WG: Environmental Impact

- Environmental Impact is **one of main drivers** to advance new technologies for future colliders
  - Wakefield colliders could lead to

  → Smaller footprint (less concrete, land use, construction impact)

  → Lower power consumption: Acceleration efficiency? Lower emittance?
- Responsibility to minimize environmental footprint, ideal now as early in the design-phase

Goal of this working group:

- Estimate and minimize the environmental footprint of a 10 pCM TeV scale wakefield collider

→ **Todays meeting:**

- **Define the scope of this WG.**
- **Your input and ideas.**

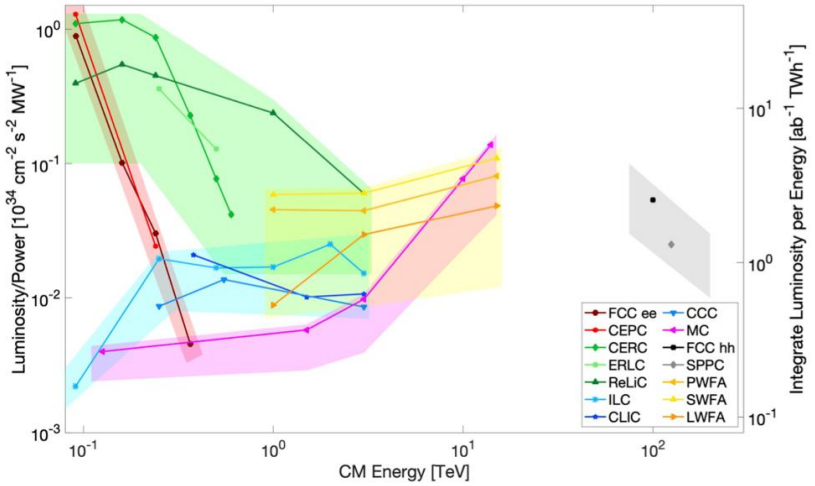
Previous Work: Operational Power Consumption

Technology	PWFA	PWFA	PWFA	SWFA	SWFA	SWFA	LWFA	LWFA	LWFA
Aspect Ratio	Flat	Flat	Round	Flat	Flat	Round	Flat	Flat	Round
CM Energy	1	3	15	1	3	15	1	3	15
Single beam energy (TeV)	0.5	1.5	7.5	0.5	1.5	7.5	0.5	1.5	7.5
Gamma	9.782+05	2.942+06	1.472+07	9.782+05	2.942+06	1.472+07	9.782+05	2.942+06	1.472+07
Emittance X (mm mrad)	0.66	0.66	0.1	0.66	0.66	0.1	0.1	0.02	0.1
Emittance Y (mm mrad)	0.02	0.02	0.1	0.02	0.02	0.1	0.01	0.007	0.1
Beta* X (m)	5.002−03	5.002−03	1.502−04	5.002−03	5.002−03	1.502−04	2.502−02	1.402−02	1.502−04
Beta* Y (m)	1.002−04	1.002−04	1.502−04	1.002−04	1.002−04	1.502−04	1.002−04	1.002−04	1.502−04
Sigma* X (nm)	58.07	33.53	1.01	58.07	33.53	1.01	50.55	9.77	1.01
Sigma* Y (nm)	1.43	0.83	1.01	1.43	0.83	1.01	1.01	0.49	1.01
N_bunch (num)	5.002+09	5.002+09	5.002+09	3.132+09	3.132+09	3.132+09	1.202+09	1.202+09	7.502+09
Freq (Hz)	4200	14000	7725	11000	36000	19800	46856	46856	3435
Sigma Z (um)	5	5	5	40	40	40	8.4	8.4	2.2
Beamstrahlung parameter	15	78	6590	1	6	515	2	37	22466
n_γ	1.5	1.5	5.7	2.2	2.2	8.4	0.8	1.5	5.7
Single Beam Power (MW)	1.7	16.8	46.4	2.8	27.0	74.4	4.5	13.5	31.0
Two Beam Power (MW)	3.4	33.6	92.8	5.5	54.1	148.7	9.0	27.0	61.9
Geometric Lumi (cm-2 s-1)	1.012+34	1.012+35	1.502+36	1.032+34	1.012+35	1.512+36	1.052+34	1.132+35	1.502+36
Beamstrahlung lumi	1.992+34	1.992+35	1.522+36	2.032+34	2.002+35	1.522+36	2.092+34	2.172+35	1.522+36
Wall plug to drive laser/beam eff	0.4	0.4	0.4	0.774	0.774	0.774	0.4	0.4	0.5
Laser/beam drive to main eff	0.375	0.375	0.375	0.42	0.42	0.42	0.2	0.2	0.12
Wall plug to main beam eff	0.15	0.15	0.15	0.32508	0.32508	0.32508	0.08	0.08	0.06
Site power Wall to main only (MW)	22	224	619	17	166	457	113	338	1032
Lumi/Power (1e34/MW)	0.04	0.04	0.08	0.06	0.06	0.11	0.01	0.03	0.05
GUINEA-PIG Total Lumi	1.832+34	1.852+35	4.22+37	2.082+34	2.132+35	4.22+36	1.532+34	2.582+35	62+36
GUINEA-PIG Lumi 1 % (20 %)	6.862+33	6.232+34	52+35	8.492+33	6.142+34	52+35	1.032+34	8.722+34	52+35
GP Total Lumi/Power	0.08	0.08	6.79	0.12	0.13	0.92	0.01	0.08	0.58
GP Lumi 1 %/Power (20 %)	0.03	0.03	0.08	0.05	0.04	0.11	0.01	0.03	0.05
Length of 2 Linacs (km)	1	3	14	5	15	75	0.44	1.3	6.5
Length of Facility	14	14	14	8	18	90	3.5	4.5	9.5

Table 25. Parameters of the advanced WFA-based collliders.

→ Share calculations or code with the WG who are designing the LINAC?

→ Implement into cost-optimizer?



Metric: Luminosity/Power

For scale FCC-ee ~300MW, FCC-hh~500MW

Table from the ITF report

DOI: 10.1088/1748-0221/18/05/P05018

Tunneling

ARUP LCA for CLIC & ILC

https://edms.cern.ch/ui/#!master/navigator/document?D:101320218:101320218:subDocs

Drill&Blast: ~0.4 Tonnes CO2/m @ 5.5 m diameter

Tunnel Boaring Machine:0.24-1.05t CO2/m @ 5.5 m

Environmental impact of drill and blast tunnelling: life cycle assessment.
http://dx.doi.org/10.1016/j.jclepro.2014.08.083

Performance Analysis of Tunnel Boring Machines for Rock Excavation.
https://doi.org/10.3390/app11062794

Excavation emissions per meter

Total CO2 Emissions

Concrete emissions per kg

$$E_{CO_2} = L\left[XE(r) + \pi\left((r+t)^2 - r^2\right)\rho_{concrete}CE\right]$$

Tunnel length

Tunnel radius

https://indico.cern.ch/event/1160140/contributions/5014540/attachments/2503851/4301660/CERN_sustainability_ITF_Turner_Gessner.pdf

Scope of this working group + Next steps:

- Define what to include+metrics:
  - Literature review, list possibilities (power consumption, cooling, material use,…)
  - Metrics (LDG metrics, Power/Luminosity, Power/ Physics Potential, Global Warming Potential…)
  - → Discussion →Choose what to include and metrics → **Decide by 05/2025**

- Estimate power consumption needed to accelerate beams
  - Optimize beam parameters → **Communicate with other WGs**
  - Investigate energy recycling

- Estimate CO2 footprint of the facility
  - Investigate strategies to minimize environmental impacts

→ **Synergies with WG on System Integration?**

Other relevant studies and material:

- Comparative environmental footprint for future linear colliders CLIC and ILC:
  https://edms.cern.ch/ui/file/2917948/1/Life_Cycle_Assessment_for_CLIC_and_ILC_Final_Report_July_2023.pdf
- Sustainability Strategy for the Cool Copper Collider:
  https://doi.org/10.1103/PRXEnergy.2.047001
- Sustainability and Carbon Emissions of Future Accelerators
  https://arxiv.org/html/2411.03473v2
- Sustainability for Particle Accelerators:
  https://www.astec.stfc.ac.uk/Pages/Sustainable%20Accelerator%20Review%202024.pdf
- 2021-2022 CERN Environmental report:
  https://doi.org/10.25325/CERN-Environment-2023-003