 percent of manufacturing costs.

Oil-based agriculture has resulted in enhanced soil erosion, and polluted and overused ground- and surface water. These effects diminish crop yields, and the response of global agriculture has been to increase the use of fertilizers and pesticides derived from petroleum. Increasingly, more oil is also used to pump irrigation water and to process polluted water (Pfeiffer, 2003). These measures are doomed to failure, if the

experience in the US is a guide. There, from 1945 to 1994, agriculture energy use quadrupled, but crop yields only tripled. Since then, energy input has continued to increase without a corresponding increase in crop yield (Pimentel and Giampietro, 1994; Pfeiffer, 2003). This trend of diminishing returns can only spell trouble.

Enhancing and Augmenting Philippine Energy Sources

Figure 11A shows that Philippine dependence on oil for generating electricity has decreased significantly since 1995 due to increasing dependence on coal and increasing use of domestic natural gas. By 2005, usage of oil for electricity has declined to only about 11 percent (Fig. 11B). Imported oil, however, still fuels virtually all Philippine transportation. As crude oil prices inexorably rise, the nation urgently needs to develop alternative sources of energy. To evaluate how this might be done, this report will first evaluate the main energy sources at present. The fossil fuels will find little favor in this analysis because of their role in adding carbon dioxide to the atmosphere, and thus in global warming. Following this, alternate sources of energy will be examined.



Animal Power

Few people think first of animals when enumerating sources of energy, but the Philippines has a long tradition of horse-drawn, two-wheeled *calesas* and *caretelas*, and of using carabaos and oxen for plowing, harrowing, and pulling carts. Animals, besides not requiring external sources of fuel, offer many advantages for use in transportation and farm work (Makhijani, 1990; Damerow and Bradley, 1995; Damerow 2006). They are cheaper to buy and maintain, and do not malfunction as frequently as machinery. Over time, machines deteriorate and wear out, whereas young draft animals become more skillful. An appropriate number of animals reproduce themselves without requiring major capital outlays. They provide milk, manure to use as fertilizer, and, when too old or feeble to work, they also provide meat and leather. A single animal represents a versatile source of power for plowing, harrowing, threshing, irrigation and transport. Each draft animal is a small power unit, suitable for farming a small tract of land such as many Filipino farmers cultivate. Animals are less noisy and powerful and work more slowly than mechanical equipment, thus are less likely to involve their users in accidents. An animal may not be as powerful as a machine, but it can provide power for short periods at several times its average rate. Animals can work on steeper slopes and wetter soil than machinery and, being lighter, do not damage the soil as much by compressing it.

The Philippine Carabao Center of the Department of Agriculture, established in 1992, is devoted to the genetic improvement of the animals. Present efforts are concentrating on improving their milk output (Hernandez, 2006). Efforts are also needed to breed them for strength, endurance, heat tolerance, and longevity. The ubiquitous motorized tricycles will become obsolete as fuel prices climb, and will have to be replaced by horse-drawn vehicles and human-powered pedicabs. Loss of tricycles will not be entirely unwelcome: they and their fuel are expensive imports; they pollute the air and the quiet; and, worst of all, they do not even provide their drivers with a decent living. In addition, people will be healthier if they walk a kilometer or two instead of riding.

Coal

The Philippines has 19 coal districts with estimated reserves of 2.3 billion tons of fairly young deposits, ranging in age from Eocene to Pleistocene (Flores et al., 2006; Fig. 12). Being geologically young, about 84 percent of this coal is the sub-bituminous and lignite grades that yield



FIGURE 12. Coal deposits in the Philippines. Modified from Flores et al., 2006.

relatively little energy when burned. Only the minor deposits of Catanduanes coal are the higher semi-anthracite grade. In 2004, the Philippines mined 2,726,500 tons of coal, most of it Semirara sub-bituminous (Table 2).

Total consumption was almost three times that amount, with two thirds imported, mainly from Indonesia and China (Philippine Department of Energy, 2005). The Philippine demand for coal is expected to increase to 14.7 million tons by 2008.

Oil largely replaced the world's heavy use of coal during the 19th Century largely because the mining and combustion of coal has serious environmental consequences, but coal still provides about 29 percent of all global energy, and 40 percent of electricity (International Energy Agency, 2006). Next to petroleum, it is the greatest generator of carbon dioxide and the resulting greenhouse warming. Bear in mind that every 12 kilograms of coal carbon we burn generates 44 kilograms of carbon dioxide. The oxides of nitrogen and sulfur from burning coal combine with atmospheric water vapor to form acid rain. Coal mining also causes habitat destruction, extensive erosion and river siltation, and releases toxic chemicals such as mercury and arsenic into streams and groundwater.

In developed countries, much research is being devoted to finding ways to use coal without emitting carbon dioxide. One solution would be to sequester the carbon dioxide underground. Alternatively, the complex hydrocarbon molecules in coal can be "gasified"—broken under high temperatures and pressures into hydrogen and carbon monoxide. Those gases can then be burned to generate electricity, or reunited into hydrocarbon chains like those of gasoline and diesel using the Fischer-Tropsch synthesis. This process is expensive, however, and making these fuels and using them for transportation releases nearly twice as much carbon dioxide as does burning diesel made from crude oil (Ledford, 2006). It is unlikely that the Philippine government will expend its scarce resources in sequestering carbon dioxide, gasifying coal, or making liquid fuels from it.

TABLE 2. Philippine coal production, imports, and use in 2004.

AREA	TONNES PRODUCED	PERCENT
Semirara	2,544, 663	93.33
Cebu	20,551	0.75
Negros	11,195	0.41
Zamboanga del Sur	134,929	5.39
Batan Island	12,660	0.68
Surigao	2,501	0.09
TOTAL	2,726,500	
IMPORTED FROM		
Indonesia	3,652,915	49.52
China	3,033,534	41.12
Vietnam	364,896	4.96
Australia	325,000	4.40
TOTAL	7,376,345	
PRODUCED:	2,726,500	36.64
IMPORTED	7,441,345	63.36
CONSUMED	9,490,000	
USE	MILLION TONNES	PERCENT
Power generation	7.80	76.71
Cement manufacture	1.99	19.60
Industrial processes	0.38	3.69
TOTAL	10.17	

Source: Department of Energy, 2005.

Coal combustion releases fine particles, toxic metals, and oxides of sulfur and nitrogen into the atmosphere, causing asthma and other respiratory diseases. Cardiovascular problems are also aggravated in diabetics by these pollutants (NIH, 2006). The toxic metals include the carcinogens arsenic and chromium; lead, which can damage the kidneys and cardiovascular and nervous systems; and mercury, which causes brain damage in fetuses, and motor and emotional disturbances in adults. Nitrous oxide also combines with ozone, forming smog. For these health reasons, Philippine NGOs and environmental groups are campaigning against coal-fired plants in Sual, Pangasinan; Pagbilao, Quezon; Calaca, Batangas; Toledo, Cebu; Banate, Iloilo; and Misamis Oriental. Given all these adverse effects, coal use should be reduced as much as possible, and the Philippine government should reconsider its projected increase of coal use to 14.7 million tons by 2008 (Philippine Department of Energy, 2005).

Natural gas

Discovery and exploitation of the Malampaya natural gas field off Palawan has greatly benefited the Philippines by partially substituting for imported oil to generate electricity (Fig. 10). In 2005, the Malampaya field yielded 115,870 million cubic feet of gas and 5,576,350 barrels of condensate. An additional 93 million cubic feet of gas was produced at the San Antonio gas field in Isabela (Department of Energy, 2006). The search for additional gas fields is continuing.

Beneficial to the Philippine economy as it is, we must realize that burning natural gas also pumps greenhouse carbon dioxide into the atmosphere. Furthermore, any molecule of methane that escapes during extraction and transport is twenty times as strong a greenhouse gas as a molecule of carbon dioxide. For the sake not only of the country but for humanity as a whole, we must continue to search for alternative, cleaner sources of energy.

Petroleum

An intense Philippine search for oil began in the 1950s, with little success except for the minor quantities found offshore from Palawan. Barring large discoveries in the Spratlys, the Philippines cannot expect to develop major oil fields. The Philippines consumes much more petroleum than it produces. In 2003 it used an estimated 335,000 barrels of oil per day, of which 312,000 was imported (Central Intelligence Agency, 2006). Offshore Palawan oil wells yielded only 208,000 barrels of crude oil in 2005, less than one day of Philippine consumption.

Geothermal Energy

Relatively cheap to generate, geothermal energy is also relatively clean because it uses the steam heated within the Earth and does not emit greenhouse gases. Accordingly, the world is accelerating its production of geothermal electricity. The Philippine nation is at the forefront of this increase. In 1969, the Tiwi plant in Albay province generated its first 2.5 kilowatts; by 2000, the 1,900 megawatts produced by the Philippines was surpassed only by the United States. In 2002, geothermal energy already was providing about 19 percent of the country's total electricity (Philippine Department of Energy, 2004).

Huttrer (2001) projected that by 2005 the nation would become the world's largest generator of geothermal power, its 2700 megawatts overtaking the 2376 produced by the US. Proven geothermal reserves amount to about 2,000 megawatts, and potential reserves are an estimated 4,800 megawatts. As Figure 13 shows, the tectonic and volcanic setting of the archipelago provides the Philippines with numerous potential geothermal sites. The Philippine Institute of Volcanology and Seismology (2002) listed 22 active and 27 potentially active volcanoes. The Philippines also has 359 inactive volcanic centers; many of them continue to emanate hot water and steam, and thus are very promising prospects for additional electricity.



FIGURE 13. Major Philippine geothermal energy sites. Modified from PHIVOLCS data.

<http://www.phivolcs.dost.gov.ph/vmepd/vmepd/volclist.html>.

Even without adding geothermal plants, the existing ones can effectively increase their output by being made more efficient. The standard practice is to stream the electricity from a plant into the entire national network. A fundamental principle of physics is that the farther electric current has to travel, the more energy is lost; thus, electricity should be consumed as close to its source as possible. Industry should be given incentives such as cheap rates to cluster around geothermal plants, and communities around them should enjoy cheap local rates that may help them increase their economic productivity. Deciding to open any new plant should involve analysis of its potential to serve not only existing communities and industries, but to the possibilities for establishing new industries to process untapped local resources.

Hydro and Mini Hydro Power

In 2005 the Philippines generated 8,400 gigawatt-hours of hydroelectricity, mainly at its Ambuklao, Binga and San Roque dams (Department of Energy, 2006). The government does not plan to build other large, new facilities, and proposes instead to add to the 51 existing mini hydro plants with a capacity of 82 megawatts.

Interestingly, while China and India are still building large hydroelectric projects, the developed countries are decommissioning their own dams because they have discovered that the environmental damage and the costs of displacing populations are too great. Furthermore, the popular belief that hydroelectric power is superior to fossil fuels because it does not release greenhouse gases is simply not true (Pearce, 2000; Graham-Rowe, 2005). When a dam is built and a basin is first flooded, the great quantities of tree and plant tissue are drowned and rot, forming carbon dioxide. Vegetal material then continues to wash down the basin slopes to the reservoir floor, where it rots without oxygen, forming methane that dissolves into the water. This most noxious of greenhouse gases is released as the water passes through the hydroelectric turbines. It has been estimated that each unit of hydroelectric power may actually release

three times more greenhouse gases than those released by an equivalent unit generated with fossil fuel.

Using the flow-through of small streams to generate electricity in mini hydro plants does not generate greenhouse gases. Mini hydro is not only environmentally friendly; it is one of the cheapest and most reliable ways to generate clean electricity, offering several advantages over solar, wave and wind power (British Hydro Association, 2007). Its 70 to 90 percent efficiency is unequaled. The *capacity factor* of any power-generating system is the amount of electricity that it produces over a period of time, divided by the amount it could have produced had it run on full load over that period. The typical capacity factor for mini hydro is 50 percent, compared to 30 and 10 percent respectively for wind generators and photovoltaic solar. Mini hydro power predictably varies with seasonal rainfall, and gradually from day to day, not from minute to minute like wind or solar power. Mini hydro systems can be built to last for 50 years or more.

Mountainous terrain and humid climate have endowed the Philippines with many streams. They could provide about 1,100 megawatts of additional electric power from small-scale hydropower generators, according to the Department of Energy (2005). For the period 2000-2009, DOE has identified 12 mini-hydro sites with a combined capacity of 70,000 kilowatts that would generate 300 gigawatt-hours, equivalent to the energy in half a million barrels of oil. By the end of 2009, the total mini-hydropower could reach 160 megawatts, generating 560 gigawatt-hours. The small impoundments for mini hydro could serve the domestic water needs of small communities, and seepage from them into the ground would replenish local groundwater supplies. To be maximally effective, the electricity generated by mini-hydro systems should be designed to serve their localities, eliminating the power loss incurred by long-distance transport. For all these reasons, the national government should continue to encourage and assist local communities in developing their own mini hydro system.

Wind

Prospects for electricity generation from wind are excellent in the Philippines. The 25-megawatt wind power plant on the coast of Bangui Bay, Ilocos Norte (Fig. 14) is the first large-scale wind power plant in Southeast Asia, producing 75 gigawatt hours per year. Modern wind generators such as the 15 Vestas NM82 turbines used in Bangui Bay are computerized to feed electricity smoothly into the grid and maximize power production. The blades are hydraulically activated to rapidly reduce loads of high winds, and feather in response to the sustained high winds of typhoons.

Bangui Bay is only the beginning. The World Bank (2004) estimated the Philippine potential for wind-generated power at 70 gigawatts, and identified 47 provinces with at least 500 megawatts of potential, 25 of



FIGURE 14. The wind farm in Bangui Bay, Ilocos Norte.
Photograph by Tonie Santos.

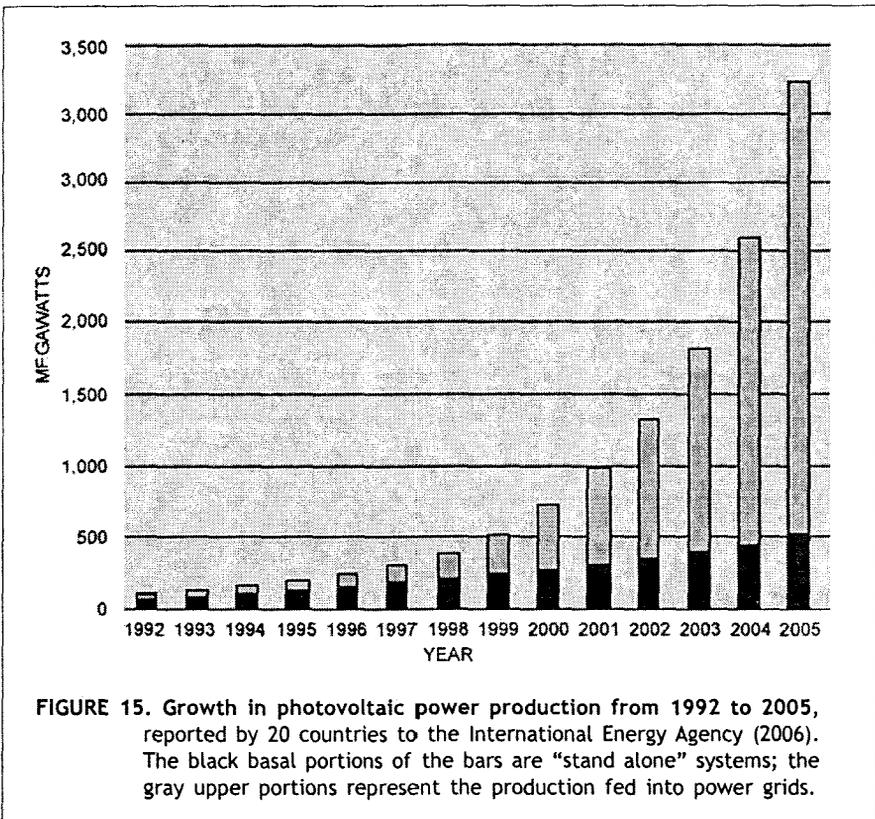
which could generate 1,000 megawatts or more. In late 2006, German funding was obtained to construct two other Ilocos wind farms with a joint capacity of 76 megawatts (Adriano, 2006).

The Department of Energy (2005) offered sixteen potential wind power sites to private investors, of which five were approved for development by various private companies.

Solar

Directly or indirectly, the Sun is the main source of energy in the world. Only geothermal, nuclear and tidal energy cannot be traced back to sunlight. The energy in coal, natural gas, oil, and plants was converted from sunlight into stored chemical energy by photosynthesizing organisms. Unequal heating of the planet by the Sun is what drives the winds, ocean currents, and waves. Solar heating of the sea surface creates the large temperature difference between it and the deep ocean waters that may be harnessed to generate energy.

The increasing costs of fossil fuels, and concern over the greenhouse gases they generate, have caused rapid growth of electricity produced directly from sunlight all over the world (Fig. 15). Being near the Equator, the Philippines receives optimal solar irradiance and is favorably located to participate in that increase. The amount of energy received by any point on Earth's surface depends on its latitude. At the Equator, peak irradiance delivers 1,020 watts per square meter. Solar radiation changes in intensity with the hour of the day, time of the year and weather conditions such as cloud cover. The total amount of solar radiation energy in a region is expressed in *Peak Sun Hours (PSH)*, the average amount of sun per square meter available per day throughout the year. One PSH provides 1 kilowatt-hour per square meter of solar energy. By this measure, Luzon and the northern Visayas enjoy 3.5 to 4 PSH, whereas the southern Visayas, Palawan and Mindanao have 4 to 4.5 (Advanced Energy Group, 2006). In contrast, the southwestern desert of the United States has 5 to 5.5 PSH, but the central and northern states have only 1 to 2.



Direct solar energy is captured in several ways. In temperate regions, "passive solar" systems are used to heat houses and domestic hot water. In deserts and semi-arid areas, megawatts of electricity are generated in large plants by using parabolic mirrors shaped like dishes or troughs to focus sunlight on fluids that in turn heat water into steam that drives turbines. Those technologies are unsuited for the often-cloudy Philippines, but photovoltaic solar, or PV, is not.

In photovoltaic systems, photons—particles of solar energy—dislodge electrons in films of semiconductor material such as silicon and convert them into electric current. The electricity can be stored in batteries

and converted to usable alternating current, or it can be fed directly into power grids. Most PV electricity generated for individual homes in developed countries does not require batteries. Instead, the current is fed into power grids with “net metering”: The home owners pay only for any electricity they use beyond the amounts they generate, and if the home system generates more electricity than it uses, the utility company pays retail rates for it.

Net metering is still not used in the Philippines, but would be efficient in large urban areas with many houses generating their own PV power. In the meantime, remote rural areas without power grids must rely on battery storage. Funded by Spanish loans, the Solar Power Technology Support Project of the Philippine Department of Energy (2006) had already installed over 9,000 solar home systems in 98 Mindanao communities by the first quarter of 2006, in conjunction with other governmental efforts to improve their socio-economic development. The program is still being expanded.

One consequence of the rapid global growth in PV power generation has been shortages and strong increases in costs for the solar panels. Driven by the strong demand, technologic innovations will inevitably reduce the prices. The Philippine government should seriously consider developing its own fundamental solar industry, benefiting from the nation’s low labor costs. It should also encourage Filipino inventors to develop other forms of solar energy. Other developing countries already use cheap, low-technology forms of solar energy to cook food and to dry fruit for storage.

Nuclear Power?

The future role of nuclear power in the Philippines continues to be discussed as a viable option. In 2002, nuclear energy provided about 17 percent of the world’s electricity (Nuclear Information Centre, 2006). Many proponents for increasing nuclear use cite its freedom from the negative climatic effects of fossil-fuel burning. The high stakes are represented in a powerful nuclear lobby. What is not generally considered

is that uranium mining, processing, and shipping entail large expenditures of fossil fuels, and that the nuclear power industry is strongly subsidized by governments (Caldicott, 2006). Nuclear wastes also pose grave health and environmental threats. From 1952 to 2004, there have been seven serious accidents at nuclear reactors, most notably the Chernobyl tragedy in the Ukraine in 1986 and the Three Mile Island disaster in the United States in 1979 (Information Please, 2006). Nuclear waste disposal and storage also is a large and growing problem. In May, 2005, large volumes of waste containing about 20 tons of uranium and plutonium fuel were leaked through a fractured pipe at a facility in England that stores and reprocesses nuclear waste (Brown 2005).

The US Department of Energy (1999) lists 25 radioactive isotopes in reactor-generated nuclear waste, of which the most important are Tritium (^3H); Cesium-137 (^{137}Cs); Strontium-90 (^{90}Sr); the three natural Uranium isotopes (234, 235, and 238) and Uranium-230 produced in nuclear reactors; four isotopes of plutonium (^{238}Pu , ^{240}Pu , ^{241}Pu), and ^{242}Pu) produced by irradiation of Uranium; Carbon-14 (^{14}C), and Technetium-99 (^{99}Tc). Some of these radionuclides have short half-lives and decay in days to a few years, but others, about 3 percent of the wastes, last for millions or billions of years. Arbitrarily, bulk wastes are assumed to be dangerous for 10,000 years, and must be contained and stored for at least that time. To give a context for that length of time, remember that human civilization is only 6,000 years old.

Storage of nuclear waste is a serious problem that the United States has yet to solve. Plans to do so at the Yucca Mountain in Nevada are hampered by scientific concern that the area is geologically unstable, and by political opposition by environmentalists and communities concerned about the transport of the wastes through their territories. The wastes also pose a threat from terrorists who might attack repositories, hijack transporting vehicles, or steal the wastes to make "dirty" bombs.

The only attempt to build a Philippine nuclear power plant, at Napot Point in Morong, Bataan, has been a serious economic tragedy (Wilson,

2004). Started in 1976 and completed in 1984, it was designed to generate 3.8 billion kilowatt-hours, and would have replaced over 200 million U.S. dollars in imported oil annually, but it has never produced *any* electricity. Corruption of the dictator Ferdinand Marcos and his cronies bloated construction costs and loans from \$600 million to \$2.3 billion, and to service the debt interest costs the country \$155,000 a day. From 1986 to 1998 alone, taxpayers have paid out 48.3 billion pesos.

The corruption was accompanied by serious defects in construction, beginning with the location of the reactor in a region of active faulting and volcanism (Torres, 1992). Mount Pinatubo is only 53 kilometers away, and the reactor site itself is on the flank of Mount Natib, which last erupted no earlier than 18 thousand years ago (Cabato et al., 2005). After Marcos was deposed in 1986, a study commissioned by President Aquino detected 4,000 reactor defects. President Ramos wanted to convert the facility into a coal-burning plant, but studies concluded that it was not feasible (Fabros, 1998).

The Bataan Nuclear Power Plant should not be activated, and no other reactors should be constructed. Nuclear waste disposal would be even more difficult in the geologically active Philippines than in the United States, and the reactor itself is susceptible to volcanic eruptions and faulting. Philippine geologic disasters are frequent, and aggravated by an apparent inability of the government to mitigate them, as exemplified in 2006 alone by the Guinsaogon landslide disaster and the Mayon lahars that respectively killed an estimated 1,500 and 1,200 people.

Biofuels

Biological substances—especially ethanol, biodiesel and biogas—are gaining popularity as substitutes for fossil fuels. They also are “carbon neutral”; when burned, they are only returning to the atmosphere the carbon dioxide they withdrew from it. It is important to know, however, that the carbon in the fossil fuels burned annually by humans is equivalent to more than 400 times the carbon fixed by all the world’s terrestrial and

oceanic photosynthesizing organisms (Dukes, 2003). Clearly, it is impossible to replace fossil fuels with biofuels completely.

Whether or not biofuels are viable energy sources is hotly debated in the United States. The key issue is the “energy balance”, the ratio of the energy yielded by the fuel to the energy expended in growing the crops, extracting fuel from them, and transporting them to the end users. David Pimentel at Cornell University and his colleagues have studied the question for more than 20 years (Pimentel and Pimentel 1979; Pimentel and Patzek 2005; Pimentel and Giampietro 2006). For ethanol from corn, Pimentel reports an energy balance of 0.59, meaning that 70 percent more energy is needed to produce a gallon of ethanol than the energy it yields. Other studies quote figures as high as 2.62—it yields 2.5 times as much energy as is spent growing it. The more typical optimistic reports, ranging from 1.23 to 1.79, come from vested interests such as the National Corn Growers Association, the National Ethanol Vehicle Coalition, and the American Coalition for Ethanol (Western Area Power Administration, 2006). As Pimentel has pointed out, and as Johnson and Libecap (2001) have verified in detail, ethanol in the United States would not be possible without large federal subsidies. Even Pimentel acknowledges, however, that the energy deficit is much smaller for biodiesel.

Philippine agriculture is much less reliant on oil than the United States, and so it should be able to produce biofuels at a much better energy balance. For inspiration we can look to another tropical country, Brazil, where sugarcane ethanol is 40 percent of automobile fuel (Marris, 2006). There, ethanol factories are powered by burning the bagasse, or cellulose waste left after pressing the juice out of the cane; some plants even sell surplus energy to the electricity grid. On the negative side, harvesters and fertilizers are fueled with diesel; sugarcane agriculture uses large amounts of water, causes soil erosion and emits nitrous oxide, a potent greenhouse gas. Pesticides and factory wastes pollute rivers, and smoke from the fields being scorched for harvest pollutes the air. Nevertheless, sugarcane yields about eight times the amount of energy from ethanol and electricity from bagasse as the amount of energy used to produce it (Macedo, 2003).

The Brazilian ethanol industry employs more than a million people, a major consideration for any country with high unemployment. In the Philippines, firewood and charcoal have long been kitchen energy staples. Liquid petroleum gas is much more widely used now, but as its price increases, systematic production of charcoal from rapidly growing trees like ipil-ipil (*Leucaena glauca* Linn) could help to fill the fuel gap, and also give livelihood to many Filipinos. Being a legume, ipil-ipil also nitrogenizes its soil, benefitting nearby plant life. Its cultivation and use can be improved by the Department of Agriculture. Furthermore, the roots of ipil-ipil, like those of any tree, represent significant quantities of carbon removed from the atmosphere and sequestered in the soil. Ipil-ipil should not be harvested entirely, to maintain that sequestration. Instead, charcoal can be made from pruning.

Commendably, the Philippine legislature recently passed a Biofuels Law requiring the development and use of renewable energy sources. Perhaps the biofuel with the greatest promise for the Philippines is biodiesel. As Table 3 shows, the three crops that yield the most oil are common to the Philippines. The chronically ill Philippine coconut industry offers the greatest potential. Avocados are valuable as food. Oil palms yield the most oil, but their cultivation in Indonesia, Malaysia and South America is causing serious environmental damage: thousands of square kilometers of primal rainforest cleared; 140 species of Indonesian land animals endangered; Sumatran tigers and Bornean orangutans now virtually extinct in Malaysia; soil erosion; streams polluted with silt and effluent from mills (Olmstead, 2006).

The Philippine Department of Energy is enthusiastic about *Jatropha* (*J. curcas* L.), an inedible, drought-resistant plant that grows easily on poor soils from seeds and cuttings. *Jatropha* seeds contain as much as 40 percent oil that burns with a clear, smokeless flame and thus can substitute for kerosene in lamps. Extensive cultivation in India typically yields 1,600 liters of biodiesel per hectare annually, and provides employment to thousands. *Jatropha* plants take only a year to produce seeds, are fully fruitful after 4 to 5 years, and bear for 30 to 40 years (REUK, 2007).

TABLE 3. Oil yields from common Philippine crops

Crop	liters oil/hectare
Corn	172
Cashew	176
Cannabis	363
Soybean	446
Coffee	459
Rice	828
Cacao	1026
Peanuts	1059
Avocado	2638
Coconut	2689
Oil palm	5950

The biodiesel yield from each liter is 0.8 liter. From Addison, 2006. The Philippine Department of Energy is also favorable about *Jatropha* (*J. curcas* L.), which is widely used for biodiesel in India, yielding 1,600 liters per hectare annually.

Furthermore, they can be planted between coconut trees, or intercropped with fruit trees, vegetables or coffee, its leaves forming a rich, fertilizing mulch. The plants also serve to reduce soil erosion. After the oil is extracted, the remaining presscake can serve as a nitrogen-rich organic fertilizer.

Another plant that can be planted between coconut trees in plantations with better soils is sweet sorghum, from which ethanol can be extracted. Ordoñez (2007, p. B5) cites many virtues of sweet sorghum: "...[it] is widely adaptable, grows rapidly... has high sugar accumulation... is toleran[t] to drought, water logging, soil salinity and acid toxicity. It is a low-input crop..."

The greatest Philippine difficulty in producing most biofuels is that they would compete for land badly needed for growing food. In China,

that is already a critical situation, according to a representative of the United Nations Development Program in Beijing (Cheng, 2006). Thus, care must be taken in any Philippine biofuel effort to balance the competing needs for food and for energy.

Yet another readily available energy source is biogas, formed by bacteria that occur naturally in organic wastes, which they digest under anaerobic—oxygen-free—conditions. It consists of 55-75 percent methane, the remaining gas being largely carbon dioxide. A cubic meter of biogas can provide the following energy equivalents: 1.25 kilowatt-hours of electricity consumed by a 60 to 100-watt light bulb for 5 to 6 hours or a one-horsepower motor for 2 hours; cooking fuel for three meals for 5 to six people; or 0.7 kilograms of gasoline. Biogas has long been generated in specially designed digesters by fermenting human and animal waste, notably in China and India. More recently, methane has been captured from municipal waste landfills. Biogas plants can vary in scale from simple single-household systems to large commercial plants producing thousand of cubic meters daily. At present, over two million people in developing countries use biomass for the most of their energy needs for cooking, heating water and space heating (Practical Action, 2006).

Beyond its potential as an energy source, usage of biogas offers several additional advantages. It would subtract from the 65 percent of atmospheric methane produced by agriculture which, molecule for molecule, is a greenhouse gas about 20 times more potent than carbon dioxide. After the gas is extracted the waste is reduced to a slurry with a high nutrient content, excellent organic fertilizer. Unlike the slurries produced in traditional waste-treatment plants, it contains no harmful bacteria, which are killed during digestion.

Thus, every Philippine chicken farm, piggery, and municipal waste-treatment plant could produce useful amounts of biogas. In developed countries, waste-treatment facilities are now routinely powered by biogas, and even produce surplus electricity.

Energy from the Sea?

Given the maritime setting of the Philippine archipelago, it behooves the nation to explore how it can harness the abundant energy in the ocean. That energy takes many forms: methane hydrates; the temperature difference between the warm surface and cold depths of the ocean; the tides; and waves. These energy sources will be discussed in turn.

Methane Hydrates

One potential source of energy that is still not being considered by the Philippine government is stored in submarine methane hydrates, also called “methane clathrates” or “methane ice” (Fig. 16).

Organic matter buried in ocean sediments under cold water deeper than 300 meters is degraded by bacteria and transformed by high pressures into a crystalline solid of methane molecules, each encased in a cage of water molecules (Henriet and Mienert, 1998; Sloan, 1998; Max, 2000). Methane hydrate looks very much like water ice and has a similar specific gravity. It can cement ocean sediments to form a surface layer as thick as several hundred meters (Dillon, 1992). Such layers are revealed by making “seismic profiles” such as shown in Figure 16C. Sound waves made with artificial explosions travel faster through sediment cemented with hydrate, as seen in the actual instrumental record.

When the hydrate is recovered and the pressure is allowed to revert to standard atmospheric pressure, one cubic meter of it will release more than 150 cubic meters of methane. Estimates of how much of these hydrates exist vary widely, potentially yielding from 850 billion to 340 trillion cubic meters of methane. Even the lower figure, however, is more than double the 368 billion cubic meters of the world’s conventional natural gas reserves (United States Geological Survey, 2004). Ocean basins of Southeast Asia, including those of the Philippines, probably contain sizeable amounts of methane clathrate (Wilde and Quinby-Hunt, 1997). China, Japan, and the United States are most interested in tapping this resource.

The technical problems with extracting deep-sea methane hydrates are difficult, however, and most deposits are probably too dispersed to be extracted economically. Utilization also poses serious environmental problems. Any methane molecule that escapes into the atmosphere is twenty times more potent a greenhouse gas than one of carbon dioxide, and when methane is burned, it yields carbon dioxide, adding to global warming. Given these difficulties, the Philippines should turn to other, more practical sources of energy.

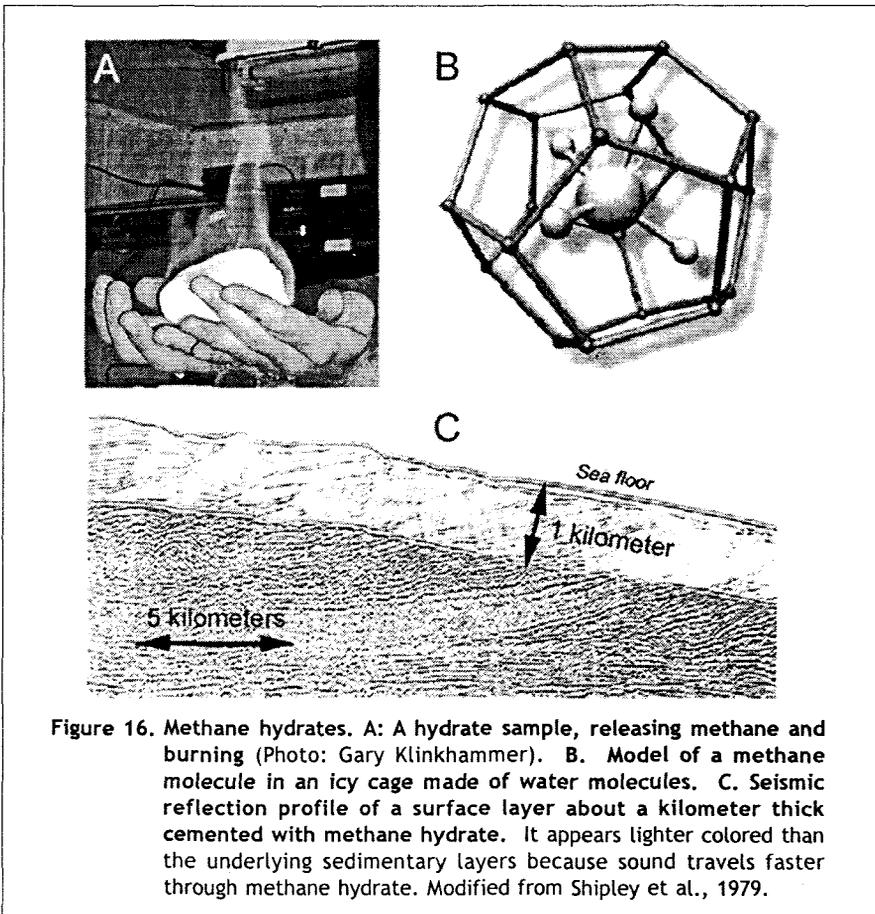


Figure 16. Methane hydrates. A: A hydrate sample, releasing methane and burning (Photo: Gary Klinkhammer). B. Model of a methane molecule in an icy cage made of water molecules. C. Seismic reflection profile of a surface layer about a kilometer thick cemented with methane hydrate. It appears lighter colored than the underlying sedimentary layers because sound travels faster through methane hydrate. Modified from Shipley et al., 1979.

Ocean Thermal Energy Conversion (OTEC)

OTEC is a technology that generates energy by using the temperature difference between the warm, sunlit surface waters of the ocean and the cold, deep waters. That difference is greatest in the tropics, and the largest difference in the world, more than 24°C, occurs off the coast of Mindanao (U.S. Department of Energy, 2005). To extract energy, cold water is pumped to the warm surface through a pipe from depths of a kilometer or more. Heat transfer between the cold and warm water is used to drive a heat engine to generate electricity. The ocean is huge and absorbs great quantities of solar energy, but extraction efficiency is only a few percent because the temperature difference is small. Nevertheless, the tectonism of the Philippines has given it several possible sites where the seafloor drops off steeply close to shore, minimizing the length of pipe needed. Few communities already are near such sites; however, the rapidly growing populations of Laoag, Vigan, and other towns shown in Figure 17 might eventually justify the expense of OTEC.

From 1993 to 1998 the U. S. National Energy Laboratory's experimental OTEC plant at Keahole Point on Hawaii was able to generate 103 kilowatts. Several other advantages that OTEC offers besides power were demonstrated there (U.S. Department of Energy, 2005). A plant that generates 2 megawatts of electricity theoretically could desalinate seawater or condense fresh water from the air to produce 4,300 cubic meters of fresh water daily. After cold seawater is used to generate electricity at an OTEC plant, it can be used to cool buildings in place of energy-expensive traditional air conditioning.

The cold seawater can also be passed through pipes buried in the soil. Not only would water condense on the cold pipes, irrigating the soil, it would cool it and plant roots, enabling plants from temperate climates to grow in the tropics, such as the more than 100 vegetables and fruits grown successfully near the Natural Energy Laboratory OTEC facility in Hawaii. The deep water brought to the surface is ideal for aquaculture—clean and rich in nutrients that nourish algae and the lobster and fish and

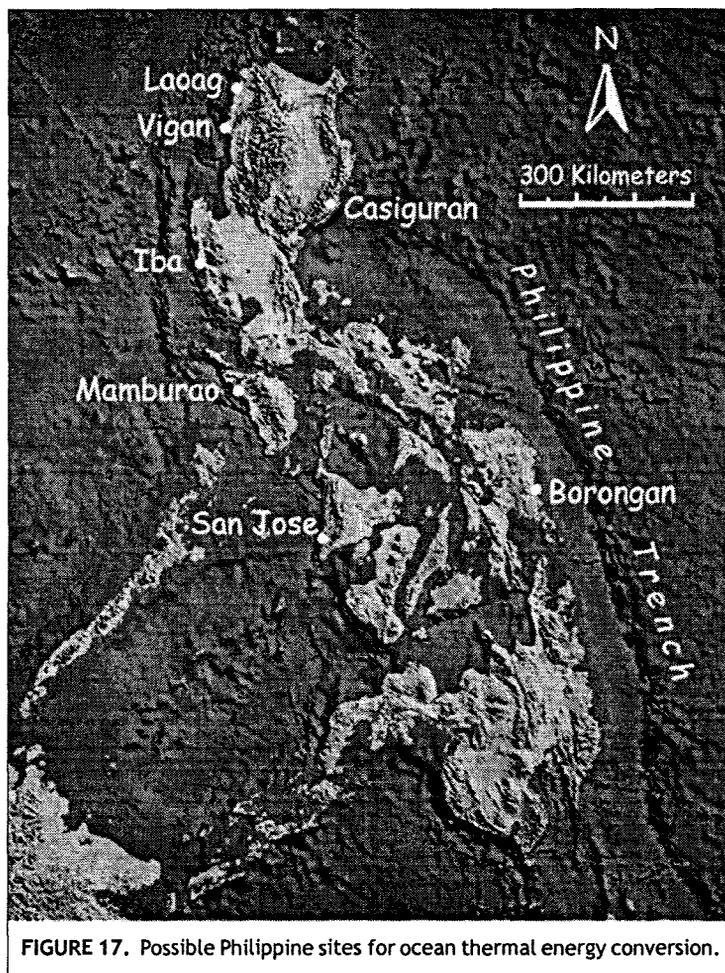


FIGURE 17. Possible Philippine sites for ocean thermal energy conversion.

other organisms that feed on them. *Spirulina* microalgae, a health food supplement, has also been successfully grown at the Natural Energy Laboratory.

The greatest drawback for OTEC is the large initial investment, beginning with the intake pipe, typically a meter in diameter and at least a kilometer long. For the Philippines to develop this resource would require

major foreign assistance. Even the United States government, after its promising beginnings in Hawaii, is no longer conducting OTEC research.

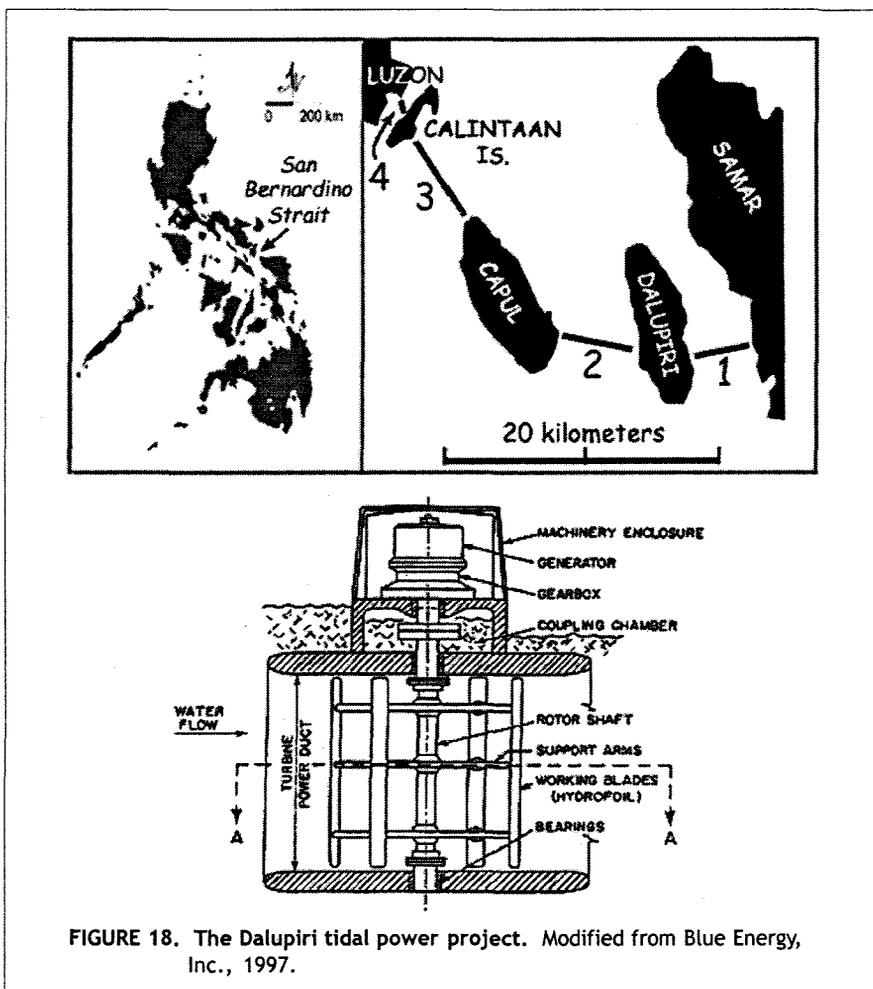
Tidal power

One of the Earth's few large sources of energy that does not come directly or indirectly from sunlight is that of the tides, the rise and fall of the ocean surface in response to the gravitational attractions of the Moon and Sun. A major advantage of this energy source is that it is absolutely predictable. Tidal energy can be harnessed to generate electricity in two ways. In places such as the Bay of Fundy and Ungava Bay in Canada, where the difference in sea level between high and low tides can be 17 meters, a dam or barrage can be built across a bay or estuary to accumulate tide height and potential energy with which to run turbines. The largest such facility in the world is a 240-megawatt plant at La Rance, France that has operated since 1966. In North America, the only such facility is the 18-megawatt generator near the town of Annapolis in Nova Scotia, Canada. Tidal ranges are little more than a meter in the Philippines (Siringan and Rodolfo, 2003), so the method is not practical.

The other technique is simply to harness the energy of fast-moving currents flowing through constricted channels. This could be done in the Philippines, but the investment would be prohibitive. An ideal site is the San Bernardino Strait between Luzon and Samar (Fig. 18), through which powerful tides flow between the Pacific Ocean and the Visayan Sea. Peak flows are about 8 knots, or 15 kilometers per hour, compared to the 4 or 5 knot (7-9 km/h) minimum generally considered necessary for such projects (Boyle, 2001). In Phase 1 of a plan, Blue Energy (1997), a Canadian company, proposes to build a line of 274 undersea Davis turbines along a 4-kilometer long "tidal fence" between Samar and Dalupiri islands. Each turbine would begin to produce electricity upon installation in the fourth year of the project. In the sixth year the completed phase would finally generate an average 1,100 megawatts.

The cost of this first phase is estimated at US\$ 2.8 billion, in part

because the system would have to be built to withstand 240 kilometer per hour typhoon winds and 7 meter high tsunamis. Blue Energy claims that all four phases would produce 25 gigawatts and cost US\$ 38 billion. Given such staggering expense, it is not surprising that the Philippine Department of Energy does not mention the project in its more recent (2005 and 2006) energy plans.



Wave Power

Unlike ocean-floor methane clathrates, OTEC and tidal power, the powerful ocean waves that batter numerous Philippine coasts offer great promise for small-scale electricity generation. The strongest sustained waves occur in temperate latitudes, but frequent storms, together with the persistent seasonal monsoonal and trade winds, propagate strong waves which, if harnessed, could provide electric current directly to many Philippine communities. Alternatively, any accessible electric grid could receive the current.

The Electric Power Research Institute (2005) offers several good reasons for developing wave power. If converters are properly sited, it is one of the least environmentally disruptive ways to generate electricity. Wave converters also can operate out of sight. Being more predictable than sunlight and wind, waves can provide reliable quantities of energy to power grids. Fairly small systems can provide a degree of energy independence to small coastal communities that are not served by power grids. Waves have higher power density than sunlight and wind, which are much more diffuse. Wave energy is solar energy that has been concentrated by the wind and oceanic processes into a form that is easier and cheaper to collect.

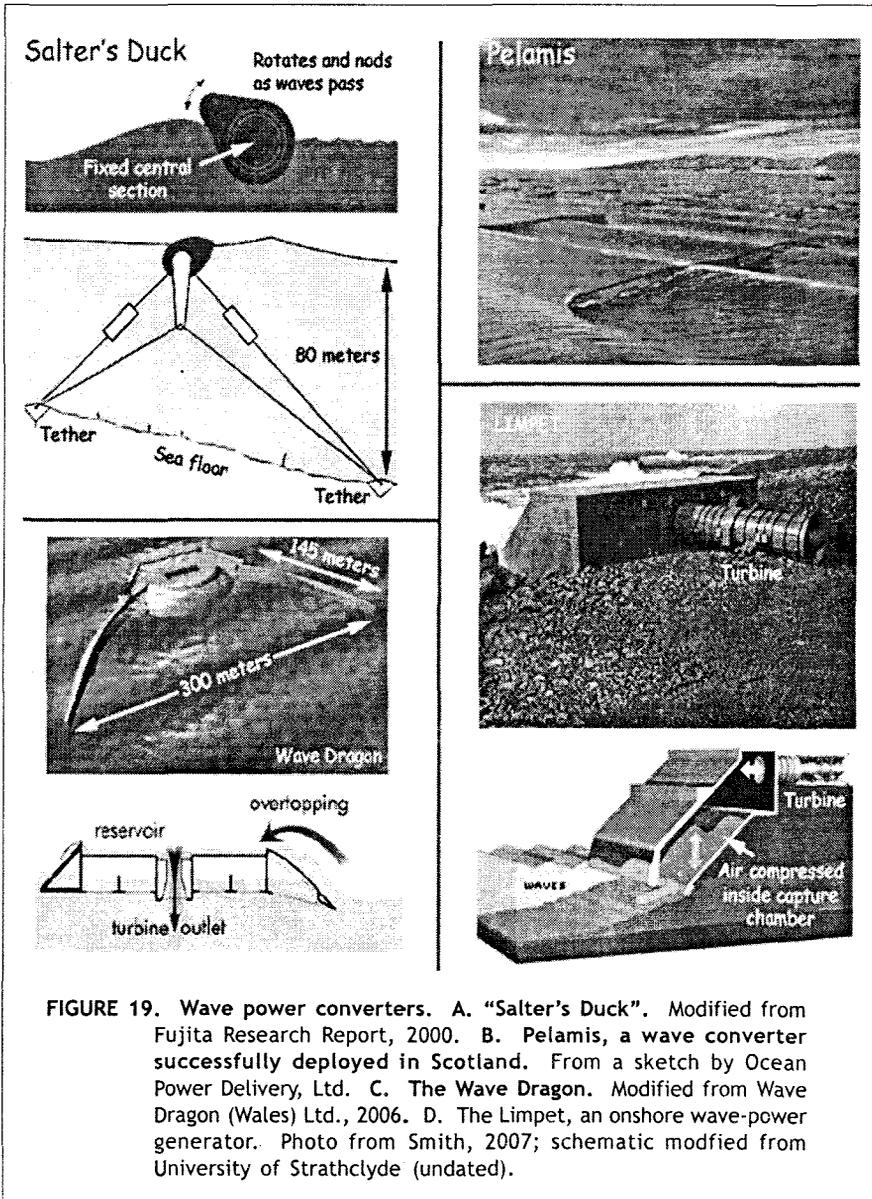
A simple formula governs wave power. If H is the height of the wave from crest to trough, and T (the wave period) is the time for each full wave to pass a stationary point, the power of the wave along each meter of its front is about $0.5HT$. By this formula, the biggest normal waves, with periods of about 15 seconds and heights of 15 meters, theoretically offer 1700 kilowatts of power per meter of wavefront. But that is exceptional; good coastal locations might yield an average of only 50 kW/m (Wikipedia, 2007).

Many different devices to harvest wave power, described in Wikipedia (2007), are being devised and tested. To encourage Filipino inventors to develop their own systems, four of them are described here and illustrated in Figure 19.

The most famous system is “Salter’s Duck”, developed in the 1970’s by Professor Stephen Salter of the University of Edinburgh in Scotland. A floating canister weighing 300 tons, the duck is tethered to the sea floor to remain oriented parallel to the incoming waves. It bobs up and down as waves pass, generating electricity from that motion. In controlled tests, the duck captured 90 percent of wave motion, and converted 90 percent of that motion to electricity. A commercial version of Salter’s Duck has not been built because its hydraulic system is too complex, and a full-scale model would be very expensive. It is also claimed that the project was terminated by secret meetings of a commission composed mainly of representatives from the nuclear and fossil-fuel industries (Green Left Online, 1992).

Pelamis, described in an undated Internet posting by Ocean Power Delivery, Ltd., has been generating enough electricity from the waves off Scotland since August 1994 for 500 households (Gartner, 2005). Named after a sea snake, Pelamis is a 130-meter long series of steel sausage-like cylinders 3.5 meters in diameter, connected with hydraulic pumps that pressurize oil to turn a generator and produce electricity. Unlike Salter’s Duck, Pelamis is tethered so that it faces the incoming waves, and undulates along its entire length as each wave passes. Current from several of the devices is gathered by a junction box on the sea floor and fed to shore through a single cable. Each full-scale version has a continuously rated power output of 0.75 megawatts. In September, 2006, proposals were being developed to construct “WestWave” off the coast of Cornwall in the UK, consisting of seven of the converters. This 5-megawatt array would empower 3,000 households.

The Wave Dragon being developed by the Welsh, Danes and other Europeans is intended to be the world’s largest wave energy converter. It consists of two 300-meter long wave reflectors that focus incoming waves up a ramp and into a reservoir. The reflectors typically capture 70 percent of the wave energy. The pressure head of the collected water is converted into electricity as the water flows out through hydro turbines. After scale-

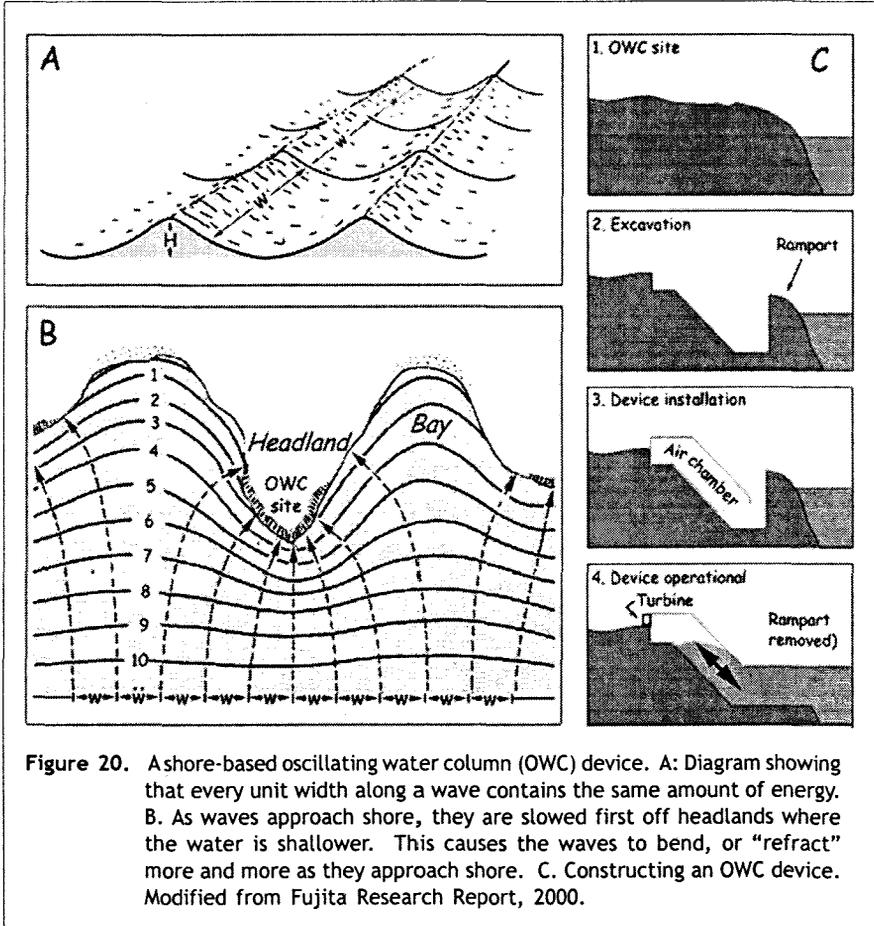


model testing, a quarter-sized prototype (27 x 57 meters) weighing 237 tons was deployed off Denmark in 2003 and successfully connected to the local power grid. Each unit will have 4 to 10 megawatts of power, depending on the prevailing waves.

These three generators have the advantage of being deployed inconspicuously offshore, but they are much harder to maintain than shore-based wave-power collectors called oscillating water column systems (OWC). One example of an OWC is the LIMPET (Land Installed Marine Powered Energy Transformer) on the island of Islay in Northern Ireland. A chamber to capture waves was carved into a rocky shore. Incoming waves alternately compress and decompress the air in the chamber, driving a turbine designed to turn in either flow direction. The demonstration plant generates 75 kilowatts of power.

Power generation of Limpet-like installations can be maximized by situating them at headlands (Fig. 20). Far offshore, every unit width of a wave has the same energy content. Nearing the shore, however, the portion of the wave off a headland begins to interact with the shallow seafloor and slow down before the part approaching a deeper bay does. This makes the wave "refract" or bend more and more, as the succession of waves numbered 1 to 10, as Figure 19B shows. Parts of the wave entering a bay are stretched and lengthened, but those approaching a headland are shortened. The net result is to focus much of the energy on the headland with large, powerful waves. For the same reason, waves arriving at a bayshore are much smaller and gentler.

The powerful wave forces make installing and maintaining a system on shore difficult. During construction, the cavity to hold the OWC has to be excavated away from the shore, leaving a temporary rampart of rock that is removed only after the system is installed. The forces may also be too large during storms; the first Norwegian OWC facility was ripped away during a storm, and storms completely submerge the Limpet on Islay (Fujita Research Report, 2000).



Summary and Conclusions

The oil age, after its inception in the later half of the 19th Century, began in earnest at the turn of the 20th, and accelerated to its climax in our own times. Usage of any finite resource like oil inevitably must reach a maximum, or peak, when half of the resource is depleted, and then decline. Peak Oil refers to the time that happens. It occurred in the United States in 1971, and may have already happened for the whole

world. Continued reliance on rapidly shrinking petroleum reserves is responsible for rapidly rising fuel prices, oil wars, and, in large part, the catastrophe of global warming.

One consequence of Peak Oil is that much attention is turning to the Spratly Islands in the South China Sea, perhaps the last place on Earth that may hold large, undiscovered oil reserves. That possibility is by no means certain, but the Philippines should collaborate fully with the neighboring countries in exploration and, should oil be found, in production and protection of the Spratlys.

The Philippines is already beginning to suffer the consequences of the world's profligate use of fossil fuel, despite its own fairly small consumption, because global warming is not restricted to national boundaries. Sea-level rise poses a serious threat to the two thirds of our population living on coastal plains, a problem that is greatly worsened around Manila Bay by excessive use of groundwater, causing rapid land subsidence and enhanced storm flood and tidal incursions. Acidification of the oceans by increased solution of carbon dioxide is wreaking havoc on coral reefs and associated life forms. The shift in Pacific Ocean climate from La Niña to El Niño prevalence may cause decreased rainfall, droughts, and fewer but more powerful typhoons that may tend to follow paths across the Philippines.

The average Filipino uses less than 1.4 barrels of oil annually, compared to the 27 barrels each American uses. This relatively modest consumption is exceedingly critical, however, for it fuels virtually all transportation, 11 percent of electricity, a huge array of plastics and other petrochemical products, asphalt to surface roads, cement manufacture, and more than two million tons of chemical fertilizers used annually. In the long run, the Philippine economy, work force and populace will benefit greatly by weaning agriculture away from petroleum.

The nation urgently needs to develop alternate sources of energy, not only to free itself from steeply rising oil prices, but also to decrease its own contribution to atmospheric carbon dioxide and global warming. It

can learn valuable lessons from another tropical, island nation. Cuba effectively underwent Peak Oil in the 1990's with the collapse of the Soviet Union, its only source of oil. Despite the added economic difficulties with the U.S. imposed economic embargo, Cuba has achieved a healthy, sustainable, organic agriculture totally independent of fossil fuels and inorganic fertilizers and pesticides (Funes et al., 2002; Pfeiffer, 2003). A great diversity of efforts to produce local food and to harness sustainable sources of energy should be brought to bear, providing employment to many workers.

The Philippines can avail itself of help from developed countries using the Clean Development Mechanism (CDM) provided by the Kyoto Protocol. A developed country can provide capital and clean technology for a project that reduces greenhouse gas emissions, in return for credits toward meeting its own emission reduction targets. Such an arrangement with Spain is already in practice in the form of the Solar Power Technology Support project of the Department of Energy that is electrifying remote Mindanao barangays with solar power. Another agreement, with Denmark, subsidizes the Bangui wind farm, and German funding has recently been obtained for two more wind farms (Adriano, 2006).

The use of petroleum to generate electricity is decreasing, but more coal is being used instead, and should not be, because it pollutes the air with toxic substances in addition to carbon dioxide. Nuclear power is another energy source that should be avoided, because it is particularly hazardous in a volcanic and earthquake-prone area.

Some of the alternate energy sources already used in the Philippines can be relied on more strongly and efficiently. These include geothermal, draft animals, biofuels; mini hydro, wind, and solar. The maritime setting offers several possible energy sources; of these, methane hydrates, ocean thermal energy conversion, and the tides are prohibitively expensive unless developed countries assist technologically and financially. Waves are the one marine source of power that can be tapped by relatively inexpensive, small-scale projects.

An inevitable, world-wide consequence of Peak Oil and the drastic increases in fuel prices is that it will no longer be economically feasible to ship food for hundreds and thousands of kilometers. Filipinos will be forced to grow their own food locally. Even city dwellers will have to learn how to cultivate vegetables in whatever space is available: in small lots, raised beds and boxes. We can learn valuable lessons from Cuba, a country that is remarkably similar to the Philippines in terms of its tropical, insular setting, susceptibility to hurricanes, and even its history as a colony of Spain. Cuba underwent Peak Oil in the early 1990's when the Soviet Union collapsed, and with it, Cuba's principal source of oil. Cuba successfully transformed its monoculture agriculture into local, diversified production of food (Funes et al., 2002; Rosset, undated), and the health of its people has improved as a result. Cuba compares quite well with the United States in terms of many socioeconomic indicators; the Philippines lags far behind (Table 4). Under duress, Cuba also had to renovate its domestic transportation system, and can teach us many lessons in how to do so.

Unchecked population growth is a given factor in any reasonable formula for the future of the Philippines and its energy requirements. Not only is the Catholic Church unalterably opposed to any effort to curb the growth of its laity; Filipinos of all religious persuasions, educational attainments and public status love children, “*mga kayamanan namin*”, and have large families. The Philippines appears to be immune to the “demographic transition” underwent by Western nations as they became industrialized, whereby large agricultural families were gradually replaced by smaller ones employed in factories and service occupations.

One result of the growing population is the increasing internal pressure for employment, for which an important safety valve is the national export of skilled and semi-skilled labor. Peak Oil will surely cut into that source of employment and income. Not only will all transportation fuels become more expensive; jet fuel is the single petroleum product that will be most difficult to replace. Jet fuels can be manufactured from coal, but any such process cannot help but be more expensive than distillation from

TABLE 4. Some significant socioeconomic statistics comparing the United States, Cuba and the Philippines. Compiled from the U.S. Central Intelligence Agency (CIA) Fact Book and the World Health Organization.

<u>CIA Socioeconomic statistics</u>	<u>United States</u>	<u>Cuba</u>	<u>Philippines</u>
Population (July 2006 est.)	298,444,215	11,382,820	89,468,677
Infant mortality rate/ 1,000 live births	6.43	6.22	22.81
Life expectancy at birth	77.85 years	77.41 years	70.21
Total fertility rate:	2.09 children/ woman	1.66 children/ woman	3.11
HIV/AIDS adult prevalence rate	0.6%	less than 0.1%	less than 0.1%
Literacy, age 15+	99%	97%	92.6%
GDP (2006 est.)	\$13.22 trillion	\$40 billion	\$116.9 billion
GDP per capita (2006 est.)	\$43,500	\$3,900	\$5,000
GDP - composition by sector			
<i>Agriculture</i>	1%	20%	14.2%
<i>Industry</i>	20.4%	19.4	32.1%
<i>Services</i>	78.7%	60.6	53.7%
Unemployment rate (2006 est.)	4.8 %	1.9%	7.9%
Population below poverty line	12% (2004 est.)	None available	40% (2001 est.)

<u>CIA Socioeconomic statistics</u>	<u>United States</u>	<u>Cuba</u>	<u>Philippines</u>
Oil production, bbl/day, 2005 est.	7.61 million	72,000	25,320 (2004)
Oil - consumption, bbl/day, 2004 est.	20.73 million	204,000	342,000
*Consumption/capita, bbl/year	25.4	6.54	1.4
Military expenditures- % of GDP:	4.06% (2005 est.) = \$536.7 billion	3.8% (2006) = \$152 million	1.1% (2006) = \$1,285,900

World Health Organization data

Physicians/ 1000 population	2.56	5.91	0.58
Nurses/ 1 000 population	9.37	7.44	1.69
AIDS deaths/ 100,000/year	14,000	<200	<500
Deaths due to TB, 2004, /100 000 HIV-negative people	0.4	1.1	48.1
Cardiovascular mortality/100,000 people, age- standardized, 2002	187.8	214.8	335.8
Maternal mortality/ 100,000 live births	14 (2000)	33 (2000)	200 (2000)

*Calculated from population and oil consumption data in this table.

petroleum, a relatively simple process. In the long term, Peak Oil will force nations to import less of our labor – and increase the need for gainful jobs at home.

Intelligent use of the large and growing Philippine work force is imperative. Labor is cheap, and even modest income buys a reasonable living. However, the labor pool inexorably will continue to grow, exacerbated by the loss of foreign employment. Thus, labor-intensive employment must be fully integrated into plans for energy development. The impact of our foreign export of labor has had a devastating impact on many families, deprived of one or both parents for long periods. New, locally based industries should encourage involvement by entire families.

One example of an industry that would provide gainful employment for many: Family-sized cultivation and processing of charcoal from ipil-ipil and similar fast-growing sources of charcoal, rendered efficient by Department of Agriculture advice and training.

A final example: Anticipating the demise of the ubiquitous motorized tricycle, one industry that should be encouraged strongly is the local manufacture of bicycles and pedicabs. We can seek financing and technologic help from Taiwan, the largest producer of bicycles in Asia.

The present scarcity of local petroleum may turn out to be a blessing. With vigorous effort, the Philippines can survive and transcend Peak Oil better than many other nations. Through careful planning, this initiative can also provide employment and income for many Filipino workers.

References

- Addison, K. Oil yields and characteristics. *Journey to Forever*. From http://journeytoforever.org/biodiesel_yield.html. Accessed 6 December 2006.
- Advanced Energy Group. The basics of solar power for producing electricity. From <http://www.solar4power.com/solar-power-contact-us.html>. 2006. Accessed 3 January 2007.
- Alley, R. B., P. U. Clark, P. Huybrechts, and I. Joughin. Ice-sheet and sea-level changes. *Science* 2005, Vol. 310 No. 5747: 456 – 460.
- Asia News. Beijing, Manila and Hanoi strike deal over Spratleys’ oil. 15 March 2005. From <http://www.asianews.it/view.php?l=en&art=27715>. Accessed 12 November 2006.
- Association for the Study of Peak Oil. Newsletter 38. 2004 February. From http://peakoil.ie/downloads/newsletters/newsletter38_200402.pdf. Accessed 28 November 2006.
- Blue Energy, Inc. Blue energy Dalupiri ocean power plant project. 1997. From <http://www.blueenergy.com/dalupiripower.html>. Accessed 20 July 2005.
- Bordonaro, Federico. The importance of the Spratly Islands. *Power and interest news report (PINR)*. 2006. From http://www.pinr.com/report.php?ac=view_report&report_id=589&language_id=1. Accessed 28 November 2006.
- Boyle, G. Tidal current power. Technology update to 1996, renewable energy: Power for a sustainable future. Oxford University Press. 2001. From <http://eeru.open.ac.uk/natta/techupdates.html#tidal>. Accessed 10 January 2007.
- British Hydro Association. A guide to UK mini hydro developments. 2 January 2007. <http://www.british-hydro.org/mini-hydro/index.asp#top>. Accessed 2 January 2007.
- Brown, P. Huge radioactive leak closes Thorp nuclear plant. *The Guardian*. 9 May 2005. From <http://www.guardian.co.uk/nuclear/article/0,2763,1479527,00.html>. Accessed 30 June 2005.

- Buringh, P. Availability of agricultural land for crop and livestock production. In D. Pimentel and C.W. Hall (Eds.), *Food and natural resources*. San Diego: Academic Press, 1989.
- Cabanes, C., C. A. Cazenave, C. Le Provost. Sea level rise during past 40 years determined from satellite and in situ observations. *Science* 2001, Vol. 294. No. 5543: 840 – 842.
- Cabato, M. E. J. A., Rodolfo, K. S., and Siringan, F. P. History of sedimentary infilling and faulting in Subic Bay, Philippines revealed in high-resolution seismic reflection profiles: *Jour. Asian Earth Science* 2005, Vol. 25: 849-858.
- Caldicott, H. *Nuclear power is not the answer*. NY: New Press, 2006.
- Campbell, C. J. and J. H. Laherrère. The end of cheap oil. *Scientific American* Vol. 278 Issue 3: 78-84. 1998 March. Retrieval at <http://dieoff.org/page140.htm>. Accessed 12 March 2005.
- Cazenave, A. Present-day sea level change: Observations and causes. *Reviews of Geophysics* 2004, 42: RG3001.
- Central Intelligence Agency (U.S.C.I.A.). Philippines. *World Factbook*. From <http://sportsforum.ws/sd/factbook/geos/rp.html#Econ>. 11 July 2006. Accessed 27 September 2006.
- Cheng, Wing-Gar. China's need for crops may curb biofuel plans. *International Herald Tribune*. 22 December 2006. From <http://www.iht.com/articles/2006/12/22/business/biofuel.php>. Accessed 25 December 2006.
- Damerow, G. Logging the new fashioned way. *Mother Earth News* Issue 143. 1994 April/May. From http://www.motherearthnews.com/Livestock_and_Farming/1994_April_May/Logging_the_New_Fashioned_Way. Accessed 5 December 2006.
- Damerow, G. and M. Bradley. Draft animals. *USDA Office for Small-Scale Agriculture Fact Sheet*. 1995 May.
- Deffeyes, K. S. Current events. 11 February 2006. From www.princeton.edu/hubbert/current-events-06-02.html. Accessed 27 September 2006.

_____. *Beyond oil: The view from Hubbert's peak*. NY: Hill and Wang, 2005.

_____. Current events. 16 January 2004. From <http://www.princeton.edu/hubbert/current-events-04-01.html>. Accessed 27 September 2006.

_____. *Hubbert's peak: The impending world oil shortage*. NJ: Princeton University Press, 2001.

Department of Energy [Philippine]. Philippine power statistics. 2006. From: [http://www.doe.gov.ph/power Power%20Stat%202005%20update042406.htm](http://www.doe.gov.ph/power%20Power%20Stat%202005%20update042406.htm). Accessed 10 October 2006.

_____. Philippine energy plan 2006 Update. 2006. From <http://www.doe.gov.ph/PEP/I%20PEP%20Overview.pdf>. Accessed 15 January 2007.

_____. New and renewable energy resource development. 2005. From <http://www.doe.gov.ph/NRE/default.htm>. Accessed 3 January 2007.

_____. Coal energy. From <http://www.doe.gov.ph/coal/default.htm>. 2005. Accessed 9 December 2006.

_____. Geothermal energy. 2004. From <http://www.doe.gov.ph/geothermal/default.htm>. Accessed 11 August 2006.

Department of Energy [U.S.], Energy Information Administration. South China Sea tables and maps. 2003 September. From www.eia.doe.gov/emeu/cabs/schinatab.html. Accessed 28 November 2006.

_____. Key radionuclides and generation processes. 1999 May 27. From http://web.em.doe.gov/lowlevel/llw_apxc.html. Accessed 28 December 2006.

_____. Petroleum: An energy profile. Publication No. DOE/EIA-0545(99), 79: 22. 1999. From http://www.eia.doe.gov/pub/oil_gas/petroleum/analysis_publications/petroleum_profile1999/profile99v8.pdf. Accessed November 25 2006.

Department of Energy - Energy Efficiency and Renewable Energy [U.S.]. Ocean thermal energy conversion. A consumer's guide to energy

- efficiency and renewable energy. 2005 September 12. From http://www.eere.energy.gov/consumer/renewable_energy/ocean/index.cfm/mytopic=50010?print. Accessed 21 August 2006.
- Department of Energy (U.S.), Energy Information Administration. South China Sea oil. 2006 March. From http://www.eia.doe.gov/emeu/cabs/South_China_Sea/Oil.html. Accessed 27 September 2006.
- Dixon, T. H. and J. Dillon, W. Gas (methane) hydrates – a new frontier. United States Geological Survey Fact Sheet. 1992 September. From <http://marine.usgs.gov/fact-sheets/gas-hydrates/title.html>. Accessed 16 January 2007.
- Dukes, J.S. Burning buried sunshine: Human consumption of ancient solar energy. *Climatic Change* 2003, Vol. 61, Nos. 1-2: 31-44.
- Electric Power Research Institute. Wave energy potential warrants further research and development. 3 February 2005. From http://www.epri.com/corporate/discover_epri/news/2005/020205_WaveEnergy.html. Accessed 17 January 2007.
- Emanuel, K. Increasing destructiveness of tropical cyclones over the past 30 years. *Nature* 2005, 436: 686-688.
- Energy Information Administration, Petroleum Supply Annual. DOE/EIA-0340(97)/1, Table 19. 1997. From http://www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/petroleum_supply_annual/psa_volume1/historical/1997/psa_volume1_1997.html. Accessed 12 February 2005.
- Fabros, C.V. The continuing struggle for a nuclear-free Philippines, The Bataan nuclear power plant. Nuclear free Philippines. 1998 October 16. From <http://www10.antenna.nl/wise/499-500/4935.html>. Accessed Sept 20,2005.
- FAO (Food and Agriculture Organization of the United Nations). World agriculture: Towards 2015/2030. 2003. From <http://www.fao.org/docrep/005/y4252e/y4252e06b.htm>. Accessed 30 November 2006.

- Flores, R.M., G. D. Stricker, R. F. Papasin, R. R. Pendon, R. A. del Rosario, R. T. Malapitan, M. S. Pastor, E. A. Altomea, F. Cuaresma, A. S. Malapitan, B. R. Mortos, and E. N. Tilos. The Republic of the Philippines coalbed methane assessment: Based on seventeen high pressure methane adsorption isotherms. United States Geological Survey Open-File Report 2006-1063. 2006 March 27. From <http://pubs.usgs.gov/of/2006/1063/of06-1063.html>. Accessed 9 December 2006.
- Fujita Research Report. Wave and tidal power. 2000 July. From <http://www.fujitaresearch.com/reports/tidalpower.html>. Accessed 16 January 2007.
- Funes, F., L. Garcia, M. Bourque, N. Perez and P. Rosset. Sustainable agriculture and resistance. *Transforming food production in Cuba*. Oakland, California: Food
- First/Institute for Food and Development Policy, 2002.
- Gartner, J. Ocean power fights current thinking. *Technology Review*. 2005 March 28. From <http://www.technologyreview.com/Energy/14268/>. Accessed 12 January 2007.
- Green Left Online. The untimely death of Salter's Duck. 1992 July 29. From <http://www.greenleft.org.au/1992/64/2832>. Accessed 12 July 2005.
- Henriet, J.-P. and Mienert, J. *Gas hydrates: Relevance to world margin stability and climatic change*. Geological Society of London Special Publication 137, 1998.
- Homer-Dixon, T. and S.J. Friedmann. Coal in a nice shade of green. *New York Times*. 2005 March 25. From <http://www.homerdixon.com/articles/20050325-nytimes-coalgreen.html>. Accessed 12 April 2005.
- Giampietro, Mario and D. Pimentel. The tightening conflict: Population, energy use, and the ecology of agriculture. NPG Forum Series. 1993 October. From http://www.npg.org/forum_series/tightening_conflict.htm 1994. Accessed 29 November 2006.
- Giampietro, M. and S. Ulgiati. Feasibility of large-scale biofuel production. *Bioscience* 1997 October, Vol. 47 Issue 9: 587-601.

- Graham-Rowe, D. Hydro's dirty secret revealed. *New Scientist* 2005, Vol. 185, No. 2488: 8.
- Grove, Noel. Oil, the dwindling treasure. *National Geographic*, 1974 June.
- Heinberg, R. Peak oil and options for a post-carbon world, pt 1. *Grinning Planet* 2005 June 14. From <http://www.grinningplanet.com/2005/06-14/peak-oil-article.htm>. Accessed 2 March 2006.
- _____. *Power down: Options and actions for a post-carbon world*. Canada: New Society Publishers, 2004.
- Hernandez, M.E.E. The Philippine carabao center has gone a long way. BAR [Bureau of Agricultural Research] Digest vol. 8 No. 3. 2006 July-September. From <http://www.bar.gov.ph/bardigest/featinst.asp>.
- Homer-Dixon, T., and Friedmann, J. S. Coal in a nice shade of green. *New York Times* Editorial/Opinion. 2005 March 25. From <http://www.homerdixon.com/articles/20050325-nytimes-coalgreen.html>. Accessed 27 September 2006.
- Hubbert, M. K. Nuclear energy and the fossil fuels. *Proceedings of the Spring Meeting*. San Antonio, Texas: American Petroleum Institute Drilling and Production Practice, 1956.
- _____. Techniques of prediction as applied to production of oil and gas. US Department of Commerce, *National Bureau of Standards Special Publication 631*, 1982.
- Huttrer G.W. The status of world geothermal power generation 1995-2000. *Geothermics* 2001 February, Vol. 30 No. 1: 1-27.
- Information Please. Nuclear and chemical accidents %u2014 infoplease.com 2000-2006. 2006 October 31. From <http://www.infoplease.com/ipa/A0001457.html>
- Institute of Petroleum. Oil – A natural resource – Who uses the world's oil? n.d. From <http://energyinst.org.uk/education/natural/4.htm>. Accessed 31 October 2006.

- International Energy Agency. Trends in photovoltaic applications in selected IEA countries between 1992 and 2005. 2006 September 20. From <http://www.iea-pvps.org/isr/index.htm>. Accessed 16 January 2007.
- _____. Key world energy statistics. 2006. From <http://iea.org/textbase/nppdf/free/2006/key2006.pdf>
- _____. *World Energy Outlook 2004*. Paris: IEA Publications, 2004. From <http://www.iea.org/textbase/nppdf/free/2004/weo2004.pdf>.
- _____. *Monthly Oil Survey*. Table 7, 2004.
- Johnson, R. N. and G. D. Libecap. Information distortion and competitive remedies ingovernment transfer programs: The case of ethanol. *Economics of Governance* 2001, Vol. 2, No. 2: 101-134.
- Jose, A.M., R.V. Francisco and N. A. Cruz. A study on impact of climate variability/change on water resources in the Philippines. *Chemosphere* 1996, Vol. 33 No. 9: 1667-1704.
- Kindell, H. H. and D. Pimentel. Constraints on the expansion of global food supply. *Ambio* 1994 May, Vol. 23 No. 3.
- Klemme, H. D. and G.F. Ulmishek. Effective petroleum source rocks of the world: stratigraphic distribution and controlling depositional factors. *Amer. Assoc. Petrol. Geol. Bull.* 1991, 75: 1809-1851. From www.searchanddiscovery.net/documents/Animator/klemme2.htm.
- Kofoed, J. P., P. Frigaard, E. Friis-Madsen, and H. C. Sorensen. Prototype testing of the wave energy converter wave dragon. Proc. World Renewable Energy Congress VIII, 2004.
- Kopaska-Merkel, D.C., B. J. O'Neill, and S.Kopaska-Merkel. Why do we need petroleum? 1993. From http://www.beloit.edu/~SEPM/Geology_and_the_enviro/Petroleum_need.html. Accessed 28 November 2006.
- Kvenvolden, K. A primer on the geological occurrence of gas hydrate. In *Gas hydrates: Relevance to world margin stability and climatic change*, 1998.
- Laherrère, J. H. The Hubbert curve: Its strengths and weaknesses. *Oil & Gas Journal* 2000. From <http://dieoff.org/page191.htm>. Accessed 24 August 2006.

- Landsea, C. How does El Niño-Southern oscillation affect tropical cyclone activity around the globe? National Oceanographic and Atmospheric Administration, Atlantic Meteorologic and Oceanographic Laboratory. 2005 October 19. From <http://aoml.noaa.gov/hrd/tcfaq/G2.html>. Accessed 1 November 2006.
- Landsea, C.W., N. Nicholls, W.M. Gray, and L.A. Avila. Downward trends in the frequency of intense Atlantic hurricanes during the past five decades. *Geoph. Res. Letters* 1996, 23:1697-1700.
- Ledford, H. Liquid fuel synthesis: Making it up as you go along. *Nature* 2006, 444: 677-678.
- Macedo, I. Assessment of greenhouse gas emissions in the production and use of fuel ethanol in Brazil (prepared for the Government of the State of São Paulo), 2004.
- Makhijani, A. Draft power in south Asian foodgrain production: Analysis of the problem and suggestions for policy. 1990 September. From <http://ieer.org/reports/energy/draftpower.pdf>. Accessed August 2006.
- Marris, Emma. Sugar cane and ethanol: Drink the best and drive the rest. *Nature* 2006, 444: 670-672.
- Max, D. *Natural gas hydrate in oceanic and permafrost environments*. Dordrecht, Netherlands: Kluwer Academic Publishers, 2000.
- McLaughlin, N.B, A. Hiba, G.J Wall, and D.J. King. Comparison of energy inputs for inorganic fertilizer and manure based corn production. *Canadian Agricultural Engineering* 2000, Vol. 42 No. 1.
- Murray, T. Climate change: Greenland's ice on the scales. *Nature* 2006, 443, 277-278. NIH [U.S. National Institute of Health]. People with diabetes more sensitive to cardiovascular effects from air pollution. 2005 May 31. From <http://www.nih.gov/news/pr/may2005/niehs-31a.htm>. Accessed 10 Dec 2006.
- National Oceanographic and Atmospheric Administration, Earth System Research Laboratory. Multivariate ENSO Index. 2006 October 6. From <http://cdc.noaa.gov/people/klaus.wolter/MEI/>. Accessed 1 November 2006.

- National Oceanographic and Atmospheric Administration, National Ocean Service Education. An oil spill primer for students. 2005 March 3. From http://oceanservice.noaa.gov/education/stories/oilymess/media/oily09a_240.jpg. Accessed 12 August 2006.
- National Research Council Commission on Geosciences, Environment and Resources. *Technical basis for Yucca Mountain standards*. National Academies Press, 1995. From <http://books.nap.edu/books/0309052890/html/R1.html#pagetop>. Accessed 27 December 2006.
- Nerem R.S., and G.T. Mitchum. Observations of sea level change from satellite altimetry. In Douglas, B. C., S. P. Leatherman, and M. S. Kearney (Eds.), *Sea Level Rise, History and Consequences*. San Diego, CA: Academic Press, 2001.
- Nuclear Information Centre (Australia). Nuclear power in the world today. *Nuclear Issues Briefing Paper 7*. 2006 September. From <http://www.uic.com.au/nip07.htm>. Accessed 29 November 2006.
- Ocean Power Delivery, Ltd. The Pelamis wave energy converter. n.d. From <http://www.oceanpd.com/Pelamis/default.html>. Accessed 17 January 2007.
- Office of Energy Efficiency and Renewable Energy (EERE), U.S. Department of Energy. What is made from a barrel of crude oil? Fact #346. 2004 November 15. From http://www1.eere.energy.gov/vehiclesandfuels/facts/2004/fcvt_fotw346.html. Accessed 18 August 2006.
- Olmstead, J., What about the land? A look at the impacts of biofuels production, in the U.S. and the world. *Grist.org*. 2006 December 5. From <http://grist.org/news/maindish/2006/12/05/olmstead/index.html>. Accessed 7 December 2006.
- Pearce, F. Raising a stink. *New Scientist* 2000, Vol. 166 Issue 2241: 4.
- Pfeiffer, D. A. Drawing lessons from experience: The agricultural crises in North Korea and Cuba - Pt. 2: Cuba—A hope. 2003. From http://fromthewilderness.com/free/ww3/120103_korea_2.html.

- _____. Eating fossil fuels. 2003 October 3. From http://www.fromthewilderness.com/free/ww3/100303_eating_oil.html. Accessed 21 November 2005.
- Philippine Fertilizer and Pesticide Authority. 1996-2001 total sales by grade in metric tons. 1992 October 1. From <http://www.fadinap.org/philippines/>. Accessed 29 November 2006.
- Philippine National Oil Corporation. Geothermal areas in the Philippines [Map]. 2000. From <http://www.energy.com.ph/Geoscientific/projects.htm>. Accessed 20 August 2005.
- Pimentel, D. and M. Pimentel. Food, energy and society. London, UK: Edward Arnold, 1979.
- Pimentel, D. and T. W. Patzek. Ethanol production using corns Switchgrass, and wood; Biodiesel production using soybean and sunflower. *Natural Resources Research* 2005 March, Vol. 14 No. 1: 65-76.
- Pimentel, D. and Giampietro, M. Food, land, population and the U.S. economy, executive summary. Carrying Capacity Network. 1994 November 21. From <http://www.dieoff.com/page40.htm>. Accessed 15 November 2006.
- Rodolfo, K. S. and F. P. Siringan. Global sea-level rise is recognised, but flooding from anthropogenic land subsidence is ignored around northern Manila Bay, Philippines. *Disasters* 2006, Vol. 30 No. 1: 118-139.
- Shiple, T.H., M.H. Houston, R.T. Buffler, F.J. Shaub, K.L. McMillen, J.W. Ladd & J.L. Worzel. Seismic evidence for widespread possible gas hydrate horizons on continental slopes and rises. *AAPG Bulletin* 1979, Vol. 63: 2204-2213.
- Simmons, M.R. Energy infrastructure: the world's arterial and circulatory system". Powerpoint presentation, Sixth Annual Rice Global Forum, Houston, Texas. 2003 September 8. From <http://www.simmonsco-intl.com/Research.aspx?Type=MSSpeechArchives>. Accessed 21 August 2006.

- Siringan, F. P. and Rodolfo, K. S. Relative seas level changes and worsening floods in the western Pampanga Delta: Causes and some possible mitigation measures: *Science Diliman* 2003, Vol. 15: 1-12.
- Sloan, E.D. *Clathrate hydrates of natural gases*. NY: Marcel Dekker Inc, 1998.
- Smil, V. Population growth and nitrogen: An exploration of a critical existential link. *Population and Development Review* 1991, Vol. 17 No. 4: 569-601.
- Smith, D. J. Big plans for ocean power hinge on funding and additional R&D. *Power Engineering International*, 2007 January.
- Swanström, N. L. P. Conflict management and negotiations in the South China Sea: The ASEAN way?. University of Oslo, Oslo: Centre for Development and Environment. 1999. From <http://community.middlebury.edu/~scs/docs/Swanstrom.pdf>. Accessed 12 November 2006.
- Texas Oil and Gas Association. What a barrel of crude oil makes. 2006. From <http://txoga.org/articles/308/1/WHAT-A-BARREL-OF-CRUDE-OIL-MAKES>. Accessed 31 October 2006.
- Torres, R. C. The vulnerability of PNPP site to the hazards of Natib volcano. *PHIVOLCS Observer* 1992, Vol. 8 No. 3: 1-4.
- Union of Concerned Scientists. Environmental impacts of coal power: air pollution. 2005 August 18. From http://www.ucsusa.org/clean_energy/coalswind/c02c.html. Accessed 11 December 2006.
- United States Geological Survey. Methane gas hydrates. 2004 January 15. From http://geology.usgs.gov/connections/mms/joint_projects/methane.htm. Accessed 20 August 2005.
- University of Strathclyde. Wave power case study: The Limpet 500. n.d.. From http://www.esru.strath.ac.uk/EandE/Web_sites/01-02/RE_info/wavecase.htm. Accessed 16 January 2007.
- Watson, R. T., M.C. Zinyowera, and R. H. Moss (eds.) Climate change 1995: Impacts, adaptations and mitigation of climate change: Scientific-Technical analyses. Contribution of Working Group II to

- the Second Assessment of the Intergovernmental Panel on Climate Change. Cambridge UK: Cambridge University Press, 1995.
- Wave Dragon (Wales) Ltd. Wave dragon wave energy converter project briefing note # 2. 2006 March. From <http://www.wavedragon.co.uk>. Accessed 16 January 2007.
- Webster P., Holland G., Curry J. & Chang H. R. Changes in tropical cyclone number, duration, and intensity in a warming environment. *Science* 2005, Vol. 309 No. 5742: 1844 – 1846.
- Western Area Power Administration (US Department of Energy). Energy balance of biofuels. Energy Services Technical Help. 2003 July. From <http://www.wapa.gov/es/techhelp/powerline/03Jul.htm>. Accessed 21 August 2006.
- Wikipedia, Wave power. 12 January 2007. From http://wikipedia.org/wiki/Wave_energy Accessed 15 January 2007.
- Wilde, P. and Quinby-Hunt, M. S. Methane clathrate outgassing and anoxic expansion in southeast Asian deeps due to global warming. *Environmental Monitoring and Assessment* Vol. 44: 149-153. Modified for the WWW May 1997. From <http://www.mariscigrp.org/sing95.html>. Accessed 31 December 2006.
- Wilson, K. Philippines: Bataan nuclear plant costs \$155,000 a day but no power. *Energy Bulletin* 2004 June 30. From <http://www.energybulletin.net/866.html>. Accessed 29 December 2006.
- World Bank. The Philippines: Wind power through carbon finance. 2004 December 9. From <http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/EASTASIAPACIFICEXT/EXTEAPREGTOPENVIRONMENT0,,contentMDK:20294993~menuPK:502932~pagePK:34004173~piPK:34003707~theSitePK:502886,00.html>. Accessed 3 January 2007.
- World Energy Council. Wave energy. Survey of Energy Resources. 2001. From <http://www.worldenergy.org/wec-geis/publications/reports/ser/wave/wave.asp>. Accessed 15 January 2007.