

Energy Waste Triad

conceptual framework and literature review



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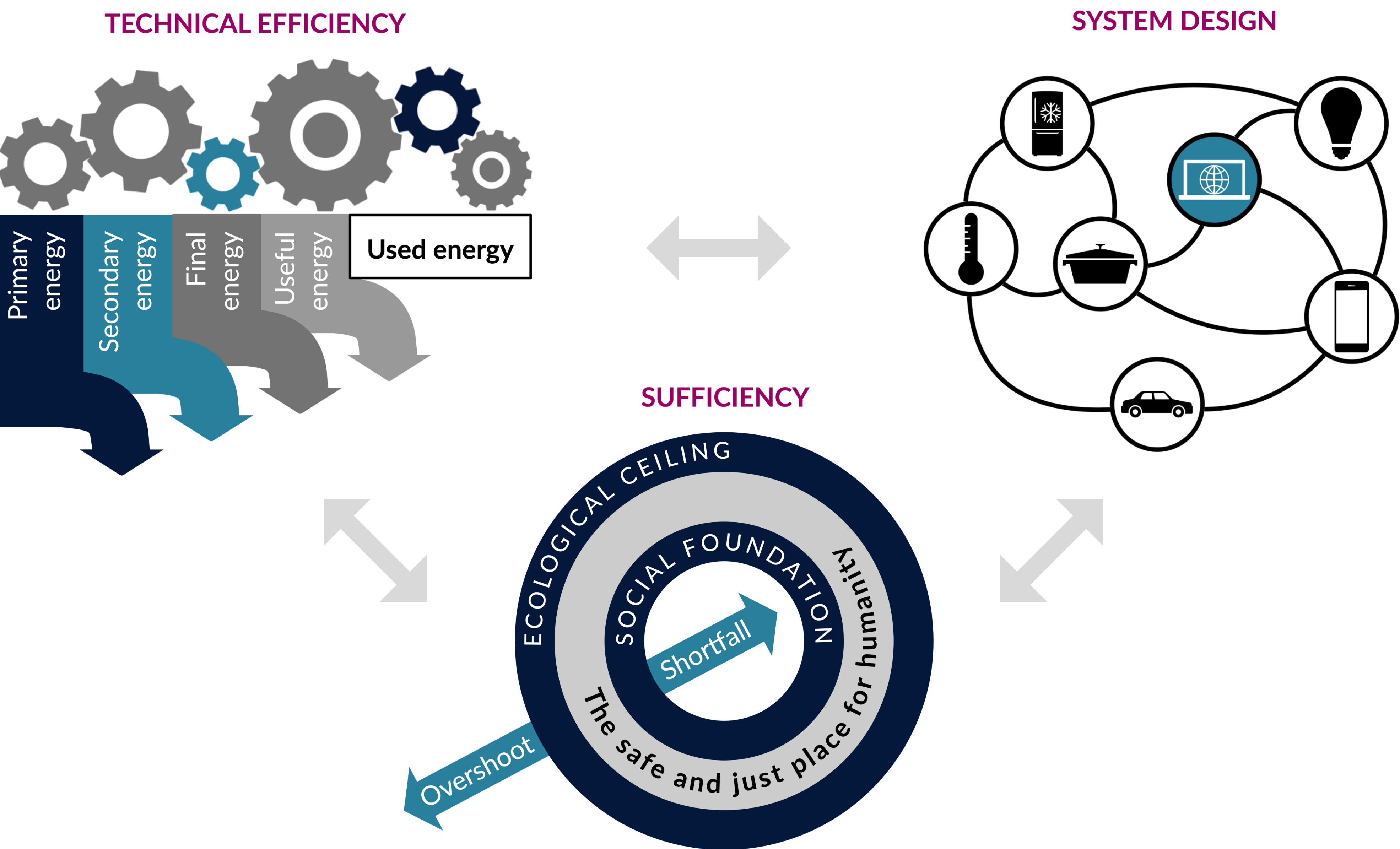


Figure 1: Energy Waste Triad

Table 1: Instances of energy waste across building lifecycle stages based on 116 journal articles.

Building lifecycle stage	Energy Waste Triad		
	Technical Efficiency	System Design	Sufficiency
Materialisation: materials extraction, production of materials and technologies	Heat losses in energy conversion [4]. Inefficiencies embedded in outdated materials, appliances and technologies [7].	Unnecessary local digital network activity and its poor integration [6]. Residual energy not recovered within the system [8].	
Transport			
Construction, including design and audit	Insufficiencies arising from outdated and unscientific decisions and standard specifications [10]. Incorrectly sized building systems and improper installation [2].	Suboptimal building design not optimised for local climate and multiple performance needs [7]. Suboptimal configuration of renewable-storage-grid systems [6].	
Transport		Same as above, but with EV	
Operation and use	System operating far from design and reference conditions: - Improper or user behaviour [28], eg idle devices or improper windows use. - Inflexible operation settings [6], eg fixed operating hours. - Mismatch between demand and supply; efficiency improvements by supply tailoring or demand response [13]. Insufficient information: - Insufficient monitoring understanding and use of existing data [7]. - Lack of awareness of energy efficiency and controlled consumption [2].	System operating far from its potential: - Misalignment between system design and occupant practices [2]. - Misalignment between operation strategy and dynamic occupant comfort [1]. - Lack of automation and control to align operation with occupant behaviour [6]. Lack of necessary information structure: - Lack of accurate forecasting [2]. - Lack of user feedback, eg though smart meters, direct power feedback or Digital Twin [3].	Consumption without restrain [1].
Transport			
Maintenance and renovation	Lack of timely fault detection, delayed or improper maintenance [5].	No consideration for trade-offs between operational vs embodied energy impacts [1].	
Transport			
Demolition			
Transport			

Note: Numbers in brackets indicate how many of the 116 reviewed papers mentioned this instance of energy waste.

Background

The domestic sector accounts for approximately 21% of total energy use and 16% of carbon emissions globally, making it a critical area for climate mitigation. While the potential to reduce domestic energy use is widely recognised, actions remain fragmented across different approaches. For example, energy efficiency focuses on technological improvements, lifecycle analysis highlights embodied energy, sufficiency questions the scale of consumption, and demand management targets behaviour patterns and timing of energy use. This paper proposes uniting these strands under a single concept — **energy waste** — to focus efforts on reducing what is considered wasteful.

Theoretical lens and methodology

Our analysis draws on our expert knowledge, a systematic review of 116 articles referencing domestic energy waste, insights from the EDOL project and peer feedback to:

- Step 1: outline the conceptual terrain of energy waste discourse;
- Step 2: develop the Energy Waste Triad framework;
- Step 3: demonstrate its application across building lifecycle stages.

The analysis is informed by systems research in general and by Meadows’ leverage points¹ in particular.

Conceptual synthesis

We developed an integrated conceptual framework — the **Energy Waste Triad** — comprising three lenses to understand energy waste:

- technical efficiency**, which focuses on energy conversion losses and technical inefficiencies;
- system design**, which considers how resources are organised to deliver services²;
- sufficiency**, which problematises socially constructed energy needs and highlights potential excess³.

We then show how the framework can be used to identify and address different aspects of energy waste across the **building lifecycle**, from material production to use, renovation and demolition..

The framework serves as a tool to visualise different aspects of energy waste, enabling them to be comprehended as an integrated whole, critically reflected upon and used to guide ongoing efforts to reduce waste.

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Selected references:

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