The
Agency of
Design

DESIGNING WITH ENERGY

Contents

INTRODUCTION

Do you know how much energy went into making the chair you're sitting on?

The energy that goes into manufacturing our material world is the largest component of our energy consumption, yet few people understand this embodied energy.

This document explains what embodied energy is, why it is important and explores new opportunities to incorporate it in the design process.

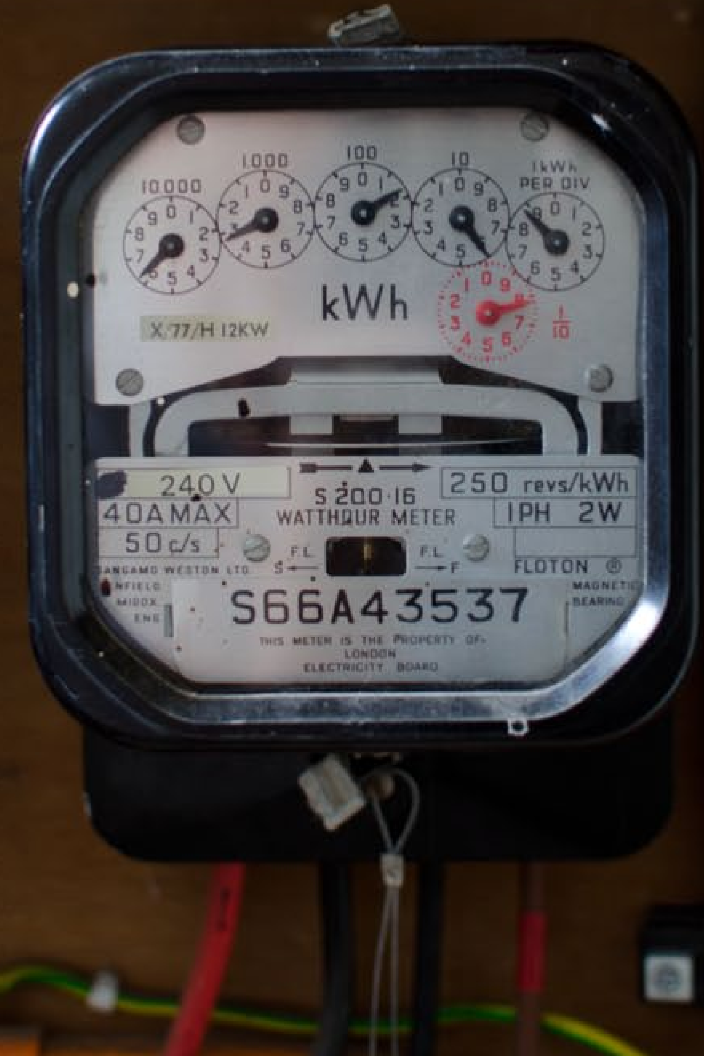
To meet CO2 targets, we need to change how energy is supplied and consumed.

Our energy consumption and its associated greenhouse gas emissions are one of the most difficult problems we face today. Our lifestyle requires the production of large amounts of energy, predominantly from non-renewable carbon dioxide emitting sources. These have the potential to cause devastating change to our climate.

As a result most nations have set ambitious CO2 reduction targets (80% reduction by 2050 for the UK) to try and curb their emissions.

Put simply; there are two approaches to achieving these targets; change the way we supply energy or change the amount we consume. While there are some promising future technologies, there are not any completely clean technologies that can change the way we supply energy in the near future.

As a result we need to look carefully at the energy we consume and see where there is potential for change.



Tackling energy consumption must include our largest energy sector; stuff.

We are becoming more aware of our direct energy consumption (heating, cooling, appliances etc.) through energy meters and smart appliances, but this is only part of a bigger picture.

The largest energy consumption sector in the UK is embodied energy [1,2]. This is the sum energy from extraction to production that goes into making our material world.

This is the energy that went into making the house you live in, the bike you ride, the phone you talk on, the pen you write with and the coffee cup you drink out of.

Energy has been invested in making almost every element of our material world.

1.Mackay, David 2009. Sustainable Energy Without the Hot Air.
2. Guardian National Carbon Calculator.

“The real issue is not our direct consumption of energy but the greenhouse gases embodied in the goods we buy.“

Monbiot (2010)

Why are we unaware of embodied energy?

While many products are labeled with their energy efficiency and power ratings, few people know how much energy went into manufacturing them.

Broadly speaking, we are embodied energy illiterate.

The problem mostly lies in the complexity of collecting embodied energy data. To know the embodied energy of a product you need to carry out a full life-cycle analysis (LCA) that ascertains the energy and carbon used to produce every element of a product from extraction of raw materials to a finished product leaving the factory. This can be complex, time consuming and expensive.

As a result not enough LCA's are conducted, so for many products we do not know their embodied energy.

A HUGE OPPORTUNITY BEGINS WITH THE DESIGNER

Understanding the energy properties of materials drives low embodied energy design.

While the complexity of life cycle analysis looks like a stumbling block for us changing our embodied energy habits, in practice we don't always need the level of detail a life cycle analysis provides.

Although not enough LCA's are conducted to compare the embodied energy of every product, we do have enough data to profile materials. By accumulating all the LCA data we can calculate an average embodied energy figure for different materials. This information is called Life Cycle Inventory data (LCI).

By engineering standards LCI data is imprecise; it has wide tolerances and can be averaged from a broad range of data sources. Despite its imprecision LCI data is extremely valuable. Rather than conducting an LCA on a manufactured product where the design decisions have already been made, this information can be used at the start of the design process where there is the greatest potential for change.

“We need metrics and aesthetics. We need to design new perceptual aids to understand the state of our natural, human, and industrial systems... We need to perceive the total embodied energy in everyday products.“

Thackara (2009)

What does a Megajoule look like?

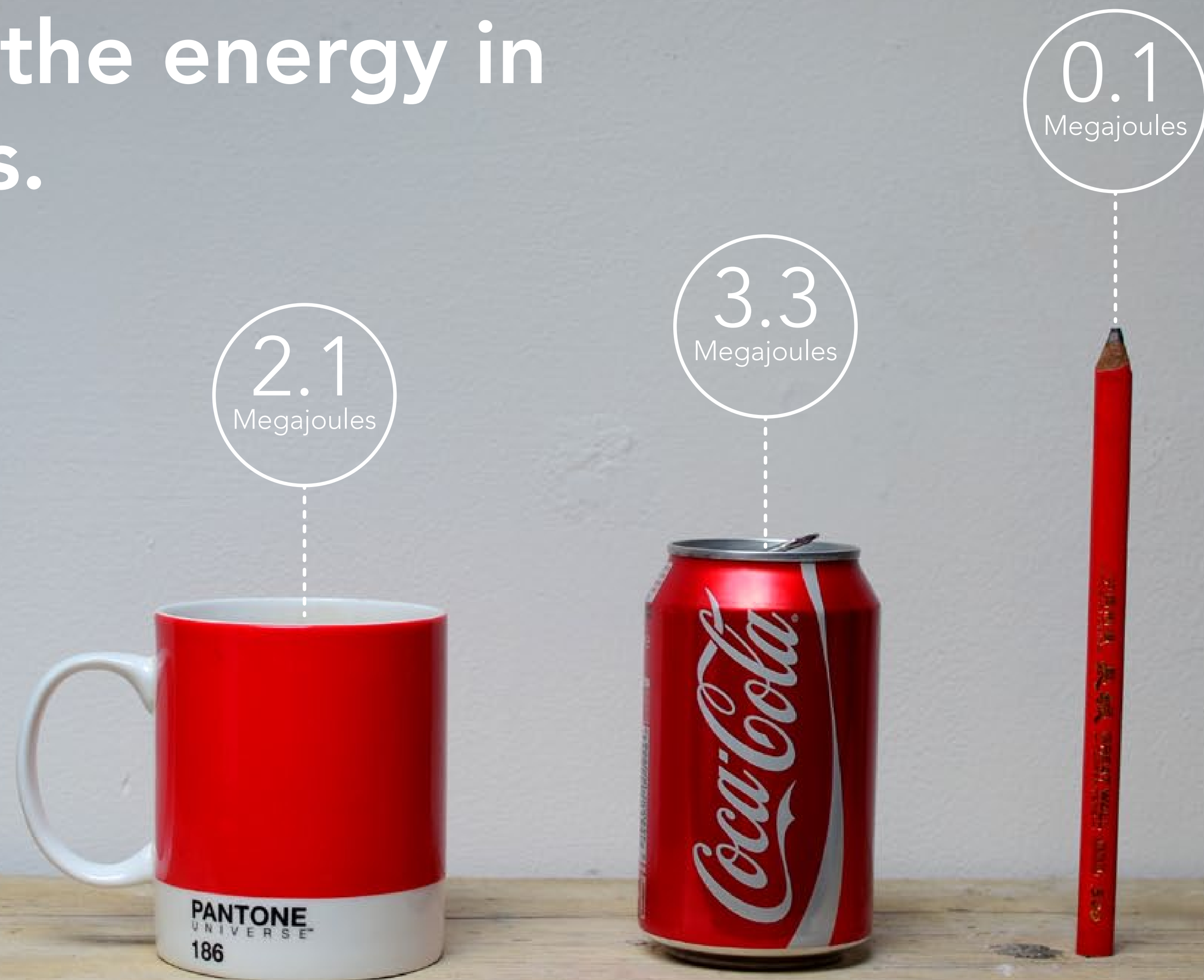
A joule is a unit of energy and is defined as the energy expended in applying a force of one newton through a distance of one metre. It is approximately the energy required to lift a small apple one meter straight up. A megajoule is 1 million joules.

Embodied energy data tells you how many megajoules of energy it took to produce 1kg of a material (MJ/kg).

This visualisation shows what volume of a material would be produced for 1 Megajoule of energy. It gives you a sense of what materials are plentiful from an energy perspective.

Understanding the energy in simple products.

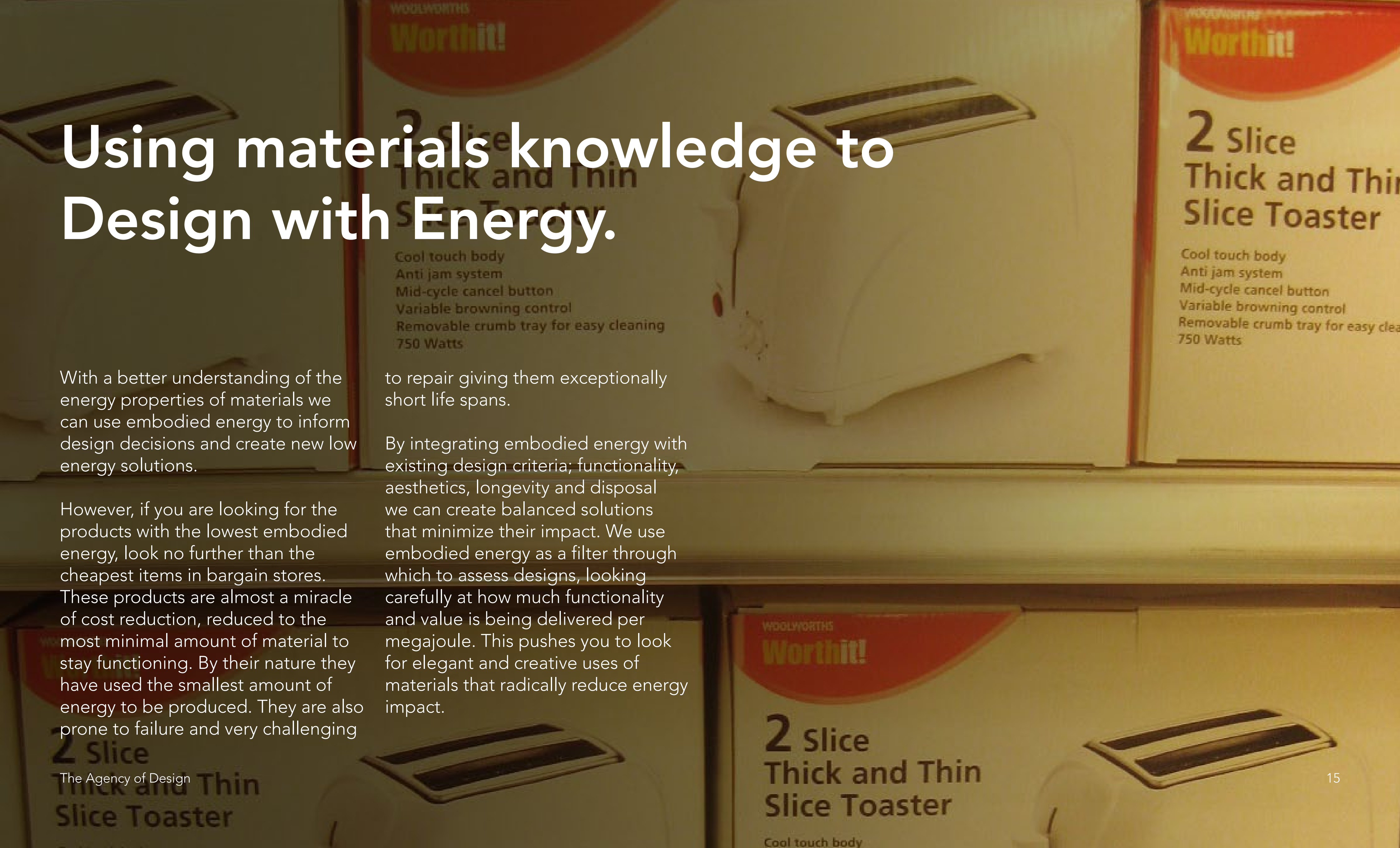
Embodied energy data makes it very easy to understand the energy in simple products. Multiplying the embodied energy figure by the weight of the product gives you a rough estimate of its total embodied energy.



Understanding the energy in complex products.

Embodied energy data allows you to calculate the energy in more complex products, giving you the energy break down of a products components. This image shows an augmented reality visualisation that scaled product components relative to their embodied energy, highlighting the energy hot-spots within a product.

Image from embodied enrgy visualisation experiments.



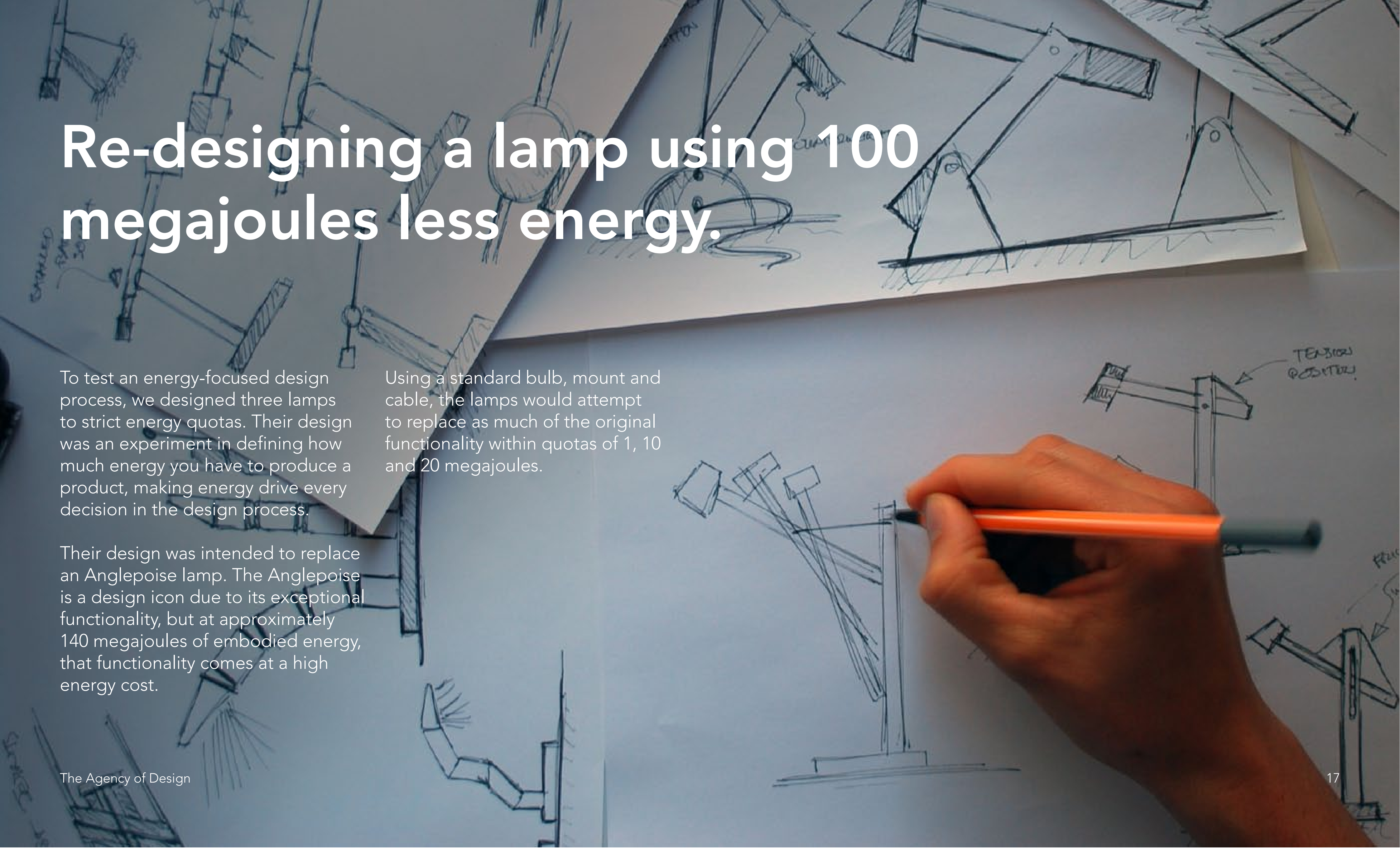
Using materials knowledge to Design with Energy.

With a better understanding of the energy properties of materials we can use embodied energy to inform design decisions and create new low energy solutions.

However, if you are looking for the products with the lowest embodied energy, look no further than the cheapest items in bargain stores. These products are almost a miracle of cost reduction, reduced to the most minimal amount of material to stay functioning. By their nature they have used the smallest amount of energy to be produced. They are also prone to failure and very challenging to repair giving them exceptionally short life spans.

By integrating embodied energy with existing design criteria; functionality, aesthetics, longevity and disposal we can create balanced solutions that minimize their impact. We use embodied energy as a filter through which to assess designs, looking carefully at how much functionality and value is being delivered per megajoule. This pushes you to look for elegant and creative uses of materials that radically reduce energy impact.

OUR PROCESS.



Re-designing a lamp using 100 megajoules less energy.

To test an energy-focused design process, we designed three lamps to strict energy quotas. Their design was an experiment in defining how much energy you have to produce a product, making energy drive every decision in the design process.

Their design was intended to replace an Anglepoise lamp. The Anglepoise is a design icon due to its exceptional functionality, but at approximately 140 megajoules of embodied energy, that functionality comes at a high energy cost.

Using a standard bulb, mount and cable, the lamps would attempt to replace as much of the original functionality within quotas of 1, 10 and 20 megajoules.

The 1 megajoule lamp.

1 megajoule doesn't give you a lot of material; this meant subtractive manufacturing processes were instantly ruled out. Instead, a formable material with the a high volume per megajoule was required.

By experimenting with a range of concrete mix ratios and fillers we formed an optimised concrete to provide maximum volume with good strength and insulation properties. A super lightweight glass filler added volume for minimal additional energy and an aluminous cement provided enough tensile strength to not need reinforcement.

The form of the lamp was designed to make the most out of the small volume of material. Multiple sitting positions and the ability to hang off its surroundings meant that it maximised the possible functionality from a small amount of energy.

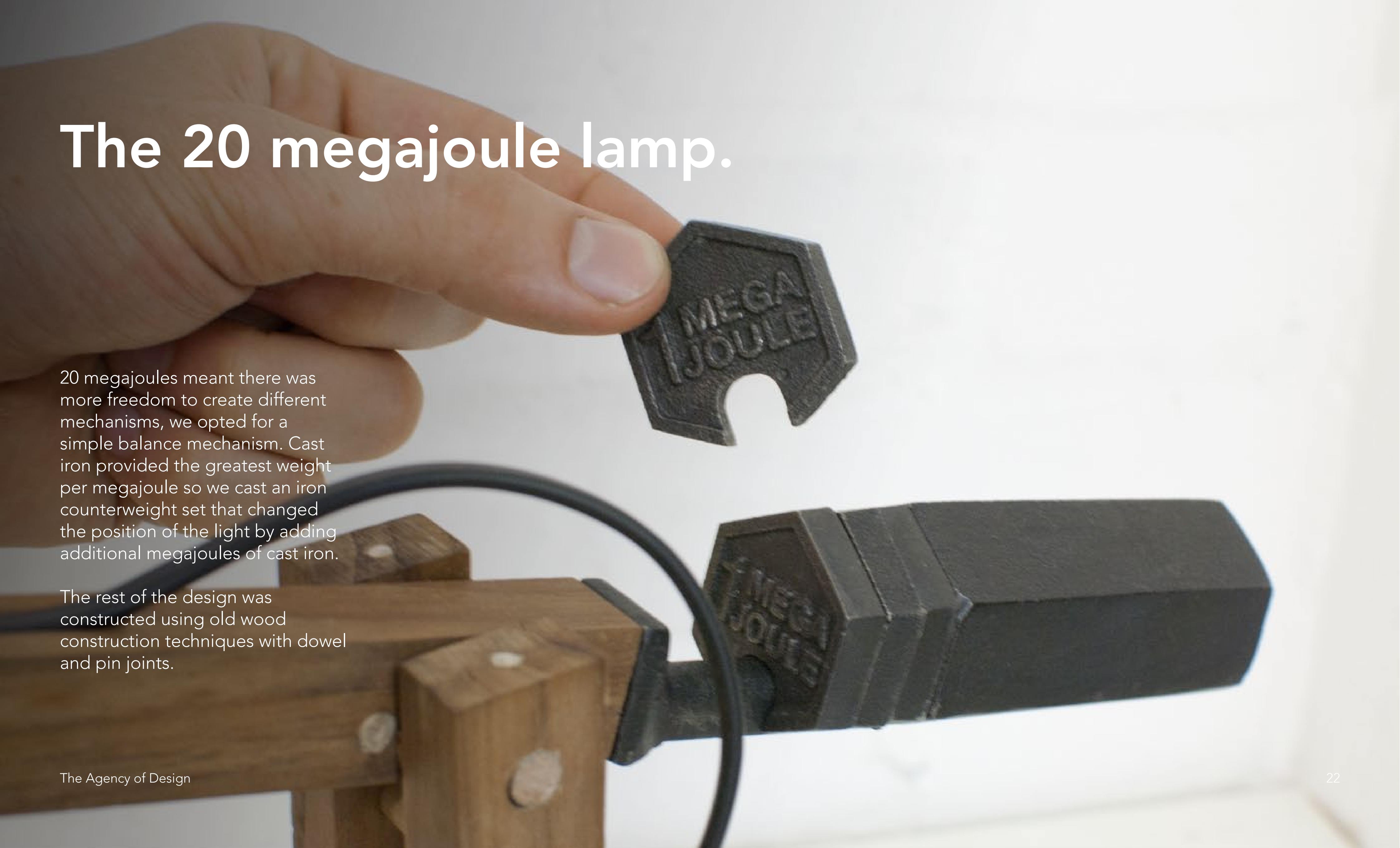
The 10 megajoule lamp.

10 megajoules meant there was a lot more material within the quota so we wanted to make a structure that was big enough to act as a task light. 10 megajoules of wood is enough to make a larger structure but adjusting the position of the light was a little tricky. As soon as a metal nut and bolt were used the length of wood you could have within the quota became a lot shorter.

The result was a mechanism reduced to its simplest form using the weight of the lamp head to create friction between a cork and oak linkage so it could stop at any position.

With press fit cables and dowel axles, the only metal used was a pair of magnets that held the lamp closed in its upright position.

The 20 megajoule lamp.



20 megajoules meant there was more freedom to create different mechanisms, we opted for a simple balance mechanism. Cast iron provided the greatest weight per megajoule so we cast an iron counterweight set that changed the position of the light by adding additional megajoules of cast iron.

The rest of the design was constructed using old wood construction techniques with dowel and pin joints.

NEW TOOLS


Concrete
Cardboard
Polypropylene
Brick
Softwood
ENERGY TRUMPS
A tool for understanding the environmental impacts of materials
Embodied Water
Embodied Energy
Embodied Carbon
32 MJ/kg
2.5 kg/kg
28 MJ/kg
1.3 kg/kg
2.7
100 L/kg
4.2 kg/kg
Extraction Intensity

“We need numbers,
not adjectives.“

MacKay (2009)

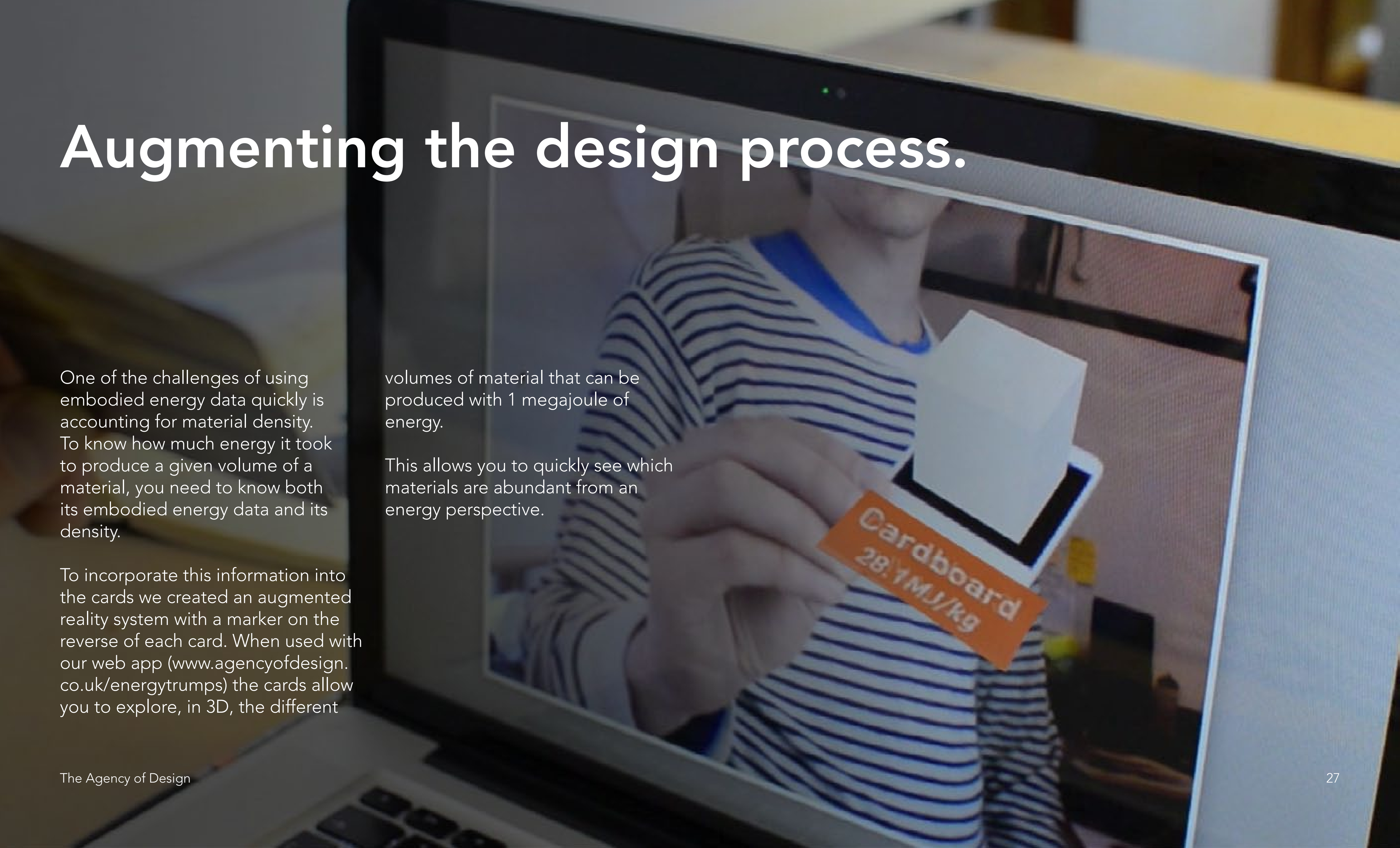
Simple tools to make energy part of the creative process.

Through our own explorations into an energy focused design process we could see how valuable embodied energy data was but also knew how little it was currently used in the design process.

We wanted to move environmental design decisions away from popular opinion or aesthetic associations and put the numbers at the heart of the design process. To do this we created the Energy Trumps, a fast visual design tool that could integrate environmetnal data into the creative process.

The cards allow you to quickly assess and compare materias, enabling you to make more informed material choices.

Augmenting the design process.



One of the challenges of using embodied energy data quickly is accounting for material density. To know how much energy it took to produce a given volume of a material, you need to know both its embodied energy data and its density.

To incorporate this information into the cards we created an augmented reality system with a marker on the reverse of each card. When used with our web app (www.agencyofdesign.co.uk/energytrumps) the cards allow you to explore, in 3D, the different volumes of material that can be produced with 1 megajoule of energy.

This allows you to quickly see which materials are abundant from an energy perspective.

CONCLUSION

Moving towards a low energy future.

Tackling our future energy challenges is almost certainly going to need more awareness of the energy embodied in our material world.

The emergence of embodied energy datasets has opened up new opportunities for understanding and designing with embodied energy. From our own experiments we believe the value of this data lies in applying it at the early stages of the design process where its impact can have the greatest effect.

The Agency of Design

We help organisations design a better future by re-thinking our physical and digital worlds.

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