Tagung: IEA SHC Task 54
Kosteneffiziente solarthermische Systeme
Johannes Kepler Universität Linz
04. Oktober, 2017

SolPol-4/5: Neuartige Kollektorsysteme aus Kunststoff

Motivation, Zielsetzungen und Highlights

solpol *A science-driven Austrian research initiative by JKU-IPMT for innovations in solar technologies with polymeric materials*

Reinhold W. LANG,
Gernot M. WALLNER und Jörg FISCHER
Institute of Polymeric Materials and Testing
Johannes Kepler University Linz, Austria

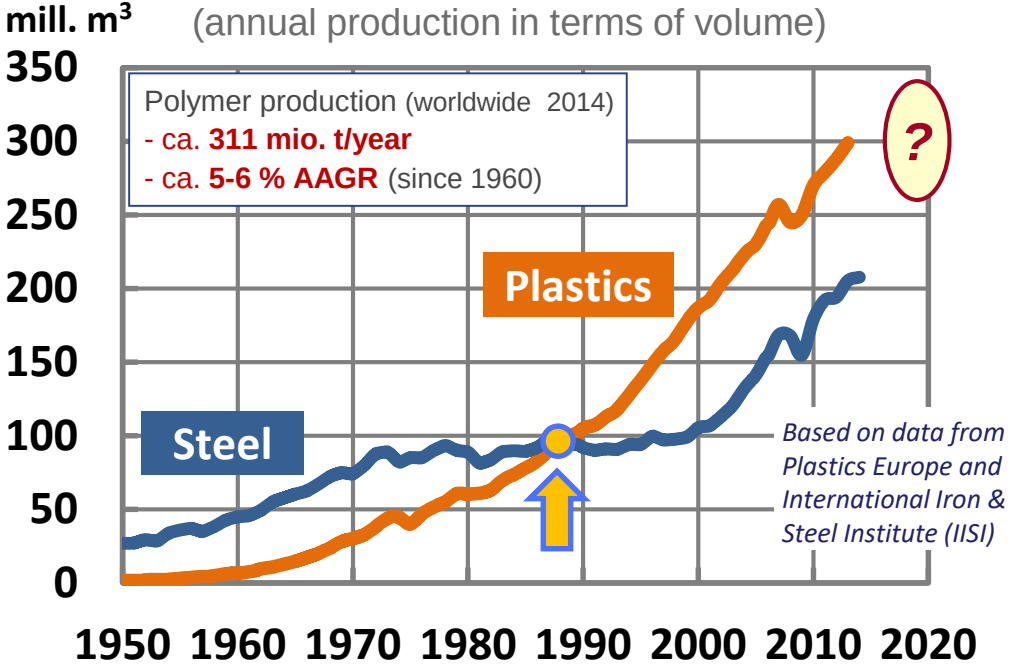
JOHANNES KEPLER UNIVERSITY LINZ

ipmt Institute of Polymeric Materials and Testing

PLASTICS – MATERIALS OF THE 21. CENTURY

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
Ecology	energy efficient products/applications
Innovation	still outstanding & extraordinary potential
Growth Potential	essentially no resource limitation

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

PLASTICS – MATERIALS OF THE 21. CENTURY !?

Kunststoffe sind *vielfältig einsetzbar* und durchdringen *alle Lebensbereiche*

- **Verpackung** (1)
  (inkl. Gütertransport/Logistik)

- **Infrastruktur- & Bautechnik** (2)

- **Mobilität** (3)

BMW i3

Boeing 787

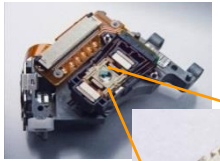
- **Information, Telekommunikation**

- **Sport/Freizeit**

Simplon

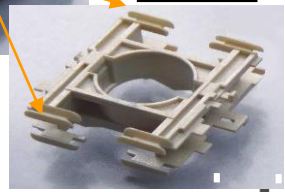
- **Medizintechnik**

- **Feinwerk-technik**



Linsenhalter
DVD-Player

3 mm



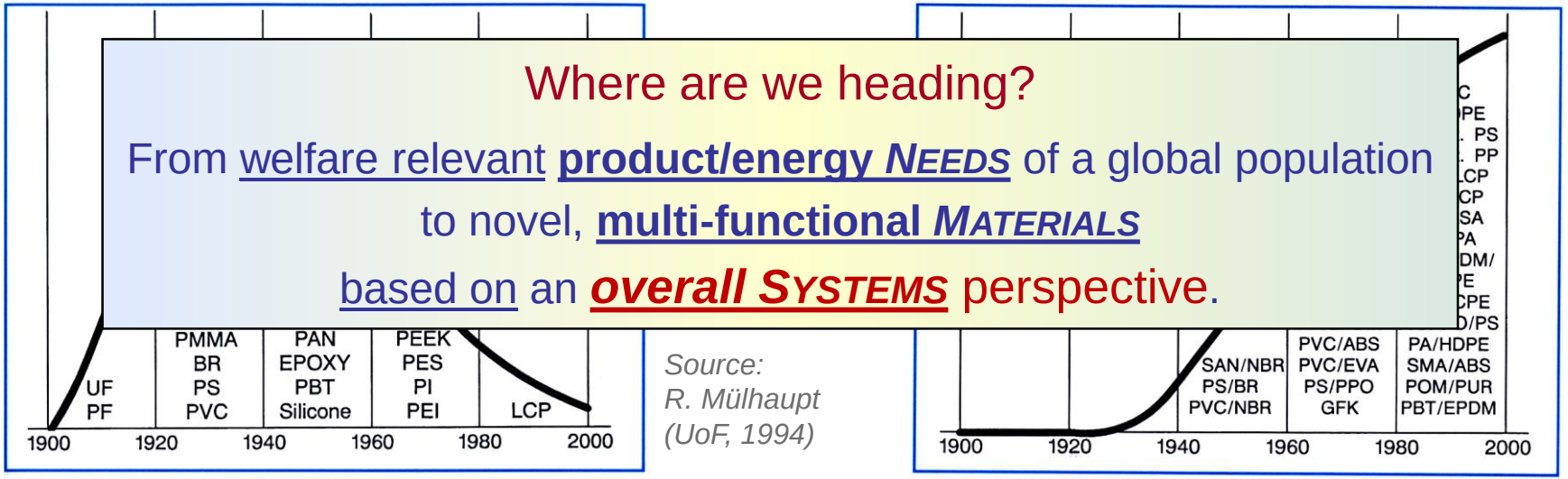
PLASTICS – WHERE ARE WE HEADING?

A HISTORY BASED ATTEMPT FOR AN OUTLOOK

THE GLOBAL GOALS
For Sustainable Development

Development of new plastics based on **new monomers**

Development of new plastics based on **existing monomers**



Where are we heading?

From welfare relevant **product/energy *NEEDS*** of a global population to novel, **multi-functional *MATERIALS***

based on an ***overall SYSTEMS*** perspective.

Source:
R. Mülhaupt
(UoF, 1994)

*From **novel materials** to **needs!***

"Innovations by accident"
(but by diligent work)

*From **needs** to **novel materials!***

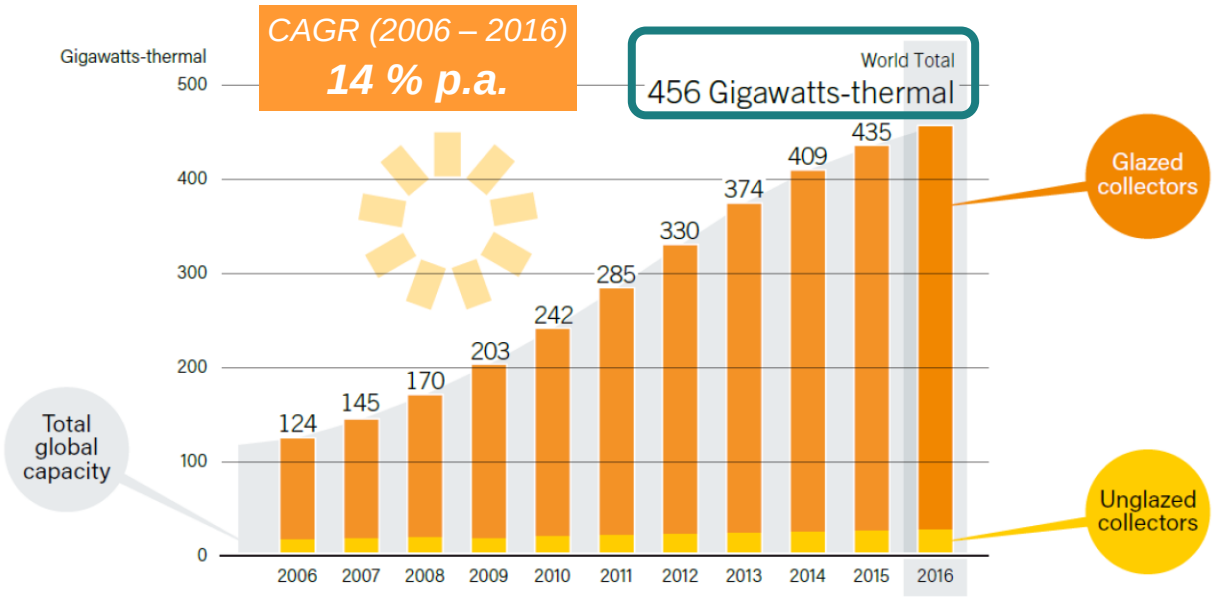
"Innovations by science"
(by diligent & systematic work)

SolarThermal Energy Technologies

A (Fast) Growing Market ?

SolarThermal – Total Global Capacity

(2006 – 2016)



Source: RENEWABLES GLOBAL STATUS REPORT (06/2017)

SolarThermal

collector additions

(worldwide 2016)

21 GW_{th} ~ 15 mio. m^2

~ **0.3 mio. tons** of material

Ca. **25-30 %** of the global end energy demand is low temperature heat

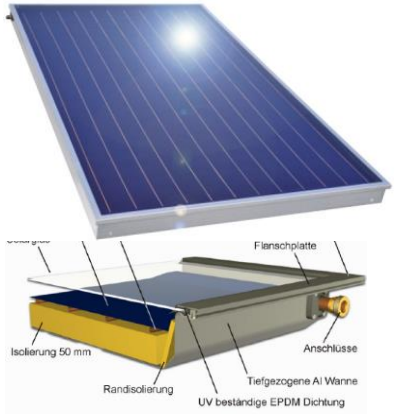
T < 100 °C

KUNSTSTOFFE ALS INNOVATIONSTREIBER & MOTOR

Features of conventional ST collectors

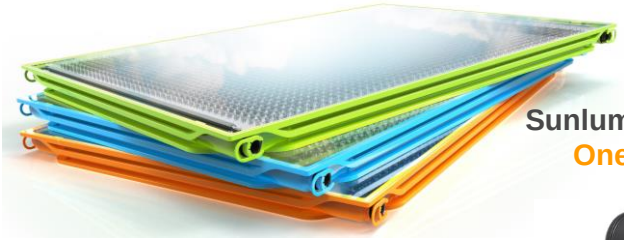
- Mostly vacuum glass pipe & flat plate collectors
- Multitude of materials with little contribution of polymers
- Cost intensive processing and production, assembly and installation

Flat plate collector



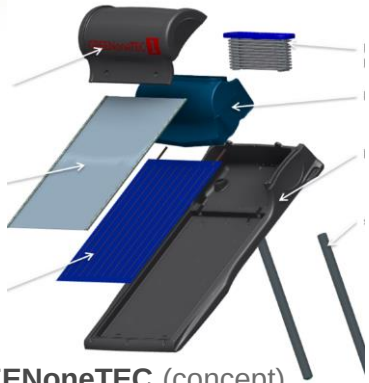
Vacuum tube (glass pipe) collector

Novel (nearly) all-polymeric ST collectors



Sunlumo Technology GmbH
One World Collector

MAGEN eco-Energy
Polymer Collector



GREENoneTEC (concept)
Thermosiphon Polymer Collector

KUNSTSTOFFE ALS INNOVATIONSTREIBER & MOTOR

2 Hauptbegründungen für ***Polymerwerkstoffe als Innovationstreiber*:**

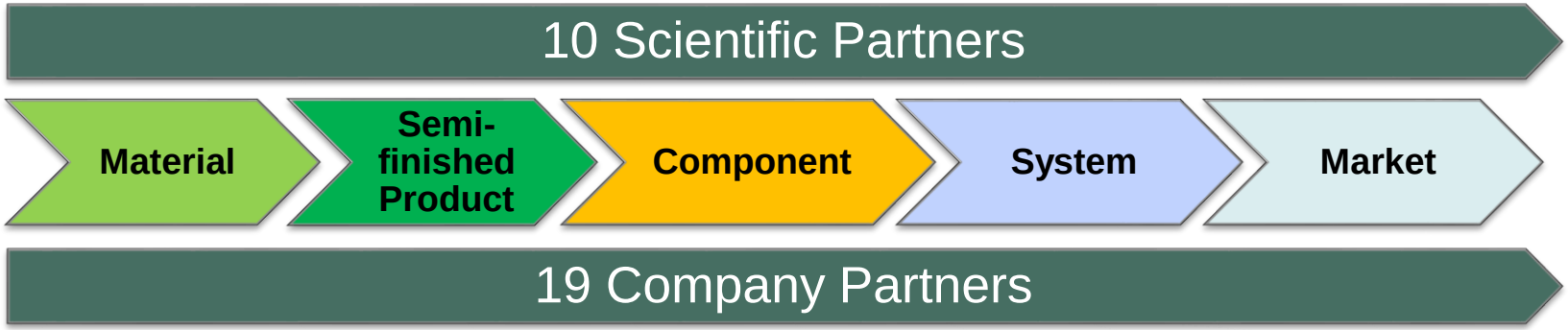
- Maßschneiderbare Eigenschaften und Verarbeitung *("Performance")*
- Kostenreduktion und Wachstumsfähigkeit

Übergeordnete Motivation & Zielsetzung von *SolPol*®:

Steigerung der Innovationskraft & Wettbewerbsfähigkeit
österreichischer Unternehmen im Solartechnologiesektor
durch mittel- und längerfristige *Forschungskooperationen von*
Wissenschaft & Wirtschaft und durch
Einbeziehung von Akteuren der ***gesamten Wertschöpfungskette*.**

THE RESEARCH INITIATIVE *SOLPOL®*

A RESEARCH CONSORTIUM COVERING THE ENTIRE VALUE CREATION CHAIN



OVERALL RESEARCH FIELDS & GOALS:

- All-polymeric **solar-thermal collector systems**
- Novel **encapsulation materials for PV modules**

FACTS & FIGURES

***SOLPOL®* project platform**

Total budget: **~14 mio. EURO**

Duration: **2010-2018** (8 years)

COMPANY PARTNERS OF *SOLPOL®*

solpol

- ***AGRU*** *Kunststofftechnik GmbH*
- ***ALANOD*** *GmbH & Co. KG*
- ***APC*** *Advanced Polymer Compounds*
- ***Borealis*** *AG*
- ***Calus*** *GmbH*
- ***Easol*** *e.U.*
- ***Engel Austria*** *GmbH*
- ***Gabriel-Chemie*** *Gesellschaft m.b.H.*
- ***GREENoneTEC*** *Solarindustrie GmbH*
- ***Greiner*** *Technology & Innovation GmbH*
- ***KE KELIT*** *Kunststoffwerk Gesellschaft m.b.H.*
- ***KIOTO*** *Photovoltaics GmbH*
- ***Lenzing Plastics*** *GmbH & Co KG*
- ***PerkinElmer*** *Vertriebs GmbH*
- ***Schöfer*** *GmbH*
- ***SENOPLAST*** *KLEPSCH & Co GmbH*
- ***Sunlumo*** *Technology GmbH*
- ***Sun Master*** *Energiesysteme GmbH*
- ***Sunplugged*** *GmbH*

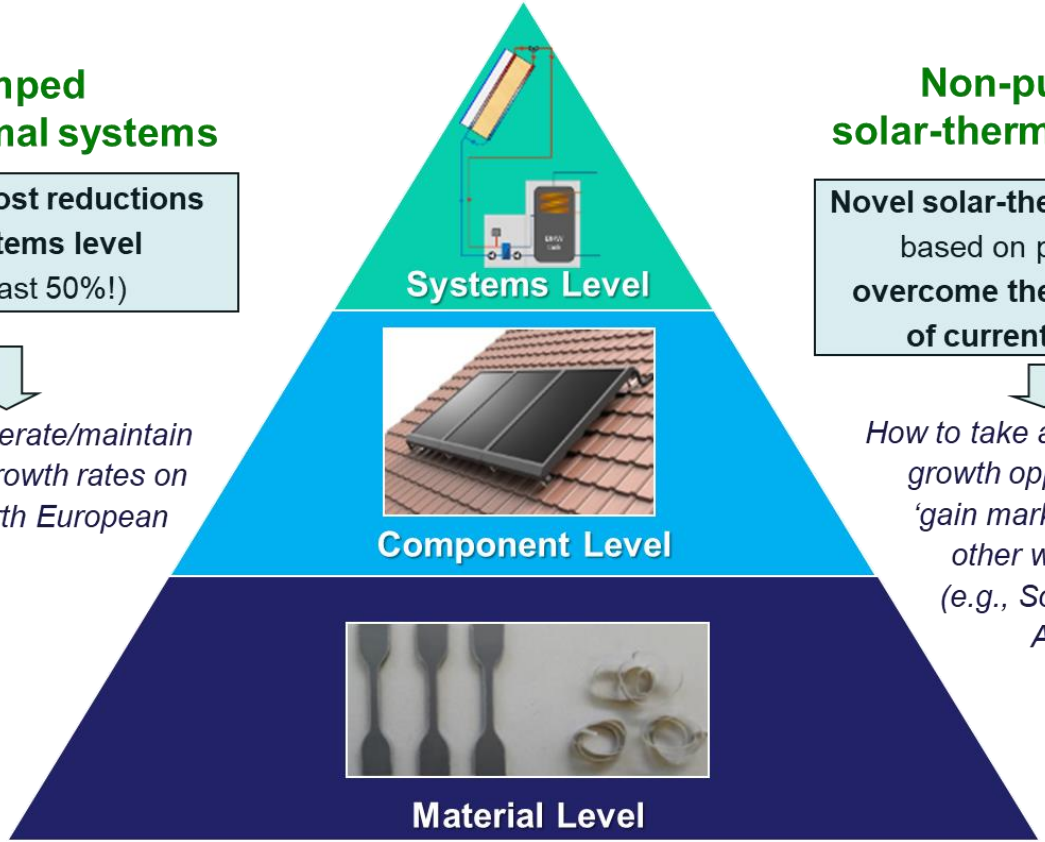
The SolPol-4/5 Solar-thermal Performance Pyramid (3 Levels)

Main Challenges and Key Questions

Pumped solar-thermal systems

Significant cost reductions on a systems level (by at least 50%!)

How to regenerate/maintain reasonable growth rates on Central & North European markets?



Non-pumped solar-thermal systems

Novel solar-thermal products based on plastics that **overcome the deficiencies of current systems**

How to take advantage of growth opportunities & 'gain market shares in other world regions (e.g., South Europe, Africa, Asia)?

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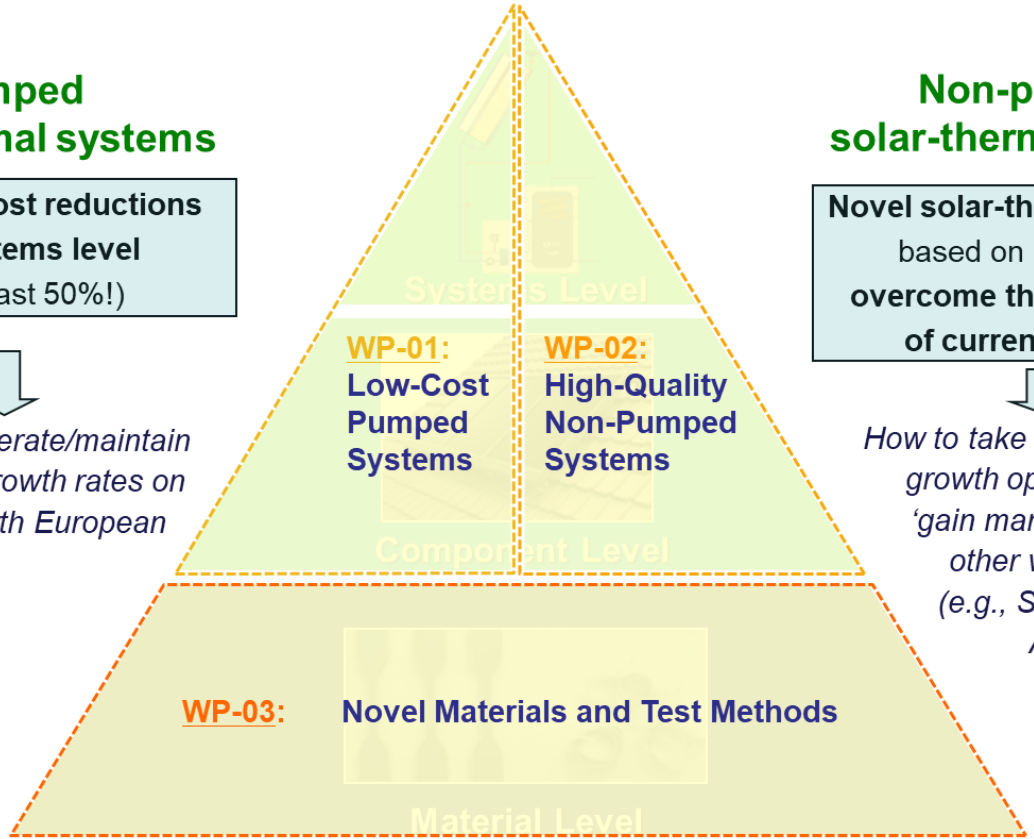

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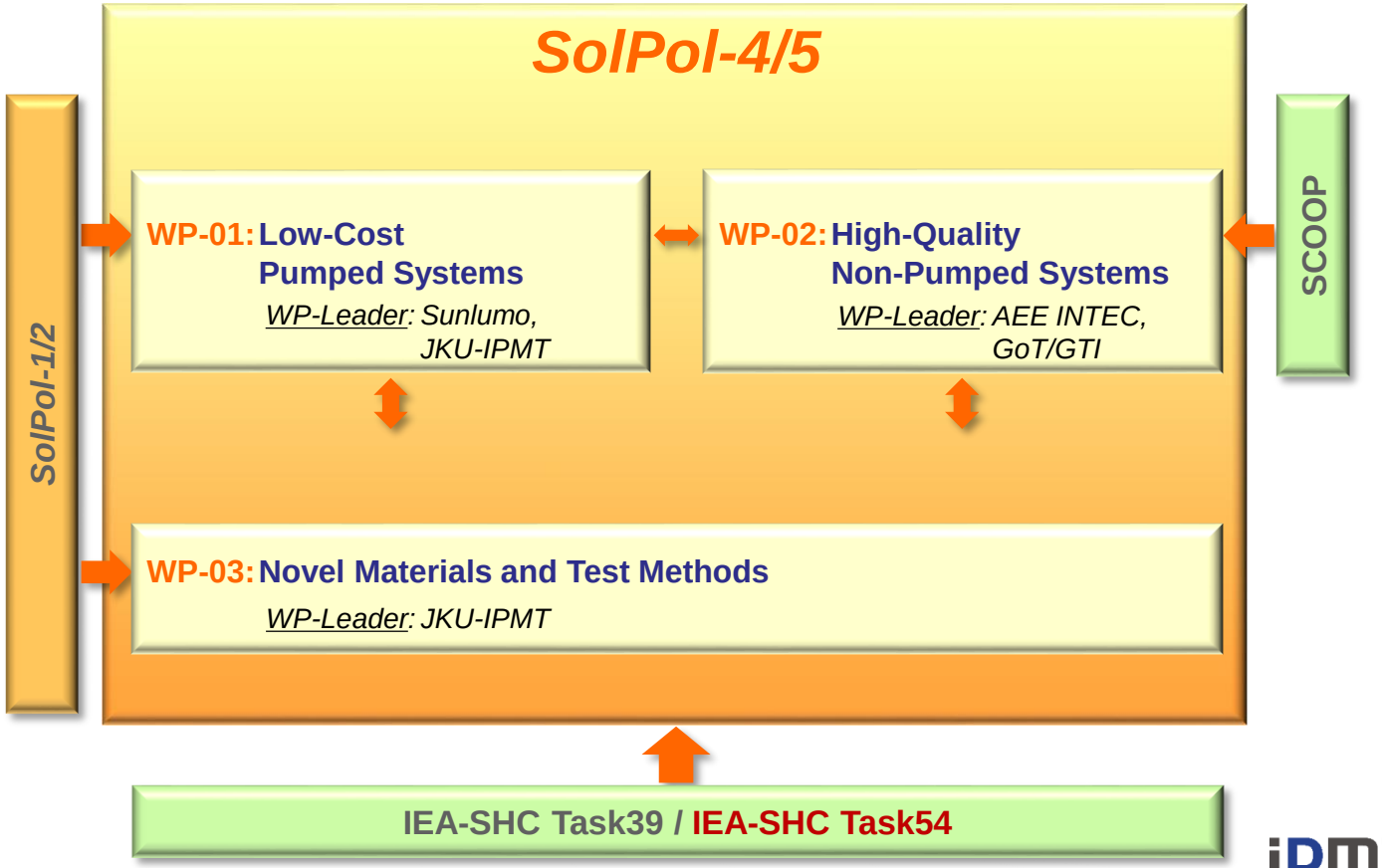
SolPol-4/5 Research Program

Towards All-Polymeric Collector Designs & Systems

Work Package (WP) structure & interaction with other projects



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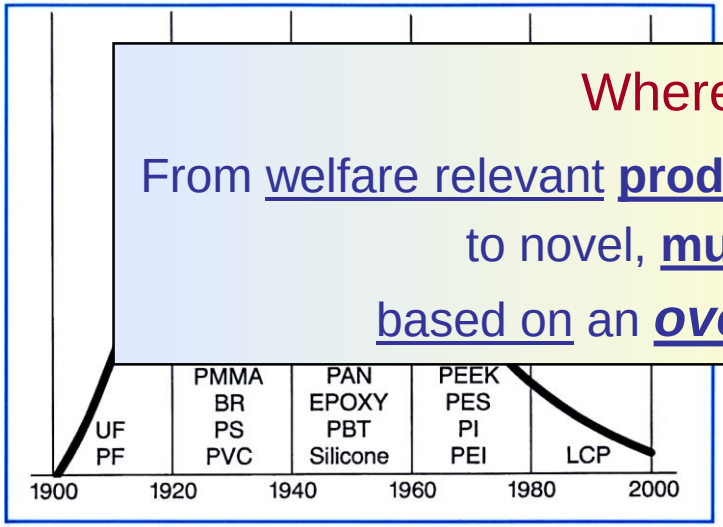

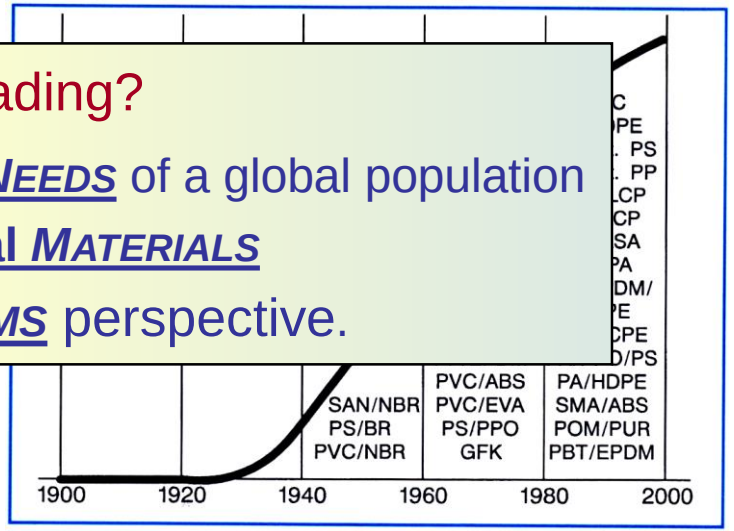

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SolarThermal Energy Technologies

Towards All-Polymeric Collector Designs & Systems

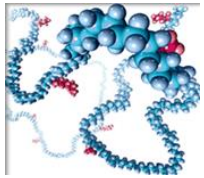
solpol

The SolPol Research Initiative of JKU-IPMT (19/10 Company/Scientific Partners)

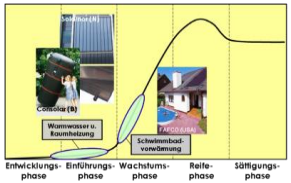
A Comprehensive Systems & Science Based Approach since 2010

From the **planetary/world systems** perspective …

…to the **engineering systems/components** perspective…



… to the **polymeric materials** perspective
with tailored polymeric materials & products …



… to **market penetration & growth?**

SOLARTHERMAL ENERGY TECHNOLOGIES

TOWARDS ALL-POLYMERIC COLLECTOR DESIGNS & SYSTEMS

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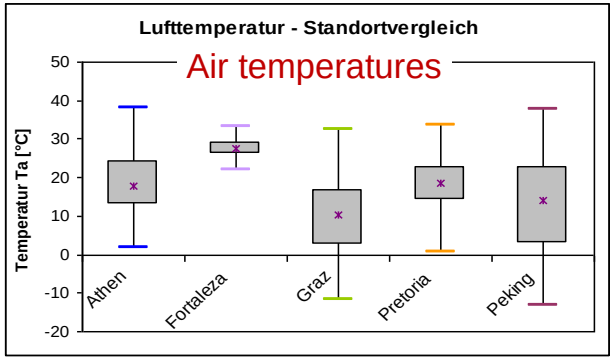
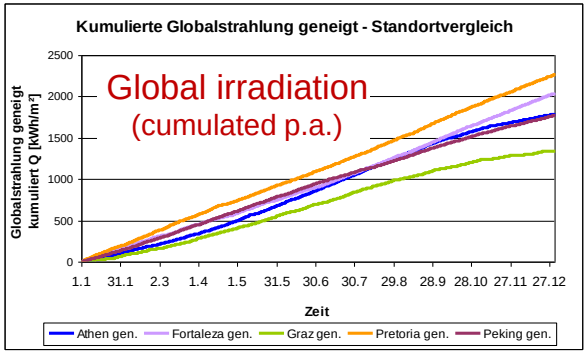
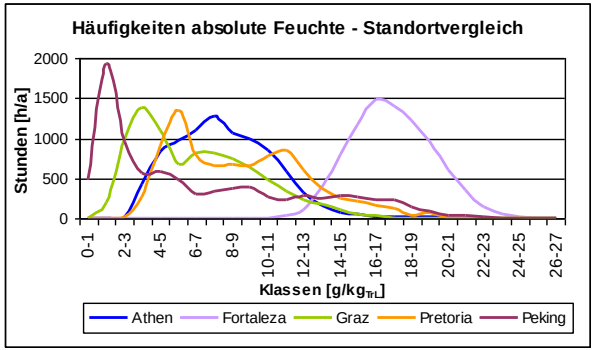
(1) The **planetary/world systems perspective**
selection of 5 representative climate regions (Meteonorm)

Relative humidity
(cumulated p.a.)

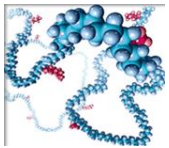




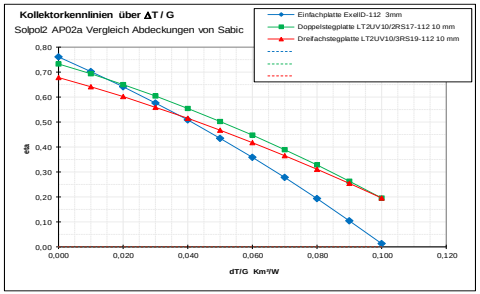


(2) The **engineering systems/components perspective**
definition of collector type and system (modeling/simulation)

(3) The **component specific materials perspective**



Quantitative material property & performance requirements



JKU

ipmt

SolarThermal Energy Technologies

Towards All-Polymeric Collector Designs & Systems

solpol

Performance Requirements for All-polymeric ST Collector Systems

More in presentation by Th. Ramschak

Source:
Ch. Fink, A. Kaiser, R. Hausner
(AEE-INTEC, Gleisdorf, A)

Temperature and pressure profile of a plastics absorber

- Temperature frequency of collector (mean temperature)
- Minimum and maximum pressure of absorber

			frequency [h/a]												pressure min [bar abs.] / pressure max [bar abs.]	
		temperature classes →	<0 [°C]		0 to 75 [°C]		75 to 100 [°C]		100 to 125 [°C]		125 to 150 [°C]		150 to 175 [°C]		175 to 200 [°C]		>200 [°C]	
Graz - domestic hot water - SFH	Reference system	emptying behaviour bad		2,46		2,47		2,61		2,68		2,74		3,70		3,70		-
				2,47		2,61		2,67		2,74		3,88		4,72		5,45		-
		emptying behaviour good	1059	2,46	7431	2,47	86	2,61	25	2,68	39	2,74	72	3,70	48	3,70	0	-
				2,47		2,61		2,67		2,74		3,70		4,10		4,58		-
		emptying behaviour very good		2,46		2,47		2,61		2,68		2,74		3,70		3,70		-
				2,47		2,61		2,67		2,74		3,74		3,96		4,09		-
	polymeric system with OHP (chiller)		1125	1,27	7462	1,29	173	1,49	0	-	0	-	0	-	0	-	0	-
				1,31		1,51		1,57		-		-		-		-		-
	polymeric system with OHP (thermotropic layer)		1129	1,27	7450	1,29	182	1,52	0	-	0	-	0	-	0	-	0	-
				1,31		1,53		1,60		-		-		-		-		-
	polymeric system without OHP		978	0,60	7337	0,60	171	0,60	148	1,00	107	1,00	19	1,00	0	-	0	-
				1,14		1,14		1,14		1,00		1,00		1,00		-		-
Graz	Reference sys	emptying behaviour good	1054	2,68	6791	2,69	547	2,76	73	2,79	106	2,83	101	4,25	86	4,25	2	4,25
				2,69		2,76		2,79		2,83		4,25		4,89		5,40		4,25
		emptying behaviour very good		2,68		2,69		2,76		2,79		2,83		4,25		4,25		4,25
				2,69		2,76		2,79		2,83		4,25		4,61		4,88		4,25
	polymeric system with OHP		1123	1,26	7243	1,29	1694	1,53	0	-	0	-	0	-	0	-	0	-

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SolarThermal Energy Technologies

Towards All-Polymeric Collector Designs & Systems

solpol

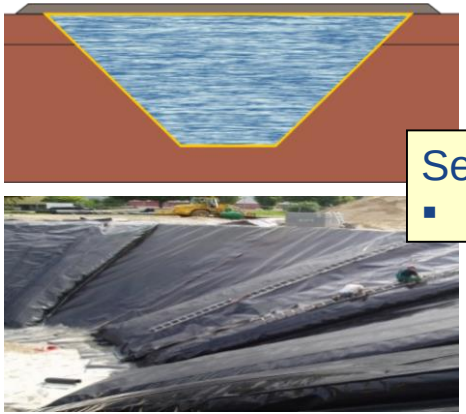
Novel Polyolefin-Compounds for Solarthermal Systems (Borealis, AGRU)

Example 1: PO absorber material

System type & service requirements

- pressurized OHC system
- service life: **20+ years**
- region: Graz (Austria)

Example 2: PO liner for buried, large-volume hot-water stores



Service requirement

- service life: **30+ years**

Research goal: **Polyolefins (PE, PP)** with

15+ °C enhanced long-term temperature resistance

(incl. science-based lifetime assessment)

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Towards All-Polymeric Collector Designs & Systems

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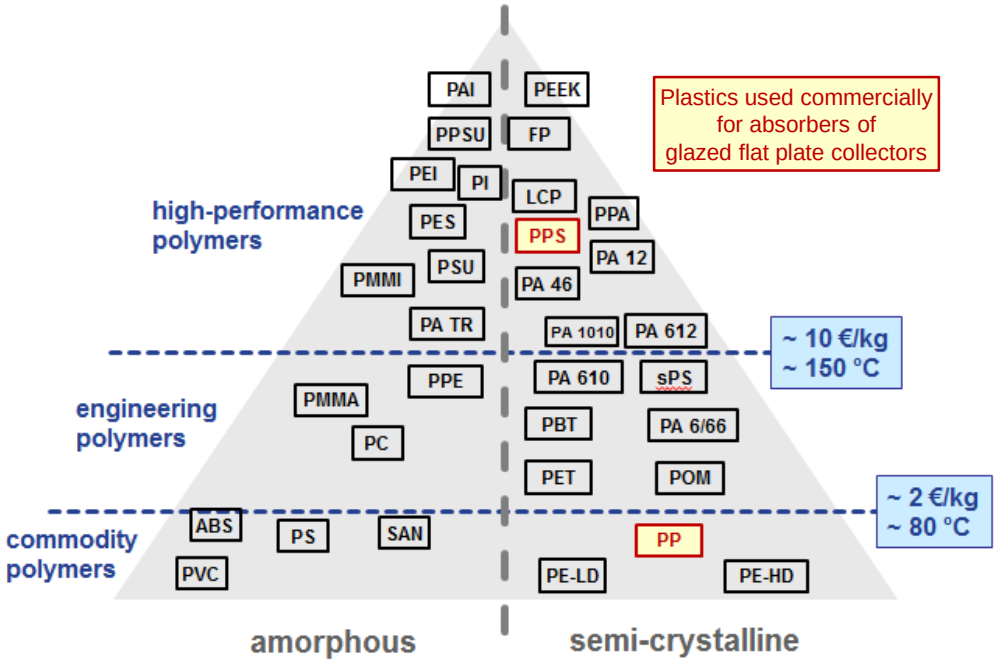
Performance/Price Pyramid of Plastics



Plastics used commercially for absorbers of glazed flat plate collectors

Primary overall aims

Performance/Price Requirements

- With OH-control:
  polyolefins (PE, PP)
  – thermal stability **plus ~15 K**
- Without OH-control:
  high-performance plastics
  – price reduction to **< 6 €/kg**

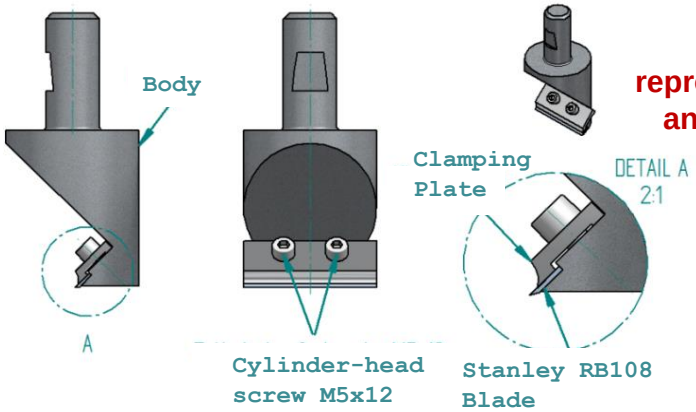
SolarThermal Energy Technologies

Towards All-Polymeric Collector Designs & Systems

Aging acceleration via micro-sized specimens

(Dissertations: K. Grabmayer, M. Povacz, M. Grabmann)

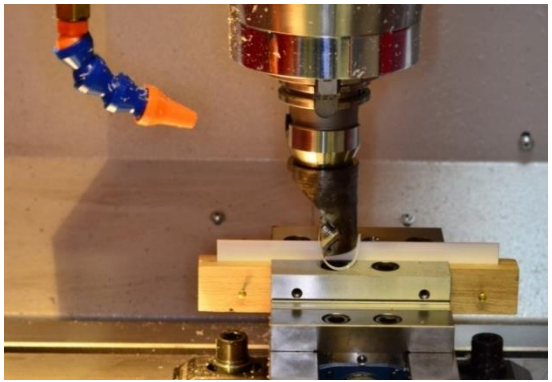
Planing tool for production of micro-sized specimens

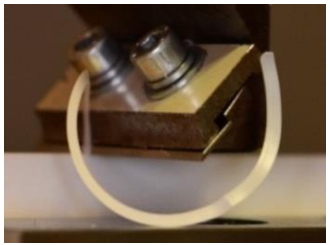


Automated production of micro-sized specimens with reproducible geometrical dimensions and material properties achieved!

More in presentation by M. Grabmann

CNC machining process





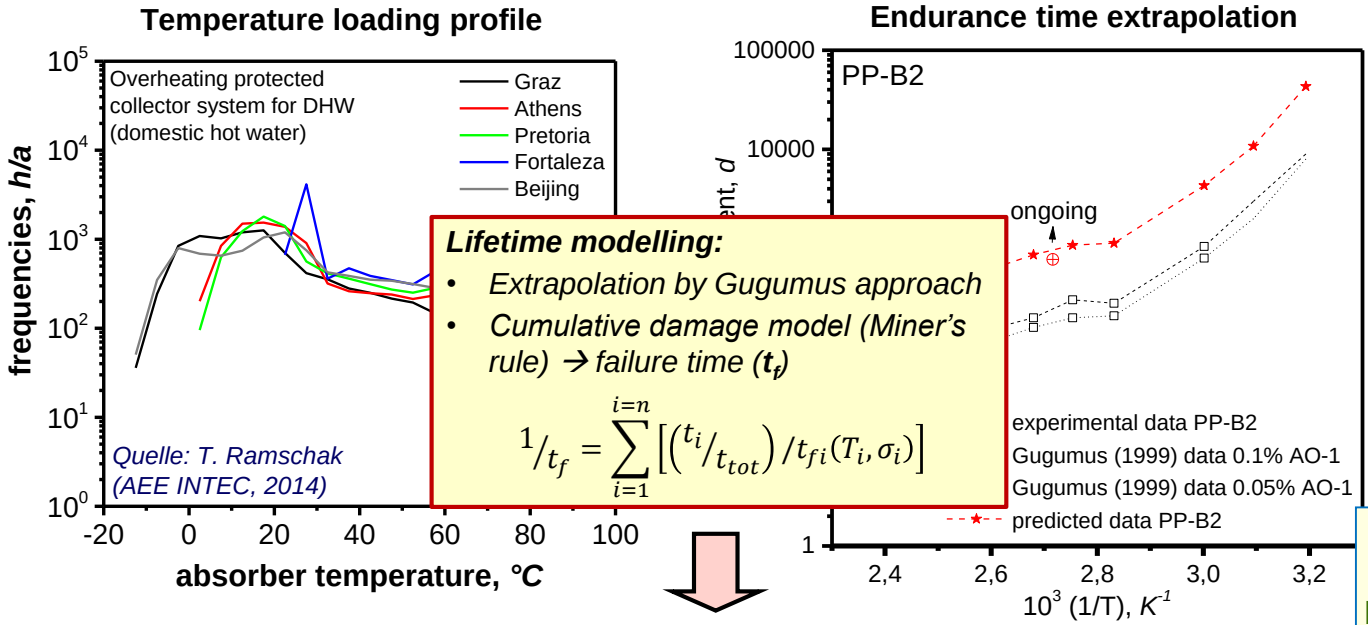
Number of micro-sized specimens produced so far (as of 2011):

- **> 30,000** for material screening
  (aging and testing for many in progress)
- **~ 2,000 for method development**

SOLARTHERMAL ENERGY TECHNOLOGIES

TOWARDS ALL-POLYMERIC COLLECTOR DESIGNS & SYSTEMS

OHC collector: Lifetime assessment for extruded PP absorbers



Lifetime modelling:

- *Extrapolation by Gugumus approach*
- *Cumulative damage model (Miner's rule) → failure time (t_f)*

$$1/t_f = \sum_{i=1}^{i=n} \left[\left(t_i / t_{tot} \right) / t_{fi}(T_i, \sigma_i) \right]$$

More in presentation by M. Grabmann

Lifetime, years	Graz, AT	Athens, GR	Pretoria, RSA	Fortaleza, BR	Beijing, CHN
PP-B1	21	15	14	8	23
PP-B2 (Borealis)	32	25	24	15	34

Source: Dissertation M. Povacz (JKU IPMT, 2014)

SolarThermal Energy Technologies

Towards All-Polymeric Collector Designs & Systems

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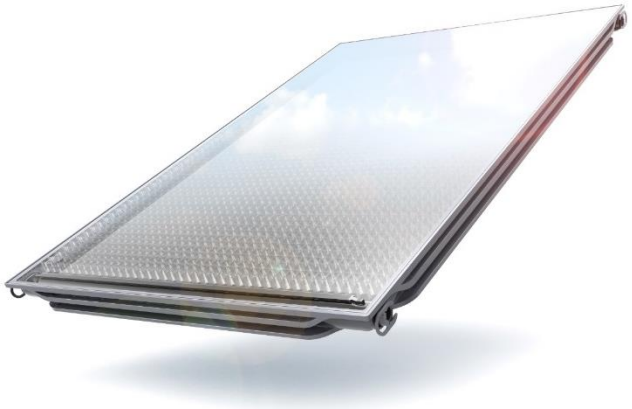
The One-World-Solar-System by Sunlumo Technology GmbH

One-World-Solar-Collector©



More in presentation by R. Buchinger

Polymer-made solar pumping group with push-fit connectors and piping

One-World-Solar-System©

with polymer-made hot water storage

SolarThermal Energy Technologies

Towards All-Polymeric Collector Designs & Systems

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All-Polymeric ISC by GREENoneTEC Solarindustrie GmbH

Integrated Storage Collector (ISC)
conventional materials
with PA-GF endcaps

working principle

More in presentation by G. Ziegler

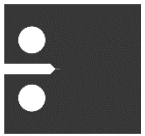
Tap water

≤ 5 ppm Cl

Drinking water

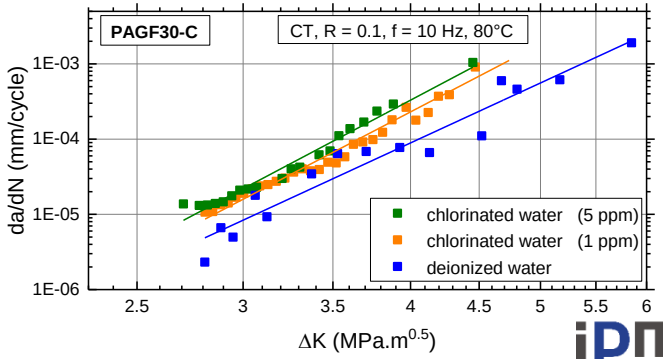
More in presentation by P. Bradler

Specimen



Test setup

Fatigue crack growth kinetics



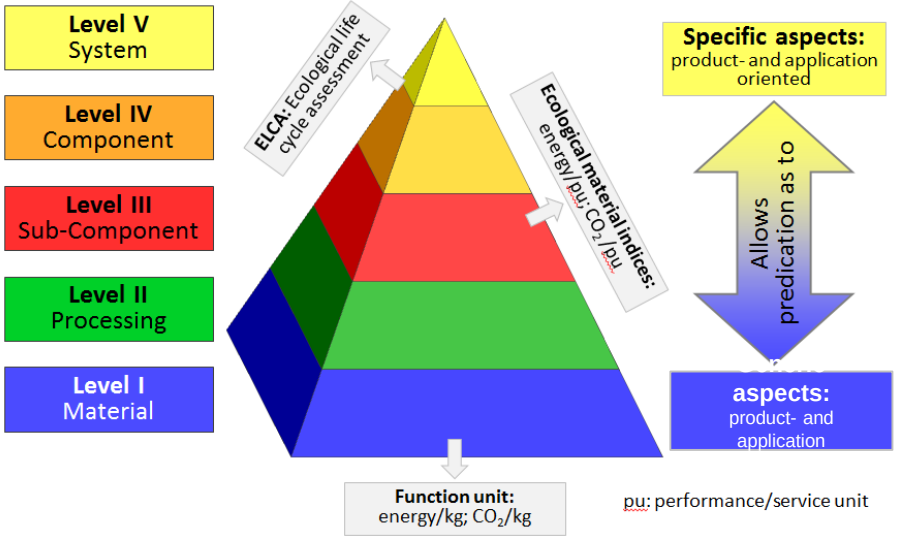
JKU

ipmt

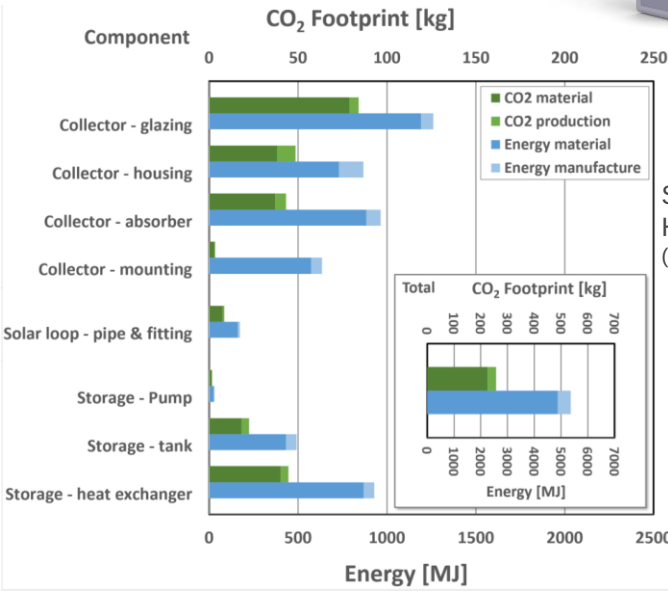
SOLARTHERMAL ENERGY TECHNOLOGIES
TOWARDS ALL-POLYMERIC COLLECTOR DESIGNS & SYSTEMS

Ecological Assessment: From *"function units"* at the materials level to *"material indices"* at the component/systems level

The Ecological Performance Pyramid
Ecological life cycle assessment (ELCA) for various product and performance levels



One-World-Solar-System
with polymer-made hot water storage
©Sunlumo Technology GmbH



Source:
H. Kicker et al.
(JKU-IPMT, 2015)

R.W.Lang, M.Svoboda, H.Kicker
Univ. of Cambridge (UK; 04/2013)

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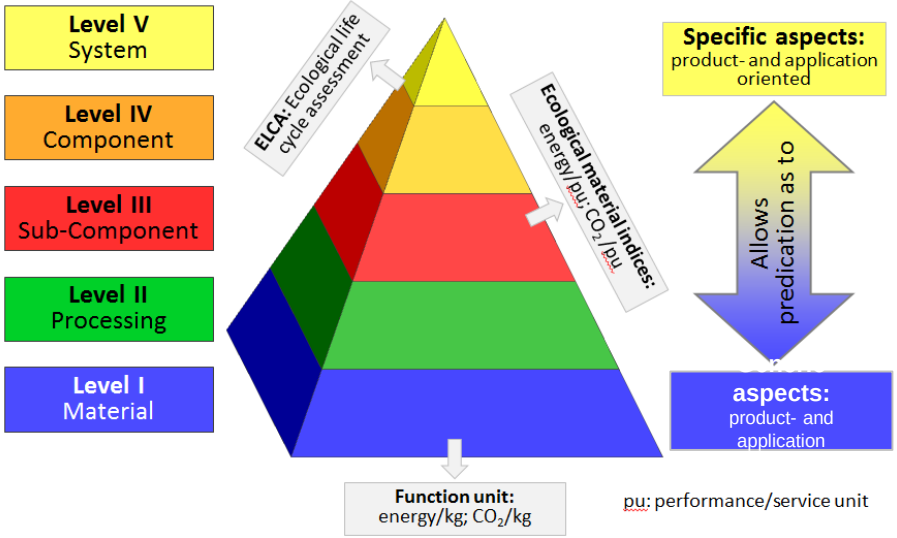

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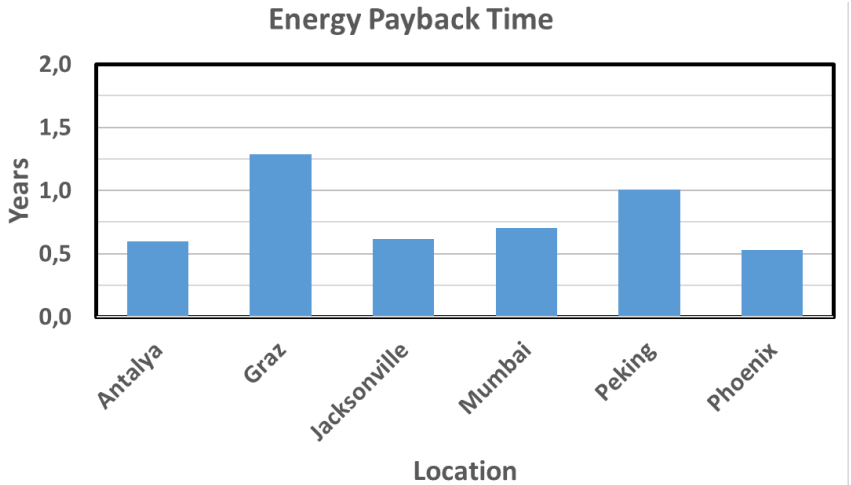
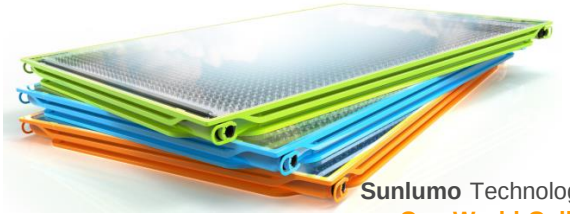


Source: H. Kicker et al. (JKU-IPMT, 2015)

THE JKU SOLPOL® RESEARCH INITIATIVE

SUMMARY AND OUTCOME SO FAR

All-polymeric solar-thermal collector systems



Sunlumo Technology GmbH
One World Collector

Award Ceremony:
28. März 2017

Die VERENA 2017 Preisträger
Sunlumo Technology GmbH
und
Institute of Polymeric Material and Testing
Johannes Kepler Universität Linz

SolPol directed by:
R. W. Lang & G. M. Wallner

JKU Linz 2016
Shanghai World Ranking
in ***Materials Sci. & Eng.***:
TOP 100 !

SCIENTIFIC-ACADEMIC OUTPUT:

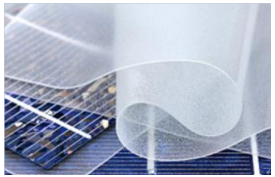
In total, some ***50+ academic theses***

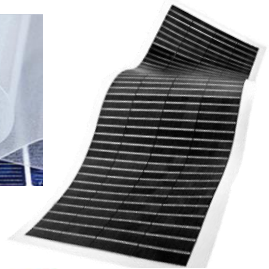
- 14+ PhD Dissertations
- 17+ Master's Thesis
- 16+ Bachelor's Thesis

Some ***40+ refereed publications***
(so far, many more to come!)

More than ***100 presentations/talks***
at nat./internat. conferences & symposia

Novel encapsulation polymers for Photovoltaics





BOREALIS Borouge

Medieninformation

Mediainfo:
22. Mai 2017

Wien, Österreich | 22. Mai 2017

Borealis verstärkt Engagement im Solarbereich mit ISOVOLTAIC

Innovative ICOSOLAR® CPO 3G-Rückseitenfolie als Ergebnis der neuen Partnerschaft mit ISOVOLTAIC

Borealis und Borouge, führende Anbieter innovativer Kunststofflösungen mit Mehrwert, geben ihre neue Partnerschaft mit ISOVOLTAIC, einem globalen Markt- und Technologieführer für Rückseitenfolien für Photovoltaik-Module, bekannt. Auf der Intersolar Europe wird ISOVOLTAIC sein innovatives Produkt ICOSOLAR® CPO 3G vorstellen – eine co-extrudierte Rückseitenfolie für Photovoltaik-Module aus Polypropylen (PP), die im Rahmen eines neuartigen Geschäftsmodells gemeinsam mit Borealis und Borouge entwickelt wurde. Sowohl der Kern als auch die äußeren Schichten der Rückseitenfolie wurden unter Verwendung PP-basierter Werkstoffe der ersten Generation von Borealis' neuer Dachmarke für Solarmaterialtypen und -produkte, Quentys™, entwickelt.

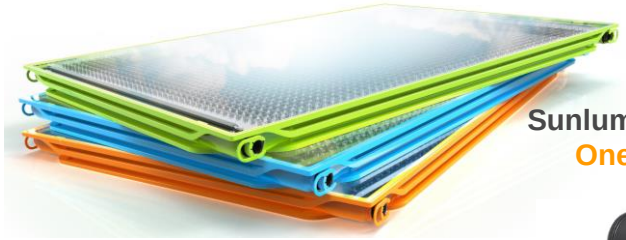
Empowering Solar: Neue Möglichkeiten für die Phc mit Quentys™

KUNSTSTOFFE ALS INNOVATIONSTREIBER & MOTOR

Features of conventional ST collectors

- Mostly vacuum glass pipe & flat plate collectors
- Multitude of materials with little contribution of polymers
- Cost intensive processing and production, assembly and installation

Novel (nearly) all-polymeric ST collectors

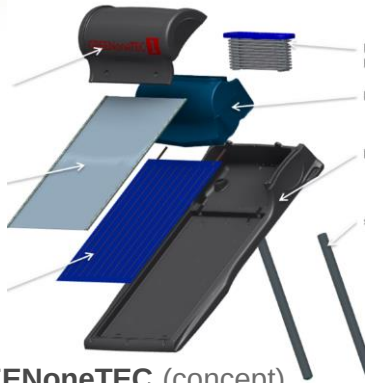


Sunlumo Technology GmbH
One World Collector

Flat plate collector

Vacuum tube (glass pipe) collector

MAGEN eco-Energy
Polymer Collector



GREENoneTEC (concept)
Thermosiphon Polymer Collector