Reducing Energy Consumption in Public Transportation

- Driving
- Charging

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Background

City Electric Bus market tendency

התכנית לחישמול התחבורה הציבורית

תמונת מצב ומתווה ליישום

במטרה להגיע לתחבורה ציבורית מאופסת פליטות (Zero emission) בכל צי התחבורה הציבורית העירוני עד לשנת 2035, הוגדרו שלושה יעדי ביניים – בשלב ראשון תכנית האצה מיידית לפיה 80% מהרכש הענפי של אוטובוסים עירוניים יהיה חשמלי וזאת בטווח הזמן של 2020-2025. בשלב השני החל משנת 2025 כל אוטובוס עירוני שירכש יהיה חשמלי. ובשלב השלישי תתבצע יציאה הדרגתית של אוטובוסים מונעי דיזל עד להחלפת כלל הצי בשנת 2035. הפעלת האוטובוסים החשמליים תעשה באופן שאינו פוגע ברמת השירות מבחינת פריסת הקווים ותדירותם.

ספטמבר 2020

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Background

12m City Bus; average grid energy consumption

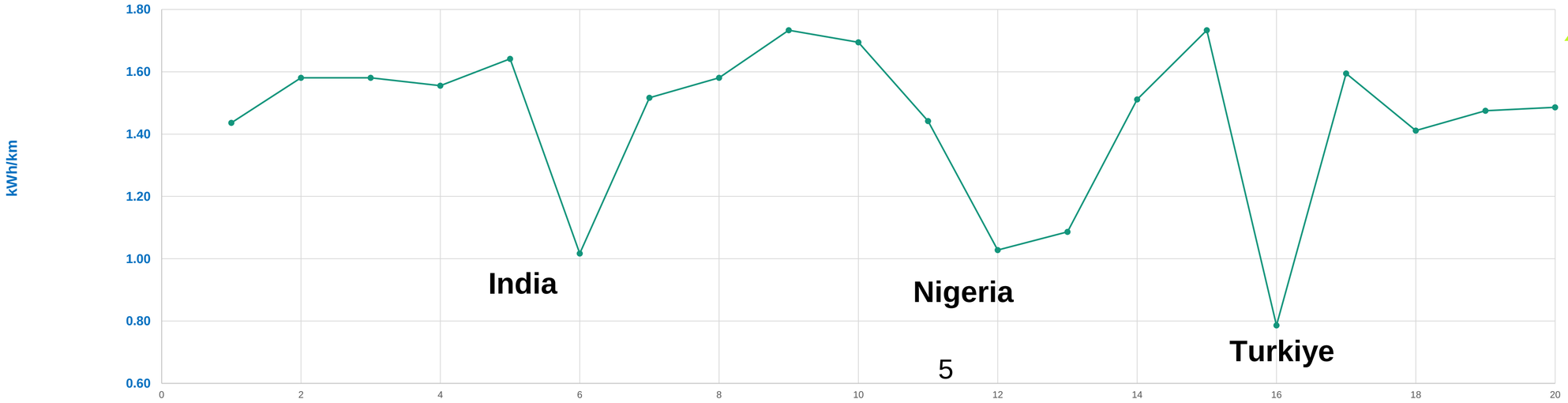
Israel:

- “Battery 2 Wheel” energy consumption is **1.0 ÷ 1.8 kWh/km**
- “Grid 2 Wheel” energy consumption is **1.1 ÷ 2.0 kWh/km**

WORLD BANK GROUP

The Economics of Electric Vehicle for Passenger Transportation

Electric Bus Energy Consumption kWh/km



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Background

12m City Bus; average Annual Energy Consumption in Israel

- Average Annual Mileage: 50,000 km
- Average Annual Energy Consumption: ~75,000 kWh
- Increasing 1% Efficiency will Save 750 kWh per one year

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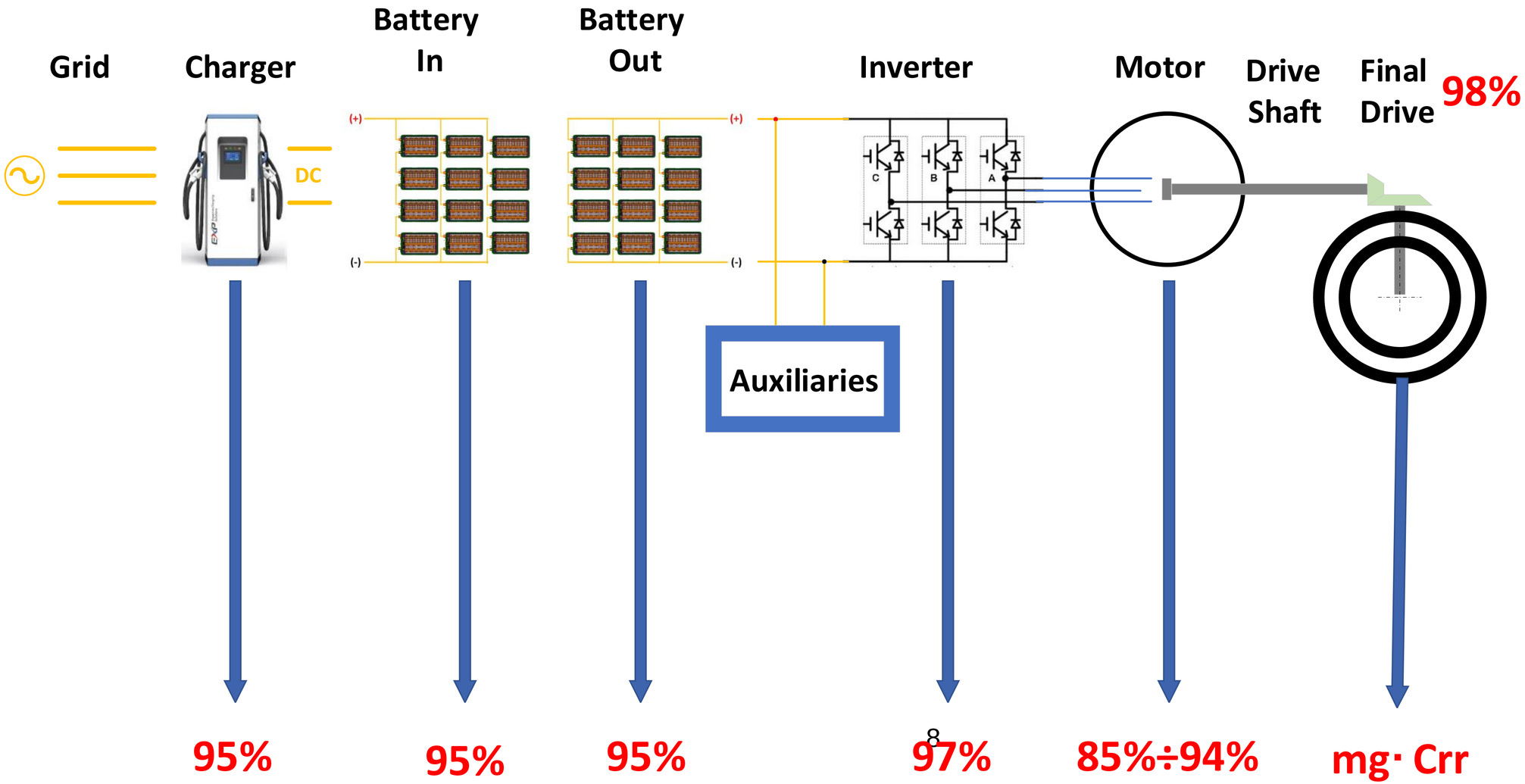
Background

Stakeholders' motivation

- Electric Bus Operators: Low-Cost, Availability → Fast Charging
- Electric Bus Drivers: Acceleration & Speed
- Israel Electric Company: Infrastructure - Low Power Consumption
- Workshops: Reliability
- Electric Bus Importers: Selling as much as Possible
- Chargers Importers: Selling as much as Possible

W2W Energy Efficiencies Chain

Powertrain



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W2W Energy Efficiencies Chain

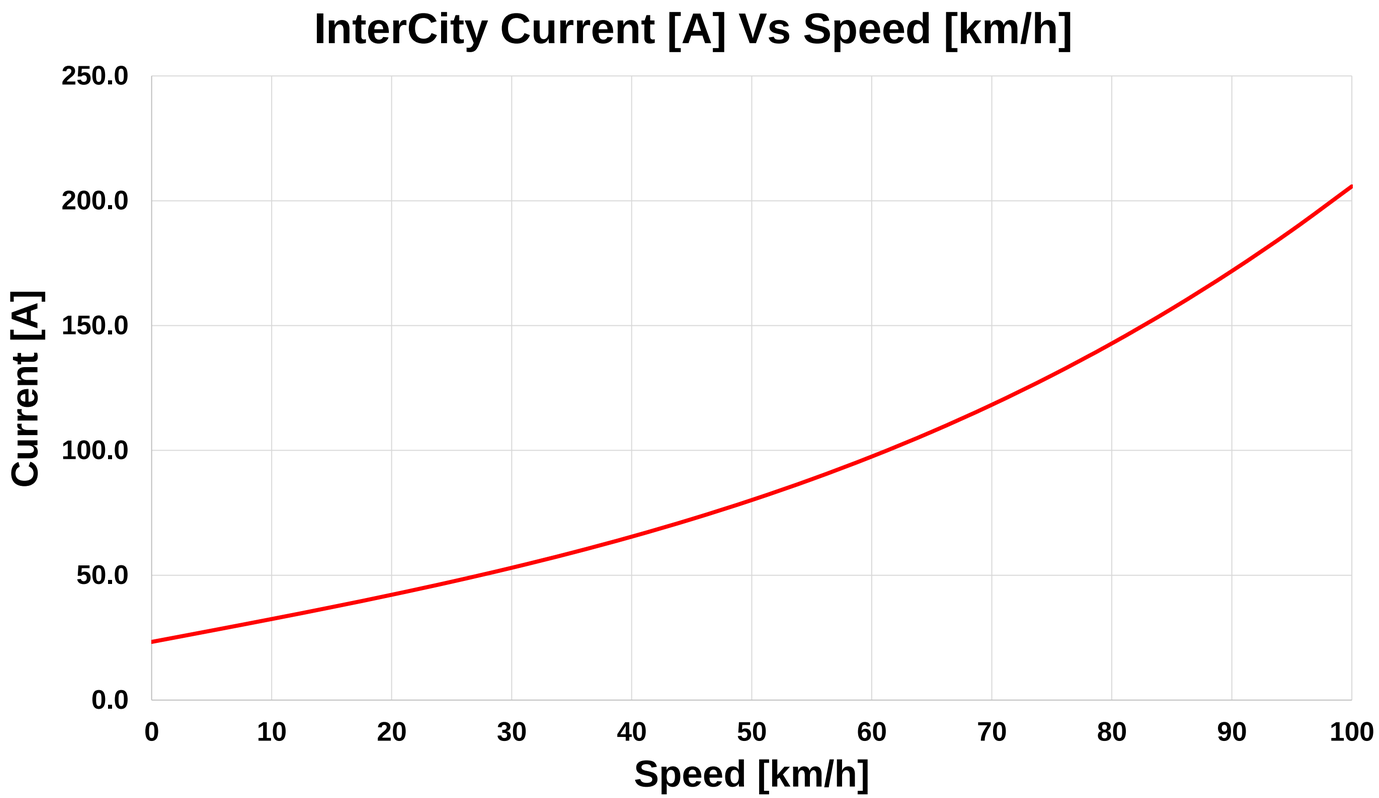
Auxiliaries

- Air Compressor
- Power Steering
- Air Conditioning
- Defroster
- 24V Systems

I^2R - High Current → High Energy Consumption

Driving – Motor Calibration

- “Damping” aggressive driving
- Acceleration should be under 1.1 m/sec²
- Current Consumption @ 40 km/h is 50A
- Current Consumption @ 60 km/h is 85A
- The Current Consumption is not linear to the speed
- Motor efficiency is decreasing at high speed
- Motor efficiency is decreasing at full throttle



CD = 0.45
M = 15,000kg
Battery Voltage = 618V

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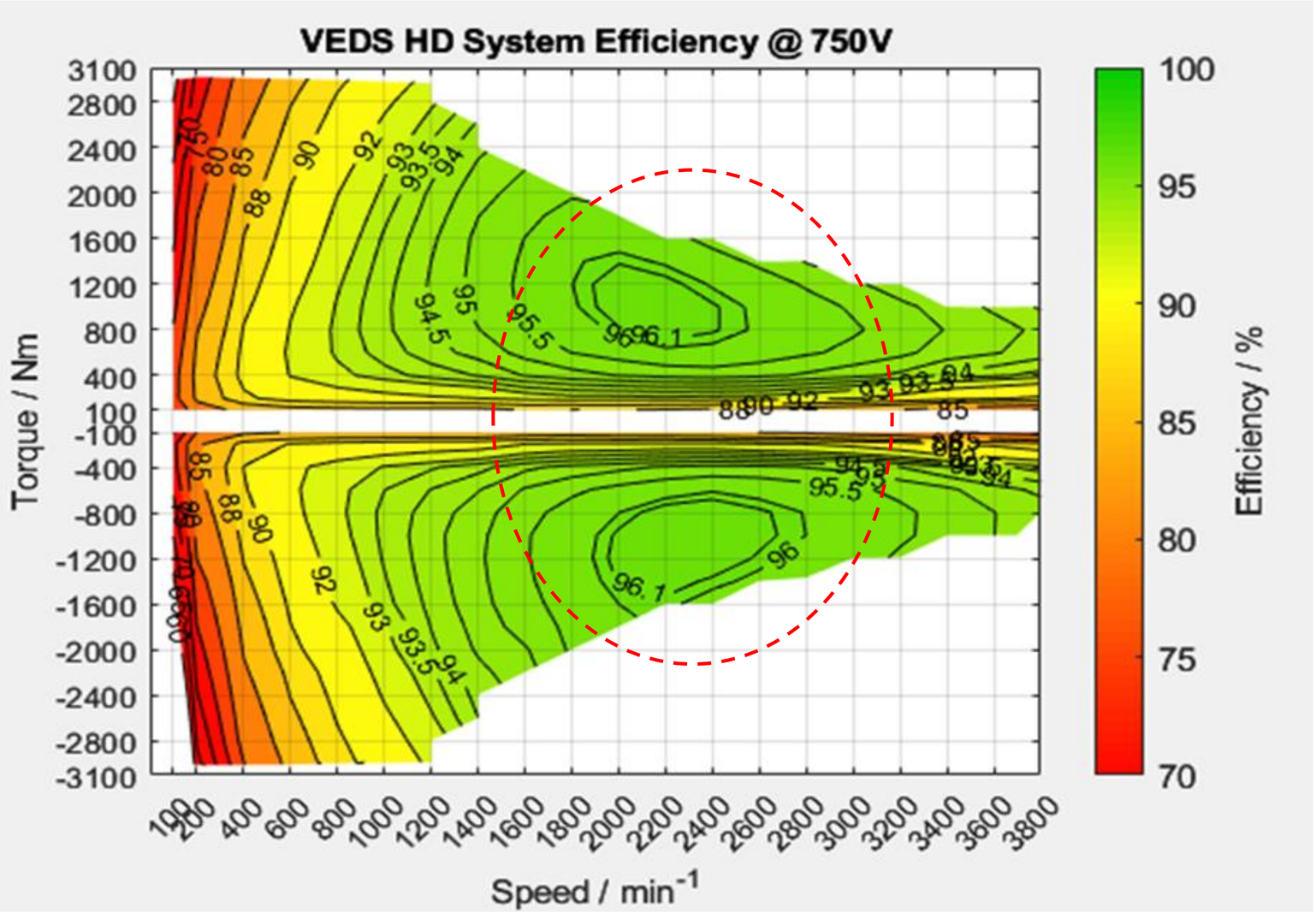
I^2R - High Current → High Energy Consumption

Driving – Motor Calibration



It is recommended to choose the motor according to the traffic profile

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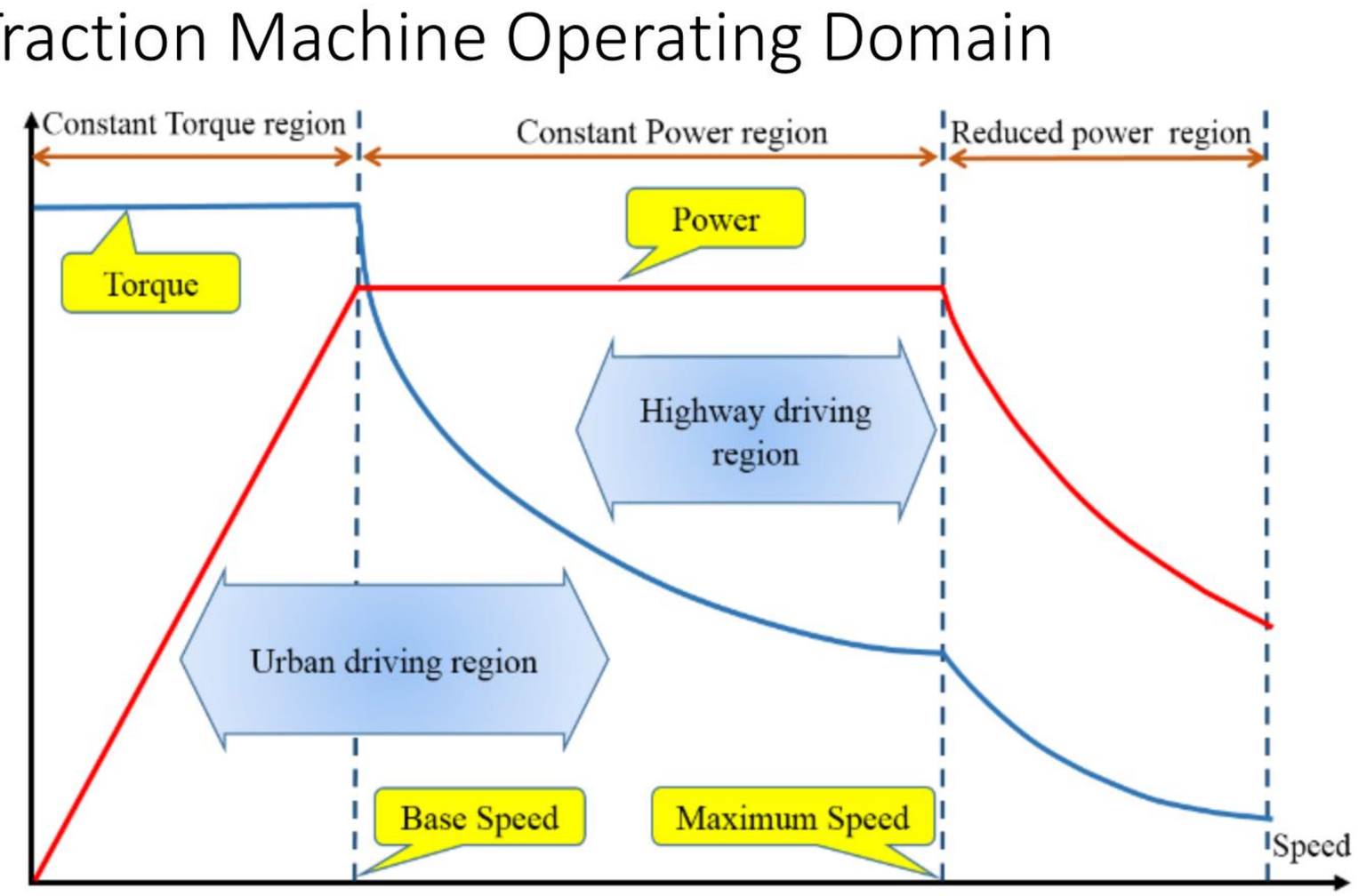
I^2R - High Current → High Energy Consumption

Driving – Motor Calibration



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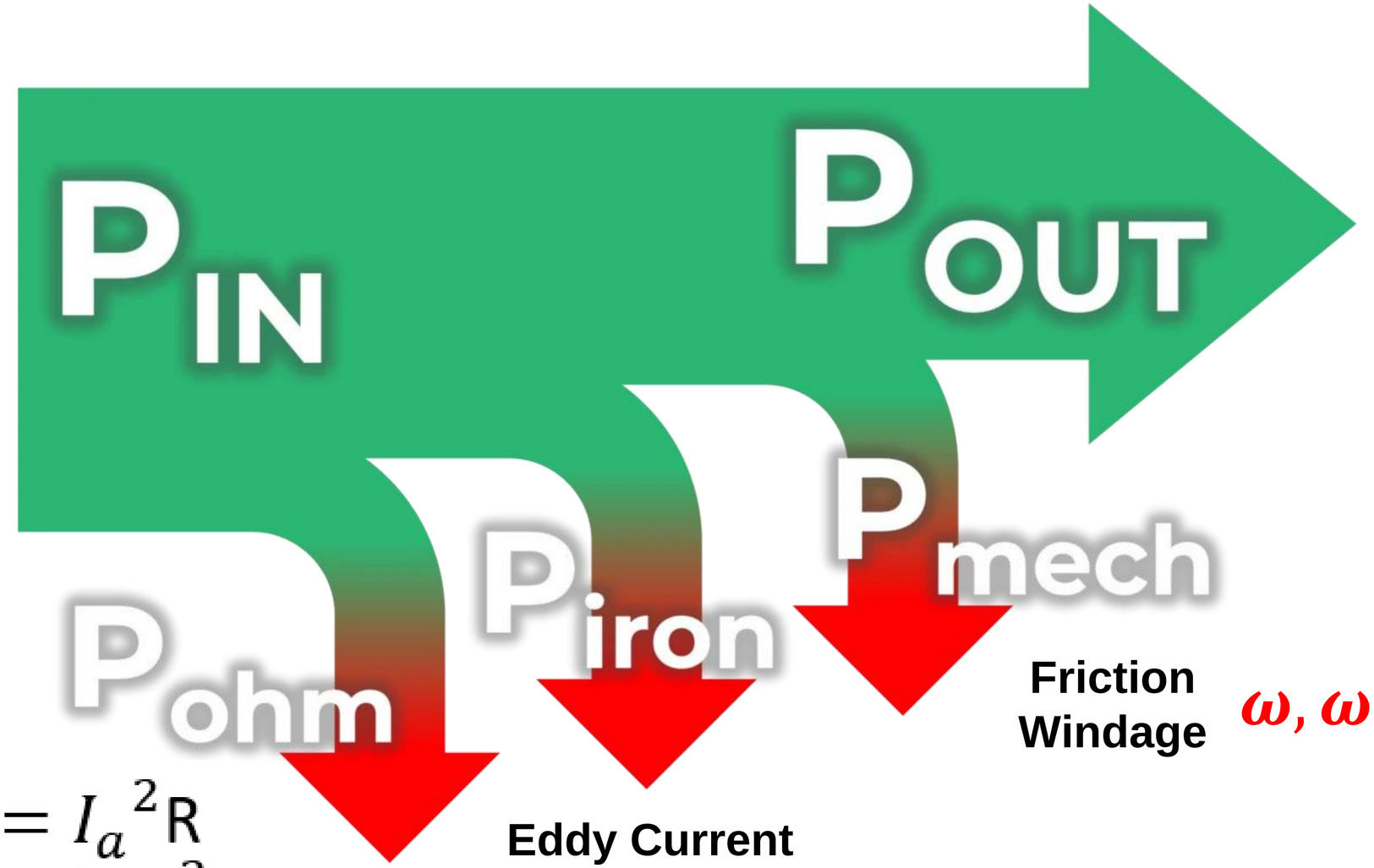
I^2R - High Current → High Energy Consumption

Driving – Motor Calibration



Friction
Windage ω, ω^3

$P = I_a{}^2 \mathrm{R}$

$P = k_c T^2$

C: copper

I^2R

Eddy Current
Hysteresis

ω

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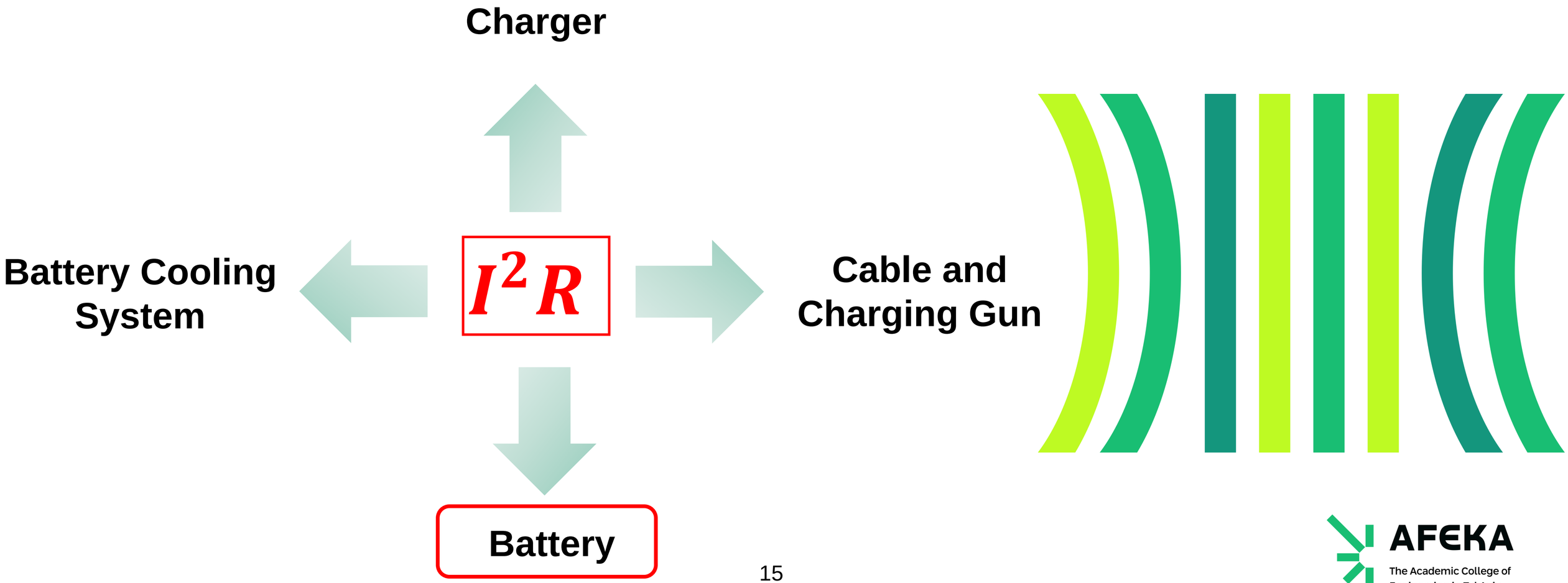
I^2R - High Current → High Energy Consumption

Driving – Motor Calibration

- Limiting Depletion Current
- Maximizing Regeneration Current
- Maximizing Regeneration Counter Torque
- Limiting Acceleration
- Air-conditioning Operational Policy
- Power Steering Operational Policy

I^2R - High Current → High Energy Consumption

Charging



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I^2R - High Current → High Energy Consumption

Charging

- Charger Efficiency:
  - Current
  - Ambient Temperature
  - Cooling System (air/liquid)
  - Maintenance
- Cable (Ohmic Losses 130W @ 200A $\Delta T \geq 30°C$)
- Charging Gun (Ohmic Losses @ 200A $\Delta T \geq 30°C$)
- Battery (Ohmic Losses 358W @ 200A $\Delta T \geq 30°C$)

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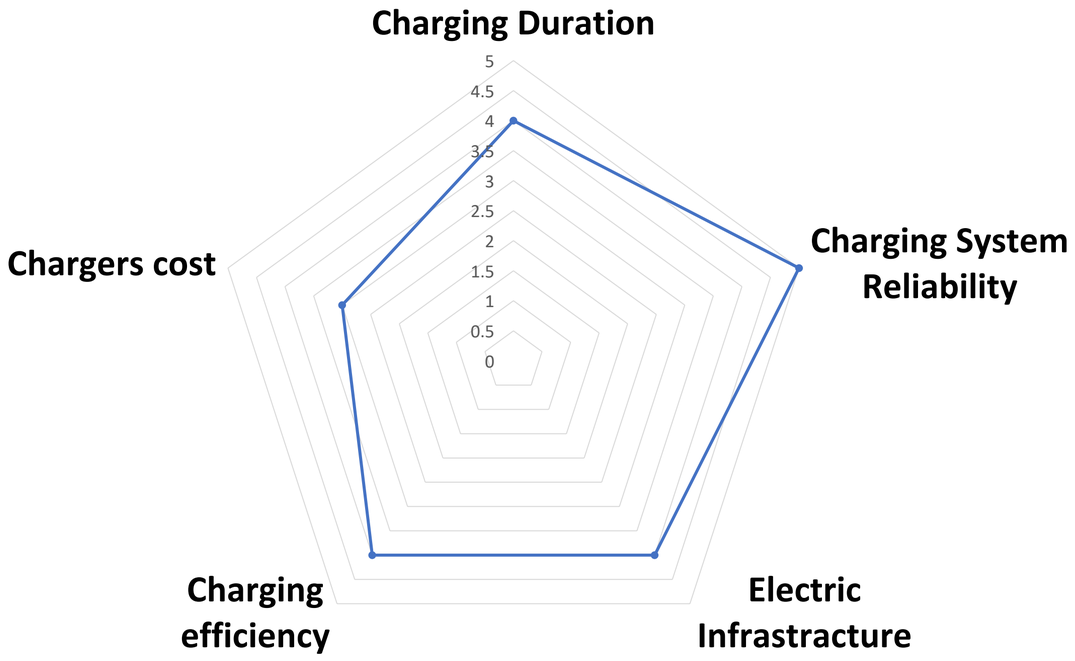
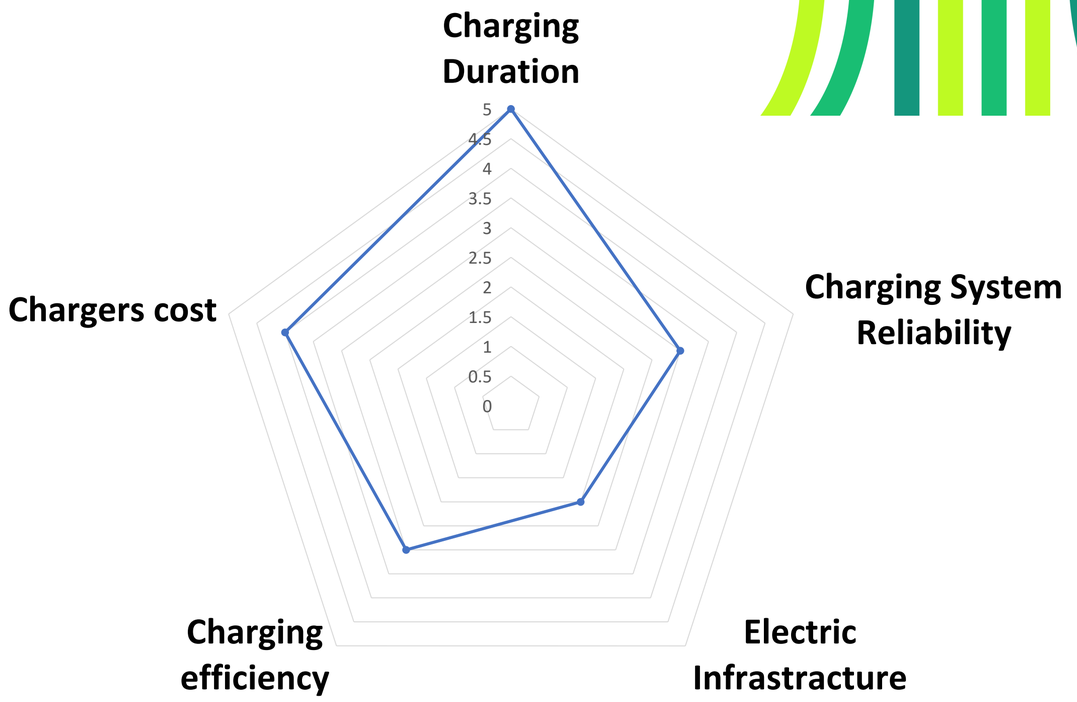
I^2R - High Current → High Energy Consumption

Charging

150A Radar



200A Radar



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Summary and recommendations

Motor Calibration

- Maximum Battery Depleting Current: **250A**
- Maximum Regeneration current: as much as possible according to battery manufacturer & OEM restriction
- Minimum Regeneration Counter Torque: per UNECE r13
- Maximum Acceleration: **1.0 m/sec²**

Charging

- Maximum Charging Current: 150A , CC (CV as long as possible)
- Maintenance: Blowers, Air Filter, Cable & Charging Gun

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Questions