Materials challenges for terawatt-scale Photovoltaics

Peter Rigby

Content

- Defining the challenge / trends in the PV industry
- Materials availability and supply chain optimisation
- PV industry strategies to meet the challenge
- EU involvement and commitment in meeting the materials challenge
- Summary and conclusions

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Defining the challenge – the context

- PV is only one of a panoply of 21st century growth industries taken for granted but which also require careful consideration and forward thinking with respect to materials availability.

  For example:
  - Batteries
  - Electric motors, generators => EV, wind turbines,
  - Micro electronics, displays & audio visuel
  - Catalysts containing precious and scarce metals
  - Etc

- The “Materials Challenge” is multi faceted and relates to:
  - Materials availability (geological, technological & geo-political constraints)
  - Cost
  - Performance

- The different facets need to be identified, quantified, categorised and a mitigating strategy developed

Defining the challenge – PV trends

WORLD-WIDE CUMULATIVE PV INSTALLED CAPACITY AND PRODUCTION TO 2050 USING THE REFERENCE, ACCELERATED AND PARADIGM SHIFT SCENARIOS

		2007	2008	2009	2010	2015	2020	2030	2040	2050
Reference	MW	3	15,707	22,999	30,261	52,114	76,852	155,849	268,893	377,263
	TWh	0	17	24	32	55	94	205	377	562
Accelerated	MW	3	15,707	22,999	34,986	125,802	345,232	1,081,147	2,013,434	2,988,095
	TWh	0	17	24	37	132	423	1,421	2,822	4,450
Paradigm	MW	3	15,707	22,999	36,629	179,442	737,173	1,844,937	3,255,905	4,669,100
	TWh	0	8	24	39	189	904	2,266	4,337	6,747

source: Greenpeace/EPIA Solar Generation VI, 2010.

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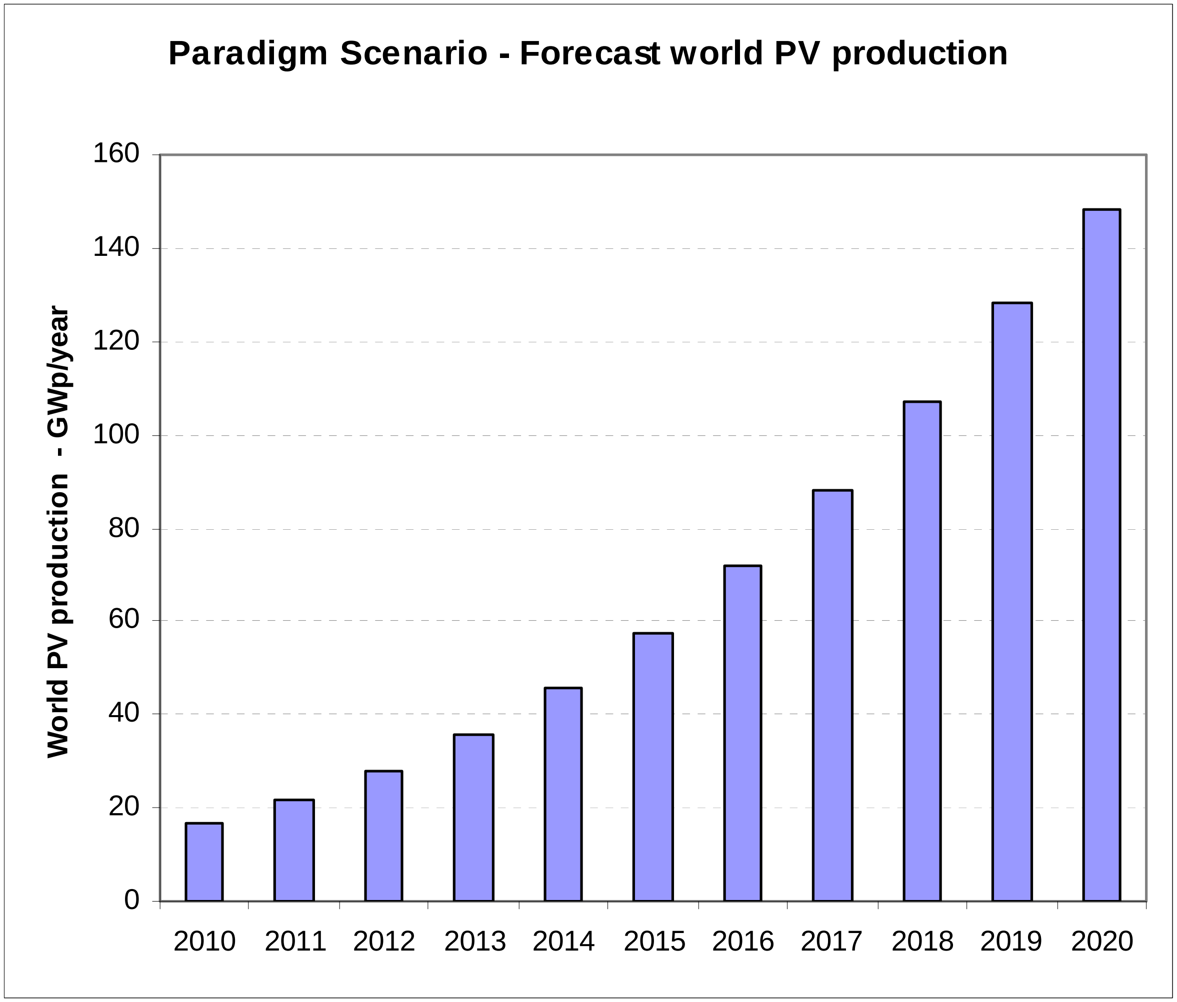
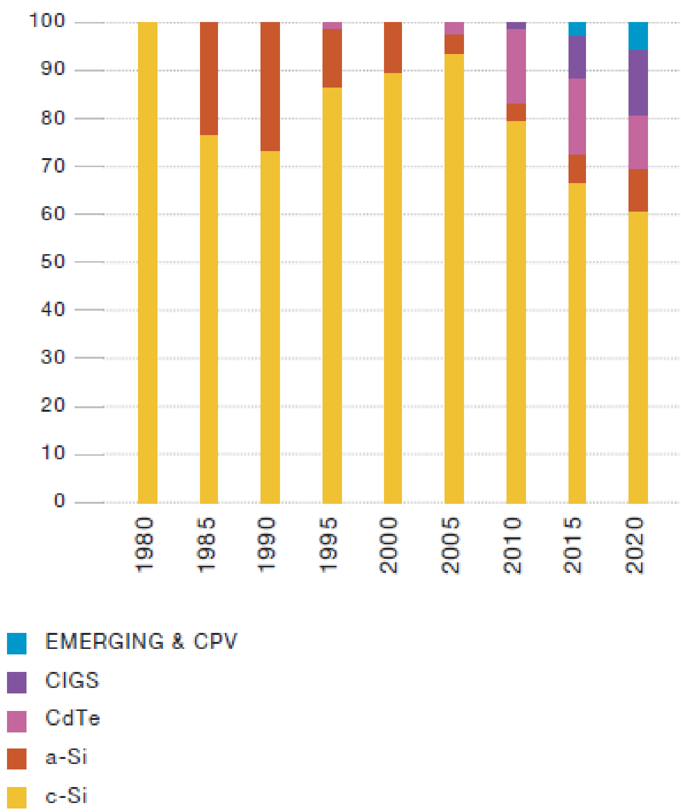
Defining the challenge – PV trends



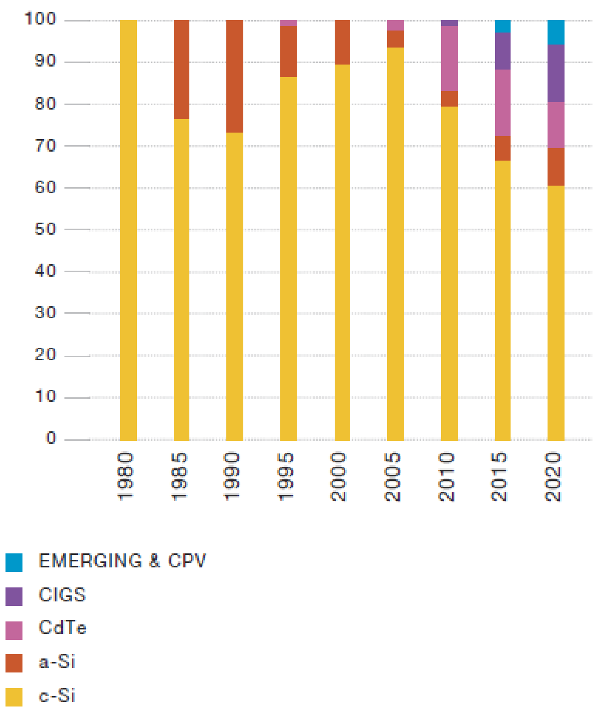
Defining the challenge –PV technology evolution



source: Historical data (until 2009) based on Navigant Consulting. Estimations based on EPIA analysis.

PV has the advantage of having several interchangeable technologies each usinmg different materials systems

Defining the challenge –PV technology evolution



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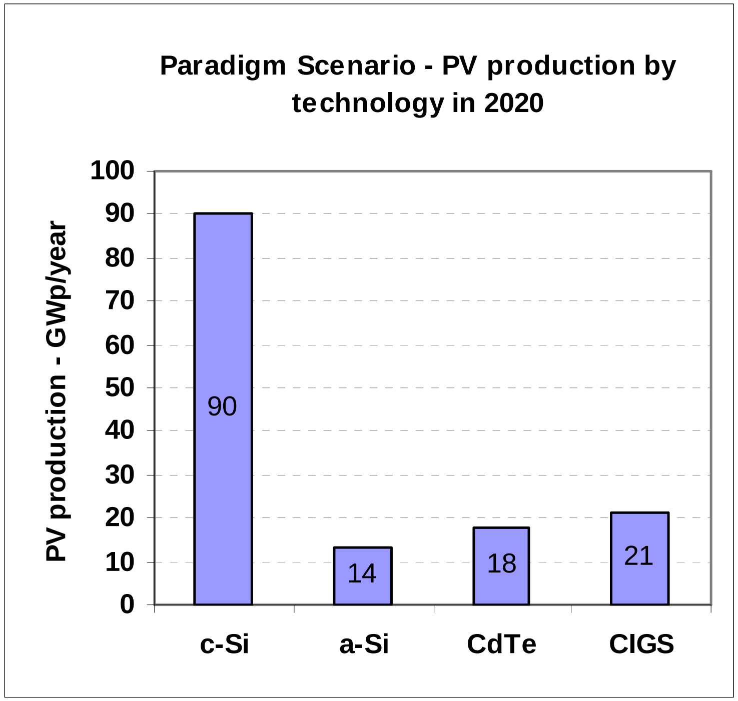

Defining the challenge – materials needs

Metal	PV production 2020	Specific metal requirement in 2020	Paradigm scenario total demand in 2020 for PV
	GWp/year	Tons/GWp	Tons
c-Si	90		
Ag		59	5310
CIGS	21		
In		53	1113
Ga		12	258
Se		50	1050
CdTe	18		
Te		56	1008

Source: Umicore

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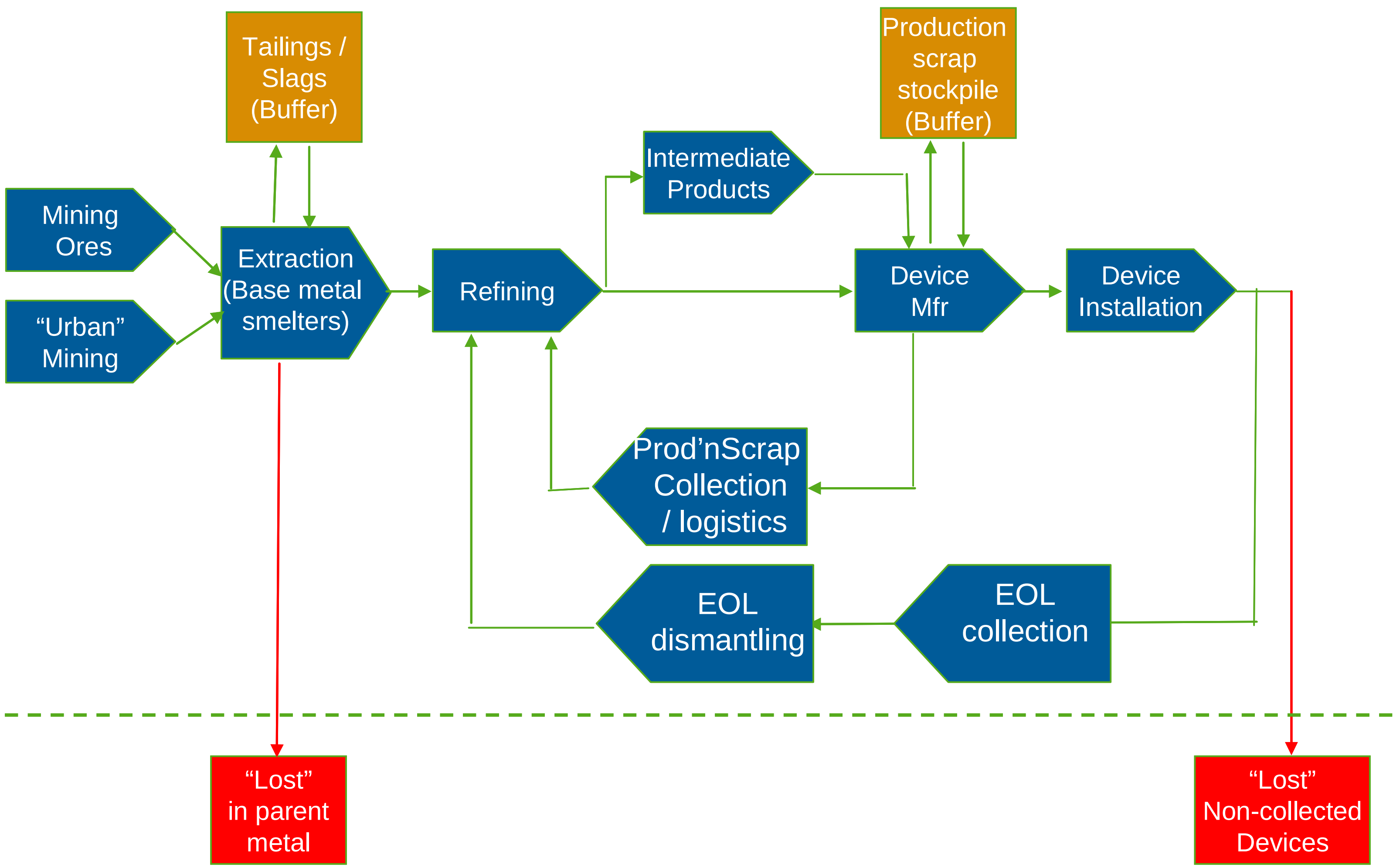
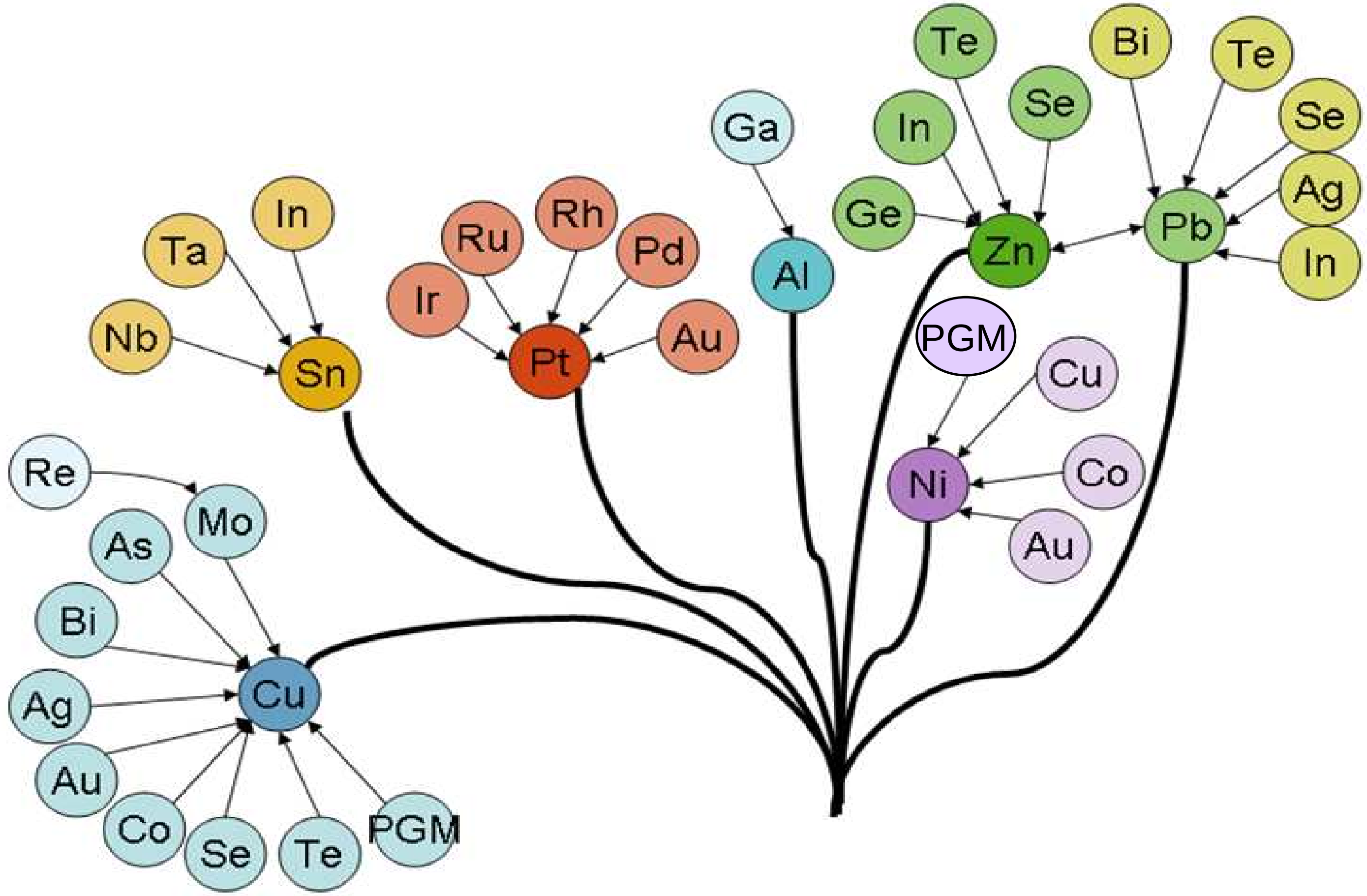
Simplified flow schematic for metals

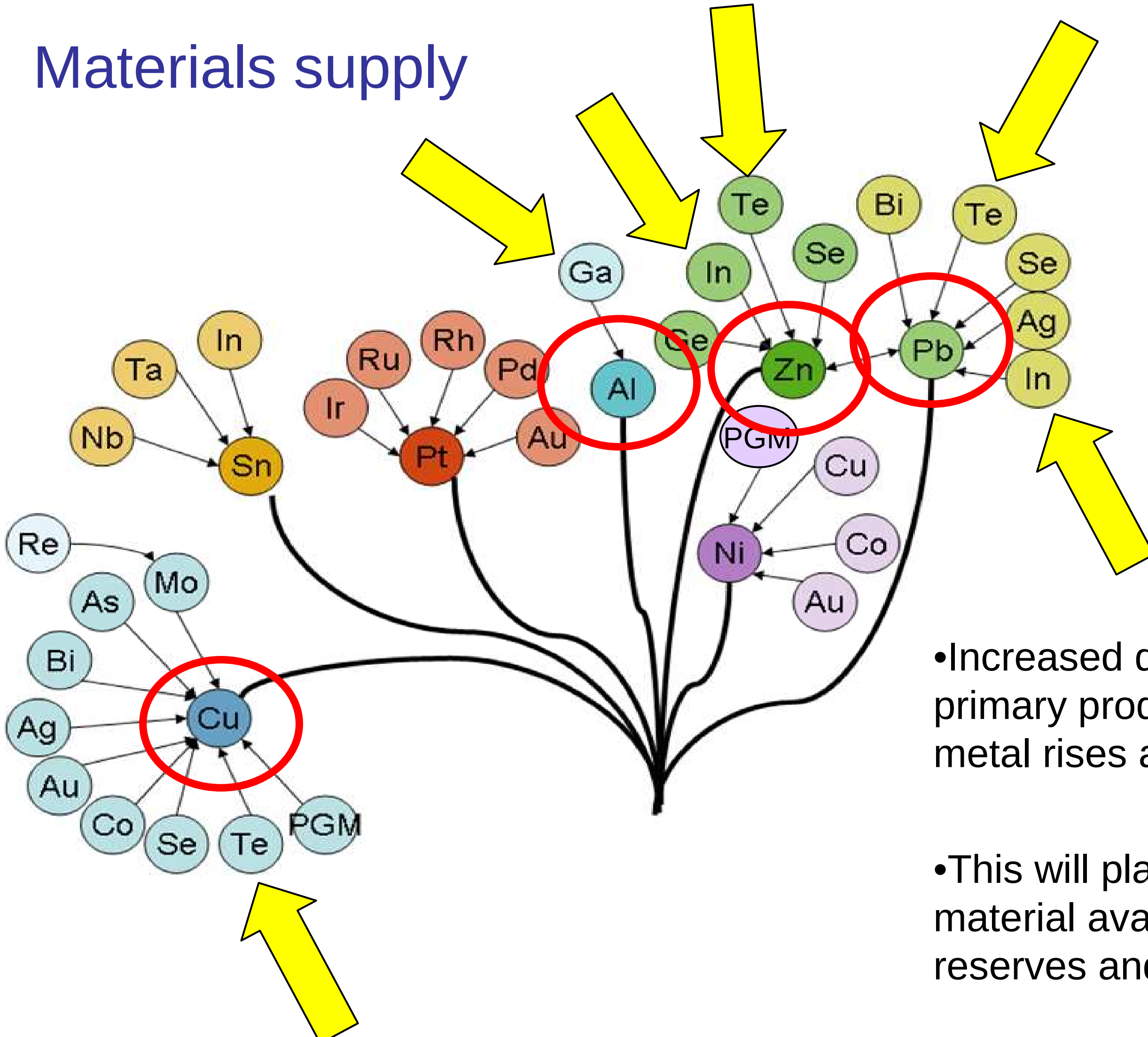


Materials supply – the “metals tree”



Source: "Hagelüken, C., C.E.M. Meskers: Complex lifecycles of precious and special metals, in: Graedel, T. , E. van der Voet (eds): Linkages of Sustainability. Strüngmann Forum Report, vol. 4. Cambridge, MA: MIT press, 2009".

Materials supply



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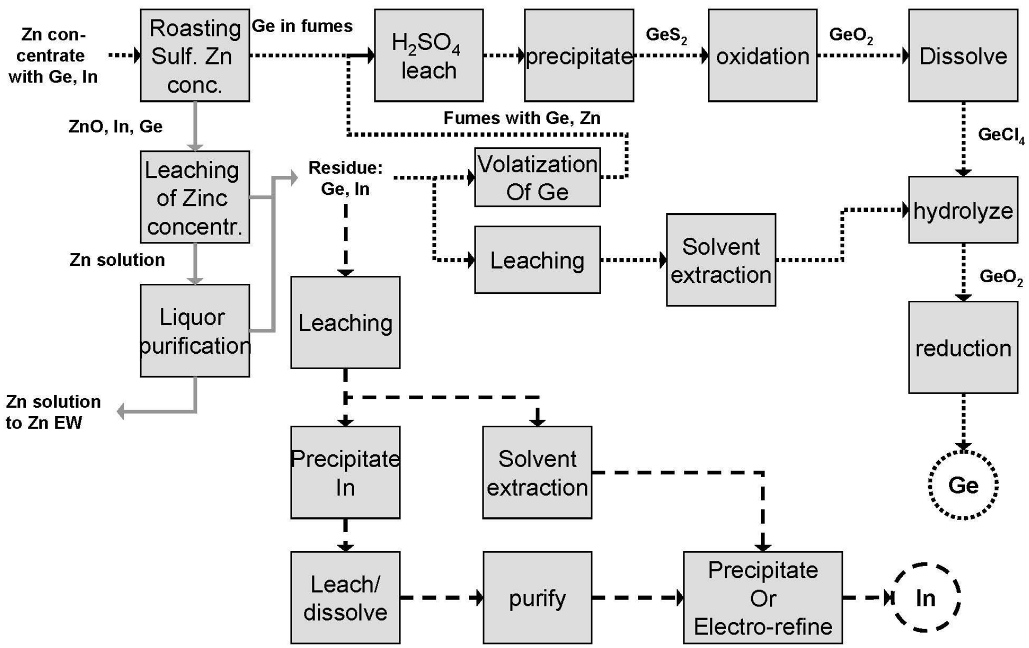
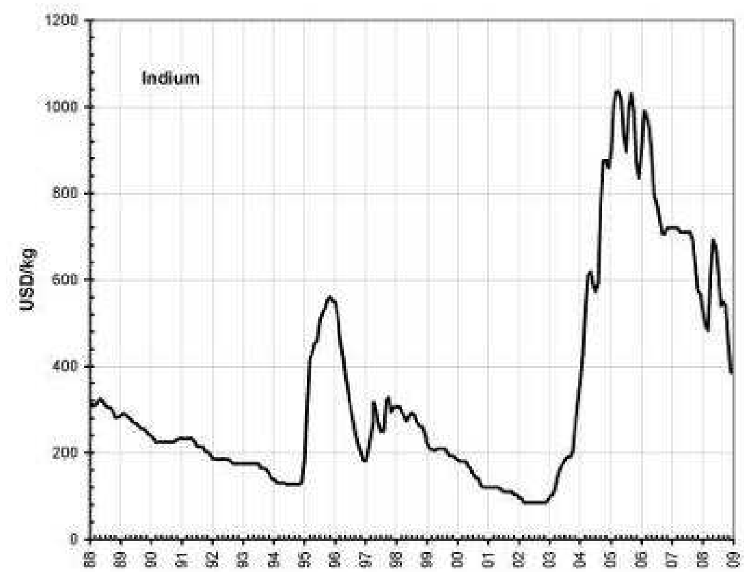
- Increased demand can only be met by primary production if demand for major metal rises accordingly.
- This will place an absolute cap on total material availability in terms of total reserves and production capacity.

…hence supply is finite

Extraction and refining are complex processes and require planning and investment. Increased demand will lead to temporary price peaks during the lead time necessary to install new capacity.





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umicore
materials for a better life

China's rare-earth policy hurts optics makers

14 Oct 2010

Export restrictions have sent the price of cerium oxide through the roof, and highlighted the industry's vulnerability to Chinese imports.

Following export restrictions imposed on rare-earth minerals by China in the summer, the **soaring price of cerium oxide** – a key material used as a polishing slurry for high-precision optics – is causing havoc in the optics supply chain.

According to industry sources, one company has already been forced to shut down as it awaits supplies of the material, while others may introduce a cerium surcharge if the situation does not change. Suppliers of cerium-based products are unable to guarantee prices beyond more than a few days.

One supplier has told a customer: "Due to the volatility of material availability, and changes in raw material pricing almost every day, if we cannot ship the order within the next five days the material is subject to price changes prior to actual shipment." The price hike is also set to hit the cost of glasses and crystals doped with rare-earth elements – although the increase is taking longer to filter through this part of the optics supply chain.

Price hike
Robert Castellano, an industry analyst at **The Information Network**, told *optics.org*: "The market price of cerium oxide has increased to approximately $50 per kilogram in September 2010 from $15 per kg in April 2010 and $9 per kg in September 2009."

That sudden price-hike has since been reflected directly in

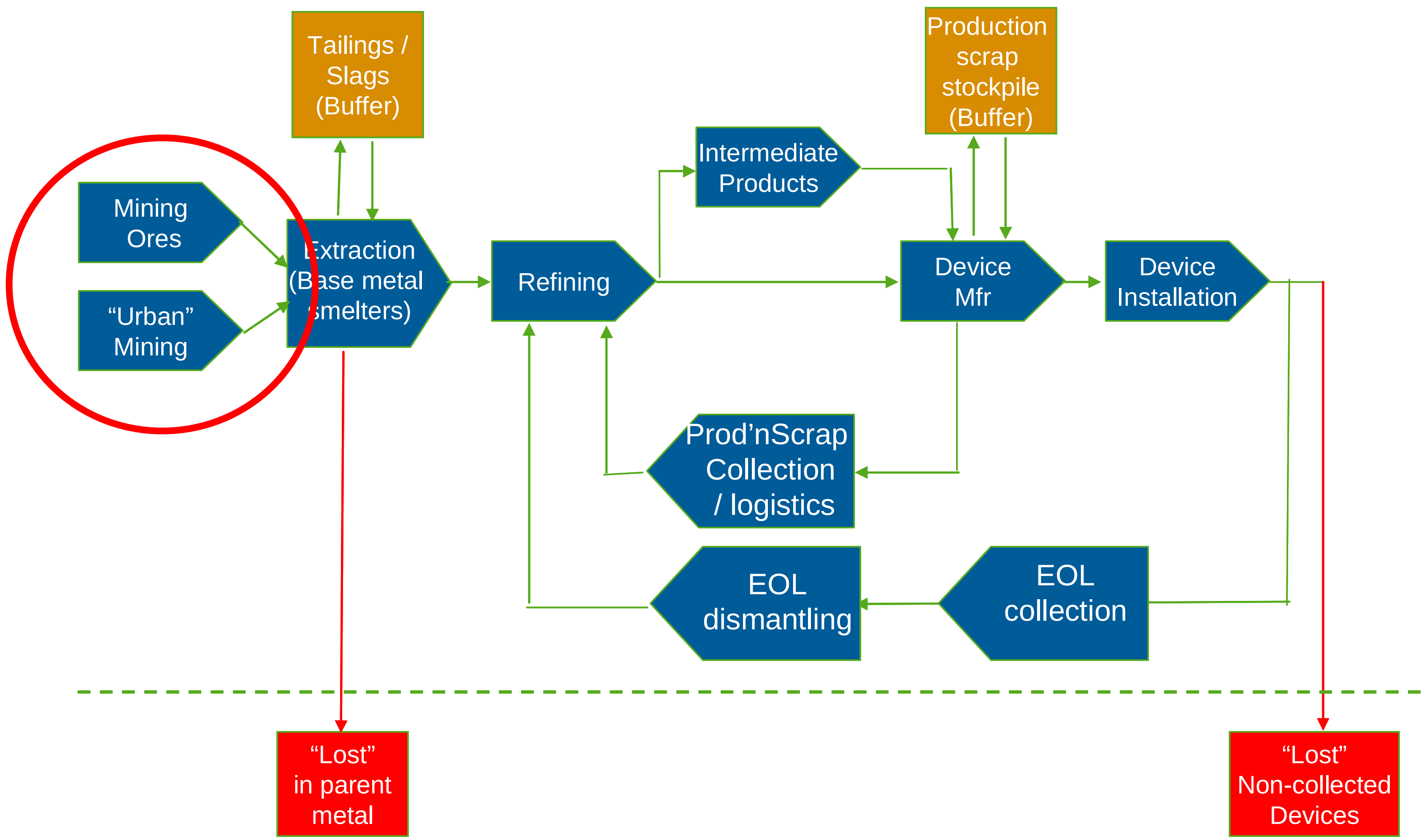
Cerium metal

Defining the challenge – materials needs

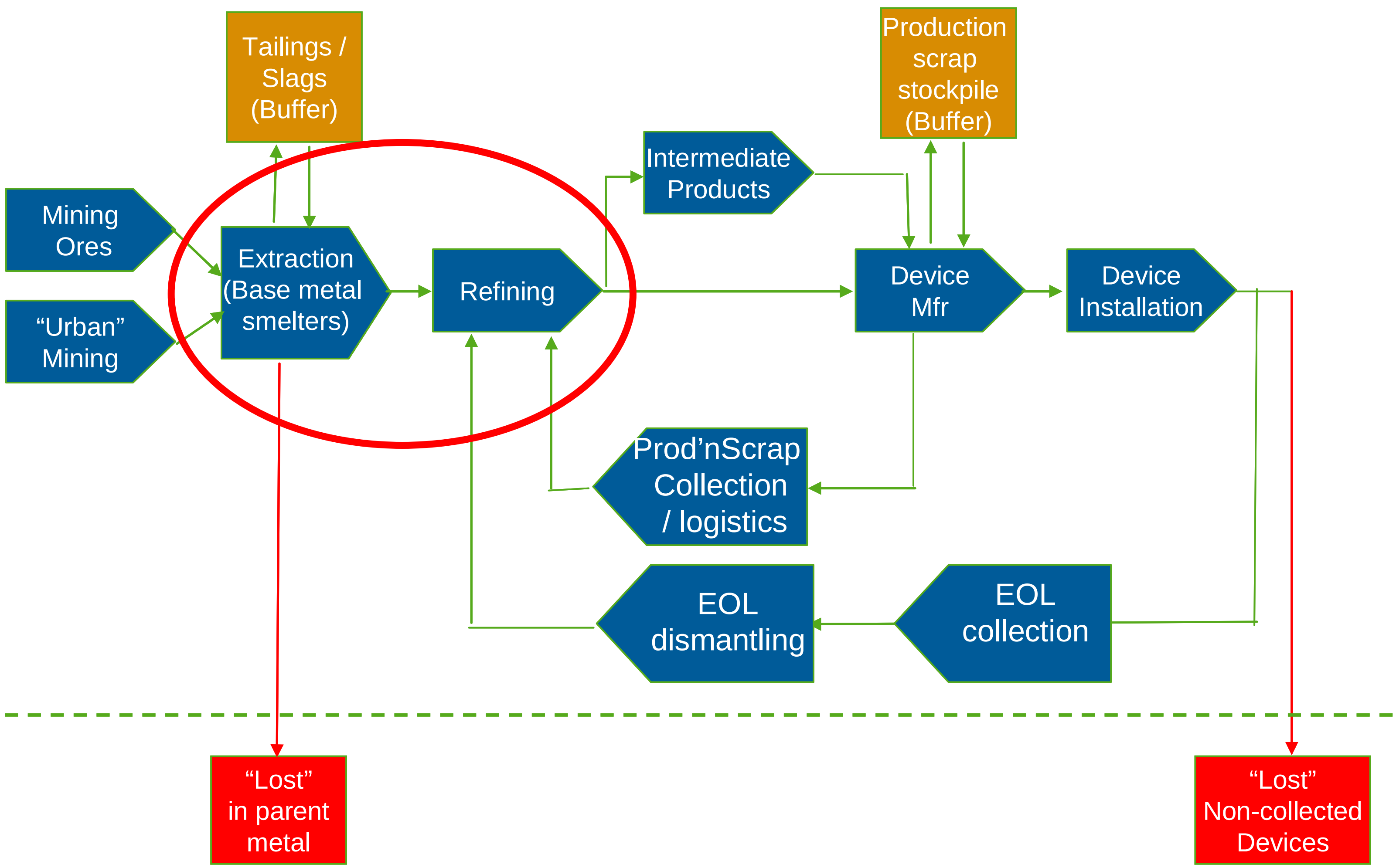
Metal	PV production 2020	Specific metal requirement in 2020	Paradigm scenario total demand in 2020 for PV	Estimated annual world wide primary production 2010	Recycled material 2010	Total production 2010	2020 PV demand vs 2010 total production
	GWp/year	Tons/GWp	Tons	Tons/year	Tons/year	Tons/year	%
c-Si	90						
Ag		59	5310			32900	**16%**
CIGS	21						
In		53	1113	550	750	1300	**86%**
Ga		12	258	110	30	140	**185%**
Se		50	1050	3000	50	3050	**34%**
CdTe	18						
Te		56	1008	465	35	500	**202%**

Source: Umicore

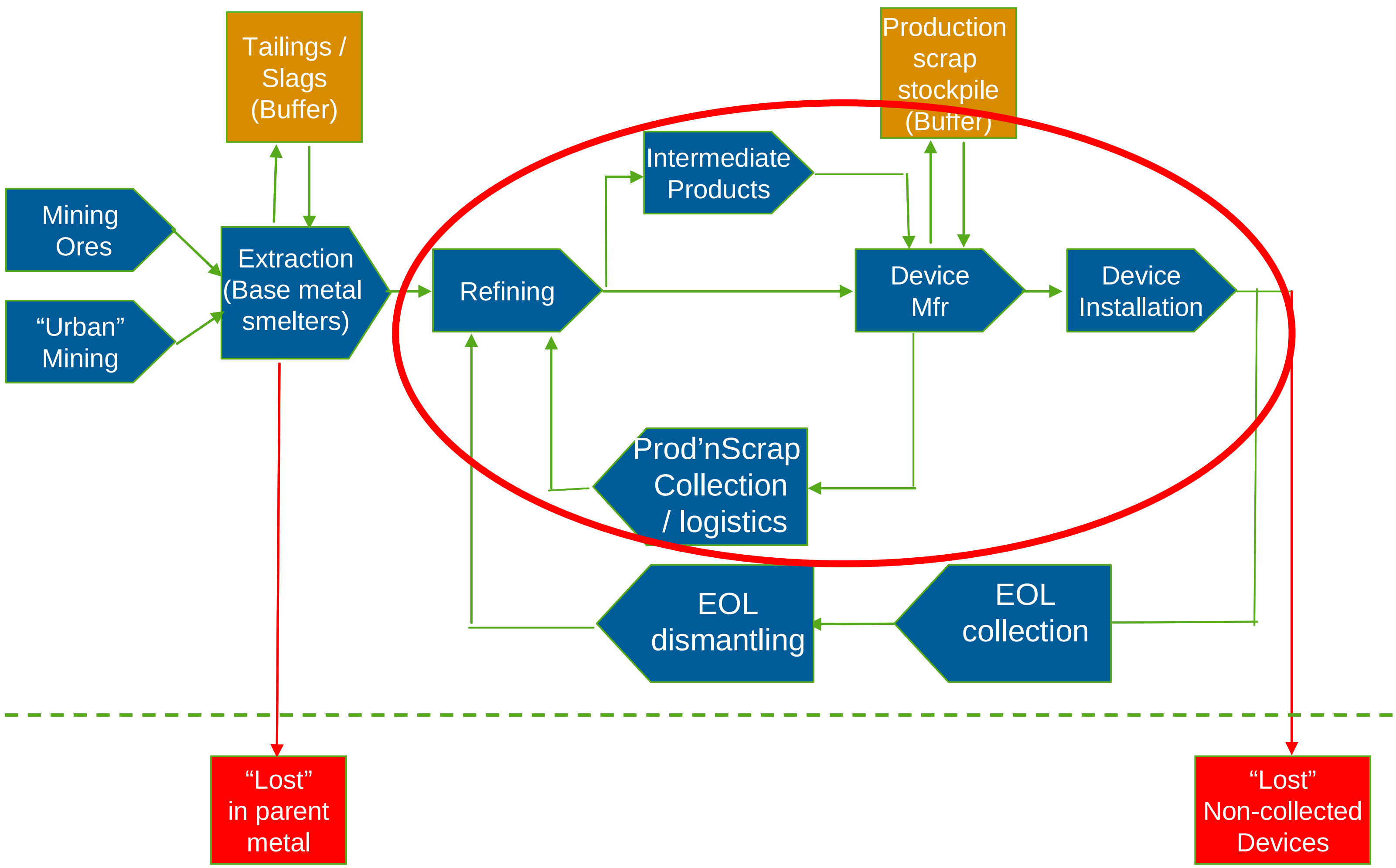
Sources – Need to better understand the resources



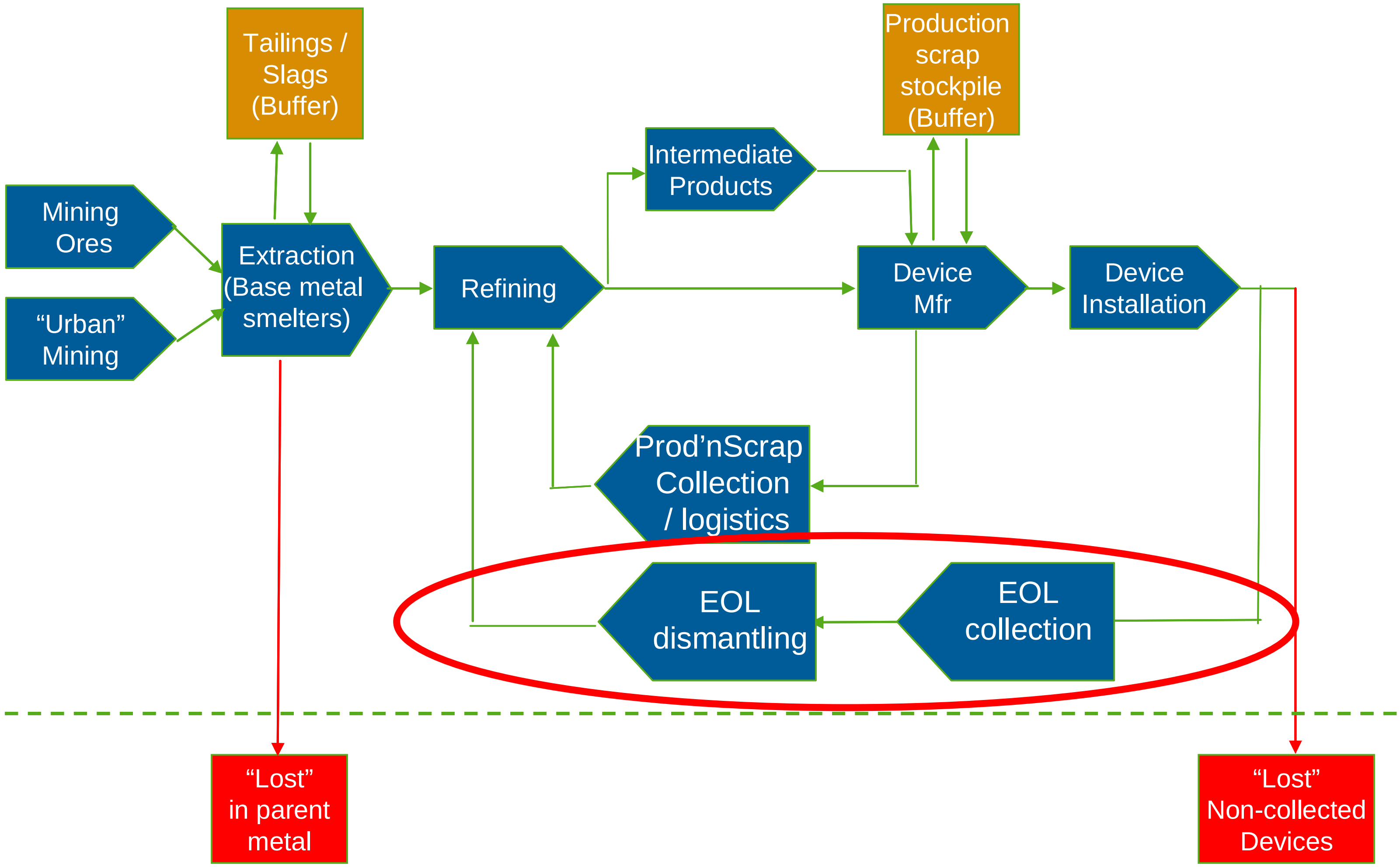
Extraction yields and primary refining – need to optimise



Production / scrap recycling – optimise material yields in device production and production waste recycling circuits



End of Life recycling – requires effective collection logistics, recycling loops and meaningful targets for metals recovery



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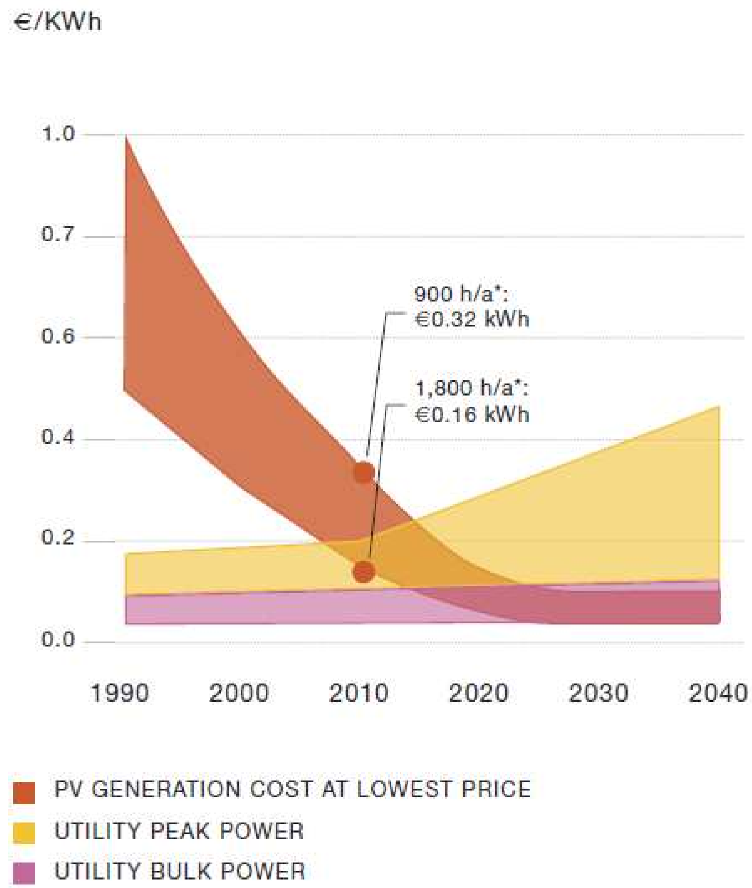
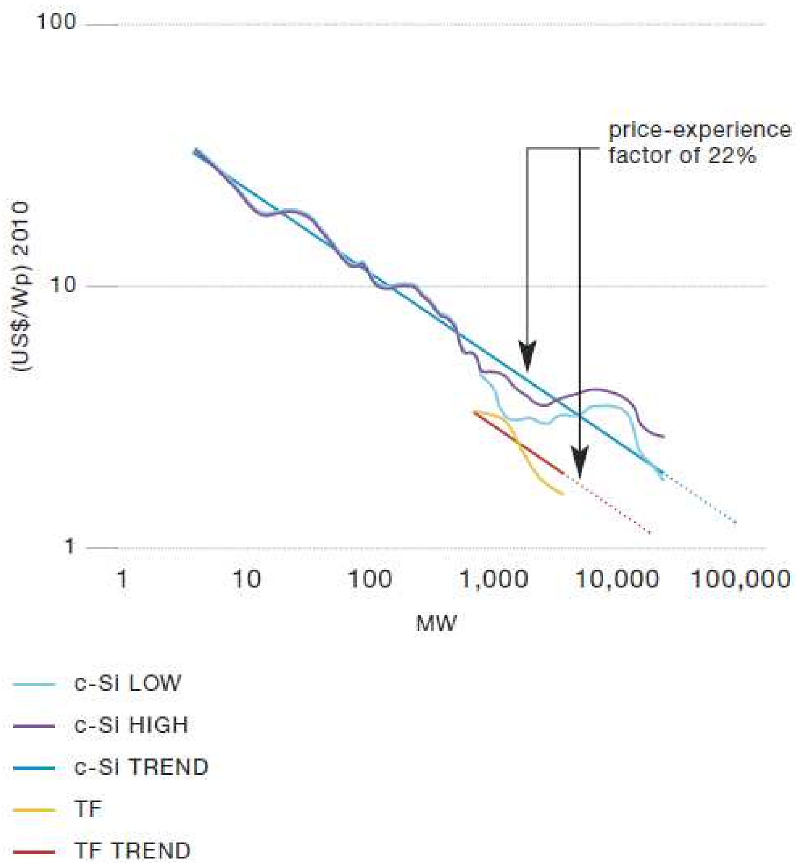
Defining the challenge – PV competitiveness



*h/a: Hours of sun per annum. 900 h/a corresponds to northern countries of Europe. 1,800 h/a corresponds to southern countries of Europe.

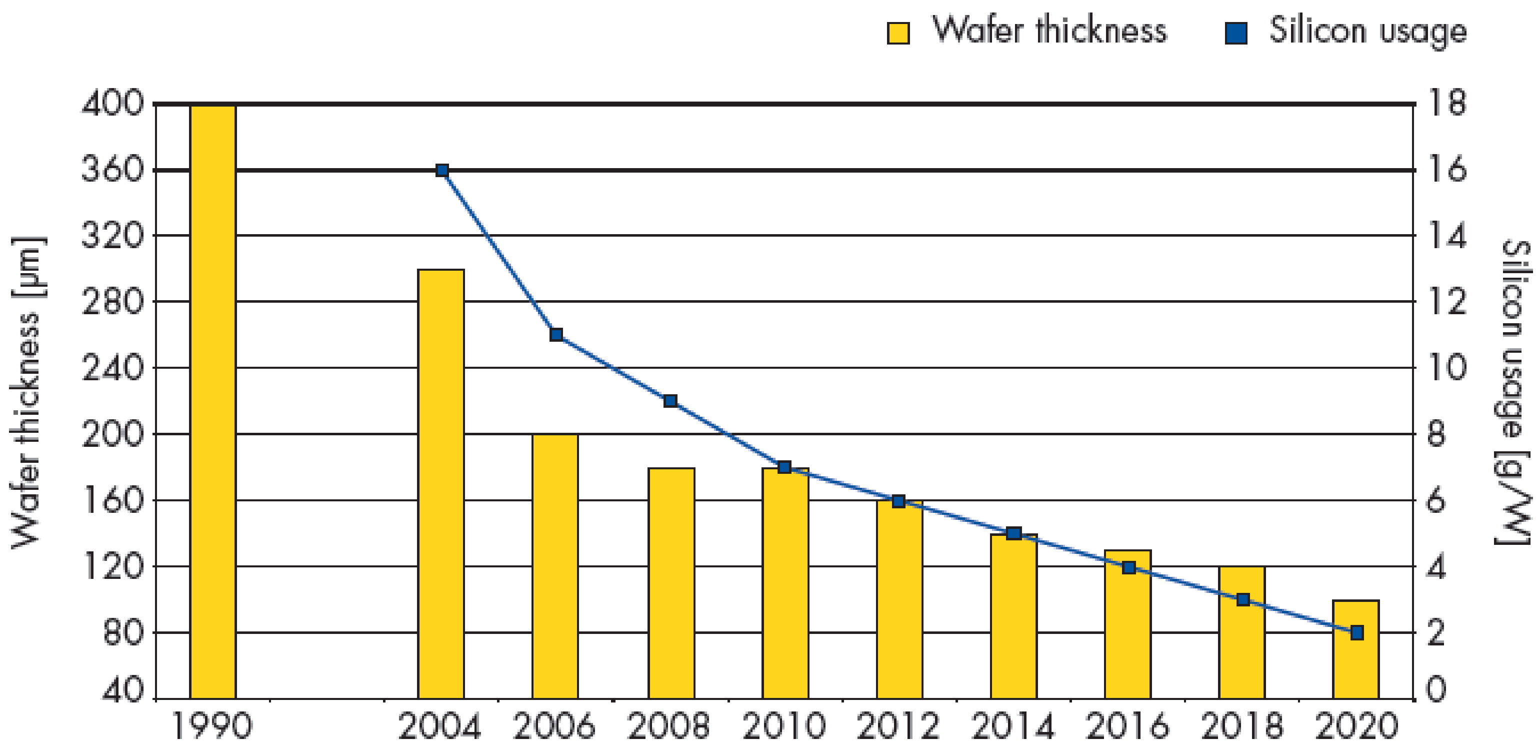
source: EPIA.

Defining the challenge –PV cost reduction



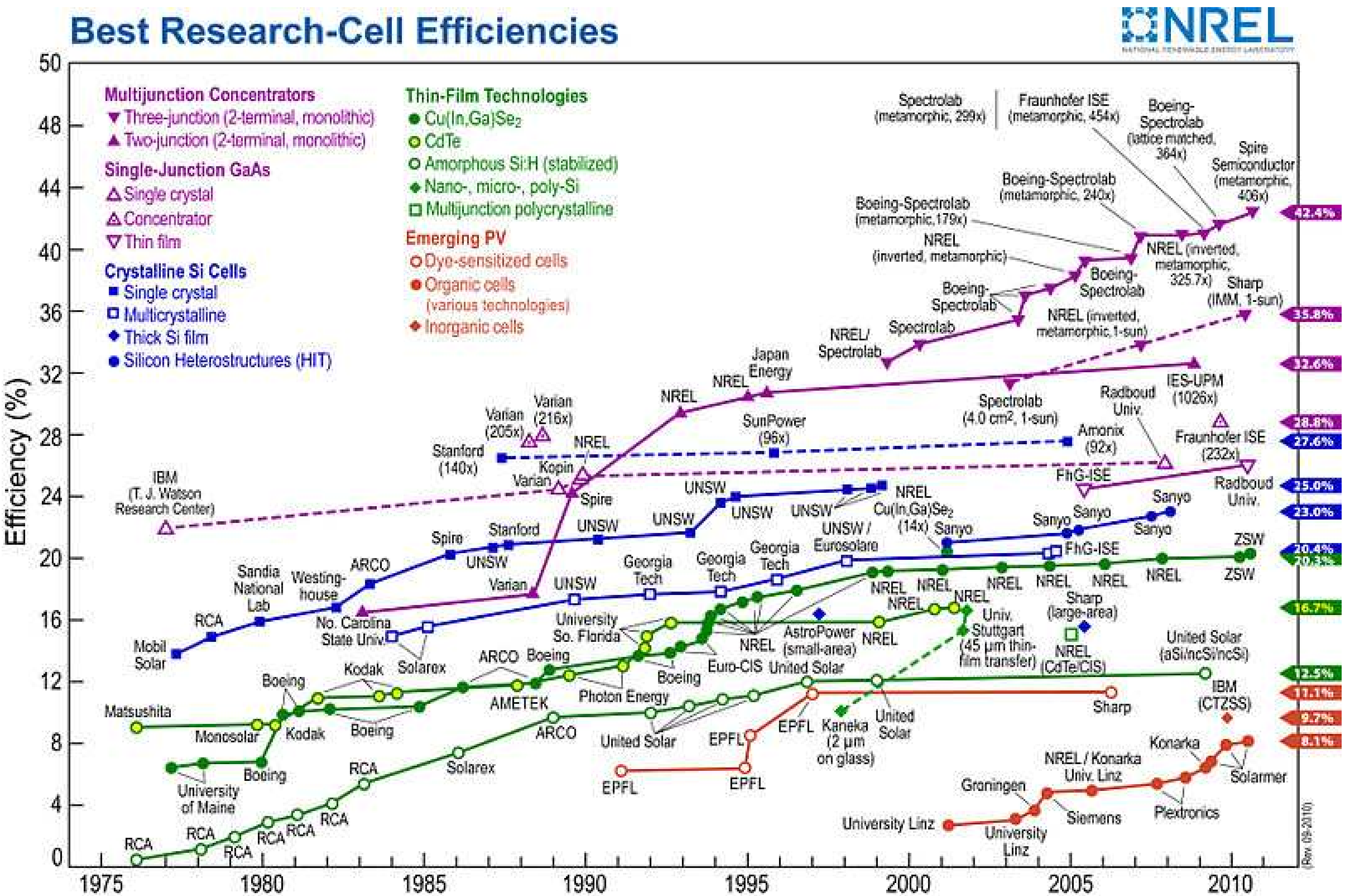
source: Navigant Consulting, EPIA.

Defining the challenge – Reducing specific material needs

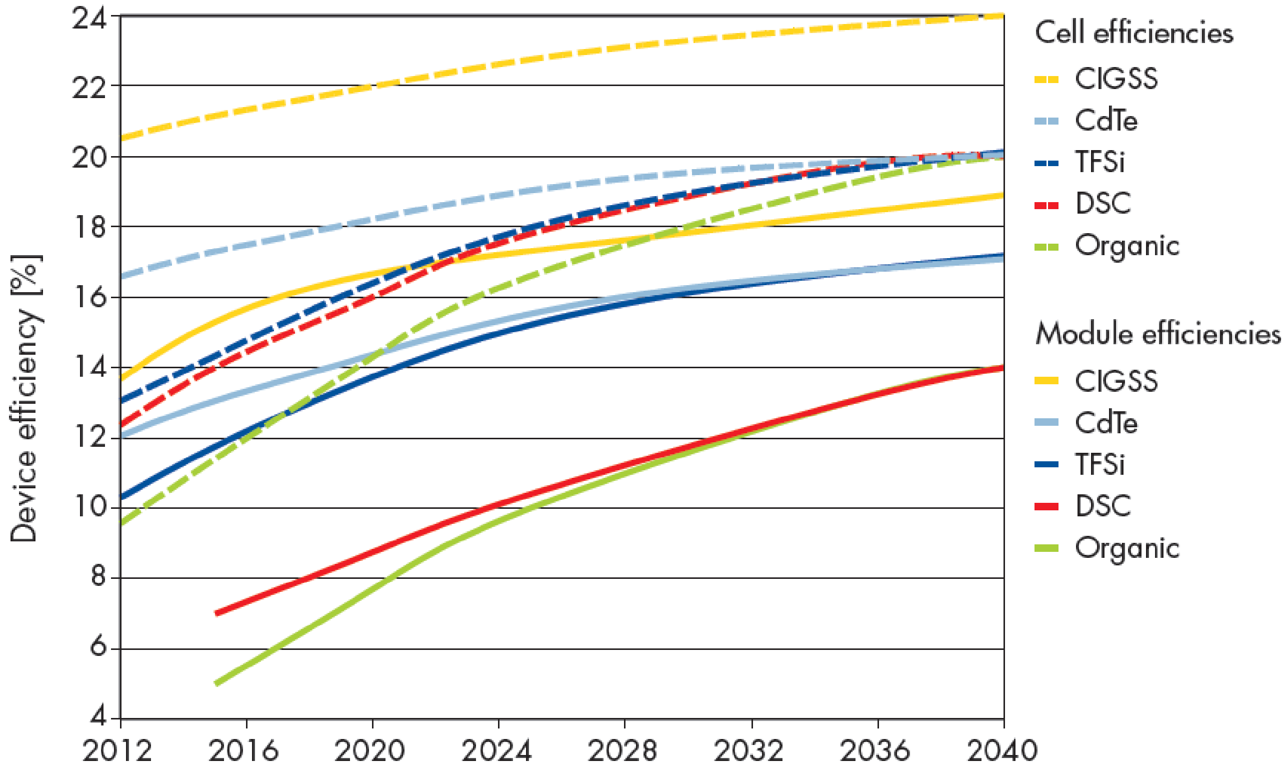


Source EPIA

Trends in the PV industry – Hiostorical improvements to efficiency



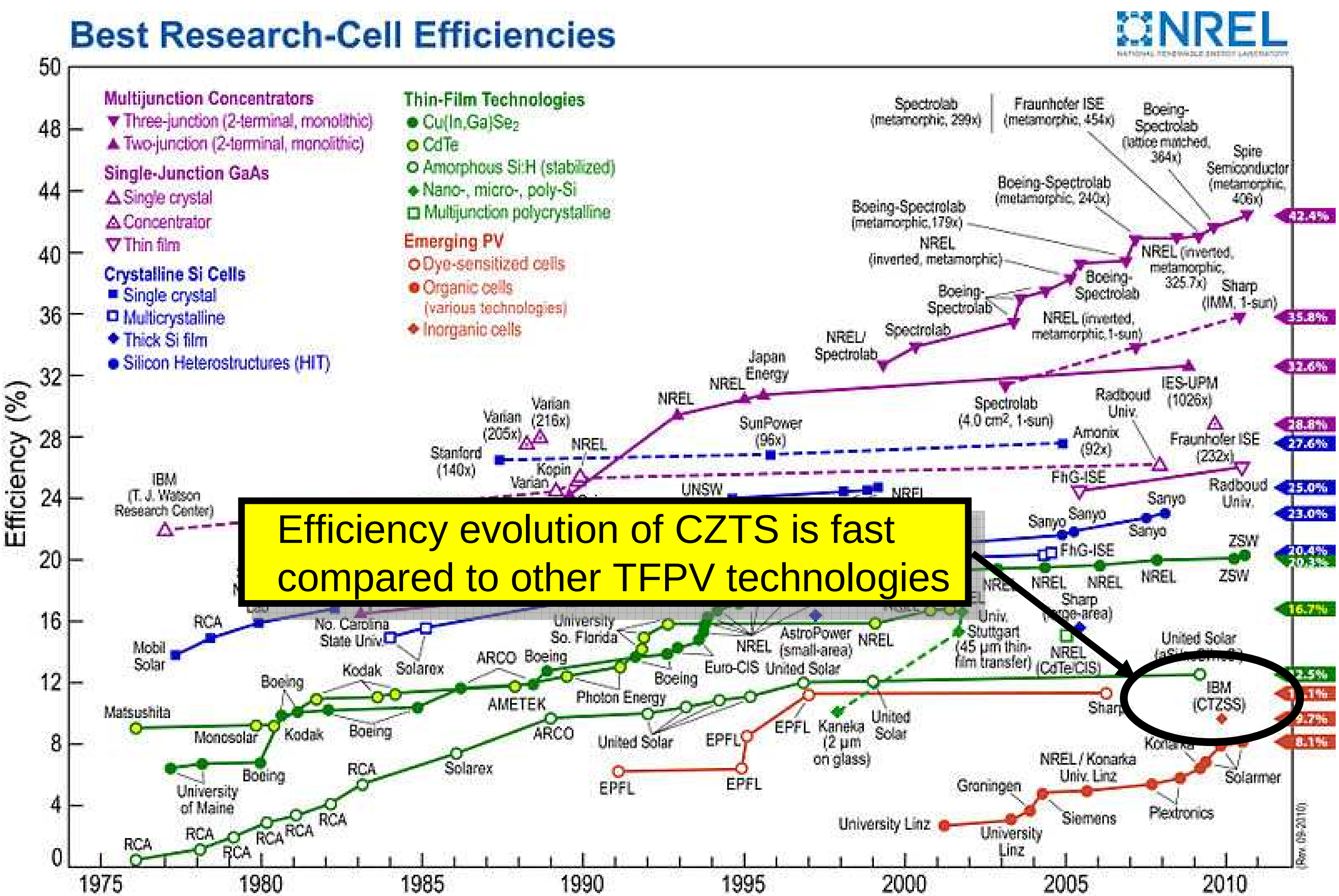
Trends in the PV industry – Efficiency improvements



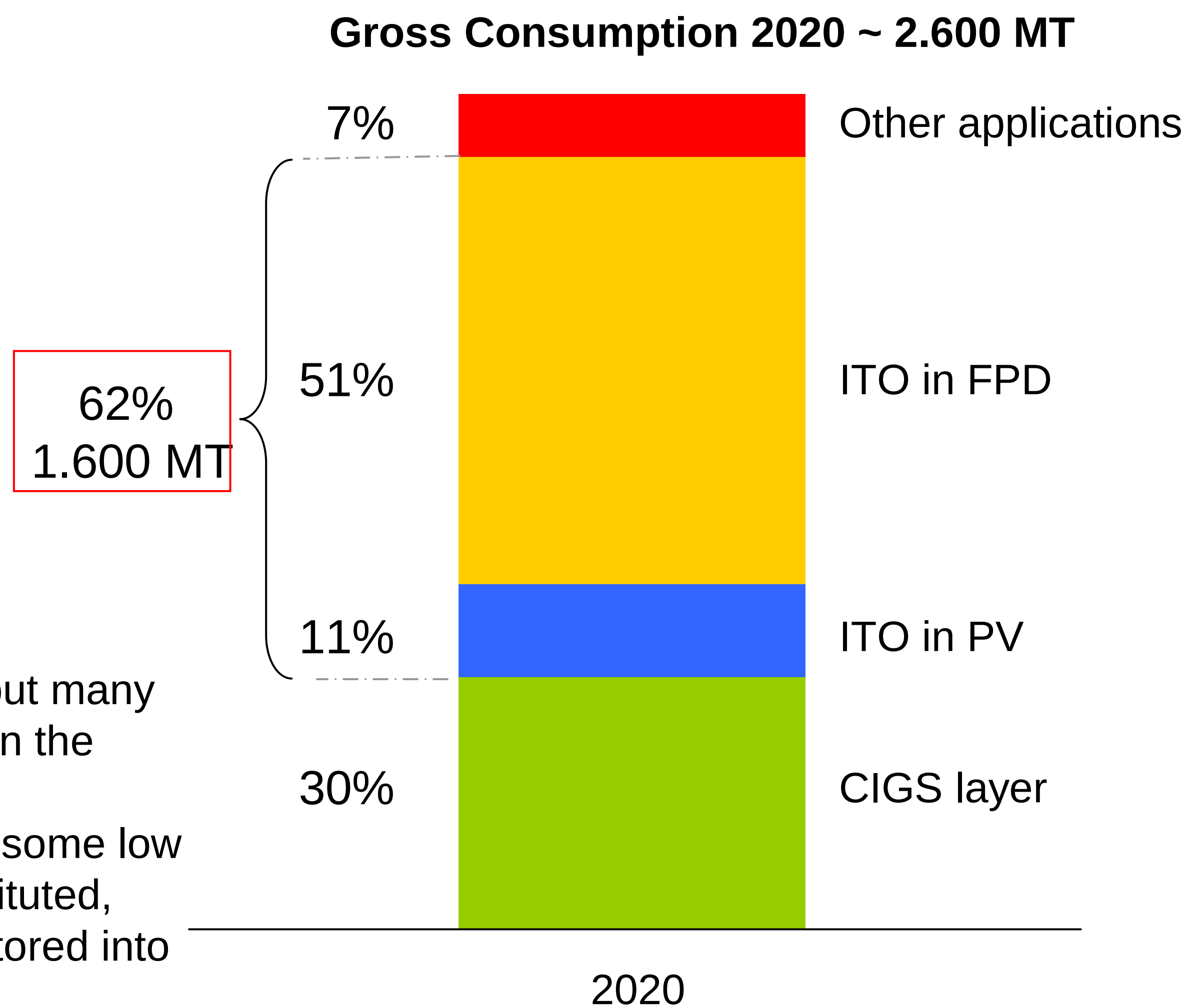
Expected evolution of TFPV technology lab record efficiencies

Source PV Technology Platform

Trends in the PV industry – Alternative chemical systems



Substitution - Indium ?



Technically very challenging, but many research groups are working on the subject.
It is reasonable to believe that some low end applications may be substituted, although this has not been factored into the demand study.

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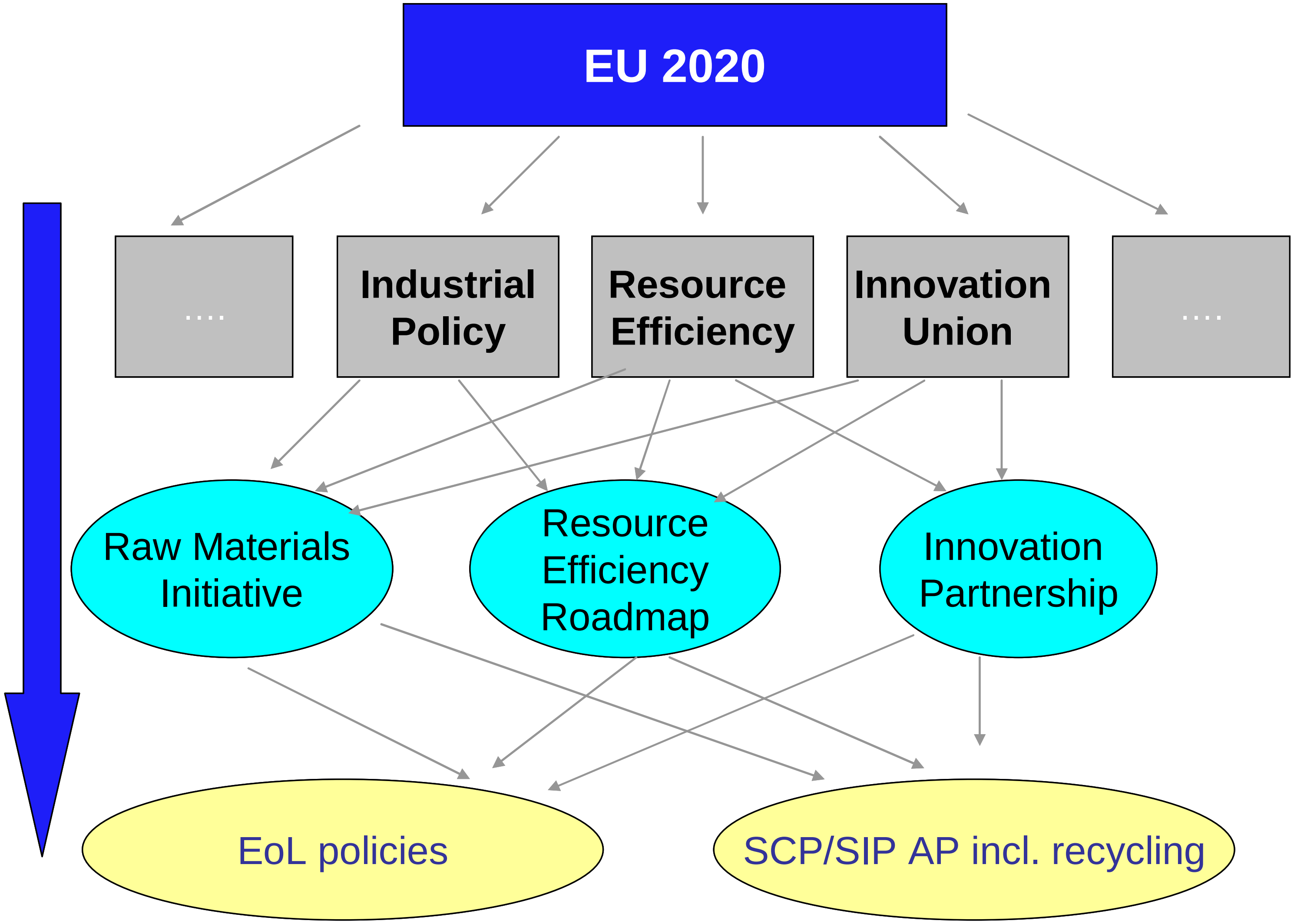
EU policies and activities with respect to materials and resource efficiency



EU Policies with respect to materials and resource efficiency

RMI – first communication report on 2008 / second communication in February 2011 to high light key issues

EIP for raw materials is in preparation under the auspices of DG Entreprise.
Its scope will cover:

- Implementation of research topics e.g. mining, processing, recycling, substitution….
- Pilot plants and financing e.g. deep sea mining, land fil mining, recycling

A road map is being prepared by ETP SMR

Innovation action partnerships – EU / US / Japan
Examples of activities:

- EU + US DOE workshop in October 2011 on access to critical materials
- Joint research
- Recycling
- Illegal waste shipments
- Trade issues

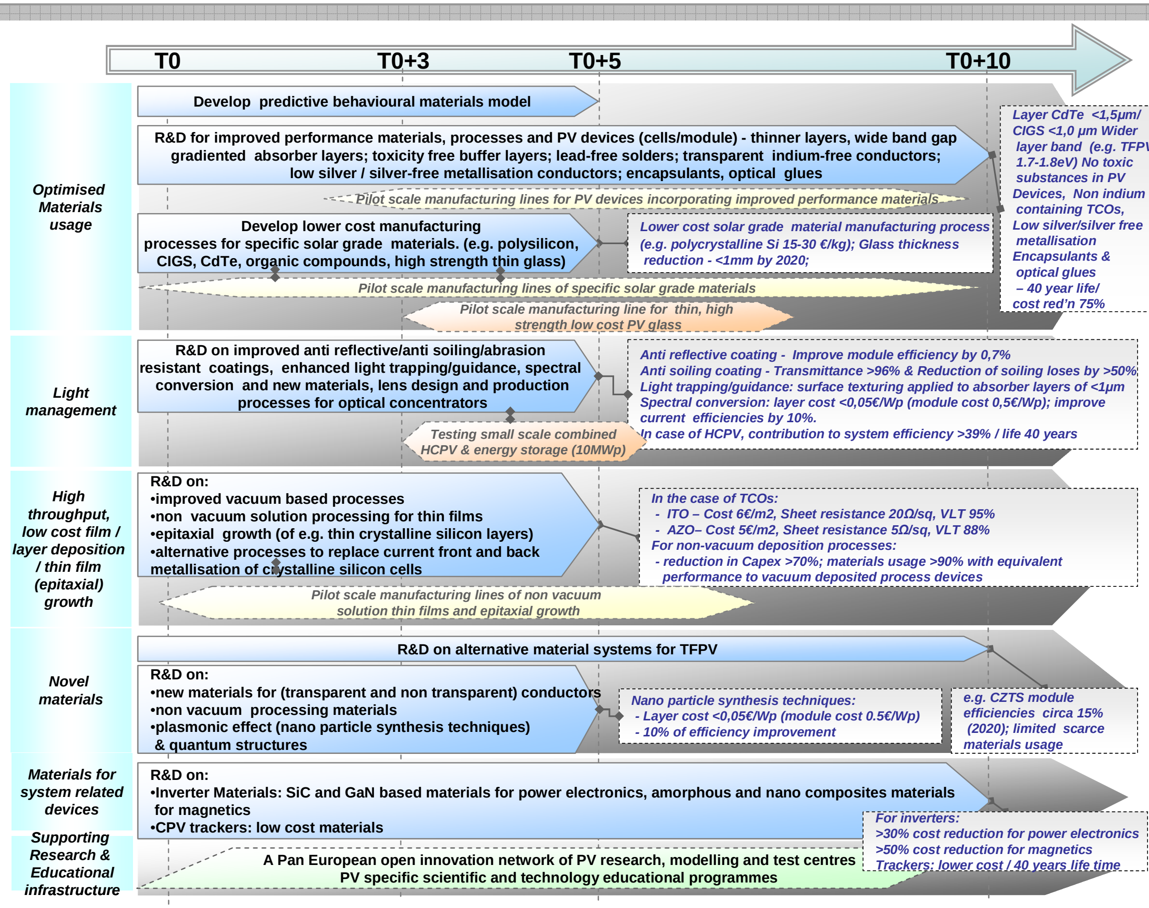
Other actions:

- Generally raising awareness of illegal shipments of waste through the media
- Recycling - linking WEEE to the RMI
- Resource efficiency – re-use, recycling, substitution

EU Policies with respect to materials and resource efficiency

SET Plan – Materials research roadmap

To be presented in November at SET Plan conference. Fully aligned with the PVTP SRA2



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Summary and conclusions

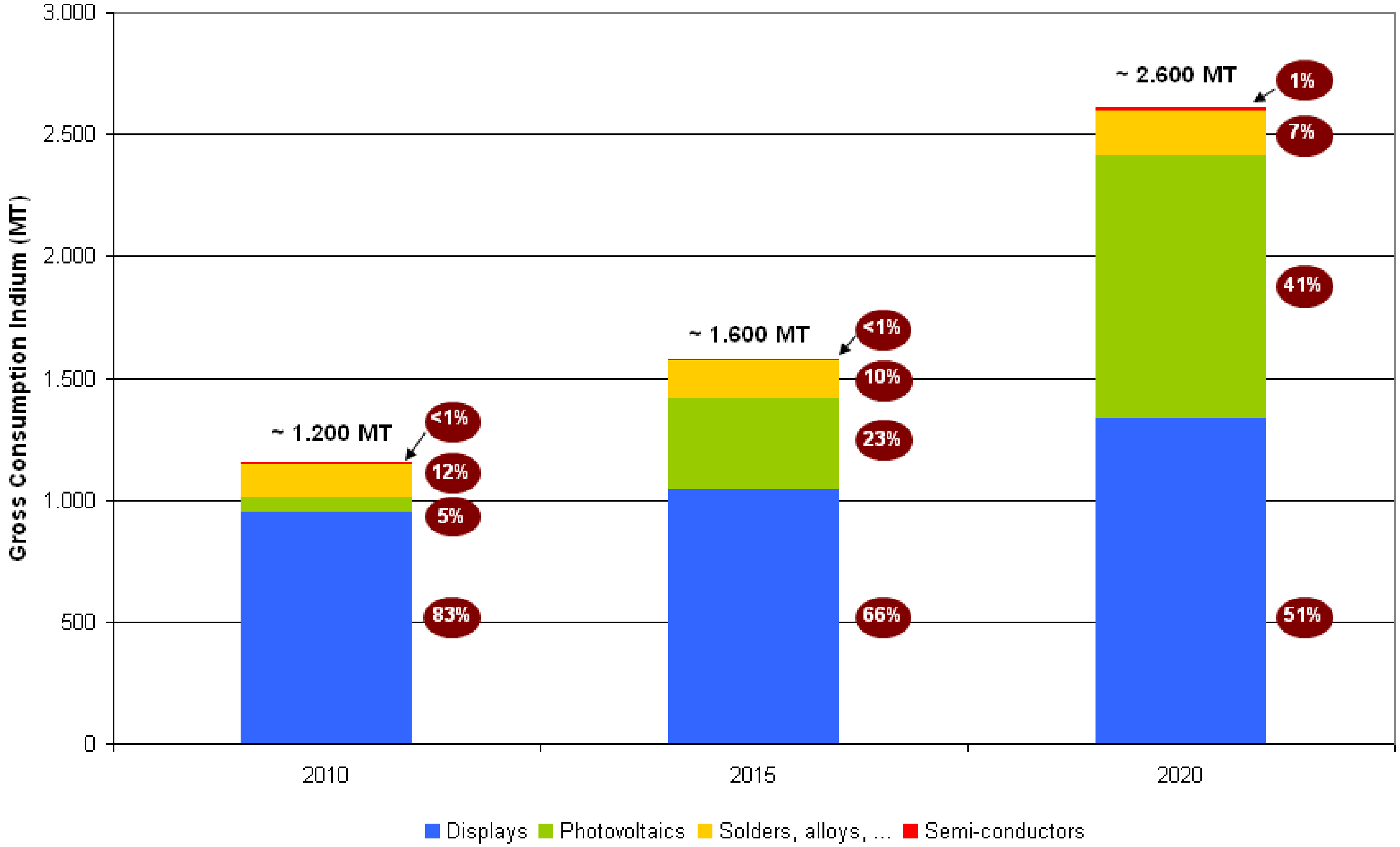
Anticipated strong growth in PV will be accompanied by stress in the supply chain for specialty (scarce) metals

The "stress" is manageable by a number of strategies:

- Improving the extraction rates and primary refining of metals
- Improving knowledge of reserves
- Optimising the in-process waste management and recycling
- Effective End of Life recycling schemes with meaningful targets
- Using less material by:
    - making more efficient devices
    - making thinner layers
    - increasing materials yield in production
- Maintaining parallel PV technologies using different materials systems and developing new substitute materials systems

Back up

Gross Consumption of Indium *



Includes change in inventory requirements, Based on annual PV production of 160 GWp

Source: Umicore