Building a Process Understanding Toolkit for Sustainable Innovation in the Circular Economy

John A. Henderson† and Robert H. Peeling
Britest Limited, Colony, 5 Piccadilly Place, Manchester, M1 3BR, United Kingdom
(†j.h@britest.co.uk)

Britest

Generating value
from process understanding

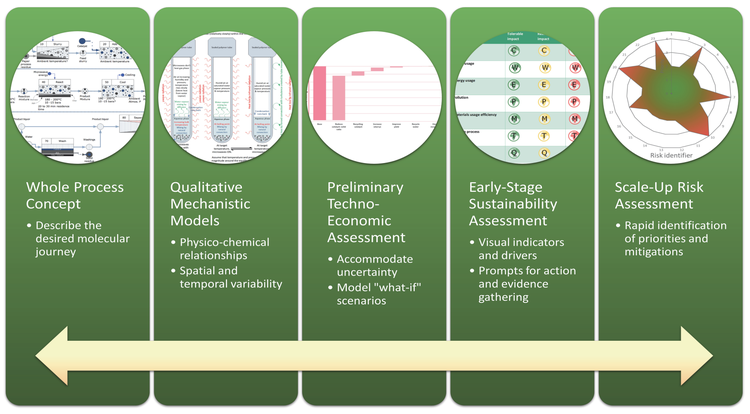
Introduction

Britest champions effective whole process understanding throughout the chemical, biochemical and related process industries. These sectors have a key role to play in the transformation required to successfully respond to the threat of climate change by supporting sustainable lifestyles according to circular economic principles. To do so scientists, engineers and business decision makers need to marry up technological innovation with a broader understanding of sustainability drivers and value chains more effectively than ever before.

Against this backdrop this poster exemplifies some new and improved approaches towards holistic qualitative and semi-quantitative models for whole process understanding aligned with these needs in areas including mapping of circular value flows, scale-up and commercialisation of biotechnologies, and advanced recycling technologies.

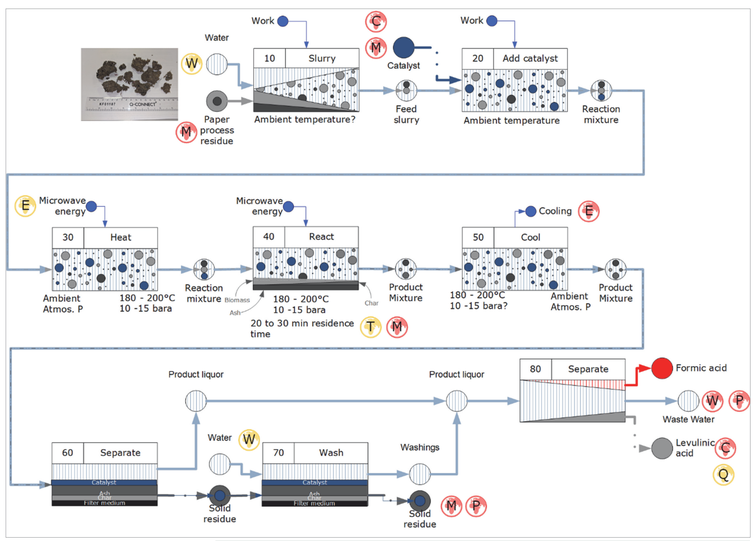
Setting development objectives

During early stage product or process development, data is usually limited. Businesses and hence project teams nevertheless need to consider whether to commit resources to continue the development, and to set development objectives that will move the project towards commercial viability. Britest's partners in the Industrial Strategy Challenge Fund (ISCF) project LevWave[1] found themselves facing exactly this challenge as they sought to develop a novel process using solid-state catalysis and microwave heating for the manufacture of levulinic acid from a by-product of the paper industry. In response, Britest developed an understanding-based methodology for setting commercialisation objectives[2] and road tested it on the Levwave technology.



Whole Process Concept & Sustainability Hot-Spots

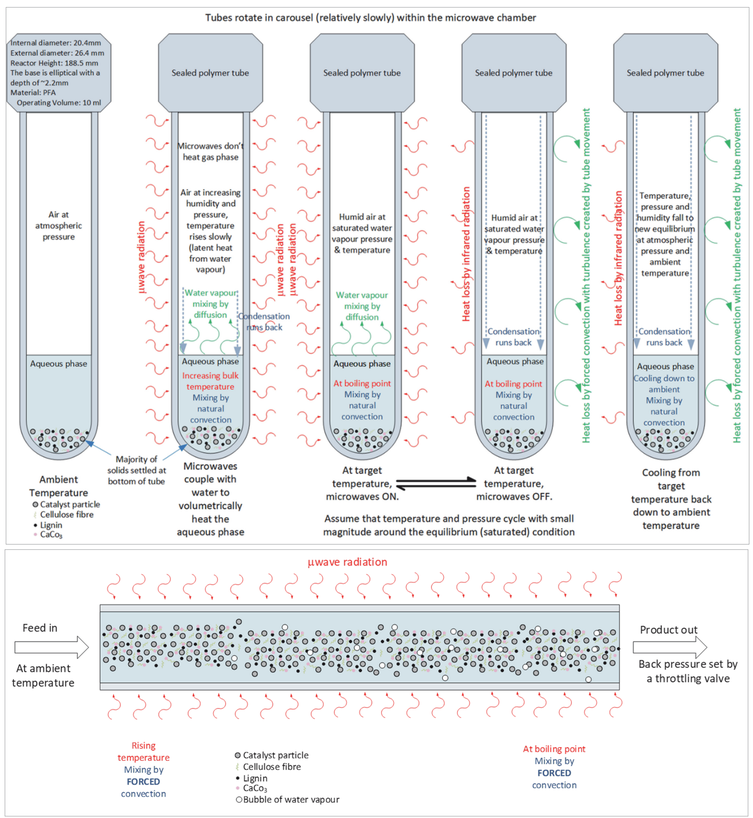
A scale and equipment independent Process Definition Diagram (PDD) describes the desired experiences (changes of *state*) that all process materials need to undergo to obtain the required product: what *tasks* must be accomplished? Subsequently this state-task network provides a visual process map upon which sustainability prompts can be marked, highlighting 'hot spots' for development and a means of tracking progress.



LevWave Process Definition Diagram annotated with Sustainability Prompts

Develop Qualitative Mechanistic Models

Equipment Rich Pictures / Rich Cartoons elucidate relationships between chemical and physical aspects and spatial and temporal variations. In this case, differences between mixing intensity between small scale batch and scaled up continuous processing are evident.

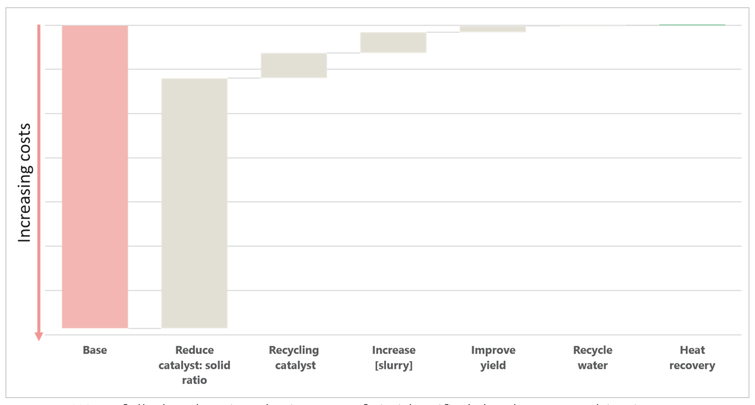


Rich Cartoon sequence for lab-scale batch-wise LevWave process (upper figure) and Rich Picture of continuous scaled-up process (lower)

Techno-Economic and Scale-Up Assessment

Preliminary TEA combines the use of Britest knowledge capture tools with the application of process engineering design principles to estimate fixed and variable costs, and thus cash flows, for the base case unoptimised process design. What-if improvement scenarios can then identify cost-supported improvement objectives.

Early-stage scale-up risks can be identified by an annotation process procedurally similar to the Sustainability Prompts approach, followed by scores-based risk prioritisation, mitigation and review cycles.

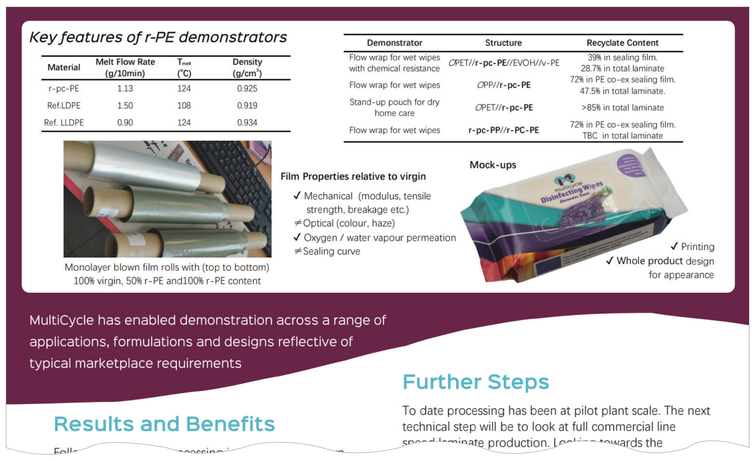


Waterfall plot showing the impact of six identified development objectives on the LevWave preliminary TEA model output costs

Exemplifying circularity

The Horizon 2020 Innovation Action MultiCycle[3] has developed, and demonstrated an industrial recycling pilot plant for problematic multilayer flexible packaging and fibre reinforced thermoplastic composites using a novel selective dissolution process to recover pure single polymers suitable for processing back into the value-added applications from which they arose.

Britest has successfully facilitated the process by which the project's principal industrial demonstrator evaluations by end user industrial partners in consumer packaging and automotive part manufacture have been translated into case studies, translating complex technical details and proprietary information into readily understood, publicly accessible, and impactful exemplars of the circular economy at work.[4]



Excerpt from MultiCycle case study in the use of recycled film-grade polyethylene from mixed plastic post-consumer waste

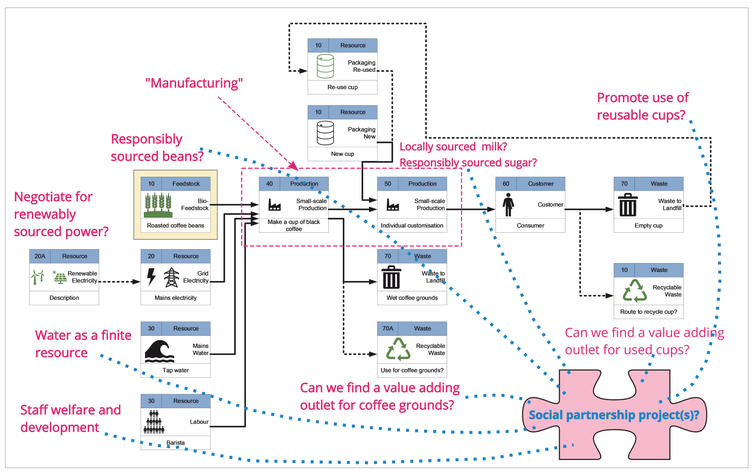
A self-guided online training tool drawing on MultiCycle's activities and findings, intended to support capacity building in industry and in education to promote the adoption of new recycling technologies, is also available. The materials in the guide may be adapted for reincorporation in other training and educational resources.

Value chains visualised

Building on the EU STYLE project's Ideal Toolkit Framework[5] (for a pragmatic tool to check the sustainability implications of technological solutions) Britest has worked to broaden the concept of 'whole process' design thinking, recognising that innovation for sustainability almost invariably takes place across a broader system of which manufacturing and its immediate inputs and outputs form only a part. Such supply-process-service systems can be explored in the form of a Supply Chain Definition Diagram (SCDD), taking in relevant upstream and downstream supply chain considerations as well as the physical, chemical, or biochemical processes of manufacture.

The functional elements of which a SCDD is composed include

- Feedstocks
- Transport (including loading and unloading)
- Production (including packing/unpacking and storage)
- Customers
- Resources – Energy, Water, Labour and Packaging
- Wastes and emissions, and
- Services – Data Management, Process Control, Decision Making, Recovery, Abatement, Disposal etc.



Fancy a coffee? A Supply Chain Definition Diagram emphasises the whole system not just the manufacturing steps and products.

References
1. https://gtr.ukri.org/projects?ref=50057
2. Peeling, R.H., *An understanding-based methodology for setting commercialisation objectives for an innovation project - a case study for platform chemicals from paper sludge*, Paper Technology International, 2022, *In press.*
3. http://multicycle-project.eu/
4. http://multicycle-project.eu/2022/04/27/case-studies-in-circular-industrial-applications/
5. https://www.britest.co.uk/multicycle/

Acknowledgements
The authors gratefully acknowledge financial support for parts of the work described in this poster. Innovate UK funded project 50057 LevWave through the Industrial Strategy Challenge Fund (ISCF) call for transforming foundation industries: fast start projects. MultiCycle received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 820695.

COLLABORATION
INNOVATION
VALUE

www.britest.co.uk