

Sustainability in the Phosphorus Value Chain

P-BASED FLAME RETARDANTS AND FIRE RETARDED PLASTICS

Public

Dr. Wolfgang Wanzke
BU Additives
Sustainability Manager
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what is precious to you?

Clariant at a Glance

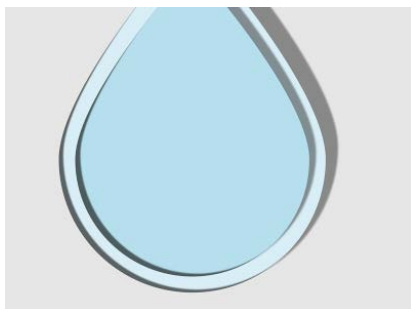
A global player in the specialty chemicals business

TOTAL SALES IN 2015

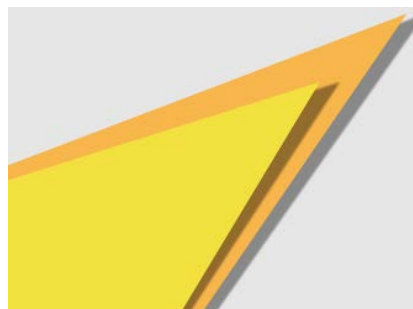
5.807 Mio CHF

Employees 2015: approx. 17.000

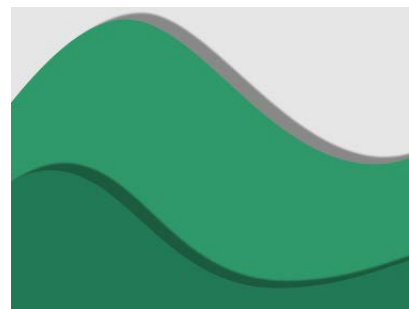
CARE CHEMICALS



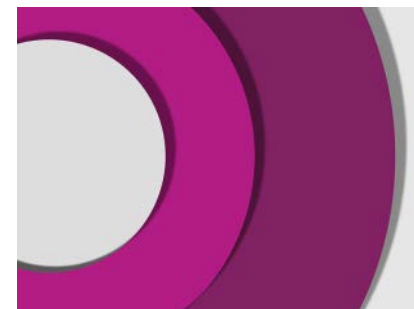
CATALYSIS



NATURAL RESOURCES



PLASTICS & COATINGS



Strong commitment to sustainability:

MEMBER OF

Dow Jones
Sustainability Indices

In Collaboration with RobecoSAM 



ROBECOSAM
Sustainability Award
Silver Class 2016



TOGETHER FOR
SUSTAINABILITY

Clariant in the P Value Chain

- **Leading supplier of P-based flame retardants for engineering plastics and coatings**
- **Uses a few thousand tons of elemental phosphorus and intermediate products based on P_4 per year**
- **Flame retardant portfolio was developed to more sustainable products in several steps**

Our vision on sustainable FRs:

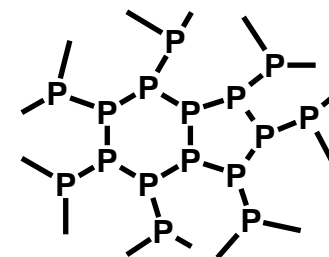
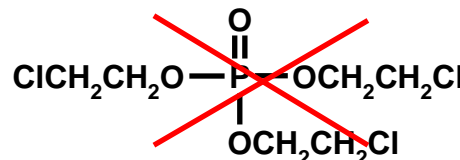
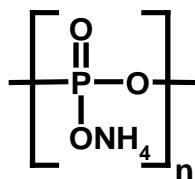
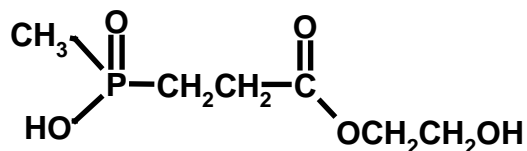
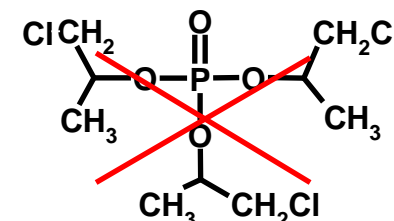
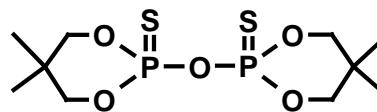
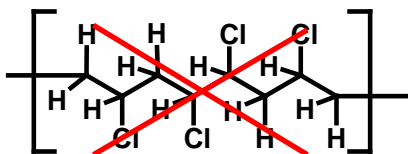
Phosphorus based flame retardants produced from recycled P with renewable energy, as part of a future circular P-economy



FR Portfolio Development@Clariant

Step 1: Halogen-Phase-out

- Situation 1990ies: heterogeneous product mix based on Phosphorus and/or Chlorine based products
- Decision 1995 (when the business still was with Hoechst AG): phase-out of all halogenated Flame Retardants:
 - TCEP, TCPP
 - Chlorinated Phosphate-Oligomers
 - Chlorinated paraffines



Looking for the “Ideal Flame Retardant”

Basic Needs

- FR Performance
- Cost Performance
- Legal Compliance

Maintain properties over polymer lifetime

- no migration in polymer / no leaching
- low impact on mechanical properties

Stable and safe processing

- no vapor pressure or volatility
- thermal stability
- low water solubility



Ideal FR

Maintain properties of polymer

- minimal interference with polymer structure
- applicable in various polymers
- colorless

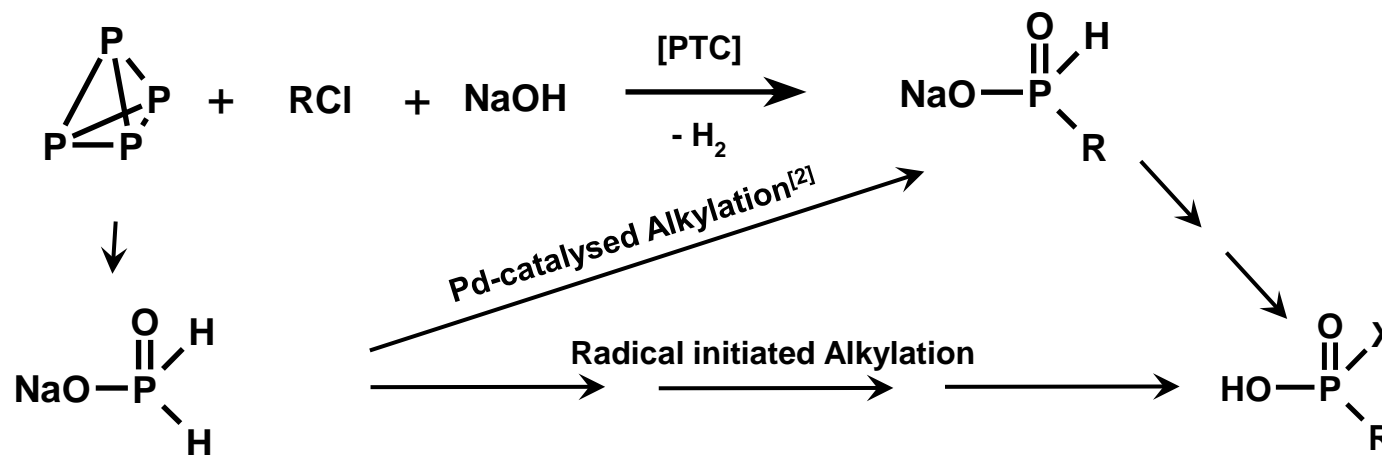
Halogen-free and safe FR

- no bioavailability
- no physiological activity
- sustainable

FR Portfolio Development@Clariant

Step 2: Development of new sustainable P-FR-s – organic Phosphinates

- Exploration of Phosphinate Chemistry based on well available raw materials yellow phosphorus^[1] and sodium hypophosphite^[2]



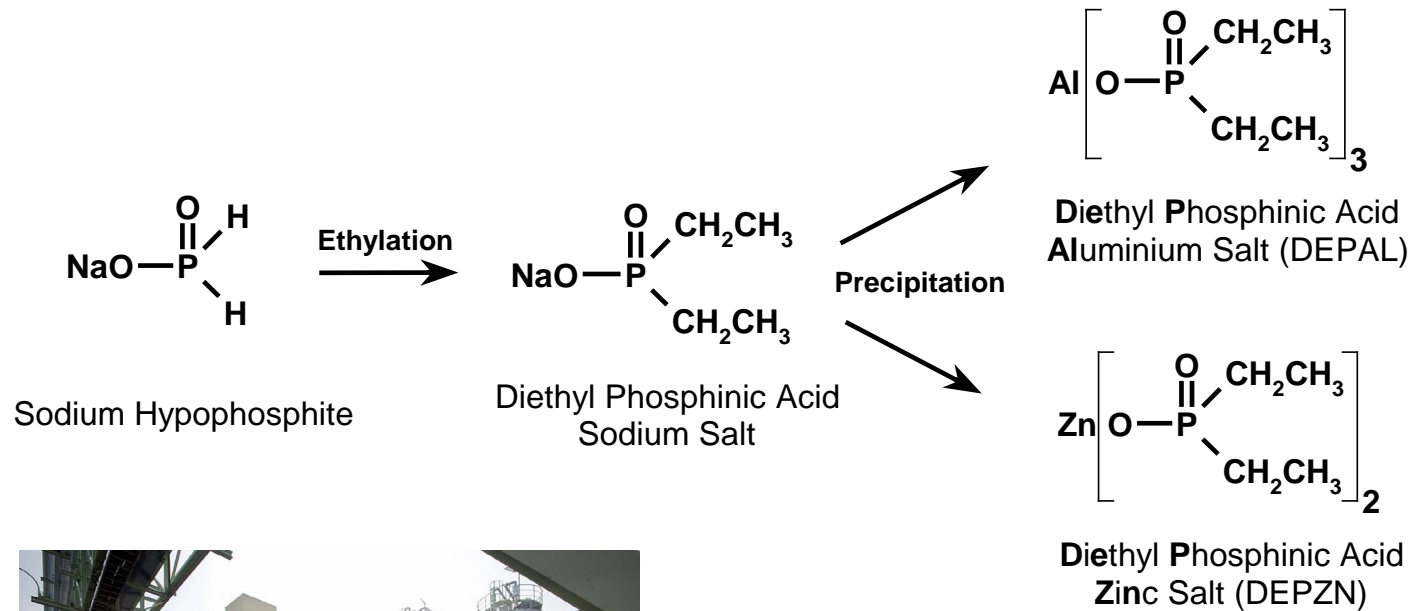
Disubstituted Phosphinic Acids

[1] Weferling, N., Sicken, M. and Hörold, S., Phosphorus, Sulfur and Silicon 177 (2002) 1757-1761

[2] Hill, M., Bauer, H., Krause, W., WO2009/010188

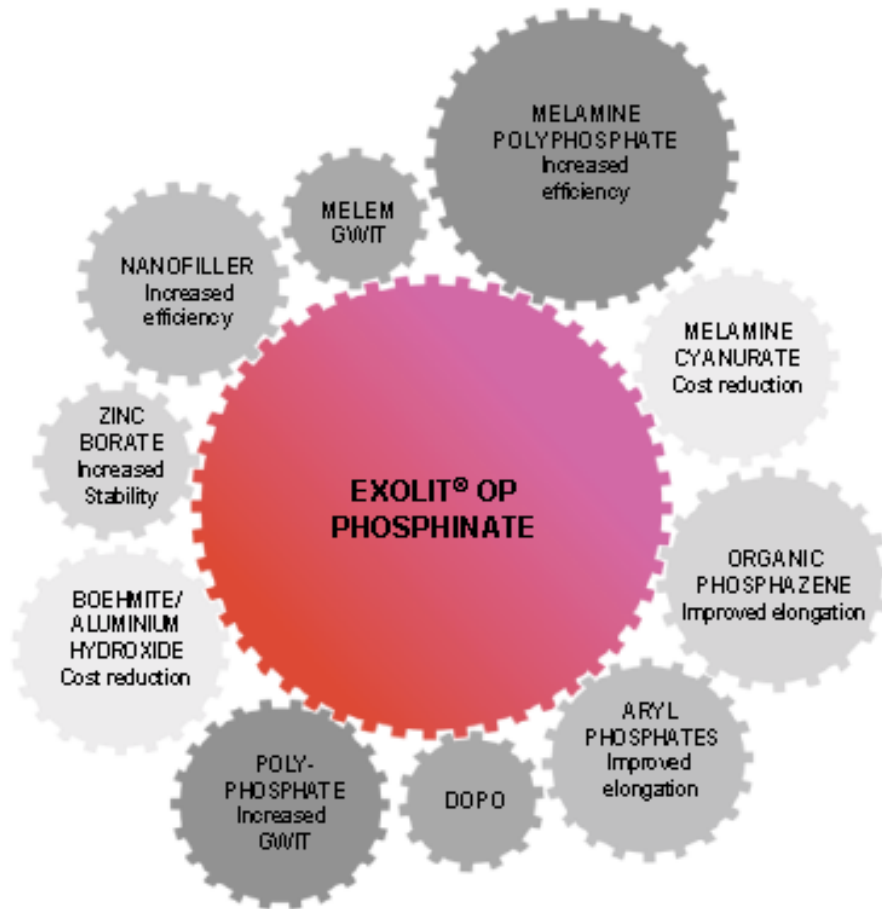
FR Portfolio Development@Clariant

Step3: Commercialization of Diethylphosphinic acid derivatives



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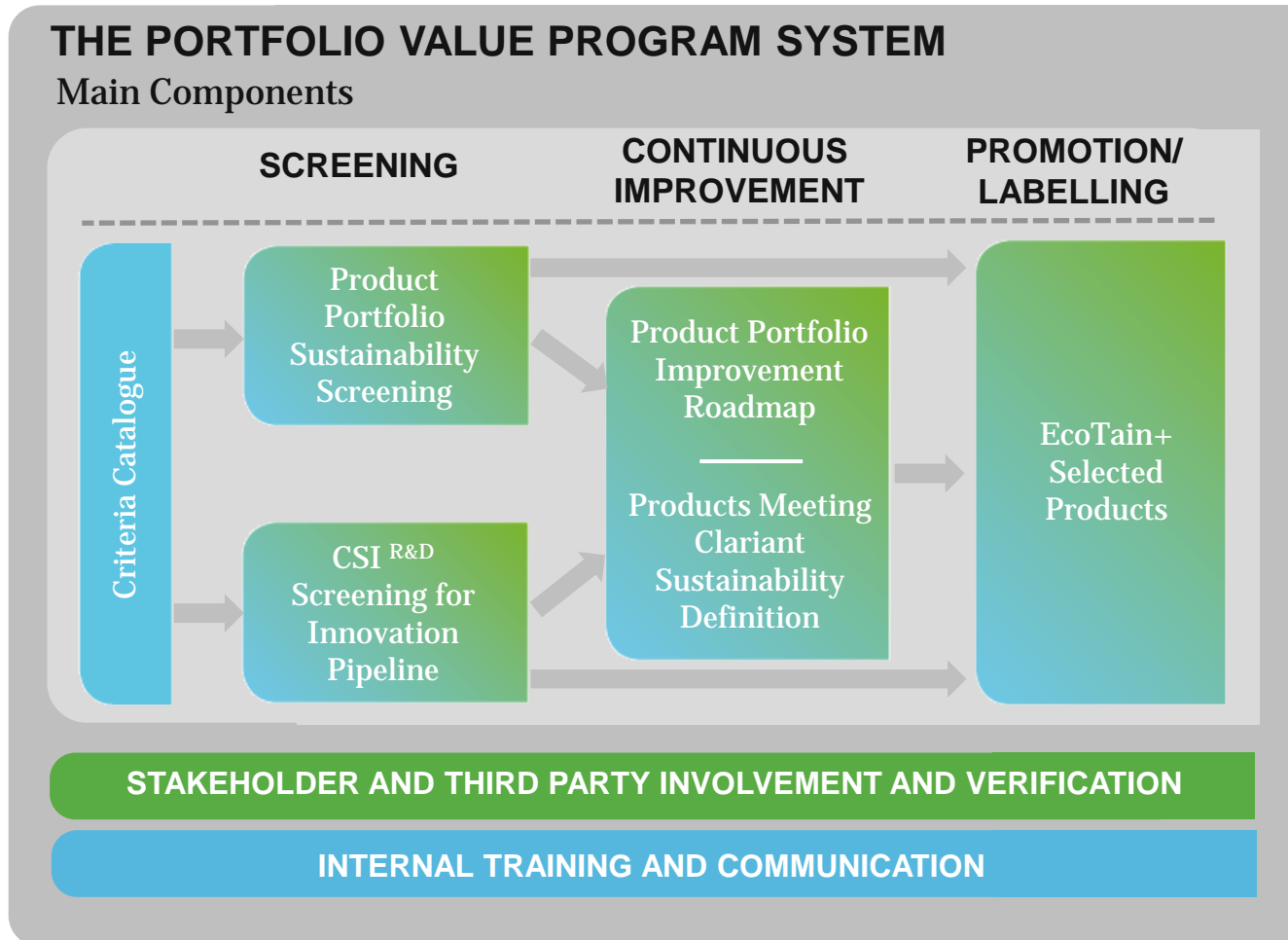
Step 4: Development of tailor made synergistic blends/recipes



- Exolit OP in combination with N-synergists and Stabilizers is an important building block for the compounding industry
- Exolit OP 1240, Exolit OP 1260 for Polyesters
- Exolit OP 1230, Exolit OP 1311, Exolit OP 1312, Exolit OP 1314, for Polyamides

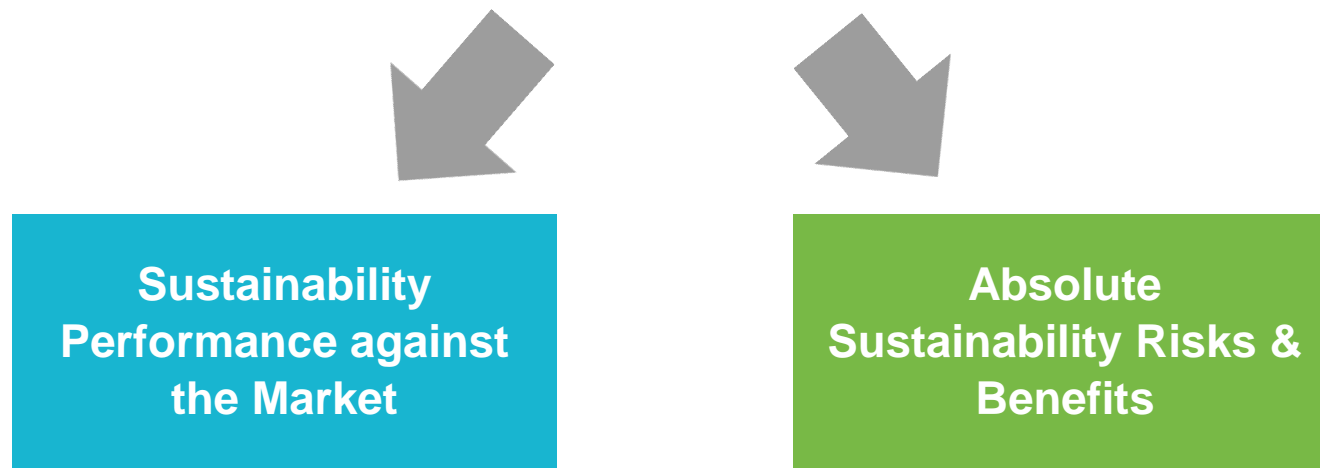
How Sustainable is our Portfolio ?

A new system of evaluation











The Assessment Process

TWO “LENSES” ARE USED TO LOOK AT PRODUCT SUSTAINABILITY



- **36 criteria** are applied following **corporate guidelines** and a **criteria glossary**
- **Team effort** with a maximum of product knowledge at the table and **data mining**
- 26 environmental criteria, 4 economical and 6 social
- The **full life cycle** of the products is addressed

The PVP System Rating Scale

PERFORMANCE OF PRODUCT GROUPING (relative to market standards)	SUSTAINABILITY BENEFITS AND RISKS OF PRODUCT GROUPING (in relation to the absolute nature of issue)
 Best-in-class performer	Sustainability Benefit 
 Higher than market standard/average	Neutral 
 Average	Medium/potential risk 
 Lower than market standard/average	High risk 
Not applicable	Not applicable
Data insufficient for assessment	Data insufficient for assessment

FR Portfolio Development@Clariant

Step 5: PVP assessment and portfolio optimization

- **Main FR Products have achieved the EcoTain®-Label:**
 - Exolit OP 1230 (Aluminium diethyl phosphinate)
 - Exolit AP 422 (Ammonium Polyphosphate)
- **Some FR grades with needs for improvements regarding sustainability**
 - e.g. Synergistic blends containing Zinc Borate (Category 2 reproductive toxicant)



Replacement of Zinc Borate by non-classified products
as part of a sustainability roadmap



Development of new “P-P-Synergism”
Exolit OP 1400

External Proof Points – e. g. Green Screen®

DfE to GreenScreen Translations	Final Benchmark Scores
Antimony Trioxide (1309-64-4)	1 = Avoid - chemical of high concern
Melamine Cyanurate (CAS# 37640-57-6)]	1 = Avoid - chemical of high concern
N-alkoxy Hindered Amine Rx Products (CAS#191680-81-6)	1 = Avoid - chemical of high concern
Phosphonate Oligomer (CAS#68664-06-2)	1 = Avoid - chemical of high concern
Zinc Borate 1332-07-6, 138265-88-0	1 = Avoid - chemical of high concern
Aluminum diethylphosphinate (CAS#225789-38-8)	2 = Use but search for safer alternatives
Aluminum Hydroxide (CAS#21645-51-2)	2 = Use but search for safer alternatives
Melamine Polyphosphate (CAS#15541-60-3)	2 = Use but search for safer alternatives
Poly[phosphonate-co-carbonate] (CAS# 77226-90-5)	2 = Use but search for safer alternatives
Resorcinol Bis-Diphenylphosphate (CAS#125997-21-9)	2 = Use but search for safer alternatives
Red Phosphorus (CAS# 7723-14-0)	2 = Use but search for safer alternatives
Substituted Amine Phosphate mixture (CAS# 66034-17-1)	2 = Use but search for safer alternatives
Triphenyl Phosphate (CAS#115-86-6)]	2 = Use but search for safer alternatives
Ammonium Polyphosphate (CAS # 68333-79-9)]	3 = Use but still opportunity for improvement
Magnesium Hydroxide (CAS # 1309-42-8)]	3 = Use but still opportunity for improvement
Polyphosphonate (CAS#68664-06-2)	3 = Use but still opportunity for improvement
Bisphenol A Bis-(diphenyl phosphate) (CAS#181028-79-5 and 5945-33-5) (BAPP)	U = not enough data for assessment
Phosphoric acid, mixed esters with [1,1'-bisphenyl-4,4'-diol] and phenol; BPBP (CAS#1003300-73-9)]	U = not enough data for assessment
	4 = Prefer - safer chemical

Recent Update

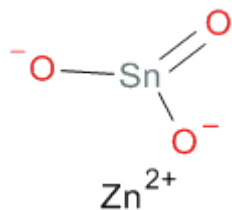


Data gaps filled ! Aluminium diethylphosphinate is now benchmark 3 !



More Life Cycle Data – e. g. ENFIRO Project

FR



Risk assessment

- Hazard
 - Environment
 - Human health
- Exposure

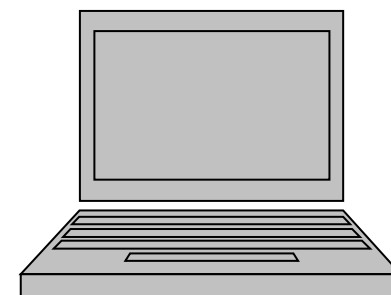
Material



Technological assessment

- Application
- Fire performance
- Leaching and air emission

Product

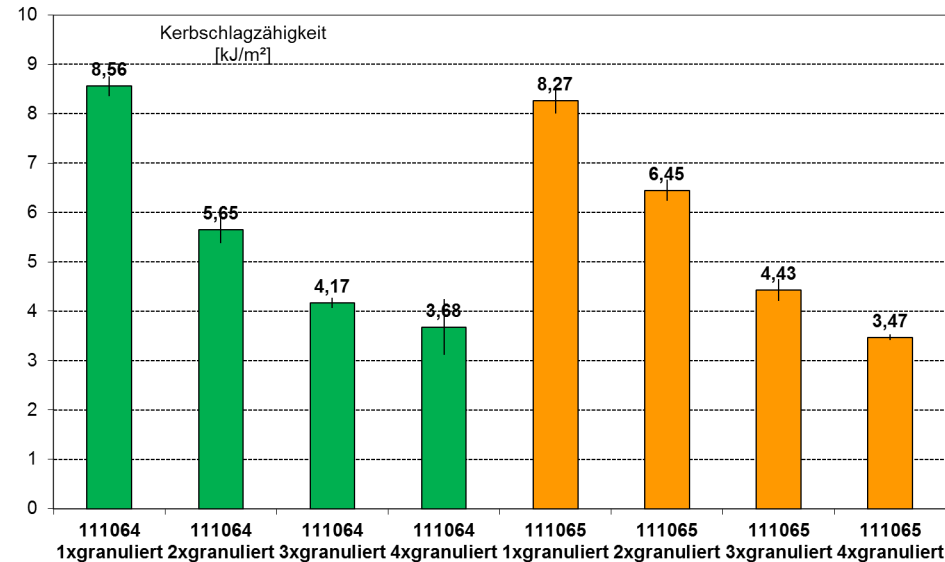
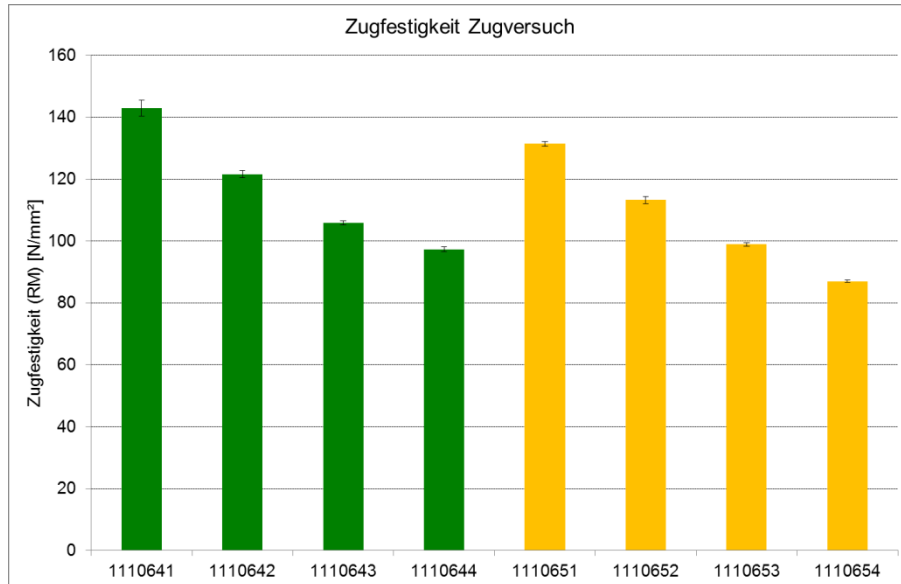
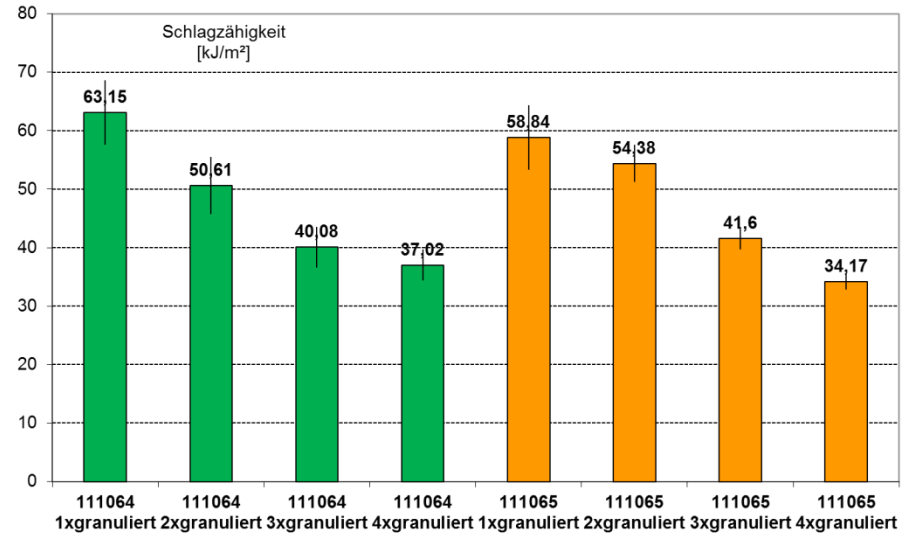


Impact assessment studies

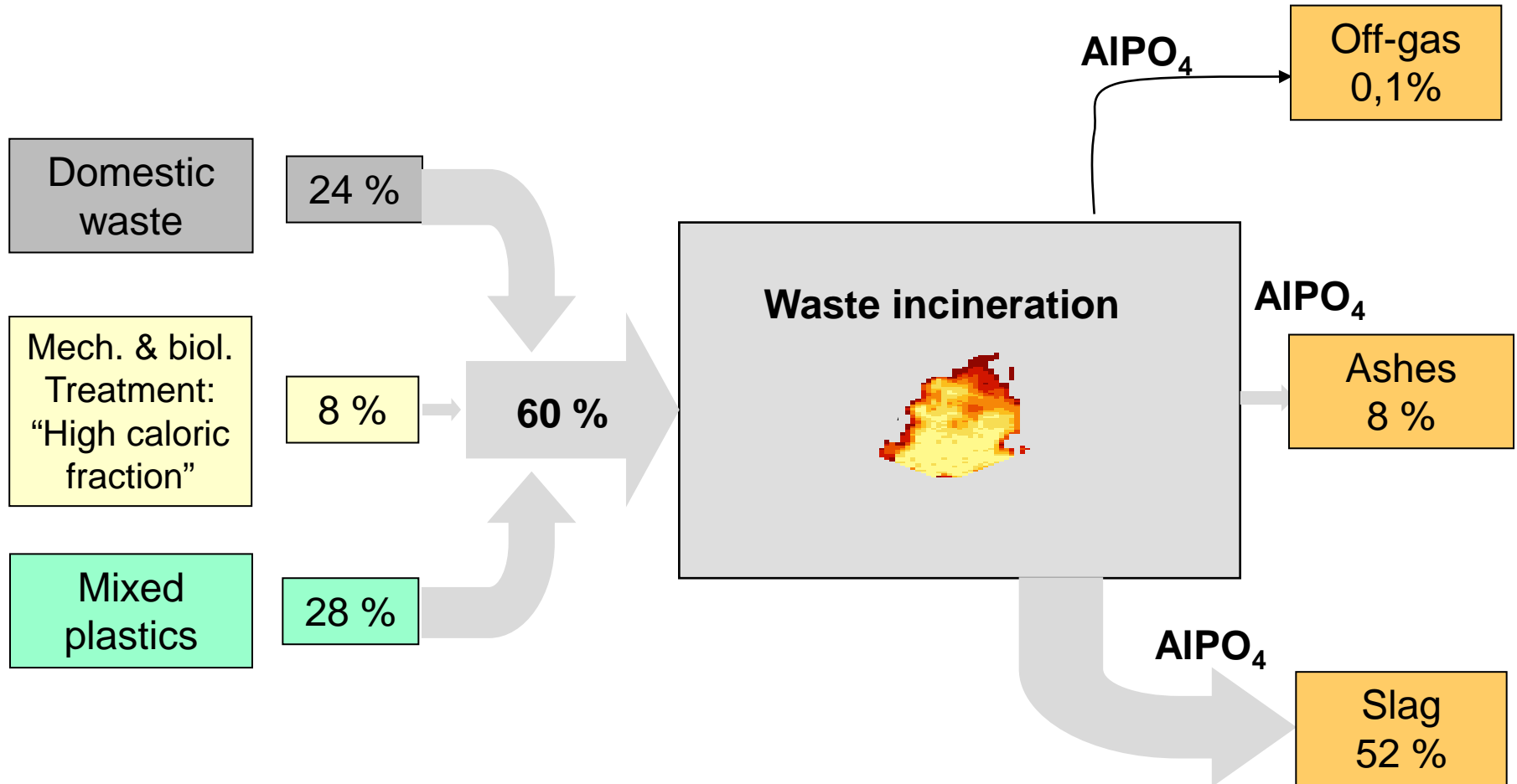
- Life cycle assessment
- Life cycle costing
- Social life cycle assessment

End of Life Scenarios - Recyclability

PA 66	39,3	39,3
PA 6	10	10
Glass fibre HP3610	30	30
Stab. 1098/168*	0,2/0,2	0,2/0,2
Licowax E	0,3	0,3
Exolit OP 1312	20	
Exolit OP 1400		20



End of Life Scenarios - Incineration



Conclusion

Phosphorus based flame retardants like the presented phosphinates or ammonium polyphosphate

- **have a very favorable sustainability profile as shown by internal and external investigations covering the life cycle of these products and flame retarded plastics made thereof**
- **Remaining life cycle issues are the**
 - **high energy consumption and the**
 - **green house gas emissions caused by the production of elemental P**
- **Both problems can be mitigated or solved, once phosphorus can be sourced from recycled phosphates and produced by using renewable energy**