School of Civil Engineering
Institute for Resilient Infrastructure (iRI)
Institute for Public Health & Environmental Engineering (iPHEE)
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Solid recovered fuels (SRF), refuse-derived fuels (RDF) and circular economy:

Incompatible or integral part?

Costas Velis

3rd International conference on sustainable solid waste management, Tinos, 2-4 July 2015

ISWM - TINOS

Energy research at Leeds

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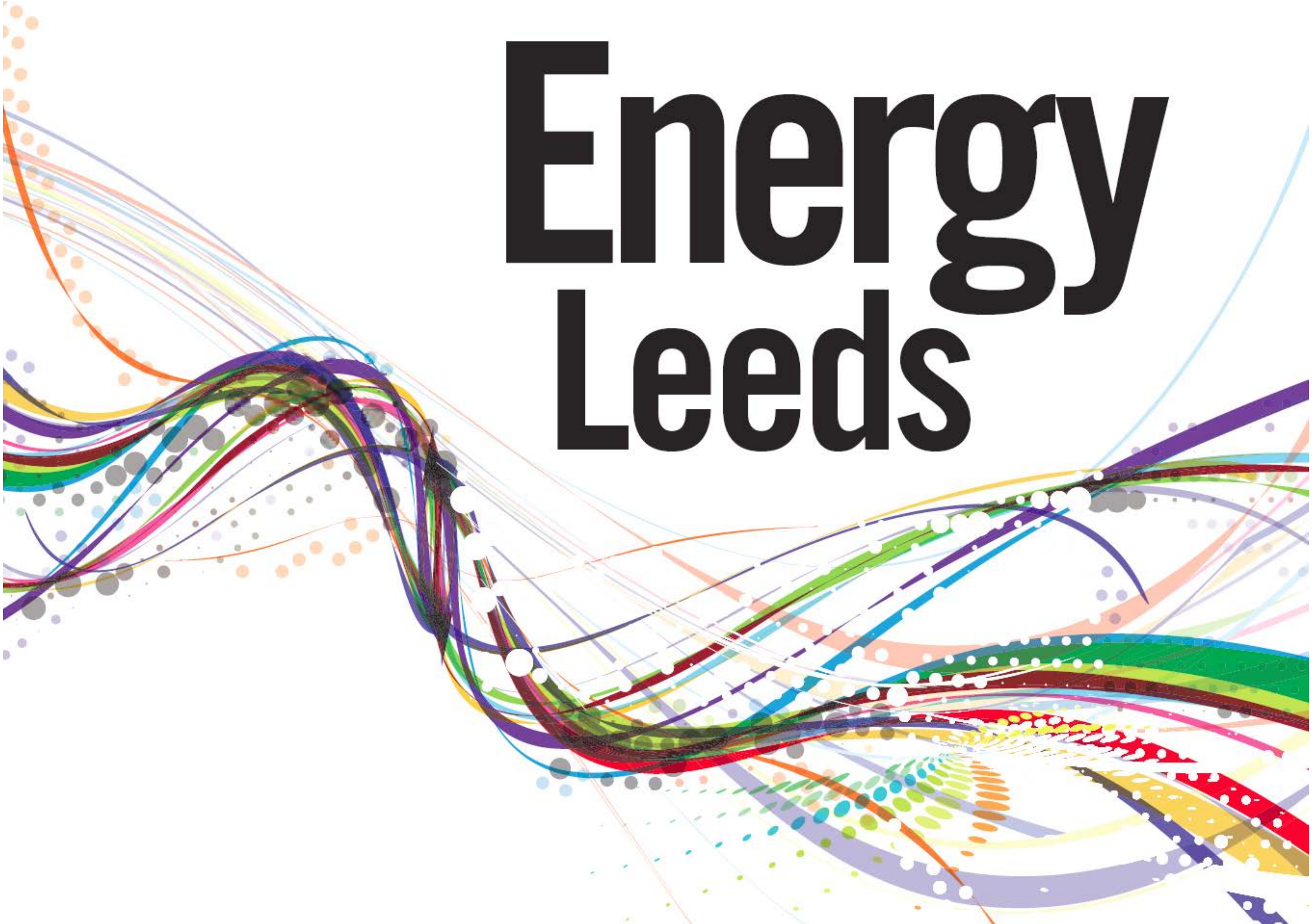

Global waste management :Annual reports
Waste Atlas Partnership

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New European resource management vision

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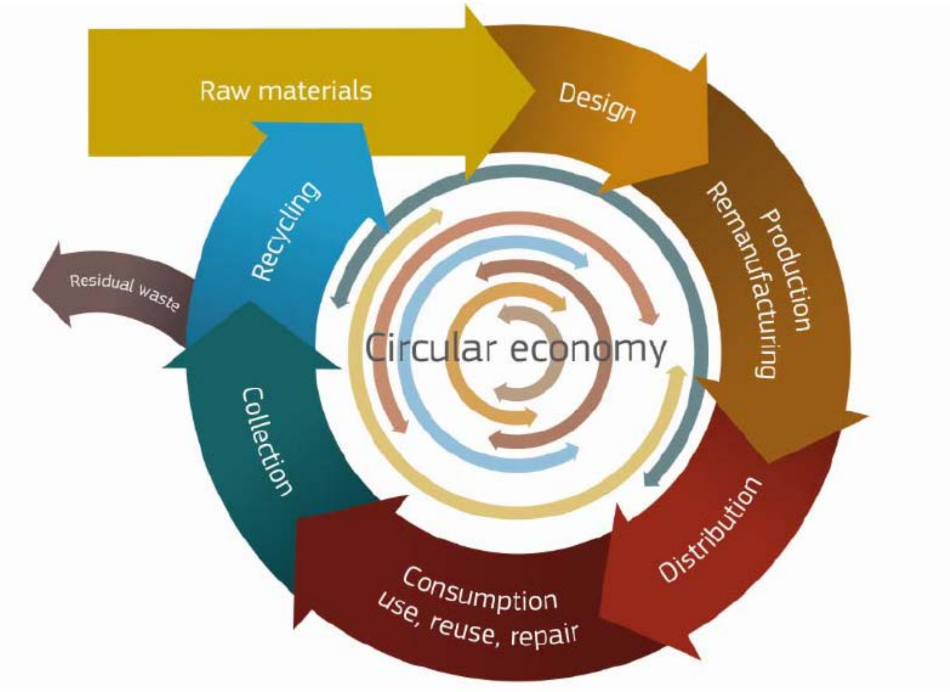

'Towards a circular economy:
A zero waste programme for Europe'

Resource management – which vision / ‘value proposition’?

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Circular economy: Ellen MacArthour foundation vison

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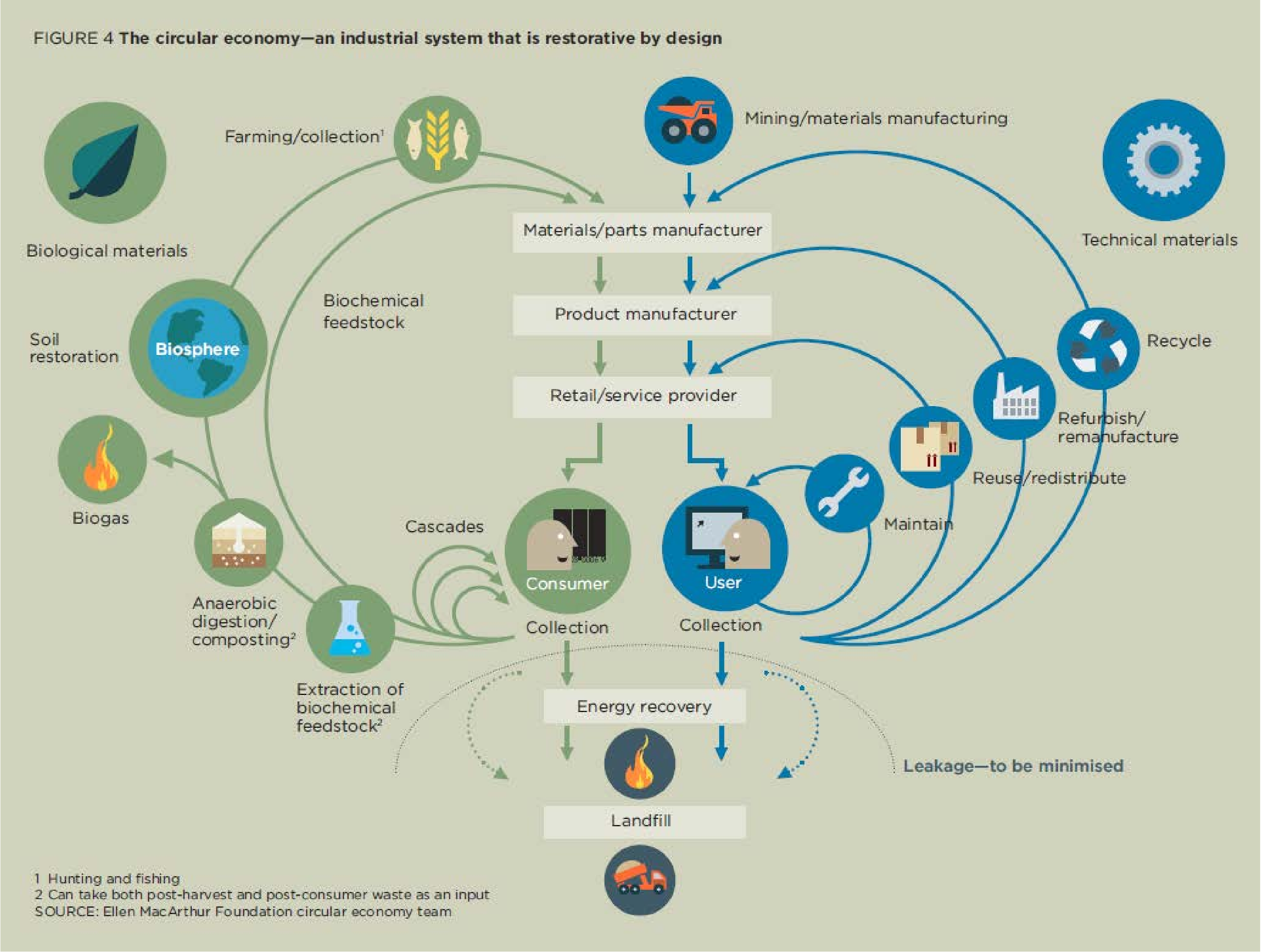

Circular economy another vison - spot a key difference

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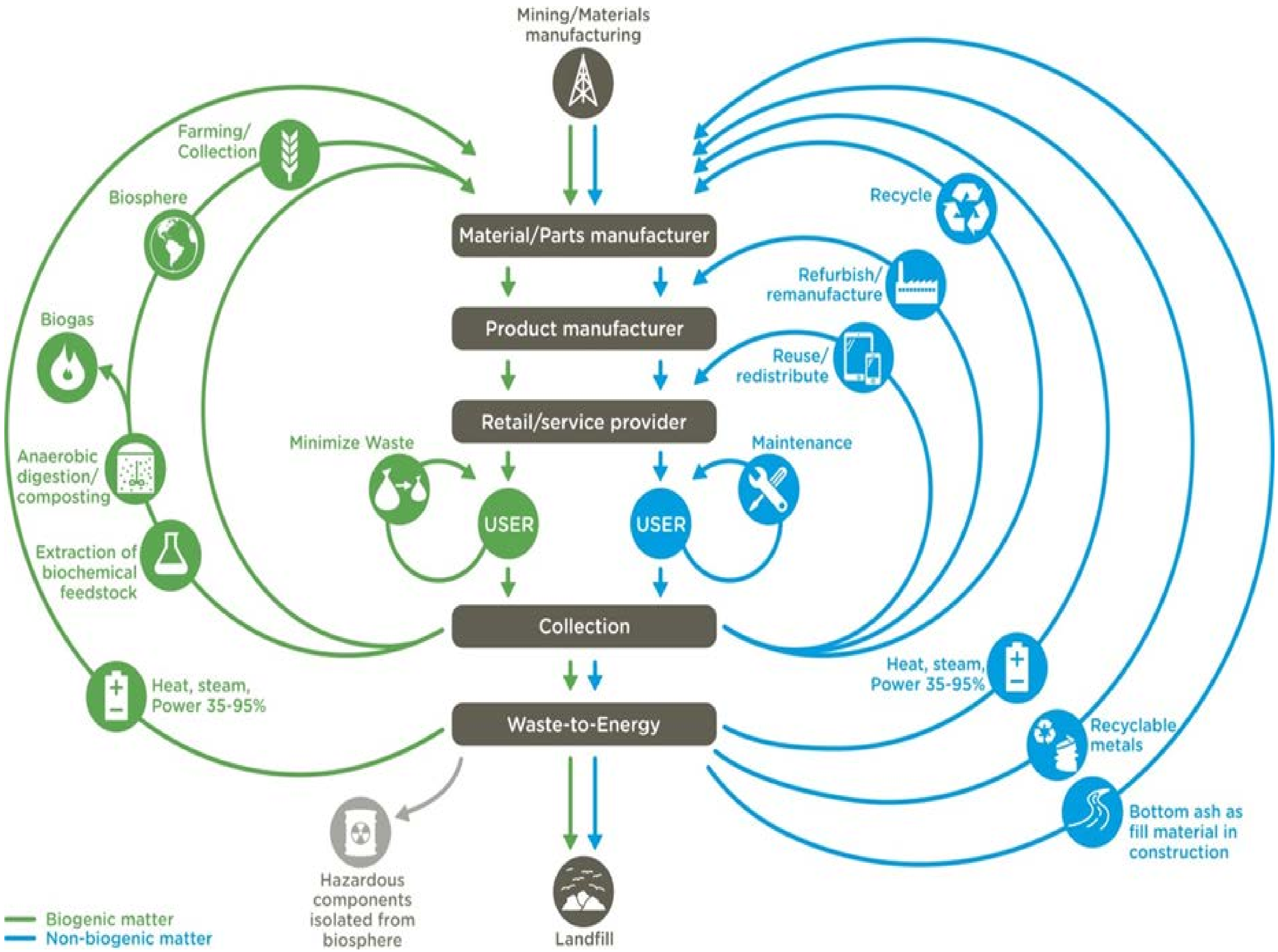

PlasticsEurope CE version

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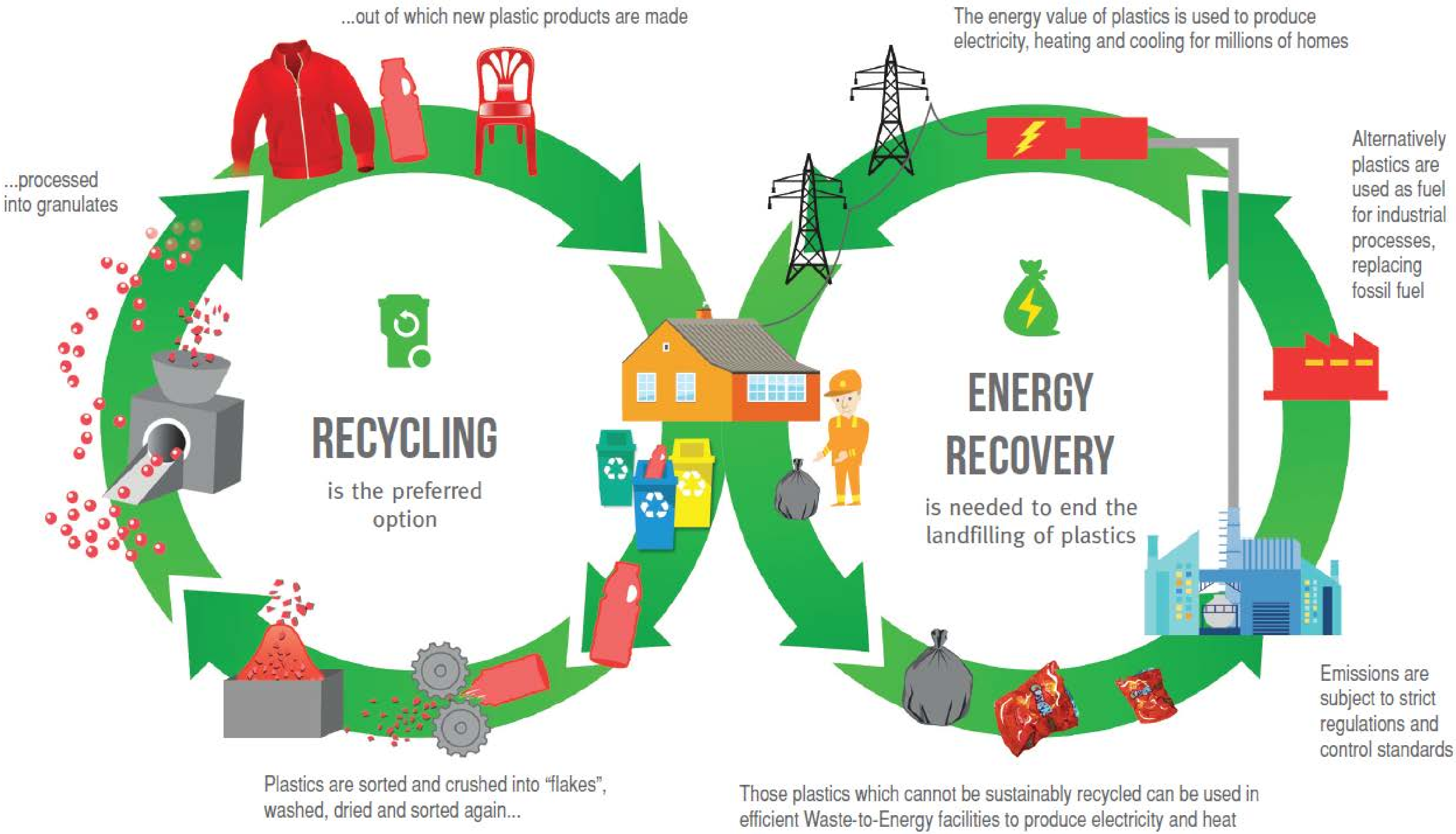

Meaning / role of "recycling"

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Goal

Basis - NOT Goal

Least considered

Focus to date

Organics/composition of MSW across 20 reference cities around the world

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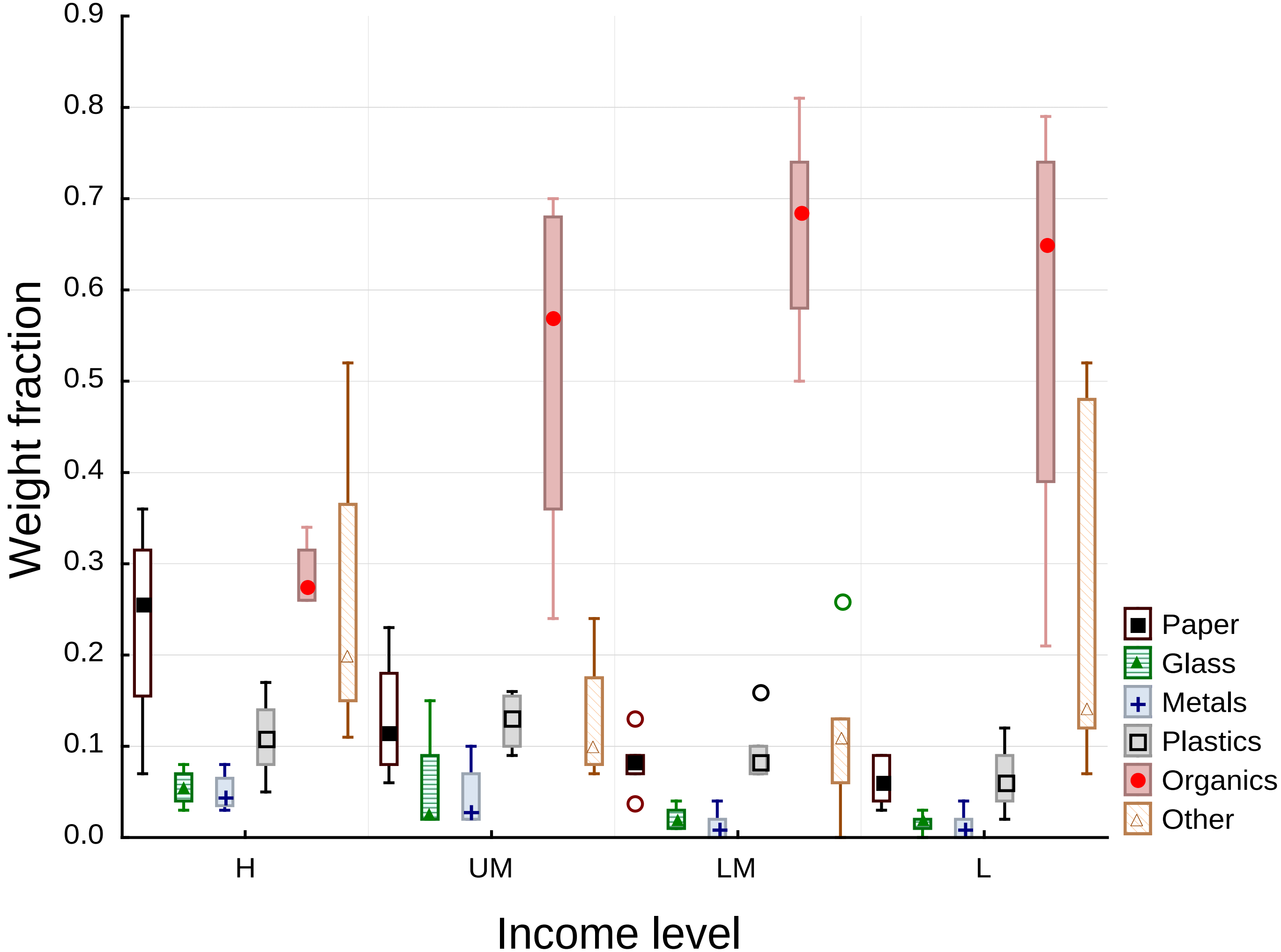

Source: Wilson et al., 2012

PP and paper & board

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TECHNICAL CHALLENGES

PP

- **Plastic complexity**
Immiscibility and incompatibility of polymers recycling
- **New pigments and inks**
Direct printed PP packaging and printed in-mould labels
- **Contamination** (food/ chemicals contained in the products)
- **Lack of recycled product specification**

PP and Paper/Board

- **Difficult identification**
Different grades of PP and Paper/Board and contamination
- **Limit of recycling cycles**
Degradation (loss in chain length of polymers and fibre length of paper)
- **Contamination (other materials)**
Affect quality
- **Lack of methods to monitor sorting**

Paper/Board

- **New inks & paper grades**
Flexographic newspapers, digital printing with liquid tonners, inkjet printing, UV cured inks, etc.
- **Energy efficiency**
- **Contamination** in the case of commingled collection

PP and paper & board

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ENVIRONMENTAL CHALLENGES

PP

- **Brominated Fluorine retardants (BRFs)** in WEEE
- **Benzophenone** (photoinitiator used in UV cured inks)
- **Contamination (**organic & inorganic compounds)
- **Volatile compounds (VOCs)** such as Alkanes
- **High molecular weight materials** (hexylsalicylate and isopropyl myristate)

PP and Paper/Board

- **Energy consumption**
- **Water consumption**
- **GHG from collection and transport, sorting and reprocessing**

Paper/Board

- **Mineral Oils**
- **Phtalates**
- **Phenol (**Bisphenol A)
- **Parabens** (butyl and propyl parabens)
- **Inorganics** (Pb, Sn, Sb pigments)
- **Other substances** (Polychlorinated biphenyls, Diisopropyl naphthalene, Organochlorine compounds)
- **CO_2 emissions**

2 approaches to recovering value

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Circular economy = (closed)-loop economy?

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NOT Goal	**Intermediate Goal?**	**Ultimate Goal**

Better society – how?

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A long chain – how to maintain througout clean material flows and environment?

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Circular + green economy?
Any dilemas?

How can we recover value from waste?
3 key dimensions of material value

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Technological options for MSW processing

Kew options for energy/heat recovery from solid waste

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Some key considerations

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SRF vs. RDF

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SRF – terminology

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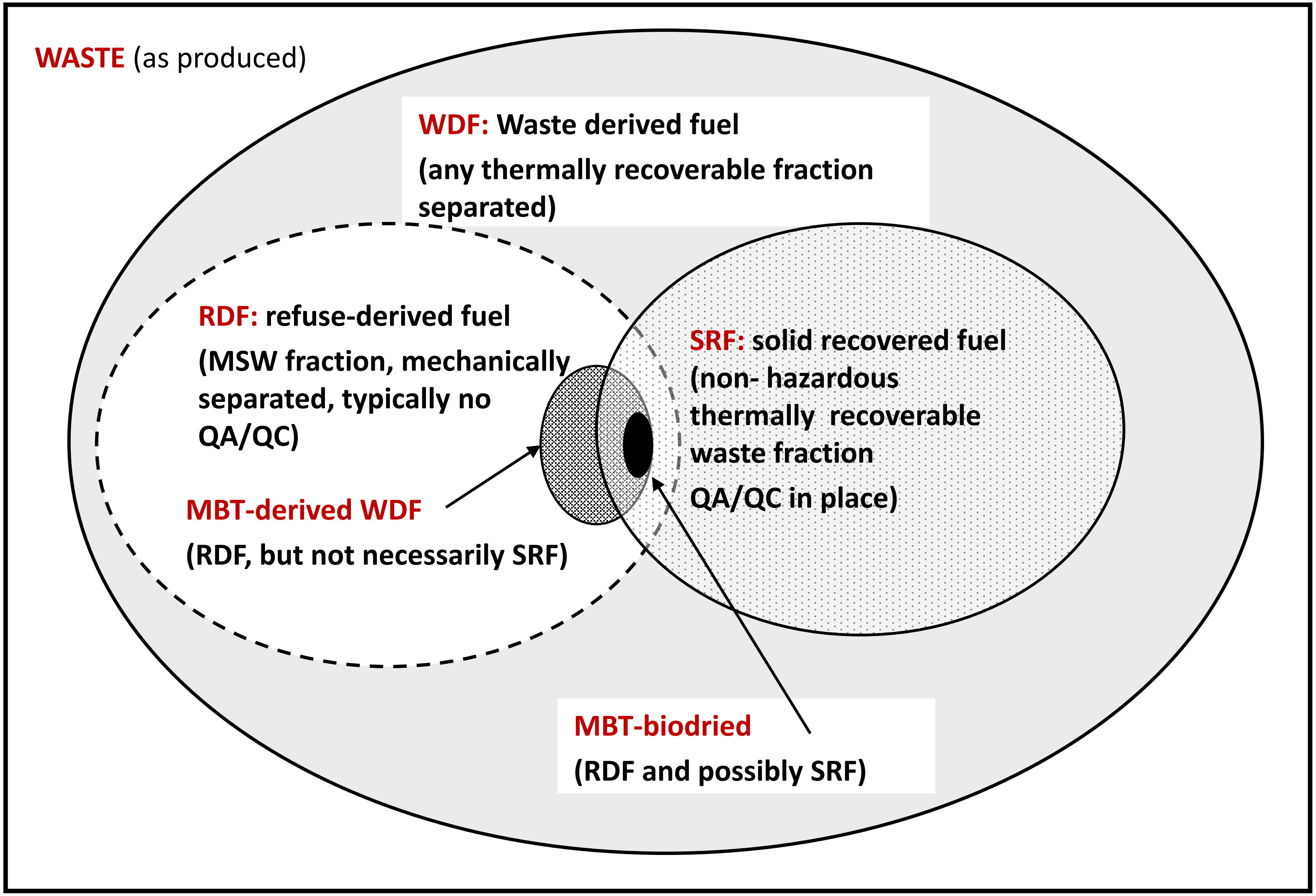

Source: Velis et al., 2010

SRF surplus in Germany 2006…

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A shortfall in disposal capacity in Germany, caused by a surplus of millions of tons of combustible waste, has led to untreated waste being baled and stored (above) at waste disposal sites, awaiting processing at a later date.

Source: Saft and Elsinga, 2006

UK RDF / SRF exports
2.4 Million tonnes in 2014

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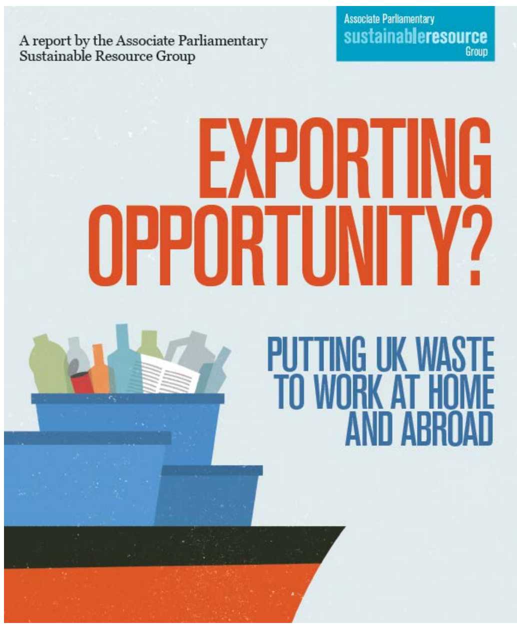

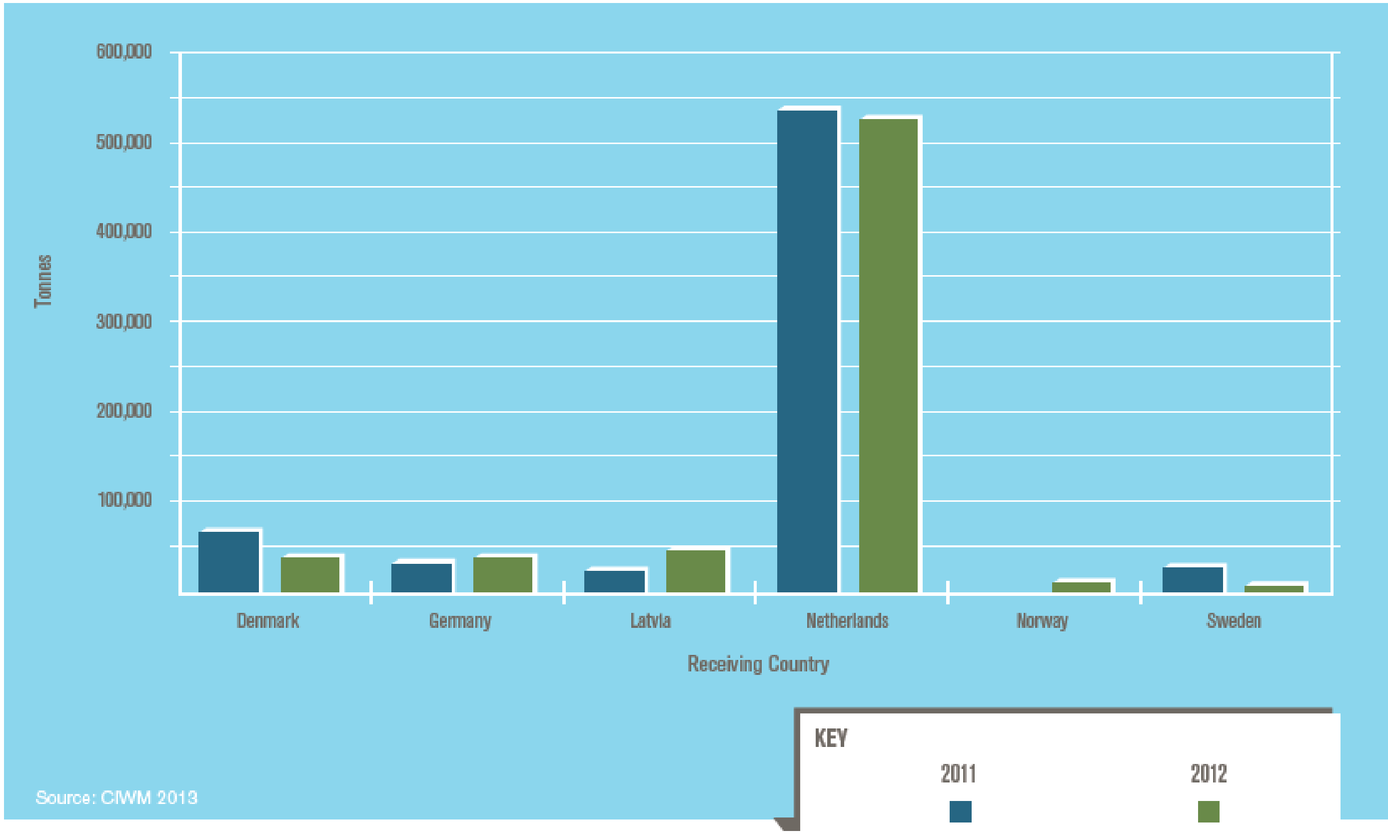

R1 EfW formula – sensitivity analysis and implications

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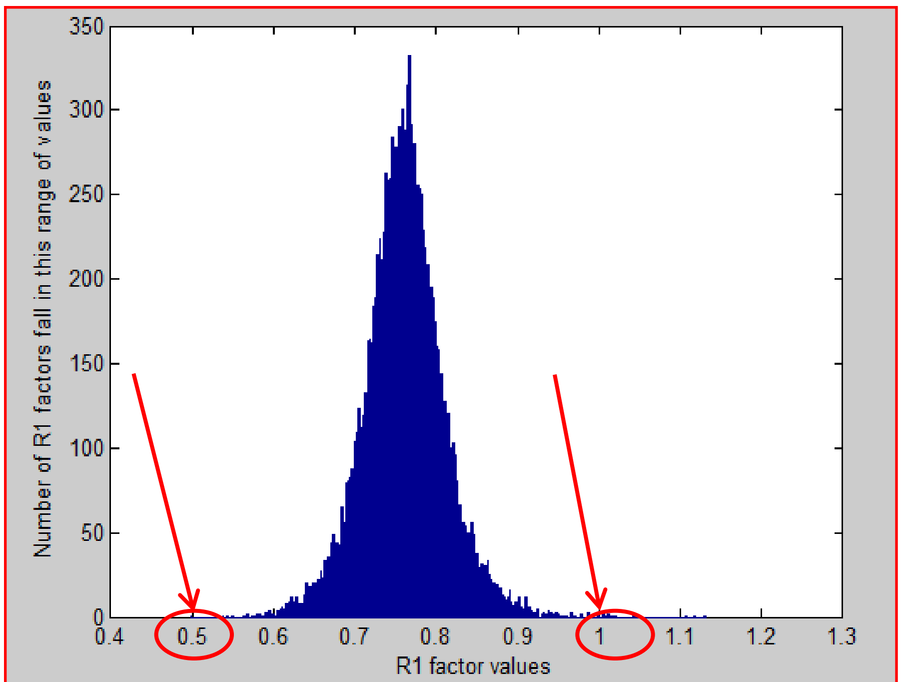
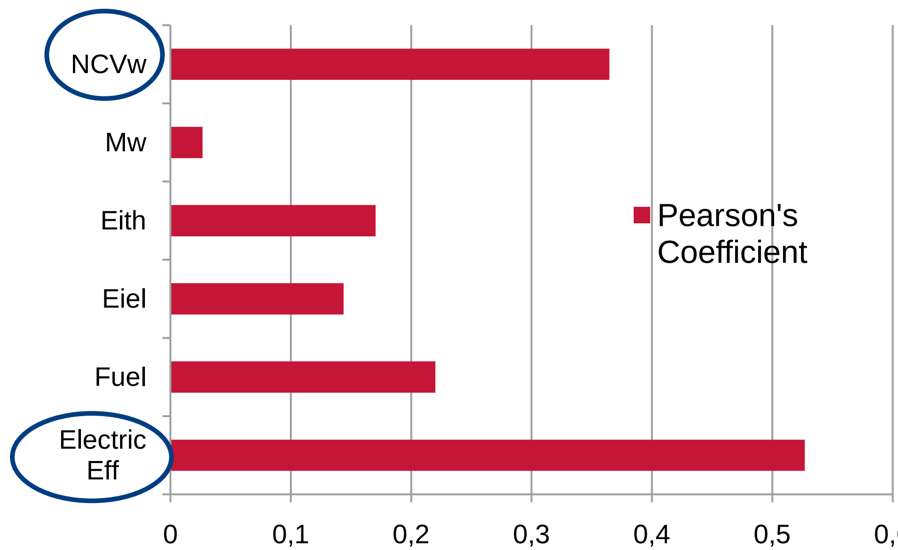
$$R1 = \frac{E_P - (E_f + E_i)}{0.97 * (E_w + E_f)}$$





Source: Chatzopoulou *et al.*, 2012

Trade-off electric vs. Thermal efficiency

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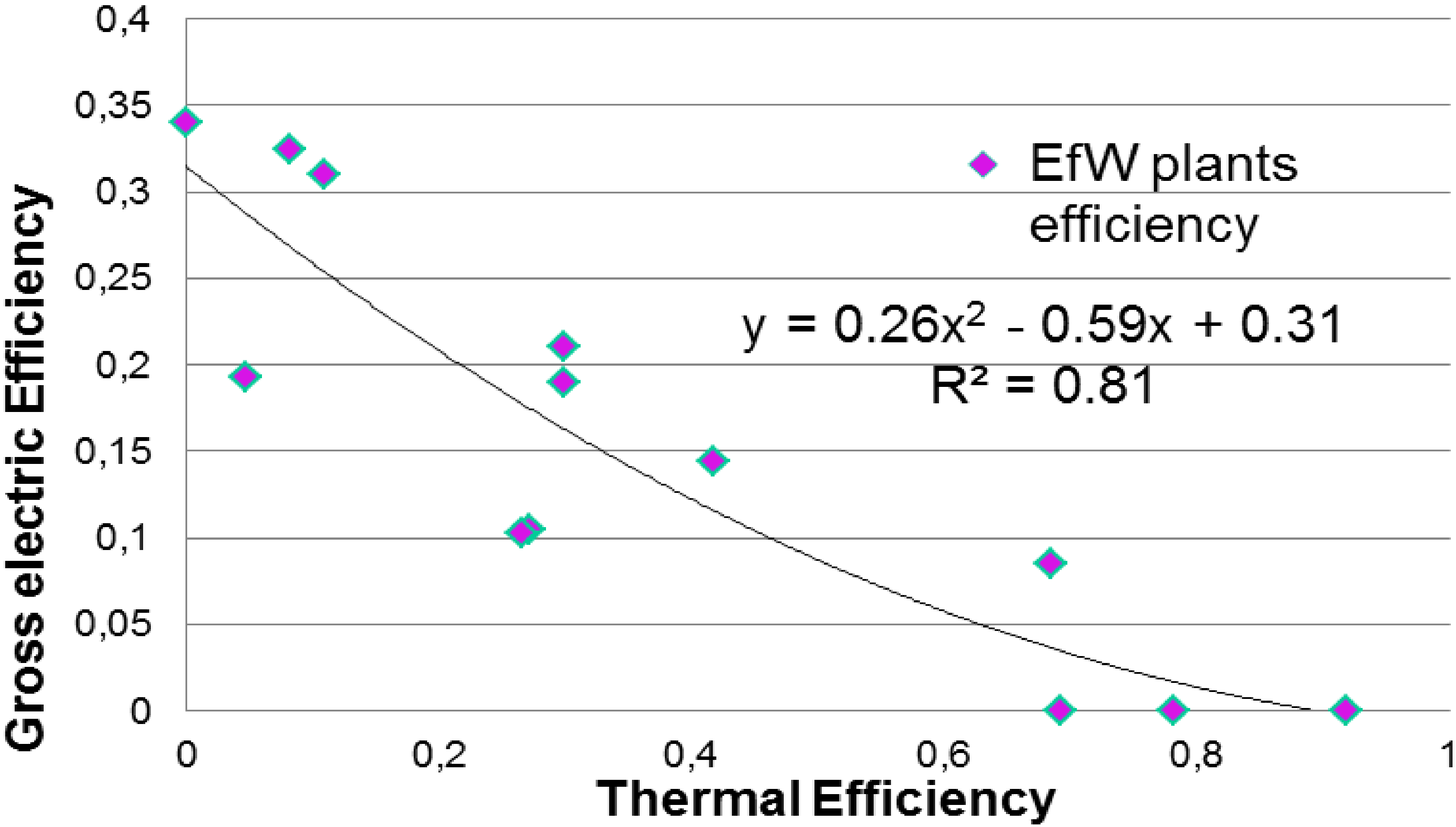

Refuse derived fuel (RDF) exports within Europe

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Which Vision For RDF?

Dr Costas Velis looks at the issue of RDF exports and asks which resource recovery vision we should be following…

The refuse derived fuels (RDF) exports rally started in 2010 and continues in full power, with latest predictions estimating some 2.4m tonnes of the material to be eventually exported in 2014 – 33 percent more than during the last year. To date, the debate in the UK largely revolves around the potential implications for new national waste infrastructure development, and the currently incurred losses financial or otherwise. But, little consideration can have been given to the essence of environmental and wider sustainability implications; and the importing countries' and wider European point of view.

Let's revisit the evidence: what happens is solely driven by direct financial forces. The UK waste industry/local authorities strive to find alternatives to the cost of £100 per tonne of landfill disposal, so the fiscal instrument works. Energy from waste (EfW) plants in Germany, The Netherlands, Sweden, Belgium, Norway and Denmark are capable of offering much more attractive gate fees (eg, at £40 per tonne of RDF; indicative baling costs are at €30 and transport cost at €40, but could be up to €80). Notably, this is considerably lower than the lowest current gate fees for EfW plants in the UK.

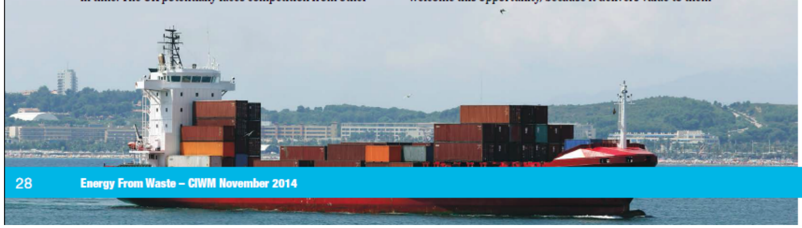
According to Profu (an independent energy, environment and waste management research and consultancy company in Sweden) these six countries have an estimated spare availability in their EfW plants at around 7.2m tonnes, which is anticipated to remain stable until 2020. However, this "overcapacity" is a tiny percentage (0.8 percent) of the entire non-hazardous waste quantity disposed of in landfills in the EU-28 (894m tonnes in 2012, according to the latest Eurostat data).

So, a key question relates to the intermediate-to-long-term dynamics of supply and demand. It is indeed doubtful whether these particularly low gate fees would persist in time. The UK potentially faces competition from other suppliers, but considering the geography and the distribution of residual waste in Europe's member states, the UK seems the obvious source for The Netherlands and Scandinavian countries, whereas Germany – featuring the bulk of the spare capacity – may have other viable alternatives. What if these 2.4m tonnes were used in UK EfW plants? This would boost the current capacity by a non-negligible 45 percent.

A main concern regards the material exported. The everyday term "RDF" in the UK denotes waste derived fuel of low quality. Instead, the term solid recovered fuel (SRF) is used for referring to a quality assured fuel that meets end-user specifications and, in particular, the relevant pan-European CEN TS/343 standards. The law allows export for only "recovery" purposes and not for "disposal". Indeed, exported material ships to R1 compliant EfW plants, demonstrating the "recovery" operation status, and often featuring combined heat and power (CHP); or to high electrical efficiency (such as the Amsterdam plant, at approximately 32 percent, the highest in the world); or to state-of-the-art, newly commissioned installations and operated at very strict emission control standards, often stricter than those applying in the UK (eg, Germany).

Given that, rather embarrassingly, CHP plants are still unusual in the UK, from an energy/resource recovery point of view, there can be little persuasive argument against the shipment: it is utilised in a more efficient way. Considering carbon emissions, life cycle assessment studies have consistently demonstrated that, despite the transport, when fossil fuels are replaced substantial savings materialise through EfW plants (eg, an average level of 600kg CO_2 equivalent per tonne of waste) stemming from the biogenic part of the material.

Indeed, the importing organisations and countries welcome this opportunity, because it delivers value to them by supporting their extensive EfW-fuelled district heating systems and contributing to their energy security in turbulent times. So, if we believe in resource and recovery and overall sustainability on a planetary scale – on energy efficiency, security and global warming potential mitigation grounds – there are clear benefits from RDF exports, at least given the realities with the UK waste infrastructure.



Of course, the UK does not gain these benefits, but at least its neighbouring nations do. The loss of some £100m paid in gate fees last year, as quoted by AMEC, is a financial resource that could have remained within the UK. To put this into perspective, it is just a fraction of modern EfW plants that use economies of scale to optimise energy recovery. While the waste processing capacity debate in the UK goes on, with many estimates available, a key fact is that the potential to deploy an equivalent capacity in the UK is negatively affected by the RDF exports. Defra's recent withdrawal of the private finance initiative (PFI) credits for the Hatfield facility comes in the long line of Merseyside, North Yorkshire County Council, Bradford and Calderdale and Norfolk County Council. The argument of meeting the 2020 Landfill Directive targets, and the established anti-EfW mentality of environmental NGOs, is biting the much-needed sustainable and efficient, new, highly performing infrastructure.

So, are the RDF exports fundamentally enabled by the lack of political support for EfW in the UK, possibly due to a long-standing legacy of misunderstandings about its sustainability and the value delivered? With respect to public and political acceptability, we lag behind the most environmentally friendly Scandinavian nations when approaching EfW.

The Best Way Forward?

WHAT IS the best way forward? Is governmental intervention needed and in what direction?

Some would argue that meeting the 2020 target is good enough: we can sit back and relax. Others, in the face of the EU-proposed 70 percent recycling rate, and the ban on disposing of recyclable materials, could also argue that we need not worry: in the long-term, thermal recovery will decline anyway. It is ultimately down to the resource recovery vision we shape for our society. Notably, the move towards a circular economy needs to be a green one, namely to build upon all of our environmental protection achievements.[1]

To this end, we do need well-designed and operated thermal processing, and this industrial activity, being the most strictly regulated regarding emissions, helps us mitigate pollution dispersion and clean our material cycles from the chemistry mistakes of the past. The 70 percent EU recycling target, whether it will be set or not, clearly does not take into account the technically feasible, and genuinely sustainable value delivered by collection for recycling. A series of recent landmark reports by the Globalisation and Waste Management Task Force of ISWA, remind us about the environmental and other complexities of the globalised waste trade.[2] When the 40 percent by weight of all waste plastics currently collected for recycling in the EU-27 are exported to China, directly or via Hong Kong, the anticipated environmental benefits may materialise, either fully or even in part.

An alternative would have been to use mechanical biological treatment plants (MBTs) to process residual waste into high quality, de-polluted and fit for purpose SRF. The SRF outlet scenario has many important advantages, potentially offering an advanced management of material flows, where the non-recyclable combustible fractions can be recovered thermally, while we minimise the dispersion of potentially toxic elements by concentration in air pollution control residues, and destroy undesirable persistent organic pollutants.[3]

However, the UK does not currently seem capable (or willing) to absorb even small quantities of SRF: it exports it to cement kilns in Latvia. Mind you, SRF and RDF stand miles apart: while we do need standards, and maybe voluntary agreements for SRF (to this end, the WARP document was a good, but not trouble-free start), there is no reason to do the same for RDF. EfW plants are robust in accepting a wide range of unprocessed mixed or residual waste... RDF is by default suitable.

Instead of standards, the Environment Agency needs to be further assisted in its great efforts to combat waste crime. And the operators new to the market need to demonstrate their processing capacity, especially with respect to suitably preparing RDF for intermediate storage – the biodegradability standards for SRF storage there may be of help. Otherwise we may just be opening a can of worms.

RDF exports may not be here for ever. In any case, we have happily been exporting millions of tonnes of dry recyclates to the south East Asia from the UK and Europe... RDF exports offer a chance to candidly reflect upon the resource recovery vision we aspire to, both in the UK and beyond. ■

References

1. http://wmr.sagepub.com/content/31/6/539.short
2. http://www.iswa.org/iswa/iswa-groups/task-forces
3. http://wmr.sagepub.com/content/31/2/113.short

The Author

Dr Costas Velis is a Chartered Waste Manager and lecturer in resource efficiency systems at the University of Leeds. He is associate editor of the academic journal *Waste Management & Research* and is involved in a series of prestigious initiatives aimed at comprehending our globalised waste and resource management systems, including the UNEP Global Waste Management Outlook and the ISWA Globalisation and Waste Management Task Force. He also chairs the Waste Atlas Scientific Committee.

Plastics recyclability - global value chains

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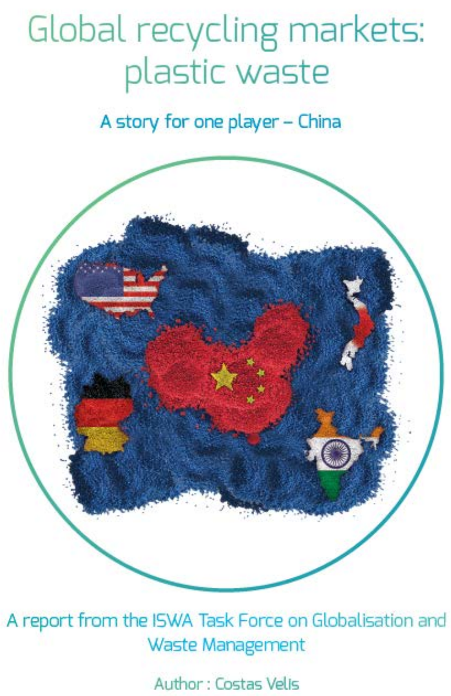

ISWA
International Solid Waste Association

Download from:
http://www.iswa.org/iswa/iswa-groups/task-forces/

Geographical alignment of sustainability?

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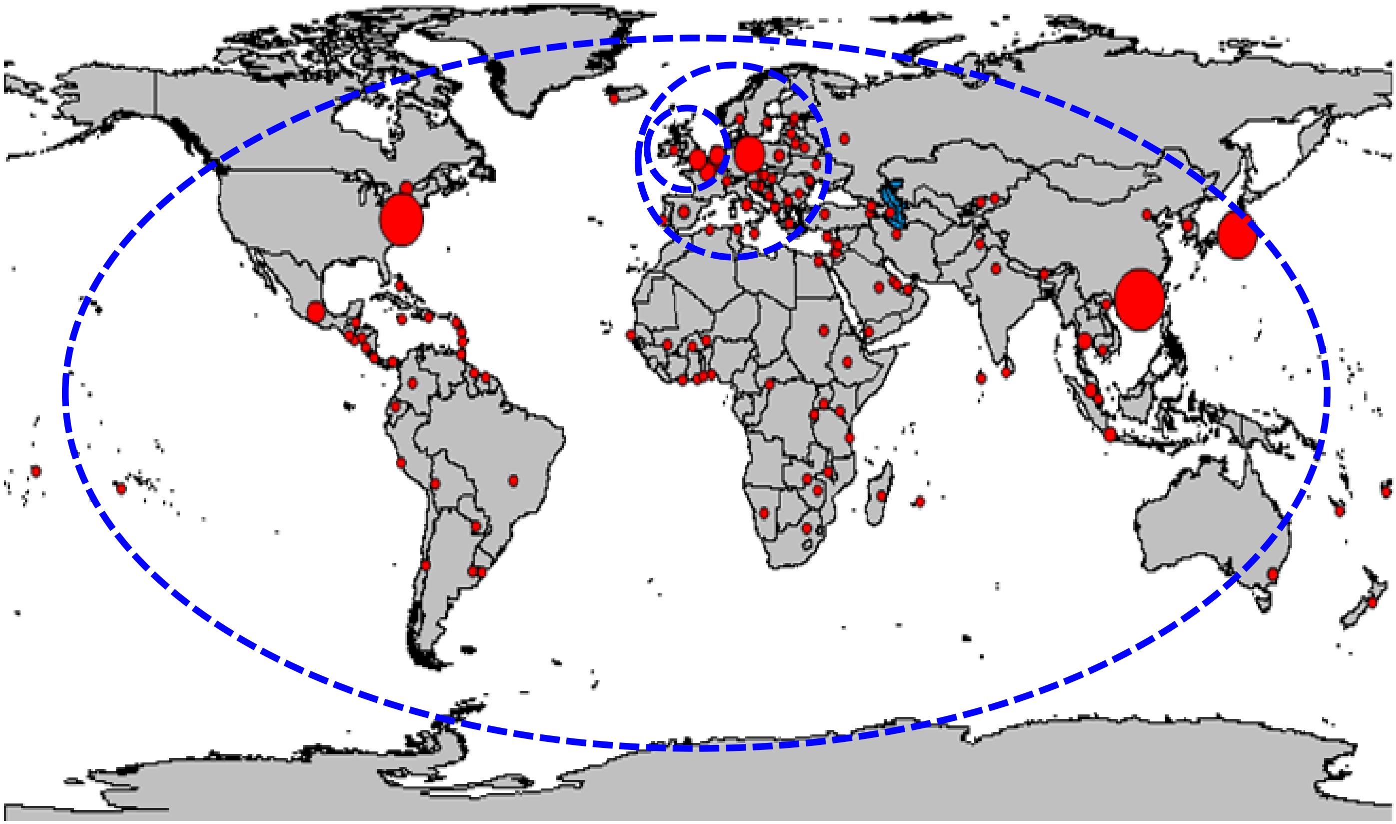

Code 3915: "waste, pairings and scraps of plastics"

Data source:
UN Comtrade - 2011

A complex and volatile market

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Global map of import transactions in waste plastic – 2011: China rules!

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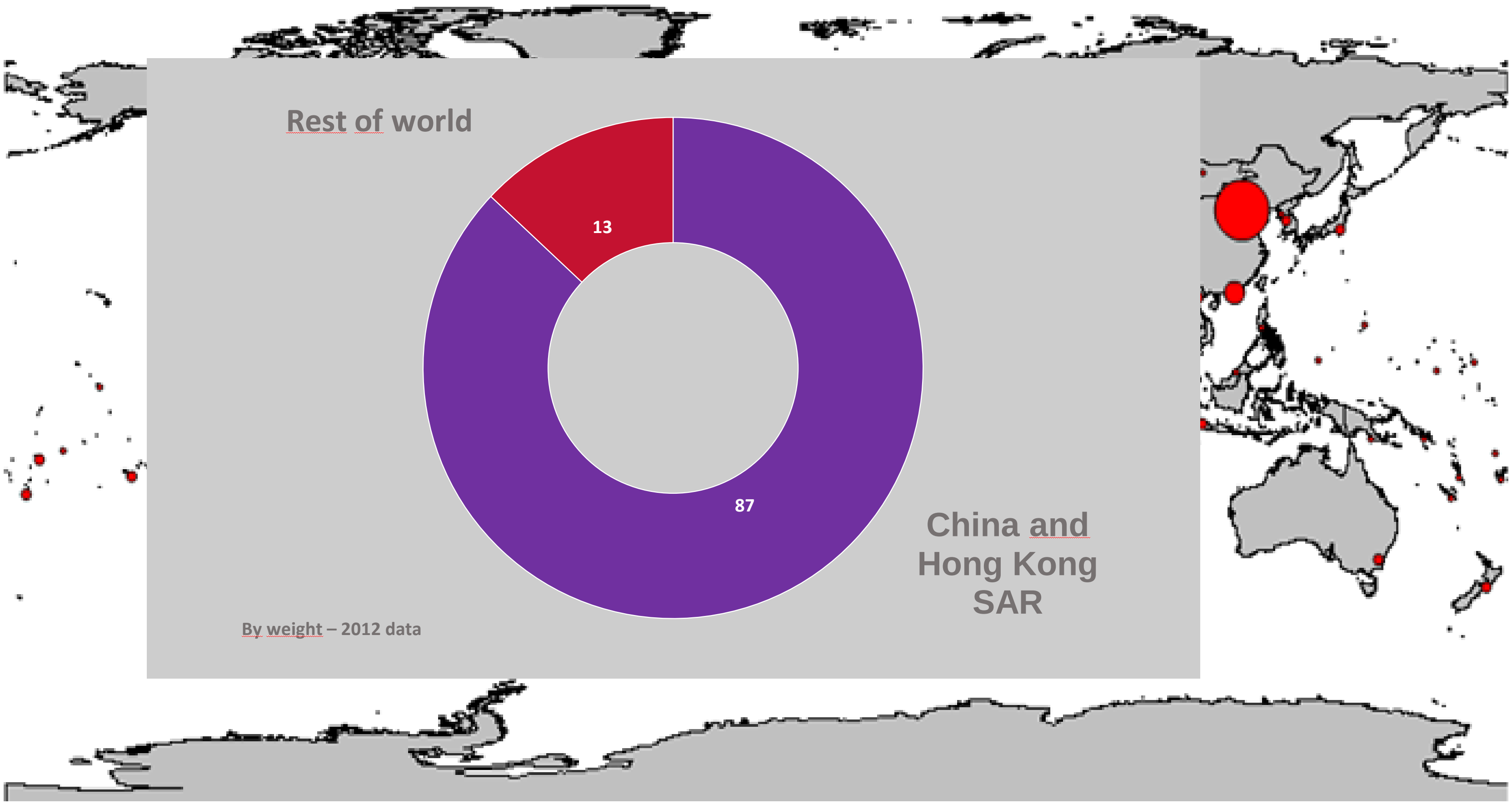

Documentary on reprocessing plastic scrap imports “Deadly waste in China”

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See at 2DF:http://www.zdf.de/ZDFmediathek#/beitrag/video/1993090/Die-Doku:-Tödlicher-Müll-in-China

MBT: mechanical-biological treatment

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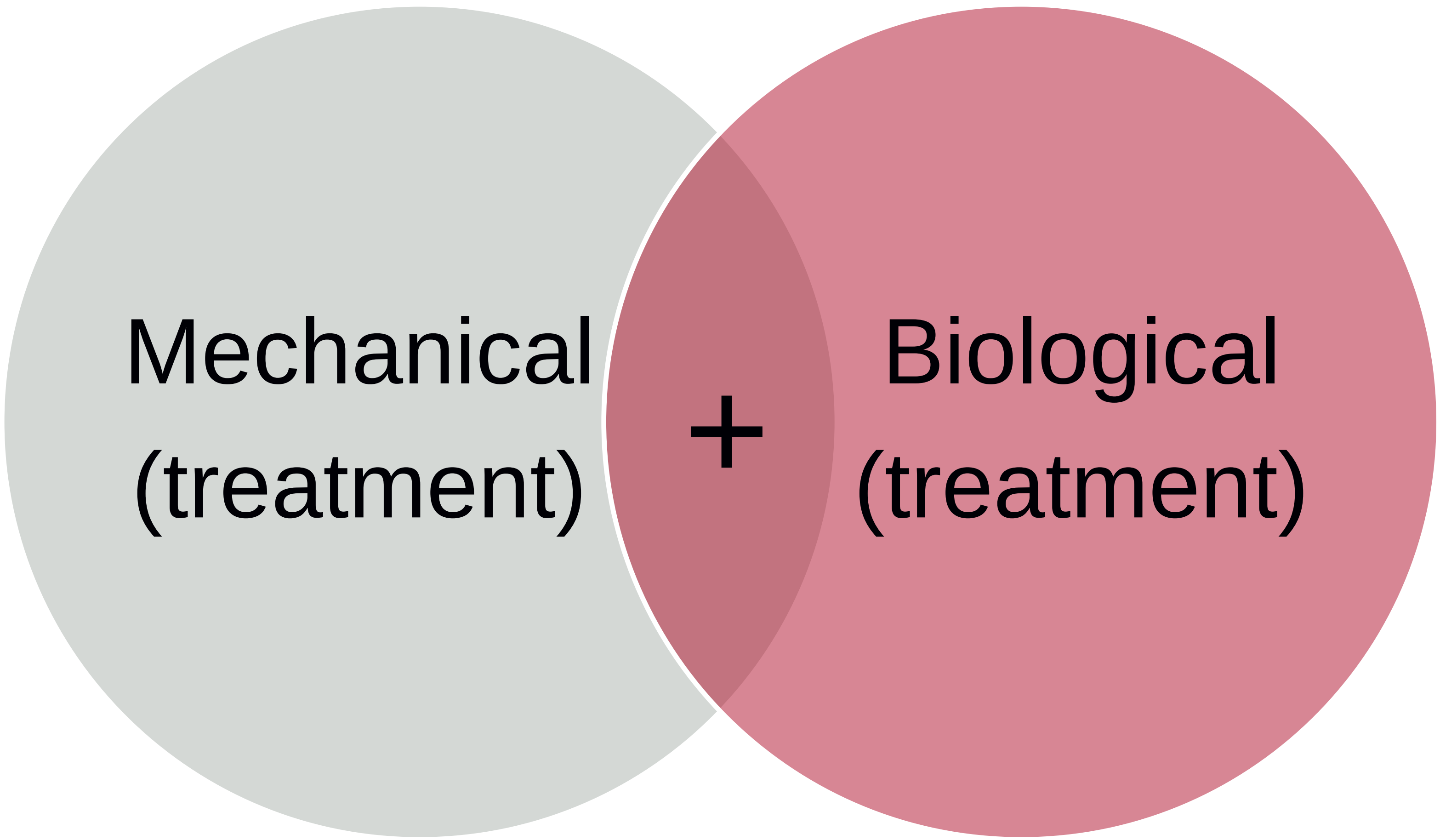

Solid recovered fuels (SRF) via Mechanical-biological treatment (MBT)

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SRF as used in a UK cement UK industry
Source: letsrecycle.com
http://www.letsrecycle.com/news/latest-news/waste-management/shanks-in-second-castle-cement-fuel-deal

A finely shredded fluffy SRF, in storage production pit
Source: Nottinghamshire Recycling Ltd.
http://www.nottsrecycling.co.uk/information/11/solid+recovered+fuel+(srf)/

Stabilat® SRF: production from different inputs to different 3D and type specs
Source: Herhof GmbH
http://www.herhof.com/en/business-divisions/stabilat/rdf-production-with-stabilat.html

Example of plastic film fluff-type SRF
Source: MID UK Recycling Ltd.
http://www.midukrecycling.co.uk/energy-from-waste/rdf-srf.aspx

Example of fluff-type SRF
Source: ERFO
http://www.erfo.info/

MBT-derived (bio-drying) SRF in the UK, mainly for cement kilns
Source: Shanks
http://www.shanks.co.uk/corporate-services/local-authority/srf-and-fuels

Solid recovered fuel according to CEN TC/343

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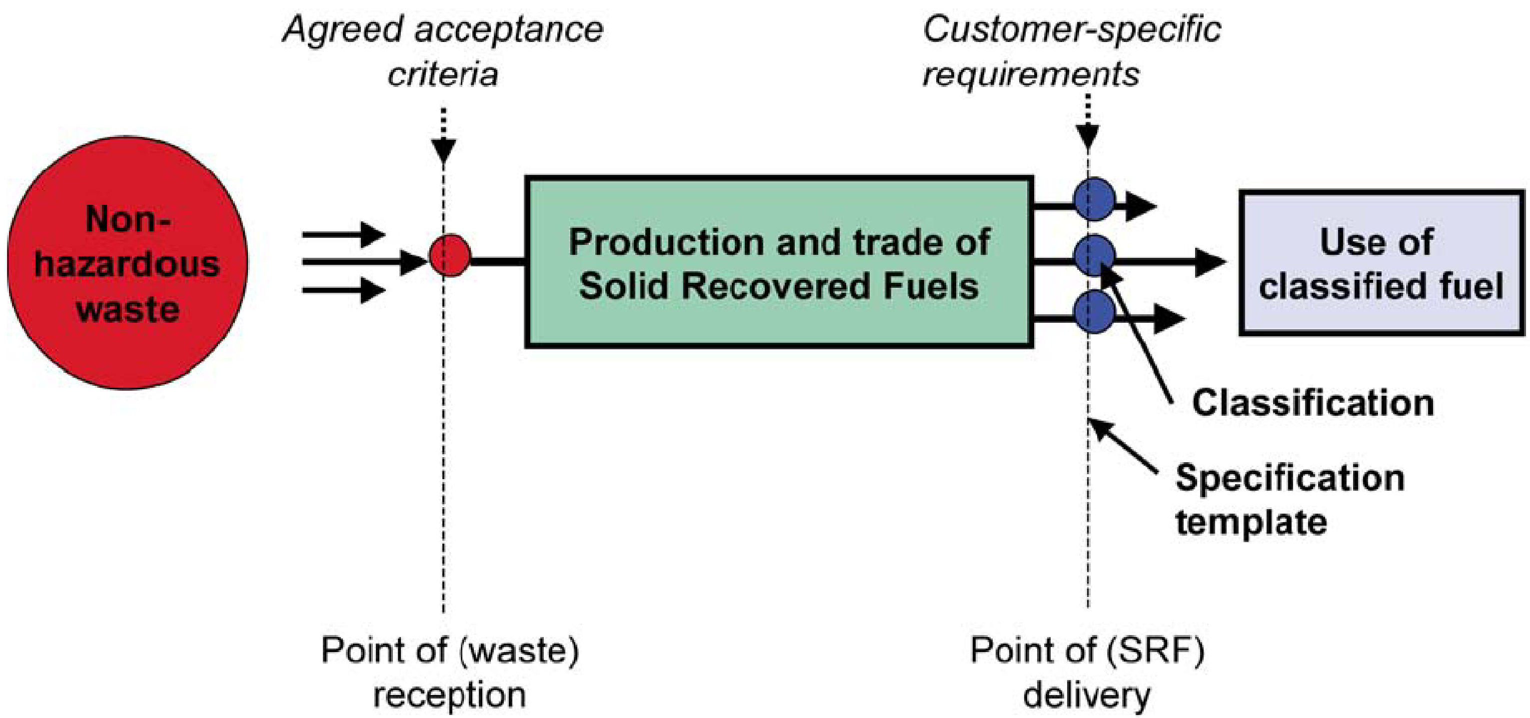
"*solid fuel prepared from non-hazardous waste to be utilised for energy recovery in incineration and co-incineration plants and meeting the classification and specification requirements laid down in CEN/TS 13359*"

ERFO: "**prepared**" means: processed, homogenised and up-graded to a quality that can be traded amongst producers and users



CEN SRF classification system

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Property category	Classification property	Desig-nation	Unit	Statistical measure[1]	Classes				
					1	2	3	4	5
Economy	Net calorific value[2] (NCV)	$Q_{p,net}$	MJ/kg (ar)	Mean	≥25	≥20	≥15	≥10	≥3
					1	2	3	4	5
Technology	Chlorine	Cl	% w/w (d)	Mean	≤0.2	≤0.6	≤1.0	≤1.5	≤3.0
					1	2	3	4	5
Environment	Mercury	Hg	mg/MJ (ar)	Median[3]	≤0.02	≤0.03	≤0.08	≤0.15	≤0.5
				80th percentile[3]	≤0.04	≤0.06	≤0.16	≤0.30	≤1.0

1 Specified sampling, sample preparation, analytical methods and statistical analysis apply. For Hg specific rules apply, according to number of assays taken.
2 NVC is the same as lower heating value (LHV): H_u.
3 The higher classification stemming from each of the two statistics controls the class.
Reference: CEN/TC 15359:2006 Solid recovered fuels – specifications and classes. European Committee for Standardisation. See:
http://www.erfo.info/CEN_TC_343.18.0.html

Cl flows to SRF in mechanical biological treatment plants (MBT)

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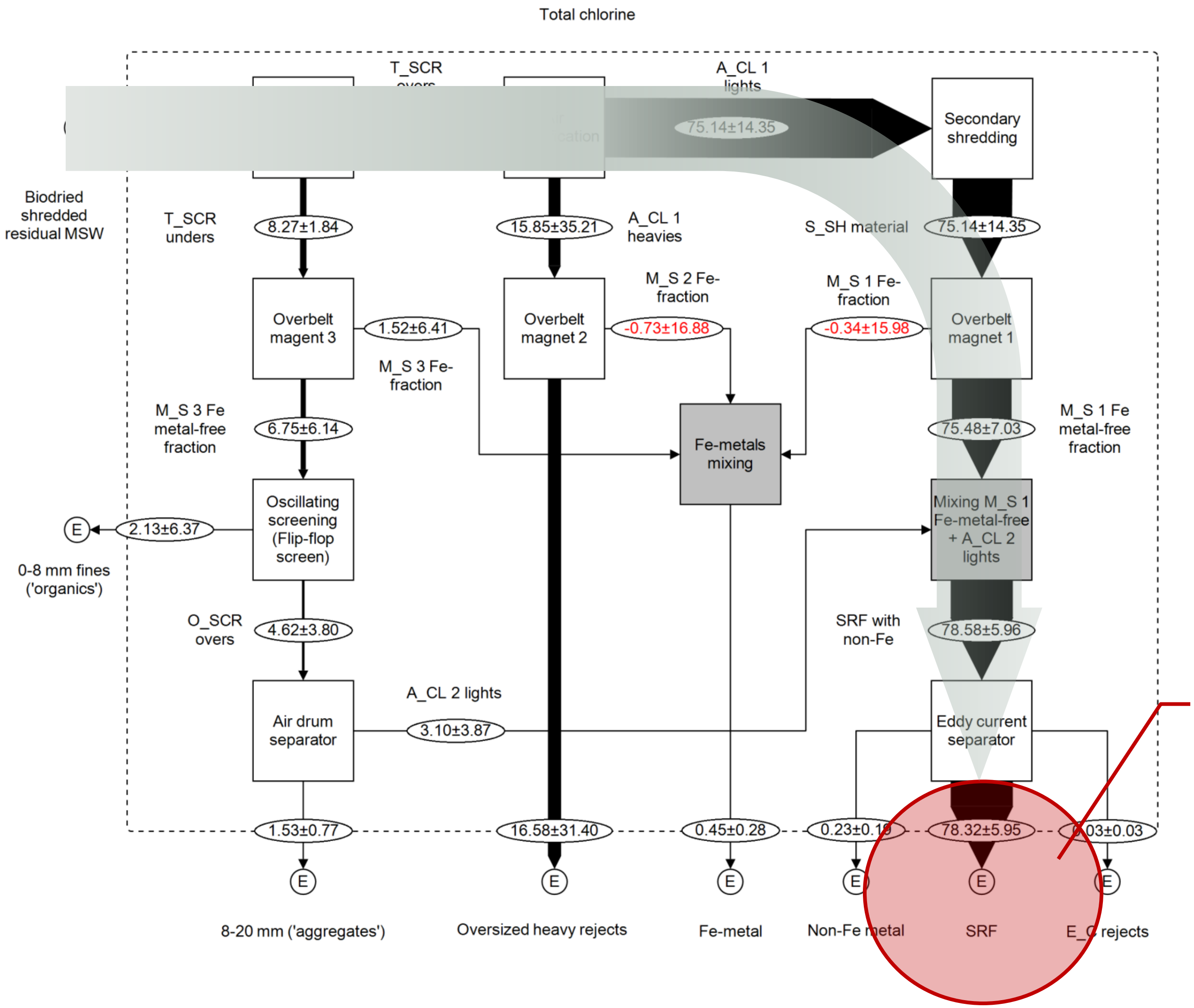

78% wt. of Cl is incorporated into the fuel output (SRF)

Biodried combustible MSW: key fuel properties

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Fuel property	Units	Biodried residual MSW	Biodried residual MSW - combustible part: Mean*	Biodried residual MSW - combustible part: $\pm U_{95,4}$	SRF desired quality	Ratio Com/SRF specs (%)
Moisture content	% w/w_d	13.4	14.4	4.6	< 15	96
Ash content	% w/w_d	44.4	28	8	< 15	188
Biogenic content ('pure')	% w/w_d	39	51	16	> 50	102
Net calorific value	MJ kg_{ar}^{-1}	14.8	15.0	2.3	20 ± 2	75
Total chlorine content	$[Cl]_{\_COM,d}$	0.47	0.61	0.42	< 0.9	68

*Arithmetic mean; Total extended uncertainty: 95% confidence limits, based on t-student distribution, at 4 degrees of freedom (d.f.).

Comparison of 3 "ideal" scenarios for SRF composition from biodried MSW

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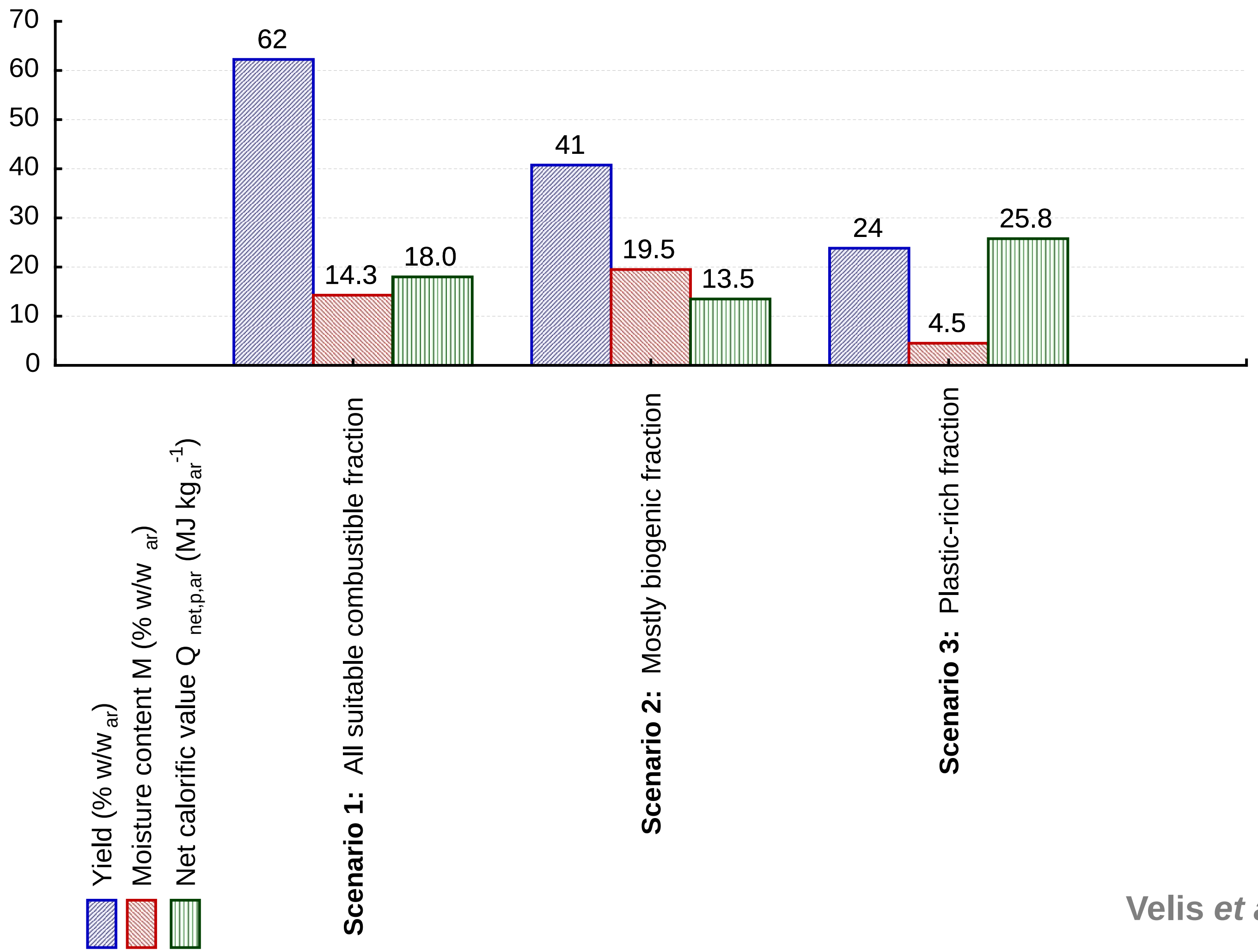

Velis *et al.*, ORBIT 2012

How much actually combustible matter is recovered in SRF?

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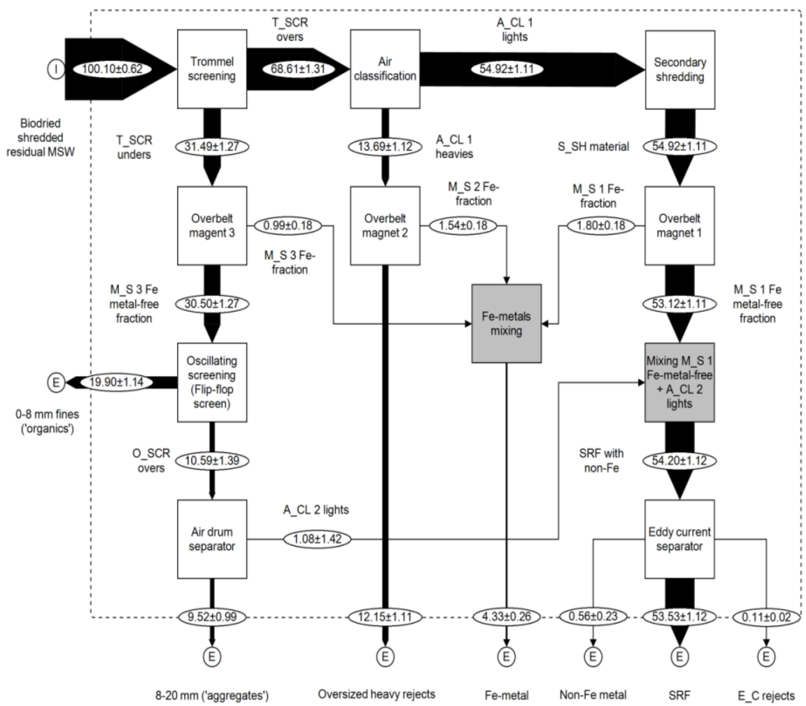
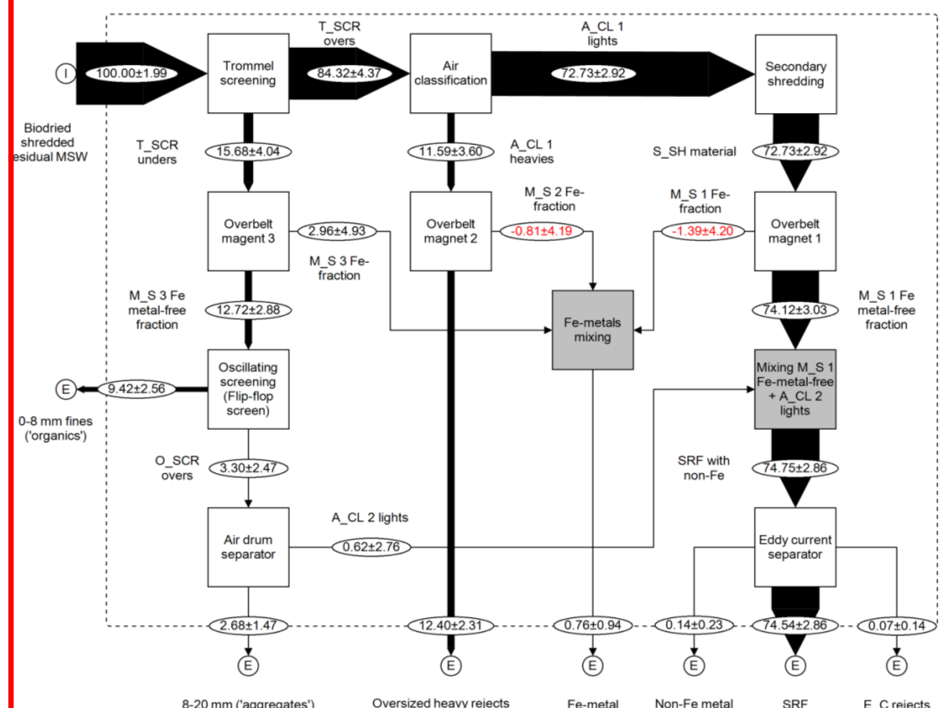
$TC(m_{comb,ar})$_SRF = 74.5±3.2%

Total mass (ar)



Combustible, ash-free mass (d)



Probabilistic modelling of Br in SRF co-combustion scenarios

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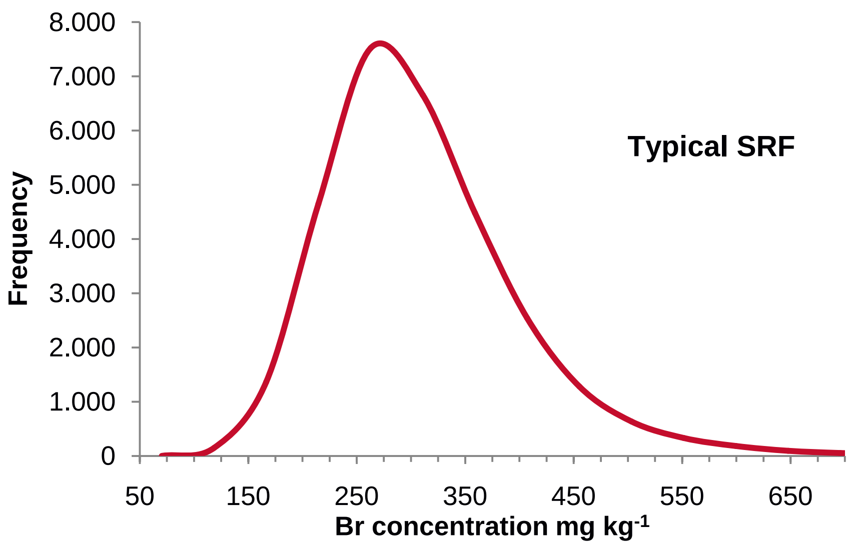

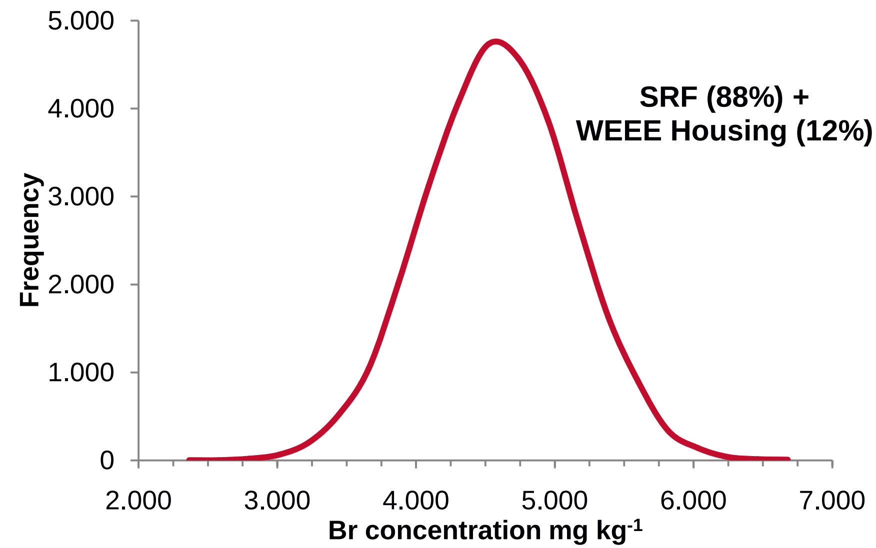

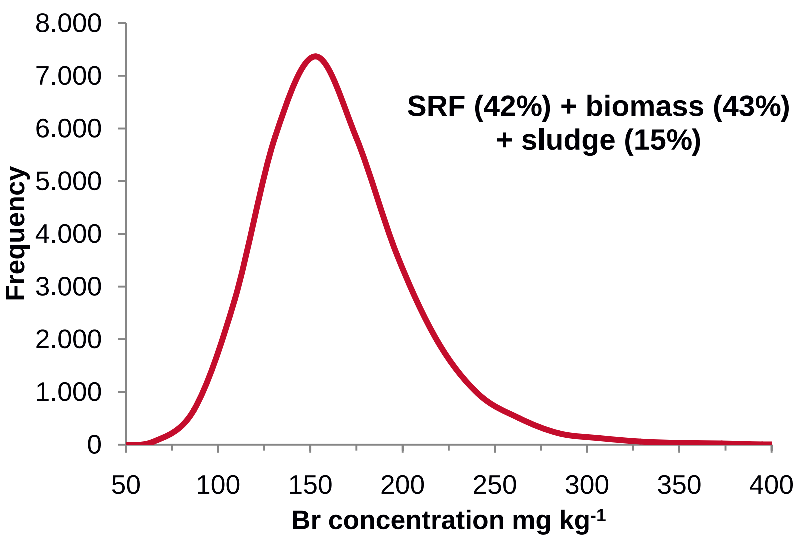

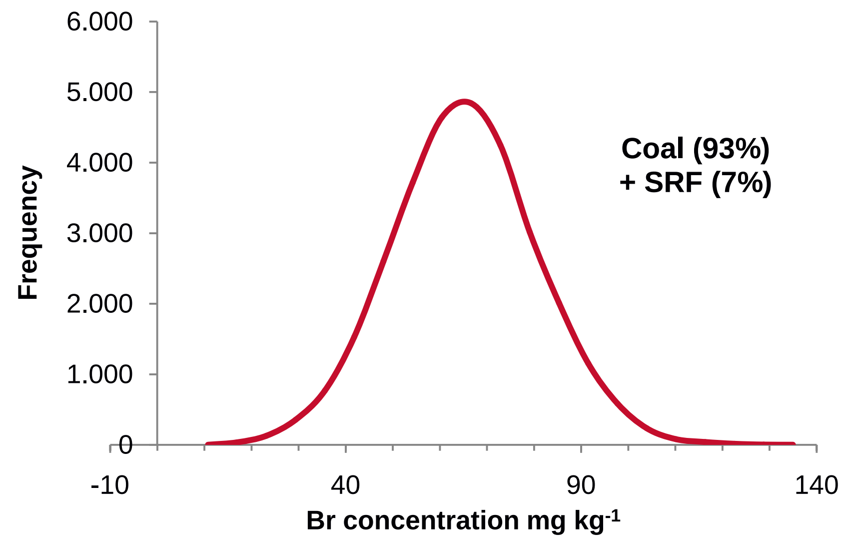

Utilisation (recovery) – According to WDF (Italy declared EoW for SRF, but…)

To achieve **'end of waste status,' criteria** for the following conditions defined by the WFD must be satisfied:

1. The **substance or object is commonly used** for specific purposes
2. A **market or demand exists** for such a substance or object
3. The substance or object **fulfils the technical requirements for the specific purposes** and meets the existing legislation and standards applicable to products;
4. Use of the substance or object will not lead to overall adverse **environmental or human health impacts**

SRF prices over time

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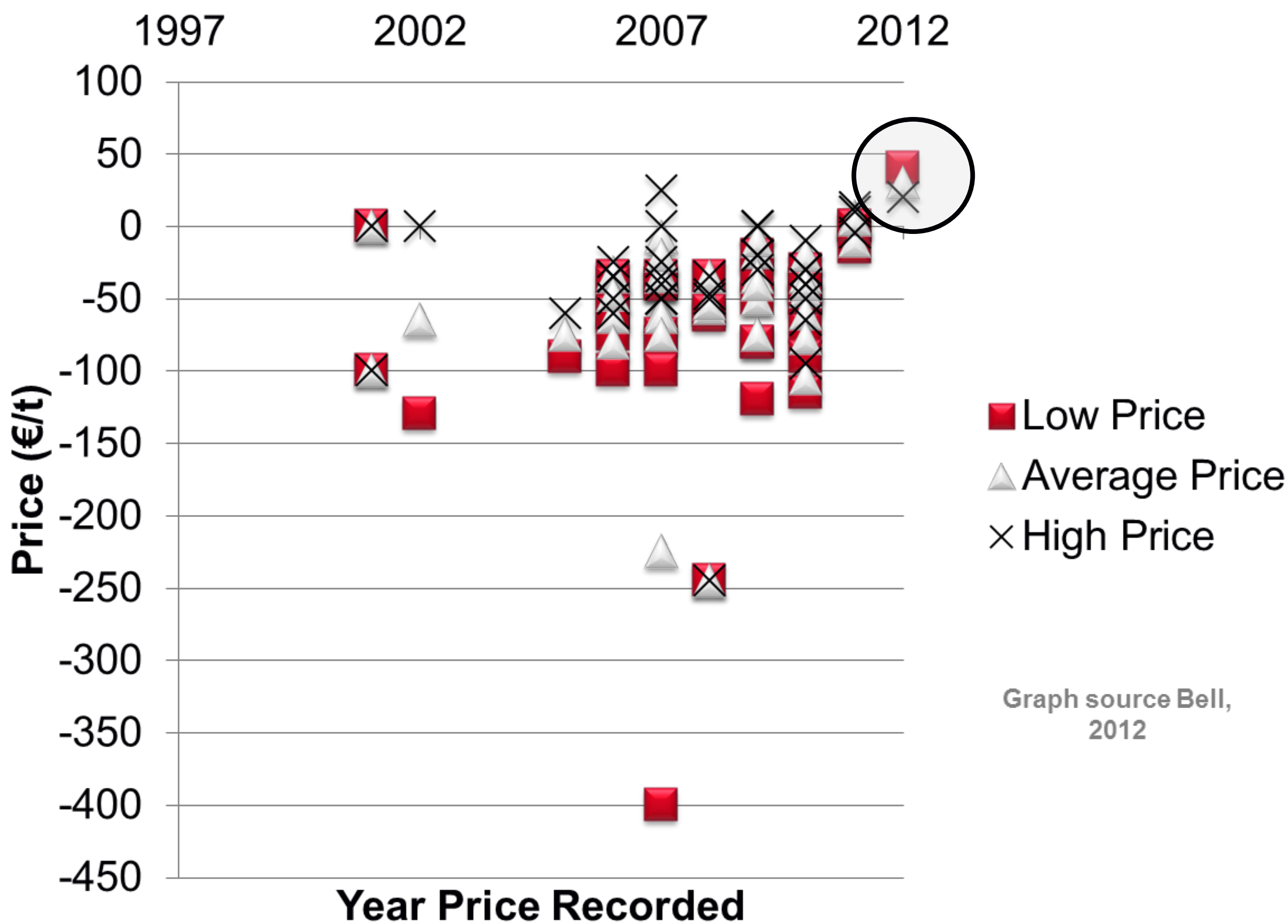

Graph source Bell, 2012

Circular + green economy?
Any dilemas?

Benefit for whom?
The Paracommons…

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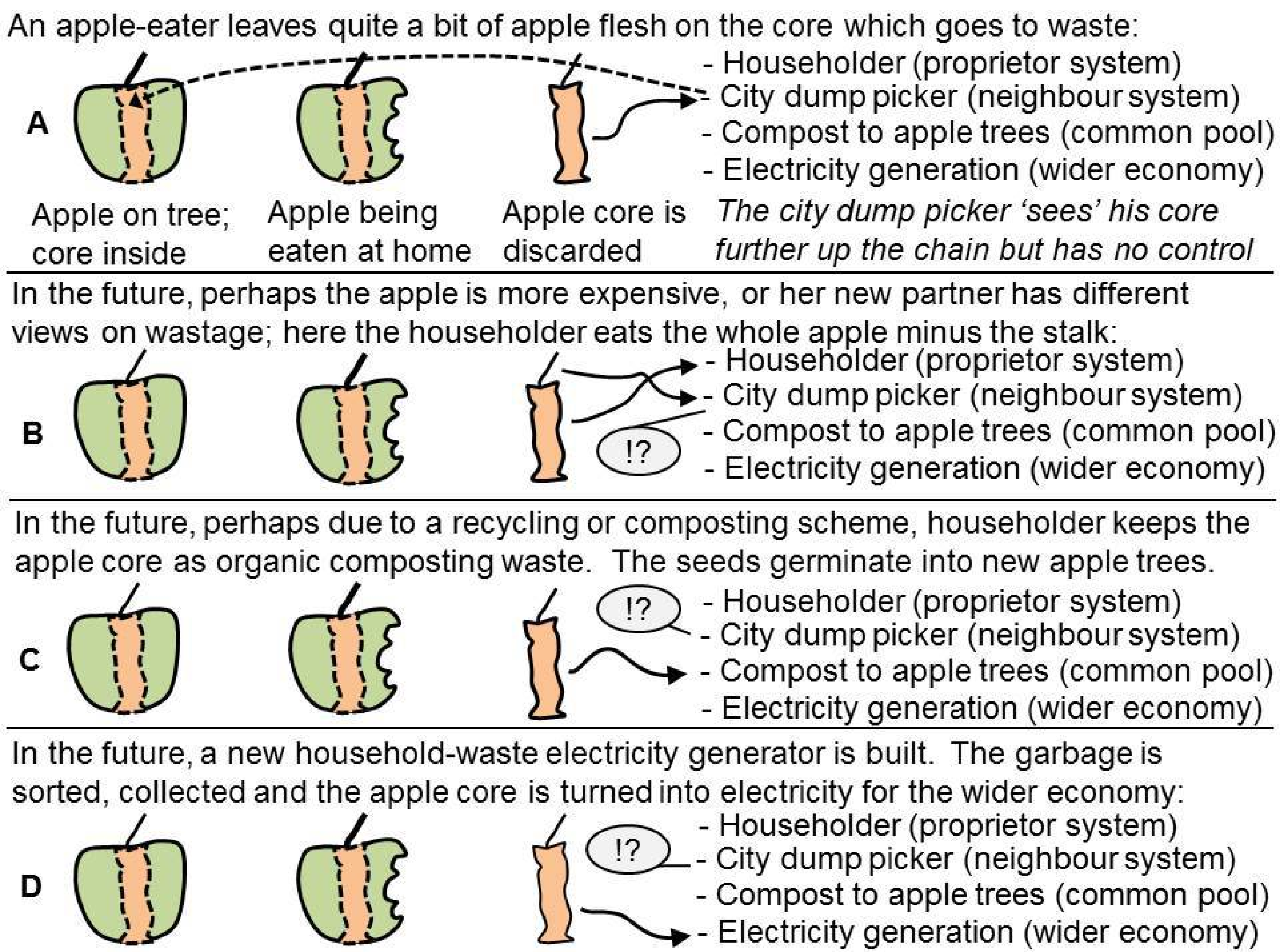

Source: [Bruce Lankford](http://brucelankford.org.uk/research/paracommons/) http://brucelankford.org.uk/research/paracommons/

Is waste hierarchy and our overall evaluation tools insufficient?

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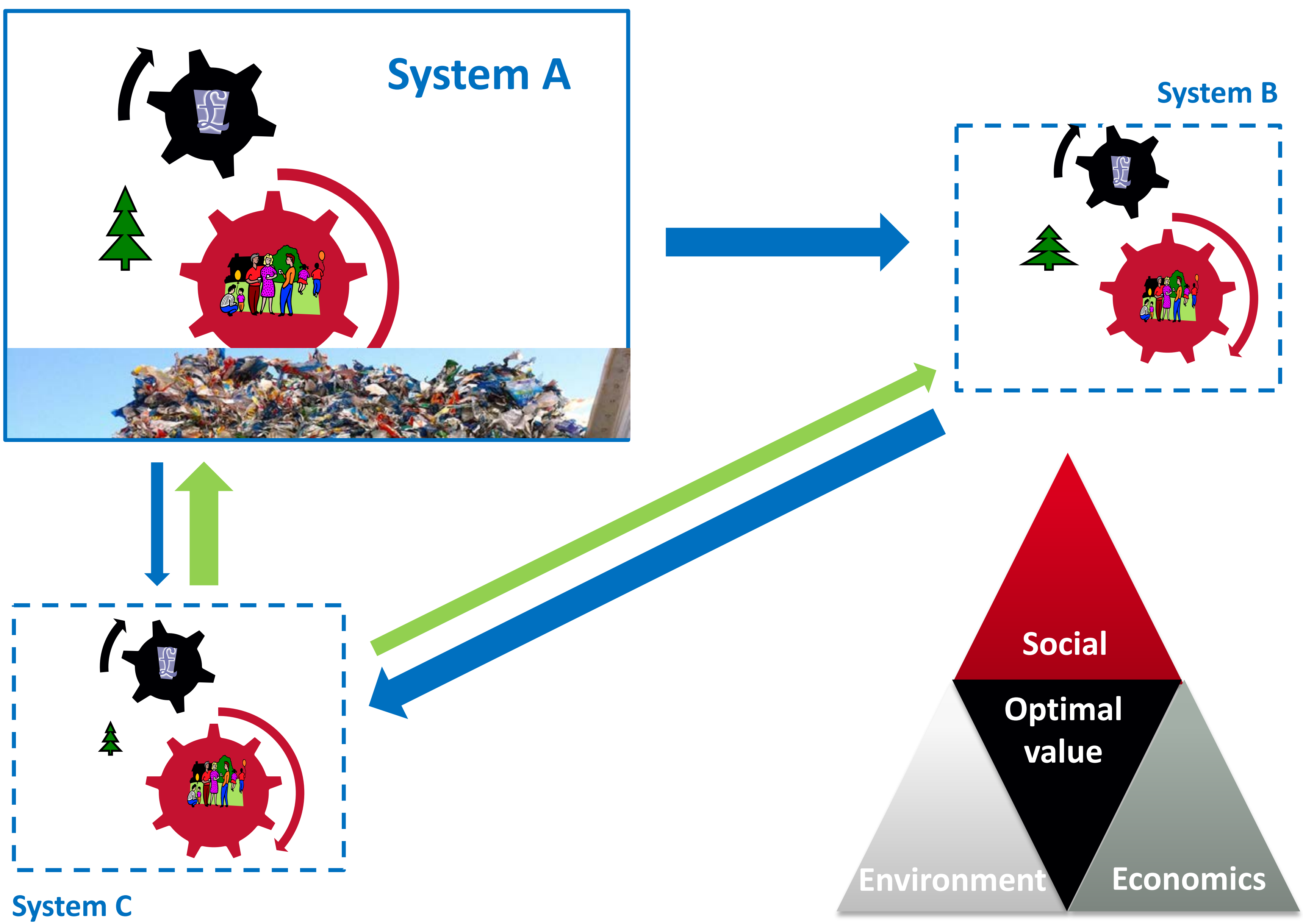
System A
System B
System C
Social
Optimal
value
Environment
Economics

C-VORR: multiple-value dimensions systems and concurrent approach

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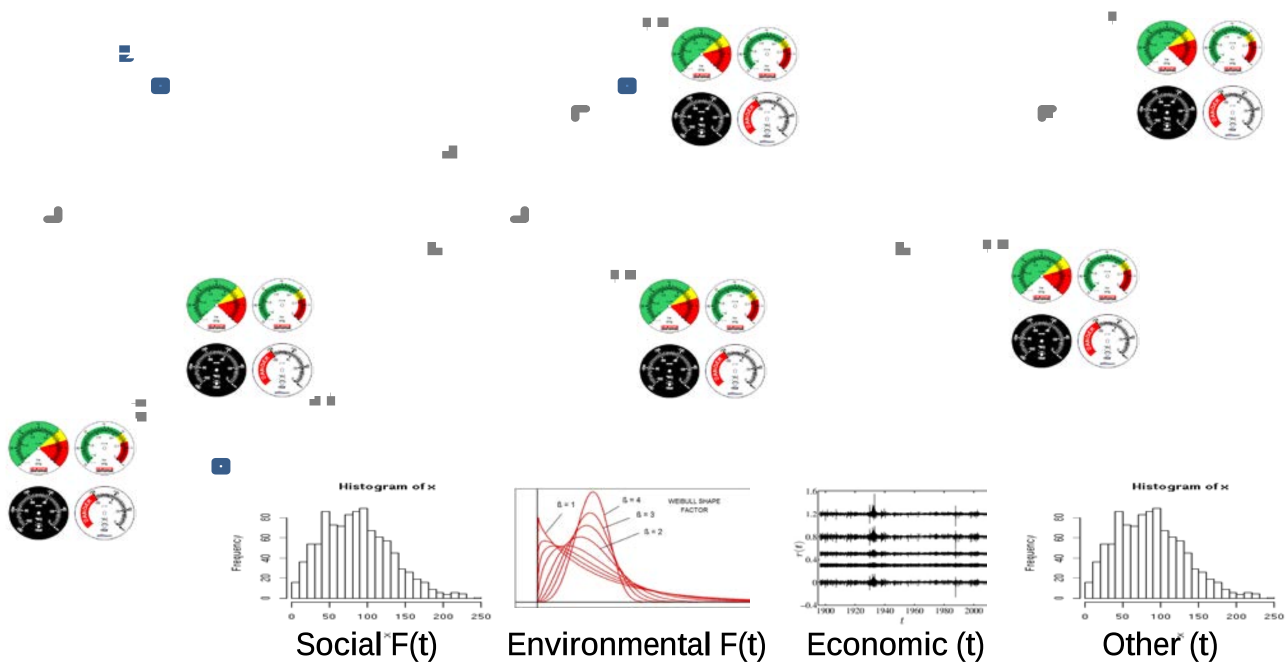

defra Department for Environment Food and Rural Affairs

NERC SCIENCE OF THE ENVIRONMENT

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

Complex Value Optimisation for Resource Recovery : not an abstract intellectual exercise…

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C-VORR is not an abstract intellectual exercise

- Co-created with industry partners
- Systems thinking critical to achieving real sustainability goals in the waste industry
- >£1M of industrial support
- Internationally leading academic partners on LCA and MFA

CVORR: enabling an evidence-based transition to resource recovery – circular economy!!

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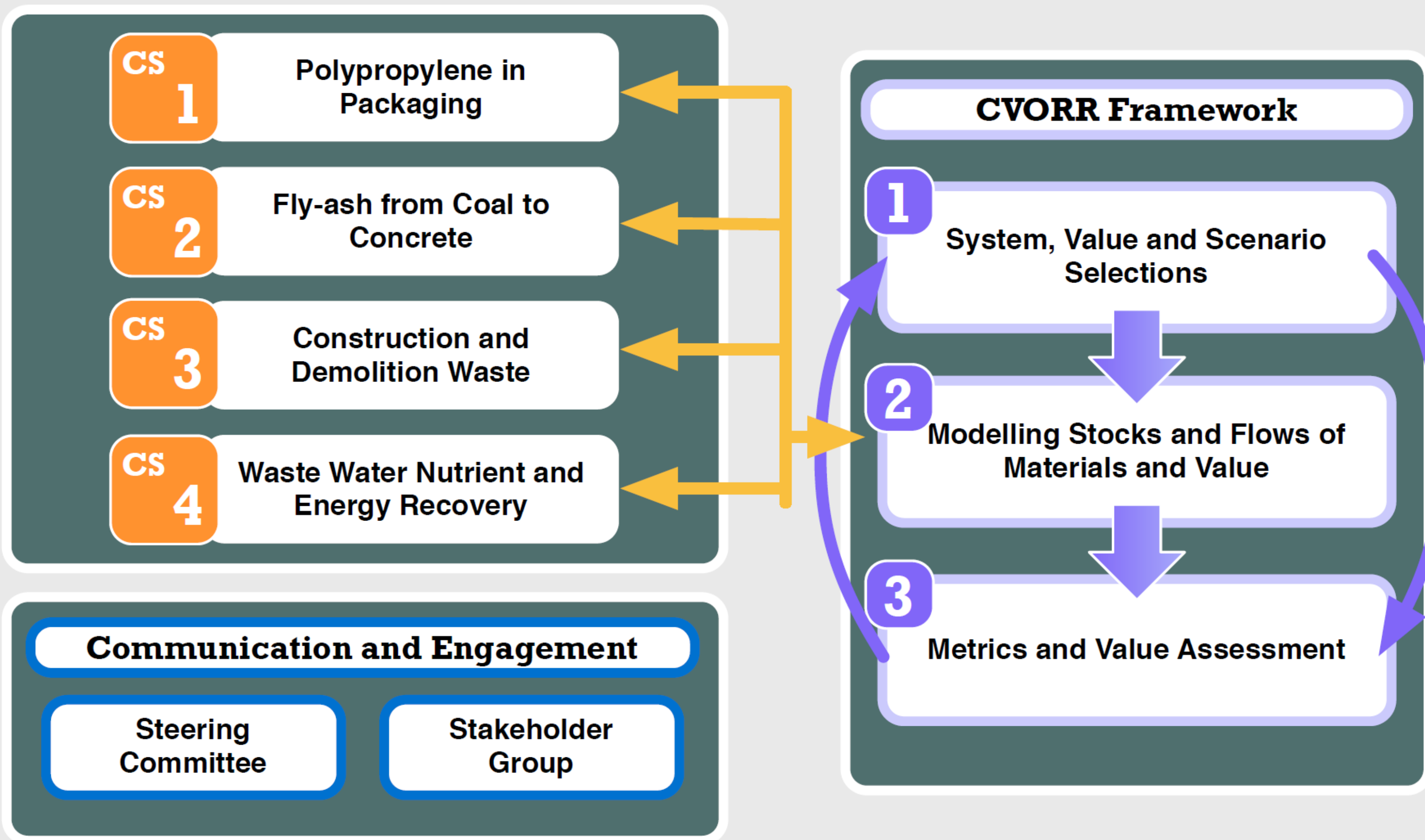

1st overall account of waste management around the world

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Global Waste Management Outlook (GWMO)

Authoritative, analytical, evidence-based, concise and visual: To be published by September 2015

UNEP

ISWA
International Solid Waste Association

International co-operation for sound waste management – cost of inacton?

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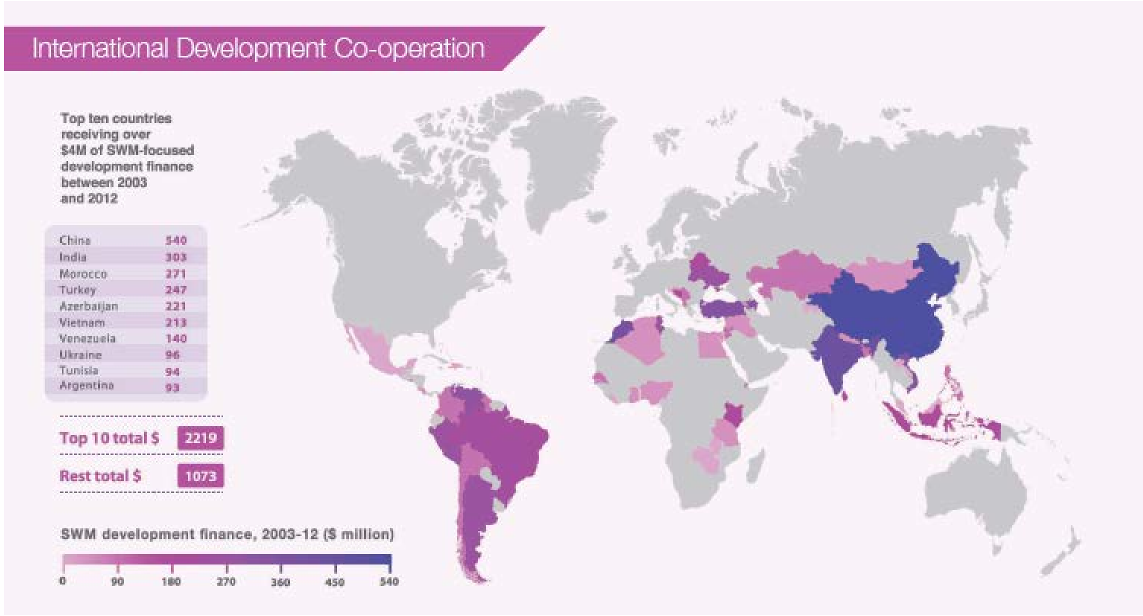

Ευχαροτω πολυ!!

Thank you for your attention!

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