Chapter 1

> Energy is the only universal currency: one of its many forms must be transformed to get anything done.

I think the fundamentals of energy is a thing in itself. What really stuck out to me in this chapter was the idea of conversions. What makes humans special is our ability to make our own converters. All animals got one from evolution (the metabolism) and we've been able to make our own (like steam engines).

TO \ FROM	ELECTRO-MAGNETIC	CHEMICAL	NUCLEAR	THERMAL	KINETIC	ELECTRICAL
ELECTRO-MAGNETIC		CHEMILUMINES-CENCE	NUCLEAR BOMBS	THERMAL RADIATION	ACCELERATING CHARGES	ELECTRO-MAGNETIC RADIATION
CHEMICAL	PHOTO-SYNTHESIS	CHEMICAL PROCESSING		BOILING	DISSOCIATION BY RADIOLYSIS	ELECTROLYSIS
NUCLEAR	GAMMA-NEUTRON REACTIONS					
THERMAL	SOLAR ABSORPTION	COMBUSTION	FISSION / FUSION	HEAT EXCHANGE	FRICTION	RESISTANCE HEATING
KINETIC	RADIOMETERS	METABOLISM	RADIOACTIVITY / NUCLEAR BOMBS	THERMAL EXPANSION / INTERNAL COMBUSTION	GEARS	ELECTRIC MOTORS
ELECTRICAL	SOLAR CELLS	FUEL CELLS / BATTERIES	NUCLEAR BATTERIES	THERMO-ELECTRICITY	ELECTRICITY GENERATORS	

Figure 1: "all matter is energy at rest, that energy manifests itself in a multitude of ways, and that these distinct energy forms are linked by numerous conversions, many of them universal, ubiquitous, and incessant, others highly localized, infrequent, and ephemeral"

- Starting the processes of enumerating the energies we know of can help give it a physical manifestation. > All known forms of energy are critical for human existence
- Smil states that matter is energy at rest, which doesn't really offer insight ### Basic definitions, units and some napkin calculations we can do with them

Chapter 3

- *remember the goal of groups of people is to reproduce*

- *how do we construct a model with which to tact on the information given by Smil*

Systems

Meadows says in her book to use data, graphs through time to analyse the flow in a system. The system in our case is a mutating one constantly dictated by stock of energy and by the flow of power. The rate of energy expenditure.

How might we develop something we can test?

A Solar Powered population: General conceptual model to approach this chapter

To simplify, before agriculture there was a fixed population of hunter gatherers that used whatever phytomass the Earth naturally produced to sustain themselves. The population of hunter-gatherers is then a function of the edible phytomass. To increase the population required enough energy to support more people. Without attempting to create more phytomass this couldn't be done. This required using the energy provided by the phytomass and invest it in producing more phytomass. This is the process of farming intensification, getting more out of the existing land.

To increase the population or improve the quality of life, early human societies needed to find ways to capture and store more solar energy. They achieved this through various means, such as exploiting more efficient hunting and gathering techniques, controlling fire for cooking and habitat modification, and developing tools and strategies for food preservation.

On the transition

Smil's inspiration is that of

> Boserup (1965, 1976) conceptualized the link between food energy and the evolution of peasant societies as a matter of choices.

These choices are once an agricultural system (land, community, no of workers etc.) reaches the limits of its productivity, people can:

- Migrate.
- Stay (and stabilize numbers).
- Stay (and let their numbers decline).
- Adopt more productive form of farming.

The last option seems like a no brainer but required large energy inputs.

> Increased productivity will support larger populations by cultivating the same (or even smaller) areas, but the net energy return of intensified cropping may not increase and may actually decline

To get more out the land, you had to put more in (work). This might not pay off.

According to Smil, everywhere in the world was slow to advance productivity of the land they had. > everywhere, it took millennia to shift from regular, extensive fallowing to annual cropping and then to multicropping.

> Carolingian Europe were overpopulated and their grain supplies were chronically inadequate, but only in parts of Germany and Flanders were new fields created in less easily cultivable areas

Enter: Farming intensification

Farming wasn't necessarily immediately energy efficient so the energy explanation doesn't offer much in the explanation of this transition. It does offer an explanation for the increase in population after the transition though with increases in population.

We can use this as a stepping stone into Smil's world though. His core thesis is that of farming intensification. This is something that led to more energy being stored on Earth and was driven by an increase in labour and capital.

The core feedback loop to Smil is the effort to raise land productivity to accommodate larger populations.

Farming Intensification

Historically, societies tried to develop ways to get more out of the land they had. There were three core features to this, common across the world:

- An increased use of animal labour.
- A focus on irrigation and fertilization systems.
- Multi cropping and crop rotation.

It's important to establish the commonalities across societies as it can give a sense of the core problems faced. There are 5 main steps to developing crops on a fixed land area.

- Ploughing: Fundamental to agriculture. The ancient Greeks and Romans used a symmetrical plow but the Han Dynasty era China developed the first Moldboard plough. With thicker soil in Europe a plow with a shaper point and a surface (plough share) to turn the soil to the side was developed.

- Harrowing and leveling the ploughed ground.
- Seeding, which was done using a seed drill in the Mesopotamia since ~1300BCE but was still done with broadcast seeding by hand in Europe until the 19th century (this method is inefficient with large amounts of seeds not planted properly).
- Harvesting: The first tool being the sickle, that replaced basic stone tooling.
- Processing: Like milling the grain by hand or with animal labour or pressing of oil.

Another trend in all cultures was a dominance of a cereal grain. The particular cereal depending on geography but in hindsight, grains seem like a solid foundation as opposed to tubers or legumes because:

- The water content of tubers is too high for long term storage and requires large storage volumes.
- Tubers have low protein. Legumes have high protein but low yields. Average yields for US cereals is 7.3T/ha in 2013 vs 2.5T/ha for legumes.
- Fairly high yields, good nutritional value, relatively (as much as 5 times tubers) high energy density at harvest and easier to store.
- Particular species dominating depended on environmental conditions.

Animal Labour Draft potential could only be translated into perfomance through a harness.

He discusses the tension between harnessing the horses power for the tasks farmers wanted it to do.

Irrigation p.76 total seasonal need of water is approximately 1,000 times the mass of the crop e.g. 1,500t of water are needed to grow one tonne of wheat.

> The energy cost of human-powered irrigation was extraordinarily high. A worker could cut a hectare of wheat with a cradle scythe in eight hours, but he would need three months (8 h/day) to lift half of its water requirement just 1 m from an adjoining canal or stream.

Fertilization It’s useful here to highlight the back of the envelope calculation Smil has showing the marginal increase in yield or the *leverage* of labour with nitrogen.

A good late Qing dynasty winter wheat harvest of about : * 1.5 t/ha * required just over 300 hours of human and about 250 hours of animal labor. * Fertilization took, respectively, 17% and 40% of these totals. * Fertilization hours are 51 and 100 hours. * 10 t/ha of fertilizer which contains 0.5% nitrogen. * Due to leaching only half that nitrogen becomes available. * 25 kg/ha nitrogen for crops. * Each kg will add 10kg of grain. So 25*10 = 250kg of extra grain.* 3% used then as animal feed. * I think what Smil is saying is that you get 200kg of flour (2.8GJ) for 51 hours of extra work (40MJ) of energy.

Constancy and change

> In most regions traditional farming progressed from extensive to intensive cultivation: its prime movers—human and animal muscles—remained unchanged for millennia, but cropping practices, cultivated varieties, and the organization of labor were greatly transformed. Thus both constancy and change mark the history of traditional farming.

Where *extensive* refers to the use of labour and capital over a large land area and *intensive* is the same over a smaller land area.

- *Extensive farming*: System of crop cultivation using small amounts of labour and capital in relation to area of land being farmed.
- *Intensive farming*: System of cultivation using large amounts of labour and capital relative to land area.

"Because extensive agriculture produces a lower yield per unit of land, its use commercially requires large quantities of land in order to be profitable. This demand for land means that extensive agriculture must be carried on where land values are low in relation to labour and capital, which in turn means that extensive agriculture is practiced where population densities are low and thus usually at some distance from primary markets." How Asia Works? [1]

Claim: Farming became more intensive

What data would we expect to see for this claim? There seems to be evidence due to increase in methane emissions in ancient societies and population increases. This along with the development of more advanced tools and use of tools (scaling up labour and capital inputs).

Case Study for the more extensive approach: Egypt

> Emmer wheat and two-row barley were the first cereals, and sheep (Ovis aries) were the first domesticated animals.

It seems that Egypt due to geography took a more extensive approach. Specifically, they did not develop the irrigation systems of China as the Nile banks had low gradient.

Case Study on large organisation : China

The largest and longest lasting contribution to the agricultural system in China was irrigation. Sichuan's Dujiangyan still supports 10 million people to this day.

[1] http://www.ecifm.rdg.ac.uk/

> The construction and unceasing maintenance of such irrigation projects (as well as the building and dredging of lengthy ship canals) required long-range planning, the massive mobilization of labor, and major capital investment. None of these requirements could be met without an effective central authority. There was clearly a synergistic relationship between China's impressive large-scale water projects and the rise, perfection, and perpetuation of the country's hierarchical bureaucracies.

- Large waste recycling coordination admired by the west. "at least 10% of all labor in Chinese traditional farming was devoted to managing fertilizers"

Even in the early 20th century China was getting large yields on farming largely due to minimal mechanization, human labour dominating.

Human and animal labour as the prime mover just could not sustain a reliable food supply. Why?

The environment tells you when you work

> The shift from foraging to farming left a clear physical record in our bones. Examination of skeletal remains from nearly 2,000 individuals in Europe whose lives spanned 33,000 years, from the Upper Paleolithic to the twentieth century, revealed a decrease in the bending strength of leg bones as the population shifted to an increasingly sedentary lifestyle (Ruff et al. 2015).

Smil uses about 800kJ/h for a rate of work and 15GJ/t for cereal that could be stored. Farming wasn't always really intensive work. But in a sense, it couldn't really be or else no one would have scaled the mountain of work for it to become stable. What it did include was a life determined by the seasons.

The Intensification feedback logic

> Whether theres a harvest depends on water, how big it is depends on fertilizer - Chinese peasant

More draft animals (1) fueled more fertilization (2) and in some places aided in irrigation systems (2). More powerful prime movers and water supply also increased the yields from multicropping and crop rotation (3). All these combined to be able to support not just more people, but more animals which starts the cycle again.

Malthus model

The trade-off for having children as ways of developing labour was positive.

Chapter 4

Animate energy in this chapter I think means *derived from a living organism*.

- Smil's opening paints this picture of an inconsistent progress of humans

> inconsistent food surpluses that they [societies] produced with the aid of a few simple tools and the exertion of their muscles and the draft of their animals sufficed to support the unevenly advancing complexity of urban societies.

- There are a number of achievements in this period though with regards to energy output: the pyramids, baroque churches, increased transportation infrastructure and metallurgy advances.
- This is a similar point made with farming of 'Constancy and Change'.
- This period is about utilising animate movers in the most efficient way possible which involed 1) better organisation of the application of animate power (pulleys, levers etc.) and 2) Technological innovation (new energy conversion or increasing efficiencies of established processes). What's the difference between these two?
- Figure 4.1 shows an example of the progression of a water wheel in the sense of increasing technical knowledge.

Chapter Summary according to Smil

- First appraise the kinds, capacities, and limits of all traditional prime movers (human and animal muscles, wind, water) as the combustion of phytomass fuels, mostly wood and charcoal made from it (or crops where regions deforested).
- Next, Look in some detail at the uses of prime movers and fuels in critical segments of traditional economies (food preparation, provision of heat and light, transportation, construction, and in color and ferrous metallurgy.

Animate Power and Simple Machines

What does a purely animate energy world look like, what are its limitations?

- Societies that derived any kinetic energy from animate power could not provide reliable food supply or material wealth consistently to its inhabitants (think, medieval Europe). Power applied is driven by metabolic requirements.

Levers

- Work is force applied over a distance.
- In the case of a lever this distance is measured from the fulcrum.
- Increase the distance and you can apply less force for the same amount of work.