Korea Green Car Fuel Economy Schemes;
Status and Prospect

18 Oct. 2013

Kyung Wan RHO
I. Overview of Korea Fuel Economy Scheme

II. Green Car Policy & Tax Incentive

III. Study on Reform of Tax Incentive Criteria

IV. 5-cycle Test Results of HEV, EV & PHEV
I. Energy Consumption in Korea

- In 2010, 96.2% of total primary energy supply was imported
- Transport sector accounts for nearly 20% of total final energy consumption
- Vehicle stock has increased dramatically
  - Production volume was 4.56M in 2012, increased by 19.1% compared to 2008
  - Domestic sales volume amounted to 1.41M in 2012, increased by 22.2%
  - Registered vehicles accounted for 18.87M in 2012, increased by 12.4%
I. Korea Fuel Economy Labeling Scheme

- **The Energy Use Rationalization Act of 1989 mandated:**
  - Labeling scheme encourages consumers to purchase fuel efficient vehicles
  - Auto companies must put fuel economy information on new vehicles (labels)

- **Scope of vehicles**
  - All PCs, buses with 15 seats or less, and trucks with GVW of 3.5 tons or less

- **Approval of label value**
  - Fuel economy of a new vehicle must be approved by KEMCO, before being entered into market
  - KEMCO annually issues about 300 approvals for new vehicle models

- **Test methods to determine label value**
  - MOTIE-KEMCO must develop test procedures for measuring fuel economy
  - Prior to 2012, only the City test (FTP-75) was used
  - After 2012, use the adjusted 5-cycle test formula by the results of City test (FTP-75) and Highway test (HWFET) to reflect the real world
I. Adjusted 5-cycle Formula

**Calculation of combined fuel economy**

\[
Combined\ FE = \frac{1}{0.55 \cdot \frac{1}{5\text{-cycle\ City\ FE}} + 0.45 \cdot \frac{1}{5\text{-cycle\ Highway\ FE}}}
\]

**5 cycle City FE**

\[
Y = 0.007639 + 1.1886 \cdot X
\]

\[
R^2 = 0.9964
\]

**5 cycle Highway FE**

\[
Y = 0.004425 + 1.3425 \cdot \frac{1}{\text{HWFET \ FE}}
\]

\[
R^2 = 0.9709
\]
I. New Fuel Economy Labeling

• New fuel economy label
  - Beginning from 2012
  - Grade, City, Highway and combined F.E.
  - CO₂, QR code and Legal basis
  - Fuel economy data are also posted on http://bpms.kemco.or.kr/transport_2012 website

• Grade system of fuel economy value (unit: km/L)

<table>
<thead>
<tr>
<th>Grade</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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</thead>
<tbody>
<tr>
<td>~2011 (FTP-75 result)</td>
<td>≥15</td>
<td>14.9~12.8</td>
<td>12.7~10.6</td>
<td>10.5~8.4</td>
<td>≤8.3</td>
</tr>
<tr>
<td>2012~ (Adjusted US Combined result)</td>
<td>≥16</td>
<td>15.9~13.8</td>
<td>13.7~11.6</td>
<td>11.5~9.4</td>
<td>≤9.3</td>
</tr>
</tbody>
</table>

Label

KOREA ENERGY MANAGEMENT CORPORATION
## I. Fuel Economy Website

### 자동차 표시연비

Energy Saving is the life.

<table>
<thead>
<tr>
<th>자동차</th>
<th>연비</th>
<th>CO2 배출량</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fusion Hybrid</td>
<td>102</td>
<td>117</td>
</tr>
<tr>
<td>Clio IV</td>
<td>103</td>
<td>118</td>
</tr>
<tr>
<td>Polo 1.6 TDI Blue Motion</td>
<td>104</td>
<td>119</td>
</tr>
<tr>
<td>BMW 520d</td>
<td>105</td>
<td>120</td>
</tr>
<tr>
<td>기아 K5</td>
<td>106</td>
<td>121</td>
</tr>
<tr>
<td>현대 Santa Fe</td>
<td>107</td>
<td>122</td>
</tr>
<tr>
<td>포드 Escape</td>
<td>108</td>
<td>123</td>
</tr>
<tr>
<td>닛산 Leaf</td>
<td>109</td>
<td>124</td>
</tr>
<tr>
<td>혼다 Civic Hatchback</td>
<td>110</td>
<td>125</td>
</tr>
</tbody>
</table>

[Link to Fuel Economy Website](http://bpmsec.kemco.or.kr/transport_2012/car/car.choice.aspx?System=)

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KOREA ENERGY MANAGEMENT CORPORATION
I. Outcome of New Fuel Economy Labeling

- The grade ratio of vehicles approved in 2011

- The grade ratio of vehicles approved in 2012
I. Korea CAFE

- The Energy Use Rationalization Act of 2006 mandated:
  - CAFE promotes more fuel efficient vehicles in domestic market
  - Auto companies must comply with CAFE standard every year

- Scope of vehicles
  - All passenger cars with 10 seats or less and with GVW of 3.5 tons or less

- Test methods to determine fuel economy
  - Prior to 2012, only the City test (FTP-75) was used
  - In 2012, the combined results are used by 55% of City (FTP-75) and 45% of Highway test (HWFET) results

- Korea CAFE standards

<table>
<thead>
<tr>
<th>Year</th>
<th>≤ 1,600cc</th>
<th>&gt; more than 1,600cc</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006 ~ 2011 (FTP-75)</td>
<td>12.4 km/L</td>
<td>9.6 km/L</td>
</tr>
<tr>
<td>2012 ~ 2015 (US Combined Mode not adjusted)</td>
<td>17 km/L or 140g/km (application of different standard for each automaker according to their vehicle curb weight)</td>
<td></td>
</tr>
</tbody>
</table>
I. Korea CAFE

**Korea CAFE and GHG standards**
- Automakers can select either CAFE or GHG standard every year
- MOTIE takes charge of CAFE standard and ME of GHG standard
- Automakers must comply with 30% of total sales volume in 2012, 60% in 2013, 80% in 2014 and 100% in 2015

<table>
<thead>
<tr>
<th>Equation of Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CAFE (MOTIE)</strong></td>
</tr>
<tr>
<td>- <strong>CAFE standard</strong> = Total sales volume of vehicles / ∑(Sales volume of each model / FE standard of each model)</td>
</tr>
<tr>
<td>* FE standard of each model = 28.4577 – 0.007813 x m</td>
</tr>
<tr>
<td>* m = vehicle curb weight of each model</td>
</tr>
<tr>
<td><strong>GHG (ME)</strong></td>
</tr>
<tr>
<td>- <strong>GHG standard</strong> = 140 + a x (M – 1423.2)</td>
</tr>
<tr>
<td>* a = 0.0484 for makers with 4,500 units of sales volume in 2009, 0.0588 for others</td>
</tr>
<tr>
<td>* M = sales volume weighted average VCW of each automaker</td>
</tr>
</tbody>
</table>
I. Results of Korea CAFE

- Results of CAFE and GHG emissions
  - The average fuel economy of passenger cars has increased an average of 5.6% every year since 2006, and the average CO2 emissions has decreased an average of 5.3% annually.

* Test Cycle: FTP-75
I. Prospect of Korea CAFE

- New CAFE standards

- MOTIE will introduce the new CAFE standards for passenger cars and light trucks which will be applied from 2016 to 2020 or 2025

- Target values have not been decided yet, but the new standards will require the auto companies to improve their fuel economy as high as that of Japan (23.3km/L in 2020) or EU (27.6km/L in 2020)
II. Green Car Policy

- Korean Government has launched the **program of Future Car Development** as a part of new growth engines in 2004

  Government has established “**Act on the Promotion of Development and Distribution of Environmental-friendly Automobiles**” in 2004

  * Environmental-friendly Automobiles: EV, PHEV, FCEV, HEV, CDV, NGV, etc.

- The five year plan for environmental-friendly automobiles has been established for the first time in 2006

- Government announced Green Car Roadmap in Dec. 2010

  - [Production] 1.2M units in domestic and 0.9M units for overseas by 2015
  - [Promotion] 21% of domestic market share(3.3M tCO2 reduction) by 2015
  - [Investment] KRW 1.7 trillion(USD 1.4 billion) from government by 2015
II. Green Car Tax Incentives

- The Environmental-friendly Automobiles Act of 2004 mandated:
  - To develop and promote green cars in domestic market
  - Auto companies must comply with the criteria of green cars if they want to get tax incentives (max. USD 2,600 for HEV and max. USD 3,500 for EV)

- Eligibility criteria for HEV
  - Only the City test (FTP-75) are used

<table>
<thead>
<tr>
<th>Engine Displacement</th>
<th>Gasoline</th>
<th>Diesel</th>
<th>LPG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 1,000cc</td>
<td>25.5 km/L</td>
<td>-</td>
<td>20.6 km/L</td>
</tr>
<tr>
<td>1,000 ~ under 1,600cc</td>
<td>20.6 km/L</td>
<td>27.2 km/L</td>
<td>16.5 km/L</td>
</tr>
<tr>
<td>1,600 ~ under 2,000cc</td>
<td>16.8 km/L</td>
<td>19.1 km/L</td>
<td>13.5 km/L</td>
</tr>
<tr>
<td>More than 2,000cc</td>
<td>14.0 km/L</td>
<td>16.8 km/L</td>
<td>11.1 km/L</td>
</tr>
</tbody>
</table>

- Nominal voltage of Traction Battery must meet over 60V

- Eligibility criteria for EV
  - Combined Fuel Economy must meet over 5.0km/kWh
  - Combined Range of NEV must be over 27km, and EV must meet over 82km
III. Defects of Criteria

- **Defects of Eligibility criteria for HEV**
  - No reform of the eligibility criteria for HEV since 2009
  - Causing the customer confusion because of using the FTP-75 mode results without the derived 5-cycle adjustment

- **Defects of Eligibility criteria for EV**
  - Determined the criteria of EV with the prototype vehicles in 2011
  - Causing the customer confusion because of using the combined mode results without the derived 5-cycle adjustment

- **Improvement direction of Eligibility criteria**
  - Protecting the customer confusion by using the derived 5-cycle adjustment
  - Reflecting the development level of HEV since 2009
  - Considering the energy efficiency of the mass product EV in the market
  - Adding the tax incentive criteria for PHEV
III. Study on Criteria Reform

- **Research Process**
  1. Analysis of Technology and Policy of Green Cars in Domestic & Overseas Market
  2. Layout of Technical Items of HEV, EV and PHEV respectively
  3. Technical Analysis of HEV, EV and PHEV with the 5- cycle test
  4. Selection of Criteria Items of HEV, EV and PHEV from Technical Items
  5. Development of various Scenarios to determine Eligibility Criteria
  6. Proposal of the final Criteria for HEV, EV and PHEV to Government

- **Scenarios to reform the criteria of HEV, EV and PHEV**
  - Application of the 2012 Korea CAFE result
  - Application of the average of the submitted fuel economy in 2012
  - Application of the ranked vehicles in the top 10% in terms of Fuel Economy
  - Application of the 2020 Korea CAFE target
  - Application of the technical level of HEV and EV in the USA
  - Application of the tax incentive criteria for Green Car in the Europe
## III. Technical Items of HEV

### HEV Technical Items

<table>
<thead>
<tr>
<th>Battery</th>
<th>Nominal Voltage (V)</th>
<th>Capacity (kWh)</th>
<th>Weight (kg)</th>
<th>Cycle Life (times)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor</td>
<td>Power (kW)</td>
<td>Torque (N·m)</td>
<td>Life (years)</td>
<td></td>
</tr>
<tr>
<td>Vehicle</td>
<td>Curb Weight (kg)</td>
<td>Footprint (m²)</td>
<td>Warranty (year)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adj usted Combined</td>
<td>combined Mode</td>
<td>FTP-75</td>
<td>HWFET</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>US06</td>
<td>SC03</td>
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<td></td>
<td>Cold FTP</td>
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</tr>
</tbody>
</table>

### Considerations
- Related Energy Efficiency
- Need of Advanced Technology
- Easy to measure
- Easy to verify
- Technical Weight
### EV Technical Items

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
</tr>
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<tbody>
<tr>
<td><strong>Battery</strong></td>
<td>Nominal Voltage(V)</td>
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<tr>
<td></td>
<td>Capacity(kWh)</td>
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<td>Footprint(m²)</td>
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<td></td>
<td>Warranty(year)</td>
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<tr>
<td></td>
<td>Charging Time(hrs)</td>
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<tr>
<td></td>
<td>Easy to Plug - standard</td>
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<tr>
<td><strong>Fuel Economy</strong></td>
<td>Adjusted Combined</td>
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<tr>
<td></td>
<td>Combined Mode</td>
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<tr>
<td></td>
<td>FTP-75</td>
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<td></td>
<td>HWFET</td>
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<td>US06</td>
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<td>SC03</td>
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<td>Cold FTP</td>
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</tbody>
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[Considerations]
- Related Energy Efficiency
- Need of Advanced Technology
- Easy to measure
- Easy to verify
- Technical Weight
## III. Technical Items of PHEV

### PHEV Technical Items

<table>
<thead>
<tr>
<th></th>
<th>Battery</th>
<th>Motor</th>
<th></th>
<th></th>
<th>[Considerations]</th>
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<tbody>
<tr>
<td></td>
<td>Nominal Voltage(V)</td>
<td>Power(kW)</td>
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<td></td>
<td>- Related Energy Efficiency</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Torque(N-m)</td>
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<td></td>
<td>- Need of Advanced Technology</td>
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<td>Life(years)</td>
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<td>- Easy to measure</td>
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<td>Capacity(kWh)</td>
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<td>- Easy to verify</td>
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<td>Weight(kg)</td>
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<td>- Technical Weight</td>
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<td>Cycle Life(times)</td>
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<td>Footprint(m²)</td>
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<td>Warranty(year)</td>
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<td>Charging Time(hrs)</td>
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<td></td>
<td>Fuel Economy(km/L)</td>
<td>Adjusted Combined</td>
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<td>- CD+CS</td>
<td>Combined Mode</td>
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<td>- CD</td>
<td>FTP-75</td>
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<td>Range(km)</td>
<td>HWFET</td>
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<td></td>
<td></td>
<td>US06</td>
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<td>SC03</td>
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<td></td>
<td>Cold FTP</td>
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</tbody>
</table>
IV. Test Vehicles for 5-cycle Test

- Vehicle Technical Items Analysis
  - 5-cycle test to check Fuel Economy and Range under the various environment
  - [HEV] HMC YF Sonata, Lexus GS450h
  - [EV] Kia Ray EV, GM Spark EV
  - [PHEV] Toyota Prius PHEV, GM Chevy Volt
IV. HEV 5-cycle Test Results: F.E.

**HMC YF Sonata**

- FTP-75: 100%
- HWFET: 111%
- US06 (high speed): 78%
- SC03 (A/C on): 69%
- Cold FTP (-7°C & heat on): 70%

Fuel Economy (%) NEC tolerance > 1%

**Lexus GS450h**

- FTP-75: 100%
- HWFET: 111%
- US06 (high speed): 78%
- SC03 (A/C on): 79%
- Cold FTP (-7°C & heat on): 74%

Fuel Economy (%) NEC tolerance > 1%
IV. EV 5-cycle Test Results; Range

- **FTP-75**
  - KIA Ray EV (high speed) (A/C on) (-7℃ & heat on) 100%, 85%, 74%, 63%
  - GM Spark EV (high speed) (A/C on) (-7℃ & heat on) 100%, 85%, 57%, 63%
  - Range (%): FTP-75: 100%, HFET: 85%, US06: 59%, SC03: 74%, Cold FTP: 63%

- **HWFET**
  - KIA Ray EV (high speed) (A/C on) (-7℃ & heat on) 100%, 85%, 74%, 63%
  - GM Spark EV (high speed) (A/C on) (-7℃ & heat on) 100%, 85%, 57%, 63%
  - Range (%): FTP-75: 100%, HFET: 85%, US06: 59%, SC03: 74%, Cold FTP: 63%

- **US06 (high speed)**
  - KIA Ray EV (A/C on) (-7℃ & heat on) 100%, 59%, 37%, 15%
  - GM Spark EV (A/C on) (-7℃ & heat on) 100%, 57%, 37%, 15%
  - Range (%): FTP-75: 100%, HFET: 85%, US06: 59%, SC03: 74%, Cold FTP: 63%

- **SC03 (A/C on)**
  - KIA Ray EV (A/C on) (-7℃ & heat on) 100%, 59%, 37%, 15%
  - GM Spark EV (A/C on) (-7℃ & heat on) 100%, 57%, 37%, 15%
  - Range (%): FTP-75: 100%, HFET: 85%, US06: 59%, SC03: 74%, Cold FTP: 63%

- **Cold FTP (-7℃ & heat on)**
  - KIA Ray EV (A/C on) (-7℃ & heat on) 100%, 59%, 37%, 15%
  - GM Spark EV (A/C on) (-7℃ & heat on) 100%, 57%, 37%, 15%
  - Range (%): FTP-75: 100%, HFET: 85%, US06: 59%, SC03: 74%, Cold FTP: 63%
IV. EV 5-cycle Test Results; F.E.

- **KIA Ray EV**
  - FTP-75: 100% (Fuel Economy: 100%)
  - HWFET: 86% (Fuel Economy: 86%)
  - US06 (high speed): -39% (Fuel Economy: 61%)
  - SC03 (A/C on): -25% (Fuel Economy: 75%)
  - Cold FTP (-7°C & heat on): -34% (Fuel Economy: 66%)

- **GM Spark EV**
  - FTP-75: 100% (Fuel Economy: 100%)
  - HWFET: 56% (Fuel Economy: 56%)
  - US06 (high speed): -56% (Fuel Economy: 44%)
  - SC03 (A/C on): -39% (Fuel Economy: 61%)
  - Cold FTP (-7°C & heat on): -50% (Fuel Economy: 50%)
IV. PHEV 5-cycle Test Results; AER

**Toyota Prius PHEV**

- FTP-75: 100%
- HWFET: 166% (+66)
- US06 (high speed): 0%
- SC03 (A/C on): -87 (13%)
- Cold FTP (-7°C & heat on): 0%

**GM Chevy Volt PHEV**

- FTP-75: 100%
- HWFET: 95%
- US06 (high speed): 63%
- SC03 (A/C on): 59%
- Cold FTP (-7°C & heat on): 0%

**All Electric Range (%)**

- Toyota Prius PHEV (high speed) (A/C on) (-7℃ & heat on)
- GM Chevy Volt PHEV (high speed) (A/C on) (-7℃ & heat on)
IV. Toyota Prius PHEV Test Results (I)

[Graphs showing Toyota Prius PHEV test results for FTP-75 mode and Cold FTP-75 mode.]

- Engine Start
- Battery SOC (%)
- Test time (sec)
- Engine revolution (rpm)
- Vehicle speed (km/h)
IV. Toyota Prius PHEV Test Results (II)

[Graphs showing test results for CD (AER) and CS modes under HWFET and US06 modes.]

- **CD (AER) Mode**
  - Battery SOC (Lower graph)
  - Engine revolution (Upper graph)
  - Vehicle speed (Upper graph)
  - Test time (x-axis)

- **CS Mode**
  - Battery SOC (Lower graph)
  - Engine revolution (Upper graph)
  - Vehicle speed (Upper graph)
  - Test time (x-axis)

- **Engine Start**

[HWFET mode]

[US06 mode]
IV. GM Volt PHEV Test Results (I)

[FTP-75 mode]

[Graph showing battery SOC and engine revolution over test time for FTP-75 mode]

[Cold FTP-75 mode]

[Graph showing battery SOC and engine revolution over test time for Cold FTP-75 mode]

Engine Start
IV. GM Volt PHEV Test Results (II)

[Graph showing battery SOC and engine revolution for HWFET and US06 modes]

- **HWFET mode**
  - Engine Start

- **US06 mode**
  - Engine Start
IV. PHEV 5-cycle Test Results; CS F.E.

**Toyota Prius PHEV**

- **FTP-75**: 100%
- **HWFET**: 88%
- **US06 (high speed)**: 61%
- **SC03 (A/C on)**: 62%
- **Cold FTP (-7°C & heat on)**: 78%

**GM Chevy Volt PHEV**

- **FTP-75**: 100%
- **HWFET**: 102%
- **US06 (high speed)**: 66%
- **SC03 (A/C on)**: 40%
- **Cold FTP (-7°C & heat on)**: 81%
THANK YOU

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