Autonomous driving: the hidden enabling technology for a sustainable mobility model

Rome, 14/11/2023 – Keynote speech

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We have a problem...
Demographic growth

Industrial revolution – Antibiotics - Vaccinations

Anthropogenic planet modifications
Residual budget: 2000 GtCO₂ (to stay below +2°C)

It is less than 5% of CO₂-equivalent of fossil fuel still available
CO2 emissions share

Cumulative

Today

2016 rankings by per capita emissions

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>CO2 emissions (per capita)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Saudi Arabia</td>
<td>16.3T</td>
</tr>
<tr>
<td>2</td>
<td>Australia</td>
<td>14.3T</td>
</tr>
<tr>
<td>3</td>
<td>United States</td>
<td>10.0T</td>
</tr>
<tr>
<td>4</td>
<td>Canada</td>
<td>11.6T</td>
</tr>
<tr>
<td>5</td>
<td>South Korea</td>
<td>9.9T</td>
</tr>
<tr>
<td>6</td>
<td>Russian Federation</td>
<td>9.9T</td>
</tr>
<tr>
<td>6</td>
<td>Japan</td>
<td>9.01T</td>
</tr>
<tr>
<td>8</td>
<td>Germany</td>
<td>8.9T</td>
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<tr>
<td>9</td>
<td>Poland</td>
<td>7.7T</td>
</tr>
<tr>
<td>10</td>
<td>South Africa</td>
<td>7.4T</td>
</tr>
<tr>
<td>11</td>
<td>Islamic Republic of Iran</td>
<td>7.1T</td>
</tr>
<tr>
<td>12</td>
<td>China</td>
<td>6.4T</td>
</tr>
<tr>
<td>13</td>
<td>United Kingdom</td>
<td>5.61T</td>
</tr>
<tr>
<td>14</td>
<td>Italy</td>
<td>5.4T</td>
</tr>
<tr>
<td>15</td>
<td>France</td>
<td>4.5T</td>
</tr>
<tr>
<td>16</td>
<td>Turkey</td>
<td>4.2T</td>
</tr>
<tr>
<td>17</td>
<td>Mexico</td>
<td>3.6T</td>
</tr>
<tr>
<td>18</td>
<td>Brazil</td>
<td>2.0T</td>
</tr>
<tr>
<td>19</td>
<td>Indonesia</td>
<td>1.77T</td>
</tr>
<tr>
<td>20</td>
<td>India</td>
<td>1.67T</td>
</tr>
</tbody>
</table>
From +1° to +4°...?

Stop at +2°? (stick on the budget)

Adaptation & Resilience? (overshoot the budget)
Remark: relative contribution of GHG emissions (EU focus)

28% of UK GHGs were from Transport in 2018

- Transport: 28%
- Energy Supply: 23%
- Business: 18%
- Residential: 15%
- Agriculture: 8%
- Other: 5%
- Waste: 4%
Car-based personal mobility model

the mistake #1 (in retrospect, after 1B cars) = personal ownership
Megatrends: CONGESTION / car density

<table>
<thead>
<tr>
<th>Country</th>
<th>cars per 1000 inhabitants</th>
<th>total number of cars</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>831</td>
<td>275,913,237.00</td>
</tr>
<tr>
<td>Canada</td>
<td>790</td>
<td>30,754,600.00</td>
</tr>
<tr>
<td>Australia</td>
<td>782</td>
<td>20,335,000.00</td>
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<tr>
<td>Poland</td>
<td>771</td>
<td>29,369,800.00</td>
</tr>
<tr>
<td>Italy</td>
<td>755</td>
<td>45,487,900.00</td>
</tr>
<tr>
<td>France</td>
<td>668</td>
<td>45,297,000.00</td>
</tr>
<tr>
<td>Germany</td>
<td>628</td>
<td>52,275,833.00</td>
</tr>
<tr>
<td>Spain</td>
<td>627</td>
<td>29,707,581.00</td>
</tr>
<tr>
<td>Japan</td>
<td>624</td>
<td>78,461,953.00</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>600</td>
<td>40,800,000.00</td>
</tr>
<tr>
<td>Netherlands</td>
<td>588</td>
<td>10,248,388.00</td>
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<tr>
<td>Malaysia</td>
<td>542</td>
<td>17,728,482.00</td>
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<tr>
<td>South Korea</td>
<td>485</td>
<td>25,167,409.00</td>
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<tr>
<td>Russia</td>
<td>395</td>
<td>58,116,046.00</td>
</tr>
<tr>
<td>Mexico</td>
<td>391</td>
<td>50,400,000.00</td>
</tr>
<tr>
<td>Argentina</td>
<td>373</td>
<td>17,000,000.00</td>
</tr>
<tr>
<td>Colombia</td>
<td>324</td>
<td>16,500,000.00</td>
</tr>
<tr>
<td>Thailand</td>
<td>280</td>
<td>19,576,630.00</td>
</tr>
<tr>
<td>Turkey</td>
<td>254</td>
<td>21,763,186.00</td>
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<tr>
<td>Ukraine</td>
<td>245</td>
<td>10,500,000.00</td>
</tr>
<tr>
<td>South Africa</td>
<td>232</td>
<td>13,570,330.00</td>
</tr>
<tr>
<td>China</td>
<td>226</td>
<td>319,000,000.00</td>
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<tr>
<td>Brazil</td>
<td>215</td>
<td>46,200,000.00</td>
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<tr>
<td>Iran</td>
<td>175</td>
<td>14,500,000.00</td>
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<tr>
<td>Indonesia</td>
<td>82</td>
<td>22,587,923.00</td>
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<tr>
<td>Nigeria</td>
<td>61</td>
<td>13,000,000.00</td>
</tr>
<tr>
<td>India</td>
<td>59</td>
<td>80,888,051.00</td>
</tr>
</tbody>
</table>

List of countries with more than 10M cars sorted by car density
Megatrends: CONGESTION / travelled distance (EU)

Change in distance travelled by car for selected countries

[Bar chart showing distance travelled by car for selected countries from 2000 to 2019.]

Remark: simultaneously-used cars

Active vehicles during a weekday (07/03/2018)

Analysis from a dataset of billions of trips, taken from 4M of insurance telematic boxes.
85% of the cars in Italy (2022) are used less than 5% of time.
Electric car and personal ownership: a mismatch

The longer the range, the longer the lifetime: For a 1200 cycles battery: **500Km range = 600.000+Km lifetime**

**Average mileage: 10.000km/year**
"Affordability" of BEV (subsidy...)

EU

Case study using real data: E-Private Mobility Index

Italy (Rome, Bari, Brescia) - functional feasibility for hub-to-hub mileage AND economic breakeven

Private electrification seems reasonable up to (max) 20%
The Mobility As A Service (MAAS)

and

Mobility On Demand (MOD)

(«car sharing»)
Cross-links…

Fossil fuels

«mismatch»

Electric

«perfect fit»

- large mileage
- globally-optimized recharge
- (shorter trips)
- (smaller vehicles)

Personal

Shared
Mass-market Mobility-As-A-Service: is there a cultural barrier?....NO

Younger consumers are less likely to use private cars now and plan to increase their use of public transit and micromobility.

**Share of respondents by age group, %**

<table>
<thead>
<tr>
<th>Age group</th>
<th>Private Vehicle</th>
<th>Public Transit</th>
<th>Taxi/ride-hailing</th>
<th>Carsharing</th>
<th>Micromobility</th>
<th>Pooled shared mobility</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;30</td>
<td>42</td>
<td>20</td>
<td>8</td>
<td>9</td>
<td>11</td>
<td>9</td>
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<tr>
<td>30–45</td>
<td>49</td>
<td>13</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>&gt;45</td>
<td>77</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

**Planned use by mode of travel in the future, Gen Z**

- **Use more**
  - Private vehicle: 32
  - Public transit: 43
  - Micromobility: 41
  - Shared mobility: 32
  - Pooled shared mobility: 32

- **Use less**
  - Private vehicle: 31
  - Public transit: 23
  - Micromobility: 18
  - Shared mobility: 24
  - Pooled shared mobility: 19

Note: Figures may not sum to 100%, because of rounding.
More than 4 times per week.

*Taxi/ride-hailing/carsharing: Source: McKinsey Mobility Consumer Pulse Survey*
Car-sharing, today (limited effectiveness – «niche»)

High (attractive) level of services

(too) many cars

Low mileage-per-car

High cost (user) or non-profits (provider)

Source: McKinsey Center for Future Mobility

«deadlock»
Enabling technology for mass-market Mobility As A Service: Autonomous Car

High (attractive) level of services

Few cars

High mileage-per-car

Low cost (user) and profits (provider)

L4- (un-manned, low-speed)

L5 (robotaxi)
Case study: Autonomous MAAS in Padua

Replacement target: cars with 90% trips «in-in»

- Optimal Vehicles Number: 4300
- Users per car (efficiency): 8.0
- Replaced private cars: 34,500 (30%)
- Average Mileage: 44,000 km/y
- Average Wait Time: 2min 40s

Simulation (using real data) of a robo-taxi service with autonomous driving
New mobility model

- Fossil fuels
- Personal
- Human-driven
- Electric & H2
- Shared
- Autonomous
Consecutio – the “right” sequence of the events

Electric, personal car (20% - 30%)

Autonomous Level 3+ or more

Mobility As A Service - MAAS

Electric, MAAS (85% - 90%)

Enabling technology
«Big-Bang» of the mobility model transformation
A 100KWh personal car battery can be used as a local battery accumulator for micro-generated renewable energy

- Why using a sophisticated battery technology designed for mobile application for local storage?
- Carrying around a big battery decreases the efficiency of the car in (5% of time) mobility
- How many households can apply this concept (in vertical cities)?
- Same concept can be applied for MAAS/MOD cars...
OBJECTION: Power- to H2 – to X ? (the «E-FUEL» path)

➢ Energy transition reaching zero CO2 emissions by mid-century is feasible
➢ Direct electrification is most efficient and least cost

Christian Breyer
Professor for Solar Economy
IFAC Symposium on
Control of Power and Energy Systems
online, June 23, 2022

Electric-Energy – TO – Wheel efficiency is extremely low (<<10%)
Autonomous Vehicles Technology: roadmap

Autonomous robo-driver: a massive technical problem, still to be fully solved (in mixed human-AI traffic)
Roadmap to Autonomous Vehicles: timing?

Subject to progress on the technical, infrastructure, and regulatory challenges, up to 15% of all new vehicles sold in 2030 could be fully autonomous.

L3, 2035 prediction: 10%-95% range...
A political dilemma...

San Francisco,
October 2023
A political dilemma...

Scenario 1: Introduce when slightly safer (10%) than humans

Scenario 2: Delay AV introduction until nearly perfect

The «good for the individual» is playing against the «good for all»?

Are we ready to accept the errors of technology?

Who’ll be the winner in AV technology?

Virtual mobility = AMAZON-ization of mobility? (people-moving or goods-moving?)

**Uber**

**Uber-ization**: mobility as a service

**Amazon**

**Amazon-ization**: goods-mobility
The YAPE (Your Autonomous Pony Express) spinoff project
Scenario#1: robotaxi + soft mobility+smart logistics
Scenario #2: …a full-digital world…? (threat for physical mobility)
car-based personal mobility model

the mistake #2 (in retrospect, after 1B cars) = mixing function & fun
Bifurcation | landing point

Today: function & fun (40M)

"robo-taxi" MAAS = public transport (<10M)

Emotional ("red") vehicles (private owner or "service")
The birth of Autonomous Motorsport
Artificial Intelligence in motorsport: the Automatic Control gap

Automatic control & A.I. are clearly the next big leap in automotive

The gap with motorsport cars is growing and becoming constantly more significant
Indy Autonomous Challenge (1st example of full-scale autonomous motorsport)
Autonomous Challenge @ CES (Las Vegas) 1/7/22: the birth of Autonomous racing

First ever competition:
- fully autonomous
- multi-agent (head-to-head)
- high-speed (up to 280kmh)

Winning team: Polimove, Politecnico di Milano
Dallas, Las Vegas, Monza…

Autonomous Challenge @ Monza 18/6/2023 (winners: 2:05:87) [current speed record on an autonomous car on a road course circuit: 273.4 KPH / 169.8 MPH]

Autonomous Challenge @ Texas Motor speedway on 11/11/2022 (winners)

Autonomous Challenge @ CES (Las Vegas) 7/1/2023 (winners) [current speed record on an autonomous car on an oval circuit: 290.0 KPH / 180.2 MPH]
World record - (27/4/2022) - Space Florida launch&landing facility, at NASA Kennedy Space Center in Cape Canaveral, FL

New world record holder for a fully-autonomous car: \textbf{309.3kph=192.2mph} (two-ways average, average over 1Km); 310.4kph=192.8mph (two-ways average, average over 100m); 311.9kph=193.8mph (top speed). The previous record was held by Roborace since 2019 (282.4kph=175.5mph, two-ways average, average over 100m).
**Possible interactions: autonomous motorsport future formats**

<table>
<thead>
<tr>
<th>Car Driver</th>
<th>A.I.(autonomous)</th>
<th>Real car (on-track)</th>
<th>Simulated Car</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car 1</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Car 2</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Car 1</td>
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<tr>
<td>Car 2</td>
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<tr>
<td>Car 1</td>
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<td></td>
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<tr>
<td>Car 2</td>
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<td></td>
</tr>
<tr>
<td>Car 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car 2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Classic Motorsport**
- **Classic Gaming**
- **«Sim-Race» of A.I. Drivers (first step of Indy Autonomous Challenge)**
- **Indy Autonomous Challenge**
- **Human vs. A.I. but 1 real car and 1 Holo-car on track**
- **Human vs. A.I. on real cars (ultimate goal, higher complexity)**
AR-Glasses: an enabling technology for hybrid-racing
1000 Miglia Autonomous Drive (1000-MAD)
The challenge: high road diversity and public engagement

Mille Miglia: “the most wonderful race in the world” [Enzo Ferrari]
Authorization 2023 (D.M.70 «smart road»): more than 200km!!!

Full-crossings of:
➢ BRESCIA
➢ FERRARA
➢ MODENA
➢ PARMA
➢ MILANO
➢ BERGAMO

+ 100km of A26 (ASPI)

2nd permission (6/6/23) grant in the 5-years history of DM70 – by far with the largest mileage
Converted Maserati MC20...and MC20 “CIELO”
1000 Miglia 2023

"Unveil" (Brescia, 11/6/2023)
1000 Miglia 2023
Milano 16/6/2023
Conclusions

Autonomous car will revolutionize the mobility model

Autonomous car will be the enabler of massive electrification

Technology still immature for large-scale deployment

Pushing the limit of this technology will speed up the development and acceptance process