EPSRC
Pioneering research and skills

ANNUAL REVIEW 2014-15

EPSRC Centre for Innovative Manufacturing in INDUSTRIAL SUSTAINABILITY

MEMBERS

Growth is a good thing isn't it? It underpins our economy, gives us financial security and sense of wellbeing. When we don't have growth our news flow is filled with doom, financial markets retreat and asset values fall. We can conclude therefore that growth is good and we can look forward to new markets growing where 100's millions of new aspirational consumers want the benefits that the developed economies have enjoyed for decades. What's not to like about that for all concerned?

Well here's the rub; we have more than enough data around us already to know that if we meet the needs of these new consumers by producing goods and transporting them around in the way we do today we will not have sufficient resources on the planet to do this. Our model of normality, with gently cycling growth and recession on a general upward trend, peppered with the odd minor crisis, will be broken. Within a single lifetime we could become seriously unstuck. Forecasts suggest, for example, that we may only have 60 harvests left in the world before we exhaust the earth.

What are we going to do? I'm an engineer, industrialist and a free market thinker. So, my response is a "call to arms" for technological solutions. We need to meet the needs of consumers, continue to improve and enrich lives, but this needs to be done in a sustainable way. It is all entirely possible, if we mobilise our best scientific and engineering minds, and if we view this as a business opportunity rather than a crisis borne from the inconvenient truth.

A good example of this is within the industry that brought me up – Automotive. Faced with the pressures of CO_2 reduction, the engineering community set-to and have established a very serious and credible electric vehicle industry, paving the way for more sustainable transportation. This in turn will drive a demand and a market for more sustainable electricity generation (including a richer mix of nuclear power to buy us time to develop more solutions). This represents a very tangible commercial opportunity driven by a "call to arms" on CO_2 reduction for cars.

Now is the time to take action on the bigger picture. Do we want prosperous sustainable growth that we can all enjoy, or a squabble and fight for resources as precious as food and water?

With the help of this report and the resources of the EPSRC Centre for Industrial Sustainability we are well positioned in the UK to make a business opportunity from a growing problem. We will not regress, we will find solutions if we have the will. But we need a plan, and planning for this is difficult when life currently feels so comfortable.

A quote from the industrialist, the late John Harvey Jones, captures the moment:

"Planning is an unnatural process; it is much more fun to do something. And the nicest thing about not planning is that failure comes as a complete surprise rather than being preceded by a period of worry and depression"

Let's get planning....

Dick Elsy
CEO, High Value Manufacturing Catapult

ANNUAL REVIEW **2014-15**

Executive Summary

This report marks 4 years of work at the Centre and the rewards of that effort are apparent in much of the content. All of the value, innovation and quality that has been created is as a result of the incredible dedication and hard work of our research and support communities.

We are continuing to operate with over 60 researchers, a support group and governance operation comprising another 16 (mainly part-time). With 18 member organisations and currently active industrial research in over 34 companies and in conjunction with 13 Universities the Centre is meeting its goal of becoming a National Centre operating on an international stage.

At the outset of our journey we set out 3 Grand Challenges - Eco Efficiency, Eco Factories and Sustainable Industrial Systems. We also held back some funds to ensure that as the industrial landscape evolved we could respond. The research portfolio now shows how we have been able to meet all of these aims. We have 29 research projects and PhDs active in our original Grand Challenge areas and in addition we have added new Challenges in Sustainable Business Models and Circularity where we have another 10 research projects and PhDs.

Our desire to create an impact remains core to our development and we have doubled (to 20) the tools available to industry in the past year. In conjunction we have pushed hard on our outreach activities to ensure that both tools and other research knowledge is being made available as widely as possible.

Enabling all of this, the core funds from the EPSRC have been added to with £10M from a range of sources (both private and public) and we expect to beat our initial business plan of £14M in total funding by around 20%. All of these funds have been spent on researcher time and effort to maximise the value to our partners and the UK economy.

I hope you find this review illuminating and if you are not already part of our network and would like to join in please get in touch with me or anyone in the team.

Professor Steve Evans
Centre Director, University of Cambridge

Highlights

20 *TOTAL TOOLS*

8 *NEW CASE STUDIES*

5 *PHDS COMPLETED*

30 *LIVE*

46 *NEW PUBLICATIONS*

147 *COLLABORATORS*

18 *MEMBERS*

58 *TOTAL RESEARCHERS*

Contents

ANNUAL REVIEW **2014-15**

Challenge and Vision

Imagine a world of factories that clean the water they use, where the air is cleaner leaving the factory than coming in and which use locally available materials in advanced processes to create personalised versions of global products, and which offer the highest value jobs. Such an idealised factory is not only needed, as predicted in various international reports, but is possible.

Our research has shown a pathway to that vision of a positive manufacturing future.

Because of our work, we now know better how to bring efficiencies into more and more factories, with ever more technologies emerging to help on that journey; we are also learning how to change our business models, how to make material circular and how to transform the industrial system. Now, in our fourth year, the EPSRC Centre for Industrial Sustainability is busy taking that hard earned knowledge and turning it into tools that manufacturers can use directly, and with increasing frequency.

We are working with our industrial partners on their new factory designs – such as the Vitsœ factory in Leamington Spa, or planning a new jeans factory for Saitex that will be 'net-positive' (cleaner and more equitable than its inputs), or helping create a benchmark 60,000 staff industrial park for Brandix.

Marks & Spencer are using our business model research to guide their efforts to reduce customers total clothing waste by 50% while delivering higher value, while Altro and FMCG collaborators are using our new insights on changeovers to make themselves even more eco-efficient.

The importance of non-labour resource productivity does not diminish and we are bringing this knowledge into industry and into policy making, while our circularity research has found new and helpful ways to operationalise the concept and make it practical.

Looking to the near future we can see a number of key trends and have invested in some already. Gamification is an exciting way to communicate knowledge and we are already using this with Airbus.
We expect much more modelling content in our future research as we move from identifying the key variables that matter to characterising those variables and simulating them. We are using agent-based modelling to explore business models and also real time data feeds to simulate operation performance under variable conditions. In response to industry demand we have increased our research into sustainable design and into circularity (sometimes together).

We are very happy to be supported by knowledgeable and ambitious collaborators, who keep pushing us.
And keep pushing us…. This should be clear from reading the rest of this annual review. If you want to join us in this endeavour, do get in touch.

UNIVERSITY OF CAMBRIDGE · Cranfield UNIVERSITY · Imperial College London · Loughborough University

ANNUAL REVIEW **2014-15**

Sustainable Business Tools

20 TOOLS

SUSTAINABLE BUSINESS TOOLS

Efficiency

Factory Resource and Energy Efficiency (FREE) toolkit

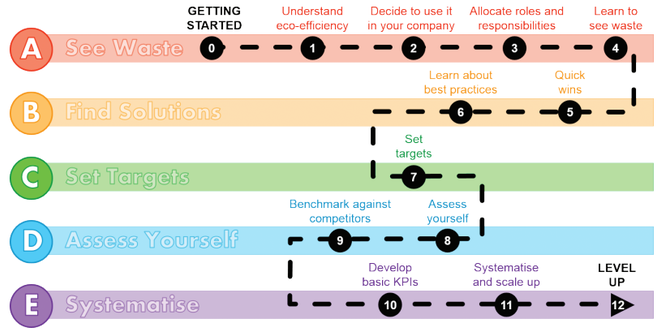
The FREE toolkit guides manufacturers through their eco-efficiency journey with simple tools and games which are engaging and easy to use as they require little (if any) data to get started.

This helps overcome the first barriers to implementation and gain momentum for more advanced activities. The toolkit helps identify improvements, strengths and weaknesses through examples of good practices and sustainable manufacturing models, assess current practice maturity (qualitative) and develop performance indicators (quantitative).
The FREE toolkit also provides a strong framework on which companies can develop their own approach to eco-efficiency: as companies understand how eco-efficiency fits into their operations, they can customise their use of the FREE toolkit to match their specific needs. It can be used internally or across supply chains.

The tools are mapped against five key elements for eco-efficiency:

1) See waste. What is your waste worth? Learn to identify waste in your factory.
2) Find solutions. How can you remedy it? Quick wins to more advanced tactics for resource efficiency.
3) Set targets. What's the size of the prize? Determine potential benefits and set targets.
4) Assess yourself. Where are you now? Establish current performance and benchmarking.
5) Create good habits. Where to from here? Identify improvements in a systematic way, and make it a routine activity.

For more information contact Dr Mélanie Despeisse,md621@cam.ac.uk.



Energy Efficiency Card Game

This tool uses a card game format to engage staff in varied roles in eco-efficiency activities and enable them learn about good practices for energy saving improvements in a factory environment.

As well as highlighting how energy can be saved, it also highlights the potential barriers to change and how they can be overcome. The game has been piloted with Airbus SAS at their factory in Broughton. It was played with 4 different groups of Airbus staff and the feedback provided positive support for the value of the game and some insight into how it might be adapted to suit specific manufacturing scenarios.

If you would like to find out more about the game and how it might be applied in your business please contact Dr Mélanie Despeisse, md621@cam.ac.uk.

SAITEX

CASE STUDY

Factory Eco-Efficient Modelling in the Apparel Industry

Saitex International specialises in high-end apparel production. Situated in the heart of Ho Chi Minh City, Vietnam, the company has a 4000 strong workforce, producing over 15,000 pieces of clothing per day.

The Challenge

Saitex are interested in understanding how their factories and major technical assets are performing from a sustainability perspective. Centre researchers worked with Saitex using the Factory Eco-Efficient Modelling Framework (FEEM) to assess the eco-efficiency of a state of the art laundry and wet-processing facility under several senarios. This facility combines innovative methods and hi-tech assets ranging from water recycling, solar energy, air management systems and green-chemistry. The goal of this work was to increase the eco-efficiency of energy and material flows across laundry assets as well helping Saitex to fulfil the environmental segment of their strategy (figure 1), and aid in their decision making process for new capital assets.

Our Approach

Three FEEM models were created in situ at the factory. These models were built to show the performance of assets, with a focus on energy and material resources. The analysis interpolates daily-average data into a per-hour view; using data composition to derive profiles for specified assets such as washing, drying and laser-etching etc. This helped verify current asset performance for all operational zones and showed where further efficiency gains could be achieved.

Following this detailed per-second energy and material data was captured from the high-resource consuming assets, noted as having potential for improvement from the cursory modelling.

The detailed model formed the baseline for scenario testing of future-state simulations of laundry energy and material flows. These have been developed to show productivity improvements, resource savings, and help Saitex in their decision making process for new aerial-dryer assets within their laundry facility. Detailed modelling of these assets was undertaken using eco-efficiency indicators such as energy per unit, take time per process, and lead time for 15000 (current) to 20000 (future state) product volume. The modelling approach provided estimates of how to minimise lead time and energy usage, whilst maximising shop-floor productivity and increasing the volume of apparel output per day.

Outcomes

Saitex used the detailed modelling results in their decision making process to confirm the inclusion of an extended and new aerial drying system. This future state model showed improvements in the key areas of productivity and resource eco-efficiency. Indicators disclosed from the detailed modelling are given in figure 2.

Next steps

The FEEM modelling undertaken has helped Saitex in their decision making process, and is now being used as a guide for how the future aerial drying system will be implemented. Saitex are working with the Centre in a joint activity to establish a new innovation centre within their LEED platinum certified sewing plant and to develop a masterplan for apparel sector sustainability. This will create an open source platform for: IT, Infrastructure, and integrated real-time factory and supply chain modelling which will educate Saitex's workforce and stakeholders, with the goal of making Saitex the first net positive apparel manufacturer, and a world leader in Industrial Sustainability.

Wider Lessons

The application of FEEM is appropriate across sectors, irrespective of available data, types of process, or scale of operations. Cursory data analysis can confirm eco-efficiency opportunities, which can then be verified and tested using detailed scenario simulations. For more information, contact doctoral researcher Aanand Davé, a.dave@cranfield.ac.uk.

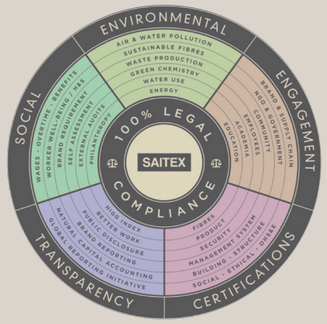


Figure 1

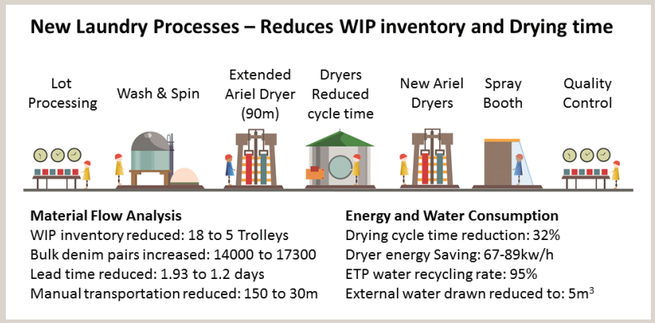


Figure 2

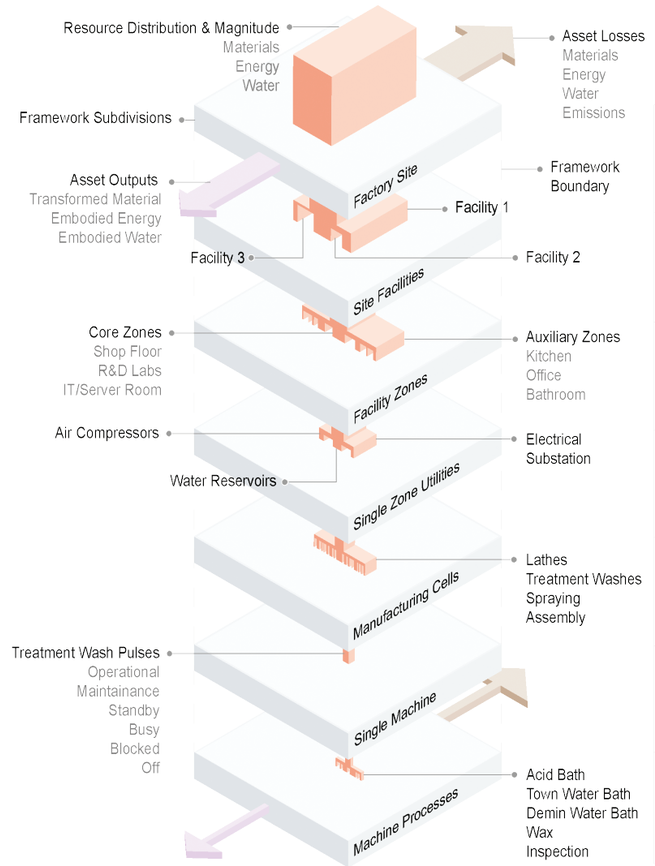
Factory Eco-efficiency Modelling (FEEM) Framework

As progress is made in eco-efficiency, further advances become more challenging.

An expansion of scope, integrating resources across functional boundaries of manufacturing, utilities and facilities assets, is necessary to accommodate further efficiency opportunities. This can be achieved with the FEEM framework, an operational resource modelling framework for managing assets and making informed decisions as well as an aid in practical implementation and paybacks.

The framework is used to analyse asset resource consumption and improve operational eco-efficiency from the factory site boundary to machine processes.
Each subdivision of the framework considers assets at greater detail by progressively modelling finer data granularities. All model subdivisions focus on the dynamic behaviour of system inputs, outputs, controllers and losses to show asset eco-efficiency, based upon resource magnitude and time-step granularity factors. Framework models provide users with the ability to compose, model and analyse the eco-efficiency of their factory assets within and across available data granularities. To date the FEEM framework has been successfully trialled with 7 companies from different industry sectors.

For more information contact doctoral researcher Aanand Davé, a.dave@cranfield.ac.uk.

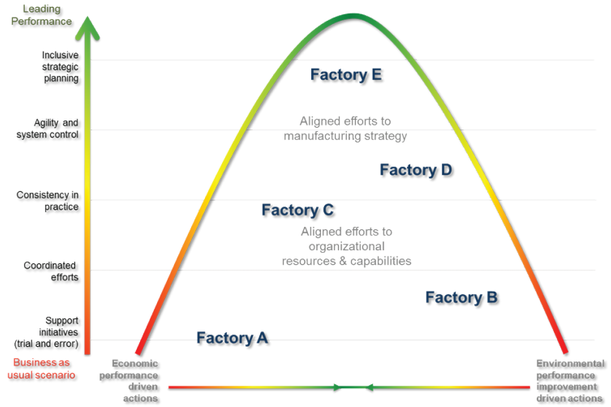


The Capability Assessment Grid for Eco-efficiency (CAGE)

The capability assessment grid for eco-efficiency (CAGE) is a maturity-based framework that describes how manufacturing systems evolve towards achieving sustainability goals such as eco-efficiency.

The grid develops visualisations about the maturity of manufacturing practices in factories and potentially generates recommendations for improvements at various organizational levels. As a tool it can be used in various industrial settings and help practitioners break down and convert complex sustainability challenges into manageable work-packages for wider workforce engagement. In more detail, as a management tool it can be used to reduce variability of perceptions about environmental performance and help practitioners develop a common language about eco-efficiency improvement projects. The tool has been trialled with industry at many levels, either in peer-to-peer workshops with environmental managers from various companies or with practitioners from industries with multi-site manufacturing configuration (i.e. aerospace) or single-site process facilities (construction materials). The graph demonstrates how maturity of practice (vertical axis) guides improvements in eco-efficiency (curve turns green). The two aspects of eco-efficiency (i.e. economic performance and environmental performance) become equally important in decision making at high-maturity levels.

For more information on CAGE contact doctoral researcher Lampros Litos, ll443@cam.ac.uk.



altro

CASE STUDY

Making Sense of Eco-Efficiency with the Capability Assessment Grid

Altro is a leading UK manufacturer of safety flooring and wall cladding systems. Driven by a continuous improvement spirit, the company already had notable achievements in waste recycling and process improvements.

The Challenge

As in many process industries, Altro has traditionally focused on product quality at process level with less focus on progress towards energy and resource efficiency at facility level. Part of the reason for this is that although energy and resource efficiency were an objective supported by top-management, it has not always been clear how this objective translates to daily operational practices. Altro were looking for a way to enhance their understanding of sustainable manufacturing and to design an ideal sustainability plan for their business

Our Approach

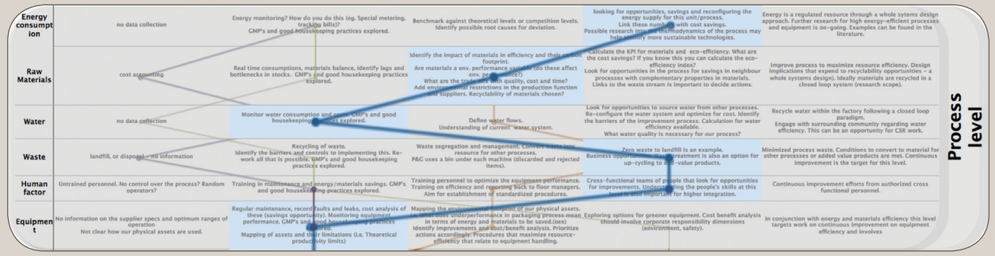
The Capability Assessment Grid for Eco-Efficiency (CAGE), a practice maturity assessment tool developed as part of a PhD research project, was used to help Altro break down the concept of eco-efficiency into workable packages of improvement areas. The tool has been designed in a way that grades types of manufacturing practices on their potential to enhance eco-efficiency across a range of organizational levels (from process to top management). The application of the tool was performed in two phases. First was a self-reflection phase where Altro's engineers and managers were asked to provide their perspective of Altro's production system maturity. The second was a workshop phase which provided all of the interested practitioners with a structure to discuss the strengths and areas for improvement in the production system as well as the capabilities that can support improvements in energy and resource efficiency. "[The process].... did back up what we already knew and what we needed to do and gives some credibility to the message we need to give to the Board on the future direction of our company sustainability programme."

Outcomes

CAGE helped deconstruct the idea of eco-efficiency and build a case for eco-efficiency improvements to present to top-management. One of the outcomes was a step change that involved engineers being able to express a need for sustainability benefits when looking into future projects. "It was a benefit for us all to have an open and honest discussion with ourselves regarding eco-efficiency. We now just need to do the work internally to understand where we need to be going with sustainability and what steps will add value most."

Next Steps

CAGE can be applied in various scenarios and industries. The tool is currently being used to investigate the alignment of maturity across the supply-chain for a company that outsources its production. The aim is to understand what parts of that system can effectively become vehicles of improvement across all stakeholders to promote energy and resource efficiency. For more information contact doctoral researcher Lampros Litos, ll443@cam.ac.uk.



Part of a CAGE assessment grid

SUSTAINABLE BUSINESS TOOLS

Tech

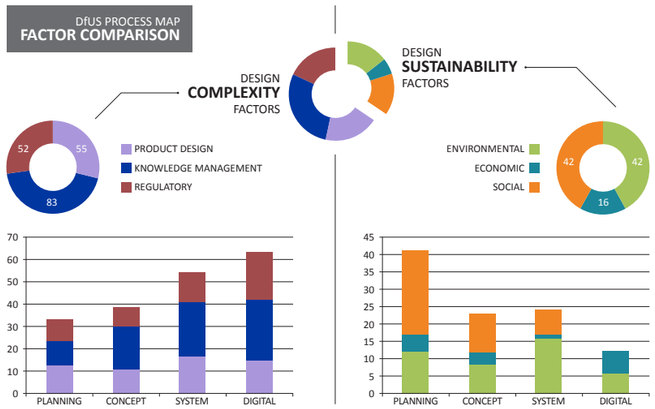
Designing Ubiquitous Sustainability into Product Design Processes

A framework has been developed to help companies embed sustainability considerations within their established product development processes.

This is achieved through a systematic investigative method that can be used to assess existing design practices and identify both the critical features of the business and products that need to be improved, as well as any available opportunities already used within the design processes that can be employed to readily, and efficiently include consideration of sustainability.

By using this framework a company can therefore identify targeted and customised opportunities for improvement of sustainable design, expand understanding of their processes and products, and evolve towards a situation in the future where sustainability considerations are an embedded part of their design process – towards 'Ubiquitous Sustainability' in design.

For more information contact Dr Leila Sheldrick, L.Sheldrick@lboro.ac.uk.

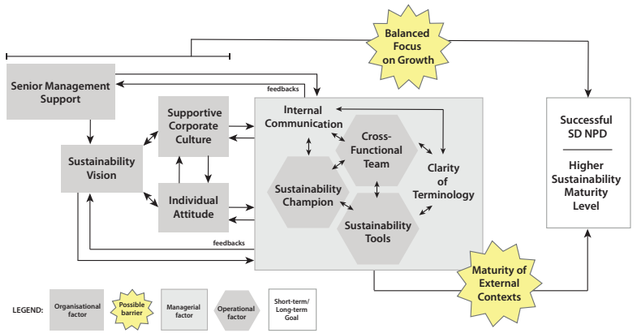


Framework of Relationship of FMCG Sustainable Design Factors

The conceptual framework explains the iterative relationship of 11 factors that influence the successful implementation of sustainable design at the front-end of new product development process within the fast-moving-consumer-goods (FMCG) sector.

This framework shows what factors precede others, how factors reinforce the others. It also presents two potential roadblocks that may fundamentally inhibit the entire practice. The roadblocks are particularly conspicuous within the FMCG industry, where its principal orientation is on consumers' needs. The framework guides FMCG practitioners with steps to follow in order to diagnose their sustainable design implementation practice and to develop more holistic sustainability strategy in a long-term view.

For more information contact Dr Curie Park, curieous@gmail.com.

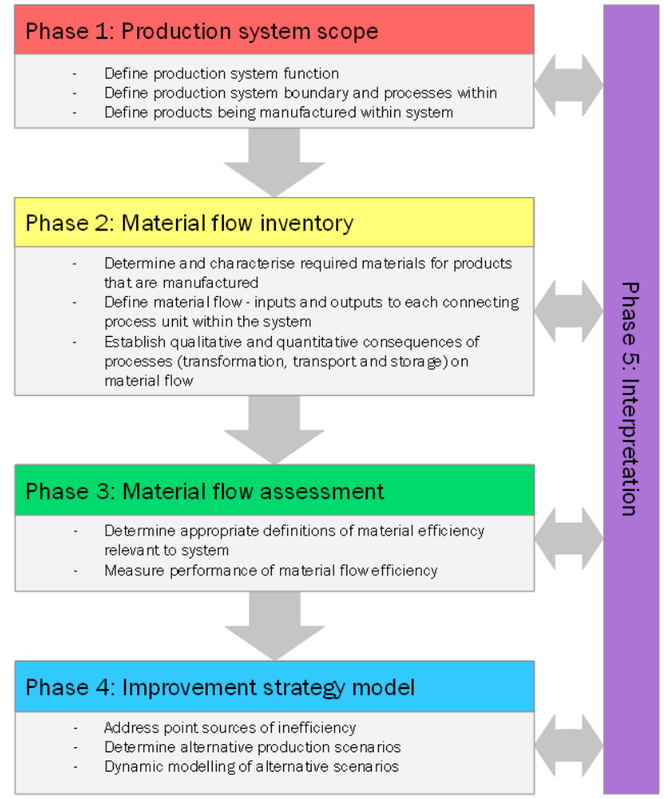


Material Flow Assessment in Manufacturing (MFAM) Framework

The MFAM framework is used as a basis for investigation of the material efficiency in the manufacture of products.

The assessment of material efficiency is based on the objectives of using less material processing to produce a unit product, to improve production yield, and to reduce the environmental impact of material processing. The framework uses a combined quantitative and qualitative approach to give structure to the investigation of complex systems, with the aim of uncovering innovative opportunities for improvement. The framework consists of five distinct phases: 1) production system scope, 2) material flow inventory, 3) material flow assessment, 4) improvement scenario modeling, and 5) interpretation. These phases are largely interdependent, with phases 1–4 following a largely sequential but potentially iterative progression. The fifth phase meanwhile runs in parallel with the other phases as an iterative and reflective mechanism, interpreting the results and applying suitable decision-making process. MFAM has been used to improve material flow and resource efficiency at a Unilver factory.

For more information please contact Dr Oliver Gould, O.J.Gould@lboro.ac.uk.



CASE STUDY

Improving Material Flow for Resource Efficiency

Unilever is a multinational fast moving consumer goods company manufacturing a number of global brands across foods, refreshment, home care and personal care categories. The Unilever Sustainable Living Plan was introduced in 2010 and demonstrates an ongoing commitment to sustainable business growth across the entire value chain. Improving resource efficiency in the manufacturing phase through reducing environmental impact and minimising both resources used and waste created is a key business focus.

The Challenge

Material flow in manufacturing systems is directly related to the efficiency of material consumption. Making changes to material flow can therefore enhance overall material efficiency and minimise environmental impacts in manufacturing. Material flow in manufacturing systems typically defines resource consumption, thus efficiency. The major challenge for this case study was to identify ways to improve material flow and resource efficiency in a Unilever factory.

Our Approach

This case study involved the implementation of the framework for Material Flow Assessment in Manufacturing Systems (MFAM), previously developed as part of activities within Resource Efficient Manufacturing Grand Challenge. This framework was implemented to model quantitative and qualitative material flow in a Unilever factory, to identify and model efficiency improvement options.

Outcomes

Key aspects of the manufacturing system were identified through material flow modelling. The system involved production of multiple products, requiring multiple materials and relatively few discrete processes. It was identified that resource consumption was variable during product changeovers and that there was potential for inefficiency and a significant opportunity to lessen environmental impact. The changeover requirement was defined by qualitative material flow within the system, specifically the temporal flow of potentially cross contaminating materials (PCCM). As these materials contacted all processes in the system, in order to eliminate potential contamination a strict cleaning protocol is in operation which required significant resource consumption.

The study outlined two initial options for material flow improvement, firstly through resource efficient scheduling and secondly through resource efficient assembly. The first solution involved using computational methods to generate production plans for a given product order requirement that minimised the cumulative resource consumption associated with the product changeovers. The second solution involved redesign of the assembly system to eliminate the requirement for intensive changeovers entirely.

Future work

The next step in the study is to quantify the relative resource efficiency benefits of each solution and carry out cost benefit analyses to recommend the preferred option. Further work may include the design of reconfigurable processing equipment to enhance PCCM isolation at a process level. Finally, the distribution of the manufacturing system across multiple sites could allow for strict PCCM isolation at site level, by producing pre-packed PCCM doses.

Wider Lessons

The MFAM framework was conceived to be applicable to manufacturing systems of any type, producing any range of product and at any scale. Hence the implementation of the MFAM by any business will enable greater understanding of material flow and assist in identifying innovative options for material efficiency improvements. For more information contact Dr Oliver Gould, O.J.Gould@lboro.ac.uk.

Gould, O. & Colwill, J. A framework for material flow assessment in manufacturing systems. J. Ind. Prod. Eng. 32, 55–66 (2015).

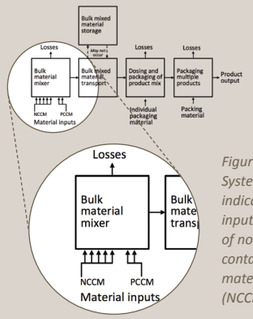


Figure 1. System design, indicating the input and flow of non-cross contaminating materials (NCCM) PCCM.

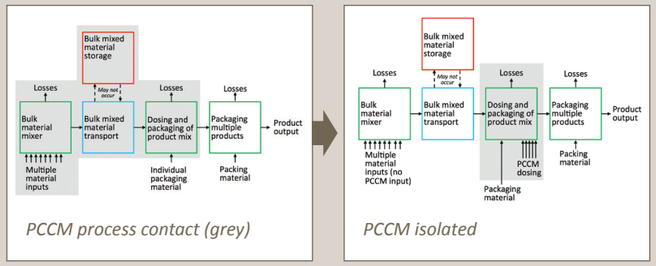


Figure 2. Assembly design changes for isolation of PCCM to eliminate resource intensive changeovers.

SUSTAINABLE BUSINESS TOOLS

Business Models

Sustainable Business Models Suite: Transforming businesses to deliver uncaptured and sustainable value

Is your business getting the full benefit of the value you are creating for customers and other stakeholders? Could your current business model be actively destroying value for others, ultimately affecting the organisation's ability to capture value in the long run?

Answers to these questions and more are explored using three powerful innovation tools which make up the Sustainable Business Models Suite: Cambridge Value Mapping Tool, Sustainable Value Analysis Tool, and Business Transformation Tool. Together these tools enable new perspectives on value forms - missed, destroyed, surplus and absence and provide a structured approach to discover failed value exchanges among stakeholders and an organised method for implementing sustainable change in a business. The Sustainable Business Model Suite is used through workshops to help practitioners who want to gain a more complete understanding of the economic, social, and environmental value created by a business, and to explore opportunities for transforming the current business model towards a more sustainable one. The tools can be adapted to the size and complexity of the business from new start-ups to established multinationals. More information on the individual tools can be found in this section of the report.

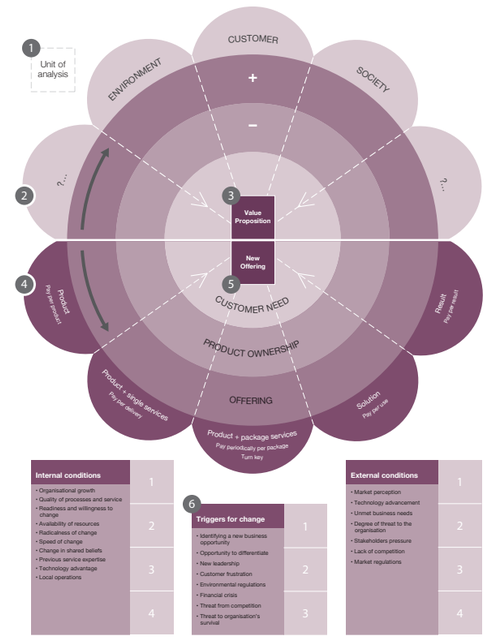
For more information please contact Dr Doroteya Vladimirova, dkv21@cam.ac.uk.

Business Transformation Tool

The Business Transformation Tool has been developed to support a business in turning a new value opportunity into a new business model.

It helps design change programmes to implement business model innovations and develop action plans. The tool provides a structured approach to understanding and managing complex multi-dimensional change and long-term sustainable business transformation. The tool has been used in workshops with 16 companies.

For more information please contact Dr Doroteya Vladimirova (dkv21@cam.ac.uk).

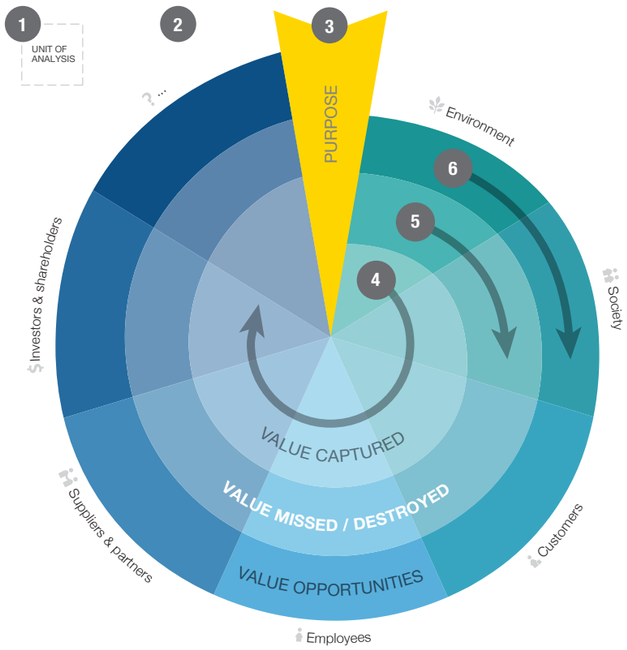


The Cambridge Value Mapping Tool

The Cambridge Value Mapping Tool has been developed to elicit failed value exchanges among multiple stakeholders in the network of the firm and uncover new value opportunities through a structured and visual approach.

The tool assists in systematically analysing various forms of value in a business and network and stimulate innovation in sustainable value creation. The tool adopts a multi-stakeholder perspective, through which the exchange of value can be analysed and potential stakeholder conflicts identified to create positive value in the network.
It provides a new perspective for practitioners to understand and create new economic, social, and environmental value from their business. The Cambridge Value Mapping Tool has been used in industry through a multitude of group workshops or in-house bespoke workshops. The tool is also used as teaching material at the University of Cambridge other academic institutions.

For more information please contact Prof Steve Evans, se321@cam.ac.uk.

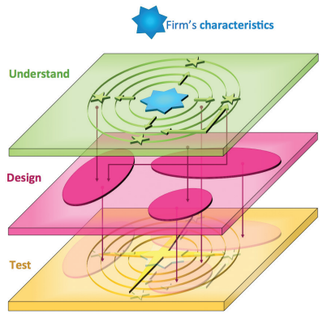


Better Models in Business Models - BM²

The BM² tool is being developed to help companies identify opportunities for disruption and innovation of their business models which will lead to more economically, socially and environmentally sustainable businesses.

In a 3-year project funded by the EPSRC, we are developing a computer-based tool to help companies identify and visualise opportunities for business model innovations that result in creating and capturing more value in the wider system of the firm. The purpose of the tool is to identify key leverage points for intervention in the system, and reduce the uncertainty and risk of changing a firm's business model.

If your organisation is looking to experiment with new more sustainable business models please contact Dr Doroteya Vladimirova, dkv21@cam.ac.uk.

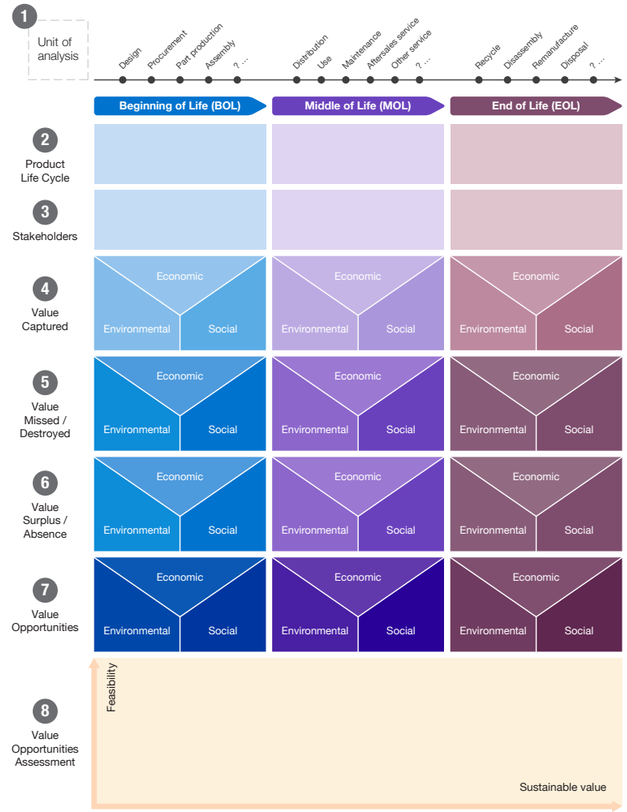


The Sustainable Value Analysis Tool

Sustainable Value Analysis Tool (SVAT) is designed to help manufacturing companies identify opportunities to create sustainable value by analysing the captured and uncaptured value throughout the entire life cycle of products.

Uncaptured value exists in almost all companies. Some uncaptured value is visible, e.g. waste streams in production, co-products, under-utilised resources, and reusable components of broken products; some is invisible, e.g. over capacity of labour, insufficient use of expertise and knowledge. Reducing any kind of the uncaptured value would create sustainable value. However, identifying the uncaptured value and creating value from it is not always easy. The tool supports this process, providing companies with a scheme to systematically look for each form of value uncaptured (i.e. value surplus, value absence, value destroyed and value missed) at the beginning, middle and end of the product life cycle, and with a method to turn the identified value uncaptured into value opportunities. The SVAT has been well received in 25 manufacturing companies across various sectors and of various sizes. It helped them find opportunities to create value internally and to discover the potential of creating mutual value externally. The tool has also been used for other purposes such as research, consultancy, business education and university education.

Contact doctoral researcher Miying Yang, my306@cam.ac.uk, to find out how you could use SVAT to find opportunities to create value in your business.



Sustainable Business Model Archetypes and the Business Model Innovation Grid

Sustainable business model archetypes are groupings of mechanisms and solutions that contribute to building up the business model for sustainability. The archetypes were developed based on collaborative research as part of the EU project SustainValue.
The aim is to develop a common language that can be used to accelerate the development of sustainable business models in research and practice. Plan C, a non-profit organisation in Belgium are using the archetypes as part of their future strategy focused on tackling resource scarcity. A blog was developed to introduce the BMIX – a business model innovation grid with a multitude of approaches and 100 real life business cases to inspire businesses to reconceive their businesses and make them future proof. There is an ongoing collaboration with Plan C to use the archetypes and BMIX as part of workshops and source more innovative cases to inspire businesses.

For more information contact Dr Nancy Bocken, nmpb2@cam.ac.uk , or visit the Plan-C BMIX website at http://www.plan-c.eu/bmix/.

CASE STUDY

Case Study: Growing Businesses Sustainably with PrISMS

The Practical and Innovative Solutions for Manufacturing Sustainability (PrISMS) programme was a three-year activity for the East of England funded by the European Regional Development Fund and led by the Institute for Manufacturing Education and Consultancy Services (IfM ECS). The programme provided funded support for smaller manufacturers and start-ups with the aim to transform the growth prospects of these businesses by helping grow revenues and profitability, make products and operations more sustainable, and create new jobs and safeguard existing ones in the firms taking part and across their supply chains. A key focus of the programme was energy efficiency. Research from Centre projects fed into the programme to help integrate sustainability considerations into interventions using tools such as eco-ideation, value mapping and elements of the FREE toolkit.

The Challenge

Significant opportunities to reduce power consumption exist across the manufacturing sector but there is considerable scepticism within the SME community over consultants promising short payback projects with a cost up front. In fact, not one of the companies engaged through PrISMS had tried this approach before. When quizzed more closely, one of the MDs explained "If you had come to us proposing a project which cost us £5K but promised £50K savings we would have told you to go away". Furthermore, manufacturing SME's are reluctant to commit to energy savings projects because of lack of knowledge in Energy Resource Management and not having access to the range of equipment needed to develop the evidence base from which to work with. Additionally, there is a lack of understanding of the cost savings possible.

Our Approach

The PrISMS programme was delivered by experienced IfM ECS facilitators all of whom had worked in manufacturing at a senior level for many years and had supported hundreds of start-ups and SMEs. The programme was designed to require as little time as possible from the company's management and to ensure that knowledge and skills are transferred to the companies involved, enabling them to build capabilities in key areas of the business. Support was offered to start-ups in such areas as identifying key areas of focus and evaluating promising opportunities, and developing the business strategy and a sustainable business model. More established businesses were helped to understand key issues and priorities, identify most appropriate markets and products, build the needed capabilities, and reduce environmental impacts. Programme partner Ecopare provided energy monitoring and energy optimization solutions. The range of companies engaged covered a variety of sectors.

Outcomes

In total 123 companies engaged in the Prisms programme. During the programme the turnover growth in the top 60 was £16m with 126 new jobs created and 201 jobs preserved. Twenty SMEs engaged in energy monitoring and optimisation activities. The resulting annual savings opportunities identified exceeds £200K. Some of these opportunities needed modest capital spend to be realisable (e.g. LED lighting). Some of the companies took on the efficiency ideas and developed them further. In all over >1000 tonnes of carbon was saved.

Recommendations

One possible approach for future non-funded work with SMEs might be to charge a company only once benefits exceeding the cost of engagement are identified. This then becomes a no lose gamble for both sides on the assumption that an experienced consultant would only deploy monitoring where it was clear energy costs (and therefore potential savings) were significant.

Next steps

It is to be expected that broader/deeper engagement with the sector would bring similar opportunities to reduce power consumption, including with medium-sized businesses which are significant power users. The PrISMS engagement focused on electrical usage, but it might reasonably be assumed that gas and water usage might present similar opportunities. For more information contact Anna Rowntree at prisms-enquiries@eng.cam.ac.uk.

SUSTAINABLE BUSINESS TOOLS

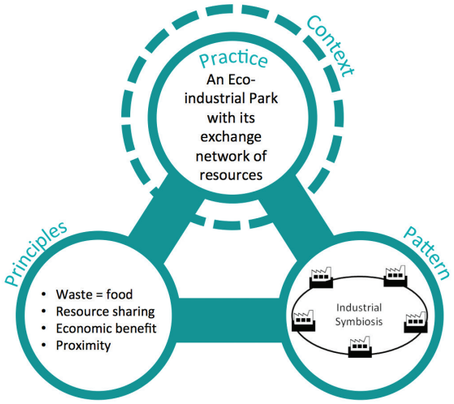
Systems and Innovation

Principles – Pattern – Practice

Principles - Pattern - Practice is a design language for discussing a specific industrial system of a business with its partners, and for collectively envisioning future sustainable industrial systems.

The purpose of this tool is to create a shared understanding among the diverse participants and decision makers involved in designing a sustainable industrial system. An industrial system can be collectively described and coherently understood in terms of its pattern, its set of principles, and the associated practice decisions. This tool helps identify the underlying principles of an industrial system based on manufacturing decisions. Through this tool, practitioners can discuss the manufacturing decisions (practice) and underlying principles of their current industrial system. They can then use this terminology to ideate about future sustainable industrial systems. The tool's ability to describe sustainable industrial systems is demonstrated for Industrial Symbiosis as an example in the accompanying figure.

For more information, please contact doctoral researcher Sudhir Rama Murthy, ssrr3@cam.ac.uk.



Sustainability-oriented innovation: The search for variety in hybrid organizational forms

Sustainability-oriented innovation (SOI) involves a search for variety-creating opportunities in hybrid organizational forms which share potentially conflicting logics - that is, between public, non-profit and for-profit partners.

SOI does this by identifying responses to tensions that arise in such engagements. This tool provides a systematic approach for appraising opportunities in searching for sustainability-oriented innovations. It adopts a behavioural and institutional perspective in which unusual partners can engage and collaboratively source information to learn about what types of partnerships and incorporated logics support a better search for sustainable opportunities. The tool, therefore, stimulates thinking about sustainability oriented search processes and the suitability of different hybrid organizational forms used to create a larger variety of sustainability-oriented products and processes. The tool does this by appraising tensions and their resultant variety-generating responses that – owing to different search principles - change the course of search or result in the discovery useful information and knowledge. Academics and practitioners can use this tool to understand how to effectively increase variety in organizations searching for sustainable opportunities. This tool will be tested with multi-national organizations.

For more information please contact doctoral researcher Stefan Hemel, Stefan.hemel@cranfield.ac.uk or Dr Palie Smart, palie.smart@cranfield.ac.uk.

Industrial Sustainability Competency Development Toolkit

The Industrial sustainability competency toolkit supports businesses and individuals in exploring possible future industrial systems and identifying priorities and actions that can be taken to move towards sustainable industrial systems.

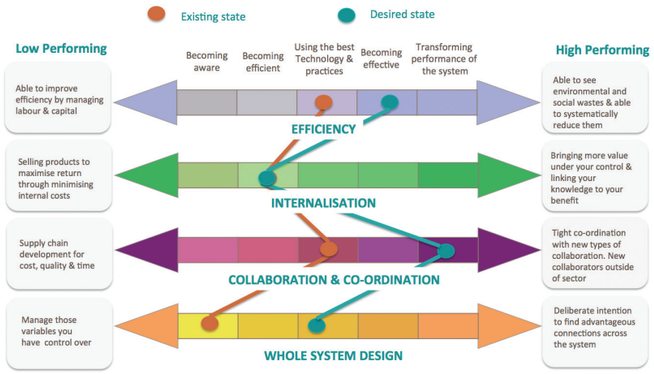
The toolkit can be used by organisations to diagnose current performance, identify potential areas of action which can deliver substantial performance improvements, and develop a collaborative plan for long-term competency development.

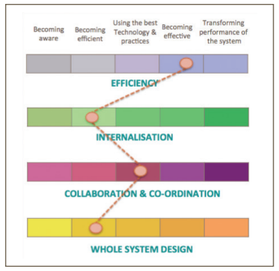
The dimensions of performance proposed are:

1) Efficiency – how well are current operations operated?
   (Focus on energy, water, materials input and waste and water output)
2) Internalisation – what is the approach to business model innovation?
   (Seek value from its waste)
3) Coordination and collaboration – how effective is the business at identifying and working with unusually valuable partners?
4) Whole system design – how effective is the firm in conceptualising and implementing radically improved new system designs?

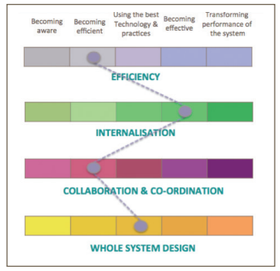
Competency assessment helps companies understand what they need to be good at in order to support the transition to a sustainable industrial system. Existing competency in efficiency, internalisation, collaboration & co-ordination, and whole system design are explored and compared with the performance of other organisations. Areas for improvement can then be identified and prioritised.

For more information please contact doctoral researcher Lloyd Fernando, ldf21@cam.ac.uk, or Prof Steve Evans, se321@cam.ac.uk .

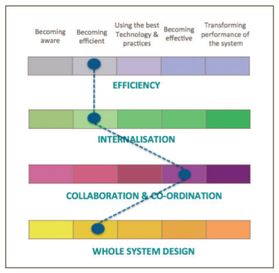




Automobile



FMCG



Apparel

CASE STUDY

Competencies to Deliver World Class Performance

Brandix India Apparel City (BIAC) is a 1000 acre, Special Economic Zone in Visakhapatnam (Vizag) in the state of Andhra Pradesh, India. It embodies an avant garde 'Fibre to Store' concept with a current implementation and a clear plan to expand a large scale apparel system that can deliver world class performance from fibre-to-store including strong environmental and social performance.

The Challenge

BIAC needed to understand the skills and competences required to deliver world class sustainability performance improvements. BIAC and the Centre for Industrial Sustainability are working with Vizag academic partners to deliver specific improvements in technology and practice and to help create a local system capable of supporting a world leading activity.

Our Approach

Researchers from the Centre have enabled the creation of various new competences using tools and methods developed by the Centre - in particular, the Industrial Sustainability Competency Development Toolkit. Four major competences have been identified (efficiency, internalisation, collaboration and co-ordination, whole system design) that move manufacturing from benchmark excellent to world leading in industrial sustainability.
This programme focusses on the competence of internalisation, which implies bringing costs that others externalise into the control of BIAC. Specifically BIAC seek to internalise waste by using internal and external (partner) knowledge to find new uses for waste.

Outcomes

The first set of projects have been identified and are in planning for implementation:

- Improving value capture - C rolls and big cut waste – improve the value recovered from C roll waste and big cut waste. Current valorisation methods see the rolls sold to a recycler.
- Improving value capture – Chemical sludge - improve the value of chemical sludge produced by the BIAC effluent treatment plant by improving the quality of the waste by tackling both inflow and post processing stages.
- Improving value capture – Effluent water - recovering value from water, which is currently processed by BIAC to meet local regulations and which is then disposed of out to sea, by employing a number of strategies to valorise the wastewater tackling both inflow and post processing stages.
- Efficiency – Fabric mill dyeing and finishing - improving the current operation of dyeing and finishing processes in the fabric mill, reducing the amount of energy, water and waste produced by processes.
- Finding the best next partner - understanding the process of selecting partners to maintain or enhance the economic, social and environmental performance and long-term sustainability of the city.

Next steps

A group of BIAC staff will be brought up to the highest level of competence so that skills and knowledge are transferred and BIAC become capable of systematically innovating to deliver new levels of economic, environmental and social performance. By 2016 BIAC will have increased economic value from waste and by 2020 BIAC will have zero waste to landfill.

Wider Lessons

The competency assessment tools and methodology can be used by companies from other sectors to diagnose the current performance and identify potential areas of action, which can deliver substantial performance improvements, and develop a collaborative plan for long-term competency development.

For more information contact doctoral researcher Lloyd Fernando, ldf21@cam.ac.uk.

Eco-ideation

The eco-ideation tool was developed to facilitate the generation of product and process ideas giving step change reductions in CO2 emissions.

To develop the tool, the features of products and processes, which drive product life cycle carbon emissions, were characterized with a set of indicators. A visual traffic-light tool shows these indicators on a sliding scale between best (''green'') and worst (''red'') conceivable performance. A leading question is linked to each slider to stimulate eco-ideation. The aim of each leading question and slider is to stimulate a separate 'mini-eco-ideation' session. The eco- ideation method consists of the following steps: (1) For each question and slider, envisage current performance (which is often still in the 'red' areas), (2) Generate ideas, which move the slider to the green side (i.e. lowest carbon emissions), (3) List ideas and follow up with an idea selection process. The eco-ideation method is being used by several companies and has been part of the early stage venture toolkit used by the ECS PrISMS project at IfM, University of Cambridge.

To find out more contact Dr Nancy Bocken, nmpb2@cam.ac.uk.

PRODUCT DESIGN	3 **COMPACTING:** How compact is the product? Can the product be sized up or diluted at a later stage of the product life cycle?	Compact / Dense	Medium compactness and density	Outsized / Dilute
	4 **COMPONENTS/ INGREDIENTS:** How energy intensive are components and ingredients? For example, plastic is less energy intensive than steel; and paper is less energy intensive than plastic; Animal-based is more energy intensive than vegetable based, keeping weight and distance travelled equal.	Non-energy-intensive	Room for improvement	Energy-intensive
	5 **RAW MATERIAL EFFICIENCY:** How efficiently are raw materials used?	Efficient: Low use and loss. Reusable, Recyclable	Room for improvement	Inefficient: High use/loss. Disposable, Non-Recyclable
	6 **DURABILITY/ EFFECT/ EXPERIENCE:** Is the product durable? Is the effect or experience long-lasting? Can the product be used in a targetted way to fulfill the required functions?	Durable / Long-lasting / Can be used in a targetted way	Medium effect, not very targetted	Short-lifetime / Short-lived effect / Unfocused
	7 **END OF LIFE:** Can the product be entirely used up, or is it endlessly reusable?	0% waste at end of life / Endlessly reusable	Some recycle, repair, disassembly, reuse issues	100% waste / Not reusable, repairable or recyclable
	8 **INTERMEDIATE PACKAGING:** How often is the product repacked throughout the supply chain?	One shelf ready pack	2-3 repackings	4 or more repackings

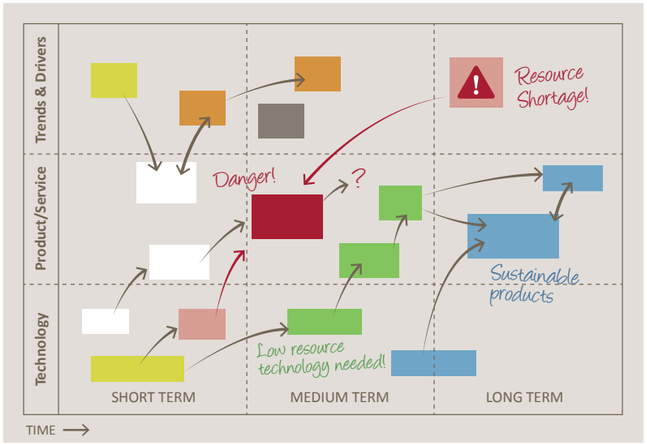
Resource Aware Roadmapping

Technology roadmapping is a strategic planning tool used widely in the manufacturing sector for aligning commercial and technology functions in firms.

Developed in the 1970s by Motorola, the tool was developed when firms faced different challenges to the present resource constrained world. As such, this research has focused on identifying how the tool can be updated to help firms recognise and manage the impact of future resource constraints on their business.

The revised tool guides participants through a series of simple activities to help them recognise how the availability of vital resources will impact their current product lines. The simple visual structure of the roadmap encourages participants to recognise how future resource shortages will place particular product lines at risk, encouraging them to reconsider their strategic vision. This could involve investing in alternative or low-resource technologies. In essence, the tool helps manufacturing firms devise more sustainable business strategy for a resource-constrained world.

Contact doctoral researcher Elliott More (egm27@cam.ac.uk) for more information.



SUSTAINABLE BUSINESS TOOLS

Circularity

Circularity Toolkit

A multitude of collections of principles have sprung up around the ideas of 'closing loops' and 'waste = food' over the last 15 years, such as Circular Economy (EMF, 2012), Blue Economy (Pauli, 2010) and Cradle to Cradle (McDonough and Braungart, 2002).

However, these collections put forward different interpretations of 'circularity' and have distinct underlying assumptions and departure points, making it difficult to determine what 'going circular' means for your business. The Centre's Circularity Toolkit can help with this: tools unpack different forms of circularity, give an overview of the implications of various ways of organising it and finally zoom in on how to develop strategies for implementing circularity within your production processes, co- and by product generation and/ or on the level of components and products. Showcased at Resource 2015, the Circularity Toolkit is evolving based on insights from practice.

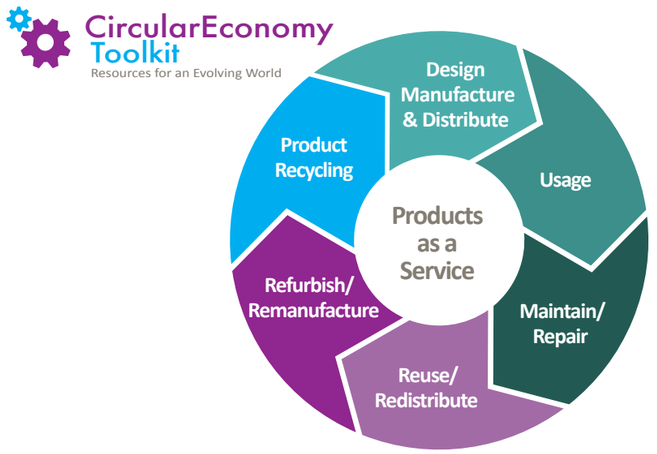
If you are interested in trialling the current prototype contact doctoral researchers Fenna Blomsma at f.blomsma12@imperial.ac.uk or Geraldine Brennan at geraldine.brennan09@imperial.ac.uk .

Circulareconomy toolkit.org

The traditional linear take-make-dispose supply chain is placing pressure on our resources and material costs.

In a more 'circular' economy, materials are continuously reused to minimise resource depletion. With a vast number of possibilities for creating value out of the Circular Economy, it can be challenging to assess all the options. Building on literature, industry surveys and case examples, a Circular Economy Toolkit was developed to assist companies in their move to a circular economy. The website includes benefits, guidelines, examples and key challenges. It includes a 5-minute opportunity assessment tool and the materials to run your own workshop. The website has been accessed by people in over 75 countries. The toolkit was developed on the ISMM course at IfM, University of Cambridge in 2013 by Jamie Evans and supervised by Dr Nancy Bocken. The toolkit will continue to run and develop going forward. At present a collaborative project has started with WRAP to develop the toolkit further, and expand its content and usage.

For more information contact Dr Nancy Bocken (nmpb2@cam.ac.uk).
http://www.circulareconomytoolkit.org/
http://www.rebus.eu.com/getting-started/circular-economy-assessment-toolkit



ANNUAL REVIEW **2014-15**

Research

12 MAIN PROJECTS
29 DOCTORAL PROJECTS

RESEARCH
Efficiency

Sustainable Manufacture in Aerospace Industries

This study aims to quantify current resource efficiency in an aerospace composites manufacturing plant, identify and rank areas for improvement and propose new projects in order to address resource inefficiencies.

The researchers will work on-site at Bombardier Belfast's manufacturing facility for the majority of the project to scope and plan the project and gather the necessary data. Processes will be mapped and justification for process methodologies and settings will be documented. Final analysis will identify resource utilization at each step of the process and rank the data using Pareto analysis. This information will be used to identify key areas of focus for future proposals on sustainable manufacturing in aerospace as well as the potential approaches to be used (material/process/technology solutions). This study addresses two of the Centre's three grand challenge themes: 1. Eco-Efficiency - The project will identify areas for practice innovation; 2. Eco-Factory - The project will identify new technologies/processes that may be developed/implemented in a future proposal.

For more information contact Prof Eileen Harkin-Jones at the University of Ulster, e.harkin-jones@ulster.ac.uk.

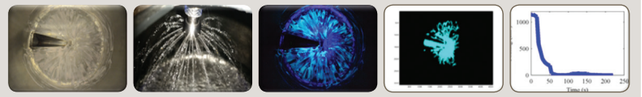
Cleaning-in-place Monitoring

Cleaning-in-place (CIP) is a widely used technique applied to clean industrial equipment without disassembly.

However significant environmental impact stems from the excessive amount of water, energy, time and other resources required. In this project, an automated process monitoring system has been developed to detect the surface fouling within system components with the aim of reducing the time and resources required during the cleaning stage of equipment.

A vision-based sensing unit comprised of an ultraviolet light (UV) source and a wide angle camera has been used to detect protein-based surface fouling, which fluoresces under UV illumination. An experimental campaign of CIP tests has been carried out varying the fouling agent (yogurt, ice cream etc.) and the wash cycle parameters. Digital images acquired during the washing cycle are subjected to an image processing algorithm which extracts significant information on fouling levels and its removal rate in terms of surface extension and thickness to support decision making in cleanliness assessment.

For more information about this project, please contact Dr Alessandro Simeone, A.Simeone@lboro.ac.uk.



1. Fouling application *2. Start washing cycle* *3. Image acquisition* *4. Image processing* *5. Decision making support system*

CASE STUDY

Assessing and Reducing Economic and Environmental Impacts of Changeover Operations

Altro is a leading UK manufacturer of safety flooring and wall cladding systems. Driven by a continuous improvement spirit, the company already had notable achievements in waste recycling and process improvements.

The Challenge

As a growing company Altro provides a variety of flooring options to its customers. While this large product range is beneficial for business it brings a significant burden to its manufacturing operations through changeover impacts. Furthermore, market trends are moving towards more customized products at smaller quantities which increases the number of changeovers Altro has to manage. They described the situation; “When we looked at our downtime over the past few months, the largest downtime was in the month with the highest number of changeovers.” As the number of changeovers increases the environmental and economic impacts associated with the changeovers will lower Altro’s sustainability performance. Therefore, it was a key objective to improve changeover performance by targeting these impacts.

Our Approach

Doctoral researcher Ergun Gungor visited Altro’s production facility to observe several changeover operations. Data gathered as a result of these non-participatory observations was coupled with interviews with the management team. This data was analysed to identify and understand high impact points during a changeover process. Once we combined the data gathered from the site visits with our experience from previous visits with other companies, it was possible to put forward suggestions that would reduce the changeover impacts by taking short and long term actions both in practice and technology.

Outcomes

Our findings suggest that Altro could improve their changeover performance drastically by following several short-term low cost solutions and a few medium-high cost long term solutions. Most of the short term solutions were practice related and could be implemented fairly easily. These include applying a SMED methodology to their system and externalising as many steps of the changeovers they can. Better information management also takes their performance one step further. A large portion of impacts occur as a result of the everyday decisions made by operators. Reviewing and upgrading the changeover standard operating procedures will allow Altro to cut its changeover times by almost half. Furthermore, operational changes will also help to reduce solid waste and material losses, throughout the entire changeover process.

Next steps

In order to improve changeover performance, Altro will pursue the suggested changes, while building on this preliminary study. Changeover operations require embracing a continuous improvement approach and consideration of changeover processes within the product and process innovation.

Wider Lessons

After visiting many factories producing a wide range of products, we have learnt that changeover impacts are clustered around knowledge, design and management causes. While the factors affecting each impact type may change, the improvement should start by focusing on these root causes. For more information contact doctoral researcher Ergun Gungor, zeg21@cam.ac.uk.

EFFICIENCY

Doctoral Research Projects

Factory Eco-efficiency Modelling
Aanand Davé

As progress is made in eco-efficiency, advances become more challenging. To accommodate further opportunities, an integrated understanding of factory resources across the functional boundaries of manufacturing, utilities and facilities technical assets is necessary. This research uses innovative data composition and modelling methods to assess the eco-efficiency performance of technical assets, and applies eco-efficiency practices to simulate potential factory scenarios. This research supports progress towards more sustainable factories by aiding in the decision-making process.

Energy and resource efficiency in production facilities
Lampros Litos

Case studies on energy and resource efficiency in factories reveal wide opportunities for improvement that go beyond technical solutions. To better understand and control the underlying conditions, this research maps and characterizes the practices and techniques that affect environmental performance in production facilities.

Practicing doing more with less environmental impact in factories
Simon Roberts

By understanding good practice in factories, this research aims to develop the tools and techniques that foster improvement programmes. Investigating the dynamics of improvement activities, and comparing how teams routinely assess environmental performance in different factories, will uncover how manufacturers are doing more with less environmental impact.

Assessing the environmental impact of single-use medical device disposal
Dr Madeleine Yates

This study explores the environmental impacts of single-use medical device (SUD) disposal and compares the different routes these can take. It demonstrates how disposal behaviours in healthcare settings can affect these environmental impacts and identifies how this information can be used to reduce these.

Gaining Manufacturing Flexibility, while Improving Sustainability through Eco-effective Changeovers
Ergun Gungor

Changeovers in manufacturing can be costly in economic and environmental terms. This research investigates ways to improve the performance of changeover operations in manufacturing by capturing a range of strategies and tactics while providing the capability to quantify the “true cost” of changeover operations to the company and the environment.

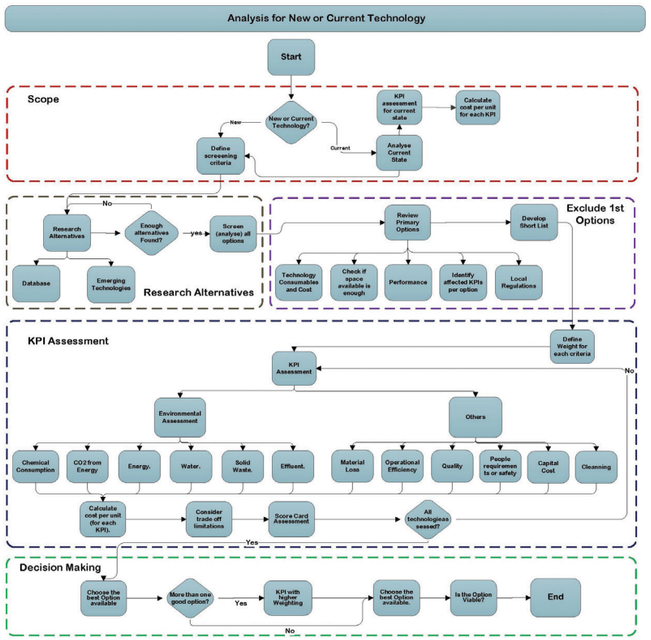
RESEARCH Tech

Technology Choices Tool

The technology choices project addresses the absence of structured approaches that consider the environmental impact of a process or enables comparison between processes.

This project will develop a tool to guide Process Designers to make conscious decisions about the technologies and hardware (the "how") they choose based on the desired function (the "what") and environmental considerations (the "impact"). Key to this decision making process is the effect technology selection has on the key overall environmental impacts of a manufacturing route. The key environmental KPI's upon which technology choice will impact including material, energy, water, solid waste, effluent and air emission. The project will use literature review and interview to gather the requirements, technologies and metrics and use decision trees/criteria to guide decision making according to process need. The prototype spreadsheet based tool will be tested in Unilever and other Centre collaborators.

For more information on the project contact Dr Peter Ball, p.d.ball@cranfield.ac.uk.



Resource Efficient Manufacturing

A resource constrained future is a reality that the manufacturing industry must be well prepared for. Increasing consumption of finite materials is unsustainable.

Yet the demand for products and services is increasing. To sustain their activities, manufacturers must find ways to radically improve how materials are used, ensuring the minimisation of resource consumption. This project investigates ways to achieve the aims of Resource Efficient Manufacturing (REM) with a focus on controlling the flow of materials as the key to minimising resource consumption and environmental impact. Existing approaches to examine material flows are not sufficient in helping to identify practical measures to improve efficiency and effectively support their implementation. The outputs of this project aim to support decision making for substantial resource efficiency (water, energy and material) improvements across the manufacturing sector. We are investigating how manufacturing processes, production systems and supply-chains can be made more efficient, providing management tools, assessment methods and practical technologies to this end.

For more information contact Dr Oliver Gould, O.J.Gould@lboro.ac.uk.

High Speed, Energy Efficient Manufacturing of Cadmium Telluride Solar Cells

This project, which commenced in January 2016, is funded by an EPSRC Call on Energy Resilient Manufacturing.

Researchers are investigating reducing the energy payback period for photovoltaics by laser annealing. The energy payback time (EPBT) of Cadmium Telluride (CdTe) photovoltaic panels is typically in excess of two years. Their high embodied energy is largely due to post-process annealing which is required in order for the panels to function correctly. Traditionally, this is done in an oven, where the entire panel is heated to approximately 450°C. In this project a laser-based system is proposed to heat only the top surface of the panel, thus reducing the energy requirements (EPBT) and allowing the process to be completed at room temperature in an open-air environment.

For this, an 808 nm diode laser is used, and is mated to a Holographic Optical Element (HOE), which is capable of complex customisation of the laser irradiance profile. Heat transfer simulations are used to predict the optimal heating profile and the time-temperature cooling curve of the material, and then a HOE is created to meet this requirement. This allows the laser process to be customised in order to maximise the speed and energy efficiency of the process, as well as optimising the optical and material properties of the panel itself.

For more information contact Nick Goffin, N.Goffin@lboro.ac.uk.

Normal laser beam *HOE* *Optimised laser beam*

Robotic Disassembly

With ever increasing demand for electronic devices in almost every sector, the quantity, size and types of electronic waste is rapidly increasing.

Once these products reach End-of-Life (EoL), recycling technologies often rely on fragmentation and separation techniques to recover the various materials. These forms of large volume recycling activities are often unable to recover the small quantities of Strategically Important Materials (SIMs) found in these devices. To facilitate recycling of complex electronic products, which include varying amounts and types of SIMs, novel recycling technologies and processes have been developed to increase recycling efficiency. In this context, robotic disassembly processes have been investigated to improve the quantity, quality and value of recovered SIMs from e-waste. A proof of concept case study, in collaboration with Toyota, was carried out based on EoL hybrid vehicle electronic components; the project was approached in a 3 stage methodology 1) manual, non-destructive disassembly, 2) automated semi-destructive disassembly, and 3) validation and optimisation of processes. Experimental results indicate significant potential for further automation in the recycling industry, especially for EoL vehicles and waste electronics.

If you are interested in engaging with this project please contact Dr Michael Barwood, M.Barwood@lboro.ac.uk or smart@lboro.ac.uk.

CASE STUDY

Robotic Disassembly of E-waste for Enhanced Material Recovery

Due to the large quantities, varying sizes and types of waste, current recycling technologies often rely on fragmentation and separation techniques and processes. These forms of large volume recycling activities are unable to recover small quantities of Strategically Important Materials (SIMs). To facilitate recycling of complex modern products, which include varying amounts and types of SIMs, novel recycling technologies and processes have been developed to increase recycling efficiency.

The Challenge

It was identified that Waste Electronics and Electrical Equipment (WEEE) is a key area that needs to be addressed. In conventional mechanical recycling facilities, processing often results in poor liberation and incorrect sorting of materials resulting in losses of SIMs, therefore pre-processing of waste streams prior to fragmentation is critical for successful recovery of SIMs. In this context, robotic disassembly processes (Figure 1) have been investigated to improve the quantity, quality and value of recovered SIMs from e-waste.

Our Approach

A proof of concept case study, in collaboration with Toyota, utilised an automated robotic disassembly cell as a flexible approach to pre-concentrate SIMs from WEEE components often found in End-of-Life (EoL) hybrid/ electrical vehicles. This process involved manually extracting selected WEEE components from EoL Vehicles (ELV), followed by robotically disassembling the WEEE component to liberate the parts containing the SIMs.

The SIMs rich parts are then sent for processing, separately from the remaining WEEE components. The case study was completed using a standard six-axis Staübli RX160 robotic arm, a specially designed set of pneumatic tools, and a standard modular fixturing platform. The robot has been setup to diagnose error statuses of the system and respond by suspending the operation, alerting the operator and waiting for further instruction or error resolution while the tools are capable of a number of operations, including cutting, drilling/milling, and gripping.

Outcomes and Future Challenges

Figure 2 shows the three steps involved which include manual disassembly of hybrid ELV WEEE components, automated semi-destructive robotic disassembly of these components, and finally validation and optimisation of robotic operations using further experimentations. Table 1 summarises an example dataset which demonstrates that there is significant potential for increasing automation within the recycling industry, especially within automotive and WEEE sectors. Aside from lack of manufacturing and material data regarding the WEEE components, several other challenges were identified and are now under further investigation, these include 1) robot tool and fixture design, 2) component material and design complexity, and 3) physical limitations of robots. Investigations regarding the mitigation of these challenges and how more effective automated solutions can be implemented are underway.

Main Conclusion

This research has revealed that there is an ever-increasing gap between manufacturing and EoL processes, where manufacturing processes have continued to advance, utilising new materials and construction techniques, while the EoL processes have not significantly improved over the last 30 years. There is a considerable potential for introduction of further automation within EoL processes, demonstrating that such automation will improve the quality and value of recovered materials.

Figure 1

1. Manual, non-destructive disassembly

Provide manual disassembly data including level of disassembly required, material contents and construction details.

2. Automated semi-destructive disassembly

Perform automated disassembly based on manual disassembly data, while exploring automated processes and techniques.

3. Automation validation and optimisation

Validate and optimise automated disassembly processes to improve speed and repeatability.

Figure 2. Three stage approach to robotic disassembly of WEEE components for SIM pre-concentration.

Name (Construction / Value)	Component overview		PCB / component W.R. (g/g)	DT (Minutes)			Material recovery value (£/Unit)	D_c(M) (£/unit)	D_c(A) (£/unit)
	Before	After	V.M.C	M.	I.A.	O.A.	PCB recovery rate (%)		
Power mgmt ECU (Simple / High)			229/723	1.7	3.0	1.9	1.45	0.43	0.38
			Ag, Au, Pd & Cu				100%		
Airbag ECU (Simple / Low)			80/267	1.4	1.8	1.6	0.46	0.35	0.32
			Ag, Au, Pd & Cu				100%		

Table 1: Example of experimental results from two different components, W.R.= Weight Ratio; DT = Disassembly Time; M. = Manual Disassembly; I.A.= Initial Automated Disassembly; O.A.= Optimized Automated Disassembly; V.M.C. = Valuable Material Composition; DC = Disassembly Cost

RESEARCH TECH

TECH

Doctoral Research Projects

Exploring ways to develop the sustainable design process: using 'up-design' thinking
Jee-Yeon Choi

This research is concerned with design thinking and the associated skills needed to bring 'up-design' to practical reality. The aim is to develop a guide for product makers to help them implement design thinking in their development processes.

Reducing the environmental impact of wind turbine blades
Jacky Liu

This research includes investigating the wind turbine blade waste inventory, understanding the environmental impact of wind turbine blades during its whole life cycle and quantitatively assessing the end-of-life options for wind turbine blades.

The integrated sustainable design of product and manufacturing systems
Pasuree Lumsakul

This research is exploring future design processes that will enable more responsive and sustainable co-development of products and manufacturing systems. This aims to maximise flexibility and responsiveness of manufacturing operations and design processes through understanding how to promote increased collaboration and embedded consideration of sustainability throughout.

Sustainable life cycle management
Ioannis Mastoris

Sustainability is often considered as an add-on dimension of decision-making in organisations. This project is increasing our understanding of how sustainability aspects can be integrated into decision making across the organisation. This helps manufacturers to identify opportunities for improving and ease the processes of integration of sustainability aspects in decision making.

CO2 Emissions from the cement industry
Daniel Summerbell

This research seeks to examine the main sources of CO2 emissions from the cement industry and identify opportunities to reduce them. We are now collaborating closely with a local cement manufacturer to perform an in-depth analysis of their factory.

Influencing factors for sustainable design implementation in the front-end of new product development process within the Fast-Moving-Consumer-Goods sector
Dr Curie Park

Whilst the anthropogenic impact of the Fas-Moving-Consumer-Goods sector is substantial, the sector is less explored from a sustainable design perspective. By comparing five FMCG cases at various sustainability maturity levels, this study confirms and elaborates the factors that influence the sustainable design implementation from the front-end of the New Product Development process. Among a total of 11 factors and 32 elements, two new factors including balanced focus on growth and maturity of external contexts are specific to FMCG. The higher the sustainability maturity level, the more positive, frequent evidence is observed. A framework visualises the iterative relationship among the factors. The research is anticipated to guide FMCG practitioners in diagnosing their sustainable design implementation, and developing more holistic sustainability strategy in a long-term view.

RESEARCH
Business Models

Business Models for Sustainable Industrial Systems

Business Models for Sustainable Industrial Systems is a three-year project funded by the EPSRC.

The project is looking to advance the research and practice on business model innovations that support industrial sustainability. The aim of the project is to develop a novel way of helping companies find and visualise opportunities for business model innovations that result in more sustainable businesses. Agent-based modelling techniques will be applied to unravel complex behavioural characteristics and contexts that have the potential to disrupt the current business model.

If your organisation is interested in experimenting with new more sustainable business models please contact the lead researcher on the project Dr Doroteya Vladimirova, dkv21@cam.ac.uk.

REDRESS

REDRESS is a collaborative project between M&S and Cambridge and funded by the Innovate UK competition 'Supply Chain Innovation Towards A Circular Economy'.

It is a 2-year project to drive garment recovery and retained value through business model and supply chain innovation. This project seeks to accelerate M&S Plan A commitments around reducing waste. The focus for this project will be to significantly reduce the environmental impact of raw materials in M&S' clothing supply chain. The team is applying circular economy thinking and business experimentation processes to drive greater garment recovery and retained value. The outcomes of the project can be applied to textile and other industries.

To find out more about this project, contact lead researcher Dr Nancy Bocken, nmpb2@cam.ac.uk.

BUSINESS MODELS
Doctoral Research Projects

Business models for the secondary use of electric vehicle batteries
Na Jiao

Batteries retired from electric vehicles (EVs) still have enough capacity for further applications such as low-speed vehicle traction and stationary energy storage. This research takes a multi-stakeholder's perspective and explores business models for the post-vehicle applications of EV batteries. The second-life batteries have the potential to link the transport and energy sector and generates new stakeholders.

A capability study for business model and eco-efficiency for enterprise transformation
Yan Li

This research explores to identify the capabilities needed for better integration and implementation of business model innovation and eco-efficiency. An instruction tool aims to develop to help industry explore and analysis a good solution of their enterprise transformation.

Sustainable business models to improve nutrition and health: A study into the collaboration between the food and health care sectors
Kirsten Van Fossen

This research aims to improve our understanding of an emerging phenomenon—increasing integration of food and health care actors. The expected outcome is a framework clarifying the alignment of incentives among actors, which will contribute knowledge regarding how and why they work together to create business models supporting healthy nutrition.

Sustainable value creation for product-service systems (PSS)
Miying Yang

This research seeks to help manufacturers identify opportunities for sustainable value creation. A Sustainable Value Analysis Tool (SVAT) has been developed to analyse value uncaptured throughout the product life cycle and to identify value opportunities. The tool has been validated and used in workshops for various purposes, including research, consultancy, business education and university education.

RESEARCH
Systems and Innovation

Energy and Resource Management Systems for Improved Efficiency in the Process Industries (MAESTRI)

MAESTRI is a four-year project funded by the European Commission through the Horizon 2020 programme which starts on September 2015.The project brings together 15 organisations from 5 different countries to advance the sustainability of European manufacturing, specifically focusing in the process industries. The main objective is to create both concepts and tools to facilitate the adoption of energy and resource efficiency improvement strategies in process production systems of any company (large, medium or small). This will be realised through the development of a flexible and scalable management system which will be tested in four real industrial settings across a variety of activity sectors. The centre will be leading the research on Industrial Symbiosis within the MAESTRI project. The research activities will include the analysis of successful industrial cases and this will support the development of a library of case studies and will lay the foundation for a toolkit and guidelines supporting the design and implementation of Industrial Symbiosis activities in manufacturing companies.

Please contact Dr Maria Holgado at mh769@cam.ac.uk for more information.

Sustainable Manufacturing for the Future

This joint six month research project between Coca-Cola Enterprises and Cranfield University is investigating the current sustainability landscape across the supply chain, including topics such as resource security, the circular economy, sustainable technologies and waste management.

It also looks to the future, forming a vision of what a sustainable factory will look like in 2050. An initial workshop was held and comprised industry experts, supply chain and academics including many from the Centre for Industrial Sustainability. The output was a white paper released in June and identifies six major themes set to shape the future of sustainable manufacturing: People, Big Data, Technology, Collaboration, Value and Resilience. These topics have been the subject of intensive research by three Cranfield masters students (Ana Lima, Antonio Andrea Spanò and Cynthia Adu). The focus will be on how we can achieve rapid and fundamental change, and will explore further working across boundaries not only in the food and drink manufacturing sector but across the entire manufacturing industry. The white paper is available here:

http://www.cokecce.co.uk/news-and-events/news/coca-cola-enterprises-and-cranfield-university-identify-six-major-themes-set-to-shape-the-future-of-sustainable-manufacturing

A second white paper will be released in October, 'Sustainable Manufacturing for the Future – projecting the future landscape across the food and drink industry in Great Britain' (working title).

For more information contact Prof Mark Jolly, m.r.jolly@cranfield.ac.uk, Dr Peter Ball, p.d.ball@cranfield.ac.uk, or Selena Taylor, seltaylor@cokecce.com.

MINDER

MINDER explores the feasibility of using UK industry to increase the grid penetration of renewable energy, by load shifting electrical demand.

This is an example of a smart grid application in which selected loads such as heating, ventilation and air conditioning (HVAC) are shifted without seriously affecting the service they provide. In this way, electrical demand is managed in order to balance the grid in the face of variations in supply that are typical of renewable energy technologies. HVAC services represent electrical loads from devices such as chillers, in which pumps and fans are controlled using variable speed drives. This allows a degree of control that is ideal for demand management. MINDER will demonstrate the principles of smart demand management and explore the feasibility of a much larger project to explore the potential benefit of deploying demand management using industrial buildings on a national scale.

For more information contact Dr Rick Greenough at De Montfort University, rgreenough@dmu.ac.uk.

Configurations for Sustainable Industrial Systems

The aim of this research is to develop knowledge and tools that will help those with a stake in manufacturing explore how their system might be configured in the future and how they can actively prepare for those challenges today.

From the challenges of engaging with the circular economy, to the language which helps unlock industrial system design, from developing scenarios to understanding how innovation and value creation can be enhanced through relationships and experimentation, the researchers have engaged with industry and leading thinkers to develop knowledge and tools which can help manufacturers tackle these problems. The work has revealed insights about what approaches have the potential to move towards more sustainable industrial systems, and the collected knowledge from the group is being incorporated into a new programme for those who seek to lead change in industry, developing pioneering projects that lead a wave of change across the system.

If you'd like to learn more about the Pioneers Programme contact Dai Morgan, dcm32@cam.ac.uk.

RESEARCH SYSTEMS AND INNOVATION

CASE STUDY

Beyond Material Flows: Exploring Adnams' Business Ecosystem

Established in 1872, Adnams Plc. is an East Anglian brewery with a turnover of c. £66 million (2014) and directly employs 400 people. Adnams are sustainability pioneers and have won numerous sustainability awards, most notably the Queen's Enterprise Award for Sustainable Development (2005, 2012).

The Challenge

Inspired by circular economy principles, Adnams have created environmental and financial value in their own operations; cycling waste heat in their processes and building a distribution centre that requires no mechanical heating or cooling. However, they wanted to better understand how to create environmental, social and financial value through the relationships outside their organizational boundary. The circular economy characterises organizational relationships in terms of their physical flows placing less emphasis on how value is created through relationships. Addressing this gap, this PhD research explored the social dynamics of value creation within Adnams' business ecosystem in order to inform their search for value creation opportunities.

Our Approach

A qualitative exploratory study was designed to understand the nature of the organizational influence in 30 key relationships and implications for Adnams value creation strategies. Organizational influence was defined in terms of a resource dependency view of power dynamics incorporating Archer (1995)'s distinction between structural (physical goods or man-made artefacts) and cultural resources (concepts and ideas). From this perspective, physical material flows are considered structural resources while Adnams sustainability values and leadership are examples of cultural resources.

Outcomes

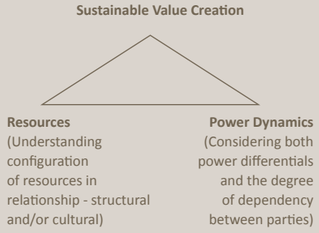
Power dynamics mediate how value creation occurs in relationships. Within this ecosystem the impact of power on value creation varied due to the unique configuration of resources in each relationship. This suggests a one-size fits all approach to value creation strategies is likely to be ineffective. Secondly – whilst perceptions play an important role in establishing stakeholder salience and informing decision making, they do not by themselves always provide an accurate indication of the power dynamics at play. Thirdly, it is easy to focus on the transactional aspects of organizational relationships which emphasise the size of the financial exchange related to the service or product (structural resource). However, Adnams were perceived to be able to create value creation opportunities beyond purely their structural resources – using their cultural resources to 'punch above their weight'.

Implications

These findings infer that cultural resources matter when it comes to value creation, so approaches like the circular economy which focus only on the tangible elements such as the material, energy, information and financial flows reveal only part of the picture. Sensitizing managers to the link between sustainable value creation, resource configurations and power dynamics (as depicted in Figure.2) can help organizations to avoid falling into traps associated with under-emphasising the role of power and influence in the value creation process. Finally - developing a better understanding of power dynamics within an organization's key relationships can inform more nuanced approaches to stakeholder management, supporting better decision making and inform managers' search for value creation opportunities.

For more information contact doctoral researcher Geraldine Brennan, geraldine.brennan09@imperial.ac.uk.

Archer, M. 1995. Realist social theory: the morphogenetic approach, University of Cambridge.



Linking sustainable value creation, resources and power dynamics

Adnams commitment to being a values led business (reproduced with permission)

SYSTEMS AND INNOVATION

Doctoral Research Projects

Exploring the impact of power-dynamics on sustainable value creation within a business ecosystem
Geraldine Brennan

Extending the concept of "loops" or material and energy flows to social systems, this research explores symbolic flows like power and influence between organizations. An in-depth case study exploring stakeholder relationships within Adnams business ecosystem highlights the impact of power dynamics on value creation opportunities.

Industrial sustainability competencies framework
Lloyd Fernando

This research seeks to better understand competencies that improve sustainability related performance. Four competencies: efficiency, internalisation, collaboration and co-ordination, and whole system design are identified from across 25 companies, that aid the development of next-generation sustainable factories and industrial systems. The research provides evidence on specific sub-competences that aid the development of the core-competencies.

Increasing the resilience of manufacturing to resource shocks (Rare Earths)
Liam Gardner

The aim of this research is to develop a framework for companies to identify the vulnerability of their business to restrictions in resource availability (primarily rare earths), and support the selection and development of REM and risk management strategies to increase the resilience of the business.

Searching for sustainability-led innovation: Reconciling the unintended consequences of conflicting organizational logics
Stefan Hemel

This research explores how distinct organizational logics impact the search for sustainability-led innovations. Using a paradox perspective, the research will aim to identify strategies for reconciliation of paradoxical tensions to help companies resolve social, environmental and economic trade-offs and deliver innovations for sustainability.

Long term planning for sustainable manufacturing using systems thinking
Sotirios Levakos

This research aims to enable manufacturing businesses to contribute to and improve the transition towards sustainable industrial systems. Drawing insights from systems theory and theories of change, a scenario based method is being developed to support long term strategic planning in manufacturing businesses.

Diffusion of sustainability practices across the supply chain - a collaborative approach
Handson Pimenta

This research focuses on collaborative initiatives between buying firms and their suppliers in order to create sustainability business value and innovation. A framework was designed and indicates how firms are engaging the suppliers and transferring sustainability practices and what opportunities there are to transfer (diffuse) more.

Design of sustainable industrial systems: Principles – Pattern – Practice
Sudhir Rama Murthy

This research bridges sustainability principles to industrial practice by understanding industrial systems in terms of their patterns. Industrial systems can be delineated in terms of their principles, pattern, and practice. Every pattern correlates to a specific set of principles – the same pattern manifests in different contexts as different industrial systems in practice. This nuanced understanding of one's industrial system can guide sustainable manufacturing decisions.

The effect of language on sustainability performance
Jules Saunderson

Focusing on metaphors used in discussing issues relating to sustainable development, this research is exploring whether different metaphoric frames can be deployed in order to inspire a more positive, proactive and productive conversation.

A framework for including 'social value' considerations in product life cycle assessment
Felix Shin

The aim of this research is to improve the overall sustainability of the EU28's toy industry (focusing in the UK) through the development of a framework for a decision support tool for reducing impacts whilst upholding and cultivating the inherent values of toys.

Experimentation to further radical sustainability-oriented innovation
Ilka Weissbrod

This research seeks to understand how experimentation acts as enabler of radical innovation efforts. Through interviews principles emerged of how individuals can increase the organizational capability of experimentation. A longer term case study enabled the testing and refining of these enabling principles.

RESEARCH SYSTEMS AND INNOVATION

CIRCULARITY

Doctoral Research Projects

Developing reverse logistics maturity model to stimulate and assess transition to circular economy

Serhan Alshammari

To understand, investigate and assess the underlying conditions which impact and influence the design of a reverse logistics model and enable enterprises to achieve best practices through mapping best practices associated with those underlying factors which will support the sustainable industrial systems to be part of circular economy.

How to understand and use ‘circularity’ as a basis for innovation

Fenna Blomsma

This research seeks to understand the influence of perceptions and beliefs on innovation projects aimed at closing material loops and how these shape the direction and outcomes of such projects. The aim is to develop better processes for ‘circularity’ driven innovation projects.

Developing reconfigurable recycling processes to support closed-loop economy

Tegan Pringle

This research seeks to apply the benefits of reconfigurable manufacturing to recycling systems to facilitate a closed-loop approach to waste management within manufacturing. By drawing from four key areas of design, modelling, management and technology, this research seeks to provide a system approach to reconfigurable recycling.

Communications for the user adoption of new ‘circular’ business models

Zoe Rowe

This research aims to understand how communications can be used to influence user adoption of new ‘circular’ business models. Deep insights, gained from the perceptions and attitudes users hold towards such concepts, will inform a theoretical model and guide organisations in how to develop communications for the effective adoption of ‘circular’ products and services.

Recent Publications

46 PUBLICATIONS SINCE SEPTEMBER 2014

Journal Papers

Ball, P.D., 2015. *Low energy production impact on lean flow, Journal Manufacturing Technology Management, Vol. 26, No. 3, pp. 412 - 428. ISSN 1741-038X.*

Bocken, N., 2014. Sustainable Business: *The New Business as Usual? Journal of Industrial Ecology, Special Feature on Industrial Ecology as a Source of Competitive Advantage. 18 (5), 684-686.*

Bocken, N., 2015. *Sustainable venture capital – catalyst for sustainable start-up success? Journal of Cleaner Production (in press)*

Bocken, N., Rana, P. & Short, S., 2015. *Value mapping for sustainable business thinking, Journal of Industrial and Production Engineering (forthcoming).*

Bocken, N., Short, S., 2015. *Towards a sufficiency-driven business model: Experiences and opportunities. Environmental Innovation and Societal Transitions (in press).*

Davé, A., Oates, M.R., Turner, C., and Ball P.D., 2015. Factory Modelling: *The Impact of Data Granularity and Quality on Production and Building Architecture System Simulation Outputs, International Journal of Energy Sector Management, Emerald (accepted).*

Fernando, L. and Evans, S., 2015. *Case Studies in transformation towards Industrial Sustainability, International Journal of Knowledge and Systems Science, 6(3), 1-17.*

Gould, O.J.P., and Colwill, J.A., 2015. *A framework for material flow assessment in manufacturing Systems. Journal of Industrial and Production Engineering, 32:1, 55-66.*

Litos, L., Evans, S., 2015. *Maturity grid development for energy and resource efficiency management in factories and early findings from its application. Journal of Industrial and Production Engineering 1-18.*

Luo, Y., Woolley, E., Rahimifard, S., and Simeone, A. 2015. *Improving Energy Efficiency Within Manufacturing by Recovering Waste Heat Energy, Journal of Thermal Engineering, 1 (1), 337-344.*

Masood, M., and Barlow, C.Y. 2014. *Status of solid waste management practices in developing countries - A case study on Lahore, Pakistan. Waste Management, 34(4) Pages 837 - 841.*

Ruiz Puente, M.C., Romero Arozamena E., and Evans, S.E., 2014. *Industrial symbiosis opportunities for small and medium sized enterprises: preliminary study in the Besaya region (Cantabria, Northern Spain). Journal of Cleaner Production, November, 2014; DOI: 10.1016/j.jclepro.2014.10.046.*

Shaw, I. and Ozaki, R., ‘Enacting environmental accountability in housing design: *practices of visibility’, accepted for publication in Energy Policy.*

Shaw, I. and Ozaki, R., ‘Emergent practices of an environmental standard’, Science, Technology, and Human Values, published in Online First, DOI: *10.1177/0162243915589765.*

Short, S.W., Bocken, N.M.P., Barlow, C., Chertow, M., 2014. *From Refining Sugar to Growing Tomatoes: Industrial Ecology and Business Model Evolution. Journal of Industrial Ecology (accepted).*

Tao, Y., Morgan, D. and Evans, S., 2015. *How policies influence the implementation of Industrial Symbiosis: A Comparison between UK and China, Asian Journal of Management Science and Application (Forthcoming).*

Tyl, B., Valet, F., Bocken, N., Real, M., 2015. *The integration of a stakeholder perspective into the front end of eco-innovation: a practical approach. Journal of Cleaner Production (in press).*

Yang, M., Vladimirova, D., Rana, P., and Evans, S. 2014. *Sustainable Value Analysis Tool for Value Creation. Asian Journal of Management Science and Applications.*

Conference Papers

Ball, P.D. and Lunt, P., 2015. Success factors in deploying industrial energy efficiency: *a pan-European case study, EurOMA 2015 26 June - 1 July, Neuchâtel, Switzerland.*

Barwood, M., Lie, J., Pringle, T., and Rahimifard, S., 2015. *Utilisation of reconfigurable recycling systems for improved value recovery from e-waste, 22nd CIRP Conference on Life Cycle Engineering 7- 9 April 2015, Sydney, Australia.*

Benedetti, M., Cesarotti, V., Holgado, M., Introna, V. and Macchi, M., 2015. *A proposal for Energy Services’ classification including a Product Service Systems perspective, 7th CIRP IPSS Conference, Industrial Product-Service Systems 21-22 May 2015, Saint-Etienne, France.*

Bocken, N., Holgado, M., Evans, S., 2015. *Challenges and opportunities in circular business model innovation for clothing from a retailer perspective, ISIE Conference, 7-10 July 2015, Surrey, UK.*

Bocken, N.M.P., Rana, P. , Athanassopoulou, N., Ilevbare, I. , Phaal, R., 2015. *A Strategy Process for Early Stage Ventures to Develop Sustainable Value Opportunities, Sustainable Design & Manufacturing Conference, Seville, 12-14 April 2015.*

Bocken, N.M.P., Prahbu, J., 2014. *Sustainable business model innovation for the developed and developing world based on Jugaad innovation principles, Sustainability Science Congress, 22-23 October 2014, Copenhagen.*

Bocken, N.M.P., Bakker, C., De Pauw, I., 2015. *Product design and business model strategies for a circular economy, Sustainable Design & Manufacturing Conference, Seville, 12-14 April 2015.*

Brennan, G. (2014). Business Models for Sustainability: *Informed by Ecosystem Concepts. 34th Strategic Management Society (SMS) Annual International Conference: Strategies for a Networked World. 20-23rd September 2014, Madrid, Spain.*

Davé, A., Ball, P.D., Salonitis, K., Astfalck, C., 2015. *Factory Eco-Efficiency Modelling: Framework Development and Testing. SDM 2015 International Conference on Sustainable Design and Manufacturing 12-14 April 2015 Seville, Spain.*

Davé, A., Salonitis, K., Ball, P.D., Adams, M., Morgan, D., 2015. *Factory Eco-efficiency Modelling: Framework Application and Analysis. GCSM 2015 Global Conference on Sustainable Manufacturing 16-18 September 2015 Ho Chi Minh City/Binh Duong, Vietnam.*

Despeisse, M., Kishita, Y., Nakano, M., and Barwood, M., 2015. *Towards a circular economy for end-of-life vehicles: A comparative study UK - Japan. 22nd CIRP Conference on Life Cycle Engineering 7- 9 April 2015 Sydney Australia.*

Gould, O.J.P., Simeone, A., Colwill, J.A., Willey, R., and Rahimifard, S. 2015. *A material flow modelling tool for resource efficient production planning in multi-product manufacturing systems. 48th CIRP Conference on Manufacturing Systems, 24 - 26 June 2015, Ischia (Naples), Italy.*

Gungor, Z. E., & Evans, S., 2014. *Eco-effective changeovers; changing a burden into manufacturing capability. Proceedings of the 12th Global Conference on Sustainable Manufacturing. Johor Bahur, Malaysia 22nd - 24th of September, 2014.*

Hemel, S., Smart, P., Macdonald, E., & Pilbeam, C. 2014. *Searching for Sustainability-led Innovation: Reconciling the Unintended Consequences of Conflicting Organizational Logics. 6th International Conference on Corporate Sustainability and Responsibility, 8-9 October 2014, Berlin, Germany.*

Holgado, M., Evans, S., Vladimirova D., and Yang M., 2015. *An internal perspective of business model innovation in manufacturing companies, Proceedings of the IEEE 17th Conference on Business Informatics, Lisbon, Portugal, pp. 9-16.*

Lehmann, M., Bocken, N.M.P. , Steingrímsson, J.G., Evans, S., 2015. *Incorporating Design Thinking into Sustainable Business Modelling, Sustainable Design & Manufacturing Conference, Seville, 12-14 April 2015.*

Litos L., Evans S., 2015. *Developing sustainable manufacturing strategies through practice maturity assessment, SDM 2015 International Conference on Sustainable Design and Manufacturing 12-14 April 2015 Seville, Spain.*

Fernando, L., Evans, S., 2015. *Competences necessary to improve the ability of organisation to design sustainable futures, SDM 2015 International Conference on Sustainable Design and Manufacturing, 12-14 April 2015 Seville, Spain.*

Jiao, N. and Evans, S.E., 2015. *Secondary use of electric vehicle batteries and potential impacts on business models. SDM 2015 International Conference on Sustainable Design and Manufacturing, 12-14 April 2015 Seville, Spain.*

Pimenta, H.C. and Ball P.D., 2014. *Environmental and social sustainability practices across supply chain management – a systematic review, Advances in Production Management Systems (APMS), 20-24 September, Ajaccio, France.*

Pimenta, H. and Ball P.D., 2014. *Analysis of environmental sustainability practices across upstream supply chain management, 12th Global Conference on Sustainable Manufacturing (GCSM), 22-24 September 2014, Johor Bahru, Malaysia.*

Pimenta, H.C.D, Ball, P. D, Julien, D. Morgan, D., 2015. *Towards a conceptual framework for diffusion of environmental and social sustainability practices across the supply chain, 2nd Intl. EurOMA Sustainable Operations and SC Forum 23-24 March 2015 Barcelona, Spain.*

Rama Murthy, S., Morgan, D. and Evans, S., 2015. *Industrial Ecology Principles and Industrial Practice - Exploring the Linkage, ISIE2015 - Taking Stock of Industrial Ecology 7-10 July 2015 University of Surrey, Guildford, UK.*

Shin, L.F., Colwill, J.A., and Young, R., 2015. *Expanding the scope of LCA to include ‘Societal Value’: A framework and methodology for assessing positive product impacts, 22nd CIRP Conference on Life Cycle Engineering 7- 9 April 2015 Sydney, Australia.*

Simeone, A., Woolley, E., and Rahimifard, S., 2015. *Tool state assessment for reduction of life cycle environmental impacts of aluminium machining processes via infrared temperature monitoring. 22nd CIRP Conference on Life Cycle Engineering 7- 9 April 2015 Sydney, Australia.*

Summerbell, D., Cullen, J., and Barlow, C., 2015. *Performance Analysis of a Cement Plant. ISIE2015 - Taking Stock of Industrial Ecology 7-10 July 2015 University of Surrey, Guildford, UK.*

Uusitalo, T., Kortelainen, H., Rana, P., Kunttu, S. and Evans, S., 2014. *Methods and tools for sustainable manufacturing networks – results of a case study, World Congress on Engineering Asset Management, 28-31 October 2014, Pretoria.*

Book Chapter

Brennan, G., Tennant, M. and Blomsma, F. (2015). *Chp.10. Business and production solutions: Closing the Loop in Kopnina, H. and Shoreman-Ouimet, E. (Eds). Sustainability: Key Issues. EarthScan, pp.219-239.*

ANNUAL REVIEW **2014-15**

Policy

Manufacturing Commission

The Centre for Industrial Sustainability has been instrumental in working with politicians to set up and run the Manufacturing Commission in 2015.

The commission is a cross party and cross sector Parliamentarian and industry-led body which drives new thinking around industrial policy in the UK. It conducts high-level research inquiries and makes recommendations to government and industry in order to instigate positive change in the UK manufacturing sector. Centre Director, Prof Steve Evans, Deputy Director, Prof Shahin Rahimifard and High Level Group Members Barry Sheerman MP and Prof Adisa Azapagic are all members of the Commission.

For more information contact Michael Folkerson, Michael.Folkerson@PolicyConnect.org.uk.

Inquiry into Industrial Sustainability

The Manufacturing Commission launched an inquiry into Industrial Sustainability in February 2015.

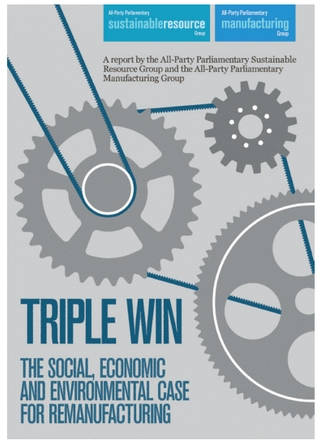
Co-chaired by Centre Director Prof Steve Evans the inquiry is seeking to understand how UK manufacturing can help achieve long-term economic, environmental and social sustainability and is looking at government's role in this. The inquiry will seek to make practical policy recommendations addressing key issues and themes currently affecting UK manufacturing and which threaten the UK's potential industrial growth, including questions over innovation, skills, finance and taxation, energy, SMEs, trade and investment. A number of organisations have provided written evidence, and the final oral evidence session was held in late July. The final report is expected in October 2015.

For more information contact Michael Folkerson, Michael.Folkerson@PolicyConnect.org.uk.

All Parliamentary Report on Remanufacturing

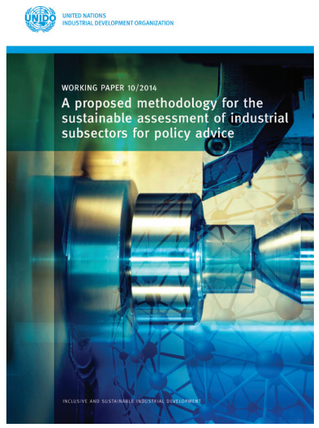
The Centre is part of the All-Party Parliamentary Manufacturing Group (APMG) which encourages the exchange of knowledge and understanding between Parliament and the UK's diverse manufacturing industries, helping to raise the profile of manufacturing both inside and outside of Parliament. Steve Evans was part of the steering group which collected evidence for the report, 'Triple Win The Social, Economic and Environmental Case for remanufacturing', published by the APMG and the All Party Parliamentary Sustainable Resource Group in December 2014. This report followed an eight-month inquiry chaired by Rt Hon Caroline Spelman MP and Barry Sheerman MP.

For more information contact Michael Folkerson, Michael.Folkerson@PolicyConnect.org.uk.



UNIDO ASEAN Region Project Working Papers

Centre researchers worked with the United Nations Industrial Development Organization (UNIDO) on a project to assess the economic, environmental and social dimensions of the industrial policies of the Association of Southeast Asian Nations (ASEAN), with the aim to encourage sustainable economic growth within the region. The work was focused on providing an analysis of the sustainability aspect of the existing economic environment, which would then inform policymaking. Two working papers were published in 2014: 'Sustainable assessment of chemical industries for policy advice – the case of the Philippines, Thailand, Indonesia and Viet Nam' and 'A proposed methodology for the sustainable assessment of industrial subsectors for policy advice'. For more information contact Prof Steve Evans, se321@cam.ac.uk.

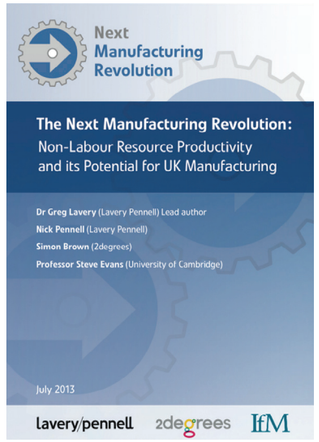


Non-Labour Resource Productivity

The heightened importance of productivity as identified by the UK government and business leaders shows the prescience of the NMR research into non-labour resource productivity in 2013.

The launch of the NMR report has been a catalyst for businesses and policy makers to engage with the opportunities it identified for improvements in the UK economy. It was the first report to explain environmental performance in an accessible language of non-labour resource productivity providing strong evidence for a critical productivity gap in the UK. There has been continued activity with UK businesses as a result of the report as well as international events such as the first sustainability event held by National Business Association of Colombia (ANDI) which took place in early June in Columbia. The event was inspired by NMR and featured Steve Evans as a keynote speaker.

For more information and to download the NMR report visit www.nextmanufacturingrevolution.org.



Foresight Report

The Centre had a strong influencing hand in the development of the Future of Manufacturing Foresight report published by the Government Office of Science the October 2013.

Prof Sir Mike Gregory acted as a reviewer, whilst Dr Mike Tennant lead the key evidence paper on sustainability and manufacturing, with support from Nancy Bocken, Geraldine Brennan and Dai Morgan. Steve Evans had the most prominent role, being part of the lead expert group that commissioned the research papers, attended workshops and sifted through the evidence to write the report. The Report continues to be discussed and debated, informing business and policy makers in their forward thinking. Over the last 12 months the Centre has discussed and presented on the sustainability elements of the Foresight report for: IKEA, Royal Academy of Engineering Seminars, World Federation Sporting Goods Industries annual global meeting, and the Chinese Academy of Sciences; and led workshops in Vietnam, China, and Sri Lanka.

POLICY

Doctoral Research Projects

Policy support mechanisms for Industrial Symbiosis: a comparative study between UK and China.
Yuan Tao

This project seeks to understand how policies act as driving mechanisms in promoting industrial symbiosis. Through comparing different policy supportiveness to develop industrial symbiosis between UK and China, this research aims to find out what policy works well under what conditions and what policy does not.

ANNUAL REVIEW **2014-15**

Cohort Development Programme

Through the Cohort Development Programme the Centre is meeting its goal to increase the capacity for change, by developing researchers who not only have deep technical skills derived from their research, but a broader understanding of business and sustainability. This understanding cannot be built solely from textbooks, papers and laboratories, but is strengthened and deepened by engaging with practice, exchanging with peers and broadening horizons of experience.

In order to support these needs the Centre developed the cohort programme, bringing together students of manufacturing, design and industry with a common interest in sustainability. Over the last 4 years, the programme has provided a range of opportunities for researchers to gather and engage in activities to improve their research practice, build networks and expand personal horizons.

Events have ranged from research practice – helping understand the tool building process - to communication skills, practicing how to communicate research ideas succinctly to industry. The community has also exploited social media such as Facebook to maintain contact between events and share the latest news and conferences.

The cornerstone of the programme is an annual retreat which brings students, researchers, senior academics together to develop shared understanding, and personal vision for their role in the future of manufacturing. This year the 62 attendees were drawn from 11 UK institutions and included guests from Sweden, Finland, Netherlands, Germany, Italy and Spain. With 22 nationalities representing five continents it was a truly international event.

The weeklong gathering featured a range of sessions with senior academics and industrialists, sharing an up to date view on the current state of manufacturing, and the challenges which are facing the industry. Researchers were encouraged to consider their role in the world, and were challenged to develop their own personal vision for the future of manufacturing. There were also opportunities for interest groups to gather and share experience – for example a circularity task force was set up by one of the researchers to convene all those with interest and activities relating to the circular economy.

The PhD can be a lonely process – with each one providing unique challenges and proving intellectually, professionally and emotionally challenging. By providing opportunities for people to come together and learn from each other and exchange knowledge and discuss experiences, we aim to make that process slightly less lonely. At the same we hope to create the environment where a community of leaders who will be able to take on the sustainability challenges facing industry, whether they are in industry, policy or research. If you know people who might like to join this community, please contact Dr Dai Morgan, dcm32@cam.ac.uk.

ANNUAL REVIEW **2014-15**

Outreach

In addition to our direct action research and implementation support with industry, the Centre takes its knowledge out to many audiences through activities and events such as workshops, webinars, industry conferences, science festivals, and our own annual conference. A few examples of these types of activates are below.

OUTREACH

Outreach to Industry

Working with the Cambridge Institute for Sustainability Leadership (CISL)

Our relationship with CISL (www.cisl.cam.ac.uk) offers an important mechanism for access to business leaders through our involvement in the education programme and various action projects. Centre team members have provided input to workshops, seminars, and other activities, and through this relationship, we have been able to reach more than 100 companies.

An example of this is the Sustainable Business Tools Laboratory (Lab) which took place in Cambridge in July 2015. The lab was led by Prof Steve Evans and Dr Doroteya Vladimirova of the Centre, with colleagues Dr Maria Holgado and Miying Yang along with several CISL staff. The intensive 2-day Lab provided participants with a deep dive into new tools for sustainable businesses, with a specific focus on learning from real business challenges. Participants had the opportunity to work with three tools developed by the Centre for Industrial Sustainability: the Cambridge Value Mapping Tool, Sustainable Value Analysis Tool, and the Business Transformation Tool. The workshop featured representatives from around 18 businesses including BP, BT, Ernst & Young as well as Mid cap and SME manufacturing companies. The lab was very well received achieving overall satisfaction scores of over 95%. For more information contact Dr Doroteya Vladimirova, dkv21@cam.ac.uk.

Another example of the Centre's work with CISL is the workshop led by Dr Nancy Bocken of the Centre together with Jeremy Bassett from Unilever (Unilever Ventures) on 'Disruptive Innovation' for the annual colloquium of The Academy of Business in Society (ABIS) and Cambridge

Institute for Sustainable Leadership (CISL), 'Transforming Tomorrow: Leadership for a Sustainable Future '. The workshops on radical innovation and sustainability were well-attended by academics and industrialists from all over the world.

Centre for Industrial Sustainability 2015 Webinar Series

The Centre's 2015 webinar program kicked off in early February with a webinar on 'Eco-efficiency: New understanding and emerging tools' with presentation from researchers from Cranfield and Cambridge. Since then four more webinars have been offered on communicating sustainability, sustainable value creation through maintenance, exergy analysis for resource efficient manufacturing, and manufacturing resilience strategies for critical material use. Additional webinars in the ongoing series include impacts of changeover processes in factories, embedding sustainability in design, and Eco-intelligent process monitoring. The webinars and slides can be accessed from the centre's website at www.industrialsustainability.com.

Industry Visits to the Centre

Throughout the year the Centre for Industrial Sustainability hosts industry groups who are interested in learning more about Centre research activities. Airbus visited the Centre in May to run their two-day Industrial Energy Efficiency Network Workshop which gave an opportunity for the Airbus team to interact with the Centre's researchers and for knowledge exchange on research projects relevant to Airbus activities. In June the Centre hosted EEF's Climate, Energy & Environment Policy Committee for their annual away day. In a full-day event, the Committee members had the opportunity to meet PhD researchers, listen to presentations on current research and the tools developed through research, and to understand how the Centre works. Other businesses to visits the Centre included Altro, Heraeus Noblelight, WFSG, Saitex, Global Paradigm, and ASICS.

Industrial Sustainability Workshops

Researchers have been trialing the Centre's sustainable business tools through workshops with industry. In-house workshops have been delivered to: Hugo Boss, ASDA George, Altro, WFSGI, Sustainable Apparel Coalition, Saitex, MAS Holdings, Heraeus Noblelight and Brandix. As an example, PhD researcher Lloyd Fernando and Prof Steve Evans led two-day workshops on system mapping and capability assessment in Vietnam and Sri Lanka. The workshop in Vietnam for employees of jeans manufacturer Saitex, included people from all parts of the company including the CEO, operations staff, finance staff and IT staff. In Sri Lanka, the workshop attendees were from two leading apparel manufacturers, Brandix and MAS Holdings. The companies found that the workshops helped improve their understanding of sustainable industrial systems and envision future systems. It also helped the organisations to focus on the capabilities that they need to develop.

Workshop Taster Sessions

Centre researchers offered sustainable business tools workshop taster sessions at the IfM in Cambridge in September 2014 and July 2015 for manufacturers, consultants, academics and third sector organisations. Workshop topics included eco-efficiency, circularity thinking toolkit, sustainable business modelling tools, system mapping and capability assessment, and factory environmental performance improvement.

OUTREACH

Outreach to Other Organisations

Forum for the Future

The Centre is also engaged with Forum for the Future, non-profit organisation for sustainable development, providing inputs for internal briefings, collaborating on specific activities, providing workshop support and input to strategic development activities - and learning from their efforts and achievements the area of system innovation and change.

IEMA

Centre researchers have delivered webinars on eco-efficiency and enabling innovation for the Institute for Environmental Management and Assessment (IEMA). Previously Centre PhD researcher, Lampros Litos, in collaboration with IEMA, facilitated an exploratory workshop on eco-efficiency in production. Although aimed mainly at industrial practitioners within the iema network with a working knowledge of production operations, the workshop also attracted a wider audience such as consultants and city council managers. The workshop provided an opportunity for colleagues facing similar challenges in eco-efficiency to learn from each other as well as an opportunity to contribute to leading edge research in eco-efficiency and environmental performance.

Hangyang University Sustainability and Manufacturing Summer Workshop

The Centre's second annual summer workshop for graduate students from the Graduate School of Management of Technology Hanyang University in Korea took place at the IfM, Cambridge in August. Twenty five students attended the 5 day workshop which included lectures on Industrial Sustainability from a Systems Perspective, Sustainable Business Models, Open Innovation, Nanotechnology, Laser Technology, International Supply Management as well as many other topics. For more information on the Centre's summer workshop programme please contact Jee-Yeon Choi, jyc30@cam.ac.uk.

OUTREACH

Conferences

Cutting Edge Research and Inspiring Keynotes at Centre's Annual Conference

The EPSRC Centre for Industrial Sustainability held its Fourth Annual Conference at Fitzwilliam College Cambridge on 6-7 July. The two-day conference, attended by 165 people, included a mix of presentations from industry and academia as well as an exhibition of tools developed for industry by Centre researchers and industrial partners. Keynotes were delivered by Ramon Arratia, Sustainability Director at Interface, Sanjeev Bahl, President at Saitex, Professor Gunther Seliger, Chairman at Technischen Universität (TU) Berlin, and CIS Director, Professor Steve Evans. The event also featured presentations given by Centre members including Toyota, Unilever, Marks & Spencer, EEF (the Manufacturers' Association) and collaborators Elvis & Kresse, the United Nations Industrial Development Organization (UNIDO), University of Ulster, High Value Manufacturing (HVM) Catapult, Centre for Renewable Energy Systems Technology (CREST), IfM Education and Consultancy Services (IfM ECS), and many Centre researchers and academics from the universities of Cambridge, Cranfield, Imperial and Loughborough. One delegate commented, 'This conference has become the highlight of my year. The work being presented is cutting edge and the keynotes are truly inspiring- seldom do I feel more passionate about sustainability than when I reflect on the conference material'. Films of many of the conference presentations can be viewed from the Conference Presentations webpage www.industrialsustainability.org/publications-videos/conference-presentations/.

Sustainability Live

The Sustainability Live exhibition and conference took place at the NEC in Birmingham from April 21-23. Intended for energy and sustainability management professionals, the event included a 3-day conference on the subject 'From Risk to Resilience'. At the conference Dr Peter Ball of Cranfield University presented a case study on 'Visual ways to present data' in the session 'Powering change: is data the new feedstock for sustainability solutions?'. Dr Maria Holgado spoke on 'Transforming businesses to deliver uncaptured and sustainable value' and Miying Yang both of the University of Cambridge spoke on 'Sustainable Value Analysis Tool' in the session 'Value unchained: the shift from competition to collaboration' Both sessions were well attended. Cranfield doctoral researcher Aanand Davé was invited to have a poster at the Sustainability live exhibition in the Innovation Zone where

innovative emerging technologies were highlighted. The poster 'Industrial Eco-Efficiency Modelling - Data-granularity framework for measuring and predicting asset performance' was very well received and generated much interest in Aanand's research.

Resource 15

The Centre for Industrial Sustainability participated in the Resource15 conference at Excel in early March. Resource is a 3 day event where 11,000 professionals share learning and explore opportunities to be circular and resource efficient.
As well as managing a busy stand Centre researchers also gave two workshops during the conference: 'New Tools for Sustainable Businesses' led by Dr Doroteya Vladimirova, Dr Maria Holdago, and Miying Yang of the University of Cambridge and 'Circularity Thinking: Ways to Navigate the Circular Economy' with Centre PhDs Fenna Blomsma from Cranfield and Geraldine Brennan from Imperial College London.
In addition, Professor Shahin Rahimifard of Loughborough University participated in a panel discussion on the future of supply chains in manufacturing alongside the Ellen McArthur foundation representative Sven Herrmann and other industry collaborators.

Manufacturing the Future 2014

The Centre for Industrial Sustainability took part in the 3rd EPSRC Manufacturing the Future Conference which was hosted by the EPSRC Centre for Innovative Manufacturing in Continuous Manufacturing and Crystallisation (CMAC) in Glasgow Scotland. Tools and research outputs were showcased at the Centre's stand in the conference exhibition and Centre PI, Prof Sir Mike Gregory, gave a plenary presentation on 'Building UK Manufacturing Capabilities' and another presentation on 'Sustainable industrial systems in manufacturing'. In addition, Centre Director Prof Steve Evans presented on 'Emerging research theses in industrial sustainability'.

OUTREACH

Centre Member and Stakeholder Outreach

Centre Members Meeting at Annual Cohort retreat

Centre industrial members are invited to join Centre staff and the extended cohort for a members meeting at the annual cohort week in January.
The meeting provides an opportunity for Centre industrial members to share their challenges in industrial sustainability and engage in dialogue with the researchers. In turn, the researchers are given an opportunity to share their knowledge and experience. Members and researchers find this day to be incredibly useful and productive.

All Stakeholders Day – Identifying Key Research Challenges to 2030

Over 70 people including Centre staff, members, and collaborators attended the Centre's annual All Stakeholders Day on 4 June in London. During the morning, Centre researchers presented on the progress and outputs of ongoing projects to staff and members. This was followed by a PhD poster session which provided an opportunity for Centre members to discuss current research one-on-one with the students. In the afternoon Centre collaborators joined the group for a workshop on identifying key research challenges to 2030.

OUTREACH

Schools Outreach

Cambridge Science Festival 2015

Staff from the Centre for Industrial Sustainability entertained children and young people with 'Sustainability Games' during the Cambridge Science Festival at the Institute for Manufacturing on 21 March 2014. Children learned about manufacturing resource efficiency in the Chocolate Egg Factory Board Game. In another game Centre PhD researchers and staff explained the life of a plastic bottle from raw material, to plastic, to a filled bottle. We then looked at lots of options for the bottle other than a landfill: reuse, recycling to become an input to manufacturing another product or incineration to create energy. This game included an interactive online activity and quiz and hands-on puzzle. Over 200 people played our Sustainability Games!

Cardiff Sixth Form College

In conjunction with Tyf, EEF Wales and Cardiff Sixth Form College, the Centre is developing a programme designed to link sixth formers and industry by giving them the skills to identify waste and opportunities to save money in manufacturing firms. The aim is for sixth formers to develop skills and understanding of sustainability and industry whilst helping manufacturing firms become more productive. The scheme is set to pilot in Autumn 2015 with the programme to be extended to other schools if successful.

ANNUAL REVIEW **2014-15**

Leadership

Executive Group

Prof Steve Evans
Centre Director
Chair, Executive Group
Cambridge University

Ian Bamford
Commercial Director
Centre for Industrial Sustainability

Dr Derek Pedley
Knowledge Transfer Network

Dr Mike Tennant
Co-Investigator
Imperial College London

Dr Jorge Arinez
Group Manager
Manufacturing Systems R&D
General Motors

Prof Sir Mike Gregory
Co-Investigator
Cambridge University

Prof Shahin Rahimifard
Deputy Director and
Co-Investigator
Loughborough University

Roy Willey
Environmental Care Manager
Unilever

Dr Peter Ball
Co-Investigator
Cranfield University

Steve Hope
General Manager
Environmental Affairs and
Corporate Citizenship
Toyota Motor Europe

Hugo Spowers
Company Architect and
Technical Director Riversimple Ltd.

High Level Group

Barry Sheerman MP
Chair
Member of Parliament for
Huddersfield

Ian Bamford
Secretary
Commercial Director
Centre for Industrial Sustainability

Andrew Churchill
Managing Director
JJ Churchill, Ltd

Richard Miller
Head of Sustainability Technology
Strategy Board

Prof Günther Seliger
TUBerlin
Prof Adisa Azapagic
University of Manchester

Andrew Buckley
Membership & Marketing Director
EEF

Prof Steve Evans
Centre Director
Cambridge University

Tim Page
Senior Policy Officer
Trades Union Congress

Dr Stephan Biller
Chief Scientist for Advanced
Manufacturing
GE Global Research

Paul Calver
Global Value Chain Specialist
UK Trade and Investment

Steven Fawkes
Founder and Principal EnergyPro Ltd

Lynva Russell
Board Member and former Chief Exec
Policy Connect

Adisa Azapagic
University of Manchester

Our People

Dr Chang Yong Ahn
Academic Visitor

Serhan Alshammari
PhD Researcher
s.alshammari@cranfield.ac.uk

Dr Peter Ball
Co-Investigator
p.d.ball@cranfield.ac.uk

Ian Bamford
Commercial Director
imb31@cam.ac.uk

Dr Claire Barlow
Senior Lecturer
cyb@eng.cam.ac.uk

Dr Michael Barwood
Research Assistant
M.Barwood@lboro.ac.uk

Fenna Blomsma
PhD Researcher
f.blomsma12@imperial.ac.uk

Dr Nancy Bocken
Senior Research Associate
nmpb2@cam.ac.uk

Geraldine Brennan
PhD Researcher
geraldine.brennan09@imperial.ac.uk

Jee-Yeon Choi
PhD Researcher
Jyc30@cam.ac.uk

Dr James Colwill
Lecturer
j.a.colwill@lboro.ac.uk

Aanand Davé
PhD Researcher
a.dave@cranfield.ac.uk

Dr Mélanie Despeisse
Research Associate
md621@cam.ac.uk

Prof Steve Evans
Centre Director
se321@cam.ac.uk

Lloyd Fernando
PhD Researcher
ldf21@cam.ac.uk

Dee Dee Frawley
Networking and Marketing Co-ordinator
ddf21@cam.ac.uk

Liam Gardner
PhD Researcher
l.gardner@lboro.ac.uk

Dr Oliver Gould
Research Assistant
O.J.Gould@lboro.ac.uk

Prof Sir Mike Gregory
Co-Investigator
mjg@cam.ac.uk

Ergun Gungor
PhD Researcher
zeg21@cam.ac.uk

Stefan Hemel
PhD Researcher
stefan.hemel@cranfield.ac.uk

Dr Maria Holgado
Research Associate
mh769@cam.ac.uk

Luoke Hu
Academic Visitor

Na Jiao
PhD Researcher
nj268@cam.ac.uk

Dr Weon Vin Lee
Academic Visitor

Martin Lehmann
Academic Visitor

Sotirios Levakos
PhD Researcher
sl656@cam.ac.uk

Yan Li
PhD Researcher
yl483@cam.ac.uk

Dr Xiao Li
Academic Visitor
Xl395@cam.ac.uk

Lampros Litos
PhD Researcher
ll443@cam.ac.uk

Jacky (Pu) Lui
PhD Researcher
pl384@cam.ac.uk

Pasuree Lumsakul
PhD Researcher
p.lumsakul@lboro.ac.uk

Ioannis Mastoris
PhD Researcher
im359@cam.ac.uk

Sharon Mey
Centre Administrator
cis-admin@eng.cam.ac.uk

Elliott More
PhD Researcher
egm27@cam.ac.uk

Sandra Naomi Morioka
Academic Visitor
snm37@cam.ac.uk

Dr Dai Morgan
Research Associate
dcm32@cam.ac.uk

Hiroshi Nakamura
Academic Visitor

Ritsuko Ozaki
Senior Research Fellow
r.ozaki@imperial.ac.uk

Dr Jae-Hwan Park
Lecturer
jhp37@cam.ac.uk

Dr Curie Park
Research Assistant
curious@gmail.com

Handson Pimenta
PhD Researcher
h.c.pimenta@cranfield.ac.uk

Tegan Pringle
PhD Researcher
t.a.pringle@lboro.ac.uk

Sudhir Rama Murthy
PhD Researcher
ssrr3@cam.ac.uk

Prof Shahin Rahimifard
Deputy Director
s.rahimifard@lboro.ac.uk

Simon Roberts
PhD Researcher
simon.roberts@cranfield.ac.uk

Zoe Rowe
PhD Researcher
z.o.rowe@cranfield.ac.uk

Jules Saunderson
PhD Researcher
j.saunderson12@imperial.ac.uk

Alexander Schurig
Academic Visitor

Dr Leila Sheldrick
Lecturer
l.sheldrick@lboro.ac.uk

Felix Shin
PhD Researcher
k.l.shin@lboro.ac.uk

Dr Alessandro Simeone
Research Associate
a.simeone@lboro.ac

Dr Palie Smart
Reader
palie.smart@cranfield.ac.uk

Daniel Summerbell
PhD Researcher
dls43@cam.ac.uk

Yuan Tao
PhD Researcher
yt289@cam.ac.uk

Dr Mike Tennant
Co-Investigator
m.tennant@imperial.ac.uk

Hana Trollman
Administrator
H.Trollman@lboro.ac.uk

Kirsten Van Fossen
PhD Researcher
kev22@cam.ac.uk

Dr Doroteya Vladimirova
Senior Research Associate
dkv21@cam.ac.uk

Ilka Weissbrod
PhD Researcher
ilka.weissbrod@imperial.ac.uk

Dr Elliot Woolley
Lecturer
e.b.woolley@lboro.ac.uk

Miying Yang
PhD Researcher
my306@cam.ac.uk

Collaborators

&Share
4CMR
2 Degrees
ABB
Acumen Fund
VTT Technical Research Centre of Finland
Adnams
Airbus
Angelantoni (Archemedes Solar)
Asda (George at Asda)
BIS
Auto-Plas
William Jackson Food Group
BLT Precision
Westfield Health
Boots
Bosch
World Federation of Sporting Goods Manufacturers
Brandix
Brunel University
Cambridge Institute for Sustainability Leadership (CISL)
Wrap
Camden Boss
Campari
Carbon Trust
Cardiff University
Chalmers University
Centre for Process Innovation, Teesside University
AB Sugar
Centre for Renewable Energy Systems Technologies
CLAAS
Coca-Cola Enterprises
Colacem
Cucchinelli
CSC
De Montfort University
DIN, The German Institute for Standardization
Dragon Rouge
Dufaylite
Dupont
Dyson
Ecopare
Centre for Ecology and Hydrology
ELCON Solution Oy
Elvis & Kresse
EMR
The Engineering Quest
European Outdoor Group
European Safety Flooring
Europlaz
Extremis Technology
FIDIA S.p.A.
Forum for the Future
Forward Composites
Frankdale Foods
Frontier Markets
General Motors
EEF
Global Paradigm
Grant Instruments
Green Investment Bank
Hall Stage
Hanson UK
Hanyang University
Harlow Group
Heraeus Noblelight
HVM Catapult
Hugo Boss
iema
Indian Institute of Management in Ahmedabad
Jackson Foods
JJ Churchill
Jaguar Land Rover
KAIST
Kyocera
Knowledge Transfer Network
Lavery Pennell
Loccioni
Loughborough Design School
Marks&Spencer
Martec Conservation
Massachusetts Institute of Technology
Methodos
Milbank
MSolve Ltd
Newton Commercial
ILVA
NiTech
Nike
O'Herlihy & Co
Open University
Photofabrication Ltd
Plan-C
Policy Connect
Politecnico di Milano
Power Vision Ltd
Riversimple
Royal College of Art
Saitex
Screens at work
Shanghai Jiao Tong University
Shearline
Stanley-DeWalt Italia
Steltube
Sustainable Apparel Coalition
Technical University of Berlin
Technical University of Delft
TUC
UKTI
UNIDO
Umbra Group
Unilever
University of Bath
University of Bristol
University of Cantabria
University of Cardiff
University of Genova
University of Liverpool
University of Manchester
University of Minnesota
University of Strathclyde
University of Stavanger
University of Surrey
University of Ulster
University of Wales, Trinity St David
University of Warwick
Venture Studio
Veragon
Vera Solutions
Vitsoe
Vanners
Vodafone
Veolia
Xeros

EPSRC Centre
for Innovative
Manufacturing in
INDUSTRIAL
SUSTAINABILITY

UNIVERSITY OF CAMBRIDGE

Cranfield UNIVERSITY

Imperial College London

Loughborough University