SEA circular
solving plastic pollution at source

SEA of Solutions
partnership week for marine plastic pollution prevention
11-14 november 2019

Status and potential solutions for chemicals of concern in plastic

Roland Weber[1,2], Nicolò Aurisano[3], Peter Fantke[2,3]
[1]Spain-Stockholm Convention Regional Centre (SCP/RAC) associated expert; POPs Environmental Consulting, Schwäbisch Gmünd, Germany
[2]International Panel on Chemical Pollution, Zürich, Switzerland
[3]Technical University of Denmark, 2800 Kgs. Lyngby, Denmark

UN environment
United Nations Environment Programme

Mediterranean Action Plan
Barcelona Convention

Regional Activity Centre for Sustainable Consumption and Production

Increasing production & consumption – transgressing global boundaries

Marine Plastic Pollution

Plastic Waste Trade Crises in South&East Asia

Reduction, restriction and phase-out of (selected) plastic products

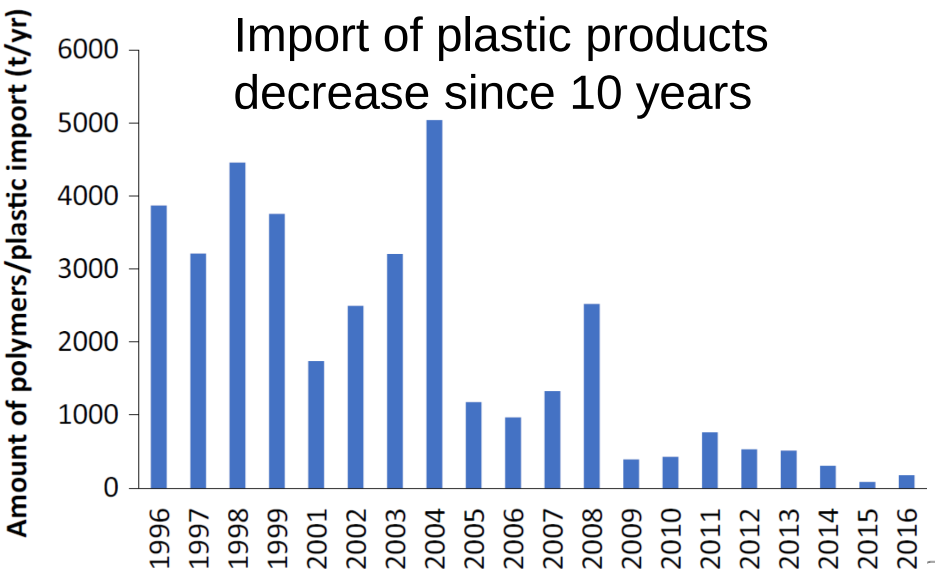
- Considering the waste hierarchy, reduction and phase out of (selected) plastic products is a priority. This reduces also chemical additives.
- Already a range of activities of restriction and reduction of the use of plastic (UNEP 2018 SINGLE-USE PLASTICS - A Roadmap for Sustainability)
  - Restriction of plastic bags (more than 60 countries)
  - Restriction of single use plastic (EU; Rwanda)
  - Phase out of micro-plastic in consumer products

Philosophy of Late King Bhumibol Adulyadej of Thailand:
"Sufficiency Economy"

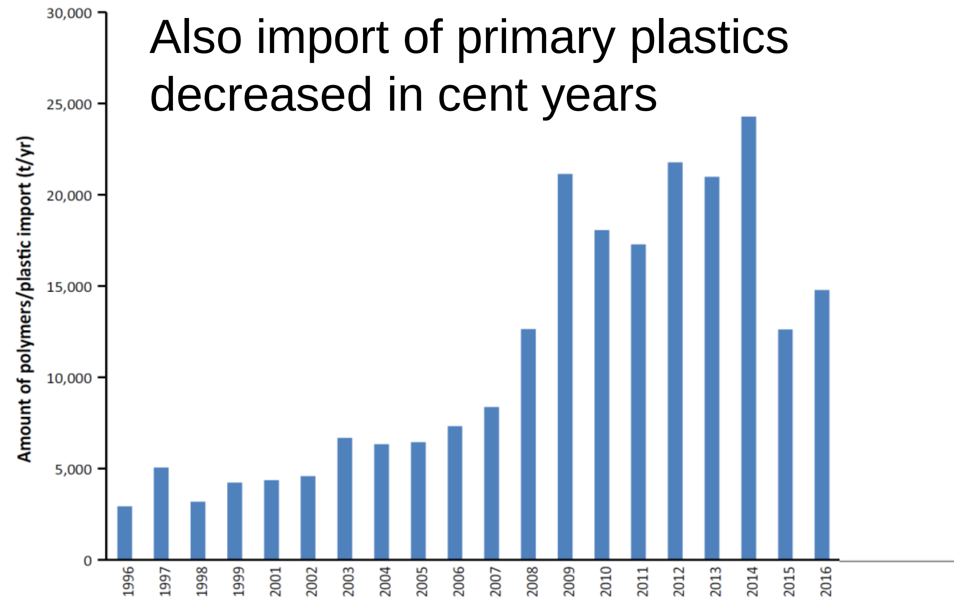
Rwanda – African champion in plastic reduction

- Rwanda demonstrates that with bans, restrictions & strict enforcement, a significant reduction of plastic import and use can be achieved

Import of plastic products decrease since 10 years



Also import of primary plastics decreased in cent years



- Strong political enforcement
- Weak plastic industry in Rwanda

While in other African countries plastics imports increased

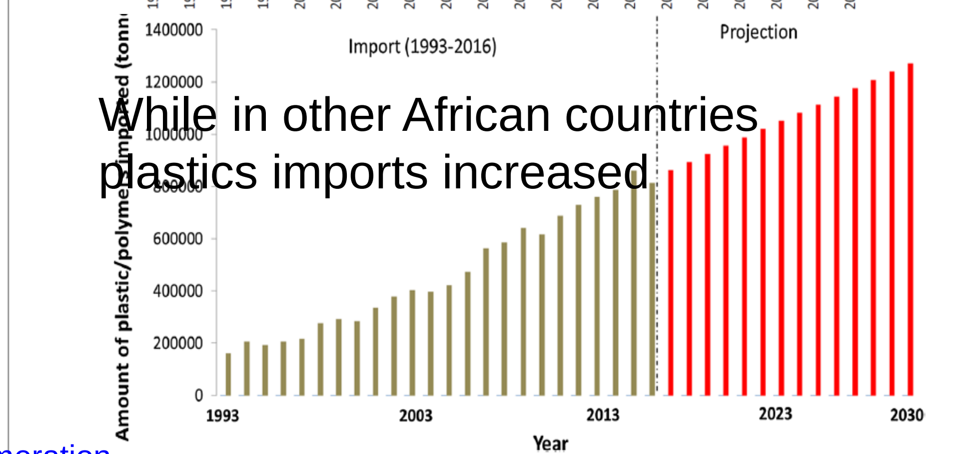


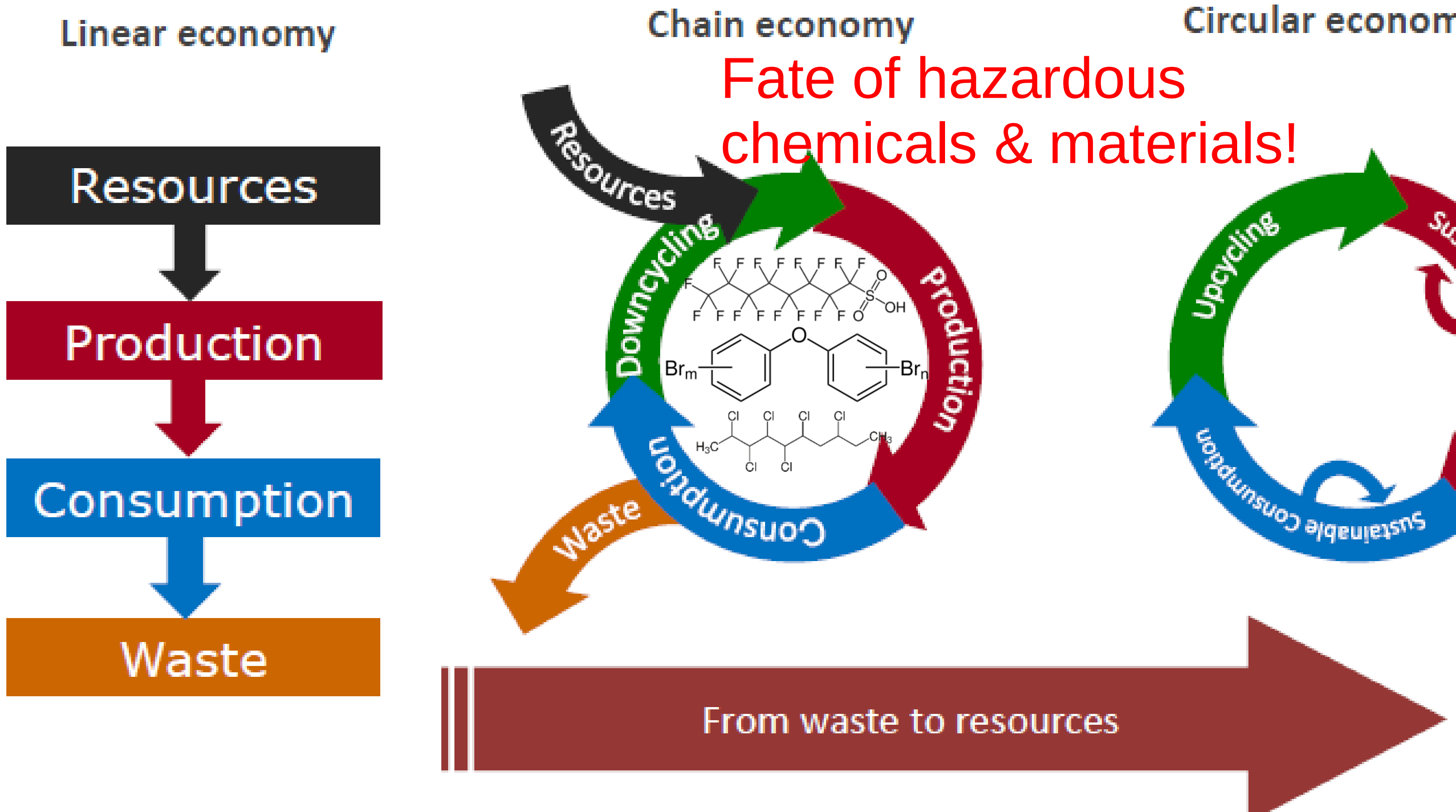
Fig. 4 Time trend of plastic/polymer import into Morocco

Babayemy et al. 2019 Environ Sci Europe 31:60.
https://link.springer.com/article/10.1186/s12302-019-0254-5#enumeration

Need & problems to move to Circular Economy

Considering the waste crises and the limit of resources, humanity needs to move to circular economy (stressed by GEF, UNIDO, EU)

http://ec.europa.eu/smart-regulation/impact/planned_ia/docs/2015_env_065_env+_032_circular_economy_en.pdf

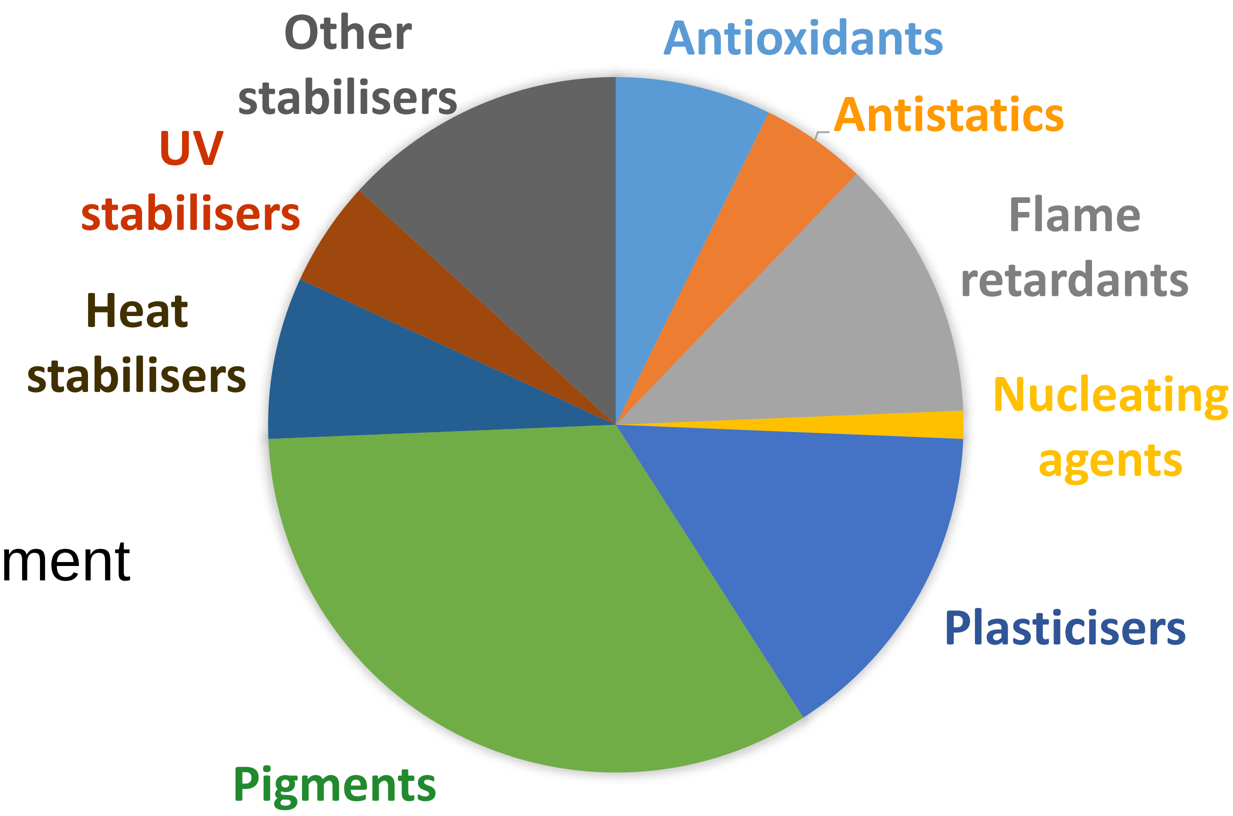


Bonnet (ARC+) Circular Economy, saving resources, creating jobs, Green Week Brussels June 2014

When moving to a (more) Circular Economy, POPs and other hazardous chemicals need to be controlled and phased out.

Plastic contain a wide range of chemical additives

- Plastic is a mixture of polymer (e.g. PVC; Polystyrene, PE, PP) and additives which are needed for the performance of a plastic.
- 9 major types of functional additives & pigments (ECHA)
- Plastic frequently contain 6 additives and more.

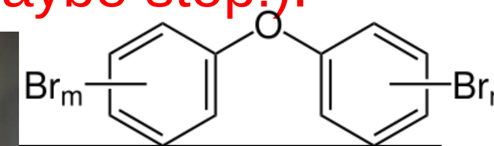


ECHA Assessment

PBDE/BFR contamination in recycled plastic

- High levels of PBDE & PBDD/F in recycled plastic in sensitive uses!
- Risks to human health demonstrated (Chen et al. 2009; Ionas et al. 2016).
- Challenge to control recycling in developing & emerging economies.
- Two provisional Basel Convention low-POP limits pending for decision (50 ppm and 1000 ppm). If 50 ppm would become limit it would have considerable impact on recycling of WEEE plastic (maybe stop!).



PBDE in carpet padding (DiGangi et al, OHC , 2011)

PBDE in children toys China (Chen et al, ES&T 43, 4200, 2009)

PBDE in thermo-cup Samsonek & *Puype (2013) Food Add. & Contam.*
Prof. Miriam Diamond: Salad servers

⇒ A) Need of a better life cycle management and control.

⇒ B) Need of non-toxic alternatives for clean material cycles.

Life cycle management & control for circular economy: Moving towards more circular WEEE plastic management

Procurement	Processing	Selling

Procurement

- Growing supply
- Land-filled/Incinerated

↓

- Self-replenishing
- Sustainable and growing supply

Processing

- Mechanical 'mining' process

↓

- < 10% of energy
- <10% of water consumption
- Save about 1-3 tons CO_2/ton

Selling

- "Green" products
- Virgin-like quality possible

↓

- More sustainable business
- PCR plastics

Back to EEE plastic!

Life cycle management & control for circular economy: Moving towards more circular WEEE plastic management

- Full scale plants to separate PBDE/bromine-containing polymers. Stockholm PBDE BAT/BEP guidance to support global phase-out.

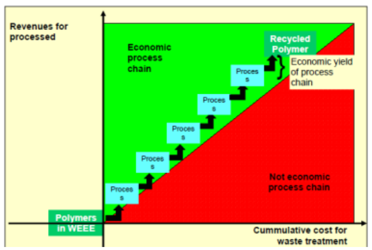
WEEE input	Separation techniques	Polymers Separated	Quality of separated polymers	PBDE/bromine Elimination (RoHS compliant products)	Development Stage*	Reference
Mixed polymer from WEEE (Austria, China)	Not disclosed	A) Low-bromine types of ABS, HIPS and PP	A) Good (Customer specify)	Yes bromine rich fraction incinerated	Industrial scale	MBA Polymer Patent
Small electronic equipment, White goods (Switzerland)	Includes XRT	bromine and PVC free polymers	Good	Yes	Industrial scale	(Gerig 2010)
WEEE polymers (UK)	Undisclosed	Low-bromine types of ABS and HIPS	Good	Yes	Industrial scale	(Morton 2007)
WEEE polymers (Germany)	Undisclosed (incl. S/F and Electrostatic)	Low-bromine types of PP, ABS and HIPS	Good	Yes	Industrial scale	(wersag 2011)
Mixed polymer from WEEE (Germany)	Successive Grinding and XRT	bromine and PVC free polymers	Not approved yet	Yes	Industrial scale	(Adamec 2010)

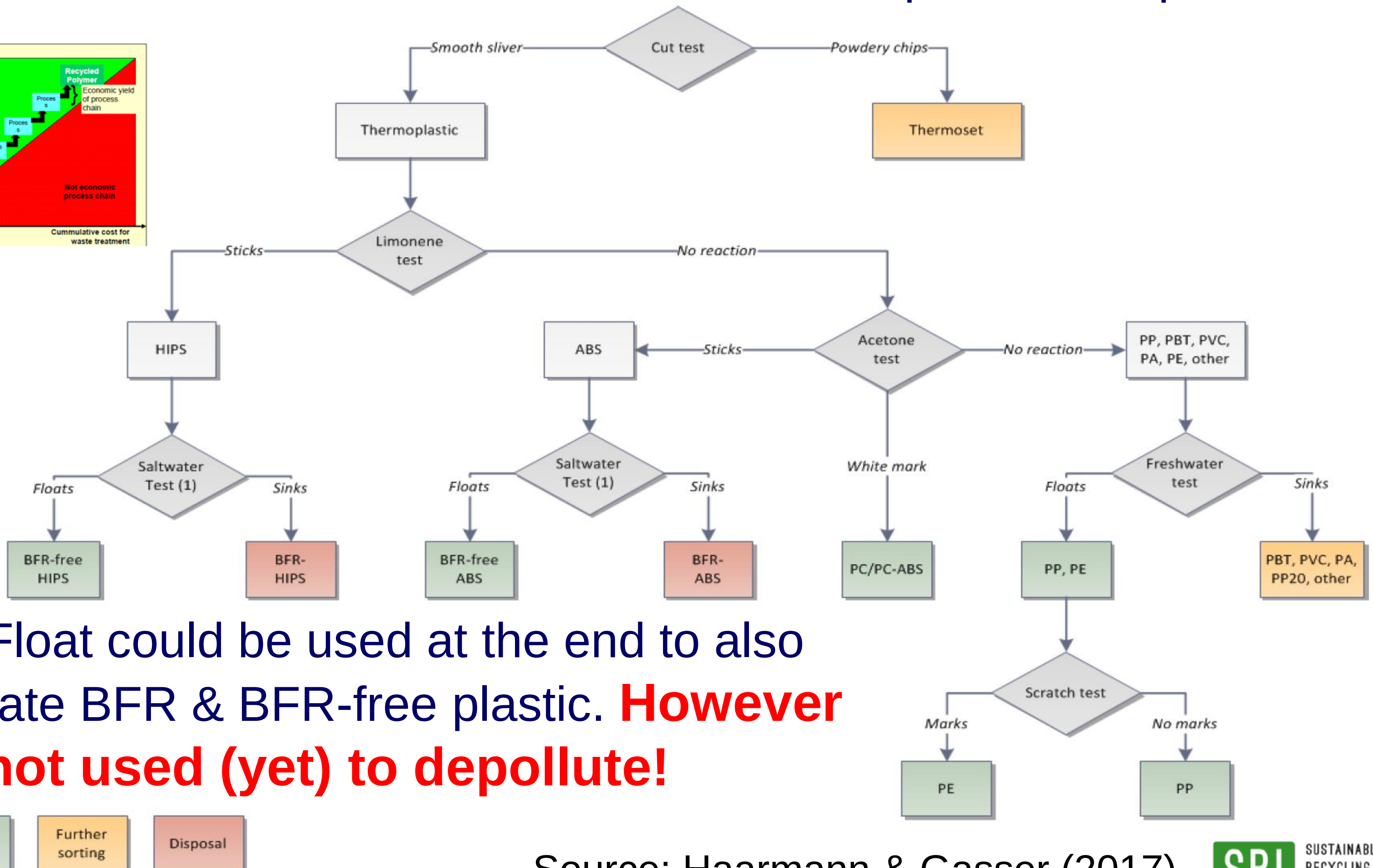
- Separation reach ca. 100 ppm PBDEs. Hence stop if 50 ppm-limit.

STOCKHOLM CONVENTION

Separation and upgrading steps in the recycling of (WEEE) plastic: Indian informal recyclers

- Informal recyclers developed separation of plastic with simple tools.
- With these methods 10,000ds of tonnes WEEE plastic is separated.



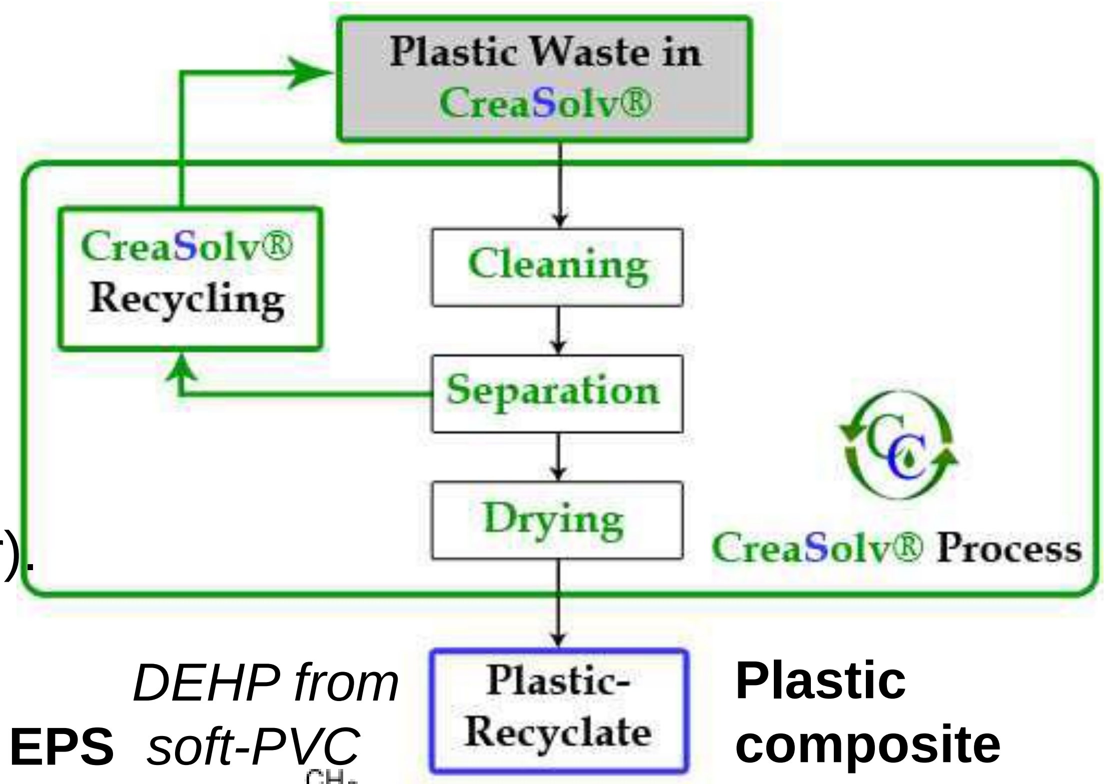


- Sink/Float could be used at the end to also separate BFR & BFR-free plastic. **However it is not used (yet) to depollute!**

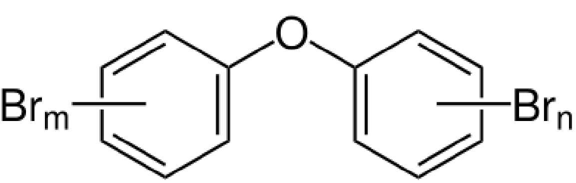
Source: Haarmann & Gasser (2017)

Recycling of plastic with legacy additives? CreaSolv®

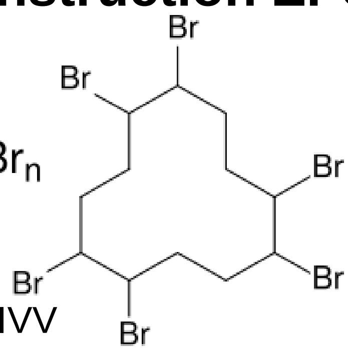
- CreaSolv® process enables separation of e.g. BFRs from BFR plastics by a solvent-based recycling approach .
- BFR are separated as a BFR rich residue and may be used for Bromine recovery (circular).



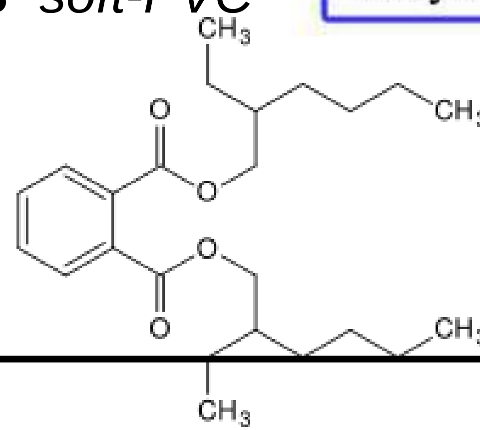
PBDE/BRs from WEEE plastic



HBCDD from construction EPS



DEHP from soft-PVC



Plastic composite packaging materials

(Full scale plant in Indonesia)

CreaSolv® is a registered trademark of Creacycle, Gmbh, Grevenbroich, Germany

Fraunhofer IVV

Need of non-toxic alternatives for circular economy!
POP-BFR often substituted by other BFRs

When looking to substitution history of PBDEs we find that often **regrettable alternatives** were chosen which are now also listed as POPs or are of concern.

Polymer	Content [%]	POP-BFRs	Alternative introduced
High impact polystyrene	**11–15**	**OctaBDE**	**DecaBDE, Br-polystyrene Ethane 1,2 bis(pentabromophenyl)**
Epoxy resin	**0-10**	**PentaBDE**	**TBBPA**
Polyamides	**13–16**	**OctaBDE**	**DecaBDE, Br-polystyrene**
Polyolefins	**5–8**	**OctaBDE**	**DecaBDE, propylene dibromo styrene**
Polyurethanes	**10-18**	**PentaBDE**	**Brominated polyols**
Polyesters	**8–11**	**OctaBDE**	**Brominated polystyrene**
Unsaturated polyesters	**13–28**	**PentaBDE**	**TBBPA**
Polycarbonate	**4–6**		**Brominated polystyrene**
Textiles	**12–15**	**PentaBDE**	**DecaBDE, HBCD**

For DecaBDE industry voluntary phase-out was concluded with US EPA – however emerging economies continue production & many exemptions in Stockholm listing.

Modifications in the substitution approach to achieve a successful phase-out and replacement of hazardous chemical additives

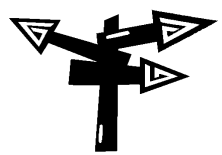
Current practice		Recommended practice
Voluntary by some producers/countris	Phase-out agreement	Binding, cross-sector, national/regional/global
Pre-selction to known, similar substances	Inventory of alternatives	Function oriented design Structural different substances
Incomplete assessment or burden shifting	Assessment of alternatives	Complete assessment incl. life cycle impacts
Incremental substitution similar hazard profile	Selection of alternatives	Fundamental substitution overall reduced haz. profile
No or slow phase-out	Phase-out implementation	Effective phase-out

Fantke et al. (2015) Sustainable Chemistry and Pharmacy 1, 1-8

Alternatives Assessment and Available Tools for chemical substitution

Identify Chemical of Concern | Select Priority Uses | Identify Alternatives | Characterize Alternatives | **Compare Alternatives** | Score Alternatives

Capacity building needed!



Design for the Environment U.S. EPA

GREEN SCREEN FOR SAFER CHEMICALS

Pharos

optimized by MBDC

ToxCast™

TiPED Tiered Protocol For Endocrine Disruption

NSF SUSTAINABILITY CERTIFIED

UL

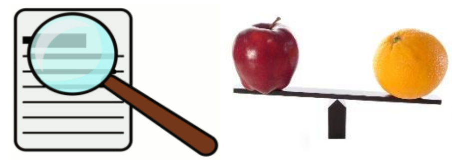
eiolca.net

Economic Input-Output Life Cycle Assessment

iSUSTAIN™ Green Chemistry Index

GaBi Software

Ken Geiser (Lowell Center for Sustainable Production)



Compare Alternatives

Compare hazard profiles

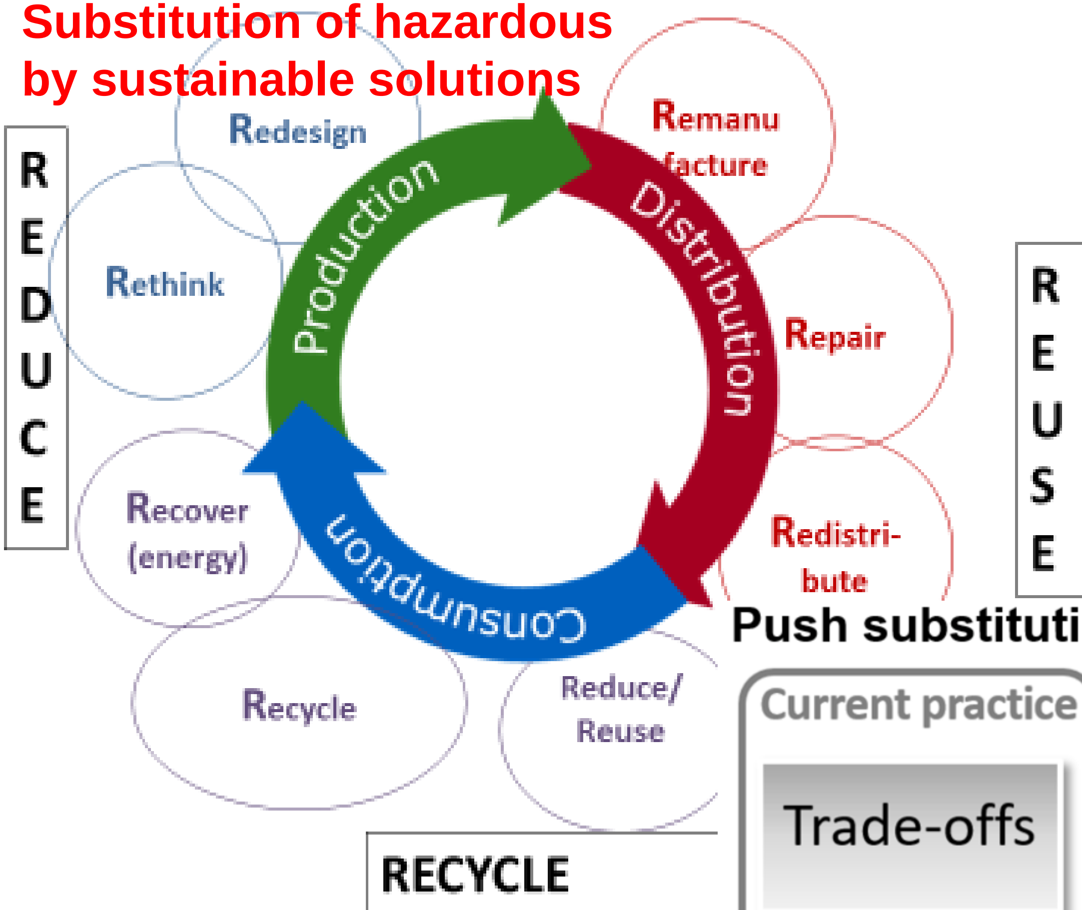
Use available screening tools

- TURI's P2OASys
- **CPA's Green Screen**
- HBN's Pharos

GUIDE ON SUSTAINABLE CHEMICALS

Push substitution into the product design phase

Substitution of hazardous by sustainable solutions



Push substitution into product design processes

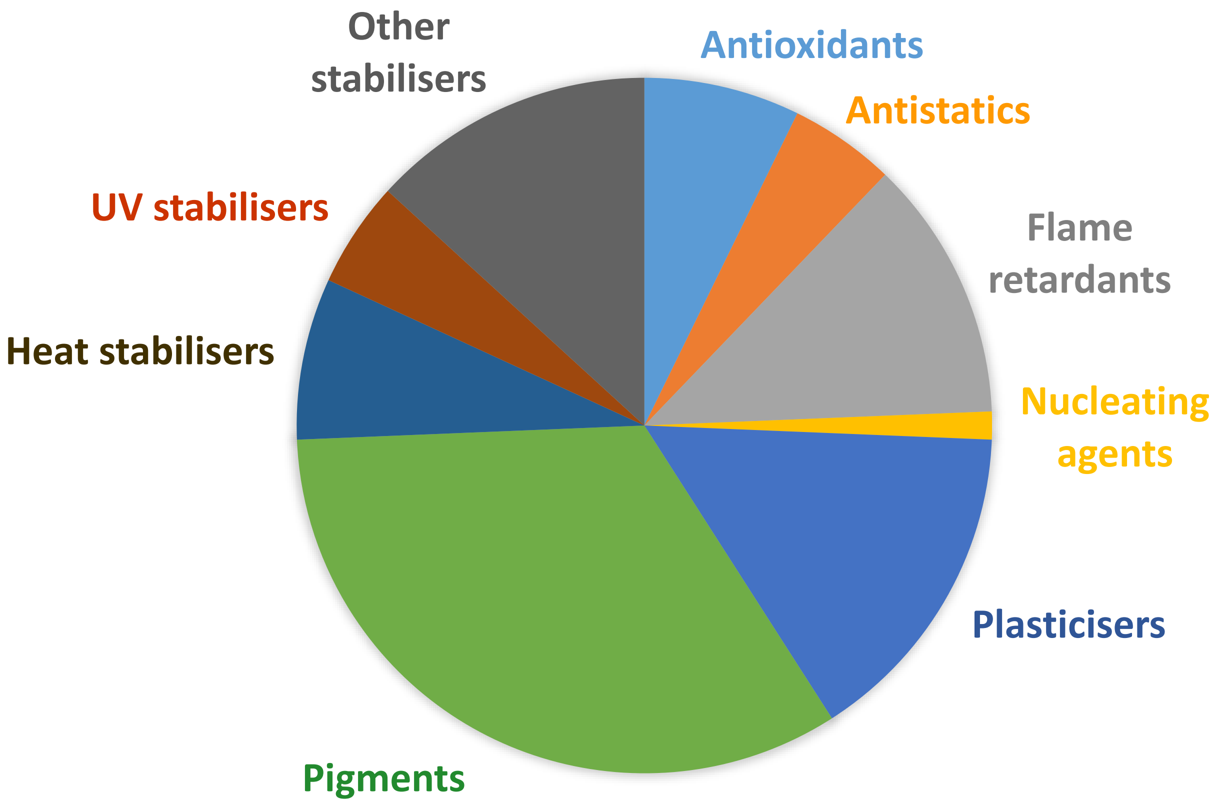
Current practice

- Trade-offs → **Performance needs to be combined with environmental sustainability during design**
- Qualitative → **Qualitative metrics need to be replaced by quantitative life cycle-based metrics**
- Relative → **Relative improvement needs to be increased to meet targets for sustainability**

ECHA: Overview of confirmed plastic additives

418 substances confirmed to be used as plastic additives in EU >100 t/a (under REACH):

- 9 types of functional additives & pigments
- Additional info: polymer type(s), typical concentration



Not covered: Monomers, polymers, cross-linkers, Transformation & degradation products

Overview available at: https://echa.europa.eu/mapping-exercise-plastic-additives-initiative

Assessment needs & overview of used substances – Compilation of compounds present in plastics

For a review for UNEP, a list of >1300 chemicals (not only additives) found in plastics were compiled:

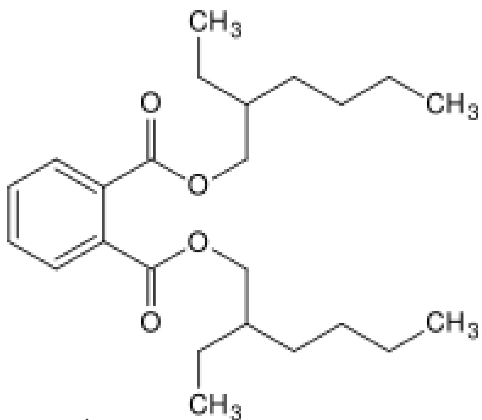
- National and international agencies (e.g. ECHA overview)
- Database of Chemicals associated with Plastic Packaging (CPPdb, Groh et al. 2019 Sci Total Environ. 651, 3253-68) with more than 900 chemicals identified as likely associated with plastic
- Studies from academia on plastic products covering different sectors (e.g. plastic toys, childcare products)
- Plastic-specific consumer products studies (DK EPA)

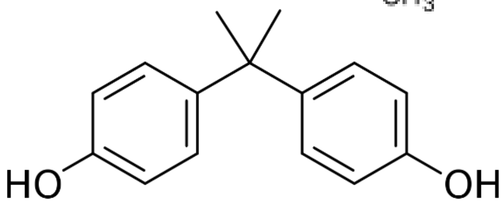
References: ECHA 2019, DK EPA 2018, Abe et al. 2012, Al-Natsheh et al. 2015, Biedermann-Brem et al. 2018, Bouma & Schakel 2002, Chen & Zhang 2013, Chen et al. 2009, US CPSC 2010, Ionas et al. 2014, Johnson et al. 2011, Korfali et al. 2013, McCombie et al. 2017, Stringer et al. 2000, Xie et al. 2016, Hansen et al. 2013, Stenmarck et al. 2017, Groh et al. 2019

Use areas & substances of concern to start substitution

Within a review for UNEP, substance groups of concern and plastic use areas of concern were identified. These can be targets for substitution:

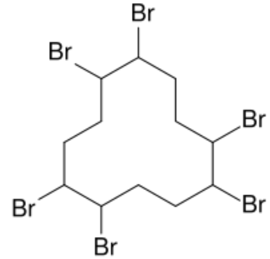
- Toys and other children’s products
- Packaging including food contact materials
- Medical devices
- Synthetic textiles and related materials
- Electronical and electronic equipment
- Building materials

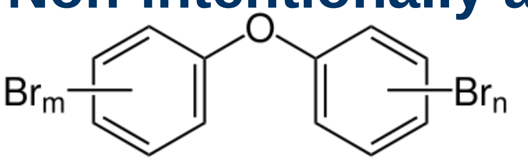


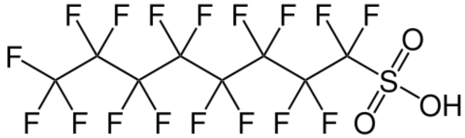


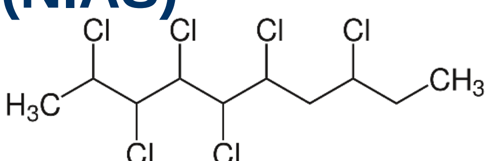
Major plastic additive groups of concern:

- Flame retardants • Per- and polyfluorinated substances
- Phthalates • Bisphenols • Nonylphenols • Heavy metals
- Polyaromatic hydrocarbons (PAHs) • Biocides • UV filters
- **Non-intentionally added substances (NIAS)**





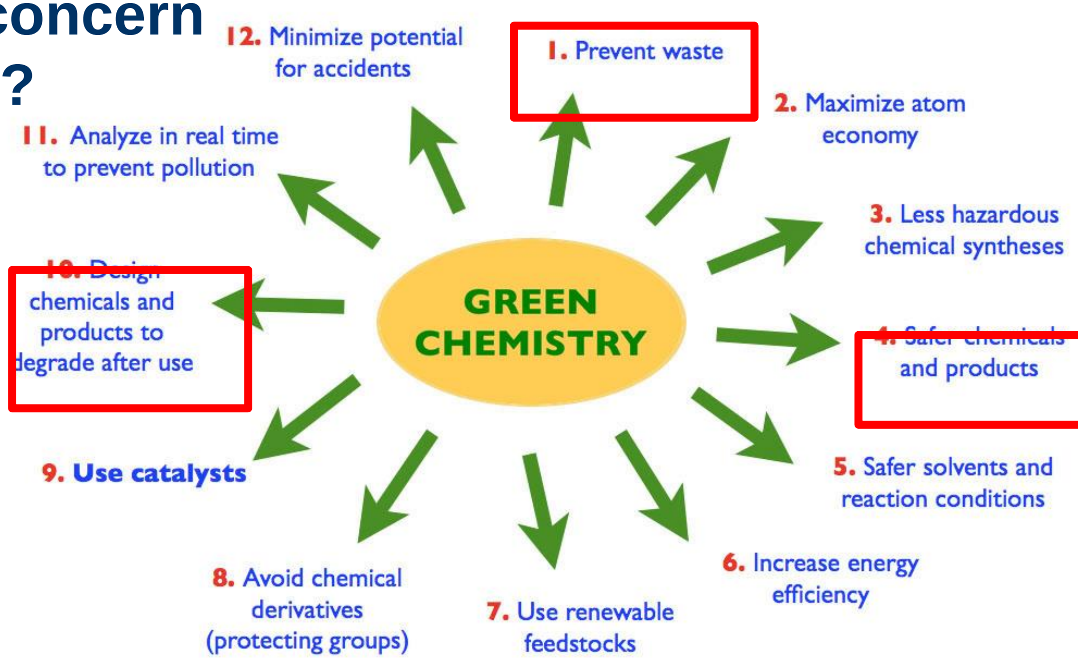




Multilateral Environmental Agreements – Opportunity to substitute hazardous by green/sustainable chemicals

- The substitution/phase-out of hazardous chemicals on international level started within the Stockholm Convention (POPs) and is a promising mechanism to mainstream more sustainable and greener chemicals and other alternative solutions.
- The phased out of hazardous chemicals is at the same time the business opportunity for sustainable and green chemicals!.

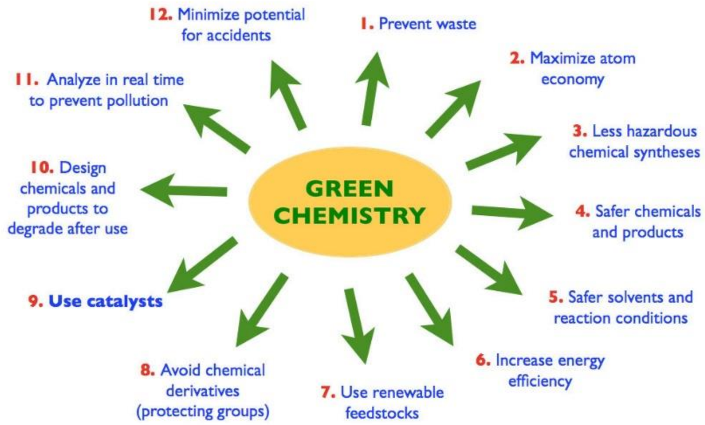
- **Could other additives of concern be addressed within SAICM?**



Anastas and Warner (1998)

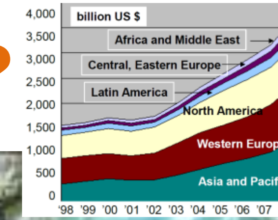
Efforts for a way forward

- Understanding: Many hazardous chemicals and groups of chemicals of concern are used in plastic as additives for a range of purposes.
- Ongoing compilation and assessment of additives on policy level (e.g. ECHA), UN level and by international research community (e.g. FPF).
- Within the Stockholm Convention, the substitution and phase-out of hazardous chemicals is already substituting some POP plastic additive on international level within a Convention mechanism.
- A range of restrictions and substitution of additives on national level.
- Several SAICM emerging policy issues or other issues of concern link already to additives (Chemicals in Products, Endocrine disrupting chemicals; Haz. chemicals in the lifecycle of Electronic, PFAS, Nano).
- Could chemicals of concern be addressed within SAICM and beyond SAICM 2020?
- Please note: The phased out of hazardous chemicals is at the same time a business opportunity for more sustainable and green chemicals! Regulatory and technical efforts!



Anastas and Warner (1998)

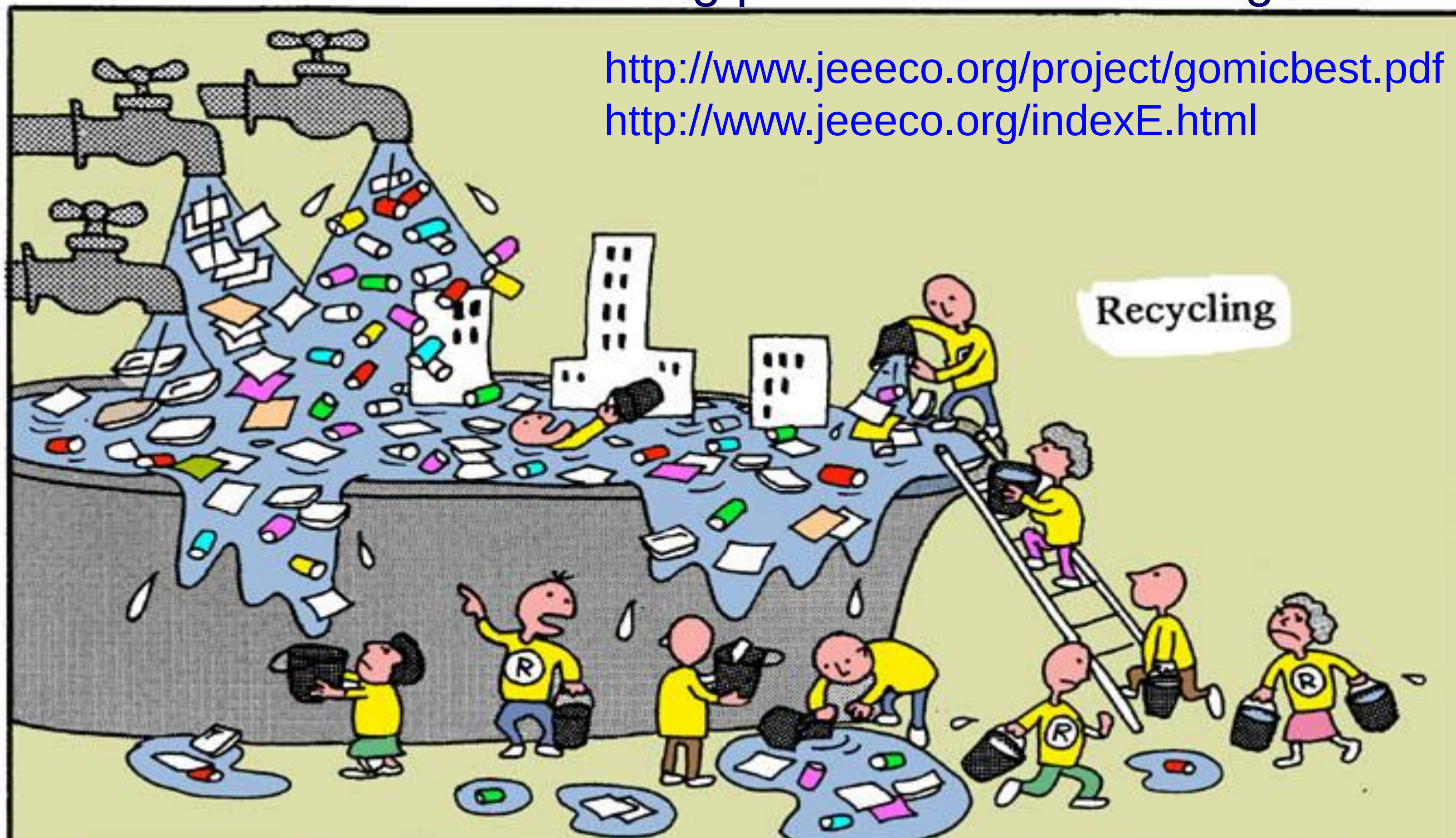
Thank you for your attention! Questions?



Plastic Waste Trade Crises in South&East Asia

Sustainable Consumption - Sufficiency Economy

In addition to circular economy & substitution, **reduction** of unnecessary chemicals/products need to be a priority for sustainable consumption (SDG 12). This will result in reduction of chemical release and exposure and therefore contribute to reaching pollution reduction targets in SDGs.



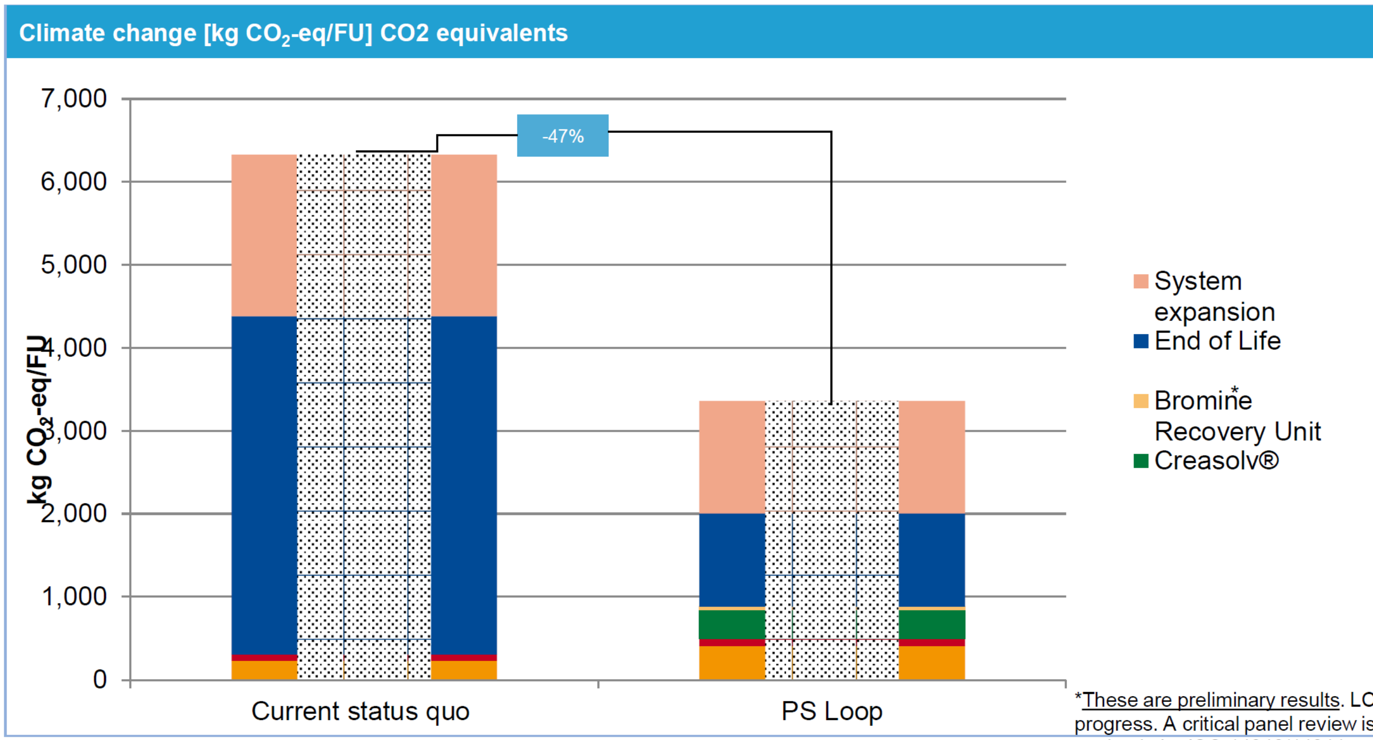
National policies of "Sufficiency Economy" of Thailand or the "Ecological Civilization" of China where sufficiency is/should be an inherent part.

Risk for plastic recycling by legacy additives

BASF
We create chemistry

Climate Change – Overall*

Intermediate results



*These are preliminary results. LCA calculation is still in progress. A critical panel review is currently taking place in order to check the ISO 14040/14044 conformity. These results are based on environmental impact and are not including a total cost assessment.

* Current stauts quo: Material mix A 87.9 % incineration of inert matter, 12.1 % incineration of polystyrene
PS Loop: Material mix B 87.4 % incineration of inert matter, Plastics (0.1 %) incineration, Metals 90% recycling/10% landfill

Current and recommended substitution practice

Current practice

Voluntary by some producers/countris	Phase-out agreement
Pre-selction to known, similar substances	Inventory of alternatives
Incomplete assessment or burden shifting	Assessment of alternatives
Incremental substitution similar hazard profile	Selection of alternatives
No or slow phase-out	Phase-out implementation

Fantke et al. (2015) Sustainable Chemistry and Pharmacy 1, 1-8

Food for thoughts:
Review finding: Pollution on soil larger than water

- Increasing plastic fragments accumulation in agricultural soils is an urgent issue. In China, ca. 1.25 Mt of plastic films were used in fields.
- These large quantities of plastics will generate fragments that will have a negative effect in the soil health and performance (Liu et al. 2014).
- Also in China, plastics were found in all soil samples in a range from 7,100 to 42,960 particles/kg, predominantly fibres. More than two-thirds were associated with soil aggregates and the rest was dispersed (Zhang and Liu 2018).
- The estimated annual input of MPs into farmland soil in Europe and North America is in the range of 44,000 to 430,000 t. Application of sewage sludge in bio-amended soils is one of the largest sources of MPs (Nizzetto et al. 2016).
- These figures are larger than the estimated numbers of MPs in the oceans, 93,000 – 236,000 t (Van Sebille et al. 2015).