School of Earth & Environment
FACULTY OF ENVIRONMENT

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More tools in the policy box: Can exergy analysis give new insights on energy use and rebound?

Dr Paul Brockway p.e.brockway@leeds.ac.uk

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UKERC
UK Energy Research Centre

Can exergy analysis give new insights to energy use and rebound?

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1. **The issue: climate mitigation and thermodynamic failings of mainstream energy economics**
2. **An alternative approach: using exergy analysis to study economy-wide energy use and rebound**

The problem: the need to reduce carbon emissions

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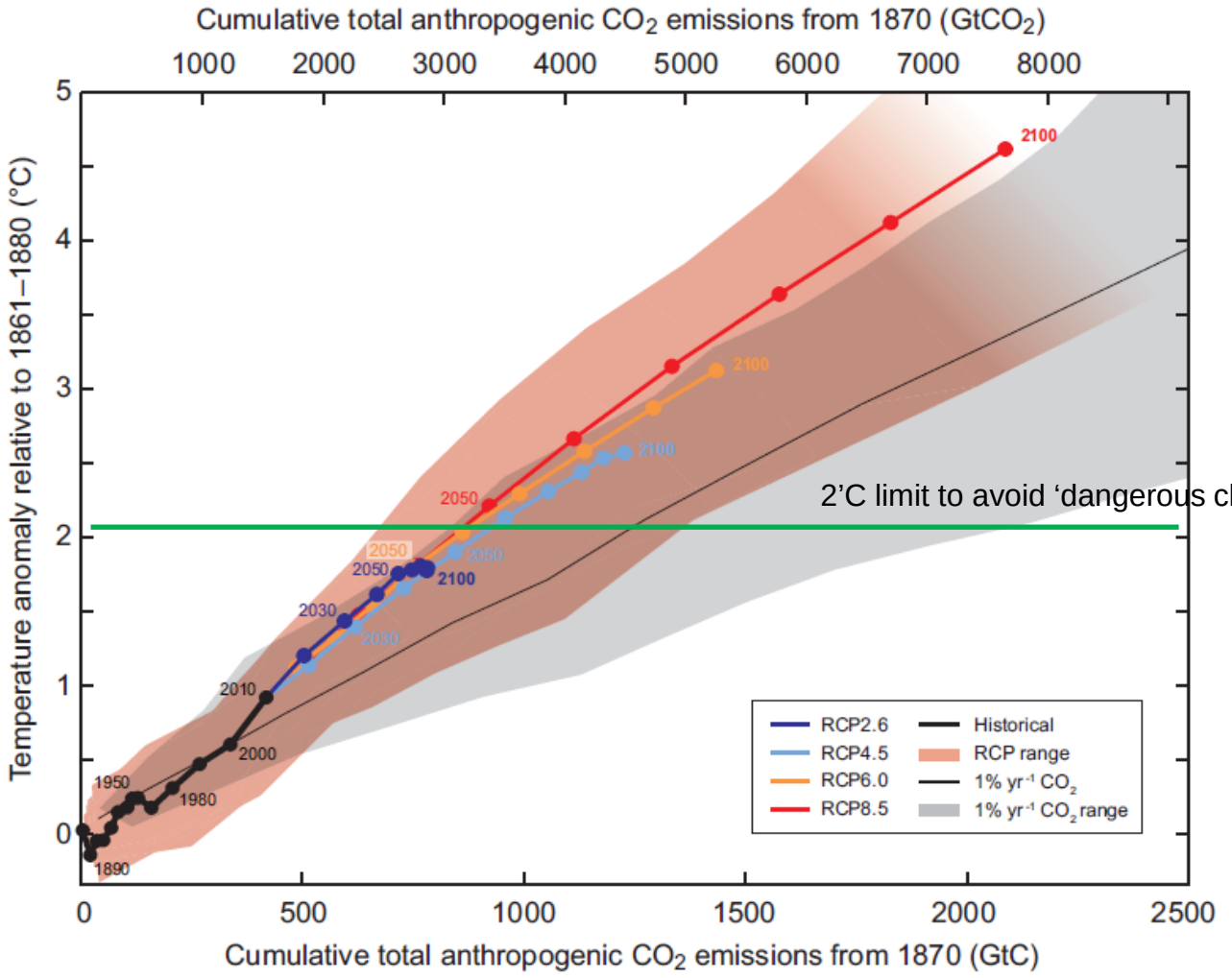

2’C limit to avoid ‘dangerous climate change’

The ‘solution’: 1. energy reduction and 2. decarbonisation

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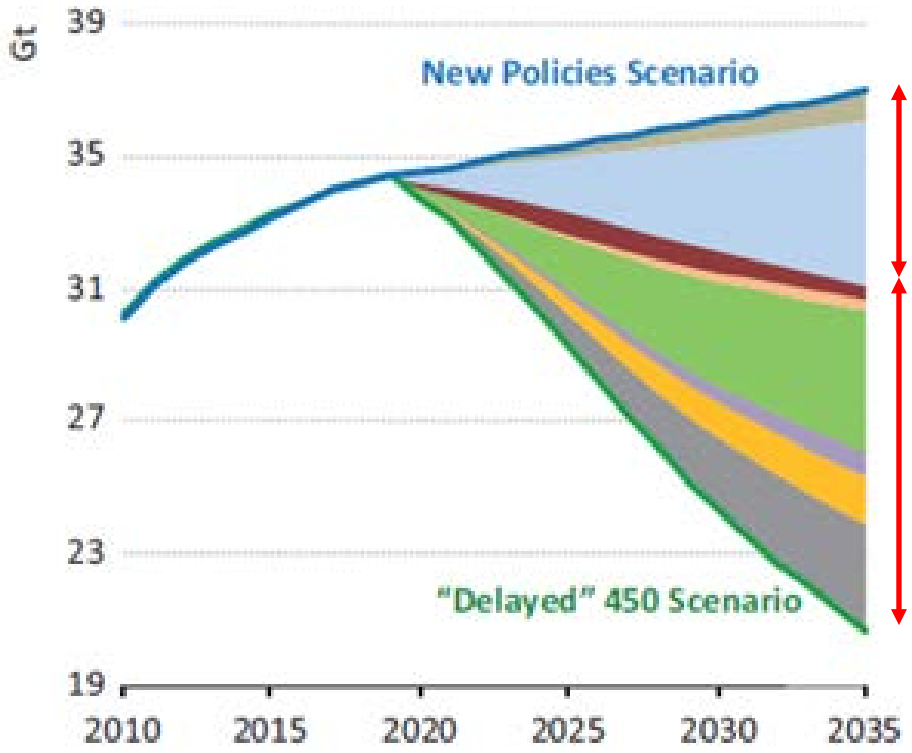

CO_2 Abatement	2025	2035
Demand	5%	5%
End-use efficiency	27%	31%
Power plant efficiency	11%	3%
Fuel and technology switch	2%	2%
Renewables	25%	26%
Biofuels	5%	5%
Nuclear	9%	9%
CCS	15%	20%
Total (Gt CO_2)	**6.2**	**16.4**

Thermodynamic failings of mainstream energy economics

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Key energy questions remain unanswered in relation to wedge #1 (energy reduction):

1. How should we measure energy efficiency?
2. How large is the energy rebound effect?
3. How much energy will we need in the future?

Can exergy analysis give new insights to energy use and rebound?

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1. **The issue: climate mitigation and thermodynamic failings of mainstream energy economics**
2. **An alternative approach: using exergy analysis to study economy-wide energy use and rebound**
   - **Qu. 1: Energy (exergy) efficiency**
   - **Qu. 2: Energy rebound**
   - **Qu. 3: Future energy demand**

An alternative approach: Thermodynamic based exergy efficiency

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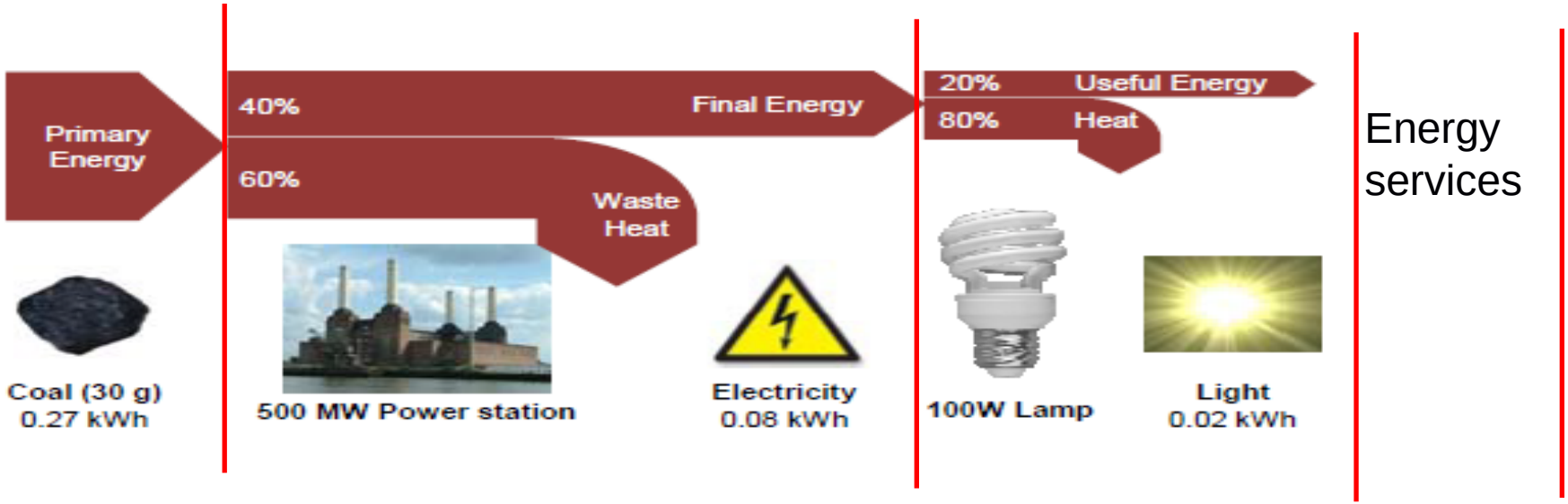
Exergy is the usable part of energy

Useful exergy is the minimum exergy input to achieve task work transfer:



Courtesy of T. Domingos, IST, Lisbon

Exergy analysis@ national-level

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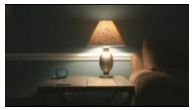
Direct heat


Electricity




Transport


Manual Labour

Exergy analysis: methodology at national-scale

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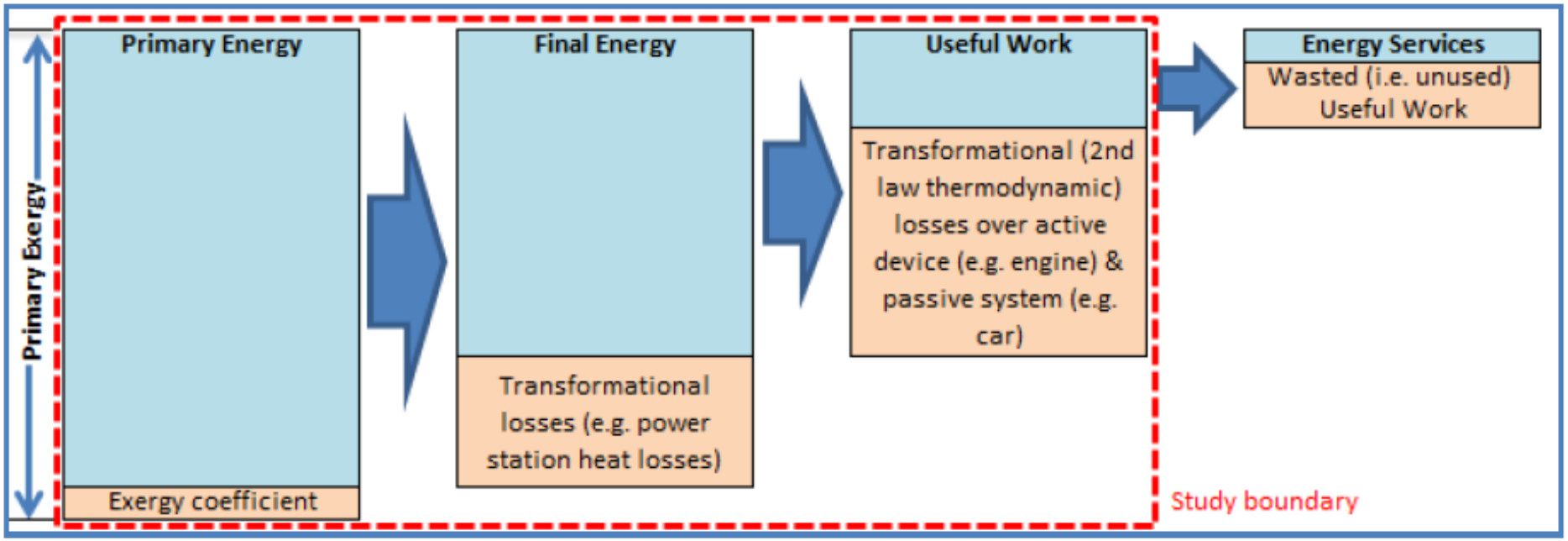

Exergy analysis: methodology at national-scale

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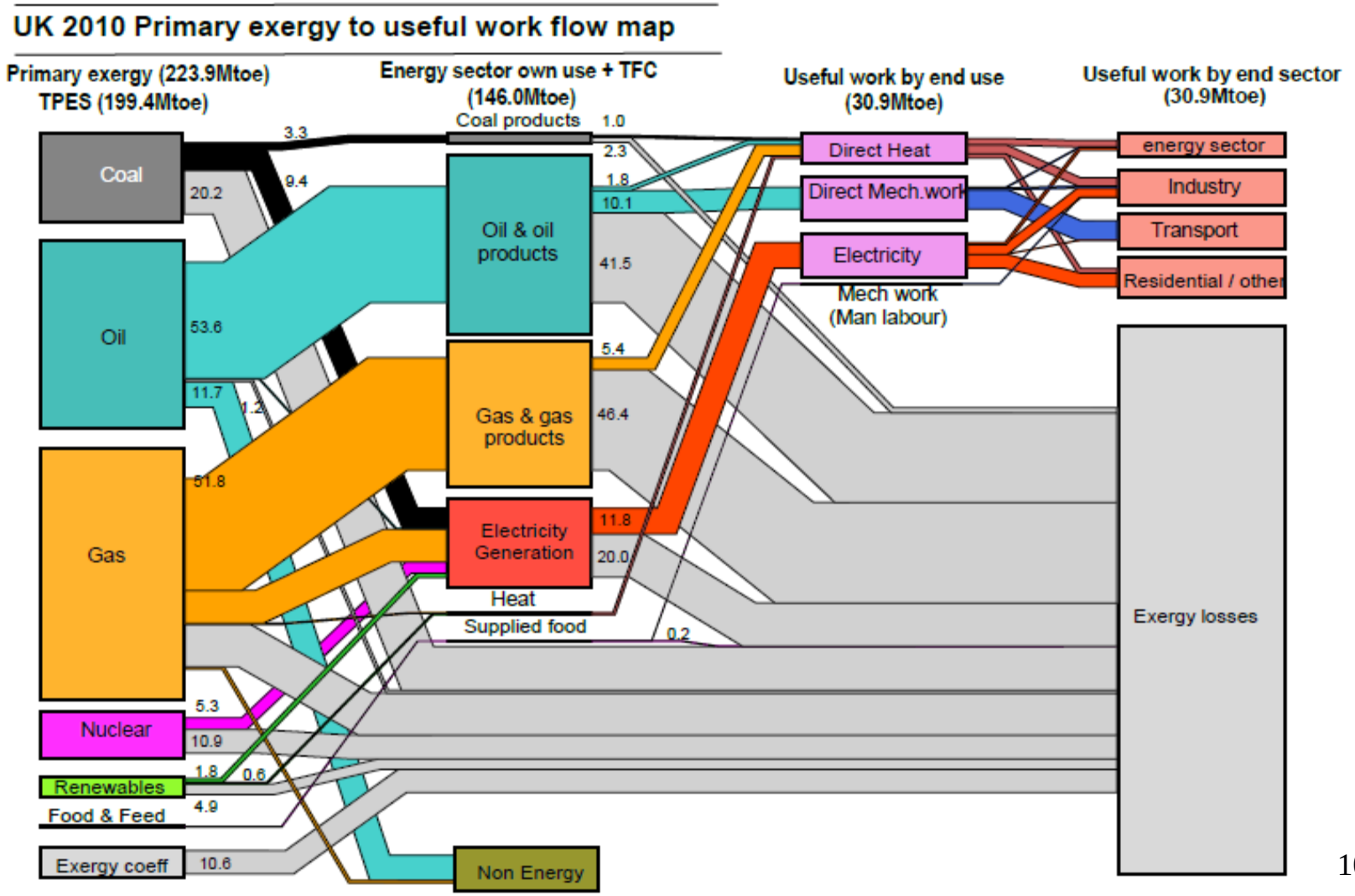

Qu. 1: National-level energy efficiency: 15% ceiling due to efficiency dilution

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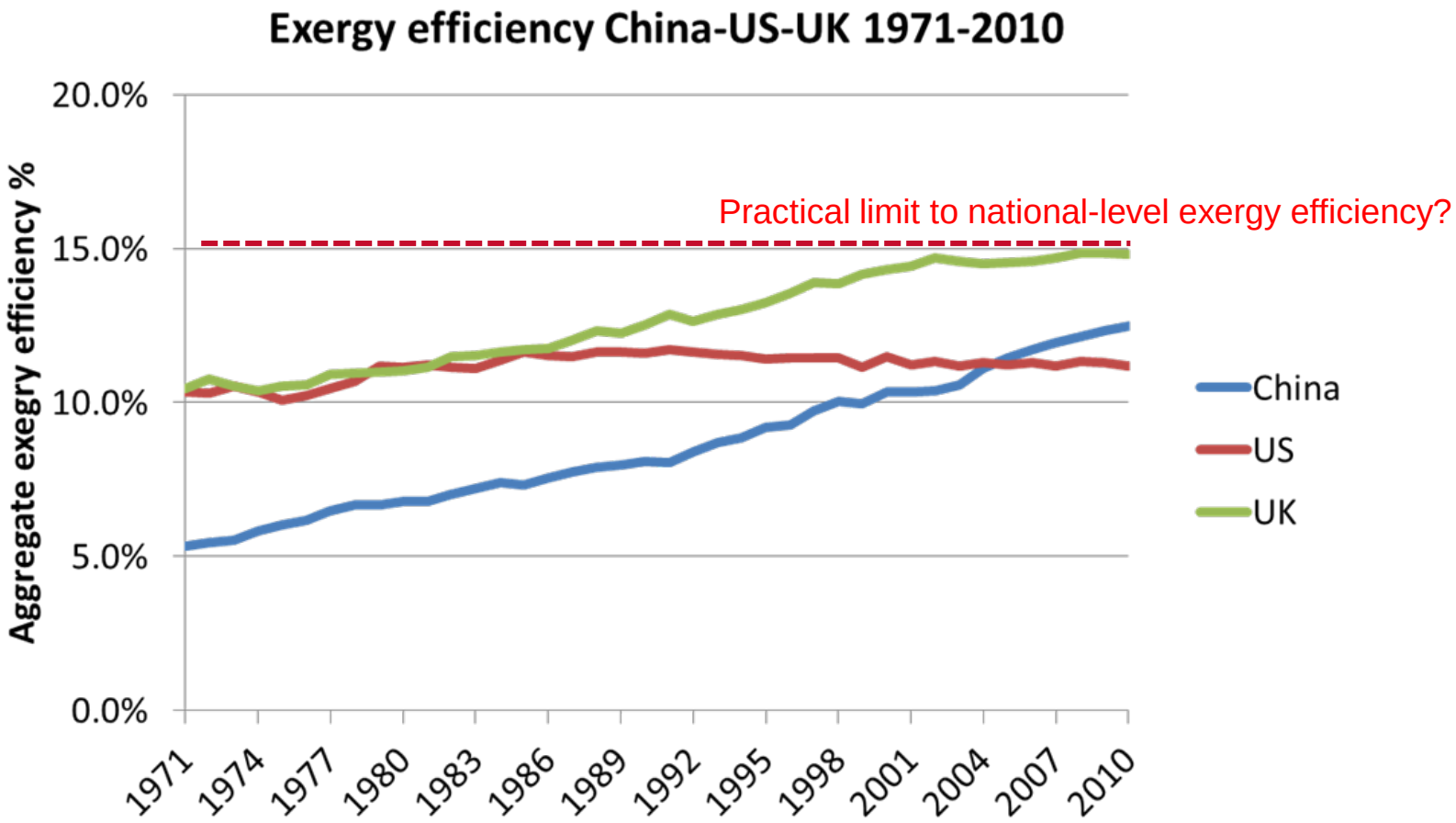

US-UK data from Brockway, P. et al (2014) *Divergence of trends in US and UK aggregate exergy efficiencies 1960-2010*, Environ. Sci. Technol. 48, pp.9874−9881

Qu. 2: Energy rebound: missing from energy models and energy policy

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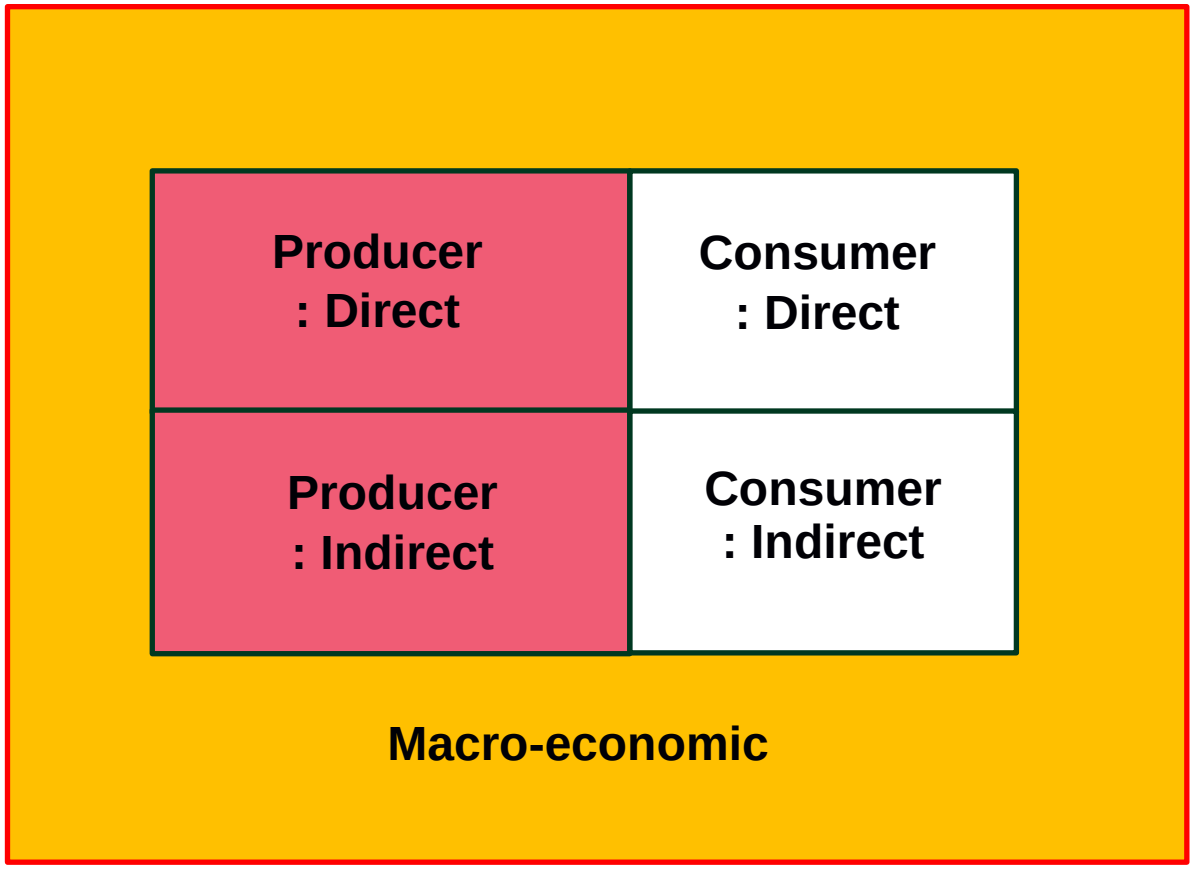

Components of energy rebound

Qu. 2: Energy rebound – exergy approach may unlock new rebound insights

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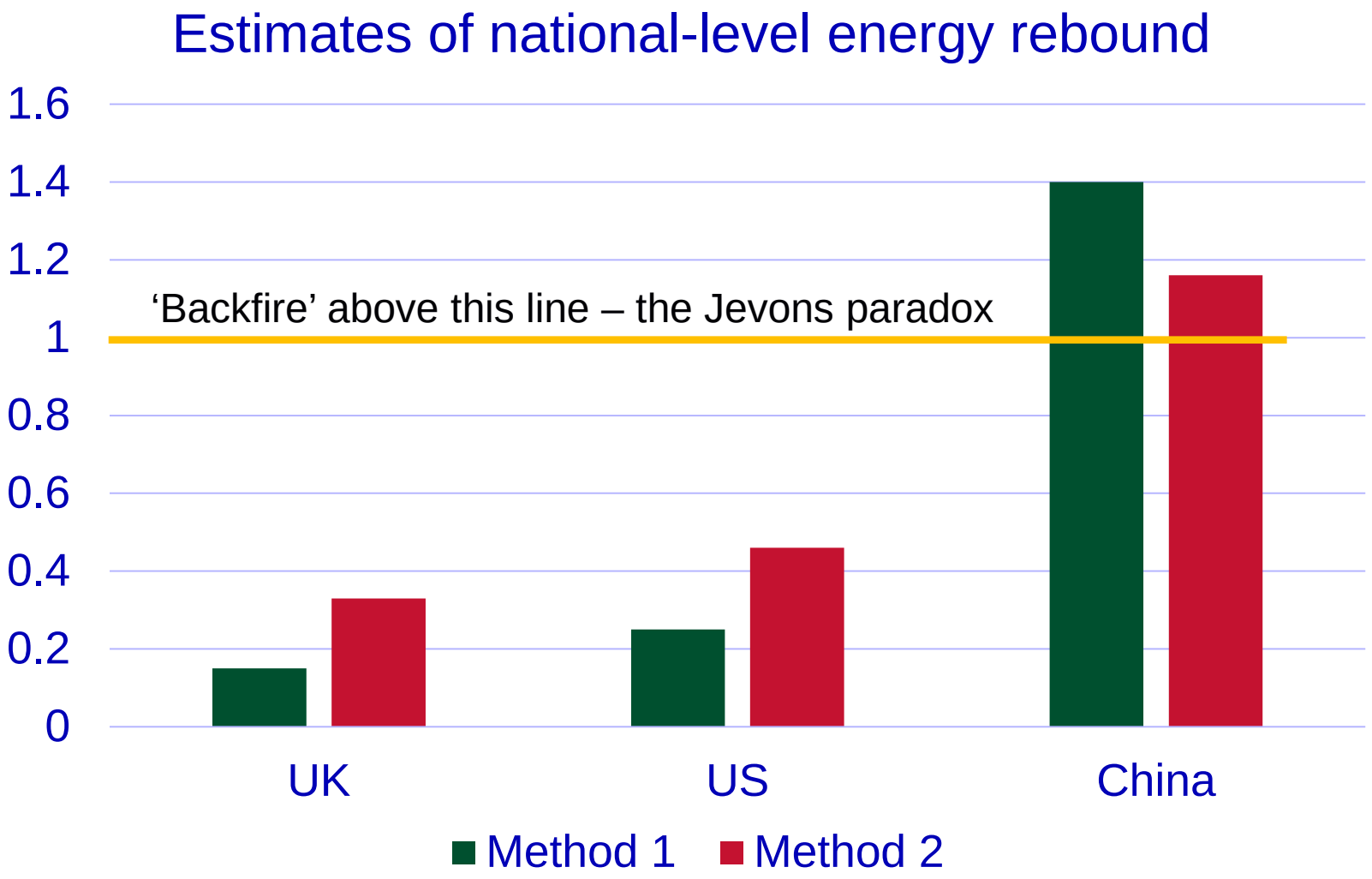

Qu. 3 – future energy forecasts: insights from exergy analysis

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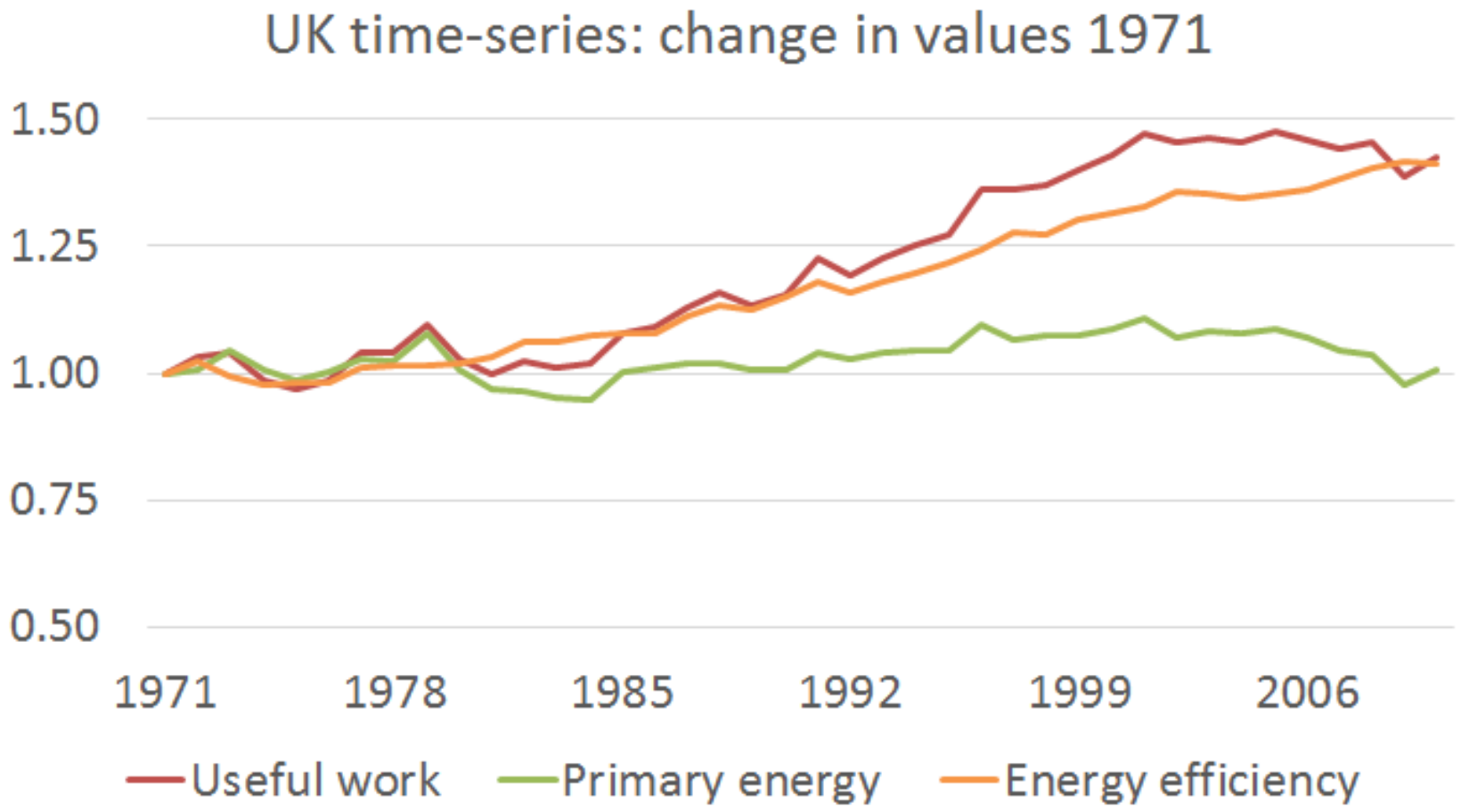

Qu. 3 – primary energy scenarios using exergy approach

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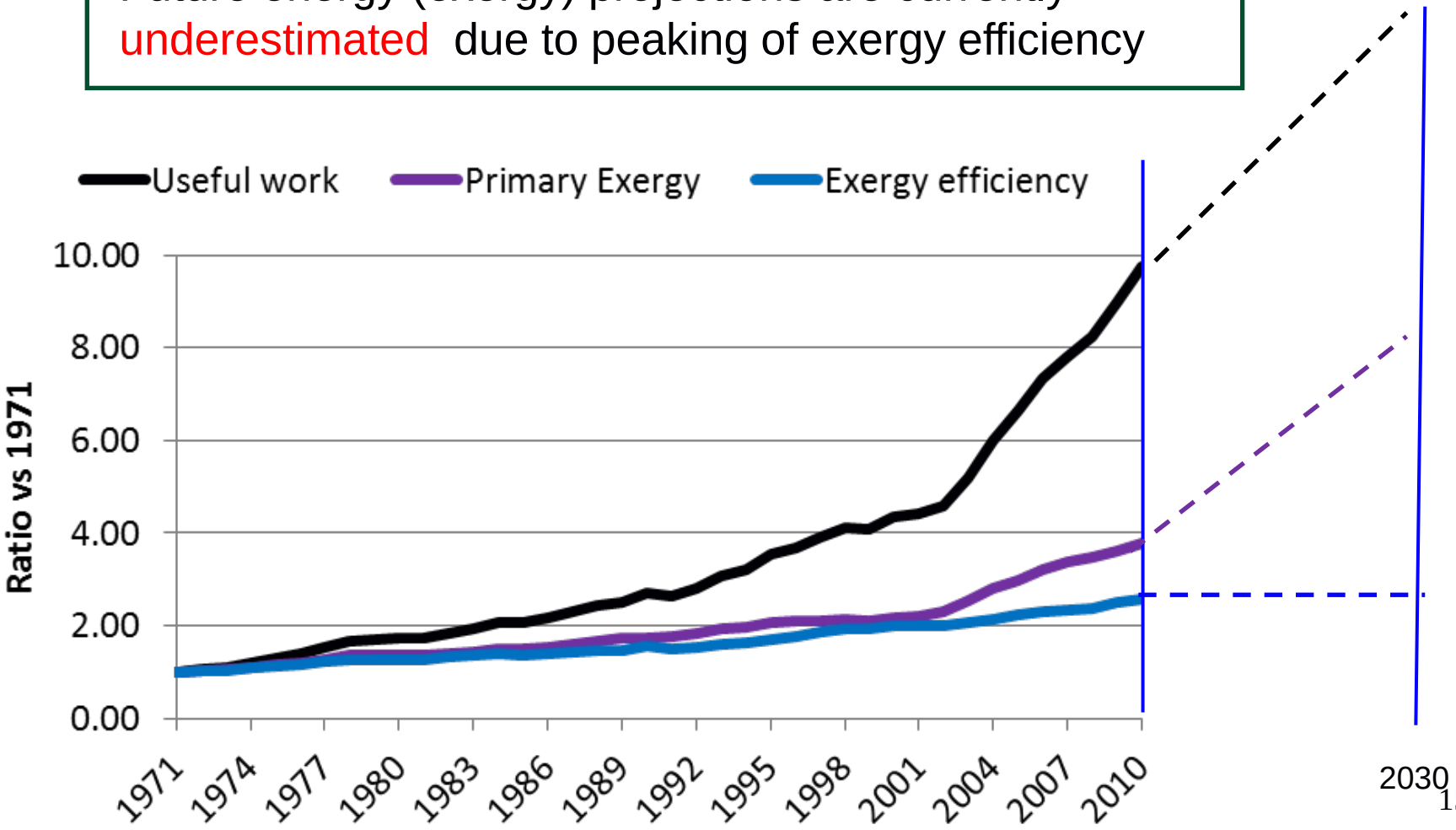
Future energy (exergy) projections are currently underestimated due to peaking of exergy efficiency



Qu. 3 – primary energy scenarios using exergy approach: results for China

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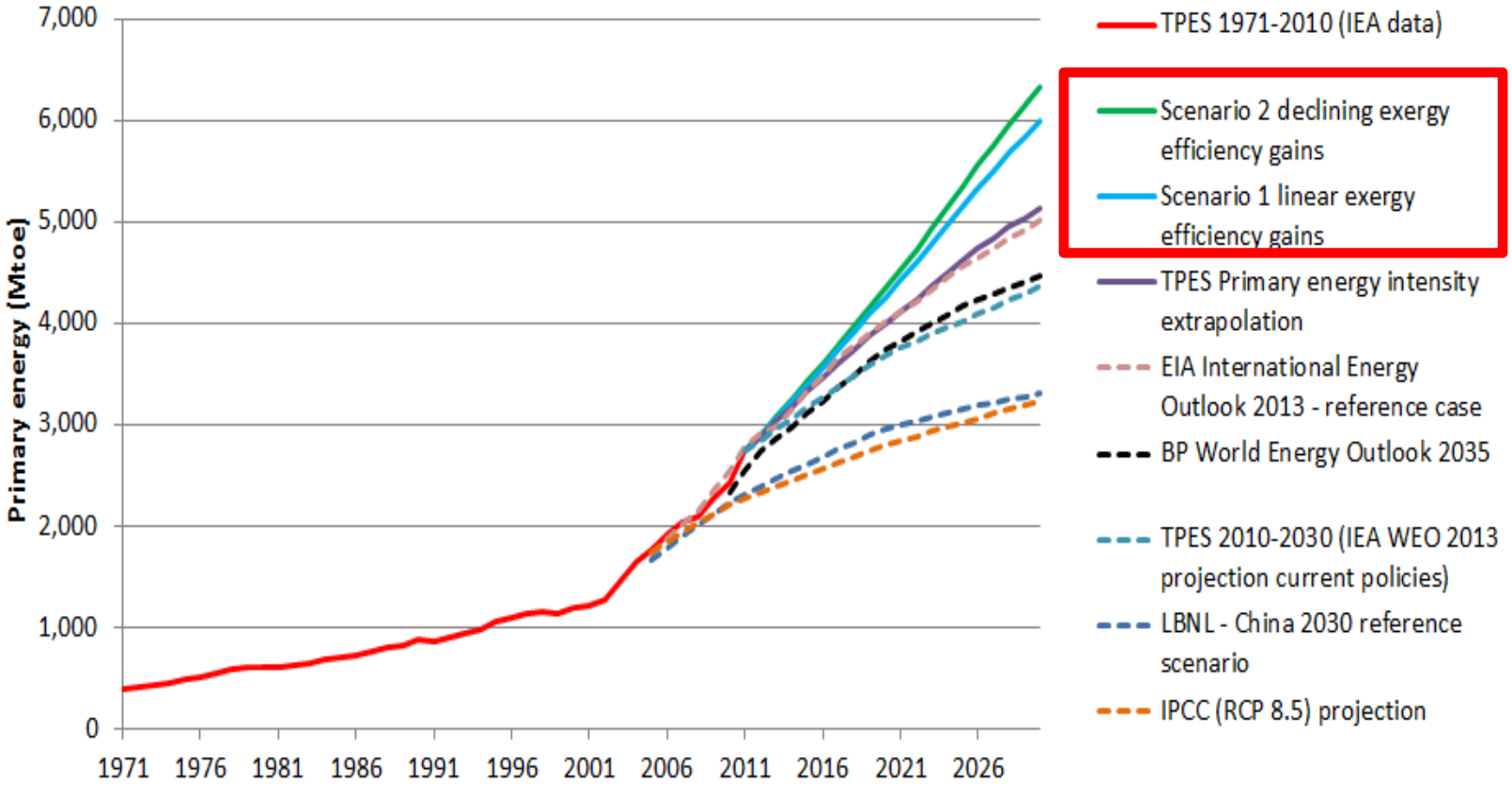

Source: Brockway, P. et al (2015) *Understanding China's past and future energy demand: an exergy efficiency and decomposition analysis* Applied Energy http://dx.doi.org/10.1016/j.apenergy.2015.05.082

Conclusions

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1. Given time issues, we need to be using all the tools in the policy box.
2. Exergy-based studies suggest energy efficiency and energy supply policies need to be account for:
   - Efficiency dilution
   - Energy rebound
3. Exergy analysis can be included in mainstream modelling approaches: equilibrium, econometric, cost-optomisation.

Thank you for listening

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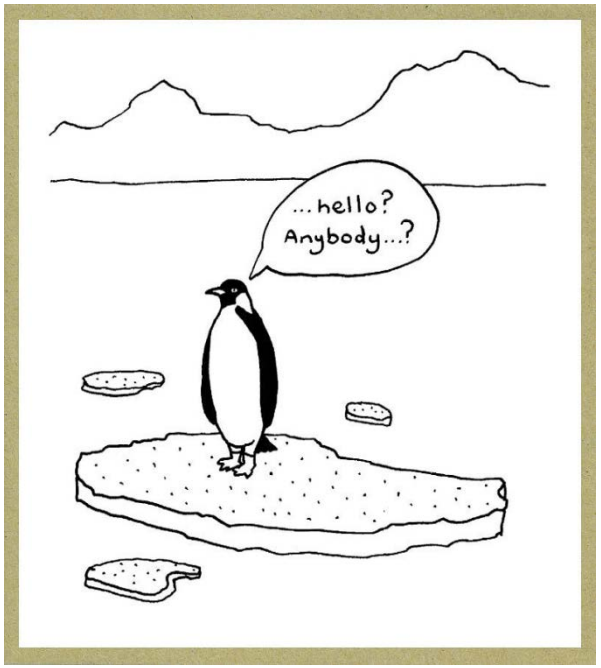

Energy economists

Exergy economists

- Brockway P.E., Barrett J.R., Foxon T.J. & Steinberger J.K. (2014) Divergence of trends in US and UK aggregate exergy efficiencies 1960-2010. *Environ. Sci. Technol*. **48**, pp.9874−9881 Available at DOI: 10.1021/es501217t
- Brockway P.E., Steinberger J.K, Barrett J.R. & Foxon T.J. (2015) Understanding China's past and future energy demand: An exergy efficiency and decomposition analysis. *Applied Energy* **155**, pp.892–903 Available at DOI: 10.1016/j.apenergy.2015.05.082