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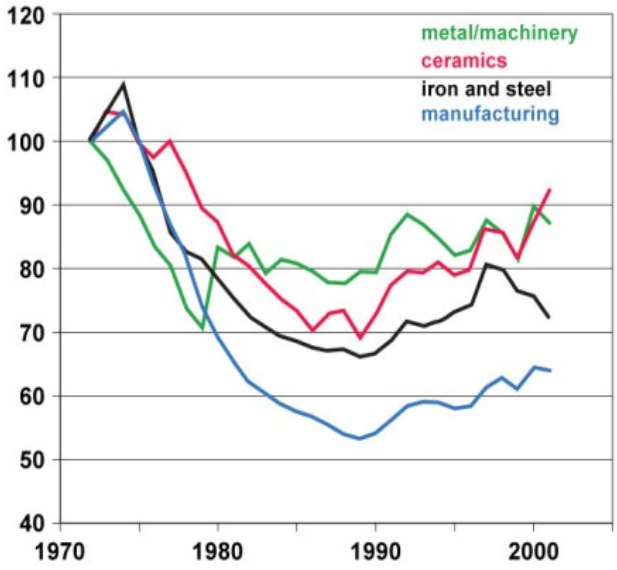
By Vaclav Smil

The phenomenon is unmistakable (albeit largely unnoticed), and the contrast lends itself to all kinds of symbolic interpretations: Japan's unending retreat from being a highly respected polity and economic powerhouse, widely expected to become the 21st century's global ichiban, has entered troubled waters. As a result of that downward economic trend, whose beginning was signaled by the collapse of the Nikkei index in 1990, Japan's GDP managed the real (inflation-adjusted) annual growth of just 1.1% between 1991 and 2006, while during the preceding 15 years the country's GDP had nearly doubled. [1] But this long-lasting economic and social malaise has been accompanied by a substantial (17%) increase in Japan's primary energy consumption. This is remarkable because pre-1990 Japan was the world's most consistently, and most admirably, energy-efficient economy that had always managed to do with relatively less energy. [2]

Overall efficiency of Japan's energy conversion (usually measured as the amount of primary commercial energy used to generate a unit of GDP) was high before the first OPEC oil price crisis in 1973-74, when the Western nations were wasting energy with abandon. During the early 1970s it took about twice as much energy to produce a dollar of GDP in the US as it did in Japan. [3] And when Europe and North America belatedly embarked on unprecedented energy conservation programs during the late 1970s, they found that the already frugal Japan was becoming even more energy-parsimonious. This great energy conservation drive was going strong through 1985, when OPEC's hold on the global oil market collapsed and oil prices fell from the historic high of nearly $40 in 1981 to less than $10; its effects would linger through the 1980s. By 1990 the US needed about 30% less energy to produce a dollar of GDP than it did in 1974—but Japan had lowered the average energy of its economy by another 35%. [4] Consequently, despite the pronounced appreciation of its currency (by 1990 the purchasing power parity was ¥193/US$), Japan was thus even further ahead of the US in energy conservation than it had been before the first oil price crises of the early 1970s.

But then an unexpected reversal took place. Between 1990 and 2005, the energy intensity of the US economy (using inflation-adjusted monies) fell by another 12%, but the energy intensity of the Japanese economy first stagnated and then, by the year 2000, was actually about 6% above the 1990 value. By the year 2005 it was still about 3% higher. A closer look at the reasons for this reversal shows two surprising factors. First, Japan's fabulous industrial energy conservation machine had seized up (Fig. 1). Energy intensities (that is, energy used per unit value of product) of all major industries—after falling by 20-50% between 1973 and the late 1980s—had reached their lowest levels between 1988 and 1990, and had risen and stagnated afterwards: By the year 2000, the energy intensity for the iron and steel industry, manufacturing, and ceramics were about 12%, 15%, and 17% above the 1989 level respectively. [5]

Fig. 1. Energy intensities of Japan's major industries



Why did this happen? Fig. 1 clearly indicates that the rate of improvement was already considerably lower during the late 1980s than it had been during the late 1970s and early 1980s, and hence it would have been unrealistic to expect further large efficiency gains during the 1990s. This sequence is universal: the least expensive, technically the easiest or the most rewarding energy conservation measures ("low-hanging fruit" in the engineering parlance) are taken first, and subsequent improvements depend much more on the cost of energy: During the 1990s, world oil prices remained stable and low, discouraging more expensive conservation measures. But this does not explain the post-1990 reversals of industrial energy intensity trends. Those are attributable to several concurrent trends.

First, as large numbers of more efficient energy converters and processes that were installed before 1990 began to age, their performance began to deteriorate. Assiduous maintenance and upgrading can prevent such deterioration, but in many cases these steps were not taken because companies were short of funds as they faced contracting markets and foreign competition, or as they channeled their investment into setting up new facilities overseas (especially in China) and neglected the domestic infrastructure. Contraction and stagnation of the Japanese economy and foreign competition also meant that many industries began to use their assets less intensively, and lower utilization

capacities often translate into higher energy (and monetary) costs per unit of production. Finally, some industries tried to stay competitive by concentrating on production of higher-quality items that are often much more energy-intensive than the mass produced varieties that now come increasingly from China and India (stainless steel vs. ordinary sheet steel; composite materials vs. ordinary ceramics).

The second reason was that Japanese citizens—after generations of relatively frugal living—had finally began to spend more on their interior environment, and nowhere has this increase been clearer than in the rising consumption of electricity. Between 1990 and 2005, Japan's generation of electricity rose by about 33% in absolute, and by about 28% in per capita terms—but per capita residential electricity consumption rose by about 45%, to roughly 2,200 kWh/year. [6] This was by far the fastest increase in using any form of residential energy: Between 1990 and 2005, consumption of liquid fuels (dominated by kerosene for heating) barely changed (going up by less than 3%), and the combustion of natural gas (for cooking and heating) went up by less than a quarter. Japan's excellent surveys of the ownership of household electricity converters explain the reasons for this rise (Table 1). [7]

Table 1. Ownership of household electric converters (units/1,000 households)

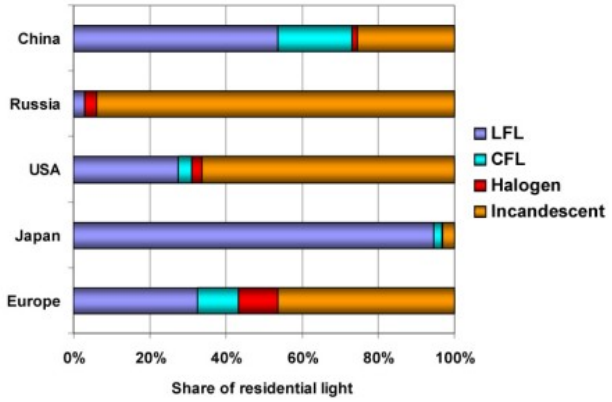
Converter	1990	2005	Multiple
Room AC	1131	2347	2.1
Color TV	1927	2140	1.1
Stereo	867	1312	1.5
VCR	834	1192	1.4
Washing machine	358	1086	3.0
Microwave oven	761	1038	1.4
Refrigerator (> 300 L)	682	820	1.2
Personal computer	100	999	9.9
Dishwasher	NA	192	NA

Between 1990 and 2005 the ownership of automatic washing machines tripled; installation of room air conditioners more than doubled; there were 50% more stereos, about 40% more VCRs, 20% more large refrigerators (with the volume in excess of 300 liters), and about 10% more color TVs. Moreover, in 2005, virtually every household had a personal computer, and nearly a fifth of them had a dishwasher, items that were relatively rare in 1990. And Japanese bought more lights: Between 1990 and 2005, the average consumption of electricity for residential lighting went up by about 50%, to nearly 300 kWh/year/capita or nearly 950 kWh/household; this was still slightly less than half of the average U.S. household rate, but more than 20% higher than that of Germany, 30% higher than that of the UK, and twice as high as that of France. [8]

Consequently, it would seem that Japanese homes are increasingly filled with electric (and electronic) gadgets. The fact that they still have fewer lights per household than the three largest European economies—17, compared to 18.5 in France, 20.1 in the UK and 30.3 in Germany (the U.S. mean is 43)—is not a useful comparative metric. Japanese

lights are far more efficient than those in other affluent countries, because 95% of them are fluorescent lights—mostly the tubes that produce up to 95 lumens of light per watt compared to just 10-15 lumens per watt (lm/W) for standard incandescent bulbs. [9] In contrast, only about 45% of Europe's lights and 35% of U.S. lights are either linear or compact fluorescents (Fig. 2).

Fig. 2. Shares of different lights in 2005



Consequently, the proper indicator of lighting intensity is the actual quantity of illumination, the amount of lumens available per unit of household area. In Japan (using the average household area of 95 m^2), this rate is about 515 lm/m^2 compared to 315 lm/m^2 in the U.S. and 450 lm/m^2 in Germany: High lighting efficiency and the relatively small area of Japanese dwellings more than compensate for a significantly smaller number of lights in Japanese homes (Table 2). [10] But it is by no means clear to what side of an international comparative ledger this primacy belongs.

Table 2. Residential lighting in Japan, USA and Germany (2005)

Indicator	Japan	USA	Germany
Lights per household	17	43	30
Average light efficacy (lm/W)	64	18	27
Average light power (W)	45	65	50
Electricity for lighting (kWh/year/household)	940	1950	780
Average household area (m^2)	95	160	90
Installed light density (lm/m^2)	515	315	450
Light operating time (hours/day)	3.4	1.9	1.5

On one hand, light usage in Japan points to strongly collective Japanese behavior and exemplary frugality (95% use efficient fluorescent lights), traits that other nations would find useful in their effort to lessen the impact of modern civilization on the global environment; on the other hand, standard linear fluorescent lights are neither the most spectrally-optimized nor beautiful sources of illumination, and hence their near-universal usage can be seen as a sign of relative impoverishment and, as is so often the case in Japan, as yet another inexplicable acceptance of bad taste in a culture that is so devoted to beautiful design.

And the Japanese, people with an even greater chronic sleep deficit than Americans, keep their fluorescent tubes and compacts lit much longer than do people in any other affluent nation, averaging about 3.4 hours a day per light, compared to 1.9 hours in the U.S., 1.5 hours in Germany and a mere hour in France. [11] In a search for specific factors that would explain this significant difference I suggest three realities, none of them unique to Japan but all of them quite pronounced in that country. The first factor that contributes to longer use

of electric lights is Japan's ubiquitous long-distance commuting that often starts and ends in darkness. Consequences of the chronic cumulative sleep deficit induced by this practice are well illustrated by a recent survey by InfoPlant market research: two-thirds of males and 71% of females sleep when riding a train. [12]

The second factor is a sleep pattern common among Japanese high-school students: napping (inemuri) during the late afternoon and then studying late at night and into the early morning. Steger concluded that "regardless of possible considerations of whether it makes sense, this rhythm seems to be a set sleeping pattern for students in general, and in particular for high-school students preparing for exams. Since everyone follows a similar rhythm, it is difficult for an individual to change or even seriously question it." [13] Finally, there is a traditional Japanese arrangement of infants and small children sleeping with the parents, who are readily accessible to children during waking episodes: this practice obviously leads to more light-switching at night, besides making yonaki, sleep-related nighttime crying, more common and a matter of concern for the country's pediatricians. [14]

There is little doubt that the Japanese would illuminate their households even more if electricity prices were lower. Japan's national electricity market was expanded in 2005, but (unlike in many other countries) large (and vertically integrated) utility companies (dominated by the giant Tokyo Electric) do not allow their customers to switch to other suppliers. [15] Even so, the mere threat of further market reforms has helped to reduce electricity prices, albeit only modestly: Between 2000 and 2005 they fell by about 5%. For decades the combination of increasing intensity of outdoor lighting and high densities of Japan's residential and industrial areas, and of the country's transportation corridors, has created large bright patches of light across large parts of the archipelago seen on nighttime satellite images (Fig. 3). [16] Good news is that, regardless of what is going on in the outside world, there is now also considerably more light inside the Japanese homes.

Fig. 3. Nighttime satellite image of Japan's lights superimposed on a
daylight satellite image of the archipelago and its eastern neighbors.

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broadly over issues of environment, energy, food, population, economics, and policy studies. He wrote this article for Japan Focus. Published on April 2, 2007.

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Notes

1. Calculated from annual data series in: Statistics Bureau. Japan Statistical Yearbook. Tokyo: Statistics Bureau. The most recent volume is online: www.stat.go.jp/english/data/nenkan.

2. I dealt with various consequences of that transformation in: Smil, V. 2006. Japan and China: The next fifty years. Japan Focus Summer 2006: www.japanfocus.org/products/details/2213.

3. See, among many others: Smil, V. 1987. Energy Food Environment: Realities, Myths, Options. Oxford: Oxford University Press; Smil, V. 1992. How efficient is Japan's energy use? Current Politics and Economics of Japan 2(3/4): 315-327.

4. I have used purchasing power parity, rather than official exchange rate, to calculate the Japanese value from official energy and GDP statistics.

5. For the US data see: Energy Information Administration. 2007. Energy consumption, expenditures, and emissions indicators, 1949-2005. Available online: www.iea.doe.gov/emeu/aer/txt/ptb0105.html. For the Japanese data see: The Energy Conservation Center. 2006. Handbook of Energy & Economic Statistics in Japan. Tokyo: The Energy Conservation Center.

6. Energy Conservation Center Japan. 2007. Japan Energy Conservation Handbook. Tokyo: ECCJ.

7. Statistics Bureau. 2007. Japan Statistical Yearbook 2007. Tokyo: Statistics Bureau.

8. Compiled from data in 2007 and 1992 editions of Japan Statistical Yearbook.

9. Waide, P. 2006. Light's Labour's Lost: Policies for Energy-efficient Lighting. Paris: International Energy Agency. Available online: www.iea.org/Textbase/work/2007/cfl/Waide.pdf.

10. Improvements in the efficacy of electric lights are traced in detail in: Smil, V. 2005. Creating the 20th Century: Technical Innovations of 1867-1914 and Their Lasting Impact. New York: Oxford University Press; Smil, V. 2003. Energy at the Crossroads: Global Perspectives and Uncertainties. Cambridge, MA: The MIT Press. Compiled and calculated from

data in Waide [9], Japan Statistical Yearbook and Statistical Abstract of the United States.

11. Even in sub-Arctic Sweden with short winter days the average usage is only 1.35 hours/lamp.

12. Trains are the Japanese second bedroom. What Japan Thinks, 7 December 2005. Available online: whatjapanthinks.com/2005/12/07/trains-are-the-japaneses-second-bedroom

13. Steger, B. 2006. Sleeping through class to success: Japanese notions of time and diligence. Time & Society 15(2-3): 197-215. If you have electronic access to Time & Society, I highly recommend this illuminating analysis.

14. Fukumizu, M. et al. Sleep-related nighttime crying (yonaki) in Japan: A community-based study. Pediatrics 115 (1): 217-224.

15. Sioshansi, F.P. and W. Pfaffenberger, eds. 2006. Electricity Market Reform: An International Perspective. Amsterdam: Elsevier.

16. The image is available at: Kitamoto, A. 2007. Earth in the Night: Nighttime Lights of the World Data by DMSP Satellites. Tokyo: National Institute of Informatics: agora.ex.nii.ac.jp/~kitamoto/research/rs/world-lights.html.en