INREP
Towards Indium free TCOs

Develop and deploy valid and robust alternatives to indium based transparent conductive electrode materials as electrodes

Towards more sustainable TCO layers: Environmental effects of replacement of ITO by alternative materials

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 641864

INTRODUCTION

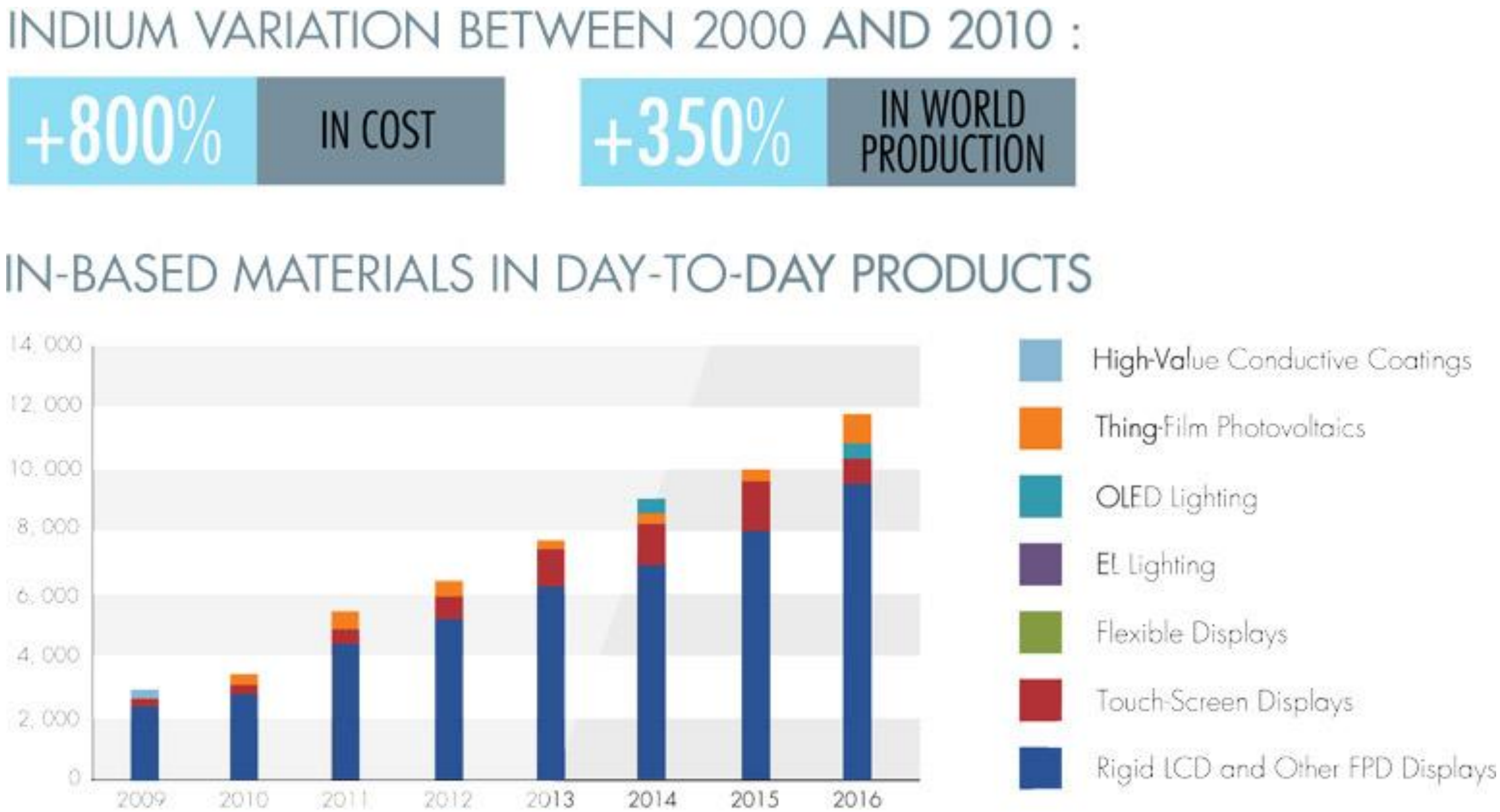
- Increasing use of smart electronics in key industrial sectors

- Transparent conducting films (TCO):important component in numerous electronic devices such as photovoltaic cells, touchscreens, LEDs

Currently, indium tin oxide (ITO) is commonly used for TCO layers manufacturing

Image sources: maxpixel.freegreatpicture.com, wikipedia.org (Nokia 5800 XpressMusic, LED throwies chaos)

GROWING DEMAND FOR ITO



- Due to growing demand for electronics containing TCOs and depletion of Indium resources, **development of valid and robust alternatives to indium is essential -> INREP PROJECT**

Image sources: INREP website

INREP PROJECT IN A NUTSHELL

The goal of INREP is to develop and deploy valid and robust alternatives to indium (In) based transparent conductive electrode materials as electrodes for four key applications:

FOUR APPLICATIONS AND RELATED PROCESS

/ High efficiency PV cells:

/ GaN based LEDs:

/ Organic LEDs:

/ Touch-screen monitor:

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Image sources: INREP website

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Challenge: ensure that the developed alternatives have lower impact on environment in whole life cycle of the product

→ Evaluated with **Life Cycle Assessment (LCA)**

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Image sources: INREP website

LIFE CYCLE ASSESSMENT (LCA)

- Analysis technique enabling to evaluate the impact of a product on environment over its entire life cycle (manufacturing, distribution, usage and disposal)
- Improvement assessment which is consistent with ISO standards
- Analysis enables also to propose process improvements

Challenges:

- Data collection
- System boundaries
- Evaluation of impacts
- Verification???

Image source: https://en.wikipedia.org/wiki/Sustainable_materials_management

LIFE CYCLE ASSESSMENT (LCA)

LCA steps

- Determination of the best method for evaluation of a given system
- Goal & scope definition
- Inventory analysis
- Impact assessment
- Improvement assessment

Image source: https://en.wikipedia.org/wiki/Sustainable_materials_management

LIFE CYCLE ASSESSMENT OF DIFFERENT IN-FREE TCOS

Goal & Scope of the study

- **LCA analysis** for 5 different materials **(ITO, ZnO, ZnO:Al, ZnO:B, SnO_2)** and 3 deposition techniques **(physical/ chemical vapor deposition, atomic layer deposition)**
- Environmental impact expressed per $1cm^2$ of deposited layer
- System boundaries drawn around the deposition process
- LCA tool used: SimaPro database

Materials	Analysed deposition technique
ITO (benchmark technology)	PVD
ZnO	PVD
ZnO:Al	PVD, ALD
ZnO:B	CVD
SnO_2	PVD

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INVENTORY ANALYSIS

Data collection

- **All data** concerning the deposition process was collected from **lab-scale devices** of our partners
- **Exemplary data** set for Inventory analysis data for the benchmark layer (ITO, PVD technique)

Inputs/outputs	Unit	Amount
Cooling water	m^3/cm^2	2,80E-05
ITO target	g/cm^2	1,01E-04
Argon gas	m^3/cm^2	1,21E-07
Oxygen gas	m^3/cm^2	9,88E-10
Electricity	kWh/cm^2	7,53E-05
Waste for reuse, recovery, recycling	g/cm^2	6,01E-03
Waste for final disposal	g/cm^2	1,54E-05
Waste water without treatment	m^3/cm^2	1,33E-10

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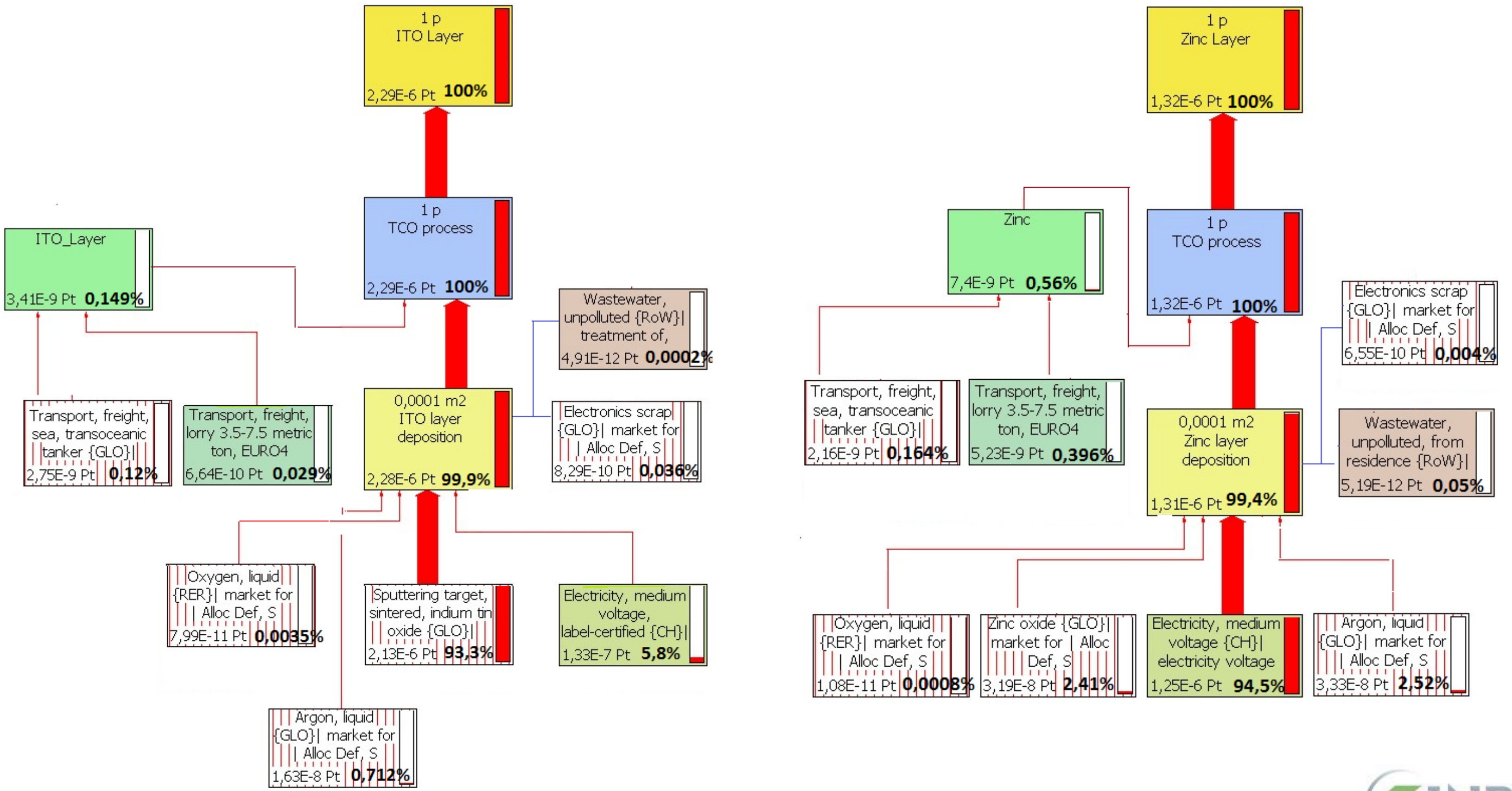
IMPACT ASSESSMENT RESULTS

Layers deposited by Physical vapor deposition (PVD)

ITO vs. ZNO layer

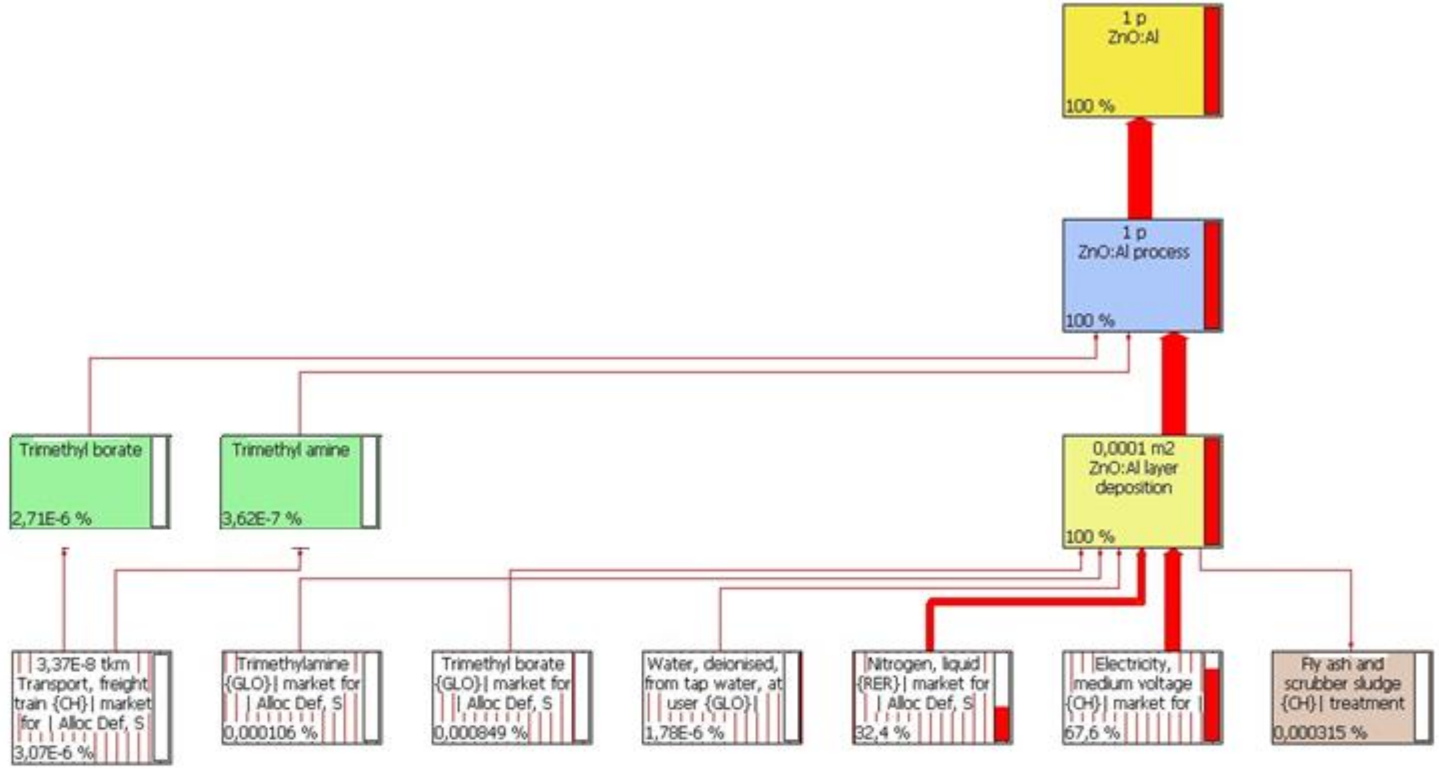


Overall impact: 2.29E-6 vs. 1.32E-6 Ecopoints

IMPACT ASSESSMENT RESULTS

Layers deposited by Atomic layer deposition (ALD)

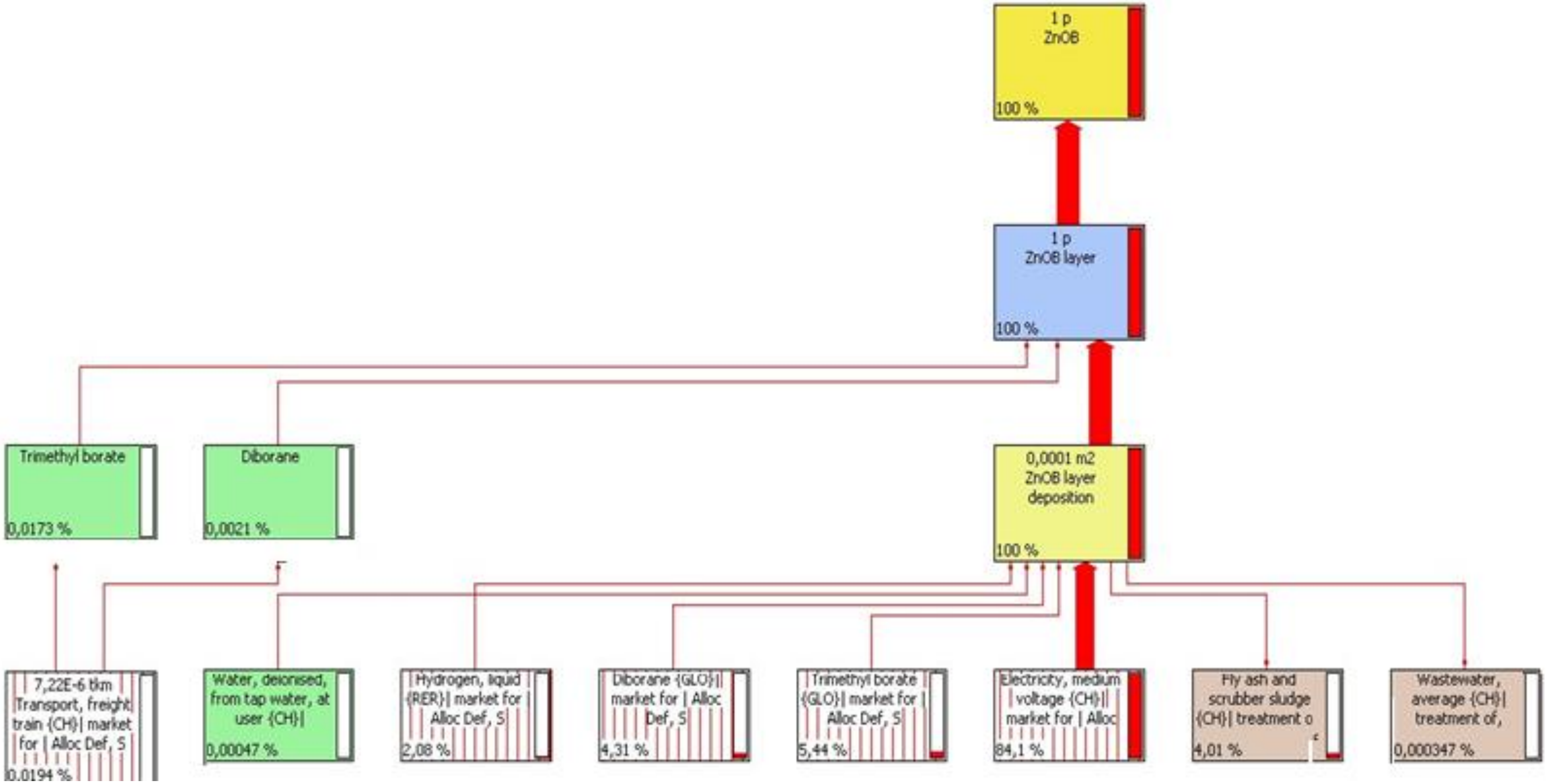
ZnO:Al layer



Overall impact: 2.5E-3 Ecopoints

IMPACT ASSESSMENT RESULTS

Layers deposited by Chemical vapor deposition (CVD) ZNO:B



Overall impact: 8.47E-5 Ecopoints

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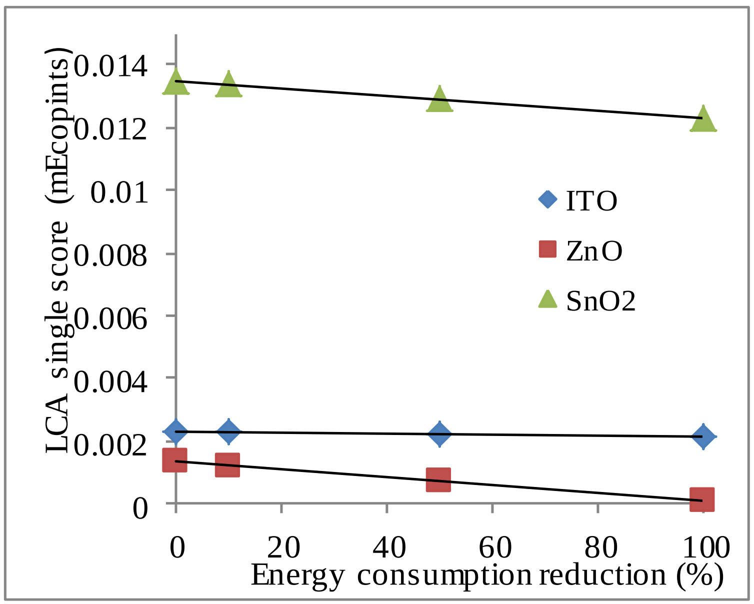
IMPROVEMENT ASSESSMENT

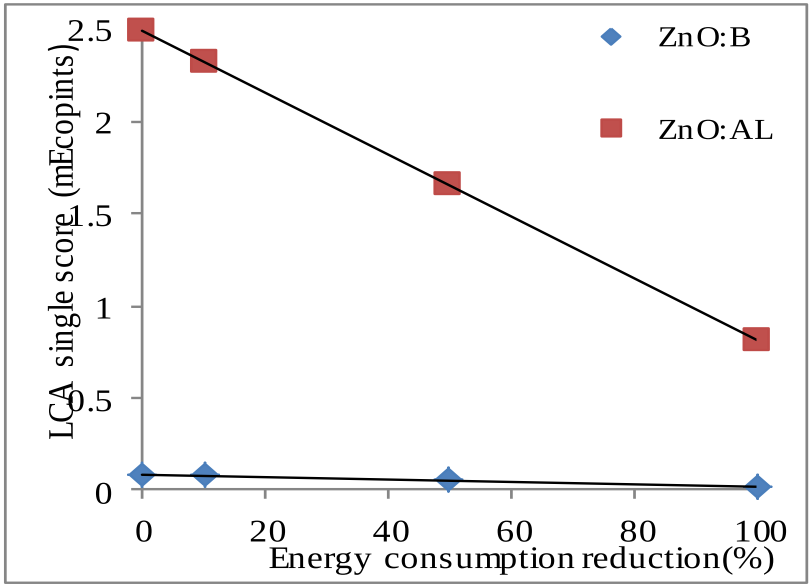
Are those results valid also for an industrial scale production?

Can we further improve the process?

Sensitivity analysis of energy efficiency (deposition process)



Layers deposited by PVD technique



Layers deposited by CVD (ZnO:B) and ALD (ZnO:Al) technique

CONCLUSIONS

Key outcomes:

- Replacement of ITO by ZnO proved to be a successful strategy for minimization of environmental impact for the TCO layer deposition process
- Further process improvements should be focused on energy efficiency (for all deposition techniques)
- PVD technique has the lowest environmental impact

Next steps:

- Optimisation of TCO layers composition with respect to cost, environmental impact and quality of the layer

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Thank you for your attention

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