Energy Saving through Promotion of Cooling Seasonal Efficiency CSPF

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The Japan Refrigeration and Air Conditioning Industry Association

Contents:

1. EER and CSPF (or SEER)

2. Evaluation of inverter unit by CSPF

3. Effect of local load and hour fraction

4. Promotion of CSPF in ASEAN

5. Case study of LCCP (or TEWI)

6. Conclusion

1. EER and CSPF (or SEER)
1) Definition

EER: Energy Efficiency Ratio

= Cooling capacity ÷ Power input

(usually only at 35°C)

CSPF: Cooling Seasonal Performance Factor

(SEER: Seasonal Energy Efficiency Ratio)

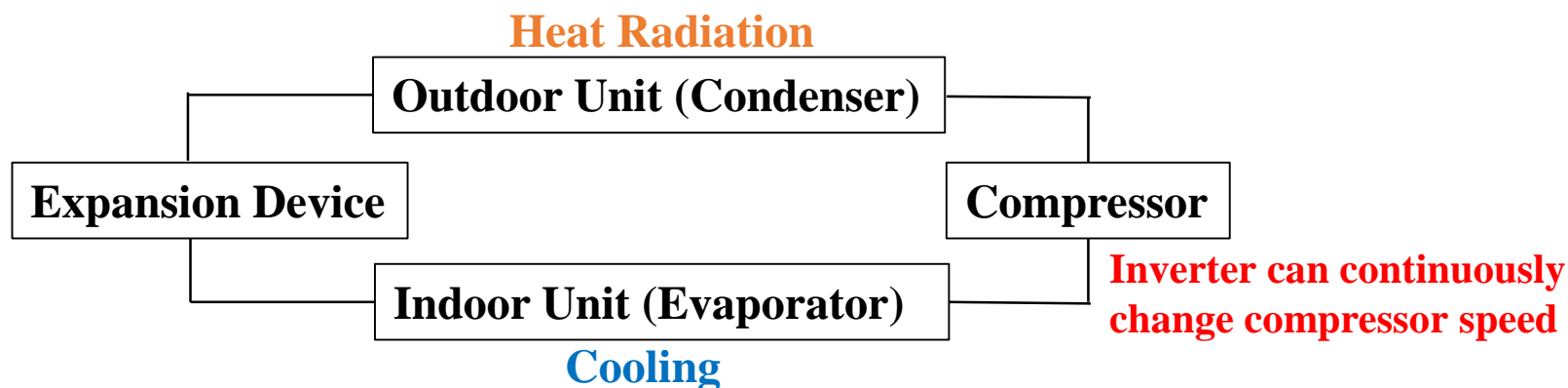= Total cooling load ÷ Total power consumption

1. EER and CSPF (or SEER)
2) Difference

EER: One point efficiency at 35°C outdoor temperature

■ **Higher efficiency at medium temperatures is not evaluated.**

CSPF: Average efficiency for all operating temperatures
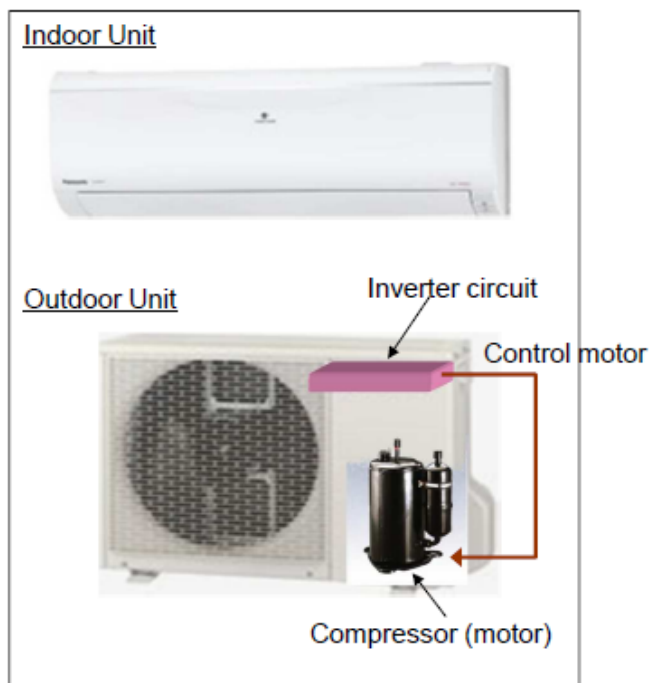
■ **Reduction of efficiency by on-off operation is considered.**

■ **Advantage of inverter unit which continuously operates at medium temperatures is evaluated.**

Heat Radiation
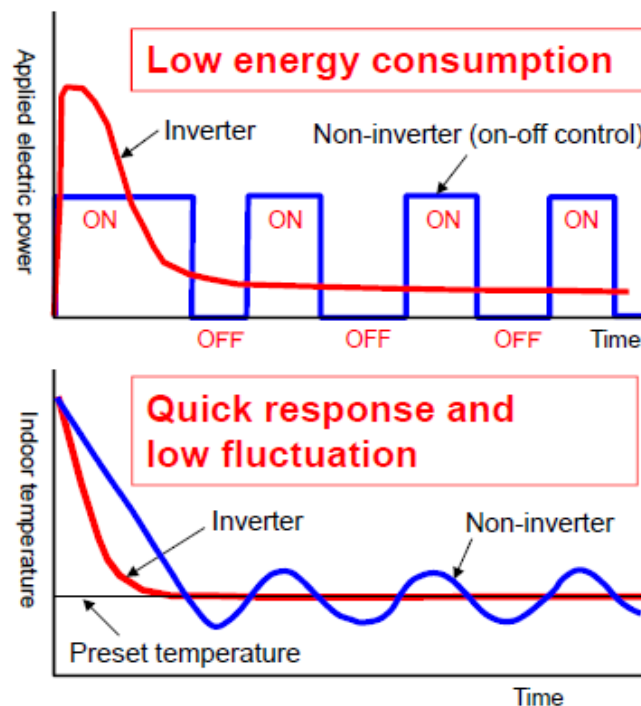
Outdoor Unit (Condenser)

Expansion Device	Compressor

Indoor Unit (Evaporator)

Cooling

Inverter can continuously change compressor speed

1. EER and CSPF (or SEER)
3) Features of inverter air conditioner

Part load operation

● Inverter Air Conditioner

Indoor Unit

Outdoor Unit

Inverter circuit

Control motor

Compressor (motor)

● Features of Inverter Air Conditioner

Low energy consumption

Applied electric power

Inverter

Non-inverter (on-off control)

ON   ON   ON   ON

OFF   OFF   OFF   Time

Quick response and low fluctuation

Indoor temperature

Inverter

Non-inverter

Preset temperature

Time

Energy saving: Low power consumption   **Comfort: Low indoor temperature variation**

1. EER and CSPF (or SEER)
4) History of CSPF

1992: SEER was adopted in USA.

2005: APF (Annual Performance Factor: cooling and heating)

was adopted in japan.

2007: Investigation of CSPF started in ISO TC86/SC6/WG1.

2012: EU-Ecodesign regulation using SEER was published.

2013: ISO 16358-1, 2, 3 were published.

(-1 for cooling, -2 for heating and -3 for annual efficiency)

2014-2016: Japan promoted adoption of CSPF in national

standard and installation to local regulation in ASEAN.

2017: Amendment draft adding T3 high ambient calculation
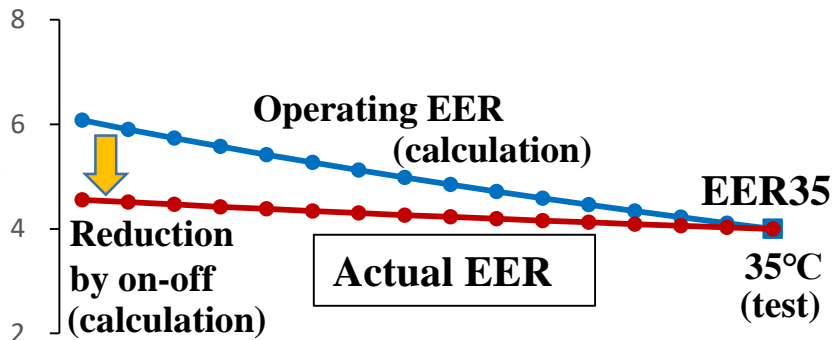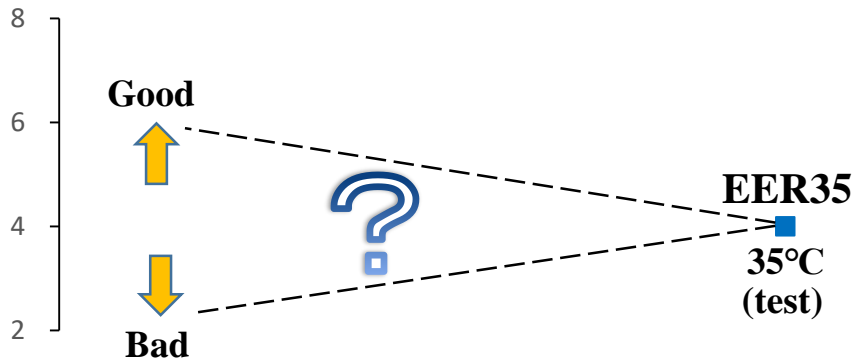
was released and is under process for approval.

1. EER and CSPF (or SEER)
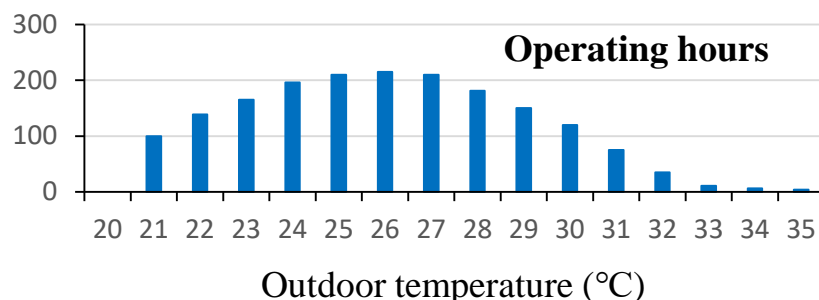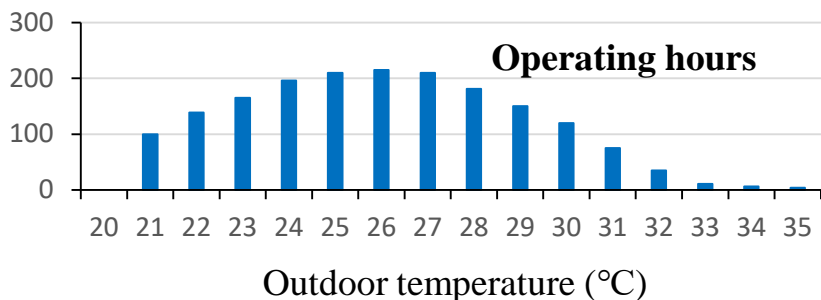## 5) Conventional EER and CSPF

EER35 is used here to distinguish from operating EERs under 35°C.

Conventional EER cannot evaluate efficiency in majority zone.

CSPF is a kind of average of actual EER for all operating temperatures.
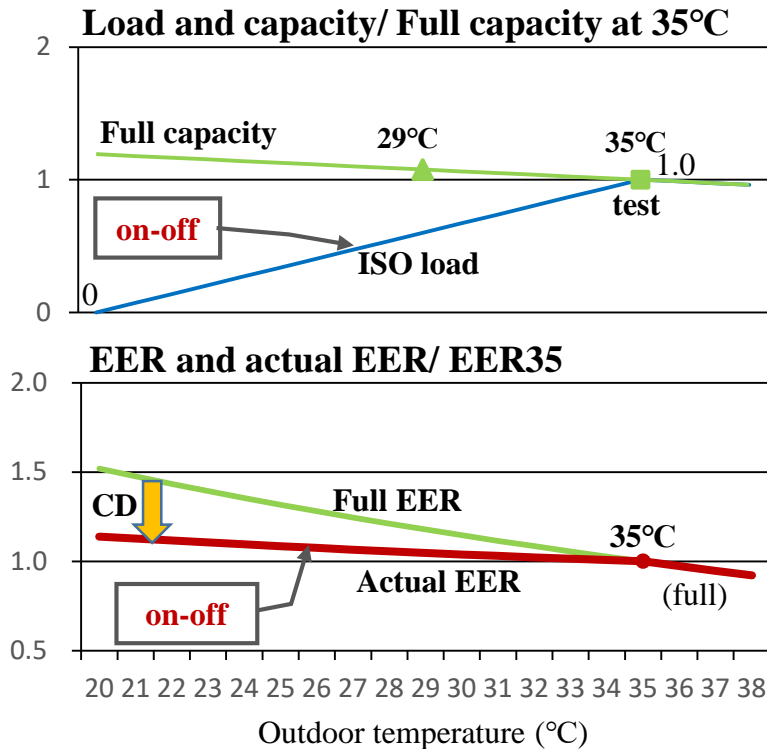
Good

Bad

EER35

35°C (test)

Operating EER (calculation)

EER35

Reduction by on-off (calculation)

Actual EER

35°C (test)

Majority zone

Operating hours

Outdoor temperature (°C)

Operating hours

Outdoor temperature (°C)

2. Evaluation of inverter unit by CSPF
1) Fixed speed and inverter

Fixed speed unit

Load and capacity/ Full capacity at 35°C

Full capacity
29°C
35°C
1.0
test
on-off
ISO load
0

EER and actual EER/ EER35

CD
Full EER
35°C
Actual EER
on-off
(full)

Outdoor temperature (°C)

20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38

Inverter unit

Load and capacity/ Full capacity at 35°C

Full capacity
29°C
35°C
1.0
test
Half capacity
tc
on-off
ISO load
0.5
test
capacity change
0

EER and actual EER/ EER35

Half EER
capacity change
CD
tc
Actual EER
Full EER
35°C
on-off
(full)

Outdoor temperature (°C)

20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38

Actual EER decreases from full EER by on-off under 35°C.
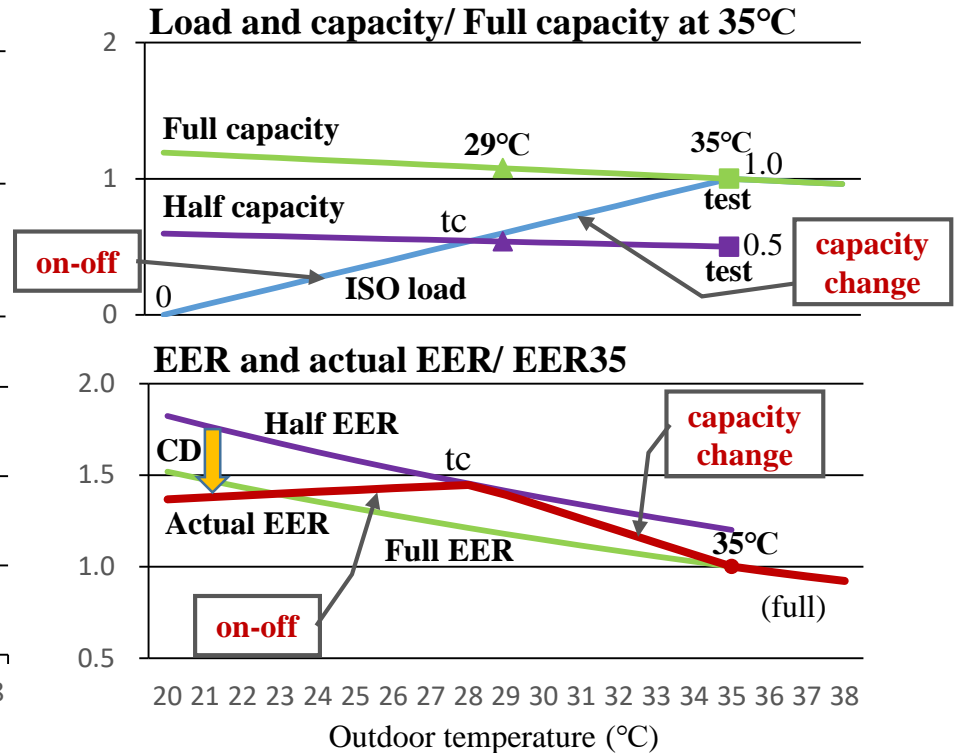
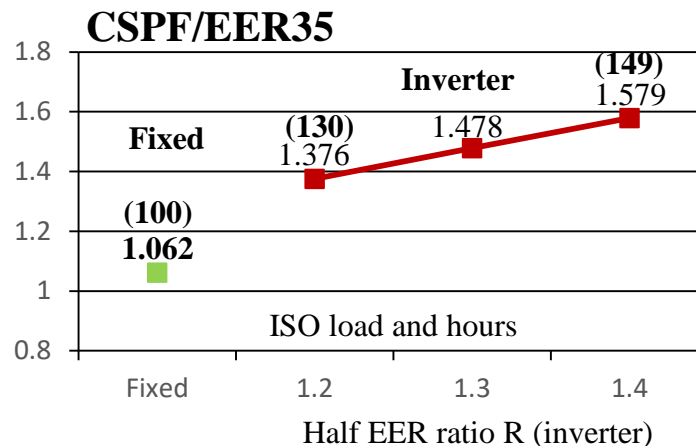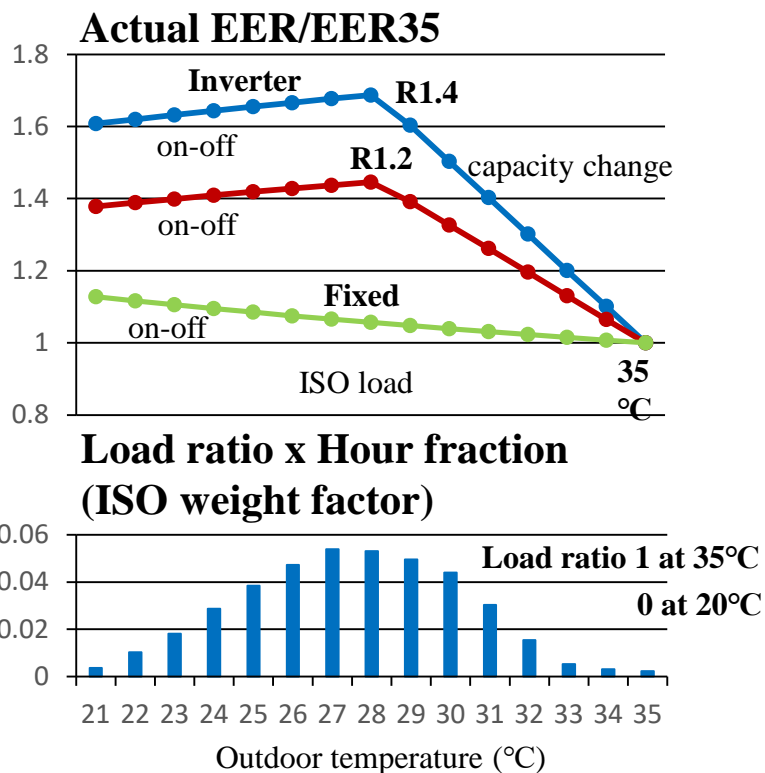**Actual EER increases from full EER by capacity change from 35°C to tc, and decreases from half EER under tc.**

CD: Degradation coefficient = 0.25

tc: Cross temperature of load and half capacity (°C)

2. Evaluation of inverter unit by CSPF
2) CSPF ratio to EER35

Actual EER/EER35

Inverter R1.4
on-off
R1.2
on-off capacity change
Fixed
on-off
ISO load
35 ℃

CSPF/EER35

Inverter (149) 1.579
Fixed (130) 1.376
(100) 1.062
1.478
ISO load and hours
Fixed   1.2   1.3   1.4
Half EER ratio R (inverter)

Load ratio x Hour fraction (ISO weight factor)

Load ratio 1 at 35℃
0 at 20℃
21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
Outdoor temperature (℃)

R = [Half EER/Full EER] at 35℃
= usually 1.2 to 1.4

Load ratio = Load/ [Full capacity at 35℃]
Hour fraction = Hours/ Total hours

EER35 = Full EER at 35℃ (conventional EER)

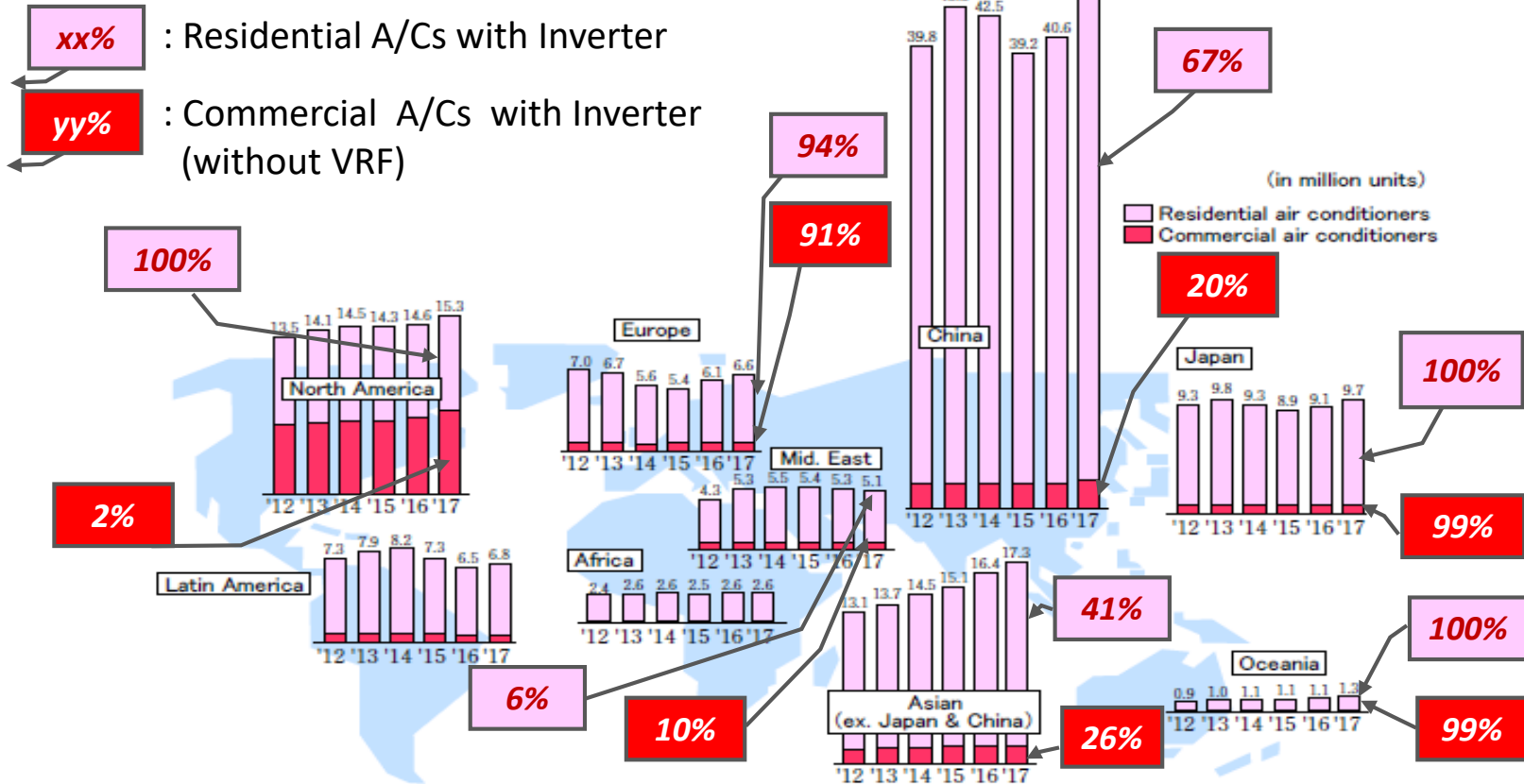[CSPF/EER35] is a kind of average of [Actual EER/EER35] weighted by [Load ratio x Hour fraction].

CSPF/EER35 of fixed speed unit is constantly 1.062 for ISO load and hours.
CSPF/EER35 of inverter unit changes by half EER ratio. It is usually 30 to 50 % higher than fixed speed.

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2. Evaluation of inverter unit by CSPF
3) Global sales and percentage of inverter unit

Global sales in 2017 : 111 M-units

xx% : Residential A/Cs with Inverter

yy% : Commercial A/Cs with Inverter (without VRF)

100%

2%

94%

91%

67%

20%

100%

99%

6%

10%

41%

26%

100%

99%

(in million units)
Residential air conditioners
Commercial air conditioners

North America
13.5 14.1 14.5 14.3 14.6 15.3
'12 '13 '14 '15 '16 '17

Latin America
7.3 7.9 8.2 7.3 6.5 6.8
'12 '13 '14 '15 '16 '17

Europe
7.0 6.7 5.6 5.4 6.1 6.6
'12 '13 '14 '15 '16 '17

Mid. East
4.3 5.3 5.5 5.4 5.3 5.1
'12 '13 '14 '15 '16 '17

Africa
2.4 2.6 2.6 2.5 2.6 2.6
'12 '13 '14 '15 '16 '17

China
39.8 43.3 42.5 39.2 40.6 45.9
'12 '13 '14 '15 '16 '17

Japan
9.3 9.8 9.3 8.9 9.1 9.7
'12 '13 '14 '15 '16 '17

Asian (ex. Japan & China)
13.1 13.7 14.5 15.1 16.4 17.3
'12 '13 '14 '15 '16 '17

Oceania
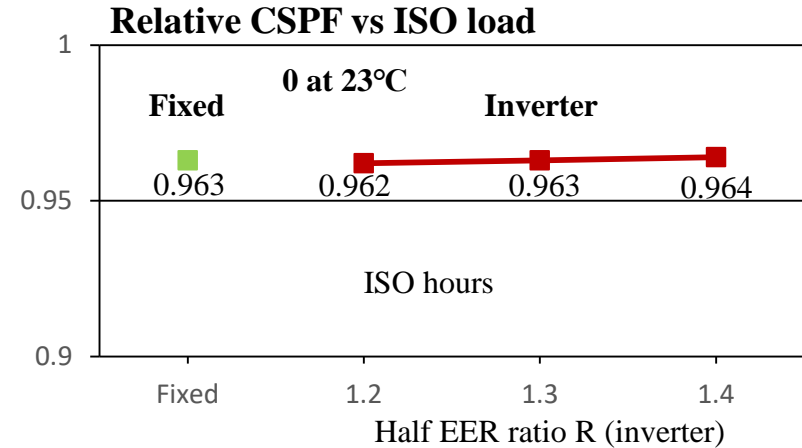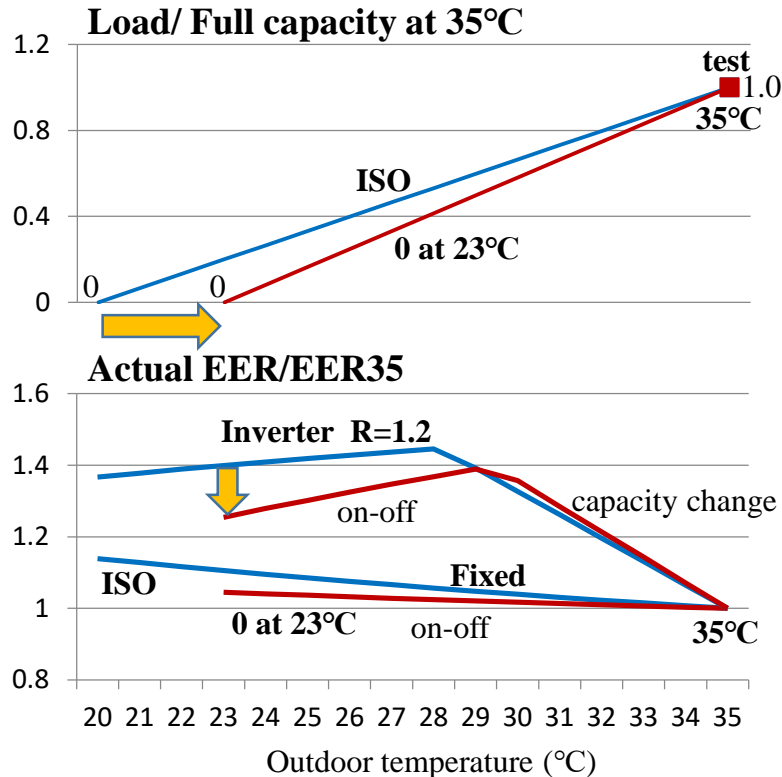0.9 1.0 1.1 1.1 1.1 1.2
'12 '13 '14 '15 '16 '17

**Market proportion of inverter unit is about 50 % or less in ASEAN countries except Singapore.
There is no technology other than inverter which is more effective for energy saving.**

3. Effect of local load and hour fraction
1) No load temperature

ISO load is 0 at 20°C. Load for Hong Kong, Taiwan and India is 0 at 23°C.

Load/ Full capacity at 35°C

test
1.0
35°C

ISO

0 at 23°C

0   0

Actual EER/EER35

Inverter R=1.2

on-off

capacity change

ISO

0 at 23°C   on-off

Fixed

35°C

Outdoor temperature (°C)

Relative CSPF vs ISO load

0 at 23°C

Fixed   Inverter

0.963   0.962   0.963   0.964

ISO hours

Fixed   1.2   1.3   1.4
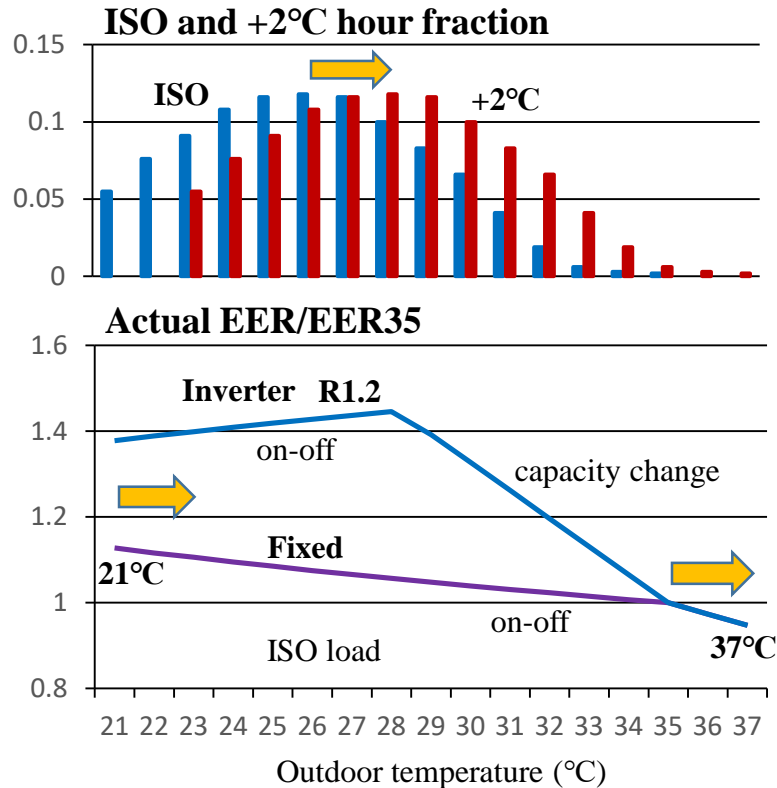
Half EER ratio R (inverter)

R = [Half EER/Full EER] at 35°C
 = usually 1.2 to 1.4

EER35 = Full EER at 35°C (conventional EER)

When no load temperature becomes higher, reduction rate of actual EER in on-off zone becomes greater.
However, reduction rate of CSPF is same for all types of unit.
Relative evaluation of unit efficiency does not change by no load temperature.

3. Effect of local load and hour fraction
2) Temperature shift hours

ISO and +2°C hour fraction

Actual EER/EER35

Outdoor temperature (°C)

Relative CSPF vs ISO hours

Half EER ratio R (inverter)
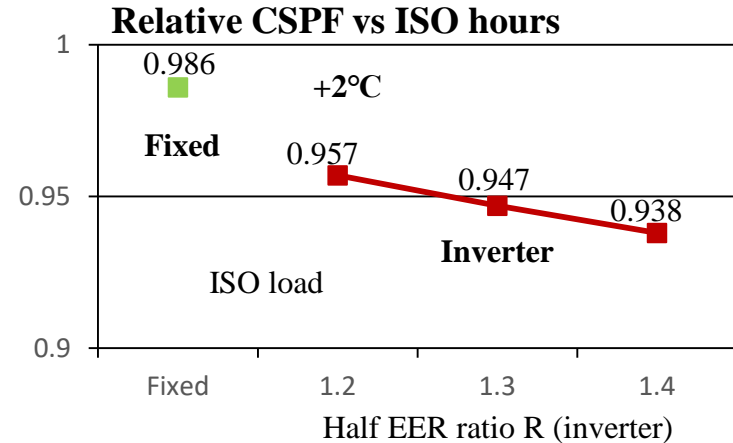
Hour fraction = Hours/Total hours
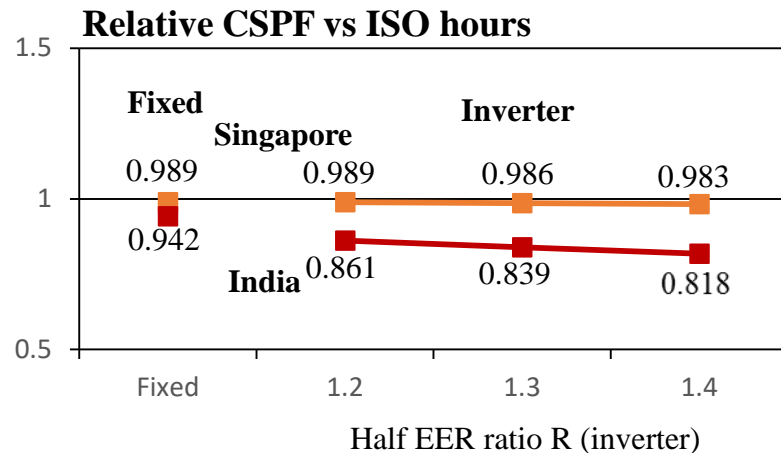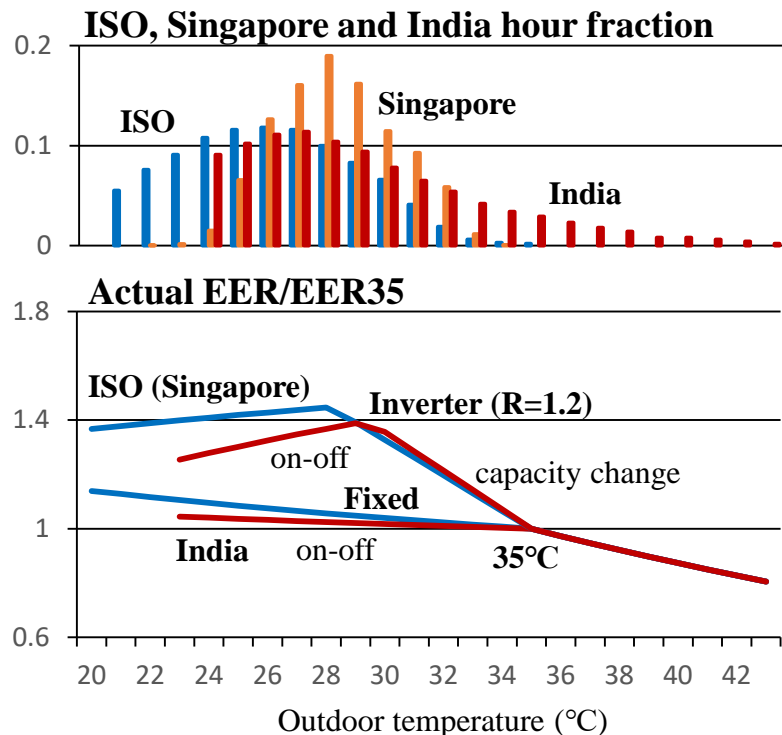
R = [Half EER/Full EER] at 35°C
= usually 1.2 to 1.4

EER35 = Full EER at 35°C (conventional EER)

CSPF decreases by +2°C shift, because actual EER at higher temperature side is lower than at lower side.
Reduction of CSPF by +2°C shift for inverter unit is 3 to 5 % greater than fixed speed.

Reduction of CSPF for ASEAN climate is smaller than this case. This is shown next.

3. Effect of local load and hour fraction
3) Singapore (Typical ASEAN climate) and India hours

ISO, Singapore and India hour fraction

ISO

Singapore

India

Actual EER/EER35

ISO (Singapore)

Inverter (R=1.2)

on-off

capacity change

Fixed

India   on-off

35℃

Outdoor temperature (℃)

Relative CSPF vs ISO hours

Fixed

Singapore

Inverter

0.989   0.989   0.986   0.983

0.942

India 0.861   0.839   0.818

Half EER ratio R (inverter)

Hour fraction = Hours/Total hours
EER35 = Full EER at 35℃ (conventional EER)

R = [Half EER/Full EER] at 35℃
= usually 1.2 to 1.4

Mean temperature for Singapore is higher than ISO. However, reduction of CSPF is small, because hours are concentrated with no hour over 35℃. **For ASEAN, CSPF practically will not change from ISO hours.**

Reduction of CSPF for India is much greater. **ISO hours may be unsuitable for India.**
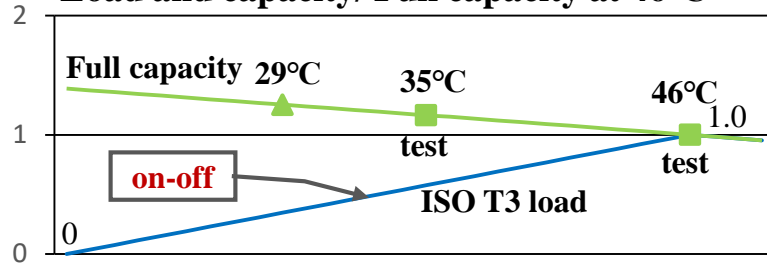
3. Effect of local load and hour fraction
4) Proposed ISO T3 calculation (Amendment draft)

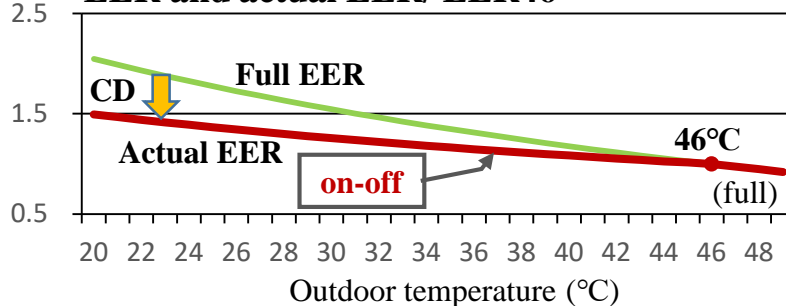**ISO T3 load and hours represent Middle East.**
Although test points and load are different from T1 climate, characteristics of actual EER is similar.

Fixed speed unit

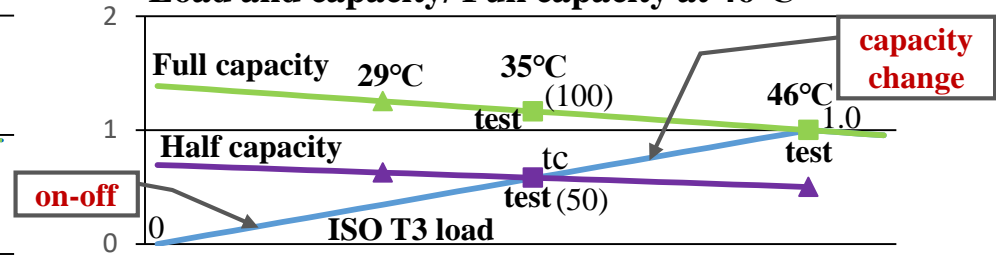**Load and capacity/ Full capacity at 46°C**

EER and actual EER/ EER46

Inverter unit

Load and capacity/ Full capacity at 46°C

EER and actual EER/ EER46

Outdoor temperature (°C)

Actual EER decreases from full EER by on-off under 46°C.
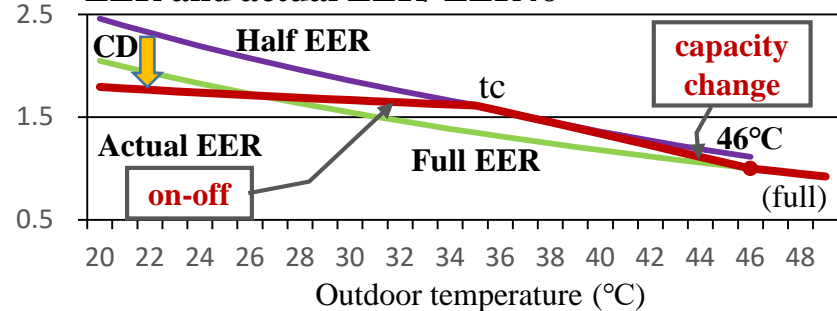
Actual EER increases from full EER by capacity change from 46°C to tc, and decreases from half EER under tc.

CD: Degradation coefficient = 0.27

tc: Cross temperature of load and half capacity (°C)

3. Effect of local load and hour fraction
5) CSPF by T1 and T3 calculation

ISO T3 hours are based on average temperatures of Liyadh, Saudi Arabia and Abu Dhabi, UAE.
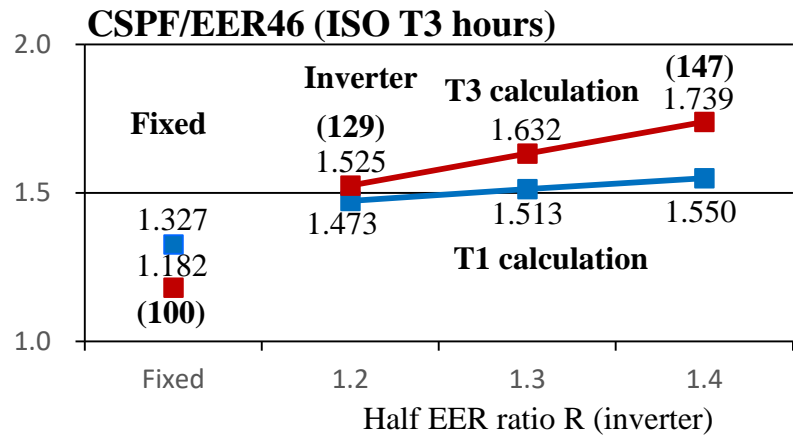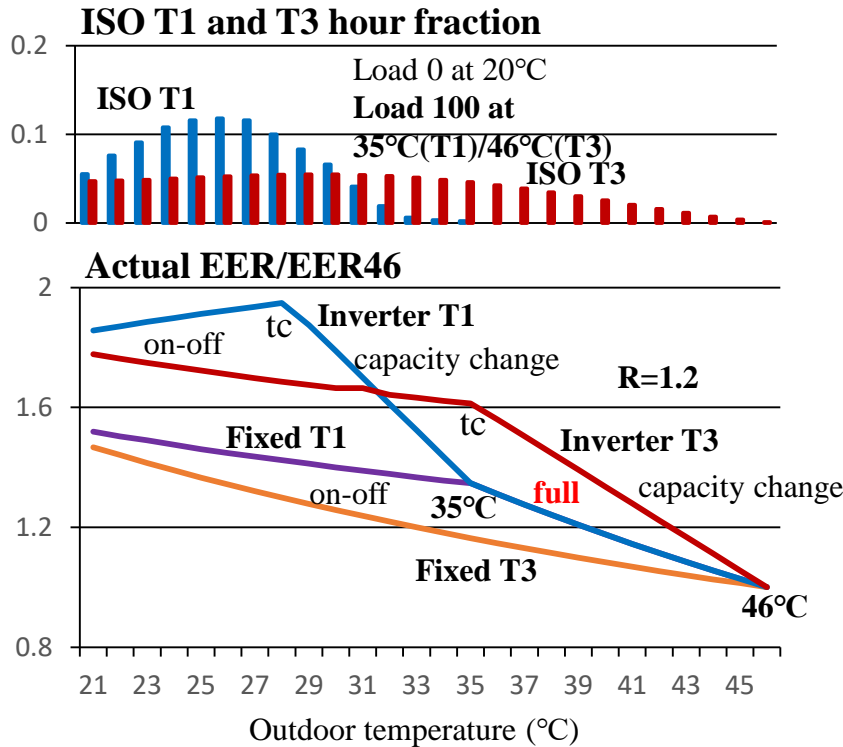
Hour fraction = Hours/ Total hours

EER46 = Full EER at 46°C (conventional T3 EER)

R = [Half EER/Full EER] at 35°C
 = usually 1.2 to 1.4

In T1 calculation, inverter unit cannot increase capacity over 35°C. This will not match actual unit selection.
In T3 calculation, CSPF for inverter unit is 30 to 50 % higher than fixed speed at usual half EER ratio.

Energy saving effect of inverter is almost same for any climate if unit capacity is correctly selected for load.

4. Promotion of CSPF in ASEAN

METI Project on Adoption of international standard and installation to local regulation (IS-INOTEK/JEMA, FY2014 to 2016)
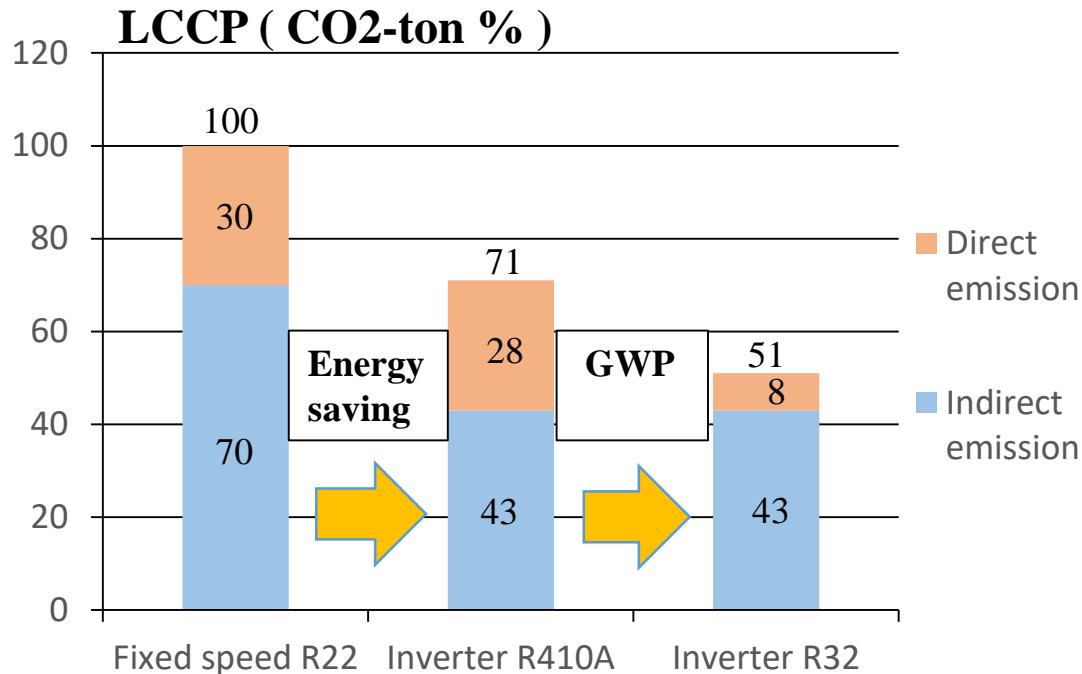
■Promotion of new international standard (ISO16358-1) to ASEAN countries
■Training program and round robin tests by JATL (Testing Laboratory)
■Harmonization of standards among ASEAN countries

	2014	2015	2016	2017	2018
Thailand		CSPF Standard◆			
	MEPS/HEPS EER		▲CSPF Draft ◆	▲CSPF	
	Labeling CSPF Study	▲CSPFLabeling Inverter	▲CSPF Labering for Fixed Cap.		
Malaysia		CSPF Standard◆			
	EER & Weighted EER	▲ CSPF Draft	◆	▲CSPF	
Philippine	CSPFStandard ◆				
	EER	CSPF Study	▲CSPF Draft ◆	▲CSPF	
Indonesia			▲CSPF Standard		
		EER & Weighted EER			
Singapore	CSPFStd◆				
	EER & Weighted EER	◆Label level up	CSPF Study	▲CSPF Draft	
Vietnam		CSPFStandard ◆			
	▲CSPF for Inv.	▲CSPF Label and MEPS for all type			

▲Initiation ◆Completion ■ ■Standardization ■ ■Regulation

5. Case study of LCCP (or TEWI)
1) Case of cooling only in summer daytime

LCCP (CO2-ton %)

Chart values:
- Fixed speed R22: Total 100 (Indirect 70, Direct 30)
- Inverter R410A: Total 71 (Indirect 43, Direct 28)
- Inverter R32: Total 51 (Indirect 43, Direct 8)

Energy saving → **GWP** →

Legend: Direct emission, Indirect emission

Air Conditioners

Full capacity: 4.0 kW
Full EER: 4.0 (fixed), 5.0 (inverter)
Half EER ratio: 1.2 (inverter)
Refrigerant charge: R22-1.4 kg/
    R410A-1.1 kg/ R32-1.0 kg
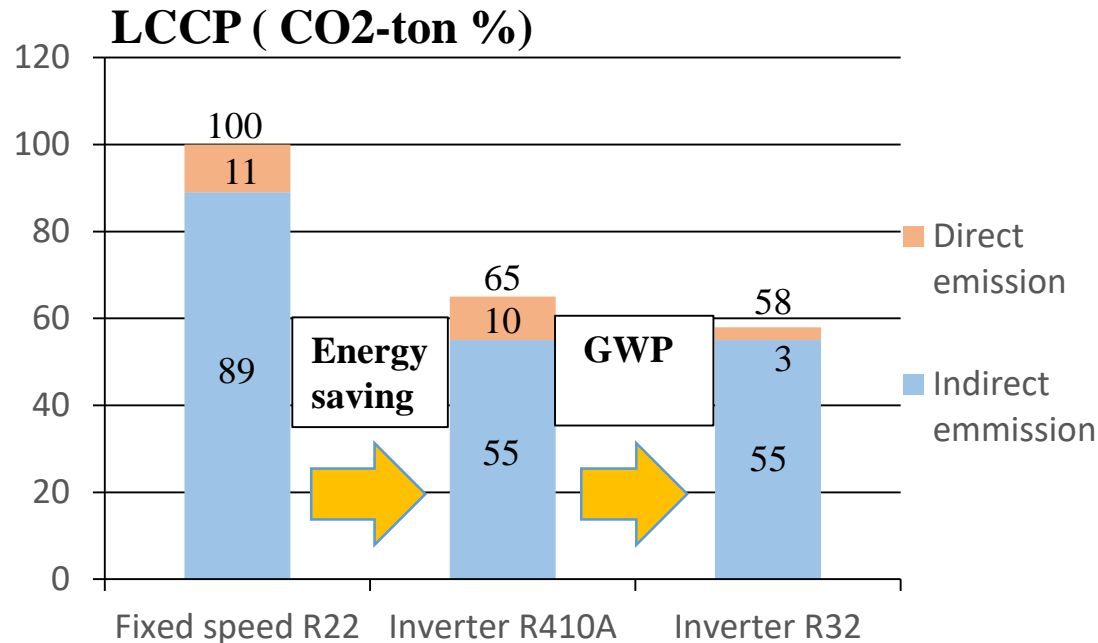GWP: R22-1810/ R410A-2090/
    R32-675

Conditions

Emission factor: 0.49 CO2-kg/kWh
Life: 12 years
Operation: 1817 hours/year (ISO T1)
    ISO T1 hour fraction
Leakage: 0 %/year
Refrigerant recycle: 30 %

LCCP: Life Cycle Climate Performance
TEWI: Total Equivalent Warming Impact
Direct emission: based on GWP of refrigerant
Indirect emission: based on Power consumption in operation

In order to correctly evaluate power consumption, seasonal efficiency CSPF must be used instead of EER.

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5. Case study of LCCP (or TEWI)
1) Case of all year round cooling

LCCP (CO2-ton %)

Chart values (Fixed speed R22): Direct 11, Indirect 89, total 100
(Inverter R410A): Direct 10, Indirect 55, total 65
(Inverter R32): Direct 3, Indirect 55, total 58

Labels: Energy saving → , GWP →

Legend: Direct emission (orange), Indirect emmission (blue)

Categories: Fixed speed R22, Inverter R410A, Inverter R32

Air Conditioners

Full capacity: 4.0 kW
Full EER: 4.0 (fixed), 5.0 (inverter)
Half EER ratio: 1.2 (inverter)
Refrigerant charge: R22-1.4 kg/ R410A-1.1 kg/ R32-1.0 kg
GWP: R22-1810/ R410A-2090/ R32-675

Conditions

Emission factor: 0.7 CO2-kg/kWh
Life: 12 years
Operation: 6570 hours/year (75 %) ISO T1 hour fraction
Leakage: 0 %/year
Refrigerant recycle: 0 %

LCCP: Life Cycle Climate Performance
TEWI: Total Equivalent Warming Impact
Direct emission: based on GWP of refrigerant
Indirect emission: based on Power consumption in operation

For regions to use cooling all year round, operating power consumption has major effect for total emission. Higher efficiency may be more effective than lower GWP to reduce total emission in these regions.

6. Conclusion
1) Conclusions

■ Conventional EER evaluates efficiency only at 35°C, but CSPF evaluates average efficiency for all operating temperatures.

■ CSPF for inverter unit is usually 30 to 50 % higher than fixed speed unit.

■ For high ambient T3 climate, load and calculation method are different, but energy saving effect of inverter unit is almost same.

■ For the purpose of LCCP study, seasonal efficiency CSPF must be used instead of EER in order to correctly evaluate power consumption.

■ Higher efficiency may be more effective than lower GWP to reduce total emission in regions to use cooling all year round.

6. Conclusion
2) Advantages of CSPF

■ **Consumer: More selection for energy efficient products in actual use.**

■ **Government: More measures to reduce power consumption and climate impact in actual use.**

■ **Manufacturer: More opportunity to fairly demonstrate energy saving products**

Thank you!