Industrial scale solar thermal energy: the opportunity in agri-processing

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Solar heating in agri-processing workshop

17 November 2016

STIAS Stellenbosch

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Motivation

Why we are here today

- South Africa has
  - Rising energy prices
  - Some of the greatest solar radiation on earth

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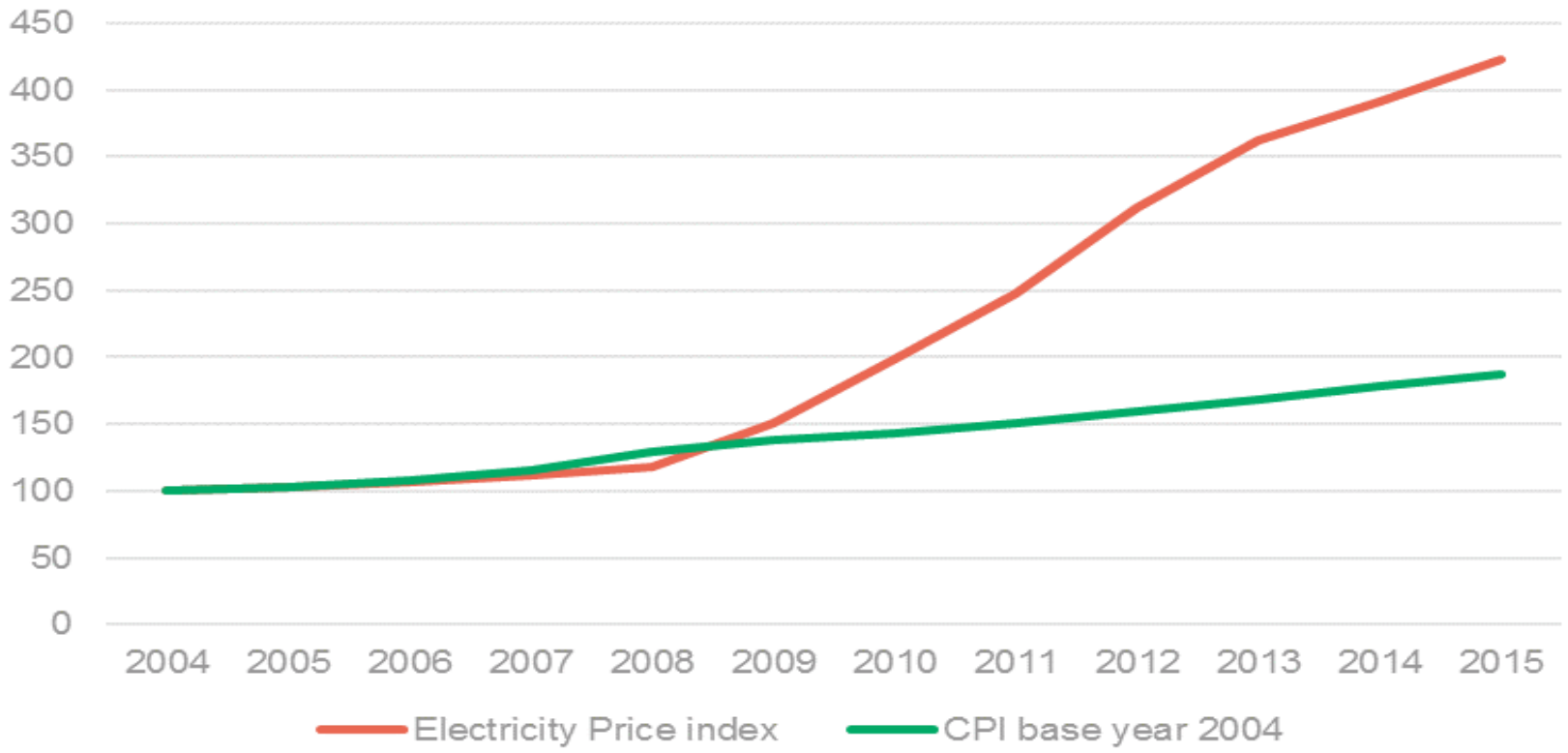
Rising energy prices

- Electricity price rising significantly faster than inflation (CPI)



Source: Own calculations based on NERSA tariff book and StatsSA CPI

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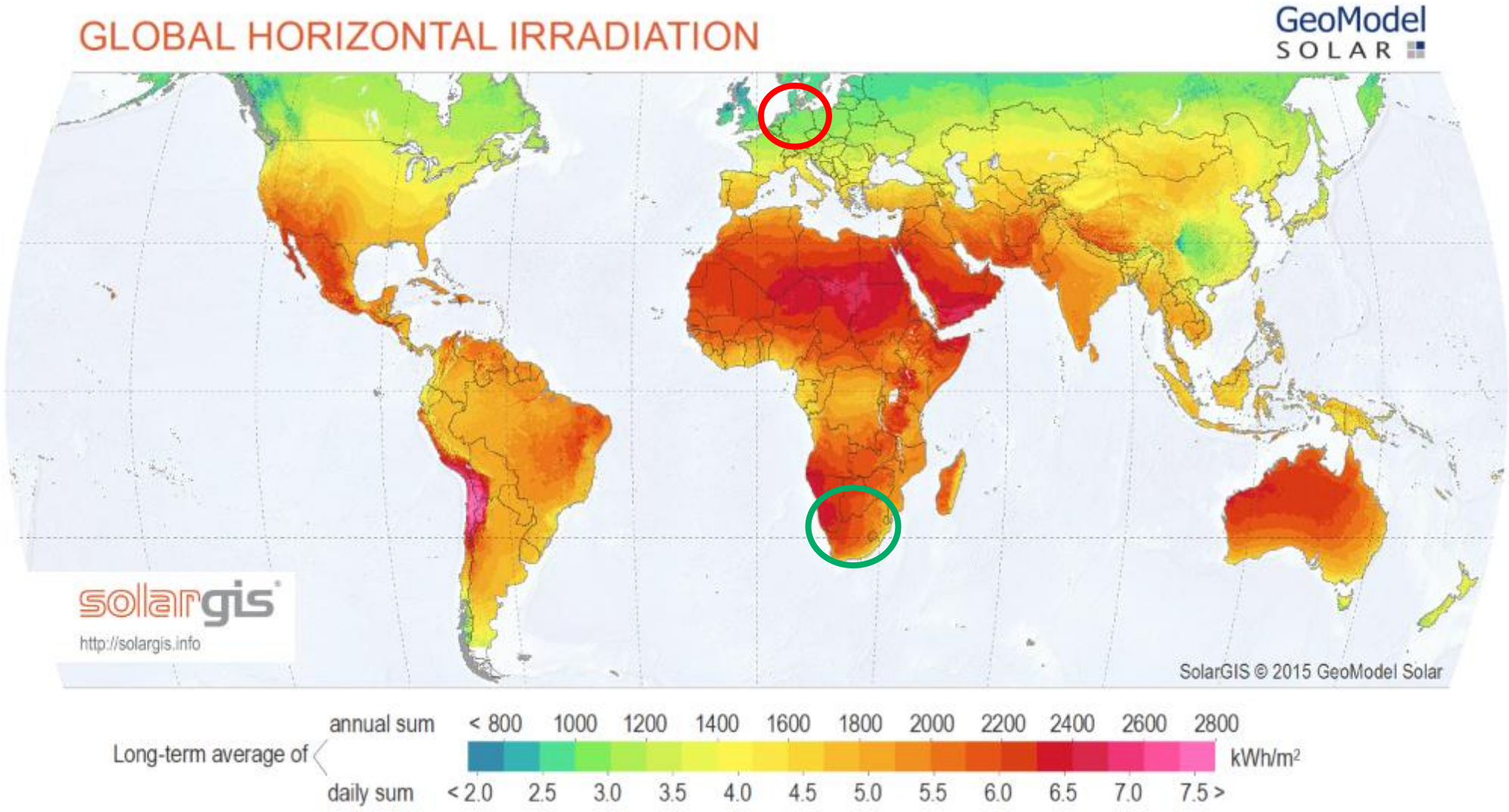
Solar Energy

South Africa's untapped resource

- SA
  - 1 055MW$_{th}$
- Austria
  - 3 541 MW$_{th}$
- Germany
  - 12 281MW$_{th}$



Source: Solargis

Motivation

Why we are here today

- South Africa has
  - Rising energy prices
  - Some of the greatest solar radiation on earth
- Agri-processing has
  - Significant energy demand for heat (79%)[1]
  - Most of which is at low temperatures (less than 160 °C)[2]

1. Lamperia (2014) 2. AEE Intec (2009)

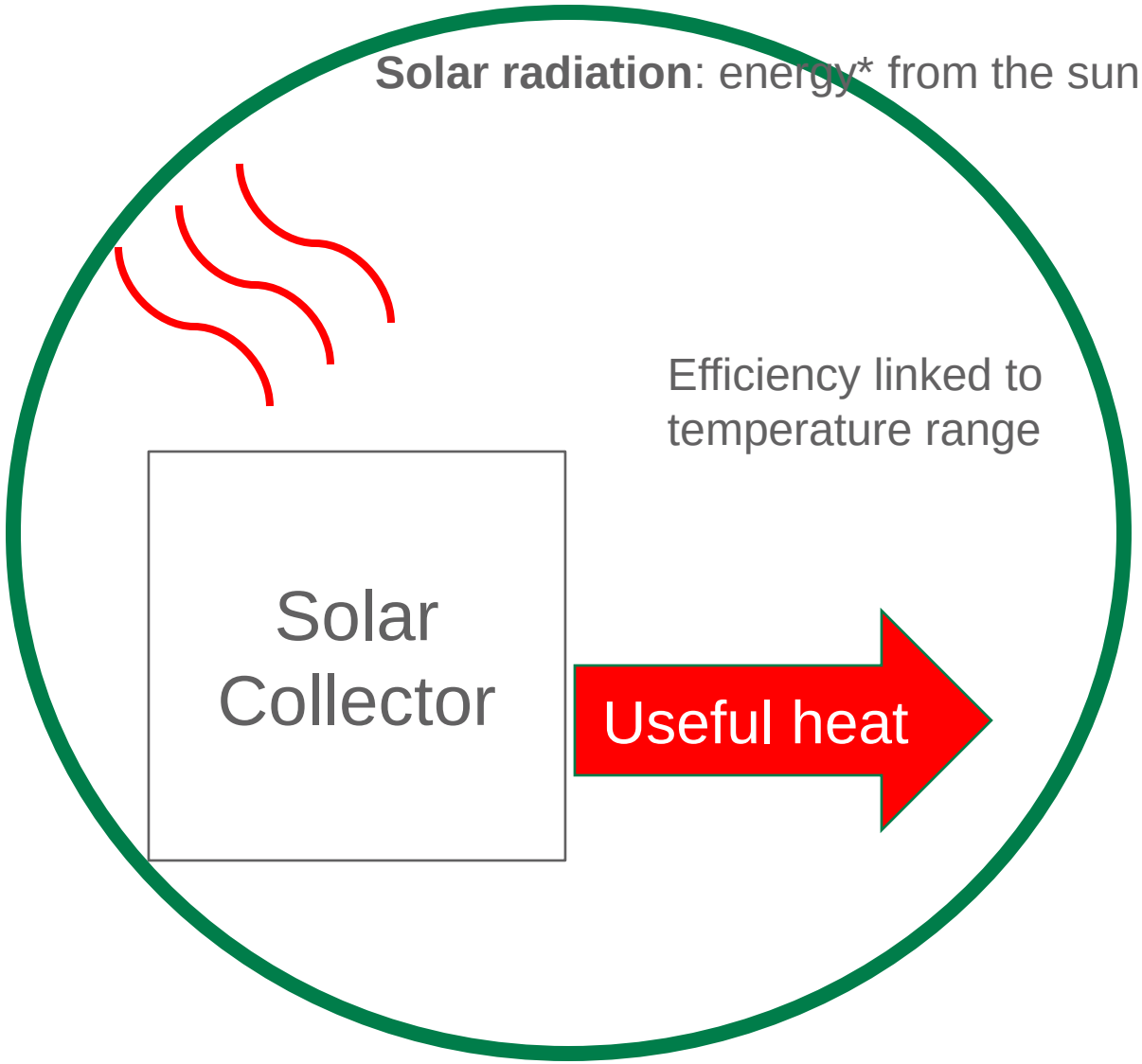
Motivation

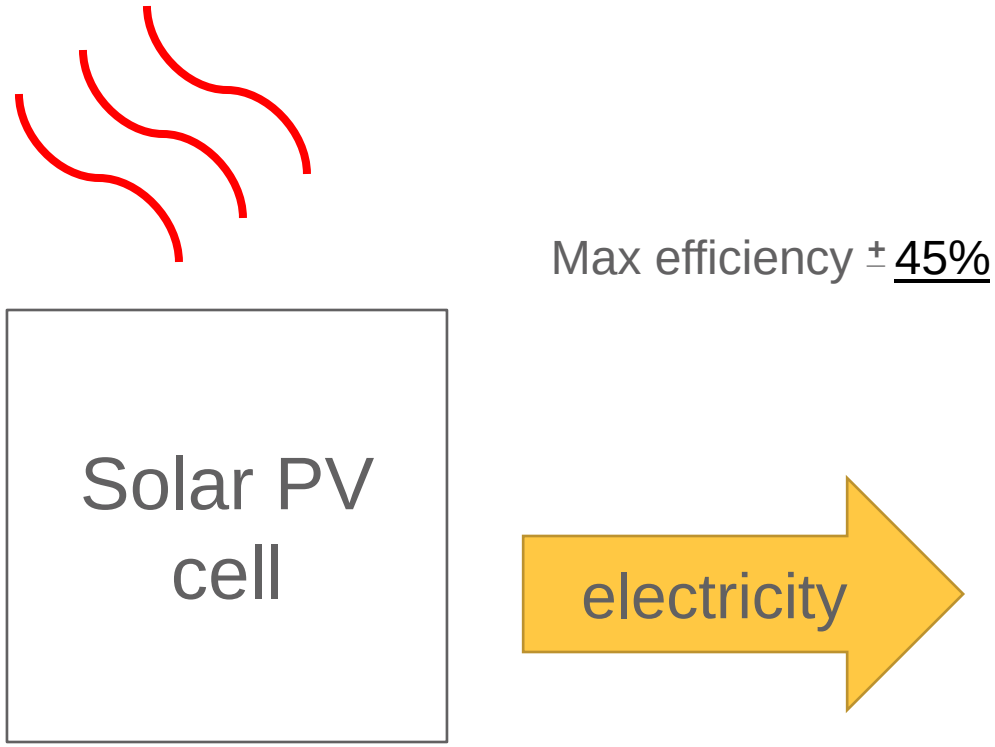
Why we are here today

- South Africa has
  - Rising energy prices
  - Some of the greatest solar radiation on earth
- Agri-processing has
  - Significant energy demand for heat (79%)[1]
  - Most of which is at low temperatures (less than 160 °C)[2]
- Solar thermal
  - Most efficient and economic at low temperature ranges (less than 160 °C) [2]
  - Financially feasible replacement of most fossil fuels[3]

1. Lamperia (2014) 2. AEE Intec (2009) 3. Joubert, Hess & Van Niekerk (2016)

Solar thermal vs solar PV





*In the form of electromagnetic radiation from the infrared (long) to the ultraviolet (short) wavelengths

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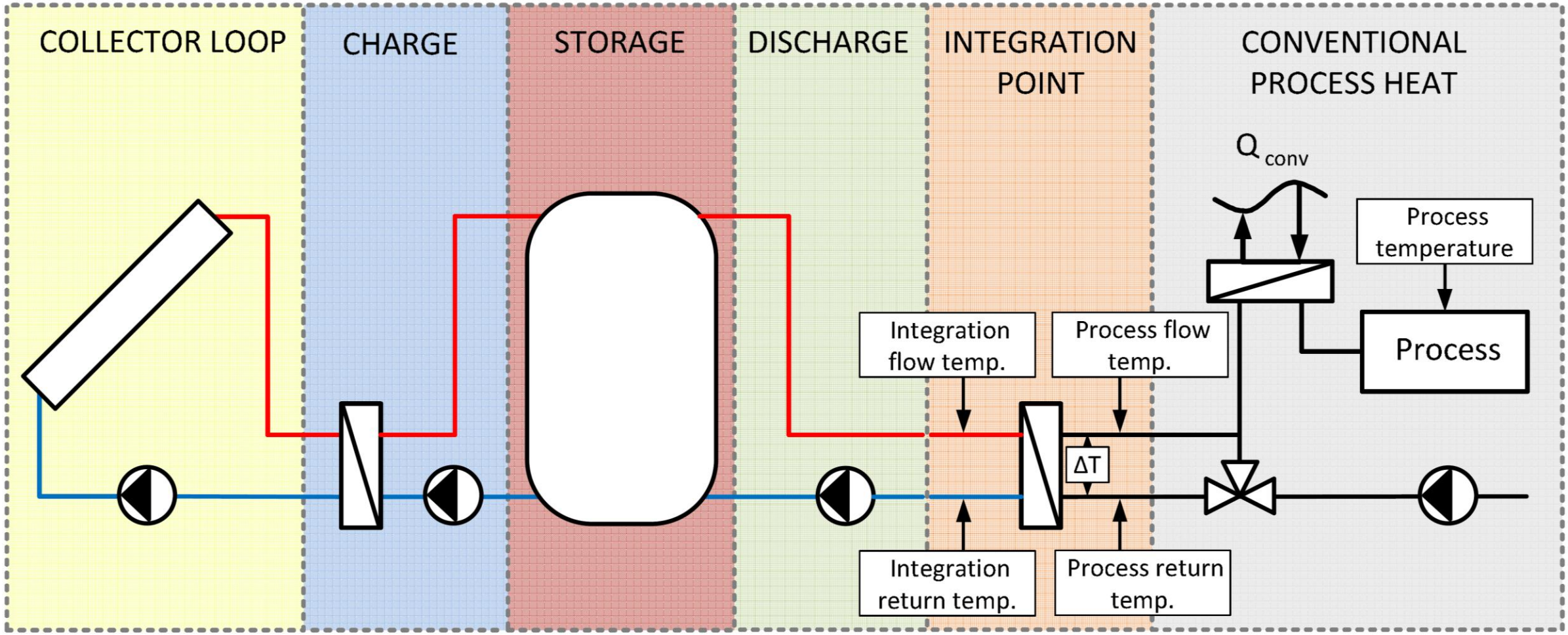
How solar thermal systems work

The basics



Source: Helmke & Hess (2015)

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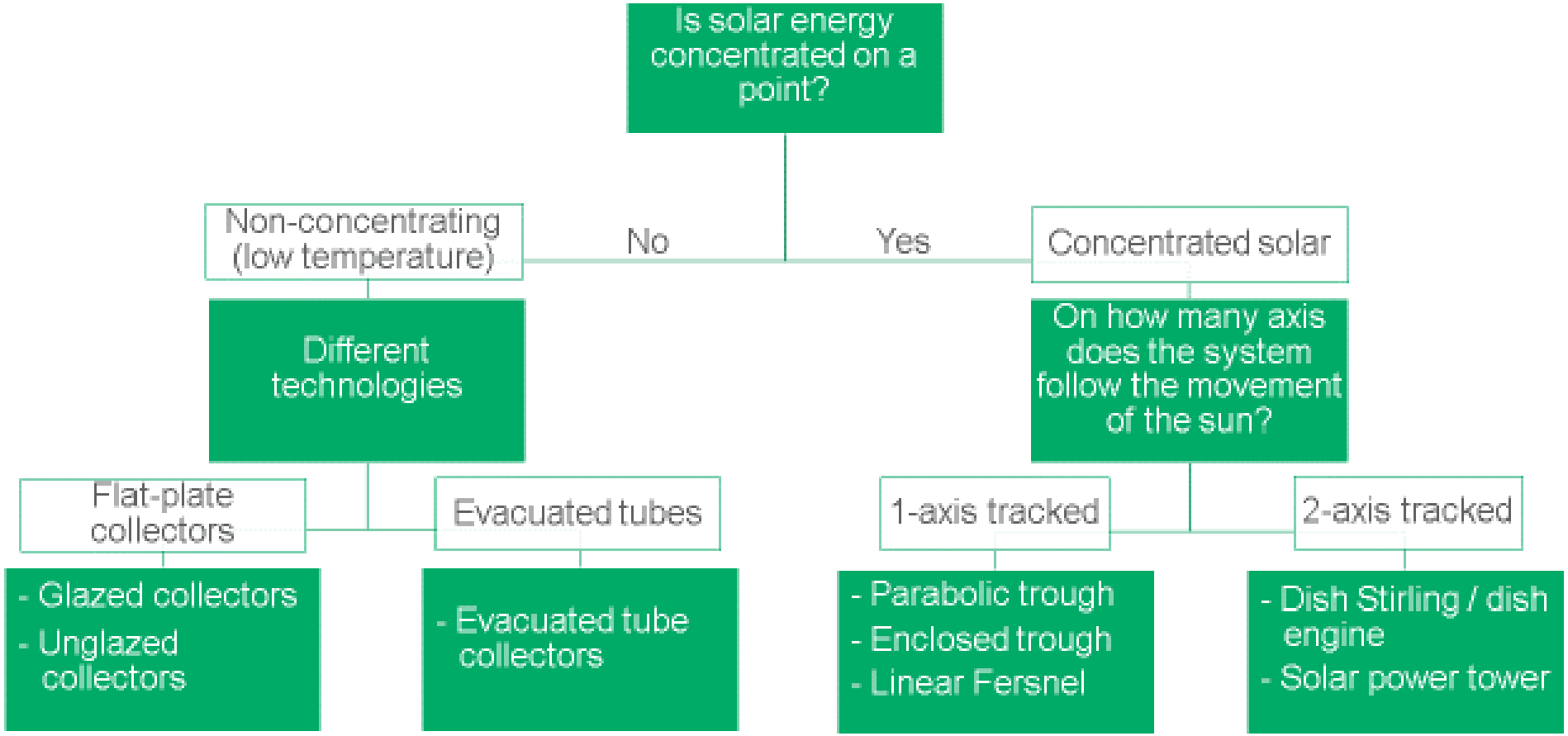
How solar thermal systems work

Solar collectors overview



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How solar thermal systems work

In summary

- Ability to store energy is key selling point
- Most economic at low temperature applications (less 160°C)
  - Wide range of collectors that are applicable to different heat levels
  - Solar heat can be integrated in different ways
- Generally still in conjunction with traditional heat source
  - Rule of thumb: solar fraction of 60% in South Africa

    i.e. 60% of energy per annum provided by solar thermal system

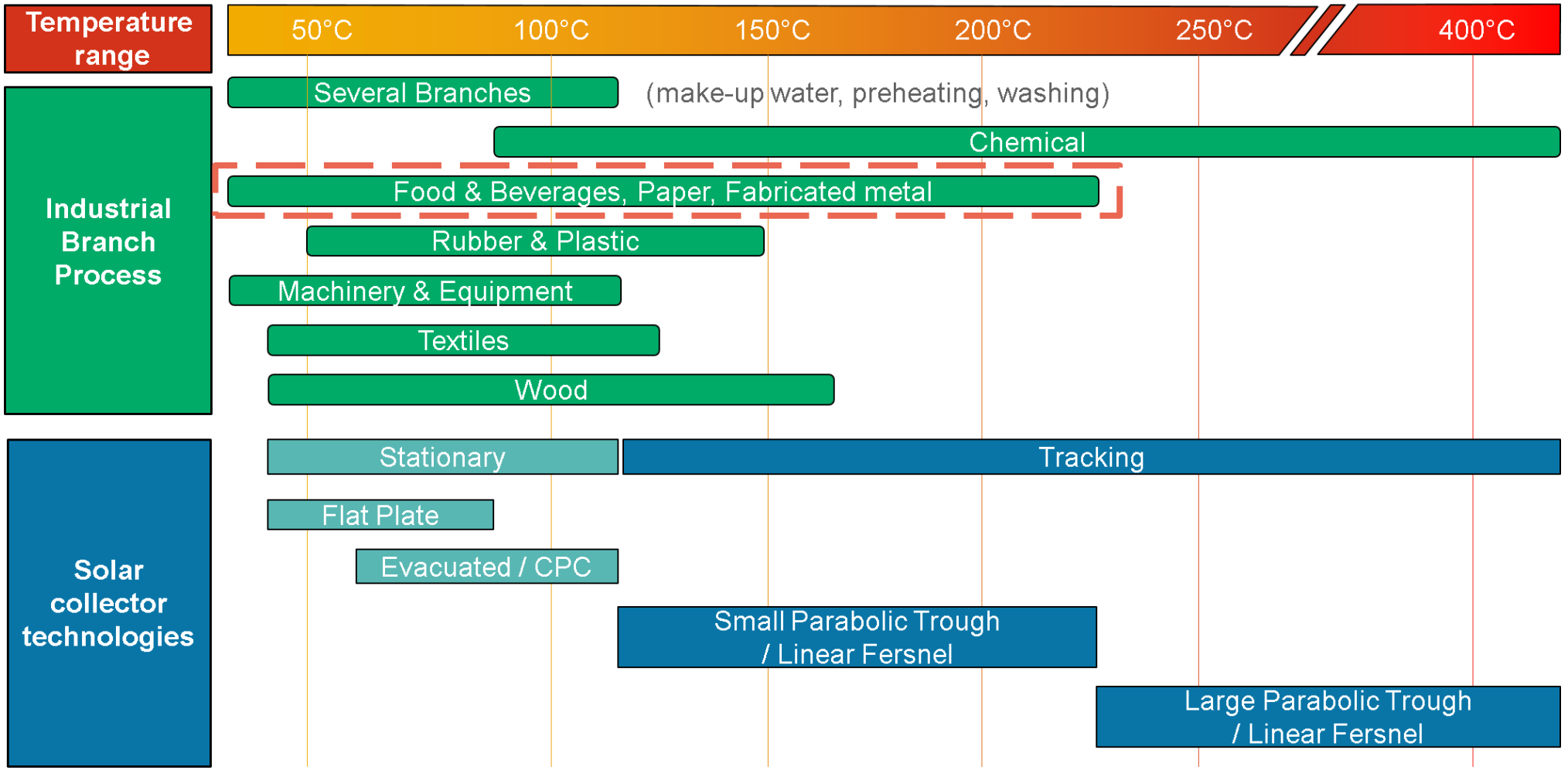
Why focus on agri-processing

- Agri-processing is highlighted as key sector for government support
  - Industrial Policy Action Plan (IPAP) by Department of Trade and Industry (dti)
  - Agripark programme of Department of Rural Development and Land Reform (DRDLR) & Department of Agriculture, Forestry & Fisheries (DAFF)

- Most of agri-processing heat is within the low temperature range (less 160°C)
  - Mostly warm water and some steam e.g. cleaning fats requires 65°C
  - Avoids losses from conversion

Why focus on agri-processing

Linking solar thermal and agri-processing



Adapted from Horta (2015)

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Why focus on agri-processing

Industrial sectors and processes with the highest potential for solar heating

Industrial sector	Process	Temperature level (°C)
Food and beverages • Milk products • Fruits / vegetables / herbs • Sugar • Beer • Fats / oils • Chocolate / cacao / coffee • Starch / potatoes / grain mill products • Bread / biscuits / cakes • Wine / beverage • Meat • Fish • Aroma • Baby-food	drying washing pasteurising boiling sterilising heat treatment	30 – 90 40 – 80 80 – 110 95 – 105 140 – 150 60 – 90

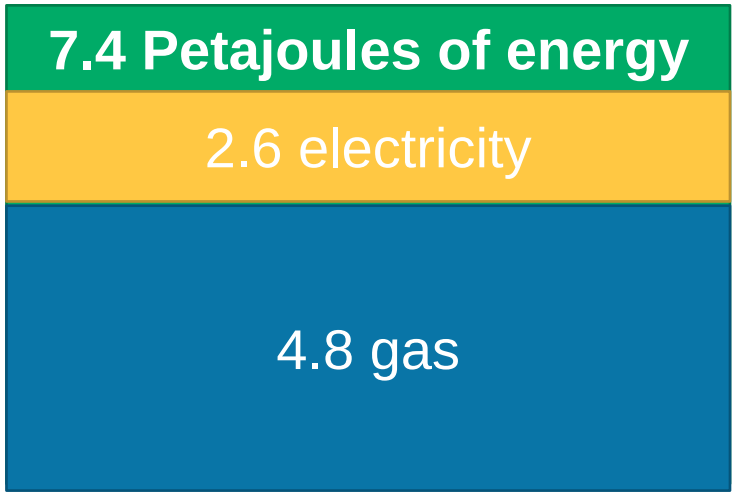
Source: Based on AEE Intec (2009) and Matrix of Industrial Processes (accessible online at: http://wiki.zero-emissions.at/)

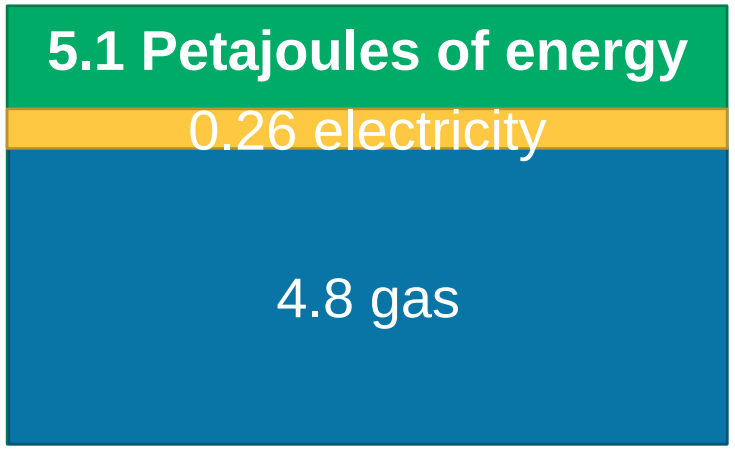
Energy in food & beverages

Used for heat

Assume:
1) 50% supplement with solar thermal
2) 60% solar share

DOE energy balance 2012



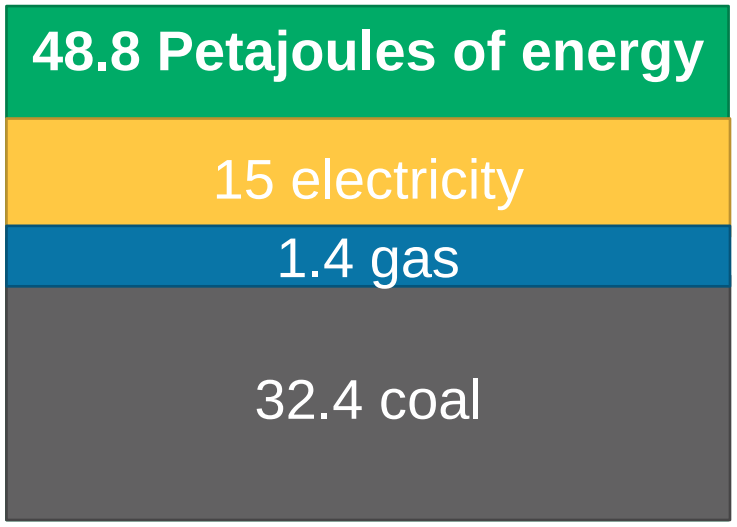


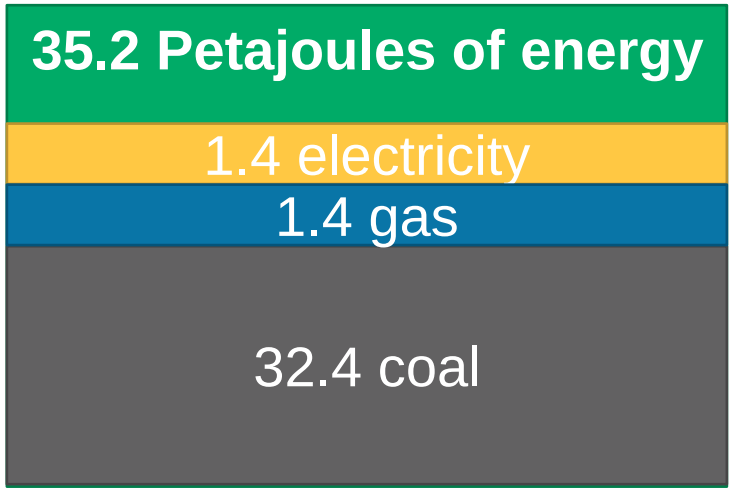
425 GWh per annum

425 000 m^2 of installations

110 922 CO_2e (tonne / annum)

SATIM model energy use 2006





3 758 GWh per annum

3 758 000 m^2 of installations

942 556 CO_2e (tonnes / annum)

*Not to scale

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Solar Thermal for Process Heat

South African Case Studies

Owner	Industry sector	Collector	Year	Gross area [m²]	Storage volume [litre]
BMW Manufacturing	Automobile	Evacuated tube	2012	200	24 200
Tanker Services, Imperial Logistics	Logistics	Evacuated tube	2013	67.5	5 000
Cape Brewing Company	Food & Beverage	Flat-plate	2015	120.6	10 000
Floraland	Flowers	Flat-plate	2012	288	20 000
ACA Threads	Rubber	Evacuated tube	2013	100	22 000
Fairview Cheese	Dairy	Evacuated tube	2012	90	4 000
Quality Filtration System	Water Treatment	Evacuated tube	2012	75	2 000

Source: Joubert, Hess & van Niekerk, 2016.

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Solar Thermal Uptake

Drivers

- Rising energy prices
  - Solar thermal cost competitive to replace most fossil fuels[1]
    - Financially viable opportunity to replace all fossil fuels (i.e. HFO, paraffin, electricity, diesel, petrol and LPG), except possibly not coal (at this stage)
    - For example, **with zero cost increase in electricity, some projects could payback in less than 5 years when replacing electricity** with solar thermal
  - Majority of fuels are linked to volatile oil price thus solar thermal allows better long term planning

1. Joubert, Hess & Van Niekerk (2016)

Solar Thermal Uptake

Drivers

- Rising energy prices
  - Solar thermal cost competitive to replace most fossil fuels
  - Majority of fuels linked to volatile oil price thus solar thermal allows better long term planning
- Greenhouse gas emission reduction potential
  - Carbon tax of R120 per tonne CO_2e awaiting cabinet approval
- Energy efficiency incentives
  - Section 12 income tax rebates (for large installations)
  - SOLTRAIN support
- Expansions
  - Agri-processing highlighted for support
  - Easier to integrate into new build thus lowering costs
- Innovative contracting solutions e.g. ESCOs[1]
  - SANEDI ESCO register being launched

1. ESCO = Energy Service Company

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Conclusions

For all stakeholders

- Solar thermal has significant potential in agri-processing
  - 425 000 – 3 758 000 m^2 of installations
  - 110 922 – 942 556 tCO_2e savings potential

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Conclusions

For agri-processors

- Solar energy a viable opportunity:
  - Worth considering for all fossil fuels except possibly coal (at this stage)
  - Set to improve – energy prices keep rising, proposed carbon tax
  - Installations already in existence (e.g. CBC – next presentation)
- Best practice is in collaboration with energy efficiency
  - Ensures heat demands are optimised correctly as solar thermal long term solution
- Incentives and support available to encourage uptake
  - Residential and commercial buildings standards
  - Income tax rebates (large installations)
  - SOLTRAIN (presentation coming up)
- Opportunity of innovative contracting e.g. ESCos
  - SANEDI register being launched

Conclusions

For solar thermal industry

- Solar thermal industry ‘infant industry’
  - Need to move along the learning curve for prices to drop
  - Agri-processing large opportunity (425 000 - 3 758 000 m^2 of installations)
- Solar not understood by energy users
  - Perceived to be untested
  - Considered unreliable

  } Need clear and transparent communication about the costs, benefits and practical implications of these technologies
- Opportunity to overcome capital cost constraints with innovative contracting
  - Ensure registered to be ESCO (http://www.sanediesco.org.za/user/register)
- Utilise industry support
  - e.g. income tax rebates as selling point large systems
  - SOLTRAIN training and support (presentation upcoming)

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Thank you

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Additional slides

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Conclusions

For policy makers

- Agri-processing clearly supported
  - Agriparks & IPAP
  - Agriparks present opportunity to ensure development done sustainably
- Significant carbon savings of relevance to meet SA' commitments
  - 85% GHG emissions in South Africa from energy
  - Committed to 34% GHG reduction by 2020 & 42% by 2025 under Copenhagen Accord
- Solar thermal currently 'infant industry'
  - Justifies support for sector e.g. the income tax rebates
- Policy needs to clear and consistent
  - Unclear and sudden changes in policy have been damaging to industry in past
  - Considered unreliable
- SABS's systems testing is limiting
  - Component testing will enable more competition and growth (including local manufacture)
- Number of programmes working in solar space
  - Working together is key to preventing overlap and duplication

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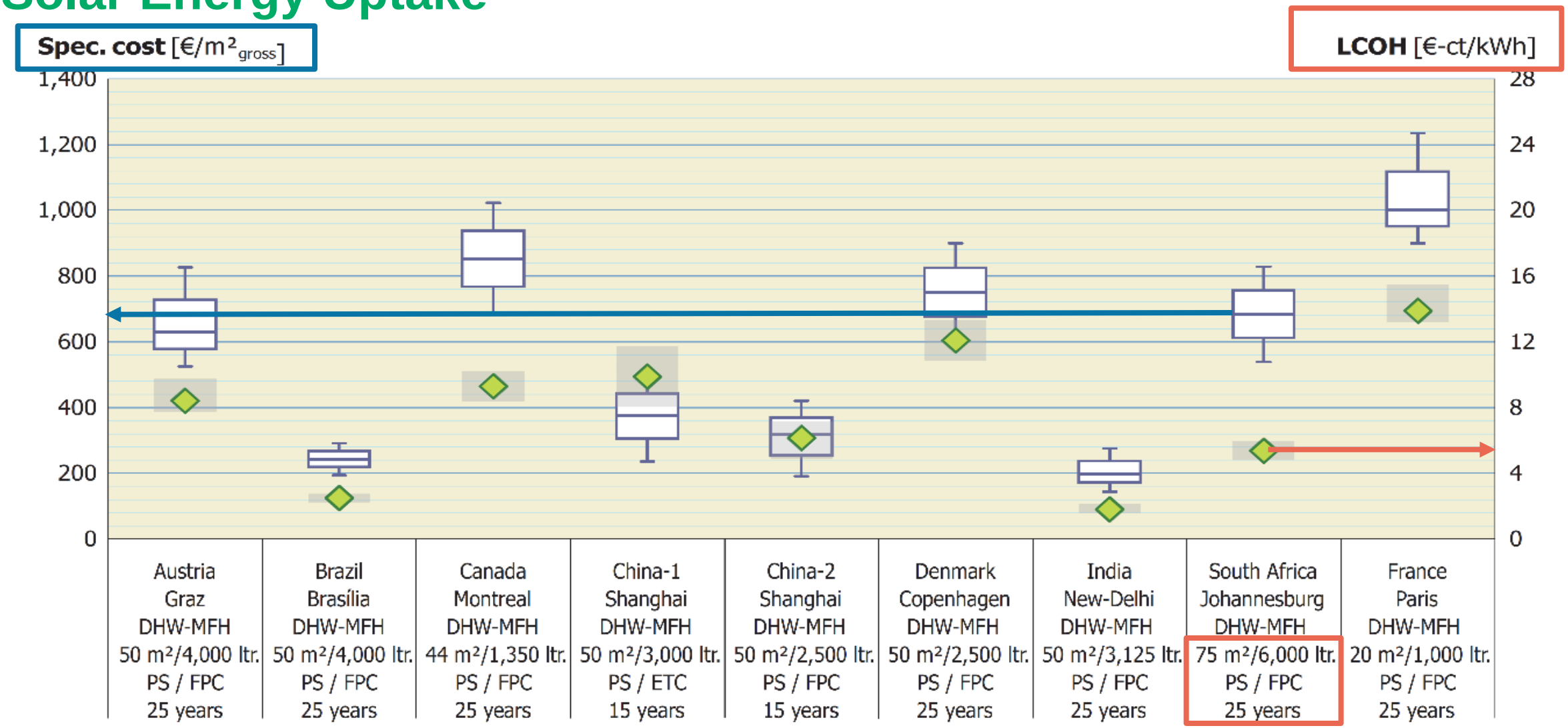
Solar Thermal Uptake

Barriers

- Relative Complexity
  - “Solar PV cables don’t leak”
  - Solar thermal generates heat optimised for specific temperature
  - Stagnation in solar thermal systems could result in damage from steam build up
- Practical limitations
  - Available roof or floor space, considering shading etc.
  - Roof strengthening for retrofits increase cost
- High cost of solar thermal
  - Requirement for systems testing by SABS limits competition in solar water heater market
    - Makes installations more costly as parts need to be imported or certified overseas
  - Infant industry

Solar Energy Uptake



Specific investment costs and levelised costs of solar thermal generated heat for large pumped domestic hot water systems. Source: Solar Worldwide 2016

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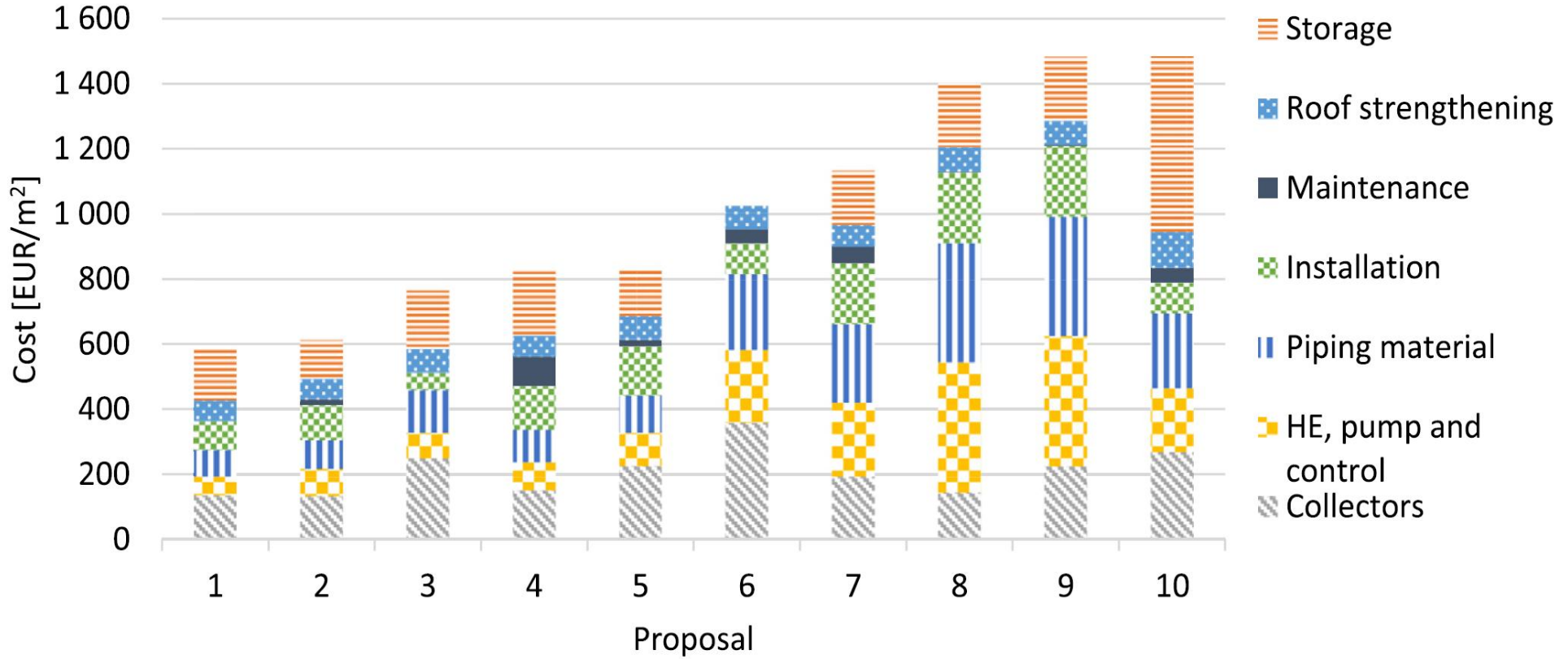
Solar Energy Uptake



LCOH [EURc/kWh]	7.0	8.4	7.3	8.9	7.9	8.6	15.1	17.9	18.8	13.1
IRR [%]	18.7	15.8	18.2	15.0	16.7	15.5	8.4	6.7	6.2	10.1
Payback [years]	8.6	9.6	8.8	10.0	9.3	9.8	13.5	14.8	15.2	12.5

CBC tender proposals with component breakdown (exchange rate ZAR/EUR = 15.3).

Table below graph shows calculated levelised costs of heat (LCOH), internal rate of return (IRR) and payback period.

Source: Joubert, Hess & van Niekerk, 2016

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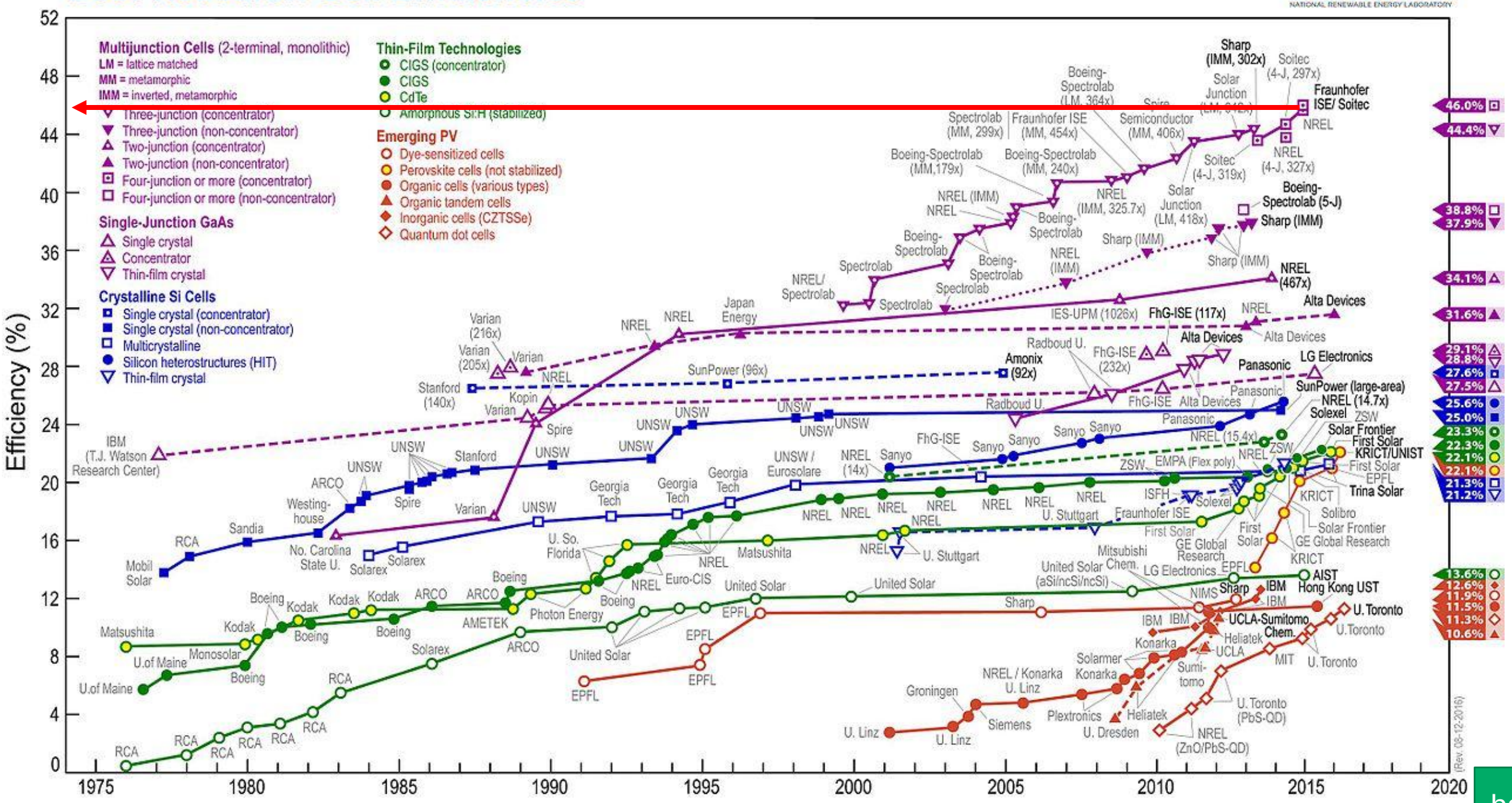
Best Research-Cell Efficiencies



Source: Sarah Kurtz and Keith Emery - National Renewable Energy Laboratory (NREL), Golden, CO

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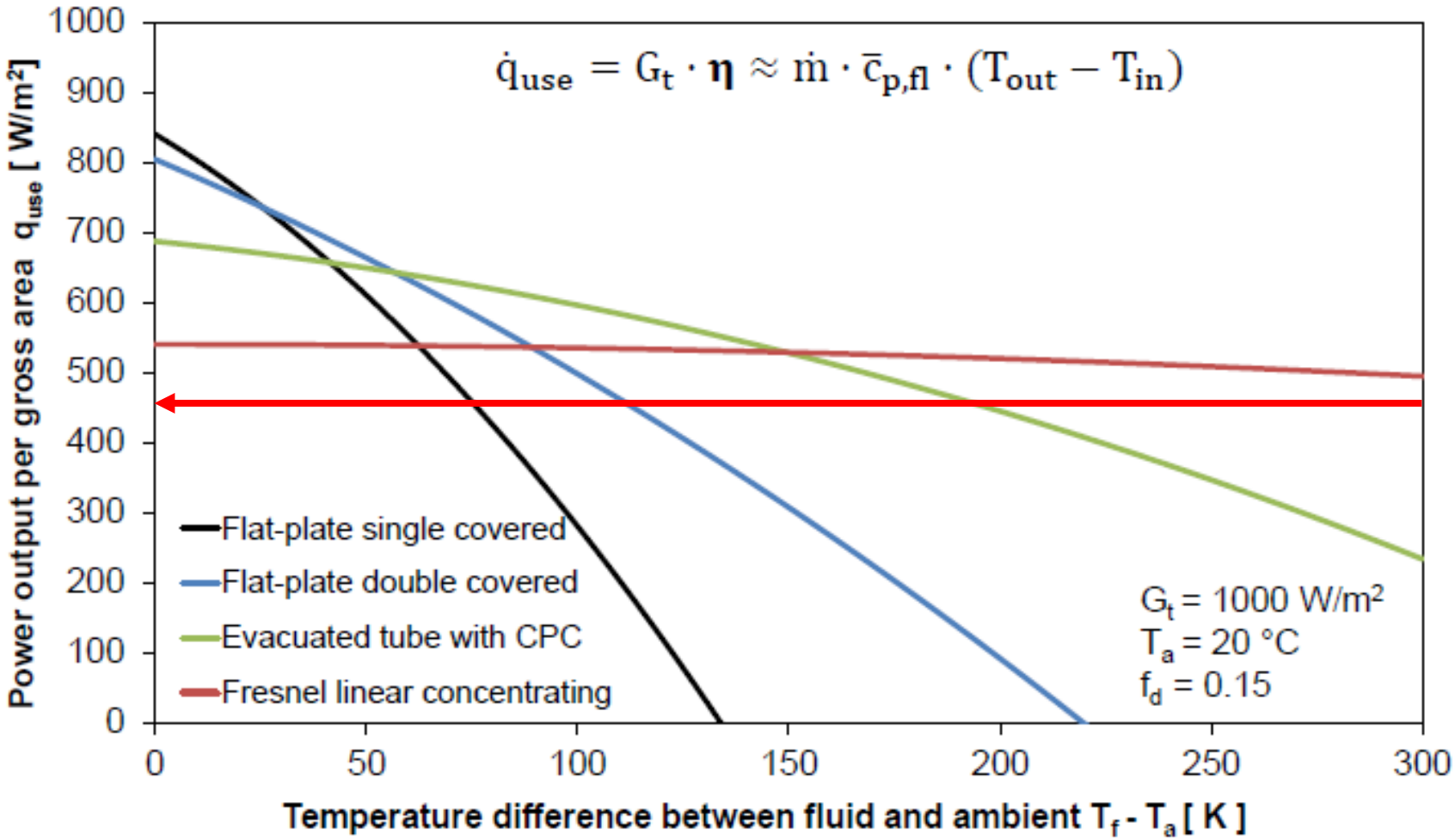
Collector Efficiency Curve

Tested power outputs of different collectors



$$T_f \approx \frac{T_{in} + T_{out}}{2}$$

in °C

$\dot{m}$ = mass flow

in kg/h

$$\bar{c}_{p,fl} \approx 4.19 \frac{kJ}{kg\,K}$$

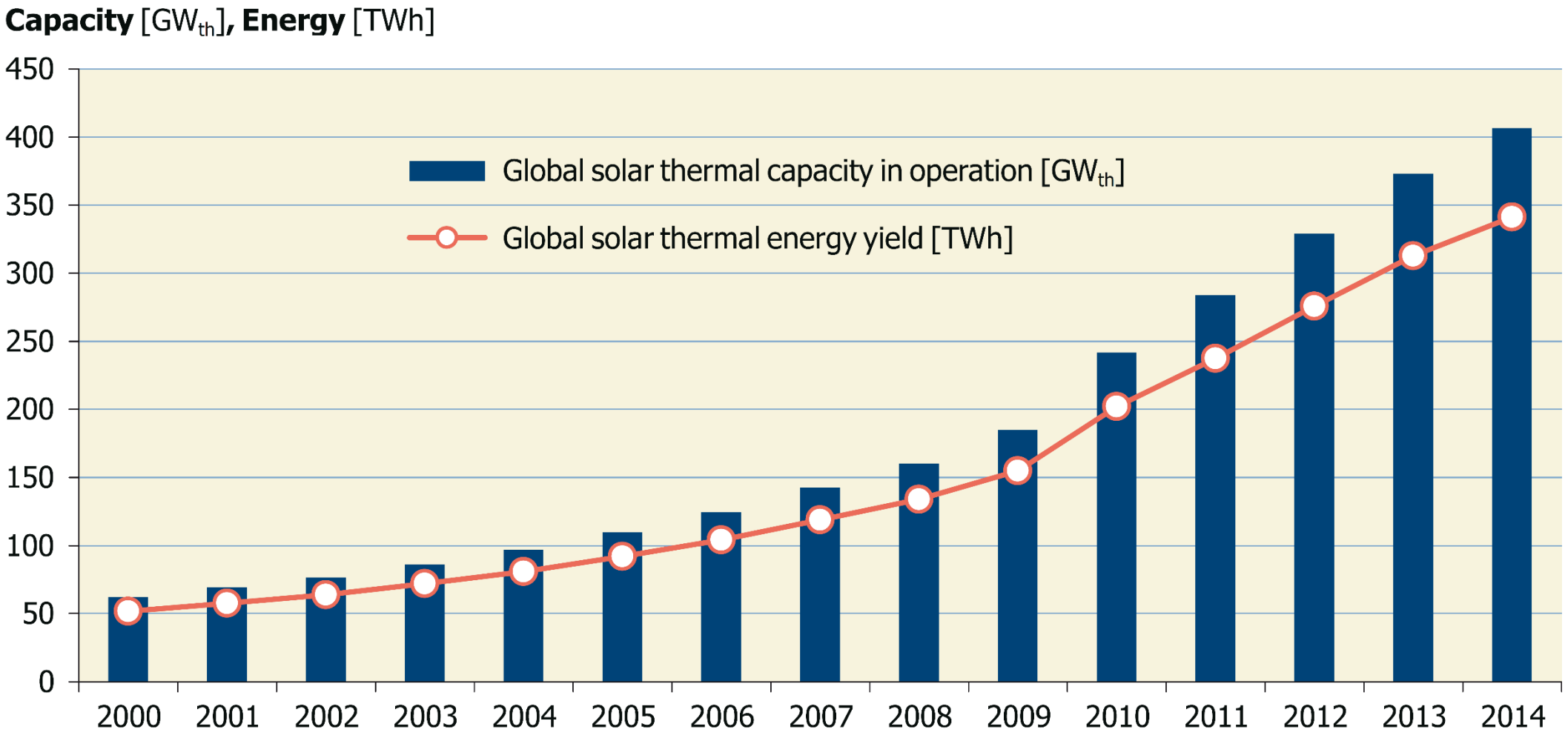
$$\approx 1.16 \frac{kWh}{m^3\,K}$$

		Milk products	Fruits / vegetables / herbs	Sugar	Beer	Fats / oils	Chocolate / cacao / coffee	Starch/ potatoes/grain products	Bread / biscuits / cakes	Wine / beverage	Meat	Fish	Aroma	Baby-food	Solar integration	Emerging technologies process intensification	Heat integration
Unit operation	Typical processes	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Cleaning	Cleaning of bottles & cases	√	√		√	√			√	√	√	√			√	√	
	Washing products	√	√					√	√	√	√				√	√	√
	Cleaning of production halls and equipment	√	√				√	√	√	√	√				√	√	√
Drying	Drying	√	√				√	√	√	√	√	√		√	√	√	√
Evaporation & distillation	Evaporation	√	√	√	√	√	√								√		√
	Distillation				√	√							√		√	√	√
	Deodorisation					√	√								√	√	
Blanching	Blanching		√					√			√				√	√	√
Pasteurisation	Pasteurisation	√	√		√				√	√					√	√	√*
Sterilisation	Sterilisation	√	√							√					√	√	√
Cooking	Cooking & boiling		√		√		√	√	√		√	√			√	√	√
Other process heating	Pre-heating & process water	√	√		√				√								√
	Soaking		√		√		√				√						
	Thawing	√									√	√				√	
	Peeling	√	√								√					√	√

Unit operation	Typical processes	Milk products	Fruits / vegetables / herbs	Sugar	Beer	Fats / oils	Chocolate / cacao / coffee	Starch / potatoes / grain products	Bread / biscuits / cakes	Wine / beverage	Meat	Fish	Aroma	Baby-food	Solar integration	Emerging technologies process intensification	Heat integration
General process heating	Boiler feed-water preheating	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√
Heating of production halls	Heating of production halls	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√
Cooling of production halls	Cooling of production halls	√	√	√	√	√	√	√	√	√	√	√	√	√			√
Cooling processes	Cooling, chilling & cold stabilisation	√	√	√	√	√	√	√	√	√	√	√			√	√	√
	Ageing	√			√				√	√	√	√				√	√
Melting	Melting	√				√											√
Extracting	Extracting		√	√		√	√									√	√
Bleaching	Bleaching		√													√	√
Fermentation	Fermentation	√*			√				√*	√	√	√				√	
Temperature level																	
20-40^{0}C		√	√		√		√		√	√							
40-60^{0}C		√	√		√		√		√	√	√		√				
60-80 ^{0}C		√	√	√	√	√	√	√	√	√	√		√				
> 80 ^{0}C		√	√	√	√	√	√	√	√	√			√				

Solar Thermal

International trend



Source: Mauthner, F., Weiss, W. & Spörk-Dür, M., 2016

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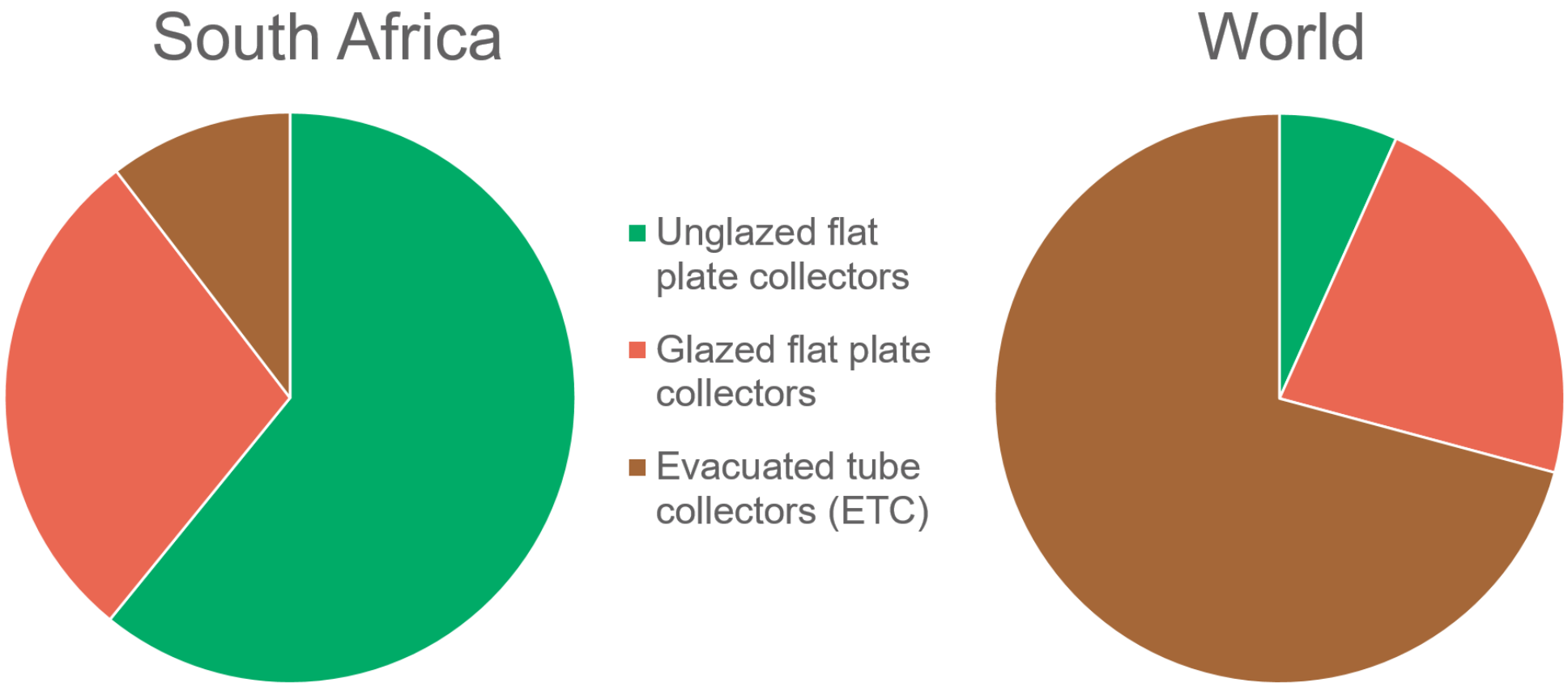
Solar Thermal

South African status quo

- Total solar thermal systems (residential and industrial) to date 1 055MW$_{th}$



Source: Own calculations based on Solar Worldwide 2016

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