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Redefining our relationship with waste: is the **waste management hierarchy** an **outdated concept?**

Costas Velis

APSE environmental services seminar 2013:

The Green Stuff

Daventry – 6-7 November 2013

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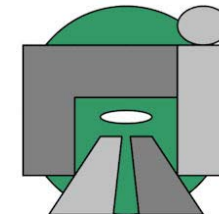


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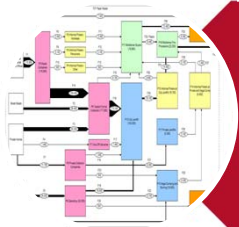


- **“If you cannot measure it, you cannot manage it”**
- Resource efficiency – historic background
- Waste plastics recycling case
- Energy from Waste case
- Recycling quality vs. quantity
- Need for meaningful evaluation framework
- The C-VORR approach at University of Leeds

Waste hierarchy is outdated because...



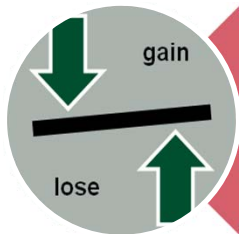
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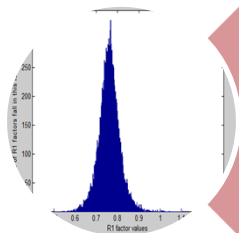
No systems - boundaries



No multiple aspects of value



No trade-offs

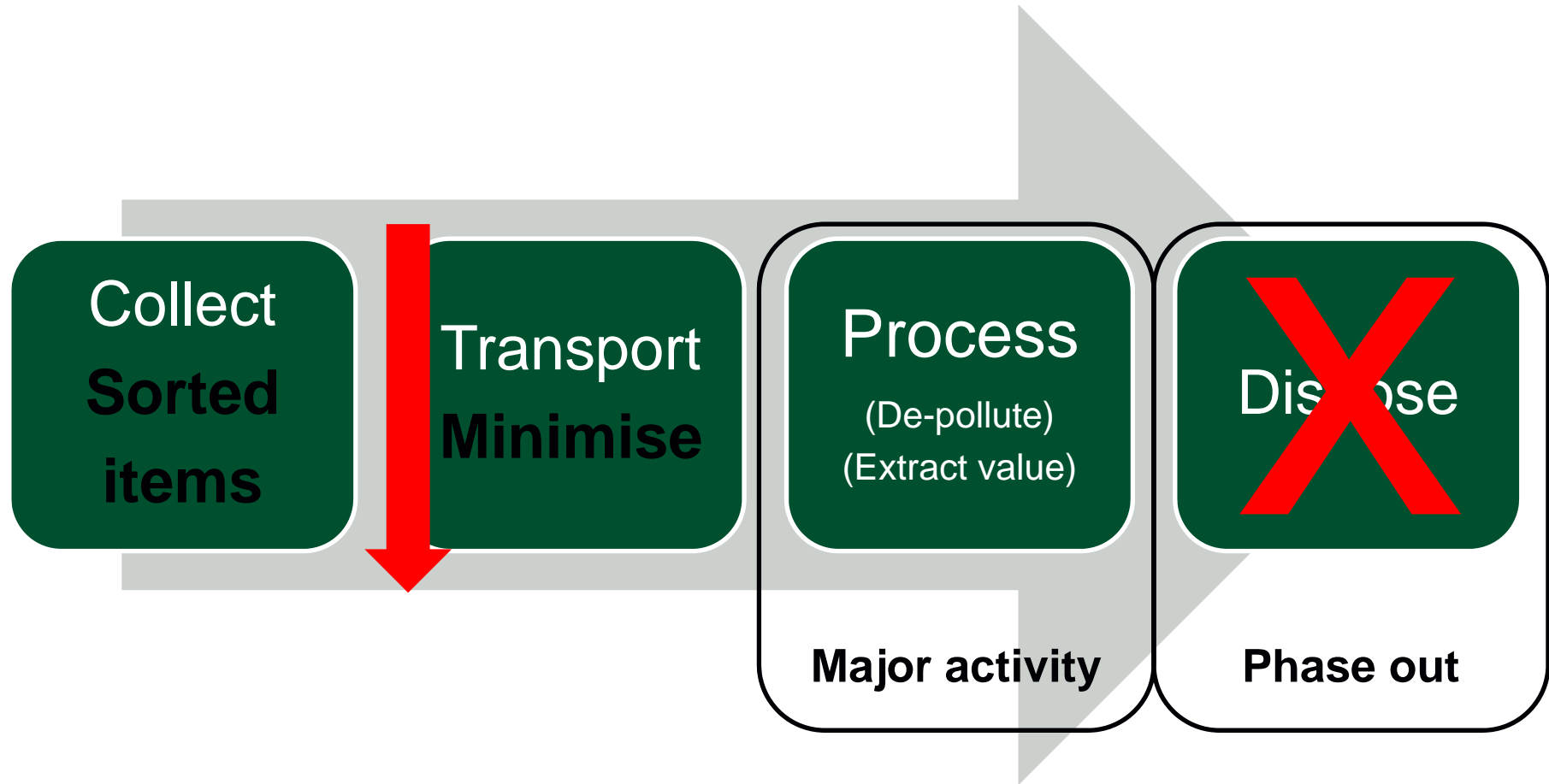


No optimisation

Dealing with waste: Key **system** parts



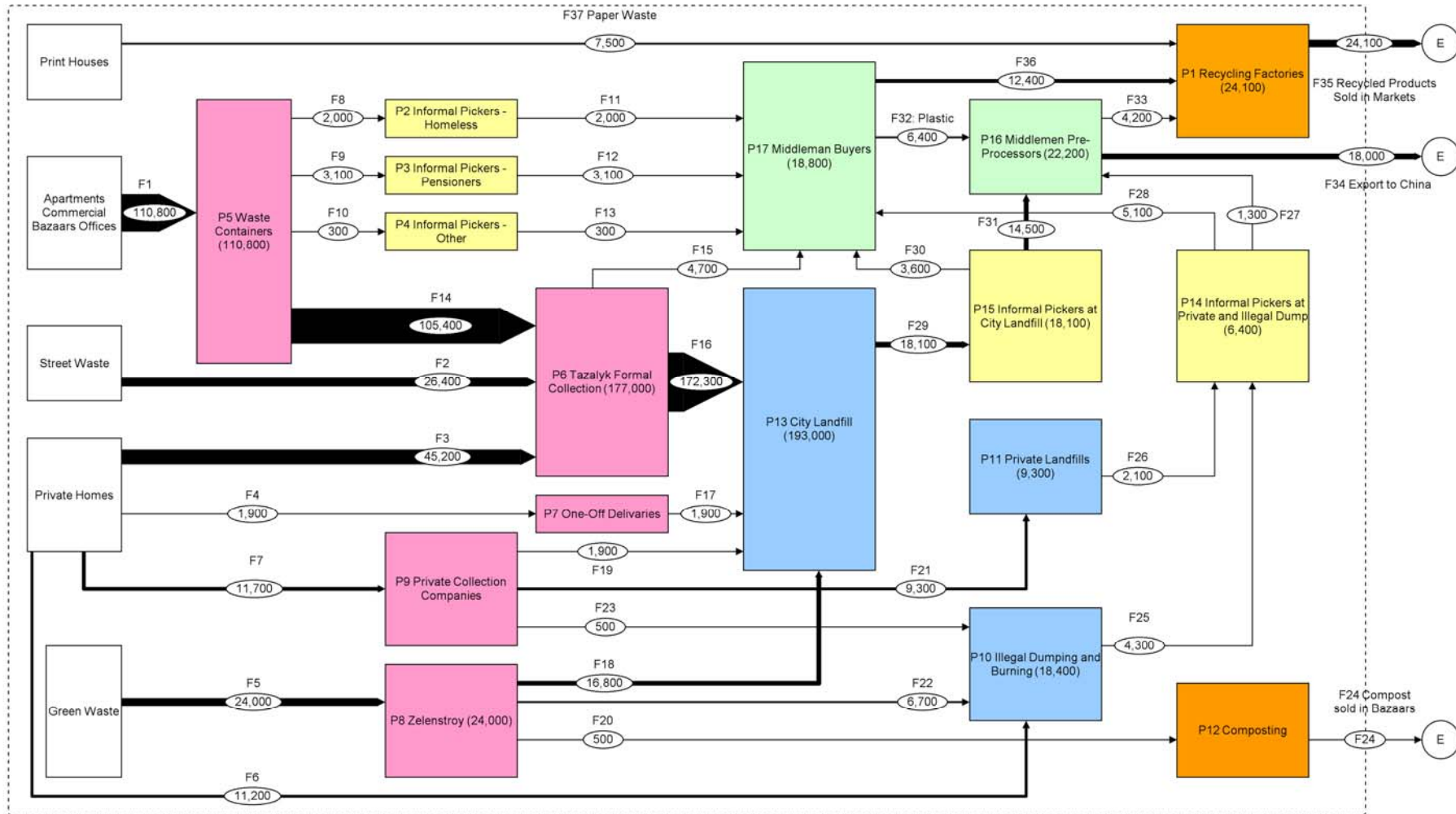
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SWM and resource recovery system in Bishkek, Kyrgyzstan

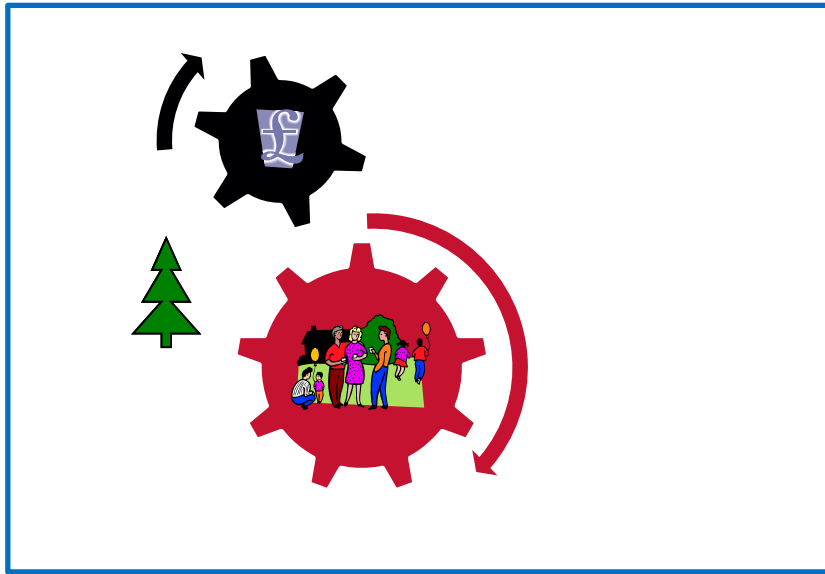


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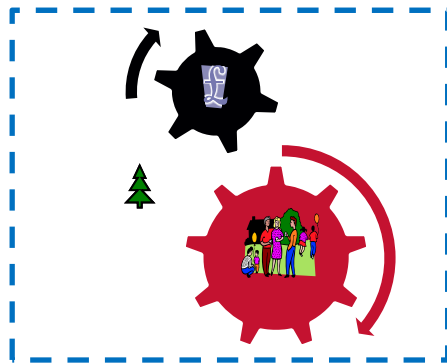
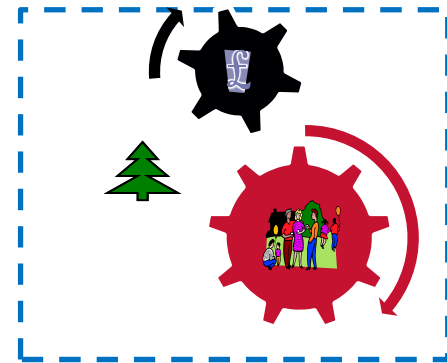


Source: Sim et al., 2013

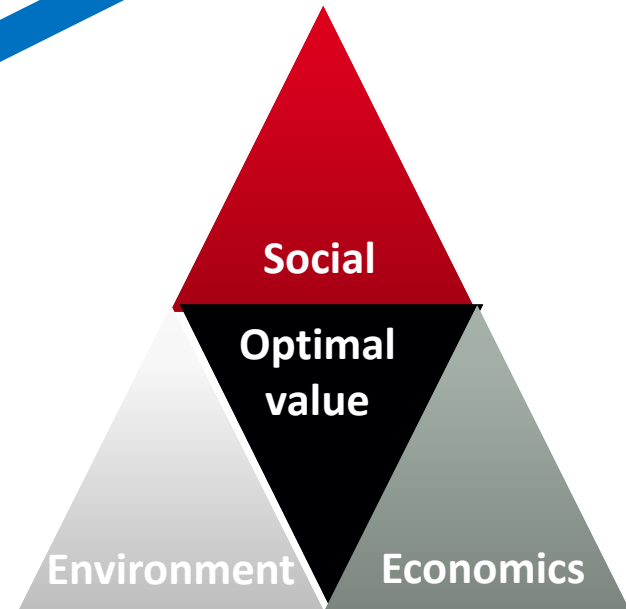
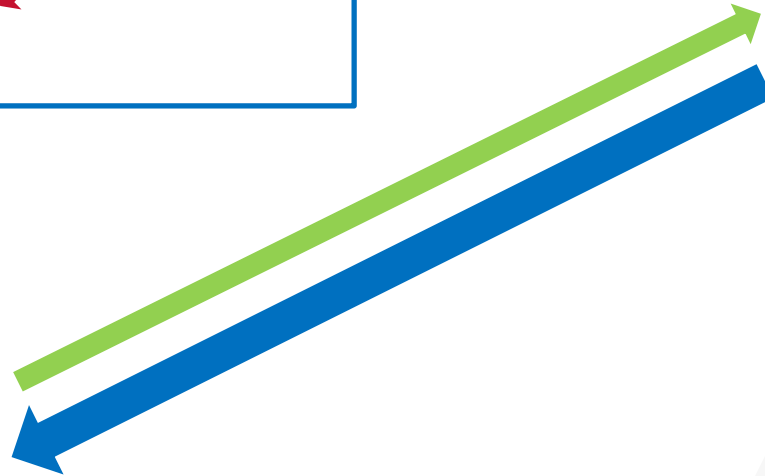
System A



System B



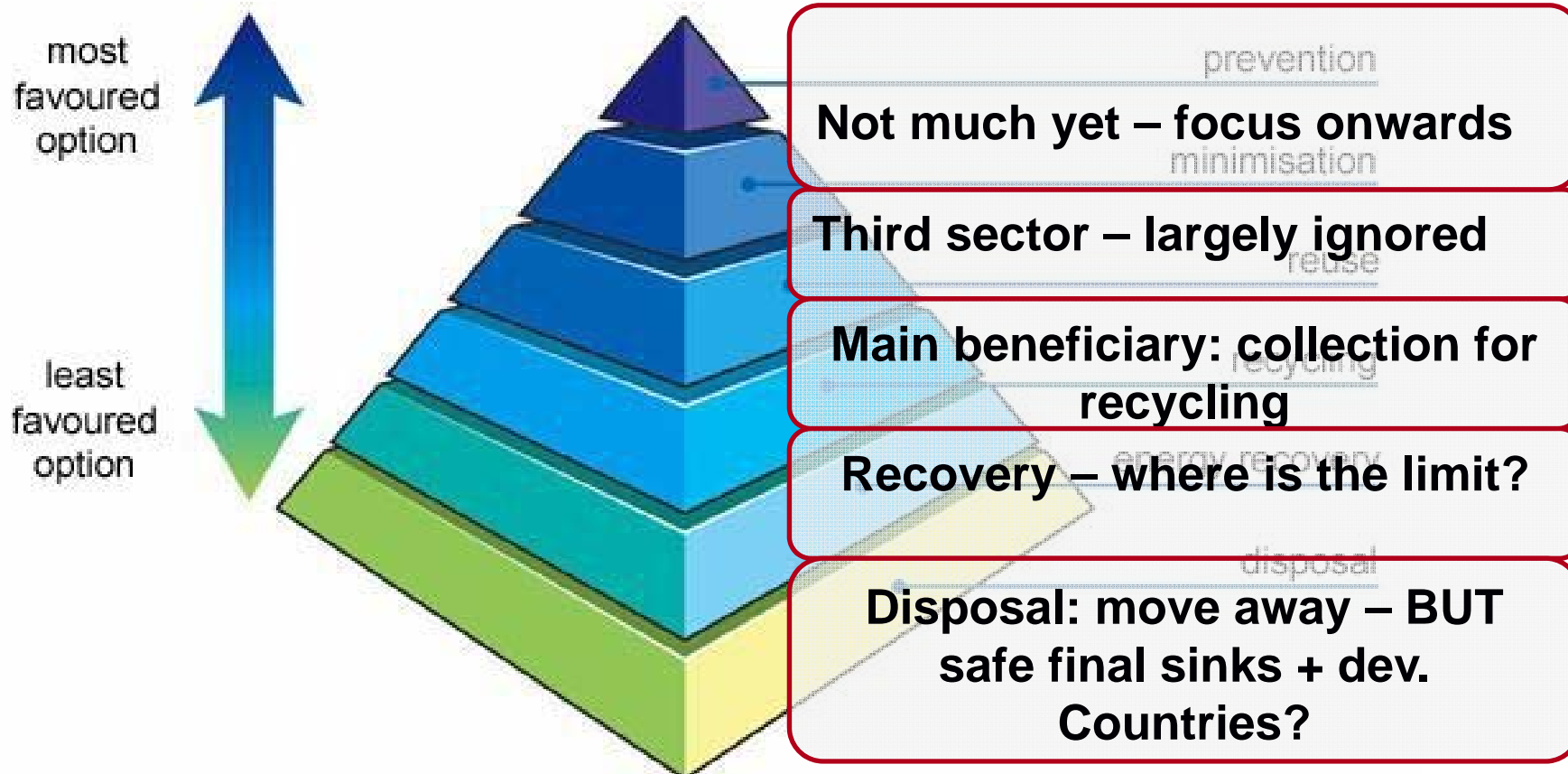
System C



Waste hierarchy according to revised WFD: 2008/98/EC Directive (Art. 4)



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Source: <http://www.ehsgs.com/company-ethos.html>

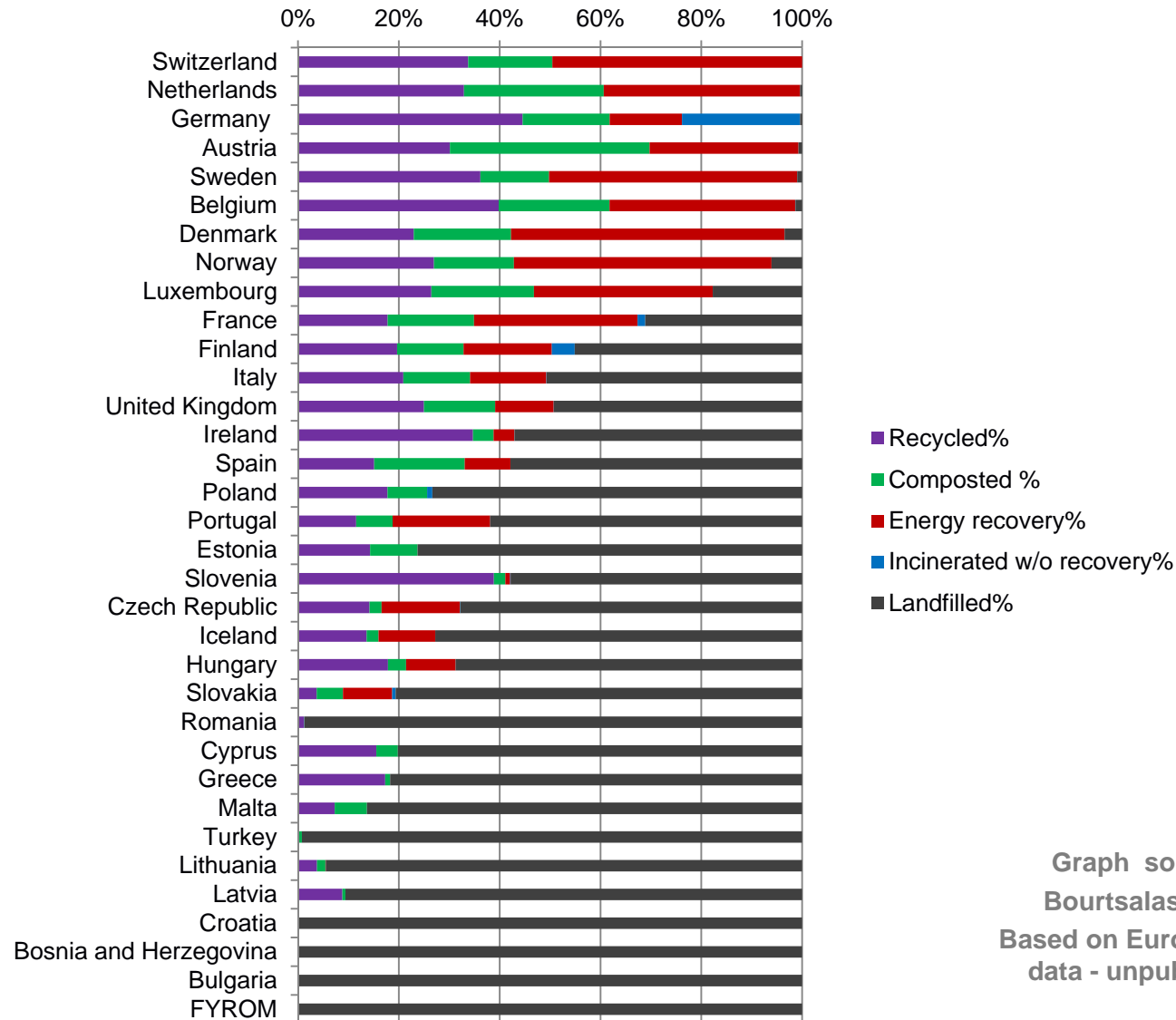
At best: just a static “environmental” hierarchy of waste processing options: simplistic >> simple?

Application of waste hierarchy in Europe



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MSW generated (% wt.)



Graph source:
Bourtsalas et al.
Based on Eurostat 2012
data - unpublished

Advance of recycling in EU



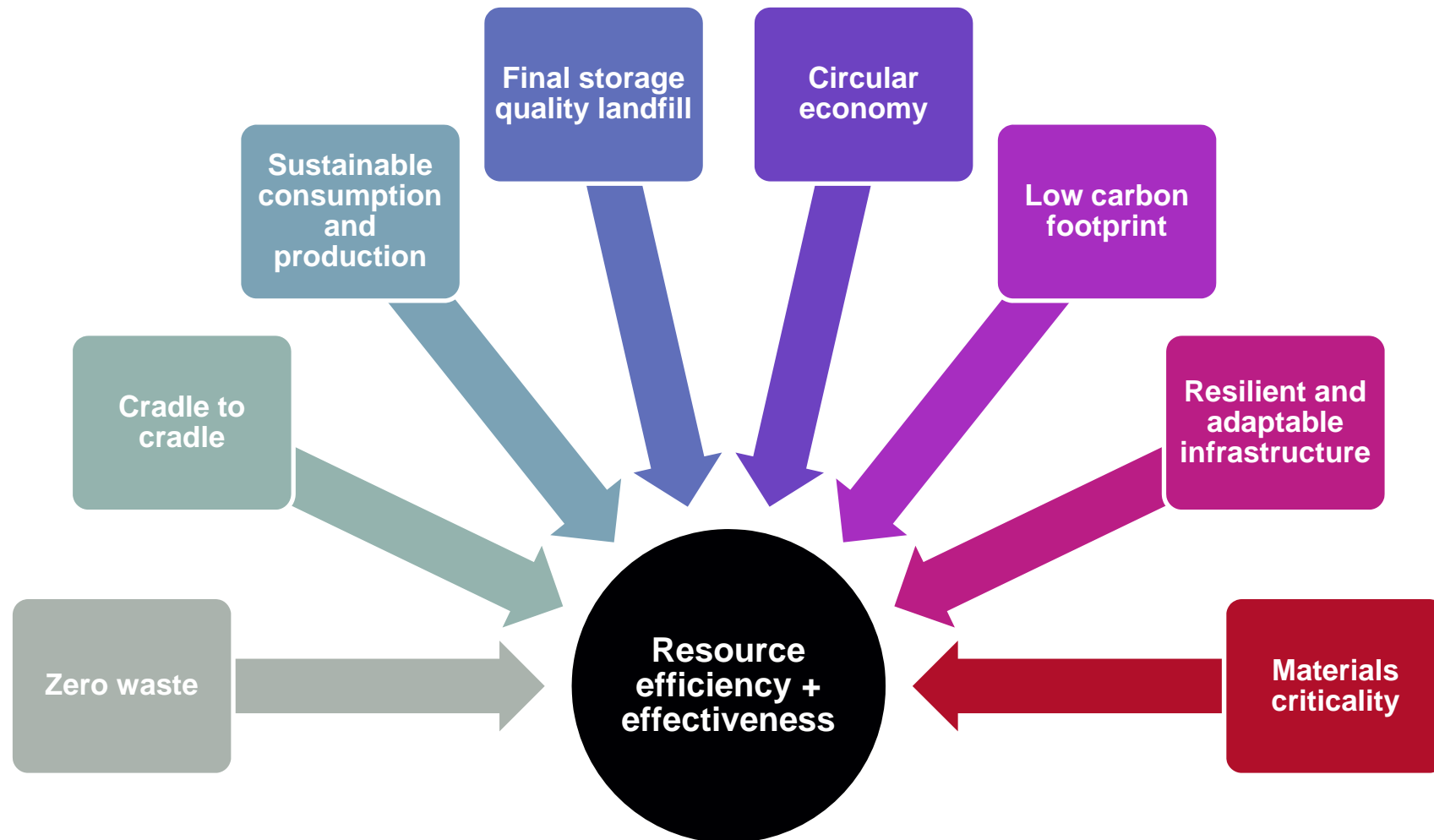
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- **1990: poor recycling levels for EU 12 MSs** municipal waste recycling rates
 - Ranged from **1 to 20% wt.**
 - Half of 12 MSs between <1 – 6% (Source: Environmental Resources Limited:1992)
- **Today: High recycling rates (40% or more) achieved** – targets set to 50%
 - Benefits and advantages of technical and bio-based (green) materials recycling / recovery management systems were rediscovered
 - Invested heavily in physical infrastructure and communication strategies, increasing public participation in separate collection schemes, and overall recycling rates to current levels of 40% or more
- **A resource efficiency and green economy motivation?**
 - **Mandatory ambitious recycling targets (side-effects?)**
 - **Not primarily commodity value of recovered materials**
 - But: recycling market as a competitive ‘sink’ - alternative to increasingly expensive landfill disposal and EfW

Concepts related to resource efficiency + effectiveness



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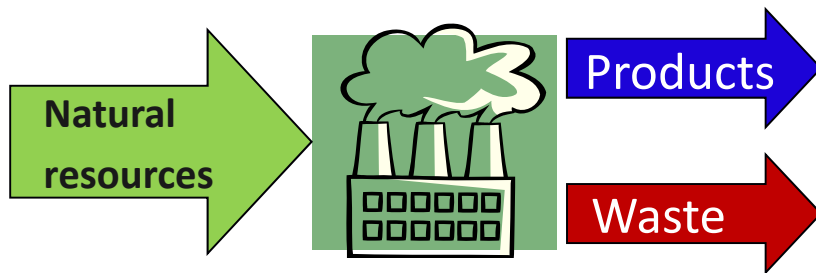


Circular + Resource efficient economy

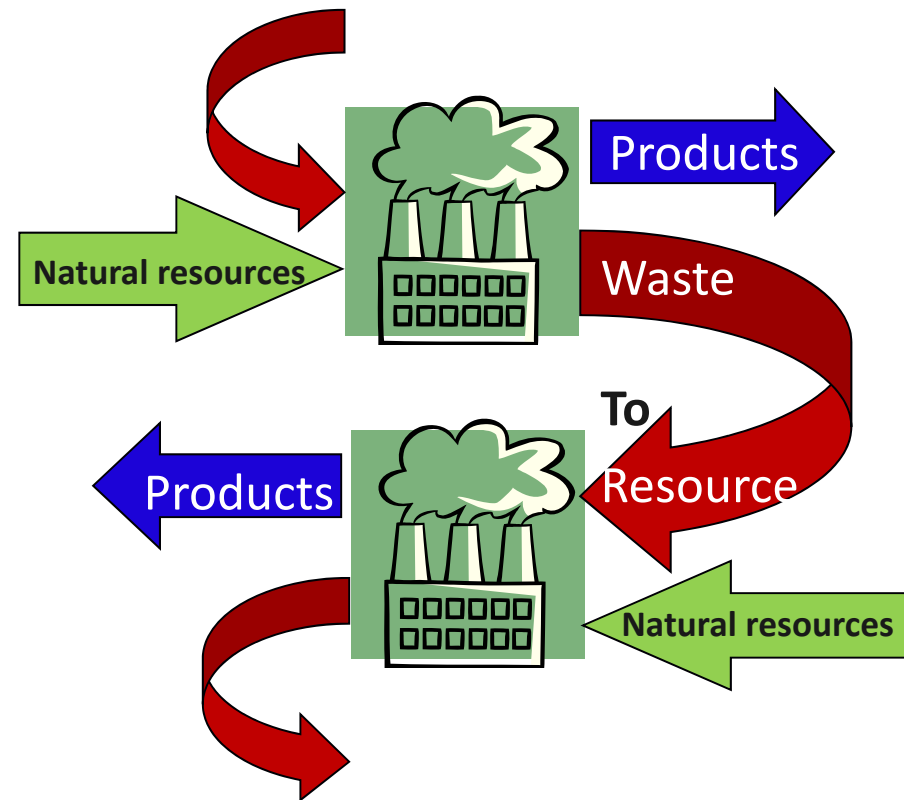


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From: Linear production system



To: Circular economy



Adapted from: **Imperial College London**
Chris Cheeseman, ICL

Roadmap to a Resource Efficient Europe (COM (2011) 571)



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REALITY

“In some Member States **more than 80% of waste is recycled**, indicating the possibilities of **using** waste as one of the EU’s key resources”

“Recycled” is connected to “using” – is it the case??

How to define / measure?

2020 aim

“Energy recovery is limited to **non recyclable materials**, landfilling is virtually eliminated and **high quality recycling is ensured**”

How to ensure / evaluate?

2020 aim

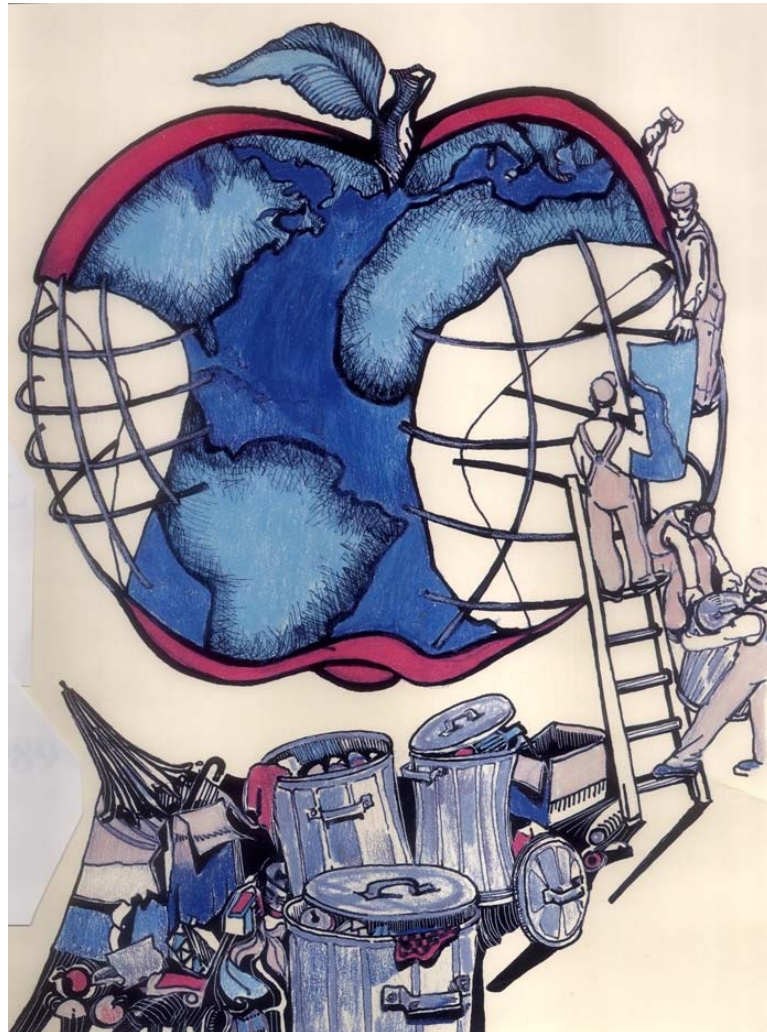
“More materials, including materials having a **significant impact on the environment and critical raw materials**, are recycled”

Differentiate based on materials criticality / impacts

Resource efficiency: a central notion for today's society



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Source: 1979 ISWA Waste Minimisation Conference, Geneva

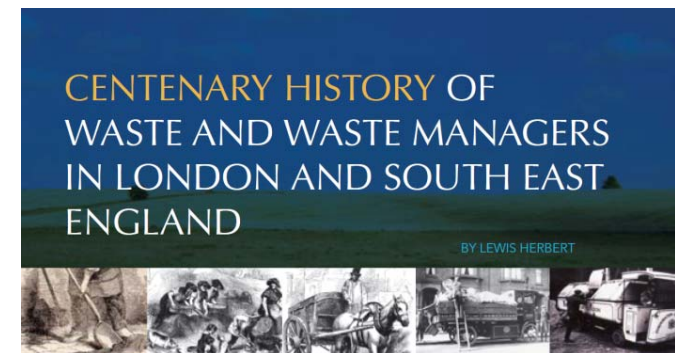
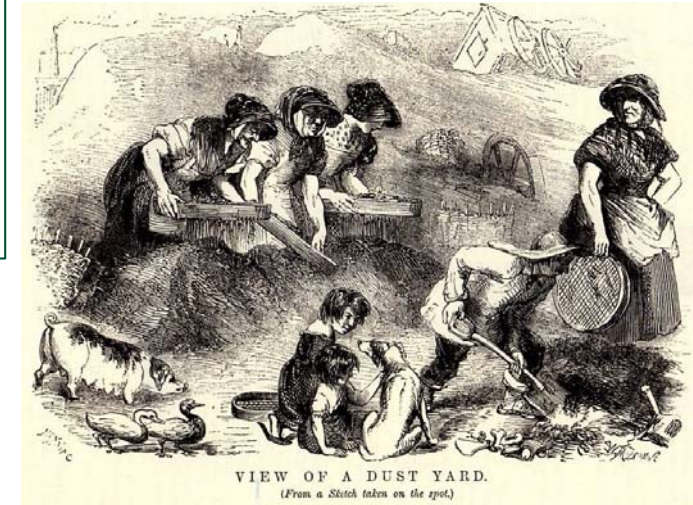
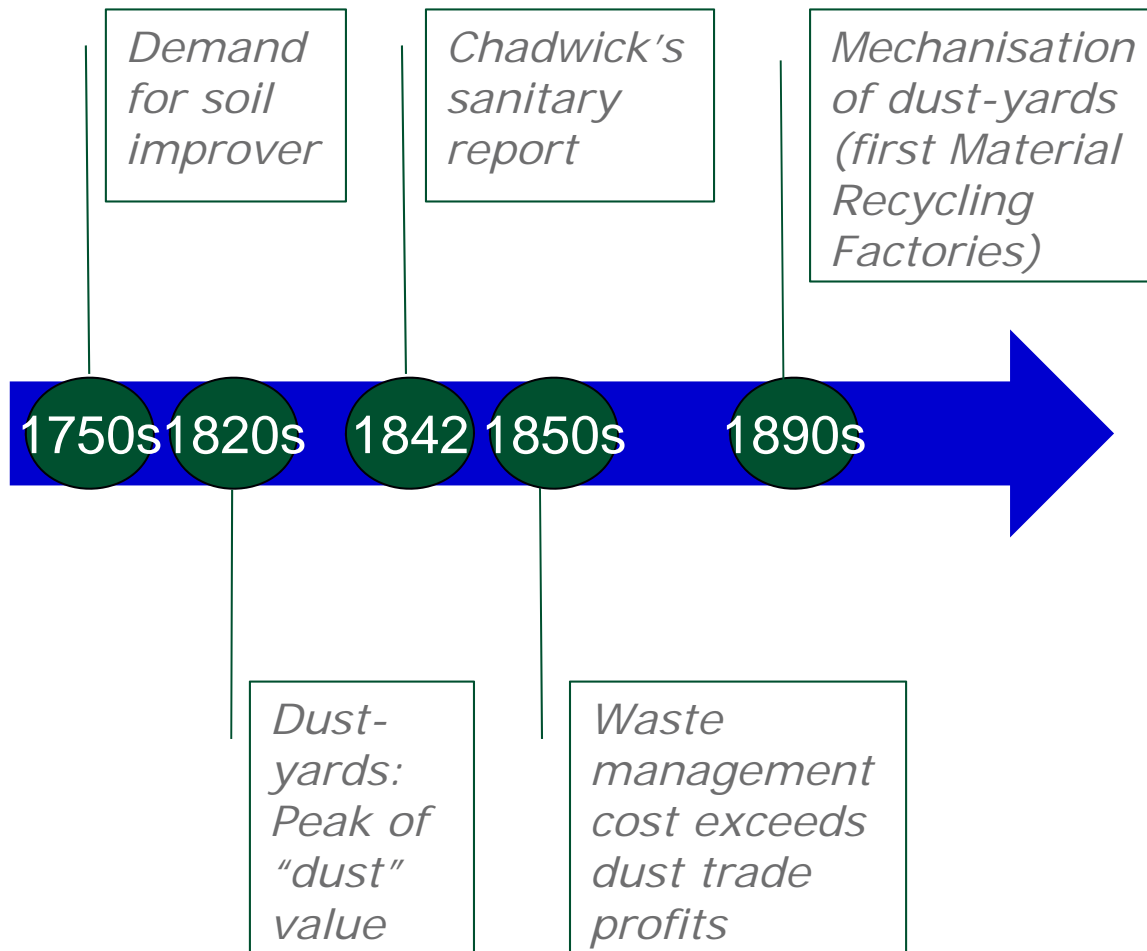
Slide source:
David C Wilson

D&W

Waste sorting 200 y ago in London Then **sanitation era** arrived



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(Velis *et al.*, 2009, Waste Management)

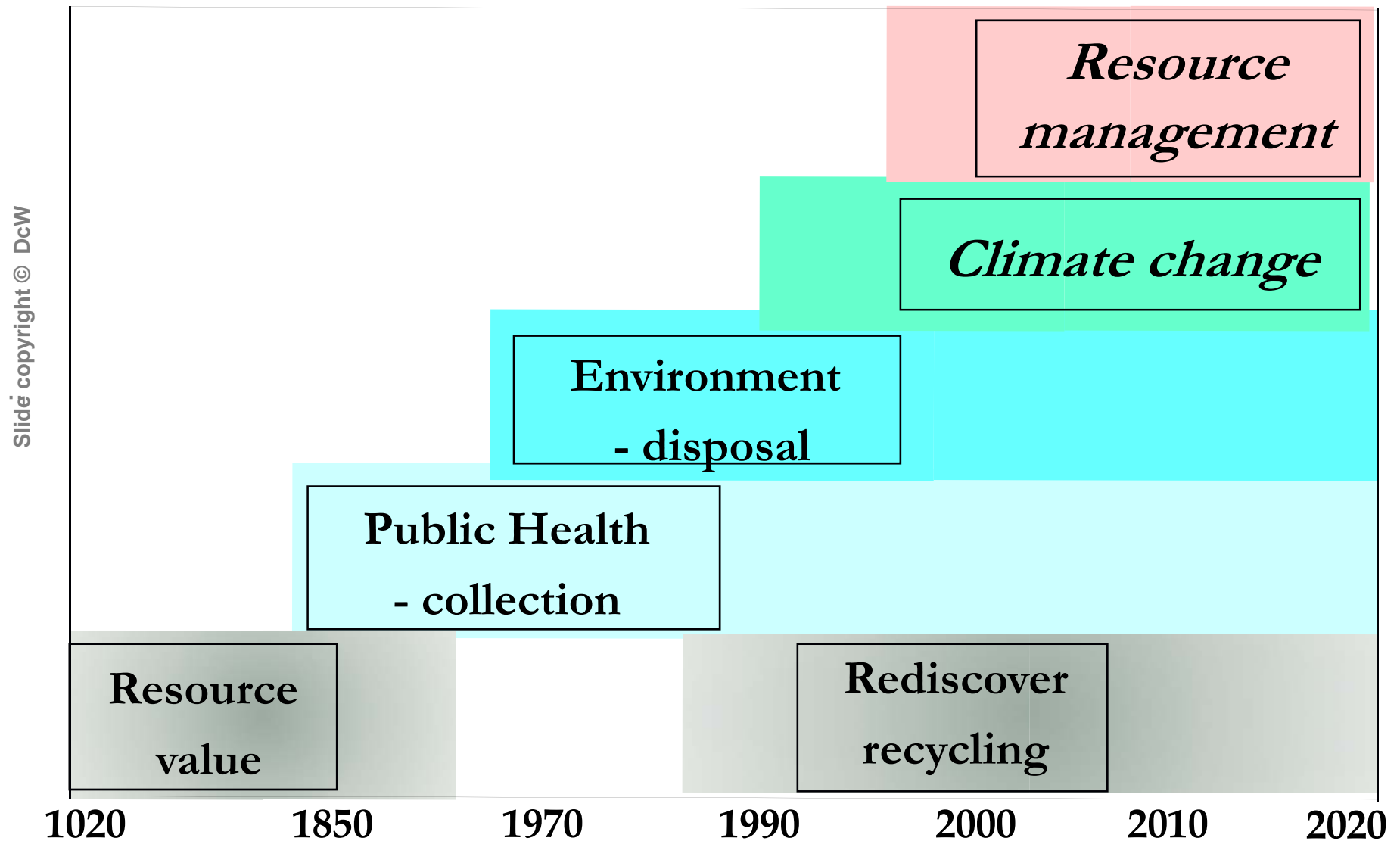
The Chartered Institution of Wastes Management

Celebrating the 100th anniversary of the creation, in 1907, of the London and Southern Counties Centre of the Chartered Institution of Wastes Management (CIWM)

Drivers for waste management



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Recycling of waste plastics: a global market



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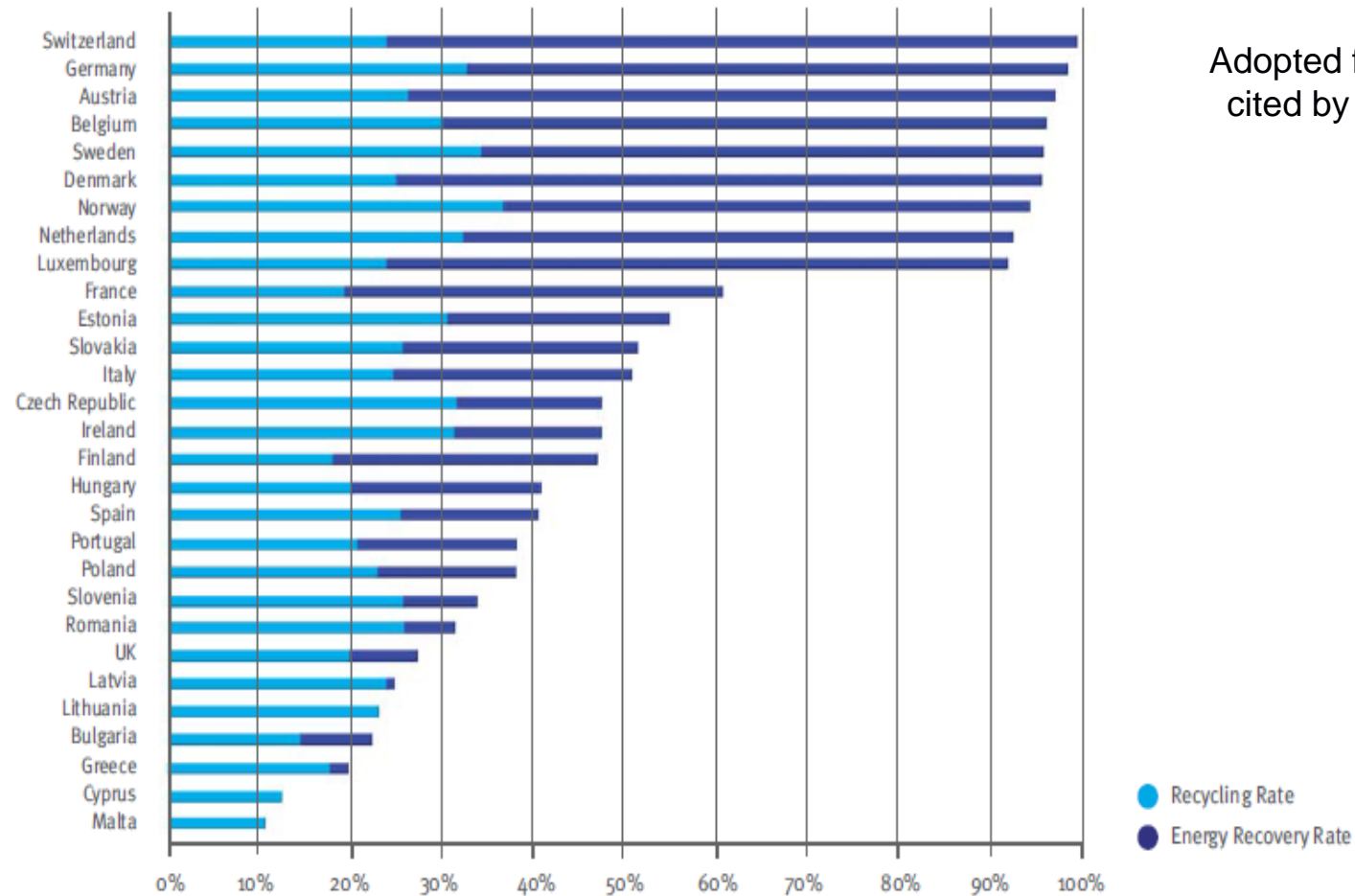
ISWA
Globalisation
and Waste
Management
Task Force

Photo by Dan Kitwood/Getty Images – Web
source: WONGBLOG (Plumer, 2013)

European waste plastics value recovery (recycling + WtE)



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Adopted from: Consultic, as cited by (Plastics Europe, 2012)

Figure 12: Total Recovery Rate by Country 2011
(Referred to Post-Consumer Plastic Waste)
Source: Consultic

European waste plastics management



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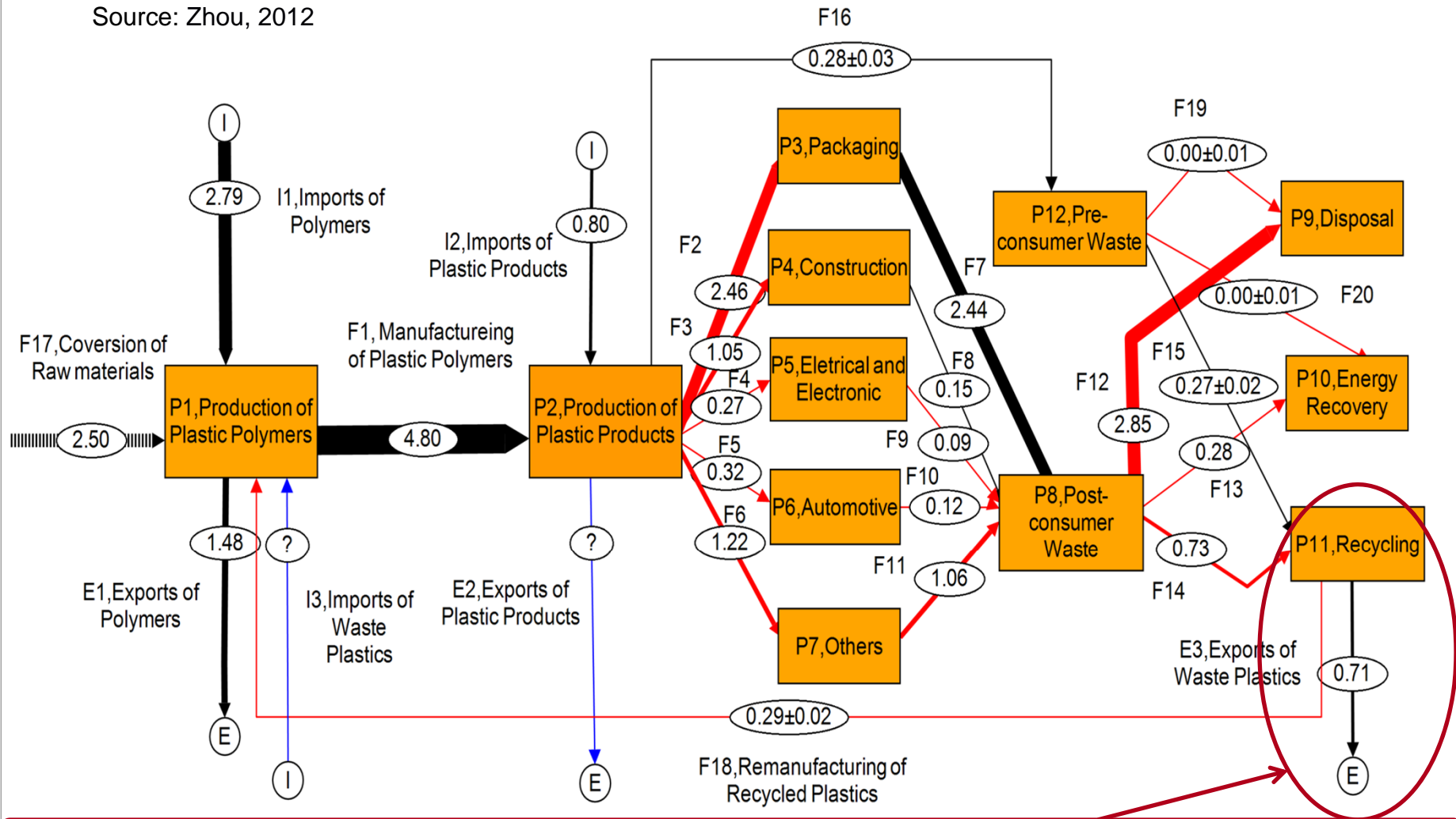
- EU-27 generates 25.1Mt waste plastics
- Almost stable since 2006 (Plastics Europe, 2012; 2011 data).
 - 6.3Mt (25.1% wt.) was sent for recycling
 - 8.6Mt, was sent for energy recovery
 - Remaining was landfilled
- *Collection for recycling ranges from 15-30% and energy recovery levels vary from 0-75% EU-27*
 - From the 6.4Mt collected for recycling (BIR 2011 data)
 - 3Mt was handled within Europe
 - **3.4Mt exported outside Europe (worth of €1.7 Billion - Extra-EU trade)**

Waste plastics flows in the UK and... beyond Reprocessed for export?



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Source: Zhou, 2012

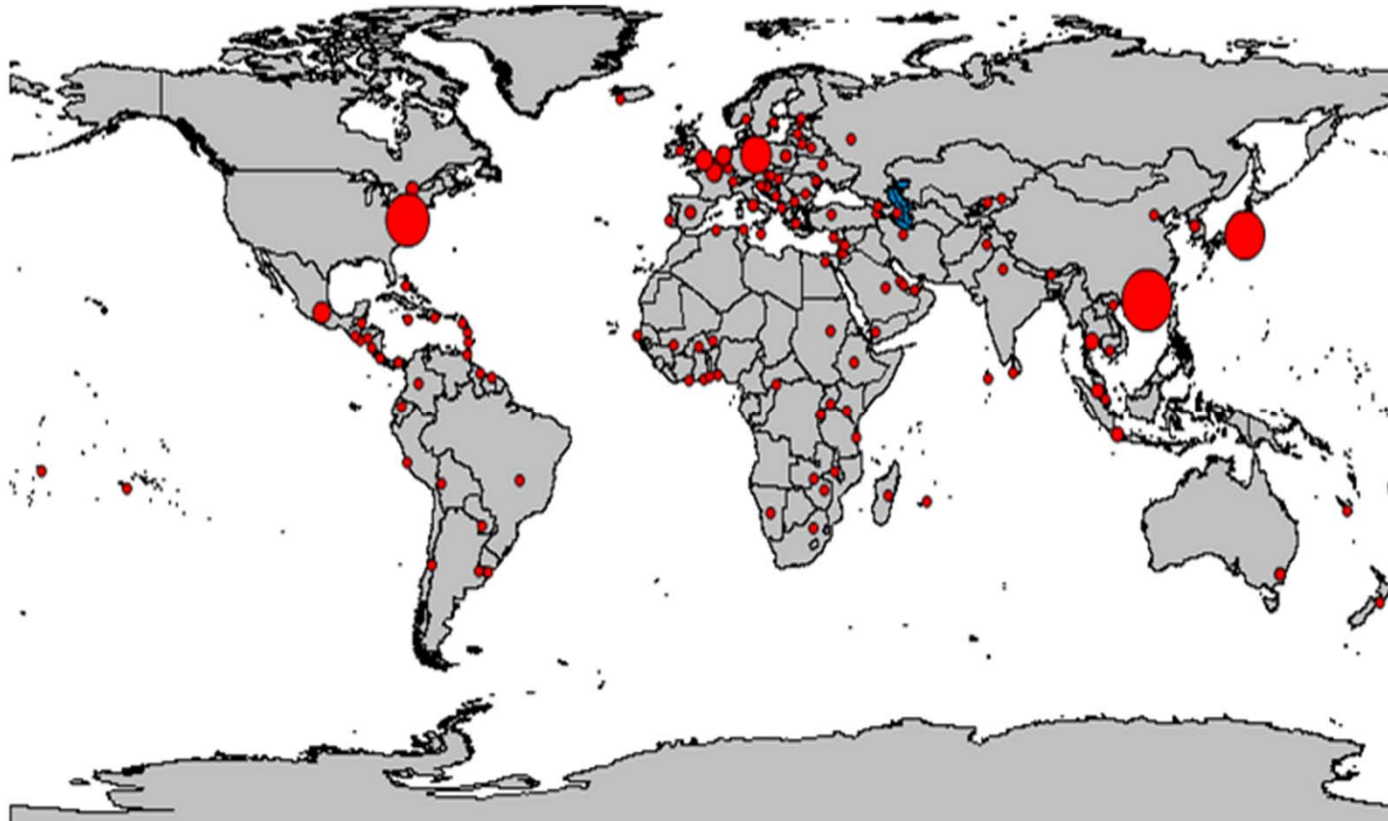


Around **70%** wt. of “recycled” UK plastics are exported

Global map of export transactions in waste plastic - 2011



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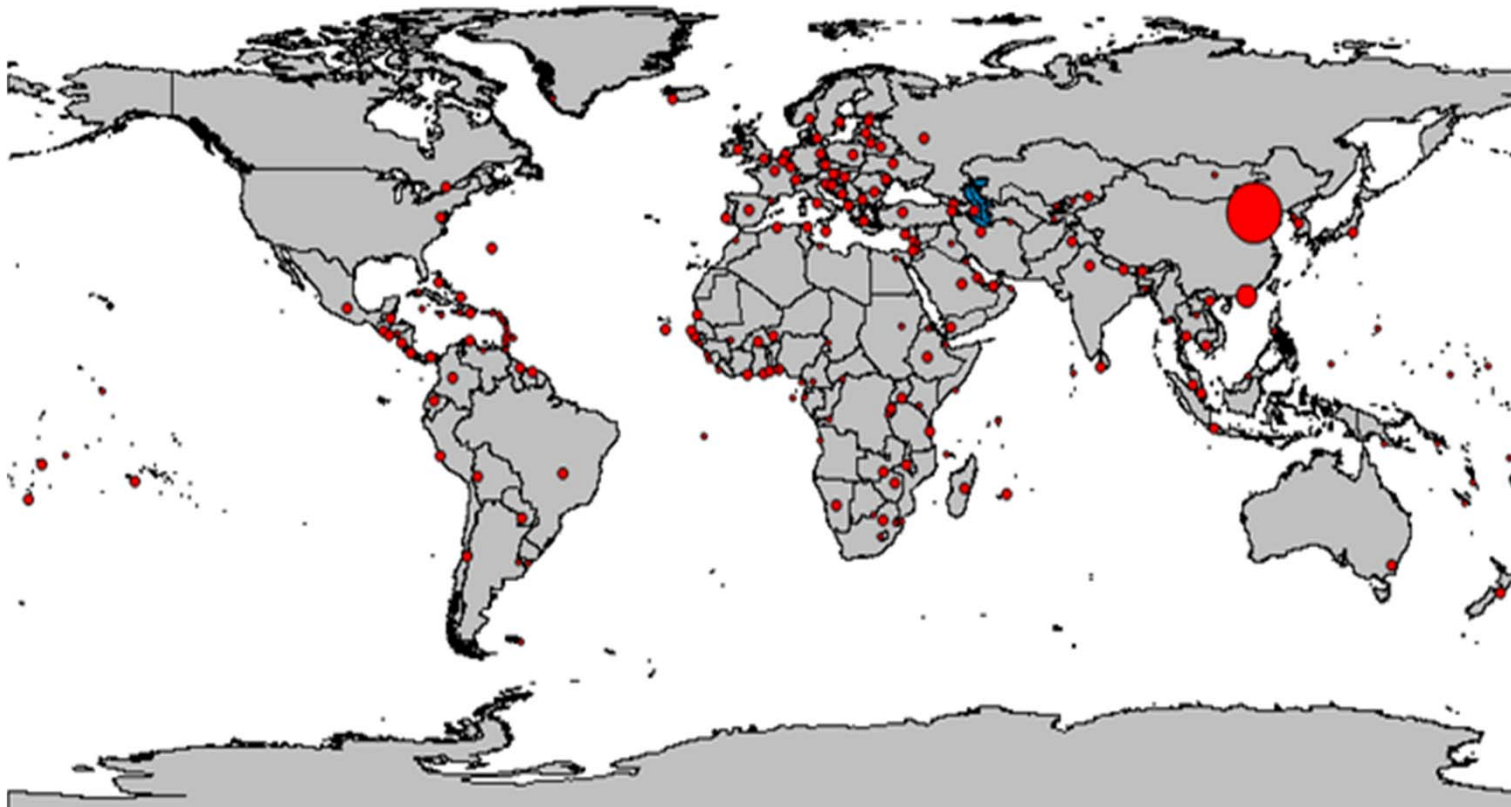
Code 3915: “waste, pairings and scraps of plastics”

Data source: (UN Comtrade)

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



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Europe depends on exporting to China (87% wt.)



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More than half of the plastic waste collected for recycling in Europe is directed to international markets

- Trend is relatively stable: 2010: 3.373Mt; 2011: 3.365Mt; 2012: 3.358Mt
- Destination (target countries) mainly Asia (South, South East, East)
- 87% wt. to China + Hong Kong SAR
- Rising trend of direct exports to China, and also to India
- Exports of Europe to South-East Asian countries to a great extent finally find their way towards China!

Overall dependence on Chinese market demand is even greater!

EU-27 imports: 0.4 Mt (vs.3.4Mt exports)

- Outside Europe countries make negligible contribution
- Norway and Switzerland being most important EU-27 suppliers

Global Plastics Recycling Markets

ISWA report info in the Press



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theguardian

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China leads the waste recycling league

EU legislation is fuelling a multibillion-dollar market. As landfill charges increase, it is often cheaper to send rubbish abroad

Kara Moses
[theguardian.com](#), Friday 14 June 2013 15.56 BST



Waste from Europe, including paper and plastic, is often sent to China to avoid landfill costs. Photograph: Kim Kyung-Hoon/Reuters

theguardian

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Resource efficiency hub

From Guardian Sustainable Business

Could China's 'green fence' prompt a global recycling innovation?

Beijing's crackdown on substandard recyclable waste has caused chaos for some western waste exporters

Katharine Earley
Guardian Professional, Tuesday 27 August 2013 12.37 BST

[Jump to comments \(3\)](#)



e-efficiency

Global plastics recycling markets: Recovery occurs in China - implications for resource recovery?



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Around **70%** wt. of “recycled” UK plastics are exported: **IMPLICATIONS?**



“A Chinese woman holds her baby as she strips labels from plastic soda bottles so they can be recycled.”
Copyright: Peter Ford/The Christian Science Monitor. After (Ford, 2013)



“Coal fired extruder in a small recycling plant in China.”
After (Jefferson 2010)



“Children sorting out tiny specks of wrong colored plastic chips. Many hundreds of bags await their eyes and fingers.” © BAN. After (Pucket et al., 2002)

There is insufficient understanding on the fate of the plastic scrap after entering China and its implications for local and global health and environmental considerations

Waste everywhere... Quantity counts!



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WEEE stockpiled: India

Source: <http://www.scrapmonster.com/news/barely-4.5-of-indias-e-waste-gets-recycled-assochem/1/5871>



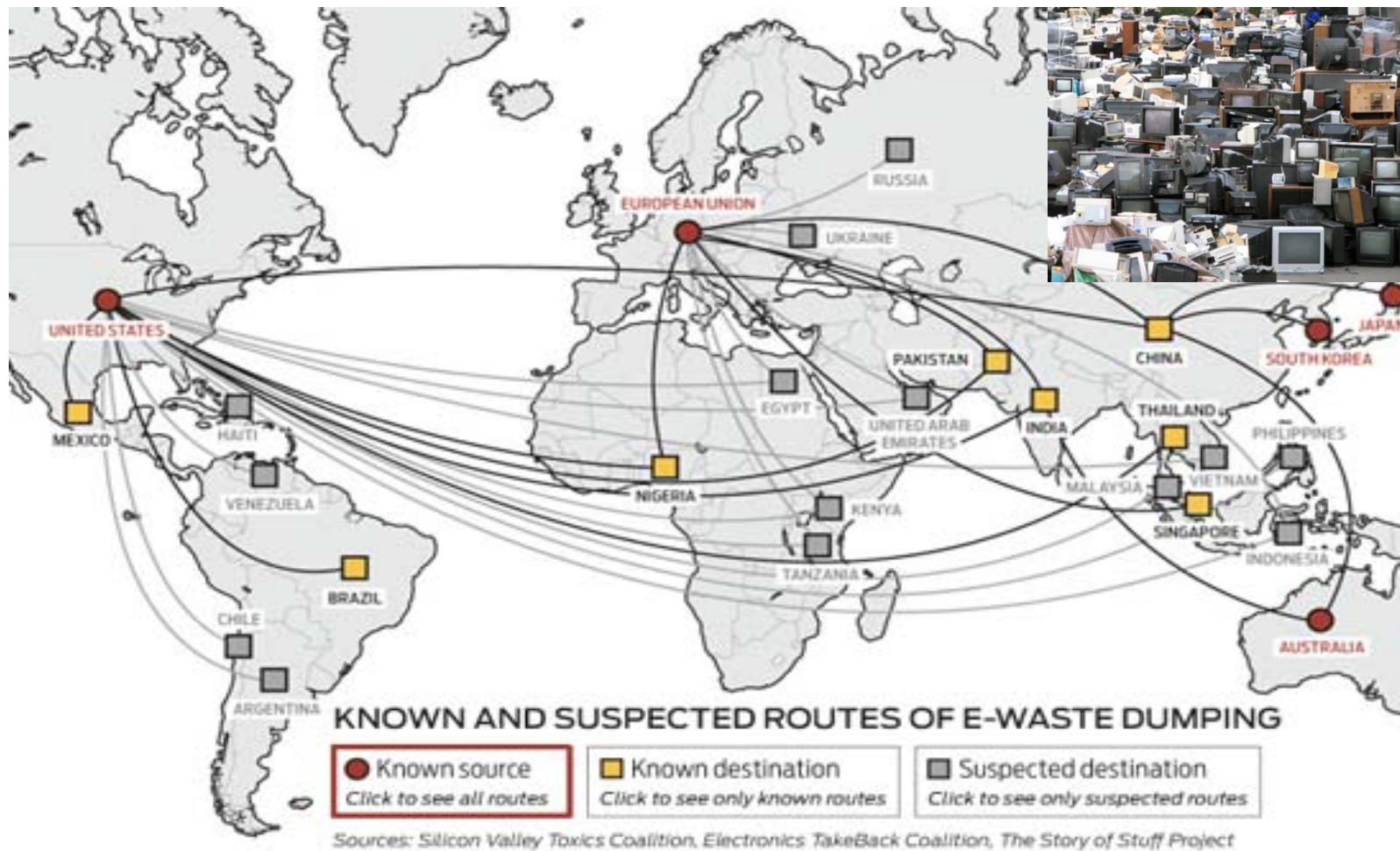
WEEE recycling: Ghana

Source: Oko Institute:
<http://www.oeko.de/aktuelles/dok/544.php?archivpart=2010>

Global scale realities: E-waste distribution



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Source: <http://www.scrapmonster.com/news/barely-4.5-of-indias-e-waste-gets-recycled-assocharm/1/5871>

Source: International electronics recovery coalition, available at <http://www.ierc.info/e-waste-dumping-an-interactive-map/>

A least environmental standards pathway?



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It has been argued that a least environmental standards path is often followed in global waste and secondary raw materials trans-shipment

So a direct link between the western consumption patterns and to small-scale low-tech reprocessing enterprises in South Asia.

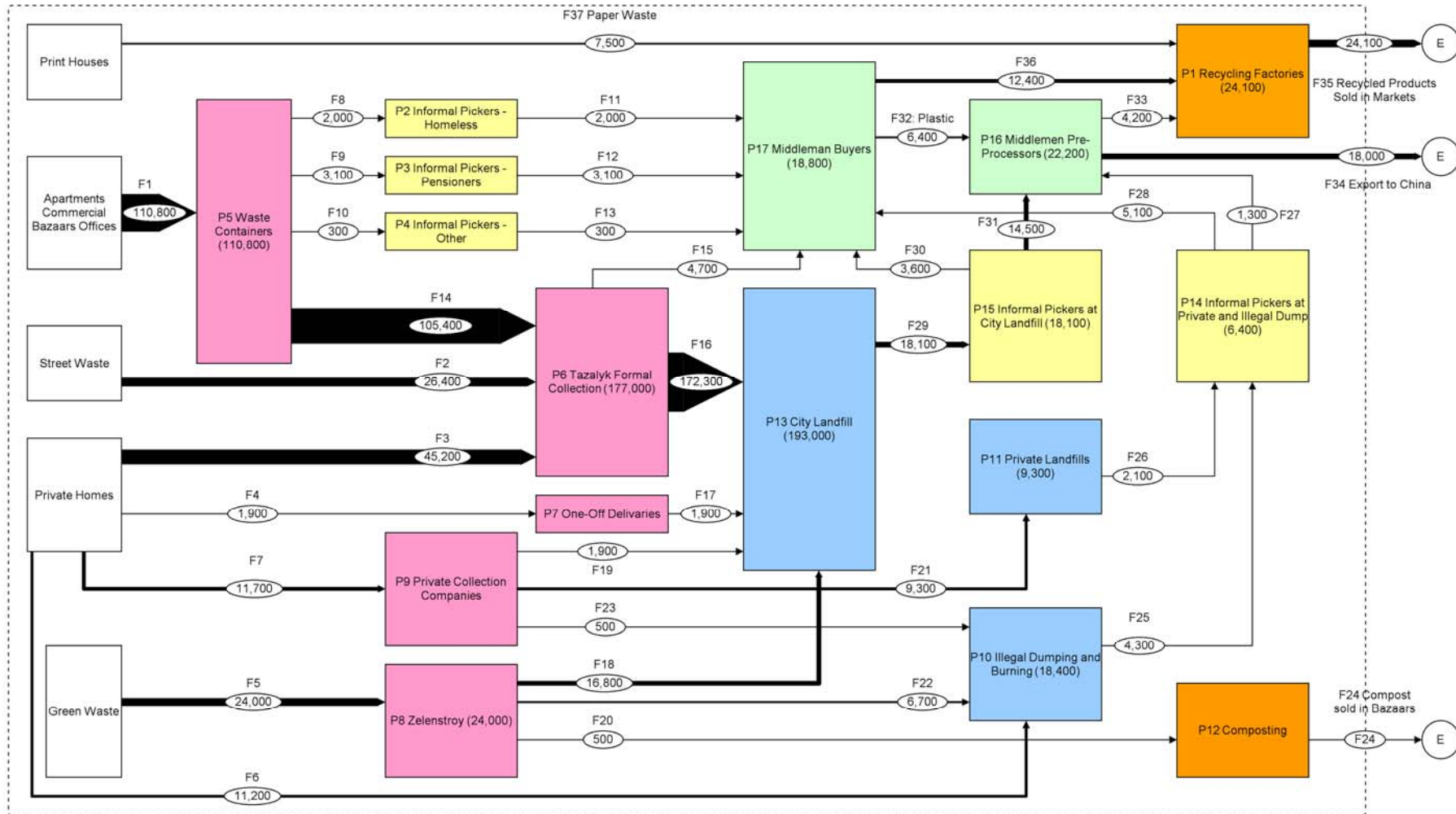
D'Amato, Iozzi *et al.*, 2012 propose a negative correlation exists between amount of exported waste and the wages in the importing countries. Hence, it seems that the trade flows always along a trail of 'least resistance'

The case of Hong Kong and China and the role of ASEAN countries in the case of waste plastics and Green Fence Operation could be also be case studies supporting such hypotheses

SWM and resource recovery system in Bishkek, Kyrgyzstan



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Source: Sim et al., 2013

Waste everywhere...



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Source Wiki – created by: Kounosu

Payatas dumpsite: Metro Manila, Philippines

Dev. countries: Informal sector recycling: A continuum / wide spectrum



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Partially misleading terminology

Definition from a 2006 GTZ study (Wehenpohl *et al.*, 2007; Scheinberg *et al.*, 2010):

'the informal solid waste sector refers to individuals or enterprises who are involved in recycling and waste management activities but are not sponsored, financed, recognised or allowed by the formal solid waste authorities, or who operate in violation of or in competition with formal authorities'



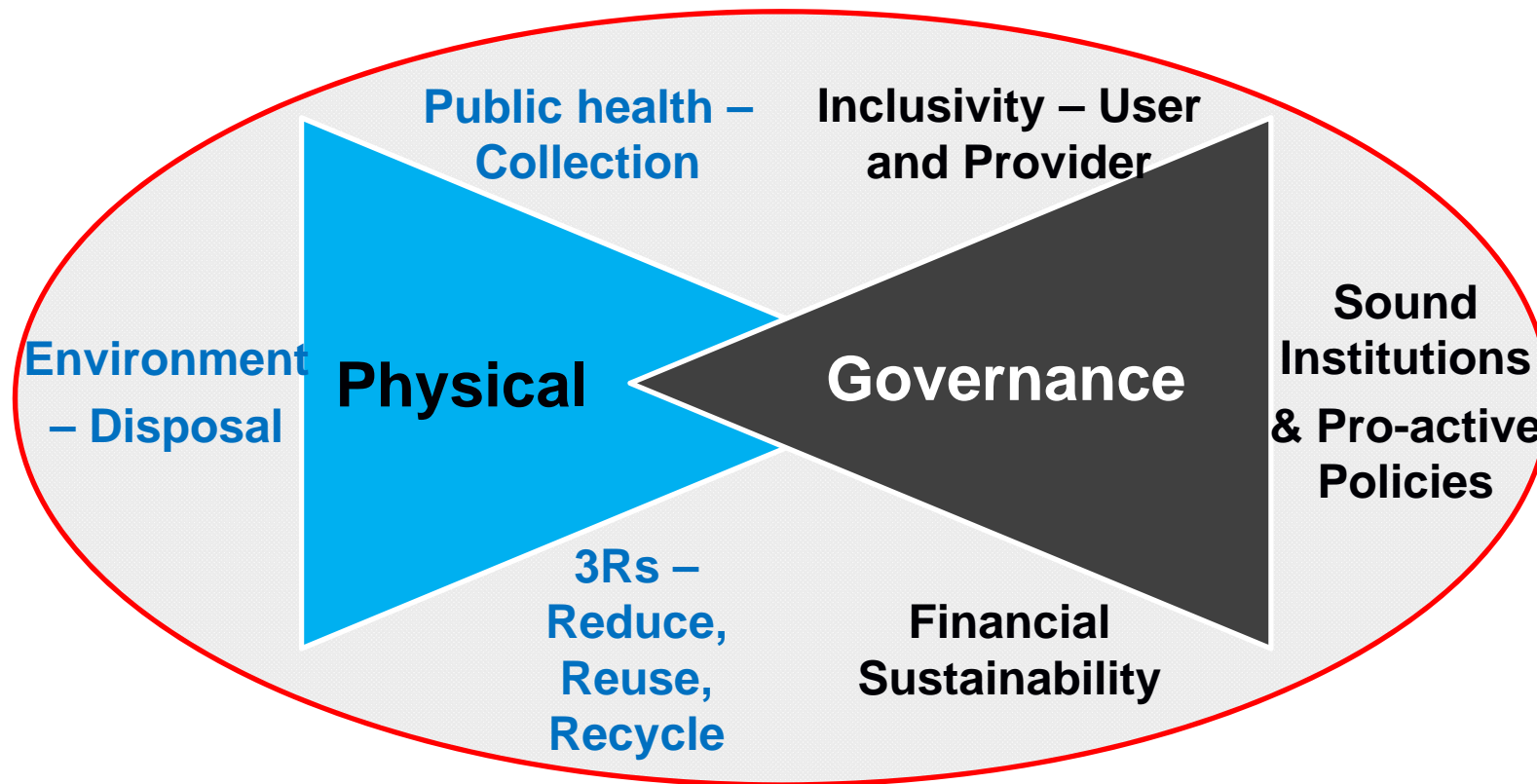
**Completely
uncontrolled
activities**

**Legal and tax-
paying formal
organisations**

Integrated Sustainable Waste Management Framework



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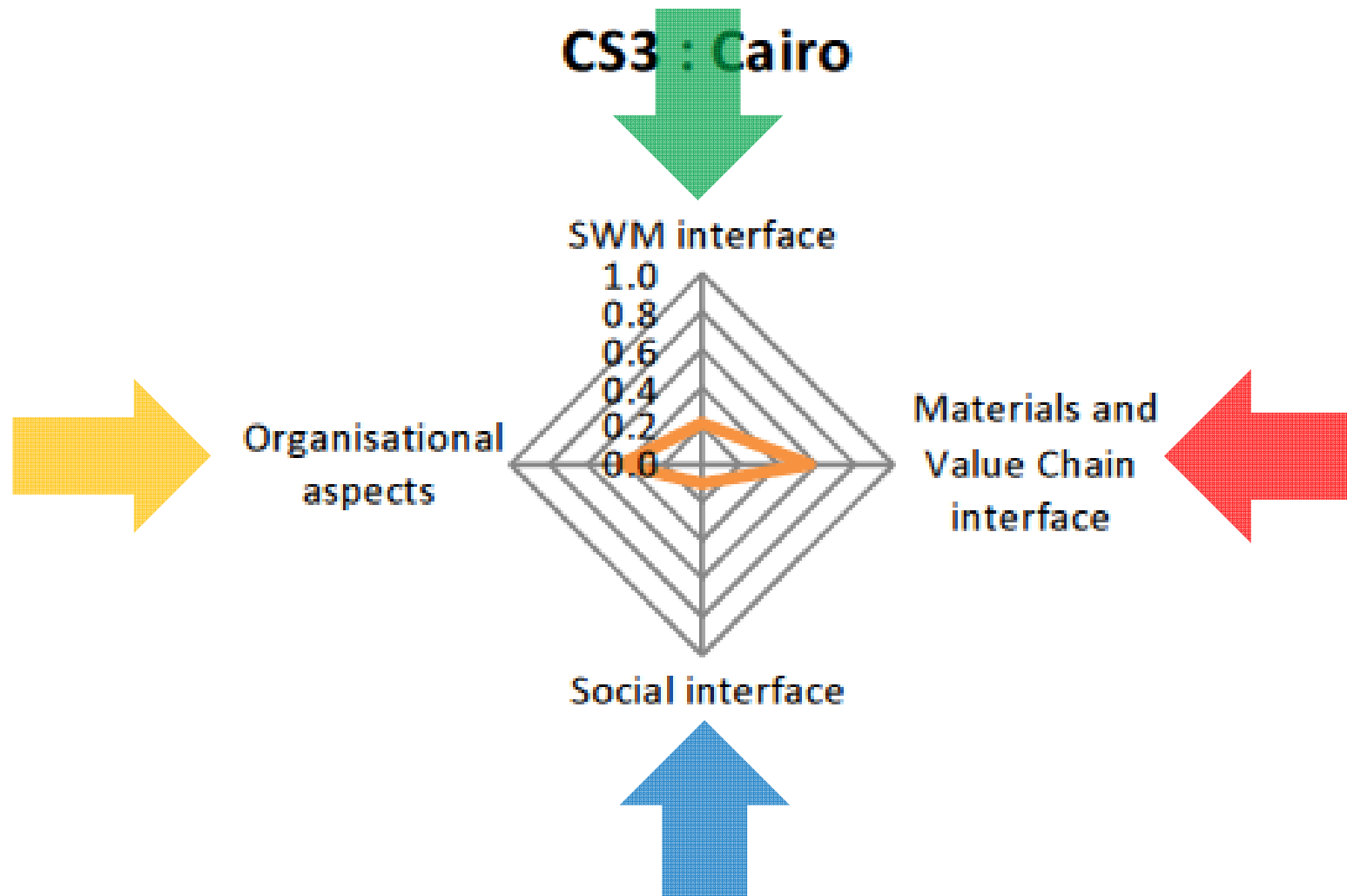


Source: Wilson et al., 2012

Integration tool for informal recycling in developing countries – 4 systems



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Source: Velis et al, 2012

Waste everywhere... Unintended flows and consequences...



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Plastics ending up at the beach



Plastics floating in the ocean

Source:

<http://thecoolgadgets.com/plastic-eating-marine-microbes-will-it-solve-ocean-plastic-contamination-issue/>

Source:

http://www.dailygalaxy.com/my_weblog/2007/12/are-there-reall.html



- **Technical materials life-cycle(s)**
- What is the **technically feasible level** of recycling?
- What is the **desirable (environmental) cost** for recycling?
- Should de-pollution of materials cycles and environment count?
- Multiple life closed loop-recycling: e.g. **Glass bottles** beer / non alcoholic beverages in Denmark: collected washed recycled up to 33 times: current incentives lead just to recycling
- **Mass basis:** aluminum equal to glass
- Water released: not recycling in EfW; recycling in composting and particularly in biodrying MBTs: at least 25% wt. losses

R1 EfW formula: defining the line between recovery vs. disposal



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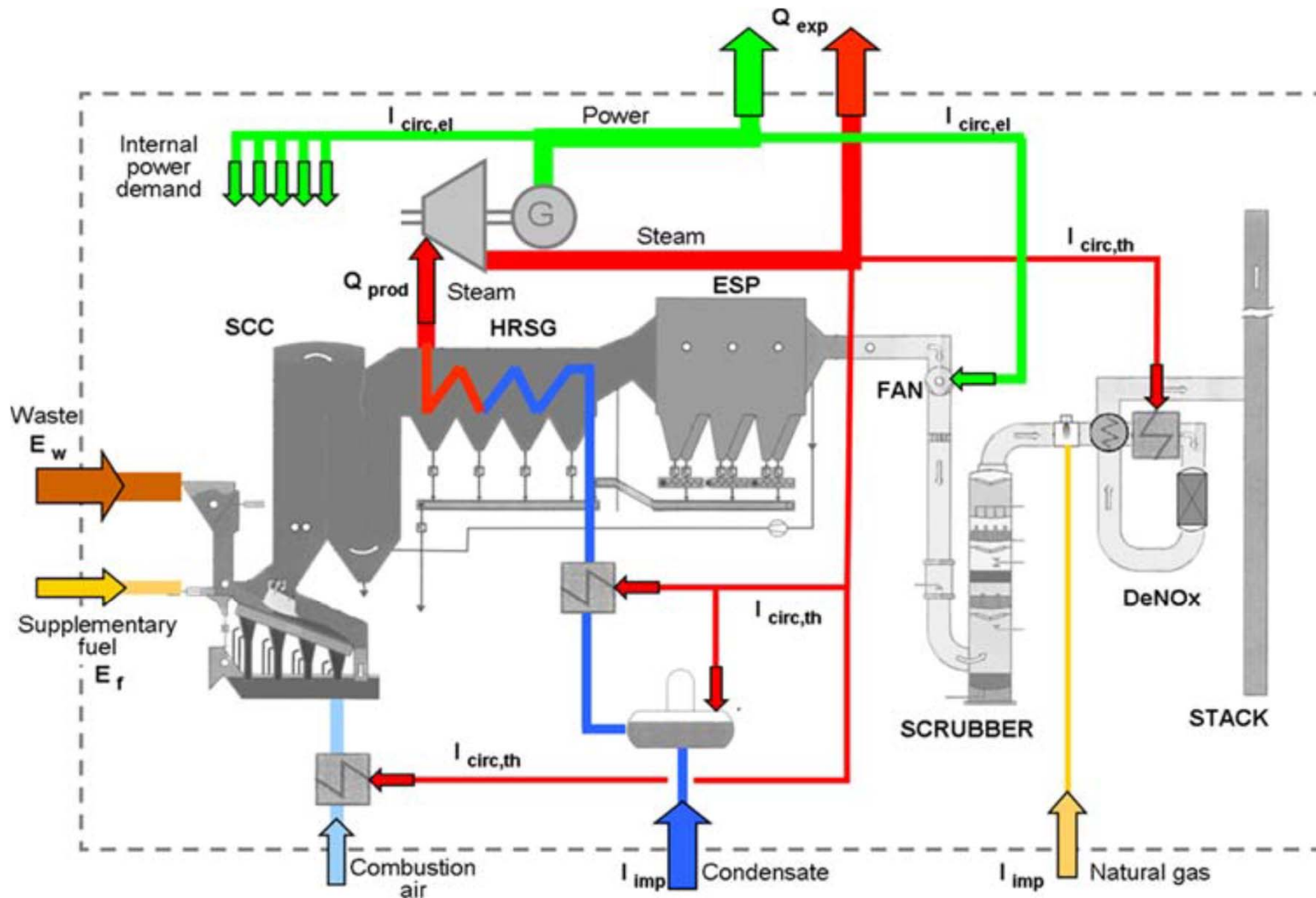
$$R1 = \frac{E_P - (E_f + E_i)}{0.97 * (E_w + E_f)}$$

- **The single most important recent development**
- WFD 2008/98/EC: allows efficient EfW facilities to be classified as ‘**energy recovery**’ operations
- ‘R1 energy efficiency Formula’
- **Systems and measurable outcome** focused approach
- Single level limit (target – inflexible): R1>0.60 for existing plants - R1>0.65 for new plants
- Issues with universal applicability – implementation (was the BREF spirit met?)

Energy from waste as **input /output system**



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Source: Pavlas and Tous, 2008

R1 EfW formula: defining the line between recovery vs. disposal



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Policy choices on background energy mix – technical capabilities

$$R1 = \frac{2.6 * E_{el} + 1.1 * E_{th} - \left(\sum_{i=1}^n \dot{m}_{f,i} NCV_{f,i} + E_{i(el)} + E_{i,(th)} \right)}{0.97 * \left(\dot{M}_w NCV_w + \sum_{i=1}^n \dot{m}_{f,i} NCV_{f,i} \right)}$$

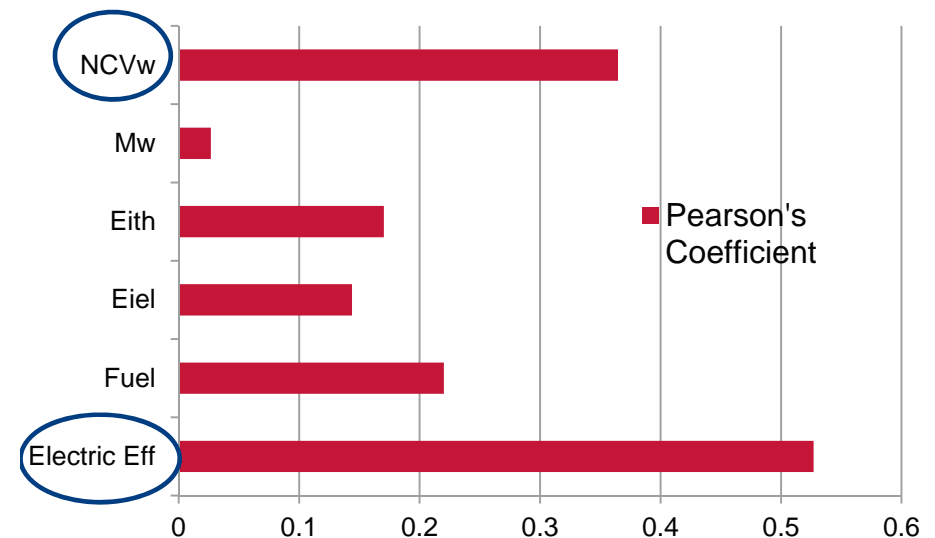
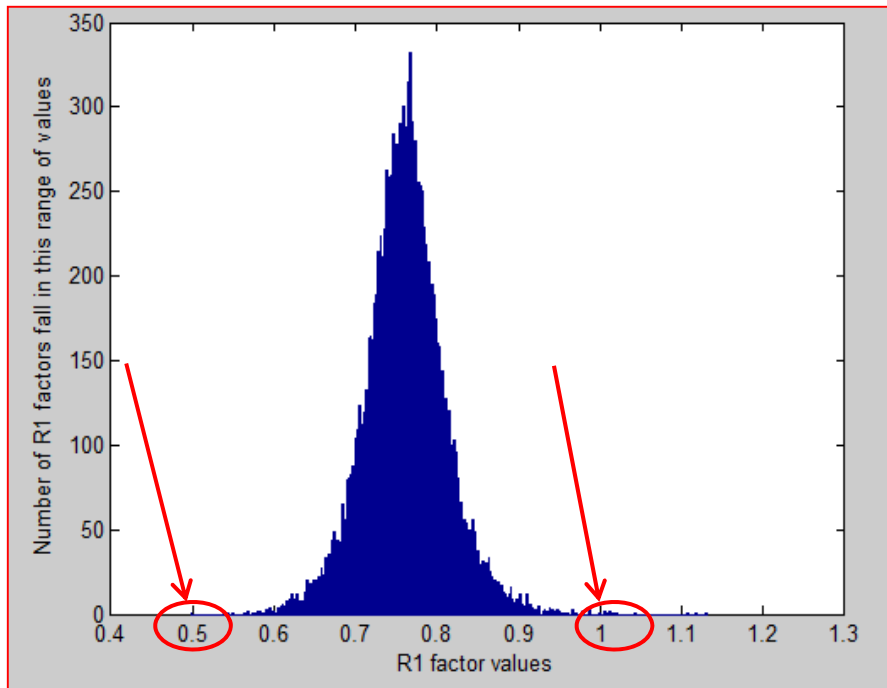
Technical corrective factor: energy losses due to radiation and bottom ash

R1 EfW formula – sensitivity analysis and implications



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Source: Chatzopoulou *et al.*, 2012



- Every mathematical formula has inherent implications
- Every system boundaries has fundamental consequences
- Policy decisions may not apply equally well universally (e.g. climate)
- Need to **typify processing and materials value chain – how?**

Recycling metals (Au, Cu, Al) via EfW: Full liberation of contraries



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aluminium		
thermo re	grain size [mm]	3-5
	net weight [kg]	1'097
date of manufacture	10.9.2012	

Some key challenges for our recycling systems



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- What EU will do if **China did not accept** any of their recyclables?
- **Why EU (and USA and Japan) have to export** so much materials? A starting point to rethink the sustainability of the current practices!
- Environmentally, **everything depends on the local (mostly Chinese) management of recyclables** - which is not 100% known to us
- Need consider the **global dimensions** of waste management
- In the **long-term Chinese monopoly in recyclables** sets the basis for a very strong, local waste management and recycling market which will manage the local recycling systems too

Waste hierarchy and resource efficiency



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- Resource efficiency contribution of recycling needs a **systems evaluation approach**: e.g. via
 - **Life cycle / Exergy + material flows analysis**
 - Closed loop vs. down-cycling: cannot be equal
 - Multiple life closed-loop recycling should be rewarded
 - What in the absence of technically feasible recycling?
 - What is the optimal **sustainable recycling** level?
 - **What if down-cycling or energy recovery is best available option?**
 - Poorly controlled export + down-cycling vs. safe energy recovery?
 - How does **material criticality** influences recycling performance evaluation?

Recycling operation modes: **BAU** vs. focusing on actual **resource efficiency quality outcomes**



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Recycling
business as usual
**High unverifiable
number**

Collected for recycling-
exported for???

No metrics – poor data –
low confidence

No End of Waste –
quality management

Multiple closed loop and
down-cycling equal

Recycling for resource
efficiency

**Quality and impact
orientated**

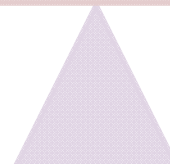
**Systems
optimisation**

Systems holistic
approach – scientific +
policy metrics as R1 EfW

Clear quantification of
contribution to resource
recovery

Meaningful waste
hierarchy level
distinctions

Lower recycling numbers
– more tangible benefits

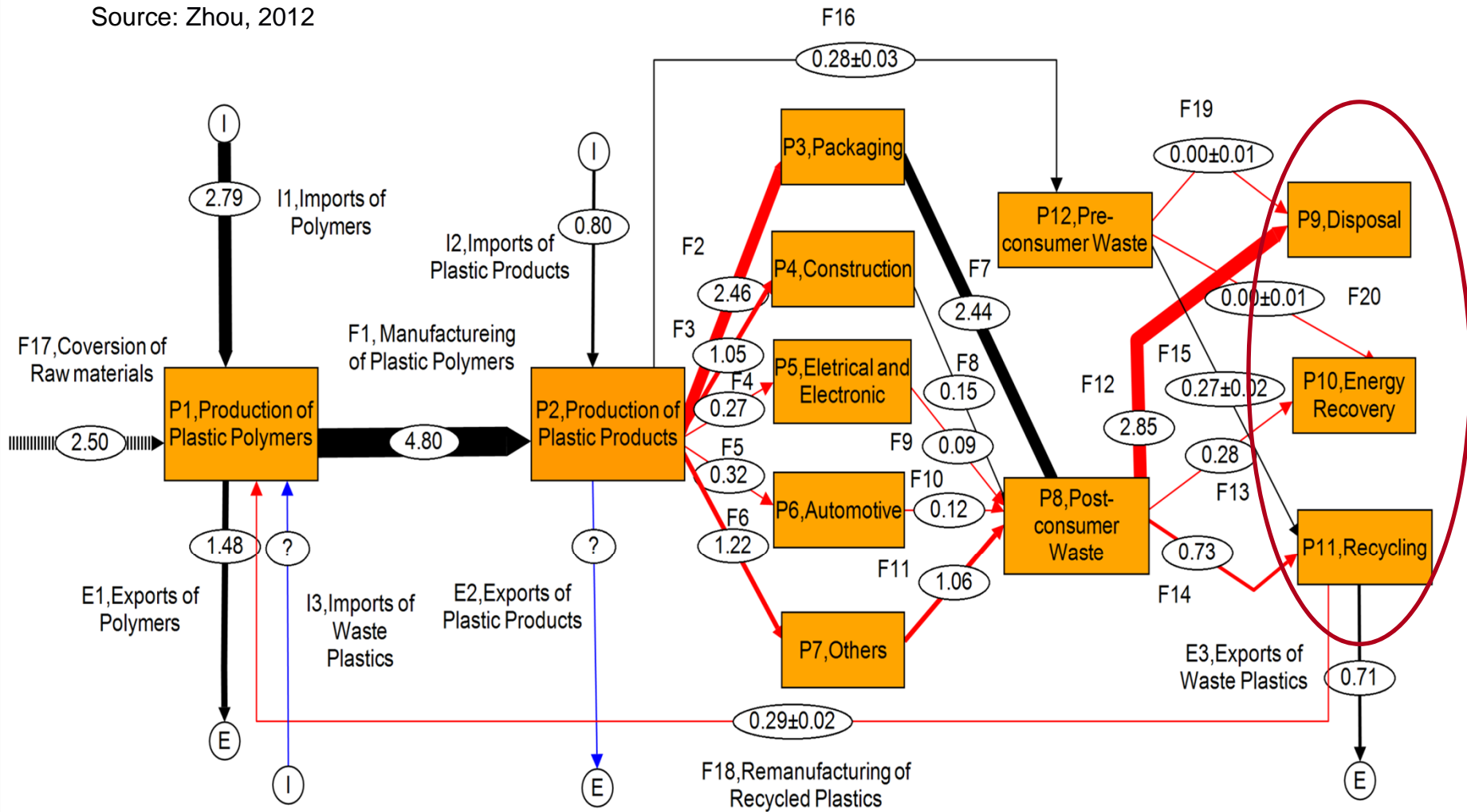


Before and after the SWM sub-system



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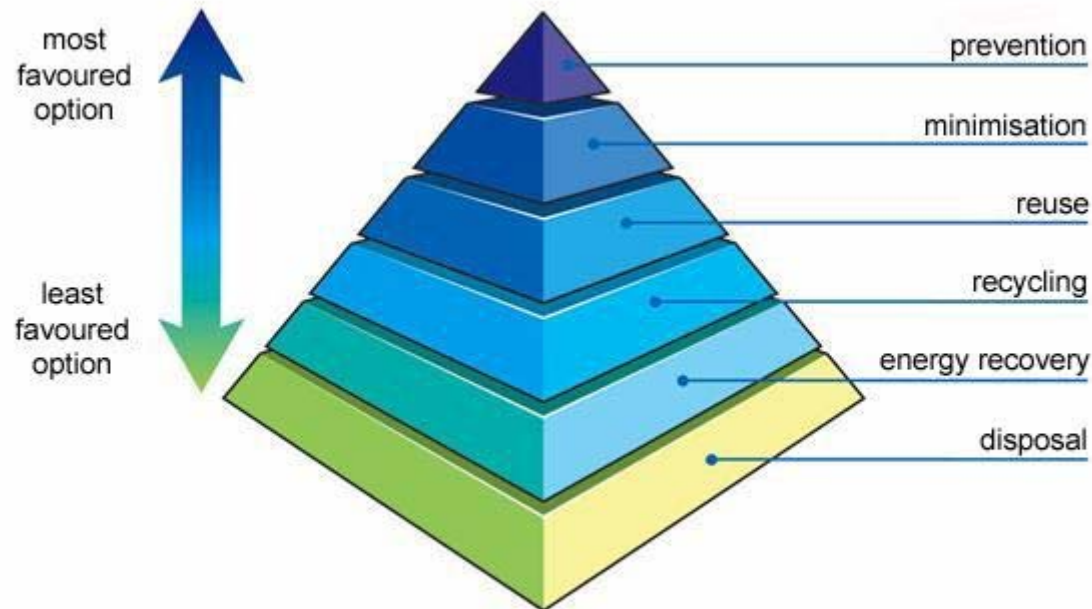
Source: Zhou, 2012



Waste hierarchy according to 2008/98/EC Directive (Art. 4)



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Source: <http://www.ehsgs.com/company-ethos.html>

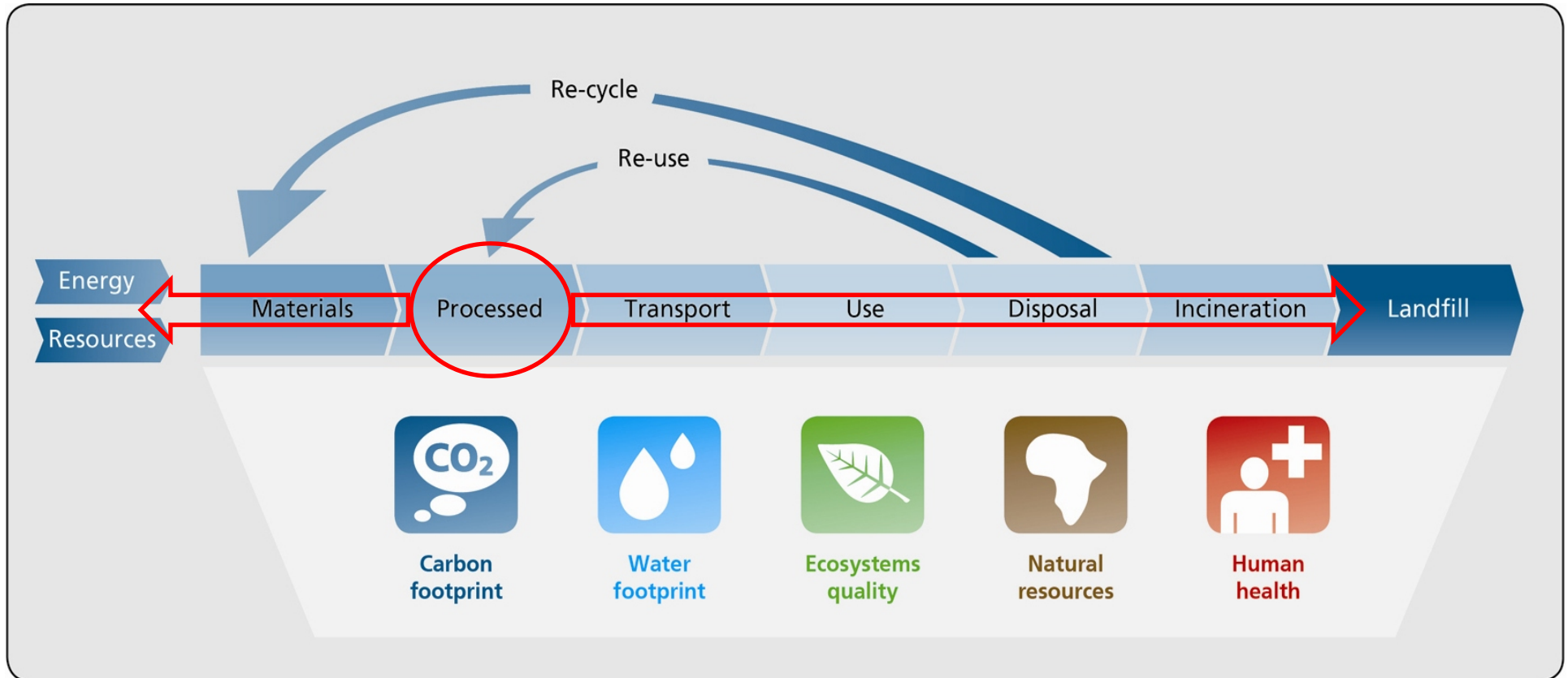
BUT: 'When applying the waste hierarchy, Member States shall take measures to encourage the options that deliver the best overall environmental outcome.

This may require specific waste streams departing from the hierarchy where this is justified by life-cycle thinking on the overall impacts of the generation and management of such waste'

Life cycle assessment: not enough, usually downstream + not dynamic



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Consequential LCA = up- /downstream consequences of a single change

Complex Value Optimisation of Resource Recovery



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WM&R editorial [31 (6), 539-540] Velis and Brunner: *'Recycling and resource efficiency: it is time for a change from quantity to quality'*

8th ISWA Beacon Conference on Waste-to-Energy Malmö, 27-28
November 2013: *'Optimising resource recovery value: the case of recycling systems'*

University of Leeds C-VORR cross-disciplinary research project:
framework and tool for

optimizing resource efficiency beyond just SWM

Complex Value Optimisation of Resource Recovery



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“If you cannot measure it, you cannot manage it”

C-VORR: novel framework and tool

**for optimizing resource efficiency beyond just
solid waste management**

Make trade offs explicit – eliminate partial accounting

Extend to comprehensive environmental and social valuation

Do not lose transparency by unnecessary aggregation

Separate objective measurement from value judgment

Explicitly design your system boundaries

Include all ‘values’ that could be of relevance

Sophisticated multi-objective optimisation

**Inform the urge to circular and green economy with real
comprehensive evidence**

Thank you!



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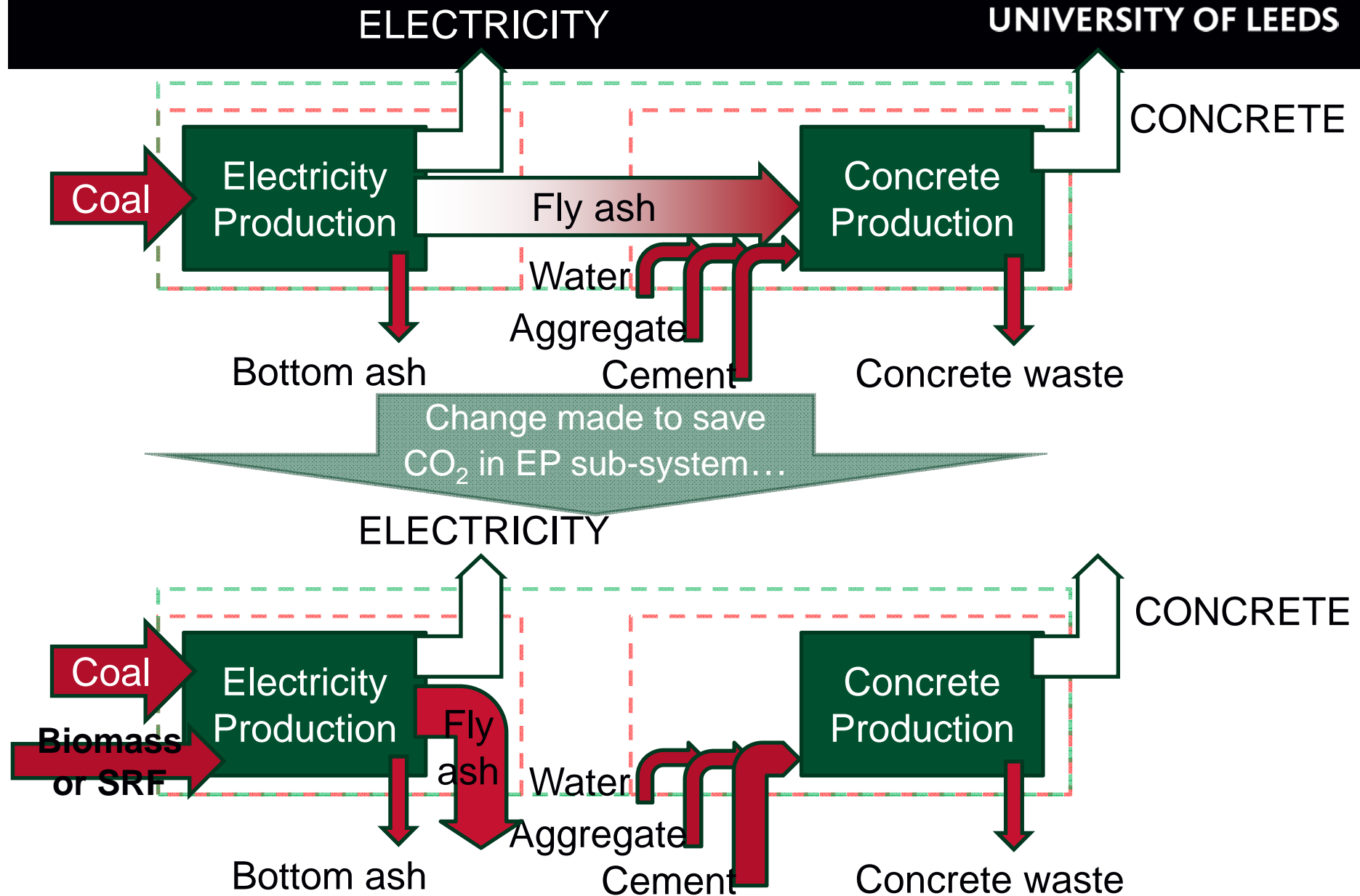


c.velis@leeds.ac.uk

Power plant – cement systems



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What happens within China?



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There is insufficient understanding on the fate of the plastic crap after entering China and its implications for local and global health and environmental considerations

- China is top consumer of plastics: **plastic products consumption** grew rapidly from 22kg per capita (kg p⁻¹) in 2005 to 46kg p⁻¹ in 2010 (Liao, 2011).
- Sufficient supply of plastic resources is becoming increasingly important.
- Long term demand for waste plastics in China is closely related to the gap between the supply and demand of primary plastics. **Chinese domestic supply** is inadequate to meet the demand- BUT capacity of the domestic petro-chemical industry develops dramatically. The production of synthetic resins doubled in the past six years, reaching at around 48Mt in 2011.
- **Almost half of the primary material is imported.** The total yearly imports of primary plastics in 2011 were 23Mt, covering just less than 50% of total demand.
- Chinese government regards that the **dependency on imports of one commodity should not exceed 50%**, and the utilisation of recycled plastics can effectively reduce Chinese dependency on imports of primary plastics
- Poyry, based on CBI China projections, predicts that the Chinese (including Hong Kong) **demand for recovered plastics could reach 29Mt by 2015**

But the 'Green Fence Operation' is rapidly changing import facts

Extracting value from waste plastics



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- If hierarchy mandatory and meaningful: clear differentiation on the level of **contribution to resource efficiency: not feasible**
- Different **UTILITY** between Re-use >> recycling >> recovery levels
- In “recycling” **virgin (raw) materials should be replaced / or End of Waste?**
- System boundaries? **MRF output vs. virgin material substitution?**
- **Overestimation** by considering rejects and emissions as “recycled”
- **Export for down-cycling** – human health and environmental risks?
- **No quality**, no material criticality, no systems / overall resource efficiency **considerations for recycling**
- **No evaluation at all.** E.g. as the EfW is leading the way to quantifying efficiency and quality via R1 and biogenic content measurement