Life-cycle Analysis (LCA):
Challenges and Solutions

As defined by leading designers at the LCA workshop

Part of Design Council's Design for Planet Festival in Dundee, November 2021

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Introduction from Protolabs

Stephen Dyson
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A key focus of Protolabs is to support design engineers and product designers in their work. Whether that be through our digital manufacturing services (3D printing, CNC machining and injection moulding) or advisory support for innovation and product development (our automated manufacturability software and a wealth of knowledge to impart) our goal is the same: give designers the tools they need to accelerate their ideas to fruition.

And we see knowledge sharing as key, which is why we choose to bring together designers to share their own experiences and learn from each other.

This ethos has led to Protolabs working with Design Council at the Design for Planet Festival in Dundee in November 2021. As part of this two-day event, we hosted a life-cycle analysis (LCA) workshop – a knowledge-sharing activity that drew on the experiences of the leading designers attending. At the workshop, firstly, people were divided into groups of four based on four of the key areas of LCA: resources and materials, production energy efficiency, minimising waste, and end of life. Secondly, each group was invited to list their main LCA challenges in relation to the group title. And thirdly, each group was then asked to identify solutions to each of the problems listed by another group. These challenges and solutions identified in the workshop form the basis of this Learning Guide.

The following chapters include more detail about this event at the Design for Planet Festival, a description of LCA and then the knowledge revealed by the LCA workshop itself. The final chapter offers further reading on LCA, including the InspirON Sustainability Series from Protolabs and other valuable resources available from Design Council.

Ultimately this document intends to support design engineers in their efforts to be more sustainable in their work. Knowledge sharing is key to this endeavour and I hope you glean something very useful from the following chapters. It is often exciting work being a designer, but the role also carries with it an increasing responsibility to support society's shift to net zero carbon emissions.

Thank you.

Introduction from Design Council

Cat Drew, Chief Design Officer
Design Council

Design shapes the world. It has a huge power to do so in a way that is good for planet and people, that is regenerative and not extractive, and that is inclusive and not exclusive. Design has admittedly been part of the reason that we are in the climate crisis, in the way that it makes unsustainable consumption easier, quicker and more desirable. But it can also be part of the pathway out.

At Design Council, our new mission Design for Planet recognises this and sets out to galvanise the 1.69m strong UK design community to design with the welfare of the planet as a priority. To put planet at the heart of the design brief. As part of how we do that, we need to share inspiring examples, build skills and learning and work with commissioners to build the market.

Watch our short film here

Design for Planet festival, organised alongside COP26, was our first big event of this new mission. It brought together 120 leading design and sustainability experts in person, and we were joined by 6,000 people online, and national design bodies from 20 countries.

One of the big learnings of the festival was that designers need to work more systemically. Not just looking at the product they are making in isolation, but seeing it as part of the wider system. Not just looking at economic value, but seeing how it is entangled with social and environmental value. Not just designers for a small set of target users, but understanding the impact of the design on wider groups of people, and on nature and biodiversity.

Life Cycle Analysis is one of a suite of tools that helps designers to think more expansively about what they're designing. It can be used throughout our **Systemic Design Framework**, at the conceptual stage to question material usage and whether the product should even be made in the first place (and what else might achieve the same outcome). And through to delivery, to assess the environmental impact of what has been produced. Our forthcoming **Design Economy** value framework will help designers look at a wider set of economic, social and democratic benefits alongside this.

I'm thrilled that we're collaborating with Protolabs on this learning paper which sets out why LCA is important and some practical ways in which designers can improve on how they reduce, re-use and recycle across supply chains, and work with local partners to keep materials in play. It is aimed at design engineers and product designers, but is useful reading for designers of all backgrounds to learn from a more systemic way of thinking and making.

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Contents

Life-cycle Analysis (LCA)

Life-cycle Analysis (LCA) is the comprehensive analysis of a product's entire life cycle system in terms of sustainability.

Through the methodology every single stage of a product's life cycle is scrutinised; from the extraction of materials from the earth, it's waterways or the atmosphere, to the manufacture of the product itself, its packaging, its transportation, the use of the product after purchase, and what happens to the product and its component parts after it is no longer used.

All of these stages obviously have an impact on the environment but an LCA can also be used to assess the impact on wider society if the brief and data is available for analysis. So, for example sourcing supplies locally will reduce carbon dioxide emissions and will also help the local economy with other local businesses employing more people. With this in mind it's worth thinking through how you define what you want to measure and also what data you will use to measure it. A LCA is a great tool to help drive improvement but you need to define what you are aiming to improve.

As far as product related environmental impacts are concerned it's estimated that over 80% of these are determined during the design phase; so LCA provides the insight needed to help make better design decisions. Many different types of LCA can be used, but in summary if more detail is required, then the more complete your LCA needs to be. There are a number of LCA-related assessments, such as Environmental Product Declarations (EPDs) which provide a standard way of declaring the impacts of manufacturing and using products. And there are 'conceptual', 'simplified' and 'detailed' LCAs which break down as shown here...

It's important to realise that whichever LCA model you use, it will be adaptable to a number of different types of project. You can use it to perform a variety of assessments; whatever best matches your project needs at any given time.

Conceptual LCA

Very basic level looking at qualitative inventory, to create flow diagrams and understand, for example, which components have the highest relative environmental impact.

Simplified LCA

Basically a full LCA but using more generic data and standard modules for energy production. A simplified assessment that focuses on the most important environmental aspects, and thoroughly assesses the reliability of the results.

Detailed LCA

The full process of in-depth data collection, highly specific to the product in question.

Also, the International Organisation for Standardisation (ISO) has published a set of standards on LCA (ISO14040 and 14044) that support an approach to the methodology to ensure its quality and consistency. More detail can be found in the further reading chapter, later in this document.

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Ten Tips For Designers Approaching LCA

The ten tips for designers approaching LCA are a very brief summary guide for those seeking to include LCA methodology in their work.

Much greater detail can be found in the later chapter 'the challenges and their solutions' (the findings from the LCA workshop), but these tips serve as a quick reference and reminder.

Ten Tips

1. **Make sure that you include the planet in the scope of the design brief**

To be effective you need to ensure that you think about the effects of the product on the planet and its people within the brief. Think about what is important and how you will measure these impacts.

2. **Reduce, re-use, recycle. But first think 'does this need to be made at all?'**

The first question that you need to ask is do you need to make this product or component at all? What else might help solve the problem or achieve a better future? If the answer to this is still yes then think about whether you can make it easier to reuse your product beyond its first life cycle. And be aware that you are using up limited natural resources, so ensure that you use them in the most efficient way possible. This goes beyond reducing material usage, to examining whether you can use recycled waste as raw materials.

3. **Consider materials carefully and optimise material use, for product and packaging**

For production, you need to consider how to optimise rather than maximise material use. Legislation can make designers too cautious so that they put more material into a product than is needed with a 'better safe than sorry' attitude. Aim to really understand what is needed and avoid over specifying. This principal is even more applicable to packaging with most consumers demanding less.

4. **Analyse where there are highest levels of waste and energy**

The more you understand your own processes and what to measure the better you will be able to pinpoint high levels of waste – whether of raw materials or energy – and then take action to eliminate, reduce or recycle and reuse.

Ten Tips

5.
Engage the whole supply chain to create efficiencies and collaborate with others to reduce waste and re-use materials across sectors

While you need to address questions within your own production facility, you also need to spread your net wider to encompass your supply chain in this drive for sustainable production. You need to discuss the same questions raised above with them and explain how you are seeking to make savings on waste and energy throughout the process with the ultimate goal of developing more sustainable products.

6.
Localise the supply chain where possible and reconsider your energy sources

Remember that sustainability is not just about the material but where it is sourced and also the energy used to produce the product. If you can develop local suppliers then you will reduce the environmental impact of transportation and help to support your local economy. Consider also how you can reduce the amount of energy you use to produce your product and the source of that energy – is it produced from renewables and is it worth investing in your own renewable supply?

7.
Create storage to reduce waste and to help with disassembly and re-use

There will still be waste that needs collecting so that it can be recycled and reused. As a society and as a business there needs to be infrastructure in place for both the consumer and for industry. There needs to be a place for manufactured consumer goods, with a storage facility to collect the different types of waste and areas where it can be disassembled, think about electronics for example. Too much waste at the moment goes straight to recycling rather than reuse. We need to reconnect waste and make it more visible.

8.
Enable on-site production

Minimise the number of locations where a product's parts and components are manufactured and reduce the size of the supply chain by bringing some of the production onsite. Work hard to make the supply chain itself more efficient.

Ten Tips

9. **Design for end of life and disassembly. Abide by Design for Planet principles of circularity and regeneration.**
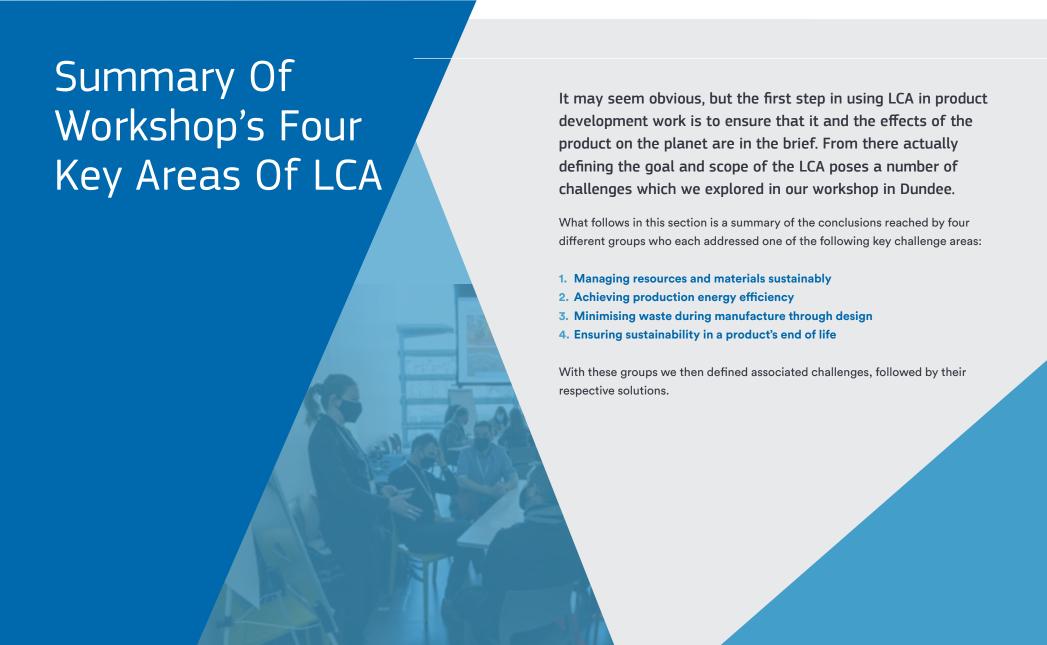
The disposal of old products will have an impact on the environment, so the challenge is to minimise this by designing it for end of life and disassembly rather than consigning it to landfill. Also consider how the product may be reused beyond its original life, so consider modularity of replacement parts, reuse and upcycling. And even better, can what you're designing actually regenerate natural resources?

10. **Share what works and what doesn't so we can learn collectively.**

We can all learn from our experience so we need an open-source model that demonstrates what works well, supports how things can be done correctly, and helps us to learn from mistakes. Designers need to experiment, try different things and learn from their collective experience. Consider how you will share your experiences with other designers so that we can all move towards more sustainable products.

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Summary Of Workshop's Four Key Areas Of LCA

It may seem obvious, but the first step in using LCA in product development work is to ensure that it and the effects of the product on the planet are in the brief. From there actually defining the goal and scope of the LCA poses a number of challenges which we explored in our workshop in Dundee.

What follows in this section is a summary of the conclusions reached by four different groups who each addressed one of the following key challenge areas:

1. **Managing resources and materials sustainably**
2. **Achieving production energy efficiency**
3. **Minimising waste during manufacture through design**
4. **Ensuring sustainability in a product's end of life**

With these groups we then defined associated challenges, followed by their respective solutions.

1

Workshop outcome: the challenges and their solutions

Managing resources and materials sustainably

All of the raw materials that we need in a product come from the Earth's crust, atmosphere, oceans or are due to living organisms and have an impact on the environment.

The first question that we need to ask is do we need to make this product or component at all? If the answer is yes then we need to be aware that we are using up limited natural resources, so we must ensure that we use them in the most efficient way possible. This goes beyond the product design, which can reduce material usage, to examining whether we can use recycled waste as raw materials. (Tip 2)

❯ **CHALLENGE**

Getting the right material

The circular economy is becoming more prominent in manufacturing with waste recycled back into production. While this is available to designers as raw material, it is still massively underused. As we will find out later recycling has implications for the end of a product's life, but right from the beginning designers need to be more proactive in using secondary raw materials and help to create a sustainable supply chain.

Creating such a supply chain is hard as it requires a great deal of effort and trust. After all, how do you know if your supplier uses sustainable production methods, particularly if they have no certification? The only real answer is to spend time doing the research by engaging with your suppliers, speaking to your network and visiting trade shows. If you are serious about developing more sustainable products then you need to put in some effort. (Tip 5)

And remember that sustainability is not just about the material but where it is sourced. If you can develop local suppliers then you will reduce the environmental impact of transportation and help to support your local economy. (Tip 6)

❯ CHALLENGE

What material characteristics do you need?

Moving onto the product development itself, material selection will depend on how your product is used, for how long and how it will be disposed of or reused. Ask yourself what physical characteristics must it have and what about its texture and colour? Will you need metal, bio-plastics, fabrics or other materials such as wood or stone?

When you are sourcing your material, you need to think about the product's entire lifecycle and whether it will affect the environment, so for example in textiles polyester can leak microplastics into waterways during washing, and recycling can be a problem if you use a blend of natural and synthetic fibres.

While you may think that biomaterials are a good answer you need to ask whether they are suitable for your product. Do they suit your product's functionality and what will the cost be? As an alternative, would your product be better using biodegradable or compostable material?

While recycling is one answer, you may decide that some non-recycled materials might be better, for example bamboo and hemp are crops that require relatively minimal resource to grow, have very distinct material characteristics, do not have any impact at the end of the product's life and you can easily recycle them.

Clearly there are lots of questions that you need to ask but it's important to keep in mind the positive impacts your material choices will have.

❯ CHALLENGE

Making greener choices

While it is important to delve deeply and get involved in the detail, you need to remain aware of the bigger picture during product development. In an ideal world there should not be any 'non-green' choices, but in reality, this may not be possible.

As we strive towards more sustainable products you should not be afraid of making mistakes or indeed including non-green materials or elements in a project. Sometimes there will be no other option or it may be a positive choice so that other elements are green.

We need to think about the whole rather than fragments and share the responsibility for a more sustainable answer. This may involve bringing together disparate components, people and even suppliers to find out how to eliminate the non-green elements that we sometimes instinctively turn to.

Establishing this culture of mutual responsibility will free us to make harder choices, move away from the accepted norm and not be held back by the fear of making mistakes or getting it wrong.

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2

Workshop outcome: the challenges and their solutions

Achieving production energy efficiency

Having selected the materials that we are using and considered their cost to the environment and local economies, we can turn our minds to the challenge of sustainable product development which was discussed by another working group.

So, how do we minimise the environmental impact of the manufacturing process?

❯ **CHALLENGE**

Dealing with poor manufacturing processes

One of the key issues that the group addressed is that in an era where we are urging the adoption of a circular economy, most manufacturing remains linear. This raises a number of questions that we need to answer. How do you make these linear manufacturing systems more circular? How do you capture the waste within the various production methods and reuse it elsewhere? And starting at the design stage how can we use the three Rs – reduce, reuse and recycle?

❯ CHALLENGE

Encompassing your supply chain

While you need to address these questions within your own production facility, you also need to spread your net wider to encompass your supply chain in this drive for sustainable production. (Tip 5). You need to discuss the same questions with them and explain how you are seeking to make savings on waste and energy throughout the process with the ultimate goal of developing more sustainable products. With this in mind it is worth localising your supply chain where possible to save the environmental costs of transportation and to benefit your local community. (Tip 6)

There are of course other questions that you need to address, not least of which are cost, competitiveness and margins. This may mean that you need to reduce the number of locations where a product's parts and components are manufactured, reduce the size of the supply chain perhaps by bringing some of the production onsite (Tip 8), and work to make the supply chain itself more efficient.

Clearly this is a big task and you will need to involve others within and also outside of your organisation. It is impossible to solve all of these issues yourself and it is important to remain focused on your own manufacturing operations. The more you understand your own processes and what to measure the better you will be able to pinpoint high levels of waste – whether of raw materials or energy – and then take action to eliminate, reduce or recycle and reuse. (Tip 4)

❯ CHALLENGE

Moving away from legacy systems

One of the biggest issues you may face are the systems that are already in place. Legacy systems usually mean older, less efficient manufacturing processes, but it also extends beyond this into societal legacy systems.

This is where design pioneers are challenging the norm. Typically, they are small to medium sized enterprises who are finding new solutions, rather than the big monopolies. Unfortunately, it is those big monopolies that can dominate and close down opportunities for those smaller organisations.

This can lead to the question of how to get such monopolies to co-operate for the good of all and society in a wider sense. For example, should Amazon become open source? This is where regulation can play a role because top-down action can help control the market to make it fairer and allow new ideas and solutions to prosper.

This levelling of the playing field will also help reduce energy use and how you think about your energy sources. While there are well defined ways that we can reduce a production facility's energy consumption, we often can't control how all of this energy is produced. National energy systems tend to be a mixture of fossil fuels and renewable energy. We need to see the true cost of energy sources because ultimately it is more expensive to society to not act on climate change than it is to act on it.

This will involve some education and the consumer having a longer-term mindset rather than just the immediate gratification of what we consume. As a society we need to 'horizon scan' and understand that product use needs to go beyond the 'now' and more into the longer term.

Such attitudes need to change if engineers are going to engage in energy efficiency and sustainable production rather than focus on their KPIs within a relatively narrow timeframe, where they are trying to hit targets rather than serving the consumer in a more sustainable way.

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3

Workshop outcome: the challenges and their solutions

Minimising waste during manufacture through design

When you manufacture a product there will be waste and potential consequences such as increased landfill and pollution. The challenge is how to minimise this and where possible recycle and reuse it.

Design engineers are generally not oblivious when they create waste in their designs especially when they consider end of life. When you understand the whole life cycle of a product you realise that it is the material that is the long-term player, the product itself is just a fleeting moment in its life; so minimising waste is primarily about making sure that you get that material back to its original form so that it can be reused. The problem is that this is often not in the brief, so designers tend not to consider it – all of which leads us back to putting the impacts on the planet in the overall design brief from the beginning. (Tip1)

❯ **CHALLENGE**

Optimising material use in production

For production, we need to think about how to optimise rather than maximise material use. In design engineering people become nervous about material use and how this might impact health and safety legislation. This can make designers cautious and put more material into a product with a 'better safe than sorry' attitude.

One interesting thought about material optimisation is to move towards on-demand production where the consumer is dictating their consumption needs more quickly so there is less need for storage and there is less chance of overproduction. It also answers the question of does this product need to be made at all. (Tip 2)

We can learn from the construction industry here who are doing a lot of work to reduce excessive steel use. The lesson is to really understand what we need to and to not over specify. (Tip3)

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❱ **CHALLENGE**

Getting around unnecessary packaging

This same principle is even more applicable to packaging. Most consumers are actually demanding less packaging now so be bold and don't make excuses, just reduce it. There really is no need for excesses in this area of product development and delivery.

❱ **CHALLENGE**

Lack of storage and dealing with waste

There will of course still be waste that we need to collect it so that it can be recycled and reused. It means that we need to have the infrastructure in place for both the consumer and for industry.

There needs to be a place for manufactured consumer goods, with a storage facility to collect the different types of waste and areas where it can be disassembled, think about electronics for example. Too much waste at the moment goes straight to recycling rather than reuse. We need to reconnect waste and make it more visible. (Tip 7)

But the problems of waste goes deeper than this. If you place a lot of energy and effort into making a product, then why are we building in obsolescence? On a deeper psychological level people want to get rid of stuff that they can't store. Instead of this, we should aim to extend the life of a product which brings us back to 'reduce, reuse and recycle', with reduce and reuse being the most important. Sadly, they are often forgotten and we default to recycling. (Tip 2)

Workshop outcome: the challenges and their solutions

4

Ensuring sustainability in a product's end of life

The disposal of old products will have an impact on the environment, so the challenge is to minimise this by designing it for end of life and disassembly rather than consigning it to landfill. (Tip 9)

Unfortunately, there is often a lack of responsibility for a product's end of life. Socialising liability for end of product life would require an audit trial.

❯ **CHALLENGE**

Producer responsibility

For the responsible producer aiming to develop sustainable products discussing these issues and liabilities needs to take place at the start of a project rather than leaving it to the end when it's often too late to act.

We need to adopt a strategic approach to end of life to develop a step-by-step response. One approach is to create a life cycle management plan which will ensure that the product is phased out properly and responsibly. This will not only make a product more sustainable but it will help avoid future disruption and help an organisation meet its regulatory requirements. Such a plan would include all aspects of product development, from conception to end of life.

❯ **CHALLENGE**

Value resources

But it is a mistake to think of a product's lifecycle as linear. What we need to do is change our mindset and use LCA to drive a circular approach that enables reuse as well as recycling, which in turn will reduce gaps in product availability and help avoid stock problems for manufacturers.

A fundamental purpose of LCA is to avoid material waste by focusing on end-of-use material capture. This means that you must consider disassembly, modularity for replacement of parts, reuse and upcycling where this is possible.

Ultimately to become more sustainable, we need to design products that make it easy to capture materials when it has completed its first use phase or the end of its first life. Beyond this the design could include second, third and many more 'use' phases. The traditional linear model of product development prevents this, but changing our focus to a circular model challenges us to consider such reuse.

Once you embark upon such thinking there is a new focus on material recovery and you are well on your way to a more sustainable future.
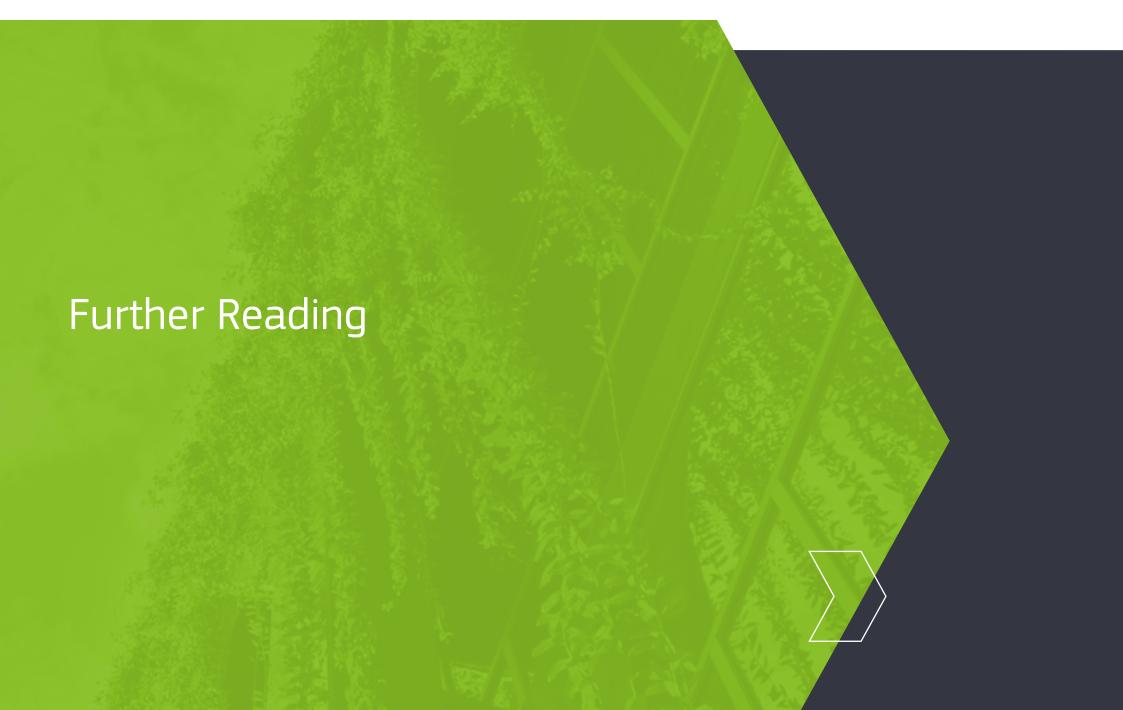
❯ **CHALLENGE**

Design for disassembly

To achieve this, you need to consider design for disassembly. Simplicity is the key here where less is generally the answer, so use fewer fasteners and reduce the number of tools you need for taking it apart and removing components or sections. It's worth taking your designer hat off at this point and think about how quickly you could take say 100 of your products apart. So, make sure that you don't use glue or epoxy, make sure that fastening points are easy to access and ask yourself whether your hands or fingers will fit. (Tip 9)

Finally, we can all learn from our experience so we need an open-source model that demonstrates what works well, supports how things can be done correctly, and helps us to learn from mistakes. Designers need to experiment, try different things and learn from their collective experience.

Further Reading

Further Reading

❯ InspirON Sustainability Series

The InspirON Sustainability Series consists of video presentations and round table discussions with the involvement of experts and thought leaders in the various fields of sustainability, including circular economy, life-cycle analysis, materials technology, renewable energy, government legislation and consumer culture. Delivered 'live' in April and May 2021, and with recorded content continuously available on-demand on **Wistia**, the series is in response to the growing urgency around climate change mitigation and how design engineers are key to this endeavour.

The video presentations delivered by the experts are grouped into four themes to help viewers navigate through the variety of content: *Inspire to Change; Technical Tools; Go Faster;* and *Thinking Big*. There are also round table and Q&A sessions that form discussion-based presentations around the key topics of sustainability in design engineering and manufacturing.

❯ Beyond Net Zero – A Systemic Design Approach

The Systemic Design Framework, launched by Design Council in April 2021, has been developed to help designers working on major complex challenges that involve people across different disciplines and sectors. It places people and planet at the heart of design.

Enabling sustainable living is one of Design Council's three key priorities outlined in their 2020-24 strategy. As part of their work to improve design standards and promote sustainable development, they conducted research into design for net zero, at the same time as developing – through their own programmes of work and engagement with Design Council experts – frameworks that support designers to come together to work on complex topics. This work can now be used by the 1.69m people working in the design economy in the UK as well as those elsewhere, the design students who will join them soon, and businesses and commissioners wanting to take a design approach to achieve their sustainability goals and climate commitments.

Read More

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Further Reading

❯ Design Economy 2022

Design Council's most ambitious research programme yet, Design Economy 2022 aims to provide the most comprehensive assessment to date of the value of design. As well as exploring the wide-ranging value of design, this three-year project also considers the role that design can play in building back better and creating a more just, healthy and regenerative world.

A three-year research programme, hosted on an interactive digital platform, Design Economy 2021 will be a growing resource for policy makers, business leaders, public sector professionals, architects and designers. It will explore a range of topics, including:

- the social and environmental value of design
- the economic value of design
- business understanding and use of design
- public sector understanding and use of design
- public understanding of design
- regional variations in the use of design
- how the design economy might evolve and change over time

The topic of LCA and its associated subject matter is included in the reporting narrative.

Read More

❯ Upstream Innovation

This guide from the Ellen MacArthur Foundation helps organisations achieve their circular economy goals for packaging. Packed with practical tips, decision support frameworks and case studies, it is designed for marketeers, product designers and packaging engineers.

As the title suggests it focuses on upstream innovation to challenge us to rethink products and services at the design stage, whether that's through developing new materials, product designs or business models. So instead of working out how to deal with waste, it explores how we can prevent waste from being created in the first place.

By providing tools, facts and real-world examples, the guide's aim is to empower you to take action and help create a circular economy for plastics. It is split into three parts; The mindset, three strategies that you can use and finally how to make it happen.