ICL

ELECTRO-PLAST 2022 Conference

High Voltage automotive powertrain fire safety: sustainable brominated polymers make the difference

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About ICL Group

- Headquartered in Israel, with plants across the globe
- Global manufacturer of fertilizer, specialty chemicals and industrial products
- World's largest producer of elemental bromine
- World's leading producer of a variety of bromine, phosphorus and inorganic Flame Retardants (FRs)
- Multiple awards for sustainability efforts, inclusion in FTSE4Good and A- Carbon Score

ICL-IP FR portfolio

Brominated FRs

Polymeric FRs:

- **FR-803P,** Brominated polystryrene for ETPs
- **FR-1025,** Brominated polyacrylate for ETPs
- **F-2000 & F-3000,** Brominated Epoxy series for ETPs and Styrenics
- **FR-122P**, Brominated SBR copolymer for XPS, EPS

Non-Polymeric FRs:

- **FR-245,** Brominated cyanurate for Styrenics & PC
- **FR-720,** TBBA derivated for PP & Styrenics
- **FR-370,** Brominated phosphate for PP & Styrenics
- **FR-1410,** DBDPE for HIPS, PE, PP, PBT, PA, UPE & Epoxy
- **F-2200HM**, Brominated Epoxy, stabilizer for XPS
- **FR-1524,** TBBA for epoxy PCBs

Phosphorus FRs

- **Fyrolflex®:**
  - RDP and Sol-DP for PC/ABS and PPO/HIPS
  - Plasticizers for PVC
- **Fyrol®:** PFRs for PU foam (rigid and flexible)
- **Phosflex®:** Plasticizers for PVC
- **PolyQuel® P100,** reactive, polymeric PFR for PCBs
- **VeriQuel® R100** reactive intermediate for PU foams

Inorganic FRs

- **FR-20,** Magnesium Hydroxide for wire & cable and Polyamides

Flame retardants

- ✓ Plastics are inherently flammable materials and Flame Retardants are a major way in which flame retardancy is achieved.

- ✓ Flame retardants **save lives**, they **prevent ignition** of the combustible material, or they help to **limit fire spread**.

- ✓ All ICL Flame retardants comply with regulations, polymeric BFR have low water solubility, no leaching or migration, due to high MW no penetration in to living tissue, no potential bioaccumulation.

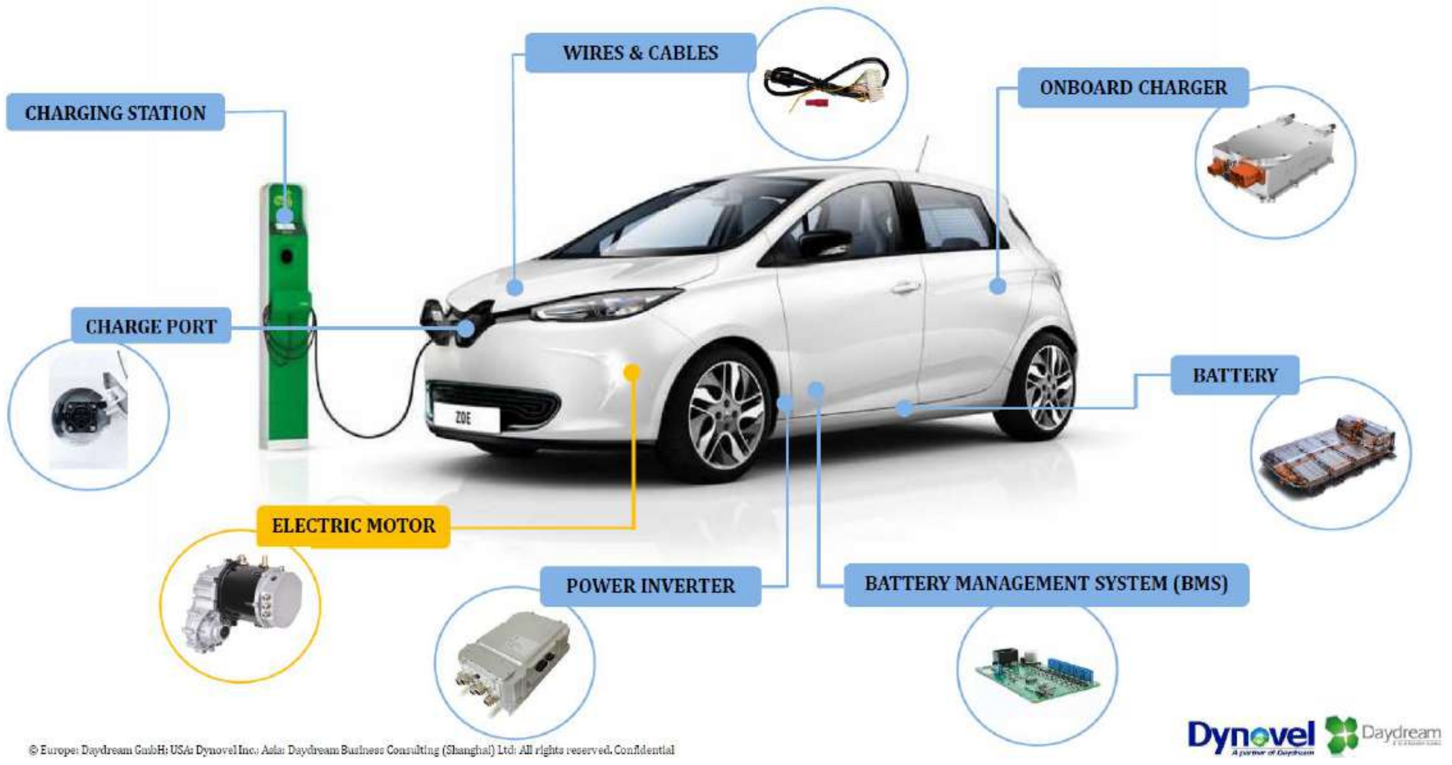
- ✓ Choosing by FR chemistry does not guarantee sustainable outcome.
  - ***SAFR®*** – A Systematic Assessment for Flame Retardants

Flame retardants use in EVs

- Interior requirements based on FMVSS 302 – not a challenge for hard plastics, PU foams need FR
- Under the hood and EV powertrain present bigger safety issue

Key Parameters:

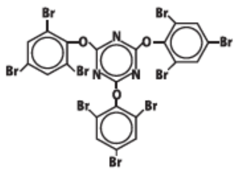
- UL94 V-0
- Mechanical properties (Impact strength, Tensile..)
- Flow
- HDT
- Glow wire test (GWIT)
- Comparative Tracking Index (CTI)
- RTI
- Thermal stability
- Hydrolytic stability



Halogens and Antimony Trioxide (ATO)

Synergism in the Gas phase

FR-245

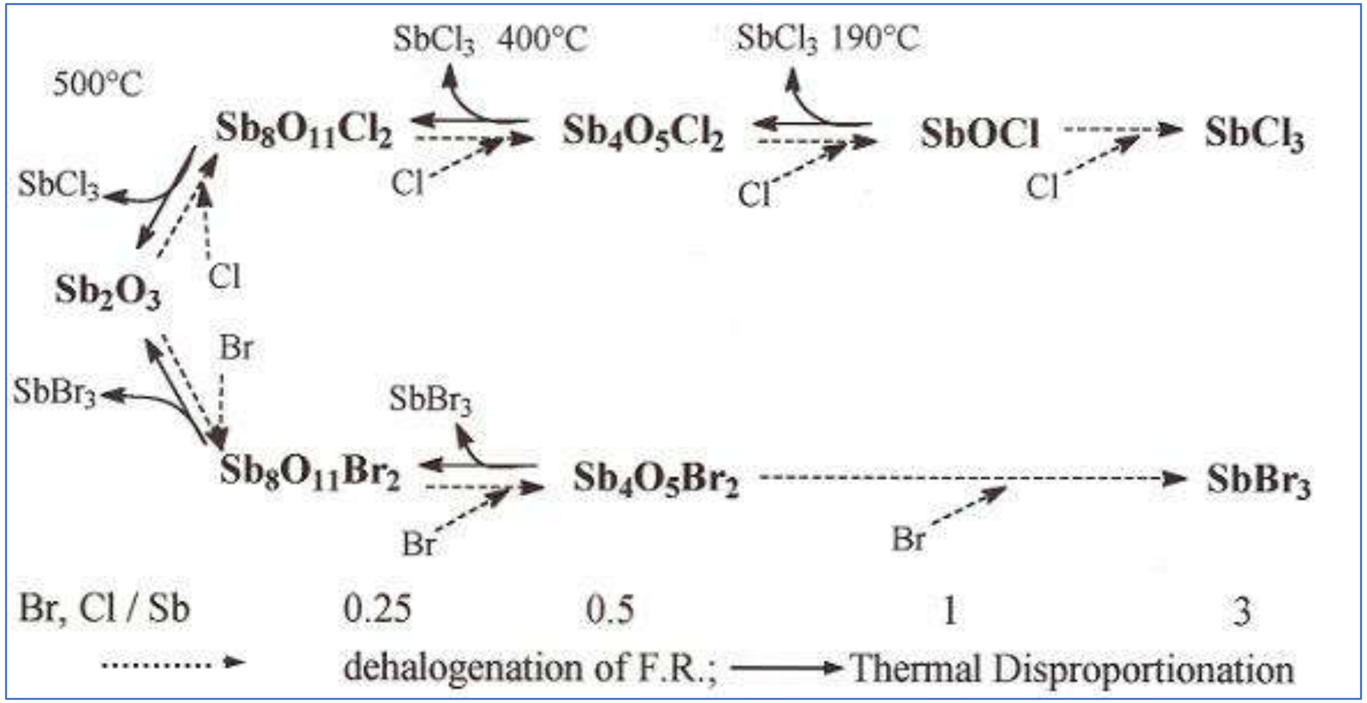


MFC – Milligram-scale Flame Calorimetry

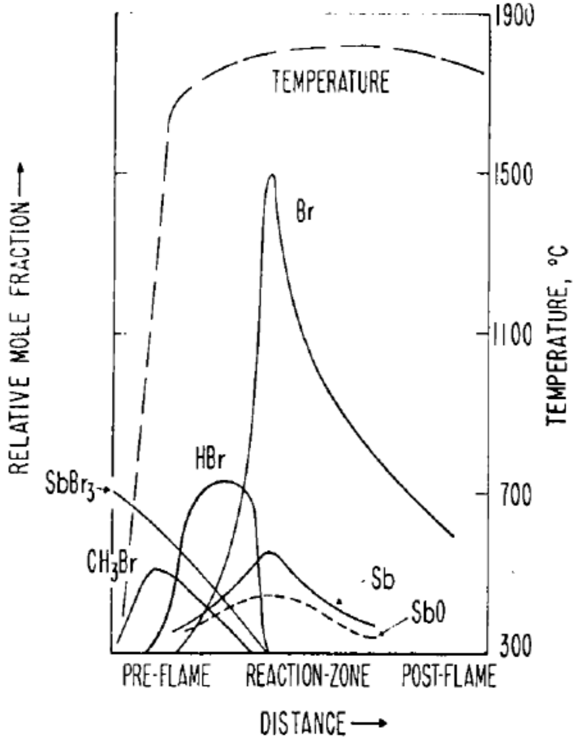
- Time to Ignition
- Time to Extinction

Halogens and Antimony Trioxide (ATO)

Synergism in the Gas phase



L. Costa, P. Goberti, G. Paganetto, G. Camino and P. Sgarzi, Polym. Degrad. Stab., 30(1990)13

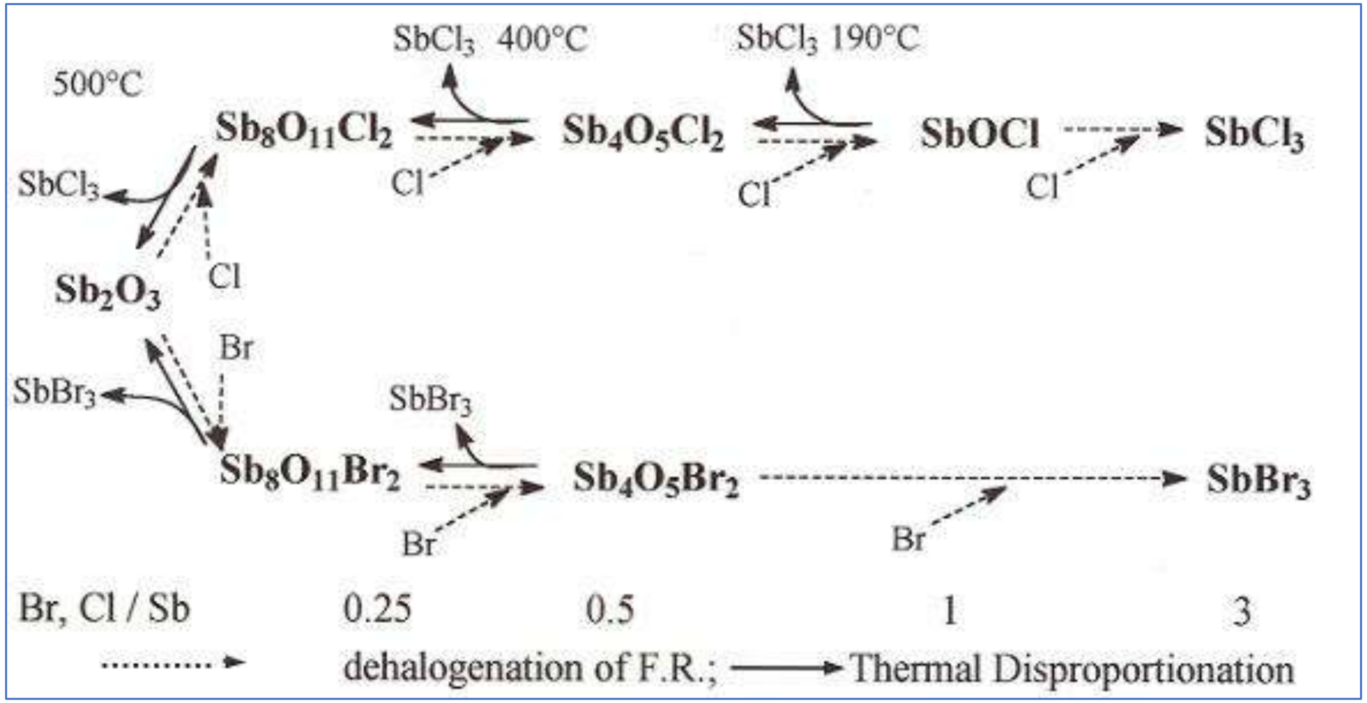


J.W. Hastie, J. Res. NBS, Phys. Chem., 77A(1973)733-748

- SbBr3 boils at 280°C
- ATO helps to transport bromine into the gas phase.

Halogens and Antimony Trioxide (ATO)

Synergism in the Gas phase



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The high energy H· and OH· radicals responsible for chain branching are removed

$RBr \rightarrow R\cdot + Br\cdot$

$Br\cdot + RH \rightarrow R\cdot + HBr$

$HBr + \mathbf{H\cdot} \rightarrow H_2 + Br\cdot$

$HBr + \mathbf{OH\cdot} \rightarrow H_2O + Br\cdot$

$SbBr_3 + \mathbf{H\cdot} \rightarrow HBr + SbBr_2$

$SbBr_2 + \mathbf{H\cdot} \rightarrow HBr + SbBr$

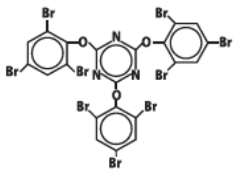
$SbBr + \mathbf{H\cdot} \rightarrow HBr + Sb$

- SbBr3 boils at 280°C
- ATO helps to transport bromine into the gas phase.

Halogens and ATO vs. other Metal oxides

Synergism in the Gas phase

FR-245



Antimony		Gallium	Bismuth	Titanium	Aluminum	Tin	Zinc	Indium
Sb2O3	vs.	Ga2O3	Bi2O3	TiO2	Al2O3	SnO2	ZnO	In2O3

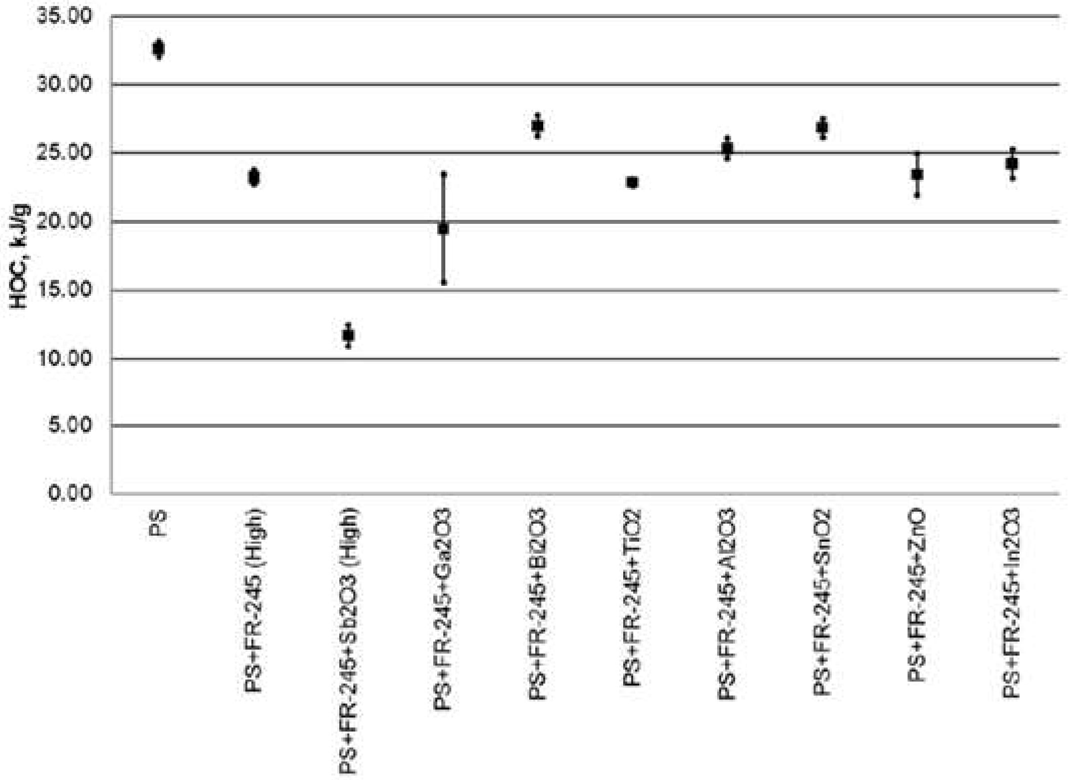


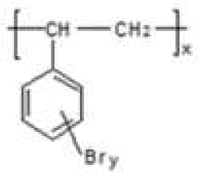
Figure 1 . HOC for PS+FR-245+various metal oxides

HOC – Heat of Combustion

(the lower, the better)

PBT V-0 formulations: BFR's + P-FR's:

FR-803P

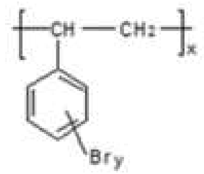


	FR-803P + ATO (Reference)	*FR-803P + Sol-DP + MPP	FR-803P + DEPAL	*FR-803P + Calcium Hypophosphite
PBT	52.2	46.6	48.5	46.6
Glass fiber	30	30	30	30
Flame Retardant	12.1 (8%Br)	15.2 (10%Br)	10.8 (7.1%Br)	15.2 (10%Br)
Synergist \ P-FR	5	7.5	10	7.5
Additives	0.7	0.7	0.7	0.7
Sum	**100**	**100**	**100**	**100**
UL 94 @ 0.8 mm	V-0	V-0	V-0	V-0
IZOD notched Impact [J/m]	77	54	63	72
Tensile Strength [MPa]	119	90	106	114
Elongation at break [%]	3.3	3.0	3.2	3.3
Modulus [MPa]	11,162	9,357	9,767	11,347
MFI, 250C/2.16 Kg, [g/10mm]	14.6	7.0	8.2	5.2
HDT [°C]	202	197	202	194
GWIT, 3.2mm [°C]	775	825	750	775
Comparative Tracking Index [V]	250	250	325	550-600

Formulations marked in [*] are ICL patents and Intellectual Property

PA66 V-0 formulations: BFR's + P-FR's:

FR-803P



	FR-803P + ATO (reference)	*FR-803P + Sol-DP/MPP	FR-803P + PFR (DEPAL/MPP)
Polyamide 6,6	44.4	44.4	44.4
Glass fiber	30	30	30
Flame Retardant	19.5 (13%Br)	19.5 (13%Br)	19.5 (13%Br)
Synergist	5	5	5
Additives + PTFE	1.1	1.1	1.1
Sum	**100**	**100**	**100**
UL 94 @ 0.8 mm	V-0	V-0	V-0
IZOD notched Impact [J/m]	92.4	83.6	85.2
Tensile Strength [MPa]	157	158	146
Elongation at break [%]	4.2	4.3	4.7
Modulus [MPa]	9647	9259	9565
Spiral Flow [Inch]	37.7	41.9	38.9
GWIT, 1.6 mm [°C]	775	875	875
GWIT, 3.2 mm [°C]	875	875	875
Comparative Tracking Index [V]	325	375	425

New development:

FR-803P + X

- V-0 at 0.8 mm
- CTI of 550-600V

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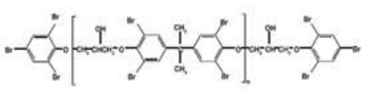
Heat-resistant polyamides (HPAs)

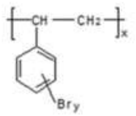
	Melting Point **(°C)**
PA66 - INVISTA	262
PA66/6T (70/30) - INVISTA	275

Comparison between PA66 and PA66/6T, BFR vs. PFR

F-3100



FR-803P



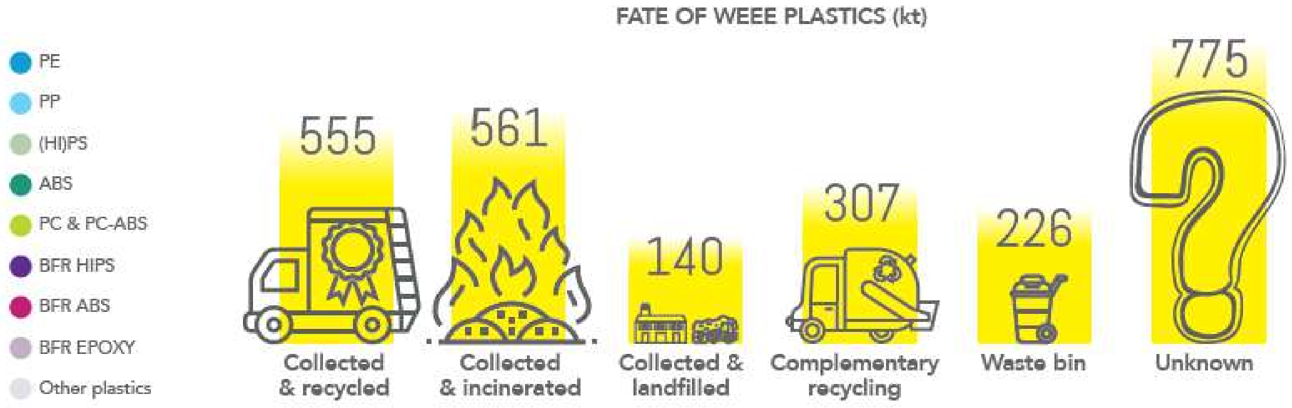
	PA66			PA66/6T (70/30)		
	FR-803P	**F-3100**	**P-FR***	**FR-803P**	**F-3100**	**P-FR***
Polyamide 66 - INVISTA	44.2	39.4	50.9			
Polyamide 66/6T - INVISTA				47.1	42.8	50.9
Glass fiber	30	30	30	30	30	30
FR	19.7 (13%Br)	24.5 (13%Br)	18	17.4 (11.5%Br)	21.7 (11.5%Br)	18
ATO	5	5		4.4	4.4	
PTFE + Stabilizers	1.1	1.1	1.1	1.1	1.1	1.1
Sum	**100**	**100**	**100**	**100**	**100**	**100**
UL 94 @ 0.8 mm	V-0	V-0	V-1	V-0	V-0	V-0
IZOD notched Impact [J/m]	94.6	73.5	86.8	95.7	89.1	90.6
Tensile Strength [MPa]	147	125	130	141	151	126
Elongation at break [%]	5.0	2.7	3.3	5.2	3.8	2.9
Modulus [MPa]	9229	9337	9951	8826	9139	9318
HDT [°C]	236	223	242	245	239	245
GWIT, 1.6 mm [°C]	775	825	725	775	825	775
GWIT, 3.2 mm [°C]	825	925	775	825	875	775
Comparative Tracking Index [V]	375	350	475	425	300	600

Sustainability

Plastics - Recycling

Waste from Electrical and Electronic Equipment (WEEE)

- The amount of WEEE generated every year in the EU is increasing rapidly.
- Out of ~9 MT WEEE:



Sofies study: Fate of WEEE plastics, 2020, EU-28 + Switzerland & Norway

- The European Commission is setting high targets, but with more and more restrictions on Mechanical recycling.
- Mechanical recycling of the heavy fraction (>1.1 g/cm3) of WEEE is not allowed due to legacy substances.
- Novel separation technologies and solvent-based technologies are the key for solving this challenge.
- ICL plays an important role in the following projects:

PolyStyreneLoop PLAST2bCLEANED NONTOX

PLAST2bCLEANED project:

- PLAST2bCLEANED is a H2020 funded project on lab and pilot level.
- The overall aim is to develop a human and environmentally safe recycling process for Waste Electrical and Electronic Equipment (WEEE) plastics (ABS and HIPS) with recovery of the polymer, ATO and BFRs.
- Technology based on **Super Heated Solvent** using high pressure and high temperature to dissolve WEEE plastics

The next challenge is scaling up from lab/pilot scale to a demo-plant or a full-scale plant.

Conclusions

- Certain plastic parts need a fire safety function (Automotive, E&E, B&C, cables …)
- Flame Retardants are a major way in which flame retardancy is achieved.
- BFR's are often the best technical solution (FR'cy, mechanical properties, GWIT…)
- Combination of BFR's and PFR's allow ATO Free formulations with improved electrical properties
- Substances of High Concern hinder mechanical recycling
- Novel separation technologies and solvent-based technologies are the key for increasing recycling yield

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Thank You

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