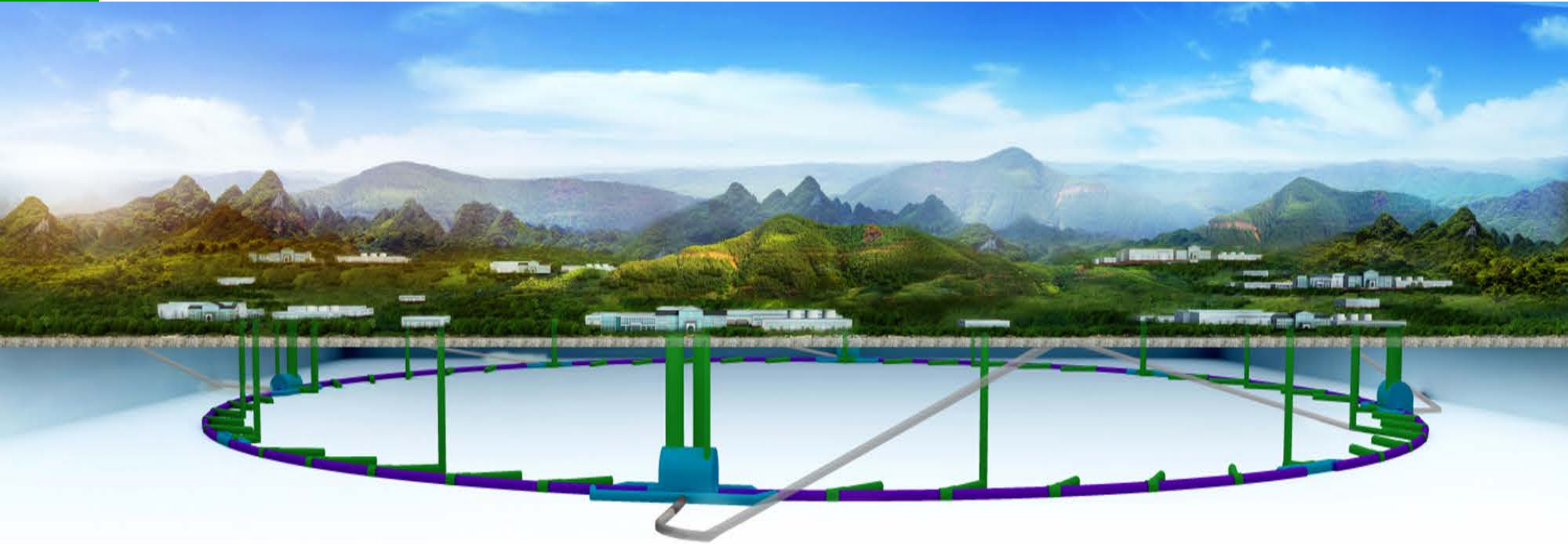
Considerations of CEPC Green Design

Yunlong Chi[1], Guoqiang Sun[2], Junlong Tang[3]

1, Institute of High Energy Physics, CAS
2, Yellow River Engineering Consulting Co., Ltd
3, Power China Huadong Engineering Co., Ltd

Contents

CEPC power consumption



CEPC power consumption source :

- Physics experiment equipment : Accelerators, Detectors etc.
- Infrastructures : Cooling, Ventilation, Air conditioning, lighting etc.

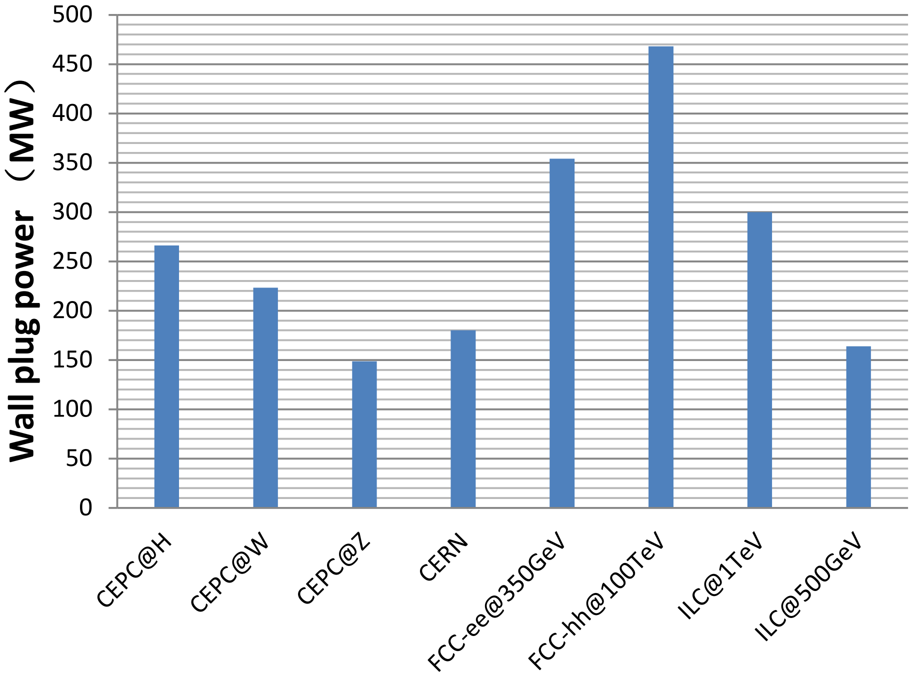
CEPC power consumption

CEPC CDR stage : 266MW (H)

	System for Higgs (30MW)	Location and electrical demand(MW)						Total (MW)
		Ring	Booster	LINAC	BTL	IR	Surface building	
1	RF Power Source	103.8	0.15	5.8				109.75
2	Cryogenic System	11.62	0.68			1.72		14.02
3	Vacuum System	9.784	3.792	0.646				14.222
4	Magnet Power Supplies	47.21	11.62	1.75	1.06	0.26		61.9
5	Instrumentation	0.9	0.6	0.2				1.7
6	Radiation Protection	0.25		0.1				0.35
7	Control System	1	0.6	0.2	0.005	0.005		1.81
8	Experimental devices					4		4
9	Utilities	31.79	3.53	1.38	0.63	1.2		38.53
10	General services	7.2		0.2	0.15	0.2	12	19.75
	Total	213.554	20.972	10.276	1.845	7.385	12	266.032

266MW

CEPC, CERN, FCC, ILC

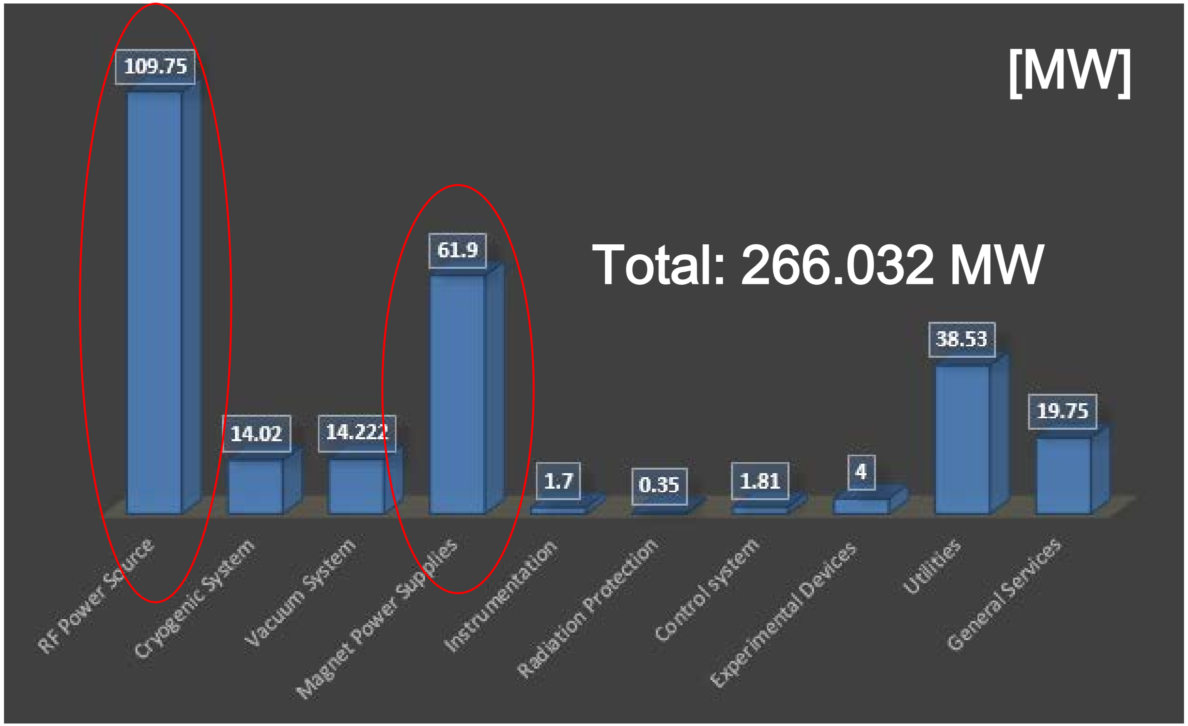


CEPC TDR stage to reduce power consumption less than 266MW by green design

CEPC energy consumption

CEPC Power Consumption – CDR

	System for Higgs （30MW）	Location and electrical demand(MW)						Total (MW)
		Ring	Booster	LINAC	BTL	IR	Surface building	
1	RF Power Source	103.8	0.15	5.8				109.75
2	Cryogenic System	11.62	0.68			1.72		14.02
3	Vacuum System	9.784	3.792	0.646				14.222
4	Magnet Power Supplies	47.21	11.62	1.75	1.06	0.26		61.9
5	Instrumentation	0.9	0.6	0.2				1.7
6	Radiation Protection	0.25		0.1				0.35
7	Control System	1	0.6	0.2	0.005	0.005		1.81
8	Experimental devices					4		4
9	Utilities	31.79	3.53	1.38	0.63	1.2		38.53
10	General services	7.2		0.2	0.15	0.2	12	19.75
	Total	213.554	20.972	10.276	1.845	7.385	12	266.032



CEPC power consumption

CEPC power Consumption

Total power load : 266MW

Annual electricity consumption: 1.773B kWh

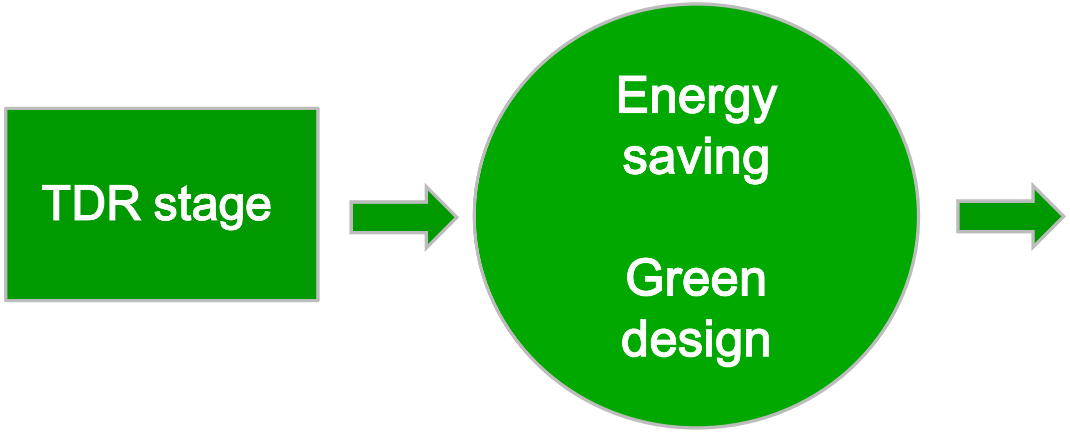
Convert into Standard coal: 638,000 ton

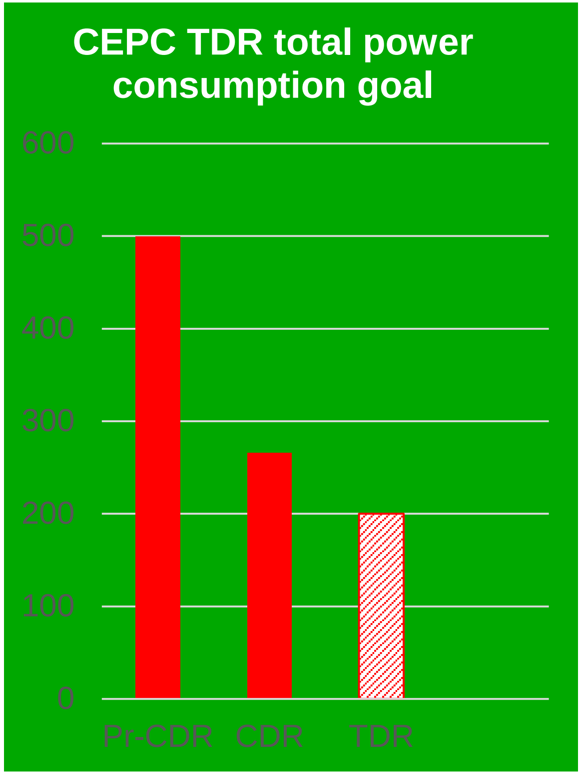
CO_2 emissions: 1,670,000 ton

CEPC power consumption

CEPC power consumption is huge,

- CEPC design must consider energy conservation and consumption reduction as well as considering sustainability.
- This is the social responsibility!





CEPC green design idea

The green design, also called **"Ecological design" , "Design for environment", "Environment conscious design" etc.**

It refers to various types of information (technical information, environmental coordination information, economic information) related to products in the product life cycle, and uses advanced design theories such as parallel design to make the designed products have advanced technology and good performance, environmental coordination and rational economics.

The CEPC green design,

- Focuses on the ecological balance between human and nature during design process,
- Environmental benefits are fully considered
- The damage to the environment is minimized.

CEPC green design idea

Heart of the green design

3R

For the CEPC design, the material and energy consumption reduction, environmental factors and pollution prevention measures are incorporated into the product design at the design stage, the environmental performance is taken as the design goal and starting point of the product, and best effort is taken to minimize the environmental.

The heart of the green design is "3R" – "Reduce", "Recycle" and "Reuse",

which not only reduces the consumption of substances and energy, but also reduces the emission of harmful substances, and fully considers the recycling or reuse in the whole process of the project.

The idea of CEPC green design :

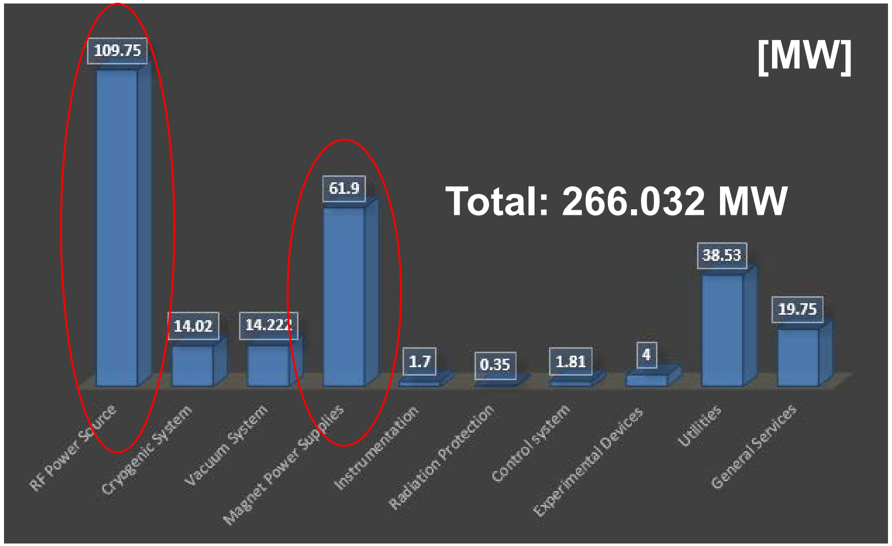
"Simple and practical", "Energy saving", "Recycling", "Green and environmental protection"

CEPC green design consideration

[1]Reduce - Reduce environmental pollution
Reduce energy consumption

(1) Advanced and efficient subsystems : Reduce RF power

- High Efficiency Klystron (is the key to reduce RF power)
- High Efficiency Power supply
  - Losses in the power converter
    - Switching & conduction losses
    - Inductors core & copper losses
  - Cables losses – clear…
  - Pulse transformers Losses
    - Core losses
    - Copper losses



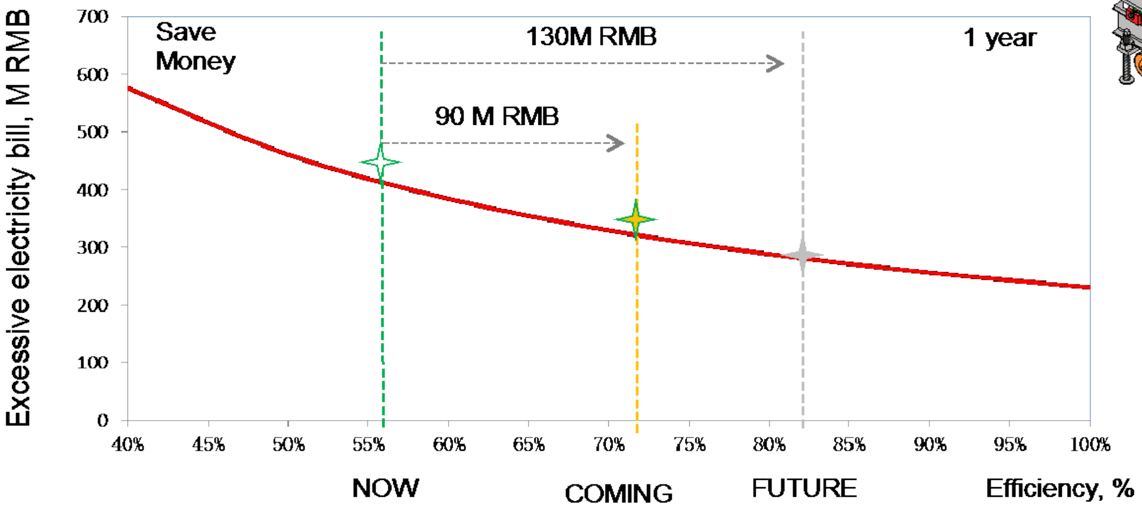
CEPC green design consideration

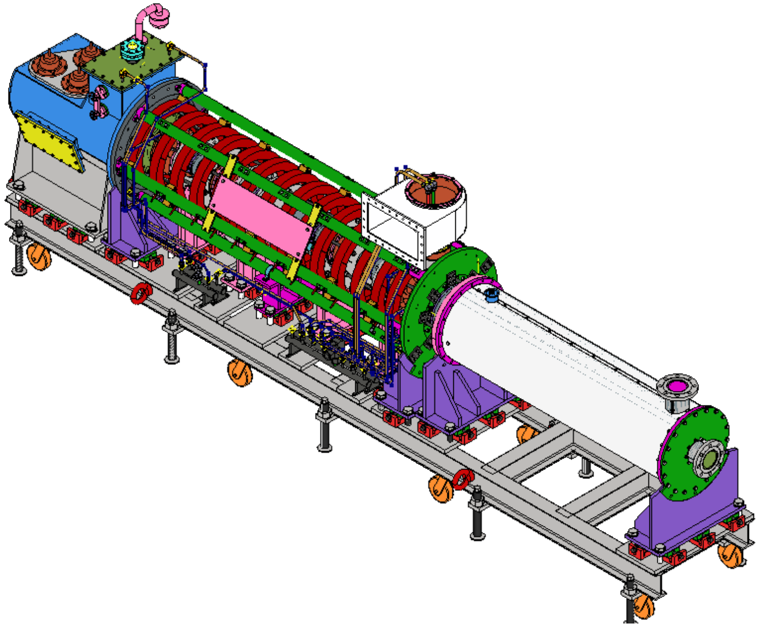
[1]Reduce - Reduce environmental pollution
Reduce energy consumption

(1) Advanced and efficient subsystems : High efficiency Klystron

CEPC high efficiency klystron R&D under going: (650MHz, 800kW, CW, ≥80%)

1st step, Low voltage single beam ;
2nd step, High voltage single beam;
3rd step, Multi beam low perveance klystron





CEPC green design consideration

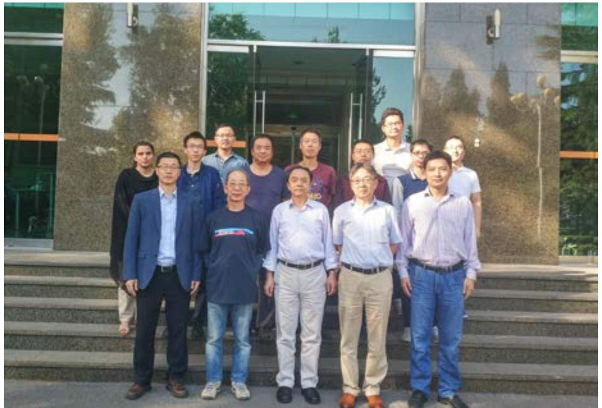
[1]Reduce - Reduce environmental pollution

Reduce energy consumption

(1) Advanced and efficient subsystems : High efficiency Klystron

New type High Efficiency RF Power Source Consortium ：

1, Institute of High Energy Physics, CAS
2, Institute of Electronics, CAS
3, Kunshan GuoLi Electronic Technology Co., Ltd
4, Beijing Institute of Radio Measurement Technology



CEPC green design consideration

[1]Reduce - Reduce environmental pollution

Reduce energy consumption

(1) Advanced and efficient subsystems : High Q_0 SRF cavity

(Low Power Loss & Energy-saving!)

	Cavity amount	Gradient (MV/m)	**Q for long period**	Gradient in horizontal test (MV/m)	Q in horizontal test	Gradient in vertical test (MV/m)	Q in vertical test
650 MHz 2-cell cavity	240	19.7	**1.5E10**	22	2E10	22	4E10
1.3 GHz 9-cell cavity	96	19.8	**1E10**	22	2E10	24	3E10

1.3 GHz 9-cell cavity for booster

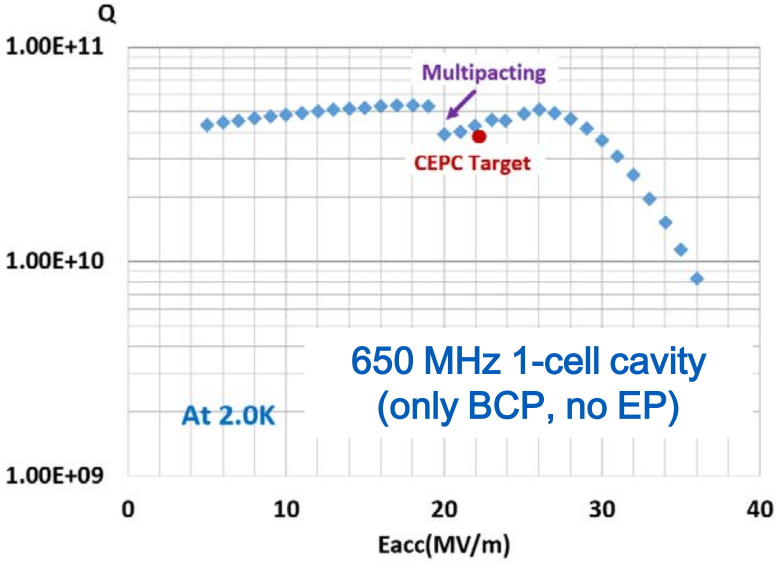
650 MHz 2-cell cavity for collider ring

CEPC green design consideration

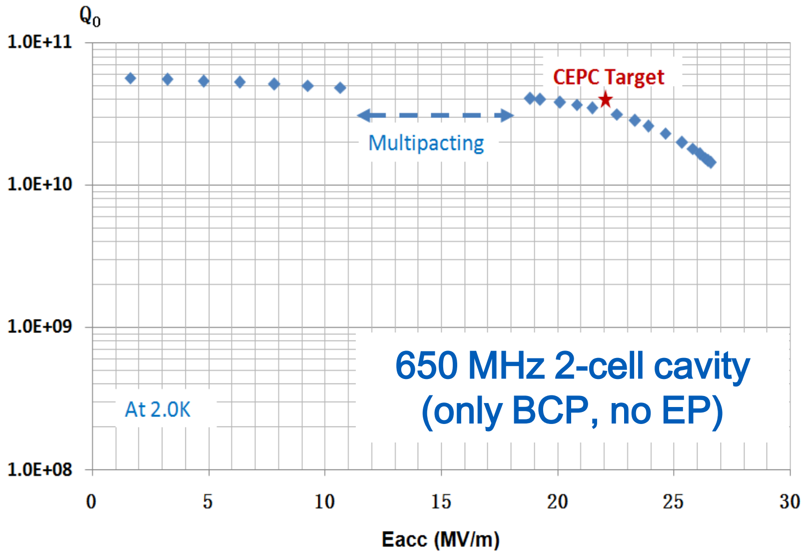
[1]Reduce - Reduce environmental pollution
Reduce energy consumption

(1) Advanced and efficient subsystems : High Q_0 SRF cavity

High Q achieved in the vertical test!



Vertical test result: Q_0=5.1E10@26.0MV/m, which exceed the CEPC target (Q_0=4.0E10@22.0MV/m).



Vertical test result: Q_0=4.0E10@19.2MV/m, which is close to the CEPC target (Q_0=4.0E10@22.0MV/m).

[1]Reduce - Reduce environmental pollution

Reduce energy consumption

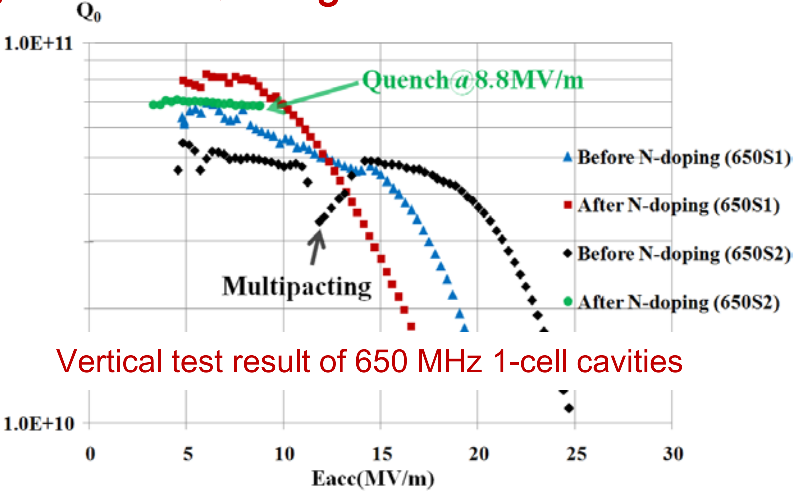
CEPC green design consideration

(1) Advanced and efficient subsystems : High Q_0 SRF cavity

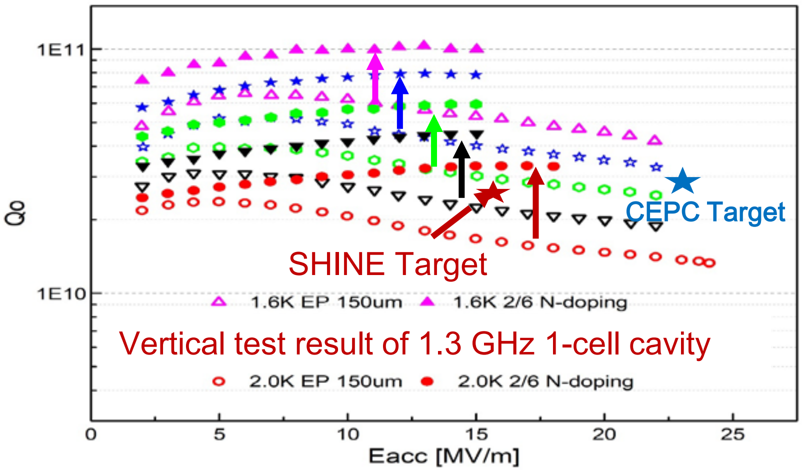
N-doping: increase Q further!

After N-doping, Q_0 increased obviously at low field for 650 MHz 1-cell cavities : Q_0=7E10@10MV/m.
But Q_0 decreased quickly at high field (>10 MV/m) because of no BCP/EP after N-doping.
After N-doping, the vertical test result of 1.3GHz 1 cell cavities reached 3.3E10@18MV/m (at 2K), which is two times of baseline. It has exceeded the

Next, increase Q at high field for CEPC TDR.



Vertical test result of 650 MHz 1-cell cavities



Vertical test result of 1.3 GHz 1-cell cavity

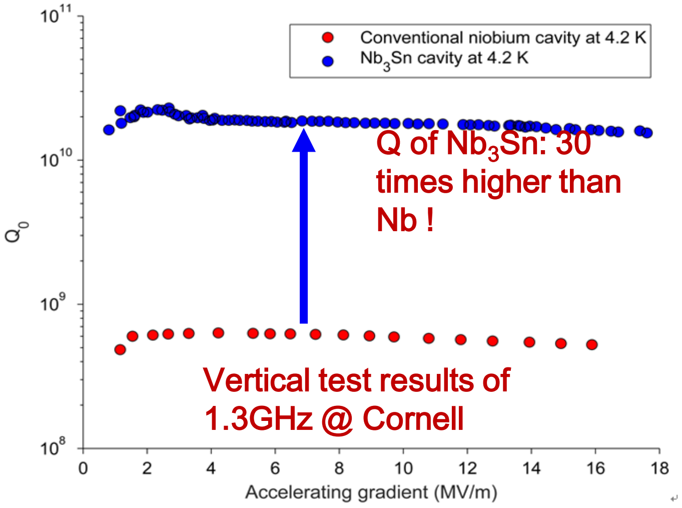
CEPC green design consideration

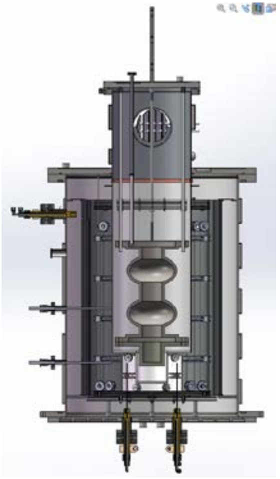
[1]Reduce - Reduce environmental pollution
Reduce energy consumption

(1) Advanced and efficient subsystems : High Q_0 SRF cavity

Nb_3Sn film: Lower cavity loss significantly——Effort to TDR!

Nb_3Sn: high Tc, much higher Q than Nb at 4.2K, higher gradient (120MV/m in theory) than Nb (50 MV/m). Nb cavity coating with Nb_3Sn film is promising in future. Related research has begun at IHEP. The furnace for Nb_3Sn coating is under fabrication now.





Parameters	Value
Min vacuum	5.0E-5 Pa
Max temperature	1400℃
Min vacuum@1400℃	9.0E-4 Pa
Uniform temperature area	Φ300mm×500mm

Furnace for Nb_3Sn coating

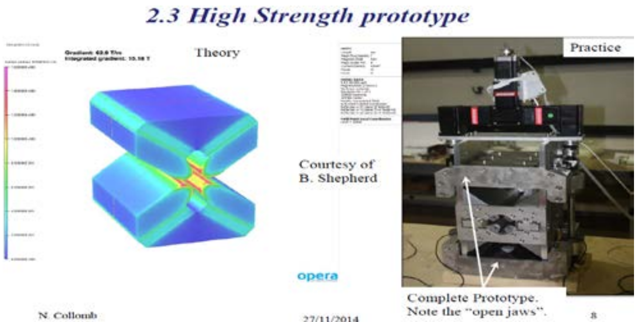
CEPC green design consideration

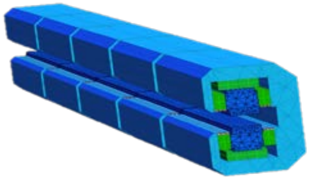
(1) Advanced and efficient subsystems : Permanent Magnet

- Advantages to using PMs:
  - Compact
  - Low power
  - No vibration
- Disadvantages can be mitigated
  - Tuning
  - Temperature variation
  - Radiation effects
- Many accelerator labs using PMs

➢ PMs can be employed in the CEPC two linac-booster transfer lines.

➢ PMs use for the ring magnet we need more R&D in the CEPC TDR stage.





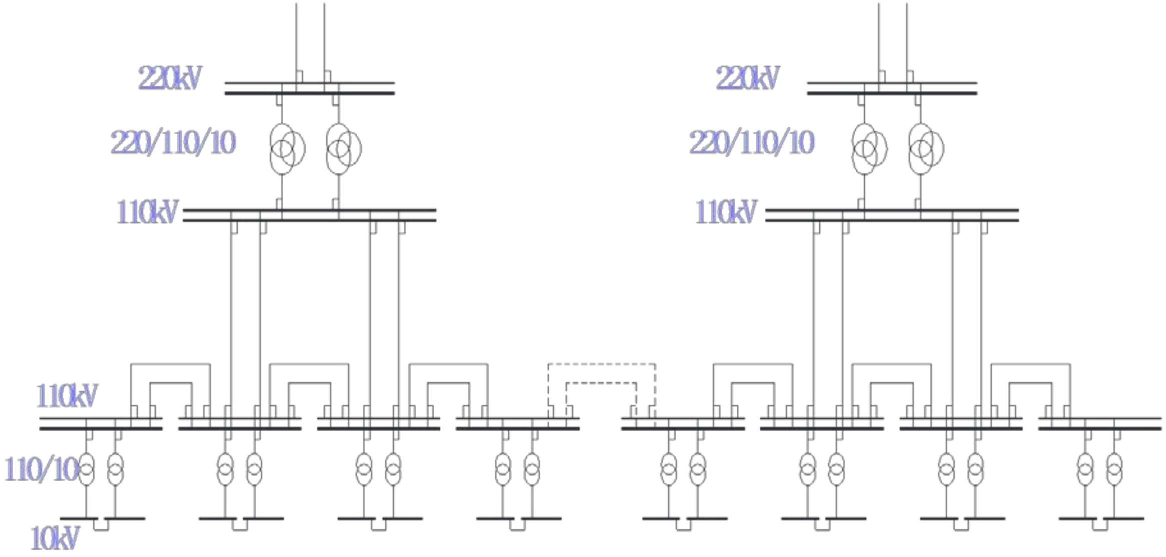
CEPC green design consideration

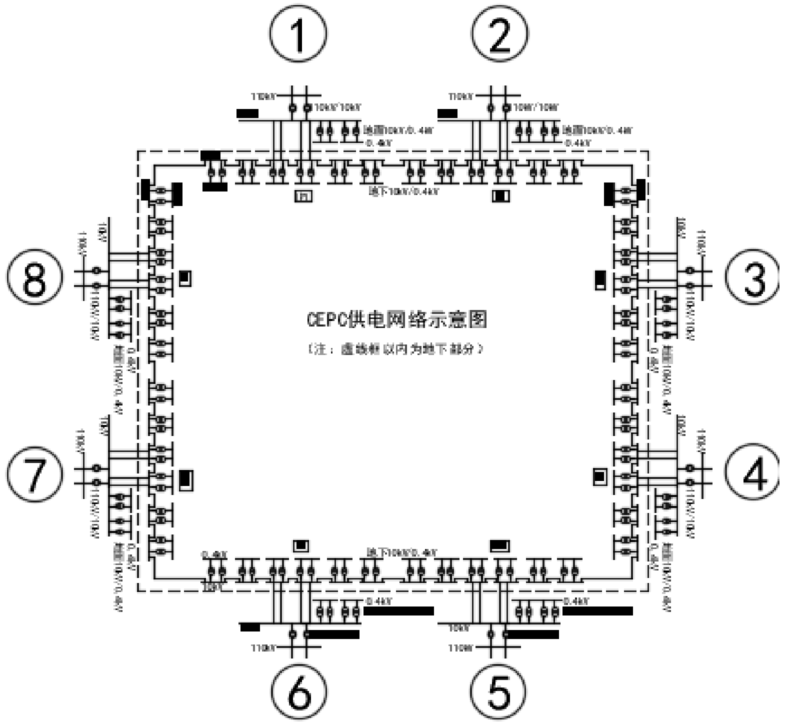
[1]Reduce - Reduce environmental pollution

Reduce energy consumption

(2) Electrical power saving design : Electrical Power supply system

CDR : eight 110kV/10kV substations design





CEPC green design consideration

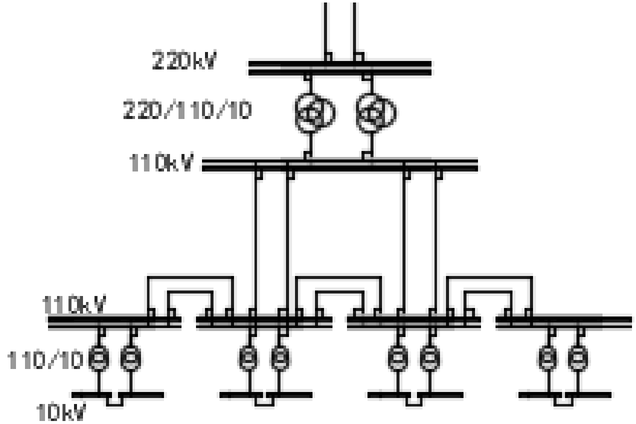
[1]Reduce - Reduce environmental pollution

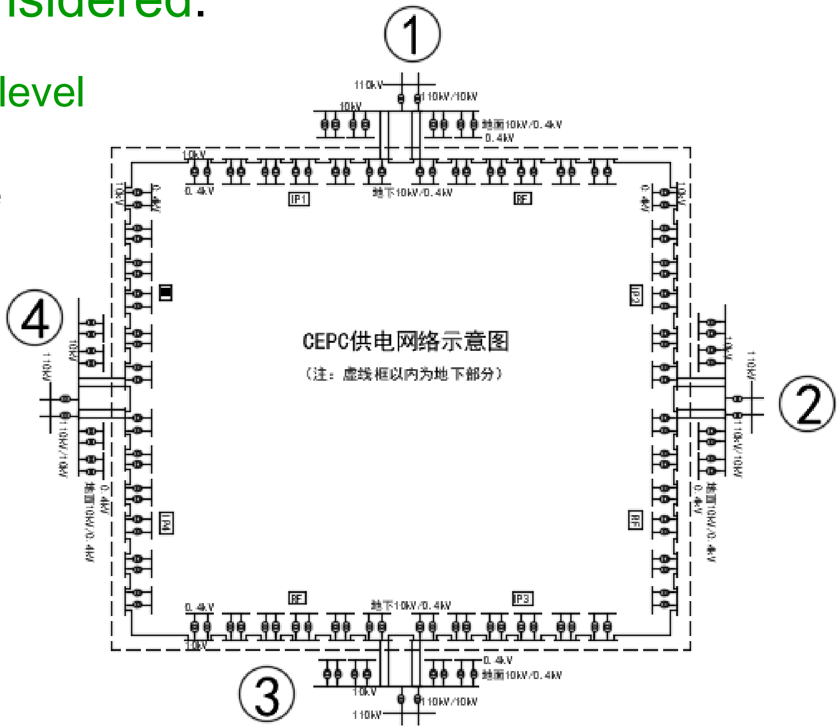
Reduce energy consumption

(2) Electrical power saving design : Electrical Power supply system

TDR : With the further optimization and reduction of the total power load of CEPC, four 110k/20(10)kV substations can be considered.

At the same time, it is considered to use 20kV voltage level power distribution instead of 10kV voltage level.
(Compared to the 10kV voltage level, the 20kV voltage level has a large power supply capacity and low loss).





CEPC green design consideration

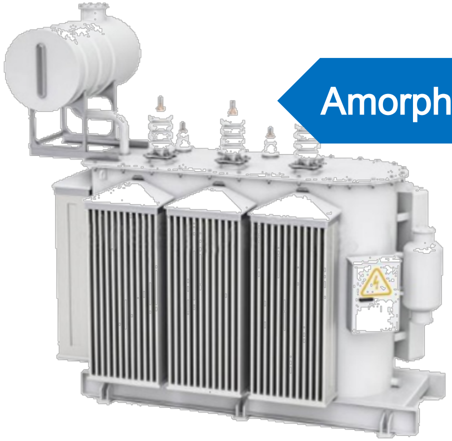
[1]Reduce - Reduce environmental pollution

Reduce energy consumption

(2) Electrical power saving design : Electrical Power supply system

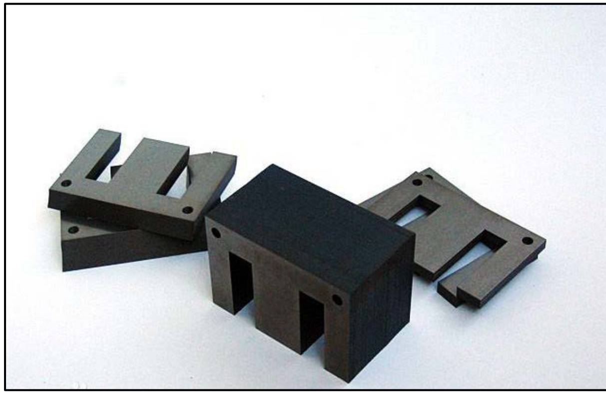
All distribution transformers use amorphous alloy transformers.

The iron loss (ie, no-load loss) of amorphous alloy transformers is 70-80% lower than that of conventional transformers.



Amorphous alloy

Silicon steel sheet



CEPC: Using amorphous alloy transformers,

Save 3 million kWh electricity per year.

Reduce CO2 emissions: 2,620 tons

CEPC green design consideration

[1]Reduce - Reduce environmental pollution

Reduce energy consumption

Conventional 10 type transformer loss

表 B.8　6 kV、10 kV 级 10 型干式无励磁调压配电变压器空载损耗和负载损耗

额定容量 kVA	A 组 空载损耗 W	A 组 不同绝缘耐热等级下的负载损耗 W B（100℃）	A 组 F（120℃）	A 组 H（145℃）	B 组 空载损耗 W	B 组 不同绝缘耐热等级下的负载损耗 W B（100℃）	B 组 F（120℃）	B 组 H（145℃）	短路阻抗（%）
30	190	670	710	760	180	700	740	790	
50	270	940	1 000	1 070	250	1 010	1 060	1 140	
80	370	1 290	1 380	1 480	330	1 370	1 470	1 570	
100	400	1 480	1 570	1 690	360	1 600	1 690	1 830	
125	470	1 740	1 850	1 980	420	1 870	1 980	2 120	4.0
160	540	2 000	2 130	2 280	490	2 120	2 320	2 480	
200	620	2 370	2 530	2 710	580	2 550	2 690	2 880	
250	720	2 590	2 760	2 960	660	2 880	3 070	3 300	
315	880	3 270	3 470	3 730	780	3 450	3 690	3 970	
400	980	3 750	3 990	4 280	890	4 100	4 350	4 640	
500	1 160	4 590	4 880	5 230	1 040	4 870	5 160	5 530	4.0
630	1 340	5 530	5 880	6 290	1 200	5 810	6 140	6 560	
630	1 300	5 610	5 960	6 400	1 160	5 950	6 330	6 800	
800	1 520	6 550	6 960	7 460	1 370	6 960	7 380	7 900	
1 000	1 770	7 650	8 130	8 760	1 560	8 250	8 730	9 420	
1 250	2 090	9 100	9 690	10 370	1 810	9 830	10 390	11 140	6.0
1 600	2 450	11 050	11 730	12 580	2 400	11 990	12 770	13 650	
2 000	3 050	13 600	14 450	15 560	2 700	14 450	15 300	16 540	
2 500	3 600	16 150	17 170	18 450	3 150	17 380	18 420	19 720	
1 600	2 450	12 280	12 960	13 900	2 400	12 930	13 720	14 690	
2 000	3 050	15 020	15 960	17 110	2 700	15 770	16 720	18 060	8.0
2 500	3 600	17 760	18 890	20 290	3 150	18 700	19 840	21 330	

Amorphous alloy transformer loss

表 B.9　6 kV、10 kV 级 15 型干式非晶合金铁心配电变压器

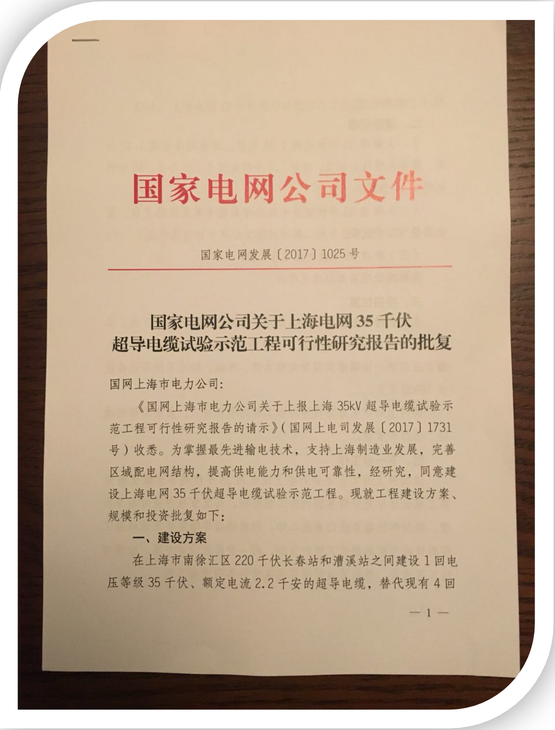
额定容量 kVA	空载损耗 W	负载损耗 W B（100℃）	负载损耗 W F（120℃）	负载损耗 W H（145℃）	空载电流（%）	短路阻抗（%）
30	70	670	710	760	1.6	
50	90	940	1 000	1 070	1.4	
80	120	1 290	1 380	1 480	1.3	
100	130	1 480	1 570	1 690	1.2	
125	150	1 740	1 850	1 980	1.1	
160	170	2 000	2 130	2 280	1.1	
200	200	2 370	2 530	2 710	1.0	4.0
250	230	2 590	2 760	2 960	1.0	
315	280	3 270	3 470	3 730	0.9	
400	310	3 750	3 990	4 280	0.8	
500	360	4 590	4 880	5 230	0.8	
630	420	5 530	5 880	6 290	0.7	
630	410	5 610	5 960	6 400	0.7	
800	480	6 550	6 960	7 460	0.7	
1 000	550	7 650	8 130	8 760	0.6	6.0
1 250	650	9 100	9 690	10 370	0.6	
1 600	760	11 050	11 730	12 580	0.6	
2 000	1 000	[illegible]	[illegible]	[illegible]	[illegible]	

CEPC green design consideration

[1]Reduce - Reduce environmental pollution
Reduce energy consumption

(2) Electrical power saving design : HTS cable for DC power transfer

一根2000A超导电缆将给3-5万家庭供电



国家电网公司文件

国家电网发展〔2017〕1025号

国家电网公司关于上海电网35千伏超导电缆试验示范工程可行性研究报告的批复

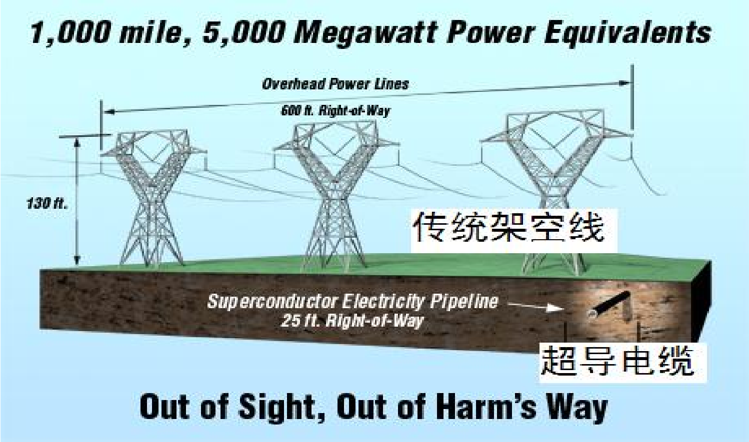
国网上海市电力公司：

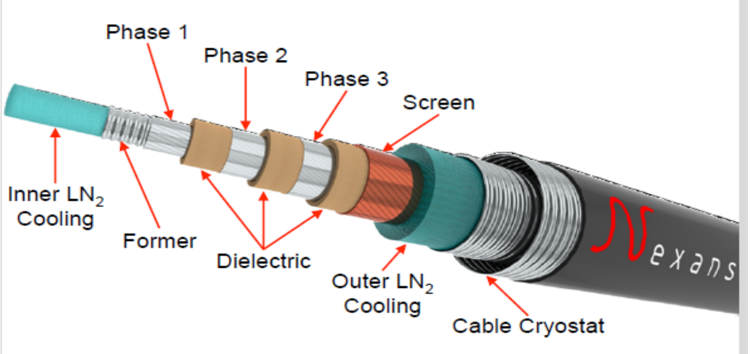
《国网上海市电力公司关于上报上海35kV超导电缆试验示范工程可行性研究报告的请示》(国网上电司发展〔2017〕1731号）收悉。为掌握最先进输电技术，支持上海制造业发展，完善区域配电网结构，提高供电能力和供电可靠性，经研究，同意建设上海电网35千伏超导电缆试验示范工程。现就工程建设方案、规模和投资批复如下：

一、建设方案

在上海市南徐汇区220千伏长春站和漕溪站之间建设1回电压等级35千伏、额定电流2.2千安的超导电缆，替代现有4回

— 1 —





CEPC green design consideration

[1]Reduce - Reduce environmental pollution

Reduce energy consumption

(3) Lighting energy saving design : LED Lighting

All LED light can save more than 70% energy
compared to conventional light sources

傳統光源和LED光源比較

Light Source	CRI	Luminous Efficacy (lm/w)	CCT	Wattage	Luminous Output	Lifetime
Incandescent	100	14	3300 K	60 W	850 lm	1k hrs
Fluorescent (T8 / T5)	80	90 (T8) 100 (T5)	4100 K	32 W (T8) 28 W (T5)	2880 lm(T8) 2800 lm (T5)	20k hrs
Compact Fluorescent	80	80	4100 K	23W	1840 lm	8k hrs
HID	65	80	4000 K	400 W	26,000 lm	24k hrs
LED / Standard White	70	100	5500 K	1 W	100 lm	35k hrs (L70)
LED / Warm White	85	80	3000 K	1 W	80 lm	35k hrs (L70)

- High energy saving
- Long life
- Good for environment protection

For CEPC, energy saving with LED lighting can save energy: 40 million kWh/year

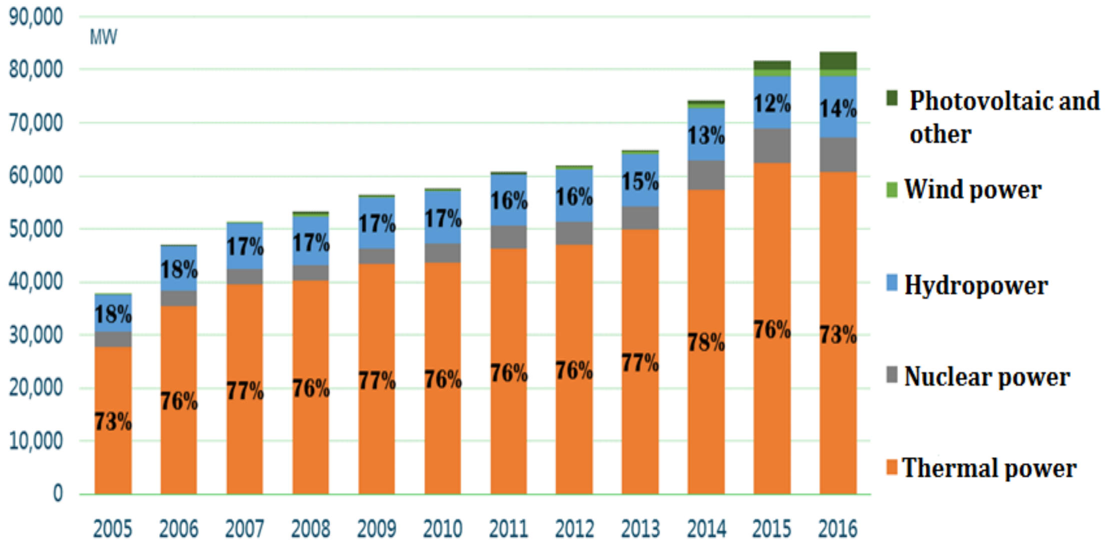
Converted to standard coal: 15,000 tons; Reduce CO2 emissions: 40,000 tons

CEPC green design consideration

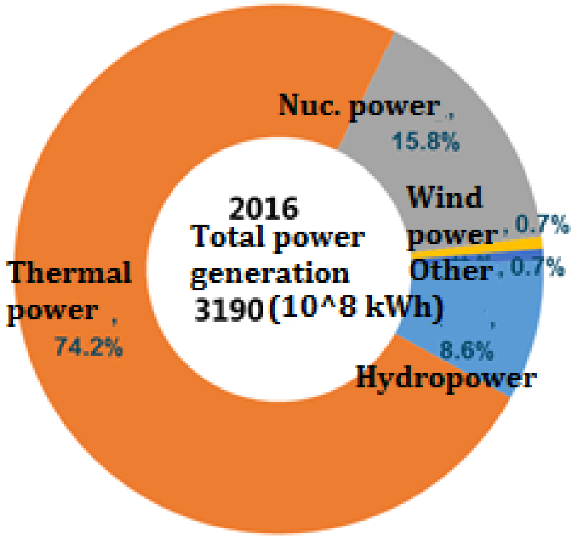
[1]Reduce - Reduce environmental pollution
Reduce energy consumption

(4) Green energy utilization

The energy source develops diversified, The renewable energy develops rapidly*



(* Grid of Zhejiang province)



Renewable energy: 19%
Non-fossil energy: 27%

CEPC green design consideration

[1]Reduce - Reduce environmental pollution

Reduce energy consumption

(4) Green energy utilization

Design Optimization

Building wind and solar energy

Science City Intelligent Microgrid

ADS technology, nuclear waste

CEPC can use of renewable energy and low-carbon electricity.

Strengthen the application of renewable energy and promote the construction of the smart micro grid in Science City

According to local conditions to build wind power, photovoltaic, biomass power plants, etc., supporting energy storage systems to improve the self-sufficiency level of the project; relying on the International Science City to promote green energy-efficient buildings and green transportation, and establish a smart micro-grid.

For CEPC,
if wind power: 50MW, solar photovoltaic : 30MW,
it will be ~30% of total power,

Can save 136 million kWh of electricity;
Equivalent standard coal: 49,000 tons;
Reduce CO_2 emissions: 130,000 tons

CEPC green design consideration

[1]Reduce - Reduce environmental pollution

Reduce energy consumption

(4) Green energy utilization

100MW Panda power plant, Area 1 km^2

25 Year 3.2 B kWh electricity

Coal 1.056 M ton,

CO_2 2.74 M ton.

CEPC green design consideration

[1]Reduce - Reduce environmental pollution
Reduce energy consumption

(5) Ventilation and air conditioning

Employ high efficient ventilation and air conditioning system,
Employ high efficiency motor to reduce energy consumption.

CEPC green design consideration

[1]Reduce - Reduce environmental pollution

Reduce energy consumption

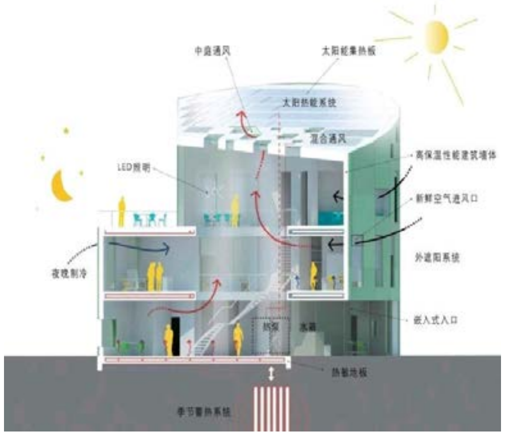
(5) Green, energy saving building

Adopt green, energy saving building design,

Which is to follow the basic methods of climate design and energy conservation, and study the building planning division, group and unit, building orientation, spacing, solar radiation, wind direction and external space environment, and design low energy consumption buildings to reduce energy consumption;

Adopt ecological environmental protection design,

Incorporate environmental factors into the design, and harmonize with the environment, and adopt environmentally friendly materials and green construction to reduce the pollution and damage of the project to the environment.



CEPC ground main building

office

Science and Technology Park

CEPC green design consideration

[2]Recycle

[3]Reuse

(1) Waste heat utilization

CEPC will generate huge amount of waste heat by the cooling system, this waste heat can be recycled, energy will be saved effectively.

According to different waste heat characteristics, there are different ways to use and applications.

表 1　不同温度梯度的余热资源利用及优缺点

温度范围 / ℃	余热来源	能源利用	能源回收利用的缺点
30 ~50	洗浴废水，空调制冷机、空压机等冷却水	通过各种形式的热泵系统升级能源的品位加以利用	资源的可利用能少，回收困难，初投资较高，回收期长
50 ~200	内燃机、退火炉、轴承等设备的冷却水	作为吸收式制冷的驱动能源，除湿，用于吸收式热泵等系统	系统的性能系数较低，有待提高
200 ~300	工业锅炉的排烟，干燥、烘干炉等的排烟	有机朗肯循环用于发电	设备昂贵，技术要求高，初投资比较高

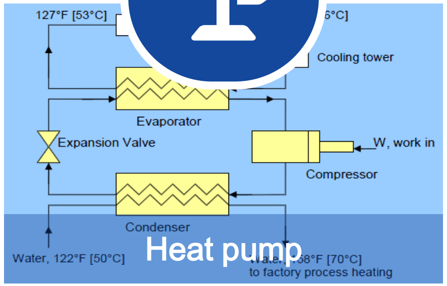
CEPC green design consideration

[2]Recycle

[3]Reuse

(1) Waste heat utilization


Heat Exchanger



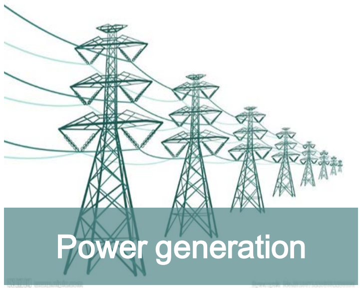
Heat pump


Waste heat energy


Organic Rankine cycle

Choose suitable heat storage materials or thermal energy technology, combined with various waste heat utilization technologies, recover waste heat from the project


Industry use


Power generation


Agricultural use


Bath water heating

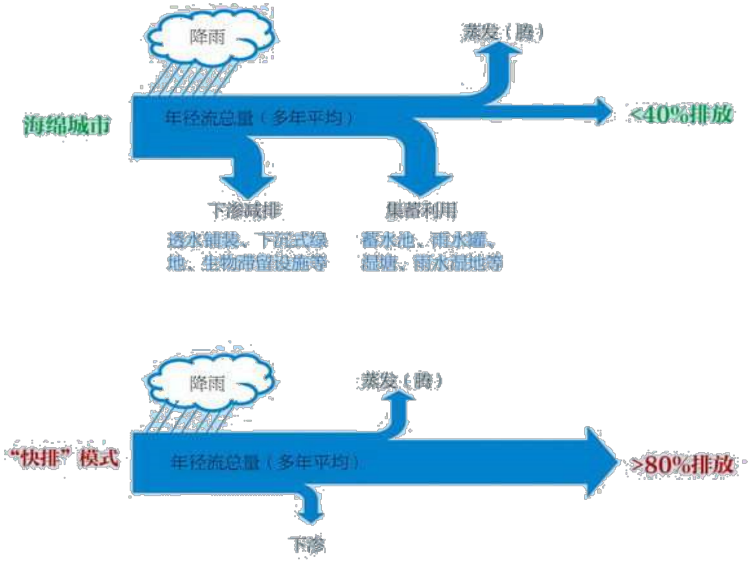
CEPC green design consideration

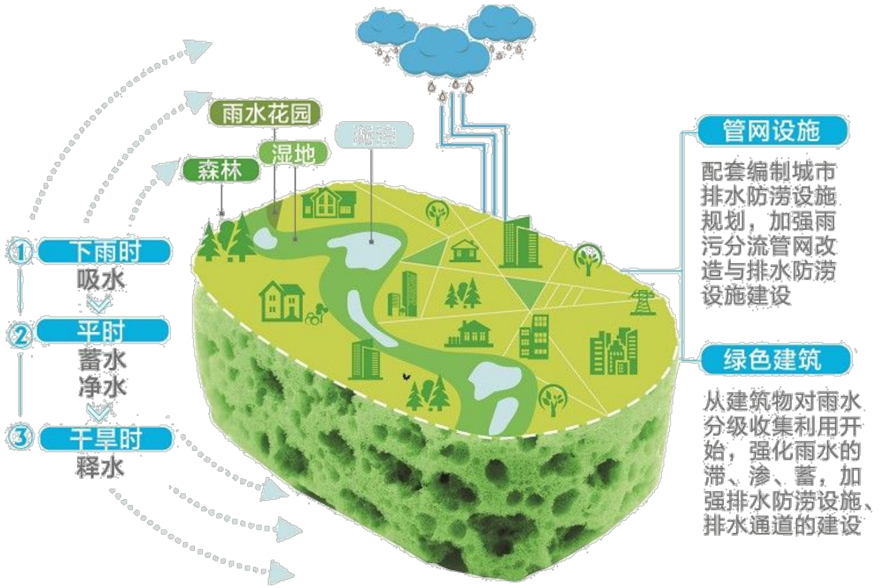
[2]Recycle

[3]Reuse

(2) Waste water utilization

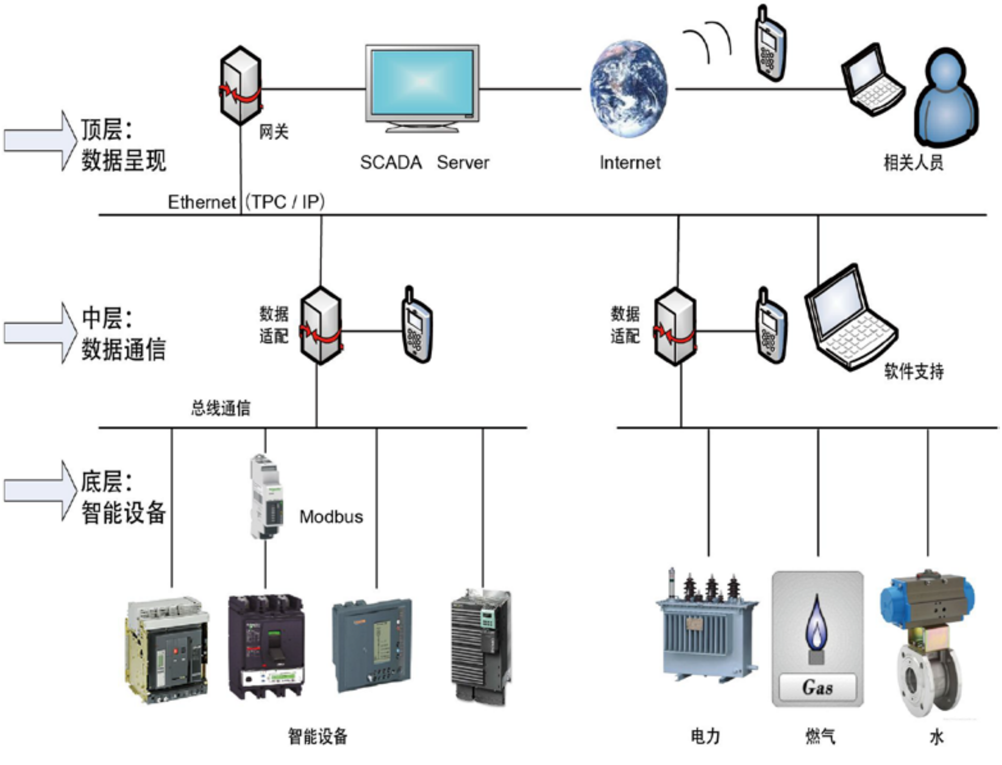
Introduce the “sponge city” design idea, collect and process rain water and waste water to establish a recycling system,
Construct a water-saving “sponge technology Science park”.





CEPC green design consideration

Construct advanced energy management system



能源管理体系结构图

As an important part of CEPC information system construction, **the energy management system adopts a layered and distributed system architecture** to collect and process energy consumption data of various items such as electricity, heat and water, and analyze the energy consumption of buildings. Through Energy project, energy monitoring, energy statistics, energy consumption analysis, key energy equipment management, energy metering equipment management and other method to achieve energy savings.

Thanks for your attention.

GREEN CEPC

FOR ENVIRONMENTAL PROTECTION