厦门大学能源研究院
School of Energy Research, Xiamen University

Economic and Market Analysis of DC Microgrid with Photovoltaic

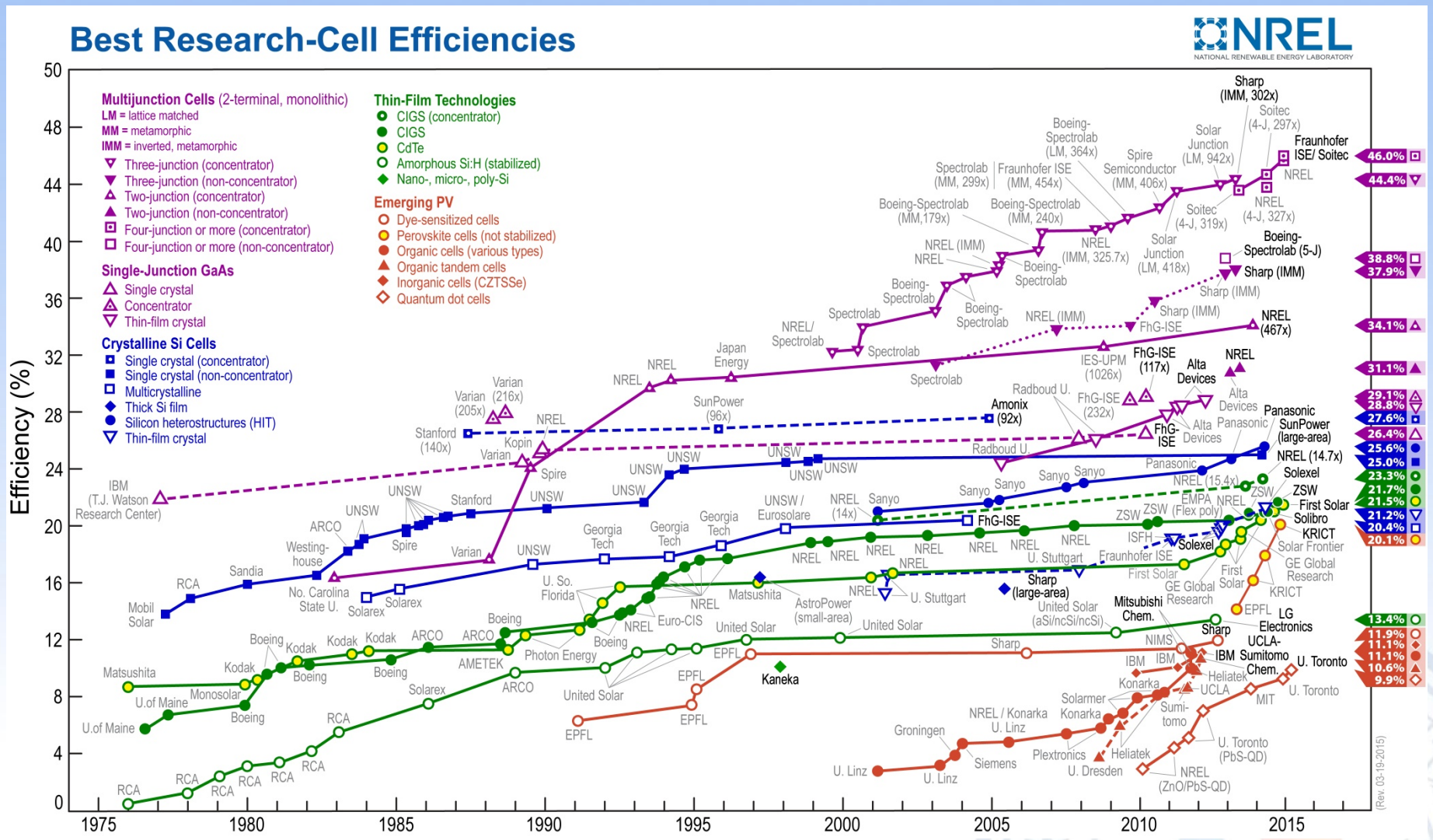
– A Case Study from Xiamen University DC Microgrid

Fengyan Zhang, Professor
Director of Institute of Solar Energy,
College of Energy, Xiamen University

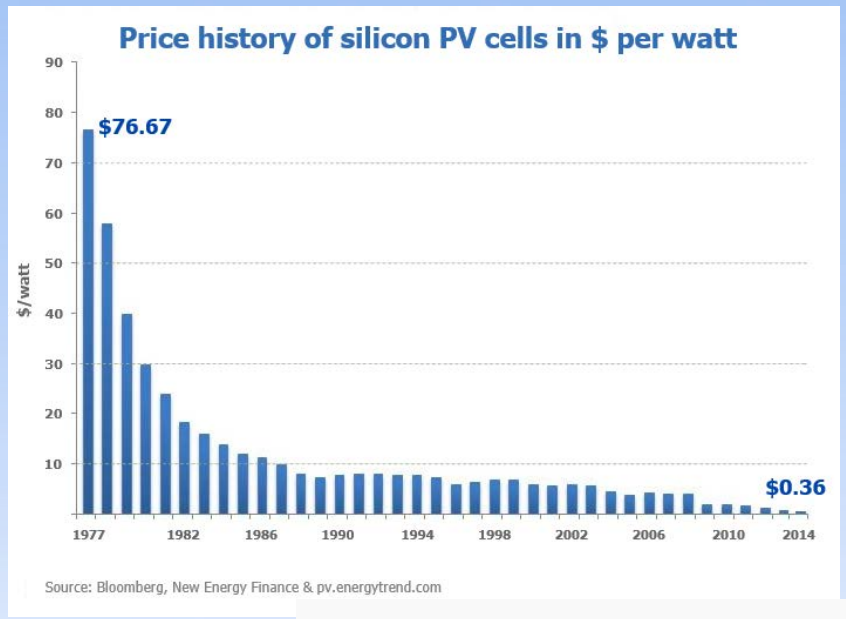
发展能源技术 共同改变世界

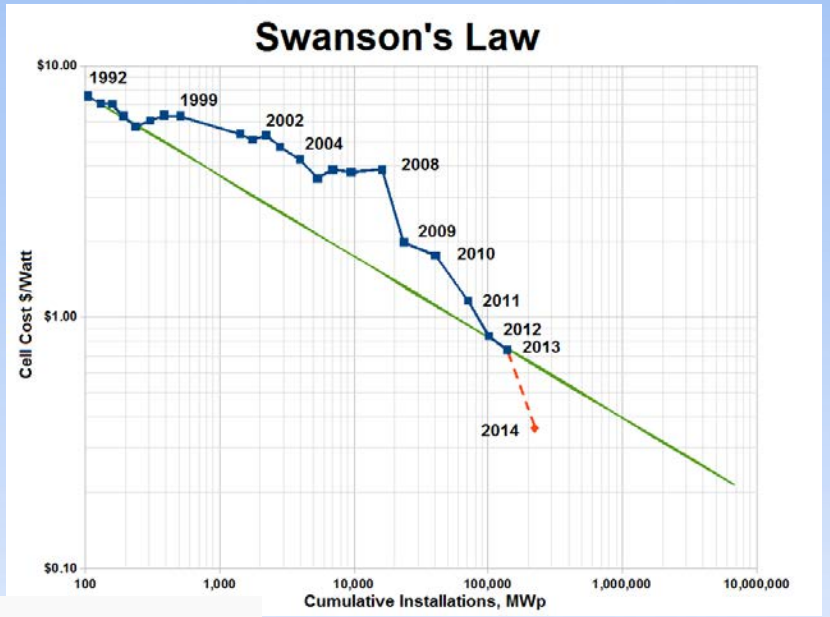
Develop Energy Technologies Change the World Together

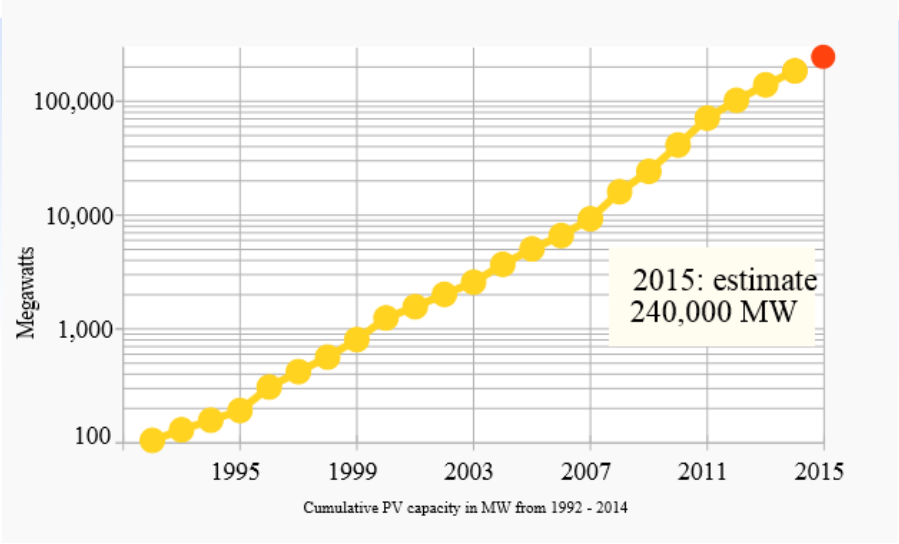
Best Research Solar Cell Efficiencies



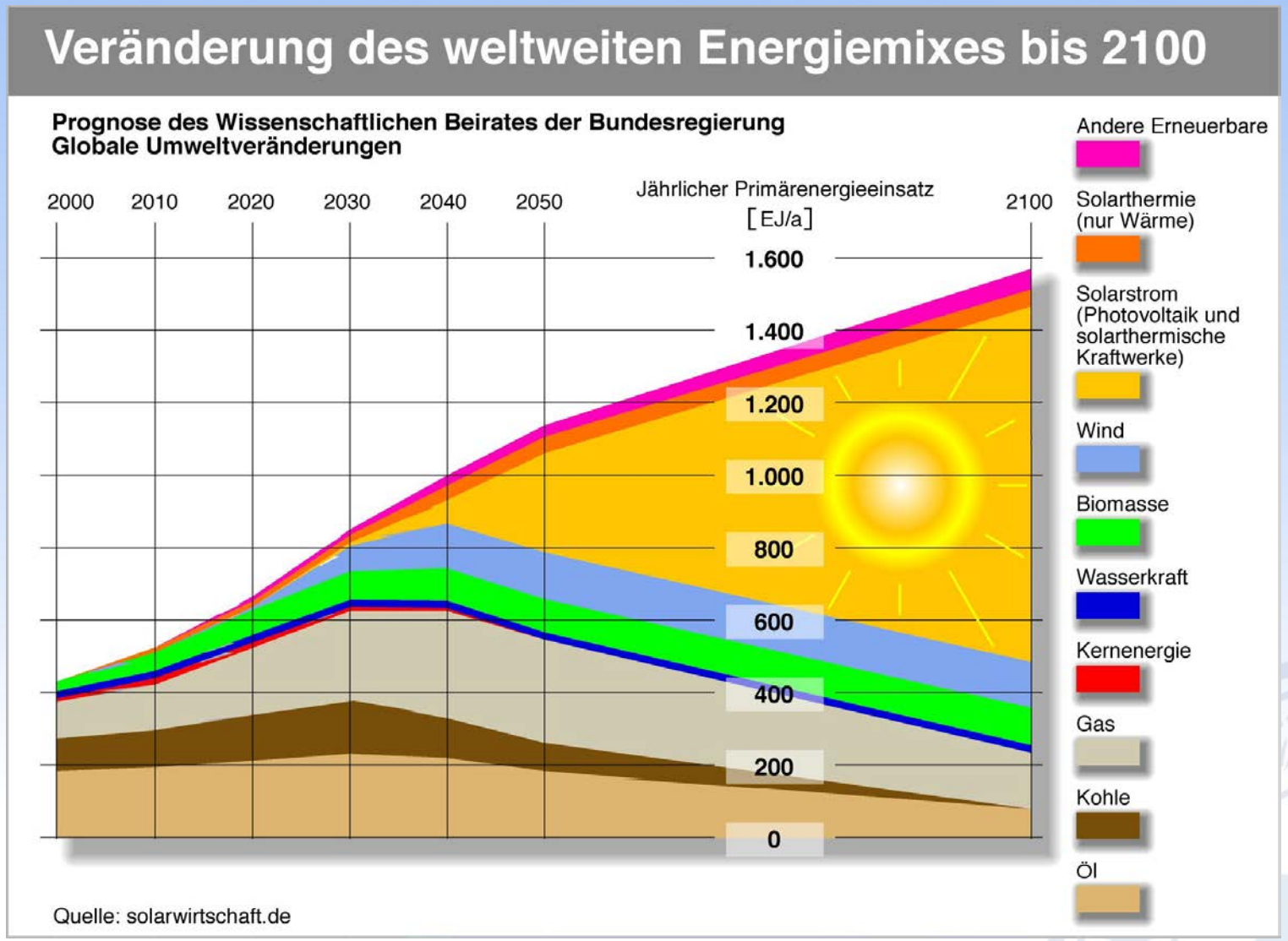
Cost Reduction of Solar Cells







Global Primary Energy Consumption Prediction



Geothermal
Other Renewable

Solar thermal
(Heat only)

Solar Electricity
(PV
and solar thermal)

Wind

Biomass (modern
traditional)

Hydropower

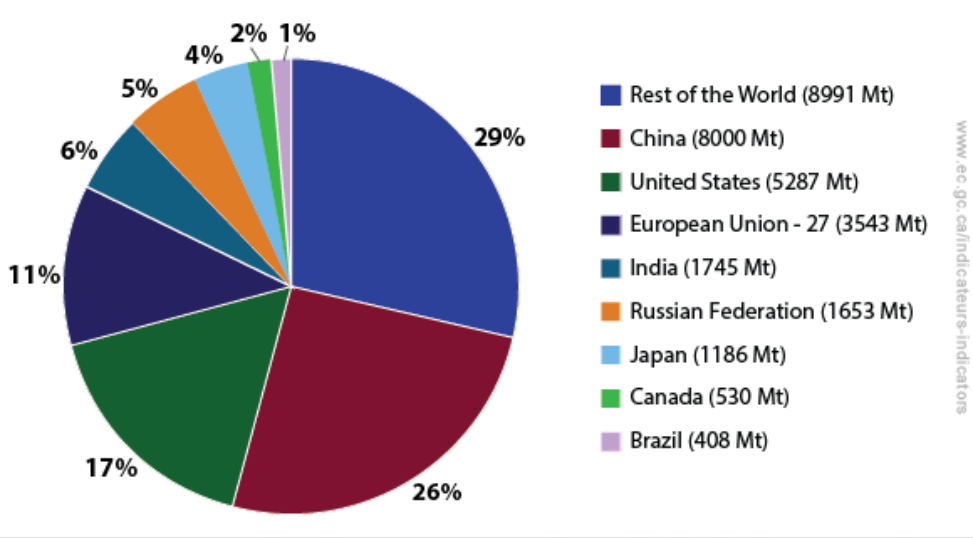
Nuclear

gas

coal

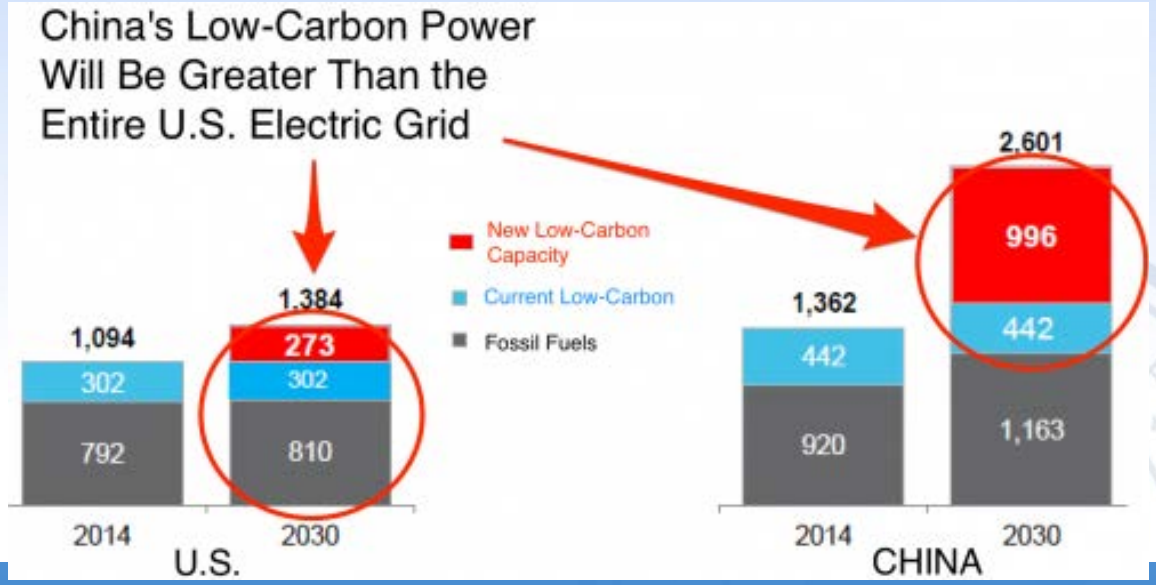
Oil

China Low Carbon Effort



Source： USEPA

Chinese government is going out of its way to streamline processes that might help the country well exceed previous years' end-of-year figures, and reach — if not exceed — this year's target of **17.8 GW**.



Michael Graham Richard (@Michael_GR)
Energy / Renewable Energy
April 22, 2015

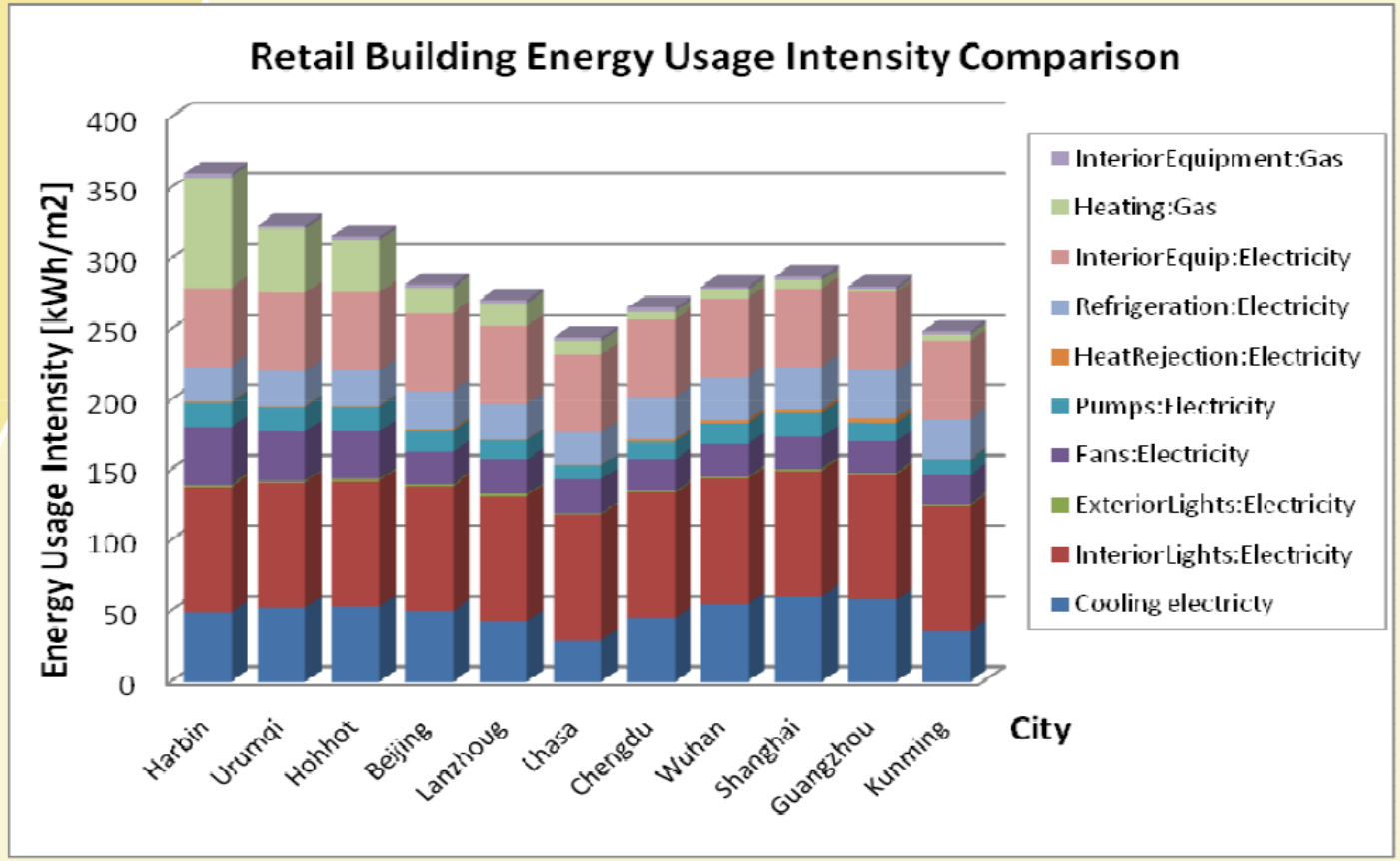
Utility Scale vs. Distributed Solar Energy

Load Analysis for Commercial Building

china_regional_CN.pdf - Adobe Reader

文件(F) 编辑(E) 视图(V) 窗口(W) 帮助(H)

20 / 30 125% 注释 共享



- 建筑
候分
- 多数
荷

27.937 x 21.587 厘米

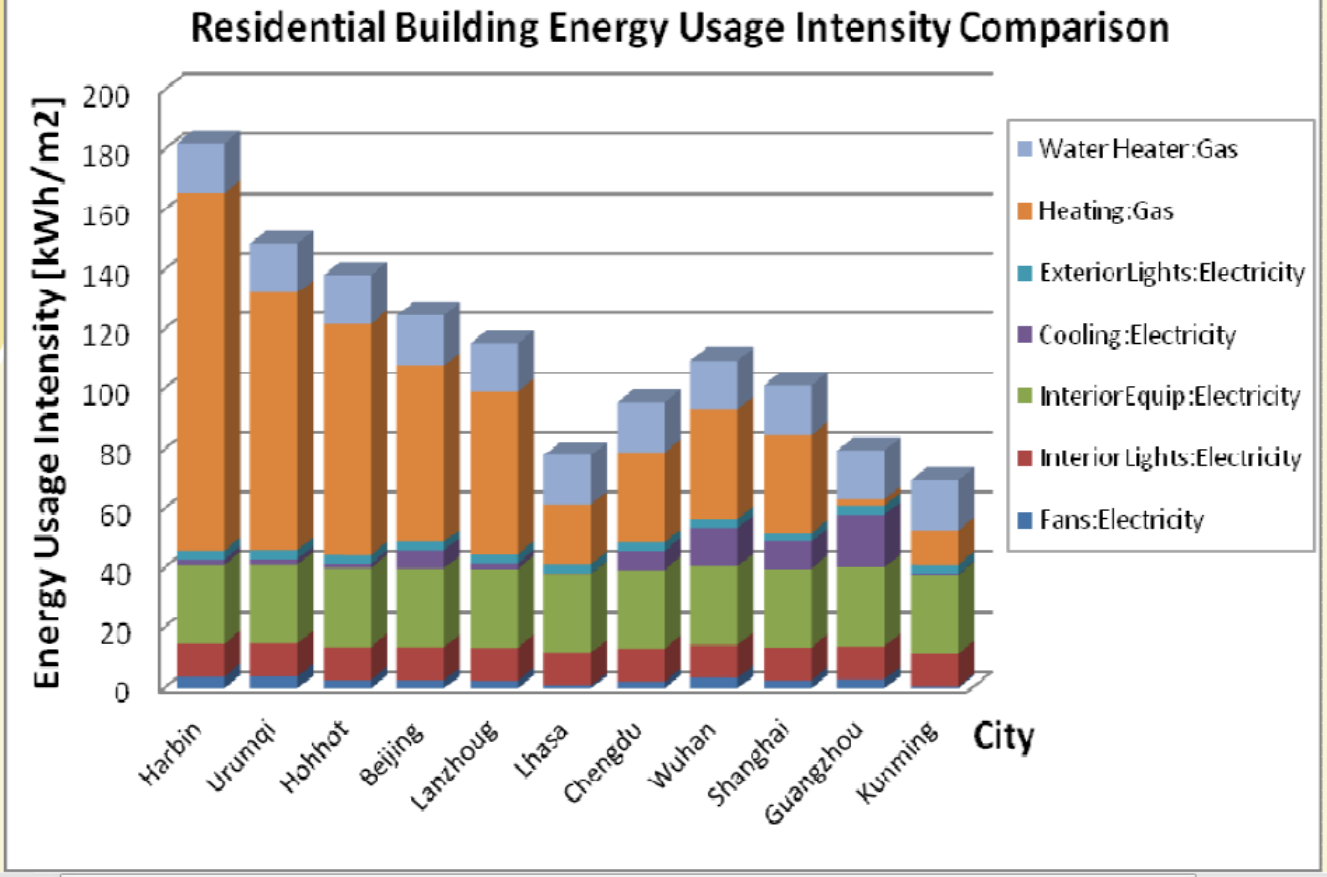
100% 18:18 2013-05-25

Load Analysis of Residential Building

china_regional_CN.pdf - Adobe Reader

文件(F) 编辑(E) 视图(V) 窗口(W) 帮助(H)

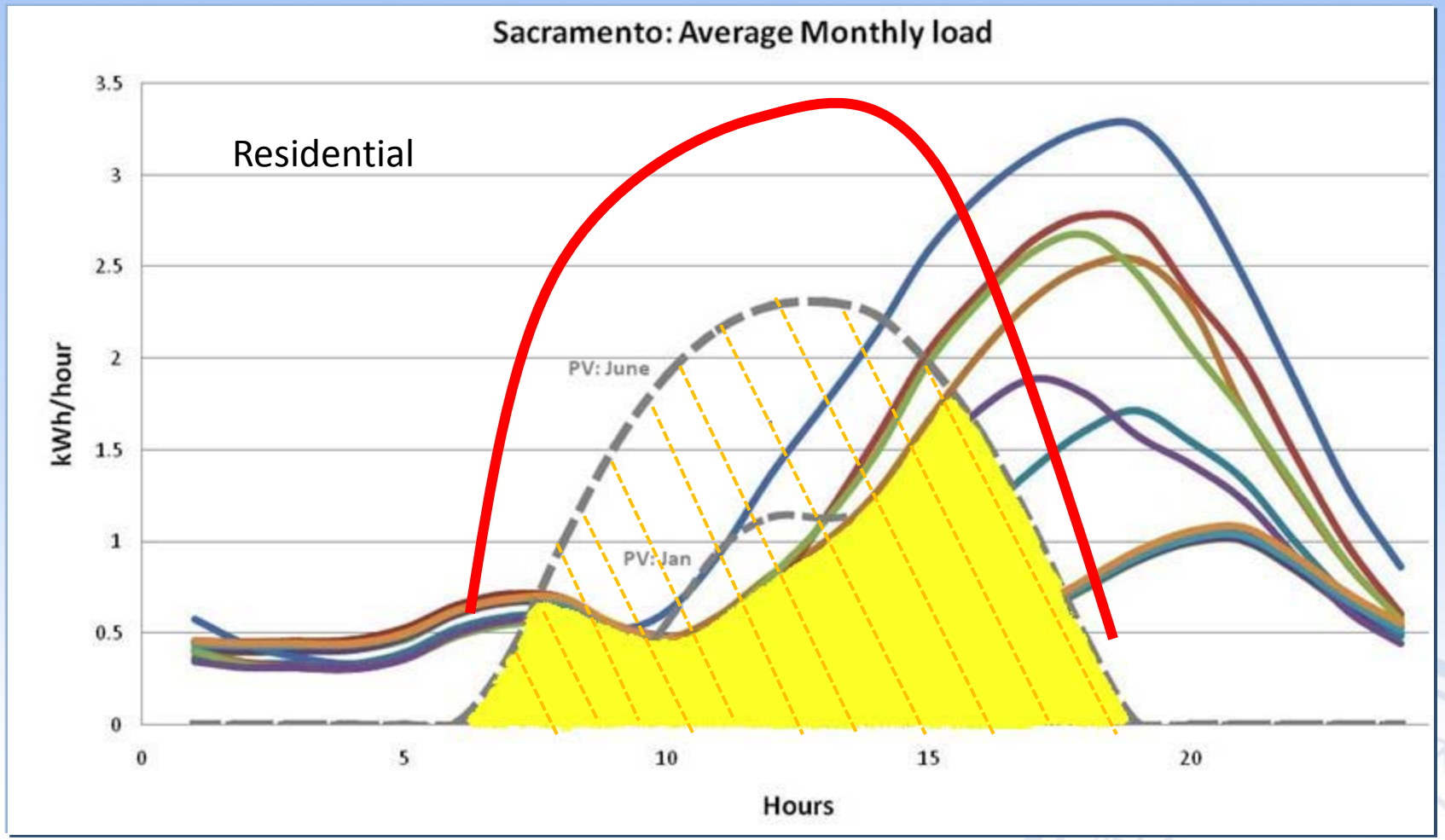
21 / 30 125% 注释 共享



- 建筑
  分区
- 北方
  量的

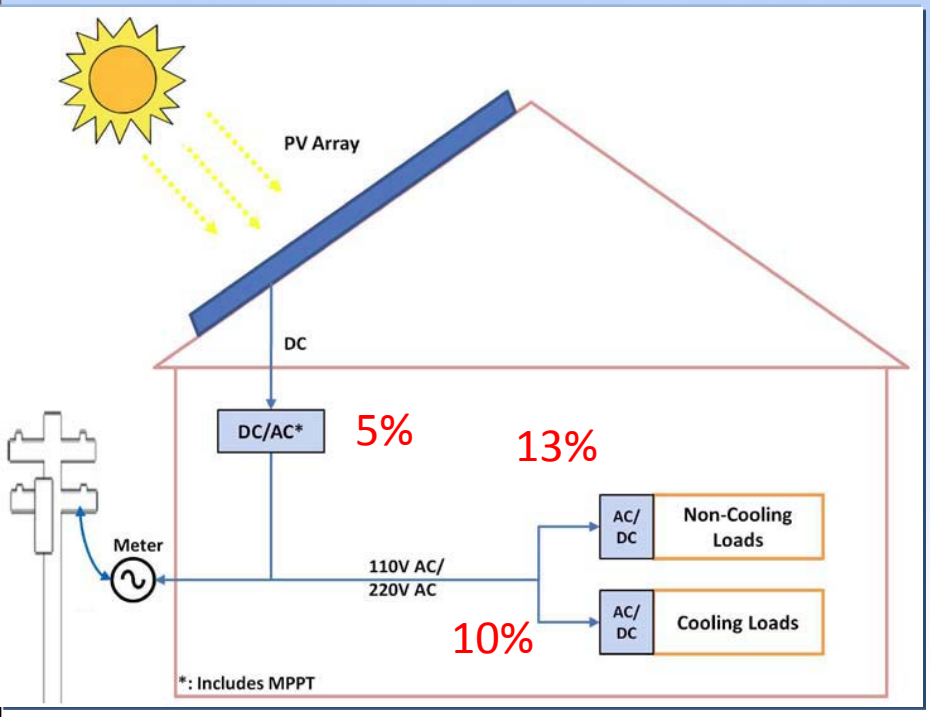
27.937 x 21.587 厘米

PV Generation and Building Energy loads

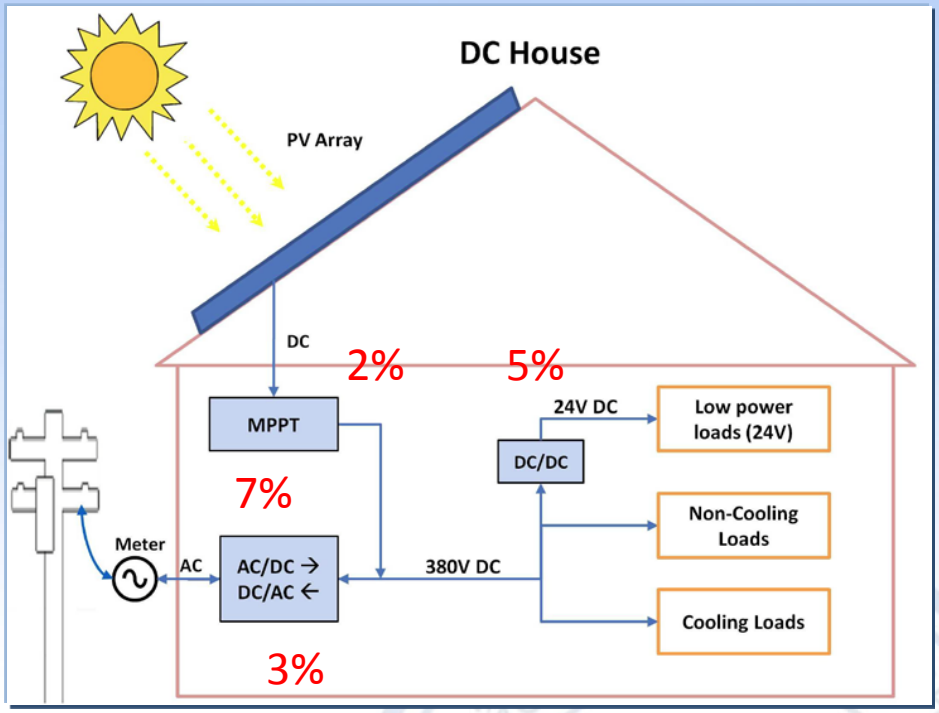


AC vs. DC on Energy Efficiency

AC



DC



Xiamen--Geological Location

YAHOO-TRAVEL

XIAMEN, traditionally known in the West as Amoy, is a surprisingly pretty city, its streets and buildings, attractive shopping arcades and bustling seafront boasting a nineteenth-century European flavor.

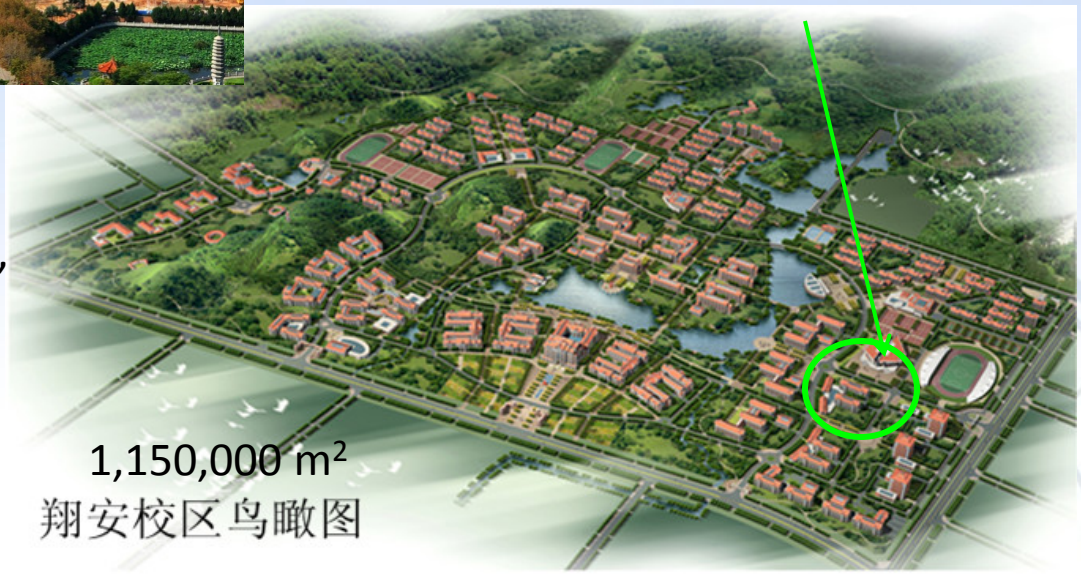
Xiamen

-- Special Economic Zone,
--Economic growth rate exceeded 15%
-- Population reaching 3.53 million

Current and New Campus of Xiamen University

Founded in 1921,
One of China's higher-level universities “211 Project” and the “985 Project”.
Recognized as one of the most beautiful universities in China.

School of Energy



1,150,000 m²
翔安校区鸟瞰图

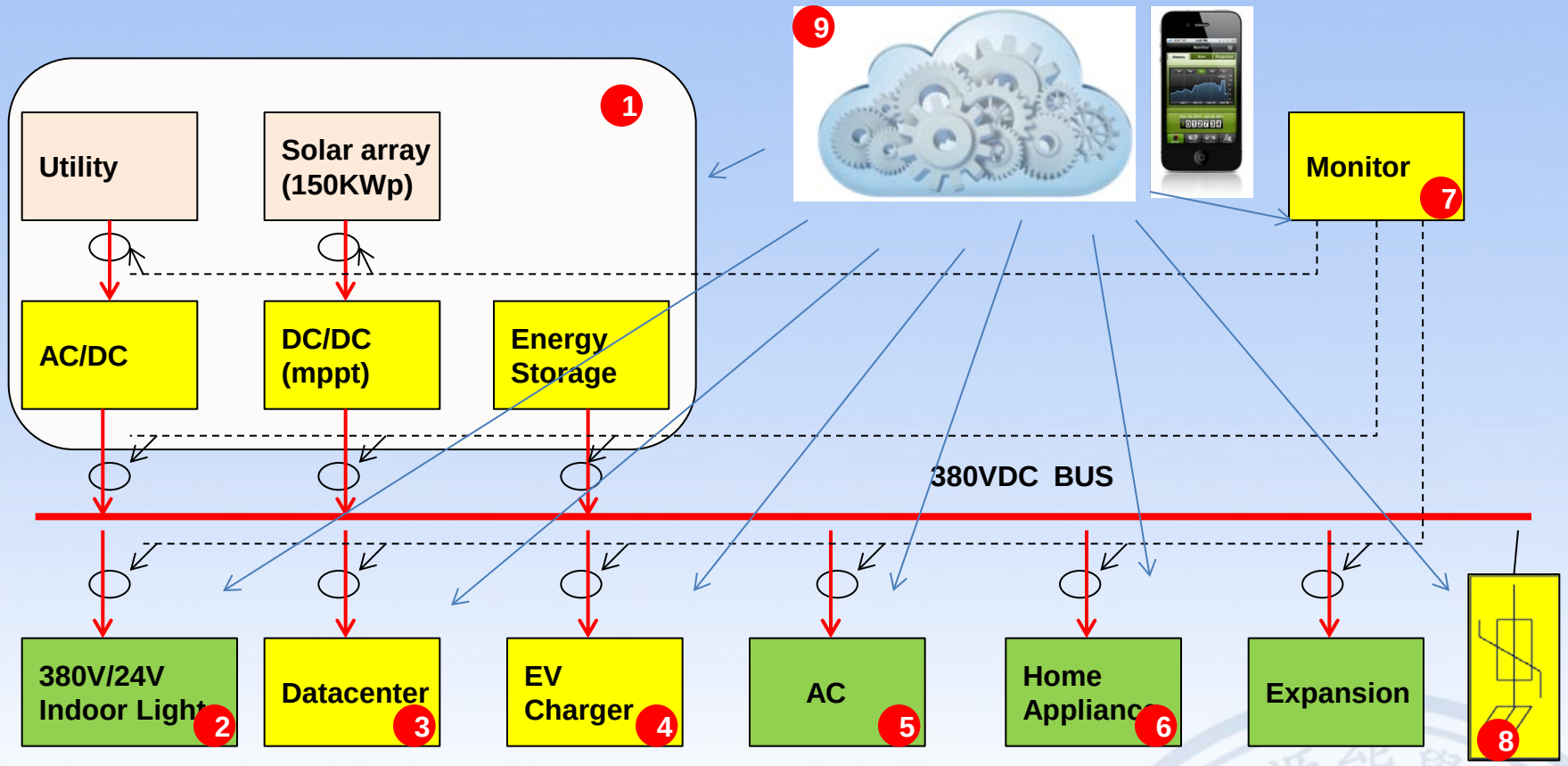
38,000 full-time students on campus,
20,575 undergraduates,
15,590 master students,
2,567 doctoral students,
2500 international students

School of Energy at Xiang An Campus

Green building
LED light,
Low E glass
Roof top and vertical green plantation
Rain water collecting
Shading

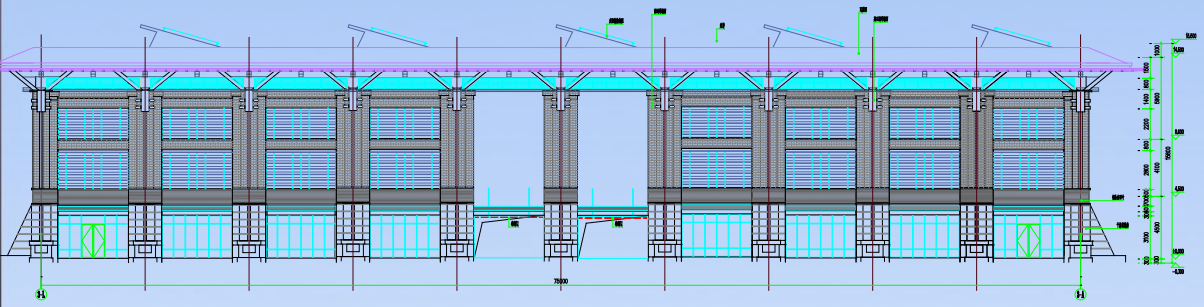
Advanced Nuclear Energy,
Solar Energy,
Chemical Energy,
Bio-energy,
Energy Efficiency Engineering and Energy Economics.

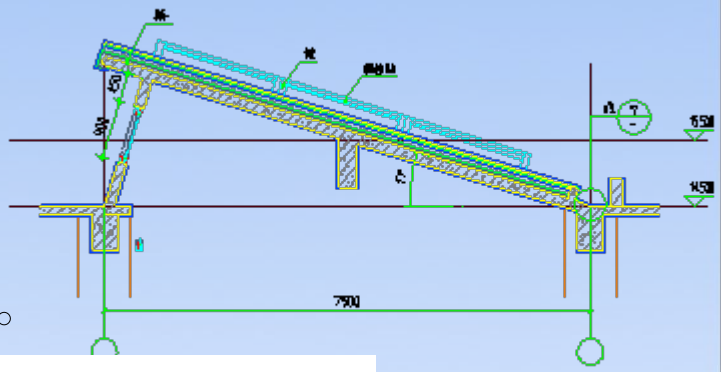
DC Microgrid at Xiamen University

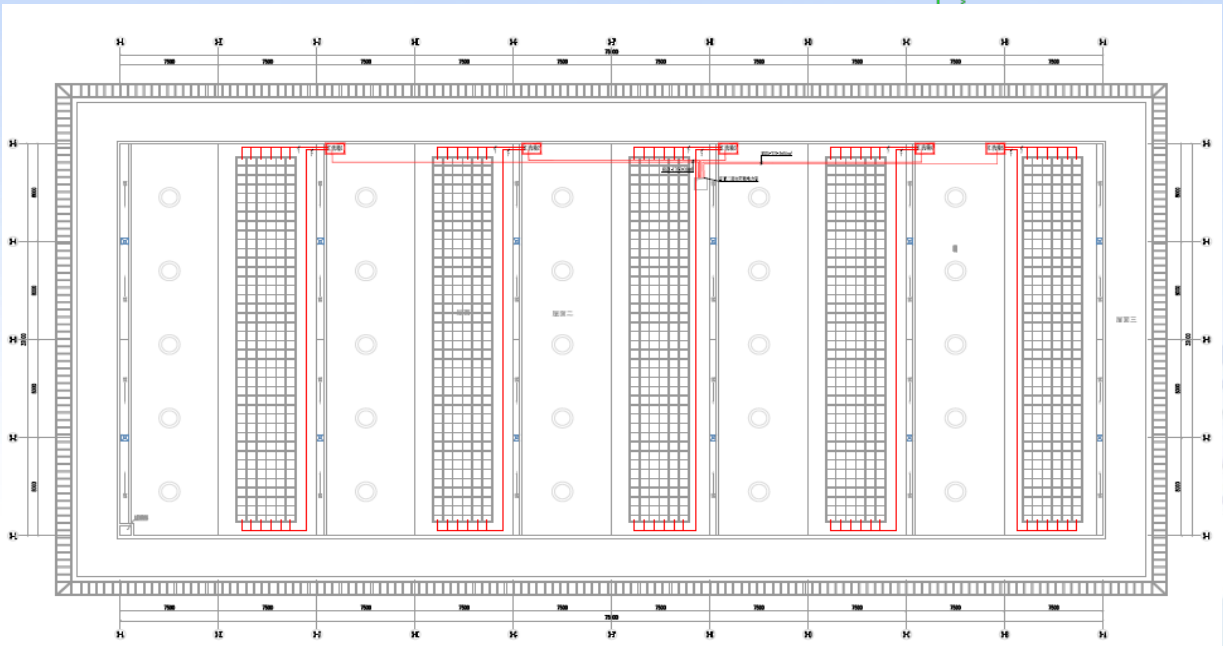


1. AC/DC, MPPT and Energy Storage
2. Indoor DC lighting
3. Data Center
4. EV Charger
5. Air Conditioning
6. Home and Office Appliance
7. 9. System Monitor and Control
8. System Safety

150KWp Roof Top Solar System



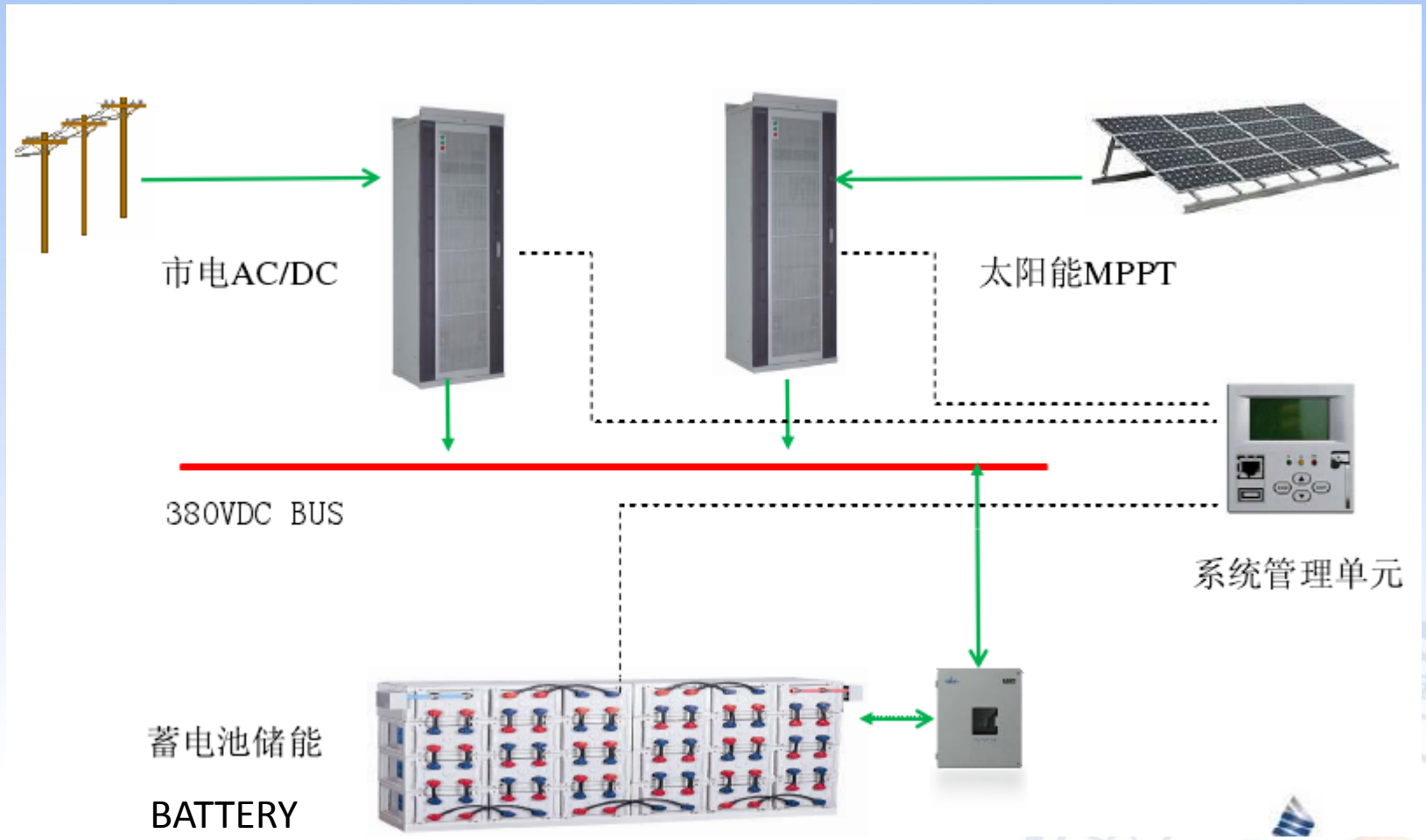




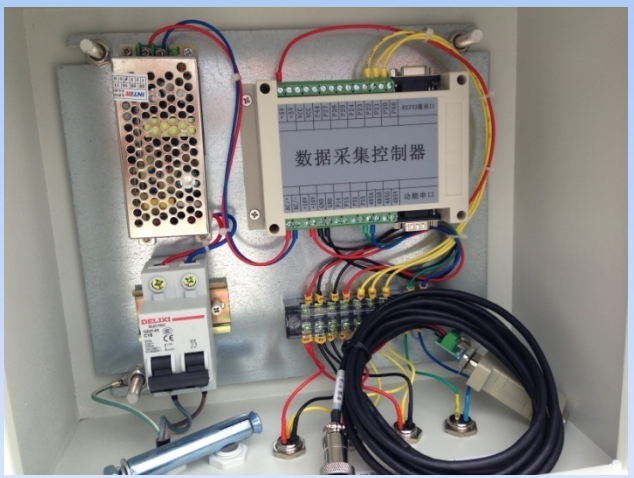
Roof Top 150KWp Solar System

Poly-Silicon: 240W， 150KWp

380V DC Power Supply System

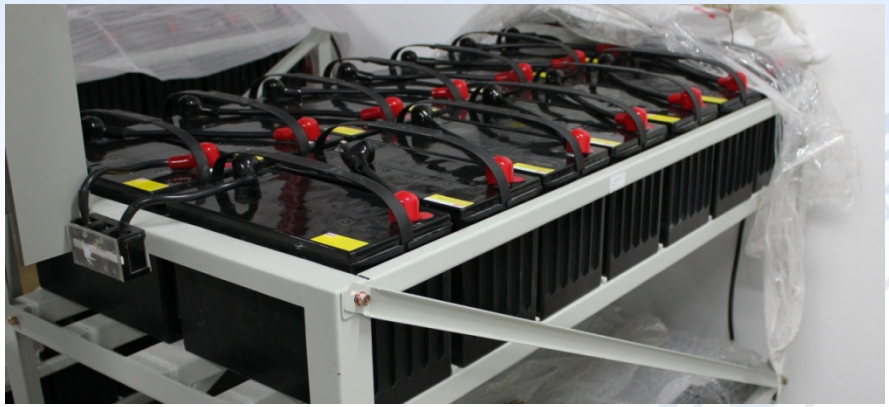


MPPT, AC/DC, Energy Storage



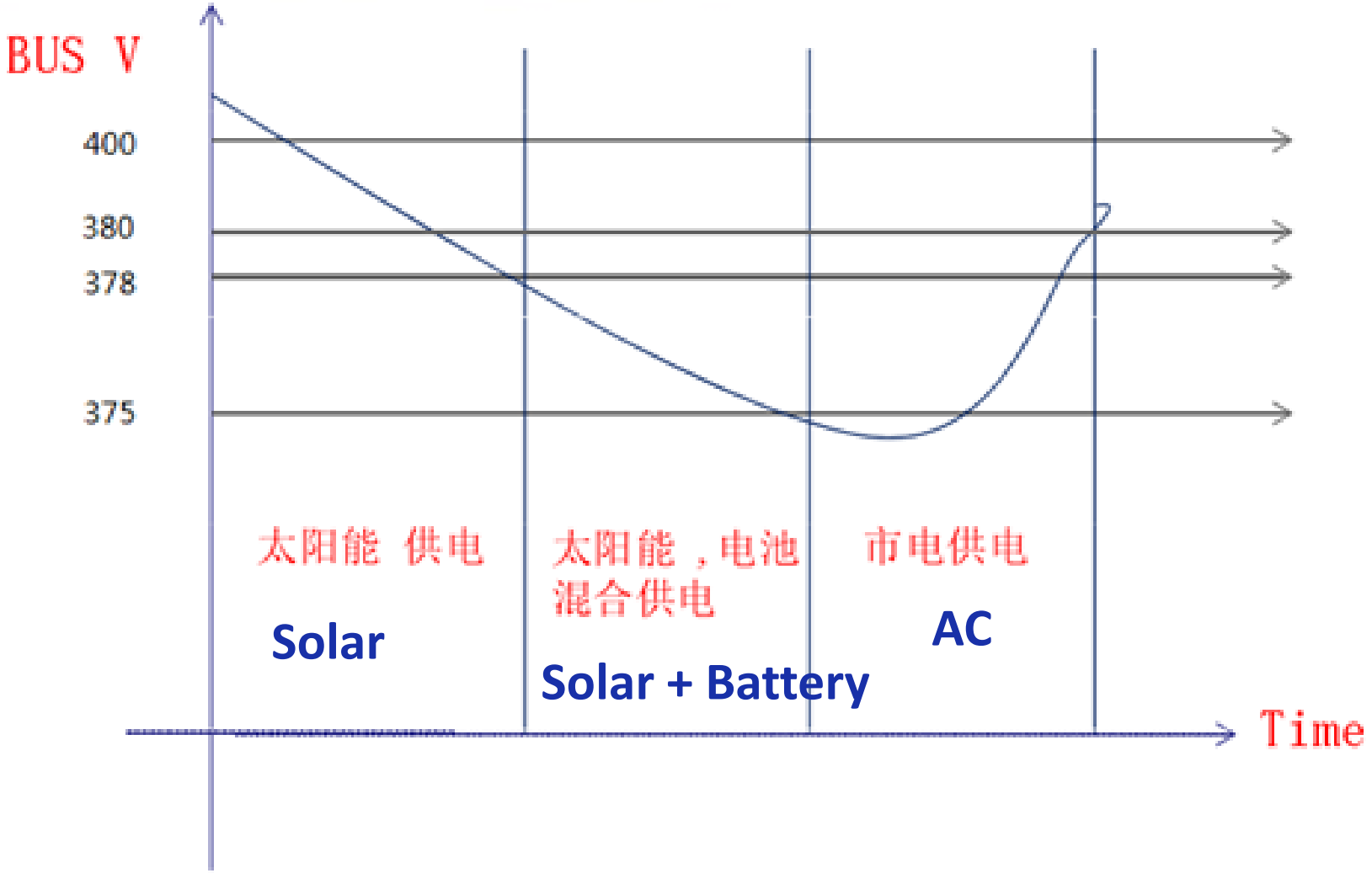
MPPT，AC/DC，

200AH
lead acid battery



Monitor
and
Control

DC Microgird Operation Logic



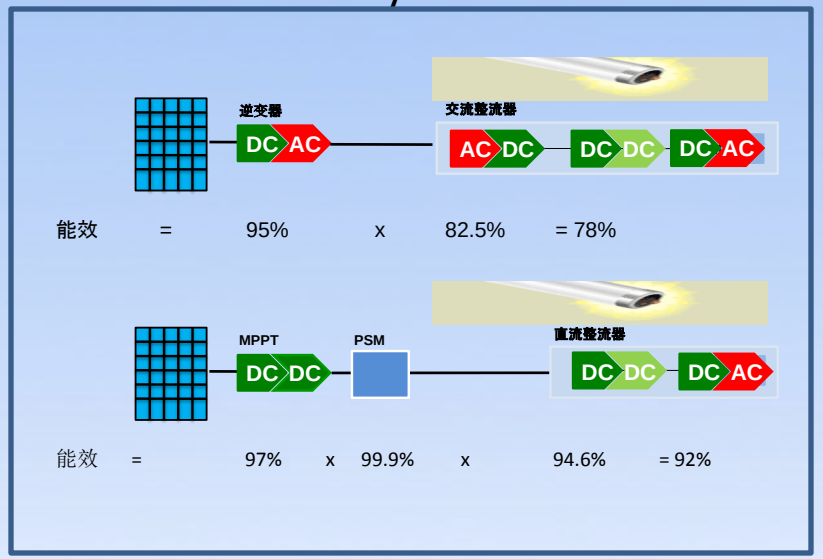
DC Loads Distribution

5 Arrays 150KW x 80% =120KW； AC back up： 120KW
4 arrays 120KW x 80% =96KW； AC backup： 96KW
（shadowing on the second array）

Loads	Power	location	
DC lighting at North Building	12kw	2号楼北楼一层照明，各层走廊照明。	
DC lighting at South Building	8kw	2号楼南楼南面中部五间办公室照明，各层走廊照明	
AC at the Engineering Building	20kw	工程房二层8个房间空调制冷（制热）	
AC at the Data Center	8kw	2号楼南楼一层	
AC at Solar room	8kw	工程房二楼	
EV	40kw	380VDC/220VAC，	
Show room	10kw	各种直流应用产品展示，	
Total	**106kw**		

DC LED Lighting

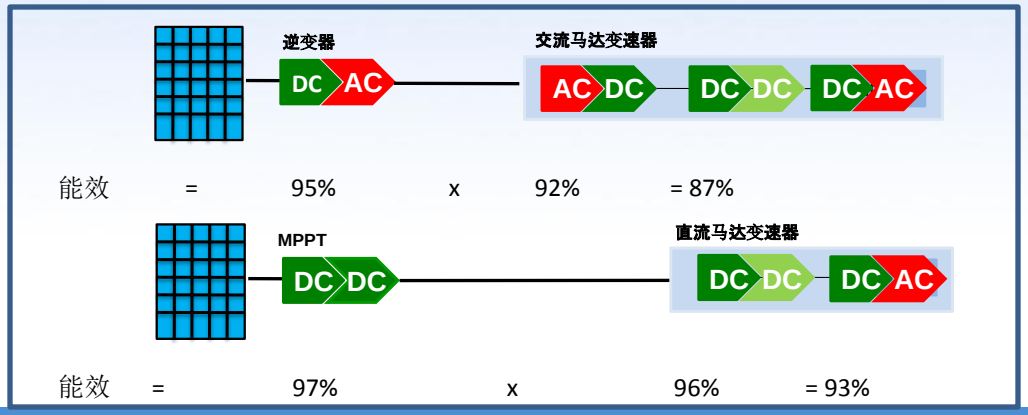
Efficiency Increase



DC Solar- DC LED Lighting

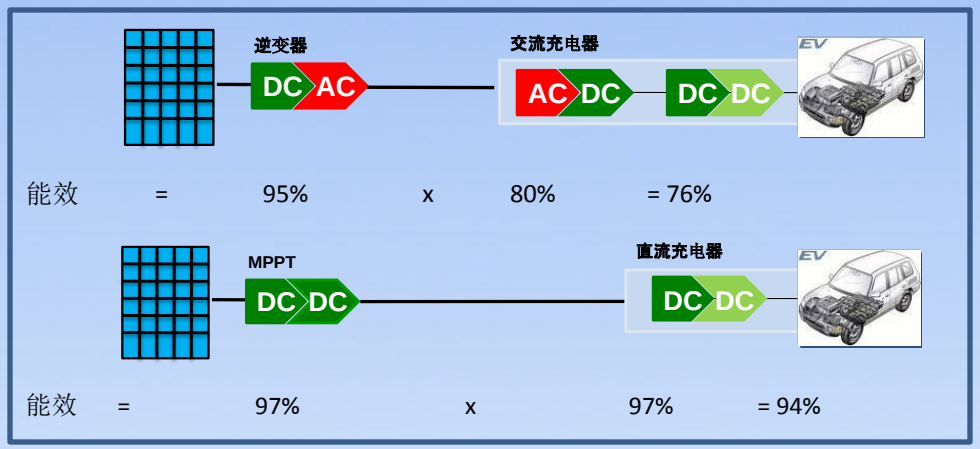
DC Air Conditioning

实验室序号 Lab #	实验室面积/平方米 Lab Area/m2	所需制冷量/kw Refrigerating Capacity/kw	空调制冷功率/kw Refrigeration Power/kw	空调电功率/kw Power/kw
小实验室1#	19.125	3.25125	3.5	2.4
小实验室2#	19.125	3.25125	3.5	2.4
小实验室3#	19.125	3.25125	3.5	2.4
小实验室4#	19.125	3.25125	3.5	2.4
小实验室5#	19.125	3.25125	3.5	2.4
小实验室6#	19.125	3.25125	3.5	2.4
小实验室7#	19.125	3.25125	3.5	2.4
小实验室8#	19.125	3.25125	3.5	
太阳能发电间	34.25	6.765	3.5*2	
信息系统间	108	28	5.1*6	
总功率（total）		60.775	65.6	



DC EV Charging Station

Top EV Car in China, BWD e6



220V AC Port。

380V-1000V DC Port。
1.5 hour full charging

300km, 60kwh

$EE = MC^3$

Energy Efficiency = Monitor, Control, Compare, Compete

Monitor
Spending in real time

Control
Recommendations

Compare
State, Country, World

Compete
Post to Facebook

Market Potential 1--DC LED lighting

Shopping Center

Hospital

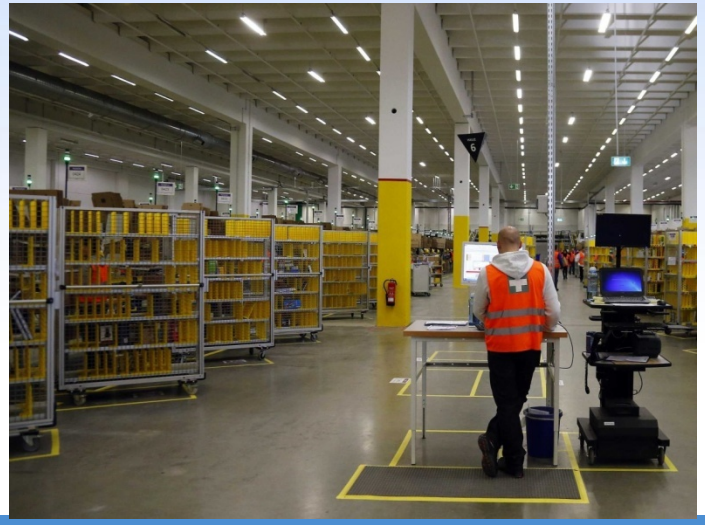
Office

School

Market Potential 1 --DC LED lighting

Tunnel

Parking Structure



Warehouse

Example

能源学院和木楼南楼共四层进行计算，其中一拖三3*20w日光灯共87套，一拖二2*20w日光灯共312套，即总共885根日光灯管，我院所有灯管均采用TCL公司20W的荧光节能灯管，相应LED灯14W,翔安校区电费0.5234 元/度。

E=900*14*8=100800W=100.8KW
P=100.8/(3*0.8)=42KW
A=2000m2, (Roof Area)
N=1000/1.6=625, (Number of Solar panels)
P=625*250=156.25KW, (solar system capacity)
n=156.25/42=3.72, (number of building powered)

Market Potential 2 --DC Air Conditioning

For Single level Buildings

Market Potential 2 --DC Air Conditioning

For Multilevel Buildings

Market Potential 3 --DC EV Charging Station

The Tesla Supercharger network is the innovative company's proprietary fast charging technology, allowing a Model S to be completely recharged in less than an hour. The design combines high-voltage fast-charging, a solar-power carport, and a **half-megawatt-hour stationary battery pack**.

It relates to the market for smart grid services. Musk said that Tesla is partnering with the utilities on grid energy storage, with Supercharger stations acting as a "grid buffer." Some utility rate structures impose large "demand charge" fees when there are large spikes in power usage. Plugging in a Model S causes about 90-120 kilowatts of electricity demand, which is a large demand spike. Placing a large battery pack, say a half-megawatt-hour next to the Supercharger station means the cars can be charged directly from that pack without the electricity grid seeing the spike.

Market Potential --DC EV Charging Station

Each station will have a solar canopy, and all the company said its goal is to "reduce peak on the grid and provide energy for charging. smart grid services—enabled by inter-connected EV charging, solar panels and stationary battery packs—might become the unexpected killer app of the electric car era.

Market Potential --DC EV Charging Station

BEIJING, Jan. 15 (Xinhua) -- The construction of electric vehicle charging stations along the 1,262-km expressway that links Beijing and Shanghai finished on Thursday.

State Grid, one of China's two grid corporations, built 50 quick-charging stations along the route, making it the country's first cross-city charging network.

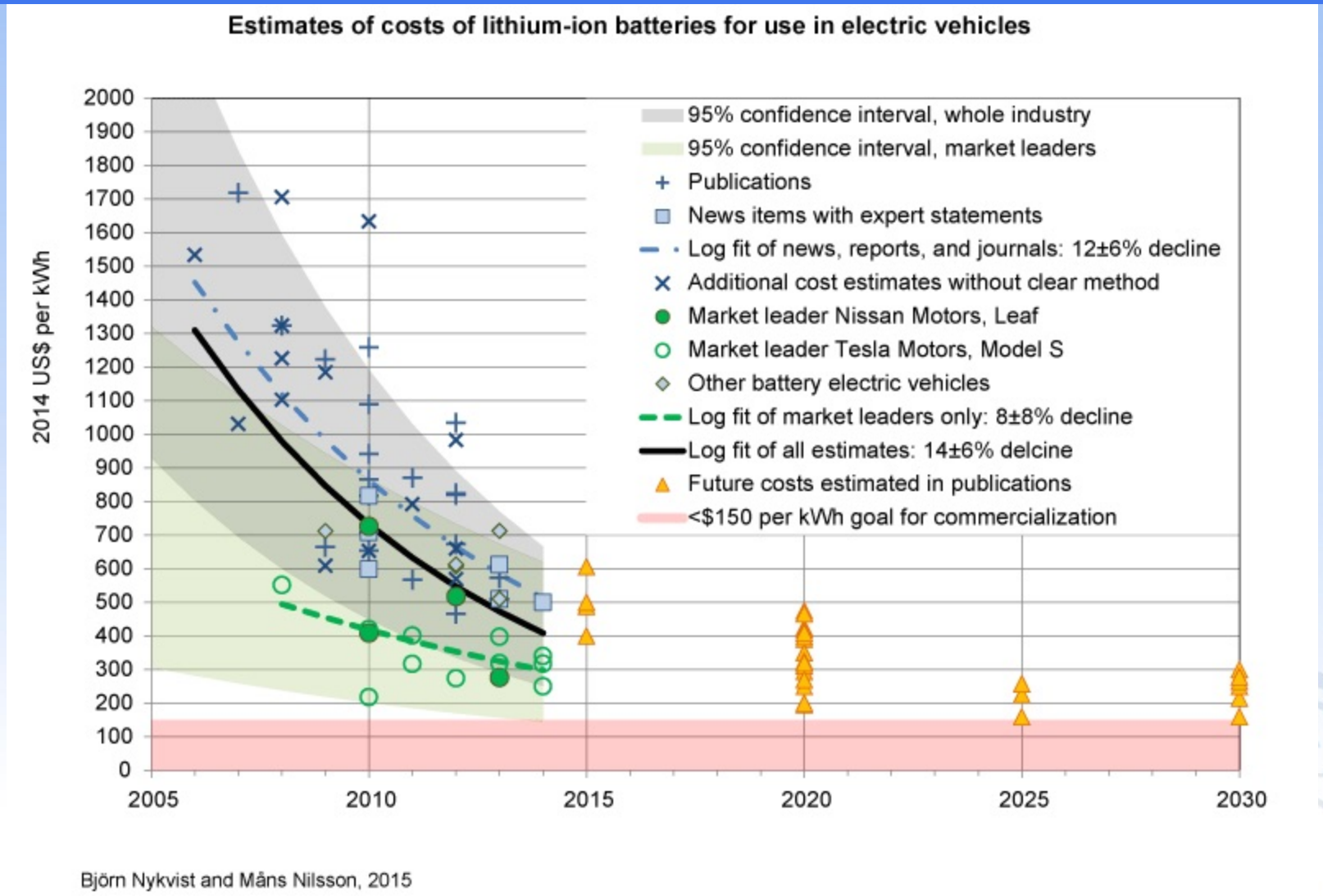
Each of the stations has eight charging poles capable of fully charging an electric car in 30 minutes. All electric cars that meet Chinese standards can use the charging facilities.

State Grid built 133 quick-charging stations with 532 charging poles along three major expressways with total length of 2,900 km in 2014.

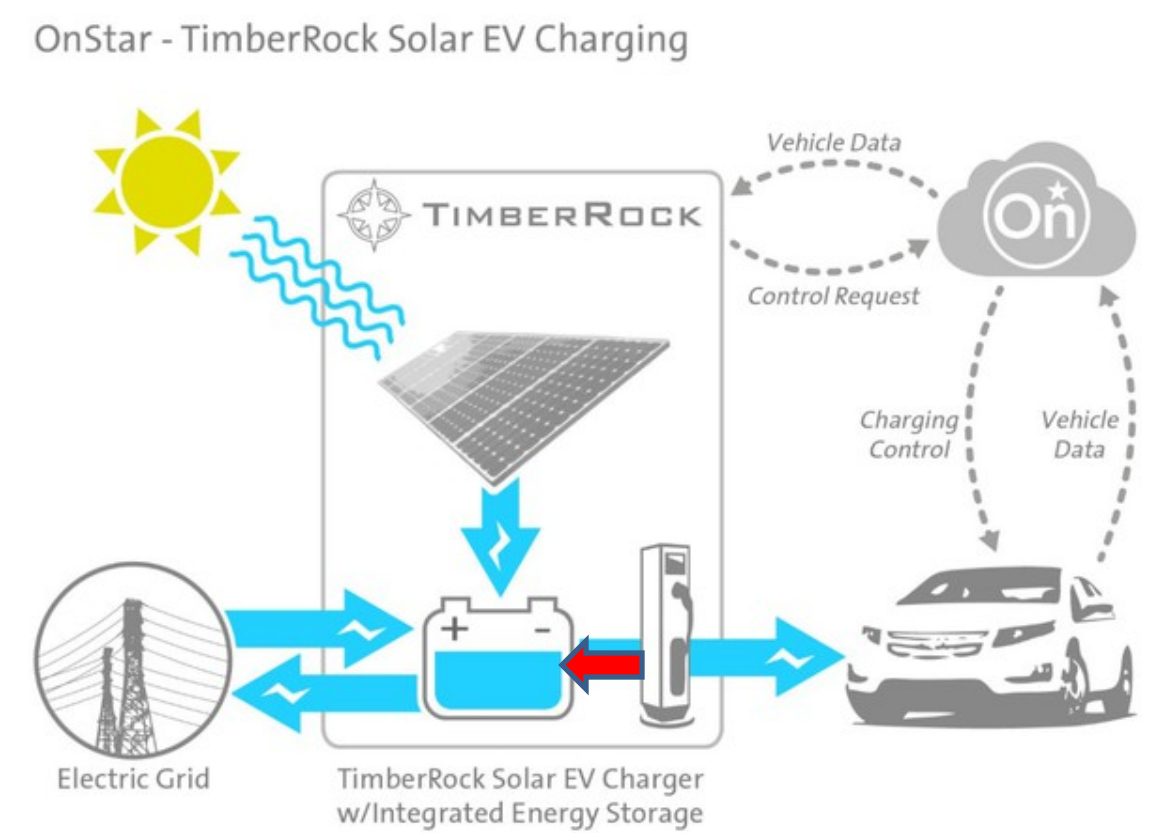
The company aims to build charging station networks along eight major expressways with total length of 19,000 km in China by 2020.

Electric vehicles are gaining popularity in China amid its "green" drive, but buyers are hesitant as they worry about a lack of charging stations

Estimate Cost of Lithium-ion Battery



EV and Future Grid



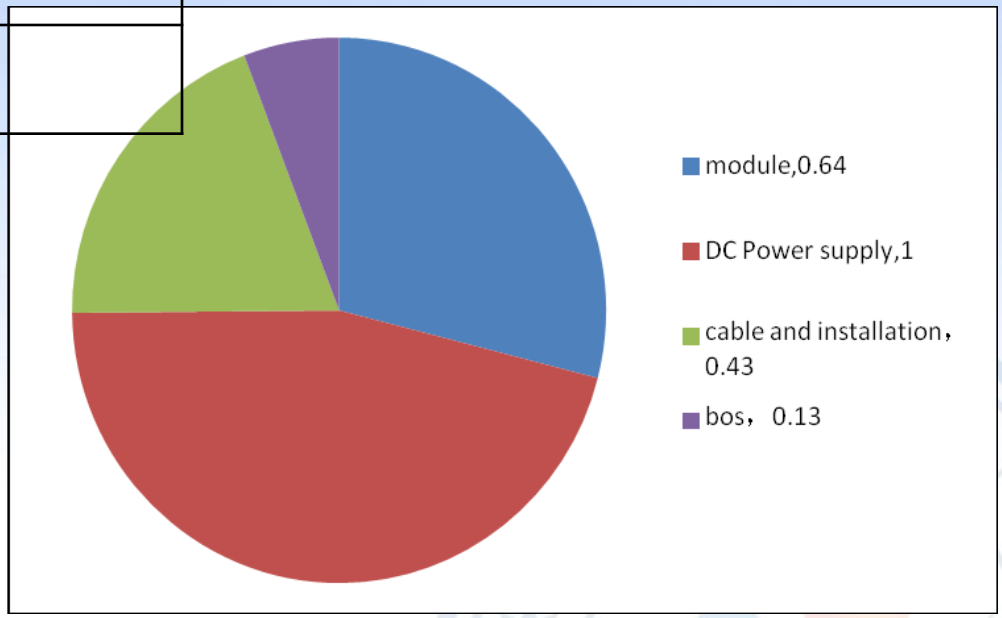
GM's OnStar and TimberRock are developing solar-powered charging stations that will store energy.

In fact, General Motors announced on Wednesday a partnership with TimberRock for EV Solar Charging with many of the elements Tesla is using in the Supercharger stations. They are explicitly going after smart grid services that will scale electric car charging rate depending on capacity needs of the grid.

Economic Analysis

	DC Power supply	DC Microgrid (Power supply+ load)
Total investment	$330K	$400K
Incremental cost	$2.2/W	$2.7/W
Cost effectiveness	$0.059/kwh	0.072/kwh
Static payback Period (no incentive)	9 years ($0.16/kwh)	
Static payback Period (w/ incentive)	5.5 years ($0.887/W)	

Cost breakdown for a DC Microgrid power supply system



With system installation cost at $2.2/W, payback time at 9 years with electricity price at .16/kwh and no incentive, we believe DC microgrid is becoming a marketable technology

Economic Analysis

Solar Module：600KRMB；**Electrical System**：950KRMB；**BOS**：120KRMB；
Installation：400KRMB；**DC Loads**：450KRMB

Total Investment：**2.06 million（DC Power Supply），**
2.5 million（DC Power Supply and DC loads）

Incremental Cost：13.7RMB/W （**DC Power Supply**）
16.7RMB/W （ **DC Power Supply and DC loads** ）

Cost Effectiveness：0.3669RMB/kwh (**DC Power Supply**)，
0.4452RMB/kwh （ **DC Power Supply and DC loads** ）

Static Payback Period：**DC Power Supply**：
18 years（no incentive）
11 years（5.5RMB/w incentive)

（calculation based on :system efficiency：83%，average irradiation time: 5.5 hours/day，25 years lifetime，power saving ：0.50RMB/kwh (residential））

9 years（no incentive）
5.5 years （ 5.5RMB/w incentive ）

（ calculation based on :system efficiency：83%，average irradiation time: 5.5 hours/day，25 years lifetime，power saving ： 1 RMB/kwh(commercial））

Third Industrial Revolution

(1) Shifting to **Renewable Energy**;

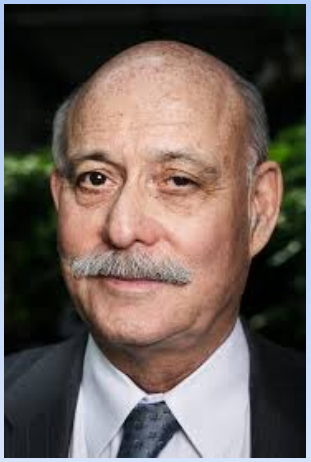
(2) Transforming the **Building** stock of every continent into **Green Micro–Power Plants** to collect renewable energies on-site;

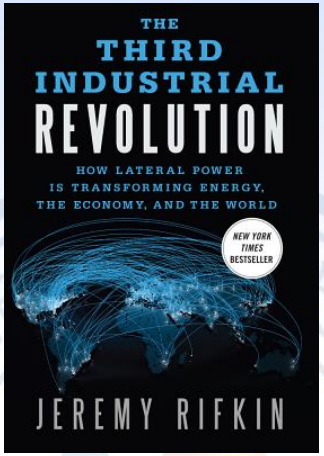
(3) **Deploying Hydrogen and Other Storage** technologies in every building and throughout the infrastructure to store intermittent energies;

(4) Using Internet technology to transform the power grid of every continent into an **Energy Internet** that acts just like the Internet;

(5) Transitioning the transport fleet to **Electric Plug-In and Fuel Cell Vehicles** that can buy and sell green electricity on a smart, continental, interactive power grid.

Jeremy Rifkin






Thank You!
Welcome to
Xiamen!