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History and Economics Provide Better Renewable Energy Strategies

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***Abstract*—Humanity's first energy source, beyond muscle power, was wood. History furnishes numerous examples of wood-using societies which perished when their forests were gone. These failed societies provide grim lessons for us today as we face a pending energy transition from fossil fuels. We will study the successful transition from wood to coal in 17th century England. From this example we will see that it was necessary to have an alternative energy source and the applicable technologies, but these alone were still insufficient. Economics dictated the final transition. If humanity chooses the wrong transition strategies, then the transition from fossil fuels to renewable sources will be too slow to prevent an ecological catastrophe.**

***Index Terms*—wood, coal, energy, transition, history, economics**

I. Introduction

HUMANITY has made many transitions in energy sources from human power to our modern world with a multitude of power sources. Unsuccessful energy transitions have greatly damaged or destroyed several dynamic, successful, and thriving societies. Therefore it behooves us to study both the failures and the one monumental success that history provides as we plan our next energy transition.

We will study the migration from wood- to coal-sourced energy. Several strong similarities exist in this transition and in those we will experience in the fossil fuel to renewable energy transition. We will also highlight major differences and analyze how these will impact our plans and our society. By studying our past we will gain insights into navigating our future.

We begin by noting how the availability of wood, or the lack thereof, has impacted other societies [1]. Wood has been mostly a depleting resource, and coal was priced and used as though it was inexhaustible and had no environmental costs. A resource that is depleted without renewing is effectively nonrenewable. Therefore the transition from wood to coal is analogous to the move from fossil fuels (coal and oil) to renewable alternatives (solar, wind, etc.).

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One critical mistake often made in developing strategies for our next energy transition is the implicit belief that a successful transition requires only alternative energy sources and the appropriate technologies. Our study of the successful transition in 17th century England will demonstrate economic payoff as a critical necessity. In fact, this was the time and place where the foundation of economics, as we know it, all began.

II. Historical Examples

A. Deforestation

Our earliest recorded histories tell us of great forests that once existed in geographies where there is now either little vegetation or simply scrub lands [2]. The Middle East had huge forests that are no longer there. The mountains of Lebanon were described as having huge cedars– the cedars of Lebanon [2]. These are described in both the epics of Gilgamesh [2] and in the Bible. King Solomon used these to build his Temple [3]. The forests were gone by 2000 BCE.

Deforestation then slowly spread westward across Europe [1] until the late 1500s when the Spanish Armada was built for the invasion of England. Huge areas of Spain were left deforested in order to build this large fleet [2]. When the Spanish Armada was destroyed in 1588 at Gravelines, a replacement fleet could not be built so easily. The victorious English had been slower than the rest of Europe in developing heavy shipping and the associated shipbuilding industry, and had yet to deplete their timber resources, which gave them a controlling advantage in world politics.

In the American Southwest, the drive to Chaco Canyon crosses barren scrub lands which were once forested [4]. The Anasazi settled there when timber was plentiful, and faded elsewhere as the timber supply depleted. Likewise, the Norse abandoned Greenland after exhausting its timber resource.

B. Easter Island

We will examine the Easter Island example in close detail because it shares very similar attributes as Earth and humanity as a whole. Easter Island is a small island (only 63 square miles in area) that is 2,500 miles west of Chile and 1,300 miles east of its nearest neighbor, Pitcairn Island. When Polynesian settlers arrived in about 900 CE, this extreme isolation meant that they had made a one-way trip to the island with no other option but to stay and live there [4].

Fig. 1. Easter Island monuments [5].

The Islanders developed a thriving society that lived peaceably and grew to a population estimated between 6,000 and 30,000 people. Their main activity and focus of their excess energy and time was to create ever larger and more elaborate religious monuments (Fig. 1). All the while, they were obliviously cutting and consuming their lush forest at an unsustainable rate. They cut down the entire forest; someone even cut down the last tree on the island!

Without wood to build seagoing canoes, they had to stop fishing, which led to severe food shortage. Suffering in a chill climate without wood fires and nearing starvation, the society collapsed. They turned against their gods who no longer protected them and destroyed their religious monuments.

Then around 1680 civil war broke out with fighting for the few things left to eat. By the time the Europeans arrived in 1722, the population had already declined by 90%. Without these external rescuers the Easter Islanders would have simply disappeared in a short time.

The significance of this example is that here was a society using wood as a material and energy source with no other alternatives. When the last tree was gone, their last option also disappeared [4]. They had no place to run toward, no alternative energy sources to use.

The lesson here is very plain and potentially grim: humanity has but one world, and there is no "away" to which we can migrate. When the Easter Islanders attained a population level that used their forests faster than could be replenished, there was still an opportunity to survive. But after crossing an ecological cliff, their doom was sealed. Humanity needs to consider what happens when an energy source plays out without a replacement.

C. Pre-Industrial England

In the late 1500s and early 1600s, England encountered numerous changes in its society. This period under Elizabeth I (1558–1603) and James I (1603–25) saw great increases in population, international exploration, and development of a seafaring military and shipping industry, all of which required a great deal of timber for shipbuilding and other uses [6]. One major change also occurring was a large increase in the use of iron. Vast quantities of wood went into making charcoal for the use of iron smelting. By the 1620s, England was suffering Europe's first really acute wood shortage. The English were forced to import timber from the Baltic and Scandinavian countries, with plans of importing timber from its new North American colonies.

Iron was smelted using charcoal derived from wood in order to achieve required processing temperatures. In fact, charcoal was the desired form of wood in all of its applications as a fuel. Entire industries would be located near supplies of wood and charcoal. By 1640, shortages of charcoal and continually increasing prices were causing disruptions to industry and even frustrating housewives.

For decades, mineral coal had been used in places where wood was simply not available (Fig. 2). The problem was that coal-burning released a heavy smoke containing sulfurous fumes that contaminated cooking and destroyed many industrial products. Moreover, coal simply could not be used for smelting iron due to its low burning temperature. For more than 500 years the Chinese had already been refining coal into coke to use as a fuel, but this process was not yet known in Europe. In 1603 the solution was suggested in England, but not until 1642 was coke derived from coal using a process similar to that for producing charcoal. At this time, coke was first used for roasting malt in a Derbyshire brewery. From that time on, coke was slowly adopted into other industrial applications. However, even when the technology became available, the universal adoption of coal in the form of coke would be postponed so long as the price and availability of wood remained tolerable. Eventually coking technologies produced superior results that ushered in the age of coal.

Several useful observations can be made. In the latter decades of the 1600s the price of wood in England first stabilized and then declined somewhat. After the initial decline in wood usage, the total consumption did eventually increase but only where wood was used as an industrial commodity rather than as a fuel. Inextricably linked to Britain's Industrial Revolution, this transition took several hundred years to fully develop and was driven by the economics of each situation. These changes occurred over an extended period of time with the bulk of the changes being observed and studied by one of humanity's greatest and most influential observers.

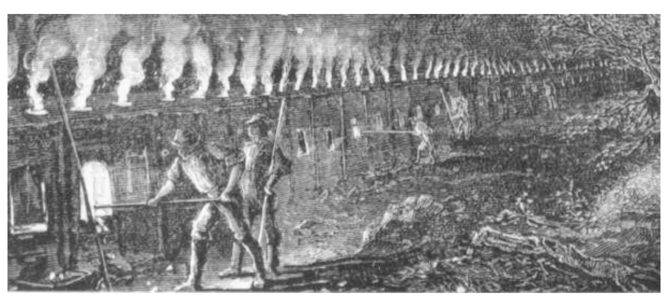

Fig. 2. Coal mining and coke burning [7].

III. Role of Economics

A. Adam Smith and his Invisible Hand

Adam Smith (Fig. 3), who is often credited as being the father of capitalism, lived in this period and in this location [8]. This technology transition and the resulting social and economic disruptions comprised a part of the data from which his economic theories were developed.

Smith was a moral philosopher who produced no utopian social theories; his method was to observe, understand, then describe the activities he saw, and conclude by explaining the underlying causes for these behaviors. In *The Wealth of Nations*, he showed that all endeavors are subject to the "laws" of economics. It may have been difficult at the time to rationalize the events that occurred during the early and middle stages of the wood-to-coal transition, but the final stages of this transition and all prevailing subsequent transitions could be clearly understood with Smith's assistance.

Fig. 3. Adam Smith (1723–1790) [9].

In *The Wealth of Nations*, which today remains the authoritative reference on the subject of economics, Smith writes the famous passage:

> *"…every individual… intends only his own gain, and he is in this, as in many other cases, led by an* **invisible hand** *to promote an end* [to benefit society] *which was no part of his intention"*

where he introduces the concept of the *invisible hand* of economics, often called *Adam Smith's invisible hand*. The underlying axiom is that any financial, social or economic transaction *will* follow the laws of economics. After all our efforts, Adam Smith's invisible hand *will* determine the course of events.

B. Comparison of Past and Pending Energy Transitions

Table I compares the similarities and differences between our historical example and our future energy transition. We consider past events to enlighten and assist ourselves in creating successful plans for a better future than if we simply muddled along with little forethought. We shall begin by looking for similarities in energy usage between 17th–18th century England and the present. The examples from history show that failure was more common than success. Humanity cannot afford to fail this time.

What is happening now with oil and other fossil fuel issues in the industrialized world bears much resemblance to what happened in England with wood. Deforestation led to forest preservation laws, similar to "wilderness areas" or "no drill zones". However, history teaches us that when shortages worsen, earlier restrictions will be relaxed. When environmental concerns and economic issues came into conflict, cost became more important than the environment. Our strategies should expect the same behaviors from our society as in the past.

TABLE I
COMPARISON OF ENERGY TRANSITIONS

Wood to Coal (England 1600–1750)	Fossil Fuels to Renewables (World Now)
Increasing fuel prices	
Fuel shortages	
National security issues	
Environmental issues	
Emerging new technologies to fill needs	
Wood was often simply unavailable	Oil/coal are still available at some monetary/environmental price
"Low" world population → local transitions	"High" world population → needed transition will be global
Similar *per capita* energy usage worldwide and across social classes	Huge deficit in energy available to the world's underclass vs. the affluent

We must consider the key differences between our current situation and that of 17th century England [7]. As the English used up their wood, price increases and wood shortages became very acute and began to disrupt society. For us, on a worldwide basis, fossil fuels are not running out yet; we can debate the date for "peak oil", but the bottom line is that fossil fuel is available if one is willing to pay the market price. The "easy oil" is probably all gone, so we will see long-term price increases with very erratic pricing in the short term due to supply and demand inelasticity. Unfortunately, before our coal and oil sand/shale resources are fully depleted, great ecological damage will have been done.

The second major difference is that there was not a large gap in annual *per capita* BTU consumption in 17th century England from the average for the rest of the world. Today, a huge difference exists between the consumption rates in the developed and underdeveloped worlds. It is easy to search for solutions that will satisfy the affluent in the world, but leave behind the huge majority of the world who are in abject poverty. The solution humanity finds must fund this energy deficit or the social stability of the world will resemble the final years of Easter Island. The technical difficulties relating to the energy deficit for the poor is well covered by Cleveland in "Energy Transitions Past and Future" [10]. The underdeveloped world will move to alternative energy sources without increasing their carbon footprint if, and only if, that is to their short-term economic benefit.

IV. Strategies toward Successful Transition

A. Requirements

Humanity has neither the time nor the margin to iterate to a successful strategy by trial and error. We must logically construct our transition strategy and then test it against standards that history and economics have provided:

- must be economically profitable,
- must be technically solid,
- should fulfill the energy load,
- must be environmentally sound, and
- must be part of a long-term strategy.

Whatever we do for alternative energy sources will likely be a collection of many different solutions, some small- and medium-sized, which add to meet the needed total energy levels. By not concentrating on a single solution large enough to replace fossil fuels, we can facilitate a gradual transition where smaller scale solutions are individually adopted as they become technologically available and economically viable. In this way, our dependence on fossil fuel sources will be eliminated in a gradual rather than disruptive fashion, providing a practical way to overcome the political and economic inertia established by the fossil fuel sector. This progressive migration will also limit any one solution from introducing a large-scale ecological problem.

A smart power grid management system must emerge as the enabling infrastructure that will adaptively harness the myriad of scattered and vastly different energy sources and distribute power to the end user. Beyond its technical role, a successful smart grid must also serve an economic role as a supply-demand arbiter that minimizes cost for the consumer and maximizes return for the producer.

In fact, economics could already implement viable interim solutions before they are technically complete. For instance, placing a price discount for interruptible electrical service and time-of-day pricing could mitigate problems of supply intermittency plaguing alternative electricity sources such as wind power.

B. Risk Considerations

The strategies we develop should explicitly examine certain dangers and create methods to deal with them.

- We should expect fuel (oil) prices to bounce greatly with supply and demand, but should not stop the transition because of temporary drops in price.
- The earlier transition ushered in huge social changes which we now refer to as the Industrial Revolution. The same will occur with our next transition.
- This will be a worldwide transition creating both winners and losers. Success will come only when the improvements are shared across the world. For instance, the carbon tax is more palatable to a developed nation than to a society living in subsistence.
- Taxes, tariffs, and economic incentives could be introduced to shift consumer decisions; this can and will work. Regulatory solutions will fail, especially on a global basis. Both economic incentives and regulatory solutions are difficult to implement in democracies, but only the former can succeed.
- The possibility exists for a disruptive new, nonrenewable, carbon-based fuel (e.g., deep sea methane hydride) to come on the world scene at a low price. This would be an ecological disaster because we have not learned how to price future ecological damage into the price of a product.

V. Conclusions

It is imperative to study energy transitions from the past– both successes and failures– to help us foresee the results of our strategies. The greatest challenge we face is to ensure that the *cold dead hand of Adam Smith* is working for rather than against us. We must accept that the end consumer will adopt a Green Technology only if it is cheaper and better than the existing one. The wood-to-coal transition only occurred after the cost benefit arrived. The move to renewable energy will therefore only occur when it becomes economically profitable. So, let us always relentlessly pursue cost reductions with shorter payback periods for our transition products and strategies.

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Prof. Cutler Cleveland of Boston University established a very high standard for establishing energy transition strategies, as shown in [10]. His personal encouragement to write this paper, with a differing perspective, was valuable and appreciated.

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[2] K. J. W. Oosthoek, "The role of wood in world history". *Environmental History Resources* (http://www.eh-resources.org/wood.html).

[3] 1 Kings 5:6-10.

[4] J. Diamond, *Collapse: How societies choose to fail or succeed.* Penguin Books (2005).
This book is essential reading for anyone trying to understand or deal with the interaction of humans with the environment. Although it does not deal explicitly with energy and the ramifications of our selections, it does offer examples and explanations of how running out of energy (wood and forests) has destroyed societies that chose wrongly. Possibly the most important element is the fact that societies choose their future, either dealing with other motivations or dealing directly with the coming problems and thus being able to transition through time successfully. This book covers societies from prerecorded history to the very recent past and present.

[5] Wikipedia file: Easter Island Statues MBL1932.png

[6] J. U. Nef, "An early energy crisis and its consequences," *Scientific American*, no. 237, 1977, pp. 140–151.
If your goal is to relate the wood to coal transition to future energy transitions, then it is important to review this summary for the period 1530 to 1800. Nef has a true gift to share the technical and social aspects together with understanding the cause and effect of the many changes occurring. The similarities with the present and projections for the future will be readily apparent.

[7] Wikipedia, File: Coke burning.jpg

[8] A. Smith, *The concise encyclopedia of economics.* 2008. Library of Economics and Liberty.
http://www.econlib.org/library/Enc/bios/Smith.html

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http://www.eoearth.org/article/Energy_transitions_past_and_future
This is one of the most thorough and complete summaries of the transition from fossil fuels to alternative energy sources. Not only is it very rich in fundamental statistics of energy, but Cleveland examines a number of factors that are usually ignored such as energy quality, energy density, power density, energy surplus (energy returned after energy investment), intermittency, and numerous other crucial factors. Not only are the technical factors well covered, but the social connections are also included with sound reasoning for each conclusion. Historical perspective is included so that connections between the social and technical are fact driven. This is an important work to peruse prior to generating any energy transition strategies.

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