Understanding HVAC Efficiency Opportunities with Inverter Technology

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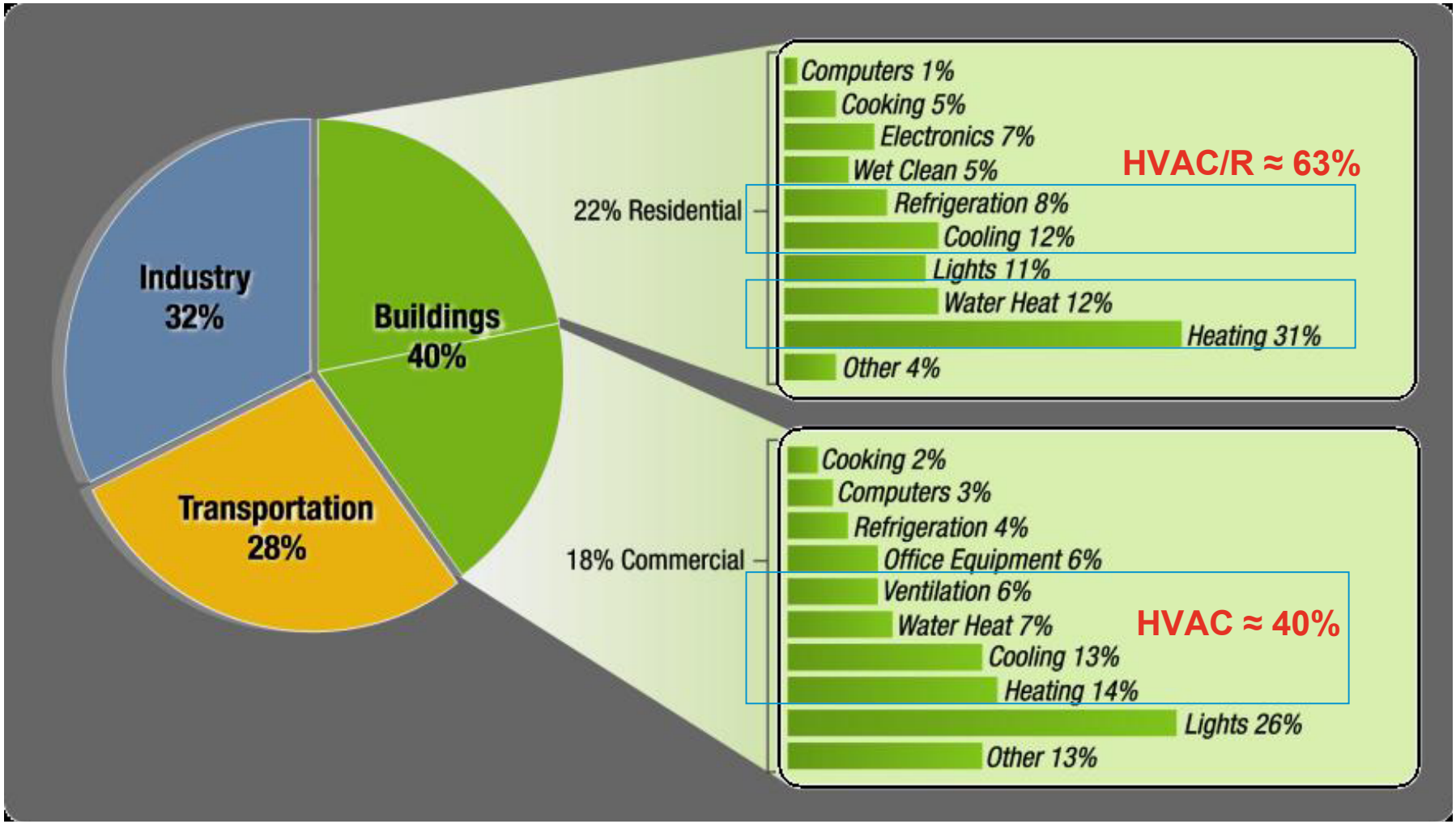
DAIKIN

Brief Introduction - Contents

- Energy Issue Related to HVAC
  - Energy Usage
    - AC Uses most Energy among Household Appliances
    - AC Demand Continues to Increase, so Does Energy Need
  - Technical Solution – Inverter
    - Energy Saving by Inverter Technology, Especially in Partial Load Condition
- Current State of Inverter Technology in the World
  - Percentage of Inverter Shipment still Small
  - Acceptance Accelerated Promoted by Policy Change
- How Does Inverter Technology Work?
  - Performance Examples
- Is Inverter Cost Prohibited?
  - Cost-SEER Curve
  - System Cost Analysis
- Inverter Technology Widens Design Options – Heat Pump Example
- Inverter Technology and Electricity Network
- Conclusion

Energy Issue Related to HVAC – Largest Energy Consumption Group

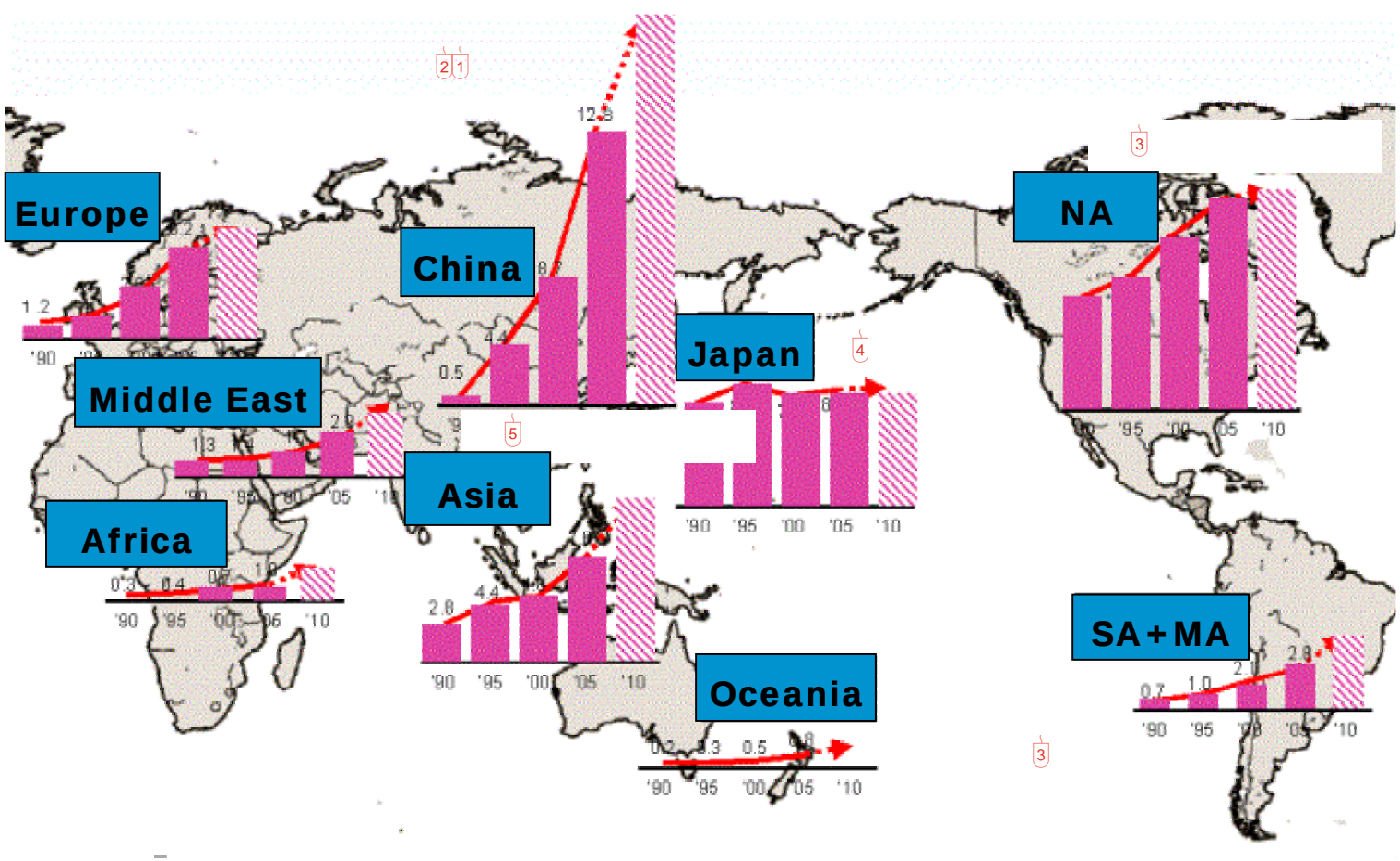


- Buildings Consume 40% of US Primary Energy
- HVAC consumes the most among all uses

Source: www.highperformance buildings.gov

A/C Demand Continues to Increase

Global A/C market continue to expand, RAPIDLY



Source: Trend of Global A/C Market (2007, by JRAIA and Daikin)

Possible Technical Solution - General

- Finding a suitable Energy Efficient Technology can be difficult
- Summary of Profiled Emerging Energy-Efficient Industrial Technologies*

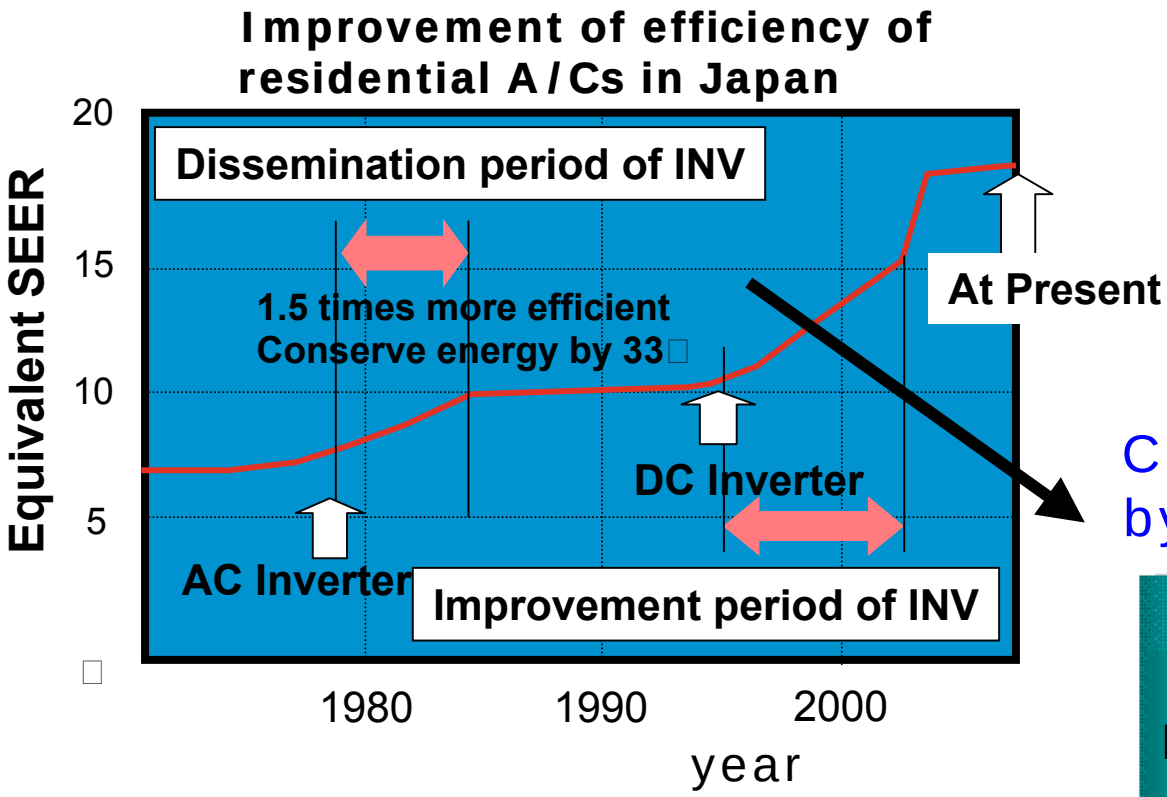
Technology	Sector	Total Energy Savings	Sector Savings	Simple Payback	Environ. Benefits
Hi-tech facilities HVAC	Crosscutting	Medium	High	4.0	None
Advanced lighting technologies	Crosscutting	High	High	1.3	None
Advanced lighting design	Crosscutting	High	High	3.0	None
Variable wall mining machine	Mining	Low	Low	10.6	None
Advance ASD designs	Crosscutting	High	Medium	1.1	None
Advanced compressor controls	Crosscutting	Medium	Low	0.0	None
Compressed air system management	Crosscutting	High	High	0.4	None
Motor diagnostics	Crosscutting	Low	Low	Immediate	None
Motor system optimization	Crosscutting	High	High	1.5	Somewhat
Pump efficiency improvement	Crosscutting	High	High	3.0	None
Switched reluctance motor	Crosscutting	Medium	Low	7.4	None
Advanced lubricants	Crosscutting	Medium	Medium	0.1	Significant

⇨ **Inverter Driven technologies have reflected such items plus more**

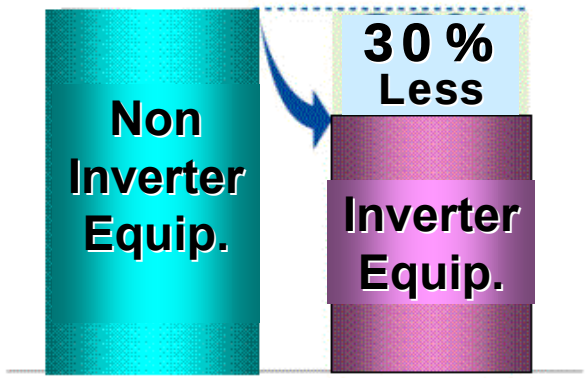
***: Excerpted from EMERGING ENERGY-EFFICIENT INDUSTRIAL TECHNOLOGIES by LBNL & ACEEE (2000)**

Inverter Provides Energy Saving Possibility

■Inverter can conserve energy by 30%



Conserve Energy by 30%!!



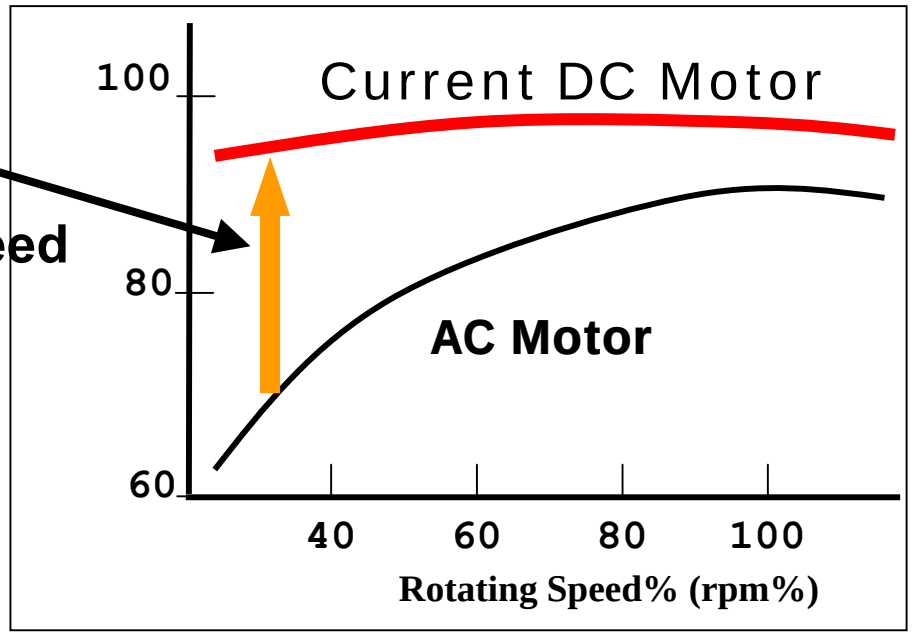
Partial Load Saving is Significant with Inverter Technology

■Higher energy conservation ratio
in terms of SEER

Inverter & DC Motor

Improve partial load efficiency
→Higher energy conservation ratio in terms of SEER

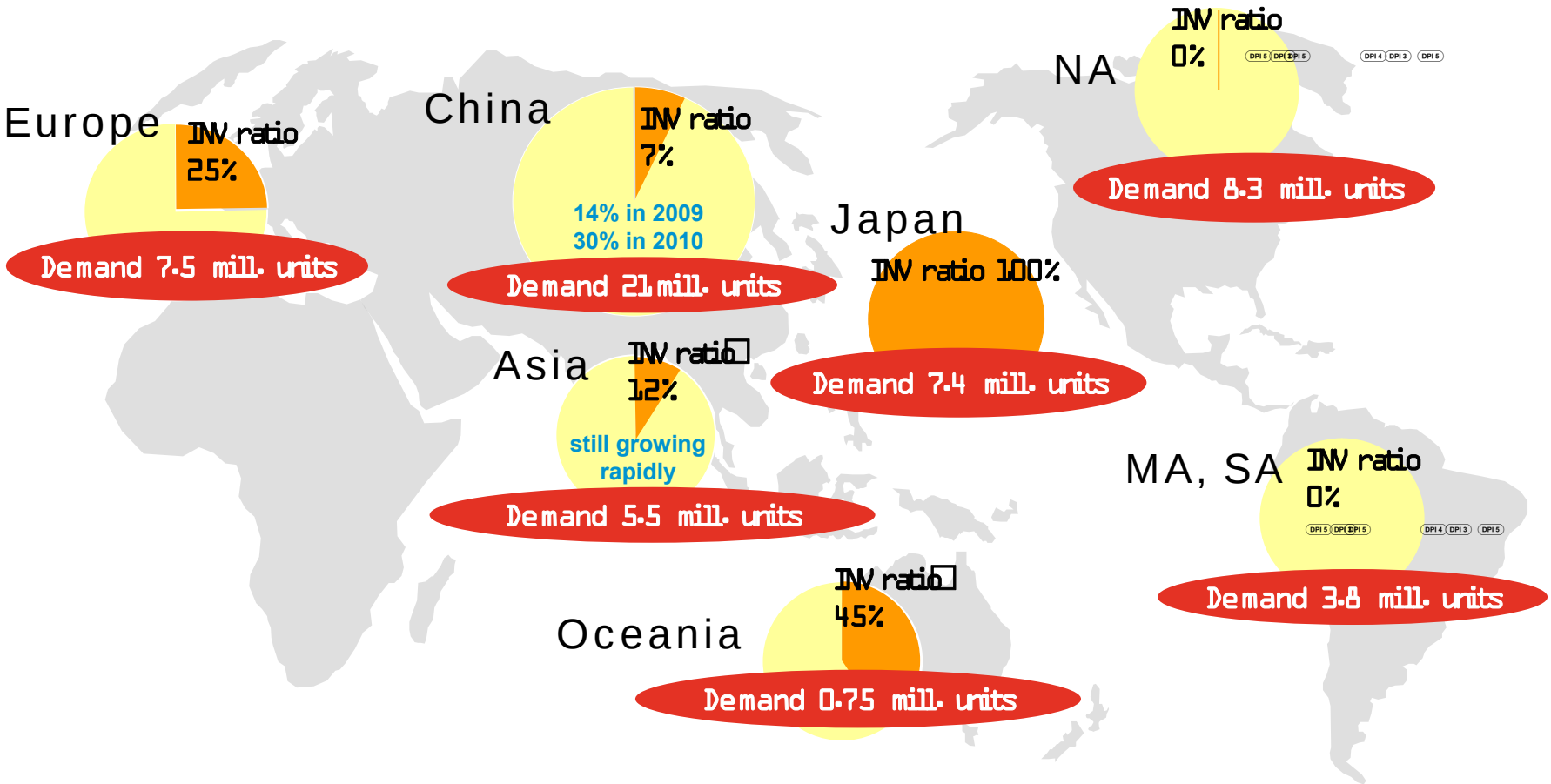
DC motor:
High efficiency while operating at slow speed



Percentage of Inverter-equipped System is Still Small

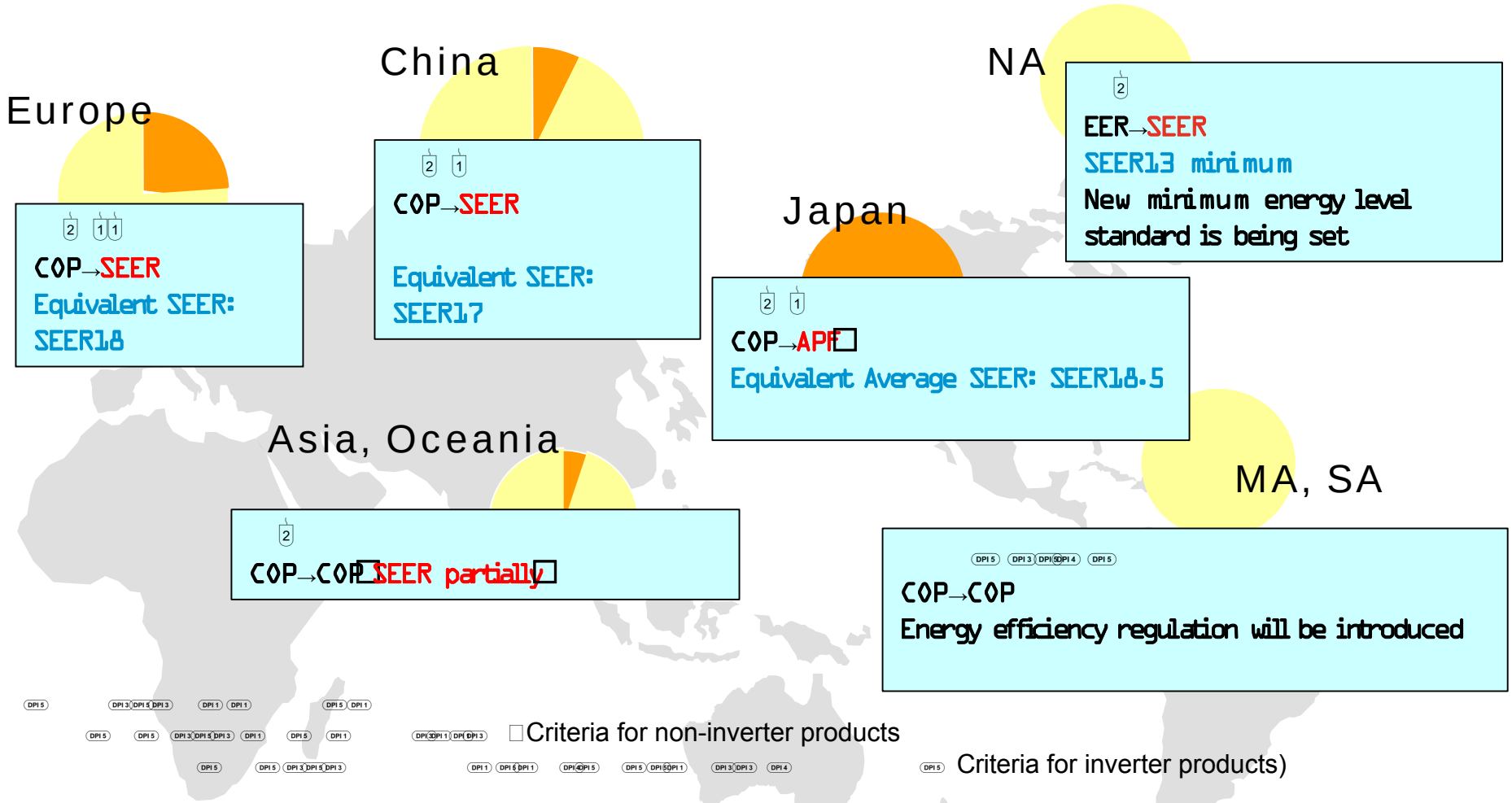
■Penetration ratio of Residential A/C with inverter is still small

Residential A/C in 2007, Daikin's survey



Adoption of Inverter System is Accelerated w/Policy Changes

■World regulations and standards adopting SEER to evaluate efficiency of A/C, increasing demand for A/C with inverter

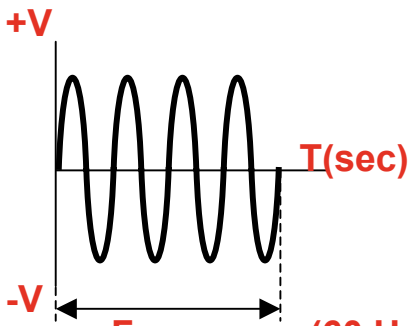


□Criteria for non-inverter products

Criteria for inverter products)

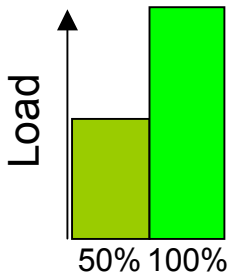
Inverter Technology – How it Works

Constant Speed System



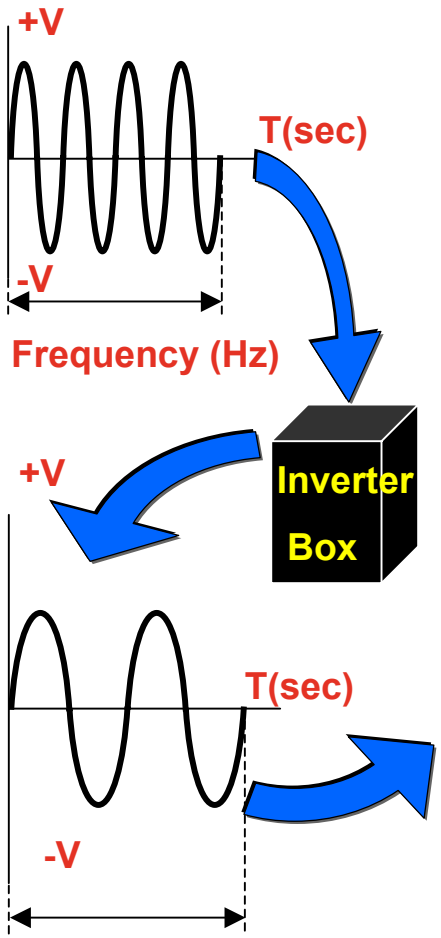
- 60 Hz AC input power drives the compressor

Standard Compressor Options
Single Speed
Un-loader
Two Speed
Two Compressors



Compressor capacity

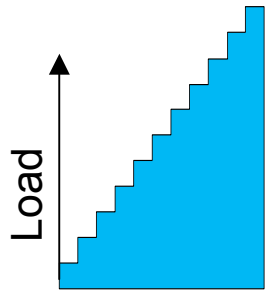
Inverter System



Frequency 30 to 130 (Hz) Example

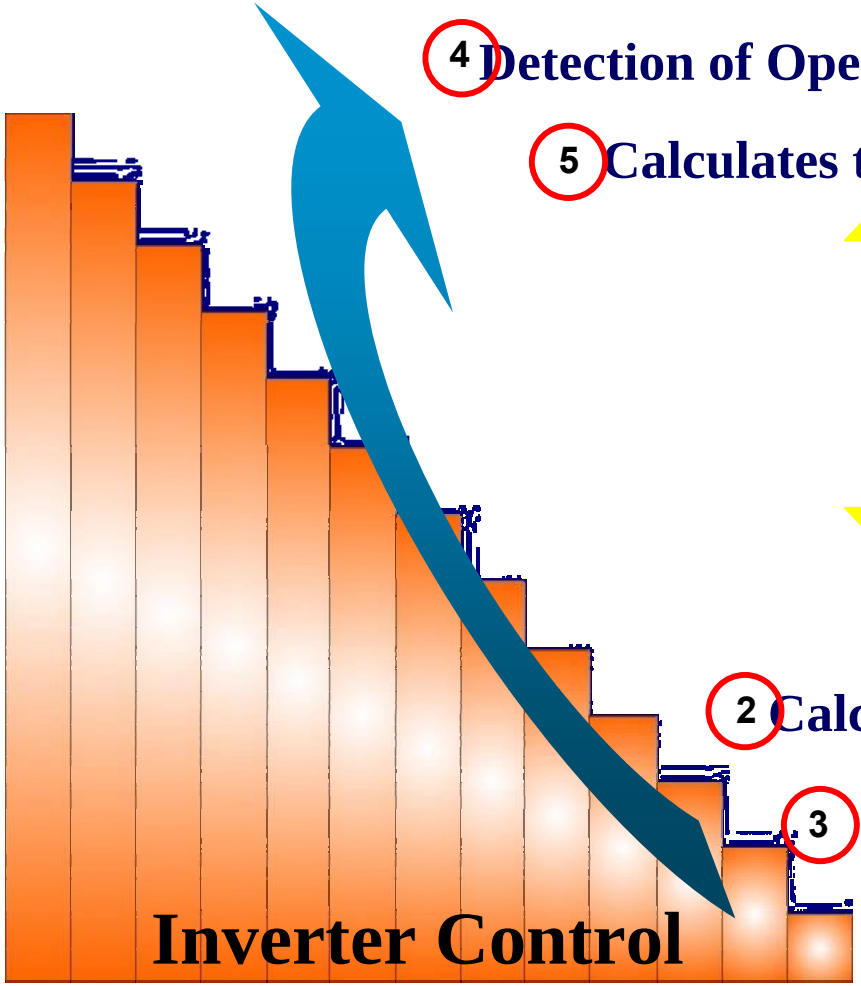
- The inverter control adjusts the supply frequency
- Thus the rotational speed of the compressor is controlled
- Exactly the right amount of refrigerant gas is pumped to meet the cooling/heating requirements

Multi-Step Principle



many capacity steps
Applied frequency

Inverter Technology – Typical Control Process



4 Detection of Operating Pressure (Suction pressure Every 20 Seconds)

5 Calculates the Deflection from target Pressure

6 Adjusts the Frequency

Up

Down

1 Detects Reference temp.
(Return air temp & setpoint)
and Outdoor temp.

2 Calculates the Corresponding Capacity

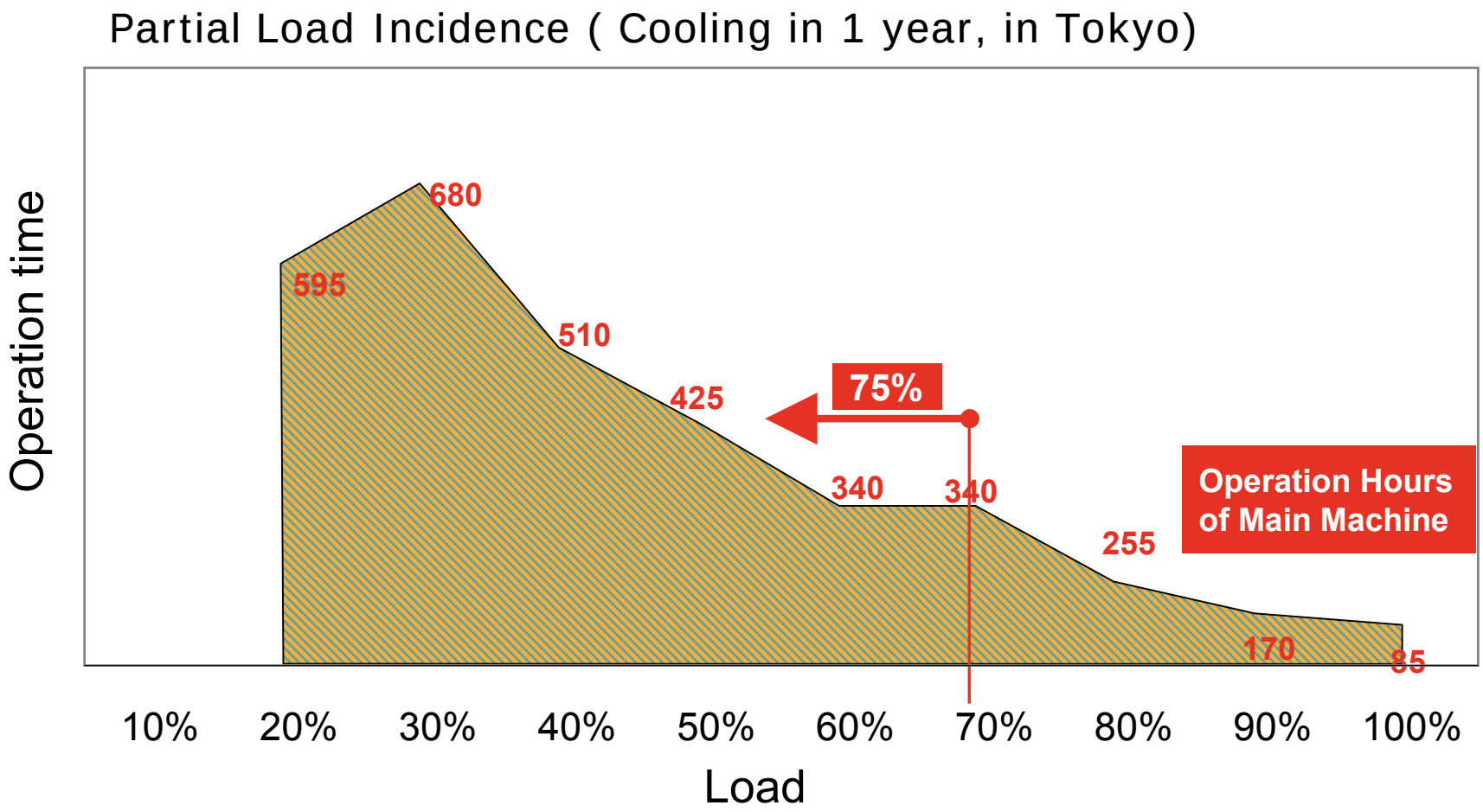
3 Controls the Compressor and Fan

Large ⟷ Load ⟷ Small

many control steps on single compressor + up to thousands Steps on Each Indoor Unit

Inverter Technology – Typical Operation Condition

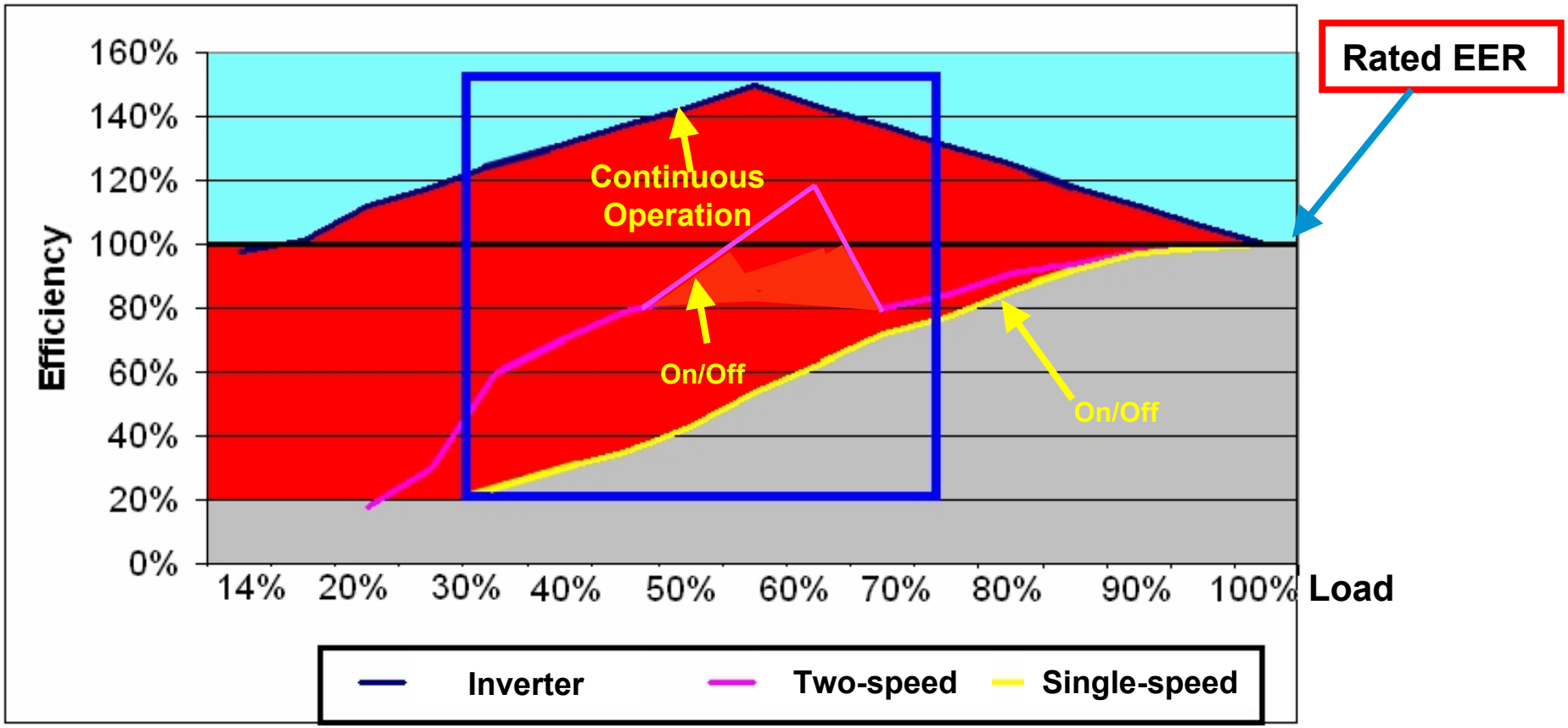
More than 75% operation time in a year is less than 70%-load of compressor.



Inverter Technology – System Efficiency Comparison

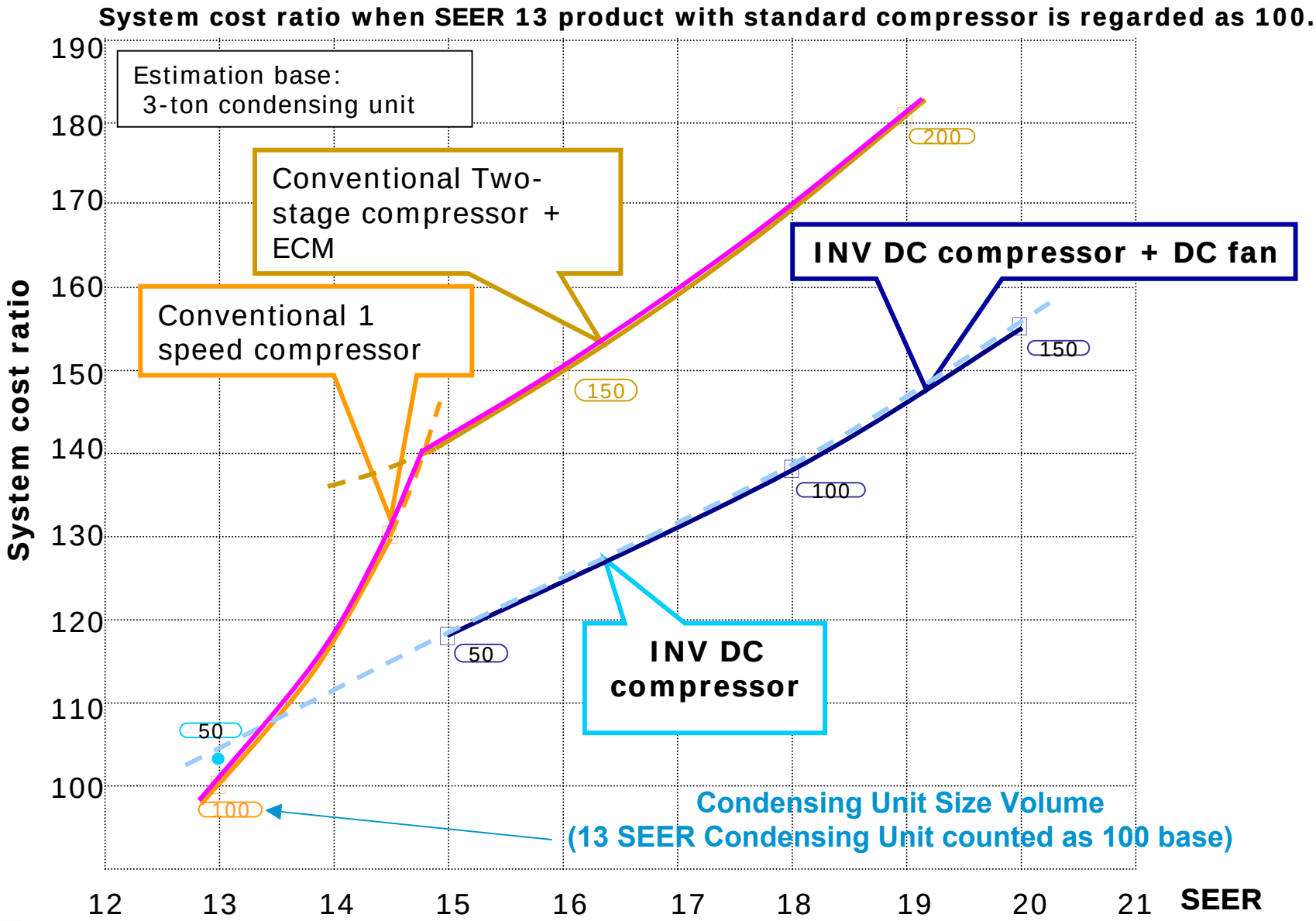
Comparison of inverter vs. two-speed and single speed compressors

(typical performance)



Using EER as a guide, all of the systems meet the efficiency rating.
But not all systems save the same amount of energy!

Inverter Cost Analysis – Cost vs. SEER Curve



Inverter Cost Analysis – “Half Size, Same cost”

◆SEER13 performance was achieved with SEER10 unit size volume

Size Comparison

Inverter Technology – Extend the Application Possibility

Inverter Technology has changed/widened design applications/options – Example of Heat Pump

With inverter, heat pump becomes very promising Solution

- Energy issue – provide a higher energy efficiency
- Environment issue – reduce CO2 emission significantly
  - Heat pump can be a primary heating system in cold climate region, gas heating as backup system because inverter-equipped heat pump can be operated at a temperature as low as 15F (usual single speed Heat Pump, 40-50F) and still maintain a relative high COP.
  - Therefore, burning less fossil fuel → CO2 emission reduction
  - Intelligence control system

Inverter Technology – Heat Pump Application (Energy)

Unit of heat from water and air 3 - 5

Renewable Energy Source

Why Heat Pump?

Space heating 4 - 6

Primary energy 2.5

e.g. Heat Pump COP=4 - 6

Electricity 1

Comparison of annual CO2 emissions from heaters in Europe (IEA report 2008)

Oil boilers: 5138Kg

Gas boilers: 3189Kg

Heat Pumps: 1770Kg

- EU parliament acknowledged Heat Pump as a "Renewable Energy Technology"
  - Dec. 17, 2008, EU parliament acknowledged "aerothermal energy" and "hydrothermal energy" as renewable energy sources in addition to geothermal energy

Inverter Technology – Heat Pump Application (Environment)

"Heat Pump" can reduce global CO2 emissions by nearly 8% (IEA)

*IEA: International Energy Agency

World CO2 emissions 27 bill. tons

Transportation
Others

30%
Building
Space
heating

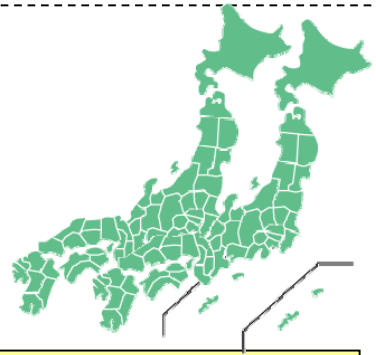
Most heaters burn fossil fuel

35%
Industry

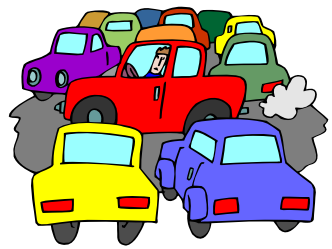
If replace with heat pumps to some extent

8% of total global CO2 emissions

Equivalent



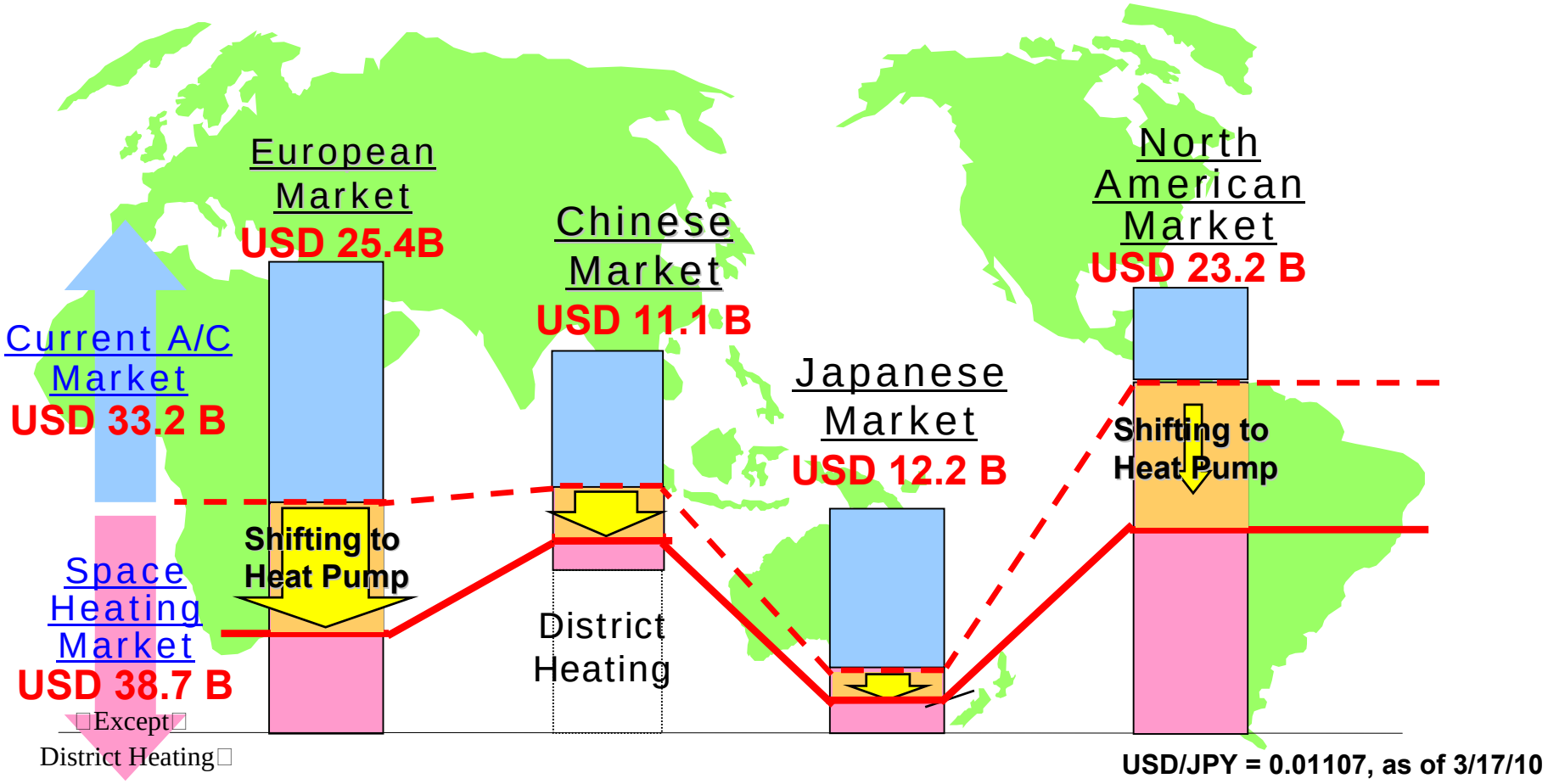
Twice as much as total CO2 emissions of Japan



CO2 emissions from 250 mill cars

Inverter Technology – Heat Pump Application (Environment)

- Fossil fuel is still dominant in global space heating market
- Inverter heat pump can help substantially reduce CO2 emission



Global water/space heating market

Source: BSRIA2006

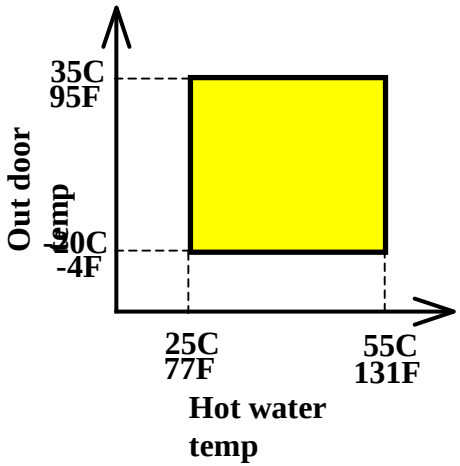
Inverter Application – Wider Operation Temp Range with More Reliability

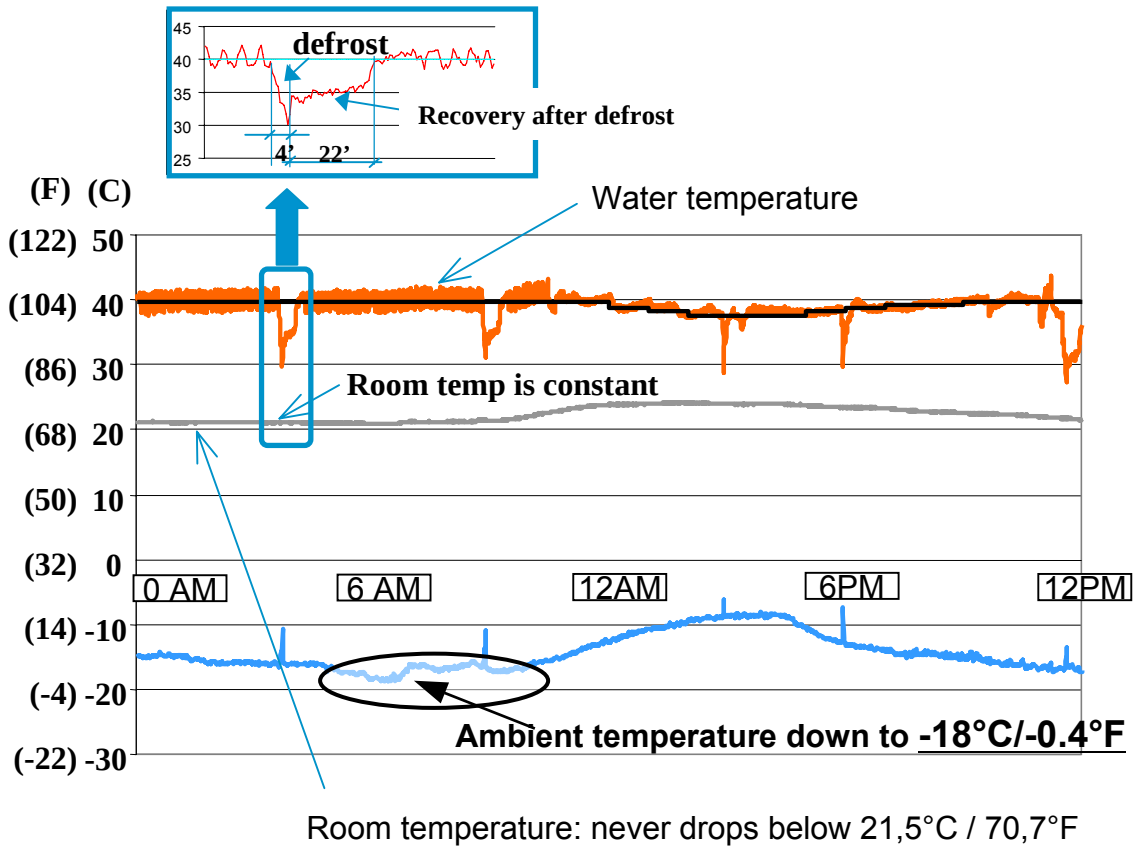
Inverter being used in air-source Heat Pump (combined DHW, space heating and cooling)

- **Wide Temperature Range -> Conventional system could not achieve**
- **System is more reliable**

Altherma in Norway

150 m²/1615 ft² house





Room temperature: never drops below 21,5°C / 70,7°F

A Typical Day in Norway

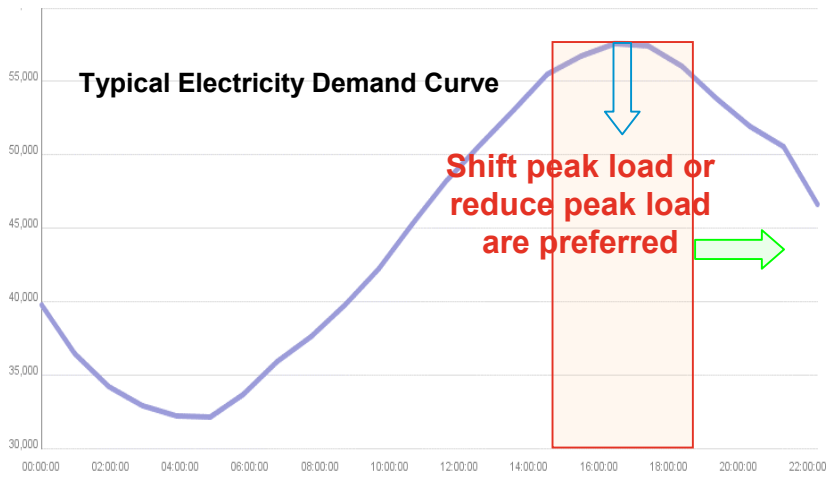
Operating area:

•It works even at -20C/ -4F

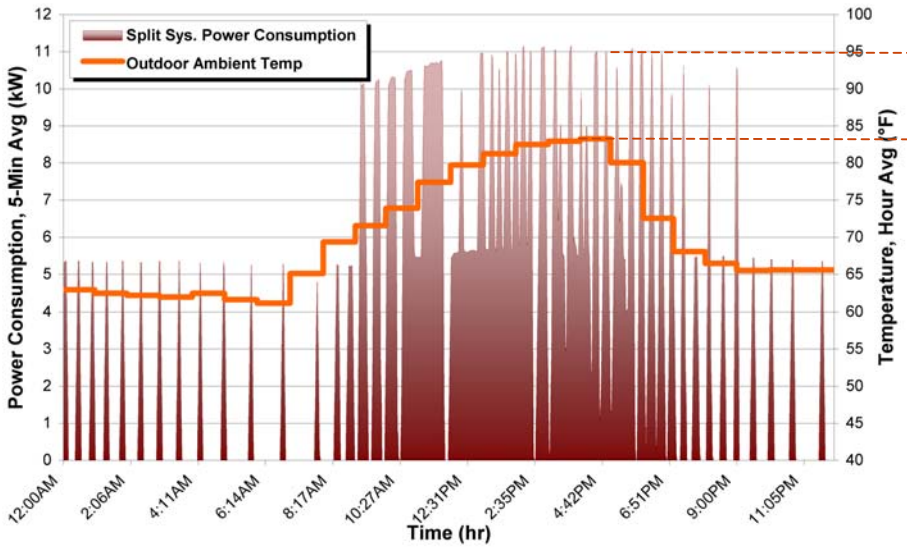
Inverter Technology – Other Typical Advantages

- No in-rush current & grid-friendly
  - Smaller circuit breaker
  - No locked rotor amps
  - No “light flicker”
- More comfort
  - Stable room temperature
- Quiet compressor startup

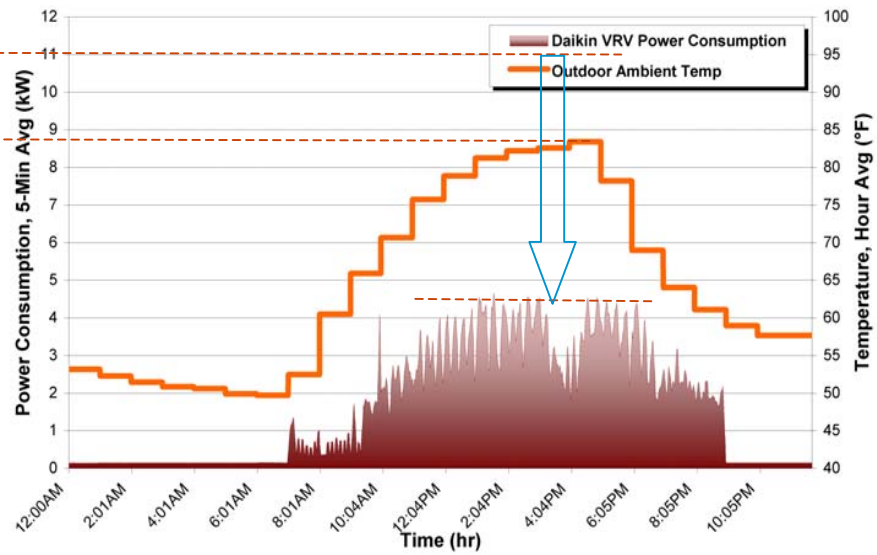
Electricity Peak Demand – Inverter can Help



- Prefer to have demand peak lower an/or shift
- Conventional AC cannot achieve the goal w/o being shut down -> consumer dissatisfied
- Inverter can lower peak



Conventional System Power Consumption Data

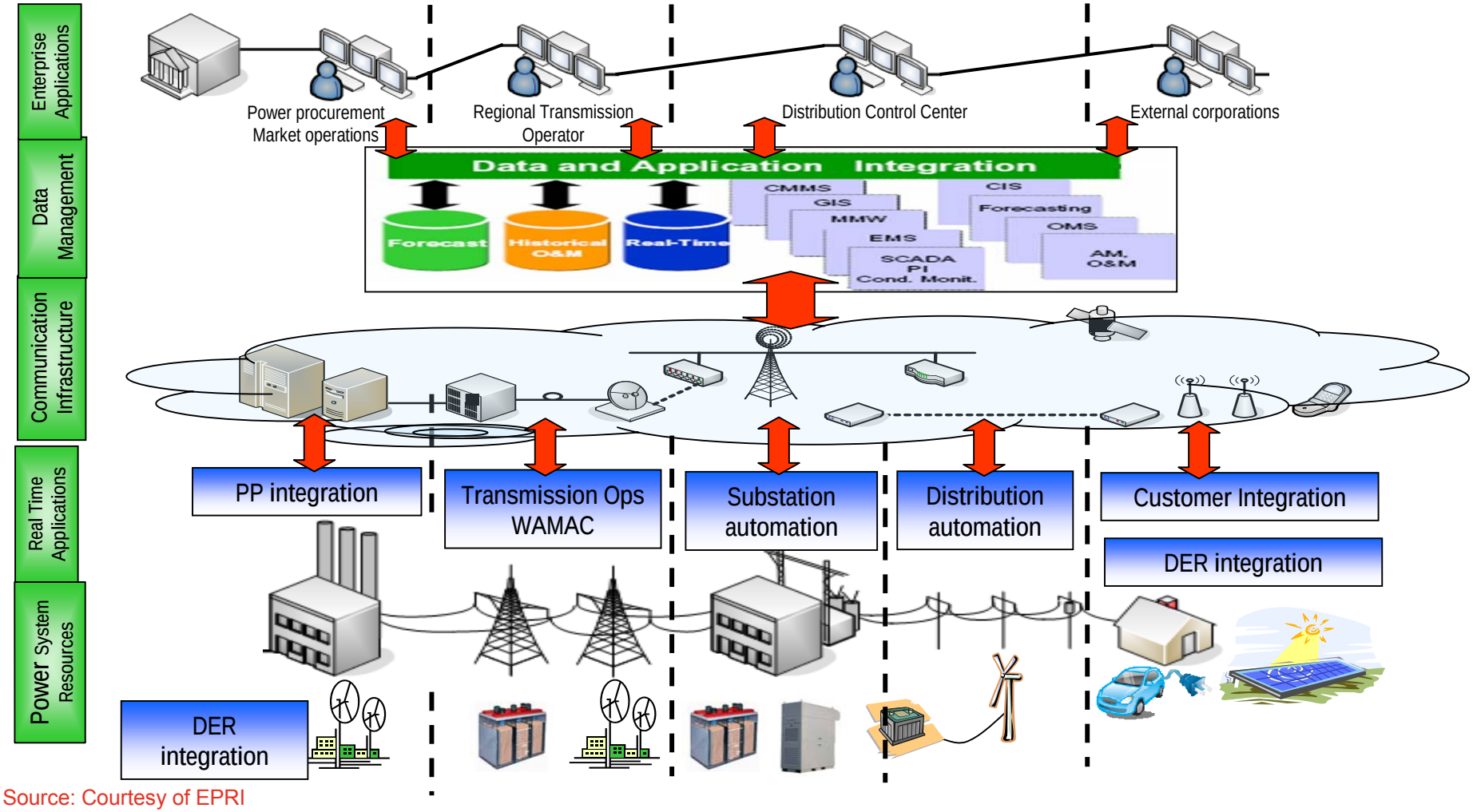


Inverter System Power Consumption Data

* Courtesy of EPRI

Inverter Technology possible to Interface with Smart Grid

- **Smart Grid is in early development stage**
  - **→Inverter technology can be integrated to a smart grid quickly because of built-in "smart control"**



* Source: Courtesy of EPRI

Conclusions

- Inverter technology offers significant benefits in energy savings, especially in part load conditions
  - Most of the time, application is in part load conditions
- Inverter technology can help to protect environment
  - Increase SEER level without large increase of equipment cost
  - Reduce CO2 emission can be achieved by heat pump
  - More comfortable solution comparing to conventional system
- Inverter technology is mature, non-proprietary technology
  - Popular in overseas markets, but not yet in U.S.
  - Adoption rate worldwide is increasing rapidly
- Inverter extends design applications/options
  - Easy demand control by Smart-Grid

Thank you for your time.

Any Questions?