Life Cycle Assessment of CLIC and ILC civil construction

A study with ARUP

Benno List

ILC Europe Meeting 5.7.23

Introduction

- **Environmental impact of large HEP projects increasingly under consideration, also in Snowmass process**
- **Civil construction has a large impact - but how large exactly?**

2 Impacts of facility construction

We can attempt a rough estimate of the carbon impact of the main tunnel alone. A bottom-up calculation is driven by the construction parameters of the tunnel. It is expected to have an inner diameter of 5.5 m, and an excavation diameter of 6.3 m. We assume that the region between those two diameters is filled with concrete, and that concrete is composed 15% of cement (and we neglect the necessary steel tunnel reinforcement). The production of cement is a significant contributor to greenhouse gas emissions, releasing a ton of CO_2 per ton of

cement created [17].[3] We thus calculate that the main tunnel of FCC-ee alone would lead to the release of 237 ktons of CO_2.

Climate impacts of particle physics

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Abstract. The pursuit of particle physics requires a stable and prosperous society. Today, our society is increasingly threatened by global climate change. Human-influenced climate change has already impacted weather patterns, and global warming will only increase unless deep reductions in emissions of CO_2 and other greenhouse gases are achieved. Current and future activities in particle physics need to be considered in this context, either on the moral ground that we have a responsibility to leave a habitable planet to future generations, or on the more practical ground that, because of their scale, particle physics projects and activities will be under scrutiny for their impact on the climate. In this white paper for the U.S. Particle Physics Community Planning Exercise ("Snowmass"), we examine several contexts in which the practice of particle physics has impacts on the climate. These include the construction of facilities, the design and operation of particle detectors, the use of large-scale computing, and the research activities of scientists. We offer recommendations on establishing climate-aware practices in particle physics, with the goal of reducing our impact on the climate. We invite members of the community to show their support for a sustainable particle physics field [1].

Submitted to the Proceedings of the US Community Study
on the Future of Particle Physics (Snowmass 2021)

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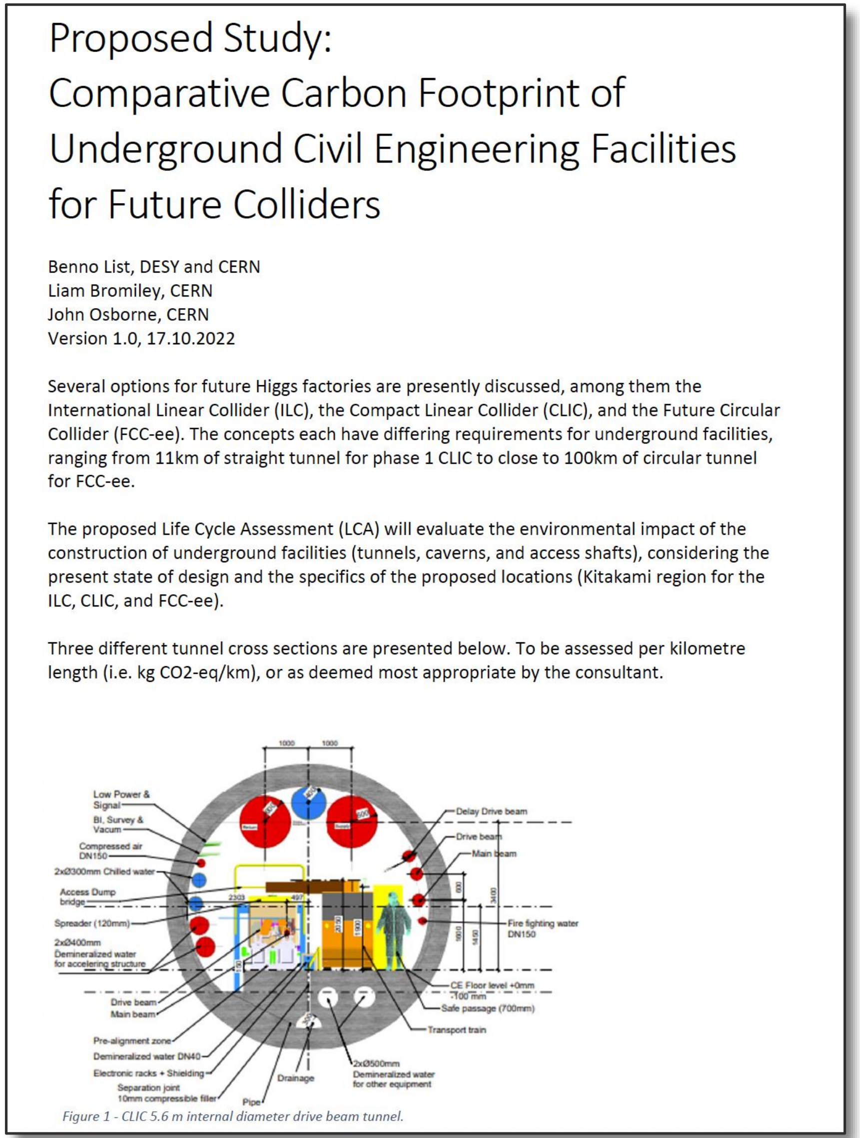
ARUP Study

- **CERN commissioned a study by ARUP (international civil construction consultancy) to study carbon footprint (and other environmental impacts) of underground civil construction**
- **Comprehensive study**
  - Covering tunnels, caverns and shafts
  - Assesses material, transport, construction
  - Covers CO2, but also other impact categories
  - According to international standards



Proposed Study:
Comparative Carbon Footprint of Underground Civil Engineering Facilities for Future Colliders

Benno List, DESY and CERN
Liam Bromiley, CERN
John Osborne, CERN
Version 1.0, 17.10.2022

Several options for future Higgs factories are presently discussed, among them the International Linear Collider (ILC), the Compact Linear Collider (CLIC), and the Future Circular Collider (FCC-ee). The concepts each have differing requirements for underground facilities, ranging from 11km of straight tunnel for phase 1 CLIC to close to 100km of circular tunnel for FCC-ee.

The proposed Life Cycle Assessment (LCA) will evaluate the environmental impact of the construction of underground facilities (tunnels, caverns, and access shafts), considering the present state of design and the specifics of the proposed locations (Kitakami region for the ILC, CLIC, and FCC-ee).

Three different tunnel cross sections are presented below. To be assessed per kilometre length (i.e. kg CO2-eq/km), or as deemed most appropriate by the consultant.

Figure 1 - CLIC 5.6 m internal diameter drive beam tunnel.

Quantitative Approach: Lifecycle Assessment LCA

Whole Lifecycle

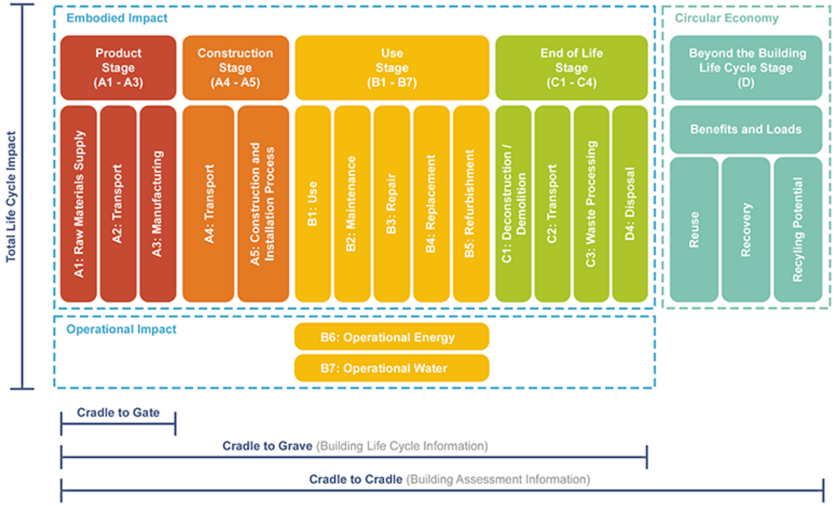
Raw materials, fabrication & construction

Usage: operation, maintenance, refurbishment

End of life: demolition, disposal

Defined in International Standards

https://browningday.com/news/lca-stages-matter-when-tracking-embodied-carbon/
https://www.buildingenclosureonline.com/blogs/14-the-be-blog/post/89547-lca-stages-matter-when-tracking-embodied-carbon



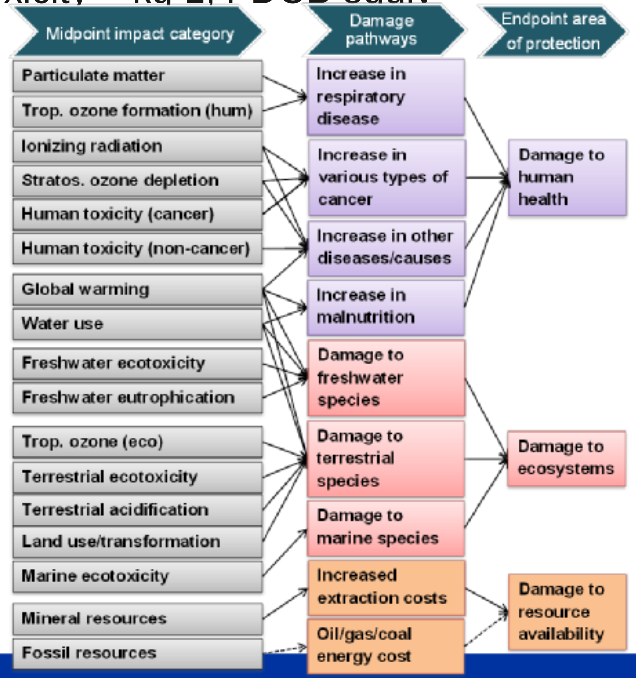
Lifecycle stages according to EN 15978

Whole Environmental Impact

Quantifying total damage by **endpoint** indicators (e.g. damage to human health) possible but difficult

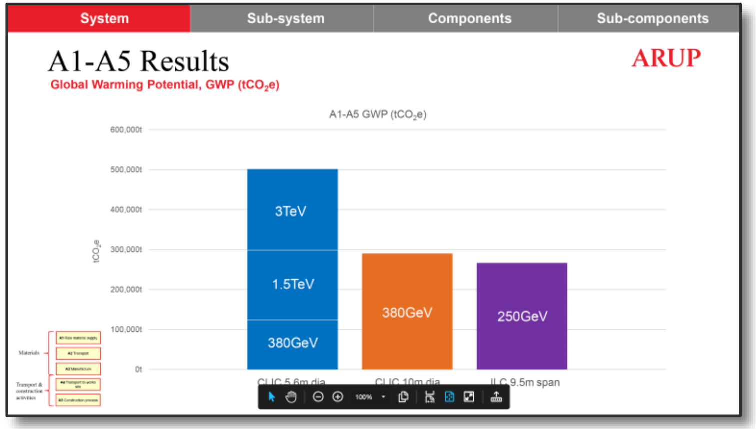
”**Midpoint** indicators” asses impact on environment in a quantitative way:

- Greenhouse Warming Potential (GWP) – kg CO2 eqiv
- Ozone Depletion Potential (ODP) – kg CFC-11 equiv
- Ecotoxicity – kg 1,4-DCB equiv

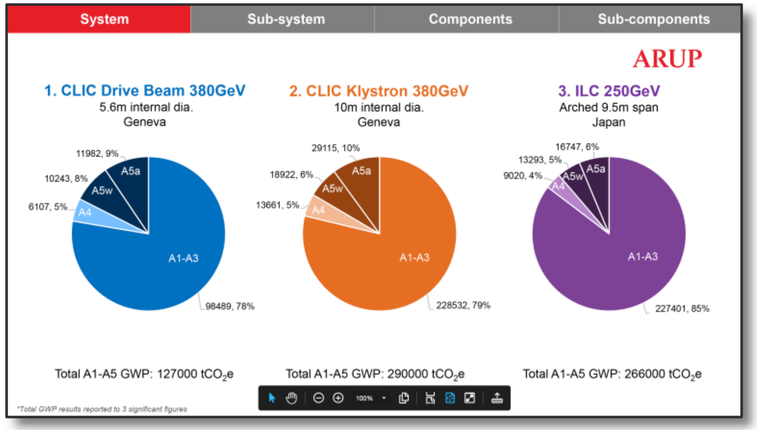


Huijbregts et al., Int. J. Life Cycle Ass. **22** (2017) 138,
DOI:10.1007/s11367-016-1246-y

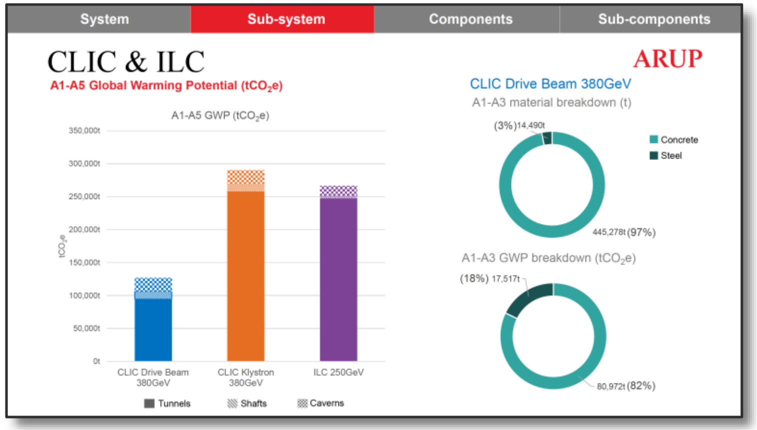
ARUP Study: Results



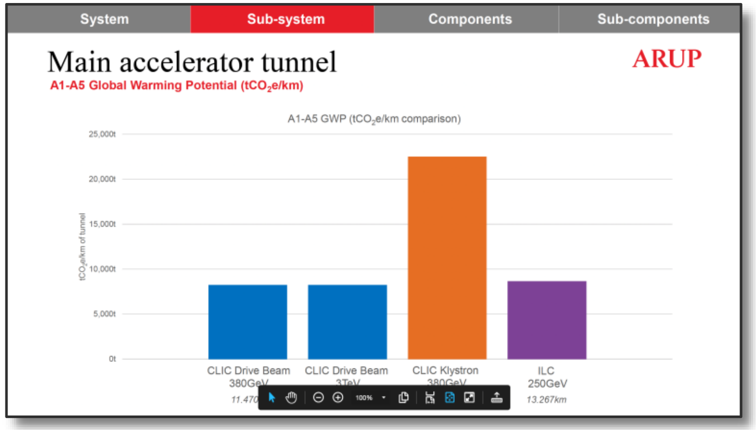
Total CO2



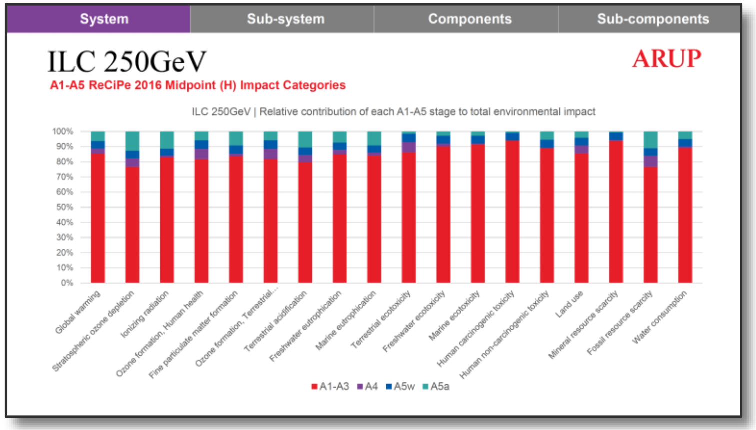
Per phase



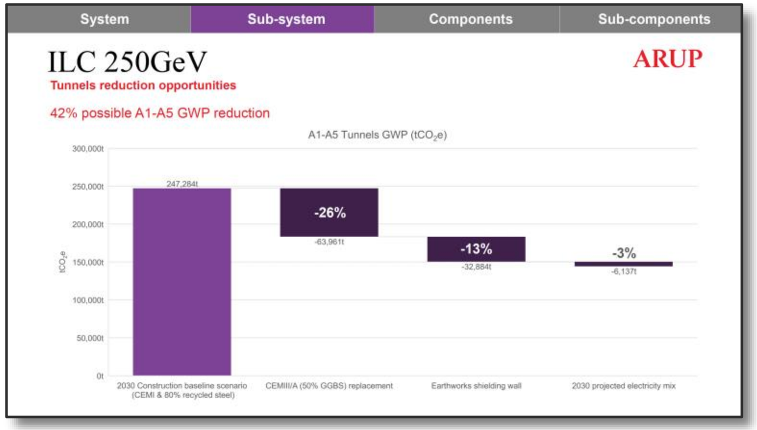
Concrete and steel



CO2 per meter (ML tunnel)



Other impacts

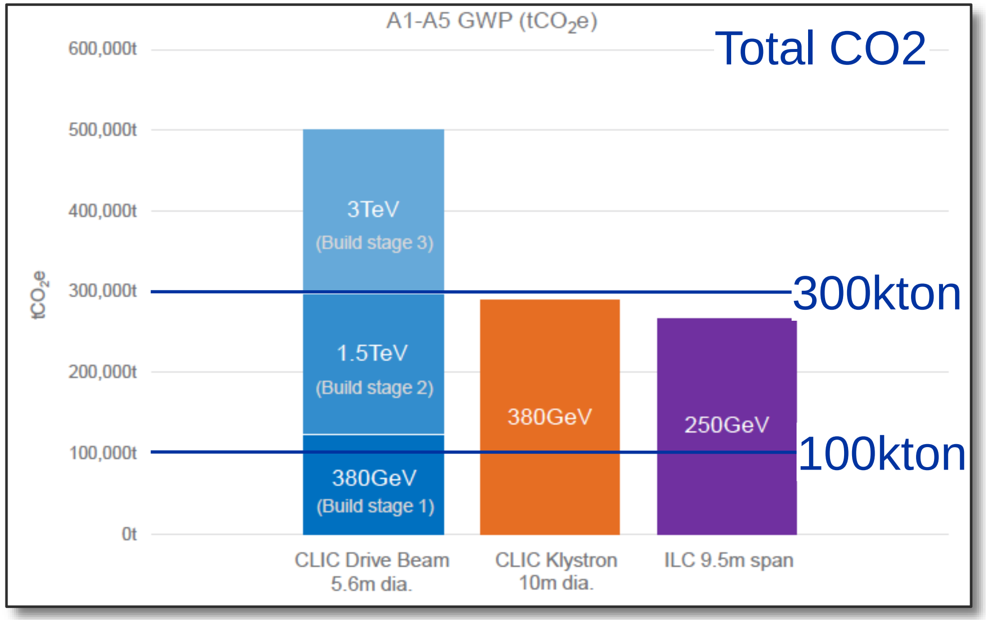


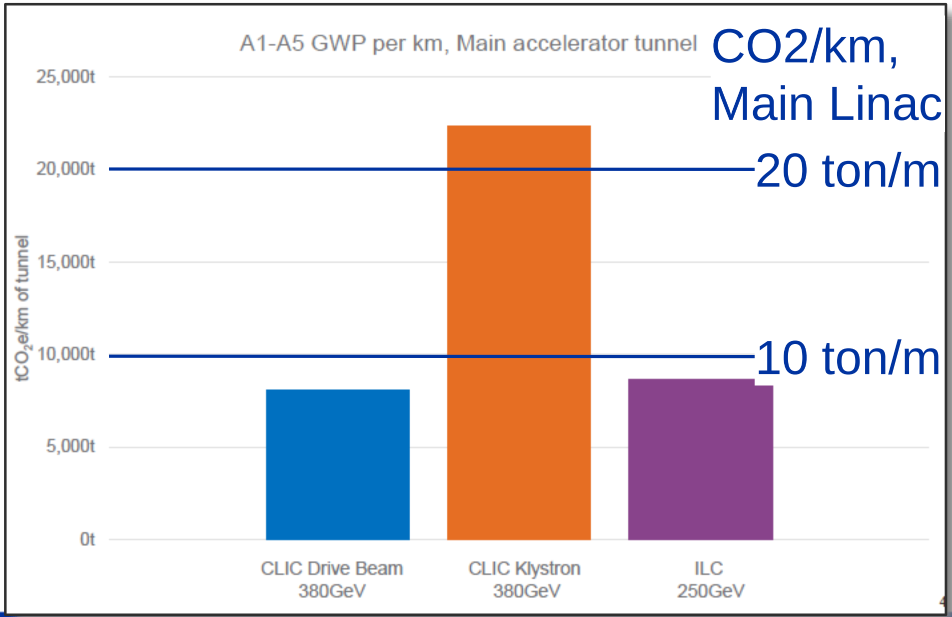
Reduction potential

Main Results

Global Warming Potential of underground civil construction:

- **CLIC 380GeV:**
  - 127kton CO2-eq (two-beam option)
  - 290kton CO2-eq (klystron option)
- **ILC 250 GeV:**
  - 266kton CO2-eq

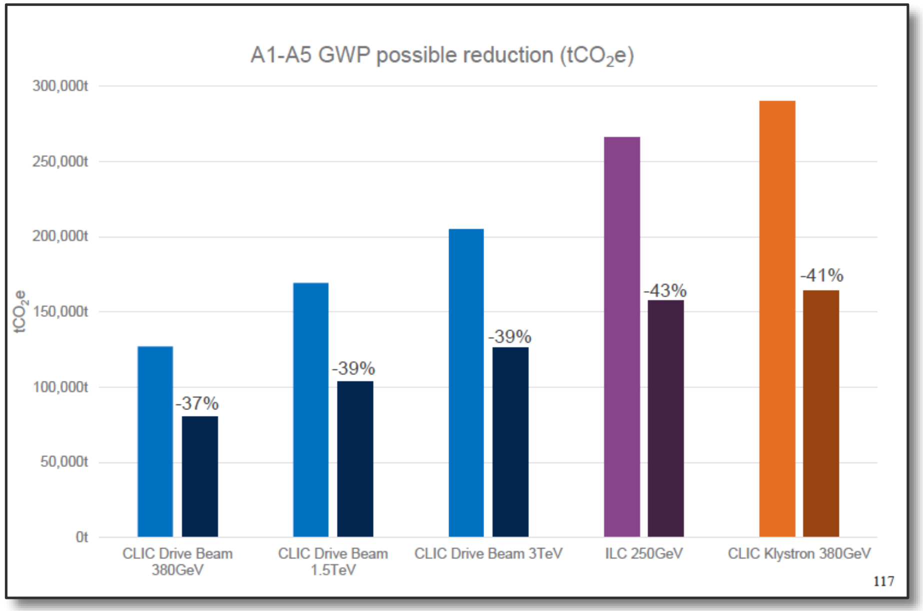


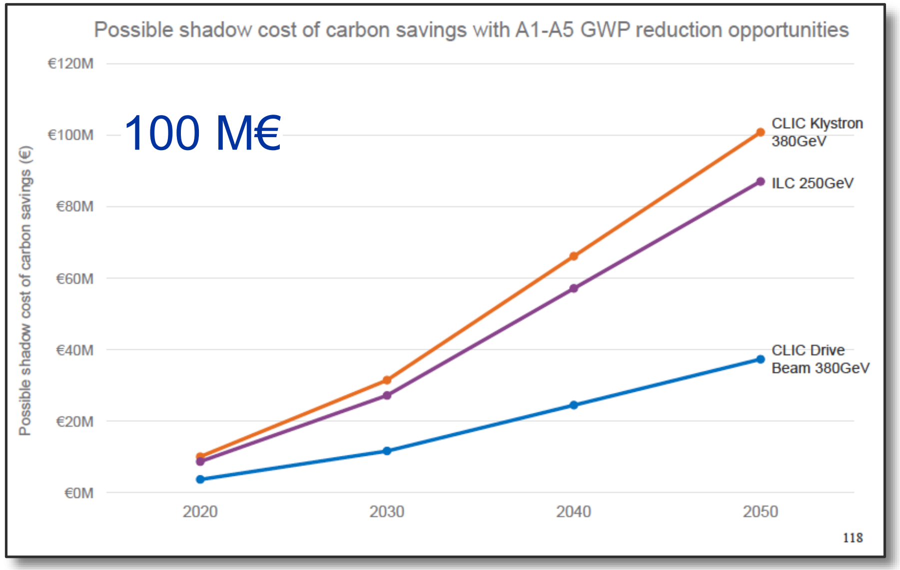


Conclusion

- Full report will be made public
- Evaluation of impact is the first step towards optimisation:
  - Report includes section on ways to reduce CO2 impact
  - “Shadow cost” of CO2 gives a monetary value to these reductions – “is it worth it”

This study sets a new standard for lifecycle assessment studies of future accelerator facilities





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