INTRODUCTION

Today, more than ever before, a concern for how energy is produced and consumed, and at what costs, weighs heavily on global awareness. Debates over the legacy and future of fossil fuels in the world's energy budget stir intense passions and contribute to economic, political, and environmental decision-making from the highest levels to the lowest. Yet few historians, let alone ordinary citizens, pay much attention to changes in societal energy supplies prior to the age of steam. To be sure, the energy-related changes in world landscapes wrought by pre-modern deforestation, cultivation, and pasturing of domestic animals did not pose threats to the continuation of civilization of the sort being agonized over today. Nevertheless, they did reshape the natural world and thereby lay the groundwork for some of today's perils.

This book deals with only one type of energy: animal muscle power. And it focuses on one part of the world, albeit an enormous one: the Afro-Eurasian land mass from approximately ten to fifty degrees north latitude. It proceeds through a series of explorations devoted to previously unasked questions dealing with patterns of human-animal relations before the year 1500 CE. Each exploration will involve a not insignificant amount of speculation, but hopefully they will sum to an enlightening picture of the world's energy profile on the eve of European colonization.

Every human society has an energy profile, that is, a pattern of energy sources that can be ranked from the most heavily used to the least. For Neolithic societies, for example, the top energy source was human muscle power, followed by burning vegetation, and, in some landscapes, river currents or wind for water transport.

At the other end of energy history, in American society today, electricity tops the list—understanding that the electricity consumed is itself variously generated through chemical reactions, hydrocarbon combustion, flowing water, wind, solar radiation, and nuclear fission. Hydrocarbon combustion for transportation, heating, and manufacturing comes second. Human muscle power for walking, running, pushing shopping carts, and shoveling snow might come third, though at a much lower proportion than in Neolithic times. But animal power, the primary energy source during most of pre-modern written history, ranks lower still.

Notionally, one could devise an energy profile for every society and propose relationships between the highest-ranking energy types and various economic, political, and social institutions associated with those types. This means that every energy profile would carry different institutional implications because of the intrinsic parameters set by the means of utilizing each energy source. For example, waterpower requires substantial monetary and physical investment in mills or turbines, but animal power can be accessed at a much simpler institutional level by using a riding or pack animal, a pair of plow oxen, or a team of horses.

Nuclear power calls for huge investment and government engagement. Electricity, however, has two modes. One, Big Electricity, involves large-scale investment and control for installing generating plants and distribution networks. The other, Small Electricity, takes the form of cheap, universally available batteries. Batteries have to be made in a factory someplace, of course, but the location, size, and government involvement in battery manufacture have little or no effect on the availability or use of the products . . . until such

time as batteries power huge fleets of vehicles and deplete mineral elements in scarce supply.

In addition, every energy profile involves environmental impacts, some intrinsic to the array of power sources and some dependent on the location, intensity, and efficiency of harnessing systems. So far, the world has coped, with varying success, with deforestation, exhaustion of rangelands, air and water pollution, and accumulation of waste products. But archaeologists have become attuned to asking whether certain bygone societies coped less well and eventually collapsed as a result.

Changes in energy profiles also connect with changes in conceptions of wealth. A society with an abundance of horses and oxen may consider itself wealthy if animal power is at the pinnacle of its energy profile, but not if the society runs on electricity and petroleum. Similarly, a society that has abundant petroleum resources, or major rivers flowing through narrow gorges, may be considered wealthy if internal combustion or hydroelectricity tops their energy profile, but possibly not otherwise.

Historically, the shift from one energy profile to another might be as consequential as a shift from one Marxist mode of production to another. Analyzing why and when shifts occur, laying out the institutional developments that cause, or are caused by, such shifts, and showing their ripple effects over time is a reasonable job for a historian.

A first cut at approximating the ranking of energy utilization within the profiles of societies at successive levels of complexity yields the following stages, though local circumstances introduce variations and anomalies at every stage.

- Primitive hominids: 1) human muscle
- Fire-using early hominids: 1) human muscle, 2) combustion of vegetable matter (wood)
- Early domestication: 1) human muscle, 2) combustion of vegetable matter (wood), 3) animal muscle (food), 4) wind and water (sailing and rafting)
- Mature domestication: 1) Animal muscle (pack and draft animals), 2) combustion of vegetable matter (wood, charcoal, dung), 3) human muscle
- First energy revolution: 1) Combustion of vegetable matter, 2) water and wind (mills and sailing), 3) animal muscle, 4) human muscle
- Second energy revolution: 1) Steam, 2) water, 3) combustion of vegetable matter and coal, 4) animal muscle, 5) human muscle
- Third energy revolution: 1) Big electricity (coal and hydroelectric), 2) internal combustion (petroleum), 3) combustion of coal, 4) human muscle, 5) animal muscle
- Contemporary times: 1) Big electricity (coal, hydroelectric, and nuclear), 2) internal combustion (petroleum), 3) small electricity (batteries), 4) human muscle

For the explorations undertaken in this book, the relevant part of this history is the era of Mature Domestication. Beyond meat-eating, which extends from the emergence of hominids to the present, the energy derived from large domestic animals takes four forms: carrying burdens or riders, pulling plows and vehicles, operating machinery, and contributing dairy products to human diets. Of course, a society that uses animal traction may well eschew either meat-eating or consumption of dairy products. Similarly, a society may be well aware of animals being used to pull plows or vehicles elsewhere yet choose to ignore this utility.

Boundaries between types of animal exploitation being neither absolute nor permanent, broad similarities of type need to be roughly delimited by time and space. Consequently, this book focuses on the period of mature domestication from roughly 4000 BCE and to the era of European colonialism after 1500 CE. During this period human-animal relations divided into six distinct zones of animal exploitation, though each zone had fuzzy and flexible boundaries. Harnessing and dairying define the most important differences from one zone to another.

Harnessing animal power triggered the most far-reaching changes in human energy utilization since the advent of controlled fire. Yet three of the six inhabited continents made little or no use of animal power before the sixteenth century CE. Moreover, the transition from exclusive use of human muscle power and fire to using animals for traction and carrying burdens may have occurred only four times. And in three of those cases — dogs pulling sleds and travois in North America, llamas carrying burdens in the Andes, and reindeer being ridden and pulling sleds in sub-arctic Eurasia — the follow-on effects, if any, had negligible impact.

Comprehending the monumental importance of the fourth case, the harnessing of cattle to carry burdens or to pull plows, sledges, and wheeled vehicles, begins with realizing that it occurred only after people had already been eating domestic cattle for approximately 4000 years. Simply put, so far as we know, some 120 generations of cow-herders lived their lives without ever thinking of tying a load to an animal's back or the crossbar of a yoke to its horns.

Archaeological evidence indicates, however, that at around the same time that some peoples began to use cattle to pull and carry things, others took to herding four new domestic animals, donkeys, horses, one-humped camels, and two-humped camels, all four of which seem to have been used from day one to carry loads or pull vehicles. Yet none of these late domesticates descend from wild ancestors native to the parts of Europe that yield the earliest archaeological evidence of cattle pulling plows, sledges, carts, and wagons. Nor did any one of the four find widespread use pulling plows during the period under discussion. Rather, all four came from the Arid Zone, where their service carrying riders and cargo would come to outweigh by far their use for traction.

Inasmuch as long centuries of tending cattle elapsed before their keepers began to use them for labor, but scarcely any time at all elapsed between the appearance of the Arid Zone's four late domesticates being employed as beasts of burden, it seems evident that the changes in animal husbandry that set in around 4000 BCE involved not just new technologies, but also a new conceptualization of human-animal relations. Archaeologist Andrew Sherratt linked the harnessing of animals for labor to the near simultaneous onset of dairying and shearing sheep for wool in what he famously called the "secondary products revolution."[1] The term gives due emphasis to the importance of these changes in animal utilization, but it does not convey their broader meaning in terms of human-animal relations.

Not only did the keeping of domestic animals yield new utilities, but some of the old values eroded, apparently as a consequence. For example, while people had been making

[1] Andrew Sherratt, "Plough and pastoralism: aspects of the secondary products revolution", in Ian Hodder, et al., eds., *Pattern of the Past: Studies in Honour of David Clarke*, Cambridge: Cambridge University Press, 1981.

blood sacrifices of cattle, sheep, and goats in large numbers for thousands of years, none of the new species of working animals ever acquired much importance as sacrificial victims.[2] Similarly, while animals, or humanoid images with animal features, abound in deep antiquity as representations of gods, a search for donkey gods, horse gods, or one- or two-humped camel gods produces few results. The most significant is the primal Egyptian identification of the wild ass of the Sahara with Set, the god of the desert. But Set underwent severe demonization in most of the Nile valley, particularly after 1200 BCE, and his dedicated animals, the ass and the pig, became subjects of food taboos. This often led to superstitious individuals scratching out the faces of donkeys in paintings depicting rural labor.

Desacralization carried over into dietary practices. Despite the fact that many settled societies from India through the lands of Greco-Roman antiquity derived most of their meat from ritual sacrifice, they seldom included the new domesticates. The peoples of the steppe who had been hunting and eating horses for thousands of years continued to do so, but neighboring regions that adopted the horse for riding or pulling vehicles, such as China, India, and the Middle East, seldom added them to their dinner menus. The same applies to donkeys and both species of camel.

To make sense of the new animal geography flowing from the spread of domestic horses, donkeys, and camels, it is useful to see human-animal relations throughout the world, circa 1500 CE, as dividing roughly into six zones After 1500, however, every zone undergoes cataclysmic distortion as European imperialism makes Zone 1 patterns and sensibilities appear to represent global norms through a wholesale transplantation of livestock, animal husbandry practices, harnessing technologies, and "scientific" understandings of animals, while relegating precolonial relations with animals, both real and imaginary, to the dustbin of the pre-modern.

Zone 1

Europe west of the steppes:

Herders conducted sheep and goats to pasturelands and drove pigs into forests to feed on nuts, but forests, mountains, and marshlands provided few tracts of rangeland suitable for extensive herding of large animals. From Neolithic times onward, the expansion of agriculture north and north-westward from southeast Europe led to humans clustering in villages and tending to fairly small numbers of livestock. Mixed farming resulted, combining cultivation with localized animal-keeping, including some horses and donkeys starting in the Bronze Age. Yoking cattle for plowing and pulling vehicles preceded extensive use of horses and donkeys, but by the Greco-Roman era, machinery operated by harnessed animals was becoming increasingly diverse. Widespread adult lactose tolerance, particularly in northern Europe, led to, or resulted from, the consumption of a wide variety of dairy products using milk from cattle, sheep, and goats.

Zone 2

[2] The horse sacrifice described in Vedic texts occurred rarely, with its primary purpose being to delimit the territorial boundaries of a chieftain's realm. And the Israelite ban on donkey sacrifice (Exodus 13.13) implies a distinction from other Canaanites though there is little archaeological evidence of large-scale donkey sacrifice.

Arid Zone from Morocco to Mongolia:
Some rich agricultural lands could be found in the Arid Zone, most notably the valleys of the Nile, the Tigris, the Euphrates, and the Indus. But even the most productive lands lay within easy reach of vast, non-cultivable grazing lands, the native habitats of wild donkeys, onagers (so-called half-asses), horses, one-humped camels, and two-humped camels. Wild cattle (*bos taurus*) once lived in better watered highland areas of North Africa and the Middle East, and archaeologists ascribe their initial domestication to these regions, including well-watered grasslands that slowly became engulfed by the Sahara Desert after 5000 BCE. Domestic versions of these animals required, or became closely associated with, impermanent human living patterns, ranging from twice yearly shifts between dry season and wet season pastures, to year-round pastoral nomadism. When cattle came to be used for laboring purposes, settled villagers used them to pull plows and operate devices associated with agriculture, such as wells, irrigation devices, and mills. But with the development of wheeled transport, more mobile social groups found them useful beyond the frontiers of cultivation.[3] Despite the appearance of horse-drawn military chariots after 2000 BCE, however, transporting riders and cargo became the most important tasks carried out by the late domesticates within the Arid Zone. Aside from western portions of the Arabian desert, where adult lactose tolerance seems to have crossed the Red Sea from the Horn of Africa, only small percentages of most human adult populations could comfortably digest liquid milk or high lactose dairy products.

Zone 3
East Asia (south and east of Myanmar):
Domestic cattle, horses, donkeys, and two-humped camels entered the northern part of this region from the Arid Zone via northwest China, which abounds in extensive arid rangelands. Northern Japan has similar districts suitable for extensive grazing of large livestock. Elsewhere, however, village cultivators predominated in broad river valleys and mountain ranges. Villagers used cattle to pull plows, and used water buffalo for the same purpose in southern parts of the zone. Domestic water buffalo and zebus, humped Indian cattle (*bos indicus*), entered the region from Zone 4. Plow harnesses in northwestern China, bordering Zone 2, featured pairs of oxen yoked together. Elsewhere, however, single animals commonly pulled plows throughout the zone. By the beginning of the Common Era, the practice of using two horses to pull chariots, a common feature of earlier warfare in northern China, disappears. Horse-carts and camel-carts subsequently used single animals. Paired oxen harnessed to carts continued in use infrequently. Cross-country transport of goods in China relied heavily on humans operating wheelbarrows, occasionally supplemented by a donkey pulling in front. Elites might ride horses or donkeys, but palanquins (sedan chairs) carried by bearers provided a more common form of personal transport. Adult lactose intolerance being almost universal, no significant dairy industry came into being.

Zone 4
South Asia:

[3] For details on the origins and early uses of wheeled transport, see Richard W. Bulliet, *The Wheel: Inventions and Reinventions*, New York: Columbia University Press, 2016.

Uses of cattle closely resembled parallel uses in Zone 1 and Zone 2, but with more extensive utilization of bullocks (castrated males, i.e., oxen) as pack animals. Native zebu cattle (*bos indicus*) and the closely related cattle in the Middle East and Europe (*bos taurus*) both appeared in remote antiquity with no clear indicator of which species first produced domestic breeds. Domestic water buffalo and yaks either appeared on the scene later, as their absence from the extensive body of lore relating to ancient cattle sacrifice in northern India might indicate, or developed elsewhere in the subcontinent. Judging from their use as plow, pack, and dairy animals, it seems likely that they were seen as cattle substitutes adapted to warmer or cooler climatic niches. Experimentation with cattle breeding led to hybridization with yaks in the Himalayas and with mithans, a bovid native to northeast India. When and how wild-captured elephants became laboring animals remains unclear, but probably postdates the appearance of other work animals. The four late domesticates played limited roles supplying labor, though royal and military elites showed a persistent desire for horses, mostly imported from Zone 2. Despite a limited percentage of adults bearing the gene for prolonged lactose tolerance, dairy products featured prominently in north Indian diets, but did not figure strongly in south India.

Zone 5
African Sahel:
Though the colonial era importation of domestic animals into different parts of Africa south of the Sahara Desert created uncertainty as to when and where African livestock herding originated, the pastoral peoples of the savanna belt, or Sahel, made that region a distinctive zone of animal exploitation.[4] North of the heavily forested tropical region, the Sahel stretches from Mauritania and Senegal on the Atlantic coast to Sudan and Kenya on the Red Sea. It includes deserts and semi-deserts along the southern fringe of the Sahara merging southward into semi-arid savanna grasslands, occasionally dotted with trees. Pastoral groups herded camels, cattle, donkeys, sheep and goats. Rock art depicting cattle herders in Saharan landscapes that are today far too arid for such herding create a strong likelihood that pastoralism originated north of the Sahel and shifted southward as desertification increasingly overtook the Ice Age grasslands from 5000 BCE onward. The absence of plows, wheeled vehicles, and sheep with wool instead of hair indicates that the "secondary products revolution" left the Sahel largely untouched. To be sure, camels and donkeys did carry riders and cargo, but the former did not show up in the region before ca. 300 BCE. Many of today's pastoral groups have genetic mutations enabling them to digest liquid milk, and milk is a common part of their diet. However, the mutations that have been identified differ from the single mutation found in Zone 1 and Zone 2 (western Arabia excepted).

Zone 6
Western Hemisphere, Australia, and Sub-Sahelian Africa:
These regions have few domestic animals dating to the pre-colonial era. Apart from dogs, which are globally ubiquitous, llamas in the Andes Mountains and dwarf goats and pigs in parts of equatorial Africa constituted the primary domestic species. Llamas carried

[4] For details, see H. Epstein, *The Origin of the Domestic Animals of Africa*, rev. ed., New York: Africana Publiushing

burdens, but not riders. Dog harnesses may have been borrowed from Alaska into northeast Asia and used to harness domestic reindeer for pulling or carrying. A reverse adoption, from Asia to arctic North America, seems unlikely inasmuch as reindeer herding never left Asia, even though North American caribou belong to the same wild species. Aside from family lineages showing colonial era Zone 1 or Zone 2 immigration, the inhabitants of this zone are universally lacking in adult lactose tolerance and hence have no indigenous dairying traditions, even though African dwarf goats are suitable for milking.

If the energy and geographic contexts within which the explorations to follow have been set seem exceptionally broad, and perhaps even grandiose, the specific topics they will address may seem, at least at first blush, to deepen the mismatch between the global big picture and fussing over peculiar details in a small corner of the canvas.

The first exploration concerns camel caravans: their rise, spread, economic function, and societal impact. The second takes up a comparison of Arid Zone animal energy and the rise of water and wind power in late medieval Europe. The third deals with the question of how dairying impacted some societies while barely existing in others that made use of the same beasts of burden. The fourth takes up the topic of hybridization and zeros in on the question of why some societies took an interest in trying to mate one domestic species with another, and how their successful experiments led to new animal industries. The conclusion will draw attention to the largely unstudied human interface between nomadic pastoralism and the multifarious uses to which animal energy was put in the Arid Zone in pre-modern times.