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Could energetic constraints be slowing economic growth?

University of Surrey
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EPSRC Early-Career Fellow
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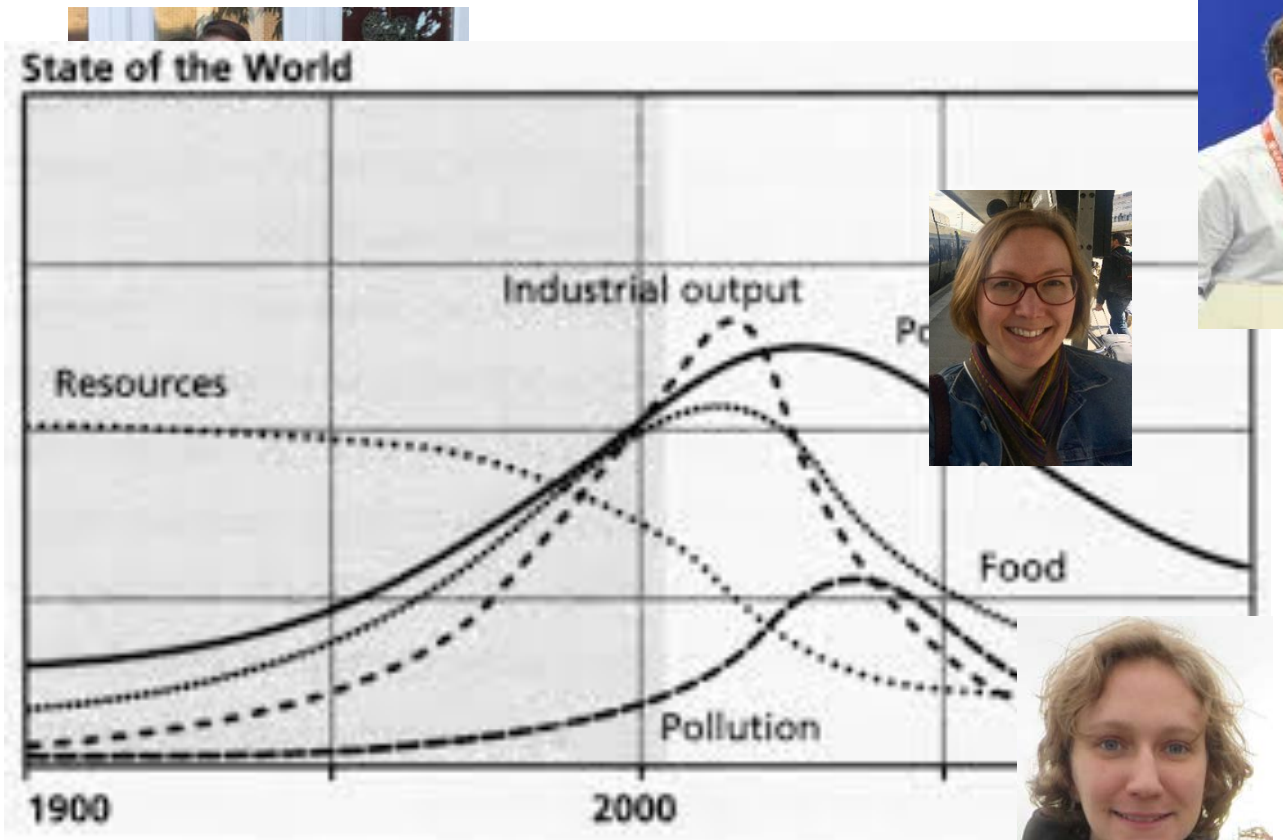
A little about me



Donella Meadows | Jorgen Randers | Dennis Meadows

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Seminar outline

1. Mainstream ignorance of the role of **energy** in 250 years of fossil-fuelled, exponential **economic growth**
2. Constraint 1 – slowing thermodynamic efficiency gains
3. Constraint 2 – reducing availability of net energy (EROI)
4. What next: influencing the data-modelling-policy chain

Future energy use assumes **absolute** decoupling

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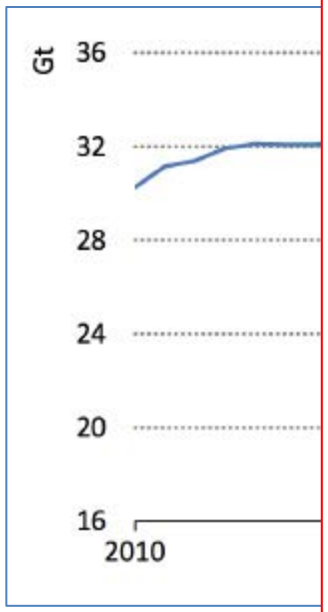
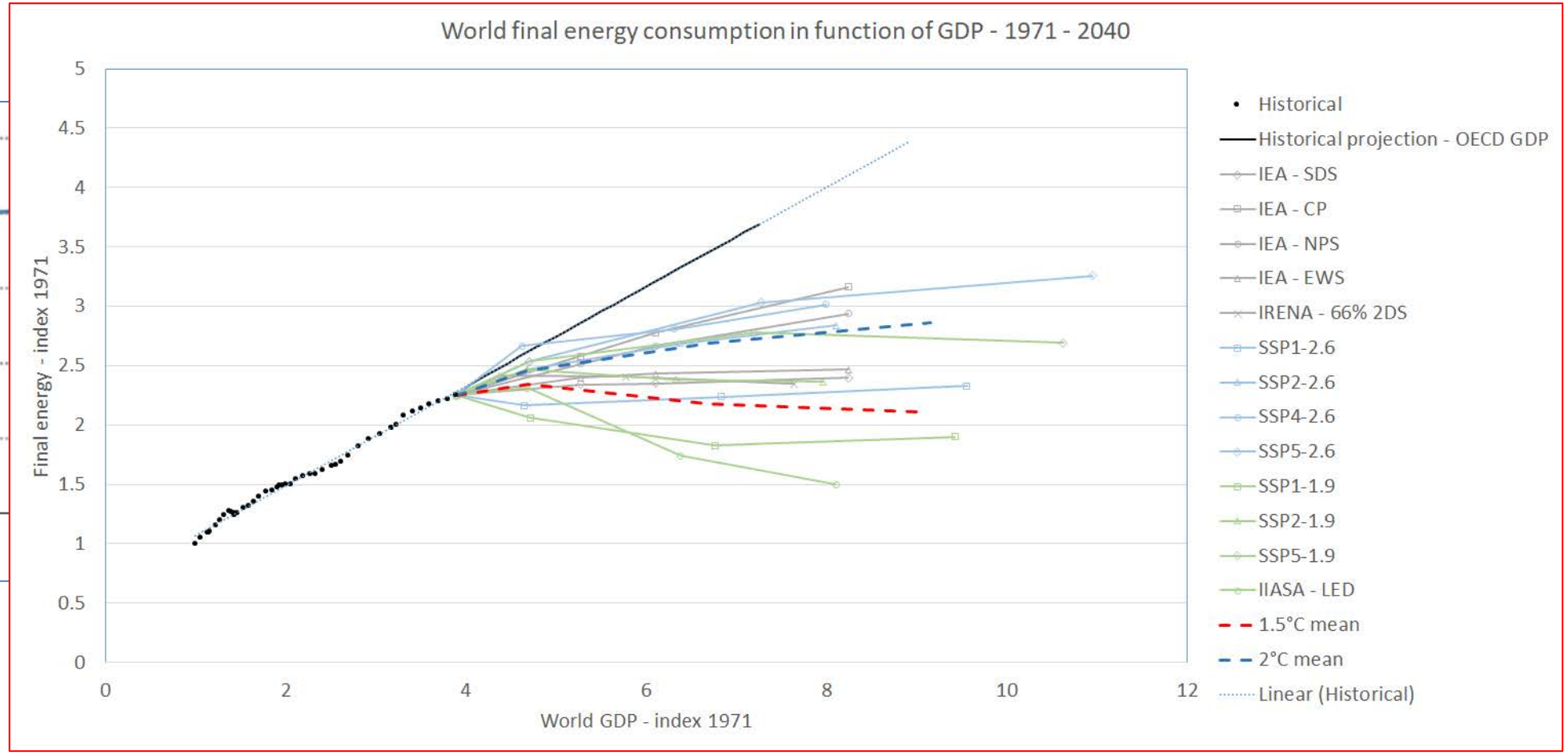
Meeting a 1.5'C Paris target





Source: Brockway et al. (2019), *draft results*

Energy-GDP decoupling

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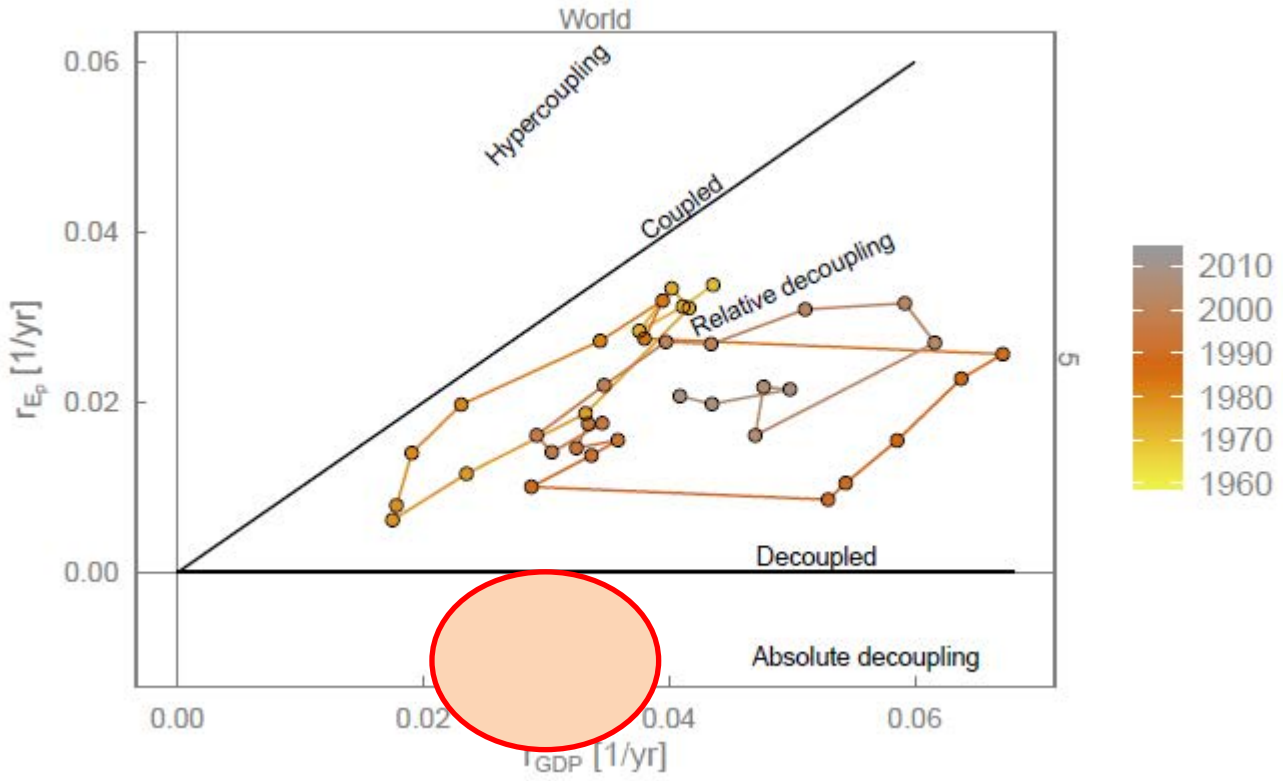
But: only RELATIVE global decoupling has occurred to date



Source: Heun & Brockway (2019), *Applied Energy*, Under review

Mainstream economic models bypass energy: assigning gap to TFP/MFP

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There is a backstory that is important to learn…

TECHNICAL CHANGE AND THE AGGREGATE PRODUCTION FUNCTION*

Robert M. Solow

IN this day of rationally designed econometric studies and super-input-output tables, it takes something more than the usual "willing suspension of disbelief" to talk seriously of the aggregate production function. But the aggregate production function is only a little less legitimate a concept than, say, the aggregate consumption function, and for some kinds of long-run macro-models it is almost as indispensable as the latter is for the short-run. As long as we insist on practicing macro-economics we shall need aggregate relationships.

draw some crude but useful conclusions from the results.

Theoretical Basis

I will first explain what I have in mind mathematically and then give a diagrammatic exposition. In this case the mathematics seems simpler. If Q represents output and K and L represent capital and labor inputs in "physical" units, then the aggregate production function can be written as:

$$Q = F(K,L;t). \quad (1)$$

3. Gross output per man hour doubled over the interval, with 87½ per cent of the increase attributable to technical change and the remaining 12½ per cent to increased use of capital.

The economics of energy analysis

Michael Webb and David Pearce

Energy analysis has assumed an apparent major importance in the planning of energy use. The authors argue that debates over the detailed aspects of energy analysis and its applications are misplaced in face of the absence of any real assessment of the purpose of energy analysis. They offer the view that energy analysis fails to achieve its stated purposes and that economic analysis already provides a rational base for planning energy use, making energy analysis either superfluous or misleading.

The object of this paper is a critical appraisal, from the economist's standpoint, of what appears now to be called energy analysis, but which has, at one time or another, been called energy budgeting, energy accounting and energy costing. The proliferation of articles on energy analysis and the fact that it has apparently been afforded serious attention in political circles and official documents,[1] are indications of the importance now attached to this technique. Remarkably, however, energy analysis has been subjected to only a minute amount of published criticism, although we are aware of extensive verbal criticism from many quarters. We seek to correct the balance as far as the published literature is concerned. While what we have to say is frequently critical in a purely negative sense, we hope that what we have to say will prompt energy analysts to define in a rigorous fashion the real uses of their studies.

Sources: Solow(1957) , Webb & Pearce (1975)

Mainstream economic models bypass energy: assigning gap to TFP/MFP

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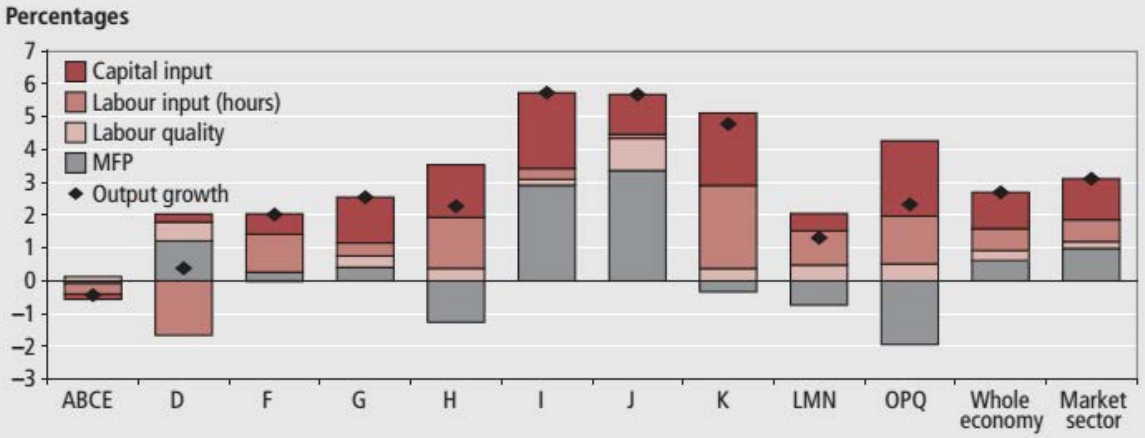
Even though their models only explain a minority of economic growth…

ARTICLE

Katy Long and Mark Franklin
Office for National Statistics

Multi–factor productivity: estimates for 1994 to 2008

Figure 2
Decomposition of annual average output growth, 1995–2008



Source: Long & Franklin (2010)

Recent slowdown in global GDP growth: this leaves few mainstream candidates

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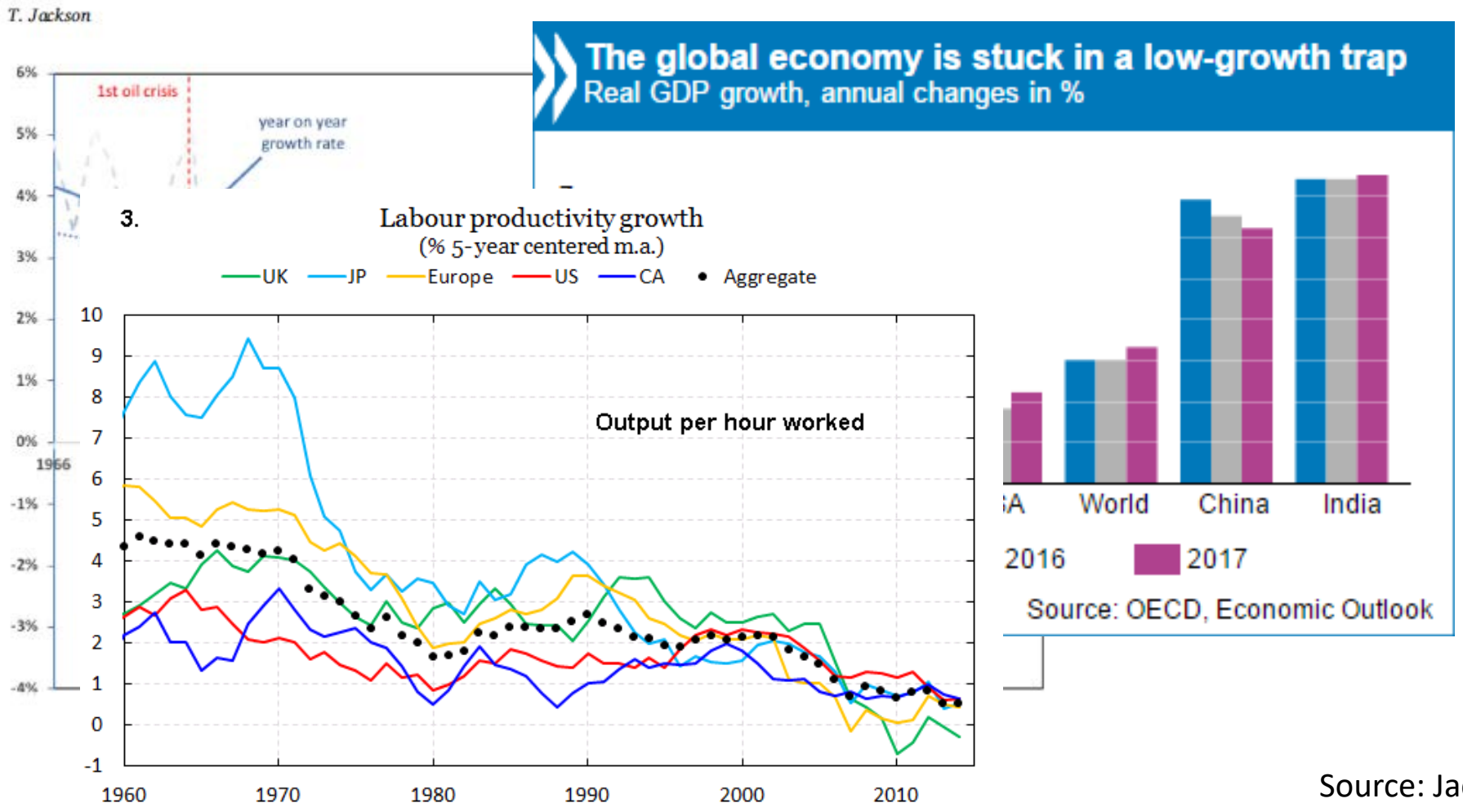
Many economists see labour productivity as the cause & thus solution



Source: Jackson (2019)

But what if the ‘productivity puzzle’ were due to energetic constraints?

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Maybe we’re missing the role of energy

So maybe we should include energy (and materials) into economic models?

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Biophysical economics makes sense in the real world

Neo-classical pizza: cooks (labour) + ovens (capital)

Biophysical pizza: cooks (labour) + ovens (capital) + ingredients (materials) + electricity (energy)

https://cdn.washingtoncitypaper.com/files/base/scomm/wcp/image/2010/06/640w/_dev_pubsys_images_1277931188_m_y_h_1.jpg

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Potential constraint #1: slowing thermodynamic efficiency gains

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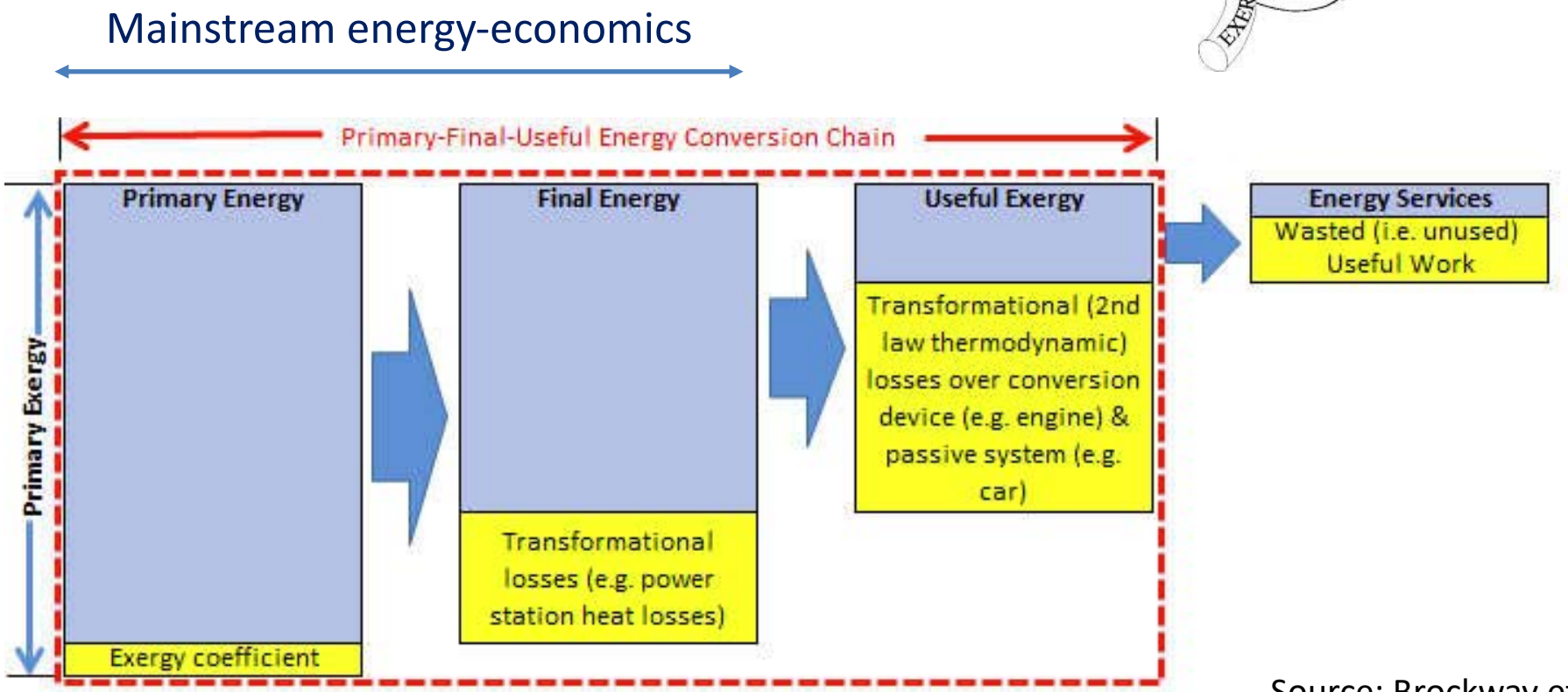
Exergy as a thermodynamically-consistent approach to energy analysis

Exergy is available energy, i.e. the energy available to undergo physical work. It is essentially a thermodynamic measure of energy quality.



Source: Brockway et al. (2015)

Primary-to-final-to-useful energy conversion

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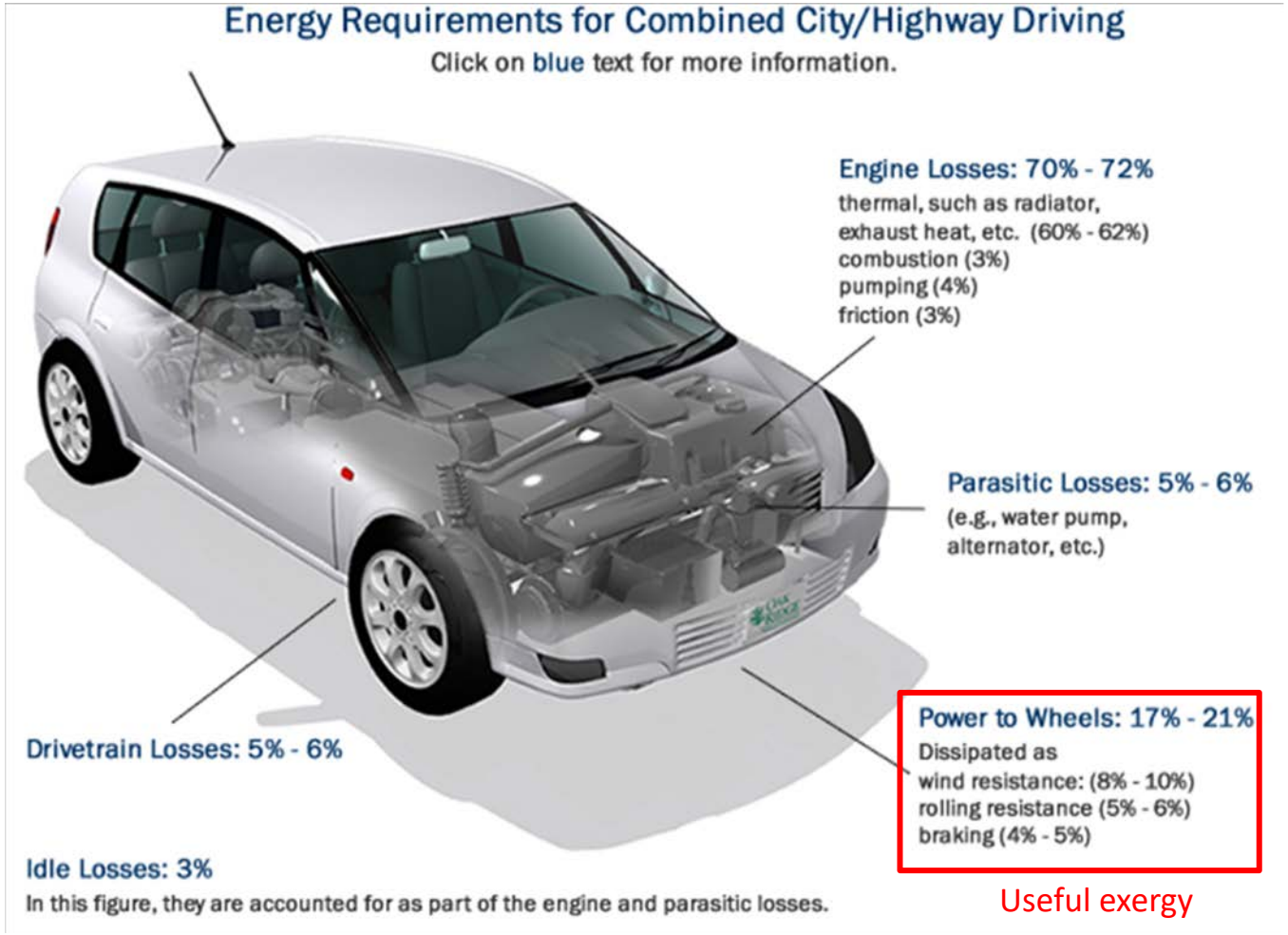
Example of a car:



Useful exergy

Some good news: more granular, economy-wide p-f-u exergy data exists

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So we can do some cool stuff, and maybe bypass mainstream economists…

Fig. 3. The global map of energy conversion efficiency.

Source: Cullen & Allwood (2010)

That means we can test the inclusion of useful exergy as input to production

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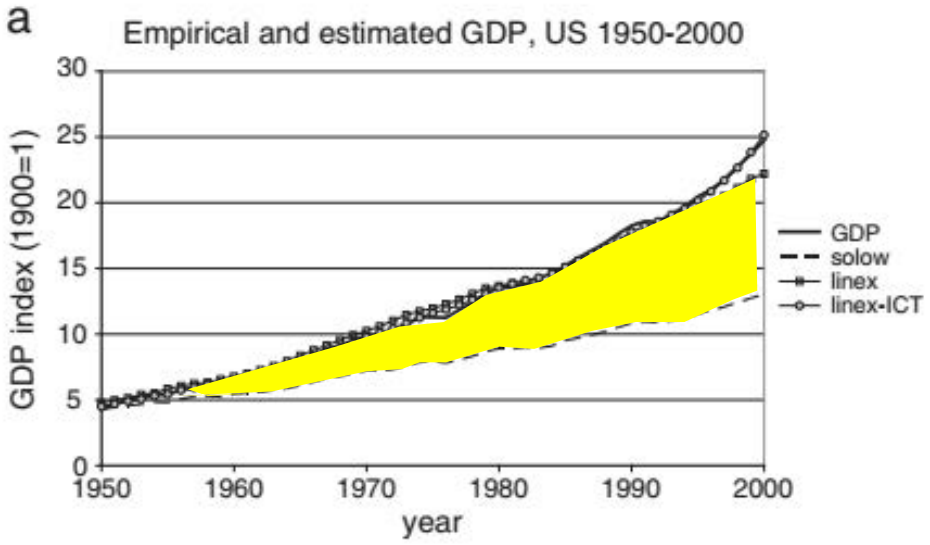
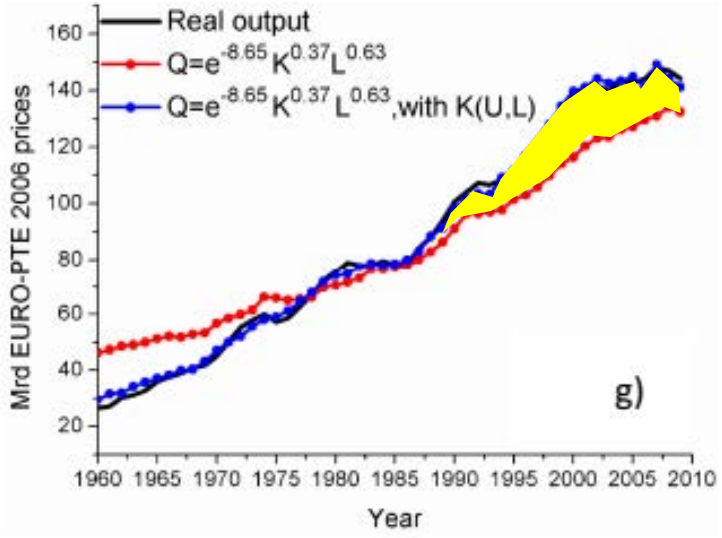
Useful exergy (U) in aggregate production functions Y = f (K,L,U)





Sources: Warr & Ayres (2012); Santos J et al (2016)

But could it also explain (at least OECD) secular stagnation?

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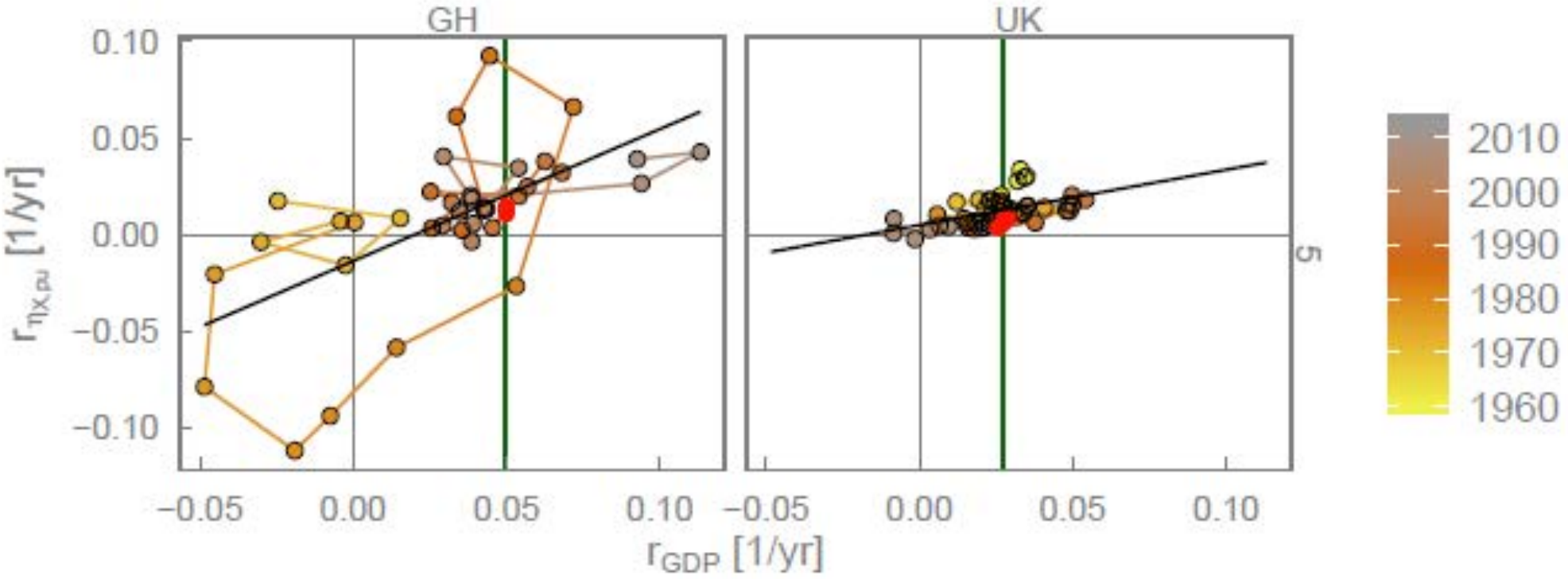
Thermodynamic final-to-useful efficiency gains are linked to GDP gains



Source: Heun & Brockway (2019), *Applied Energy*

But could it also explain (at least OECD) secular stagnation?

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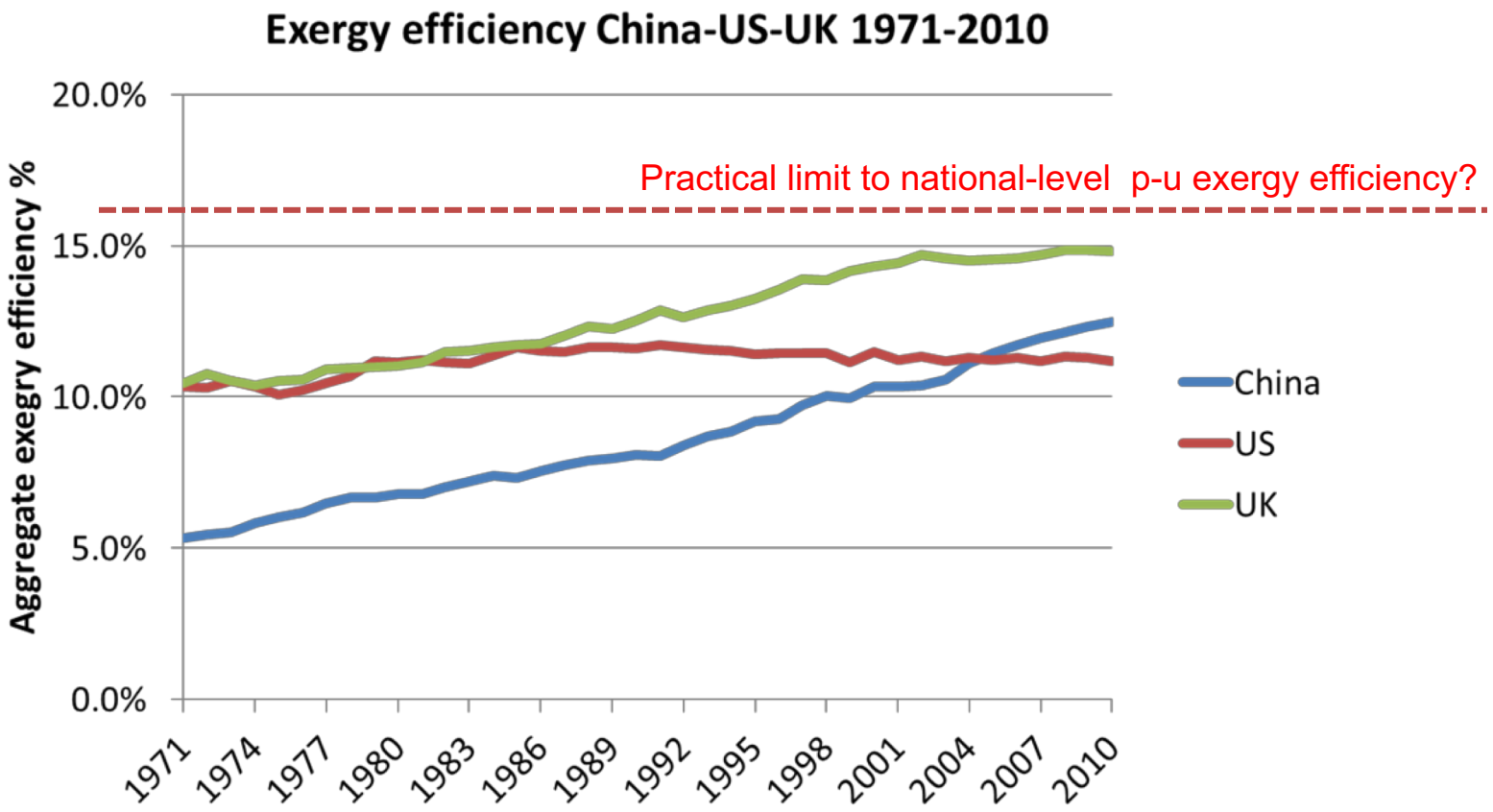
So maybe slowing efficiency might explain slowing economic growth?



Sources: Brockway et al (2014); Brockway et al (2015)

Ok, lets test this idea in an energy-economy model

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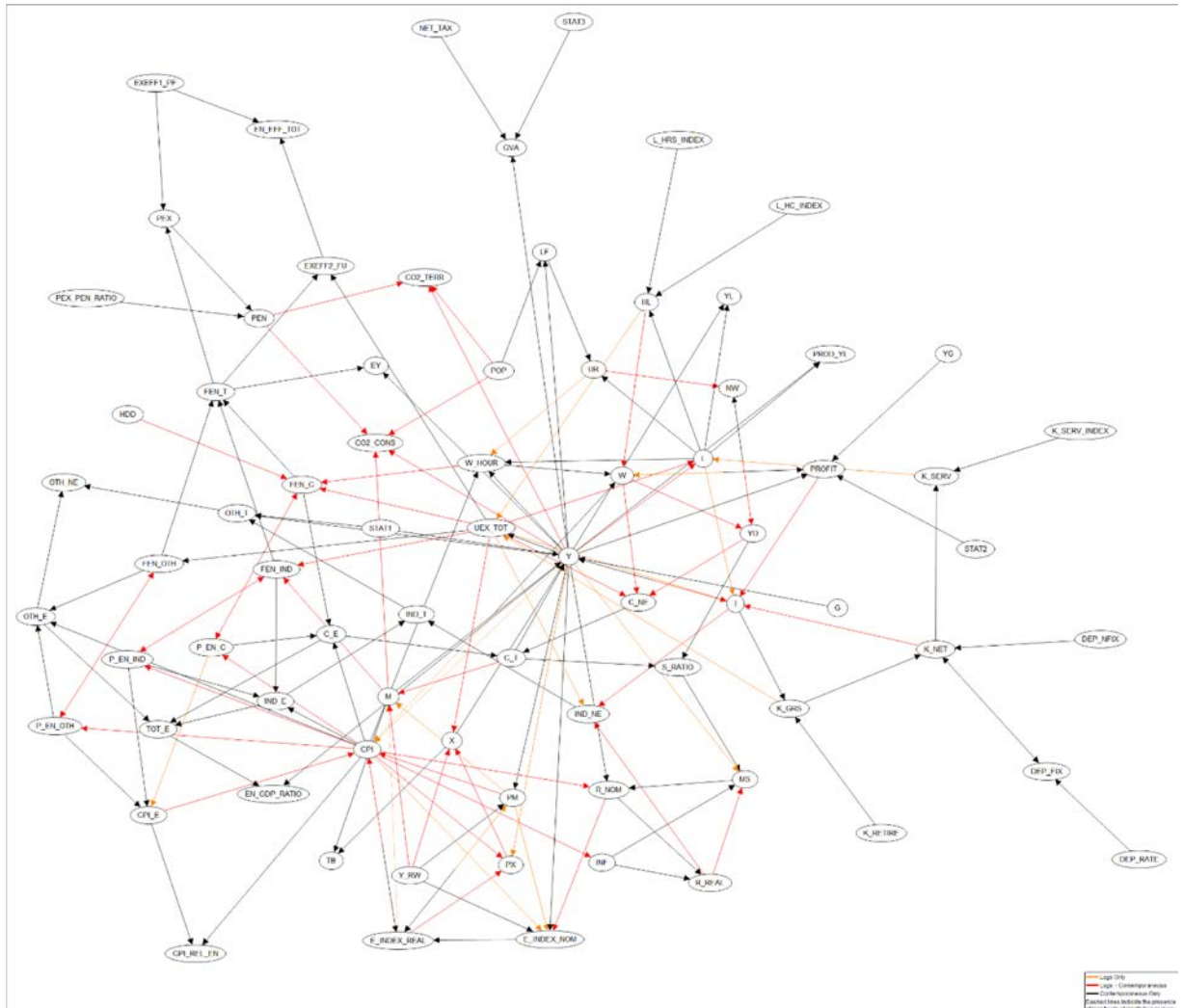
MARCO-UK = UK MAcroeconometric Resource COnsumption model



High level outline of the MARCO-UK model

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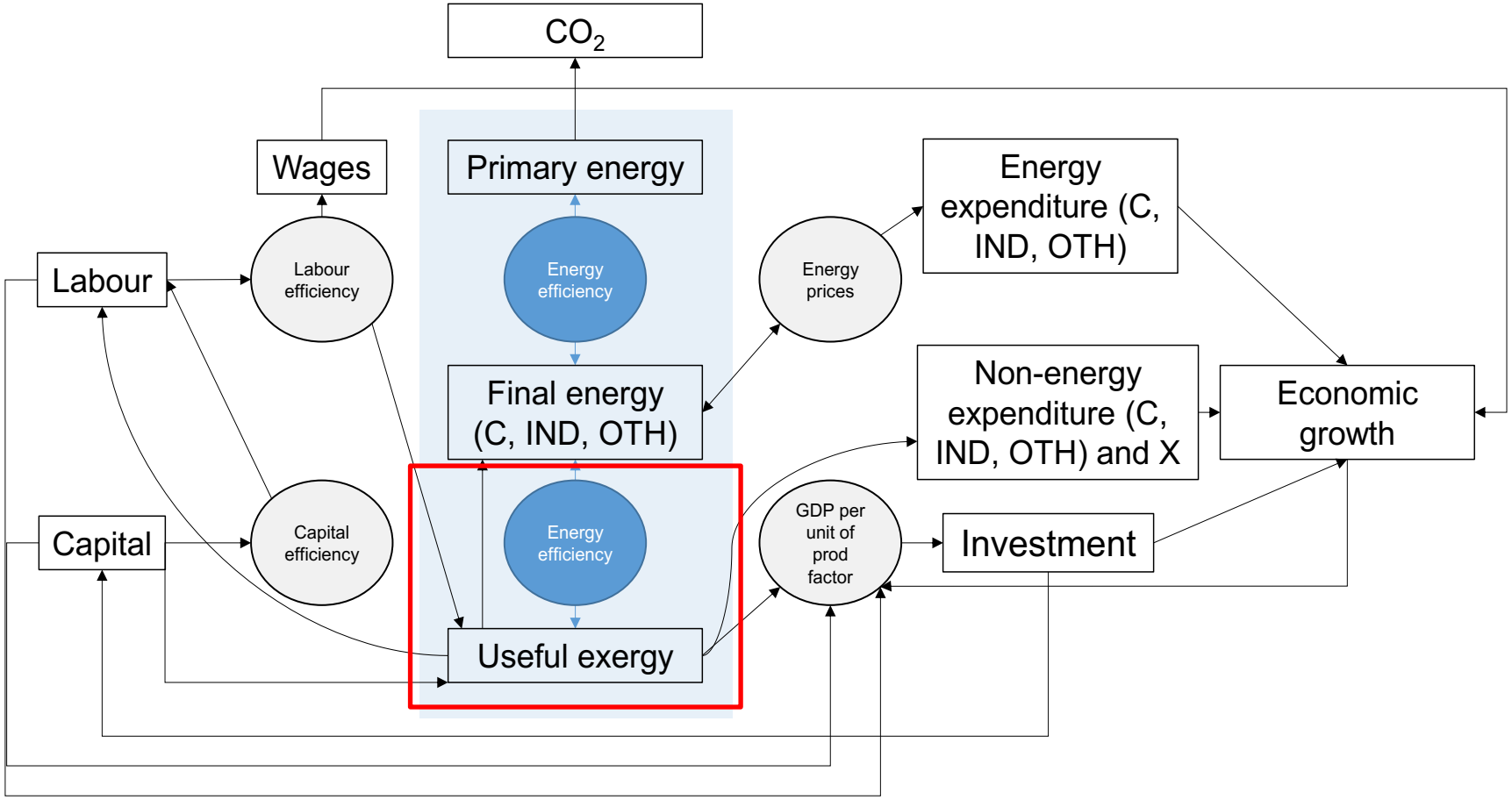
Integrating useful exergy and exergy efficiency into MARCO-UK



Source: Sakai et al. (2019)

Insight 1 - Quarter of UK economic growth from thermodynamic efficiency gains

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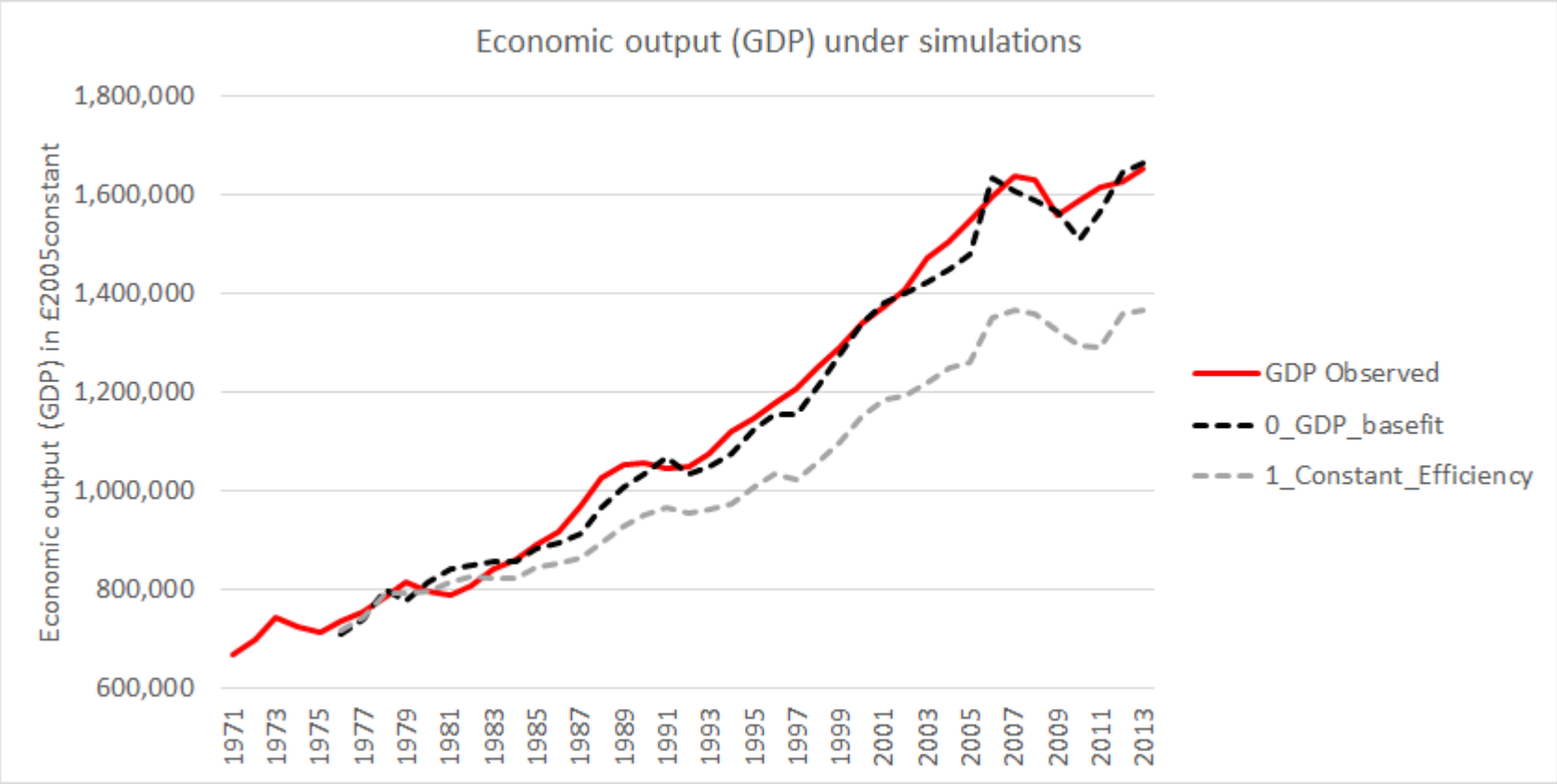
Thus efficiency gains have a key role in economic growth



Source: Sakai et al. (2019)

Insight 2: The efficiency-led growth mechanism

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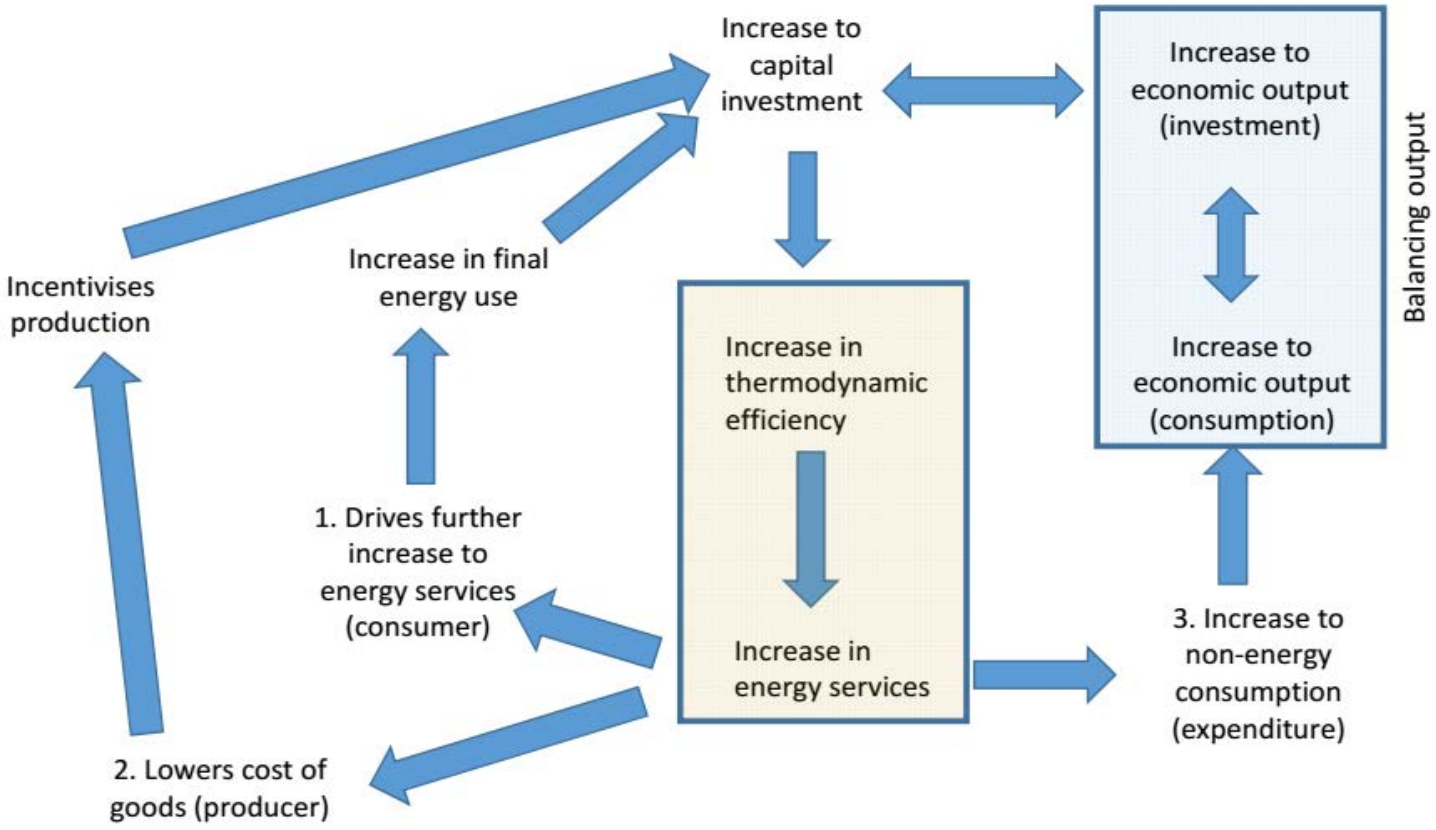
Three strands of energy rebound / feedback



Source: Sakai et al. (2019)

Insight 3: Labour has much less effect on the economy (than mainstream models)

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Capital (Y/K) vs labour (Y/L) productivity

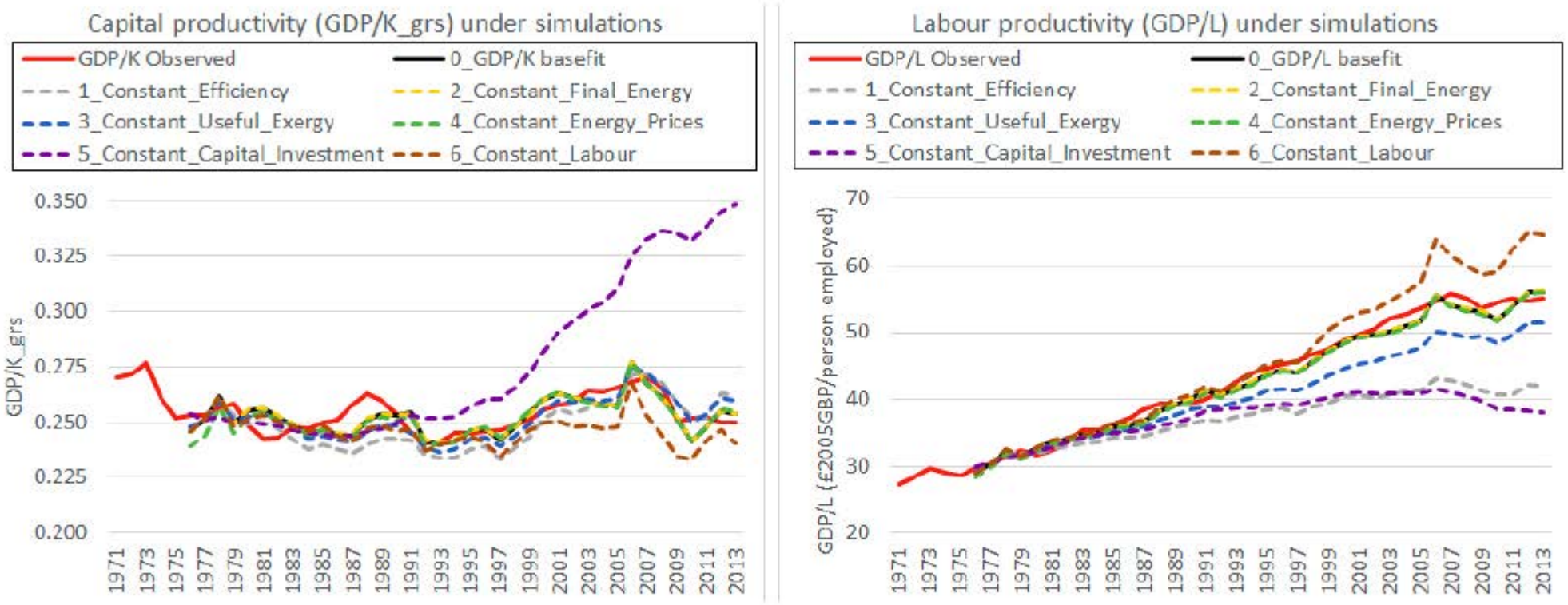

Figure 5. Capital and labour productivity under simulations.

Source: Sakai et al. (2019)

Insight 4: Meeting final energy targets will constrain economic growth

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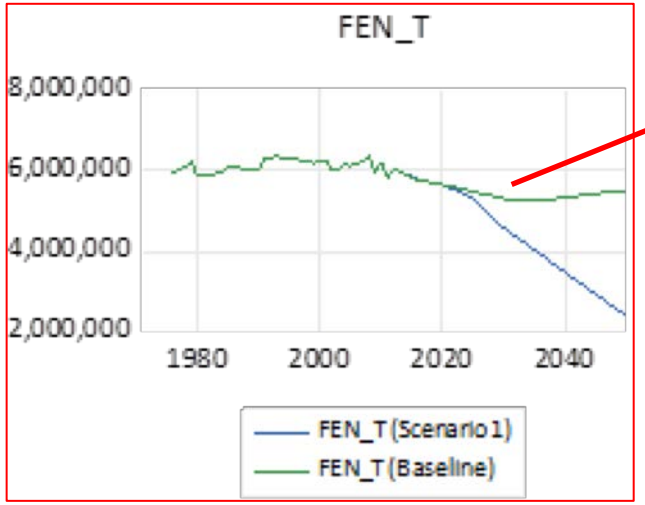
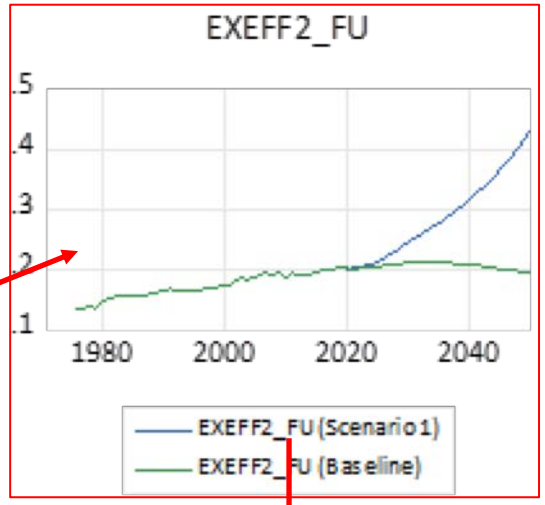
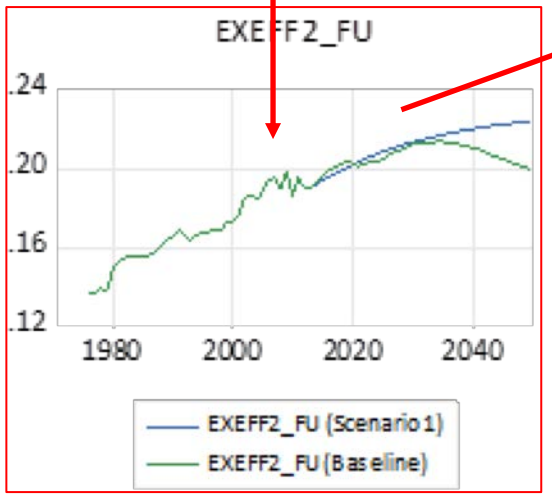
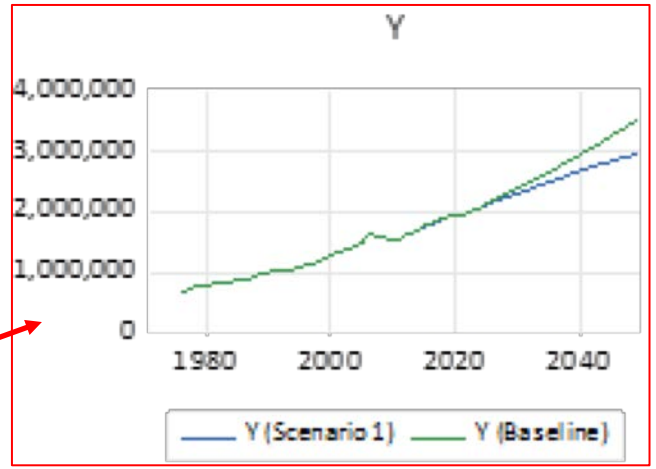
So, we may face a choice : shall we meet climate or economy goals?









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Potential constraint #2: Net energy / energy return on investment (EROI)

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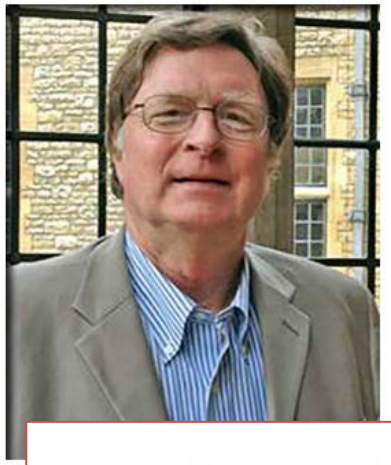
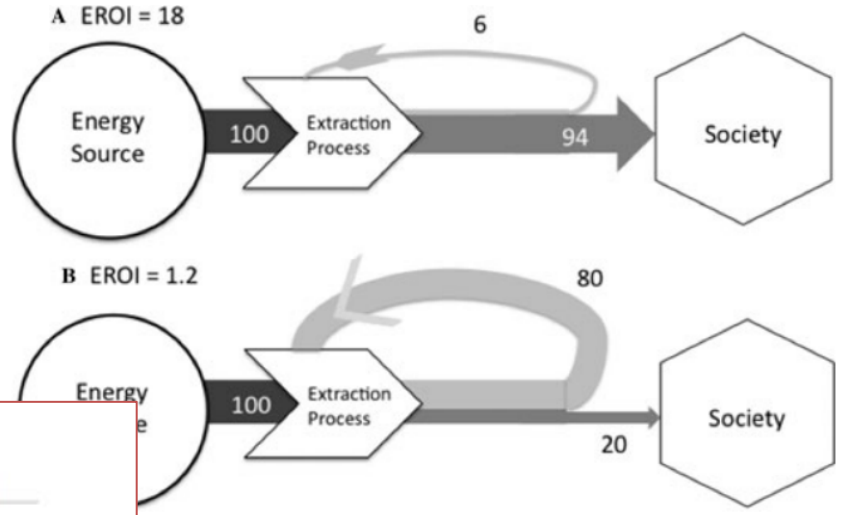
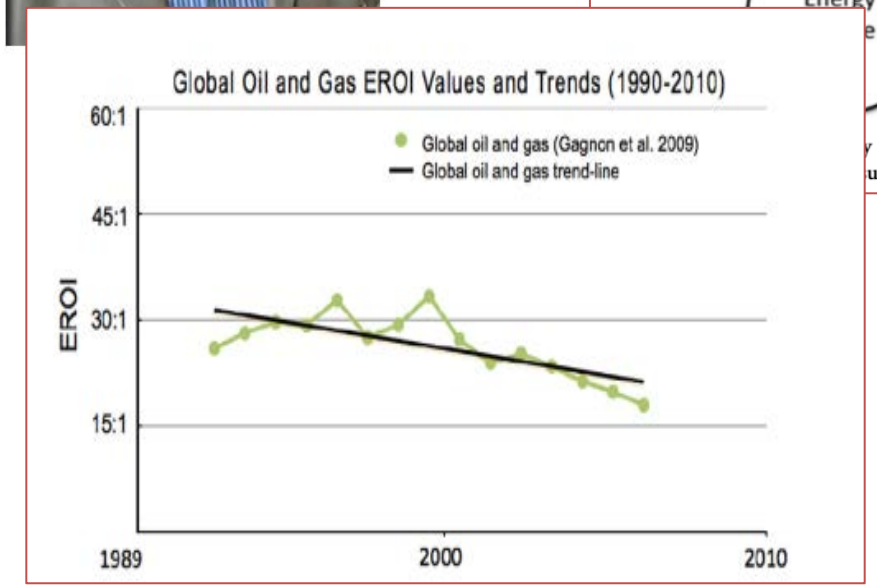
‘Declining EROI’ flag has been flown (along with ‘peak oil’) for decades





y from the point of extraction to society accounting for the energy cost of extraction. Values were uming 100 units are extracted at an EROI of 18 for A and 1.2 for B.



Sources: Hall et al (2014), Murphy & Hall (2011)

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Breaking into the data-modelling-policy chain - DATA

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There is little appetite for restarting national useful energy data collection

USEFUL ENERGY BALANCE SHEETS 1980
Supplement to *Energy statistics yearbook*

BILANS DE L'ÉNERGIE UTILE 1980
Supplément à l'*Annuaire des statistiques de l'énergie*

One of the advantages of a useful energy balance sheet is that it reveals the energy losses which occur all along the line from primary input to offtake through the final consumer's appliances. The losses thus recorded fall into four categories:

Department for Business, Energy & Industrial Strategy

DIGEST OF UNITED KINGDOM ENERGY STATISTICS 2017

Final consumption - useful energy basis

1.50 Thirdly, final consumption may be expressed in the form of useful energy available after deduction of the losses incurred when final users convert energy supplied into space or process heat, motive power or light. Such losses depend on the type and quality of fuel and the equipment used and on the purpose, conditions, duration and intensity of use. Statistics on useful energy are not sufficiently reliable to be given in this Digest; there is a lack of data on utilisation efficiencies and on the purposes for which fuels are used.

Breaking into the data-modelling-policy chain - MODELLING

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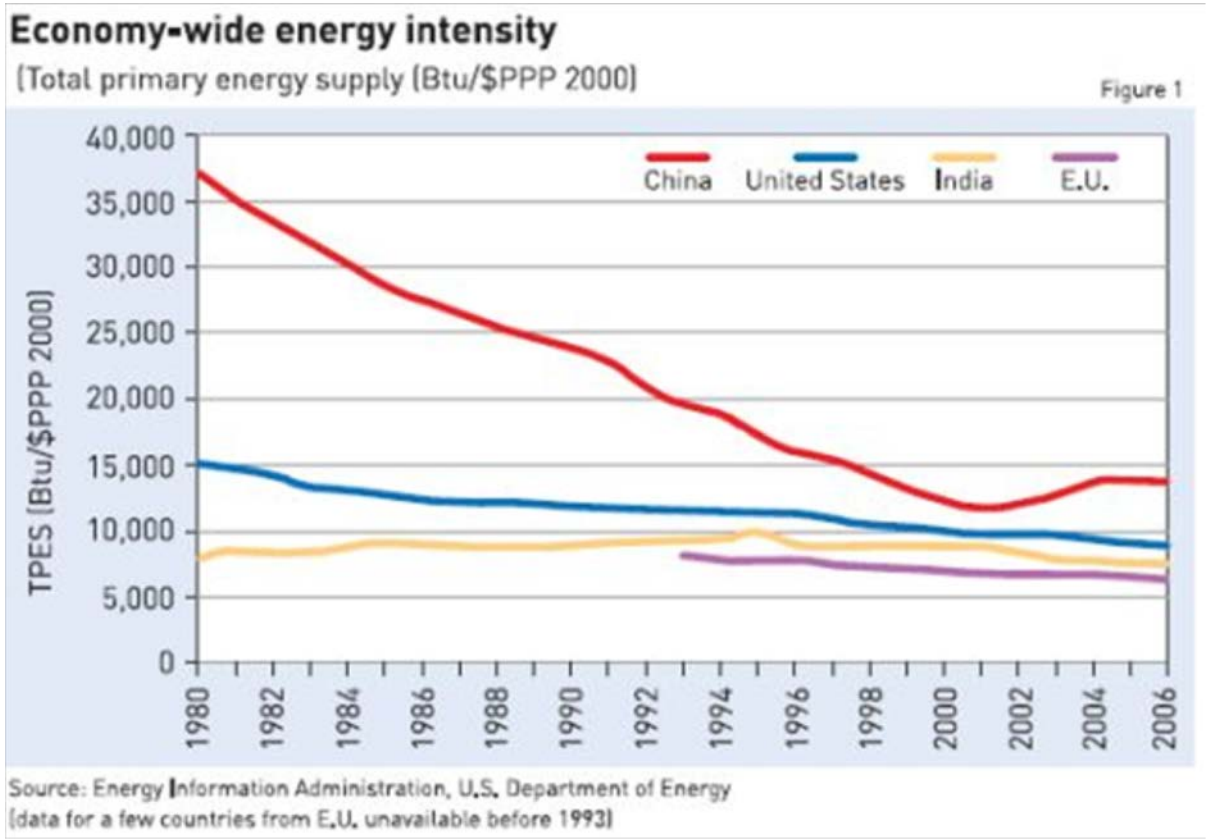
EROI and primary-final-useful exergy stages are NOT in mainstream models



Economic intensity is a long way from thermodynamic (energy) conversion efficiency

<u>Mainstream modelling</u>

"I don't know a whole load about exergy but for TIMES I guess we'd really want to understand what this brings us which we don't get already.

Prima facie, seems like any exergy conversion factors involve a whole load more modelling and assumptions than we already have. Given the highly speculative nature of TIMES in (say) 2060, not sure how helpful this would be".

Breaking into the data-modelling-policy chain – POLICY-MAKERS

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Opening this door might pull data and modelling along too

Policy-makers are looking for answers for the productivity puzzle. So they are more open to looking for alternative explanations and ideas.

There is growing appetite at Dept for Business, Energy and Industrial Strategy (BEIS) with regard to

- The inclusion of useful exergy in models,
- The role of f-u efficiency and EROI in economic growth

There are also a growing number of key influencers, that are listened to by government policy makers. These include:

- Michael Kumhof, Bank of England
- Gael Giraud, AFD

So, now is the time to be optimistic about a biophysical approach breaking into the mainstream data-modelling-policy chain. But we also have to get our own energy house in order

Thanks for listening!

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Visit our exergy economics website:

- https://exergyeconomics.wordpress.com/

Follow my decoupling project:

- https://www.researchgate.net/project/Applying-thermodynamic-laws-to-the-energy-GDP-decoupling-problem

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