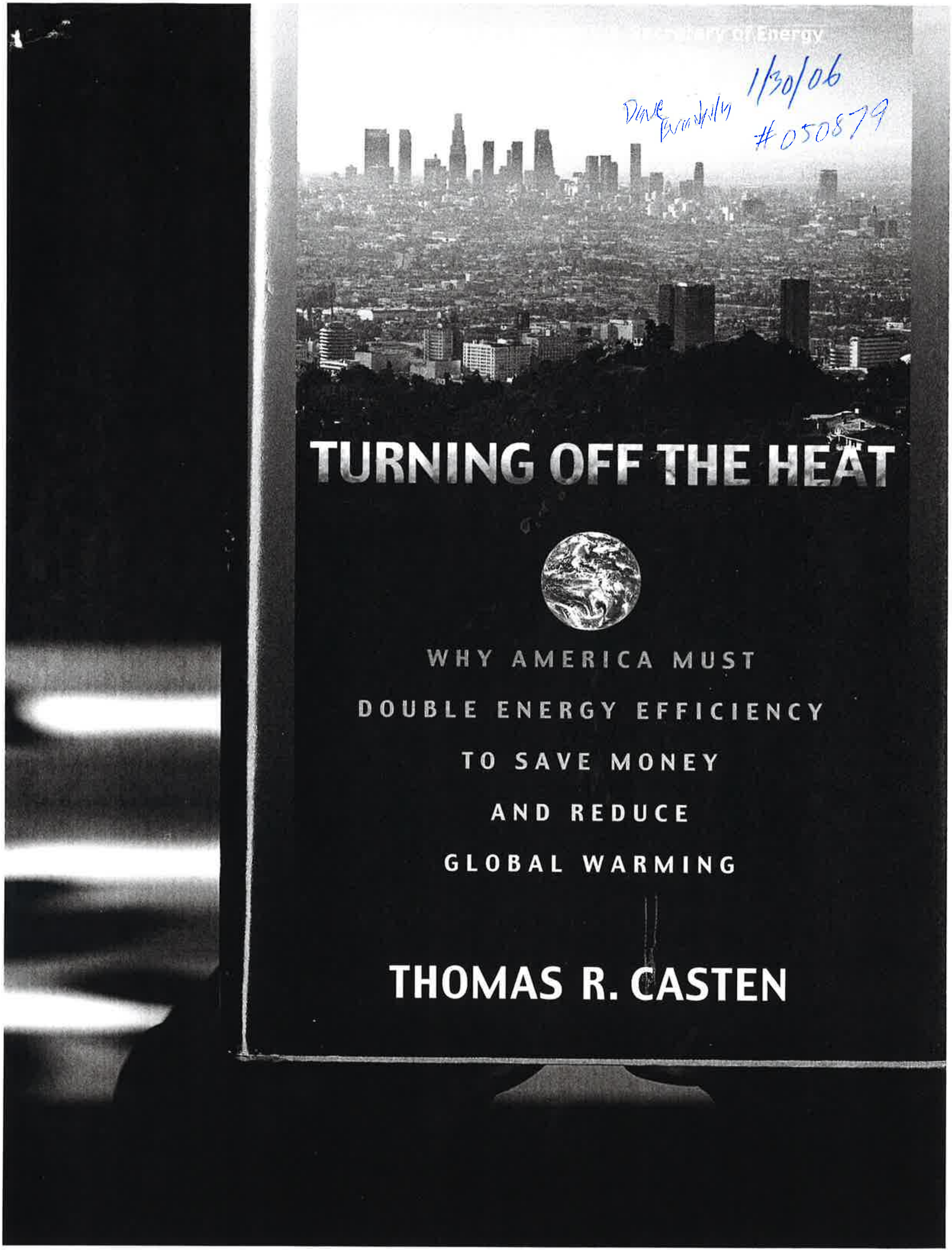

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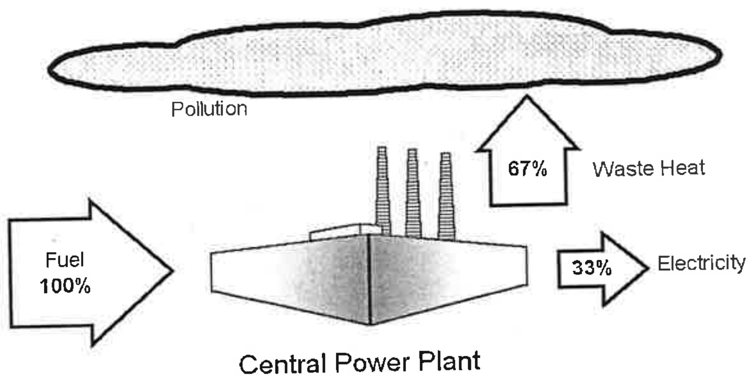
Fig. 7. Conventional Generation



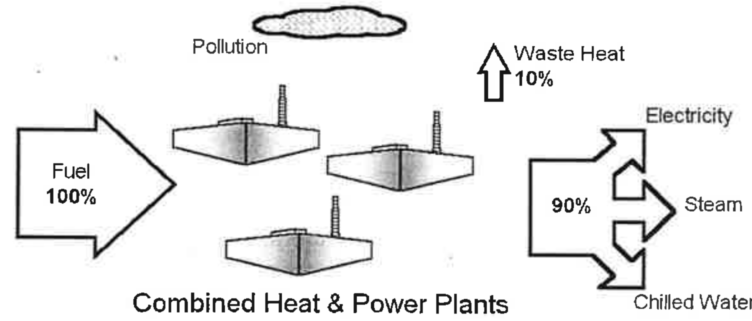
heat into a cooling tower, which evaporates water to remove the heat, and then sends the heated vapor into the air. It is this vapor condensing in the cold morning air in Colorado that you see in the picture above. Although monopoly-protected electric utilities have no incentive to recover and use this heat, a competitive power industry would stop throwing away this valuable heat and instead find ways to sell the heat to consumers.

Figure 7 depicts the typical approach to electric power generation all over the world. The numbers are U.S. average delivered efficiency in 1996.

The typical electric-only generating plant, built far from thermal users, uses 100 units of fuel to produce 33 units of delivered electricity. Two-thirds of the energy in the fuel ends up as waste heat, rejected into lakes, rivers, or cooling towers as in the picture above. The pollution is three times what it could be.

Figure 8 depicts an alternate approach—a better way to produce power. Instead of one large electric-only plant, a series of smaller "local" plants are built near thermal users—factories, universities, medical centers, and city centers. The same 100 units of fuel now produce three products: heat, cooling, and electricity. Up to 90 percent of the energy in the fuel can be converted to useful energy in these trigeneration plants and waste can be reduced to 10 percent. Generating electricity in one plant and heat in a second plant is inefficient. Why use two fires when we

Fig. 8. Combined Heat and Power (CHP)



need only one? Why use twice as much as is needed? Tomorrow, we must use one fire to produce heat, power, and when appropriate, chilling. This will save money and reduce CO_2 and other pollution.

Cogeneration plants now produce about 9 percent of U.S. power. They recapture some of the normally wasted heat and sell it as a second product. An added 10 percent of U.S. power comes from renewable energy, mostly hydro. Nuclear power produces 20 percent of the nation's electricity. Thanks to obsolete monopoly regulation, 60 percent of U.S. power comes from fossil fuel plants that throw two-thirds of the energy away as heat, producing needless pollution.

From the early part of the century on, steam-turbine technology was steadily improved, and Rankine-cycle plants used steam at higher and higher pressures. By 1960, the technology had reached maturity and stopped gaining efficiency. The best possible efficiency with steam-turbine technology alone seems to be about 38 percent, and employs highly sophisticated supercritical steam. Such technology is economic only in very large central power plants. The explanation plaque on the exhibit of a modern supercritical steam plant at the Smithsonian Museum of American History in Washington, D.C., explains as follows:

> In converting water to steam, a certain amount of the energy is used which can not be regained (as mechanical power). However, once the steam is formed, the energy which it derives from the fuel is propor-

tional to the steam's pressure. Thus, the higher the steam pressure used in an engine or turbine, the smaller the initial loss (relatively). The history of steam power, therefore, is one of increasingly higher pressures.

Today, the largest central-station steam generators are of the "once-through" type. They operate above 3,206 pounds per square inch, the critical pressure for water. At this point, the density of steam and water is the same when the temperature is above 705 degrees Fahrenheit, preventing natural circulation.

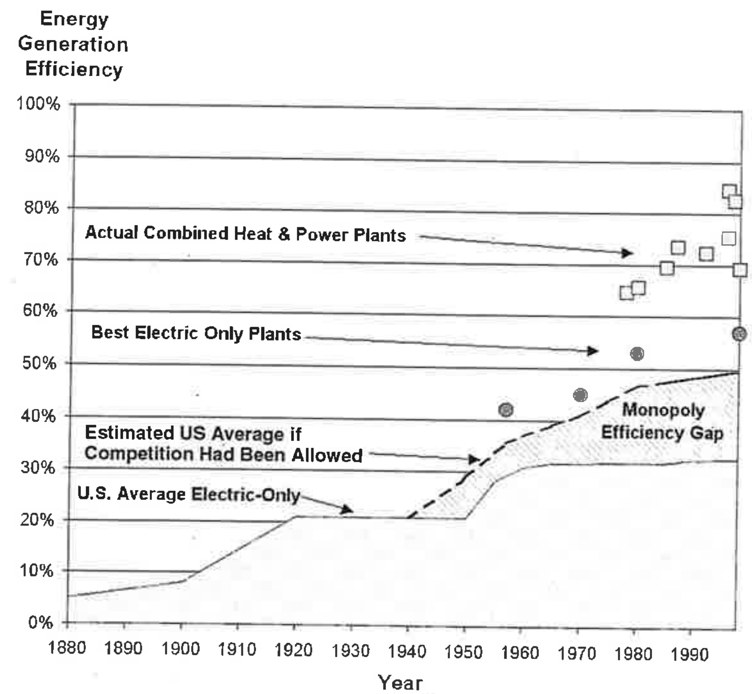
The degree of sophistication in these plants is very high, and no further gains in efficiency have been made over the past three decades. Transmitting this power to consumers through wires and transformers loses some of the electricity as heat and the net result is that, on average, only 35 percent of the fuel's energy reaches the user as electricity.

Figure 9 shows the average U.S. generating efficiency for electricity from the introduction of commercial electricity in 1880 to modern times. Edison's first generators converted only 8 percent of the energy in fuel to electricity. Efficiency then rose steadily to a peak of 33 percent, still wasting nearly two-thirds of the fuel. By the late 1950s, our society was fully electrified; there were many uses for electricity that had no competition from other energy forms, so people had to buy electricity. Monopoly protection insulated the electric utilities from competition with other electric generators, and regulators insisted that any savings from efficiency improvements be passed through to the electric customers. Faced with these rules and lack of competition, the utility industry stagnated and slowed the pace of improving its technology and efficiency. The graph shows that delivered efficiency of electricity from all U.S. thermally based generating plants has remained constant at 33 percent efficiency for four decades.

The obvious question is why the regulators have not demanded increased efficiency, and the answer is fundamental to how free markets work. ***Regulators have asked their utilities to build efficient plants, but this urging has produced small progress.***

The driving force for change in almost every endeavor is a competitor who desires to gain some share of the business, who lies awake at night trying to imagine a better way, and who then risks a new approach or a new technology. Figure 9 shows that regulatory urging has been a very poor substitute for competition in producing efficient solutions.

Fig. 9. Energy Generation Efficiency Curve[35]



During these same four decades of stagnant average efficiency, technology has improved substantially, enabling electric power to be generated much more efficiently. The series of gray circles show typical efficiencies possible from the best technology that was available at each point in time, assuming the generation of electricity was kept separate and the heat continued to be rejected into the atmosphere. The area between actual efficiency and best technology is the theoretical efficiency gap, assuming that old plants are replaced as soon as new technology is developed. This is obviously not economic because of capital costs, and even in an intensely competitive world, it would take time for the older and less efficient plants to be retired. The most important tool for achieving greater efficiency is to combine the generation of heat and power, and to supply normally