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## Viewpoint

# Sustainability transition and economic growth enigma: Money or energy?<sup>☆</sup>



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## ABSTRACT

The complex relationship between economic growth, job creation, peak oil and climate change is discussed. This starts from seven facts and leads to five propositions to deal with the consequences of these facts. The overall message is that global economic policy should be redirected, that we need a better understanding of the reasons for the current economic malaise, that “peak oil” remains a concern (despite shale “fracking”), and that climate change is a relevant economic issue demanding a serious response. There is probably only one strategy that has a chance of reversing the present

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“death spiral” of the global economy and simultaneously reducing the risk of catastrophic climate change. That path requires major investments in energy efficiency and renewable energy technologies in the near and medium term. The investments must be attractive to long-run (20–30 year) investors (pension funds, insurance companies) and probably take the form of securitized, resource-based bonds.

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## 1. Seven key facts about energy, growth and finance

Here we present seven key facts about the relationship between energy, economic growth and financial institutions and dynamics, which will provide a basis for propositions to realize a transition to sustainable energy in the next section.

*The first key fact*, a consequence of the laws of thermodynamics, is that physical materials are not created or consumed, but are moved and transformed by human actions. The transformations start with “raw” materials from nature and then add value at each stage of transformation, until they finally become products. All products eventually become wastes to be discarded and either recycled within industry or (mostly) accumulated or recycled by the environment.

The first two industrial revolutions in the 18th and 19th centuries were based largely on extraction and transformation technologies introduced to exploit pockets of high quality natural resources, notably fossil fuels (coal and petroleum) but also metals and other minerals. To simplify the following discussion, we focus only on useful energy (exergy)<sup>1</sup> resources though many comments apply also to other resources.

*The second key fact* is that the finite stores of high quality (low entropy) exergy resources in the earth are unevenly distributed and are being rapidly exhausted. Renewable resources (like sunlight and wind) are generally much less concentrated and much more costly to exploit. Moreover, the Greenhouse Gases (GHGs) from fossil fuel combustion are accumulating in the atmosphere and may be driving climate change rapidly toward an irreversible economic and social disaster.<sup>2</sup> In the absence of renewable exergy sources, more and more economic activity, and a rising share of GDP, will be required to provide useful energy for the economy. It follows that the price of energy (especially fossil fuels such as oil) will rise over time, unless recession kills demand or renewable energy takes a flight and electric or hybrid vehicles rapidly replace conventional vehicles and consequently reduce demand for fossil fuels. (For the moment, hybrids still use fossil fuels – albeit less of them – but ultimately they may utilize biofuels or hydrogen.)

*The third key fact* is that – conventional economic theory to the contrary – the global economy is not driven simply by capital and human labor. The economy cannot function without a continuous (and ever-increasing) supply of energy resources, both in the form of materials (“frozen energy”) embodied in capital stock and as an “activator” for both human labor and the machines that augment (and increasingly replace) human labor. Without energy from food (calories) humans cannot do useful muscle or brain work. Machines, which have replaced most kinds of human (and animal) labor, cannot function without exergy (i.e. electricity) that is still mostly derived from fossil fuels but eventually can be powered by sunlight or wind. The world is truly “hooked” on oil (George Bush’s words), if only because liquid fuels derived from petroleum are essential for every sort of internal combustion engine, and combustion engines power almost every sort of vehicle in the transport system, not to mention off-road construction and farm machinery. Coal and gas are also primary fuels for the electric power sector. Energy (exergy) matters far more for the economy than most economists seem to realize.

<sup>1</sup> Energy is conserved (first law of thermodynamics). Exergy is a technical term referring to the fraction of energy that is capable of doing work. The remainder is called anergy. Energy = exergy + anergy.

<sup>2</sup> The vast majority of the scientific community agrees with the above assessment, even though many governments and industry leaders ignore it, as evidenced by their strategies and policies.

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