

Life Cycle Sustainability Assessment for products/strategies

–case study of the mc-Si Photovoltaic Modules

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Research background of Life Cycle Sustainability Assessment

1. Environmental -Life Cycle Assessment (ELCA)
2. Sustainability assessment (economic, environmental, social aspects)

LCSA (Life Cycle Sustainability Assessment) (UNEP / SETAC, 2002)



Environmental-LCA(E-LCA); Life Cycle Costing(LCC); Social Life Cycle Assessment (SLCA)



-绿色产品设计/评价
(Green product design/assessment)
-绿色供应链管理
(Green supply chain management, SRM)
-环境产品声明
(Environmental Product Declaration, EPD)

Ministry of Industry and Information Technology:

《工业绿色发展规划》（2016-2020）
(Industrial Green Development Plan)
《绿色设计产品评价试点实施方案》
(Implementation plan of green product evaluation)
《生态设计产品标识》
(Eco-design product identification)



-绿色建材评价（碳足迹指标）
(Evaluation of Green Building materials)
-绿色建筑认证(美国LEED、英国BREAM均要求做LCA)
(Green Building Certification)

建筑材料（水泥、玻璃、木材。。。）
(Building materials, ex Cement, Glass, Wood...)
建筑节能技术（太阳能、地源热泵。。。）
(Building Energy Saving Technology, ex Solar, Ground Source Heat Pump...)
绿色建筑方案（装配式建筑、木构建筑。。。）
(Green Building Program, ex prefabricated construction, wooden building.....)



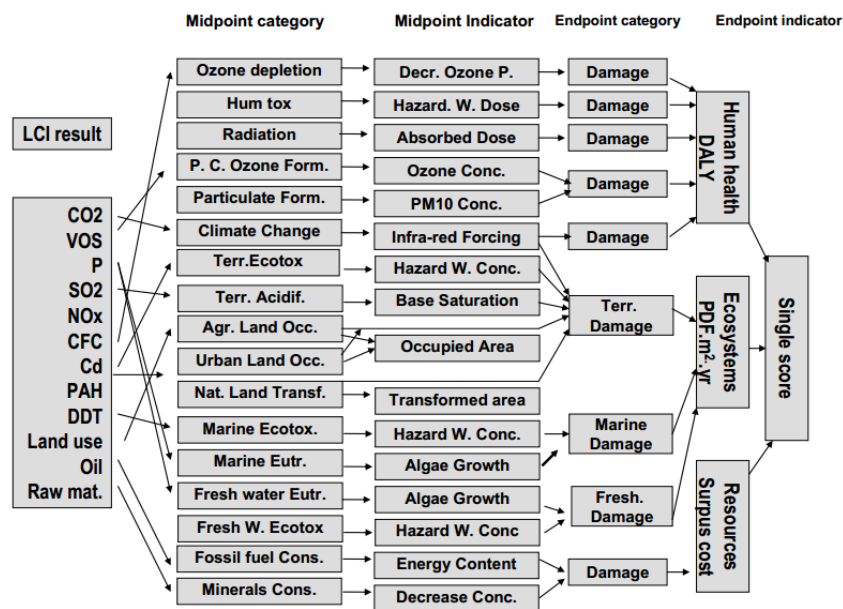
LCSA can increase decision-makers' awareness of choosing sustainable products/strategies

Research questions

1. 环境生命周期评价 (Environmental Life Cycle Assessment, ELCA)

生命周期影响评价方法常用有Eco-indicator 99、CML、ReCiPe

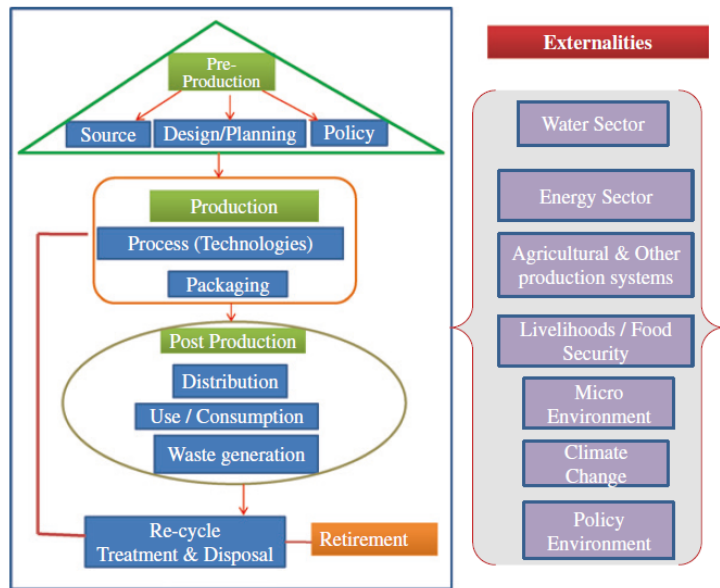
Methodology	Developed by	Country of origin
CML2002	CML	Netherlands
Eco-indicator 99	PRé	Netherlands
EDIP97 – EDIP2003	DTU	Denmark
EPS 2000	IVL	Sweden
Impact 2002+	EPFL	Switzerland
LIME	AIST	Japan
LUCAS	CIRAIG	Canada
ReCiPe	RUN + PRé + CML + RIVM	Netherlands
Swiss Ecoscarcy 07	E2+ ESU-services	Switzerland
TRACI	US EPA	USA
MEEuP	VhK	Netherlands



Impact categories and pathways covered by the ReCiPe methodology

PV module manufacturing process

2. 生命周期成本分析 (Life Cycle Costing, LCC)



Life cycle cost:

净现值法(Net Present Value Method, NPV method)、
内部收益率法(Internal Rate of Return Method)、
回收期法(Payback Period Method)等

$$NPV = \sum_{j=0}^n (CI - CO)_j \frac{1}{(1+i_c)^j}$$

PV module manufacturing process

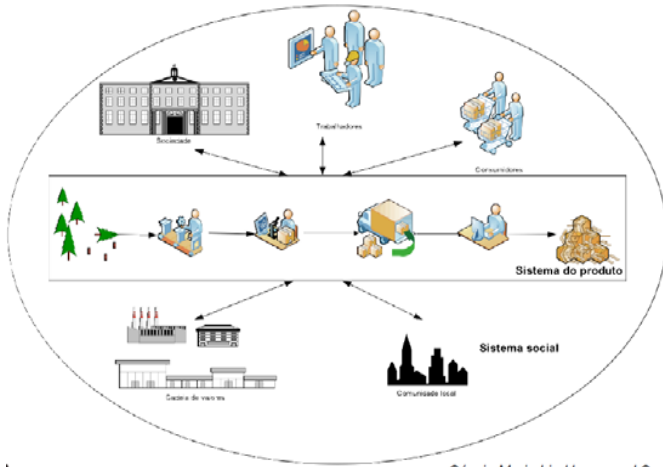
mainly include costs of raw materials, labor, electricity and packaging

$$L = L_{\text{material}} + L_{\text{labor}} + L_{\text{electricity}} + L_{\text{packaging}}$$

3. 社会性生命周期评价 (Social Life Cycle Assessment, SLCA)



Indicators are usually designed according to influences to stakeholders



Stakeholder categories	Impact categories	Subcategories	Inv. indicators	Inventory data
Workers	Human rights			
Local community	Working conditions			
Society	Health and safety			
Consumers	Cultural heritage			
Value chain actors	Governance			
	Socio-economic repercussions			

Figure 5 – Assessment system from categories to unit of measurement. Adapted from Benoit et al., 2007

PV module manufacturing process

- 劳动岗位 (employment numbers, S_{11})、
- 劳动文明程度 (labor civilization degree, S_{12})、
- 劳动收入提高 (labor income increase, S_{13})
- 生产能力提高 (production capacity improvement, S_{14})

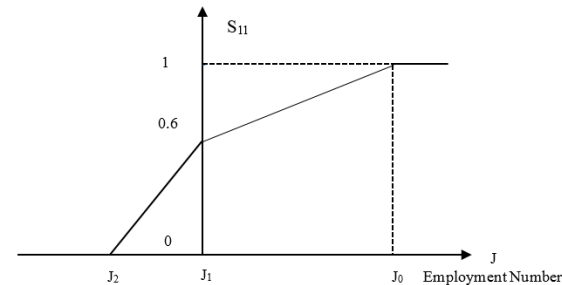
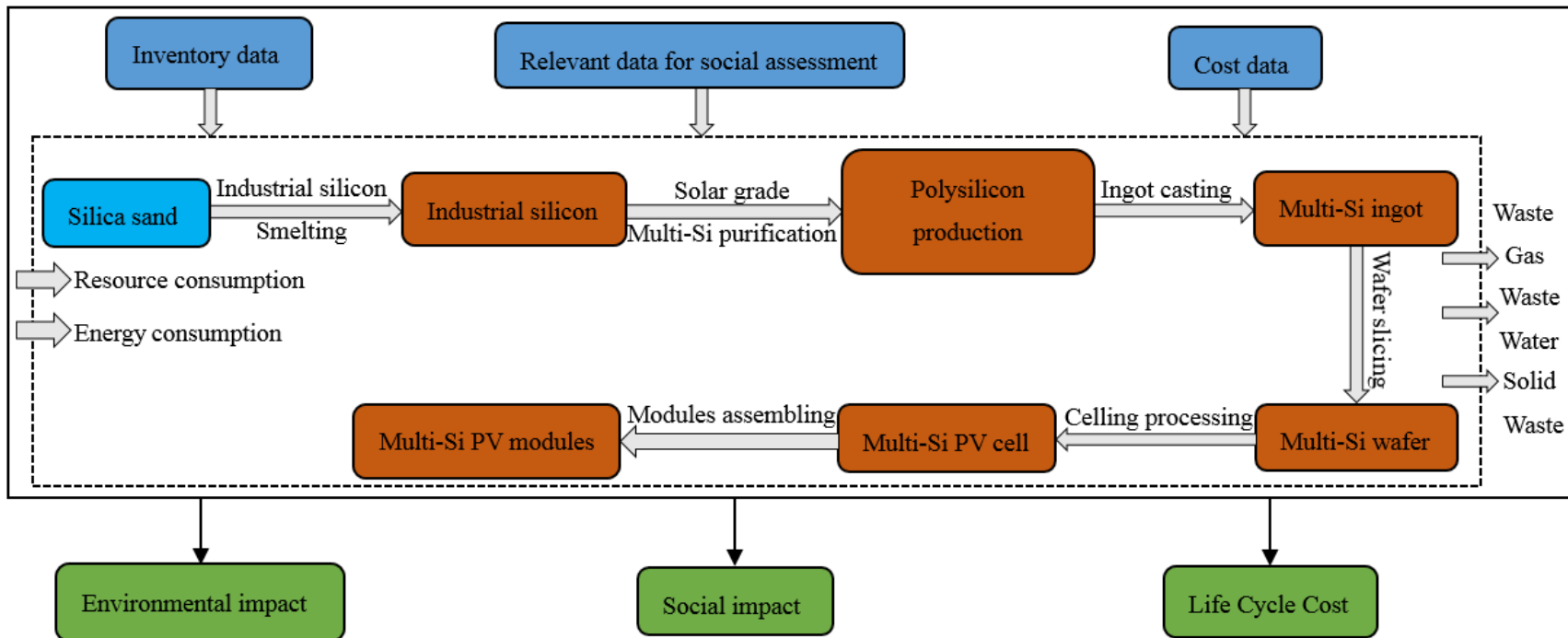


Fig.2 Employment contributions

Life Cycle Sustainability Assessment of mc-Si Photovoltaic Modules



-Beijia Huang, Zhao Juan. Economic and Social Impact Assessment of China's Multi-crystalline Silicon (mc-Si) Photovoltaic Modules Production, 2016 (special issue "LCSA", accepted in journal Industrial ecology)

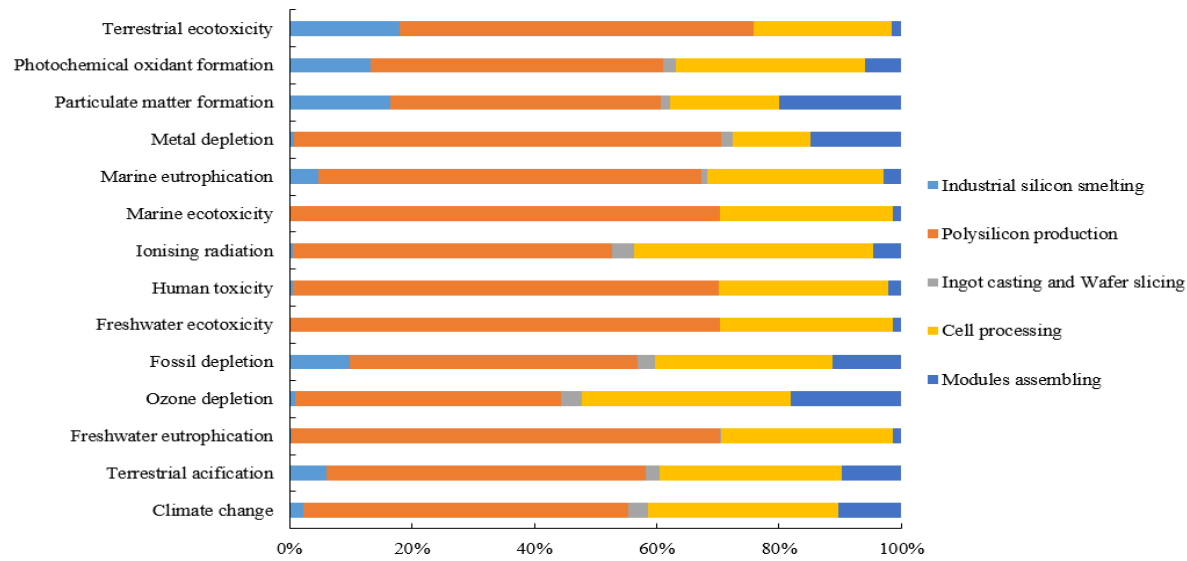


Fig. Environmental impacts in multi-Si PV manufacturing

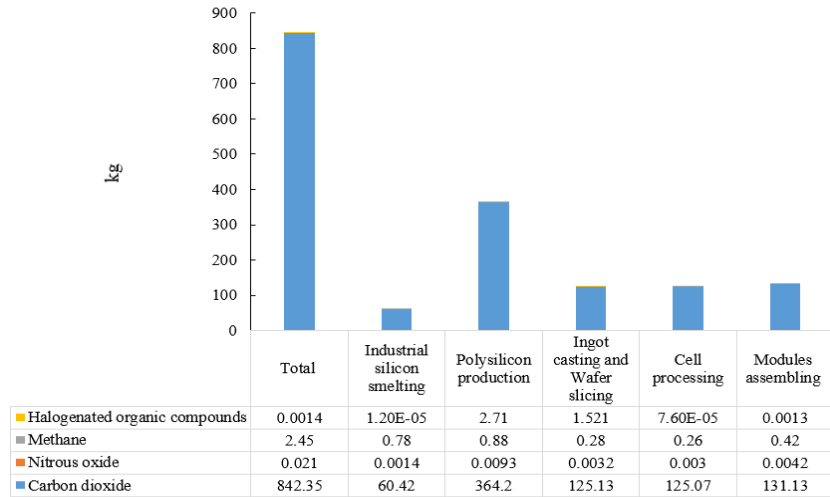


Fig. Pollutant source of climate change in multi-Si PV module manufacturing

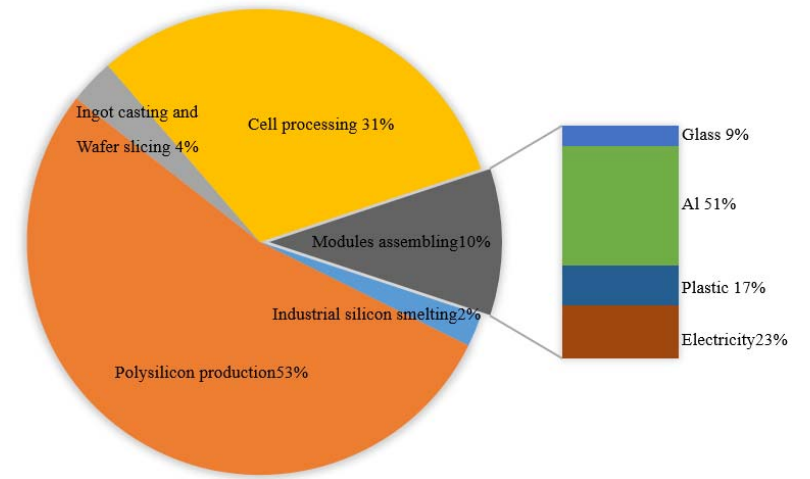
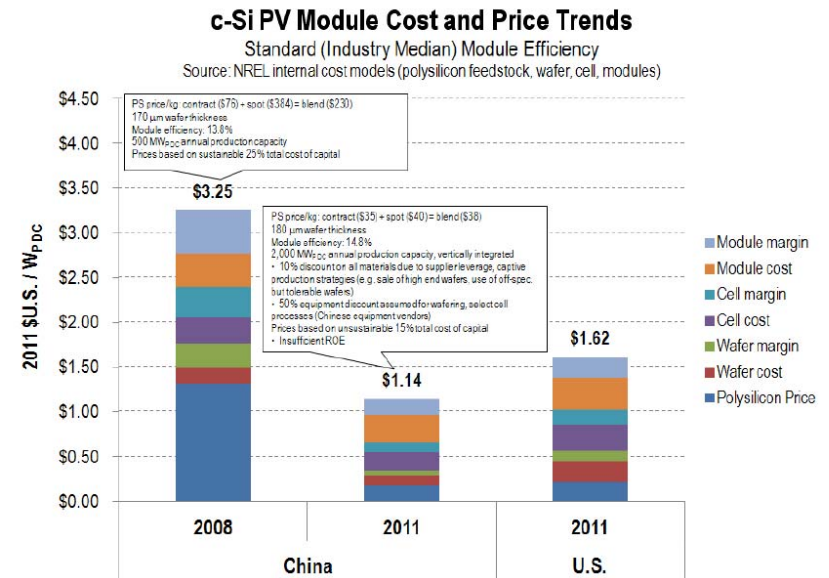
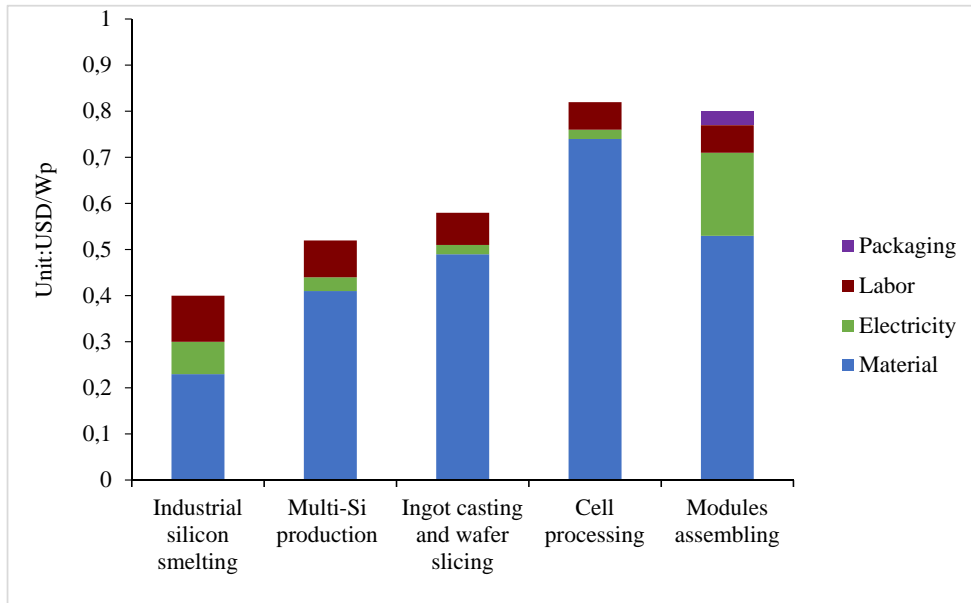
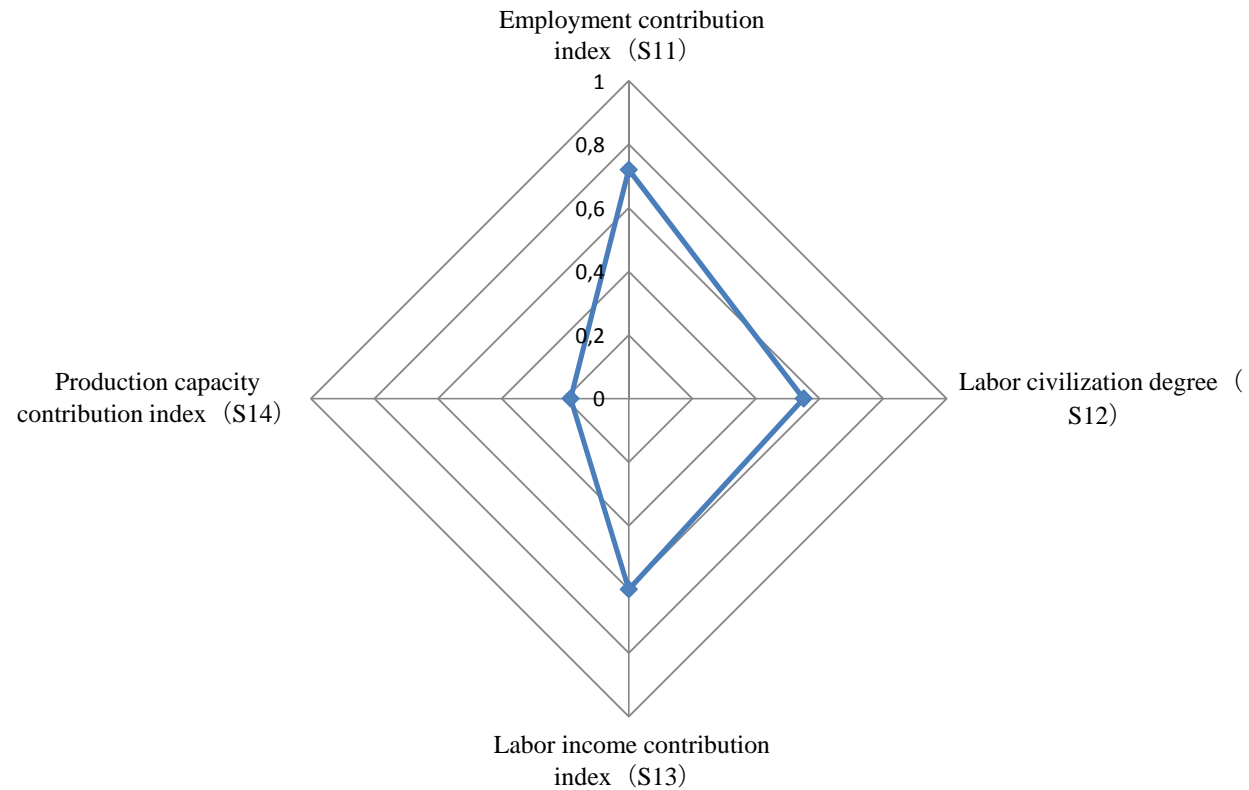


Fig. Climate change impacts of multi-Si PV manufacturing



1. Cell processing has the highest cost among the five manufacturing processes.
2. the main cost of mc-Si module production lies in raw materials and labor (approximately 70%)



S_{11} is 0.72, indicating that Multi-Si PV modules production in China has **prominent contribution of employment** by comparing with general industries;

S_{12} value is 0.55, indicating that PV components production still **relies on manual work instead of mental work**;

S_{13} value is 0.6, illustrating that **labor income** of Multi-Si PV modules production is **ordinary**;

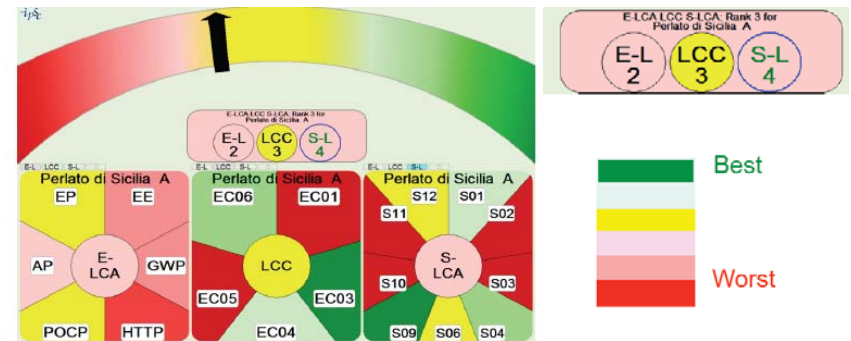
S_{14} value is merely 0.183, showing that Multi-Si PV modules production has **limited contribution of GDP**.

Further thinking

1. How to express the final LCSA result?

2. Uncertainty, comparability?

3. Local LCA methodology



Thanks for listening!