Chapter 7
Toward a Socioecological Concept of Human Labor

Marina Fischer-Kowalski and Willi Haas

Abstract Within the socioecological framework, labor figures in two contexts. One context is social metabolism: extracting and transforming materials from nature for social consumption. This is not fundamentally different from what any other animal does to secure its food and the food for its offspring, and it is, as far as we know from hunter-gatherers, not very much work. The second context is what we term colonizing activities. Colonizing activities are deliberate interventions in natural systems to modify their functioning and truly demand labor from humans; the energy transition of the Neolithic revolution is the starting point for man as a laborer. We assume that human society is currently in another energy transition in which we are moving away from the use of fossil fuels. This transition will have as many implications for human labor as the transition toward the fossil fuel-based industrial society had. In the first section, we characterize quantitative, qualitative and institutional features of human labor from a socioecological perspective. We then focus on the interrelation between sociometabolic regimes and the amount of human life time spent on labor, the respective critical capacities of human labor power (physical power, intelligence/knowledge, empathy) and the institutional forms in which labor is employed. The third section speculates about the future: what might labor look like after the ongoing socioecological transition is completed? In light of the major changes in work and life induced by the fossil-fuel-based socioecological transition, what changes might we expect from a major societal transition away from fossil fuels?

M. Fischer-Kowalski (✉) · W. Haas
Institute of Social Ecology (SEC), Alpen-Adria University,
Schottenfeldgasse 29, 1070 Vienna, Austria
e-mail: marina.fischer-kowalski@aau.at

W. Haas
e-mail: willi.haas@aau.at

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7.1 Introduction

What is the role of human labor in the socioecological paradigm? In the work of Marx, labor constitutes a fundamental relation of man to nature and is a basic social relation, a relation within society.[1] So far, the socioecological approach corresponds to Marx. Moreover, for Marx, following in the footsteps of Adam Smith, labor is the source of all wealth, the (only) creator of value.[2] In our approach, we do not really discuss the origin of use value as we have been staying within a biophysical framework as far as labor is concerned. Within this framework, labor figures in two contexts. One context, which is basically the labor Marx addresses, is social metabolism: capturing, extracting and preparing materials from nature for social consumption. This is not fundamentally different from what any other animal does to secure its food and the food for its offspring. As we know from studies on hunter-gatherers, this need not be very much work. The second context, which is explicitly addressed by our model, is what we term colonizing activities. Colonizing activities, as explained in Chap. 1, are deliberate interventions in natural systems to modify their functioning. The classical case is agriculture, and we agree with Bauer (2013) that the Neolithic revolution is the starting point for man as laborer. In both contexts, human labor directly and intentionally interferes with natural systems, but with unintended side effects. Whereas in many chapters of this book we analyze the impacts of human labor on natural systems (e.g., on land cover change or emissions from human energy use), in this chapter we focus almost exclusively on the social and cultural aspects.

The point of departure for this chapter is the assumption that human society—willingly or unwillingly and slowly or rapidly—is in a transition away from the use of fossil fuels. We expect that this transition will have as many and equally far-reaching implications for human labor as did the transition toward a fossil-fuel-based industrial society. To better understand this situation, we make an effort to characterize historical linkages between energy transitions and human labor and their quantitative, qualitative and institutional features. To our knowledge, this effort has not yet been undertaken; such a broad venture would necessitate the format of a book to make a legitimate claim for scientific dignity. What we

[1] 'So far therefore as labour is the creator of use value, is useful labour, it is a necessary condition, independent of all forms of society, for the existence of the human race; it is an eternal nature-imposed necessity, without which there can be no material exchanges between man and Nature, and therefore no life' (Marx 1867, p. 30).

[2] 'We see, then, that labour is not the only source of material wealth, of use values produced by labour… labour is its father and the earth its mother' (Marx 1867, p. 30).

may hope for, however, is to be able to draw some useful distinctions, show interesting empirical findings derived from socioecological analyses and sketch our perspective.

In the first section of this chapter, we attempt to characterize quantitative, qualitative and institutional features of human labor from a socioecological perspective.

The second section uses these distinctions and focuses on the interrelation between sociometabolic regimes (see Chap. 3) and the amount of human lifetime spent on labor, the respective critical capacities of human labor power and the institutional forms in which labor is employed.

The third section speculates about the future: what might labor look like after the ongoing socioecological transition (SET) is completed or has come to the next stage? Most analyses of 'green jobs'[3] address a fairly close future and mainly consider the future of gainful employment.[4] We open the time horizon (which also means keeping it somewhat unspecific) and ask ourselves the following question: in light of the major changes in work and life induced by the fossil-fuel-based SET, what changes might we expect from a major societal transition away from fossil fuels?

7.2 Some General Distinctions to Characterize Human Labor Quantitatively, Qualitatively and According to Its Institutional Form

7.2.1 How Can Human Labor Be Characterized Quantitatively Across Different Sociometabolic Regimes?

The starting point is the question of how to distinguish 'labor' from other human activities. A socioecological perspective helps to circumvent some of the long-standing debates around this issue and suggests viewing human labor as an element of human time use within a social (distributional) context. As humans reproduce their lives in social groups, they cooperate in various forms of a 'division of labor'. Thus, it makes sense to regard all those activities that are subject to such a division and thus constitute social interdependencies as 'labor' and to only label those elements of time use that cannot be socially transferred to anyone else as 'non-labor'.[5]

[3]For example, CEDEFOP (2009), Eurofound (2012), OECD (2010).

[4]There are some exceptions, such as the project by Hans Böckler Stiftung (2001), 'Arbeit und Ökologie'. This project looked at a broad range of conceptions of 'labor', including household work and paid civil work.

[5]Note that this definition is far from any physical definition of work. From a sociometabolic perspective, a physical definition of labor would make it very difficult to line up with social definitions; physically speaking, digesting food is as much 'work' as collecting and cooking it.

Whereas traditional time use research (Gershuny 2000) addresses time use on a descriptive and individual level only, a socioecological analysis places the time-use and activity categories in a functional context of system reproduction.[6] Depending on functional linkages, labor (time) can be distinguished from non-labor (time). We follow Ringhofer (2010) in distinguishing the following system references for time use:[7]

The reproduction of the self (such as sleeping, eating, resting, learning, having fun): This class of activities cannot be subject to a social division of labor and thus cannot be considered 'labor'.

The reproduction of household and family: These activities also address personal reproduction but in an intersubjective mode (child bearing and rearing, food preparation, daily chores…). This clearly needs to be considered 'labor'.[8]

The reproduction of the community: participation in 'public affairs' on various scales beyond the family, such as collective decision-making, voting, participation in religious and public ceremonies, military service or shared infrastructure work. This clearly has labor-like features.

The reproduction of the economy at large: On a systemic level, this is time used for the production of goods and services for anonymous consumers; individually, it is the time used for income generation on a market (and is thus close to conventional economic definitions of labor).

This approach is in line with Marx's understanding in that he defines the amount of labor hours (spent with the average skill, effort and technical effectiveness available in Marx's day; see Marx 1867, p. 31) as a standard measure of human labor. However, it clearly deviates from Marx in including household and family reproduction in the definition of labor; his focus on 'productive' and paid work prevents him from even considering this.

What share of a population's time is devoted to each function varies considerably from one socioecological regime to another. It is also related to demographic structures because they determine the share of people fit for work as well as the dependency ratio. How activities are distributed among subgroups of the population by gender, age and status is highly variable. The higher the status of a group is, the more time for self-reproduction (type 1) it will typically be entitled to.

For the individual, the question is how much labor time it needs to survive and to reproduce. This demands a minimum of activities of second and fourth types presented above. Under favorable environmental and social conditions, the time required may be very little (see Ringhofer 2010; Sahlins 1972). Under unfavorable environmental or social conditions, the time required may be more than the individual can afford over a protracted period, so it will not reproduce and will not be

[6]M. Giampietro and K. Mayumi have a long research tradition of placing human time use within a framework of system reproduction, and they see it as a key link among demography, energy use and economic output (e.g., Giampietro et al. 2012). We follow a similar perspective.

[7]For more details, see the method section in Chap. 26.

[8]In her narrative on labor in classical Greek philosophy, Hannah Arendt shows that Aristotle considered this class of labor particularly unworthy of free citizens and destined to be performed by slaves (Arendt 1958, Chap. 2).

Table 7.1 Daily working hours by sociometabolic regime for an average inhabitant and an average day of the year

		Cases	Work in the economy	Household and family work
		Numbers in (*decimal*) *hours* per day per person		
Local cases		Trinket (hunter-gatherers), India	0.8	2.1
		Campo Bello (swidden agriculture), Bolivia	2.5	2.1
		Nalang (permanent farming, traditional), Laos	3.5	2.1
Country cases	Early industrialization	Japan 1870 (traditional agriculture, beginning of industrialization)	4.4	n.d.
		Germany 1870 (traditional agriculture, cities industrialized)	3.3	n.d.
	Industrialized	France 1998/1999	2.1	2.7
		Netherlands 2000	2.1	2.4
		Germany 2001/2002	2.2	3.0
		Japan 2001	3.3	1.6
		UK 2000/2001	2.4	2.6

Sources: Trinket, Campo Bello and Nalang: Fischer-Kowalski et al. (2011); Japan 1870: Maddison (2001), p. 383; France 1998/1999, Netherlands 2000, UK 2000/2001: European Commission (2003), Eurostat database (2013); Germany 2001/2002: Eurostat database (2013), Statistisches Bundesamt (2006); Japan 2001: Statistics bureau (2011, 2013)

able to survive.[9] For the social community, demand for labor can best be seen as an economic relation, the relation between the benefit the community has (i.e., the marginal return upon additional labor) and the cost of this additional labor. In family and community relations, an additional potential laborer (an additional child, for example, or a second wife) may be sustained, although the benefit of the labor it can deliver is lower than the costs.[10] In strictly economic relations, additional labor will not be employed if the benefits do not outweigh the costs. Beyond social relations, what determines both variables, the benefits and the costs of additional labor, strongly depends on a society's energy regime (see Table 7.1).

[9]Young adult slaves working in the mines of ancient Rome had an average life expectancy of no more than two to three years (Scheidel and Krausmann 2011). Forced laborers in concentration camps in Hitler's Germany fared no better.

[10]Under tight ecological conditions, children or sick people may be sent away (such as children aged 10–12 from alpine villages in Europe in the past few centuries) or seek a ritual death (e.g., traditional Japan).

As long as labor only serves the collection and hunting of food and its preparation for consumption, it does not require much time. Moreover, an increase in labor time under such conditions may well be self-defeating: an increase in hunting and gathering in the same area will tend to deplete the sources of food and force the community to migrate. As documented in research from Cultural Anthropology (Gowdy 1998; Sahlins 1972), the hunter-gatherer regime requires the least amount of human labor from its members.[11] With the transition to the agrarian regime, the amount of labor increases, and it increases even more with the intensification of traditional agriculture (Table 7.1; also Boserup 1981; Ringhofer 2010). At first, the transition to the industrial regime may have increased labor time even further (Voth 2000), but later provided relief. This storyline is reflected in the data compiled in Table 7.1, using the working hours per day per inhabitant as an indicator. The reference to 'inhabitant' (in contrast to the more common 'inhabitant of working age') is fair insofar as the societies compared have a very different age structure and very different standards for appropriate working age. Work in the economy is lowest for the hunter-gatherer regime (0.8 h/day), rises with (traditional) agricultural intensification (with a maximum value of 4.4 h in Japan in 1870) and then drops to slightly more than two hours (Japan: 3.3) under contemporary industrial conditions.

The reason the maximum economic labor time is found under agrarian conditions is the increasing amount of colonizing activities required to feed increasing numbers of people on the same land (Boserup 1965). With the industrialization of agriculture, this situation has been greatly relieved by fossil-fuel-based technologies.

Notwithstanding doubts about limited data quality and comparability, the amount of daily time spent on household and family chores seems to be fairly invariable across sociometabolic regimes (see examples in Table 7.1).

Another approach to quantifying necessary labor is to determine the amount of time the population of a social system spends on food production. This is not so easy to estimate. The most encompassing indicator would be the proportion of the population's lifetime (in a particular year, for example) spent on food production and/or agriculture. In Japan in 1870, for example, if we assume that all the labor time given for 'work' in Table 7.1 above was for food production only, it would have been a lifetime average of 4.4 h per day. Another two to three hours per day would have to be spent on household and family reproduction. This amounts to a lifetime average of approximately seven working hours every day. Considering that in these societies children up to the age of ten (or younger for most working tasks) may make up 30–40 % of the population, the work demand on adults would

[11]Here, we need to address the ambiguity of type 3 activities (community reproduction). As repeatedly documented, hunter-gatherers often have very time-consuming social rituals. In time-use studies or statistics on working time, such rituals are normally not counted as 'labor time'. Considering that this may be the time required to maintain the cohesion of the community, it could count as labor time. However, the activities that belong to that class often bear a much more deliberate and entertaining character than household chores or agricultural work.

typically amount to 10–12 h per day. This seriously encroaches upon the minimal 50 % of lifetime required for basic personal maintenance and leaves no space for anything else.

Yet another way to approach this issue is to look at the proportion of the population that is freed from the necessity of making its living from food production. For several influential social theories, any excess lifetime that does not have to be spent on food production (or, in other terms, the socially available energy not consumed in basic provisioning of the population) is considered a measure of the 'civilization' or 'advancement' of a society (Morgan 1877; Spencer 1862; White 1943). This population share is mainly determined by two mechanisms: one is the productivity of agricultural labor, which depends on natural and technological conditions; the other is the incentive for or pressure upon farmers to produce a food surplus beyond their subsistence requirements. In preindustrial societies, the second mechanism could be estimated by adding up the proportion of agricultural produce that can be taken away from the producers by tithes and taxes. From this, one can conclude how many people can live from the surplus time freed from food-producing labor. If each farming family pays 10 % tithes and taxes, we can assume that at least one non-farm family can sustain itself on ten farm families—or, if we assume a more luxurious life for them, maybe only one non-farm family per 20 farming families. Such information on tithes and taxes exists for many agricultural systems and has been analyzed by historians (e.g., Kulke and Rothermund 2008 for India across history). Unfortunately, we do not know of any systematic compilation of such data across regions and time.

Another approach to this question is to determine the proportion of the urban (as opposed to rural) population. Although estimating urban populations is far from trivial (what size of settlement may be considered urban? How are the boundaries of urban settlements drawn?), a number of historians and modelers have generated historical (i.e., preindustrial) estimates of the size of urban populations. We will draw on these estimates in Sect. 7.3.

7.2.2 How Can Human Labor Power Be Characterized Qualitatively?

For a characterization of human labor power across sociometabolic regimes, we are looking for very abstract dimensions that bear a certain relation to energy because different sources and uses of energy characterize different sociometabolic regimes. One should be able to argue that these capacities are rooted in human nature in the sense that they are part of the natural equipment of every human being, and they should render themselves useful for social enhancement (or suppression) and training (or lack thereof). From the wide range of possible distinctions, we have selected the following three basic capacities for our analysis: physical power (as a capacity of the body), rationality/knowledge (as intellectual capacity) and empathy (as emotional/social capacity).

Physical power: Physical power is the capacity to alter physical objects through force. This capacity is related to the notion of exergy, which is the ability to perform work in a physical sense (see Ayres and Warr 2005). It is also related to the concept of energy efficiency: you can look at the human body as a kind of machine that requires a certain amount of energy input (=food) to perform a certain amount of work (exergy output). Physically speaking, the human body is not a very efficient machine because it needs much energy input just for living (its basic metabolism), and it can transform only a small amount of energy input into useful work and only for a limited fraction of its lifetime. The basic metabolic rate (BMR) depends upon age and body mass. For example, it amounts to 6.2 MJ/day (megajoules per day) for a 50 kg woman and to 9.6 MJ/day for an 80 kg man. This corresponds to fluxes of approximately 70–110 W (watts). However, heavy farm work or sports such as day-long cross-country skiing may double the daily energy demand, with typical kinetic efficiencies of approximately 20 %. Even eight hours of heavy physical work is equivalent to an output of only 2 MJ—corresponding to burning 1 kg of coal in a 10 % efficient engine (Smil 2008, p. 138). Another limitation is the relatively small 'installed power' of the human body; even well-trained young adults cannot sustain a power output flux beyond 150–170 W longer than a few minutes. The peak power delivery of trained humans is 8–12 kW (kilowatts) for several seconds (ibid., p. 134). 'Human effort, even at its best, is a most unimpressive source of mechanical energy', is Smil's summary (ibid., p. 138).

Rationality/knowledge: Rationality/knowledge represents the intellectual capacity to correctly anticipate the effects one's actions will have and to plan these actions deliberately. This capacity is related to information processing and learning from experience as well as from communication with others. Although the human brain in adults is responsible for approximately one-sixth of the BMR, brain work is, energetically speaking, light work—even intensive intellectual activity only marginally raises the brain's metabolic demand (Smil 2008, p. 128). Even more than with physical power, however, the perspective on the individual is too narrow. Rationality and knowledge should be looked upon as social properties, as being developed and maintained collectively, with individuals having only a certain share in this collective propensity. Of course, developing and maintaining a stock of knowledge and information processing generates a certain energy (and labor) demand at the social system level.

Empathy: Empathy is the capacity to emotionally anticipate and mirror the feelings of other living beings. Although modern brain research has demonstrated empathy to be an innate capacity of primates to sense the feelings of others and 'understand' (mirror) the intentions guiding the activities of others (Rizzolatti et al. 2006), this natural capacity should be expected to be strongly influenced by cultural features on the social system level. It should be looked upon not as an intellectual but as an emotional capacity, one that is crucial for human labor, which involves and functionally relies upon communication and caring for the needs of people or other living beings. Empathy as an emotional capacity rooted in a certain neuronal equipment must not be equated with a value orientation of altruism. The ability to mirror the feelings of others may just as well be used to manipulate or harm them more skillfully.

These qualitative features of human labor power have three types of interlinkages to sociometabolic regimes: they can be *functionally* (economically, technologically) more or less relevant for work performance; they may be *socially* (culturally) more or less valued and enhanced or suppressed (investment in education); and, finally, they may be *technologically* more or less supported and enhanced, or they may be more or less substituted by technology. We will follow these different pathways for our subsequent historical analysis.

7.2.3 How Can the Institutional Form of Labor Be Characterized?

In some highly stratified societies, it may be considered unworthy for the 'free man' to work for his subsistence altogether. This view is well represented, for example, by Aristotle, Hesiod and Xenophon for ancient Greece and by Cicero for ancient Rome. These thinkers highly valued a life of leisure and service to the polis for the free and self-determined citizen, but work under someone else's command was considered incommensurable with personal dignity. It is not the physical effort as such but the subjection to personal neediness or the will of others that is despicable. For Cicero, only work in the *artes liberales*, such as architecture, medicine and science, was acceptable; work as a craftsman, day laborer or merchant was unacceptable (cf. Bauer 2013, pp. 312 ff.).[12] In contrast, the Jewish-Christian tradition is marked by dual codes: man's mission is to subjugate (and redesign) the earth by his labor, and Adam was condemned to sustain his life by hard toil. Paul issued the decree that one who did not work should not eat. Later, the rule of the Benedictines saw work as a means to tame intemperance and bodily desires. With Protestantism, labor finally became a sacred duty for everyone whom God rewards with earthly wealth. Obedience is not debasing to a man but makes him agreeable to God (Bauer 2013, pp. 144 ff.).[13]

Upon reviewing the historical and anthropological literature, we identified the following broad classifications for the institutional form in which labor may be organized:

- As **family work** within personally interdependent **household systems** and a mutuality of obligations. Examples are subsistence agriculture, hunting and gathering and household work in most sociometabolic regimes.
- As **slavery**, where a master owns the laborer and has to take care of his/her reproduction or, if cheaper, buy a new one.

[12]In effect, working as a peasant was acceptable both in ancient Greece and Rome—however hard his toil, he was under his own command.

[13]This, of course, is a Western storyline of the cultural framing of labor. There is surely also a storyline for the East, one that we are unfortunately unaware of.

- As other kinds of collective, often **compulsory services**, such as the military, prisoner camps, cloisters and sometimes voluntary work, where individuals invest surplus time for the sake of a community, such as hospice services.
- As serfs within **manorial systems**, where the family receives land from the lord of the manor and owes a share of its produce as taxes and/or compulsory labor in return.
- As **self-employed** in one's own firm/enterprise. Such businesses are often household based, but they sell products and services in markets.
- As **wage labor**, where one is personally free to sell a certain quantity of time in a labor market. This form of labor has undergone an enormous differentiation process regarding professional and hierarchical specializations.

Whereas the Social Science discourses about the institutional form of labor tend to focus on self-determination, hierarchy and exploitation from the point of view of their moral and political legitimacy, a socioecological reflection needs to focus on economic and ecological functionality. Functionality as understood here refers to the effectiveness with which the natural resource base can be utilized for people's benefit at lowest environmental cost. The institutional form of labor is at least as relevant for this functionality as the technologies used.

Ultimately, in every pre-fossil-fuel social system, the amount of available labor depends on land (Sieferle et al. 2006). Because every laborer must use most of the resources he can generate by his labor power just to sustain himself and his family, any effort to have more labor power (and more riches) under control will ultimately lead to efforts to extend the territory. This, in turn, requires military power, which is again based on human labor and animal traction and thus may easily become self-defeating. Moreover, destroying the territorial competitor at least partially destroys his resource base, resulting in an enormous overall waste of resources through military conflicts.

If labor is mainly organized as family work within household systems, there can be only a small degree of division of labor and a low level of communication and learning. If there is a high labor burden, such as in agricultural systems, there is always the incentive to acquire additional wives and children to share the labor and thereby outgrow one's resource base. This organization of labor is also very vulnerable to attacks and raids and therefore may only be able to persist where there is a low population density.

Slavery, in contrast, presupposes territorial conquests that allow the social system to capture or purchase slaves for labor. This allows the system to save on a very costly aspect, namely, the family's investment in bearing children and raising them to adulthood. Thus, if a system is based on slave labor, it can afford, at the same land/food level, up to two-fifths more labor power than when it uses farmers or free laborers.[14] However, slavery is also costly because it

[14]This is estimated on the assumption of a life expectancy of 40 years; each age bracket of eight years is supposed to require the same amount of food (the first age bracket in this calculation also includes the extra food for pregnant and breastfeeding mothers and the food required for children who do not survive to the next age bracket). If slaves are sold and bought at age 16, the buyer saves on two-fifths of the lifetime investment while only losing a small part of the lifetime labor power.

requires a continuously high level of supervision and control, often made more difficult by a lack of shared language.[15] Moreover, losing young people to slavery is extremely costly for the conquered region; it may destroy the resource base there and create the worst enemies one may have. In the long run, it is probably not a very sustainable strategy. It requires continuous military expansion and supervision, and it undercuts the social learning processes to be gained from labor experiences.

Serfdom within manorial systems is a way to organize labor on a household and family basis while at the same time providing some military protection. It creates a tight coupling between the resource base (land) and labor. This retains the features of free family systems of mainly lateral differentiation (low degree of division of labor), low communication and learning and a tendency to outgrow the resource base through demographic expansion. It is better adapted to stable territorial relations, low supervision and peace than slavery systems and has thus proven to be a more efficient way to organize labor (McEvedy and Jones 1978).

Wage labor does not presuppose a coupling between a resource base and the laborer. Like slavery, it is fully flexible with regard to the material and purpose of the work. The burden of supervision is greatly relieved; because the laborer must sell his/her labor power in a market, it is in his/her interest to perform the work properly to retain market value. At the same time, the laborer must be willing to learn and will be confronted with various experiences and communication contexts that promote learning. This learning also yields benefits at the system level. It is critical, however, that there be a market with sufficient demand for labor and ways to maintain subsistence through non-working times. Wage labor as such is very well adapted to avoiding resource waste. Moreover, it does not create incentives for fertility. Children do not relieve one from labor; on the contrary, they consume time and create additional costs.

7.3 Human Labor in Different Sociometabolic Regimes[16]

As stated, although hunter-gatherers do work according to the standards of our time-use distinctions, their work is very close to what other social animals need to do to sustain themselves. With the transition to agriculture, labor becomes a much more pronounced feature of specifically human existence—both qualitatively and quantitatively.

[15]McEvedy and Jones (1978) consider this a main reason for population stagnation after a long period of growth in the ancient empires of the West and East, before the advent of feudalism.

[16]For a more elaborate explanation of sociometabolic regimes, see Krausmann and Fischer-Kowalski (2013).

7.3.1 Labor in the Agrarian Regime

7.3.1.1 Quantitative Features

Quantitatively, a critical question is how many people can be sustained from a certain piece of land and how many additional people not working the land (e.g., landlords, urban citizens, soldiers) can be subsidized. As Boserup (1981) has shown, there is a tendency to develop techniques that allow more people to live from a piece of land by intensifying land use at the expense of investing additional labor. The increased labor burden creates an incentive to have more children to share the workload. This triggers population growth, lowering labor productivity even more. If population pressure on the land is reduced by, for example, labor opportunities in urban centers, agricultural labor productivity may rise again and allow for increasing surplus production that then allows a larger urban population to be fed.[17] Nevertheless, working hours in mature agrarian systems tend to be very high (Clark and Haswell 1967, p. 3; Fischer-Kowalski et al. 2011; Fischer-Kowalski 2011). In the agrarian regime, the overwhelming majority of the population (including children and elderly) is occupied with food production most of their available lifetime. This is related to the relatively low energy return on investment (EROI)[18] of agriculture and the focus on humans and animals as the main sources of mechanical power (depending on land productivity, the EROI lies somewhere between 10:1 and 2:1; for example, maize has a 4.1:1 EROI in a draft animal agricultural system; see Pimentel et al. 1999; see also Chaps. 4 and 21 in this volume). The proportion of the population that can be sustained from the surplus of agricultural labor, even in advanced agrarian systems, ranges between 5 and 15 %. This (low) proportion is reconfirmed by typical rates of taxation and rates of urban populations across the preindustrial history of countries (see Table 7.2).

In Table 7.2, we present a few examples for the time around 1500, as this is a period in which we can expect urban settlements to sustain themselves exclusively on contributions from traditional agriculture. As becomes apparent from these numbers, population shares in settlements of 2500 or more inhabitants vary between 2 and 10 % across world regions. This means that on average for the world, it took 25 peasants to feed one urban citizen. Even in Renaissance Western Europe, 11 farmers had to contribute.

7.3.1.2 Qualitative Features

Qualitatively, the agrarian regime relies mainly on the **physical power** (and physical endurance) aspect of human labor power. This applies to the rural population

[17]This is at the core of the Nobel Laureate William Arthur Lewis' influential 'dual sector model' (Lewis 1955).

[18]More precisely, one ought to be talking about 'energy return upon energy investment' (EROEI) which measures the net energy gained by the effort.

Table 7.2 Share of urban population in 1500 by world region (settlements with 2500 or more inhabitants)

World region	Share of urban population (%)
Northern Africa	2.04
Japan	2.90
India	4.36
China	6.45
Western Europe	10.63
World	4.14

Source: Klein Goldewijk et al. (2010)

(constituting the very large majority) and, for example, to slave labor in mines and infrastructure building (if we think of the Roman Empire). There is little societal effort to improve the skills and knowledge base of those 90–95 % of the population in agricultural labor—as long as they feed themselves and deliver their tithes and taxes, they are left to themselves to organize their work. With the fellachs in ancient Egypt, with the lower castes in India, with the feudal serfs in Europe or with the African slaves in the Southern states of America, no effort is made to spread literacy or practical knowledge concerning work in agriculture.[19] Education, in the sense of societal investment in the skills and the knowledge capacity of physical labor, is largely absent. This investment remains reserved to a small minority of privileged, usually male urban elites liberated from the need to work for their subsistence, and is largely disconnected from what may be considered 'productive work' (Sohn-Rethel 1970). Religious castes and organizations contribute to the education of ideological elites[20] and to the religious indoctrination of children (e.g., Sunday schools, Qur'an schools) but do not convey functionally useful knowledge to those whose labor sustains society. Whatever great civilizational gains were achieved are rarely connected to the mass of human labor. The social tensions created by this highly unequal distribution of knowledge (even without any relation to practical application) in Europe were reflected in the widespread religious conflict over the Bible and the right of everyone to read it for himself in Europe from the 14th to the 16th century and in the efforts from above to maintain knowledge monopolies, as reflected in the burning of Giordano Bruno in 1600.

Technological enhancement and the replacement of human physical power are mainly sought in animal power: buffaloes, oxen and later horses, and elephants and camels in other regions are used for traction of ploughs, water pumps and

[19]Some exceptions exist, such as the Roman Empire's writers on agricultural technology, transmitted at least to an intermediate stratum of administrators of large estates.

[20]This certainly holds for the universities founded in Europe from the late 11th century onward. However, monasteries and religious communities in Europe (and probably similarly in the rest of the world) sometimes played an important role in systematic improvements of agriculture through experimentation and learning. Nevertheless, this does not mean that they transferred the control of such knowledge to their inferiors, let alone spread it among regional peasant populations.

carriages, whereas donkeys are used for carrying burdens. This technological solution draws on the human labor capacity for **empathy** because educating and guiding working animals requires a certain understanding and concern for their needs and feelings. Animals may be useful or even indispensable for having a higher power density than humans (details in Smil 2008, p. 174), but they do not quantitatively replace humans' physical labor (which is still required for working with and feeding those animals). In general, agrarian systems are marked by a substantial degree of public cruelty and by a cultural emphasis on heroism and the use of force. Thus, it should not be expected that the evolution of empathy will receive much social enhancement.

7.3.1.3 Institutional Form of Labor

Labor in agriculture (**>90 %**): In peripheral or unproductive regions (such as mountainous areas, marshes and sparsely populated arid regions), agricultural or pastoralist labor is usually organized as household-based family labor in accordance with family power structures and is largely subsistence oriented.

In more productive regions, labor is organized in some form of manorial (or, more precisely, feudal) systems with bonded serfs or slaves who owe a defined proportion of their produce in the form of naturalia, labor or money to the landlord.[21]

Labor outside agriculture (**<10 %**) can be organized as slave and compulsory labor (for example, in mining or construction) or as household-based self-employment (for example, in crafts, trades or transportation). The 'atomization of production was the rule…' (Christ 1984, p. 2).

Another common and important form of 'labor' is **military service**. It may be considered labor in the sense of providing food, animals, slaves and treasures by looting and by protecting one's own population from looting. However, it cannot be considered labor in the sense of producing resources; it does so only by redistributing resources between enemies and friends.

7.3.2 Labor in the Coal-Based Industrial Regime

7.3.2.1 Quantitative Features

Quantitatively, the unfolding of the coal-based industrial regime multiplies the demand for labor. Industrial labor is mainly the exertion of physical power, and much additional physical power is brought into the economy from coal-driven steam engines. Nevertheless, the demand for human labor is increasing so much

[21]It is interesting to note that an author such as Adam Smith comments on the relation between this form of labor organization and low labor productivity in agriculture (Smith 1776, Chap. 2).

that even the rapid population growth ('first demographic transition') can be absorbed. For the industrial workforce, only humanitarian legal efforts gradually achieve a reduction of daily working hours and a ban on child labor. Industrial labor is cheap, and the profits to be gained from it far surpass the surplus to be gained from land ownership. In this phase, there is clearly a positive relation between energy input into the economy and the number of labor hours: more energy does not replace but rather facilitates the use of additional human labor. In the UK, the total number of labor hours in the economy rose in line with energy use until the First World War (WWI) and in Austria, even until the end of World War II (WWII). There was a reduction of working hours when energy use stagnated, a pattern that corresponded to the period when coal dominated the energy regime. In contrast, after WWII (when the use of oil became dominant), energy use in both countries increased and labor decreased, reflecting a substitution of labor with technical energy. For the rest of the 20th century, there is no clearly discernible relation between energy use and labor hours (see Fig. 7.1).

Historians of time use (Voth 2000) have even documented that in the early phase of industrialization in the UK (18th century), the weekly working hours of urban laborers rose above the level of the previous agrarian conditions.

7.3.2.2 Qualitative Features

The **coal-based industrial regime** at the onset mainly added **physical power** through steam engines driving water pumps (in mines) and weaving looms in manufacture.[22] This additional physical power did not so much replace human labor as increase its demand because production processes could be realized at a lower cost and at a larger scale. For agriculture, there was only an indirect impact, which came through allowing (and, in part, forcing; see Wrigley 1988, 2010 for the UK) the rural population to migrate to urban centers and to **make their living on wage labor in manufacture**. Later, railways facilitated the transport of coal and food over large distances into these urban centers, thus allowing them to grow and at the same time stimulating rural surplus production. In their impact on manufacture (so-called proto-industry) and, later, industrial labor, steam engines did not improve the skill component in human labor but rather stupefied labor (see Marx and Engels 1848). The key capacity of human labor in agriculture as well as in urban wage labor remains **physical power and endurance**. Small skill segments, however, evolve further—in urban craftsmanship and engineering, in trade and finance, in the military and among civil servants.

During this regime, most countries started to introduce **publicly financed compulsory schooling for children** (including the lower classes in urban centers). Often under the supervision of the clergy, children were expected to learn

[22]The first and (for a long time in the UK) most important impact of coal was its use as a substitute for wood in heating and cooking in emerging urban centers that could not otherwise have grown in size (Krausmann and Schandl 2006).

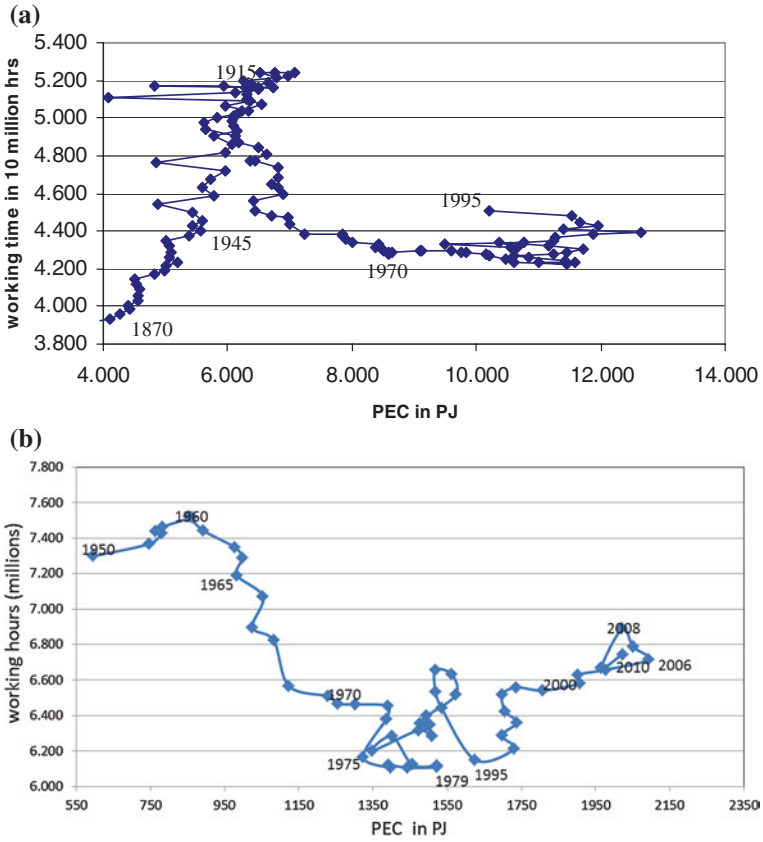

Fig. 7.1 **a** Primary energy consumption (PEC) and working hours in the UK, 1870–2000. (Source: after Krausmann et al. 2003; Schandl and Schulz 2002). **b** PEC and working hours in Austria, 1950–2010. (Source: PEC: Krausmann et al. 2003 (updated version including PEC data to 2010); working hours: TED (The Conference Board Total Economy Database™, January 2013))

reading, writing and simple forms of algebra in addition to religious beliefs. As Gellner (1988) plausibly argues, this mainly related to the functionalities of the modern nation state and the requirements of its military and had very little meaning for 'qualifying labor'. However, it created a need for teachers as perhaps the first laborers who were mainly qualified by formal education.

With **empathy**, one can observe an increasing cultural differentiation by gender: whereas men, in their work and beyond, are supposed to be tough and contain their emotions, women are supposed to be sympathetic and emotional. Empathy, one might say, becomes a female virtue, but a virtue after all (Badinter 1980; Elias 1939).

7.3.2.3 Institutional Form of Labor

The most spectacular change during this regime is the rise of free wage labor. Free wage labor, a very minoritarian form at first, increases to become the most dominant institutional form. Gradually, often by revolutions, serfdom and slavery are abolished.

In contrast to the landed aristocracy of the agrarian regime, industrialists see themselves as hard-working, as responsible for the labor process and as drivers of technical innovation. Capitalists do not see themselves as a leisure class but feel obliged to frugality and work ethics (Weber 1920).

During this phase, the separation of a sphere of production and gainful employment from the sphere of reproduction as a cozy and secluded home wisely governed by a housewife (who is not seen as 'working' but as exercising love and care) becomes an urban middle-class model that gradually spreads to other social strata (Bolognese-Leuchtenmüller and Mitterauer 1993).

7.3.3 Labor During the Rise of the Oil-Based Industrial Regime (Europe: Late 1940s to Early 1970s)

7.3.3.1 Quantitative Features

Primary energy consumption (PEC) in the economy rises, but overall labor hours decline; energy input per labor hour is no longer stagnant but rises rapidly. This novel 'substitution' effect of mechanical energy for human labor can be clearly seen in Fig. 7.1 for the UK after the World Economic Crisis in the 1920s and for Austria in the post-WWII period. From then on, the further increase in energy input is associated with a decline in labor hours: mechanical energy substitutes for labor. Until the early 1970s, there is a steady increase in energy input into the economy, and with the increase in energy, working hours decline. This is the 'golden age' of building up the welfare state, boosting private consumption, steadily increasing wage levels and reducing working time. It is also the 'golden age' of the consequences of expanding the education system becoming statistically visible in the rapid increase of 'white collar labor'[23] over 'blue collar labor' and the near disappearance of agricultural labor.

The same message Fig. 7.1 conveys for the UK and Austria, Fig. 7.2 conveys for Germany and Italy. With the implementation of the 'oil regime' after WWII, human labor hours in the economy completely dissociate from energy input. Whereas labor hours show a slight decline, energy use soars, as does the energy

[23] 'White collar labor' versus 'blue collar labor' characterizes this distinction better than the more common distinction between industrial production and services, although these distinctions, of course, overlap. See also Peter Drucker, who coined the notions 'The employee society' (Drucker 1953) and 'Wissensgesellschaft' (Drucker 1969).

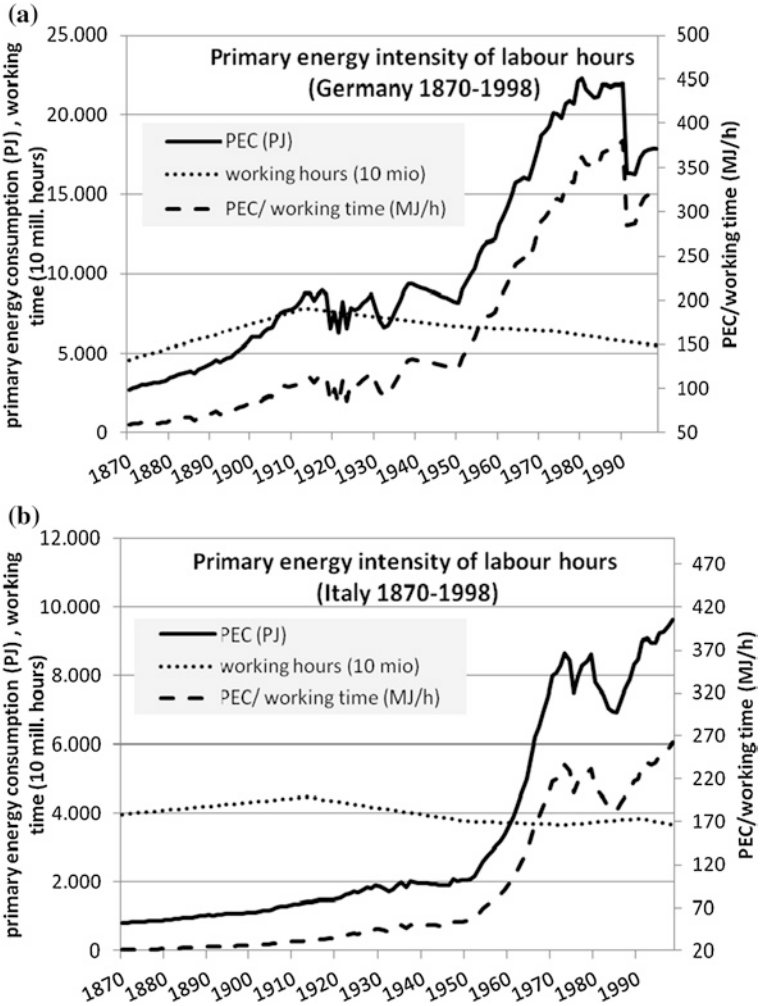

Fig. 7.2 Annual energy consumption, working hours and energy intensity of working hours for (**a**) Germany and (**b**) Italy, 1870–1998. (Sources: Cleveland (2011), Maddison (2001, 2008); PEC calculated based on background data from Pallua (2013))

intensity per labor hour. This same pattern can be found for all European countries. The decline in employment in agriculture, where the working hours per employee had been particularly high relative to all other economic sectors, plays an important role in the decline in labor hours.

Somewhat similar changes occur in the households: electric equipment (e.g., washing machines, vacuum cleaners, mixers) substitutes for physical effort from the housekeepers, and it raises the intellectual demand to handle those machines. As has been demonstrated in a number of studies, however, the overall impact is not to reduce household work because purchasing and servicing this equipment,

in combination with larger homes and higher standards of order and cleanliness, costs considerable time. In combination with the gradual disappearance of servants, the household burden upon middle-class women tends to increase.

7.3.3.2 Qualitative Aspects of Human Labor

Liquid fossil fuels and electricity allow for the **substitution of the physical power dimension of human labor by decentralized energy services**. Key technologies are the internal combustion engine used for cars and multipurpose electro-motors linked to electricity grids or powered by batteries. Liquid fossil fuels used for tractors and in chemical conversion for mineral fertilizers and pesticides also substitute for a large part of physical human and animal labor in agriculture. In effect, physical strength and prowess lose much of their economic and, consequently, cultural value.

Instead, the **knowledge dimension of human labor** becomes much more important. There is unprecedented growth in public education and knowledge production. This is the 'golden age' of expanding the public education system, propagating equal opportunities and building up a skilled workforce with capacities in information and knowledge management rather than physical power and endurance. Knowledge production, information processing and communication become major economic activities. For the first time in history, knowledge production and learning cease to be class privileges and ideological bastions; they become secular, rational and functionally related to roles in the labor market.[24] In 1973, Daniel Bell published *The Coming of Post-Industrial Society*, in which he outlined a vision of a knowledge-based service society that would overcome both the farm's and the factory's hardships.[25]

Regarding **empathy**, the gendered picture predominates: toughness and rationality for men, empathy and emotionality for women. Women as loving housewives taking care of husbands and children becomes the majority model of middle-class life.

7.3.3.3 Institutional Form of Labor

In this phase, wage labor becomes the most dominant form of labor by far. Self-employment both in agriculture and in other sectors declines, whereas employed

[24]It would be a promising exercise to document this in the OECD reports on education from the early 1960s onward. This trend was often criticized by more traditional, humanistic educational professionals. Interesting, however, is that the previous tension between religious/denominational and public/secular education that had blocked educational reforms in so many countries for such a long time gradually faded away.

[25]In politics, the term knowledge society boomed much later (and is now, for example, part of the EU's future perspectives).

labor rises. The overall participation rates in gainful employment remain largely constant. Within wage labor, there is a shift from 'blue collar' to 'white collar' labor. From the end of WWII to the early 1970s, unemployment rates remain very low.

7.3.4 Labor in the Transition Phase from the Early 1970s Onward

7.3.4.1 Qualitative Features of Labor

One might draw the following analogy: just as technological development plus increasing fossil fuel use had substituted for much of human physical work, so information and communication technologies are now **substituting for knowledge work**. Substituting for knowledge work is inherently less energy-intensive than substituting for physical work, even if it is not optimized in this direction. Nevertheless, knowledge production and knowledge handling remain key features of human work.

Coinciding with the first world oil crisis in 1973, structural change in the relation between energy and labor becomes apparent: the trend of steeply increasing primary energy input in high-income countries is over and gives way, after some sharp fluctuations, to a more stationary energy consumption, both overall and per working hour (see Figs. 7.1 and 7.2). There is no longer a discernible correlation between energy use and working time.[26]

The reduction of physical work in Europe was, of course, also greatly enhanced by the externalization of industrial production to the world's periphery, where emerging economies with very low labor costs were prepared to produce the steadily increasing amount of industrial products that Europe and other rich regions of the world wished to consume. Studies of carbon emissions from trade (Hertwich and Peters 2009) have shown, for example, that the apparent domestic growth reduction in fossil-fuel-based energy was—at least to a certain degree—compensated for by rising fossil fuel combustion elsewhere.

Intellectual educational standards in the labor force continue rising, as does school and university enrollment. Qualified white collar work increases, whereas industrial blue collar work continues to decline.

There are indications that—connected to the rising importance of marketing, services and communication processes—the capacity for **empathy** is gradually losing its exclusive female label and becoming a more important qualification for work generally.

[26]For the same period, Ayres observed a loosening of the very tight ties between exergy and economic output (Ayres and Warr 2005). He interprets this as an effect of the shift toward information and communication technologies (ICT).

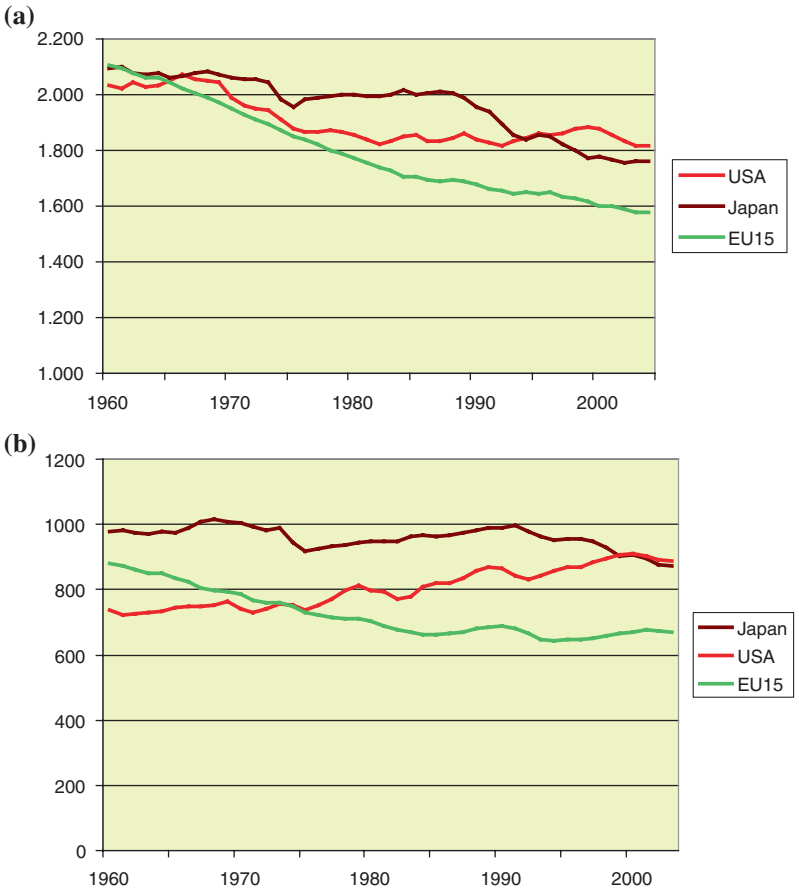

Fig. 7.3 **a** Annual working hours per employee. (Source: Maddison 2001, 2008; OECD 2000). **b** Annual working hours per inhabitant. (Source: Maddison 2008; OECD Stat Extracts, http://stats.oecd.org/Index.aspx?DatasetCode=ANHRS; own calculations)

7.3.4.2 Quantitative Features and Institutional Form

In Europe, the average annual working hours per inhabitant decline very little in the early 1970s, much less than before (Fig. 7.3b), but the working time per employee continues to decline (Fig. 7.3a). This is a symptom of increasing part-time work (particularly by females), unemployment and rising flexibility in the use of labor power.[27] Whereas Japan shows trends of declining working time similar to Europe, the US shows increasing working time per inhabitant, with stagnating

[27]In the sense of setting paid labor time on or off according to demand (in retail sale, for example, interrupting working time during the day when there is less demand or reducing cleaning services in offices during holiday periods).

numbers per employee. More generally, one might say that there are signs of the erosion of traditional well-established patterns of employment and rising insecurity, although no new pattern has established itself. The family pattern that was introduced in the course of the industrial transformation and saw its climax in the late 1960s, namely, early marriage by a large majority and long phases of female economic dependency upon males' income, gradually fades away. Females seek (and need) employment for their sustenance irrespective of family ties, they bear fewer children, and the household division of labor slowly becomes less gendered. Unemployment remains at a higher level than in the period before, and the main countermeasures considered are boosting economic growth and keeping immigration at bay.

7.4 Resume and Outlook: Indications and Latent Causes of Major Changes in Labor Due to an Ongoing Socioecological Transition?

In the introduction, we justified looking back into history by claiming that the next socioecological transition (SET), namely, moving away from fossil fuels, might have as massive an impact in the long run on the organization of human labor as the SET toward fossil fuels. Figure 7.4 illustrates some aspects of our storyline and makes an—admittedly highly speculative—effort at incorporating the

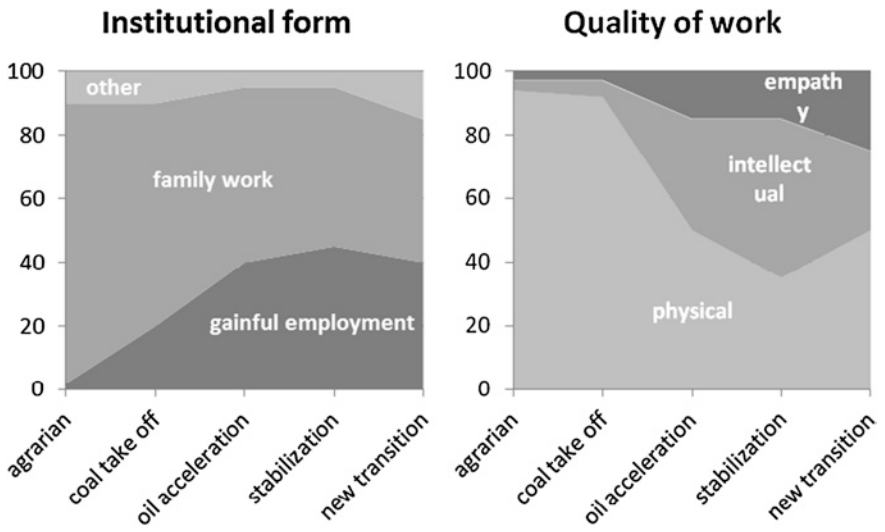

Fig. 7.4 Variation in the quality of work and its institutional form by sociometabolic regimes (work including market-oriented employment and nonmarket subsistence work, incl. household & nonmarket community work; Europe only)

structural changes we anticipate from a new sociometabolic transition and the effects these elements will have on the future of work.

The structural changes we envision in the course of the new transition in Europe would encompass the following:

- an energy shift away from fossil fuel use toward renewable energy
- a production and consumption shift away from energy—and materials-intensive products toward services enhancing human resources and capacities (supported by demographic change)
- an institutional shift toward low-maintenance infrastructures that have a lower risk of climate change impacts
- decreasing energy consumption (efficiency increases, savings)
- decreasing use of (virgin) raw materials (shift to nonmaterial energy sources, efficiency increases, recycling, reduced consumption)
- decline in outsourcing production from Europe (because of slowly decreasing wage differentials)

Why can we assume that these structural changes might lead to the changes in work we picture in Fig. 7.4?

In the right part of Fig. 7.4, we project[28] that the proportion of physical work, after a long period of decline, will rise again. This follows from the assumption that rising energy generation expenses and declining EROI will make energy more costly and less abundant. This is already observed for fossil fuels, where 'conventional' resources are becoming depleted and new, 'unconventional' resources that require much higher energy investments, such as tar sands, are increasingly used (Murphy and Hall 2010), although this trend has not yet had a major impact on energy prices. Some argue that a declining EROI can also be expected for renewable energy. In our reasoning, a decline in continuously available low-price energy could lead to a reduced substitution of human labor by mechanical energy and to an increased use of very intelligent but mechanical tools and devices. In urban areas, walking and cycling might substitute for motor-driven vehicles, in part because additional exercise benefits health.

The existing 'green jobs' reports (such as UNEP 2008) and the 'European Strategy Agenda 2020' do not elaborate on the of quality of 'green' labor in terms of physical work, intellectual capacity or empathy demanded. Recent studies for the US (Mattera et al. 2009) and for Austria (Leitner et al. 2012) identify forestry and agriculture,[29] the construction industry, waste management and trade and transport

[28]It should be noted that the numerical values in Fig. 7.3 are only illustrative. The reference frame of 100 % refers to the total of human working hours outlined in the time budget approach explained in Sect. 7.1. For these working hours, no reasonable statistics exist that would allow for a quantitative historical comparison of the quality and institutional form of labor as we attempt in Fig. 7.4.

[29]There are also other arguments for why the decline in agricultural labor in Europe may be reversed in the future. This reversal may occur due to, for example, a health-oriented increase in organic farming, decentralized energy generation or higher costs of fossil fuel-based (labor-saving) supplies.

as the main sectors of new 'green jobs'. Physical labor is clearly in demand for these sectors. Another line of reasoning sees the increasing frequency of extreme climate events as a source of additional physical labor, be it in the form of gainful employment, of nonmarket civil services ('other') or of family labor in coping with such events. This is reflected on the left side of Fig. 7.4 as a possible increase in nonmarket forms of labor (family and 'other') at the expense of gainful employment.

The above figures also indicate a continuing process of substitution of (particularly medium-qualified) intellectual or knowledge work by ICT and, eventually, its global outsourcing to lower-income countries, also facilitated by the use of ICT. The only services that are very difficult to substitute by ICT and nearly impossible to outsource to other countries are those that involve face-to-face contact with the resident population, namely, various forms of caretaking. In view of an aging population that is increasingly culturally heterogeneous and demanding, we assume an increase in the type of work that is based on empathy (at the expense of medium-qualified intellectual work) in the institutional form of collective services, family work and gainful employment.

There are new framework conditions that may have a long-lasting structural impact on work beyond the features described above. After many decades of decline, there is now (since approximately the year 2000) a sharp rise in the prices of all raw materials (commodities). Although some believe this to be a transitional phenomenon due to lagging investments, we see many indications of approaching scarcity or of rising efforts in the extraction of material and energy (Mudd 2010). If this should be the case, it might have two substantial impacts. First, the share of jobs to supply society with material and energy would rise[30] due to both lower energy returns on energy investments and declining ore grades. Second, if commodity prices (including energy) continue to be high or even rise further, this could substantially alter business strategies. There could be a shift in the dominant mode of cost reduction from labor to resources. In this case, it is not the increase in labor productivity that would be the key measure but the saving of resources, possibly at the expense of more labor (see, for example, Dobbs et al. 2012). Macroeconomically, this would mean that there is a shift in relative prices between material goods and human labor and, consequently, a decline in demand for material goods and increasing demand for human labor. Macroeconomic growth, as far as it depends on rising labor productivity, would be impaired. Increasing the share of work in caretaking, as assumed above, would have an impact in the same direction, as labor productivity cannot be enhanced much my caretaking. Furthermore, resource-saving jobs, such as renovation, repair, remaking and reusing, might gain momentum. In effect, if the purchasing power of workers is reduced, distributional conflicts over wages should become more frequent.[31]

[30]Whereas Japan in 1870 had to spend approximately 37 % of the available work time to supply their society with energy (see calculations from Table 7.1), this has declined to approximately 8 % in Europe today. Thus, an increase of several percent does not seem unrealistic.

[31]This vision strongly resembles the projections of Randers (2012). For the OECD countries, he projects labor productivity increases will lose their dynamics, consumption will stagnate or even decline because of rising shares of investment (required in adaptation to climate change, for example) and social conflicts will increase.

Finally, our societies might become less energy intensive. If the world seeks to avoid dangerous climate change (i.e., a rise in average temperature beyond two degrees), most simulations assume a global decline in primary energy use of 1 % annually (see, for example, GEA 2012; WBGU 2011). If this assumption were to be realized globally, the required decline in primary energy use for Europe would need to be much steeper. Part of this decline can be realized by avoiding losses,[32] but more expensive energy might lead to lower use. Could our societies gradually slow down again?

Acknowledgements This work originated from our contribution to the EU FP7 project 'NEUJOBS' (www.neujobs.eu) in April 2012. Our task in this project was to provide theoretical guidelines for socioecological transitions in a way that is meaningful to our partner research institutions specialized in Labor Economics or educational and demographic analyses about the future of the European labor market. The ensuing discussions and the seriousness with which our assumptions were met encouraged us to proceed on this pathway.

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[32]With coal-powered electricity generation, for example, a high proportion of the primary energy contained in coal is lost as waste heat. In the case of photovoltaic or wind power, this kind of loss does not occur. Another major case can be made for improving the insulation of buildings.

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