Development of solar energy in Africa

A challenge in terms of resource availability and recycling

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Solar Energy in Africa

Energy for all

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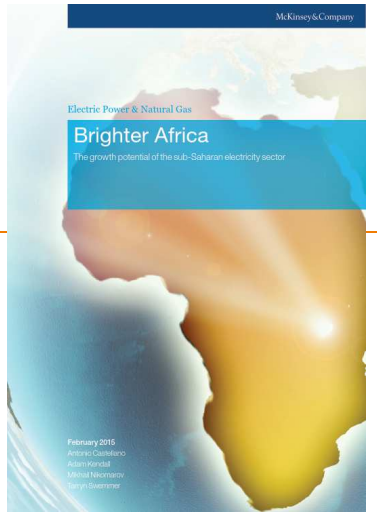
Solar Energy in Africa



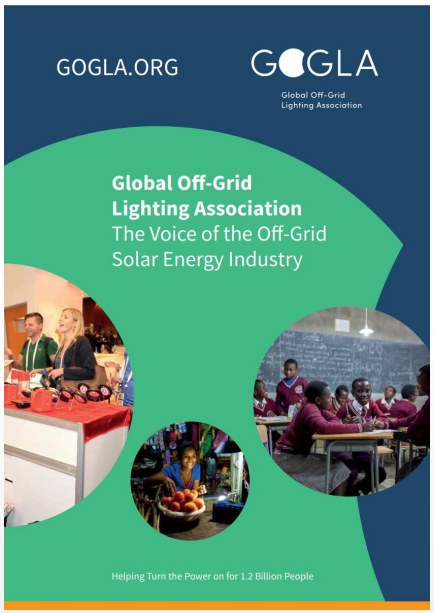
Brighter Africa
Mc Kinsey (2015)

- Solar capacity
  - Sub-Saharan Africa represents 11.4 TW of solar capacity
    - If 0,02 – 0,05% landmass covered with PV panels

- Distributed solar
  - Complementary rather than revolutionary
    - Solar will take off after 2030 : learning improvements + lower costs in technology.
    - A drop by 30 % is needed to be competitive with current grid cost (LCOE))
  - 25 % of all households
    - If Africa were to close the gap to universal electricity access, only 2 % of all energy delivered would come through off-grid connections
    - Distributed solar is likely to have a profound effect in the provision of electricity to those who do not already have it!
  - Access to capital
    - Cost cut by 50% if Africans obtain the same cost of capital as in Germany (IEA).
      - ✓ Ex. Scaling Solar (WB) to support the low-carbon expansion of Africa's power sector.

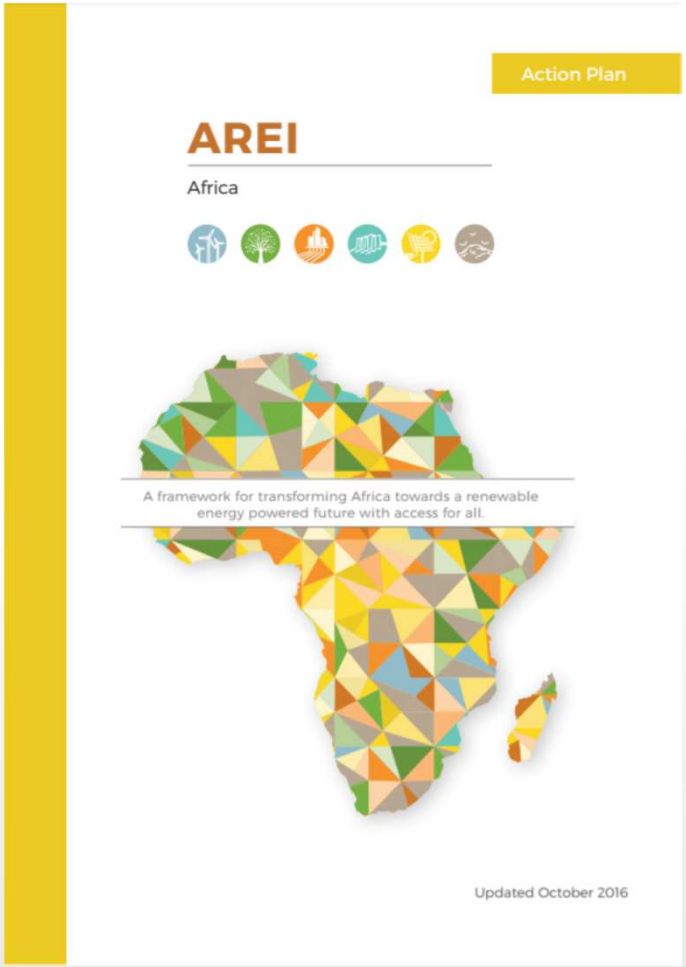
Energy for All

- A myriad of initiatives



Energy for All

- AREI African Renewable Energy Initiative
  - Africa has the largest potential
  - Jump over technology gap
    - No fossil fuels, No central
    - Intelligent energy, user-oriented, smart grids
  - 600 Mhab
    - Target 600 GW in 2030



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Solar Home Systems

Technologies

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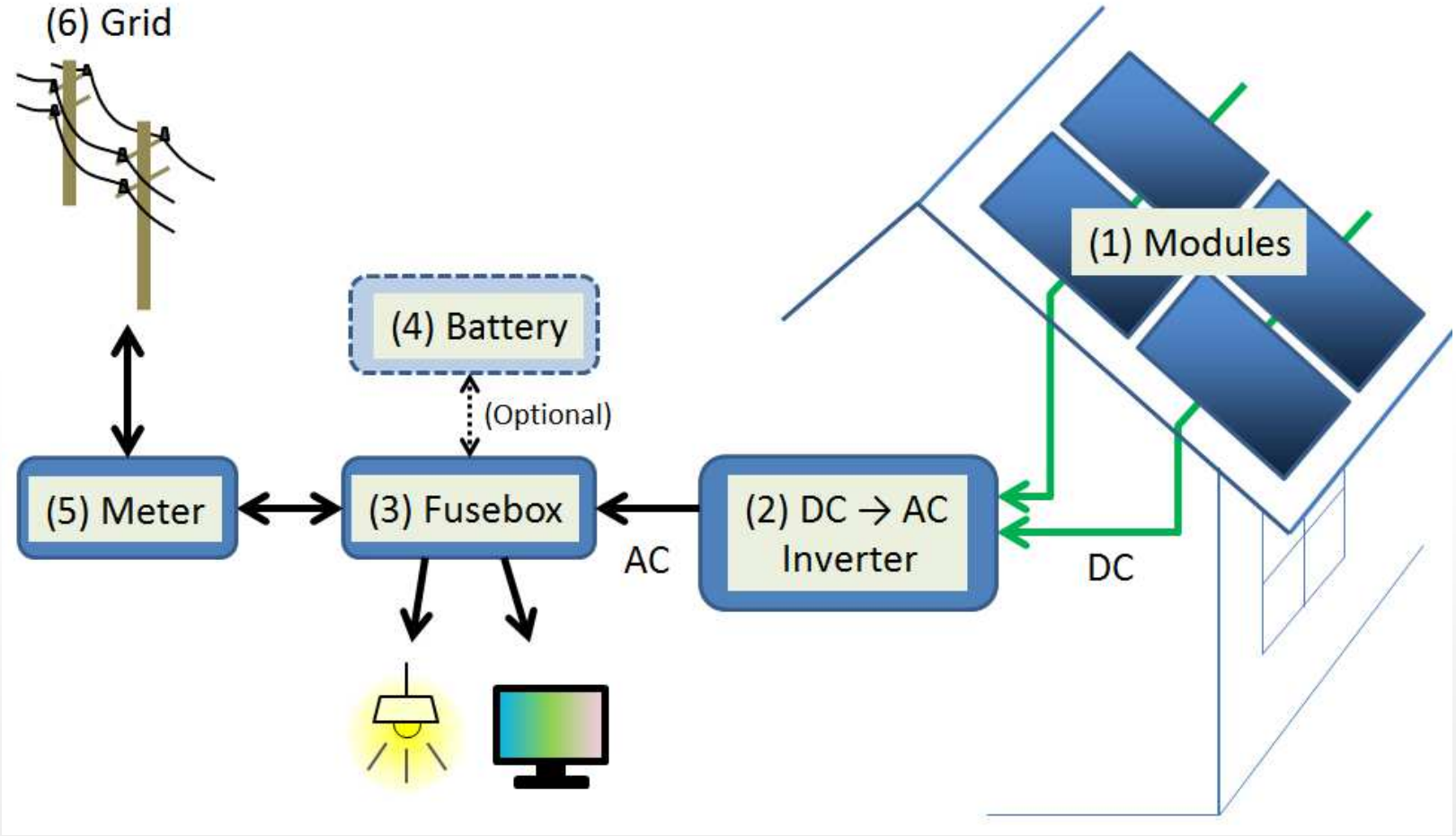
Solar Home Systems (SHS)



Solar Home Systems (SHS)

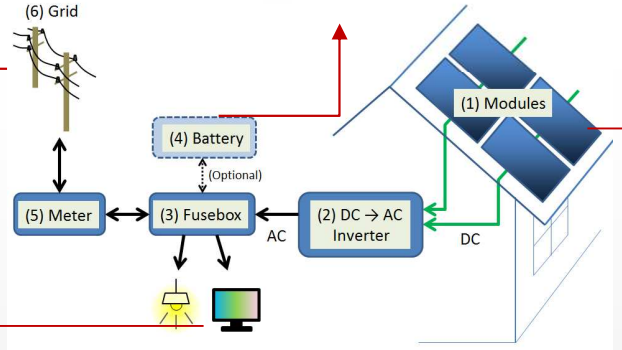
- Various technologies

<u>Battery Banks</u>
2kW-200kW
½ to 1 cycle /day

1. *Pb-acid*
2. *Li-ion*
3. *NiCd*
4. *…*

<u>Wires</u>

1. *Copper*
2. *Aluminium*
3. *Al Cu-clad*



<u>PV Panels</u>

1. *Poly-Si*
2. *Mono-Si*
3. *CdTe*
4. *CIGS*

<u>Lighting</u>

1. *Halogen*
2. *Fluocompact*
3. *LED*

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Selection Criteria

Which efficiency ?

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Selection Criteria

- Cost
- Lifetime
- Storage efficiency

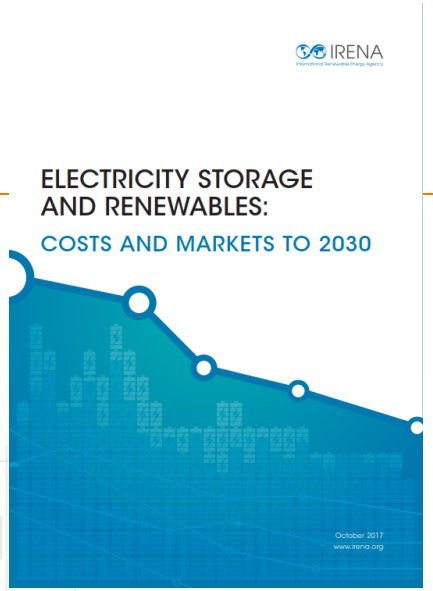
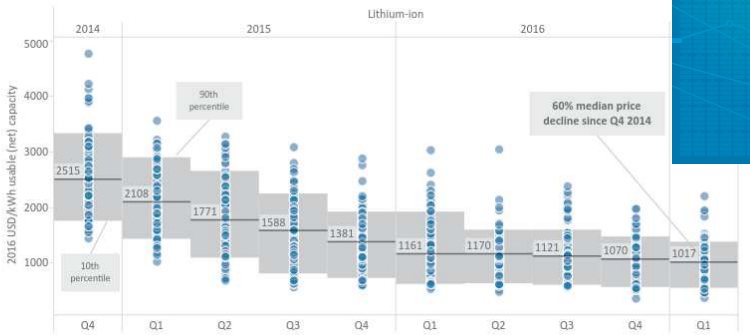
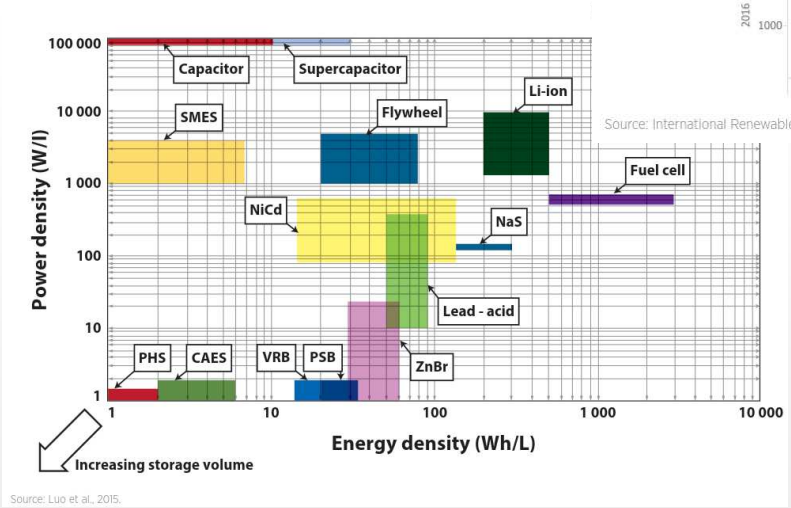


Figure 29: Home storage lithium-ion system offers in Germany from Q4 2014 to Q1 2017



Source: International Renewable Energy Agency, based on EuPD Research, 2017.



Source: Luo et al., 2015.

Li-ion > Pb-acid

- Higher lifetime and efficiencies
- No maintenance
- No gassing
- Easier to install
- Better aesthetics
- Lower total cost of ownership

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Selection Criteria

- LCA
  - Global Warming Potential
  - Toxicity
  - Abiotic Resource Depletion
  - …

Li-ion (LFP) > Pb-acid

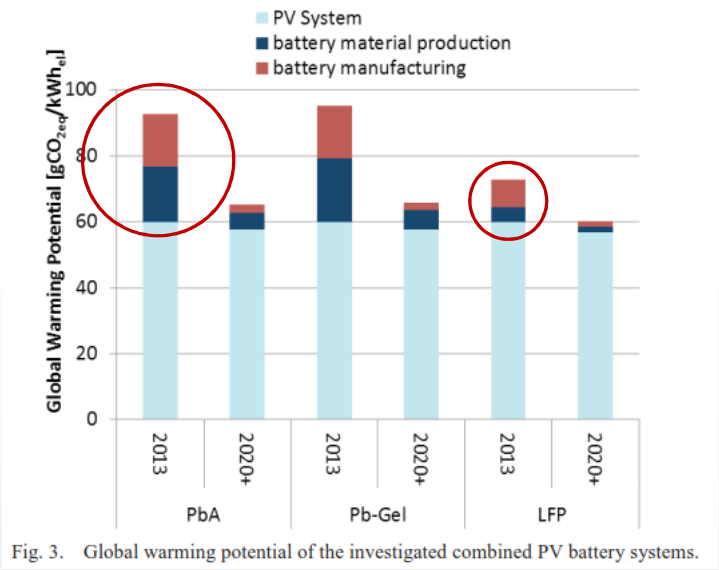

Fig. 3. Global warming potential of the investigated combined PV battery systems.

Jülch V. et al, 2015, *A holistic comparative analysis of different storage systems using levelized cost of storage and life cycle indicators, 9th Int. Renewable Energy Storage Conference, IRES2015*

Selection Criteria

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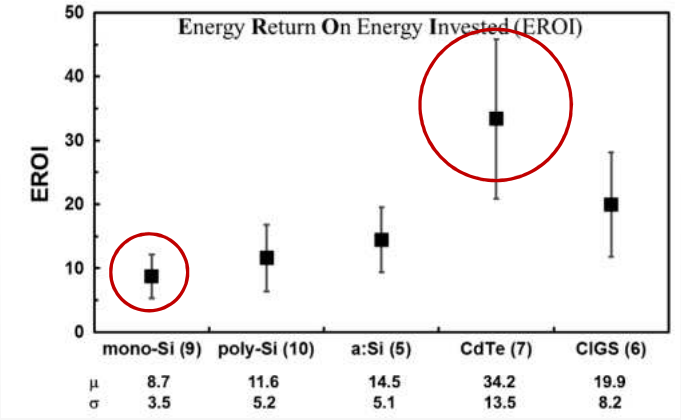
- ERO(E)I
  - Energy Return on Energy Invested

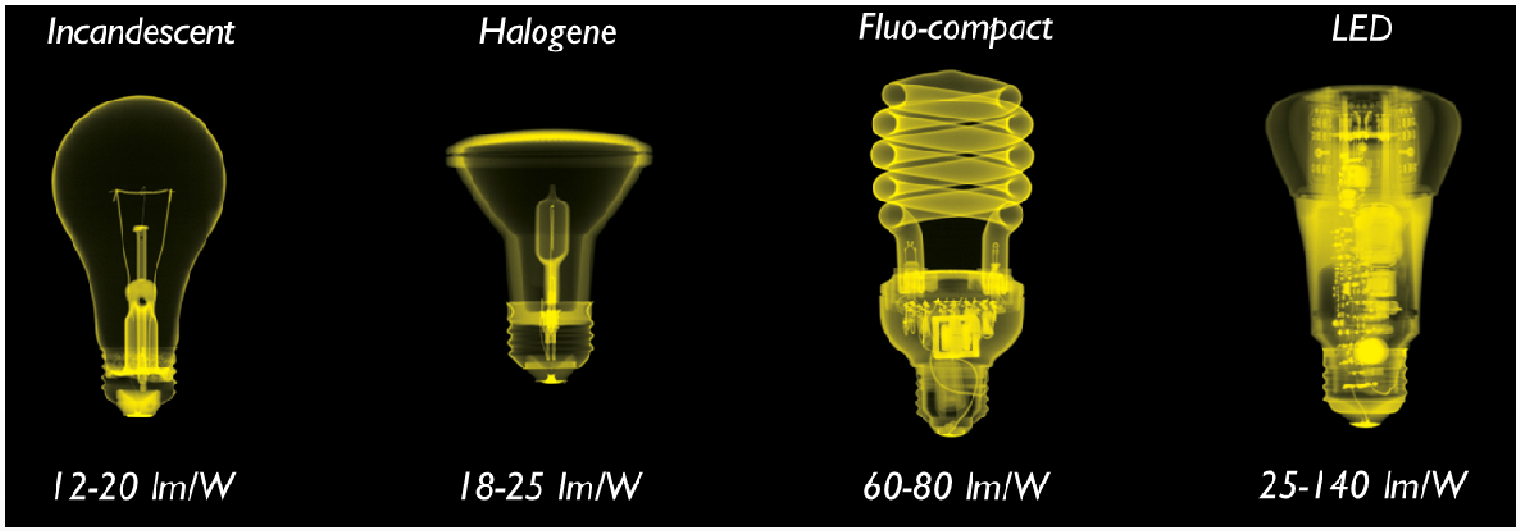
CdTe > Poly-Si



Bhandari et al., 2015, *Energy payback time (EPBT) and energy return on energy invested (EROI) of solar photovoltaic systems: A systematic review and meta-analysis, Renewable and Sustainable Energy Reviews 47, 133–141*

Selection Criteria

- Let's take another perspective



After IEEE Spectrum

Future products will not only be optimized with regard to their functionality but also their recyclability and the sustainable availability of resources.

Resource Availability
and criticality

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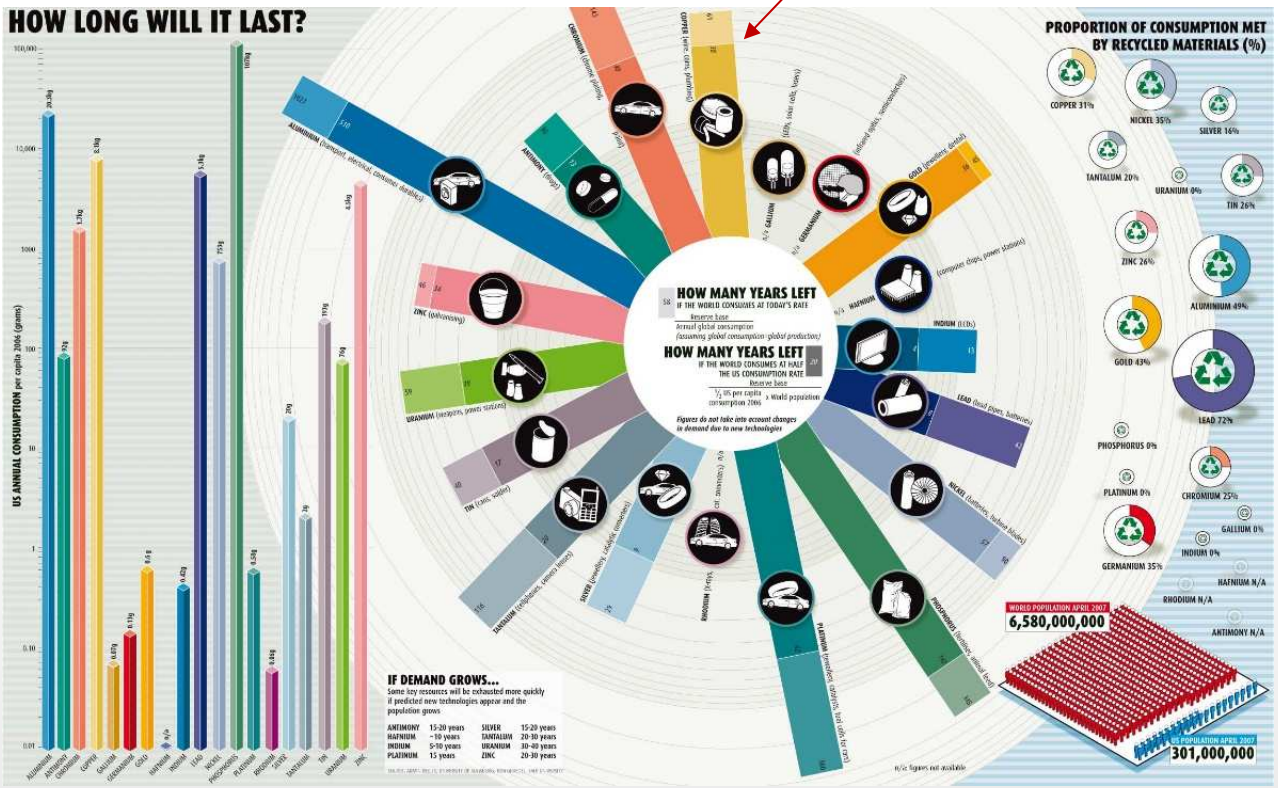
Resource availability & criticality

- Stop this graph!
  - Unnecessary alarmism

38 years of Copper left
if the world consumes at 50% US rate



A. Reller & T. Graedel, 2007

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Resource availability & criticality

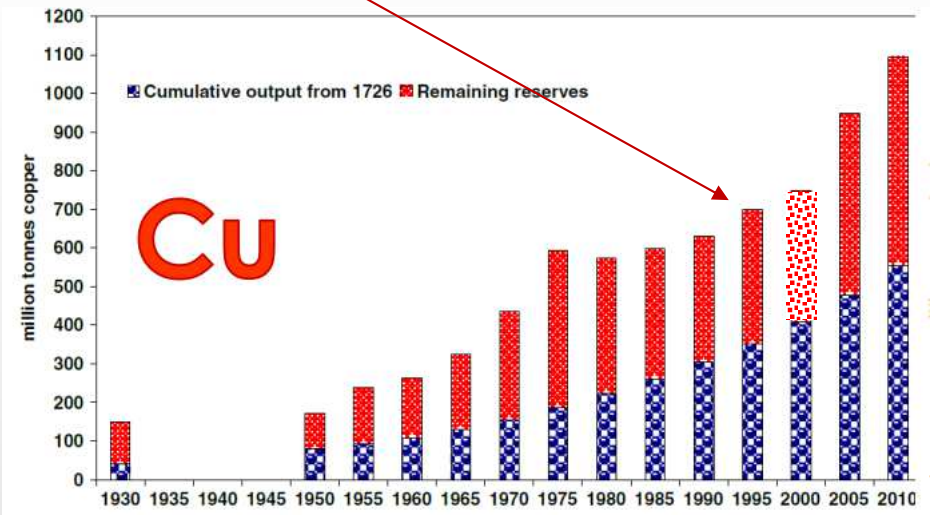
- Copper : a key metal
  - Reserves are **dynamic** and increase with
    - Metal price
    - Renewed Exploration
    - Innovation in process efficiency, etc.

COPPER in 2000
340 Mt (reserves)
12,1 Mt (annual production)

28 yrs left!

COPPER in 2017
720 Mt (reserves)
19,4 Mt (annual production)

37 yrs left!



2000 years left
(personal estimation)

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Resource availability & criticality

- Tellurium : a scarce by-product
  - Rarer than gold
  - By-product of Copper
    - » *450 g Te/ 500 t Cu*

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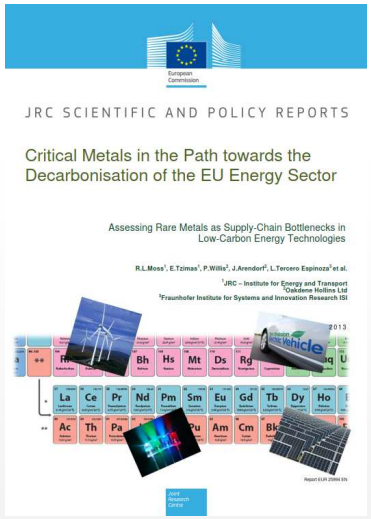


Table 83: Solar energy metals requirements

Technology	Elements	Annual EU Demand (tonnes)		Annual EU Demand / World Supply	
		2020	2030	2020	2030
Solar PV	Te	150	126	12.0%	6.9%
	In	145	121	7.6%	4.9%
	Sn	14,913	12,505	3.6%	2.6%
	Ag	619	519	1.7%	1.2%
	Ga	4	3	0.8%	0.5%
	Se	15	13	0.4%	0.3%
	Cd	109	91	0.3%	0.2%
	Cu	70,650	59,241	0.3%	0.2%
	Pb	8,672	7,272	0.1%	<0.1%
CSP	Ag	19	19	0.1%	0.1%

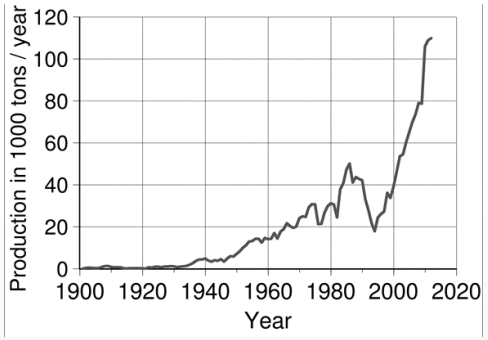
Estimated to 50,4% (2011)
Revised to 6,9% (2013)

Increase in Cu mining!

Resource availability & criticality

- Cobalt : a strategic metal
  - DR Congo
    - 53 % world production
    - > 50 % world reserves
  - Alternative deposits ?
    - Ni laterites
    - Cu-Ni sulphides

    } Requires increase in Ni mining
  - Alternative technologies ?
    - NMC Li $(Ni_{0,5}Mn_{0,2}Co_{0,3})O_2$
    - LMO, LFP, LTO,…



World mine production of cobalt (USGS)

Key active material	lithium nickel manganese cobal oxide	lithium manganese oxide	lithium nickel cobalt aluminum	lithium iron phosphate	lithium titanate oxide
Technology short name	NMC	LMO	NCA	LFP	LTO
Cathode	$LiNi_xMn_yCo_{1-x-y}O_2$	$LiMn_2O_4$ (spinel)	$LiNiCoAlO_2$	$LiFePO_4$	variable
Anode	C (graphite)	C (graphite)	C (graphite)	C (graphite)	$Li_4Ti_5O_{12}$
Safety					
Power Density					
Energy Denisty					
Cell costs advantage					
Lifetime					
BESS performance					

Recyclability

Undergoing the crush test

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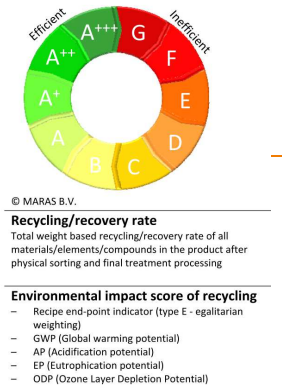
Recyclability @ end-of-life



- Mass recovery balance targets
  - Set by legislation
- Low residual value of materials
  - Need for tax incentives
  - No incentive for recovery of critical elements
- High risk linked to
  - Upscaling
  - Product design
  - Continuous evolution of technologies
- How to assess recyclability?
  - Often model-based
  - Need for physical validation (crush test)

Walloon Region - Technological Innovation Project **(Reverse Metallurgy, 61 M€)**
Modular platform to validate the recyclability of end-of-life products.

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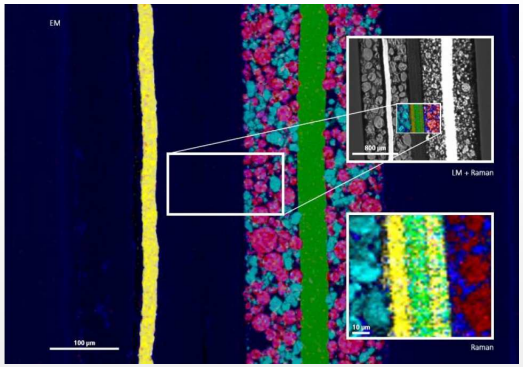
Recyclability @ end-of-life

- Collection
  - New business models needed
  - Develop product tracking
  - Limit transportation!
  - Prevent illegal exports
  - Certify recycling chains
- Regional (pre)processing
  - Easy dismantling / Sorting

Pb-acid >>> Li-ion



Microchemical stratification of an Li-ion battery revealed by Multi-Modal SEM and Raman Imaging

© Zeiss

	Pb-acid	Li-ion
Collection	Acid risk	Fire risk
Technology	Simple / Stable	Complex / Changing
Comminution	Easy	Impossible
Separation	Easy Physical	Complex Hydro/pyromet
Final processing	Regional (Africa)	International (Europe)

Recyclability @ end-of-life

- Current PV Panels recycling
  - Only lab-scale experiments
  - Sub-economic at plant scale

- Future redesigned PV panels
  - Improved dissassembling through
    - Encapsulation
    - Removable edge sealant
    - Wire saw to separate high purity Si wafer from glass

PRODUCTION OF RECYCLABLE CRYSTALLINE SI PV MODULES

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EUPVSEC 2015

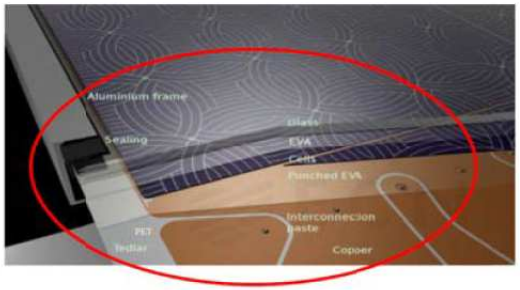

Figure 1: A cross-section of a foil-based metal wrap through (MWT) PV module

Figure 7: Overview of the removal of conductive backsheet from module, in which thermoplastic as encapsulant was applied

Figure 8: Separating solar cell from glass sheet for thermoplastic-based module. The separated cell is shown on the right

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Recyclability @ end-of-life

- Products need to be (re)designed for recycling
  - Privilege pure metals
  - Avoid mixing incompatible metals
  - Limit metal contamination
  - Avoid energy demanding processes
  - …

	Cu	Al Cu-clad
Purity	++++	15% Cu
Process	Pyromet	Pyromet + Refinery
Energy	+	+++
Final processing	Regional (Africa)	International (Europe)

Take Away

…and keep in mind

Take Away Message

- Resource availability
  - Not so critical in the short term (ex. 200 years)
  - Risk of supply chain disruption
    - Due to technical reasons (by-product of another metal)
    - Due to geopolitical reasons (strong concentration)
  - Resource Depletion is not properly modelled in current LCA

- Recyclability
  - Should be integrated in any energy policy
  - Requires efficient organisation of back-collection
  - Should privilege short loops : reuse, repair and recycle
    - Regional pre-processing facilities
  - Should lead to adopting technologies designed for efficient recycling
    - Installing regional recycling plants

Thank You