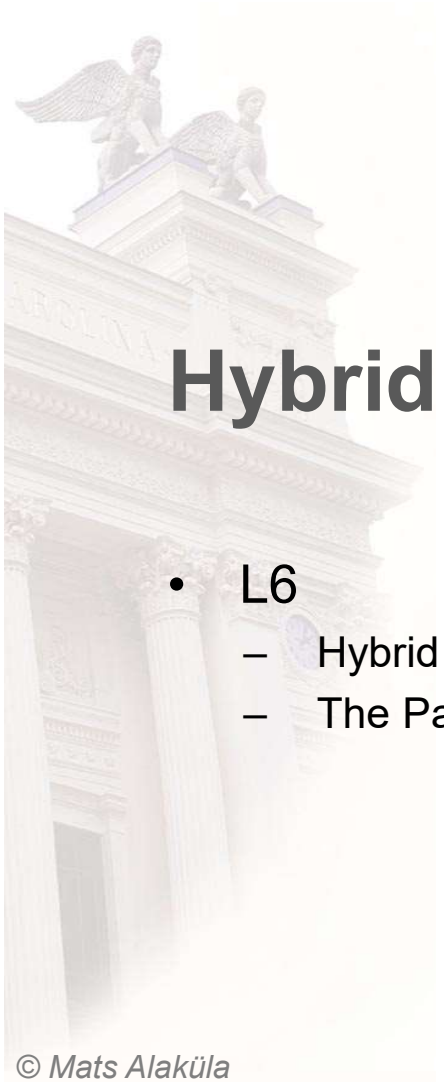

Hybrid Drive Systems for Vehicles

- L6
  - Hybrid Systems Control
  - The Parallel Hybrid

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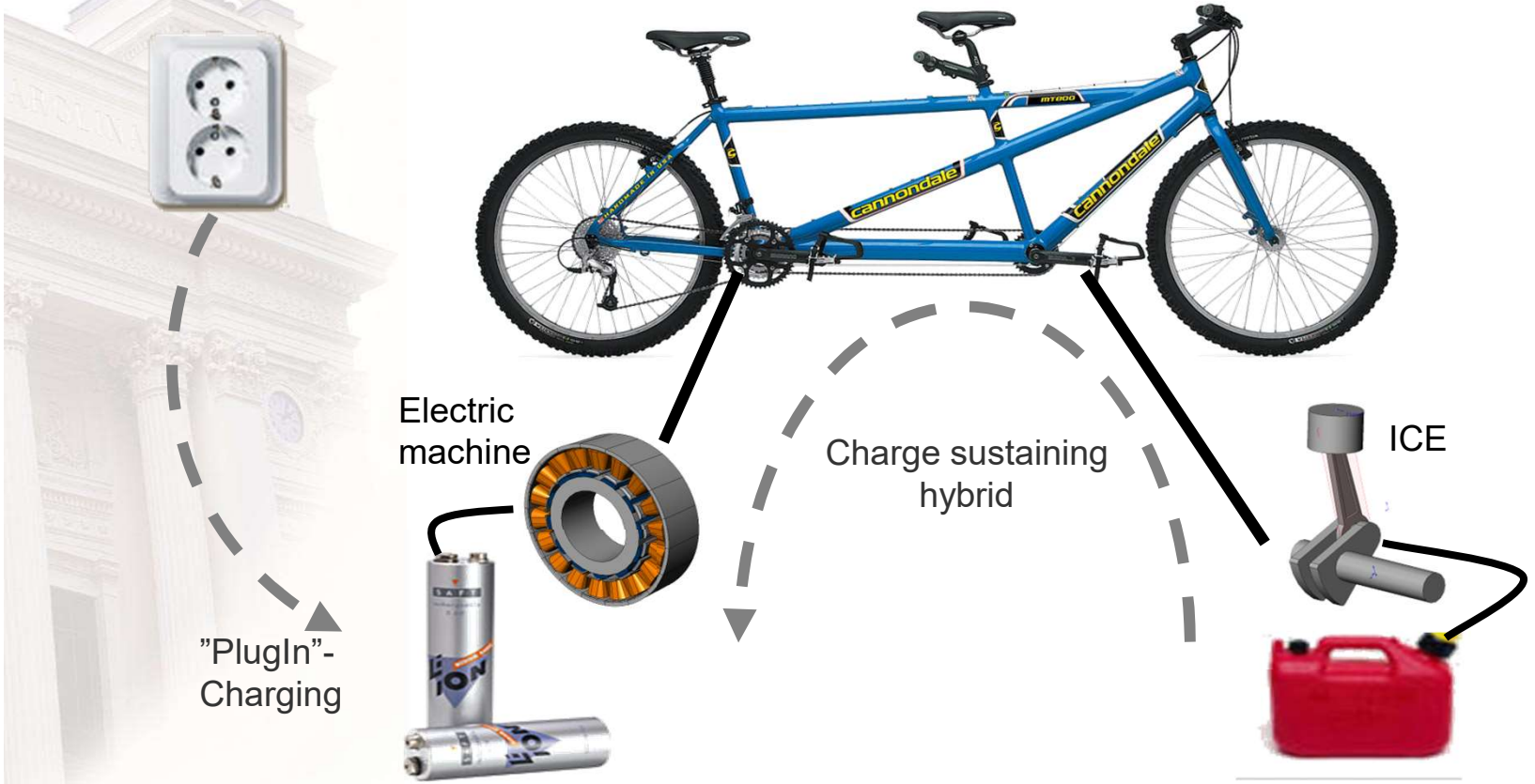
Basics on hybridisation

What is a hybrid vehicle?

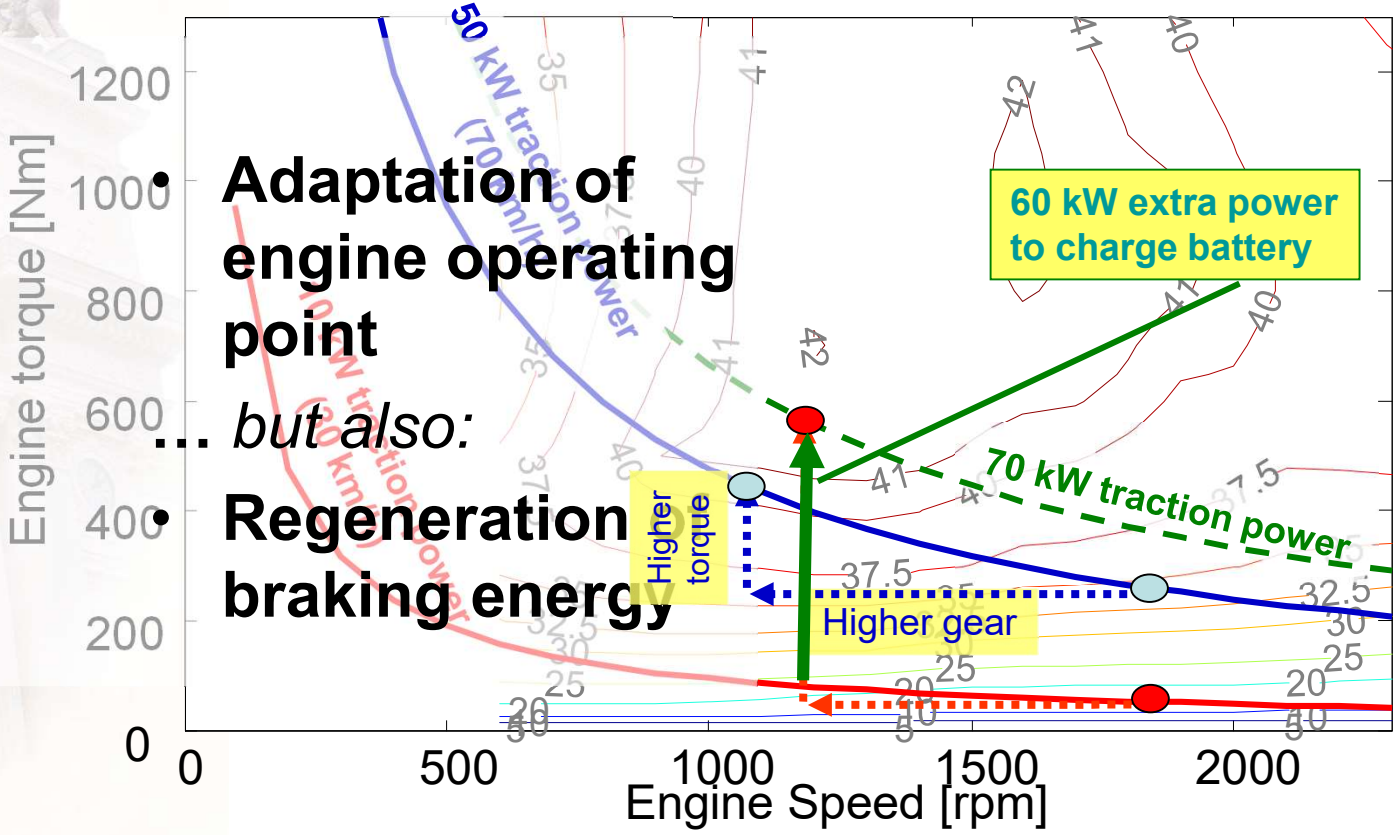


Engine use in a heavy hybrid vehicle

- **Adaptation of engine operating point**

… but also:

- **Regeneration braking energy**



Benefits?

- Reduction of fuel consumption
  - *0...50 % depending on type, driving habits etc*
- Reduction of emissions
  - *Depends more on the fuel used and the catalyst*
- Increased electric power
  - *Increased subsystem efficiency and functionality, e.g. the Air Conditioner.*
  - *Enough power for an electrically heated villa!*

Potential Fuel Saving

25 - 30 %

Refuse truck

20 - 50 %

5 - 8 %

Long haul truck

20 - 25 %

City bus

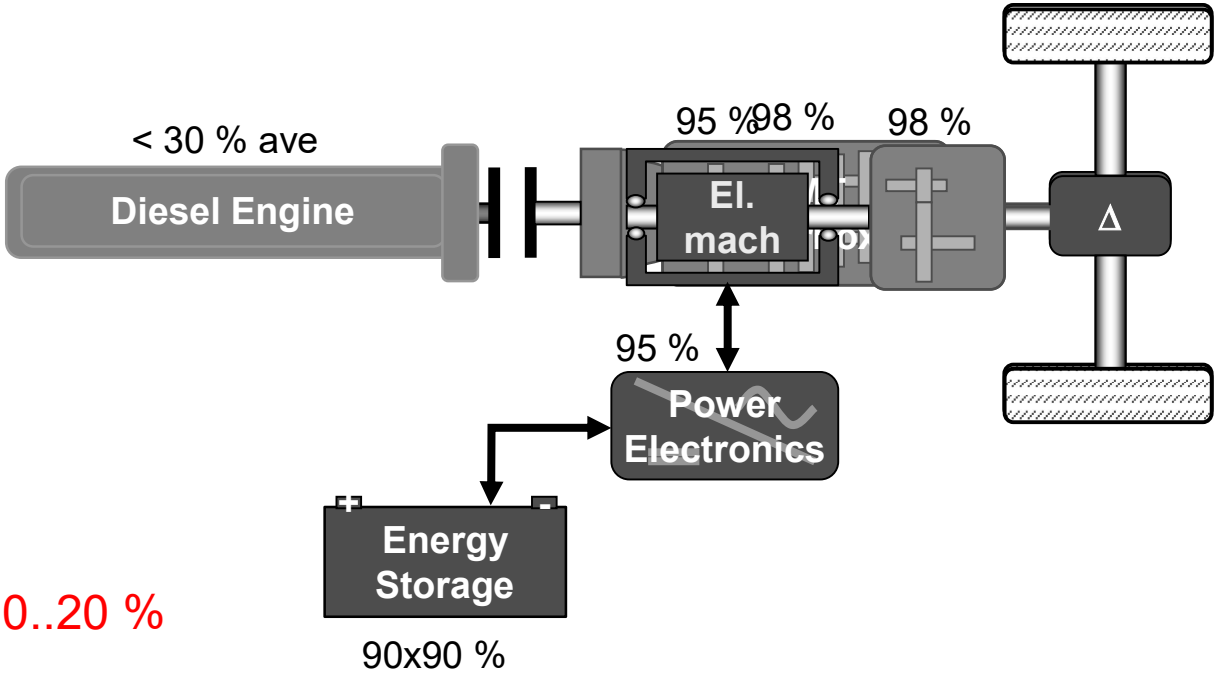
20 - 50 %

Wheel loader

Engineering

Concepts

The Conventional Drivetrain

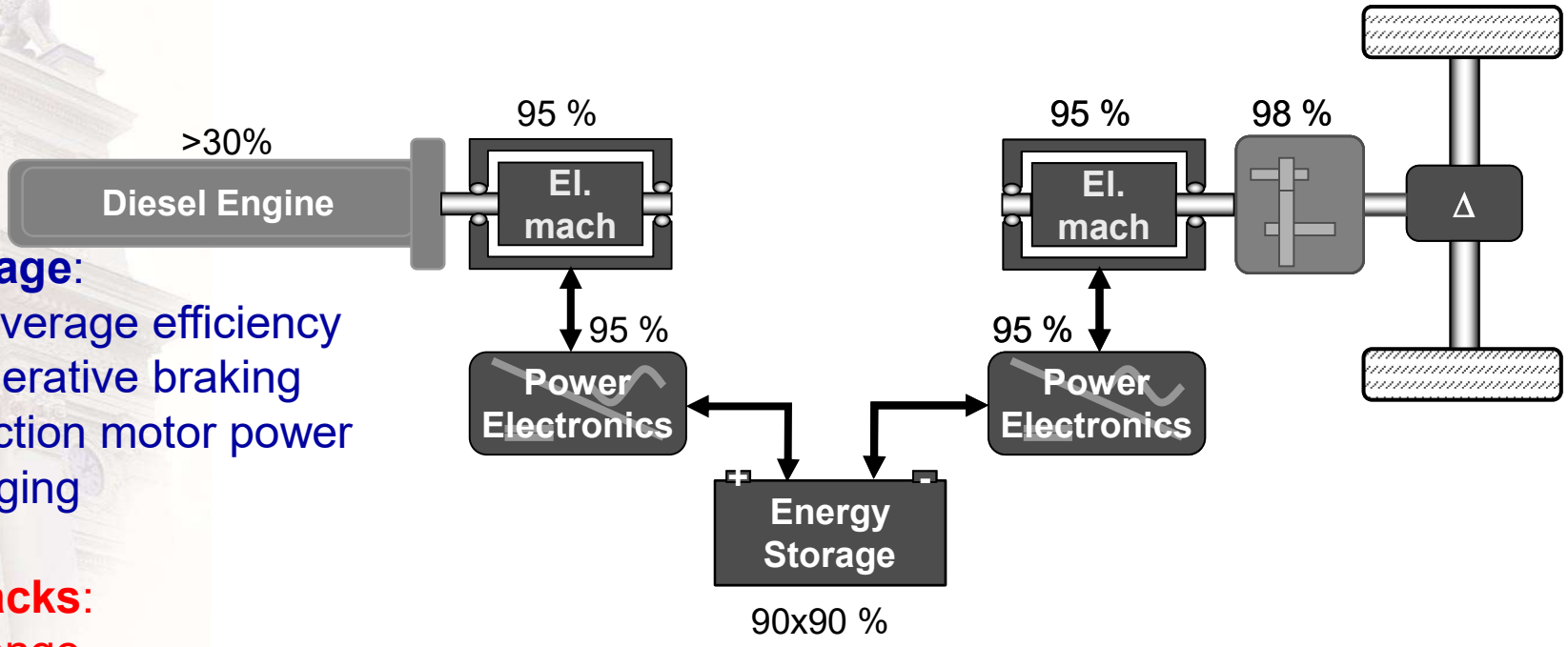


Advantage:
-High range

Drawbacks:
- Low average efficiency, 10..20 %
- No regenerative braking

Idea to solution:
- An electric vehicle

The Electric Vehicle

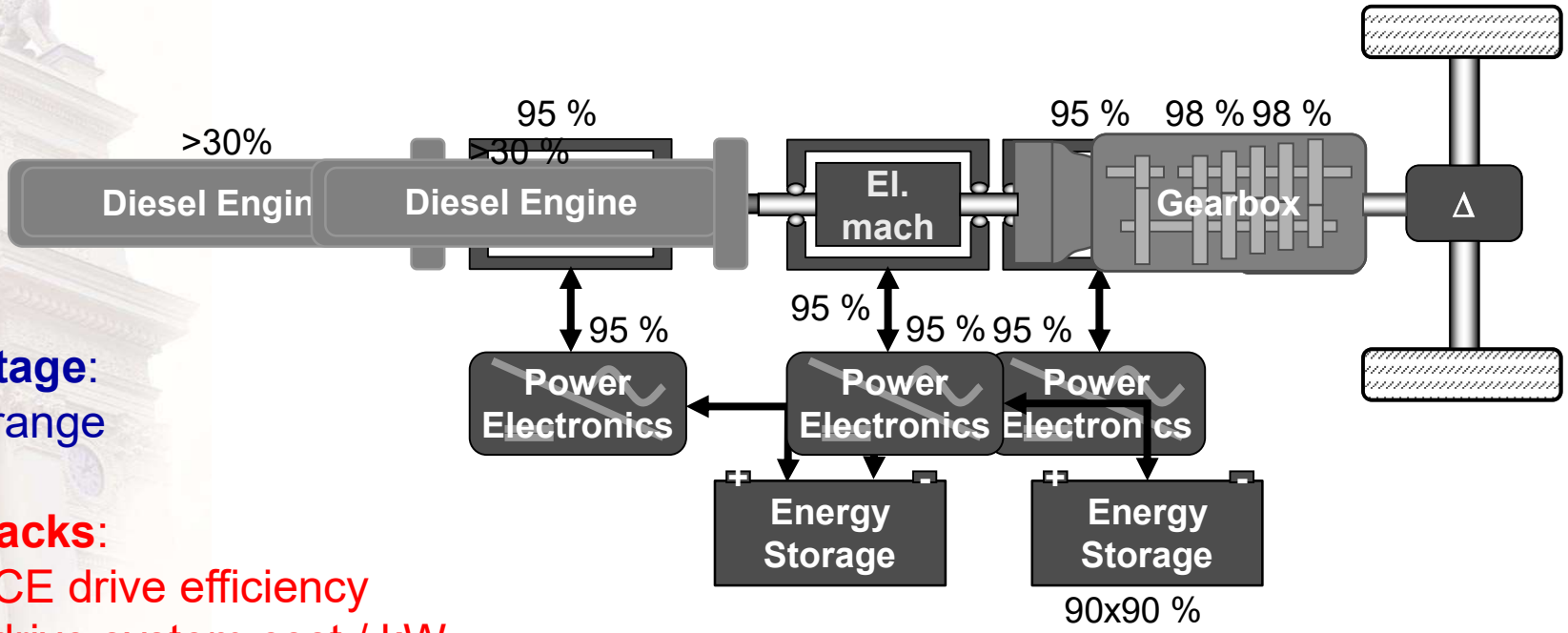


Advantage:
- High average efficiency
- Regenerative braking
  @ Traction motor power
- Packaging

Drawbacks:
- Low range
- High cost / kW tractive power

Idea to solution:
- ICE range extender -> The Series Hybrid Vehicle

The Series Hybrid Vehicle

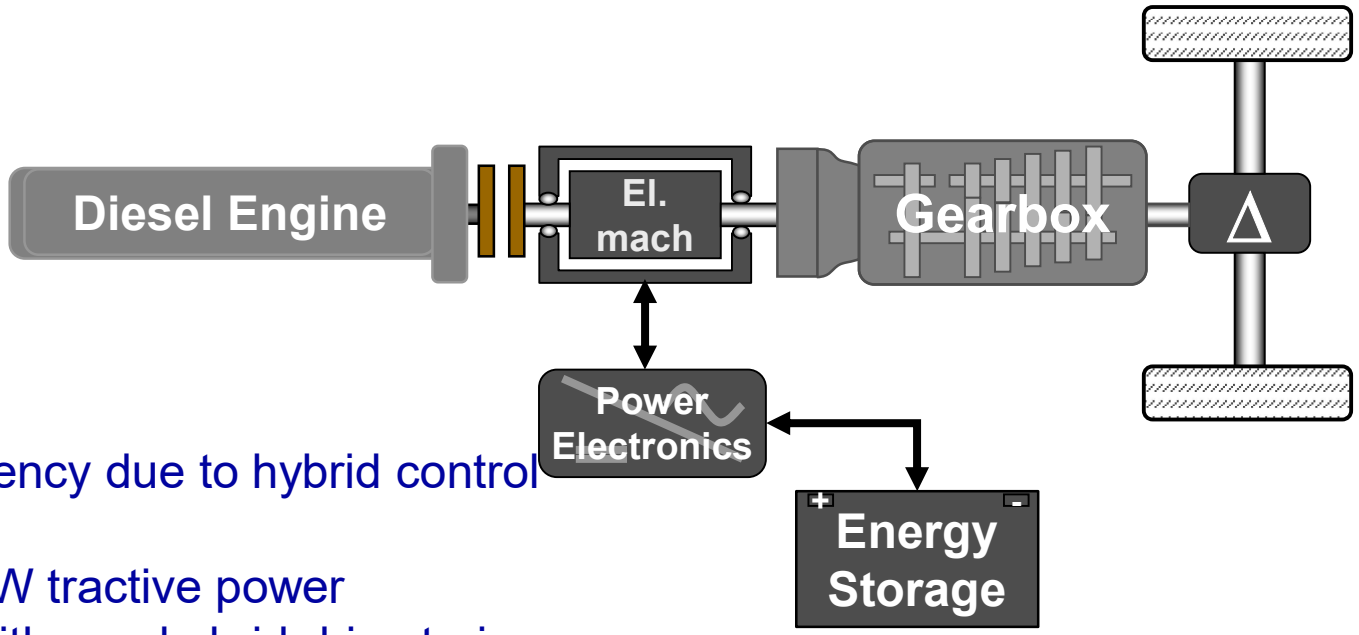


Advantage:
- High range

Drawbacks:
- Low ICE drive efficiency
- High drive system cost / kW
- All installed power NOT available on the wheels

Idea to solution:
- Connect ICE to wheels mechanically – The Parallell Hybrid

The Parallell Hybrid Vehicle



Advantage:
- High range
- High ICE drive efficiency due to hybrid control
- ICE downsizing
- Low system cost / kW tractive power
- High commonality with non-hybrid drive train
- Redundancy if electric drive malfunction

Drawbacks:
- Lower max regenerative braking due to lower EM rating than series

Hybrid Control Fundamentals

- Run the ICE as close to highest efficiency as possible, for each power level
  - Requires CVT or many transm. ratios
- Run the ICE as much as possible, but not when efficiency is too low
- Limit the ICE dynamics
  - Let the EM do the transient job

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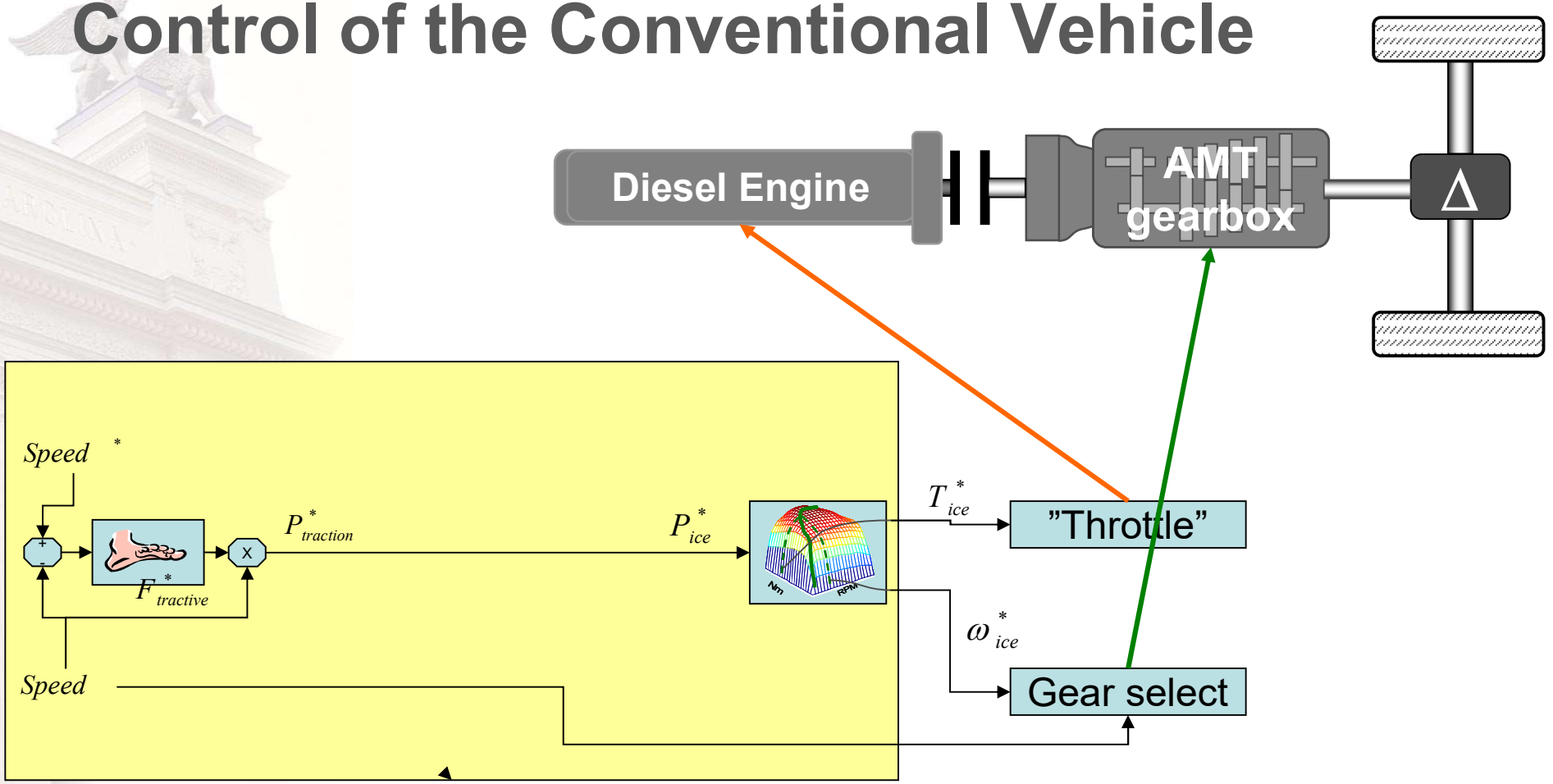
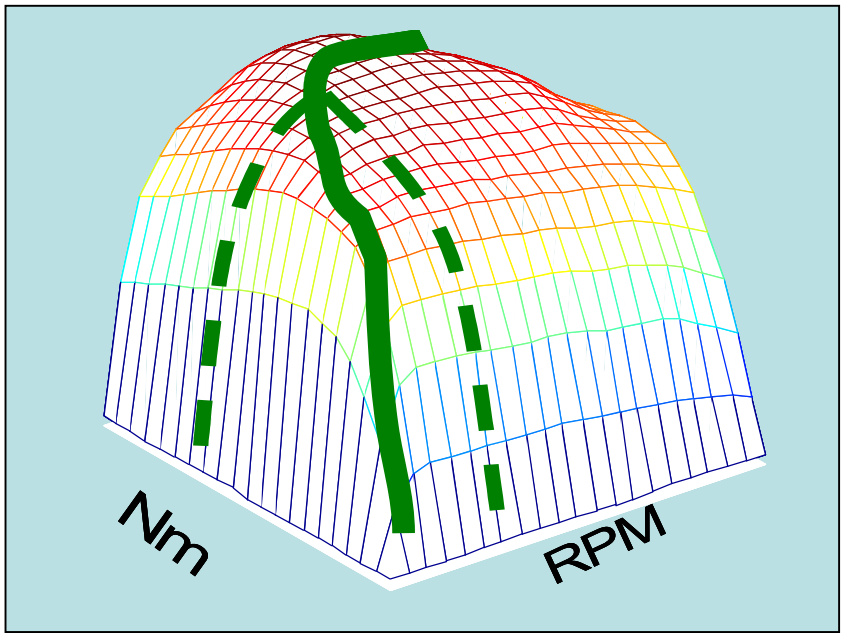
Control of the Conventional Vehicle



Optimal operating point



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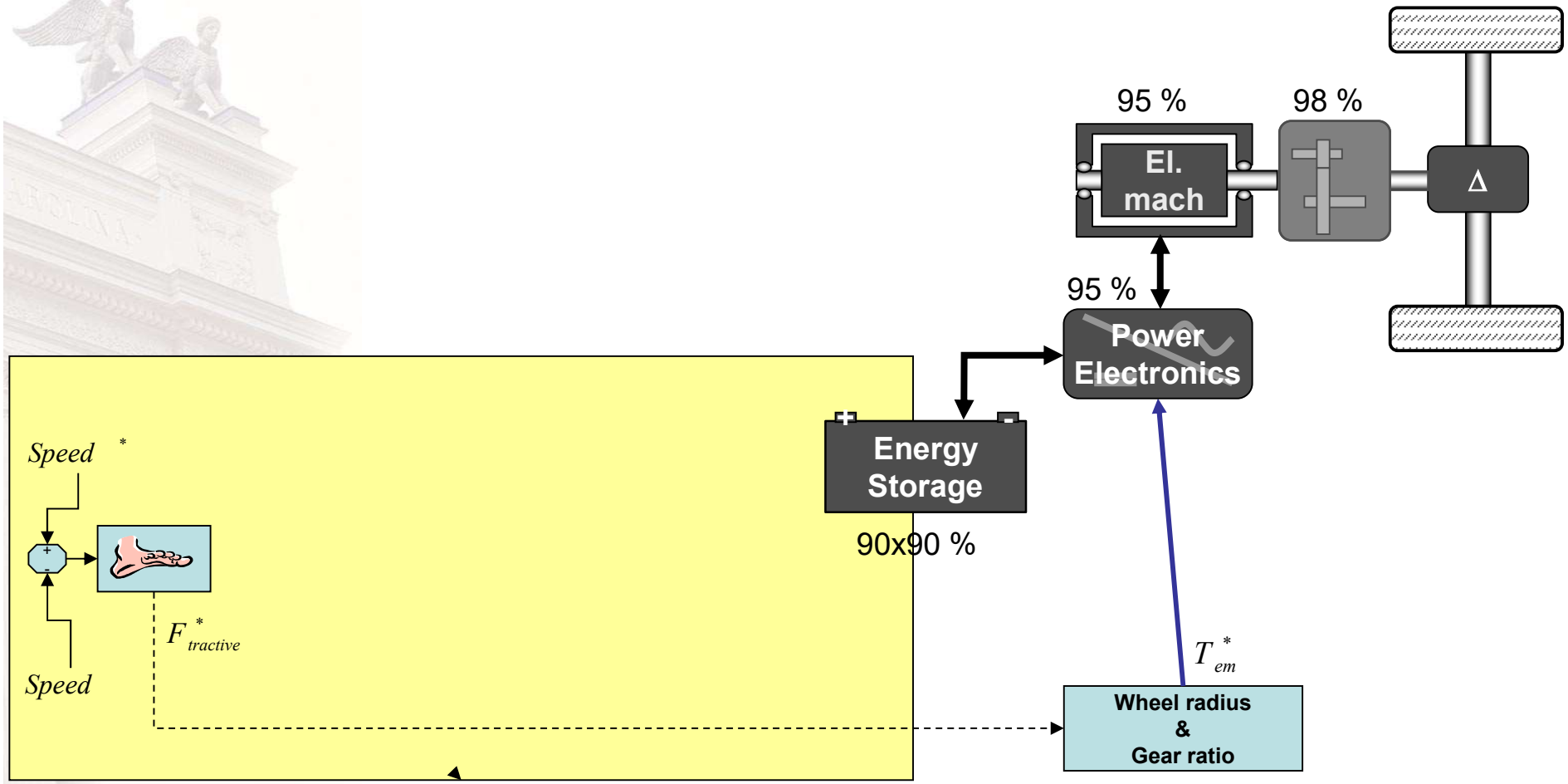

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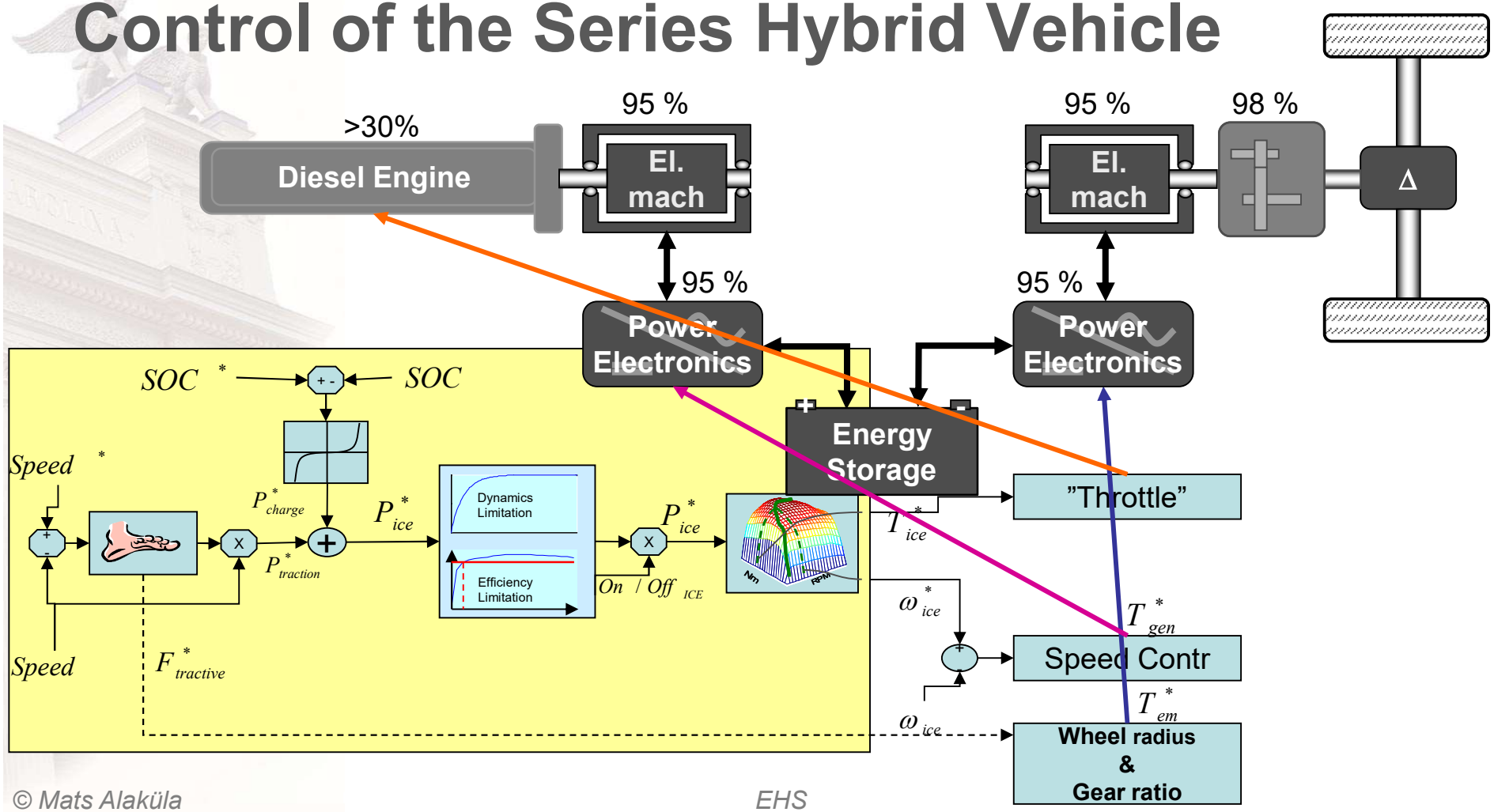
Control of the Series Hybrid Vehicle



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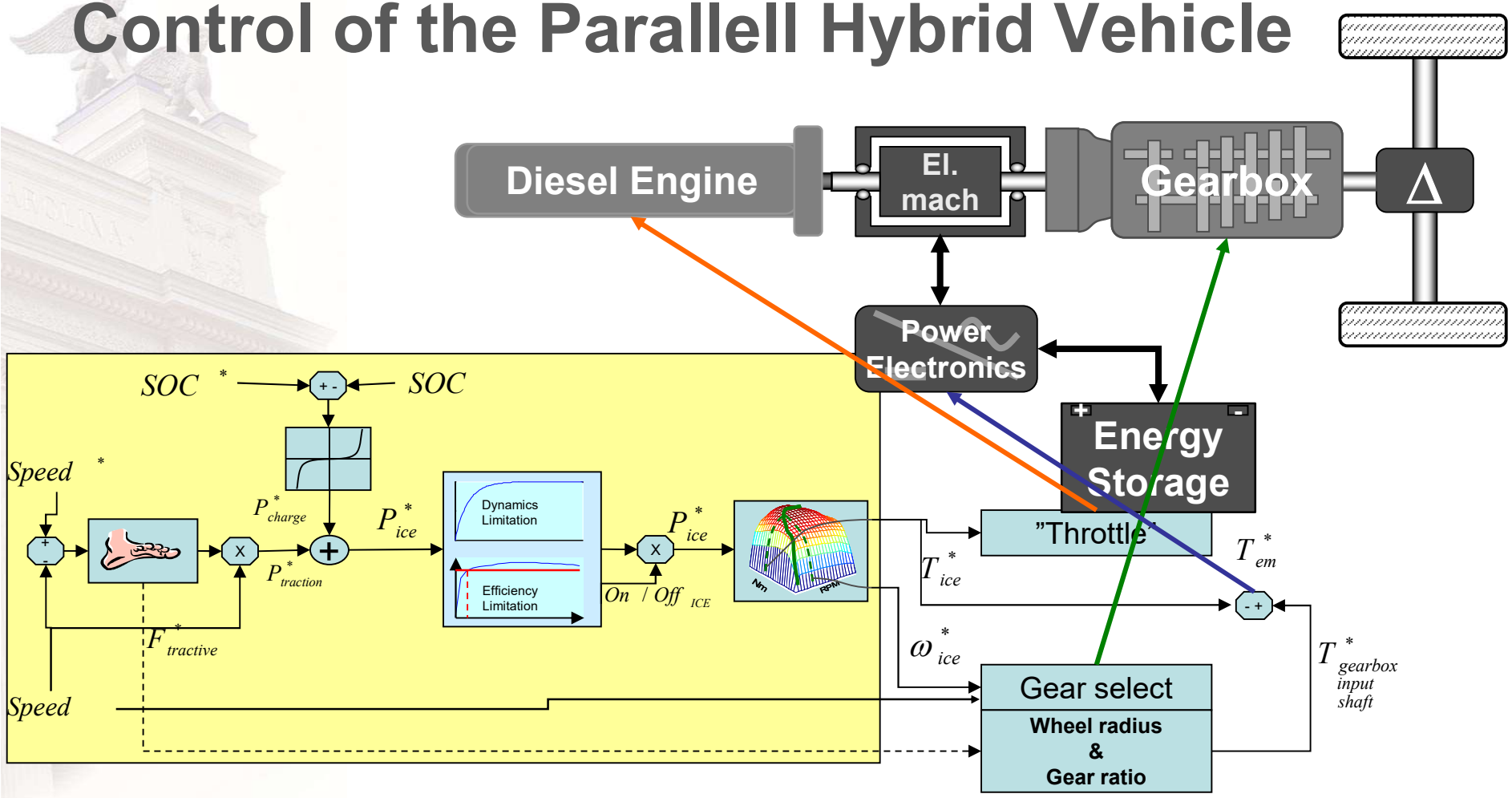
Control of the Parallell Hybrid Vehicle



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The Parallel Hybrid Model