ICHEP 2024 | PRAGUE
17-24 Jul 2024

CEPC carbon footprint and CO2 Reduction Optimization

No. 787

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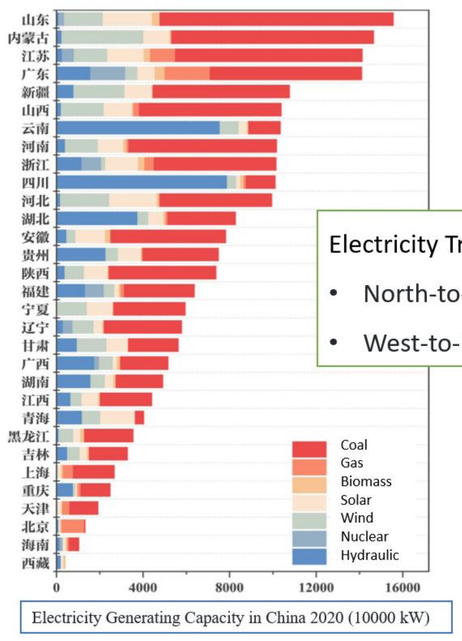
Abstract

The Higgs factory is a kind of special energy consumer and the environmental impact for the given scientific outcome must be optimized carefully. The carbon footprint of CEPC was estimated based on simplified model including both construction process and operation process. The environmental impact of CEPC with different circumference, different energy source, different SR power and different Higgs number was studied. The carbon intensity of China electric grid will be reduced rapidly by 2040 due to the development of renewable energies. Some results to compare the future colliders, including linear colliders and circular colliders, are given. Assuming all the colliders will use the same clean energy (20 ton CO2e/GWh), CEPC has the lowest carbon emission to produce one Higgs boson.

• Current Status of Chinese Electricity Grid



Electricity Generating Capacity in China 2020 (10000 kW)

Electricity Transmission:
- North-to-South
- West-to-East

Carbon intensity (kgCO2/kWh)

省份	2010 年	2012 年	2018 年	2020 年	
辽宁	0.836	0.775	0.722	0.91	
吉林	0.679	0.721	0.615	0.839	
黑龙江	0.816	0.797	0.663	0.814	
北京	0.829	0.776	0.617	0.615	
天津	0.873	0.892	0.812	0.841	
河北	0.915	0.898	0.903	1.092	Qin Huang Dao
山西	0.88	0.849	0.74	0.841	
内蒙古	0.85	0.929	0.753	1.000	
山东	0.924	0.888	0.861	0.742	
上海	0.793	0.624	0.564	0.548	
江苏	0.736	0.75	0.683	0.695	
浙江	0.682	0.665	0.525	0.532	Hu Zhou
安徽	0.791	0.809	0.776	0.763	
福建	0.544	0.551	0.391	0.489	
江西	0.764	0.634	0.634	0.616	
河南	0.844	0.806	0.791	0.738	Zheng Zhou
湖北	0.372	0.353	0.357	0.316	
湖南	0.552	0.517	0.499	0.487	Chang Sha
重庆	0.629	0.574	0.441	0.432	
四川	0.289	0.248	0.103	0.117	
广东	0.638	0.591	0.451	0.445	Shen Shan
广西	0.482	0.495	0.394	0.526	
海南	0.646	0.686	0.515	0.459	
贵州	0.656	0.495	0.428	0.42	
云南	0.415	0.306	0.092	0.146	
陕西	0.87	0.769	0.767	0.641	
甘肃	0.612	0.573	0.491	0.46	
青海	0.226	0.232	0.26	0.095	
宁夏	0.818	0.779	0.62	0.872	
新疆	0.764	0.79	0.622	0.749	

• “Double Carbon Target” in China

- **Peak Carbon Dioxide Emissions**: China has pledged to reach carbon peak by 2030, and then gradually reduce carbon dioxide emissions.
- **Carbon neutrality:** achieve a relative "zero emissions" before 2060 by planting trees and forests, saving energy and reducing emissions

2021~ 2030: realize peak carbon emissions

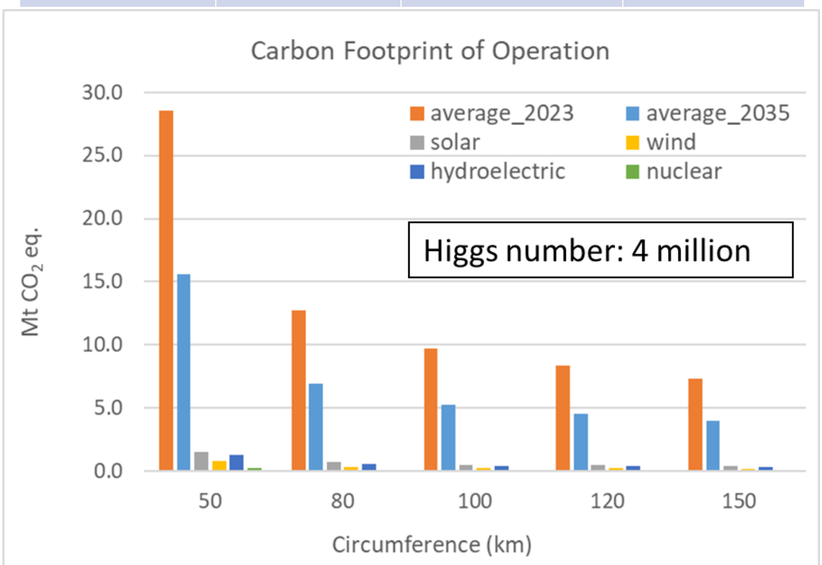
↓

2031~ 2045: rapid reduction of carbon emissions

↓

2046~ 2060: deep decarbonization, achieving carbon neutrality

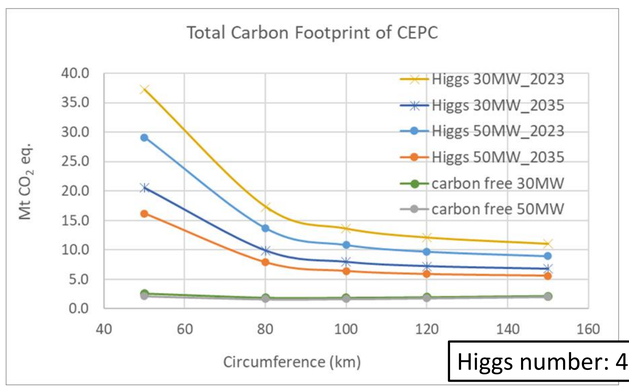
Solar (t CO2/GWh)	Wind (t CO2/GWh)	Hydroelectric (t CO2/GWh)	nuclear(t CO2/GWh)
30	15	25	5



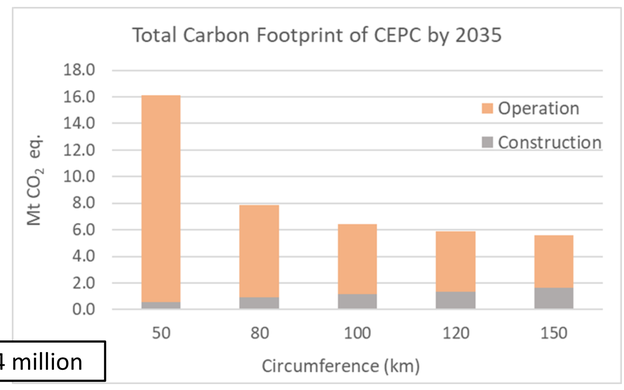
• Electricity Grid Carbon Intensity in China (2025-2035)

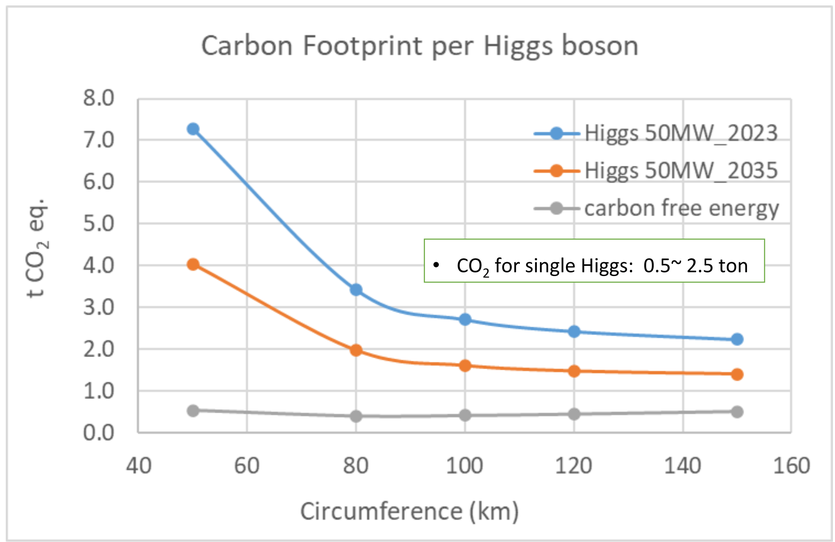
省份	2025 年	2030 年	2035 年
辽宁	0.578 (0.528-0.664)	0.496 (0.432-0.571)	0.371 (0.342-0.408)
吉林	0.564 (0.559-0.594)	0.43 (0.384-0.472)	0.216 (0.210-0.281)
黑龙江	0.654 (0.648-0.683)	0.599 (0.590-0.621)	0.504 (0.467-0.528)
北京	0.595 (0.573-0.612)	0.519 (0.476-0.532)	0.289 (0.208-0.299)
天津	0.688 (0.668-0.709)	0.536 (0.53-0.584)	0.418 (0.413-0.448)
河北	0.736 (0.714-0.784)	0.683 (0.666-0.733)	0.544 (0.512-0.571)
山西	0.707 (0.69-0.738)	0.7 (0.684-0.738)	0.598 (0.583-0.633)
内蒙古	0.8 (0.791-0.836)	0.792 (0.783-0.836)	0.673 (0.665-0.714)
山东	0.546 (0.536-0.56)	0.498 (0.489-0.506)	0.383 (0.36-0.386)
上海	0.333 (0.321-0.464)	0.325 (0.312-0.432)	0.281 (0.259-0.349)
江苏	0.601 (0.579-0.639)	0.512 (0.489-0.539)	0.411 (0.386-0.435)
浙江	0.418 (0.412-0.427)	0.386 (0.381-0.402)	0.307 (0.289-0.314)
安徽	0.755 (0.725-0.758)	0.694 (0.65-0.757)	0.596 (0.546-0.644)
福建	0.363 (0.346-0.379)	0.33 (0.322-0.358)	0.27 (0.266-0.293)
江西	0.474 (0.451-0.498)	0.436 (0.414-0.444)	0.354 (0.334-0.359)
河南	0.599 (0.553-0.621)	0.49 (0.462-0.512)	0.389 (0.356-0.409)
湖北	0.31 (0.307-0.317)	0.254 (0.247-0.316)	0.202 (0.19-0.261)
湖南	0.453 (0.447-0.46)	0.409 (0.397-0.422)	0.312 (0.3-0.331)
重庆	0.363 (0.231-0.396)	0.256 (0.193-0.304)	0.179 (0.131-0.226)
四川	0.104 (0.103-0.107)	0.075 (0.073-0.075)	0.04 (0.04-0.04)
广东	0.369 (0.359-0.382)	0.332 (0.318-0.351)	0.276 (0.269-0.295)
广西	0.336 (0.316-0.363)	0.334 (0.317-0.373)	0.279 (0.26-0.308)
海南	0.326 (0.312-0.332)	0.224 (0.188-0.236)	0.115 (0.11-0.143)
贵州	0.398 (0.393-0.408)	0.276 (0.26-0.278)	0.204 (0.146-0.206)
云南	0.1 (0.093-0.102)	0.062 (0.05-0.075)	0.025 (0.022-0.03)
陕西	0.607 (0.533-0.623)	0.601 (0.528-0.619)	0.515 (0.446-0.53)
甘肃	0.443 (0.433-0.469)	0.407 (0.391-0.439)	0.279 (0.223-0.285)
青海	0.067 (0.048-0.078)	0.032 (0.027-0.041)	0.01 (0.01-0.013)
宁夏	0.724 (0.703-0.758)	0.665 (0.643-0.714)	0.459 (0.452-0.551)
新疆	0.720 (0.601-0.745)	0.713 (0.595-0.745)	0.573 (0.516-0.599)

➢ The carbon intensity will be reduced rapidly until 2035 in China.



Higgs number: 4 million

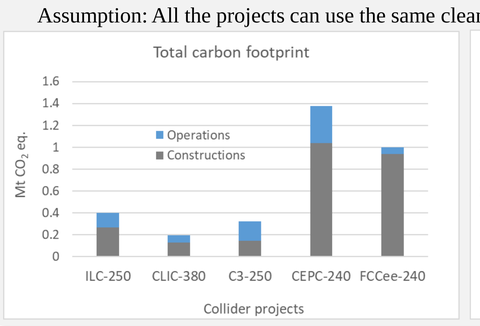


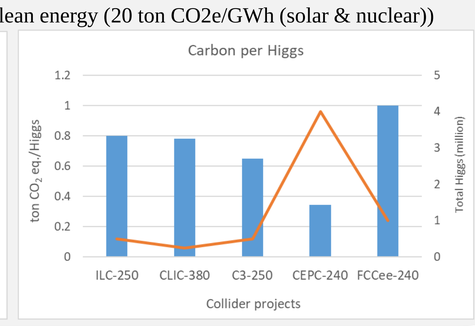


• Total Carbon Emissions of Future Colliders

	ILC-250	CLIC-380	C3-250	CEPC-240	FCCee-240
Instantaneous power (MW)	111	110	150	340	290
Annual collision month	6.2	4.6	6.2	5.0	4.2
Annual collision time (E7 s)	1.6	1.2	1.6	1.3	1.1
Operational efficiency	0.75	0.75	0.75	0.57	0.75
Higgs operation time (years)	11.5	8	11.5	10	3
Higgs number (million)	0.5	0.25	0.5	4	1

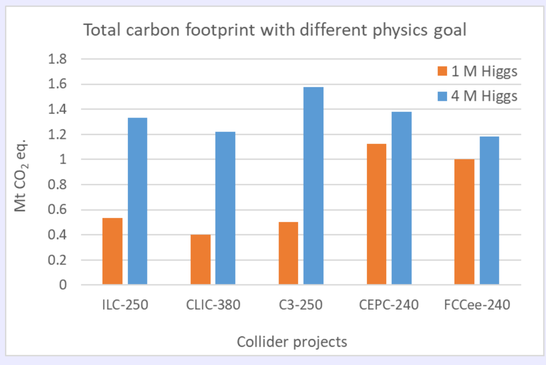
Assumption: All the projects can use the same clean energy (20 ton CO2e/GWh (solar & nuclear))

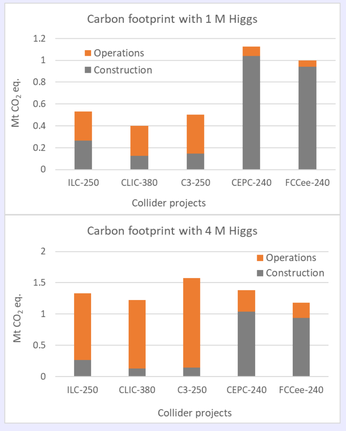




• Total Carbon emissions with different physics goal

Assumption: All the projects have same Higgs number.





- The carbon footprint of CEPC was estimated based on simplified model including both construction process and operation process.
- The environmental impact of CEPC with different circumference, different energy source, different SR power and different Higgs number was studied.
- The carbon intensity of the electric grid will be reduced rapidly by 2040 due to the development of renewable energies. And it is possible to consider using the dedicated renewable electricity plants for each collider project.
- Assuming all the colliders will use the same clean energy (20 ton CO_2e/GWh), CEPC has the lowest carbon emission to produce one Higgs boson.
- The environmental impact of CEPC and strategies to lower the carbon footprint will be studied continuously.

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