University of BRISTOL

SUSTAINABLE DESIGN OF FORWARD OPERATING BASES

Sustainable Forward Operating Bases 2012
London Hilton Olympia, 20th-21st March

Work originally presented at the 6th IEEE Intl Conf. on System-of-Systems Engineering, SoSE 2011, Albuquerque NM

G Cave, W Goodwin, M Harrison, A Sadiq and T Tryfonas

Outline

- Background and motivation
- Key facts
- Requirements and design concepts
- Simulation evaluations
- Conclusions and challenges

Background and motivation

Industrial Doctorate Centre in Systems

- Engineering doctorate programme in Systems at Bristol
  - £8M+ EPSRC sponsored (2007-2017), 70+ research students funded to today, first graduations last summer
  - 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

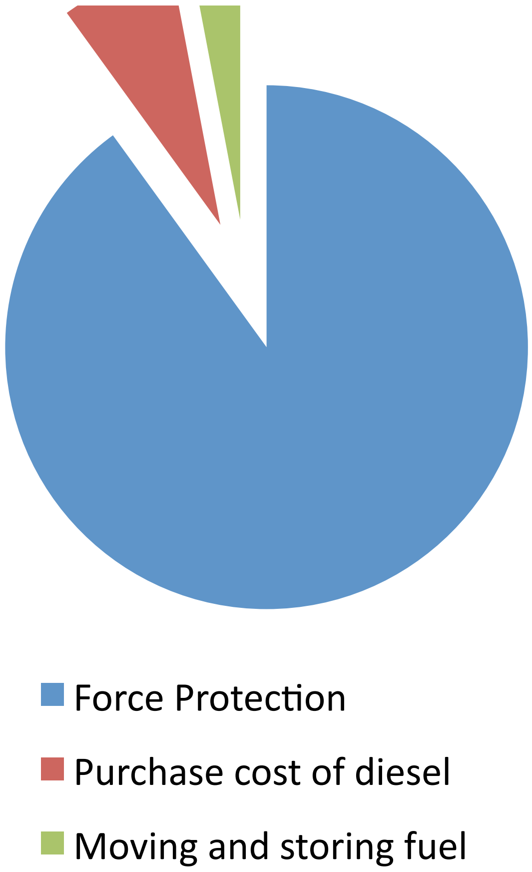
- The idea for this paper came from attending SoSE 2010 (Loughborough, UK)
- Discussed with industrial liaison the possibility of exploring the efficiency of some design concepts via postgraduate student work
- The resulting work was originally presented at SoSE 2011 last summer (Albuquerque, US)

Key facts

- FOB inwards supply chain footprint:
  - 50% fuel supply
  - 30% water
  - 20% various
- Removal of waste another potentially sizeable task

Key facts

- Protection accounts for as much as 90% of the fully burdened cost of fuel
- 3% of the total amount of fuel in Afghanistan represents 25% of the entire fuel costs



University of BRISTOL

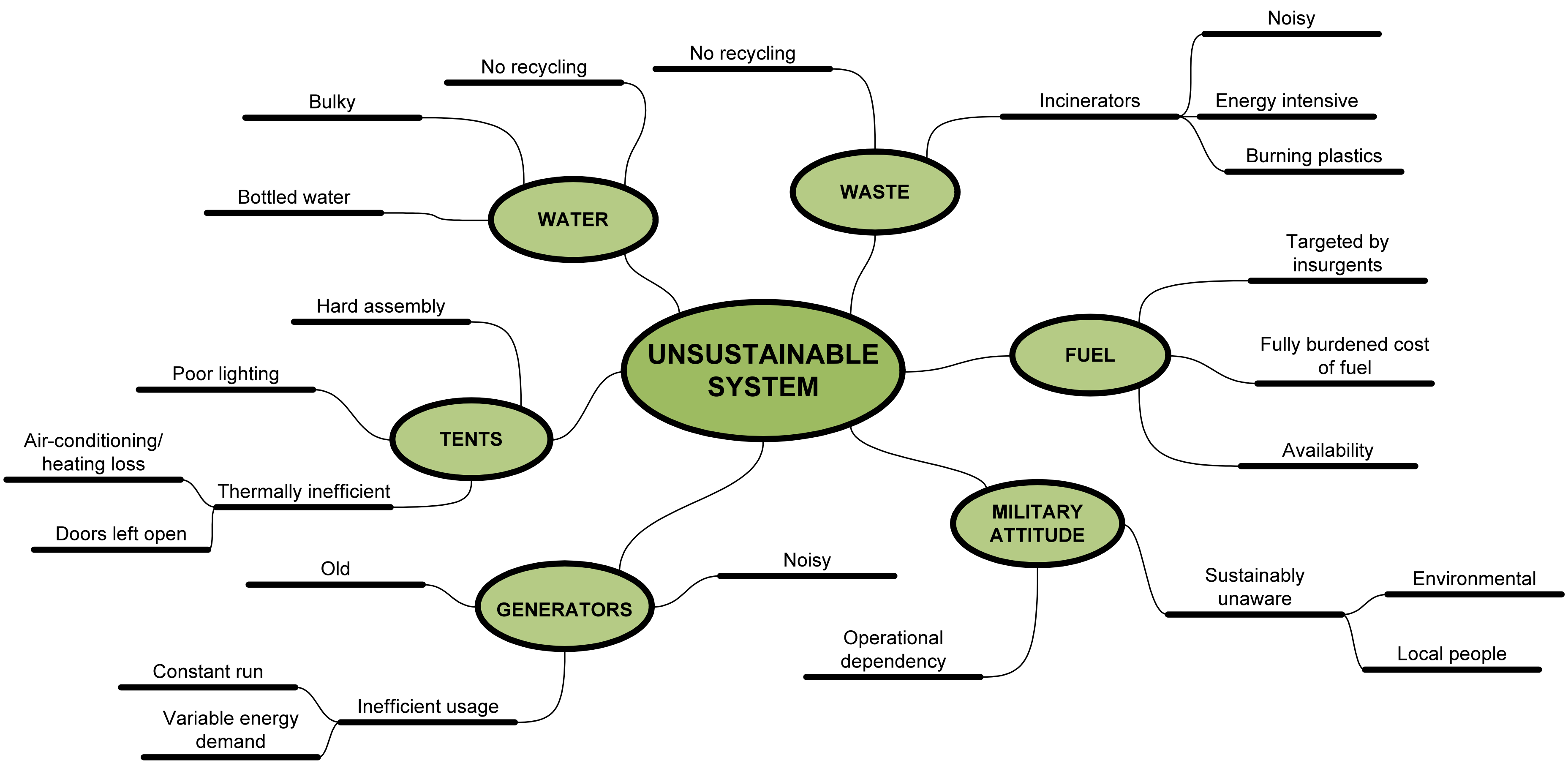
Key facts

- 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

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)

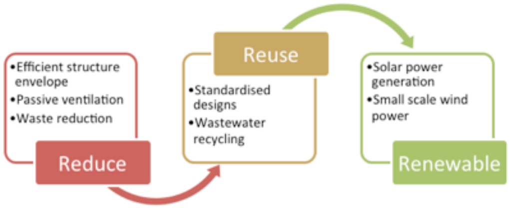
An unsustainable FOB

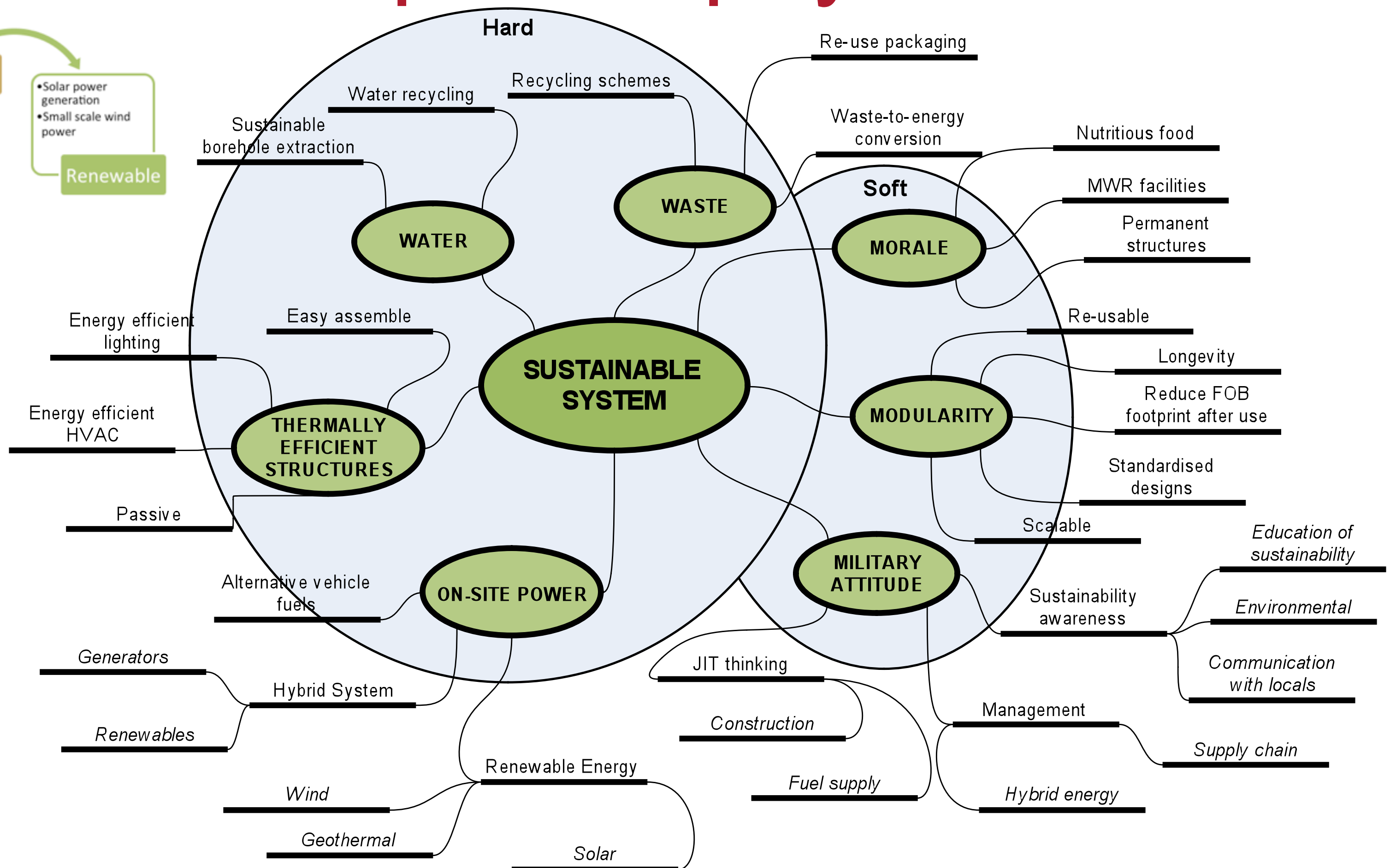


S/h analysis sample

Stakeholder	Influence	Interest	Perceived Advantages	Perceived Disadvantages
Ministry of Defence	H(igh)	H	• Reduction in operating costs to meet budget cuts • Reduction in troop casualties	• Increase in capital costs • Additional R & D costs
Afghan Military	M(edium)	H	• Reduced British military vulnerability to attack • Greater link between national militaries	• Increased use of local resources • Jealousy of improved facilities
British Army	M	H	• Reduction in supply chain casualties • Increased sustainability of FOB • Improvements to public image	• Increase in capital costs • Increase in training provision required
Soldiers Using FOB	M	M	• Improved living conditions • Reduced exposure to IED's	• Skepticism of the effectiveness of implemented technology • Additional training required
Local Residents	L(ow)	L	• Opportunities for work during construction • Increased communication with locals	• Decreased work opportunity for supply chain transportation • Increased stress on local water resources • Increased stress on land

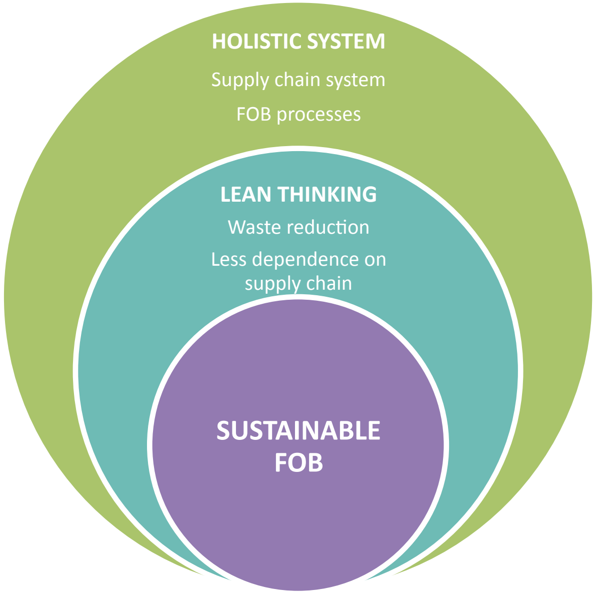
Approaching the requirements under a 3Rs philosophy

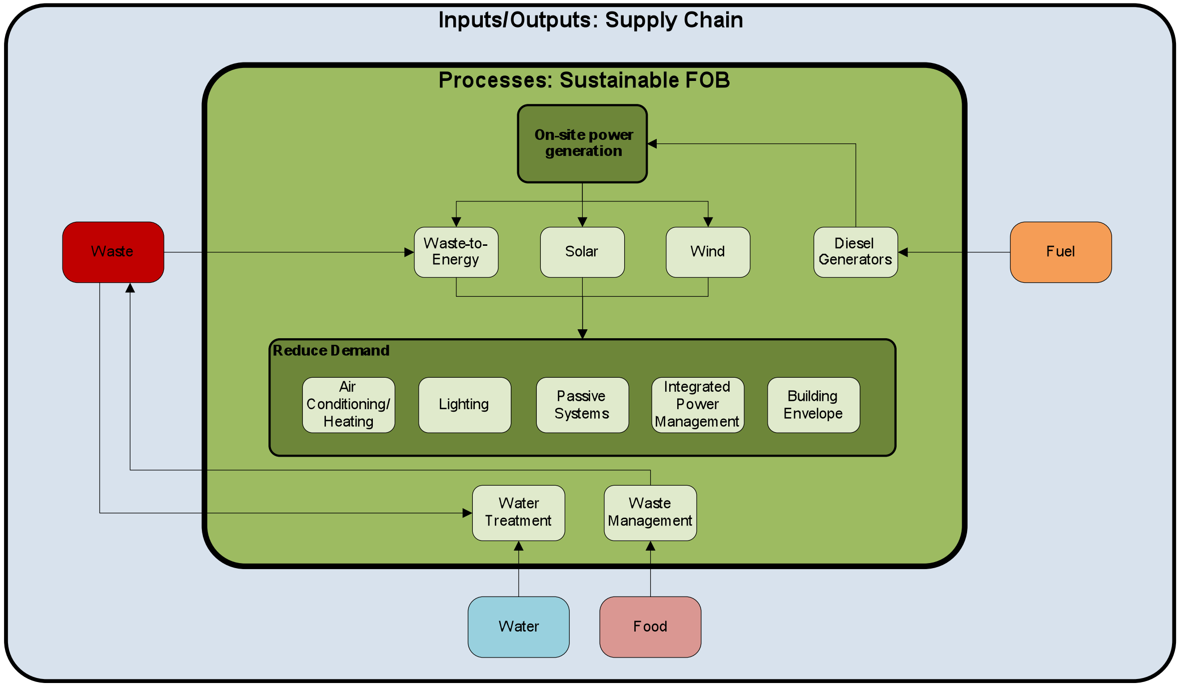




University of BRISTOL

Design rationale





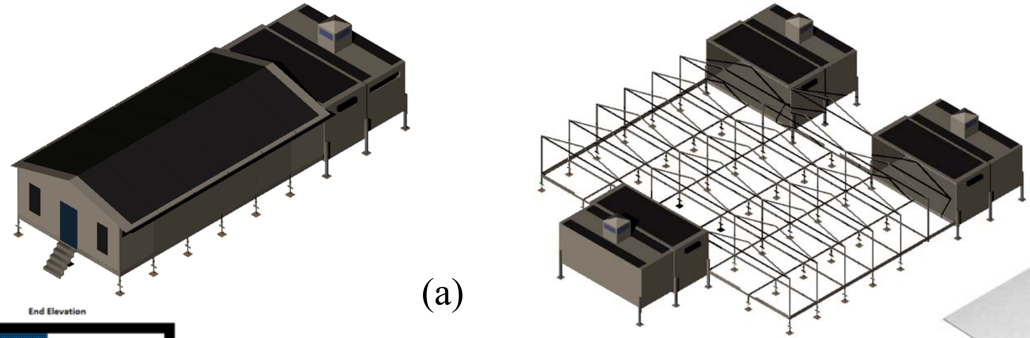
Design decisions

- 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

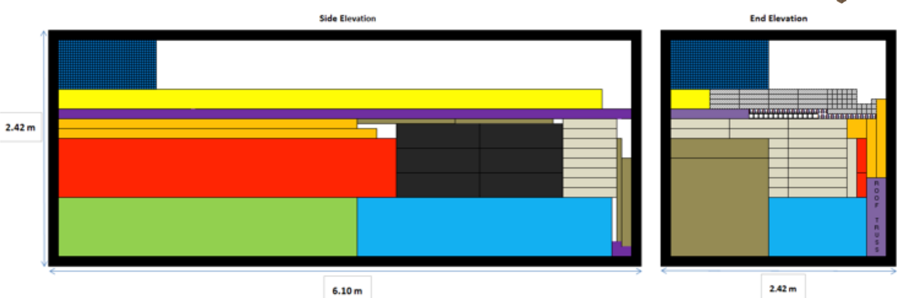
Exploring the performance of different accommodation arrangements

Multi-Criteria Analysis of Sustainability of Investigated Solutions																	
	Environmental			**Operations**							**Social**	**Economic**				**Results**	
Type of Structure	Size of Supply Chain	Ease of Re-use	Energy Efficient	Ease of Assembly	Modularity	Ease of Disassembly	Ease of Operation	Robustness	Camouflage	Reliability	Quality of Living	Initial Capital Cost	Operating Cost	Design Life	Maintenance	TOTAL SCORE	**RANK**
Tent Structure	5	5	1	5	3	4	3	2	4	2	1	4	1	3	4	47	**3**
Modular Structure	4	5	4	4	5	4	4	4	3	4	4	2	4	4	4	59	**1**
Containerised Structure	1	5	4	2	3	3	5	4	2	4	4	2	4	4	4	51	**2**

A LEGO-like standardised structure (*ST*²)



(a)



Structural Element	Quantity	Structural Element	Quantity
Floor Panels (3 x 2 - m)	12	Fold-out Single Beds with Storage (0.87 x 0.29 x 0.25 - m)	25
Side Wall Panels (2.4 x 2 - m)	12	Thin Film Solar PV Modules (5.486 x 0.394 x 0.004 - m)	40
Roof Panels (3.6 x 2 - m)	12	Fold-out Chairs (0.61 x 0.56 x 0.008 - m)	25
End Wall Panels (Assorted Heights x 2 - m)	4	Floor Beam Sections (50 x 75 x 5 x 5 - mm)	32
Prefabricated Roof Trusses (5.8 x 0.77 - m)	5	Column Sections (50 x 50 x 5 x 5 - mm)	14
Solar Chimney Panels (1 x 1 - m)	5	Structure Footings (500 mm long) and Pads (300 x 300 x 25 - mm)	33

Light Bulbs, Sensors, Socket Fixings, Cable, HVAC Ducting (Box - 1000 x 1000 x 500 - mm)

all panels are 50 mm thick

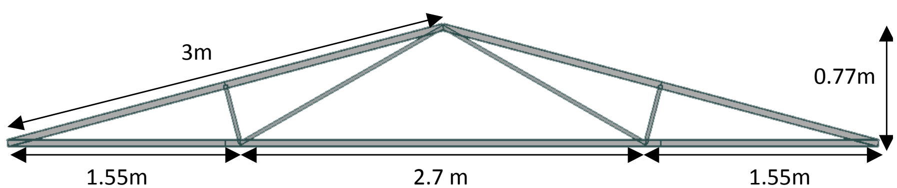


Figure 13: Standardised structure prefabricated roof truss

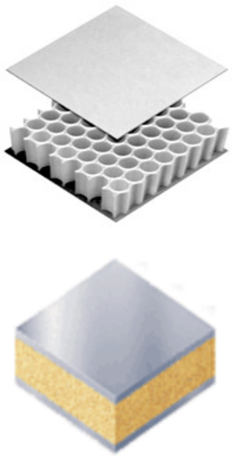


Figure 14: *Above:* GFRP/Polypropylene honeycomb panel used for the floor

Below: GFRP/Rigid polyurethane foam panel used for the wall and roof

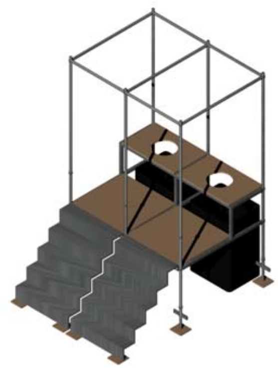
University of BRISTOL

Note: the container itself becomes part of the structure

ST^2 properties

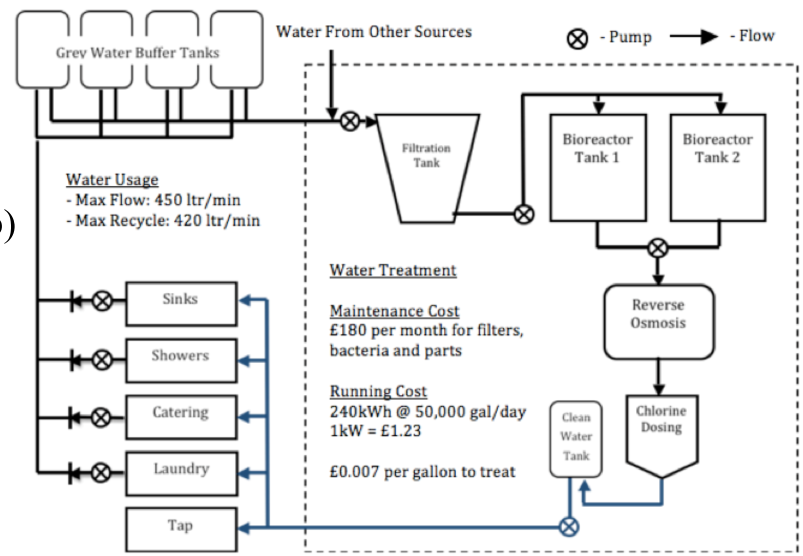
- Each block accommodates 25 men
- Fully incorporated within a standard 20ft container
- Steel structure
  - (+) excellent sectional stiffness, smaller sections can be used to provide equal support
  - (-) More expensive
- Glass-fibre reinforced plastic (GFRP)/polyurethane foam panels (sides) and polypropylene honeycomb (floor)
- Perspex windows – 7% more efficient that glass (u value of 2.7)
- Height-adjustable footings
- Estimated assembly – 4 people, 4 hours (16 man-hrs), based on equivalent amount of live event stage gear set up
- Allows for pre-calculation of power requirements, depending of size of base
- Etc. etc. – please refer to paper or the full tech report

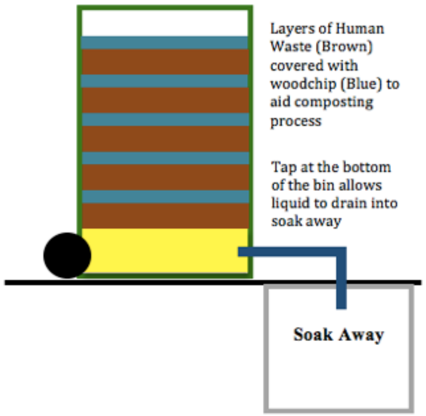
Waste water treatment



(a)

(b)



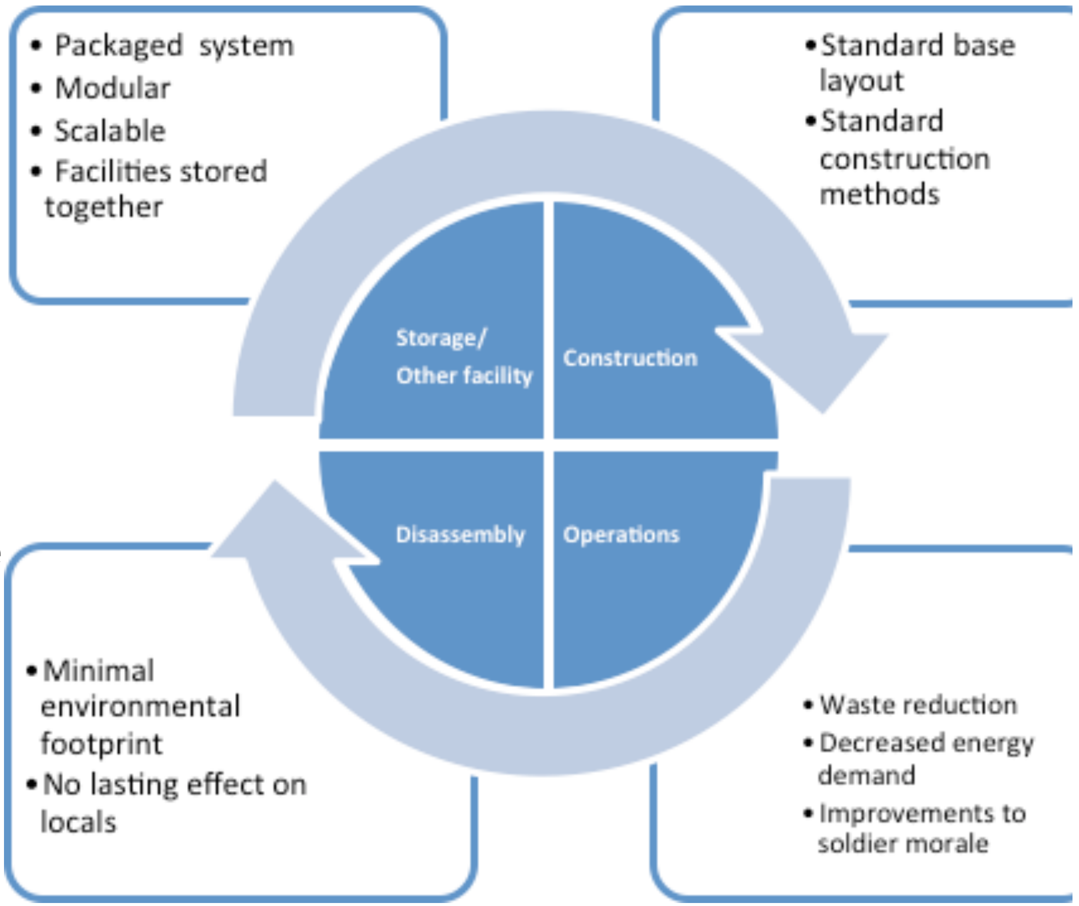


Waste water system properties

- Composting loos produce rich soil compost
  - Can be used to re-fertilise land after use or in general to maintain the quality of the soil
- Fits into two 20ft ISO containers
- 20k lt pillow tanks can be flat packed
- Peak flow rate 450lt/min
- If micro generation exists showers can plug into it for added boost
  - otherwise conventional black bag system can be used
- Aeration showerheads
  - reduce the amount of water required whilst maintaining good pressure

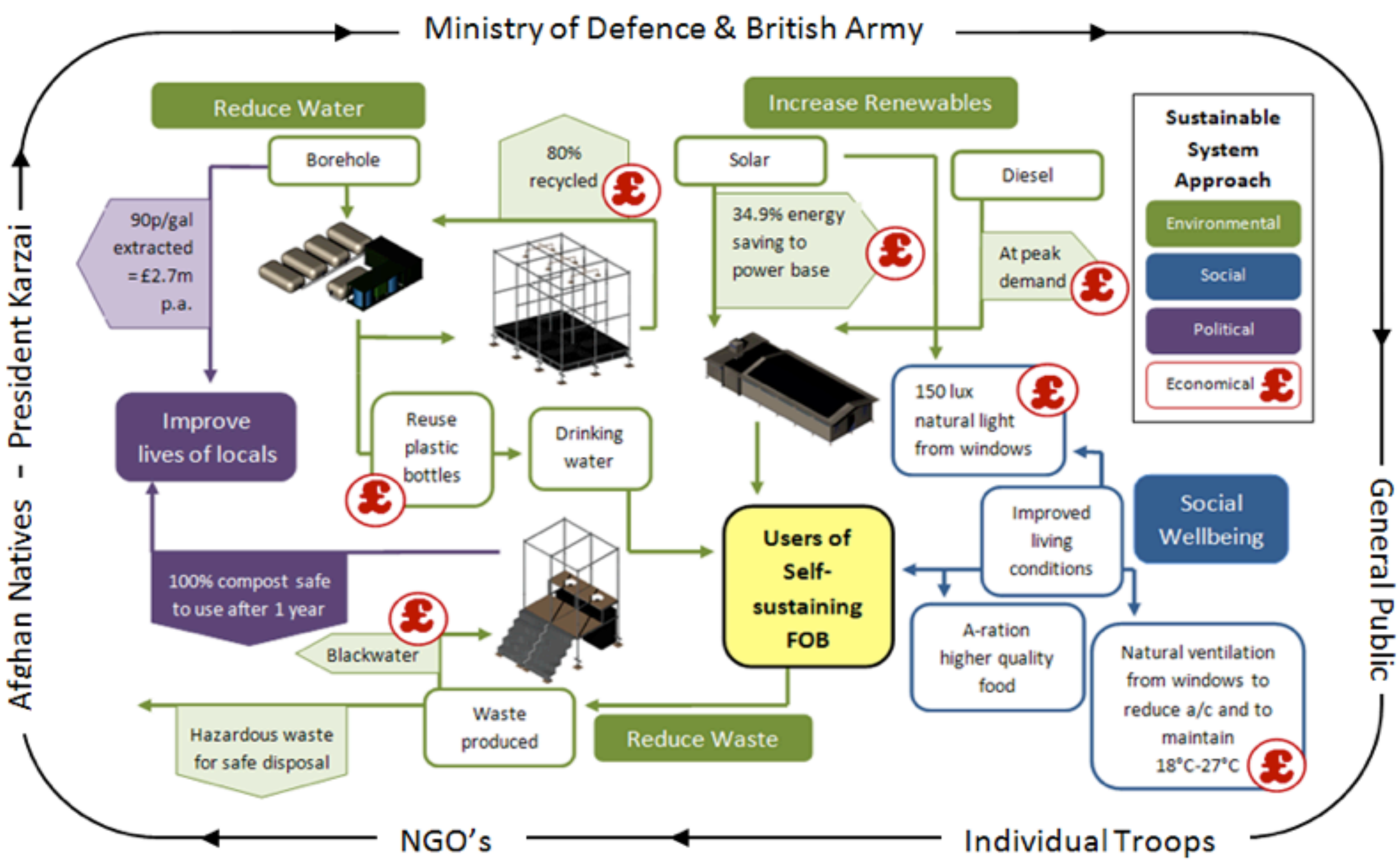
Lifecycle of our sustainable FOB concept

- The lifecycle of the sustainable FOB follows a sustainable process
- Robust and re-useable components can be removed from the site and re-used at another FOB or moved to storage
- Management of this lifecycle follows that of the 'packaged' FOB system



University of BRISTOL

Design evaluation: Areas of impact



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

University of BRISTOL

Design evaluation: Simulation based on IES VE

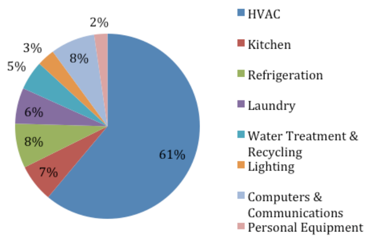


Figure 6. Energy demand in a sustainable FOB

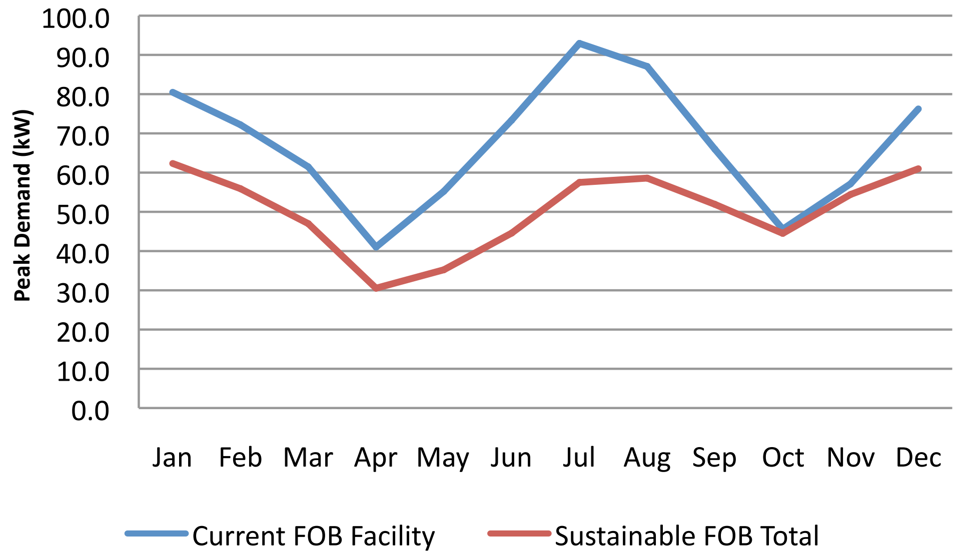


Figure 30: Comparison of annual peak demand of sustainable FOB and the current FOB

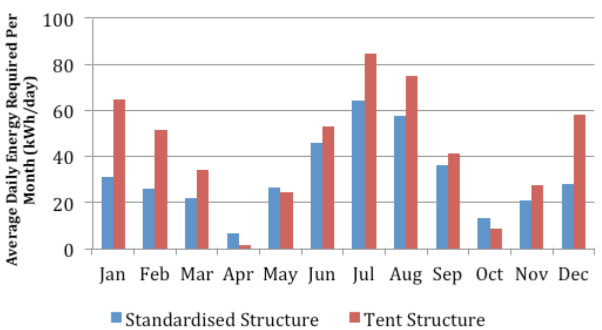


Figure 7. Heating and cooling demands of a standardised structure vs. a typical tent

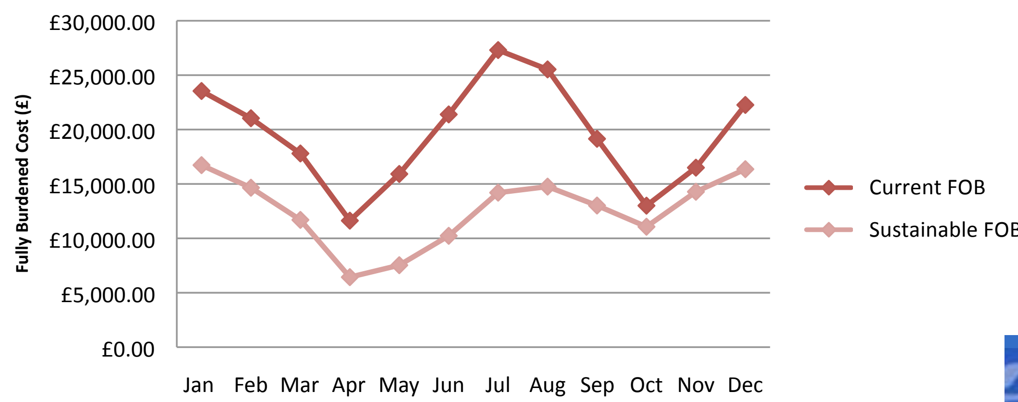


Figure 37: A comparison of the annual cost of fuel required for operating the sustainable FOB and current FOB

OK, what's the catch?

- Up-front capital expenditure is nearly doubled
- Annual operating cost nearly halved

Table 2. Aggregate figures of costs

Key Financial Information	Current FOB	Proposed FOB	% Change
Initial Capital Cost	£520,600	£972,800	+87
Annual Operating Cost	£10,400,000	£4,800,000	-54
Annual Fuel Cost	£235,100	£131,200	-44

- Not sure we can convince policy makers of the value – what do you think?

Thank you!

Any questions?

With many thanks to:

George Cave, Will Greenwood, Max Harrison and Amina Sadiq, now all MEngs in Civil Engineering