FINDING STRUCTURAL PARAMETERS FOR ENERGY EFFICIENT CITIES

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0. Abstract

Europe is going through a great social, economic and environmental period of transition. The changes the EU is currently undergoing have been causing increased awareness about sustainable development, natural resources use and energy efficiency on the agenda at the European level of policy making. However after more than forty years of the series of 'Earth Summit' conferences under UN Environmental program (UNEP) such as Rio 1992, Rio+5, Johannesburg 2002, Copenhagen climate summit 2009, Earth Summit 2012, the path towards sustainable development has not yet been clarified and is far from being achieved. Virtually all cities share concerns for the state of their environmental outlook. The relatively new problem of planning for urban energy efficiency emerges in this transition process. This will require substantial and concerted shifts in social–cultural, economic and environmental subsystems of cities. This paper presents a critical review of the literature on the context of urban energy efficiency and particularly on the 'structural' aspects of this issue. Our aim is to understand the larger context for planning for energy efficiency in Europe and clarify what the substantive content of planning for sustainability is. This means also understanding the functional-structural nature of urban energy regimes on which planning acts. Moreover this paper seeks literature to build up an understanding of what makes the city of today structurally unsustainable. The paper outlines crucial background issues in relation to energy efficiency and begins to outline a framework for further studies.

1. Why energy efficiency?

Making energy use more efficient is a way, if not the whole way, of tackling the sustainability dilemma. Energy efficiency is a strategy rather than an end in itself: the end is some form or other of sustainability. Today efficiency implies a reduction in our use of resources so that we may be able to avoid or control change and sustain what we do and have now but with lower adverse 'impacts' regarding the contextual system or systems what we have and do depend on. Our current predicament concerns the fact that our socio-technical and socio-economic systems depend systematically on our socio-ecological system and the latter is being degraded as a consequence of the activities of the former. This predicament is compounded by the fact our socio-economic system is founded on a model of growth so that to maintain what we 'have and do' including basic jobs and prosperity, it has to grow at a compound rate of 2-3% per annum. It is compounded further, and is given an ethical dimension, by the fact that most of the world is in a state of 'development' in an attempt to achieve Western 'standards' of prosperity. This demands growth rates which sometimes exceed 10%. The linkage of energy consumption with growth is not fixed but is persistent and energy consumption is going to grow globally at rates that threaten the primary sources of energy. Alternatives to these primary sources are a very small proportion of the total and there are difficult practical and technical problems in incorporating them into our existing socio-technical regimes, in particular the somewhat obvious requirement that for any system to grow it must gain substantially more energy than it uses in obtaining that energy (Hall et al 2009).

The problem of energy efficiency today has to be understood in relation to crisis and response to crisis. One crisis is of environmental degradation and resource scarcity. This is related to the crisis of global inequity not just regarding wealth and access to benefits of the socio-technical system but also in terms of the global distribution of environmental degradation. But another crisis, or series of crises – that of the global socio-economic system – is related to our response to environmental crisis and the implementation of energy efficiency. On the one hand the socio-economic system is the producer of economic benefit, as well as environmental degradation, and their distributions, while economic crisis provokes a refocusing of energies and resources invested in amelioration of environmental degradation and inequities – energy efficiency measures may be expensive and subject to cuts in government spending.

In this complex conjuncture the framing of questions becomes vital. The difficulties are theoretical as well as practical. On the one hand we have to account for the substantive limits of Earth processes. In order to do this we have to account for the capacities and flexibilities of human processes in relation to these limits. But sustainability is also a matter of thermodynamics and at this level the limits appear globally and necessarily involve global relations, and we will have to account eventually for the systemic limits – even wrong thinking – in the development process itself and the way the model based on growth means costs and benefits of development are unevenly distributed. Sustainability framed at lower scales will necessarily, according to Hornborg and others, conceal the distributional aspects of the problem – ie that the benefits may be localized and the costs displaced. An intuition of this is already well established in our concept of 'uneven development', but hidden in economic thinking in its inattention to geographical, distributional and ethical aspects of exchange relations and the way reciprocity, or equilibrium across the exchange relation, is assumed (Hornborg; Gunder Frank).[1]

In an ideal world we would be able to reduce energy demand in Europe by 73% through efficiency savings alone (Cullen et al).[2] There are however practical limits to achieving this: achieving optimum energy efficiency itself entails a high outlay of energy; we must also account for bringing the rest of the world up to a standard of living that could be called equitable, and this, even at optimum efficiency, would entail increases of energy use that would more than cancel gains. Whereas policy and aims (EU 2020) have been framed at European and national levels, it is acknowledged that the questions cannot ultimately be contained at these levels.

Final conclusions are going to be substantially influenced by the framing and starting assumptions, and if they are to be meaningful they will account for the larger contexts of planetary processes and responsibility. The main objective of EU energy policy is to reduce fossil fuel use to reduce carbon dioxide emissions. This aim is represented in the EU 20-20-20 targets: a 20% reduction in carbon dioxide emissions and 20% of energy from renewables by 2020. We will attempt here to find the way our world is structured *vis-a-vis* energy in order to understand better the structural factors involved in

[1] The wrong thinking also involves a mistaken idea of how entropy is related to the value added in the production process and what this means for the relations of the core with other parts of the world. Our technology is founded on the mechanism of exchanging value for entropy – increased value of the end product equates with increased entropy, not increased negentropy and if this is general, technology (our production system) will always cause inequality and the exchange of wealth for degradation across the core-periphery divide.

[2] Cullen, J.M., J.M. Allwood and E.H. Borgstein (2011) Reducing Energy Demand: What Are the Practical Limits? Environmental Science and Technology, 45 (4), pp 1711–1718. Buildings alone can achieve an 83% (179 x1018 J) savings, while industry can save 62% (95 x 1018 J).

urban energy use and its reduction. The context is an EU 7th Framework project Planning for Energy Efficient Cities (PLEEC), which gathers strategies and best practices from 6 small European cities in order to coordinate and spread these and develop a general model for energy efficiency and sustainable city planning. This is an ambitious aim and our aim here is to understand how small cities can contribute practically to strategies of sustainability through energy efficiency, but to put this in context so we understand what sustainability is in this planning framework (Naess) and the limitations as well as the potentials of these efforts.

2. Starting points: sustainability, global technics, economies and ecologies

The questions must start with the real limits on planetary or Earth systems. They also refer back to existing and projected energy or socio-ecological regimes and their energy requirements: What are the substantive limits on energy use? How does this relate to present-day socio-ecological, socio-technical and socio-economic regimes? What would be the minimum or practical minimum energy we require to run these? Conversely: What is the limit of efficiencies we can achieve within the existing regime and at what point do we have to consider different socio-ecological or socio-technical regimes? How do we envisage a gradual transition to a sustainable energy demand limit of the current regime? Or conversely: How do we envisage the ‘paradigm’ transition to a fundamentally different and structurally more sustainable regime? What would be the crucial issues in such a ‘paradigm’ transition and what would it entail?

If energy efficiency is a strategy aimed at sustainability we must ask what sustainability is and what could, should or must be sustained. Sustainability is a factor of persistence over time (Costanza and Patten 1995). Other answers to this question amount to predictions of what we have to do to achieve or maintain this persistence. But the definition leaves the end open and needs to be supported by answers to other questions. The first question is what to sustain? – perhaps a socio-technical/socio-economic system in the context of a socio-ecological system with concerns of equity and natural capital added. The next is what is the time period involved? – Constanza and Patten’s elegant answer involves nested hierarchies of systems and subsystems (or metasystems and systems) in which systems are contextualised in metasystems of longer persistence. The system to be sustained will be sustained in the context of another of yet longer persistence, and they see the resultant nested temporalities as fundamental. They suggest also the normative nature (or at least a normative component) of this relationship in that “a social consensus on desired characteristics which are consistent with the relationship of these subsystems with other subsystems in the hierarchy (notably ecosystems) must be arrived at” (Constanza and Patten …). Basically the ‘socio’ part of socio-technics and socio-economics is likely to *prefer* to understand clean air and water, healthy food and so on not as products of technics and economics but of a persistent relationship with the planet, powered by an even more persistent relation the planet has with the sun (Morton 2009). Today however, the viability of this normative relation of the human world (the human-technical and human-economic systems because without these we would be differently human) with Earth or Nature is in doubt: in fact it has already changed.

According to Najam et al., the relation between environment and globalisation needs to be emphasised if we want to understand the critical questions and challenges we face at every level. The form the relation takes emphasises the contradictions from the systematic perspective. ‘Globalisation’ – the socio-economic system – is no longer a subsystem, existing at a different spatial and temporal scale to ‘environment’ (Nature or Earth), but is relating as a system of the same order. This complicates what ‘limit’ means when we have become responsible not simply for our human domains and their systemic (and spatial and temporal) factors but also for their 'context' at the same order. The difficulty starts with understanding the relation between a global ecology (plate-techtonics, atmosphere, water), a global technical system (a technical modernity that distributes power and benefits globally (Hornborg)) and a global economy. The fact that humans can act at the global scale make them agents now of a global ecology.

Contra Smil the fact is we have become global and the conflation of the human world with its ostensible context the natural world is the basis of our dilemma and the justification for calling this the Antropocene.

We used to be 'in' Nature; now we have a combative relation with Nature. The nature of this 'in' needs explication – a 'vertical' relation (see Ingold).

Economic theory is unable to accommodate geography or account for unequal exchange so that economistic explanations fail to recognise the geographical displacement of ecological effects (see Radetzki in Hornborg).[3] Marx articulated a development model which understood a flow of benefit from the working to the capitalist classes. Capitalism has changed in the meantime to a nation-based early-industrial model (which spatialises Marx's exploitation by way of a globalisation of flows of resources to the industrial north), and again to the global division of labour we see today. We are articulating this model elsewhere (Read 2014).

Our influence on this planet has become pervasive and irreversible such that it is proposed we live in a new Anthropocene epoch (Stoermer; Crutzen), but also in an Anthroposphere, a humanly-made world (Baccini & Brunner). Our relationship with nature has fundamentally changed,[4] and some argue the only way 'back' to nature is through us and our technology (Zizek). For them technology in and of itself is not a force for 'alienation'. But neither is it simply the hardware; technology is a highly organised and integrated set of spaces we have created for ourselves in order to do the things we do – today at the global scale and in a technically achieved global economy. The meaning of technology today is on the one hand to differentiate our world into core and periphery, and on the other to act (directly and indirectly) at regional and planetary scales. It is hard to see how we will give this up in its entirety;[5] it is also hard to see how any sustainable world will not be sustainable because we make it so, ordering it around human capabilities and techniques.

3. The sustainability issue, interests and policy today

Energy issues and energy efficiency are on the agenda at the European level of policy making (EETO, 2011). This is in the context of a growing awareness of sustainability issues. However, after forty years of Earth Summit conferences (UNEP), the path to sustainable development has not been clarified and is far from being achieved. The World Commission on Environment and Development (WCED) in Rio de Janeiro in 1992 consolidated an approach to sustainability that said growth is the solution to rather than the cause of environmental problems (WCED 1987). Influential concepts of

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[3] This interpretation poses serious questions for what Hornborg calls the 'cornucopia model' – growth and sustainability may be won together – and demands we look again at what he calls the 'zero-sum model' that says growth somewhere means depletion somewhere else (Hornborg).

[4] The technologies of our relations with the world as a whole construct 'nature' (Smith; Luke; Nik Heynen). the social nature of nature: 1st Marx on Feuerbach; 2nd Cosmologies/ orders and their 'generalisation' in networks. Nature is 'framed' in these human constructs.

[5] It is also equipment and therefore simply hard to see.

‘sustainable development’ and ‘ecological modernisation’ (Hajer 1995) embed the assumption that growth benefits simultaneously the global economy and global ecology. At the same time there is a widespread though often passive scepticism, reminiscent, in its more politically articulate forms, of dependency theory of the 1970s.[6] An independent assessment finds the conferences “have collectively not delivered anything remotely close to matching the scale of the problem. … In particular, the US federal government is paralysed on climate change, hostage to the overrepresentation of fossil fuel producing states in the US Senate and the power of big oil money in Washington…” (Stevenson and Dryzek, 2013).

It appears that efforts at amelioration of human-induced environmental change clash with powerful interests committed to economic growth. The different points of view represent what Hornborg calls a choice between ‘zero-sum’, which implies Western affluence is based on the impoverishment of both the South and the global environment, and ‘cornucopia’, implying growth cures all, models and asks if deciding this should not be a simple empirical question. There seem however to be no ‘simple empirical’ questions involved. It is about data being used to verify the patterns we imagine to exist in the world. The causal structure we impose is what gives meaning to data, and there is more than enough flexibility of interpretation of that data (see Oreskes et al) to accommodate two or more explanatory structures. We choose our models on grounds that include worldview and interest and Hornborg suggests that an important consideration today is the interpretation we can live with. When confronted with a zero-sum interpretation while at the same time there is pressure on jobs and questions about the sustainability of European prosperity in a ‘post-political’ climate (Bauman 1998), reformist leanings are trumped by self-interest or turn to resignation.

Today it is by no means certain that the agenda of ‘sustainable development’ is viable or indeed that we are not dealing at a global level with a ‘zero-sum’ situation that demands a substantial revision of the models and infrastructure of the global economy (Jackson 2009). ‘Sustainable development’ is an historical and political, rather than scientific, concept. It is an idea that is socially and politically constructed and serves (whatever its other virtues or faults) powerful interests. Meanwhile sustainability is presented today in economistic terms as a ‘greening of the economy’ with a ‘triple bottom line’ of balancing social equity, environment, and economy (three e’s) – or people, planet, and profits (three p’s’) (see Bina, 2009). At the global political level a ‘consensus’ exists (though this should not be taken to mean full agreement even within the most powerful core countries) and has been formalised (Rio, Kyoto) regarding the strategy of sustainability through growth, while at the same time there is considerable scepticism regarding the conceptual and practical viability of this approach (Stevenson and Dryzek, Jackson, Hornborg …).

While the political power of the dissenters is small, the consequences of inadequate delivery on climate change are well-known and well-represented in mainstream media: this is that the stakes and the consequences are global and severe – also that they go beyond the degradation of the ‘natural’ environment and involve “vast numbers of environmental refugees, social instability and decimated economies” (Prince Charles). While policy and efficiency targets are aimed at particular polities like the EU or nation states, but sustainability, wherever it is framed in policy terms, is a global issue and consequences emerge globally. This goes beyond the point that greenhouse gasses and resource and other limits respect no political boundaries; the contradictions and tensions are in terms of global

[6] This said that said economic growth in the West occurred at the expense of the Third World and the global environment (Baran; Gunder Frank).

inequity and are reflected at EU level in a localised politics dominated by jobs, European economic well-being and populist objections to migration.

4. The question of substantive limits

There are however hard limits involved. Part of our problem, again according to Hornborg, is reconciling relatively flexible political and human and technical capacities aspects of the problem with the thermodynamics of our limited planet. It has been known for some time that significant planetary limits are being and are about to be exceeded. Limits for climate change, rate of biodiversity loss and the nitrogen cycle have already been transgressed and we are approaching those for global freshwater use, land use, ocean acidification and the global phosphorous cycle (Rockström et al, 2009). Rockström et al identify nine 'Earth-system processes' and associated thresholds which, when crossed, would signal unacceptable environmental change.

Energy efficiencies in any context must gain their meanings from the larger context in which they are embedded so that besides the narrow view we must take on EE in small European cities, we will try also to sketch the more global structural constraints on the assumptions sustainable growth and development depend on. Energy is a topic that is difficult to visualise and to quantify clearly, and we think of it sometimes as an elastic factor, a social and technical construction we can stretch or ignore on the basis we will solve this in the next round of technological innovation. However the magnitudes and scales involved have increased to the point where energy is just as much an issue of limits as are the availability of land and fresh water. The question of energy and limits is linked to the question of growth through the very concept of 'sustainable development' so that SD itself – if it is to be coherent (this is a real question today) – depends on the assumption of the disengagement (decoupling) of energy from economic growth. Part of our thesis is that this energy 'decoupling' is a subject we don't understand well, beyond the fact that our present economic crisis has shown that the single best way to cut the use of energy is to cut growth.

But we can come quickly to responsible working attitude to the problem by considering global limits. If our production and consumption machines are energy machines, unlimited growth – even continued modest growth – leads to absurd outcomes, and talk of 'sustainable growth' is suspect without specifying what it means, where it comes from and what this means in energy terms. In fact the background limits are already clear to see at the limit of the globe. Development and growth mean rising standards of living and consumption (also of energy) and Mathis Wackernagel and his colleagues have shown that if all were to achieve the standard of living enjoyed in the 'developed world' we would need the 'footprint' three more Earths to support them (Wackernagel et al). The distributional aspects are also clear at this level: while the per capita availability of productive land has decreased from 5 to 1.7 hectares since 1900, the per capita footprint in 'developed' countries is now 4 to 6 hectares (). The limits relating to growth are as clear: seen globally, over the past 30 years, carbon intensity per dollar of economic activity has fallen by a third. At the same time however the economy has scaled up. In the same time that efficiencies increased by a third, carbon emissions increased by 40%. The trend is consistent: the scaling up has over our industrial period has always overtaken increasing efficiencies (Jackson) and will continue to do so that to be sustainable we would have to continue producing efficiencies to levels which are not credible – basically that would lead us into negative carbon emissions – that we eventually start taking carbon out of the atmosphere as a direct consequence of economic growth. Such an economic system has not been invented and is as of now inconceivable.

Rockström et al don't give us directly a limit to the energy we may consume before limits are transgressed. One reason may be that energy use is a 'human-system process'. We also know however that the environmental crisis is itself the signal that we can no longer meaningfully separate human and thermodynamic Earth systems. Limits were at one stage in human development defined by the availability of productive land to convert solar energy into biomass. This limit was eliminated in a new energy regime based on fossil fuels, cheap transportation and a global market in resources (colonialism, neo-colonialism, the global industrial division of labour). Already in 1900 the UK's imports of biomass equalled the productive capacity of its own agricultural land (). Biomass, resources and industrial production itself were broken from their ties to locality, and the modern industrial machine transformed the equation, with effects on global distributions of power and prosperity but also in terms of environmental degradation. The limits we encounter today are quite different: instead of the limit being given on the human side of the equation by the rate of locally and renewably processing energy streaming from the sun into a form that can be converted into work, we run up against the limit of the earths capacity to deal with the consequences (emissions and climate change or resource depletion) of an economy powered by non-renewable energy. While the concept of sustainable development suggests a certain flexibility in this question, the limits appear on the Earth, thermodynamic side of the equation.

Look again at energy diagrams in Pimentel …

What the projections show us is that we need to understand human and Earth systems as fundamentally interconnected if not integral. The problem is, as Hornborg points out, our own epistemologies and the artificial distinction we make between different forms of knowledge: "It is precisely the illusory distinction between symbolic communication and technical efficacy that prevents us from recognizing the machine as a social institution [whose] efficacy hinges on the symbolic codes that mobilize the masses. … we cannot hope to understand the material agency of humans in the biosphere if we are not prepared to juxtapose materialist perspectives, on one hand, with symbolic analysis and phenomenology, on the other (Hornborg). We have to learn to theorise how a dynamic of social relations intervenes in the material realities of the biosphere (Hornborg). We treat Earth as if what we do and what we create for ourselves can be separated from it, and can be treated as a matter of 'impact' on it.

Energy and thermodynamic limits Hornborg

See Guy Baeten on sustainable mobility

5. The question of societal and practical limits

Depending on your source, 85-90% of our current energy is derived from three primary sources: oil, natural gas, and coal. The question of an energy system to meet society's future needs must start by recognising the practical limits of available sources. The biggest practical problem is the shear capacity that has to be filled by alternatives (Heinberg, 2006). Smil emphasises the magnitude of the task: "the shift to non-fossil energies is an order of magnitude larger task than was the transition from phytomass to fossil fuel, and its qualitative peculiarities will also make it more, rather than less, demanding … At the same time, only one of the many renewable energy resources has a natural flux far surpassing any prospective needs (Smil).

What is needed is new primary energy sources capable of substantially replacing fossil fuels, though secondary sources will of course play roles. A future primary energy source needs to: 1. be capable of providing a substantial proportion of all the energy currently used; 2. have a net energy yield of 10:1 or more; 3. Be without unacceptable environmental, social, or geopolitical effects; and 4. be renewable (Heinberg 57). To put the problem in perspective, globally coal passed biomass as the leading supply of energy just before the beginning of the 20th century. At that time it was being consumed at the rate of 600 GW. By 2005 fossil fuels accounted for 12 TW, a 20-fold increase (Smil), and 85-90% of total energy. In the meantime biomass use has more than doubled and accounts for the bulk of the remainder. Getting new energy systems on line is formidably difficult also due to infrastructural changes required and the costs and time this takes. Higher-tech alternatives do not feature in a practical sense today, the best available being perhaps hydro and nuclear which are also hardly new.

There are technical aspects to replacement, efficiency and growth which are crucial. Energy return on investment (EROI) is how much energy is left over after correcting for how much energy is required to generate a unit of energy at the point of extraction (Hall et al 2008). The factor of minimum viable EROI involves the idea that for any system to grow it must obtain substantially more energy than it needs to invest to obtain that energy (Farrell et al). Thus any energy system is constrained by a 'law of minimum EROI' which is calculated for oil and the most efficient biofuels at about 3:1 at point of extraction. This is the limit as most of the advantage is then lost getting the energy to point of use – refining/ conversion, transportation, distribution.[7] As most biofuels have EROI's of less than 3:1 they must be 'subsidized' by fossil fuels to be useful. 'Energy yields' (Joules per unit mass of energy source) become an important part of the calculation because although the energy yield may start high, there is an efficiency-related loss of EROI from point of extraction to point of use. If this loss is too great we end up using more energy to get energy to its point of use than that energy actually yields and some 'alternatives' end up being energy consumers!

Some biomass replacements like crop derived ethanol would require increases in land use, and land is one of the scarcity factors involved (developed lands already being 3 times over their limit of per capita land availability). In addition the current models of national and global economies are set up so they depend on the high energy yields and EROI of fossil fuels. Just to serve existing residential, industrial and transportation infrastructures, a solar-based energy regime would have to bridge power density gaps of 100 to 1000 times foreseeable PV output (Smil). Consider also that "recent costs of many renewable techniques have been actually increasing … because [they] depend on large inputs of more costly fossil energies" (Smil). The major factors here are infrastructure production and transportation (data?). Infrastructure and transportation, stubbornly dependent on oil, figure massively again in the mobility flows involved in the global industrial division of labour (Froebel et al). Though not the most visible, and often discounted, this is one of the most significant factors (data?) in energy terms today. The global mobility of production materials, components and consumer goods is behind the consumables that eventually end up in corner shops, supermarkets and megastores (Holmes). The products hide not just their energy processes but also global distributional and ethical aspects their processes of production are complicit in.

Resignation is also due to the fact in so far as there is global government this is practically and uncompromisingly supportive of business as usual. There is no other level or form of global

[7] Hunter gatherer societies operated on 10:1 EROIs and Heinberg makes the point this could be related to time over for social reproduction. Could the neoliberal neglect of the issue of social reproduction be related to energy poverty?

governance that is capable of challenging this or leveraging another direction, protected as BAU is in hegemonic normativities and legalities of private property, individual rights and its positioning in practical power relations.

6. The question of change: socio-ecological regimes and energy transitions

In what sort of framework should we understand change happening? The questions about changes need to be understood in the context of transitions of the past. Many have suggested that societies, economies, cultures and even civilizations are products of surplus energy in particular energy regimes[8] (Soddy, Ostwald, Leslie White, Joseph Tainter, John Perlin, Howard T. Odum, Frederick Cottrell, Nicolas Georgescu-Roegan, Vaclav Smil). Solar energy, converted to biomass by way of photosynthesis (Morton), drove hunter-gather and then agricultural socio-ecological regimes. A critical transition occurred with fossil fuels which powered the industrial revolution by breaking the link between energy and land.

Before this 'deterritorialisation' of energy processes an area-based, decentralised, energy system underpinned socio-economic development, and biomass accounted for 95% of society's demand of primary energy (Fischer-Kowalski & Krausmann). Then, with coal's high yields, nineteenth century technology made the long-distance transport of bulk goods economic and released the accumulative process from its attachment to the land. The modern centralisation of human systems depended on means to 'abstract' and transport value over regions (first national and then global) much larger than before. The substantive or thermodynamic means were a high-yield (harnessable) and transportable forms of energy.[9] Population concentrations and densities increased by orders of magnitude in the new regime. Sustaining these concentrations has required other revolutions. The industrialization of agriculture means *food* production, the most ur-primary energy product, now relies on external inputs of fuels, feed and chemicals – one calorie of food now requires 5 calories of energy to produce (Energy for Economic Growth Energy Vision Update 2012). Local optimization has been replaced by large-scale specialization of land-use and agriculture for export and food prices are now determined globally. Energy use per unit area in Europe increased from less than 30 GJoules/ha in developed agrarian regimes to several hundred GJ/ha in developed industrial regimes (Fischer-Kowalski & Krausmann; Krausmann et al).

Metabolic profiles of socio-ecological regimes in world history per capita annual use

	Energy	Material
Basic human metabolism (biomass intake by nutrition)	3,5 GJoules	1 tonnes
Hunter-gatherers (uncontrolled solar energy use)	10-20 GJoules	2-3 tonnes
Agrarian societies (controlled solar energy use)	40-70 GJoules	4-5 tonnes
Industrial societies	150-400 GJoules	15-25 tonnes

(Source: Fischer-Kowalski | Peyresq | 9-2007| 12 – Social ecology database)

[8] Socio-ecological regimes
[9] "machines are reifications of the wider social context of global flows of goods and services" 204

Fossil fuels transformed development so that economic expansion could be determined by the market price of textiles, slaves and coal (Hornborg) and productive capacities of central areas linked in a zero-sum logic with peripheral areas. To emphasise the point: on this account core-periphery distinctions on a global scale (see The Great Divergence, Pomeranz), globalisation and the contemporary global industrial division of labour depend on the deterritorialising potentials that came with fossil fuels.

The question of whether or not we are entering a new energy or socio-ecological system with replacement by renewables probably has to ask whether we can invent an economy that restores the link between energy and land, or alternatively can maintain the break of the link both practically and substantively (thermodynamically) without fossil fuels. The answer is not clear. Many renewables effectiveness depends on local production and local carbon accountability (coal and gas replaced by locally produced woodchips in Finland or heat pumps or other geothermal sources for example), but the question goes further than this to whether these sorts of replacements can fill the enormous energy demand of the consumer societies already established and those emerging. The real question is about this demand and will have to engage with the global production machinery of these societies next to questions of substantive thermodynamic limits and distributional effects. Real energy transition will most likely involve substantial reductions of this demand. The safe bet would be to assume that we will see business as usual and a continuing reliance on fossil fuels supplemented by replacements for some time to come and that true energy transition is still some way off. We would need to assume therefore also that the distributional and ethical issues will also not be resolved in the short term.

We do not have a viable view of the next energy transition. Local sustainability targets (regional and national targets on carbon neutrality) are not insignificant and are in some cases (Finland) well advanced. But there are systemic reasons why local successes will not aggregate to global success. The best we appear to be able to envisage at the moment involves finding replacements and efficiencies which, if they are to be minimally effective in the present energy regime, have to show similar energy yields and energy returns on investment. At the same time we know this will not be enough. It is this dilemma that produces attitudes of resignation, self-interest and denial that characterise the debate at societal and political levels.

7. The question of change: socio-technical regimes and technical transitions

The human or social means for the modern centralisation of human systems and 'abstraction' and distribution of value over national and then global regions were technical: the monetarisation of society and capital (Marx), the harnessing of energy from coal, and transportation. According to Smil "technical progress has two distinct modes as gradual, ever-working improvements of established techniques that boost efficiencies, increase reliability and lower costs … interspersed with great saltations, periods of astonishing progress that overturn old paradigms and install new ways that may last not only for generations but for centuries" (Smil). The second is that change must happen simultaneously in multiple dimensions. Rather than seeing incremental changes in individual dimensions, changes involve the coordination of simultaneous and situated change in economic, social, technological and cultural dimensions.[10] Change is a complex process and the 'inertia' of these systems has to do with this factor.

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[10] Transitions occur also in the organizational and technological structures of energy regimes. So that in the regime founded on fossil fuels there have been transitions from national to global exploitation and from colonisation to neo-colonisation founded on a 'global industrial division of labour'. Industrialisation has, in a number of steps, released material and energy flows from the ecosystem

There has been a transition from solar land-based forms to fossil-fuelled network based forms. The breaking of the link with land (along with the monetarisation and capitalisation of the economy) meant that population growth was freed from the constraints of agricultural output. This process was enabled in a series of socio-technical regimes (also ‘modernisations’) allowing the centre to “progressively improve its terms of trade and thus its capacity to appropriate the resources of the hinterland” (Hornborg). New technologies mediated network modernities and rationalities at first national and then global scales. The resulting ‘machine’ is an infrastructure modern societies, economies, and modes of action and life depend on. It underpins the global logistics the consumer society depends on (Smil 2010).[11] Large-scale urbanisation and the concentration of human resources in cities became possible on condition the logistics of food, energy and waste were taken care of. Environmental quality and justice are also issues of this ‘machine’ as extractive economies overexploit the periphery. Its power doesn’t stop here however because it is the foundation of modern technological agency and enablement.

But there have also been more transitions than one at this socio-technical level. Network-based forms have themselves undergone transformations. There has been a change to another coal and oil-based ecological regime in the second half of the last century and we may be on the brink of one now with our present compounding of crises around a stuttering economy complicated by sustainability and energy questions (Podobnik, 2006). The technology complex after the second world war was accompanied by another phase of rapid economic growth and material and energy consumption. Rapid urbanisation has been characteristic of both Western industrial phases and the one occurring now in the East and South.

We are writing elsewhere (Read 2014) about the urban changes that have accompanied energy transitions: the shift from the preindustrial to the industrial to the post-industrial city. Today we see forms of urbanisation that may again be ‘new’ – the consistent factor is that each transition so far has entailed large increases in energy and material footprint and more rather than less reliance on fossil fuels and high energy yields (data?). The call to ‘compact city’ development is, seen in this light, a call to reverse the post-war urban changes and retrofit out societies into the forms of the first industrial phase of urbanisation – to return from a ‘metropolitan’, automobile-centred suburban city, to a ‘cosmopolitan’, public-transport centred urban one – or from Los Angeles back to Amsterdam.

It is important to emphasise the limited nature of this call and the exact focus of the challenge. In practice most renewables are used to generate electricity rather than for transport or heating, which together represent about two thirds of fossil fuel use (what is it in Europe?). Meeting our limited renewable targets require large shifts away from coal, oil and gas in these sectors. The idea there needs to be change is not disputed. What is disputed or unclear – or what we are unable to grasp or act on – is what change consists of, what it requires of us, and what the actual possibilities and limits are in our responses to change? Scenarios for the future present us with different choices but the alternatives tend to exist within a quite narrow band of consumer-oriented individualism and not to address fundamental change of energy regime. Transitions of the past were unforeseen. The transitions we are

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processes which limited growth under agrarian conditions. At the same time, released from the land, humans have urbanised in two great waves, the first connected to a British industrial order and the second to an American industrial order after the second world war.

[11] It is difficult at this point to see us dismantling this enabling structure and voluntarily giving up this enablement. It may in any event be not the means we are debating but the ends (Dryzek’s model in Bina).

working towards tend to be of adjustments at the socio-technical rather than radical transformations at the socio-ecological level.

The most practical approaches (and successful as practices – though on a substantive level their contribution may be limited) have left the question open. While structural changes are demanded from science and environmental policy (), this has been substantially watered down politically. We have described the political consensus arising from the summits. In the Netherlands a recognition of the need for change has motivated the national environmental plan from the beginning but has been regularly trumped till recently by more immediately compelling priorities around economic performance and international competitiveness (Smith and Kern). Today ‘ecological modernisation’ has gained a foothold in Dutch national environmental planning, though its beginning point as a technology-led approach has been overtaken by its role as a procedural instrument to promote and facilitate alternatives (Smith and Kern).

Ecological modernisation is characterised by three perspectives: 1. a downplaying of environmental problems as consequences of industrialisation, towards understanding them as challenges for social, technical and economic reform; 2. emphasising transformation of the institutions of modernity, including science and technology, production and consumption, politics and governance, and the 'market' (local, national, and global); and 3. opposed to deindustrialist, anti-consumerist, and neo-Marxist analyses (Mol & Sonnenfeld). There is a storyline in ecological modernisation that facilitated its transformation into a procedural approach: this is that systemic change begins with the emergence of alternative practices in niche settings (Rip and Kemp, 1998; Geels, 2002). Some of these make progress and become more influential while ‘paradigm contradictions’ in the dominant system place it under pressure, and the alternative offers new ways of framing questions and alternative practices pressing for change. This became a rationale for creating policies that supported niche experiments in sustainability, whilst other policies placed incumbent systems under pressure to become sustainable. The ‘transitions approach’ sought to facilitate transitions to sustainability (Smith and Kern, Smith et al, 2005). It appeared radical, combining Kuhnian ideas about scientific change with marketing ideas about innovation. At the same time the ‘alternatives’ exist in a rather narrow band of ‘possibles’ whereas transitions of the past have tended to be ‘improbables’.

However, the relative environmental improvements could not compensate for new pressures on the environment due to growth in the Dutch economy, so that “significant advances (e.g. in terms of cleaner production) were not breaking the stubborn link between economic growth and environmental degradation” (Smith & Kern). What ecological modernisation has practically achieved is a neutralisation of the intuition that industrial growth is at odds with global ecology. “The discursive shift since the 1970s has been geared to disengaging concerns about environment and development from the criticism of industrial capitalism as such” (Hornborg 2003). An emphasis on the human (governance) side of the problem is in danger of missing the substantive thermodynamic points about limits.

A new urban transition?

Cities are at the top of the agenda in thinking about sustainability and energy efficiency. This is partly due to the centrality of cities in contemporary thinking and that cities have been understood as primary drivers of economic development and growth. We have become urban (Lefebvre; Smith). But, with huge and increasing pressures on our biological and social systems, today we are also told that cities are the problem. Cities consume 67% of all energy produced worldwide and account for 71% of CO2 emissions. It is clear also however that cities are central to a way of doing things we don't have a clear alternative for, and that they concentrate demands like production, transportation and heating that would arguably exist anyway. At the same time however the first limited contribution small cities can make has become clearer: this is to reverse as far as possible the energy consequences of the recent socio-technical transition characterized by their sprawling and their growing dependence on the motorcar.

The two major changes in energy demand in Europe are due firstly to the decline of heavy industry and the rise of the service sector and secondly to the increased demand due to the post-war socio-technical transition and the rise of the metropolitan city. The first has entailed a local reduction in demand and led to questionable claims of 'decoupling' of energy use from growth (see Jackson ch 5). This should be understood as the displacement of industrial energy use consequent on global patterns of production and the displacement of environmental degradation to the periphery. The energy footprint related to industry has arguably remained as industry has moved to other global regions and environmental consequences have been shifted with it. The transport factor associated with this logistics of production has added to the oil-dependency of the production process. Different cities, embodying different mixes of economic and demographic dynamics and different specific pathways of urban development and relations to land and energy use, produce different carbon and energy trajectories. However there are region-specific patterns and European cities have transitioned from city-based to region-based patterns of urban development and from contiguous growth outwards to polycentric expansion along major infrastructure routes. There have been changes in location patterns of businesses and housing driven by a different set of actors and in a different transport technological (the motor car and commuter travel) context. It is in the context of this new urban socio-technical regime that energy demand must be understood in Europe today. The main energy-connected results are on the one hand that the ecological footprints of cities expand to satellites and areas outside their boundaries at all scales including the global and on the other that people and businesses use more building related energy (heating, cooling and other appliances) while they travel further from home to work, school and recreation, freight transport moves fuels, food, materials, goods and components longer distances.

Are cities the source of our problems or are they the way to the solution? We can remain agnostic on the first point while acknowledging the second in a weak way: whether we like it or not the way to the future is through the present and the fact is we *are* urbanised and rates of urbanisation will likely be 70% by 2050.. While we are nowhere near tackling the whole problem we can imagine limited gains, particularly in more easily managed (especially in a transport and land-use sense) small-scaled and relatively 'flat' urban systems of small towns and rural areas such as one has in large parts of north-western Europe. We are unlikely in the near future to be dealing with a real socio-ecological transition to another energy regime. What is more feasible is a limited socio-technological transition. We have seen that socio-technological transitions of the past – like the transition from an industrial system based on national industries to one based on a global industrial division of labour – have corresponded with changes in the forms and functional logics of cities – from relatively compact 'industrial cities' to sprawling car-centred 'post-industrial' cities. In many parts of Europe and in many small towns this change has come relatively late – in the 1980s, 90s and early 2000s – and coincides with a levelling of energy use in this region. But it is the composition of this change that is interesting: industrial demand has declined (1.7% 'efficiencies' in the industrial sector per year since the 70s) while at the same time urban related (building and transport) demand have increased.

On the building side there has been success with local replacement of coal, gas and oil (from woodchips fuelled electricity in Finland to local solar, district heating, heat-pumps and other in-place sources. Here we understand it is not so much total demand as reducing or eliminating carbon emissions that is the issue. Local energy supply makes accounting (and accountability) easier to manage while the less local (European Energy Market) makes it more difficult as local power authorities are temped to take the lowest price from fossil-fuel or unknown sources. Transport has on the other hand remained stubbornly dependent on oil and transport emerges as a hidden factor in other local and non-local sectors. The strategy mentioned earlier of ‘turning back the clock’ by retrofitting cities to their more compact industrial pasts entails development towards land-use patterns that can be covered by very efficient public transport networks. Local strategies involve re-development of older, especially industrial areas and controlling development into more effective patterns to make public transport more feasible and attractive. However continuing growth in the economy, building stock and the market for consumables makes it difficult if not impossible at this stage to bring urban development within the frame of what is sustainable and equitable in a global perspective (Naess).

On the other hand: “Either we take the threat of ecological catastrophe seriously and decide today to do things that, if the catastrophe does not occur, will appear ridiculous, or we do nothing and risk losing everything if the catastrophe does take place. The worst response would be to apply a limited range of measures - in that case, we will fail whatever happens …

Humankind should get ready to live in a more nomadic way: local or global changes in environment may demand unprecedented large-scale social transformations. Let's say that a huge volcanic eruption makes the whole of Iceland uninhabitable: where will the people of Iceland move? Under what conditions? Should they be given a piece of land, or just dispersed around the world? What if northern Siberia becomes more inhabitable and appropriate for agriculture, while great swaths of sub-Saharan Africa become too dry for a large population to live there - how will the exchange of population be organised? When similar things happened in the past, the social changes occurred in a wild, spontaneous way, with violence and destruction. Such a prospect is catastrophic in a world in which many nations have access to weapons of mass destruction.

One thing is clear: national sovereignty will have to be redefined and new levels of global co-operation invented. And what about the immense changes to economies and consumption levels demanded and brought about by new weather patterns or shortages of water and energy sources? How will such changes be decided and executed?” (Zizek Joe Public v the volcano New Statesman 29 April 2010).

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