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Application of Systems Thinking to Energy Demand Reduction

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Outline

- Background and motivation
- Case studies
- Developing a systems approach for energy demand reduction
- Conclusions

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Background and motivation

Industrial Doctorate Centre in Systems

- Engineering doctorate programme in Systems at Bristol
  - £8+M EPSRC sponsored (2007-2017), 70+ research engineers funded to today, dozen+ graduations
  - 30+ industrial sponsors
  - Wide range of domains: civil, aero, mech, comp sci, elec eng
  - With applications in defence, nuclear, safety, sustainability manufacturing, automotive, IT, …

Background and motivation

Key facts

- Government objective to reduce energy demand between 26% and 43% by 2050
  - Low Carbon Transition Plan and Climate Change Act 2008
- Achieved by energy efficiency but also reduction through lower demand activities and less waste
- Current state of the Grid
  - complex supply and demand, complex infrastructure extending over the country, developed under an ‘anticipative’ design culture, i.e. with concern to respond to demand surges, not to influence or anticipate them dynamically

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Background and motivation

Key facts (cont'd)

- In the UK the drive for energy efficiency has never been stronger; but reducing demand is a 'wicked' problem
  - Transport demand 21% higher than 1990, housing 13% higher and domestic per capita consumption only 1% lower
- Great difficulty to model the energy demand system – 'the one behind the meter', i.e. people, behaviour, psychology, use of technologies, opportunity and innovation etc.
  - demand reduction interventions mostly sought to address single issues e.g. end-use equipment efficiency and operation, energy behaviours etc.
  - Simplified hypotheses about energy use (e.g. heating etc.), averaged out over the population with no regard of individual differentiating factors

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Background and motivation
Problem context

- Issues with traditional environmental assessment work
  - Scope of retrofitting – limited or already there
  - Poor performance of technology
- Diversity that requires purposeful match of methods/solutions with the specific need

Background and motivation

Research questions

- Two key questions emerge:
  - How can we understand the nature of energy demand? What types of models and other artefacts may contribute to an improved understanding of the demand drivers?
  - Can we develop interventions that are effective in reducing demand at household level in the built environment with energy technology, people, culture etc.? What would these interventions look like?

Case study I: Reducing energy demand in a school

Making sense of a school as a SoS

- Complex network of interests
- Government targets
- Local authority control
- Communities involvement
- Developers ROI
- Budget limitations and cuts
- School's performance

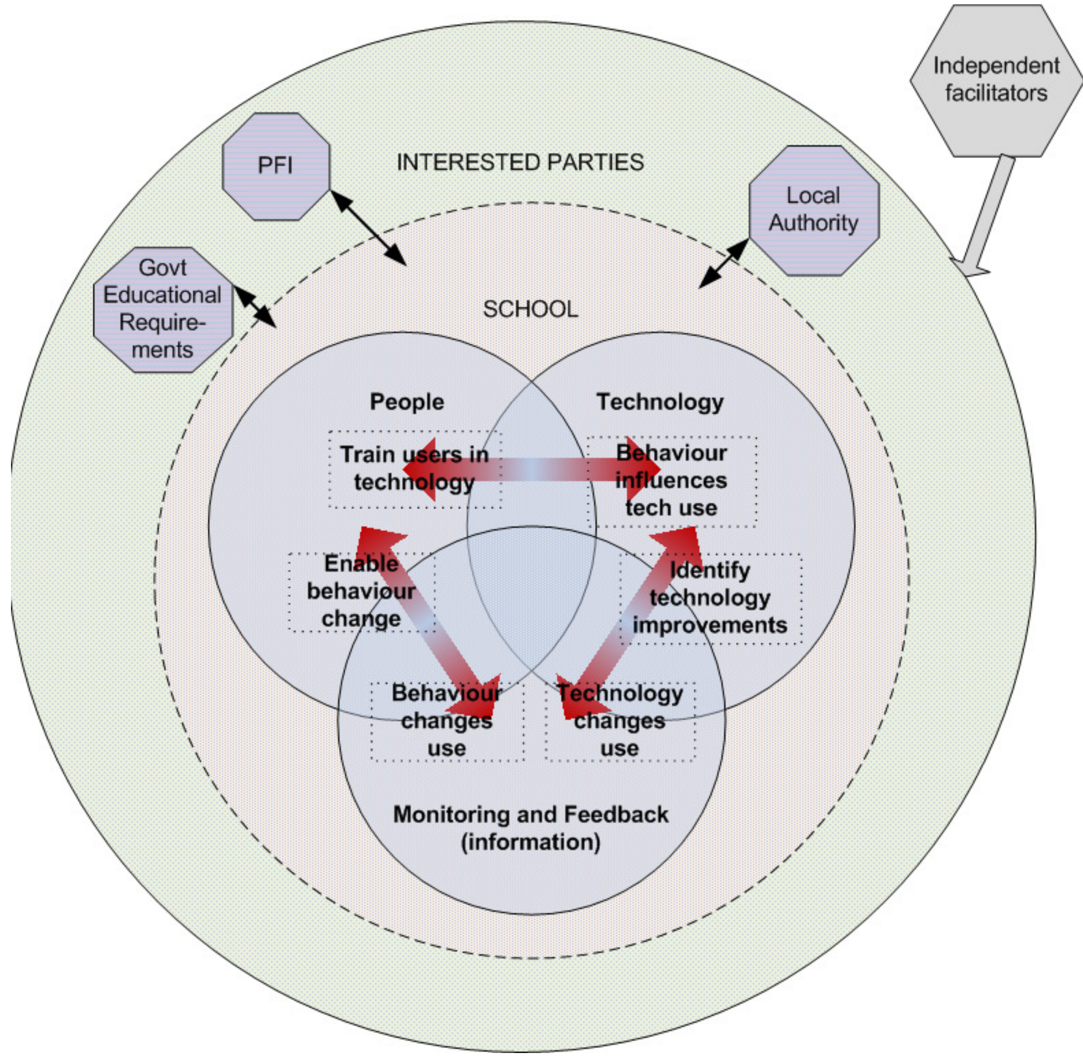

Figure III: Sustain's Integrated Schools Service

Case study I: Reducing energy demand in a school

Intervening into a school with a SoS

- Low cost, low capital approach for post occupancy interventions where major retrofitting is not an option
- The delivery of the above relies on
  - **Technology controls –** movement sensors, hippos, automated computer shutdown etc.
  - **Energy information feedback –** building on existing data collection capability to return information to stakeholders on energy use and wastage etc.
  - **Behaviour change –** board engagement, awareness workshops, streamlining of operations, training on equipment use etc.

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Case study II: Sustainable FOB

Key Facts

- Forward Operating Base (FOB): secure base of operations, usually located in remote, hostile areas, where troops are deployed to support frontline operations and combat missions
- FOB inwards supply chain footprint:
  - 50% fuel supply
  - 30% water
  - 20% various
- Removal of waste another potentially sizeable task

Case study II: Sustainable FOB

Typical deployment

- Semi-permanent or temp structures
  - B-huts and/or tents
- Larger establishments may include MWR facilities adding to the baseline power requirements
- US usually higher demands from UK equivalent
  - Typical UK req for 100 men: 17 kW
  - US guidelines:
    - ‘1kW of peak demand per person’
    - ‘company size FOB will require 1000kWh of electric energy per day’ (US Navy source)
- Several initiatives to deliver more sustainable bases, e.g.
  - Capability Vision of a Self-Sustaining Forward Operating Base, UK MoD
  - Green Warrior Implementation Strategy, US DoD

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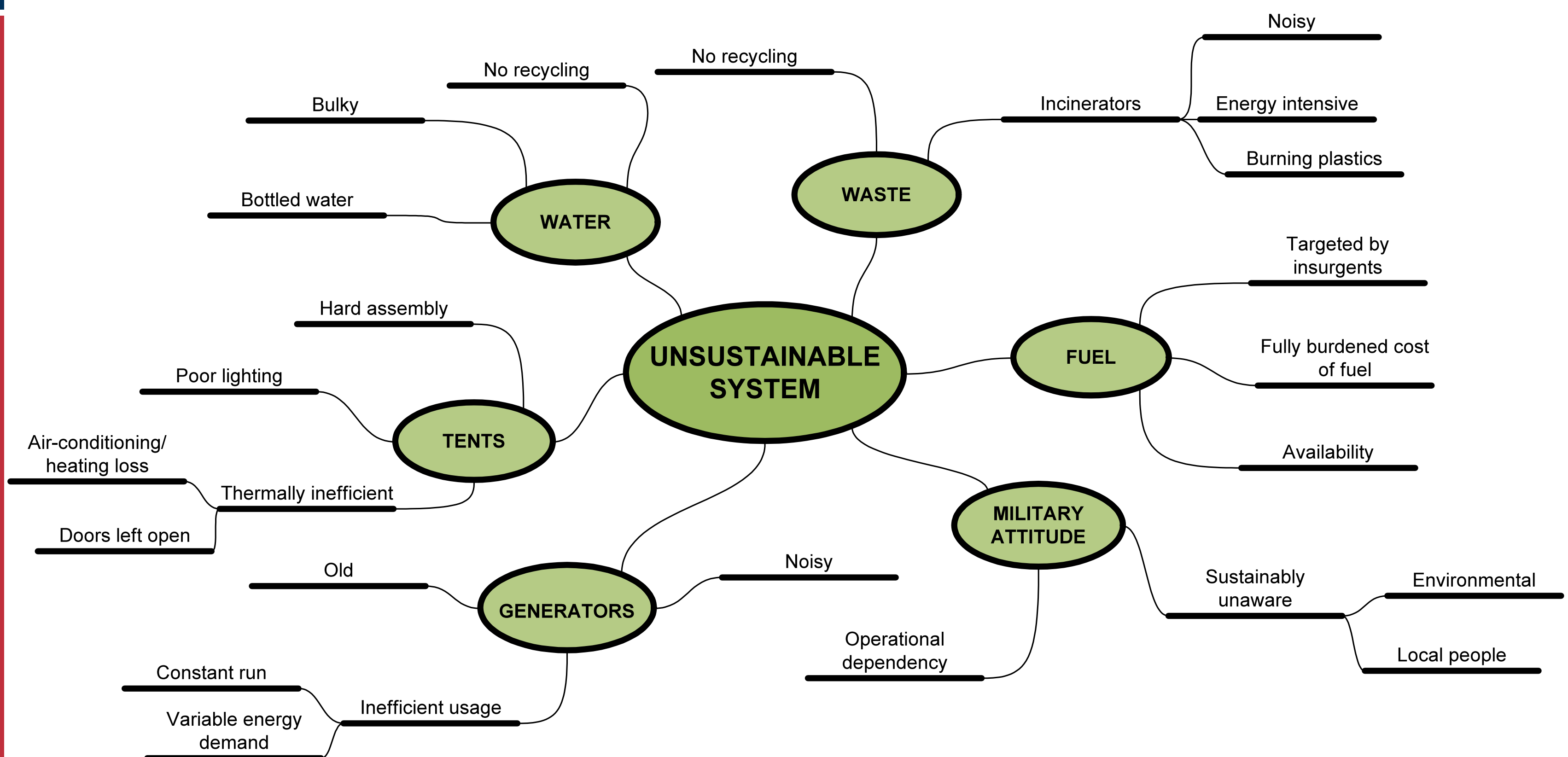
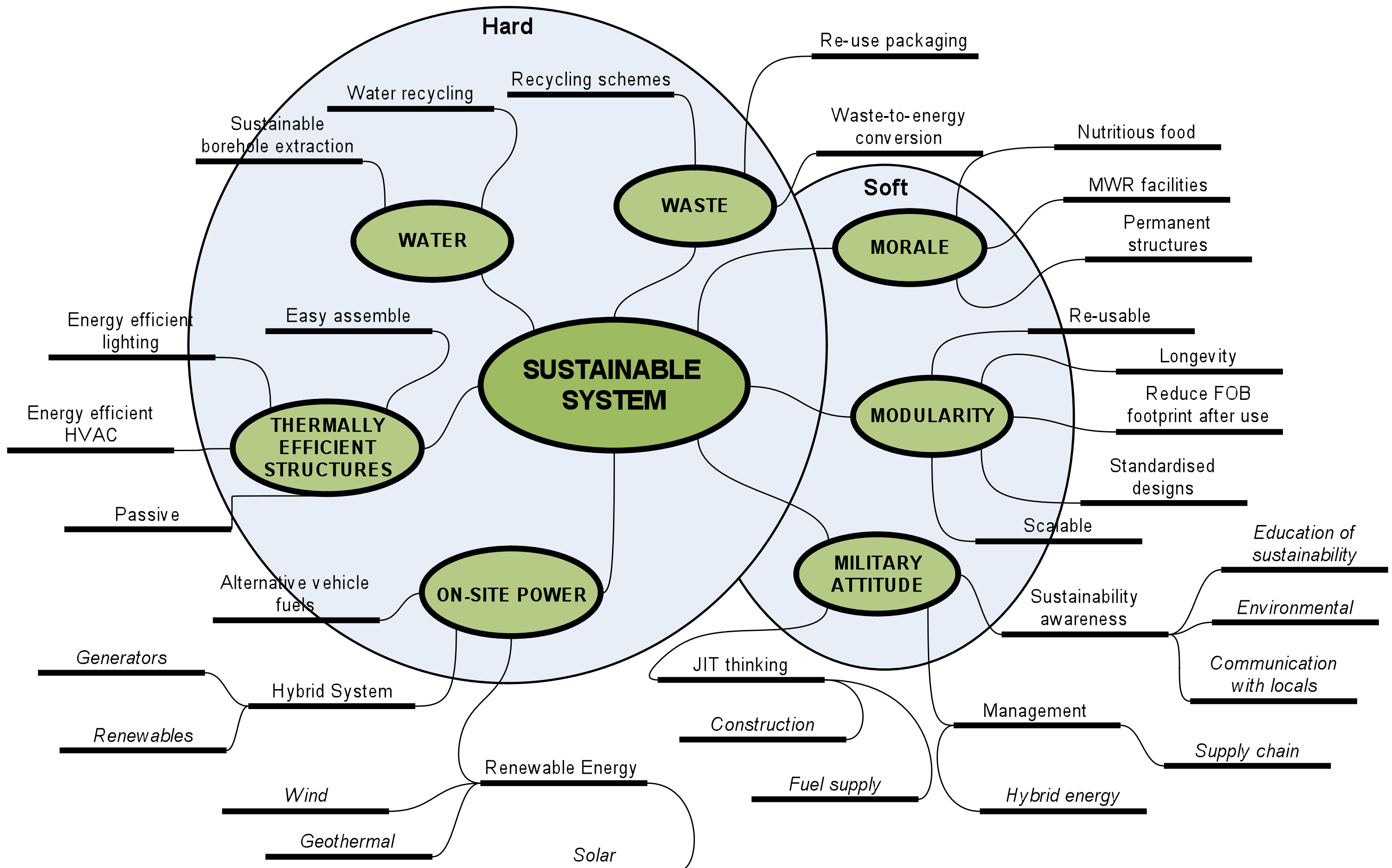
Case study II: Sustainable FOB

Understanding an unsustainable FOB



Case study II: Sustainable FOB

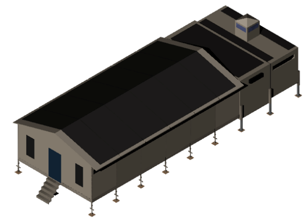
Conceptual modelling of a sustainable FOB



Case study II: Sustainable FOB

Design decisions

- Much emphasis on power generation elsewhere
  - Lots of technologies, a lot in experimental stage
  - Active element, may become additional target of insurgents
- Instead decided to focus on passive elements
  - Thermal efficiencies of accommodation structures
  - Reducing water waste through recycling and reuse



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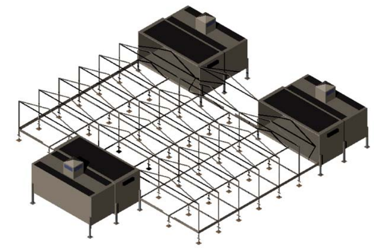
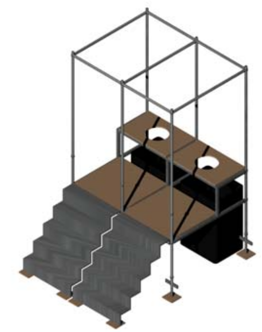


(b)

(a)



(b)

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Case study II: Sustainable FOB

Design evaluation (simulation based on IES VE)

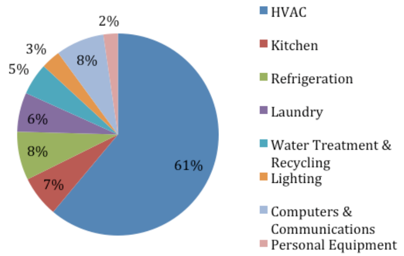


Figure 6. Energy demand in a sustainable FOB

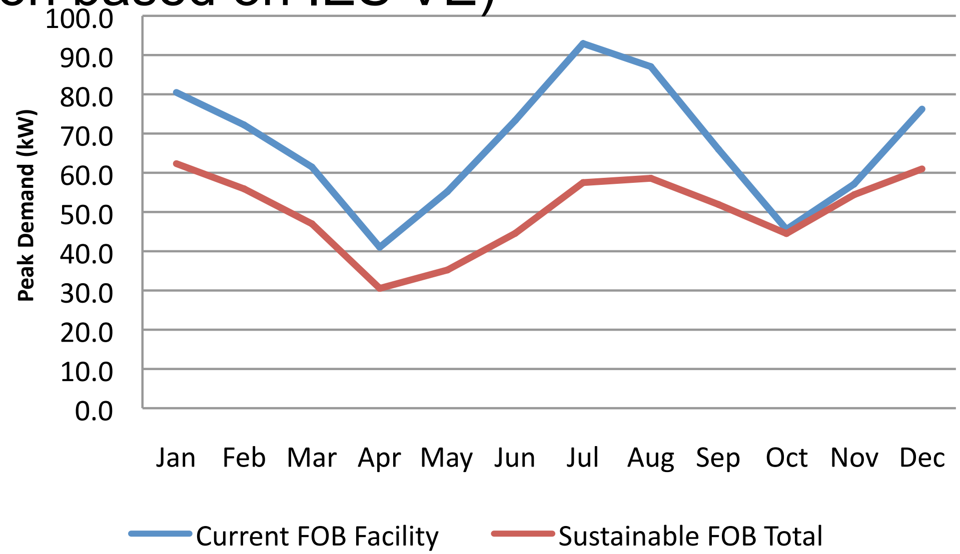


Figure 30: Comparison of annual peak demand of sustainable FOB and the current FOB

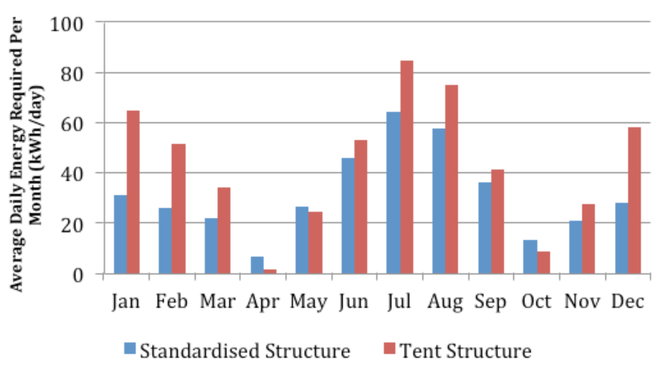


Figure 7. Heating and cooling demands of a standardised structure vs. a typical tent

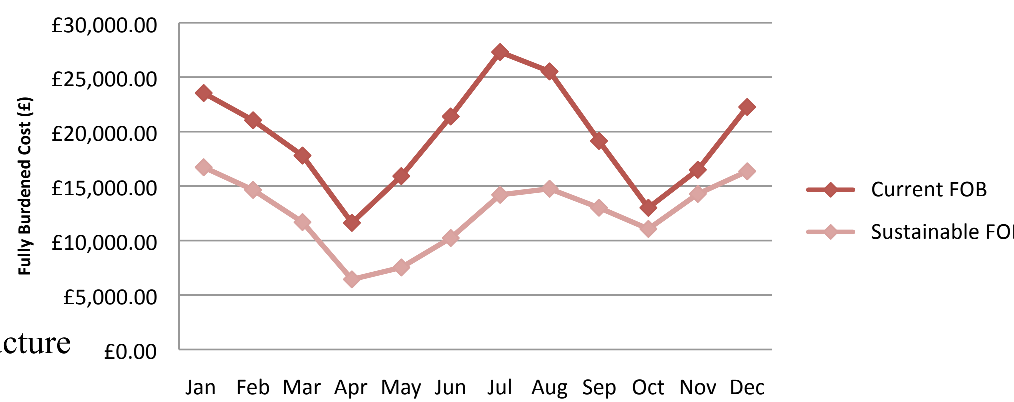
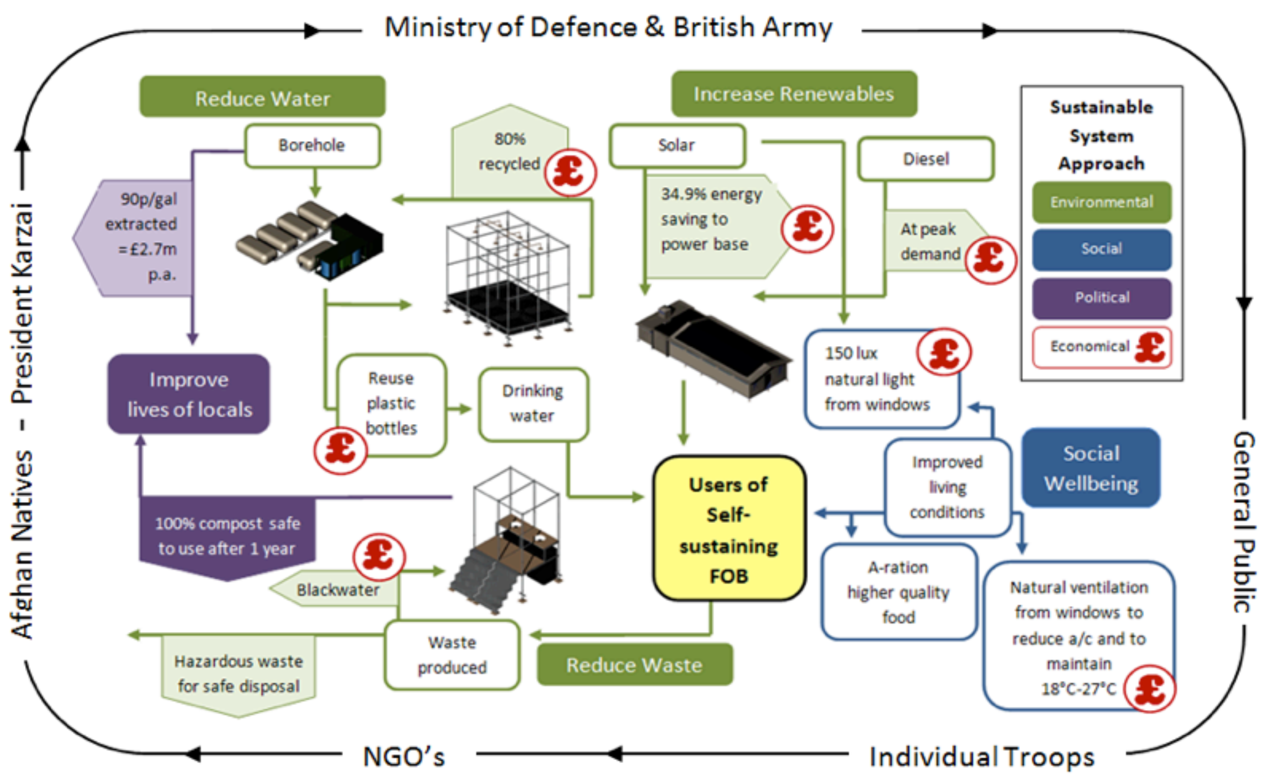


Figure 37: A comparison of the annual cost of fuel required for operating the sustainable FOB and current FOB

Case study II: Sustainable FOB

Design evaluation

- Perceived benefits from our interventions identified within the FOB and its SoS context



Developing a systems approach for energy demand reduction

- First step to capture qualitatively the complexity of the demand side
- Developing a System of Interest model (SoI), although open, with unclear boundaries
  - still helpful
- Understanding the hierarchies of interactions within and around the SoI, explored through Multi Level Perspective (MLP)

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Developing a systems approach for energy demand reduction

SoI modelling

- Domestic and commercial built environment
- ‘Flat-packed’ in a poached egg diagram hides the complexity of multiple layers
- Further need for exploring hierarchies of interacting elements

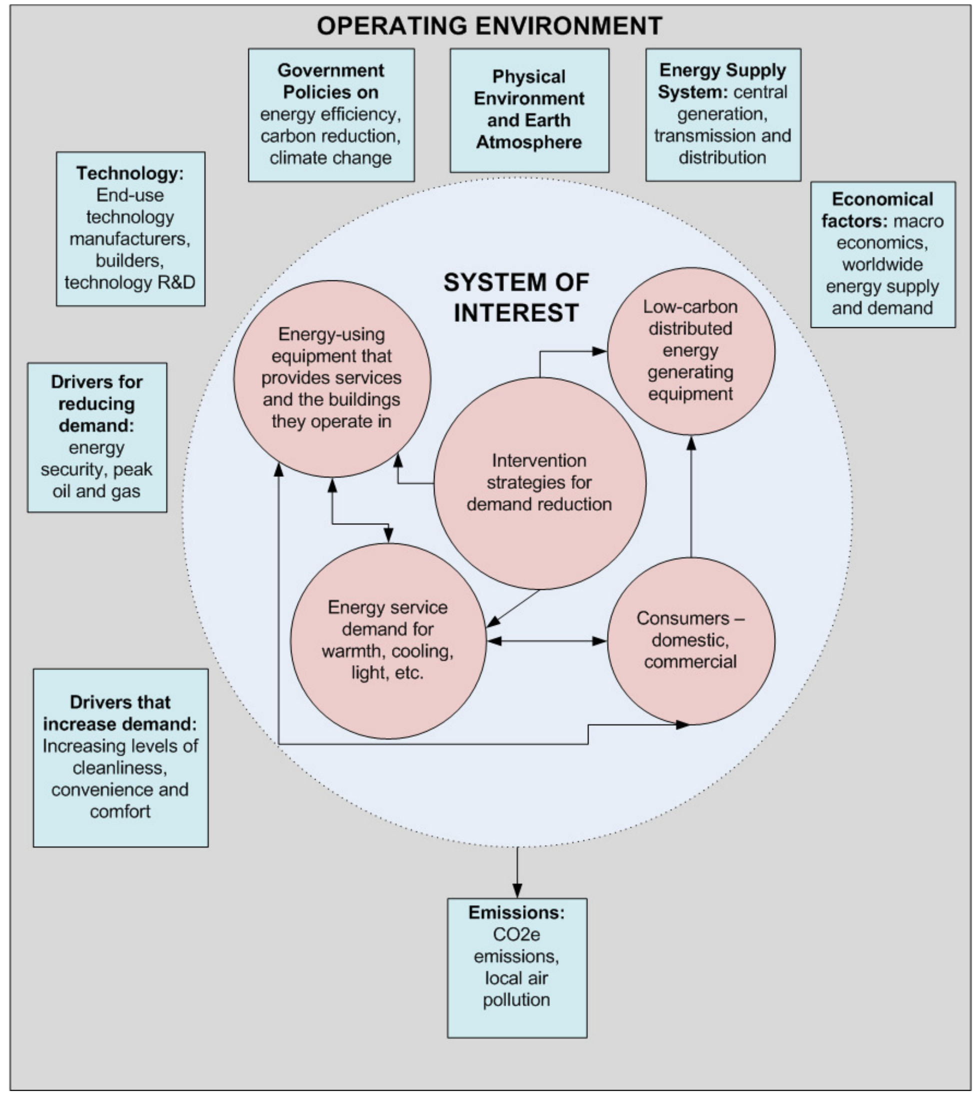

Figure I : The SoI and its Operating Environment

Developing a systems approach for energy demand reduction

MLP three-layer hierarchy

- Geels and Schot's (2007) three- layered framework, represents both the whole SoI and its exogenous environment
- Technology development trajectories set in a pattern and only incremental changes to technology pursued, as opposed to fundamental ones
- Represents well the energy sector

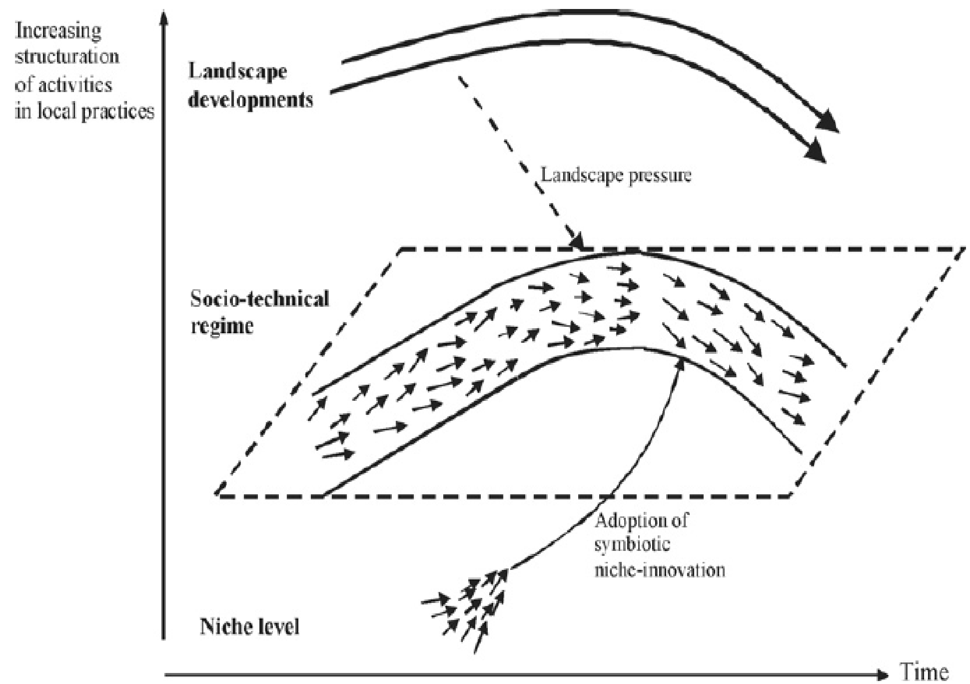

Figure II: The MLP and Transformation Pathways [1]

Developing a systems approach for energy demand reduction

Organising a System of Systems Intervention

- The SoI comprises hard…
  - Heating and lighting
  - Motors and appliances
  - The building envelope
  - Etc.
- … and soft elements
  - Enacted technology ('in use')
  - Rational (or not) behaviour
  - Etc.
- It is not possible to design effectively the former in isolation of the latter

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Developing a systems approach for energy demand reduction

Organising a System of Systems Intervention (cont'd)

- Jackson's System of System Methodologies (SoSM, 1984)

		Participants		
		Unitary	Pluralist	Coercive
Systems	Simple	Hard Systems Thinking	Soft Systems Thinking	Emancipatory Systems Thinking
	Complex	Dynamic Systems Thinking	Soft Systems Thinking	Postmodern Systems Thinking

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Developing a systems approach for energy demand reduction

Organising a System of Systems Intervention (cont'd)

- SoSM incarnations with extensions and revisions, e.g. Yang & He (2005)

Table1 The Extension to SOSM

Systems Methodology (Metaphors)		characteristic of participants in problems situation		
		unitary (team) (having common interests and sharing same value view)	pluralist (coalition) (having roughly common interests and sharing value view with some differences)	coercive (political) (there are conflicts in interests and value view)
physical property of problems situation (including environment factors)	Simple	SE OR SA SD (machine)	SSD SAST(machine, culture)	CSH (machine)
	Complex	VSD (organism, brain) GST Socio-technical thinking Contingency theory	IP (brain, culture) SSM (organism, brain culture)	ISSM? (brain, culture)
system category of problem situation based on its origin		problem of man-made or viable systems	problem of HAS	problem of soft HAS

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Developing a systems approach for energy demand reduction

Delivering a System of Systems Intervention

- Improving energy (sub)systems using traditional Systems Engineering
  - Huge body of literature
- … and energy demand behaviour using soft systems methods
  - Checkland's Soft Systems Methodology (SSM, 1990)
  - Kurtz and Snowden's Cynefin Framework (2003)
  - Action Research and immersion into the problem
- We'll explore the implications of these in a case study

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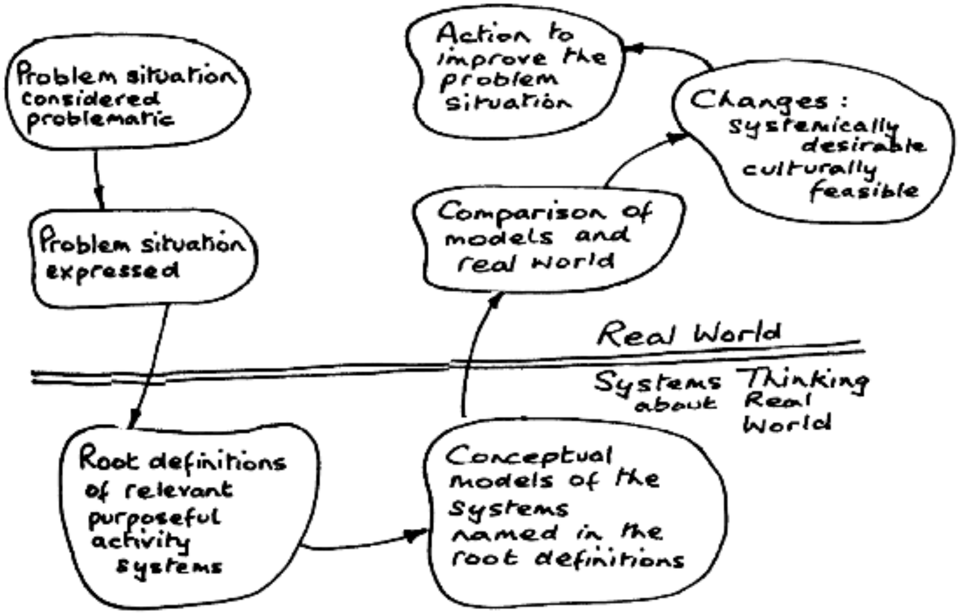
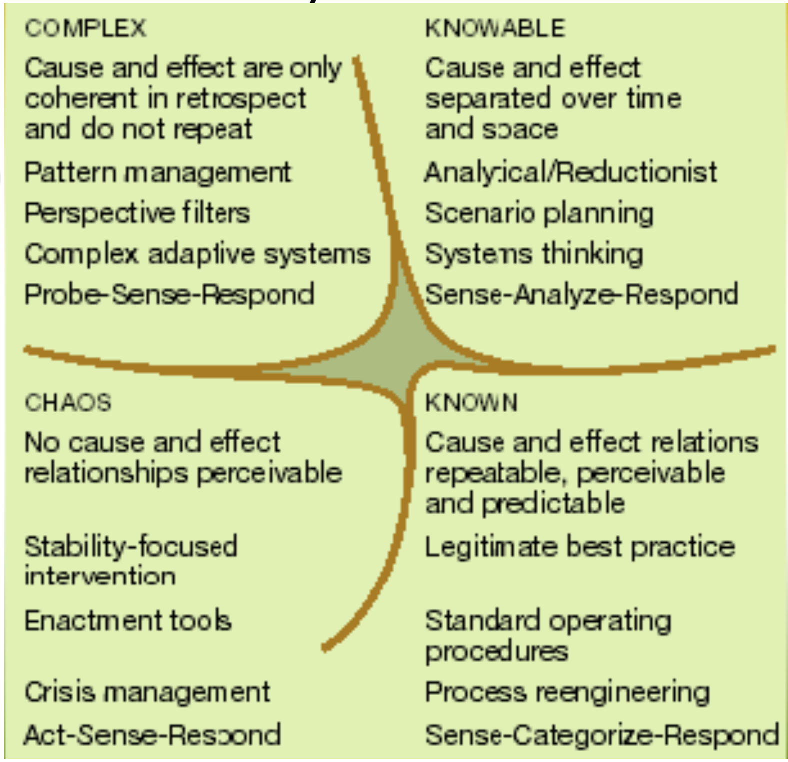
Developing a systems approach for energy demand reduction

Delivering a System of Systems Intervention (cont'd)

- Soft Systems Methodology (Checkland)



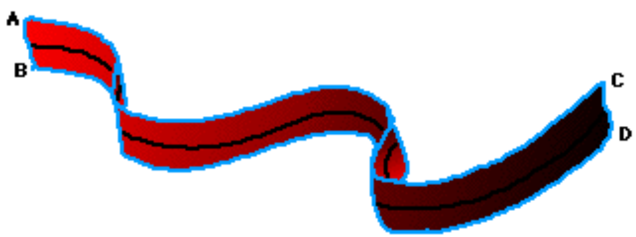


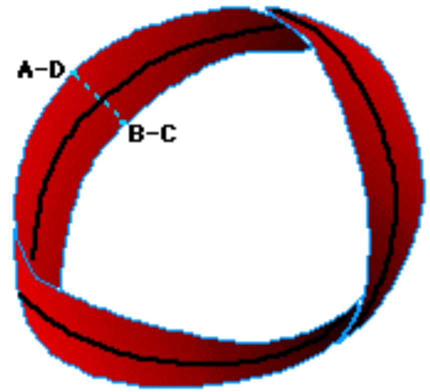
- Cynefin Framework (Kurtz & Snowden)

Developing a systems approach for energy demand reduction

A System of Systems Intervention

- Energy demand reduction through integration of hard and soft: A walk on a Mobius Band?





http://scidiv.bellevuecollege.edu/math/mobius.html

Conclusions

- In coping with the complexity of the energy demand problem the ‘System-of-Systems-icity’ manifests itself in both the domain modelling AND the intervention method
  - Analogous to Checkland’s ‘Type II’ Systems approach (‘30-year Retrospective’): Complexity in the world tackled by systemic inquiry – variety kills variety
- The Systems professional must be prepared (and equipped) to walk on the ‘Mobius Band’ that will transition the problem to the solution space from both a technical and a social perspective in a SoS context

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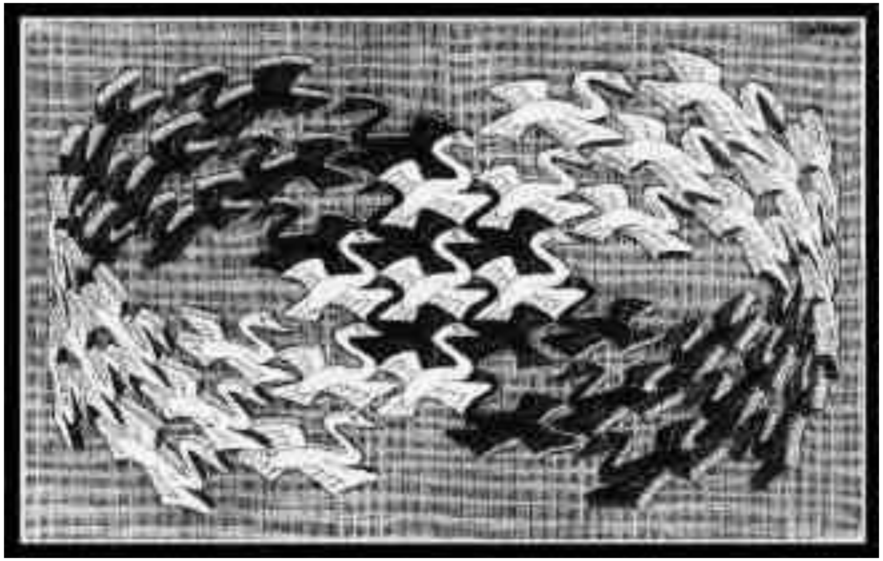
Thank you



Any questions?

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