UNIVERSITA' DEGLI STUDI DI ROMA
TorVergata

ANALYSIS OF THE IMPACT OF ELECTRIC VEHICLES ON PRIMARY ENERGY CONSUMPTION AND CARBON EMISSION ON NATIONAL LEVEL.

Bachelor's degree in "Engineering Sciences(Mechanical)"

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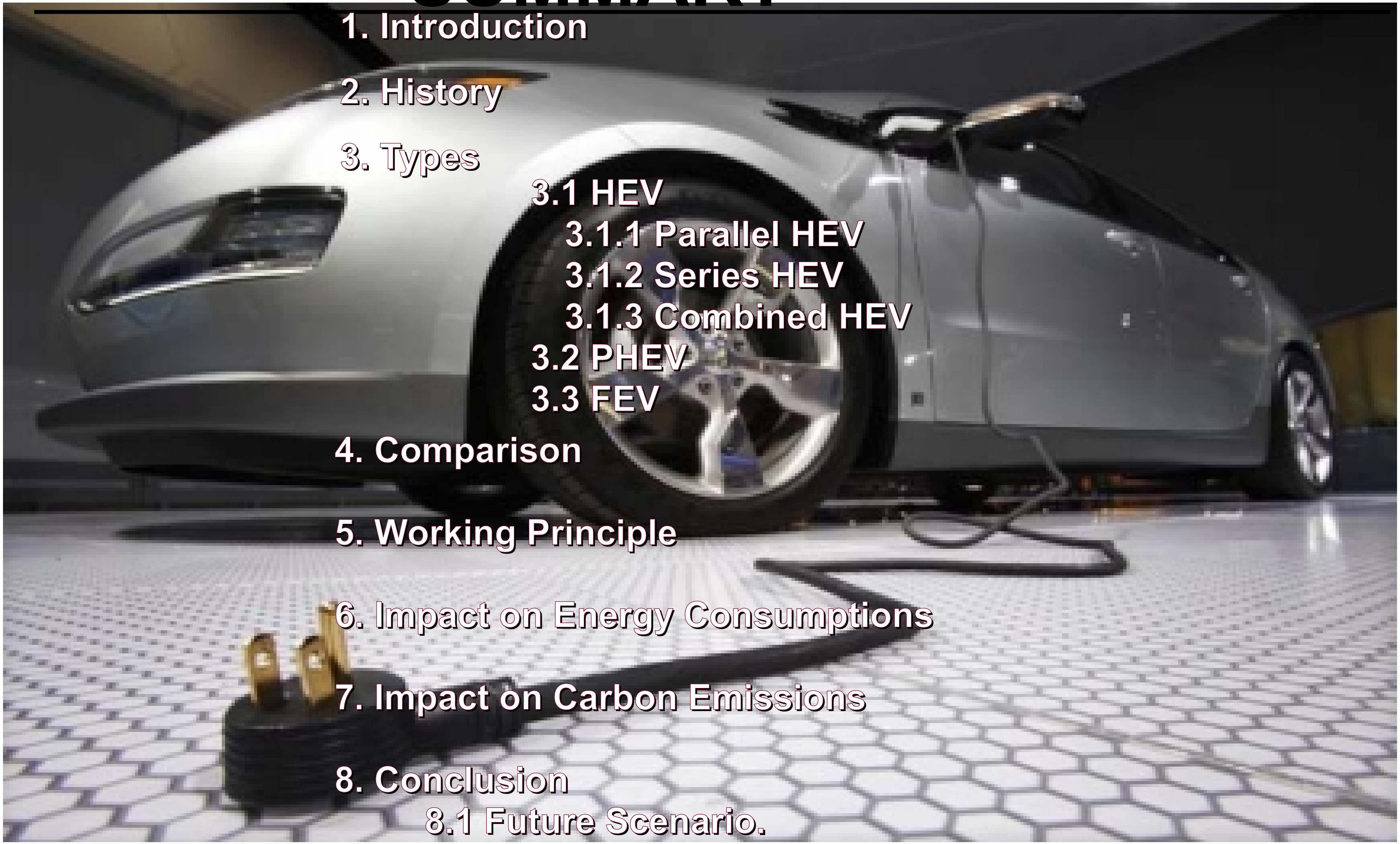
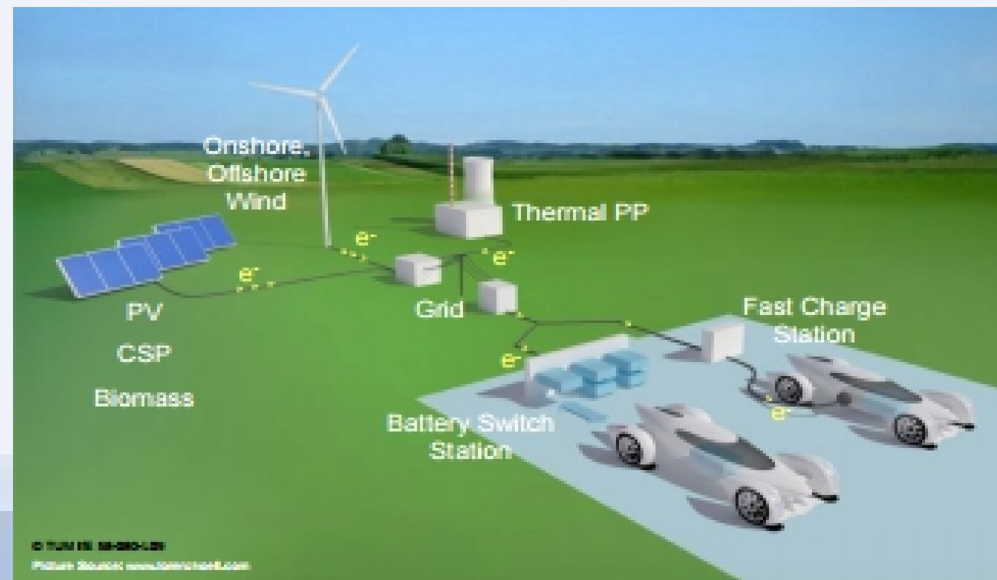
SUMMARY



1- Introduction

- An EV is a vehicle which uses one or more electric motor for propulsion, operated partly or entirely on electricity that is obtained from less carbon-intensive energy sources.
- EVs may, under some conditions reduce:
  - Noise Pollution
  - Oil use in transportation
  - **CO2 Emission**
  - **Energy Consumption**
  - etc



2- History

- ***It's hard to pinpoint the invention of EVs to one inventor or country. Instead it was a series of breakthroughs-from battery to EVs.***

- ***Thanks to William Morrison, made 1st successful 6-passengers EV around 1890***

- ***Capable of a top speed = 14 miles/hour.***

3- Types of EVs:

- EVs have 3 main types on the basis of battery's recharging mode.

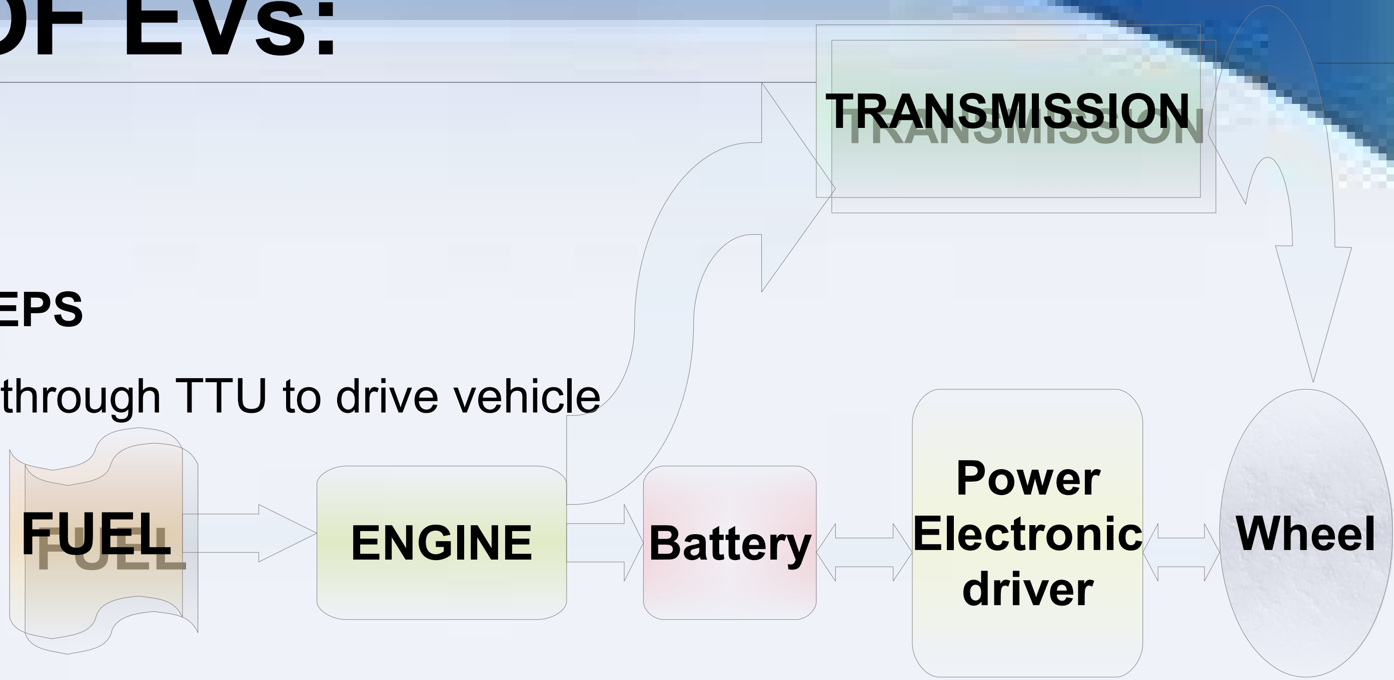
	Vehicle Type	ICE	EPS	BATTERY CHARGING
1	HEV	YES	YES	On board (Internal)
2	FEV	NO	YES	External
3	PHEV	YES	YES	Both

3- TYPES OF EVs:

3.1). <u>HEV</u>:

- Combines **ICE** with **EPS**
- Both provide torque through TTU to drive vehicle

<u>Operation mode:</u>

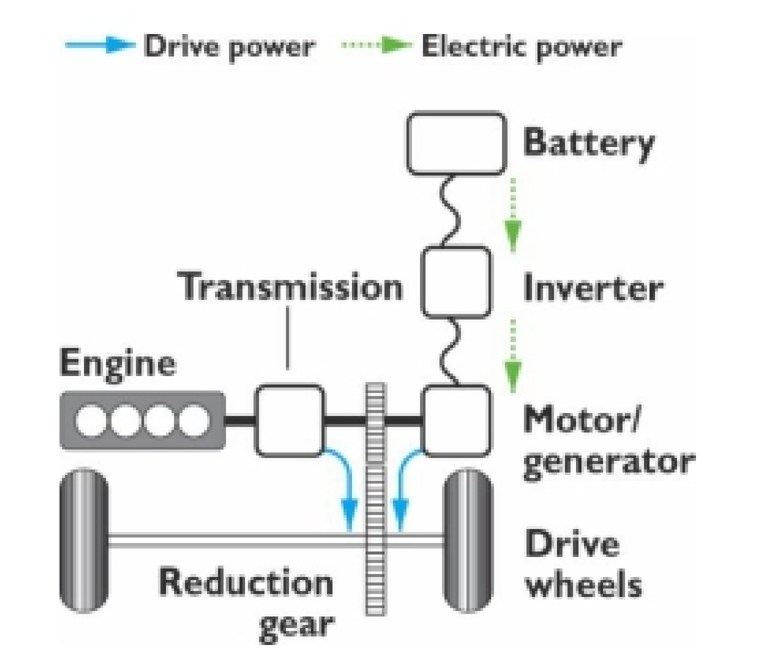


State	ICE	EPS
Low speed	NO	YES
Acceleration	YES	YES
Steady	YES	NO

Types of HEV:

3.1.1- Parallel HEV:

- Both ICE & Electric Motor in parallel connected to a mechanical transmission



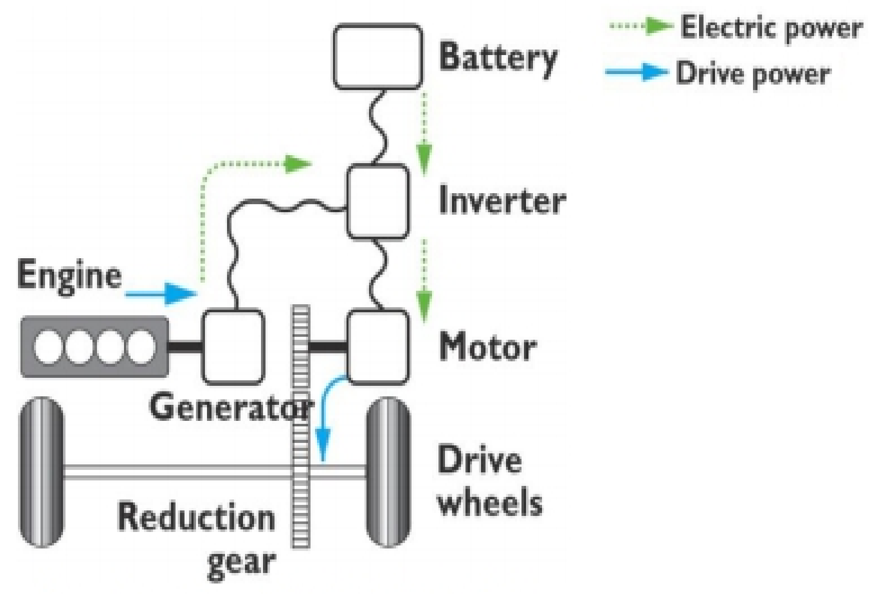
Structure of a parallel hybrid electric vehicle

- **Operation modes:**

STATE		Power required	ICE	EPS	Battery recharging
Speed	<40		NO	YES	NO
	>40		YES	NO	NO
Acceleration		High	YES	NO	YES
		Low	YES	YES	NO
Deceleration			NO	YES	NO

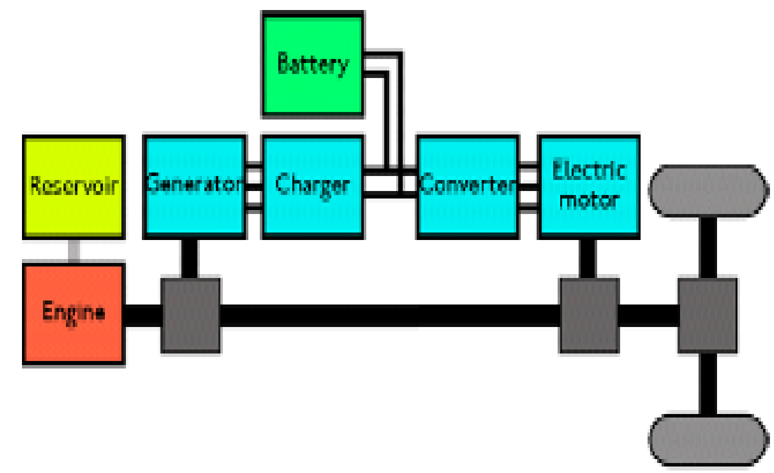
Types of HEV:

- **3.1.2- Series HEV:**
  - ICE drives an electric generator, that charges the batteries & power an electric motor that moves the vehicle.
  - When a large amount of power is required, the motors draw electricity from both the batteries & the generator.



Structure of a series hybrid vehicle

- **3.1.3- Combined HEV:**
  - Have features of both series & parallel HEVs.
  - At lower speed, operates as a series HEV.



Simplified structure of a combined hybrid electric vehicle

3- TYPES OF EVs:

- **3.2- FEV:**
  - Runs entirely on battery & electric drive train, without support of a traditional ICE.
  - Battery can be charged either in standard home electricity outlets or in external dedicated charging stations.

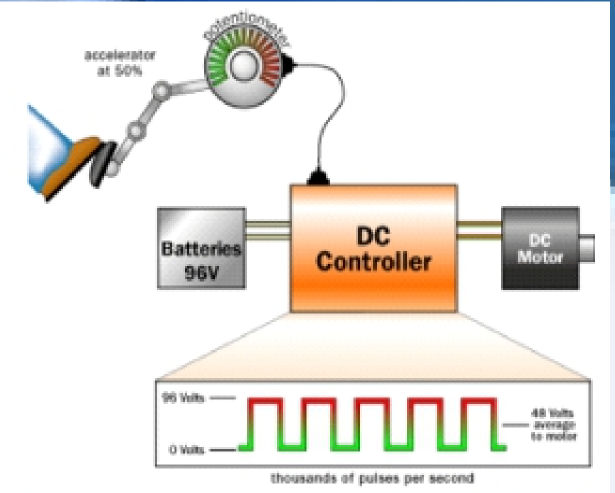


Fig. Process diagram of a typical full electric vehicle (FEV)

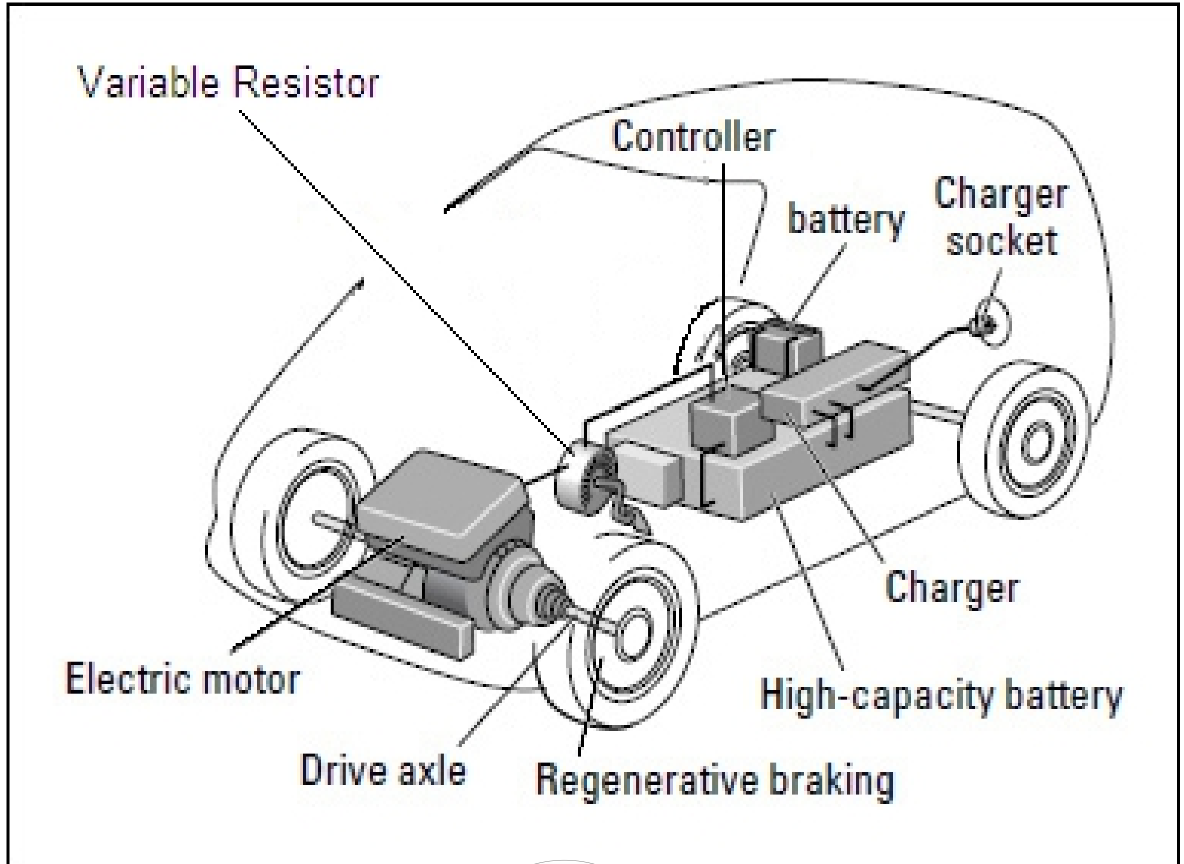
- **3.3- PHEV:**
  - Use fuel and electricity, both are rechargeable from external sources.
  - Intermediate technology b/w FEVs and HEVs.

4- COMPARISON

	Vehicle Type	Mode Of Operation	Battery Type	Max. Driving Range (km)	Top Speed (km/h)
1.	**HEV**	Charge sustaining	NiMH	900-1200 (Hybrid)	170
2.	**PHEV**	Charge sustaining	NiMH	20-60 (Electric)	160
3.	**FEV**	Charge depleting	Li-ion	120 - 390	80 - 200

5.Working Principle:

- When the vehicle is switched ON, DC current is passed from Battery pack.
- The Controller takes power from an array of rechargeable batteries and passes it on to the electric motor.
- Before passing the current to the electric motor, the controller converts the 300 V DC into a maximum of 240 V AC, which is suitable for the electric motor.
- The electric motor then converts electrical energy to mechanical energy, which moves the vehicle forward.



6- Impact on Energy Consumption:

➢ Tank-to-wheel(TTW):

$$\text{TTW Energy Efficiency} = \frac{\text{Energy transmitted to wheel}}{\text{Final Energy}}$$

	Battery type	charger(%)	Charging & discharging cycle(%)	TTW(%)
1.	Lead-Acid	86	80	60
2.	Li - Ion	89	90	72

- 40 to 28% = Lost as heat

Reference: European Association For Battery Electric Vehicles

6- Impact on Energy Consumption:

➢ Well-To-Wheel(WTW):

$$\text{WTW Energy Efficiency} = \frac{\text{Final energy Transmitted to wheels}}{\text{Primary Energy}}$$

$$= (\text{TTW Energy Efficiency}) \times (\text{WTT Energy Efficiency})$$

Primary energy convert to electricity at Power plant

Electricity produced at Power plant arrives To consumer

- **Well-To-Tank(WTT) Energy Efficiency = 44% x 92.5% ≅ 41%**

	Battery Type	WTW Energy Efficiency
1	Lead acid	60% x 41% = 25%
2	Li - ion	72% x 41% = 30%

- Only around 25%(Lead-acid) to 30% (Li-ion) of the primary energy is transmitted to the wheels
- The rest is lost as heat!

Reference: www.terna.it and www.going-electric.it

6- Impact on Energy Consumption:

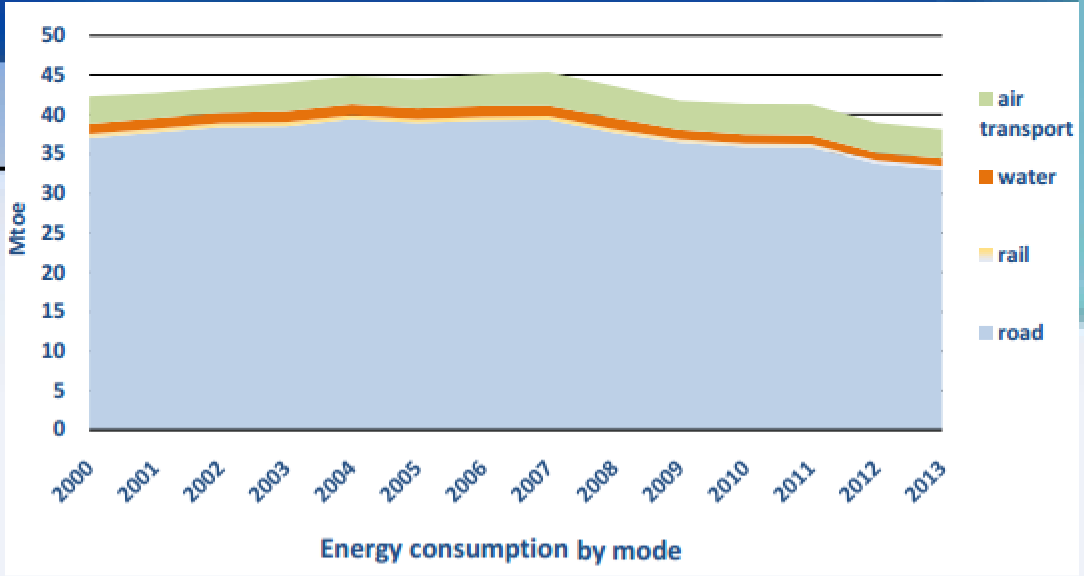
➢ Comparison with Conventional Vehicles(CVs):

		TTW(%)	WTW(%)
CVs	Diesel	< 22	18
	Petrol	< 18	15
EVs	Lead acid	60	22
	Lithium	72	27

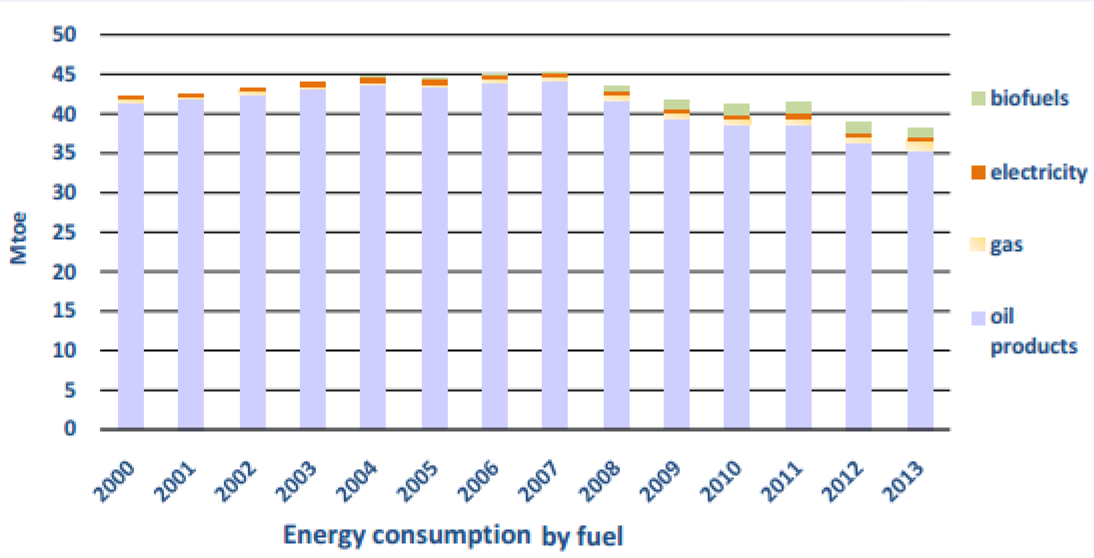
- **Lead acid batteries is on average**
  - 1.2 times better than best diesel vehicle
  - 1.5 times better than best petrol vehicle
- **Li-ion batteries is on average**
  - 1.5 times better than best diesel vehicle
  - 1.8 times better than best petrol vehicle
- It means that over 20 to 80% more Primary energy is required for a conventional vehicle than for an EV with same weight and performance(excluding driving range).

Reference: European Association for Battery Electric Vehicles

Energy Consumption: Italy



- In 2013, the energy consumption in the transport sector amounted to 38.2 Mtoe
  - **-2.3%** compared to 2012

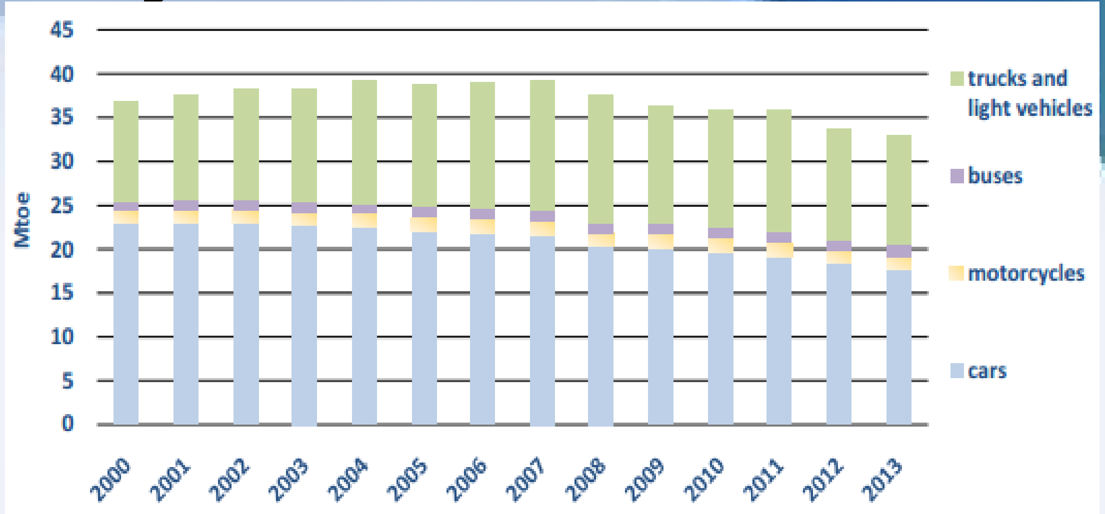


- In 2013, the energy consumption of:
  - Road transport = 86.6%
  - Air transport = 9.7%
  - Water transport = 2.6%

Reference: Energy Efficiency trends and policies in Italy , November 2015.

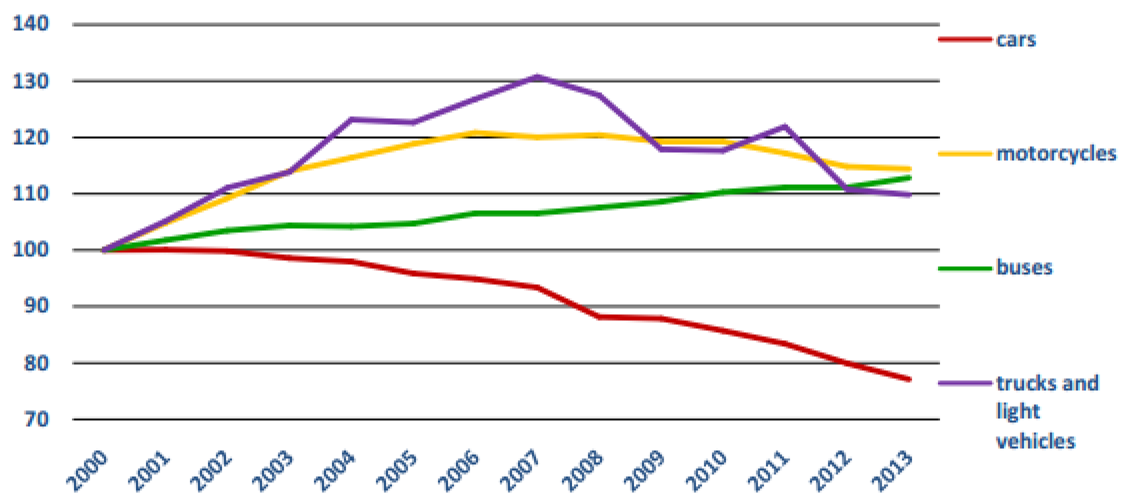
Energy Consumption: Italy

- In 2013 the energy consumption of road transport was 33.0 Mtoe:
- Cars were the main transport vehicles with a consumption of 17.8 Mtoe, 53.7% of the total energy consumption (62.5% in 2000)



Energy consumption of road transport s by mode

- Over the period 2000-2013 the energy consumption of road transport decreased by 10.8% because of:
  - More efficient new vehicles
  - Shift from gasoline to EVs
  - Economic crisis of 2007



Energy consumption trends of road transport (2000=100)

7- Impact on Carbon Emissions:Italy

Carbon emissions from EVs largely depend on the sources of electricity used.

- **TTW**
  - EVs emit nothing during their operation, TTW CO2 emissions are zero: ***therefore EVs are infinitely cleaner than conventional vehicles at least locally.***
- **WTW**
  - To compute WTW CO2 emissions, taking into account CO2 emissions generated by Electric Power Plants & Distribution of Electricity.

EVs Carbon Emissions:

$$\text{EV Carbon Emission} = \frac{(\text{Overall avg. emission}) \times (\text{EV avg. consumptions})}{1000} = 73.8\ [g/km]$$

- Overall average Emissions = 409.9 [g/kWh]
- EVs average consumption = 180 [Wh/km]

Reference: *European Association For Battery Electric Vehicles*
Electricity-specific emission factors for grid electricity;by M.Brander, A. Sood, C. Wylie, A. Haughton and J. Lovell

7- Impact on Carbon Emissions:Italy

- **Conventional Vehicles Carbon Emissions:**

$$\text{CV Carbon Emission} = (\text{Fuel consumption}) \times (\text{density}) \times \left((m_{CO2}/m_C) \,.\, X_c\right)$$

- Fuel consumption = 6.4 — 13 [l/100km]
- Gasoline density = 0.74 [kg/l]
- CO2/gasoline = $(m_{CO2}/m_C) \,.\, X_c$ = 44[kg]/12[kg] x 0.855 = 3.135

CVs Carbon Emissions =

148.5 [g/km]

301.6 [g/km]

Reference: *Electricity-specific emission factors for grid electricity; by M.Brander, A. Sood, C. Wylie,A. Haughton and J. Lovell*

8- Conclusion

- **EVs have been identified as key elements of sustainable transport.**
- **An increasing shift towards EVs offers the chance:**
  - To reduce oil imports,
  - Minimize both global (CO_2) and local (pollutants, noise) emissions,
  - Contribute to save resources and further develop a multimodal transport system
- **EVs themselves have zero emissions, although the generation of electricity required to power the vehicle must be taken into account:**
  - It's counter-productive to promote EVs in regions where electricity is produced from oil or coal
  - It might be even possible to have emission free EVs if they could be charged from only renewable energy sources.
- **In comparison with CVs:**
  - Ability to capture and store energy through RBS that:
    - Recharge the battery by applying negative torque to the drive wheels
    - Converting kinetic energy to electrical energy

8.1- Future scenario

- **EVs are a promising technology for reducing the environmental impacts of transport that depends heavily on:**
  - Cost of vehicles & batteries
  - Battery lifetime and weight
  - Customer response to cost and ranges
  - Charging point availability
  - Grid limitations to charging
  - Government policy
  - Battery and EVs production capacity limitations
  - Oil and electricity price

  The majority of current EV research is focused on how to overcome these technical barriers

- **It's not difficult to see that in the near future EVs could gain a significant market penetration, particularly in densely populated urban areas for reduction of:**

  1) Carbon emissions &

  2) Energy consumption.

8.1- Future Scenario:

➢ Italy Performance: Energy Consumption:

- In 2013 the Ministry of Infrastructure and Transport set up a PNIRE (Piano Nazionale Infrastrutturale per la Ricarica dei Veicoli alimentati ad Energia Elettrica).
- An infrastructure network will be set up with charging points:
  - 1 - 2 years, in urban and metropolitan areas.
  - 3 - 5 years, in non-urban areas and along the motorways.
- The charging points will be both public and private, in a ratio of 1 to 8.
- Future plan:
  - by 2016: 90 000 recharging points accessible to the public;
  - by 2018: 110 000 recharging points accessible to the public;
  - by 2020: 130 000 recharging points accessible to the public

Reference: ENEA , Energy Efficiency Trends & Policies in italy, November ,2015

8.1- Future Scenario:

➢ Italy Performance: Carbon Emission:

- Law No **134/2012** (Article 17-decies) introduced incentives for the purchase of low CO2 emission vehicles in the period **2013-2015**.
- The Plan also makes provision for incentives for buying vehicles with overall low emissions:
  - EUR **31.3** million for **2014**
  - EUR **40.4** million for **2015**
- At January 2014 registered vehicles = **2,584**
- About **1,820** Vehicles benefited from these incentives and have CO2 emissions between **50** and **95** g/km.

535 Electric & 541 Hybrid

Reference: ENEA , Energy Efficiency Trends & Policies in italy, November 2015

THANKS FOR YOUR ATTENTION