Circular Economy and Plastics - *Opportunities and Challenges*
Vienna, February 22-23, 2017

THE ROLE OF RESOURCE EFFICIENCY & ECO-INNOVATION FOR A SUSTAINABLE CIRCULAR ECONOMY OF PLASTICS

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STORYLINE WITH **3 KEY MESSAGES**

THE GLOBAL GOALS For Sustainable Development

CIRCULAR ECONOMY OF PLASTICS IN THE CONTEXT OF **GLOBAL CHANGE & CHALLENGES** – A POLYMER SCIENCE PERSPECTIVE:

- KEY MESSAGE 1: ***PLASTICS*** and ***SUSTAINABLE DEVELOPMENT***
- KEY MESSAGE 2: ***CIRCULAR ECONOMY*** and ***SUSTAINABLE DEVELOPMENT***
- KEY MESSAGE 3: The global ***ENERGY TRANSITION*** and perspectives for a new *"all-circular"* ***SUSTAINABLE PLASTICS ECONOMY***

… along with some brief remarks on common (public) MISCONCEPTIONS.

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GLOBAL CHANGE & CHALLENGES (1/4)

DYNAMICS OF THE HUMAN ENTERPRISE – *THE ANTHROPOCENE*

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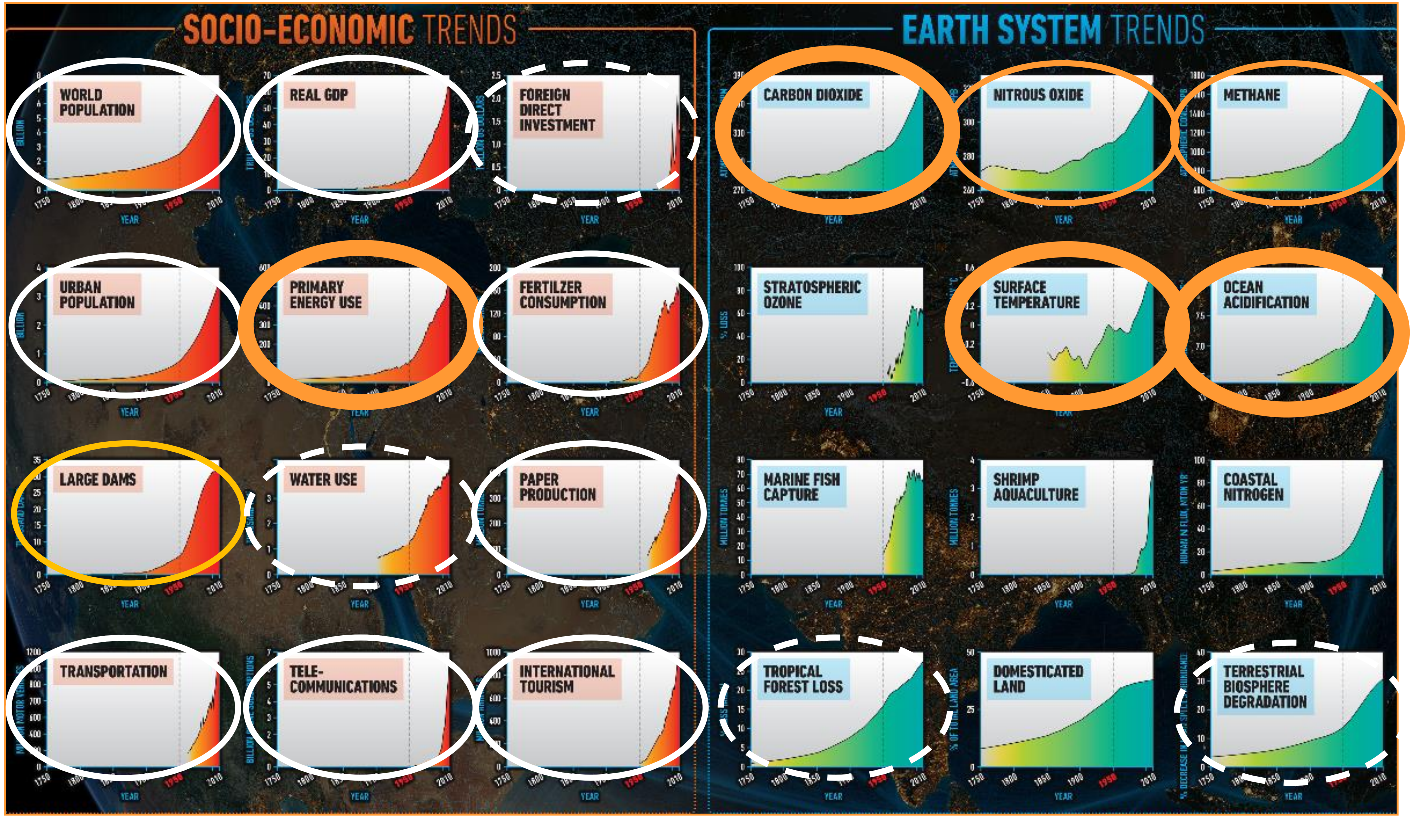
www.futureearth.org

The International Geosphere-Biosphere Programme (IGBP)
hosted by the Royal Swedish Academy of Sciences

inspired in 2000 by
P. Crutzen
(Vice Chair of IGBP)

GREAT ACCELERATION charts:
- 12 socio-economic
- 12 earth system indicators



Reference:
adapted from W. Steffen, W. Broadgate, L. Deutsch, O. Gaffney and C. Ludwig (2015), The Trajectory of the Anthropocene: the Great Acceleration, The Anthropocene Review. Map & Design: Félix Pharand-Deschênes/Globaïa

GLOBAL CHANGE & CHALLENGES (2/4)

2015 MAY HAVE BEEN A PIVOTAL YEAR

"Sustainable development" … *meets the needs of present generations* ***without compromising*** *the ability of future generations to meet their own needs.*

UN-WCED, 1987

The UN Post-2015 Agenda:

From MDGs 2015 to SDGs 2030

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STORYLINE & 3 KEY MESSAGES

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KEY MESSAGE 1: PLASTICS AND ***SUSTAINABLE DEVELOPMENT***

POLYMERIC MATERIALS are (*the*)

KEY MATERIALS for

SUSTAINABLE DEVELOPMENT *technologies!*

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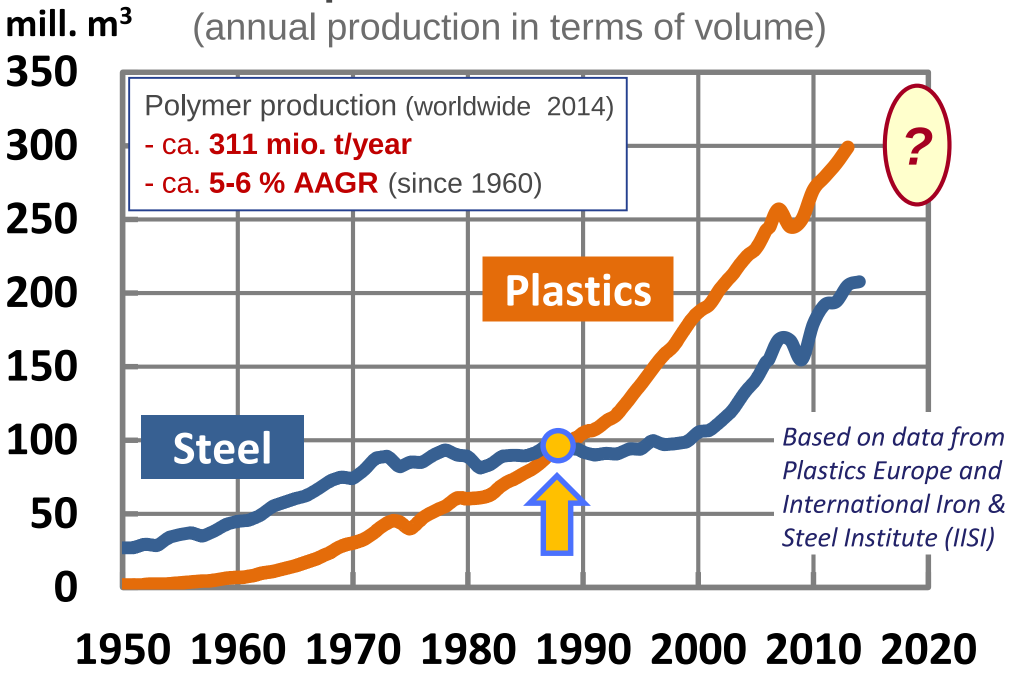
<u>Plastics</u> – Materials of the 21. Century

Historical Development & Success Factors

Development of Plastics & Steel
(annual production in terms of volume)



7 key success factors of plastics

Properties	wide range and tailorable property profiles
Design	high design flexibility; large potential for multi-functional integration
Processing	excellent processability
Economy	cost efficient products
<u>Ecology</u>	energy efficient products/applications
<u>Innovation</u>	still outstanding & extraordinary potential
<u>Growth Potential</u>	essentially no resource limitation

Plastics and polymer composites/hybrids <u>still exhibit</u> an ***<u>exceptional innovation, growth & growth rate potential</u>***, unmatched by other materials.

How to Translate the SDGs to (Polymer) Materials/Technologies?

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THE KEY IS INNOVATION !!!

*Improved **energy & product services** driven by*

- more efficiency, more (systems)intelligence
- less energy, less material
- use of regenerative resources

R. W. Lang, Inauguration Lectures (1994/2009)

Substitution of matter/energy by more intelligent solutions: IMPROVED PERFORMANCE !!!

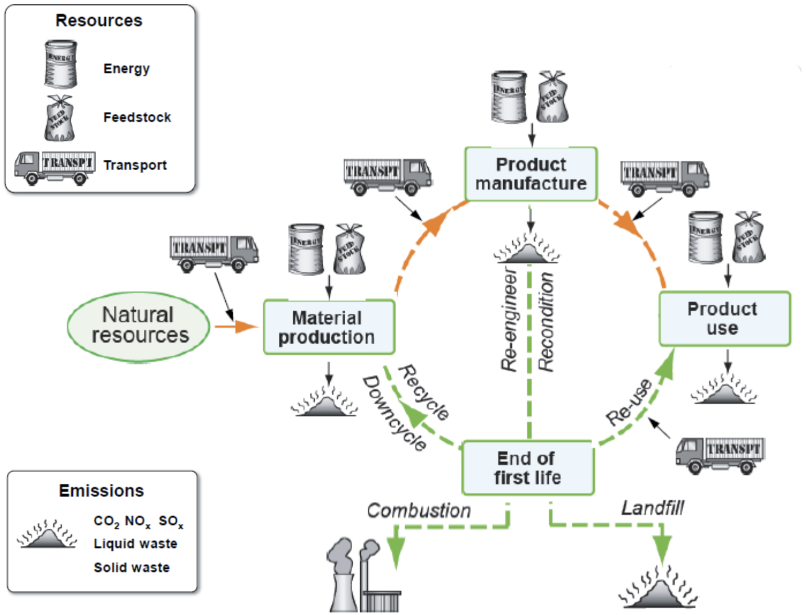
In terms of *energy/material* ***EFFICIENCY*** *per functional unit*, improvements by **factors of 4 to 8** are needed **!?**

This requires an ***OVERALL SYSTEMS APPROACH*** for optimization**!**

Plastics & Eco-Efficiency
A LC/Systems Performance Perspective

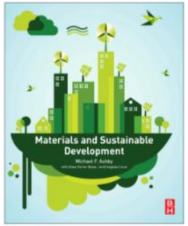
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
THE GLOBAL GOALS For Sustainable Development

The material/product life cycle

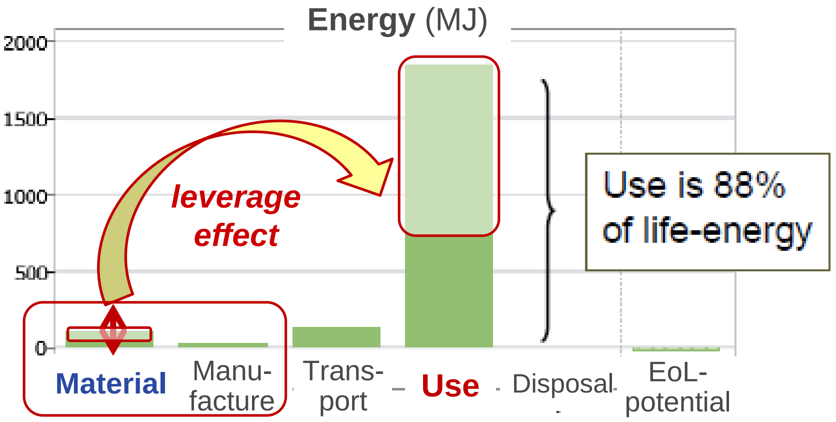


GRANTA TEACHING RESOURCES
Mike Ashby, 2015

M. Ashby
Materials and Sustainable Development
Elsevier, 2015



Typical eco-audit (LCA/PEF) result



The Innovation Challenge:
How to trigger the *greatest "overall/leverage effect"*?

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Storyline & 3 Key Messages

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Key Message 2: Circular Economy & ***Sustainable Development***

Not every *Circular Economy* path
is per se (a priori) *"SUSTAINABLE"!*

A product/application line specific *Systems Perspective*
incl. a comprehensive/full ***LC/CB Analysis*** guided approach is required
to determine *meaningful (sustainable!) recycling targets!*

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PLASTICS PERFORMANCE & RECOVERY OPTIONS

STUDIES BY DENKSTATT GMBH (H. Pilz, et al., 2010/2014/2015)

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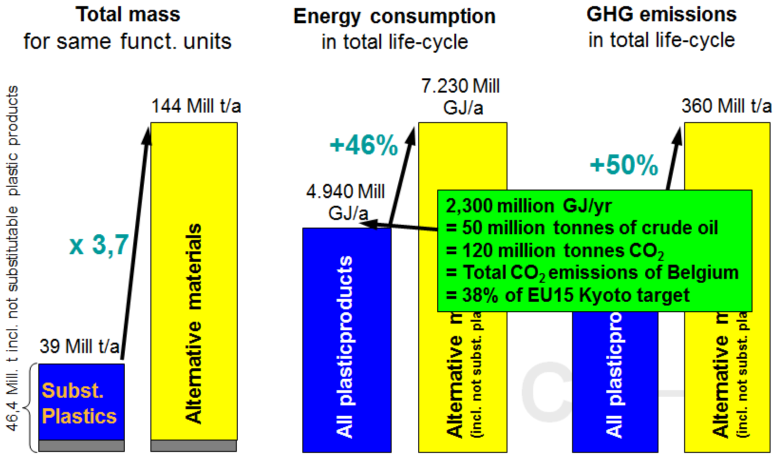
Some key findings (a selection):

- *Resource/energy/GHG efficiency can be high (best) even at low recycling rates*
- *Compared to other materials, the material/energy/GHG reduction realized by plastics packaging is often several times higher than the remaining optimization potential for higher plastics recycling*
- *For plastics waste,* ***NO general waste management hierarchy*** *for recovery options can be derived from environmental benefits*
- Eco-efficient (sustainable) recovery of post-use plastics requires a product specific **life cycle (LC)/cost benefit (CB) analysis**
- Rough estimation of maximum eco-efficient, mechanical plastic packaging recycling (incl. domestic and commercial):

  - INPUT based: **35 – 53 %**
  - OUTPUT based: **31 – 43 %**

*Source: **"Criteria for eco-efficient (sustainable) plastic recycling and waste management"***
Fact based findings from 20 years of denkstatt studies
denkstatt GmbH, 2014

Hypothetic replacement of plastics products by next-best alternative material *(Europe 2009)*
Effects on "product mass", "energy consumption" and "CO_2 emissions"



*Source: **"The Contribution of Plastic Products to Resource Efficiency"***
H. Pilz, B. Brandt and R. Fehringer, denkstatt GmbH
*(Study commissioned by **Plastics**Europe, 2010)*

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PLASTICS PERFORMANCE & RECOVERY OPTIONS

SOME PRINCIPLE CONSIDERATIONS (1/2)

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Mechanical Recycling of polymeric products/materials in the context of ***Sustainable Development*** and a ***Circular Economy***

Principle pathways of product/material recovery

- **product reuse**
  (repair, alt. application, etc.)
- **mechanical recycling**
  (materials recycling)

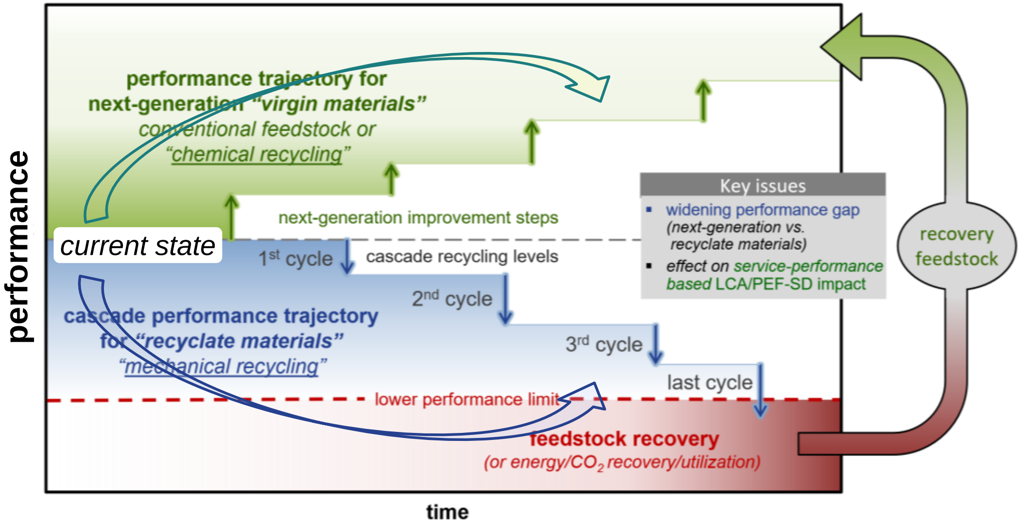
"down-cycling"
cascadic performance deterioration

- **chemical recycling**
  (feedstock recycling)
- **energy recovery** coupled with **CO_2 utilization**
  (feedstock recycling)

"up-cycling"
innovation-driven performance enhancements

The widening *performance gap*:
Mechanical recyclates vs. next generation "virgin" materials

Service relevant material performance evolution



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Plastics Performance & Mechanical Recycling

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Open Issues as to Specified Product Performance?

What about ***Qualification/Specification/Certification & Quality Assurance*** of mechanical polymer recyclates?

For virgin materials, an elaborate framework of regulations and procedures incl. test & characterization methods exits!

Teppfa Forum 2016
Brussels, 4-5 April

25th anniversary teppfa

*"… **new test methods** have to be developed to ensure that products with recycled content do not compromise on current performance and quality levels."*

Niels Rune Solgaard-Nielson
President of TEPPFA and CEO Pipelife

Opportunities & Challenges:

*Sustainable (eco-efficient) **mechanical recycling** of polymers requires the cascadic utilization of plastics recyclates (in-house & post-use) at the highest achievable **Performance Level**.*

*Hence, there is a great need for adequate **methodological tools & test methods** for a quick and reliable material characterization.*

R. W. Lang, *Plastics Pipes XVIII Berlin, 2016*

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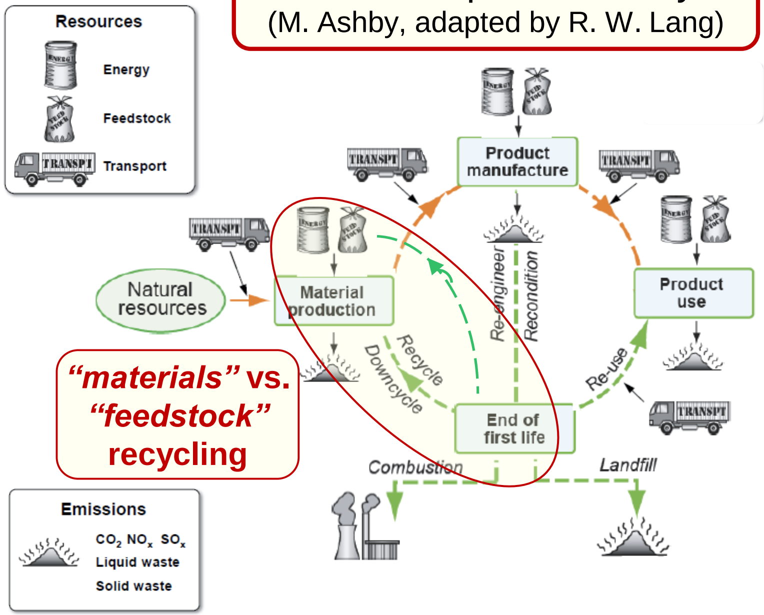
Plastics Performance & Recovery Options

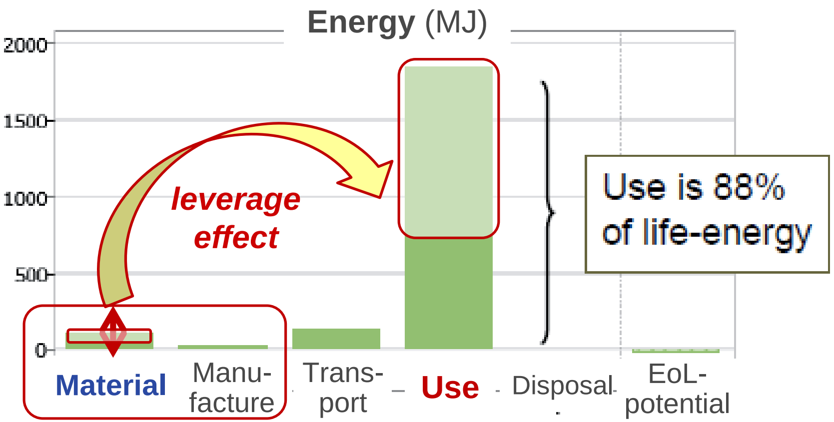
Some Principle Considerations (2/2)

Mechanical Recycling of polymeric products/materials in the context of ***Sustainable Development*** and a ***Circular Economy***

The material/product life cycle
(M. Ashby, adapted by R. W. Lang)



Typical eco-audit (LCA/PEF) result



M. Ashby (2015), *Materials and Sustainable Development* (Elsevier)

The Innovation Challenge
as to *materials vs. feedstock recycling vs. CO_2 reutilization*:
How to trigger the greatest *"overall/leverage effect"*?

STORYLINE & 3 KEY MESSAGES

THE GLOBAL GOALS For Sustainable Development

KEY MESSAGE 3: THE GLOBAL ***ENERGY TRANSITION*** AND PERSPECTIVES FOR A *NEW "ALL-CIRCULAR"* ***SUSTAINABLE PLASTICS ECONOMY***

Any *"SUSTAINABLE" CIRCULAR ECONOMY* path for *PLASTICS* must account for and reflect the ongoing ***ENERGY TRANSITION*** to renewable energies*!*

The ***ENERGY TRANSITION*** together with new options for a Circular Carbon Management (CCM; chemical/feedstock recycling, CO_2 utilization) may be a game changer for the CIRCULAR ECONOMY of PLASTICS.

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GLOBAL CHANGE & CHALLENGES (3/4)

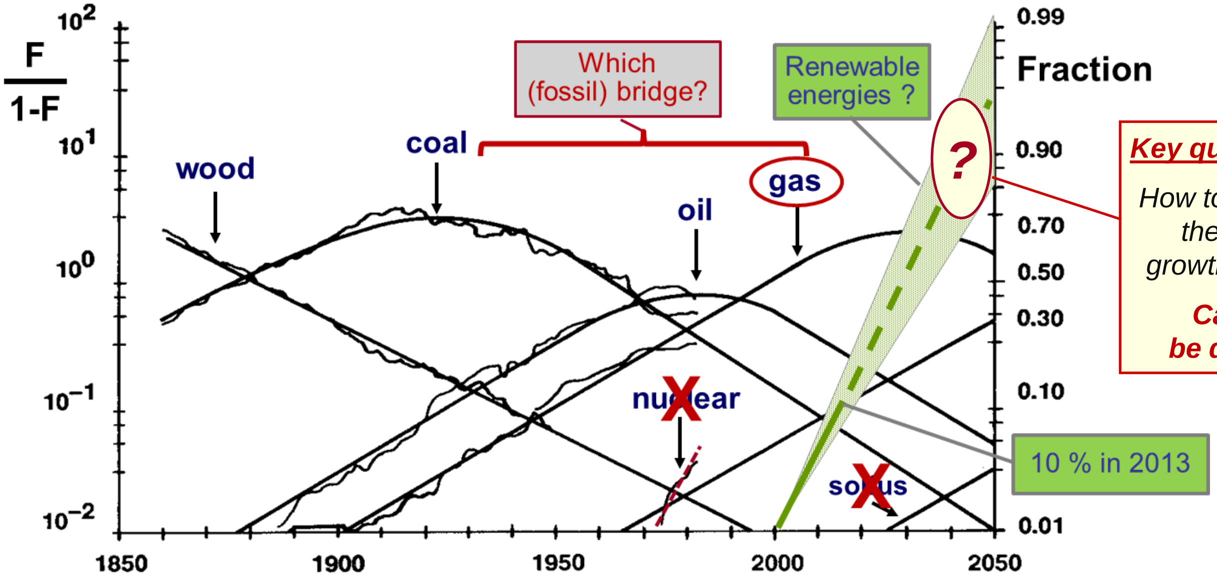
2015 MAY HAVE BEEN A PIVOTAL YEAR

THE PARIS AGREEMENT (COP 21, DEC. 2015)

Central aim: Keep **global temperature rise this century well below 2 °C** above pre-industrial levels (towards 1.5 °C).

Status: 83 Parties have ratified by Oct. 2016; the Paris Agreement will entered into force on **4 November 2016**.

Technology life cycles of primary energy classes
(IIASA 1987;
adapted by R. W. Lang 2010)



Key questions:

How to sustain the high growth rates?

Can it be done?

Source: A.Grübler, N.Nakicenovic, 1987; C.Marchetti, N.Nakicenovic, 1997 (IIASA, Laxemburg/A)

Plastics Performance & Recovery Options

A Vision for a Sustainable Future – Closing the Loops

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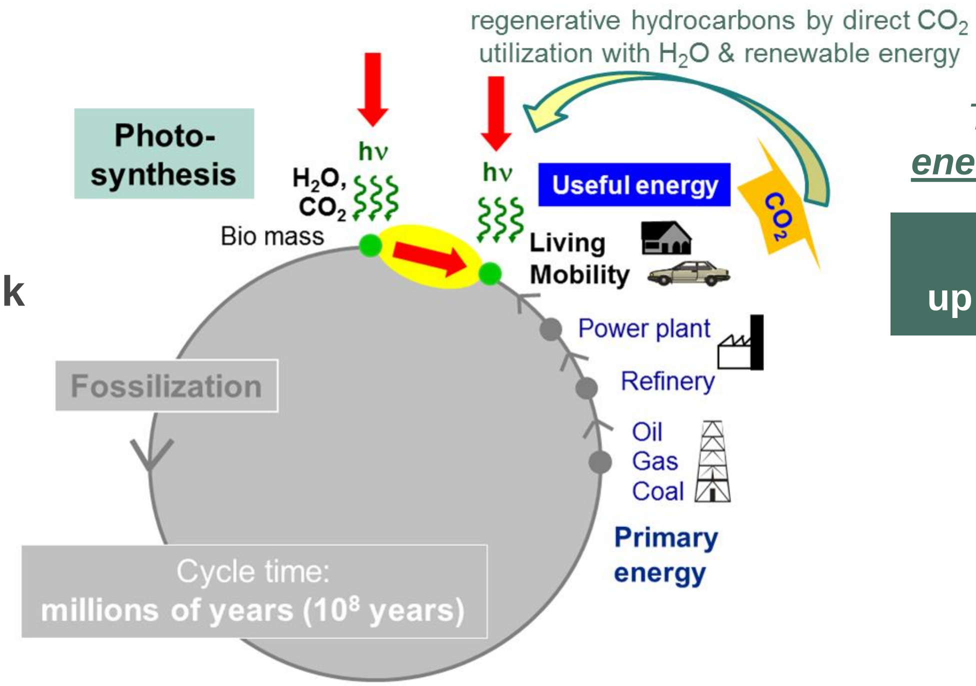
Towards an **All-Circular *"Sustainable"* Economy** of polymeric materials

From current to future energy/feedstock technologies



The fossil energy/feedstock cycle

The regenerative energy/feedstock cycle

Cycle time:
up to max. ~100 years

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Global Change & Challenges (4/4)
Some Grand Challenges and a Vision for the Future

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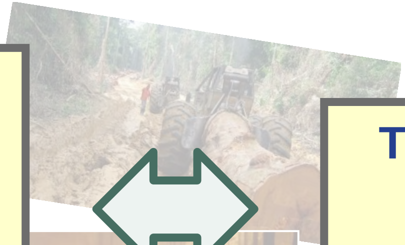
CO_2 emissions vs. ***forest clearance*** vs. ***plastics waste*** *(p.a. worldwide, ca. 2015)*

CO_2 emissions[1,5]

Net forest loss[2,3,5]

Plastics waste[3,4,5]



- **Water: H_2O**
- **Air: O_2, CO_2, …**
- **Biomass & Plastics:**
  CHO products

The matter base:
(atomic constituents)
C, H, O …

The future image of plastics is at stake:
From being** (perceived as) **a problem
to becoming part of the solution !

CO_2 emission

~140 Mt/a

< 1 km³/a

e islands:
1.3 Mio. km²

[1]glo
[2]de
[3]ow
[4]worldbank.org; globometer.com
[5]orf.at

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Plastics & Sustainable Development

Some Final Remarks

Sustainable Development … meets the needs of present generations without compromising the ability of future generations to meet their own needs.

Our Common Future (UN-WCED, 1987)

4 messages against common misconceptions

(1) **Polymeric Materials** are the **Key Materials** for **Sustainable Development** technologies.

(2) "Polymers & Sustainable Development" is more about **Performance Enhancement & Innovation** than about (physical) material recycling.

(3) This implies an increasing **diversity of plastics types** rather than a reduction of material diversity.

(4) The main (best) route for a **regenerative feed-stock** base ("circular economy") may not be bio!?

R. W. Lang, 5th Int. Materials Education Symposium; April 4-5, 2013; Univ. of Cambridge (UK)