國立虎尾科技大學
NATIONAL FORMOSA UNIVERSITY

電機資訊學院 專題演講
(台灣能源的翻轉V世代)

丁桓展
行政院原子能委員會 核能研究所
核子燃料及材料組

106.10.17

行政院原子能委員會
核能研究所
INER
Institute of Nuclear Energy Research
Atomic Energy Council, Executive Yuan

學經歷

- 學歷
  - 台北工專 電機工程科畢業
  - 台北科技大學 電機工程系學士
  - 交通大學 電機與控制工程研究所博士

- 經歷
  - 102年度公務人員高等考試一級考試及格(電力工程)
  - 行政院原子能委員會核能研究所(100-106)

- 參與計畫
  - 固態氧化物燃料電池發電系統開發暨產業化建構(100-106)
  - 「淨煤、捕碳與儲碳」主軸專案計畫管理計畫(101-103)
  - 高溫固態氧化物電解電池產氫技術開發(106)

桃園市龍潭區

- 人口11萬餘
- 地名緣由
- 作物、特產：茶米魚

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- 成立於民國57年
- 緣由

Outline

- 結論與建議－邁向V未來(還是U、L？)
- 新能源政策(What’s wrong?)
- 能源安全是什麼？
- 簡介能源之路：傳統→替代→再生
- 燃料電池簡介 (不是電池)
- Q & A

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結論與建議

- 台灣能源供應是否能順利翻轉？

  V or U or L ？

- 老王賣瓜—燃料電池在替代能源之中的潛力
- 我們也要翻轉
- 想不想在能源產業，一起翻轉(打滾)？

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新能源政策發展方向 by 105/05/25

1. 穩定開源及擴大需量管理，<u>確保供電</u>
2. 全面前瞻**節能**，提升能源使用效率
3. 積極多元**創能**，促進潔淨能源發展
4. 加速佈局**儲能**，強化電網穩定度
5. 推動<u>智慧電網與智慧電錶</u>興建
6. 培養系統整合，<u>輸出國外</u>系統市場
7. <u>電業改革</u>，提升供電效率與品質

經濟部能源局，http://www.moeaboe.gov.tw/ECW/populace/content/ContentDesc.aspx?menu_id=3165

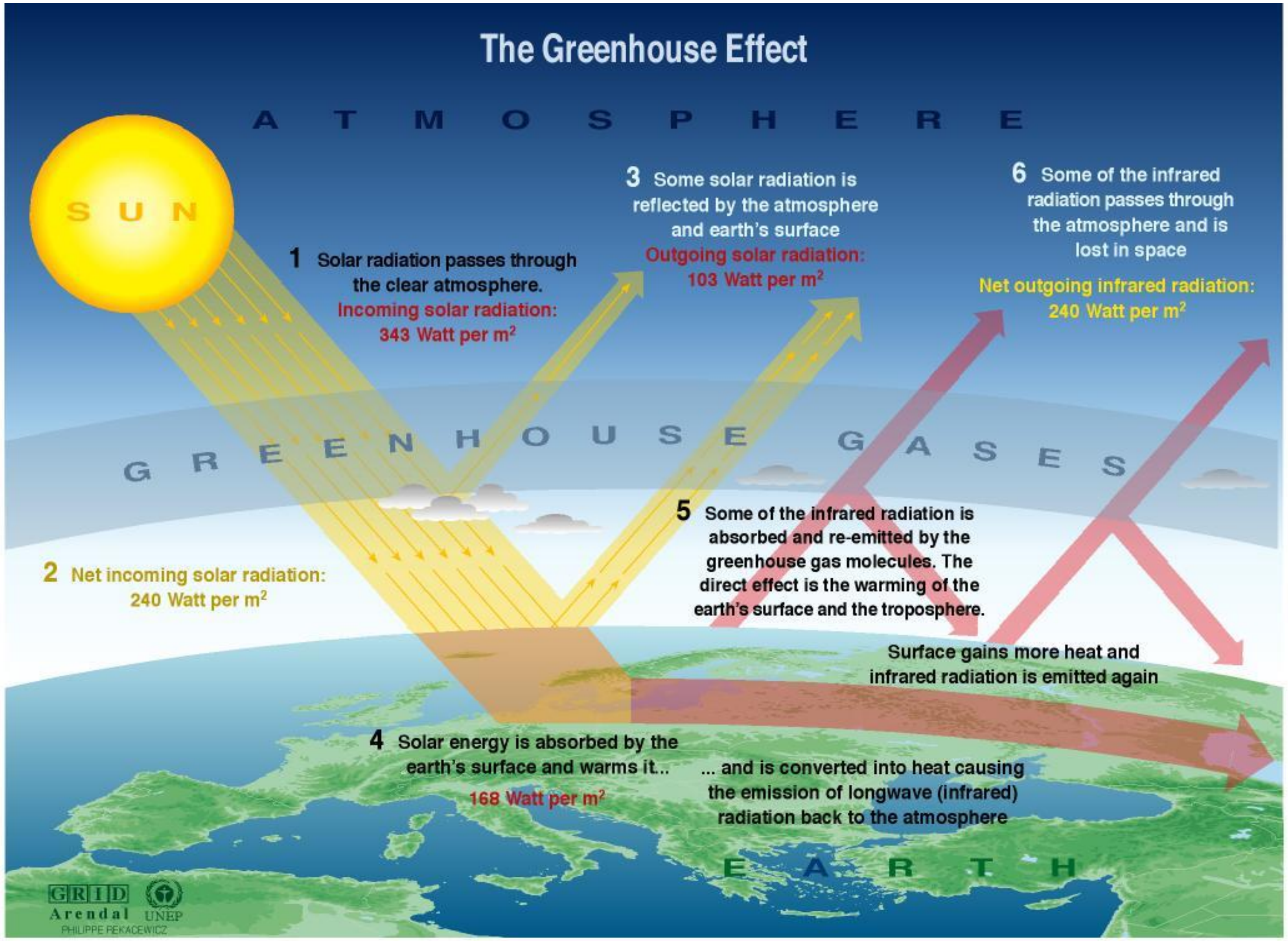
新能源政策主要內容 （7條18項）

1-1 確保未來3年(106年至108年)不缺電
1-2 規劃109至114年之長期電力供應
2-1 強制能源耗用標準(MEPS)、分級標示及節能標章推動
2-2 政府機關學校節約能源
2-3 推動產業部門節能措施
2-4 結合地方政府推動民生部門節電
3-1 確保低碳及高效率傳統基載發電
3-2 降低現有火力電廠汙染排放
3-3 全力擴大再生能源發展於2025年占比達20%以上
3-4 佈局新興能源/氫能燃料電池
4-1 改善既有抽蓄水力電廠設備，增加電力系統調頻能力
4-2 增建抽蓄水力電廠
5-1 佈建智慧電錶，積極完成關鍵通訊技術與模組開發驗證，都會區優先開設
5-2 改善既有抽蓄水力電廠設備增加電力系統調頻能力；增建抽蓄水力電廠
6-1 統籌綠能政策方向，整合產官學研資源：成立能源及減碳辦公室
6-2 推動能源產業科技研發與示範應用：沙崙綠能園區
7-1 推動廠網分離，現行綜合電業台電公司分割成發電及輸配售電2家公司
7-2 成立電業管制機關，開放發電業與售電業申設，開放電力代輸與直供、提供用戶購電選擇權

經濟部能源局，http://www.moeaboe.gov.tw/ECW/populace/content/ContentDesc.aspx?menu_id=3165

能源安全是什麼？
能源不安全嗎？

溫室效應造成劇烈氣候變遷



Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

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能源安全

- 能源資源安全：考量時間涵蓋1天至50年範圍，確保發電用原料可持續獲得

- 能源供應安全：考量時間涵蓋1秒至1天範圍,確保電力供應穩定

- <u>延伸題</u>：被鎖島了
  可以撐多久？

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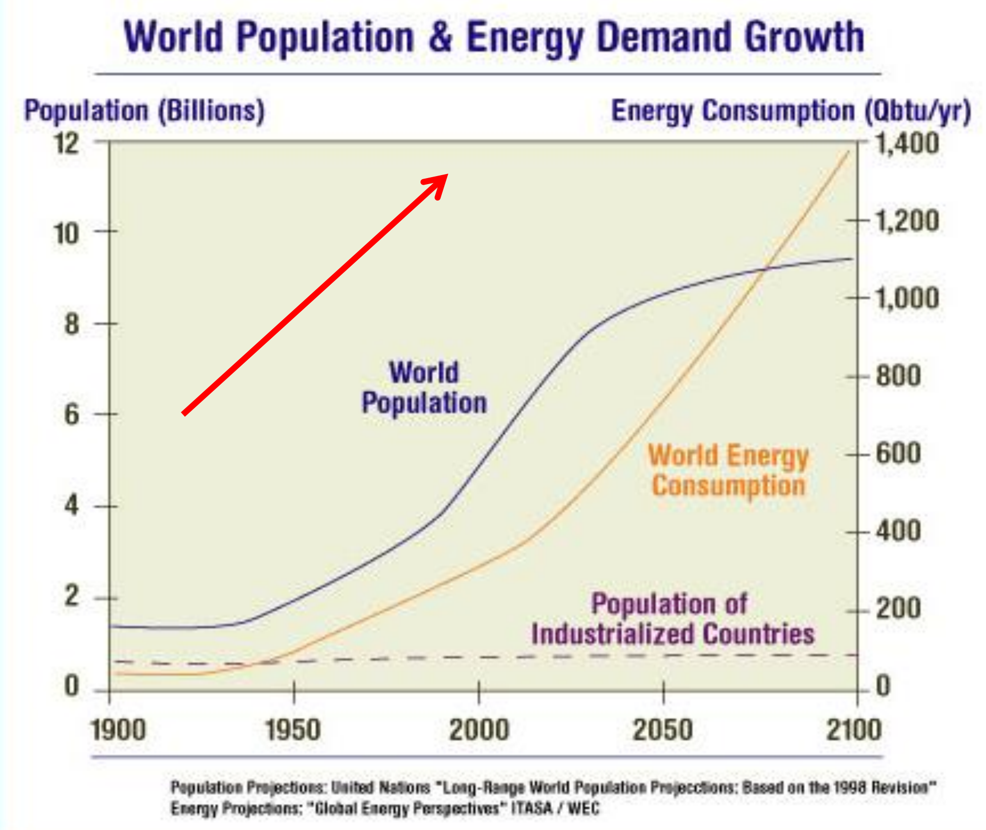
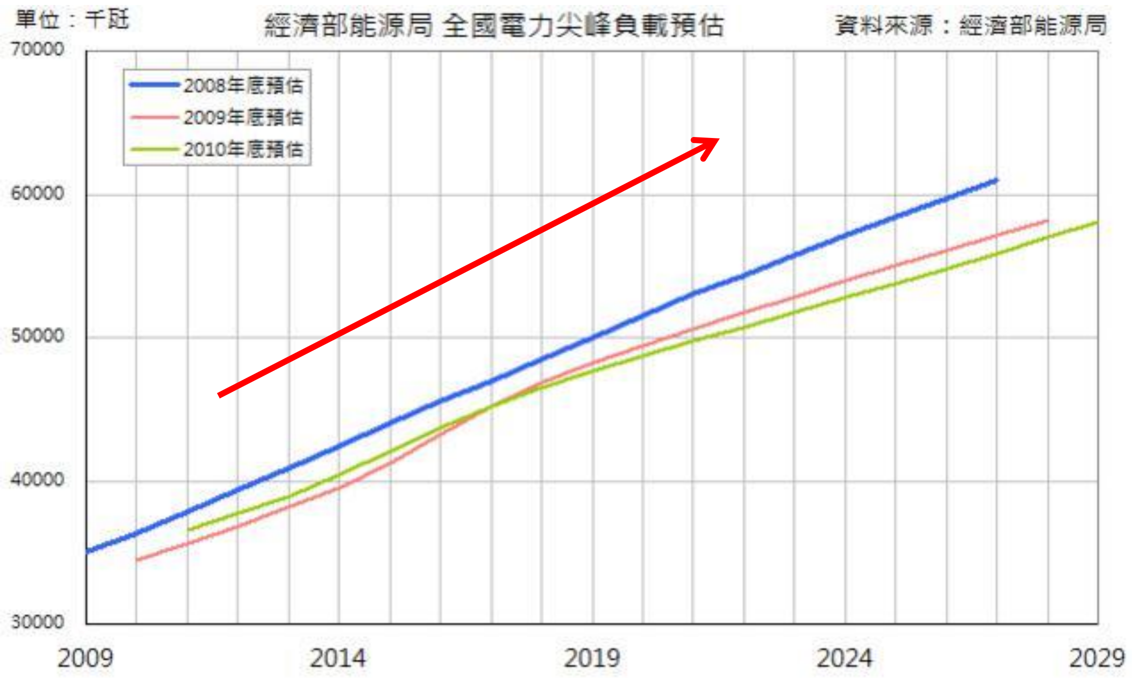
能源安全

- 能源(油、氣、煤、電)供需：由供過於求邁入**供不應求**的世代



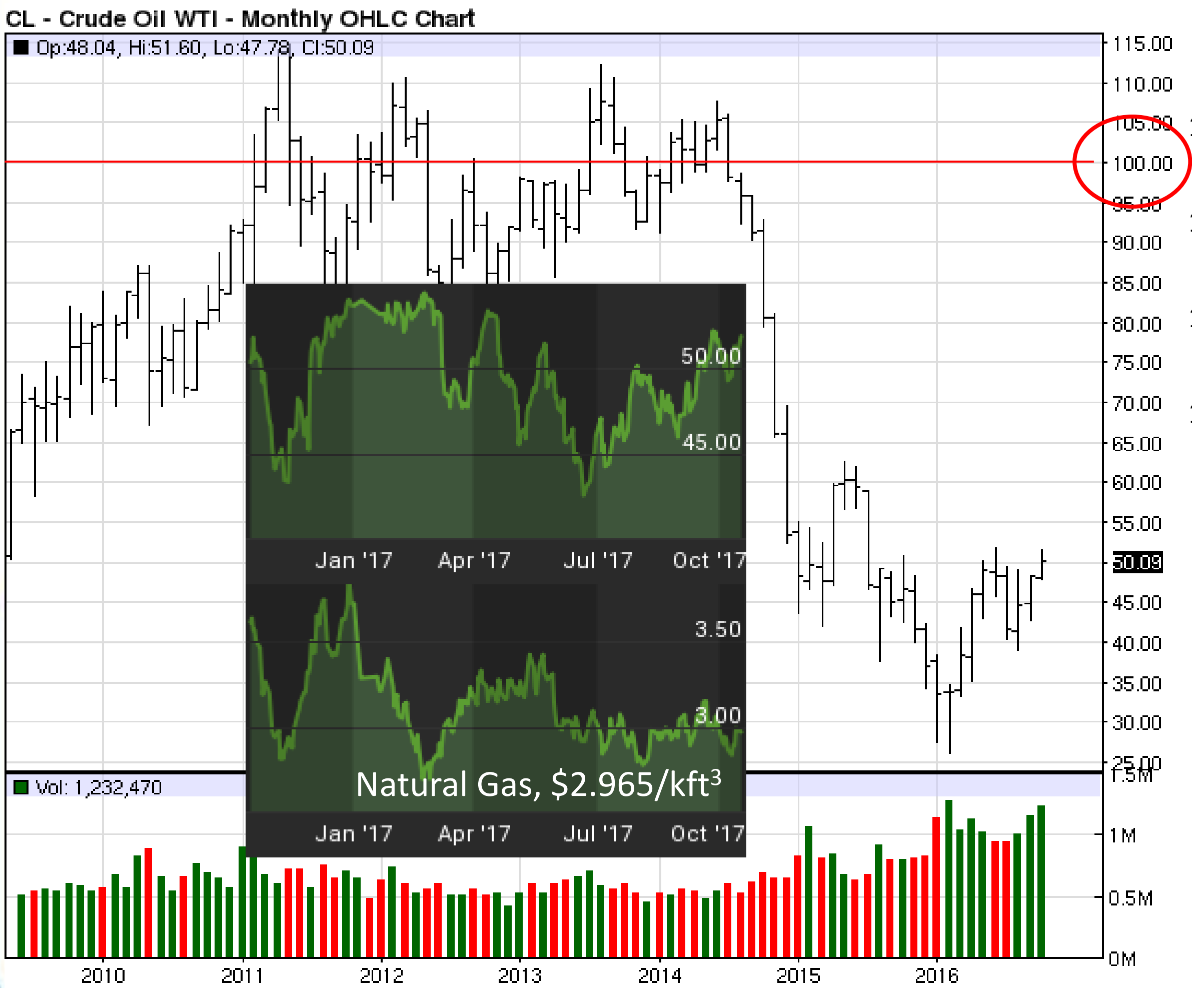


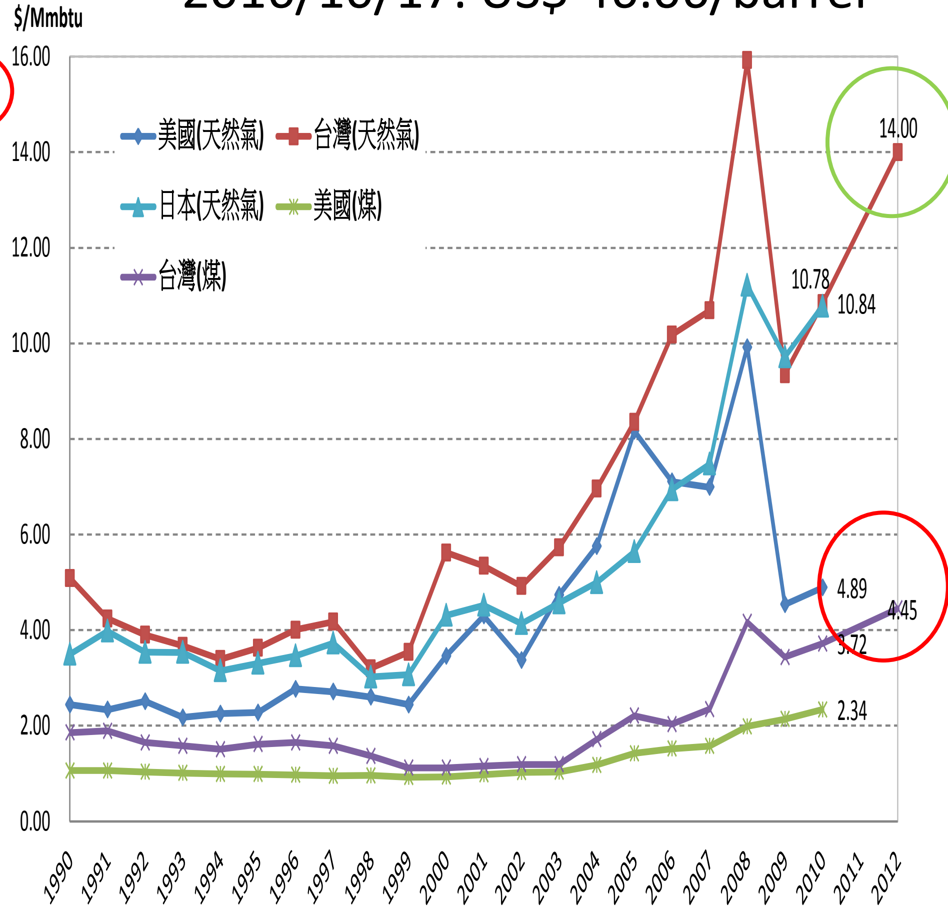
能源安全

- 油價、氣價長期走勢持續上揚

2017/10/16: US$ 51.87/barrel

2016/10/17: US$ 46.06/barrel





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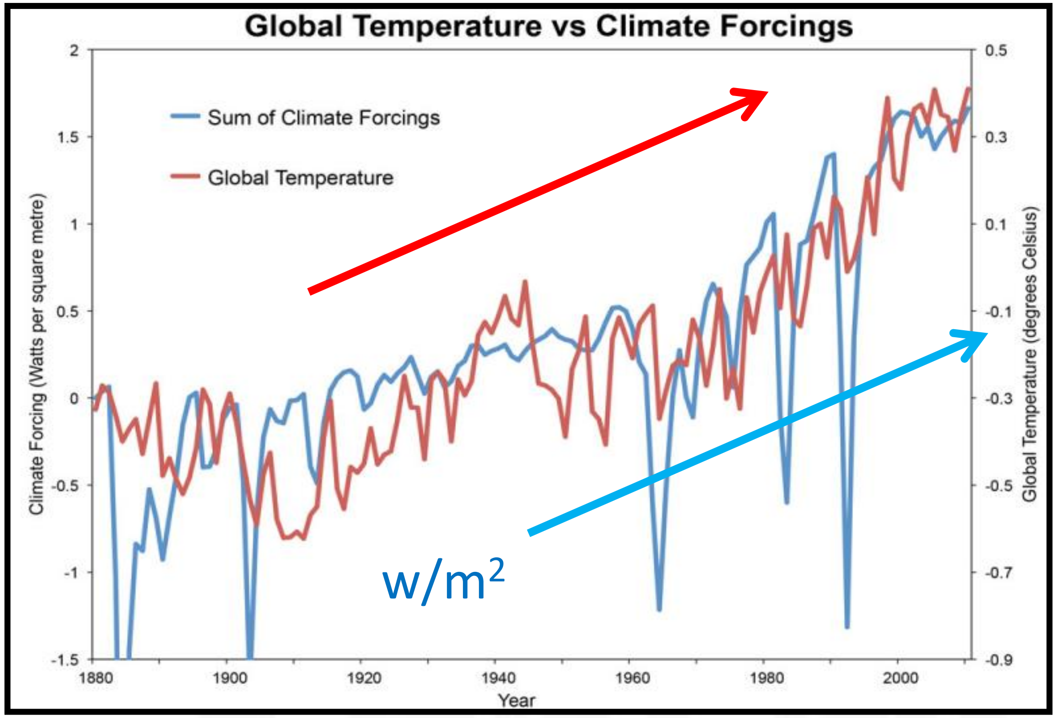
能源安全

- 環境保護新議題之威脅：二氧化碳被視為有害物質二氧化碳交易市場萌芽
- 101年5月9日，環保署正式宣告二氧化碳為空氣汙染物



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簡介能源之路：傳統→替代→再生

能源種類(傳統初級能源)

木材

煤炭

石油

天然氣

甲烷冰

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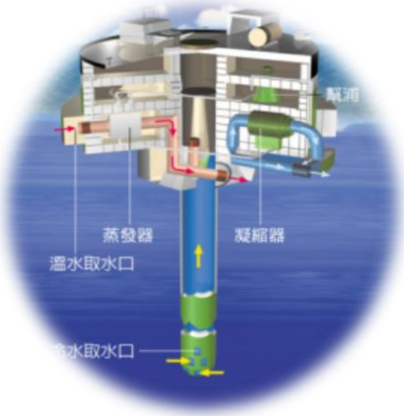
能源種類(再生能源)

- 再生能源---水力及海洋能

水力

波浪

潮汐

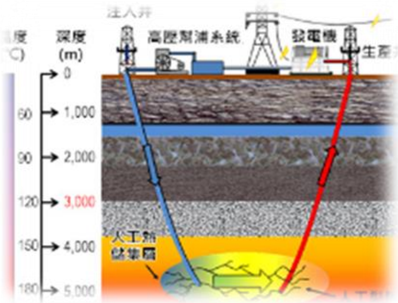


海洋溫差

能源種類(再生能源)

- 再生能源---地熱、太陽能、風力

地熱



深層地熱

風力

太陽電

太陽熱

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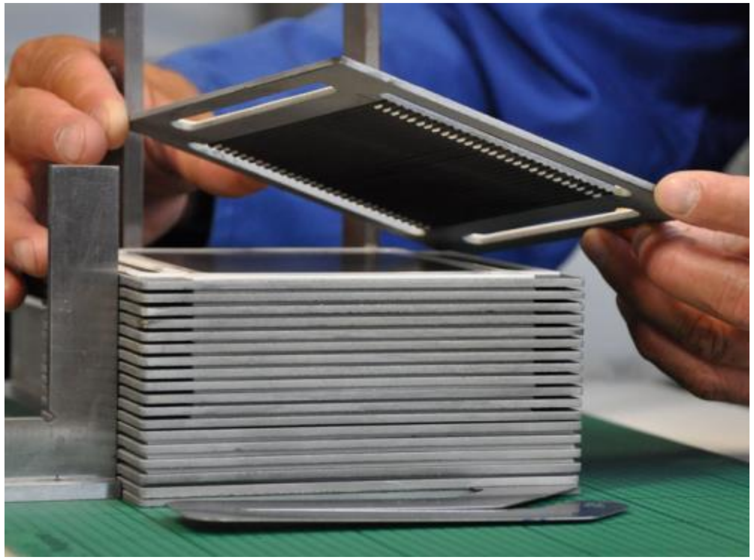
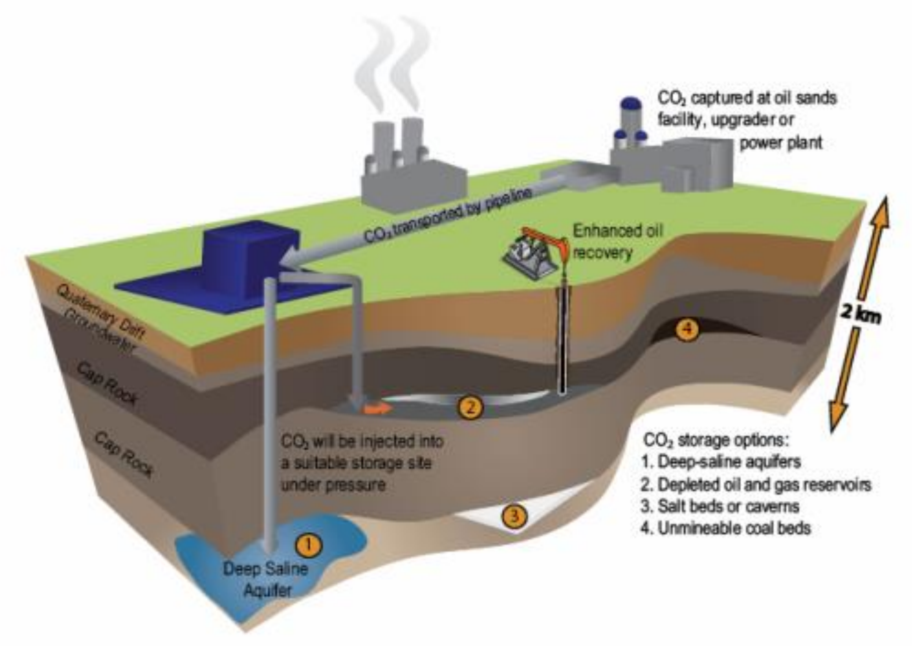
能源種類(替代能源)



燃料電池



碳捕獲、封存及再利用(CCSU)

生質能

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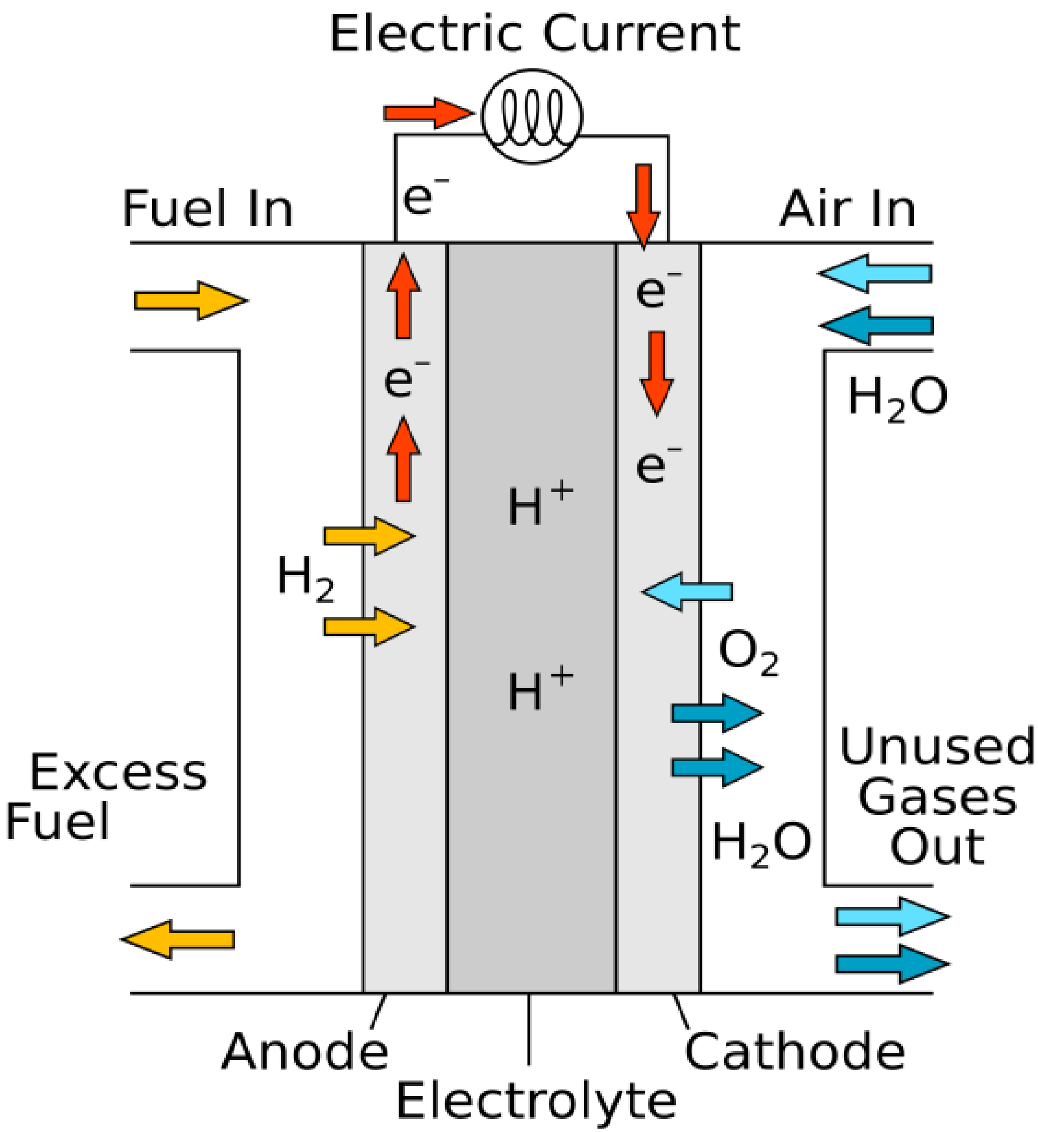
燃料電池
Fuel Cell
FC

燃料電池原理

- 設法讓大量的氫氣及氧氣化合成水、同時產生電的裝置
- 是一種發電機，不是用來儲存電力的”電池“



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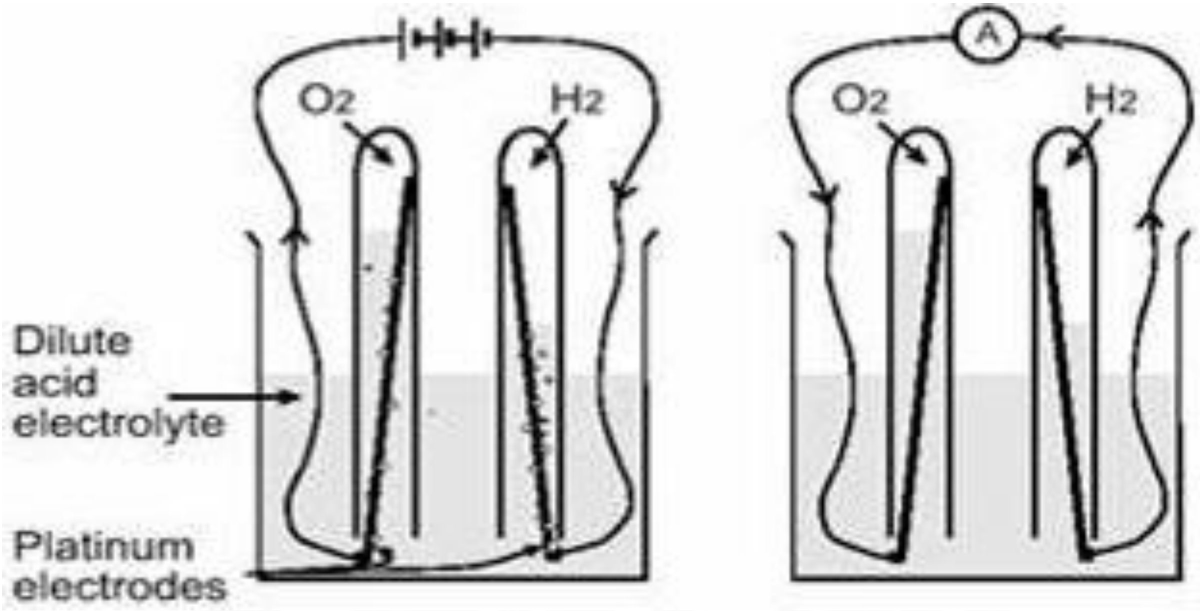
燃料電池起源

- Christian Friedrich SchÖnbein, Chemist, German, 1838
- William Robert Grove, Physicist, UK, 1839
- NASA's applications since 1960



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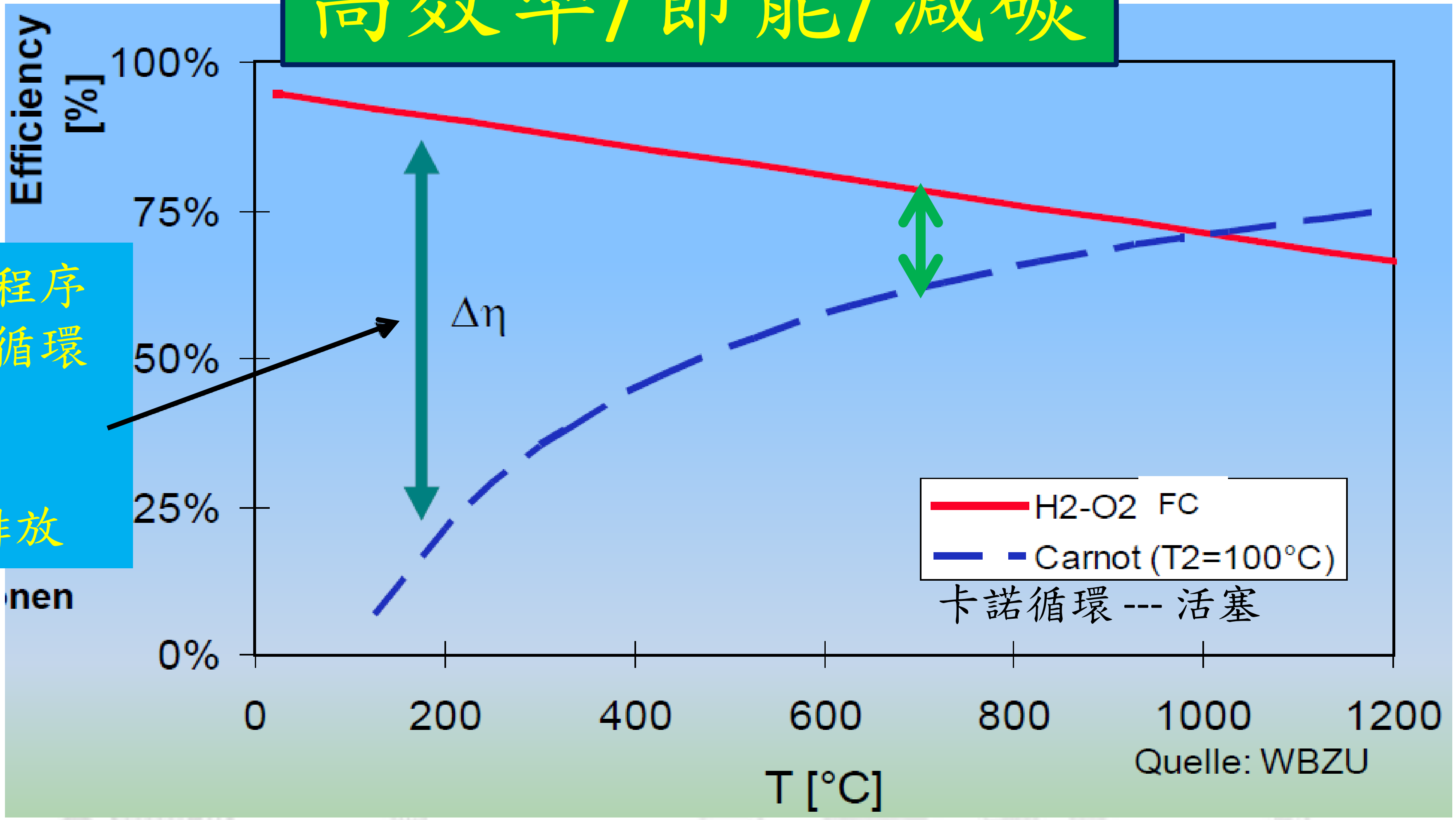
燃料電池特色

高效率/節能/減碳

- 其電化學程序比起卡諾循環更有效率
- 節能
- 減少CO_2排放



燃料電池在低溫時擁有非常高之效率！

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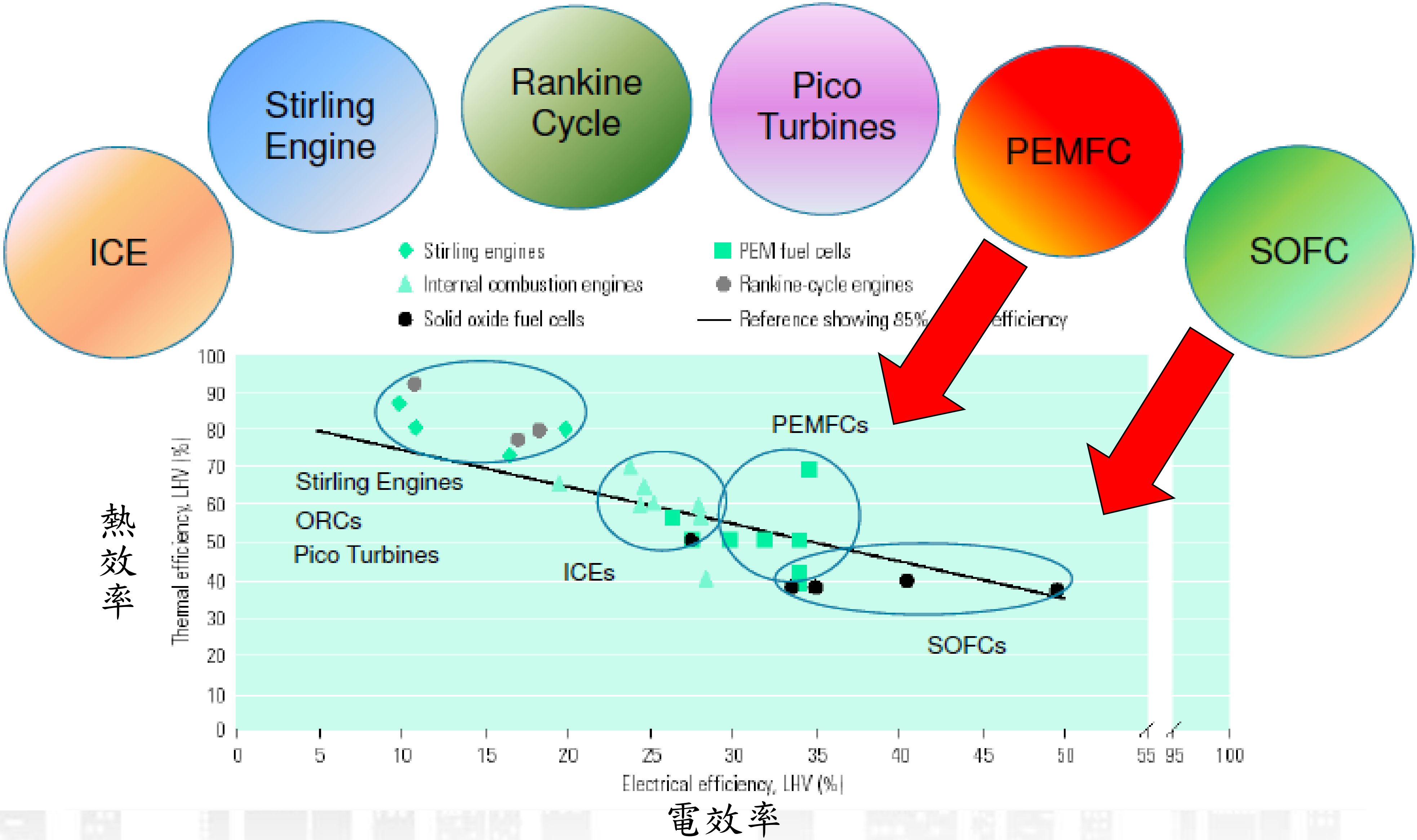
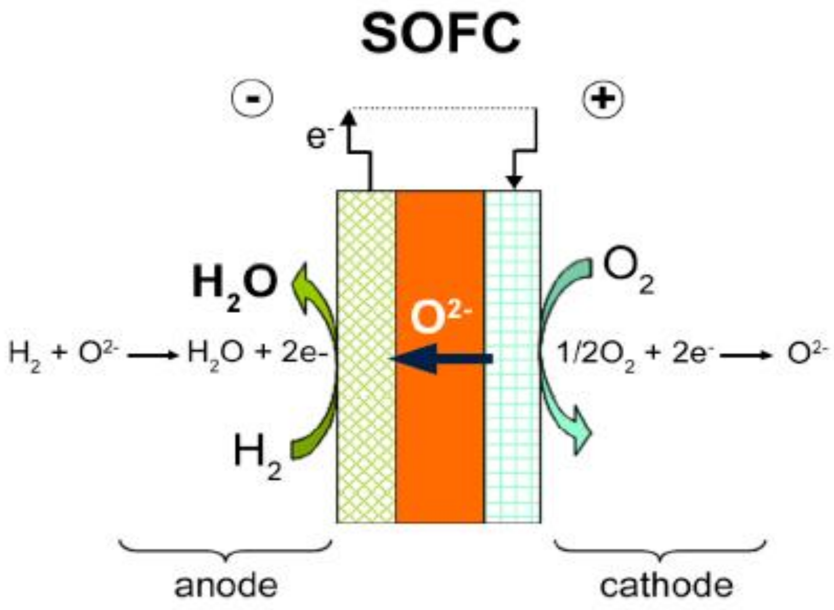
燃料電池效率比較

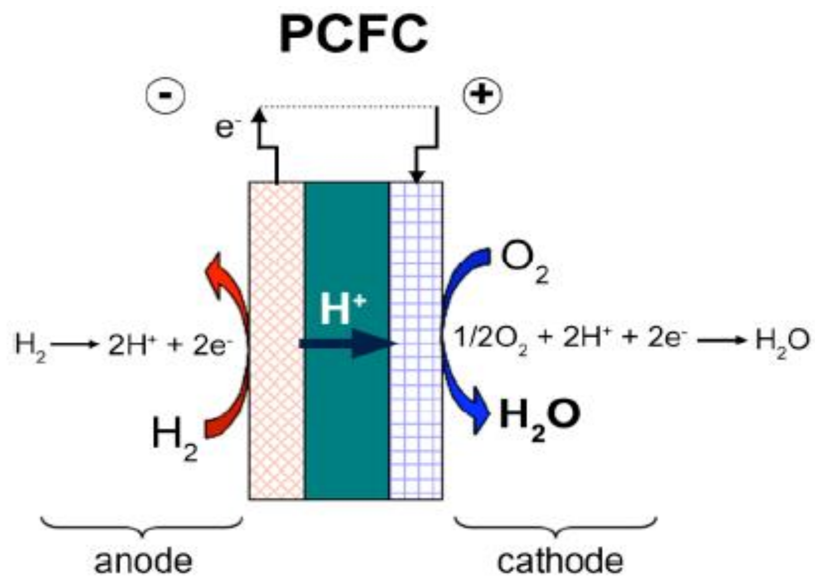


ICE
Stirling Engine
Rankine Cycle
Pico Turbines
PEMFC
SOFC
Stirling engines
Internal combustion engines
Solid oxide fuel cells
PEM fuel cells
Rankine-cycle engines
Reference showing 85% efficiency
Stirling Engines
ORCs
Pico Turbines
ICEs
PEMFCs
SOFCs
熱效率
Thermal efficiency, LHV (%)
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45
50
55
95
100
Electrical efficiency, LHV (%)
電效率

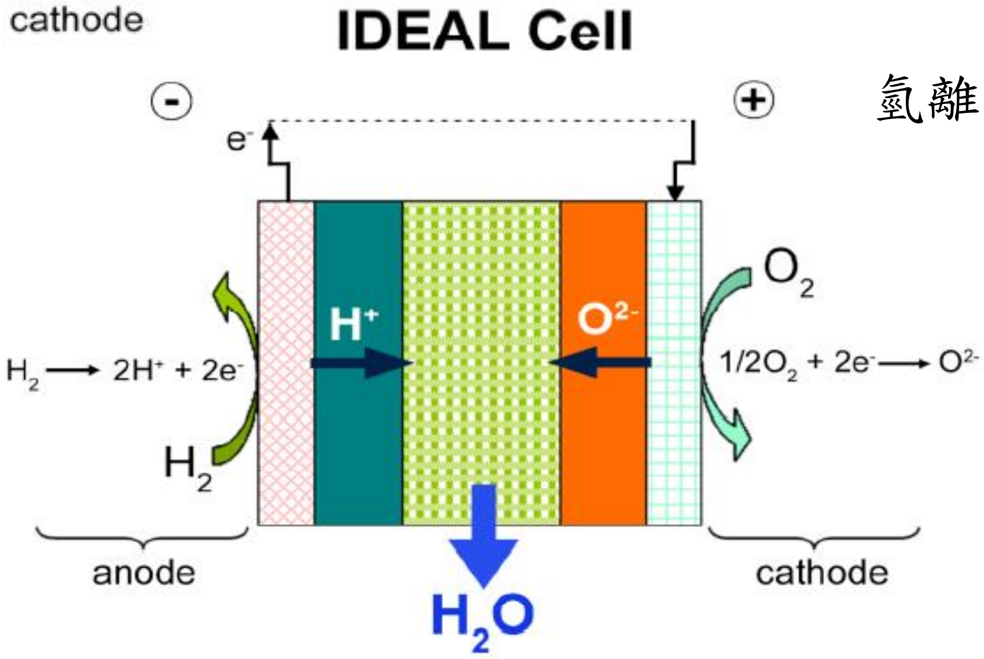
燃料電池離子傳輸形式



氧離子傳輸



氫離子傳輸



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燃料電池分類

FC種類	電解質	載子	操作溫度	燃料	系統電效率	功率範圍/應用
鹼性 (AFC)	KOH	OH-	60-120	純氫	35-55%	<5kW/軍事、太空
質子交換膜 (PEMFC)	固體聚合物(氟磺酸)	H+	50-100	純氫(含 CO_2可)	35-45%	5-250kW/車用、熱電共生、行動電源
直接甲醇 (DMFC)	固體聚合物	H+	50-80	甲醇	30%	mW-kW/筆電、手機、平板、行動電源
磷酸 (PAFC)	磷酸	H+	~220	純氫(含 CO_2、1% CO可)	40%	200kW/熱電
熔融碳酸鹽 (MCFC)	碳酸鋰、碳酸鉀	碳酸離子	~650	氫、CO_2、甲烷、其他碳氫化合物	>50%	200kW-MW/熱電、獨立供電
固態氧化物 (SOFC)	固態氧化物 (氧化釔、氧化鋯)	O2-	~1000	氫、CO_2、甲烷、其他碳氫化合物	>50%	kW-MW/熱電、獨立供電

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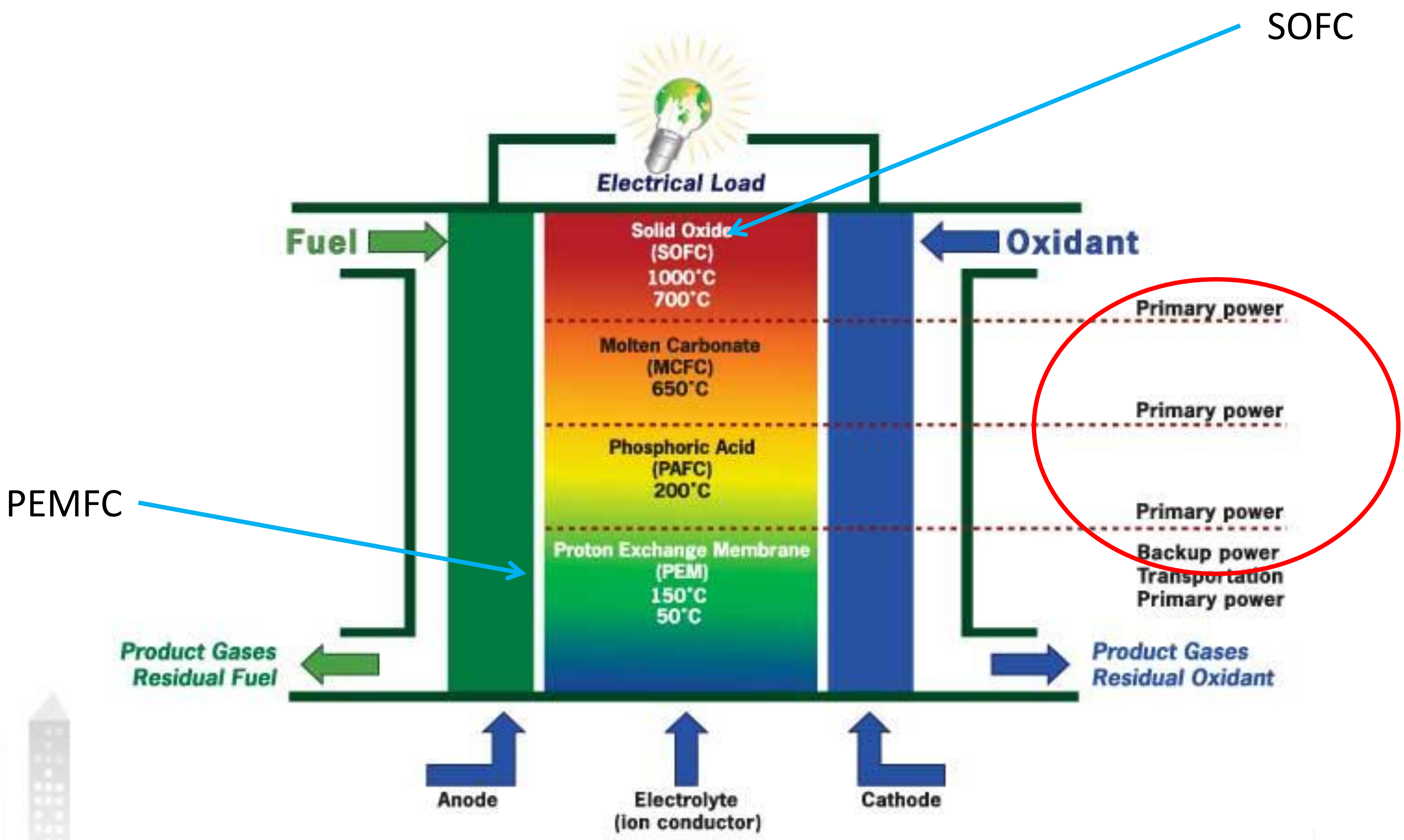
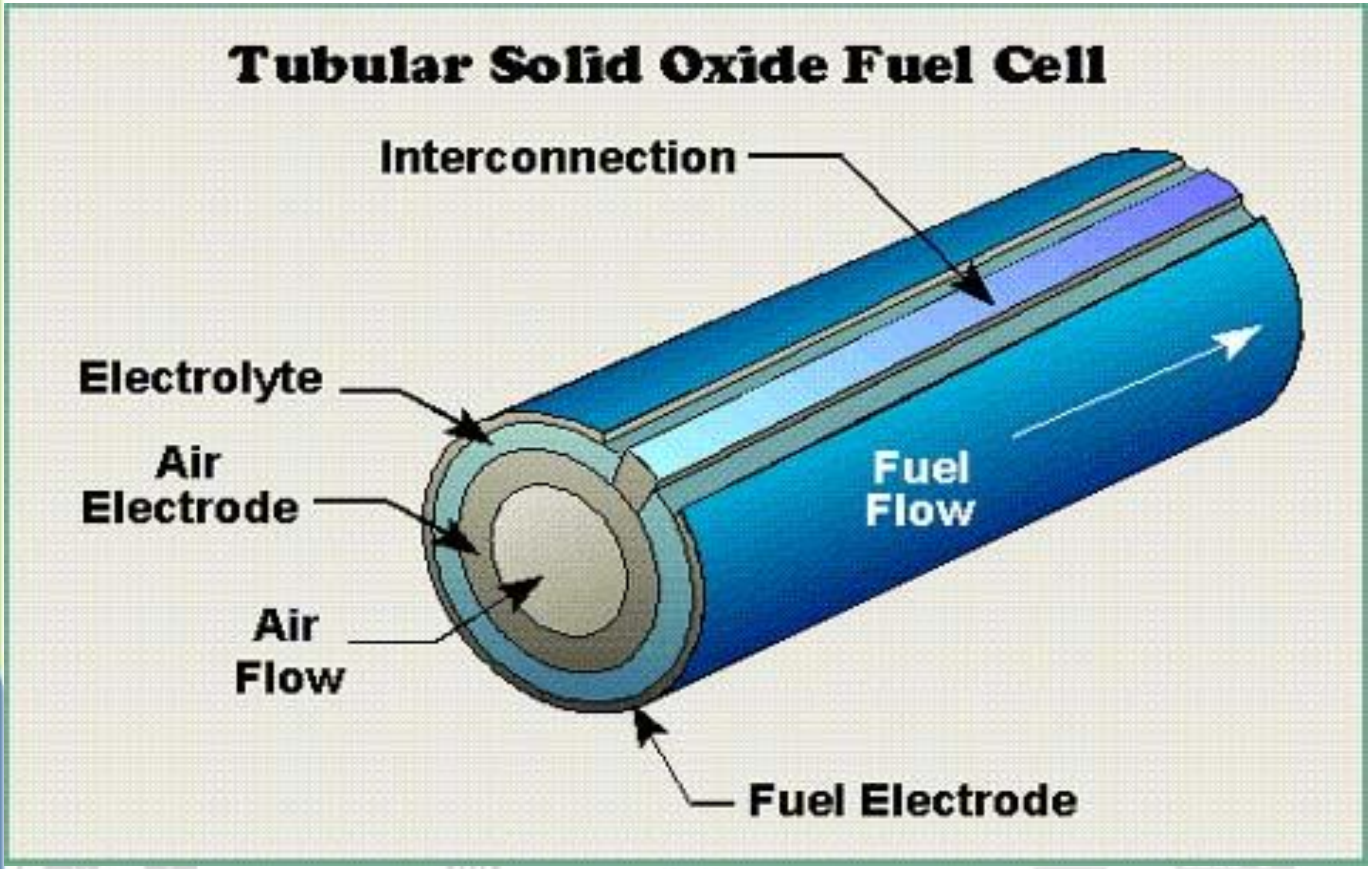
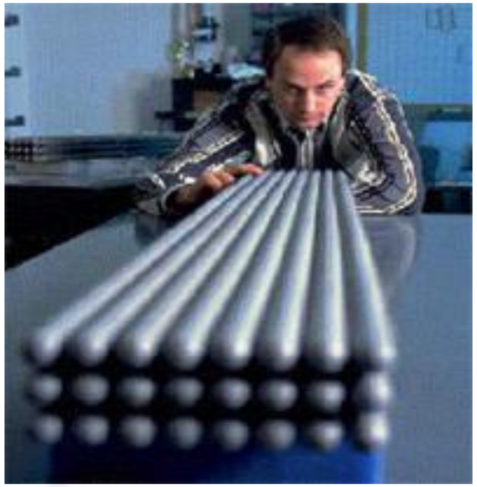
FC種類	優點	缺點
鹼性 (AFC)	• 陰極反應快使得高效能 • 低成本元件	• 對燃料與空氣之CO_2敏感 • 電解質管理問題
質子交換膜 (PEMFC)	• 減少腐蝕及電解質管理問題 • 低溫 • 快速啟動	• 觸媒貴 • 對燃料雜質敏感 • 浪費熱能
磷酸 (PAFC)	• 較高溫可用於熱電共生 • 增加燃料雜質容忍度	• 白金觸媒 • 長啟動時間 • 低電流低功率
熔融碳酸鹽 (MCFC)	• 高效率 • 燃料彈性 • 可使用多種觸媒 • 適合熱電共生	• 電池片元件高溫腐蝕及故障 • 常啟動時間 • 低功率密度
固態氧化物 (SOFC)	• 高效率 • 燃料彈性 • 可使用多種觸媒 • 固體電解質 • 適合熱電共生及熱氫電共生 • 混合/氣體渦輪機循環	• 電池片元件高溫腐蝕及故障 • 長啟動時間及高溫操作限制

燃料電池應用範圍整理


SOFC
Electrical Load
Fuel
Oxidant
Solid Oxide
(SOFC)
1000°C
700°C
Molten Carbonate
(MCFC)
650°C
Phosphoric Acid
(PAFC)
200°C
Proton Exchange Membrane
(PEM)
150°C
50°C
PEMFC
Primary power
Primary power
Primary power
Backup power
Transportation
Primary power
Product Gases
Residual Fuel
Product Gases
Residual Oxidant
Anode
Electrolyte
(ion conductor)
Cathode

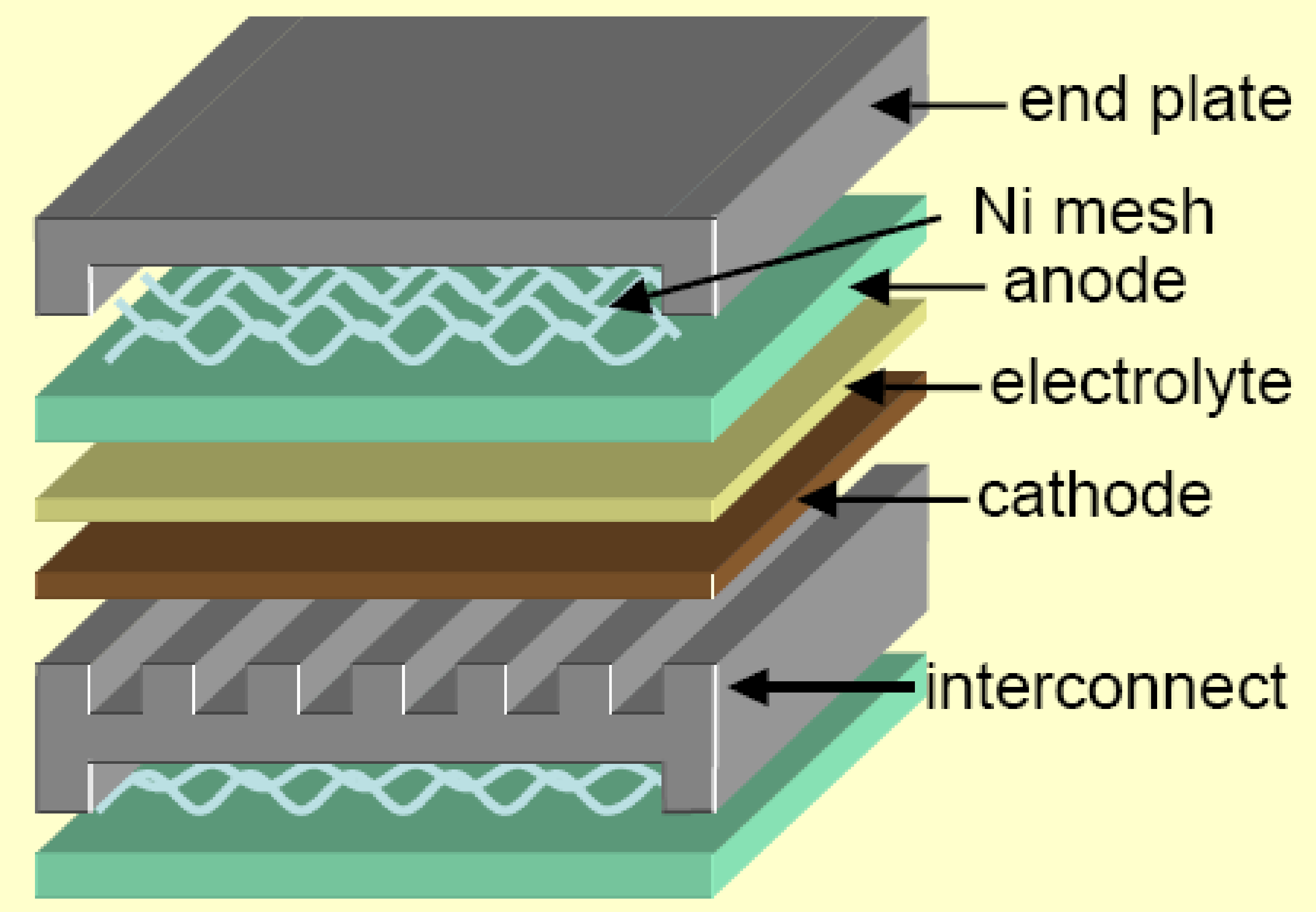
SOFC管狀構裝





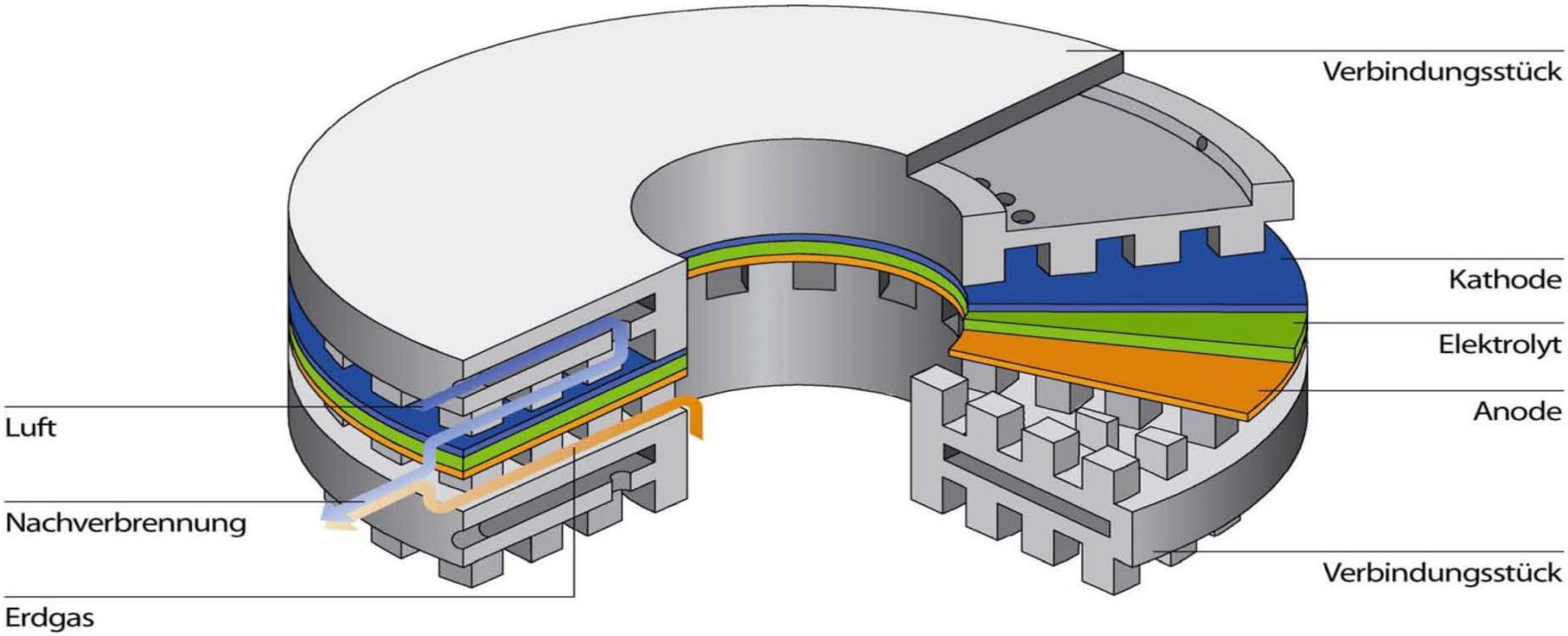
Quelle Siemens Westinghouse

SOFC平板構裝


end plate
Ni mesh
anode
electrolyte
cathode
interconnect


SIEMENS

SOFC平板構裝(碟盤)



Verbindungsstück
Kathode
Elektrolyt
Anode
Luft
Nachverbrennung
Erdgas
Verbindungsstück

SOFC多樣性燃料

System Efficiencies for different fuels
SOFC Power Plants

Case	El Eff. %	Cogen Eff %
NG or SNG	56	90
Biogas 50 % CH_4/50 % CO_2	54	86
Methanol	54	90
DME 二甲醚	54	89
Ethanol	55	80
Ammonia	57	90
Diesel	40	90

SOFC優勢、挑戰、瓶頸

優勢	發電效率高
	佈建彈性大，不會受限於熱能之需求
	與未來屋電力能源需求大之特性符合
	與未來虛擬發電廠趨勢之需求特性契合
挑戰	成本太高
	可靠度不足
熱電結合之共通瓶頸	成本過高
	產品壽命不易超過10年
	家庭的能源配比，電力比重有提高趨勢
	供熱家電的價格相當低廉

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燃料電池系統
電能管理及轉換架構

System Control & Power Management

- **Power Protection & Conversion**
  - Switchboard with Protection
  - High-Efficiency Converter
  - High-Efficiency Inverter
- **Dynamic Model Building**
  - Actuators Modelling & Identification
  - Components Modeling
    - Reformer
    - Burner
    - Stack
  - Controllers Design
- **Control Box**
  - Hardware Layout
  - Programming
  - Mechanism Design
- **Fault Diagnosis**
  - Start up Self-Detection
  - Real-time Model Reference/ Process Diagnosis
- **Maximum Efficiency Point Tracking**
  - Weighting Function Design
  - Tracking Algorithm
- **Monitoring Net**
  - Info App for End User
  - Community Data Collector
  - General Data Center

Orange: in progress
Green: in paper survey
Grey: brainstorming

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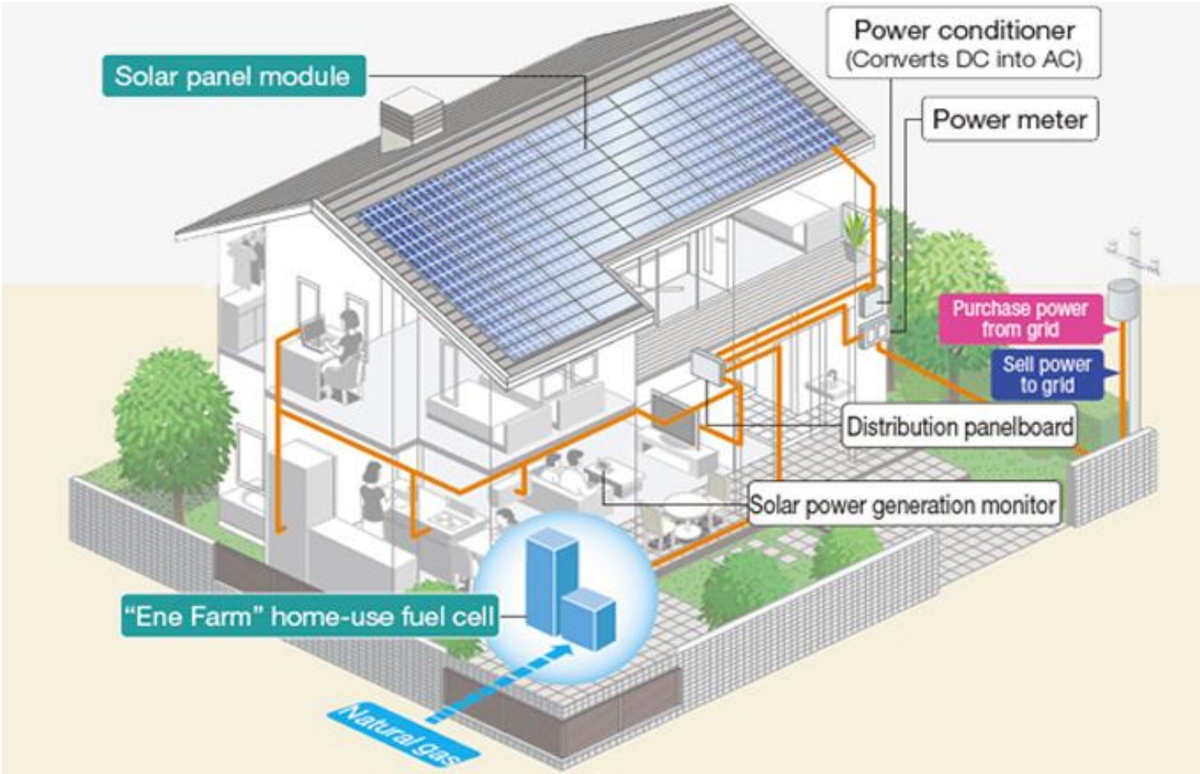
Applications of SOFC systems

- Dispatch of output power
  - Stand-alone application
    - Converting to AC power from SOFC's DC power to loads directly
  - Grid-tied application
    - Merging power with grid and being dispatched by a power company uniformly



ENE-FARM project, "Tokyo Gas and Panasonic to Launch New Improved "Ene-Farm" Home Fuel Cell," 2009

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Electrical Protection for Stacks

- Basic electrical protection
  - Overload (overcurrent)
    - Strategies: fuse, breaker, electromagnetic conductor
  - Overvoltage/undervoltage
    - Strategies: self-shutdown mechanism of DC/DC converter and DC/AC inverter
  - Inverse current
    - Strategy: power diode
  - Otherwise
    - Transformer
    - Optical coupler and relay

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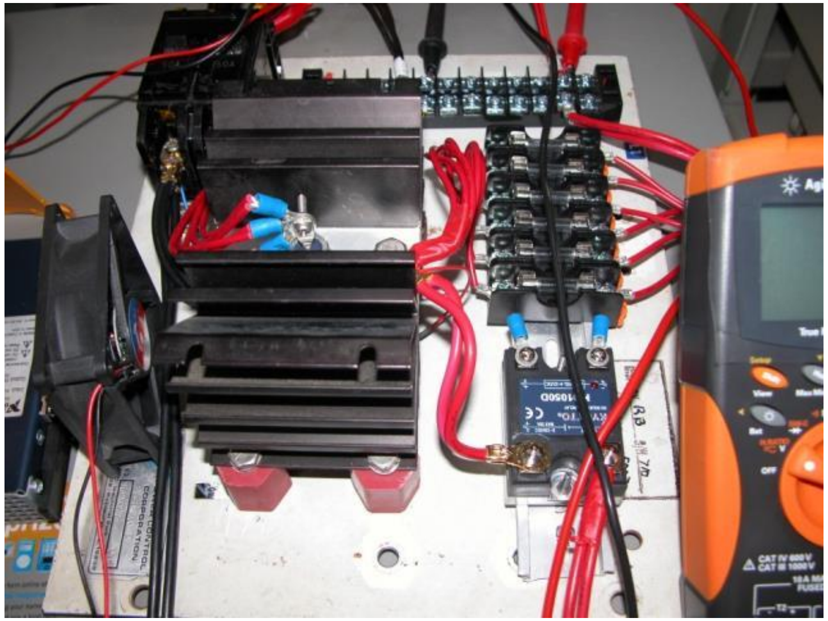
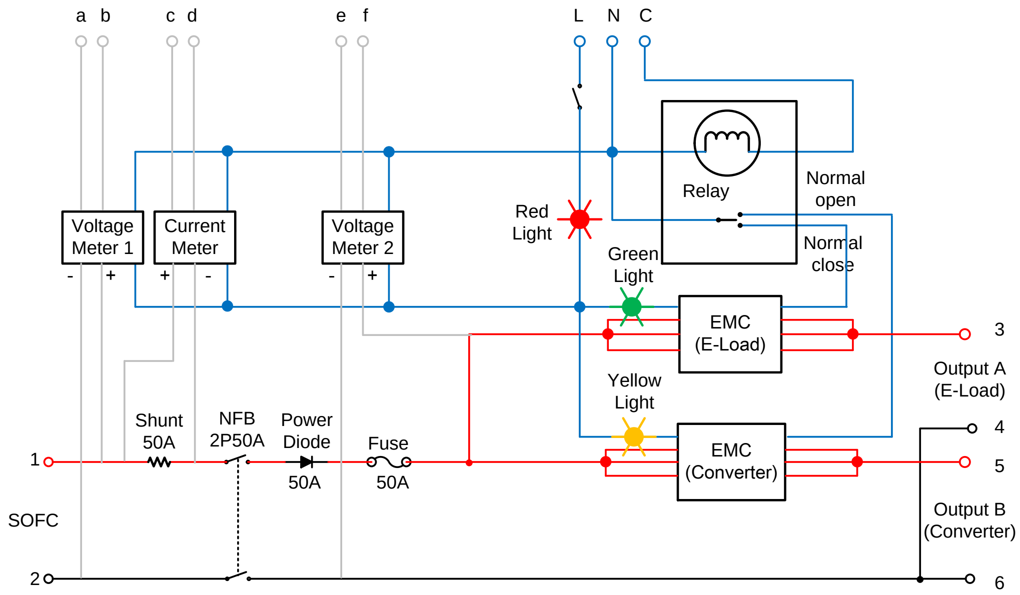
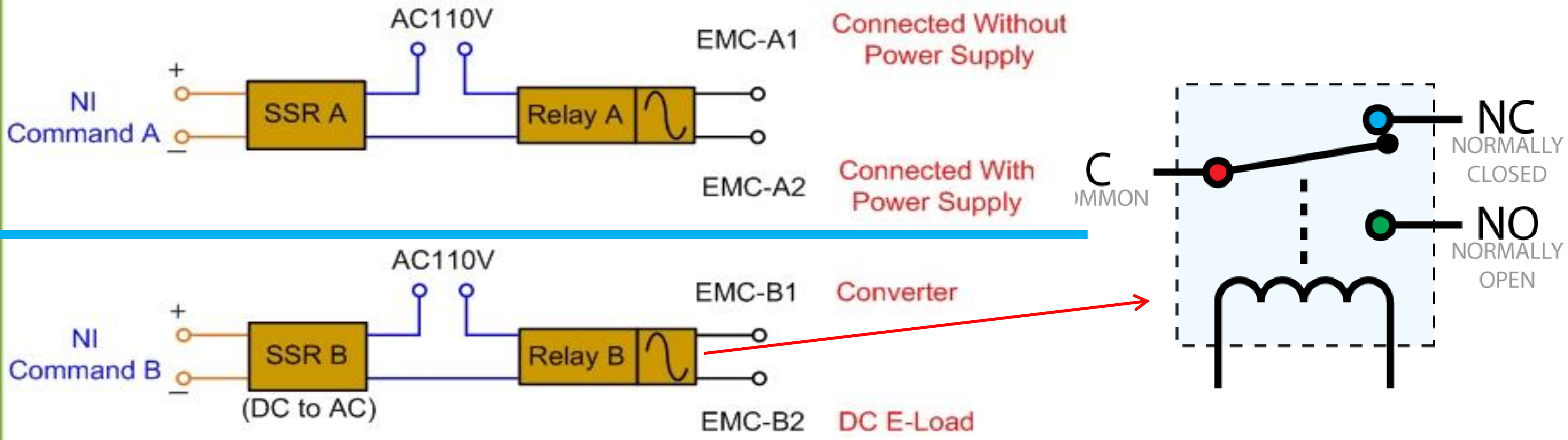
Electrical Protection Equivalents (1/2)





- NFB (No Fuse Breaker): the first stage of production which be switched manually only
- Diode: preventing against inverse current
- EMC (Electro Magnetic Connector): a controllable switch flowing main current
- Fuse: preventing against overcurrent by melting thin metal plate
- Option: capacitors/batteries being buffers, storage and output-ripple filters

Electrical Protection Equivalents (2/2)



- Relay: it contains two sets of normal closed and normal open terminals connecting each load. The switching mechanism guarantees that the operations of loads have been staggered exclusively.
- SSR (Solid State Relay): receiving NI CompactRIO's commands to switch relay
- The controller CompactRIO offers DC 5 V to switch two SSRs via the analog output module.
- The control loop (signal level) has been isolated from the main circuit (power level) by optical coupler, relay, and EMC.

Devices of Power Conversion

– DC/DC converter

- Stepping voltage up and down
- Stabilizing voltage
- Smoothing waveform
- Output spec. for 1 kW SOFC: 24 V, 48 V, and 200 V

– DC/AC inverter

- Applying AC power to loads and grid
- Output spec.: 1 P 110 V/220 V

  and 3 P 220 V at 50/60 Hz

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Devices of Power Conversion: DC/DC Converter

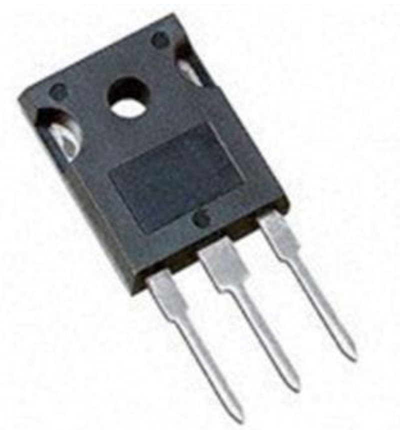
- It has alternated high current to high voltage to reduce power consumption of loads and to improve efficiency simultaneously.
- Output voltage is adjustable for a variety of loads.
- Built-in output filter weakens harmonics and improves power quality.
- Additional power source for DC loads (battery)

- Topologies:
  - Flyback
  - Forward
  - Push-pull
  - Buck
  - Boost
  - Buck-boost
  - Cuk
  - Half-bridge
  - Full-bridge

- Essentials of power electronics:

Capacitor, C

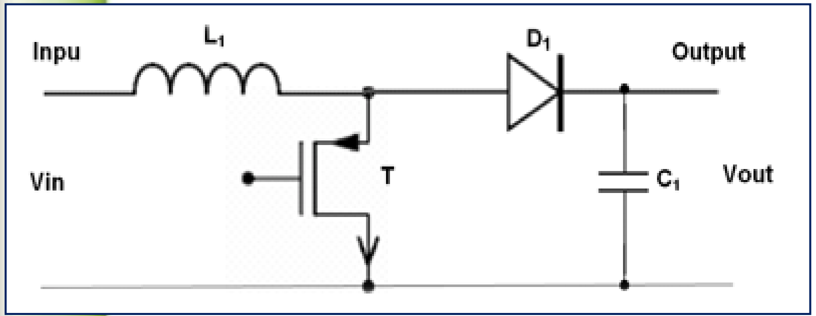
Inductor, L

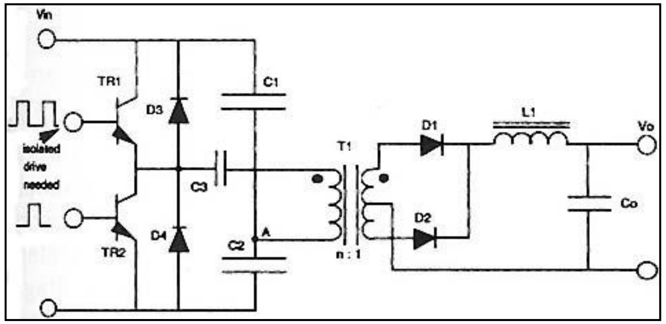


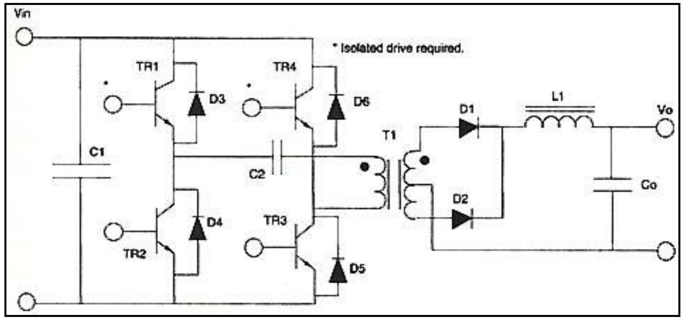
Switch

Features of Dedicated DC/DC Converter for SOFC

- Boost
- Half-bridge
- Full-bridge







- Rising the output voltage level of SOFC system
- Topologies which are suitable for 3 to 5 kW
- Complexity, switching precision, cost
- Trade-off between isolation and efficiency
- Quality of output power
- Cooling

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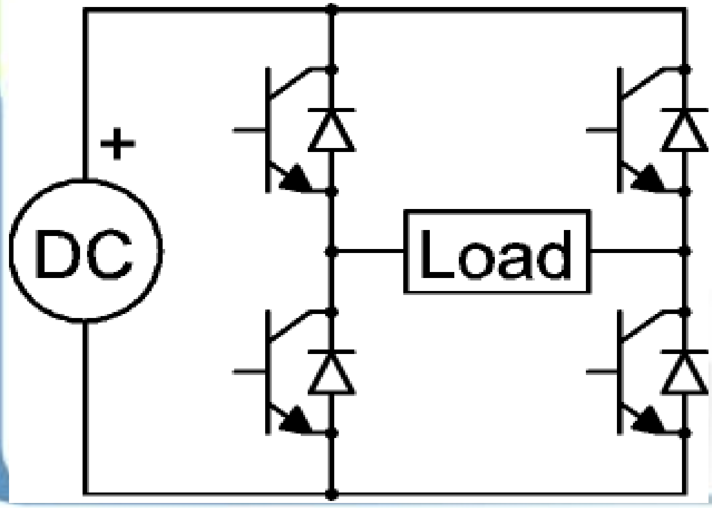
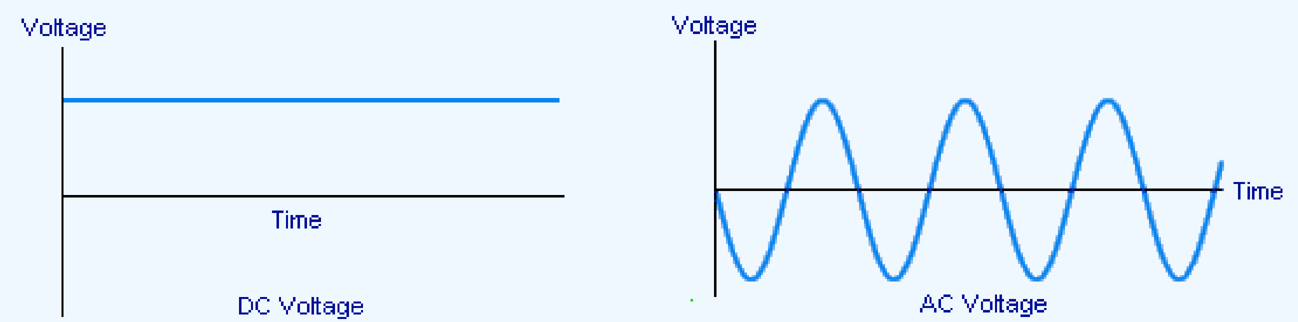
Devices of Power Conversion: DC/AC Inverter

- Converting DC power to AC power
- Applications: Stand-alone and Grid-tied
- The quality of the output power meeting power company's protocol is necessary.
- Topologies:
  - Half-Bridge
  - Full-Bridge



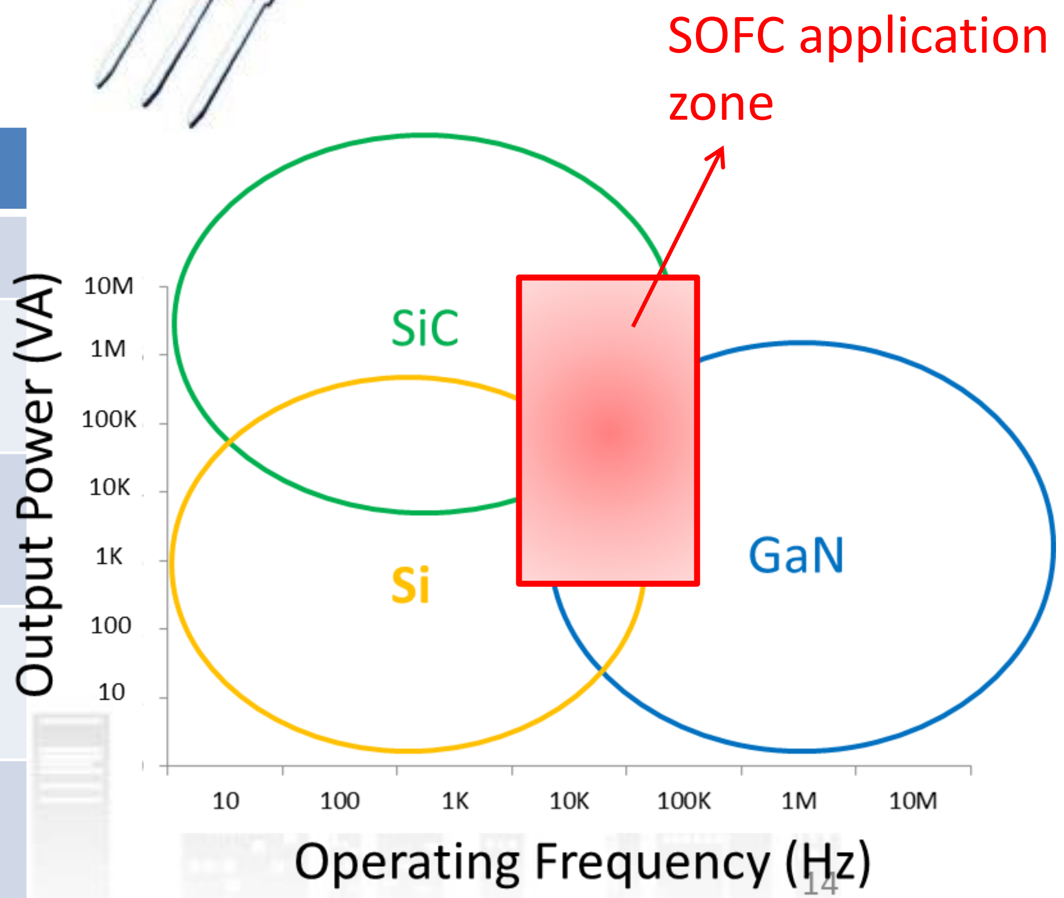


Representation of Visual Difference between DC and AC voltages

High-Efficiency Power Electronics Technique: Material

- The switching component MOSFET
  - Silicon (Si)
  - Silicon Carbide (SiC)
  - Gallium Nitride (GaN)

	Si	SiC	GaN
Conduction loss	higher	Lower	lower
Material developing time	Short	Longer	Middle
Breakdown voltage	Lower	Higher	Higher
Switching frequency	Low	Higher	Higher
Manufacturing cost	Low	Highest	higher



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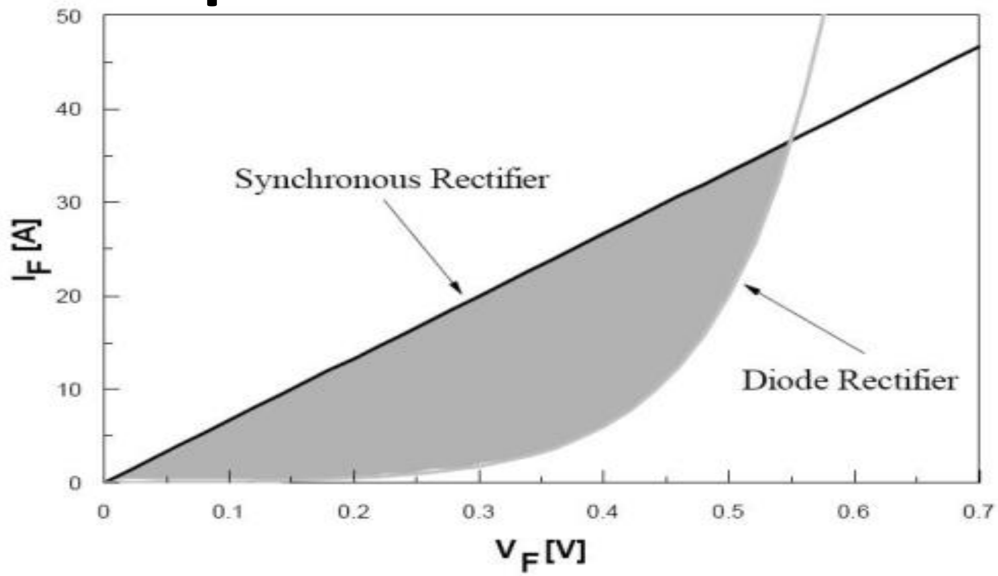
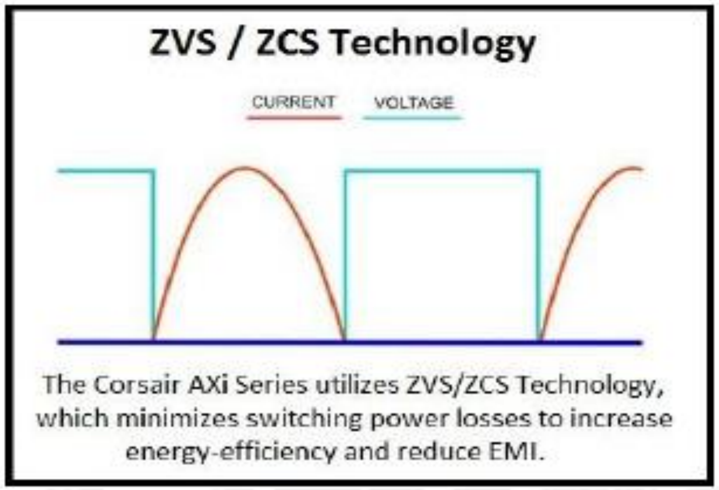
High-Efficiency Power Electronics Technique: Component

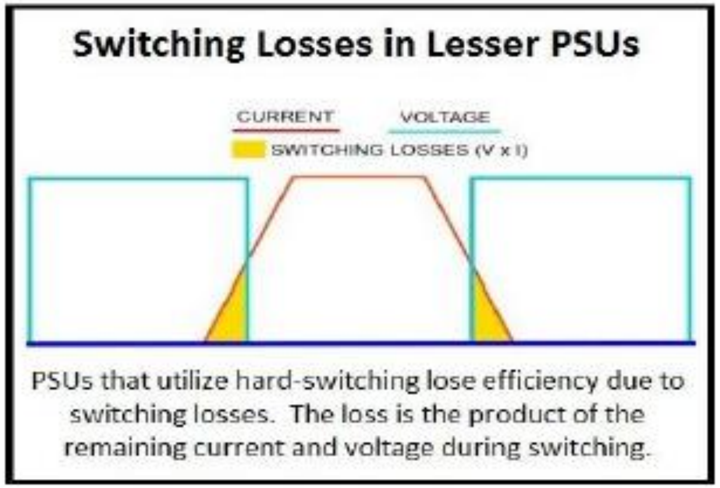
- Synchronous rectify
  - Switch replaces diode
    (Active component replaces passive one)

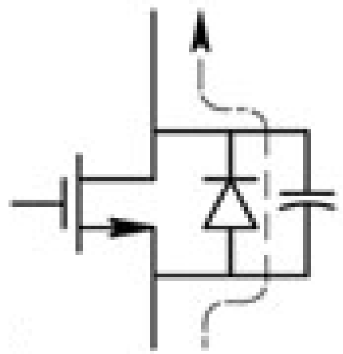
$$P_{loss}: R_{on}^2 I_s \rightarrow V_d I_s$$



- Resonant Zero Voltage/Current Switching







MOSFET + C

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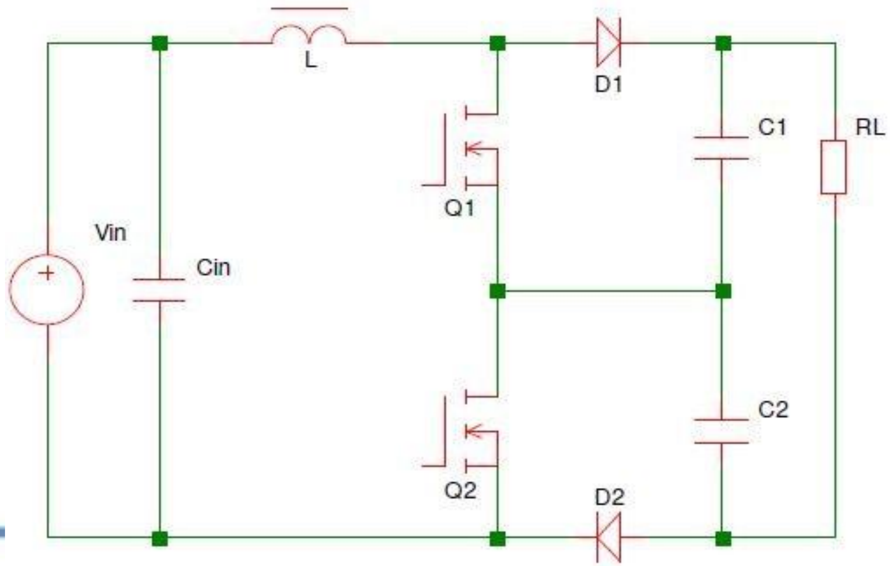
High-Efficiency Power Electronics Technique: Topology

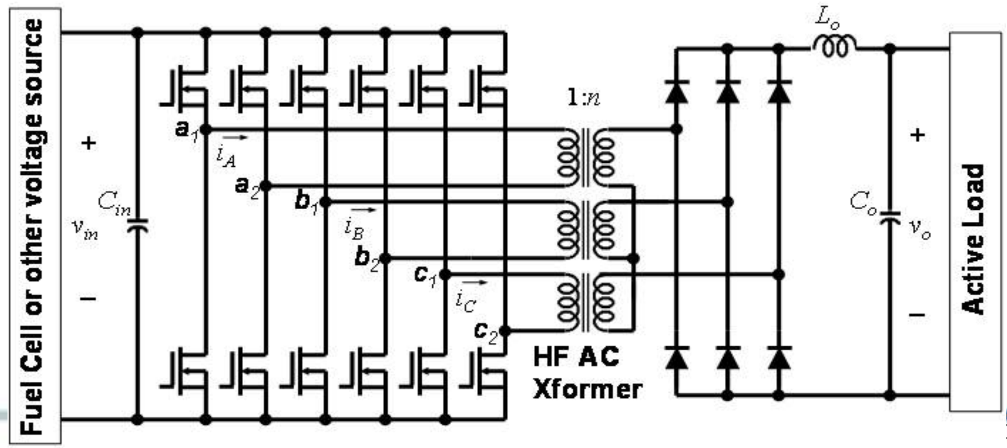
Three-Level

- Double input voltage is bearable.
- Reducing harmonics
- Slowing switching frequency to decrease consumption is allowed.
- Power factor is close to 1.



Multiphase

- More switches share burdens in a period.
- Isolation transformer can protect the primary side, which enlarges the voltage by Faraday's law of induction.
- High-frequency transformer has smaller volume.
- Application in the treatment of High power is available.
- Great Switching precision is required.



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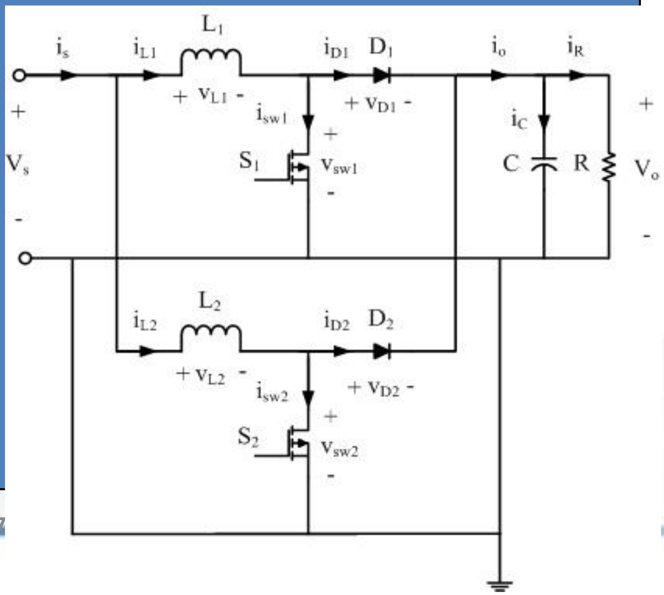
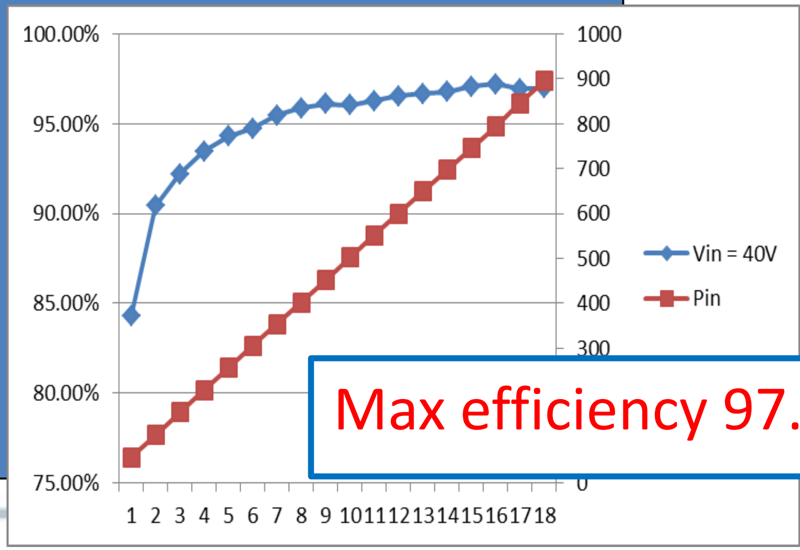
Self-Developed High-Efficiency DC/DC Converter for 1 kW SOFC System of INER

Spec	Input Voltage (V)	Input Current (A)	Output Voltage (V)	Output Current (A)	Power (W)
Min	22	0	48±1	0	0
Max	43	43 @ 25V		21	1000

Topology



Performance



Max efficiency 97.2% @ 40 V, 16 A

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Q & A