FRICTION AND ENERGY SAVING

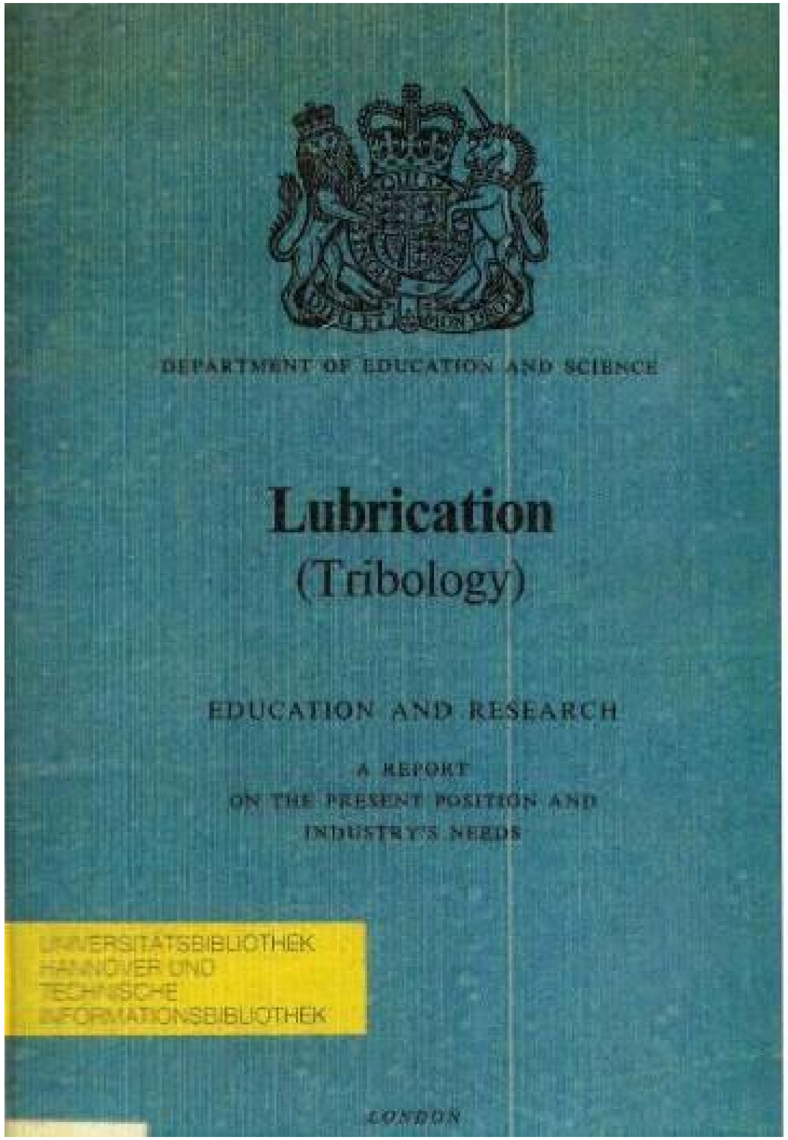
Kenneth Holmberg, VTT Technical Research Centre of Finland

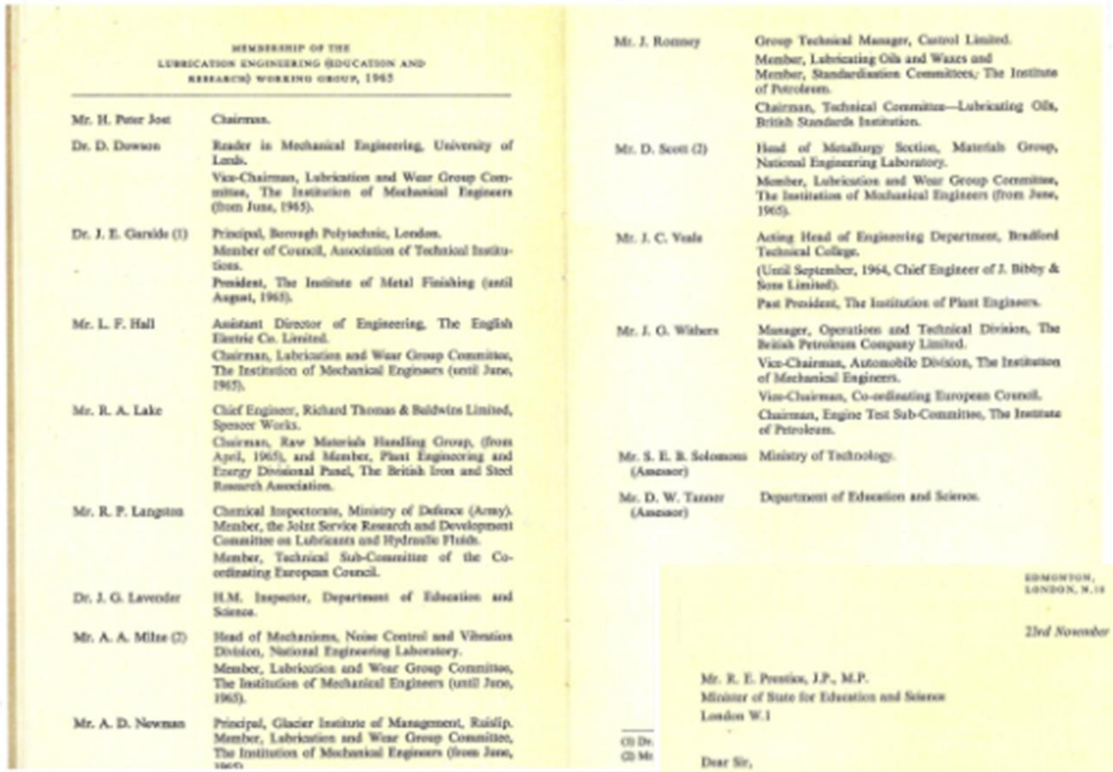
Ali Erdemir, Argonne National Laboratory, USA

50th Anniversary Celebration of the Jost Report,

2.3.2016, Institution of Mechanical Engineers, London, UK

1966 Jost Report on “Lubrication (Tribology)”

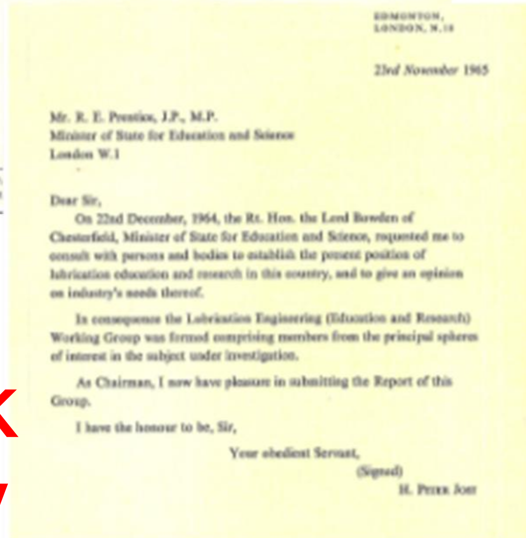




MEMBERSHIP OF THE
LUBRICATION ENGINEERING (EDUCATION AND
RESEARCH) WORKING GROUP, 1965

Mr. H. Peter Jost	Chairman.
Dr. D. Dowson	Reader in Mechanical Engineering, University of Leeds. Vice-Chairman, Lubrication and Wear Group Committee, The Institution of Mechanical Engineers (from June, 1965).
Dr. J. E. Garside (1)	Principal, Borough Polytechnic, London. Member of Council, Association of Technical Institutions. President, The Institute of Metal Finishing (until August, 1965).
Mr. L. F. Hall	Assistant Director of Engineering, The English Electric Co. Limited. Chairman, Lubrication and Wear Group Committee, The Institution of Mechanical Engineers (until June, 1965).
Mr. R. A. Lake	Chief Engineer, Richard Thomas & Baldwins Limited, Spencer Works. Chairman, Raw Materials Handling Group, (from April, 1965), and Member, Plant Engineering and Energy Divisional Panel, The British Iron and Steel Research Association.
Mr. R. P. Langston	Chemical Inspectorate, Ministry of Defence (Army). Member, the Joint Service Research and Development Committee on Lubricants and Hydraulic Fluids. Member, Technical Sub-Committee of the Co-ordinating European Council.
Dr. J. G. Lavender	H.M. Inspector, Department of Education and Science.
Mr. A. A. Milne (2)	Head of Mechanisms, Noise Control and Vibration Division, National Engineering Laboratory. Member, Lubrication and Wear Group Committee, The Institution of Mechanical Engineers (until June, 1965).
Mr. A. D. Newman	Principal, Glacier Institute of Management, Ruislip. Member, Lubrication and Wear Group Committee, The Institution of Mechanical Engineers (from June, 1965).
Mr. J. Romney	Group Technical Manager, Castrol Limited. Member, Lubricating Oils and Waxes and Member, Standardisation Committees, The Institute of Petroleum. Chairman, Technical Committee—Lubricating Oils, British Standards Institution.
Mr. D. Scott (2)	Head of Metallurgy Section, Materials Group, National Engineering Laboratory. Member, Lubrication and Wear Group Committee, The Institution of Mechanical Engineers (from June, 1965).
Mr. J. C. Veale	Acting Head of Engineering Department, Bradford Technical College. (Until September, 1964, Chief Engineer of J. Bibby & Sons Limited). Past President, The Institution of Plant Engineers.
Mr. J. G. Withers	Manager, Operations and Technical Division, The British Petroleum Company Limited. Vice-Chairman, Automobile Division, The Institution of Mechanical Engineers. Vice-Chairman, Co-ordinating European Council. Chairman, Engine Test Sub-Committee, The Institute of Petroleum.
Mr. S. E. B. Solomons (Assessor)	Ministry of Technology.
Mr. D. W. Tanner (Assessor)	Department of Education and Science.

=> <u>515 M£/year</u>
can be saved in UK
by new technology



EDMONTON,
LONDON, N.18

23rd November 1965

Mr. R. E. Prentice, J.P., M.P.
Minister of State for Education and Science
London W.1

Dear Sir,

On 22nd December, 1964, the Rt. Hon. the Lord Bowden of Chesterfield, Minister of State for Education and Science, requested me to consult with persons and bodies to establish the present position of lubrication education and research in this country, and to give an opinion on industry's needs thereof.

In consequence the Lubrication Engineering (Education and Research) Working Group was formed comprising members from the principal spheres of interest in the subject under investigation.

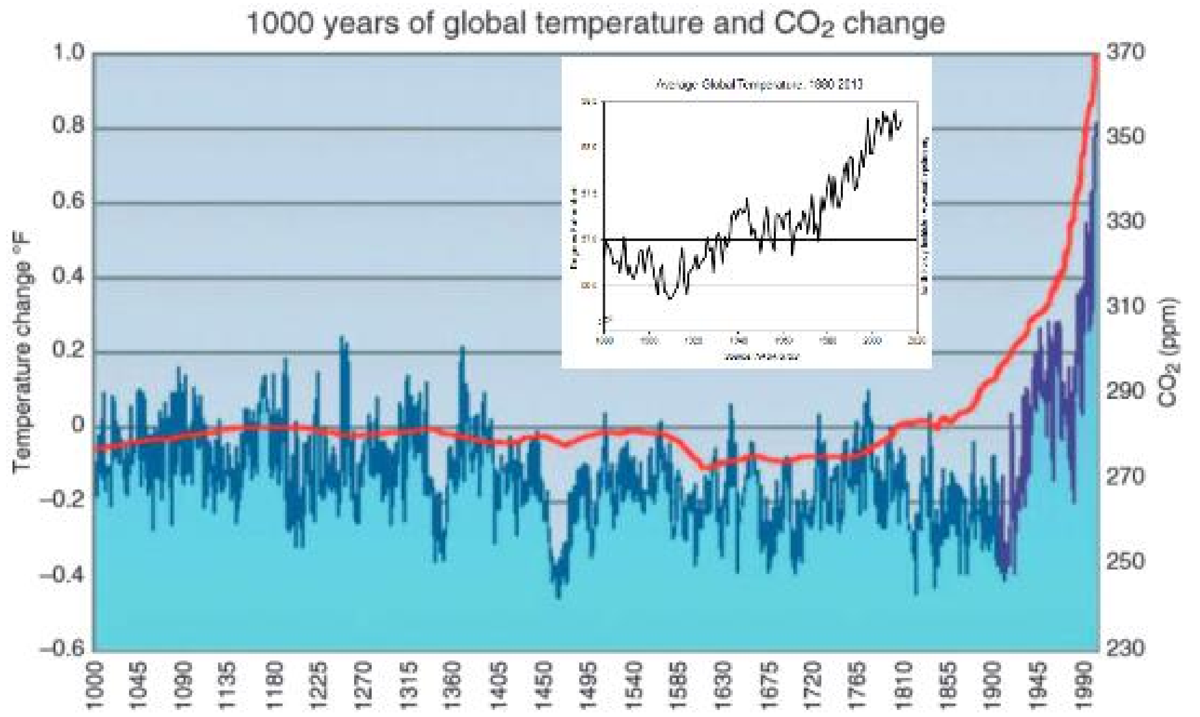
As Chairman, I now have pleasure in submitting the Report of this Group.

I have the honour to be, Sir,

Your obedient Servant,
(Signed)
H. Peter Jost

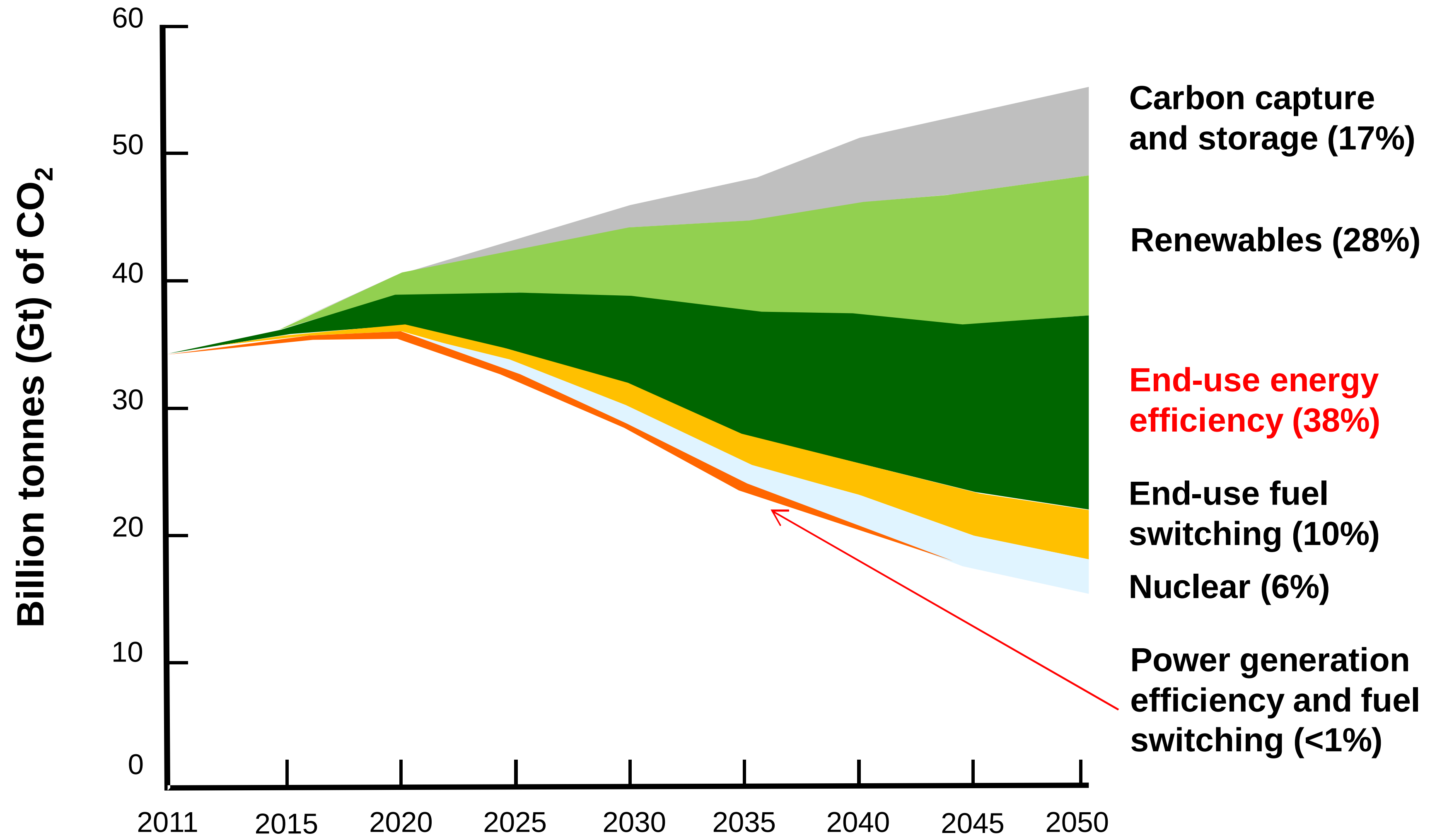
2016 Challenges for the society

- **Increased world population**
- **Increased use of energy**
- **Limitation of fossil fuels**
- **Increased emissions**
- **Climate change**



In industrial countries the cost of energy and material losses due to friction and wear is close to 5% of gross annual product.

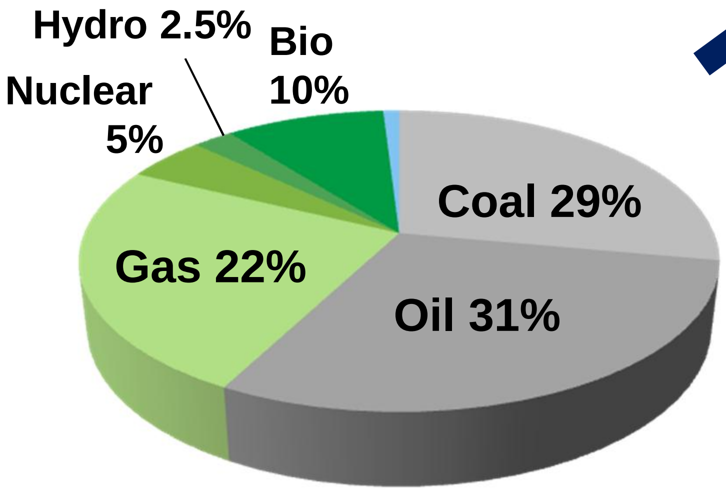
Key technologies for CO_2 emission reduction in order to limit global warming to 2ºC



Ref.: Energy Technology Perspectives 2014, Paris, OECD/IEA

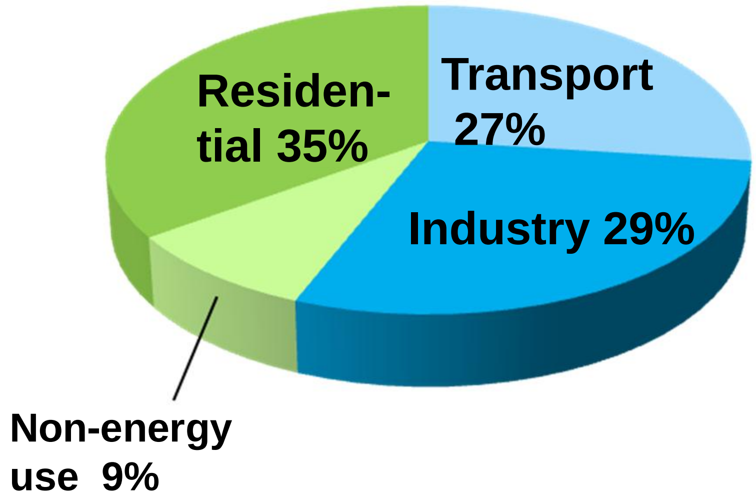
Global energy supply and consumption

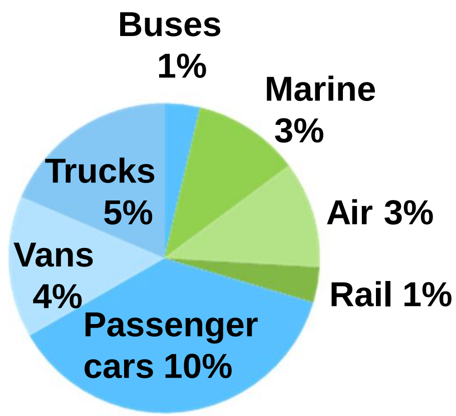
Fuel shares of global primary energy supply 2013: 570 EJ (13 540 Mtoe)

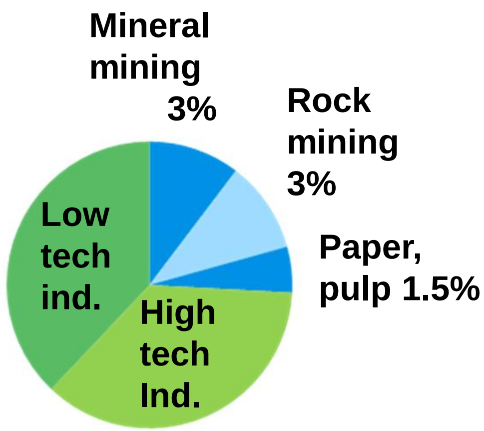


Energy industry use: 170 EJ (4 080 Mtoe)

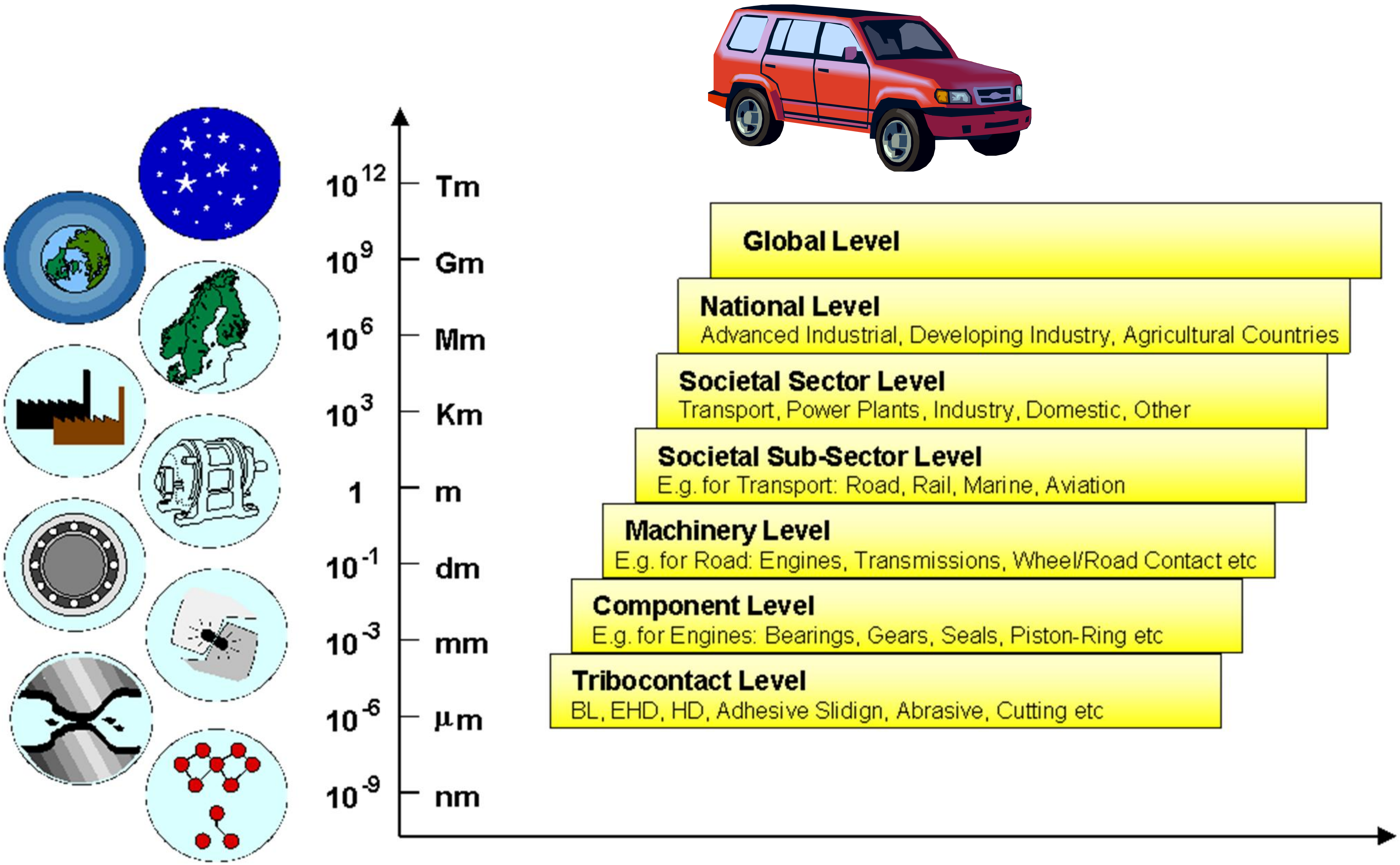
Total final energy consumption 2013: 390 EJ (9 300 Mtoe)





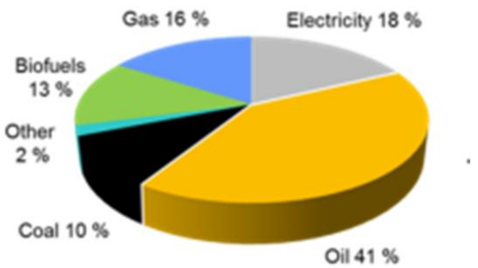


Root causes of friction losses across all scales in passenger cars



Global friction impact study methodology: case passenger cars

Fuel shares of global energy consumption 2011: 373 EJ (8918 Mtoe)

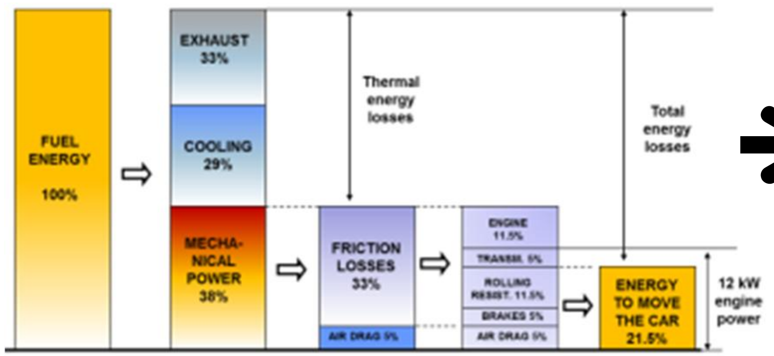


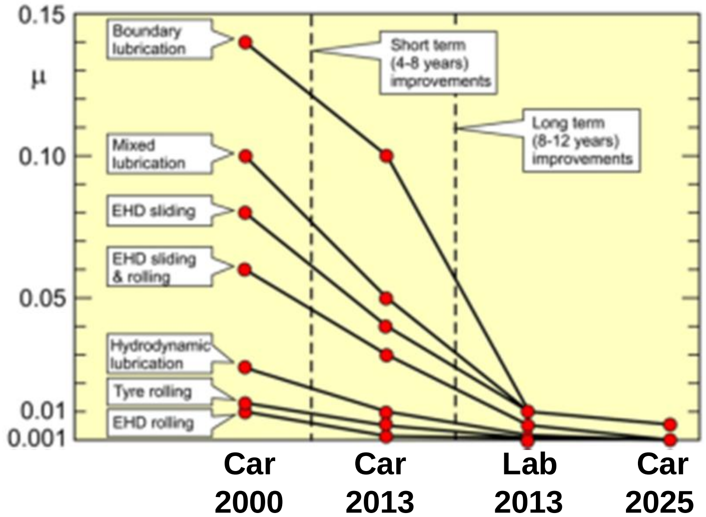
Annual car fuel consumption:
34 EJ

Number of cars:
700 million

Energy used in one global average car:
48 000 MJ/a

Definition of the global average car:
- Technical specification
- Operational conditions





- Global energy consumption
- Global potential:
  - fuel savings
  - cost savings
  - CO_2 savings

Definition of the global average passenger car 2010

- **Manufactured in 2000**
- **75 kW four-cylinder, in-line, four-stroke engine**
- **1.7 dm3 engine capacity**
- **1500 kg weight**
- **Gasoline fuelled by 70%, diesel fuelled by 30%**
- Engine oil viscosity class SAE 5W40 (age < 1 year)
- Tyre coefficient of rolling friction approx. 0.02. (Summer tires, size
- 185/65R15, age 4 years, average tyre pressure, on average road)
- Frontal area approximately 2.3 m^2
- Drag constant 0.345 (average for passenger cars of 2000 model)
- Hydro mechanical power steering
- Air condition with compressor in 25% of the cars
- Manual 5-speed gearbox. Oil SAE 75W-90 of 10 years age
- Front wheel drive
- Driving brakes based on friction linings and drums or discs

The global average driving conditions in 2010

- **13 000 km annual driving distance**
- **60 km/h average speed**
- **Average fuel consumption 8 litres/100 km**
- **12 kW engine power output on an average**
- **300 g/kWh fuel efficiency (@ 12 kW)**
- **2.5 kg CO2 emissions per fuel litre burned, or 200 g/k**
- Average braking power: 2.4 kW
- Engine oil temperature estimate: 80°C
- Gearbox oil temperature estimate: 60°C
- As an average for 612 million cars

Fuel efficiency curves (g/kWh)

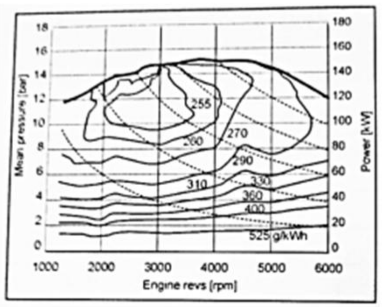


Fig. 3-9 Power and consumption curves for a car SI engine.[7]

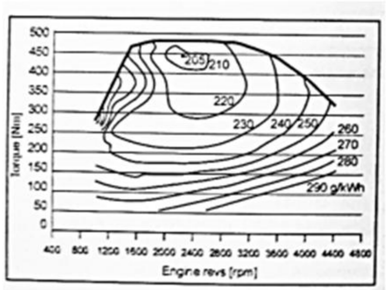
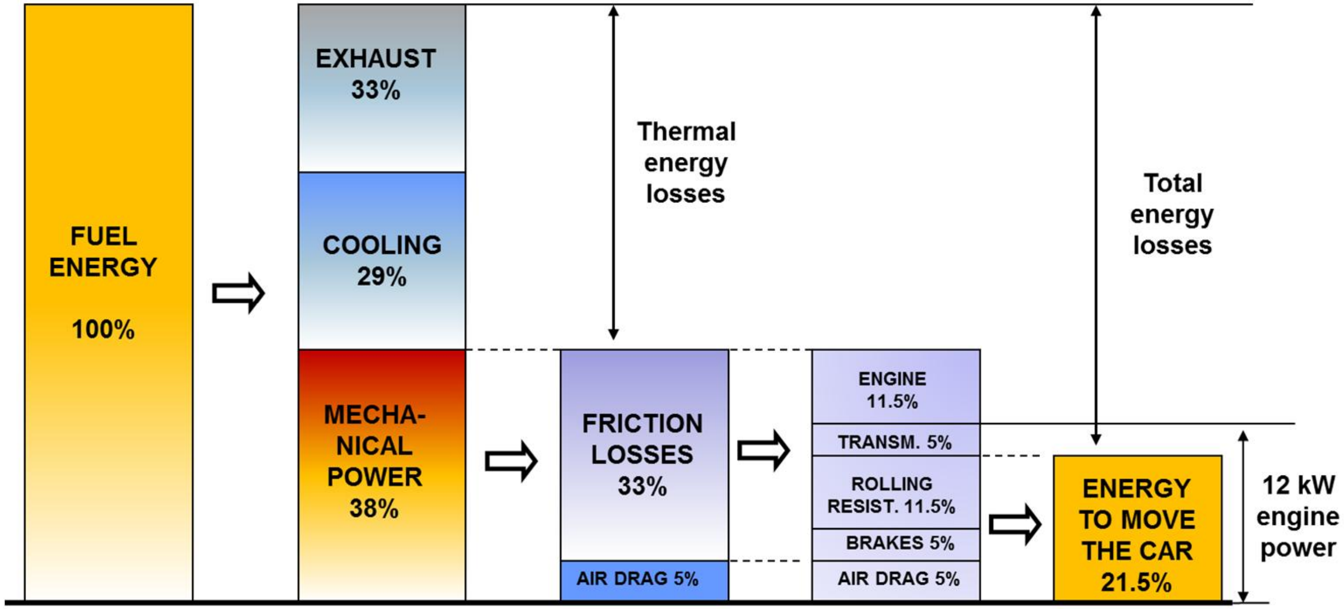


Fig. 3-10 Consumption curve, car diesel engine V8-TDI.[8]

Passenger Car Energy Consumption



Tyres 35% RF

Engine 35%

- valve train 15% ML
- bearings, seals 30% HD
- piston assembly 45%
  - HDsqueeze 40%
  - EHD 40%
  - ML 10%
  - BL 10%
- pumping, hydraul. 10% VL

Transmission 15%

- gears 55% EHD
- bearings 20% EHD
- viscous 20% VL
- seals, forks 5% ML

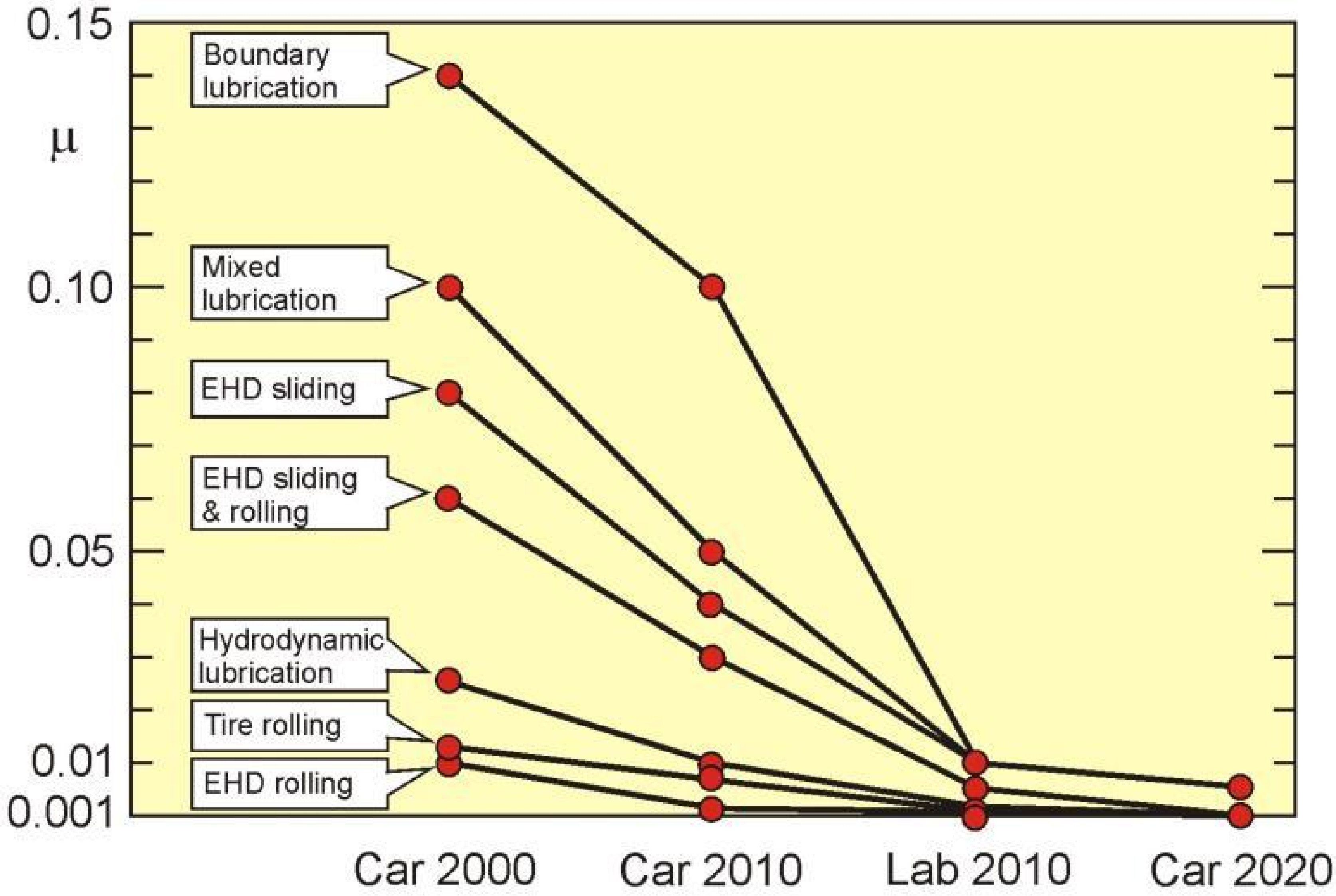
Brakes 15% SF

Friction losses in the main car components as part of the total friction losses of the car

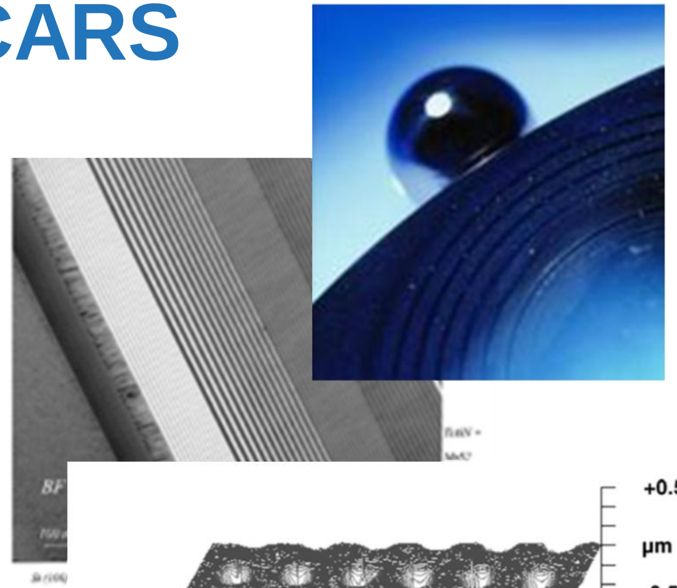
Literature data scatter

35% (12–45%) to overcome the rolling friction in the **tire-road contact**,
35% (30–35%) to overcome friction in the **engine system**,
15% (7–18%) to overcome friction in the **transmission system**, and
15% (10–18%) to overcome friction in the **brake contact**.

Trends in friction reduction for different lubrication mechanisms and rolling friction with reference to passenger car applications

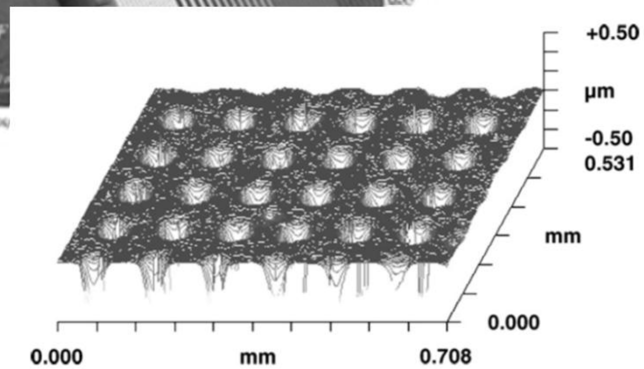


EMERGING TECHNOLOGIES FOR FRICTION REDUCTION IN PASSENGER CARS



- **Advanced coating structures**

DLC, TS, nano-composites etc:
- dry in vacuum superlubricity μ= 0.001
- lubricated 10-50% friction reduction



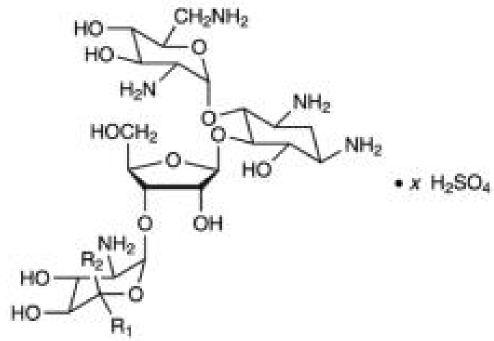
- **New surface texturing methods**

Laser surface texturing:
- 25-50% friction reduction
- 4% engine fuel reduction

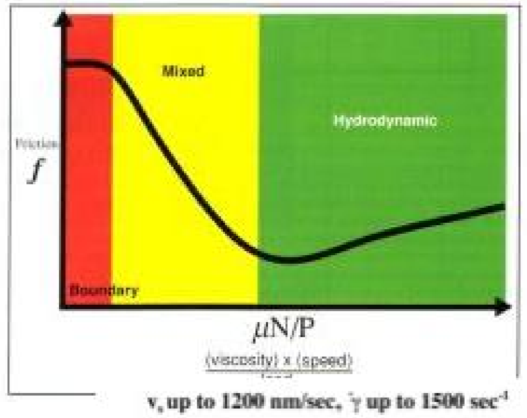
- **New boundary lubrication additives and fluids**

Glycerol mono-oleate in PAO vs DLC:
- μ = 0.005 in pure glycerol

Nanomaterials as additives like WS2, MoS2 H3BO3 and <u>graphene</u>



EMERGING TECHNOLOGIES FOR FRICTION REDUCTION IN PASSENGER CARS

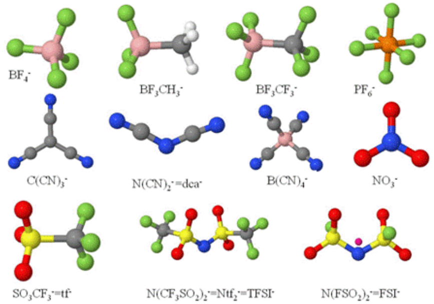


- **Low viscosity fluids**

Polyalkyl glycols

- **Ionic liquids**

25-50% friction reduction with IL

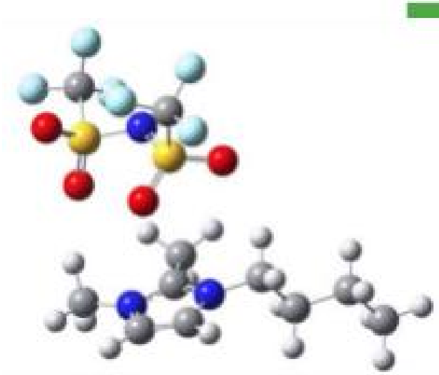


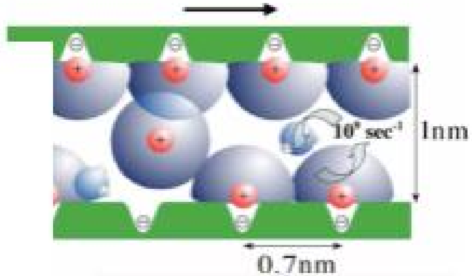
- **Biomimetics**

Biomolecular protein additives

Brushes of charged polyelectrolytes

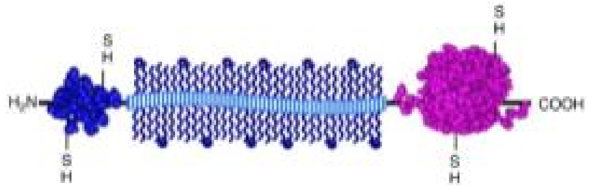
Porcine gastric mucin, glycoprotein mucin - μ=0.001-0.04



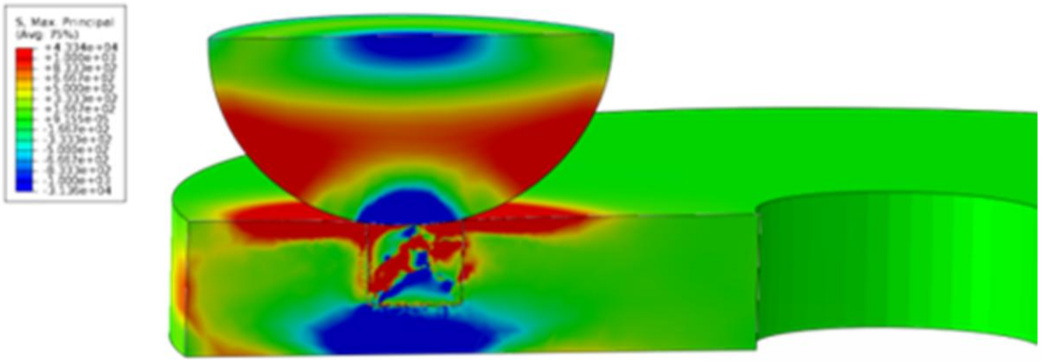


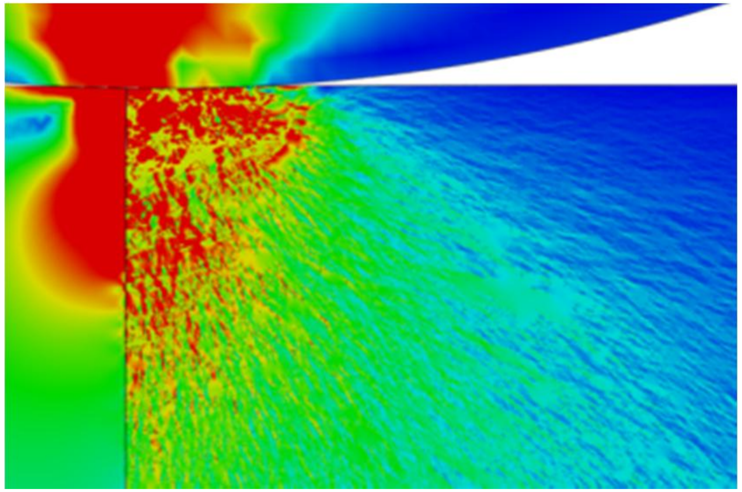
- **Low friction tyre design**

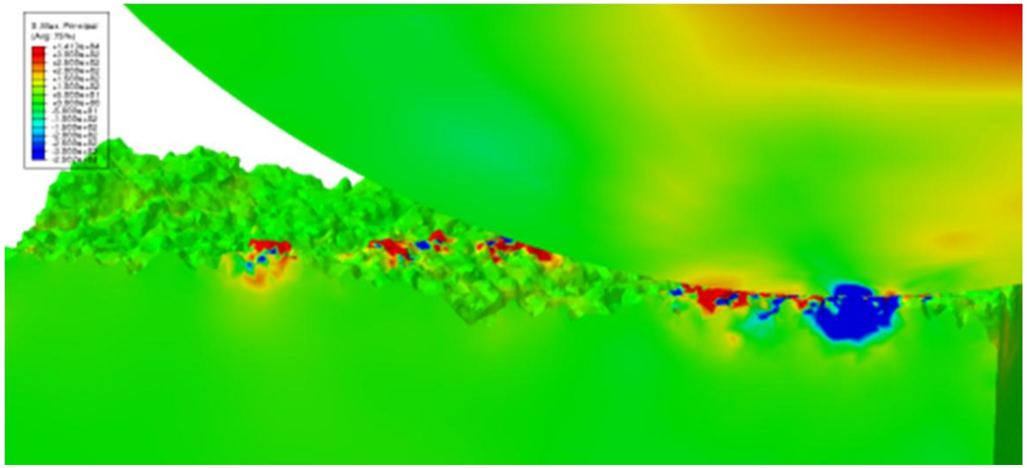
High pressure, small width etc

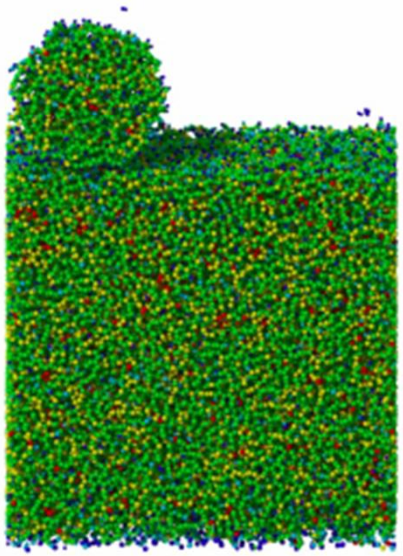


TRIBOLOGICAL OPTIMISATION BY COMPUTATIONAL MATERIAL MODELLING AND SIMULATIONS







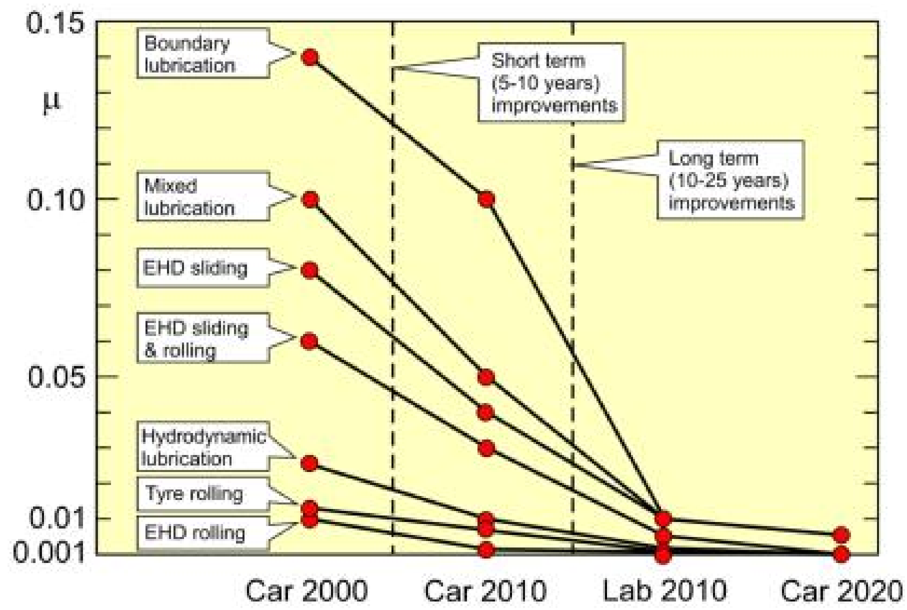


ProperTune™

FUEL CONSUMPTION AND POTENTIAL FRICTION SAVING IN PASSENGER CARS GLOBALLY

Gas and diesel oil used to overcome friction 208 000 million liters/a

Energy used to overcome friction 7.3 million TJ/a

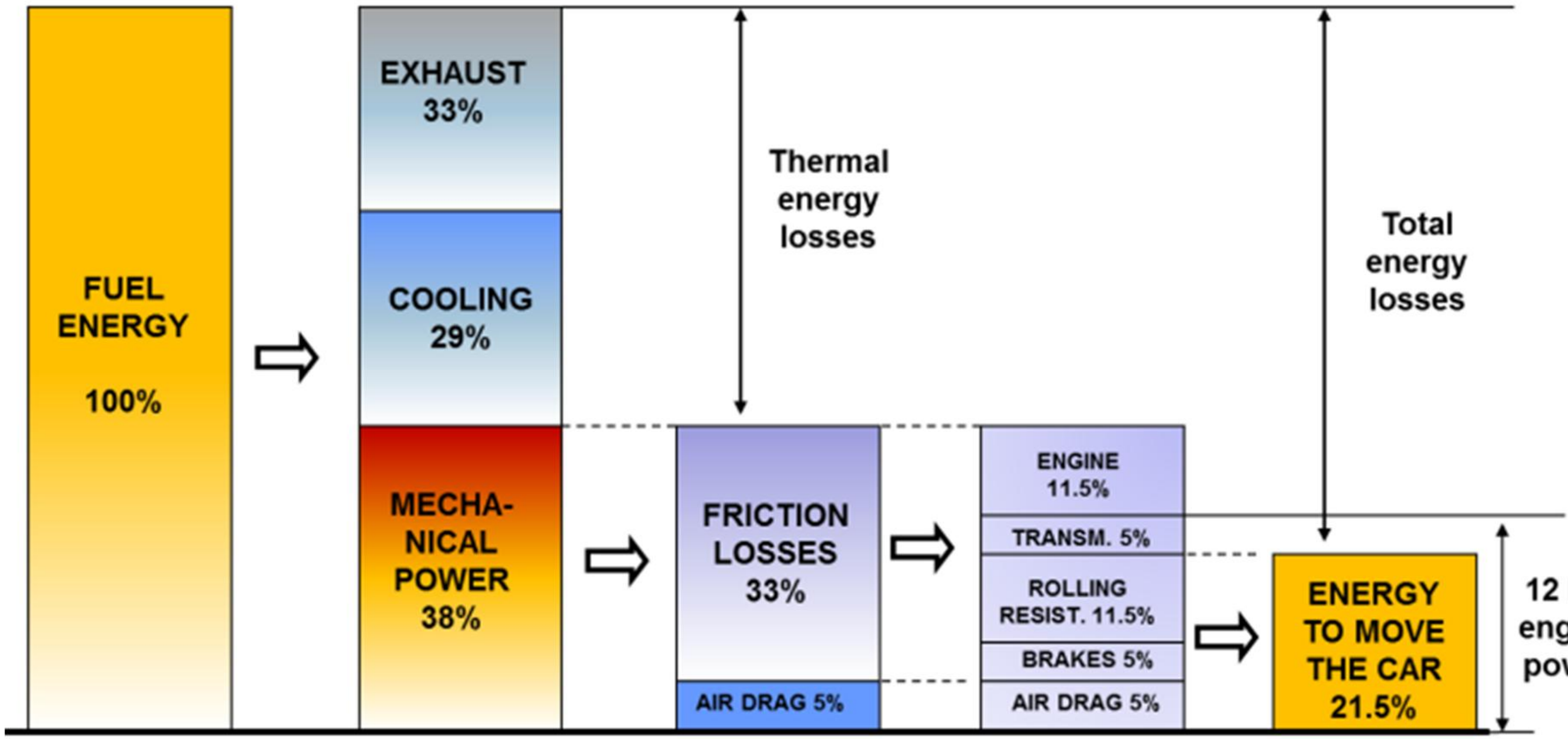


Potential savings by
- **today's best commercial 348 000 M€/a**
- **today's best solution 576 000 M€/a**
- **future (10 a) best solution 659 000 M€/a**

Realistic savings (18% reduction) after 5-10 years of focused actions:
- **oil fuel 117 000 million liters/a**
- **CO_2 emissions 290 million tonnes/a**
- **costs 174 000 million €/a**

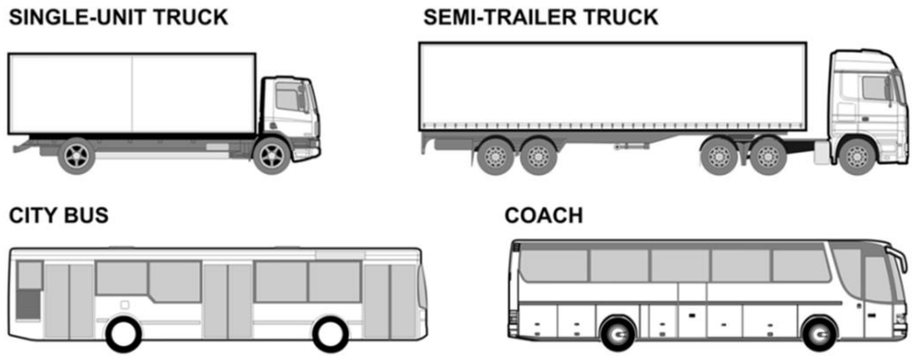
SECOND PARADOX OF TRIBOLOGY

”In a car you can save more energy by reducing friction with new tribological solutions than what in total is used to overcome friction in the car.”

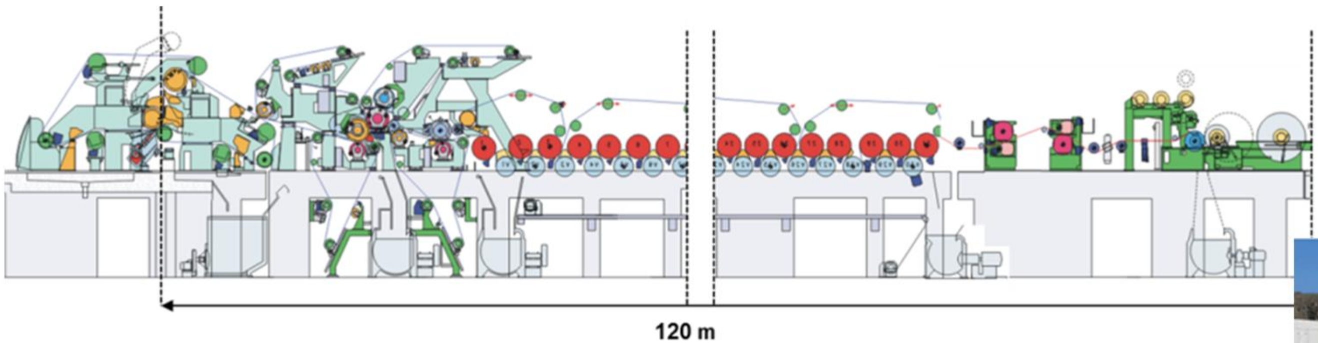


Passenger car

Heavy duty vehicles



Paper machines



Mining industry

Global summary

Transport

- about 30% of the fuel energy is used to overcome friction
- 18% potential savings can be achieved in short term (5 years) by implementing new tribological solutions
- friction losses in electric cars are ½ of those in IC cars

Industry

- about 20% of the industrial energy is used to overcome friction
- 11% potential savings can be achieved in short term (5-10 years) by implementing new tribological solutions

Residential

- about 10% of the industrial energy is used to overcome friction (=intelligent guess)
- 11% potential savings can be achieved in short term (5-10 years) by implementing new tribological solutions (=intelligent guess)

▼

Globally

- 15 – 25 % of the total energy consumption worldwide is used to overcome friction (100 milj. TJ/year)
- 7 000 milj. tonnes of CO_2 emission originates from work to overcome friction

Thank You

1. *Holmberg K, Andersson P, Erdemir A, Global energy consumption due to friction in passanger cars, Tribology International 47 (2012) 221-234*
2. *Holmberg K, Siilasto R, Laitinen T, Andersson P, Jäsberg A,Global energy consumtion due to friciton in paper machines, Tribology International 62 (2013) 58-77*
3. *Holmberg K, Andersson P, N-O Nylund, K Mäkelä, Erdemir A, Global energy consumption due to friction in trucks and buses, Tribology International 78(2014)94-114*
4. *Erdemir A, Holmberg K, Energy consumption due to friction in motored vehicles and low-friction coatings to reduce it, Chapter for Springer book "Coating Technology for Vehicle Applications", edited by Cha & Erdemir, 2015*