Smart Sustainability in
Lighting and Controls SSLC

LED Linear Lamp Life-Cycle Assessment

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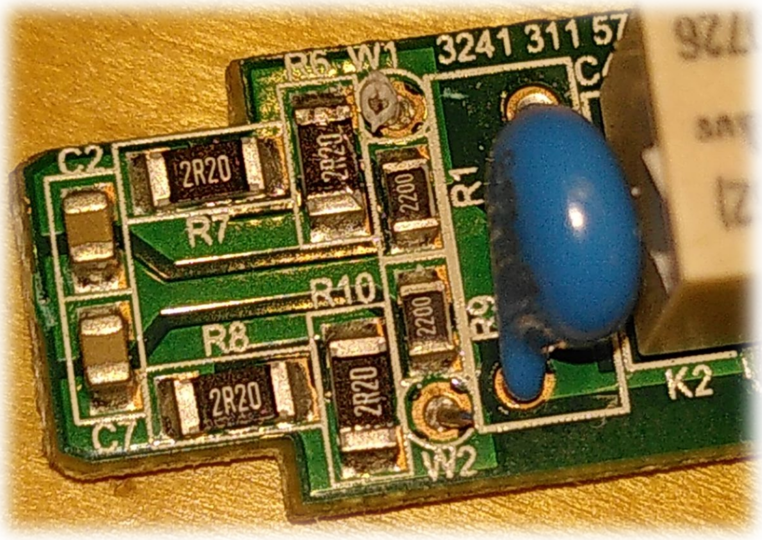

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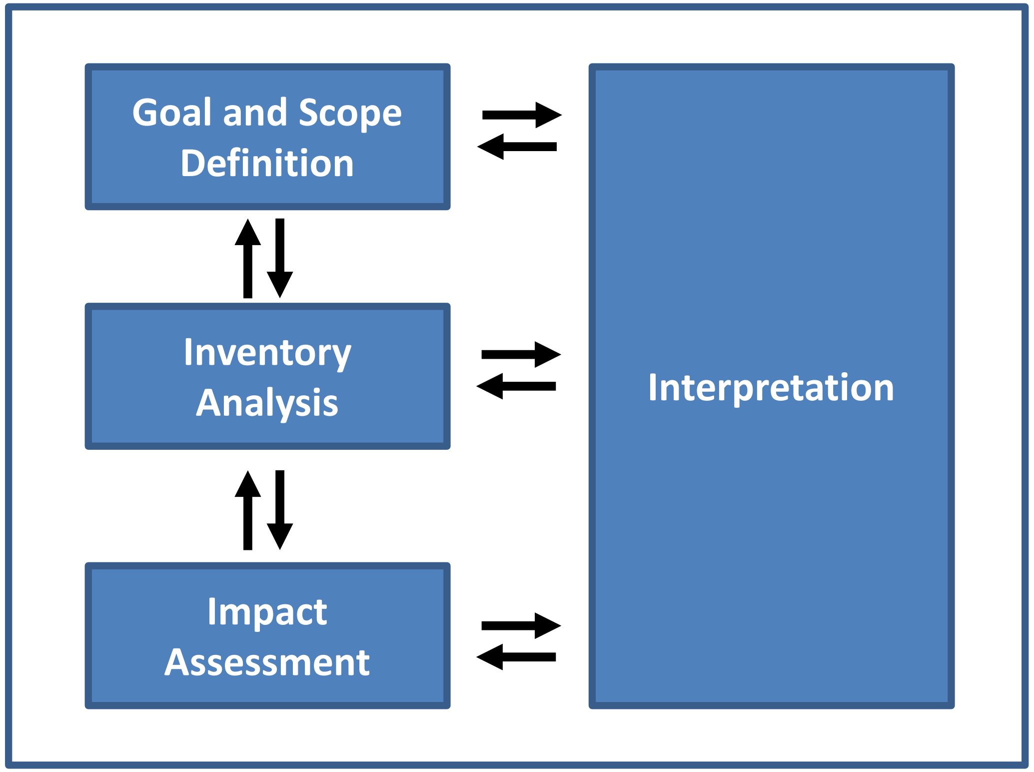
Life Cycle Assessment

Life-Cycle Assessment – a scientific methodology for quantifying the environmental and sustainability impacts of a product over its entire life cycle (i.e., from "cradle to grave").

This spans from raw material extraction and processing, through product manufacturing, transportation to the point of sale, energy consumption during its useful life, and finally disposal / recycling.

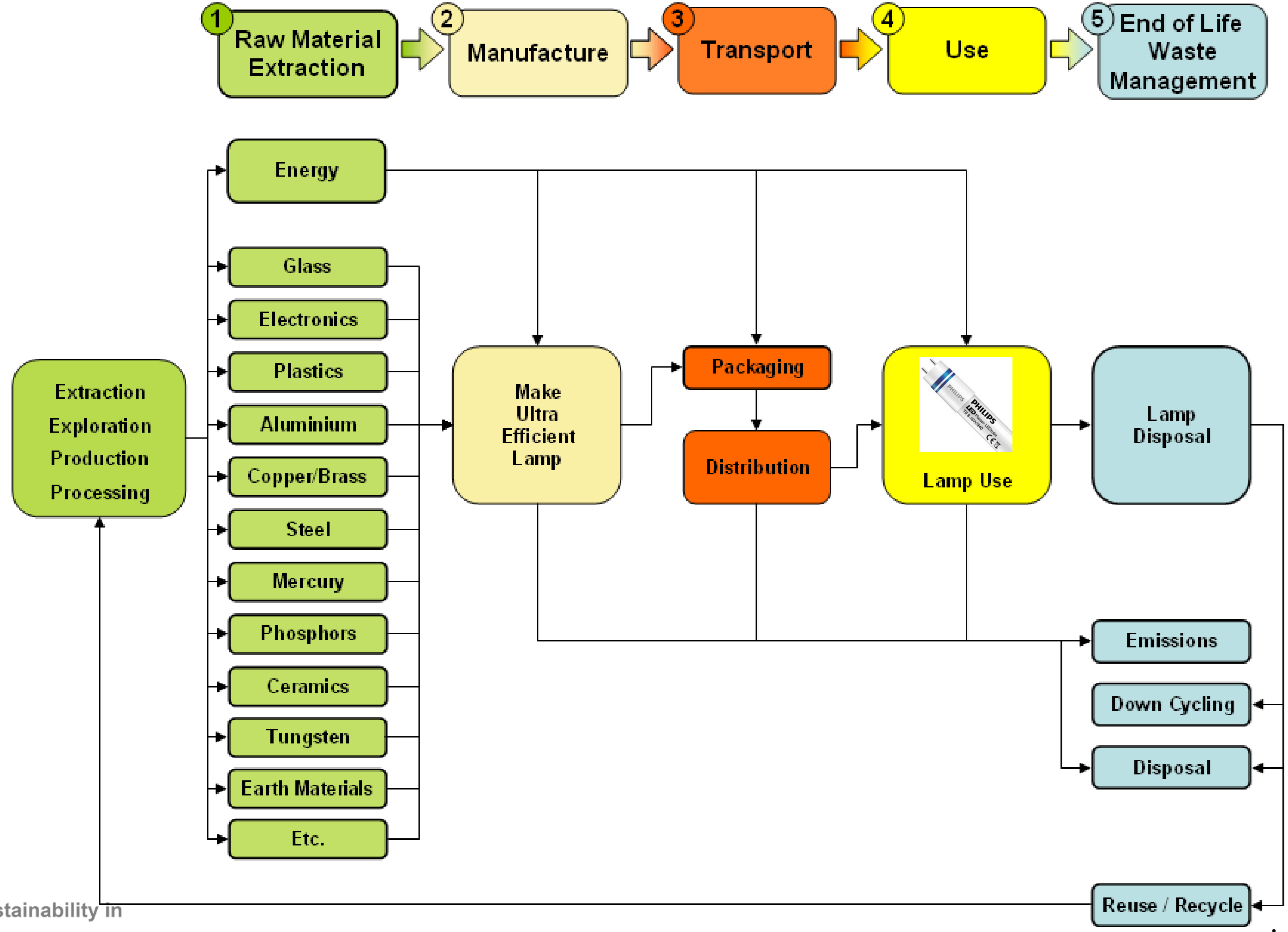
LCAs are part of ISO 14000 series of environmental management standards.

LCA Framework



Source: ISO 14044

LCA Flow Diagram – Five Stages



Comparison Selected

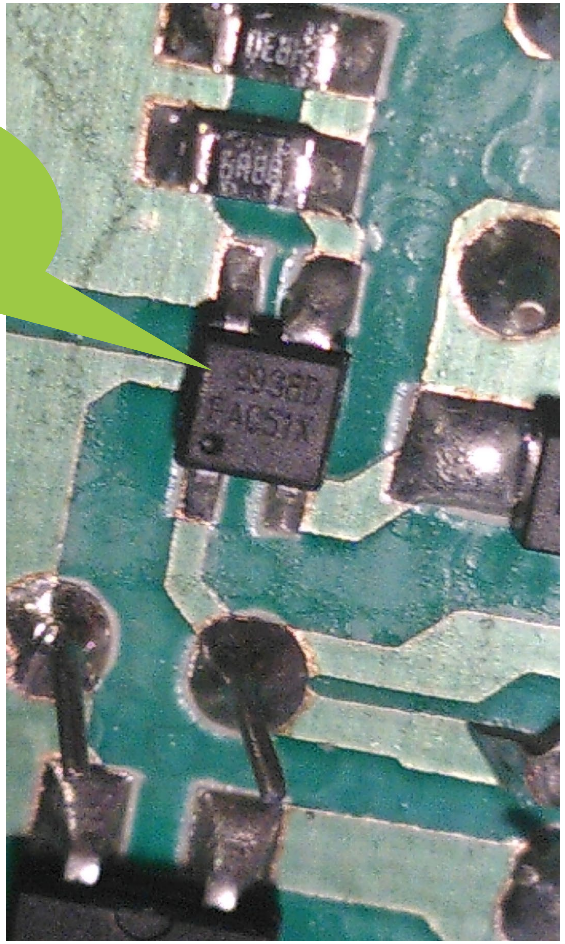
Key Question: In an existing building with operational fluorescent fixtures, is there an environmental benefit from installing retrofit LED tubes without changing the fixture?

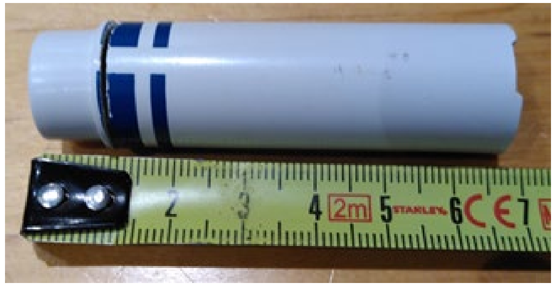
Lamp Type	Baseline	LED 1	LED 2	Notes
TL-D (T8), 60cm	18W Cool White, 20kh, 1350 lm 	8W Cool Wh., 60kh, 1000 lm, HF ballast 	8W Cool Wh., 60kh, 1050 lm, LF ballast 	Consider emission pattern, 80% fixture/tube adsorption
T5 lamp, 145cm	35W Cool White, 24kh, 3315 lm 	20W Cool White, 60kh, 3000 lm, HF 	18W Cool White, 50kh, 2800 lm, HF 	Consider emission pattern, 85% fixture/tube adsorption

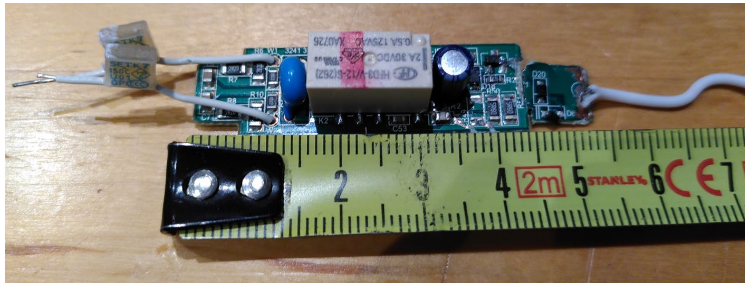
LED Tubes - Teardowns

LED Tubes: conducted a “reverse engineering” analysis, disassembling each of the four LED lamps; measuring, weighing, recording and noting part numbers where poss.

E.g., constant current power supply chip 9938D FAC51X (link)

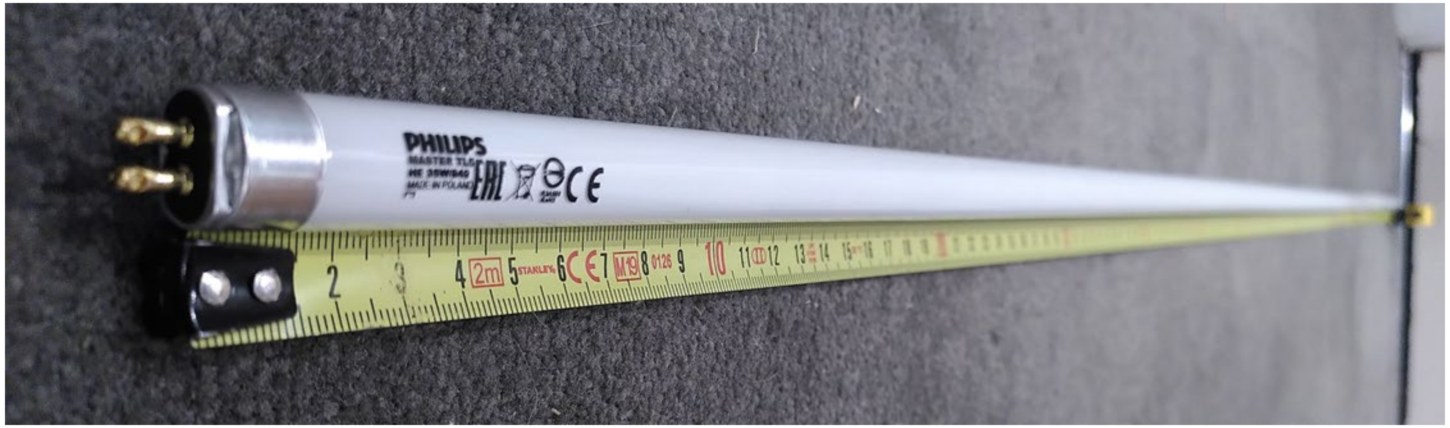


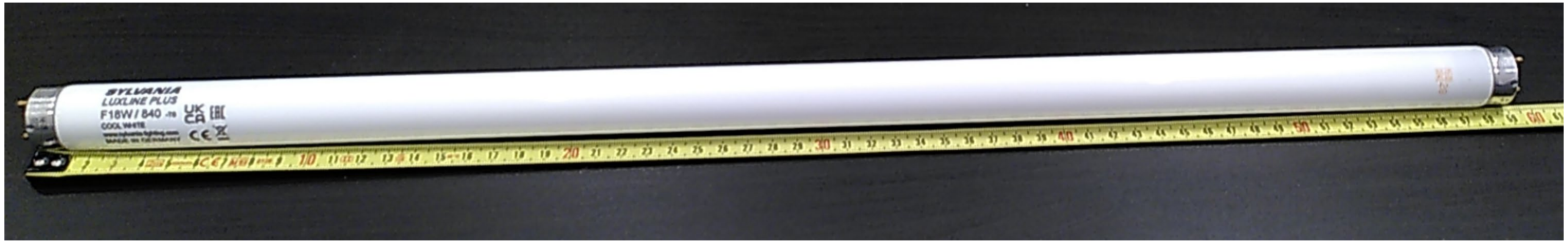




Fluorescent Tubes – Scaled from Existing Literature

Fluorescent tubes: weighed and measured both tubes, relied on published LCA literature to scale results to fluorescent tubes





Inventories – Fluorescent and LED

- From the literature review and the teardowns, we constructed parts and material inventories of the two comparisons – T8 and T5 lamps.
- Included packaging, production, transport, energy-in use (rated lifetime) and end-of-life recycling.
- Assume EoL recycling is 30% for lamp and 50% for packaging.
- For scaling, the lamp's total light service is calculated, e.g.,
  T8 FL: 21.6 Mlm-hr/lamp
  T8 LED1: 60.0 Mlm-hr/lamp
- LCA software used needs to be updated; these are indicative findings only.

T8 Fluorescent Lamp

Stage	Material Name	Amount	Units
Material	Argon gas	0.001302	kg
Material	Krypton gas	0.001302	kg
Material	Mercury	0.000005	kg
Material	Noble Earths	0.000004	kg
Material	Yttriumoxide	0.003566	kg
Material	Aluminum	0.005300	kg
Material	Glass Tube	0.071187	kg
Material	Resin Glue	0.001550	kg
Material	Solder paste	0.000150	kg
Production	Natural Gas	2	kg
Production	Power	5	MJ
Production	Packaging	0.011992	kg
Production	Manufacturing	0.084366	kg
Transport	Distribution - Sea	10000	km
Transport	Distribution - Road	1000	km
Energy in use	Energy in Use	360000	Wh
EoL	End of Life - lamp, recycling	30%	percent
EoL	End of Life - lamp, landfill	70%	percent
EoL	End of Life - packaging, recycling	50%	percent
EoL	End of Life - packaging, landfill	50%	percent

LED T8 Retrofit #1

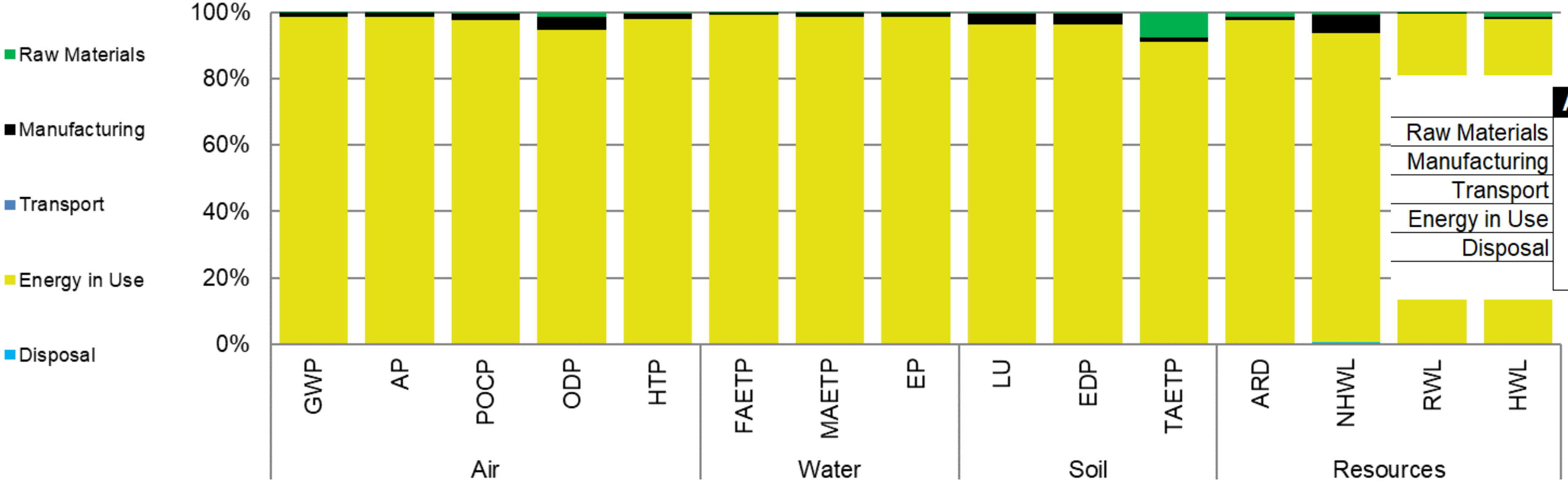
Stage	Material Name	Amount	Units
Material	LEDs (blue light)	80	pack. LEDs
Material	Extruded plastic tube	32.792	gm
Material	Metal screws, springs, pins	2.496	gm
Material	Plastic end-caps & sleves	30.951	gm
Material	Aluminium Heat Sink, extruded	26.696	gm
Material	PCB mounting for LEDs	11.106	gm
Material	Thermal fuses	0.628	gm
Material	Copper wire	0.662	gm
Material, CB1	Diode, Schottky	1	pieces
Material, CB1	Capacitotors, surface mount	4	pieces
Material, CB1	Resistors	2	pieces
Material, CB1	Capacitor, 15 nF	1	pieces
Material, CB1	SMPS transformer	1	pieces
Material, CB1	PCB mounting board for CB1	1	pieces
Material, CB2	Diode, Schottky	8	pieces
Material, CB2	Diode	1	pieces
Material, CB2	Capacitotors, surface mount	9	pieces
Material, CB2	Resistor SMD	8	pieces
Material, CB2	Resistor	11	pieces
Material, CB2	Capacitors - blue and brown	2	pieces
Material, CB2	Integrated circuit, voltage regulator	3	pieces
Material, CB2	transistors	2	pieces
Material, CB2	Surface-mounted Signal Relay	1	pieces
Material, CB2	PCB mounting board for CB2	1	pieces
Production	Power	5	MJ
Production	Packaging	0.012178	kg
Production	Manufacturing	0.119231	kg
Transport	Distribution - Sea	10000	km
Transport	Distribution - Road	1000	km
Energy in use	Energy in Use	480000	Wh
EoL	End of Life - lamp, recycling	30%	percent
EoL	End of Life - lamp, landfill	70%	percent
EoL	End of Life - packaging, recycling	50%	percent
EoL	End of Life - packaging, landfill	50%	percent

Environmental indicators considered

AP	Acidification Potential
ARD	Abiotic Resource Depletion
EDP	Ecosystem Damage Potential
EP	Eutrophication Potential
FAETP	Freshwater Aquatic Ecotoxicity Potential
GWP	Global Warming Potential
HTP	Human Toxicity Potential
HWL	Hazardous Waste to Landfill
LU	Land Use
MAETP	Marine Aquatic Ecotoxicity Potential
NHWL	Non-Hazardous Waste to Landfill
ODP	Ozone Depleting Potential
POCP	Photochemical Ozone Creation Potential
RWL	Radioactive Waste to Landfill
TAETP	Terrestrial Ecotoxicity Potential

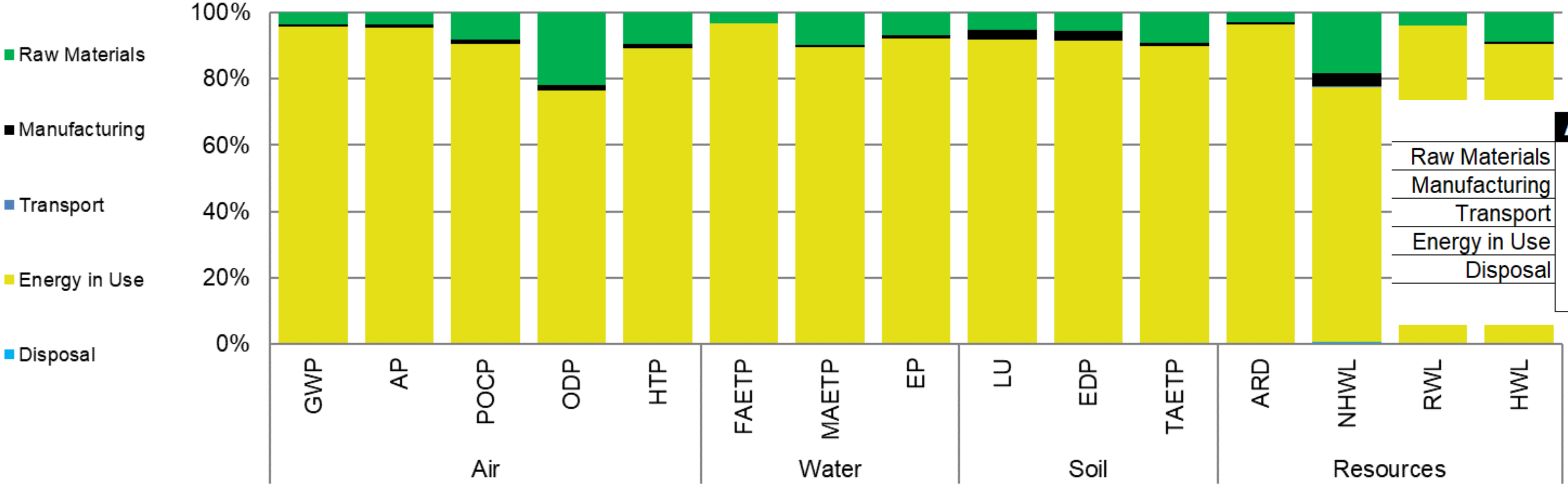
Environmental Indicator Comparison

T8 60cm Fluorescent



	Average
Raw Materials	1.0%
Manufacturing	1.9%
Transport	0.0%
Energy in Use	97.1%
Disposal	0.1%
	100.0%

T8 60cm LED 1 (HF)



	Average
Raw Materials	8.1%
Manufacturing	1.3%
Transport	0.0%
Energy in Use	90.5%
Disposal	0.0%
	100.0%

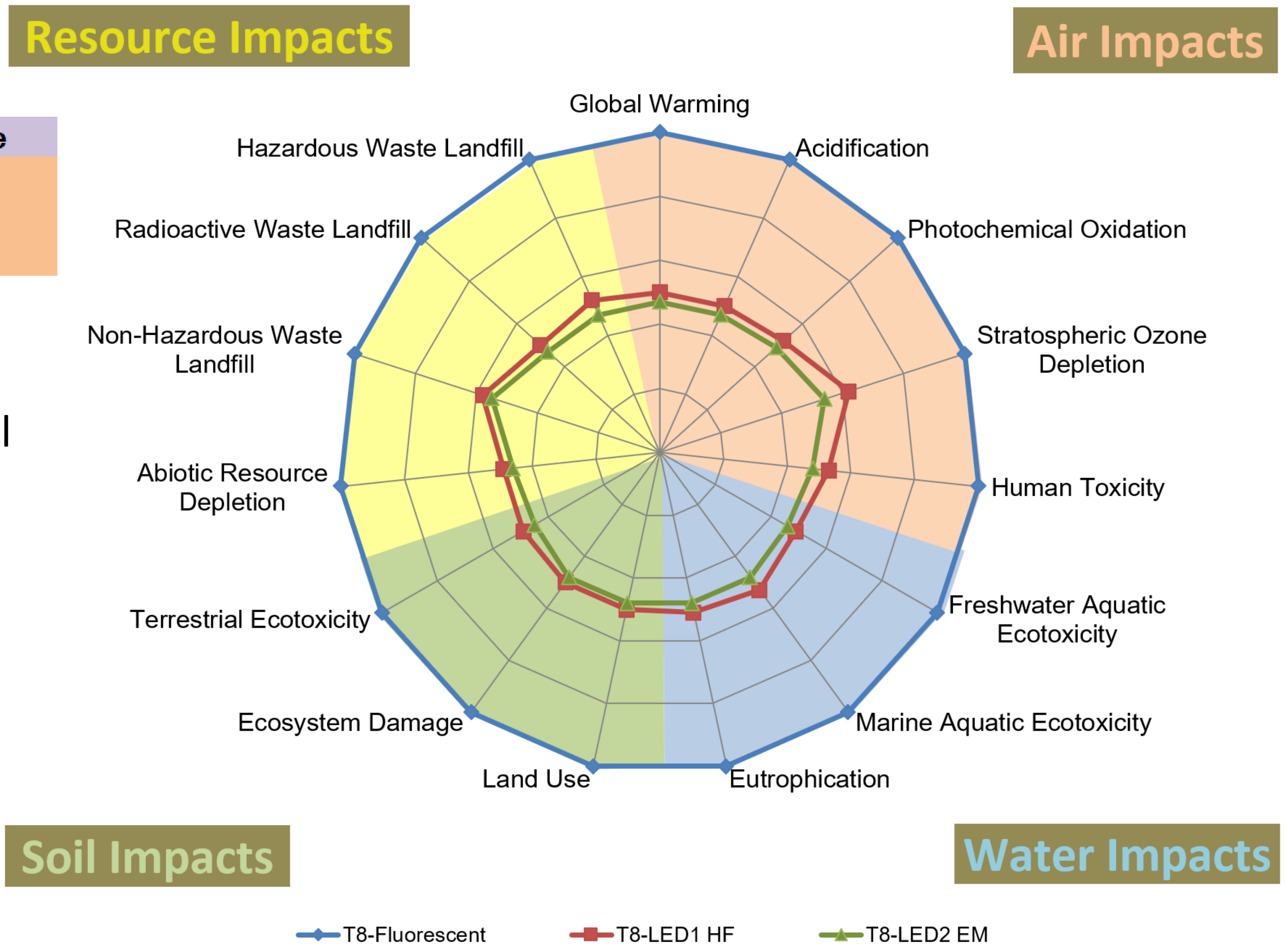
Spider Plot Explanation

- Each radius on chart represents a different environmental impact.
- Groupings are in terms of different environmental impacts:
  - **Air (orange)**
  - **Water (blue)**
  - **Soil (green)**
  - **Resources (yellow)**
- Product with the largest impact is plotted in the outer circumference.
- Positioning of points for other lighting system demonstrates their relative environmental impact to that maximum.
- Points nearer to the centre indicate lower environmental impact.

Spider Plot T8 Lamp Comparison

Light Sources	Average
T8-Fluorescent	100%
T8-LED1 HF	52%
T8-LED2 EM	48%

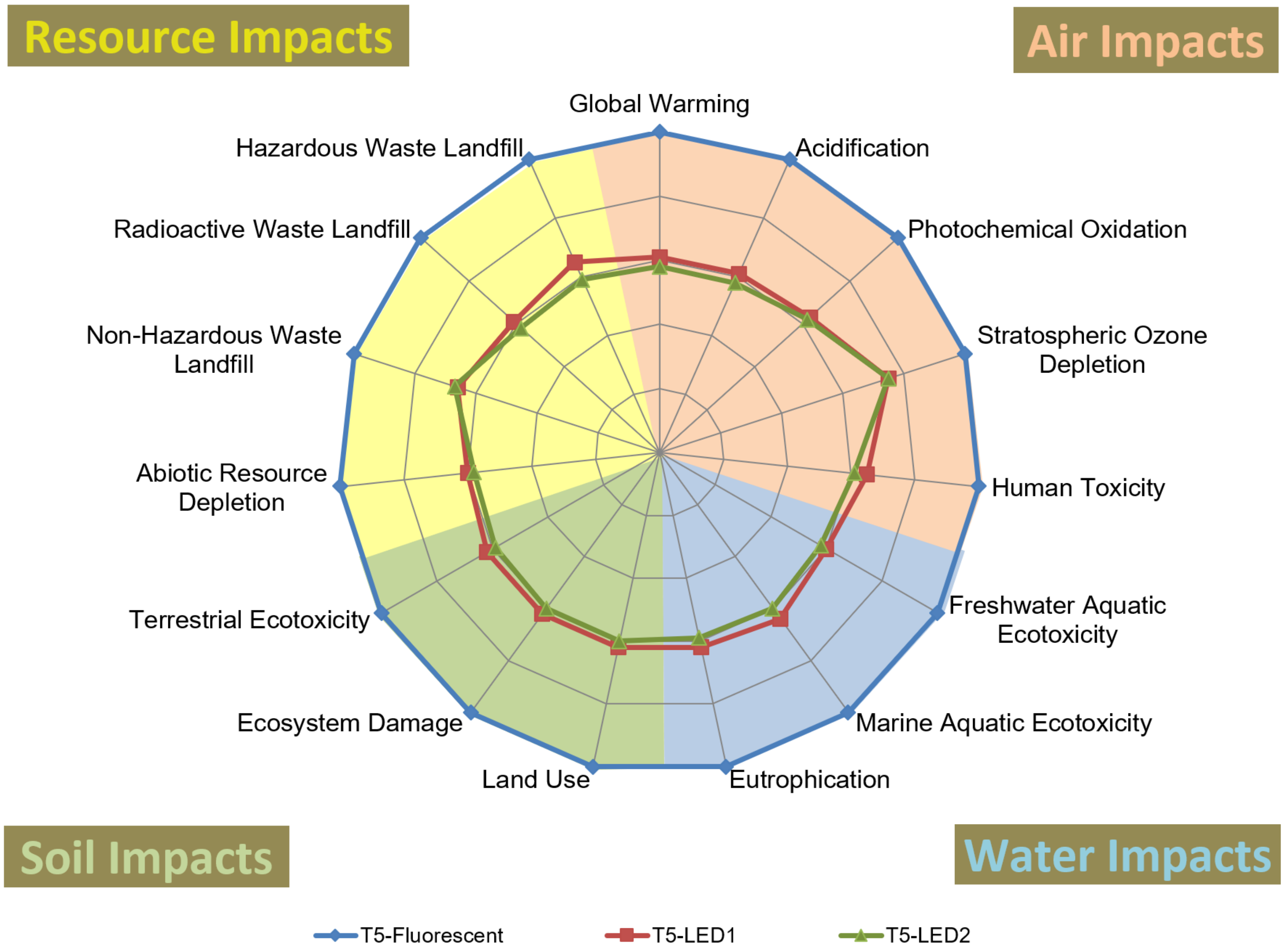
Answer: Environmental impact reduction of upgrading 60cm TL-D (T8) fluorescent is approximately **50%**



Spider Plot T5 Lamp Comparison

Light Sources	Average
T5-Fluorescent	**100%**
T5-LED1	**63%**
T5-LED2	**61%**

Answer: Environmental impact reduction of upgrading 145cm T5 fluorescent is approximately **40%**



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Conclusions and Next Steps

- Conclusion: upgrading with LED retrofit lamps has a net environmental benefit
  - Environmental impact is reduced by 50% for TL-D T8 lamps (60cm) retrofit and by 40% for T5 lamps (145 cm)
  - Lifetime – sensitivity analysis - 6kh for T8, 7kh for T5 (1-2 years)
- Energy in use is still the dominant impact factor – 97 - 98% of the impact of fluorescent lamps and 90 - 92% of the impact of LED lamps
- Cautionary note: these are preliminary / indicative findings only, need to update to more recent version LCA software
  - Currently using an old version of EcoInvent and we are updating to the latest version of SimaPro (v9.5.0.2)
- Request: we need Peer Review Team – volunteers needed (please write to: ssl.annex@gmail.com)

Thank you for your attention.

Any questions or comments?

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