



# The first solar-car and What we learn from solar-car racing.

The Thai Nichi Institute of Technology  
26. 10. 2012

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Vice president of International Solarcar Federation  
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1. Why solar-car was born ?
2. What we learn from solar-car racing ?
  - (1) Before starting to build solar-car.
  - (2) Understanding of technical parameters and component.
3. A type of engineer required these days.
4. Which way solar-car goes.



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The first solar-power-assisted electric vehicle.



1 9 1 2 Model "Baker EV"  
1 9 5 8 Solar panel mounted ( 1 0 6 4 0 pieces of solar cells )



The first solar-car for demonstration.



Only by solar power !

No battery !

1 9 7 7 “Bluebird solar car” by Prof. Ed Passerani (Alabama Univ.)  
1 9 8 2 for World’s fair in TN USA



The first solar-car "Quiet Achiever" for adventure.

Only by solar power !  
No battery !



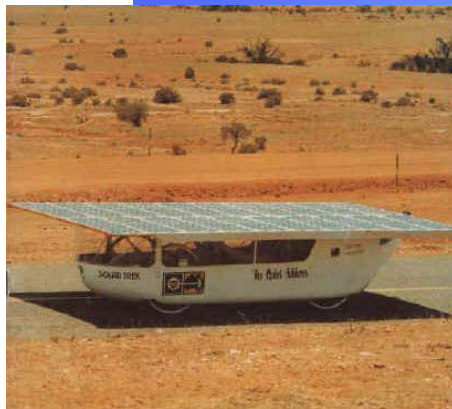
Danish Adventurer  
Mr. Hans Tholstrup



F1 Driver, Mr. Larry Perkins on driving



Crossing Australian Continent from Perth to Sydney for 20 days.



18  
December  
1982

7  
January  
1983





## Messages from all over the world !!



7 January  
1983



*It is impossible with just solar ray.*

*I was very much impressed.*

*Could you make a chance for us too.*



Start planning  
“World Solar Challenge”  
For the people.





The World Solar Challenge was born. ( 1987 )  
Darwin to Adelaide covering 3100 km



*Important ! ---- Basic regulation was born for “Brain Sport”*



Race	Year	Winner	Team	Country	Racetime (Hour)	Average Speed (km/h)
1.	1987	<a href="#">Sunraycer</a>	<a href="#">GM</a>	USA	44:54	66.9
2.	1990	Spirit of Biel	College	<a href="#">Switzerland</a>	46:08	65.2
3.	1993	Dream	<a href="#">Honda</a>	<a href="#">Japan</a>	35:28	85.0
4.	1996	Dream	Honda	<a href="#">Japan</a>	33:53	89.8
5.	1999	<a href="#">Aurora 101</a>		<a href="#">Australia</a>	41:06	73.0
6.	2001	<a href="#">Nuna 1</a>	<a href="#">TU Delft</a>	<a href="#">Netherlands</a>	32:39	91.8
7.	2003	<a href="#">Nuna 2</a>	TU Delft	Netherlands	31:05	97.02
8.	2005	<a href="#">Nuna 3</a>	TU Delft	Netherlands	29:11	102.8
9.	2007	<a href="#">Nuna 4</a>	TU Delft	Netherlands	33:00	90.87
		TIGA	<a href="#">Ashiya Univ</a>	<a href="#">Japan</a>	32:03	93.57
10.	2009	<a href="#">Tokai Challenger</a>	<a href="#">Tokai Univ.</a>	Japan	29:49	100.54
		<a href="#">Sunswift</a>	<a href="#">Univ. NSW</a>	<a href="#">Australia</a>	39:18	76.28
		OSU	<a href="#">OS Univ</a>	<a href="#">Japan</a>	34:45	86.27
11.	2011	Tokai Challenger	<a href="#">Tokai Univ.</a>	Japan	32:45	91.54



The first winner was General Motors of USA !



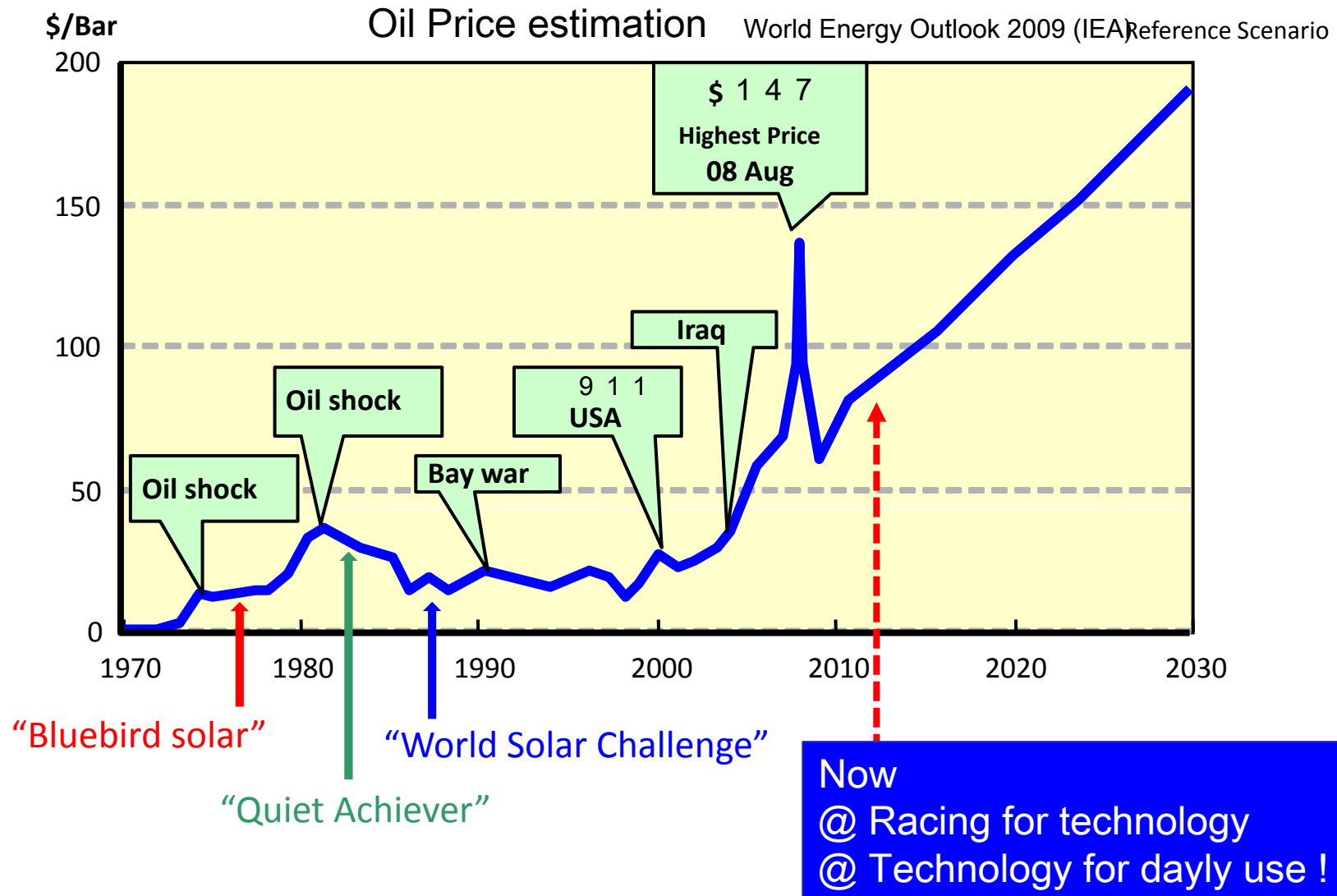
*General Smith of GM said why they have joint !*



The third winner was my Honda Dream








*Why we have been there for racing !*





1. Why solar-car was born ?
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  - (1) Before starting to build solar-car.
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# (1) Before starting to build solar-car

-  Think and confirm what you make ?
-  Which race , where to run ?  
( Flat ? , Slope ? , Circuit ? , Town to town ? )
-  How much energy is available ?  
( Sunny ? , Cold ? , Storage ? )
-  What you want to achieve ?  
( To win ? , Meeting own target ? Study many fields ? )
-  What the regulation says ?  
( Rule , Safety )

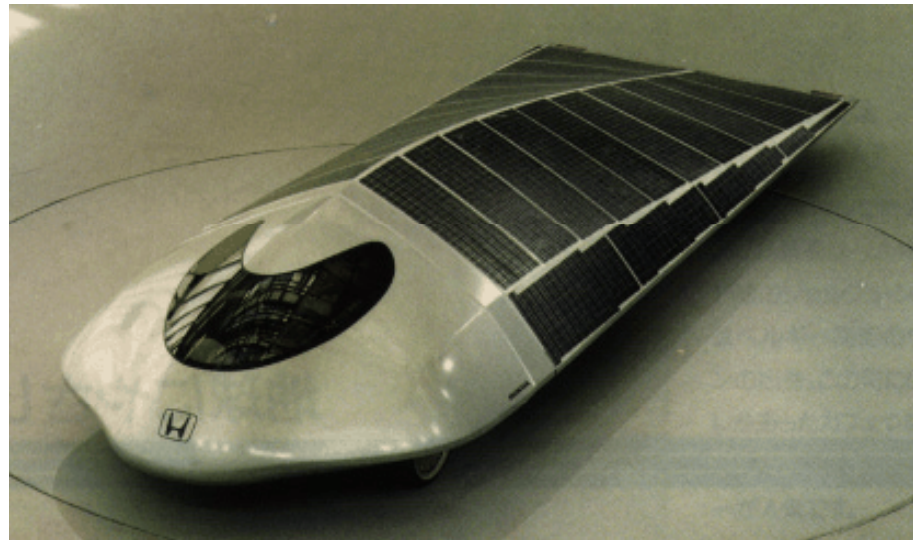




# Think and confirm what you make ?

1. “ Paragon Siam Square “ does not sell solar-car.

- Self design,  
self build,  
self drive with over 100km/h





Think and confirm what you make ?



↓ Try and error started



↑  
DORAEMON  
Promotion



Using sun power



from both sides





Think and confirm what you make ?



↓ Study tool for Kids ↑





Think and confirm what you make ?

Means what ever your design is,  
as long as your car meets event regulation,  
then you can join to race and drive your car officially.



This could be “Solar Tuk Tuk”



Solar Yacht on desert



Think and confirm what you make ?



How nice if such cars can run anytime free from petrol !

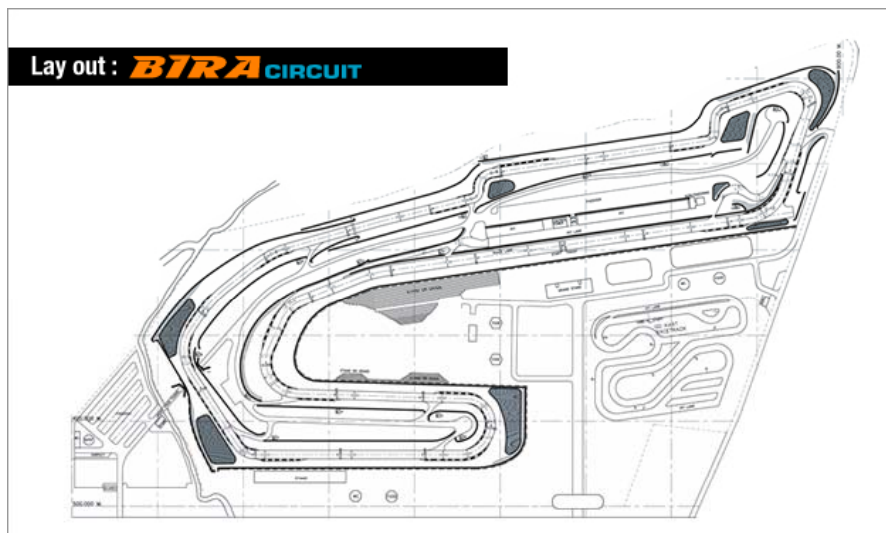




## Which race , where to run ?

BIRA Circuit

Australia 300km



- Cornering
- Acceleration and Braking
- Well paved surface



- Non stop high speed
- Weather forecast
- Aero dynamic design
- Very rough road with stones

また、

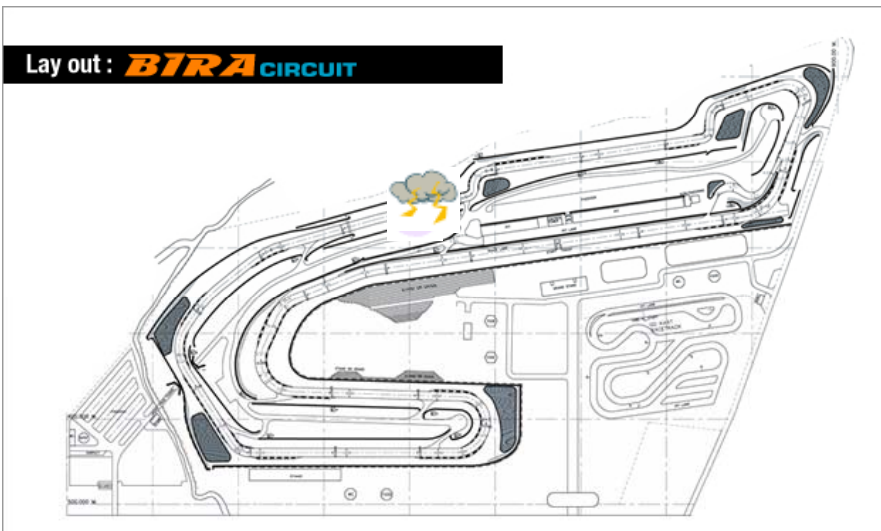


# How much energy is available ?



BIRA Circuit

Australia 300km



- 2 hours sprint or 2 days or more
- Total solar energy plus battery storage
- Total energy / Total racing time
- = Racing average speed

- 5 days or 6 days to finish
- Weather forecast on the way
- Average power
- = Average traveling speed





# What you want to achieve ?

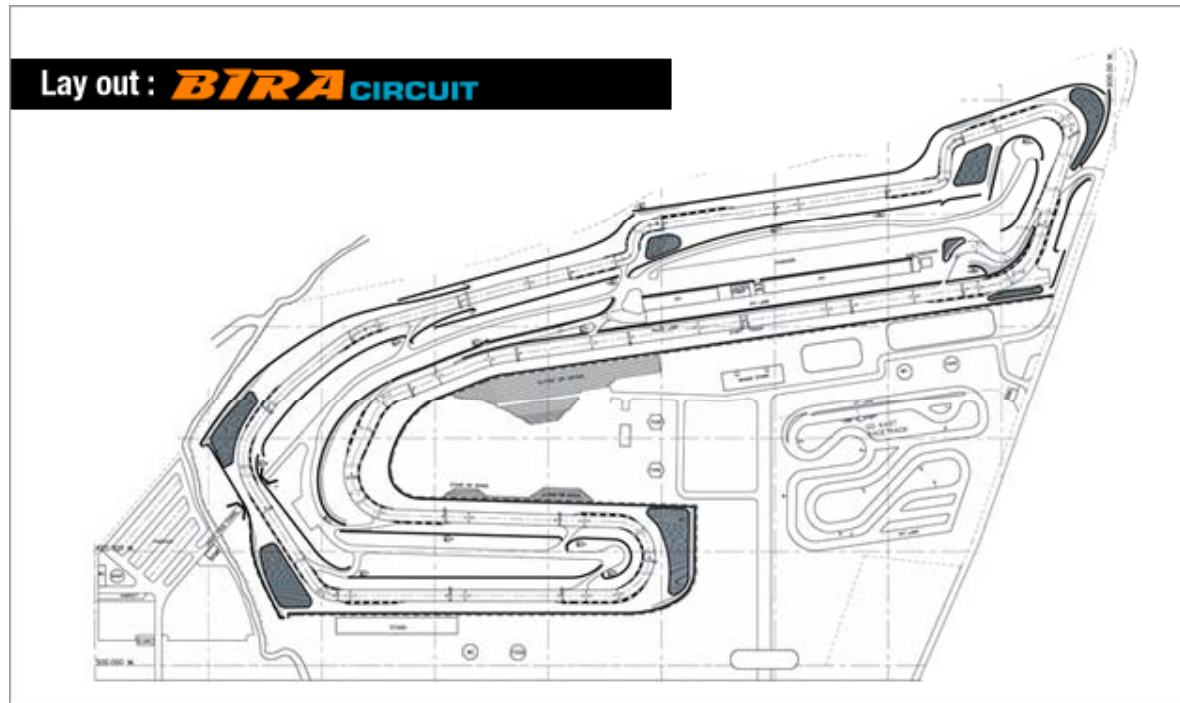
Race to win !



OR

Other purposes !

1. Beat rival team
2. Meet target performance
3. Study A,B,C of vehicle
4. Study electrical components
5. Study combination of Hard and Soft through computer
6. Study team management
7. Study promotion of the team ( for even financing )





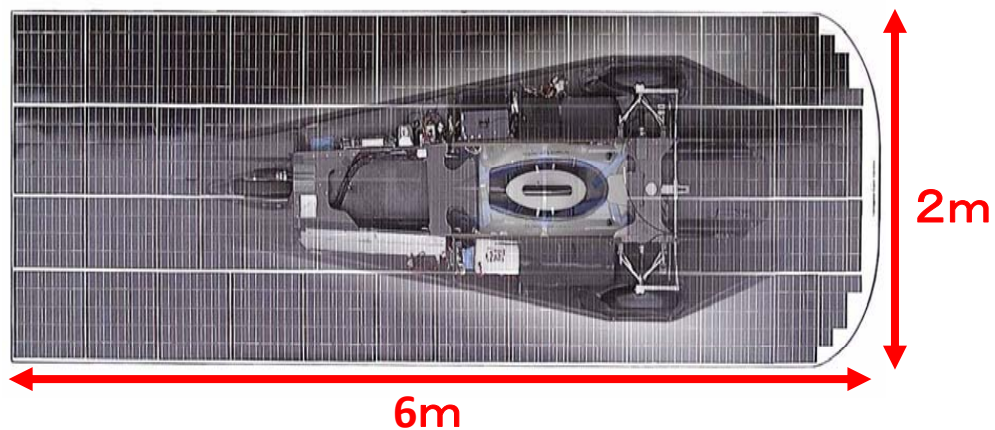
## What the regulation says ?

1. Maximum sizes of vehicle
2. 3 wheels or 4 wheels
3. Minimum and maximum weight of vehicle
4. Number of drivers
5. Minimum weight of driver
6. Maximum size or power of solar cell
7. Maximum weight or capacity of battery
8. Super capacitor
9. Performance of breaking
10. Width of view for driving
11. Seat
12. Seat position
13. Seat belt
14. Breaking light
15. Brinker light
16. Insulation of electrical wires
17. Fixing of battery

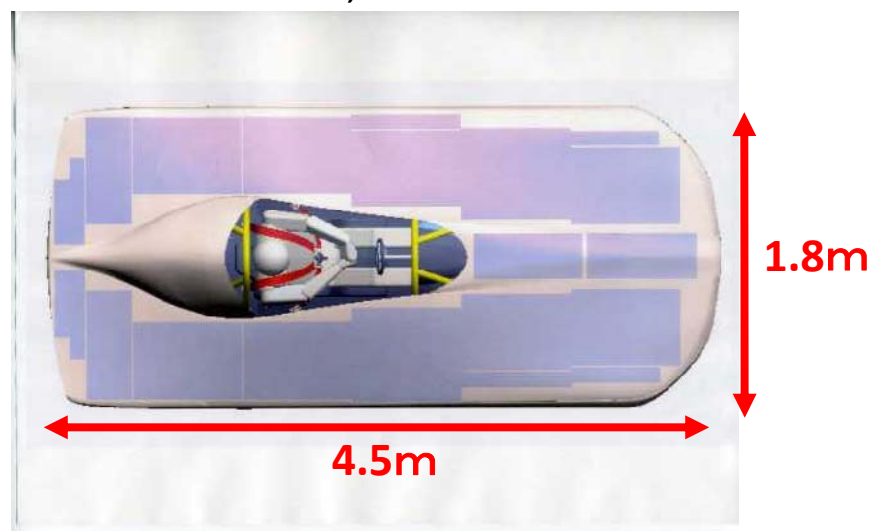


## Maximum sizes of vehicle

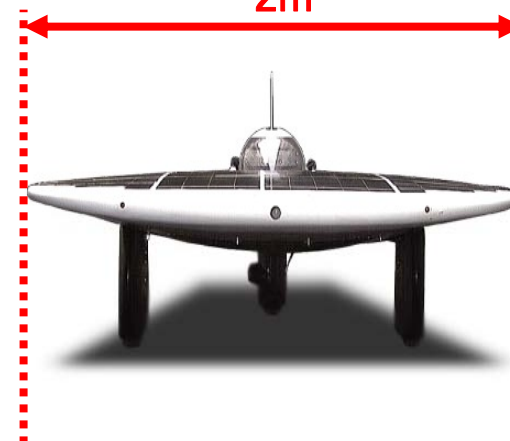
1987 ~ 2007 (20 years)



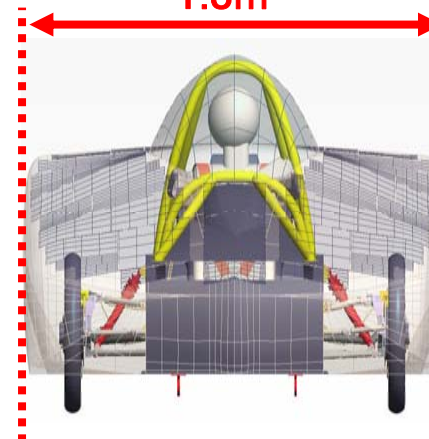
2008, 2009 ~



2m



1.8m



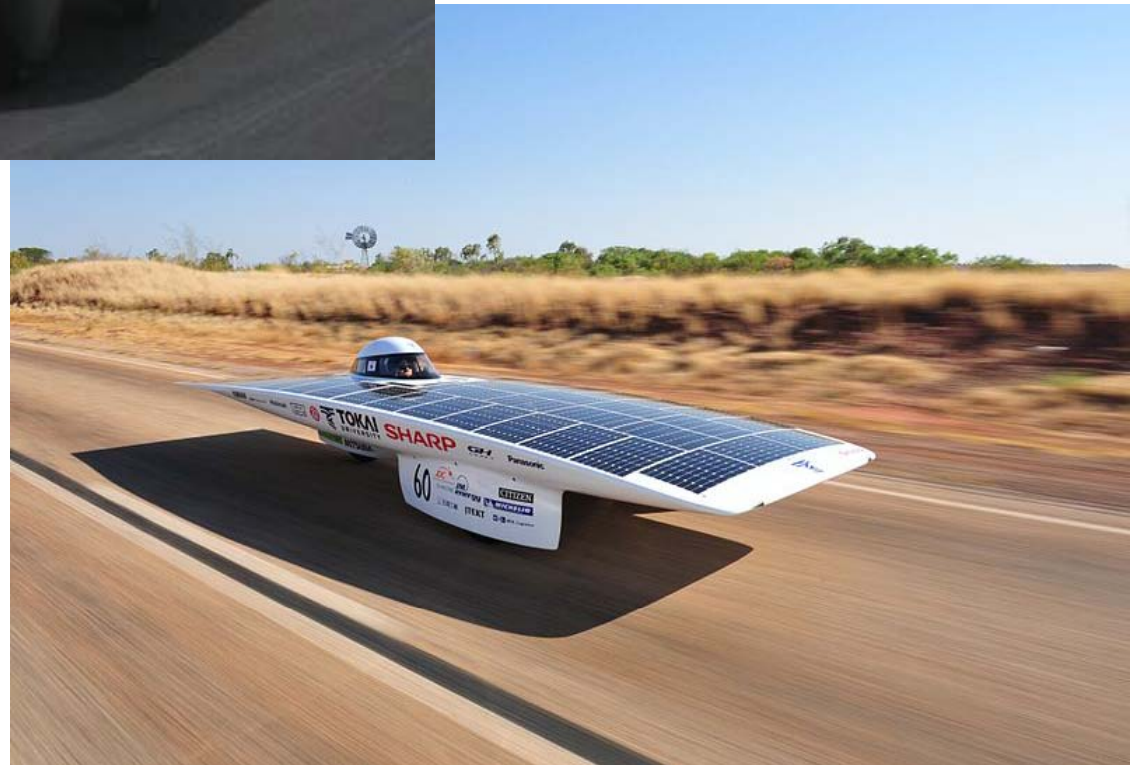


## 3 wheels or 4 wheels ?



- High speed in corner
- Steady
- Safe

- Efficient in straight
- Weak for quick steering
- Loose control on flat tire

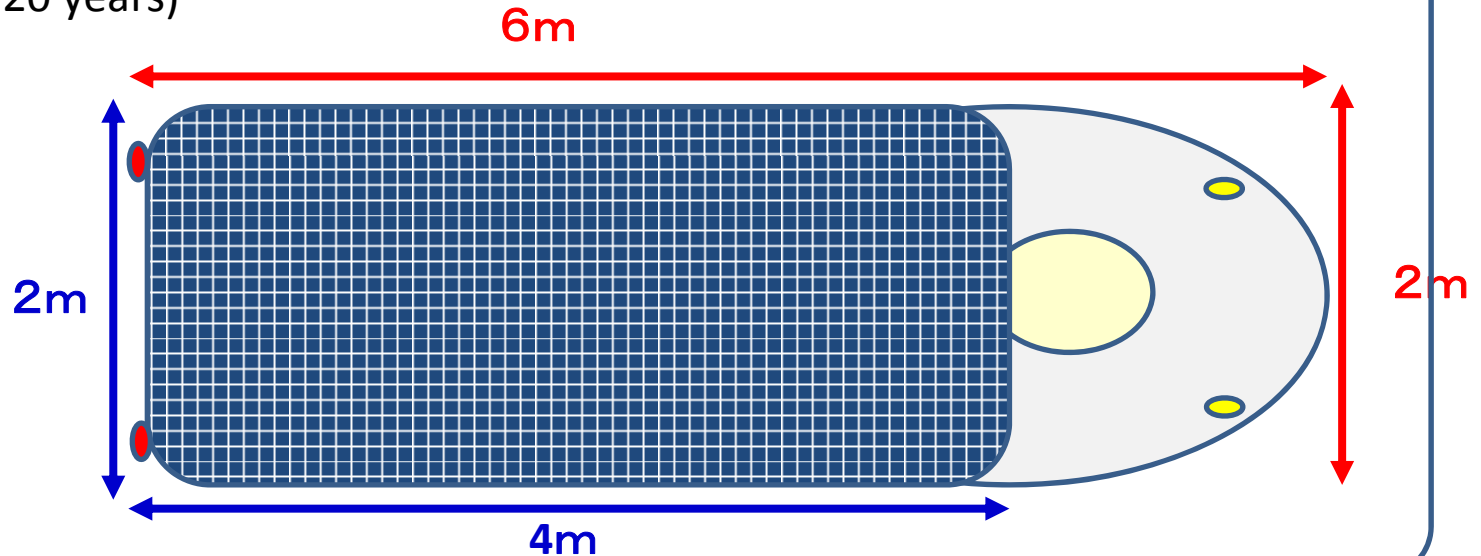




## Maximum size or power of solar cell

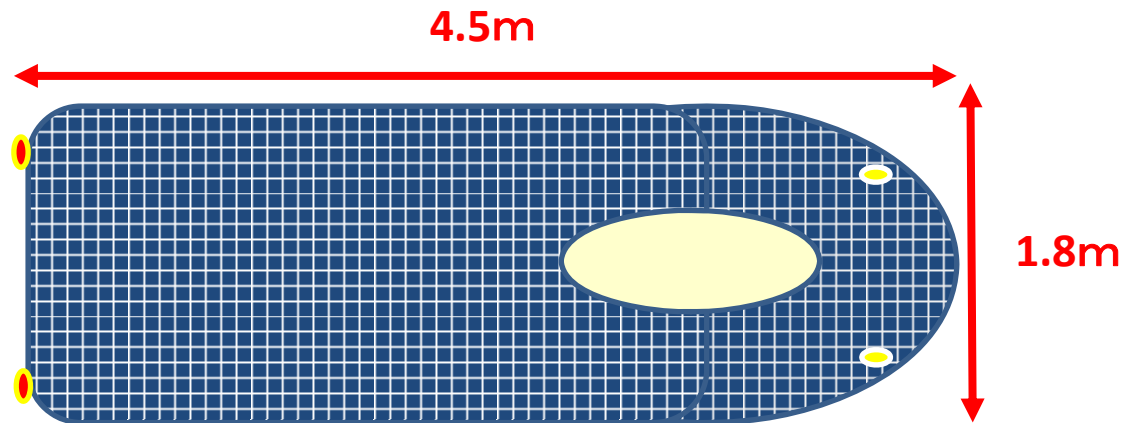
1987 ~ 2007 (20 years)

Solar cell area  
is  $2 \times 4 = 8 \text{ m}^2$



2008, 2009 ~

Solar cell anywhere  
On the vehicle

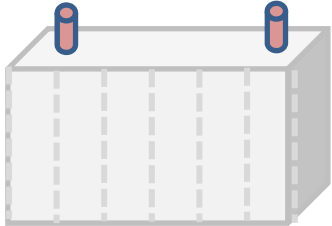
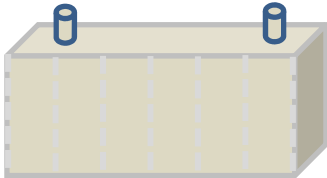
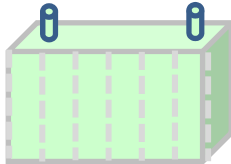

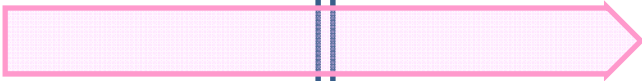


*More powerful solar cell and more design free !*





## Maximum weight or capacity of battery

Type	Lead Acid	Ni-Cd	Ni-MH	Lithium
				
Weight allowed	80kg	60kg	41kg	17kg
	<ul style="list-style-type: none"><li>+Low cost</li><li>+Easy operation</li><li>+Tough</li><li>+Low density</li></ul>			<ul style="list-style-type: none"><li>+High cost</li><li>+V-control</li><li>+Temp-control</li><li>+Safety management</li></ul>



## Performance of breaking

World solar  
Challenge  
1990



30km/h



22m

Suzuka  
~2008

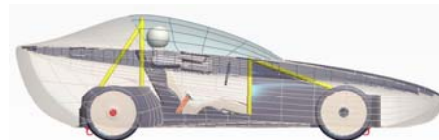


35km/h



14m

Suzuka  
2009~



35km/h

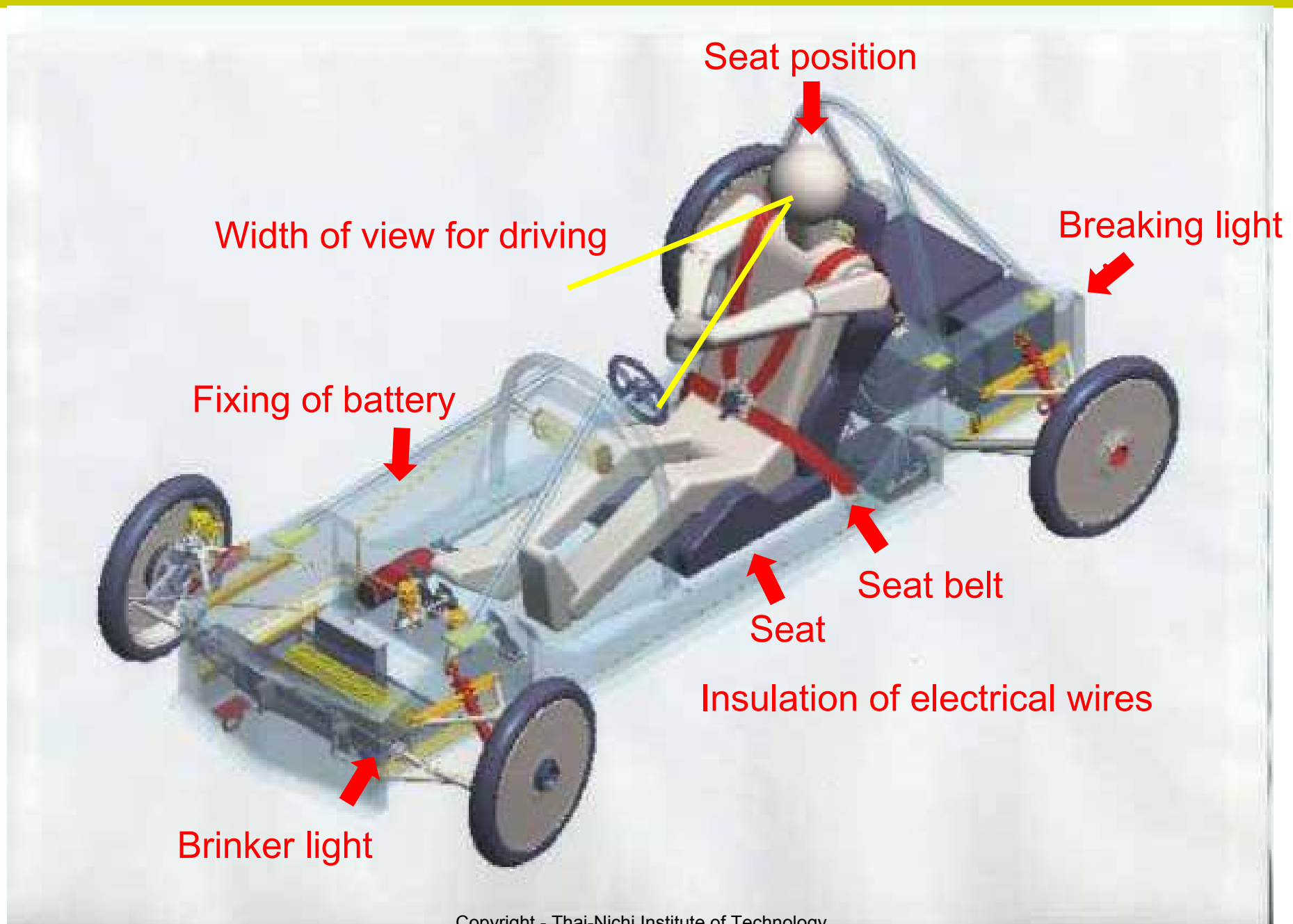


8.1m





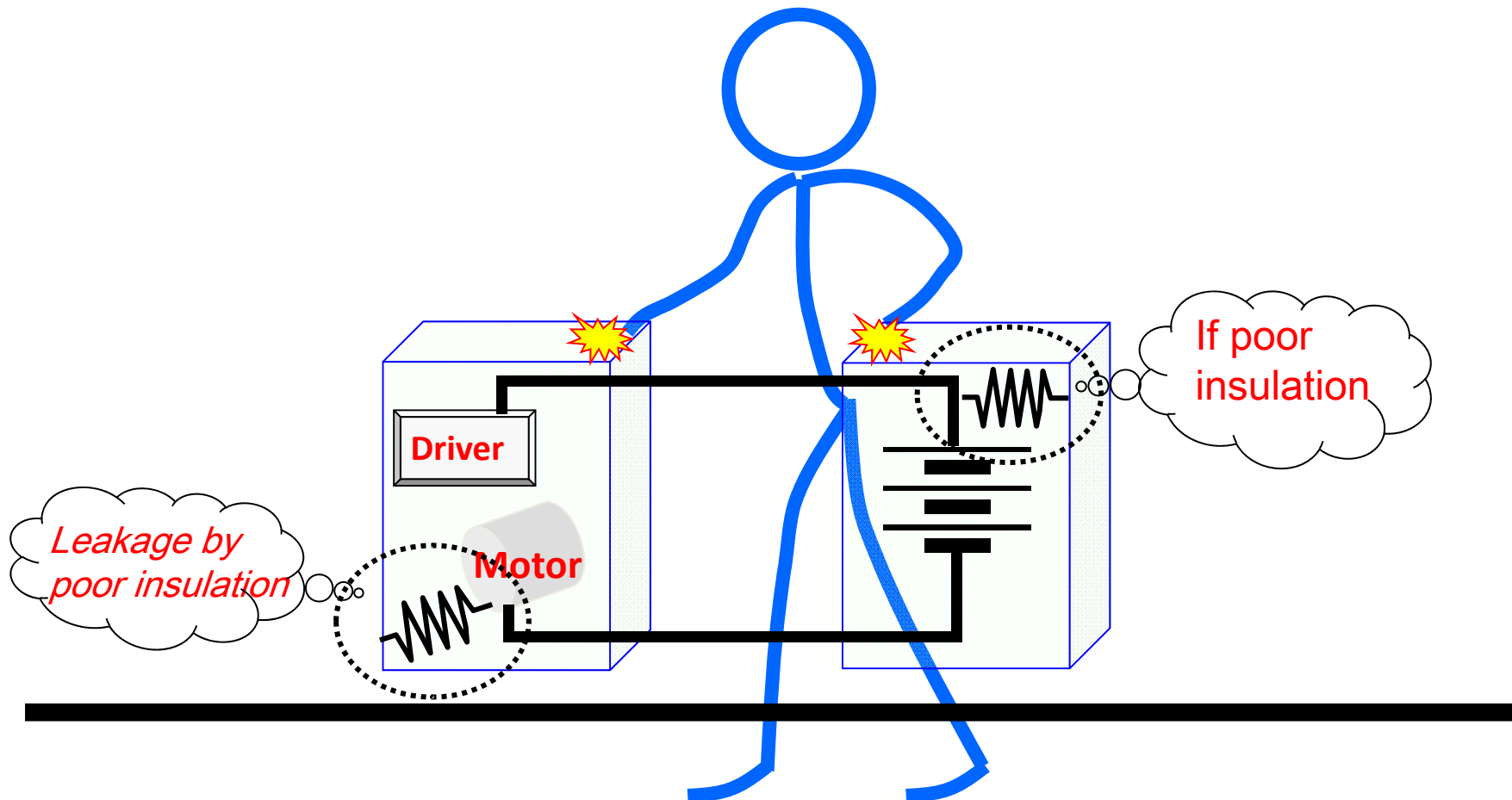
## Others for safety





## Others for safety

*If body is made of the material with conductivity ,  
There are many chances to get electrical chock deadly.*



## (2) Understanding of technical points.



Solar cell and peak power tracking



Battery and it's charging/discharging



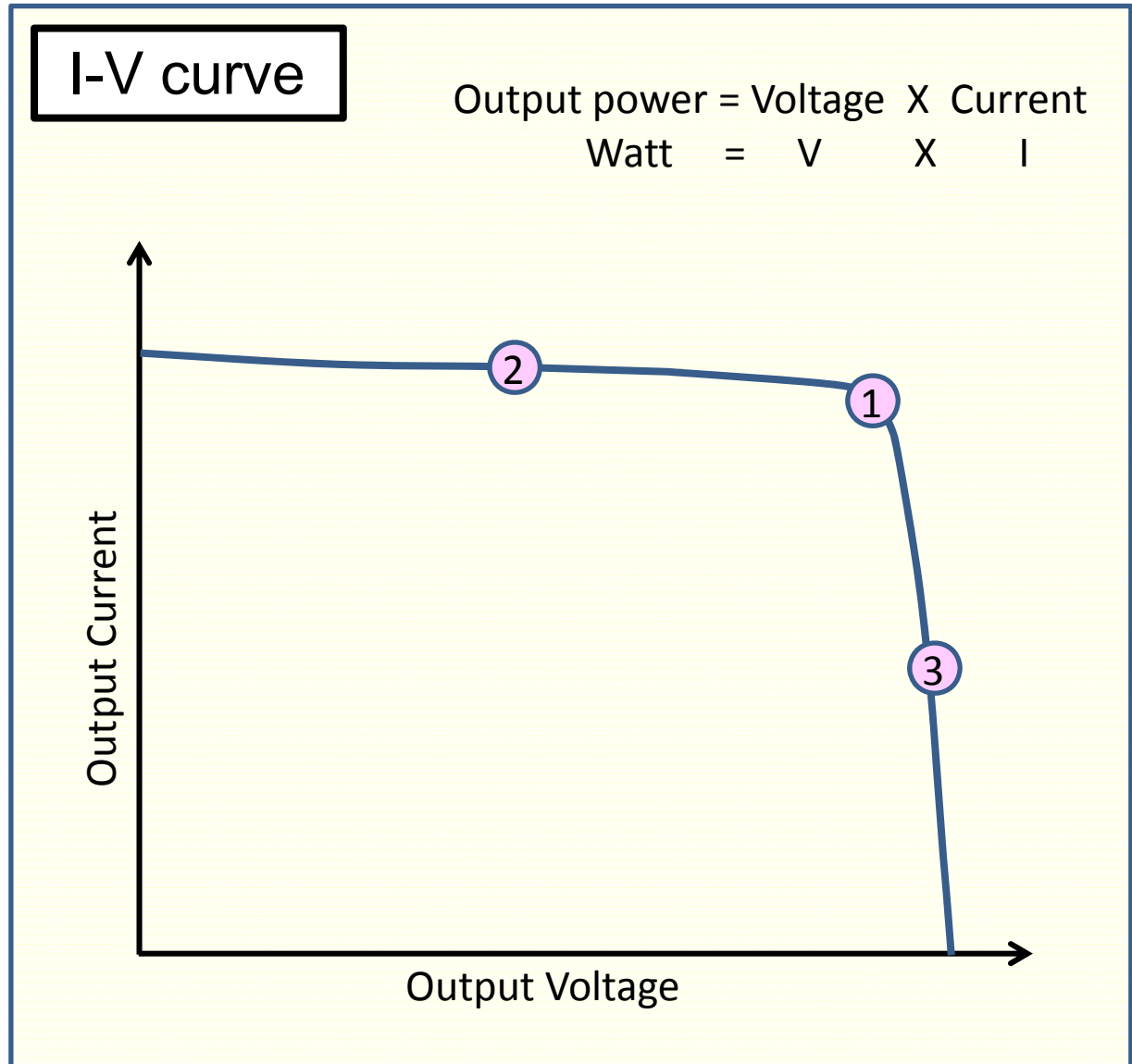
Resistance of vehicle

- 1) Aero dynamics
- 2) Rolling resistance
- 3) Efficiency of motor
- 4) Mechanical losses to wheel
- 5) Friction around wheel



# Solar cell and peak power tracking 2

Typical type of  
Silicone crystalline solar cell



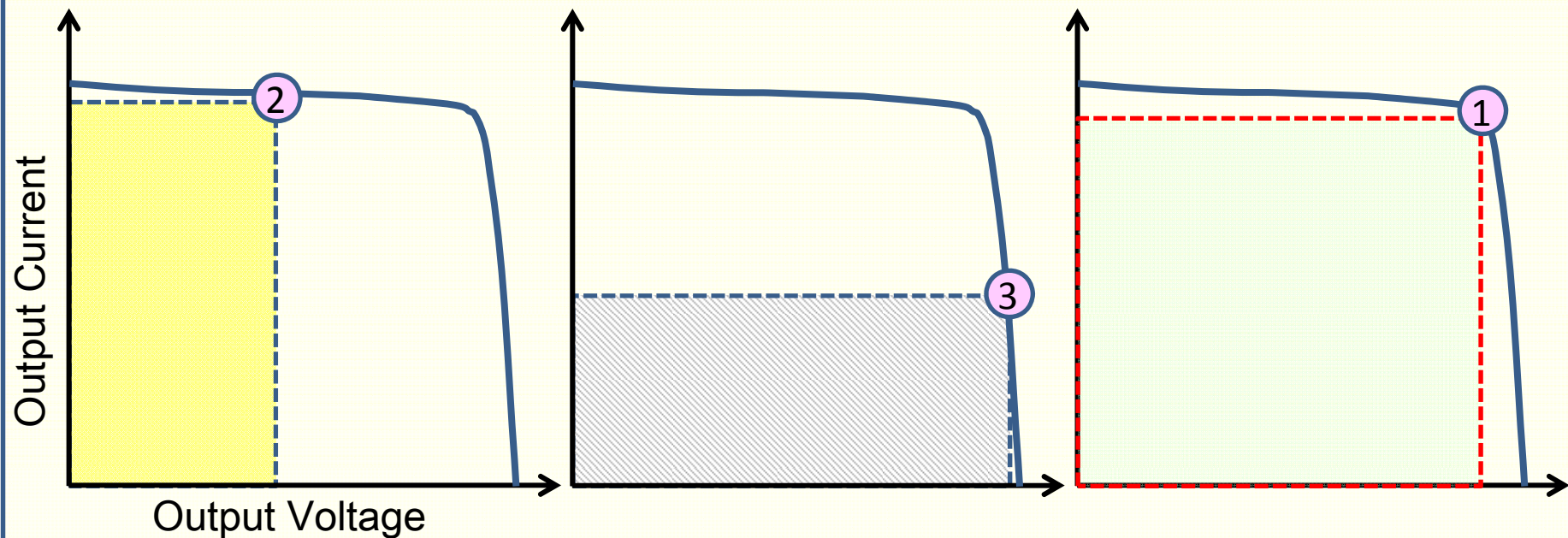


## Solar cell and peak power tracking 2

To get maximum power from solar cell, you need to adjust Voltage and Current !

$$\begin{array}{lcl} \text{Output power} & = & \text{Voltage} \times \text{Current} \\ \text{Watt} & = & V \times I \end{array}$$

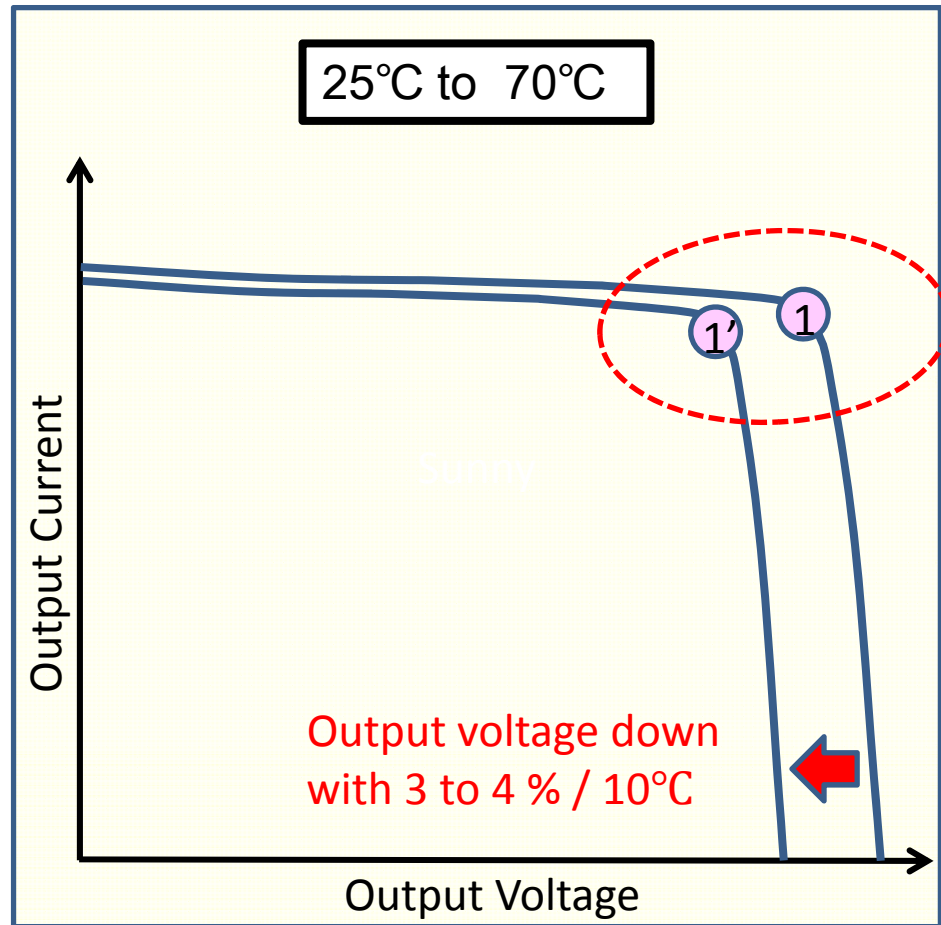
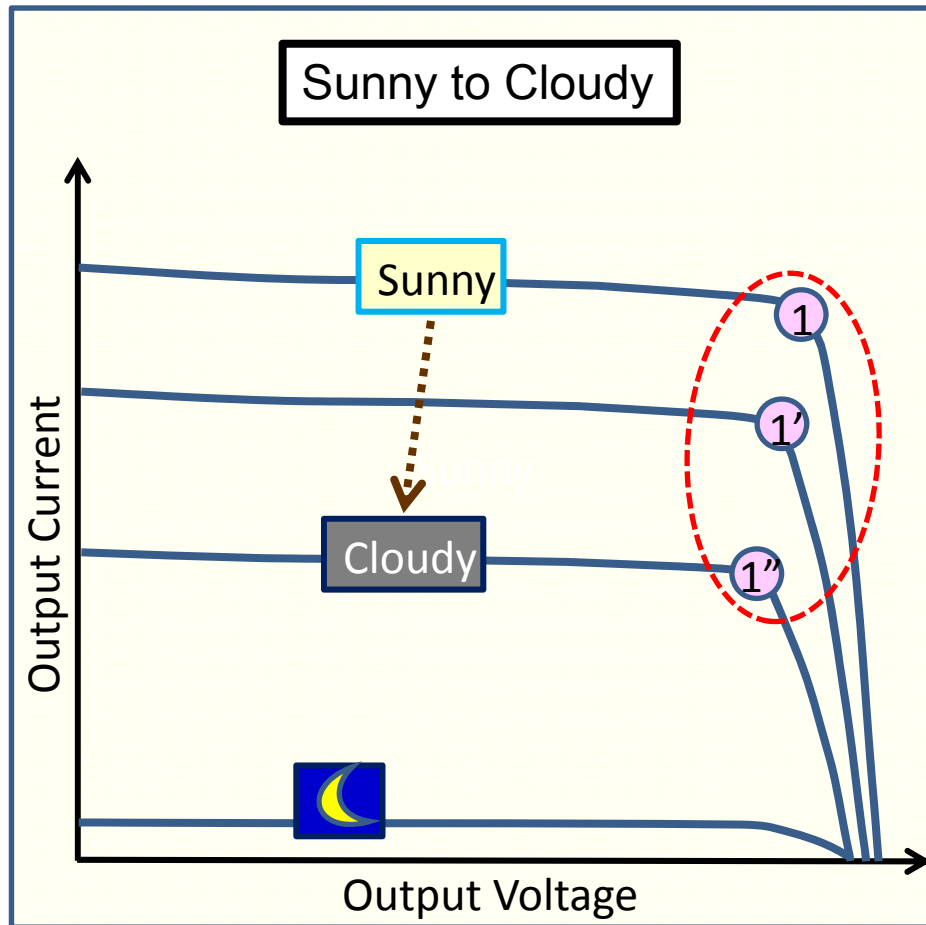
$$\text{Watt (2)} = V (2) \times I (2) \quad \div \quad \text{Watt (3)} = V (3) \times I (3) < \text{Watt (1)} = V (1) \times I (1)$$





## Solar cell and peak power tracking 2

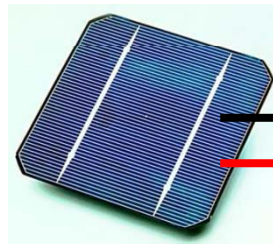
Solar cell output power changes on weather and temperature !



Peak power tracking zone



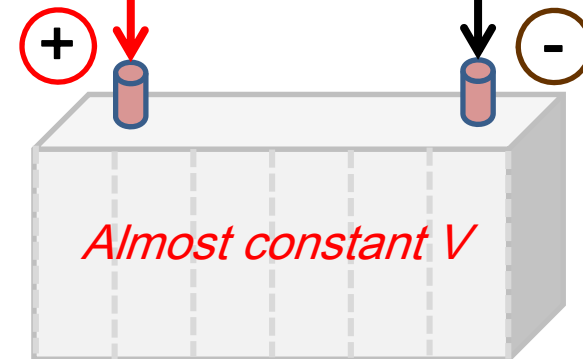
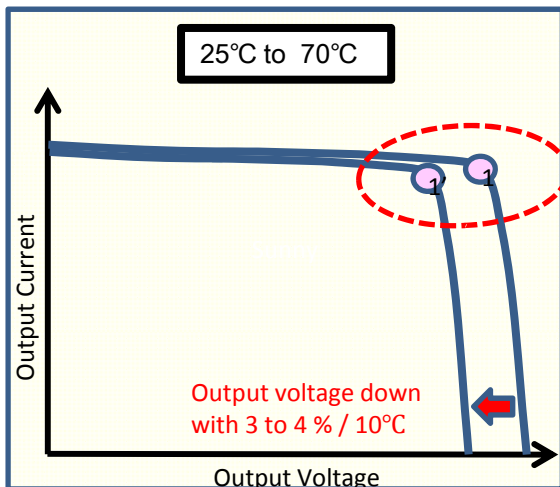
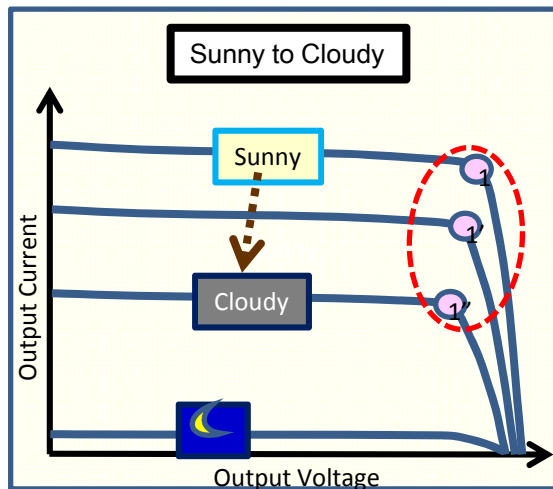
# Battery and it's charging/discharging ?



*Changing V*

Peak  
Power  
Tracker

*DC-DC converter loss*

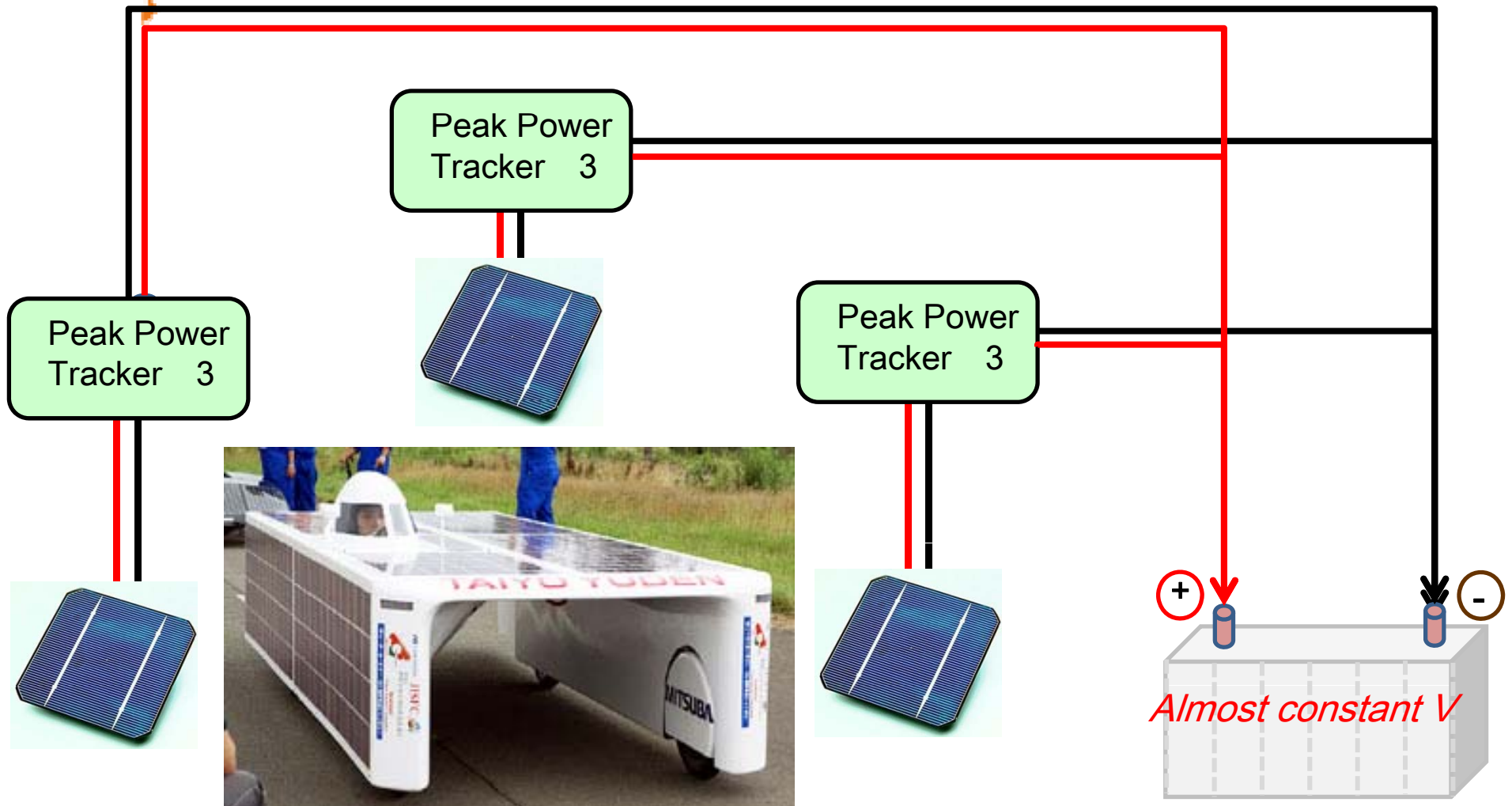


Battery has certain voltage  
To be charged and to be discharged



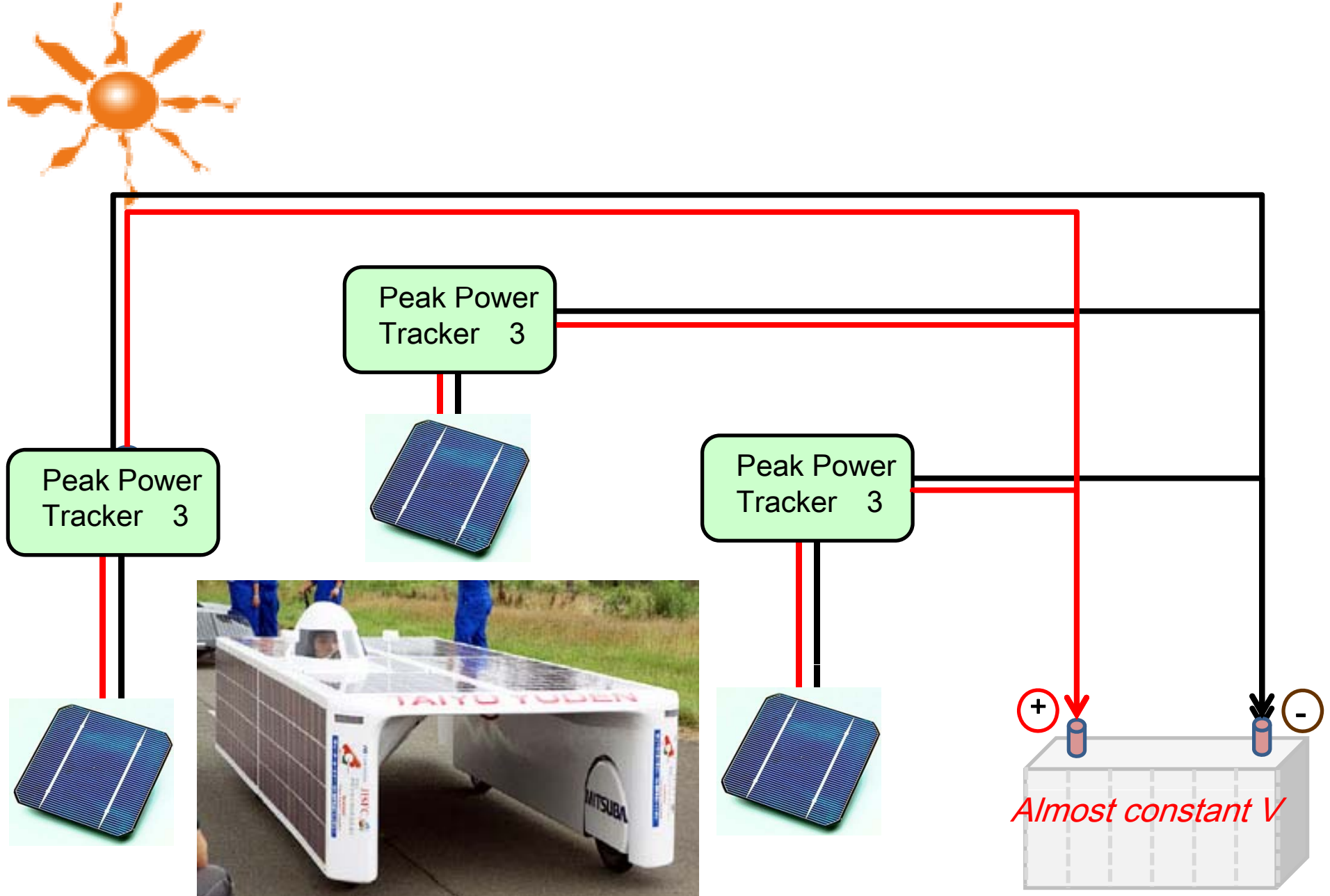


# Battery and it's charging/discharging ?





# Battery and it's charging/discharging ?





## Resistance of vehicle

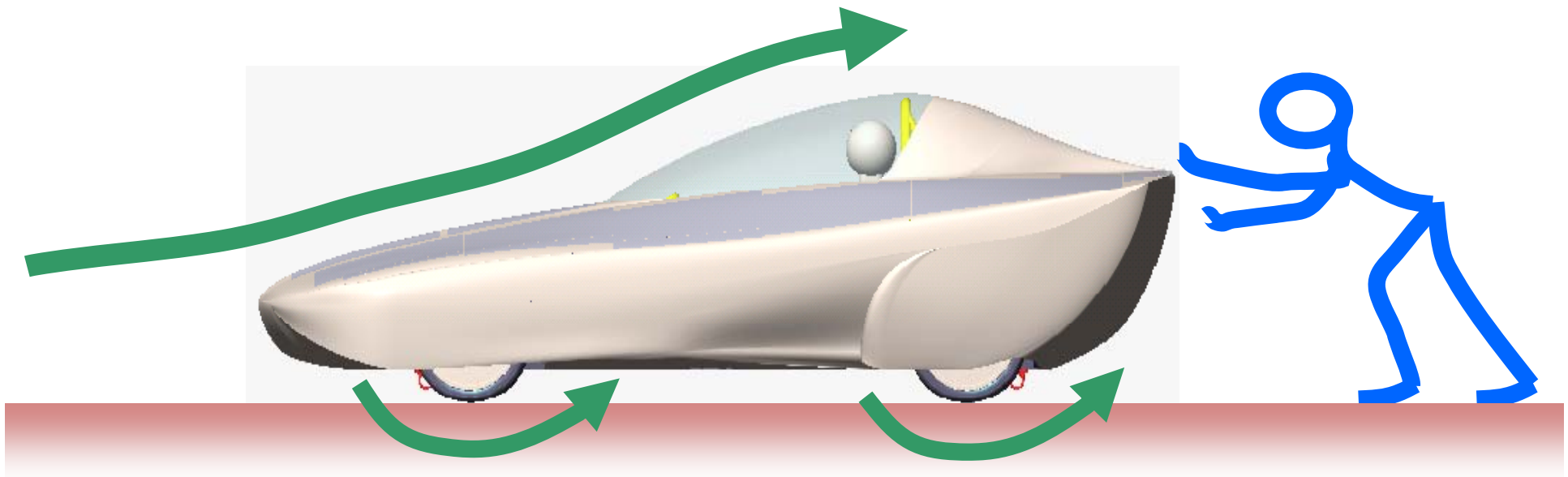
Resistance  
of vehicle

=

Aerodynamics

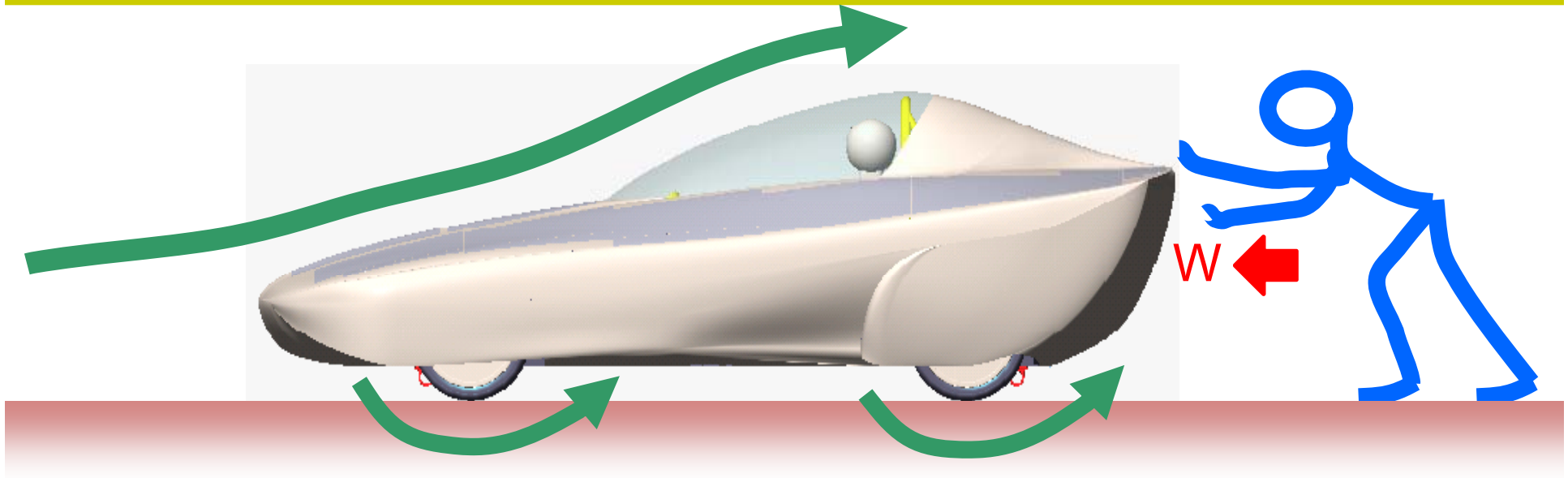
+

Rolling resistance





## Resistance of vehicle



Aerodynamics

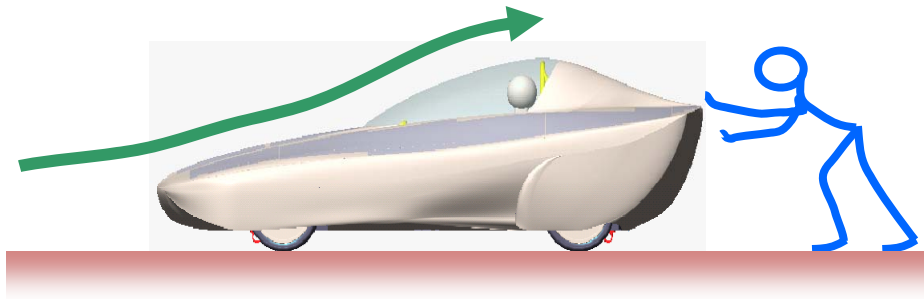
$$W ( \text{aero} ) = \frac{1}{2} \times 1.203 \times C_d \times A \times V^3$$

Rolling resistance

$$W ( \text{rolling} ) = \mu_r \times W_t \times 9.8 \times V$$



## 1) Aero dynamics

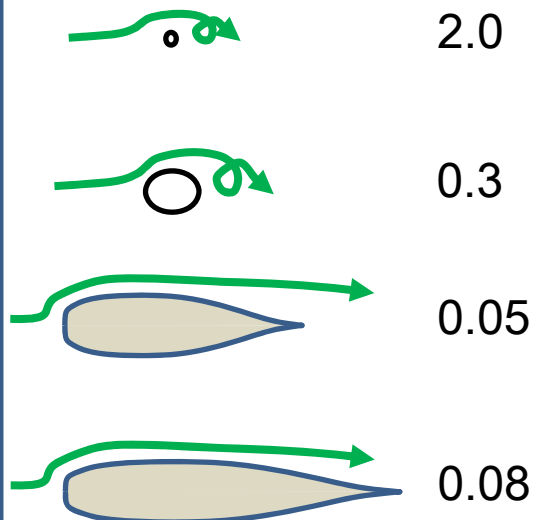


W ( aero )

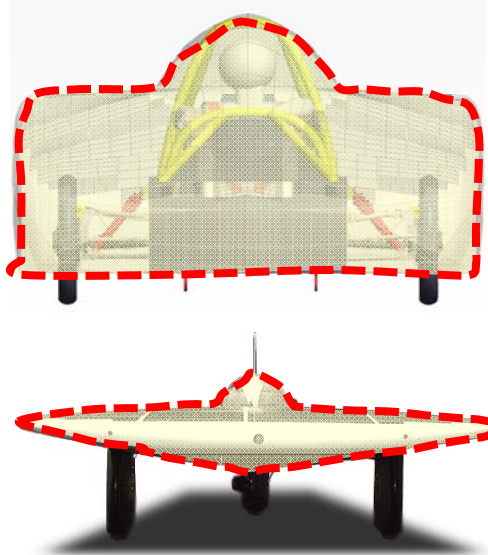
$$= \frac{1}{2} \times 1.203 \times C_d \times A \times V^3$$

### Aerodynamics

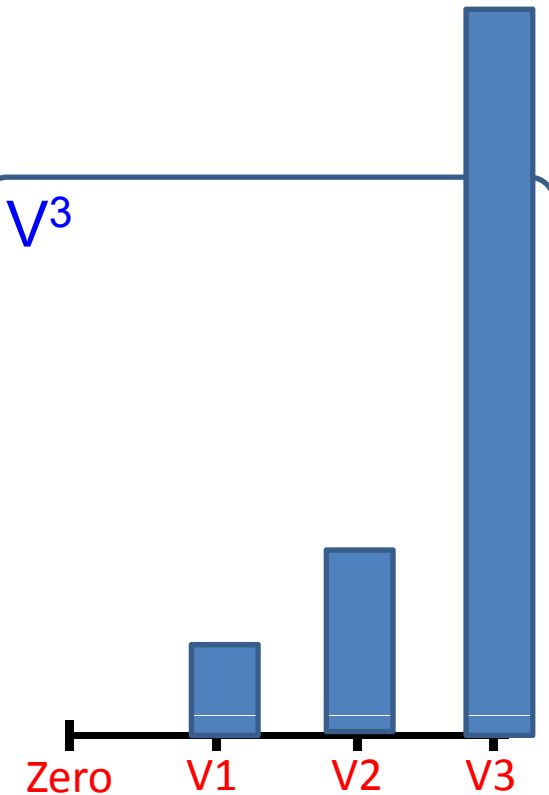
Cd



A = area size m<sup>2</sup>

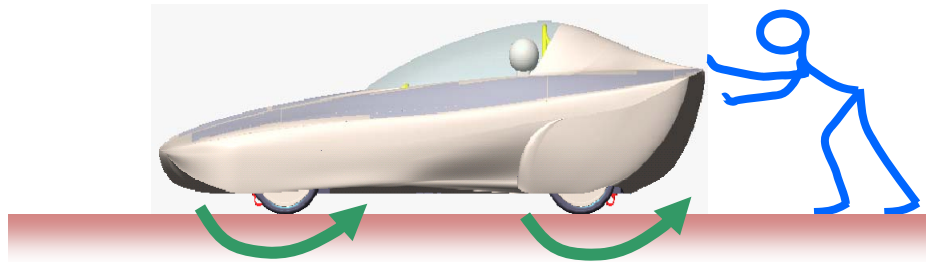


V<sup>3</sup>





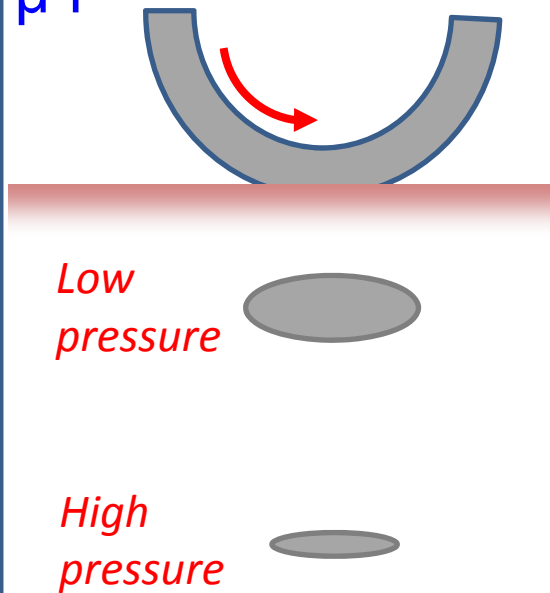
## 2) Rolling resistance



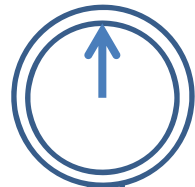
$W$  ( rolling )

$$= \mu_r \times W_t \times 9.8 \times V$$

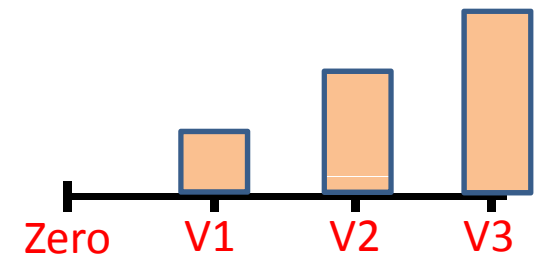
$\mu_r$



$W_t = \text{Vehicle weight}$

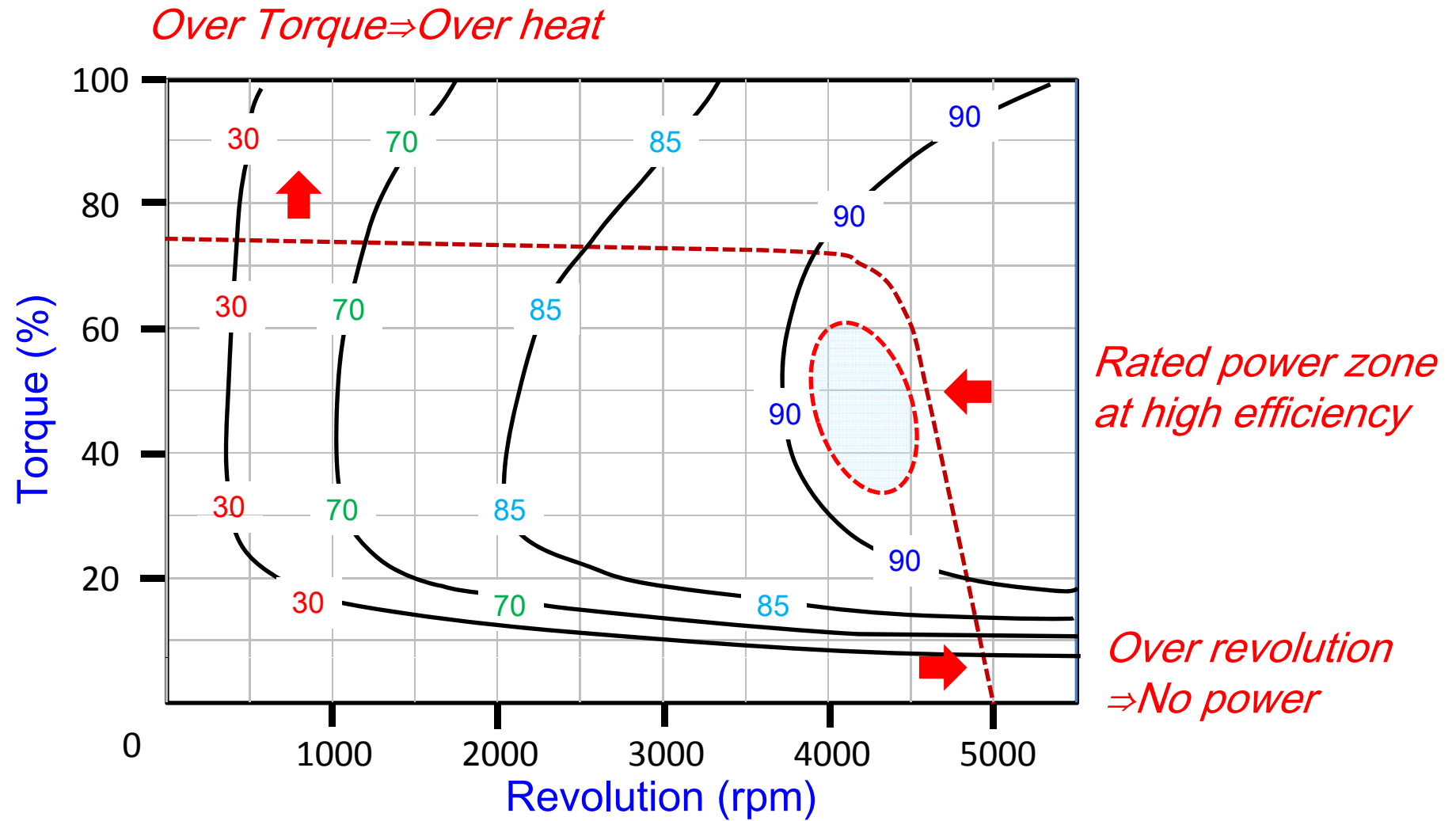


$V$





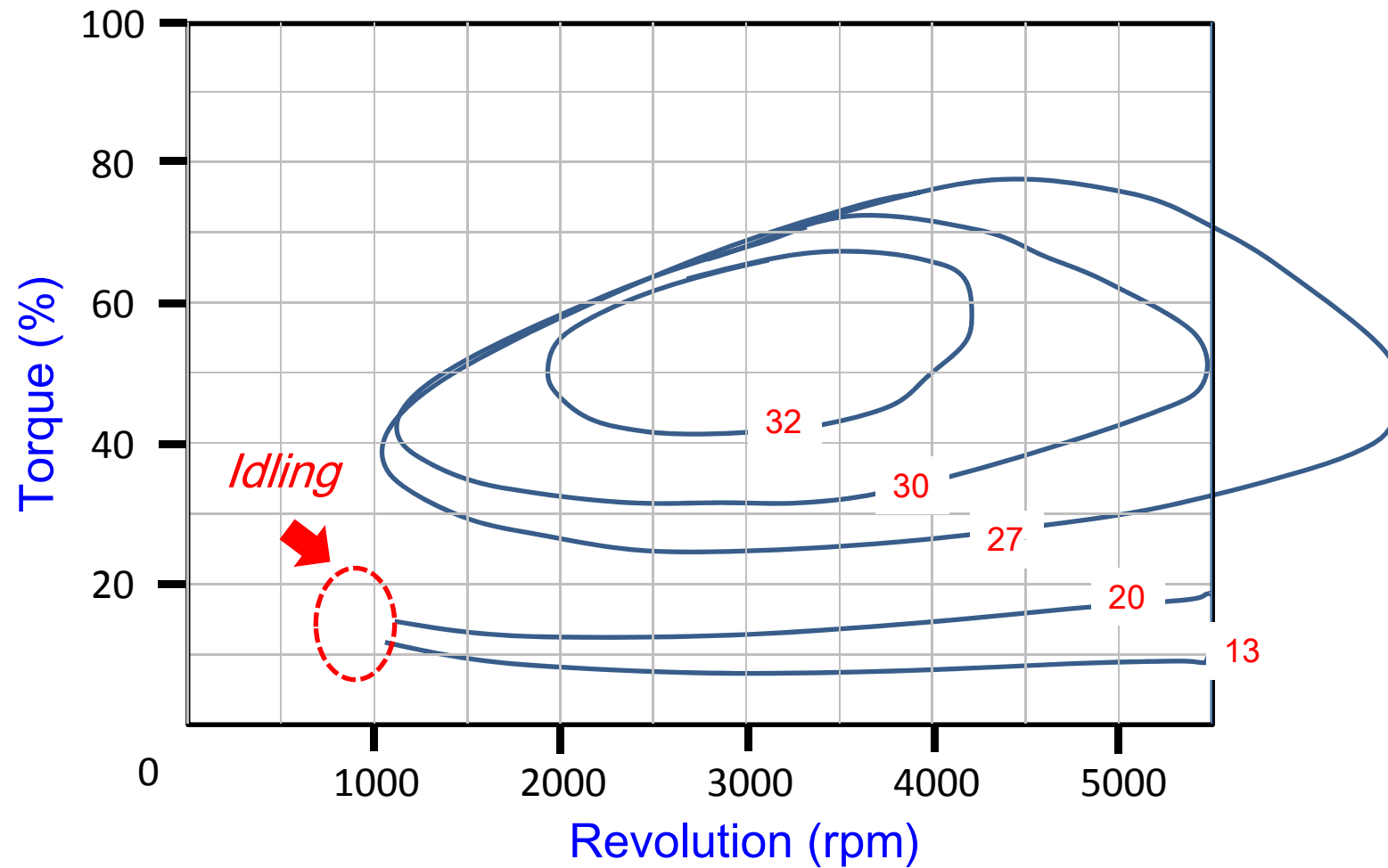
## Efficiency of motor





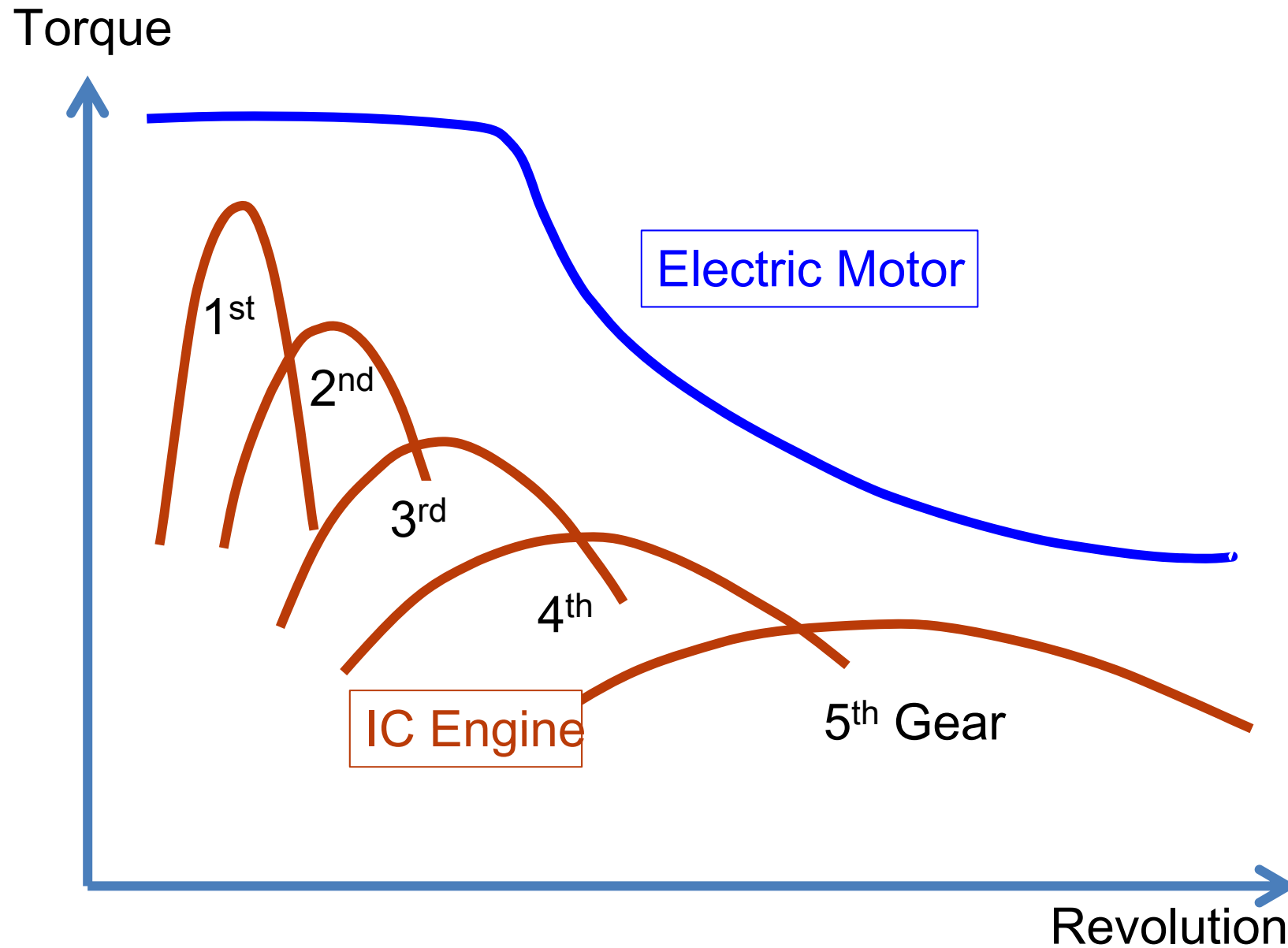


## Efficiency of internal combustion engine





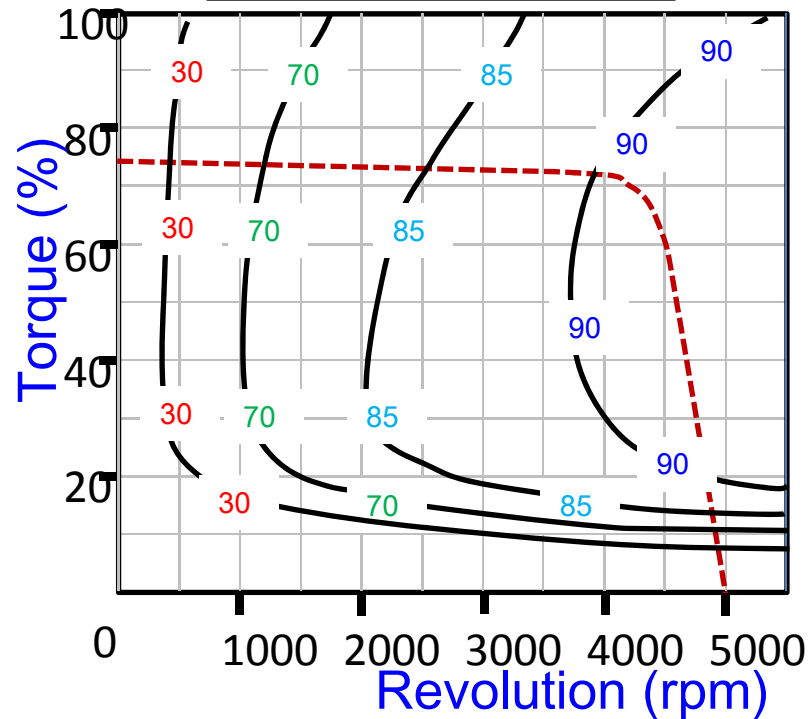
## Comparison of power to wheel



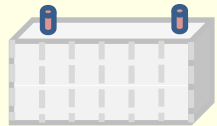


## Energy and efficiency comparison

### Battery and motor

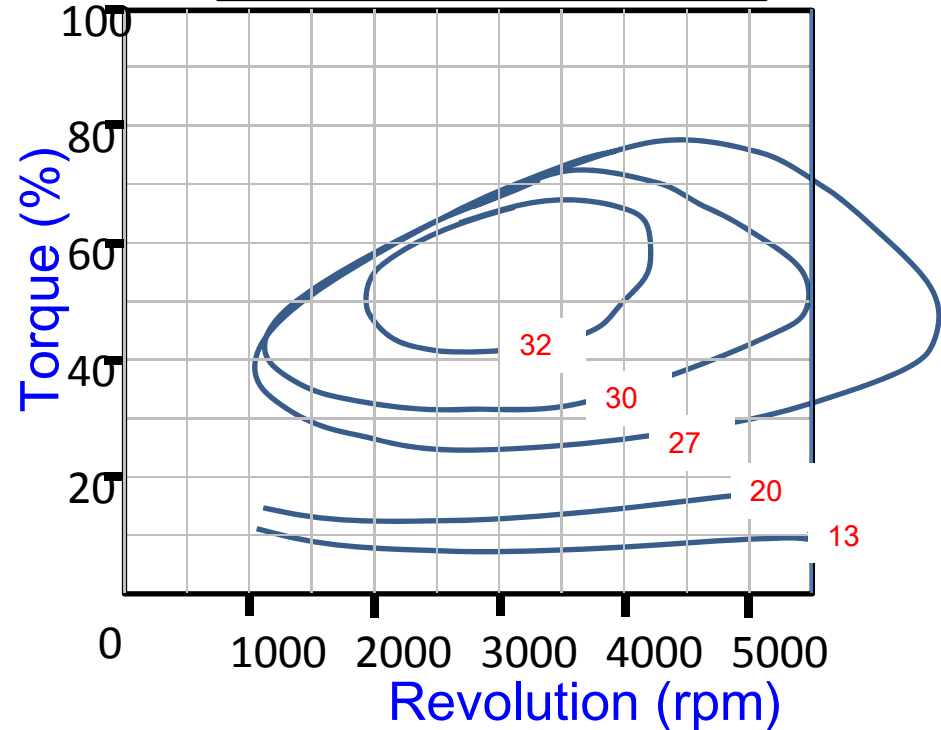


Lead Acid  
Battery



- Regulation
- 2.4 kWh/80kg
- X 90%
- = 2.16 kWh/80kg

### IC engine and gasoline



Gasoline



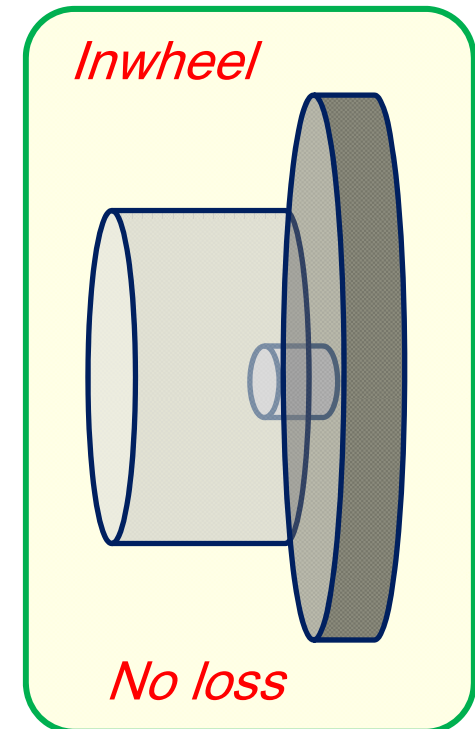
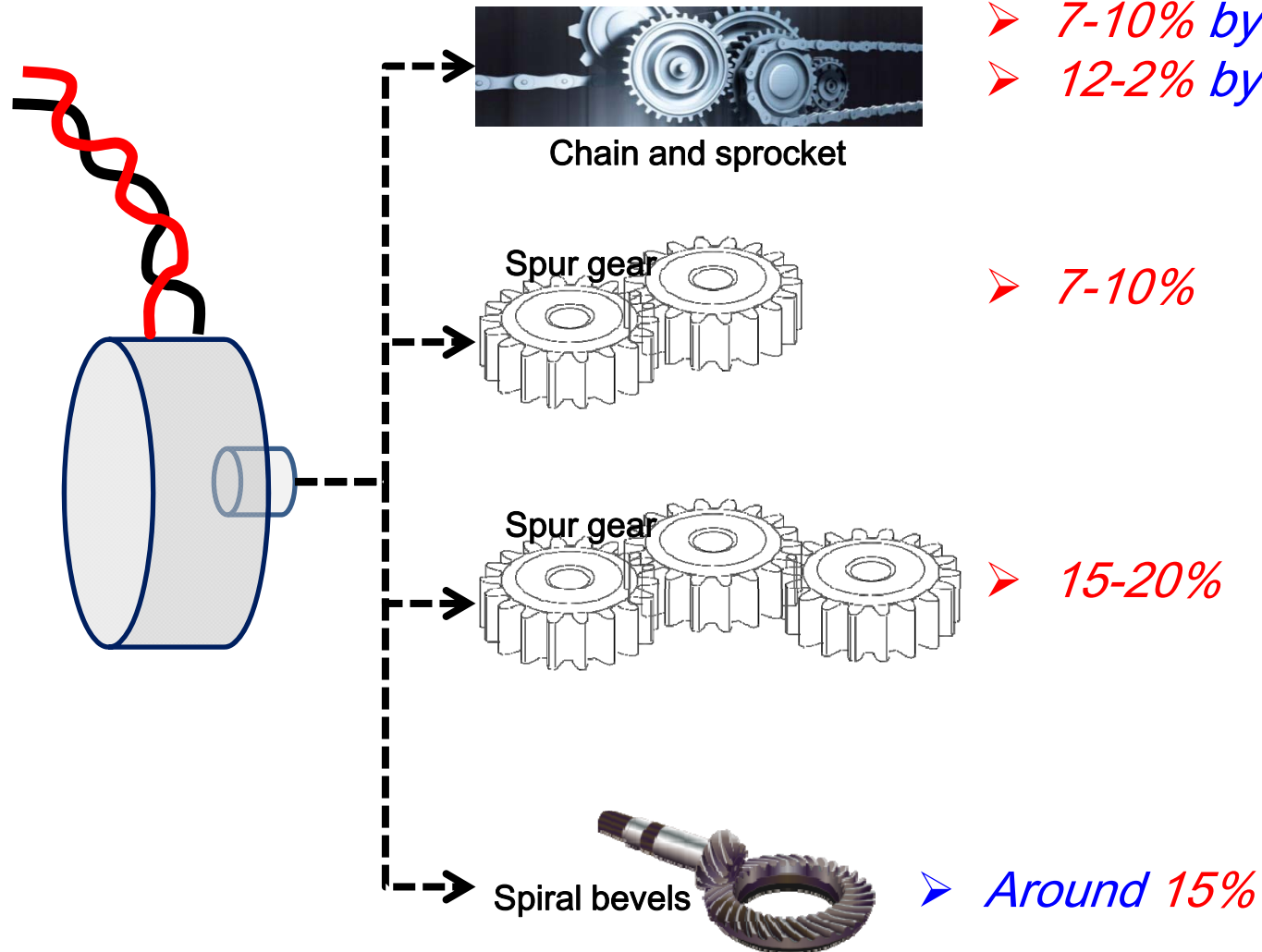
- 40 L Tank
- 384 kWh/32kg
- X 25%
- = 96 kWh/32kg



# Mechanical losses to wheel

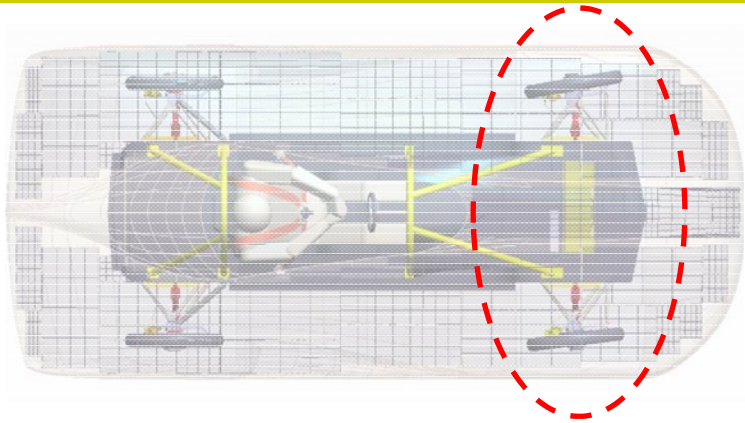
## Losses

- 7-10% by bicycle type
- 12-2% by motor cycle type

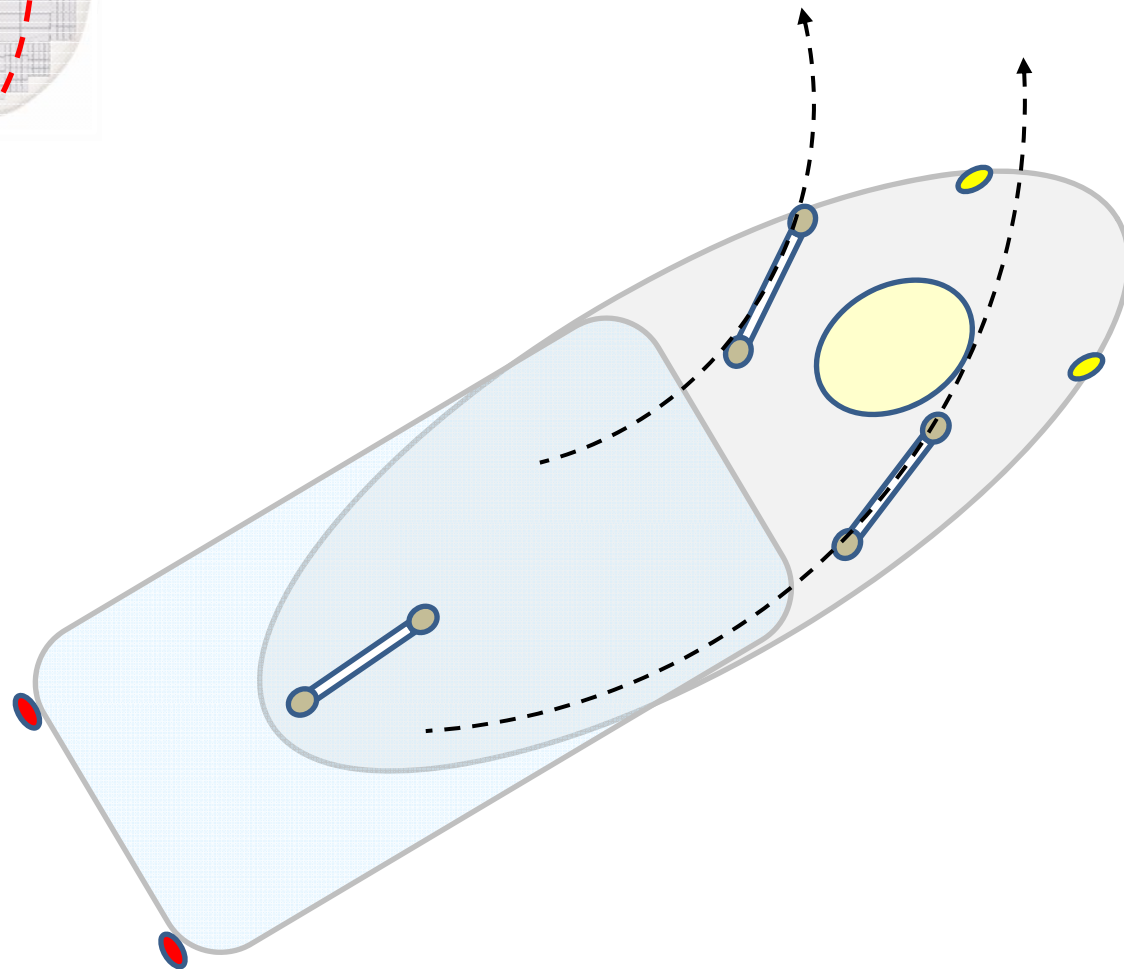
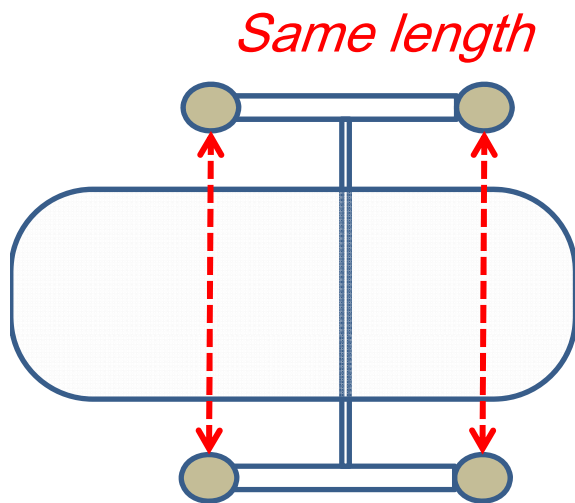




## Friction around wheel

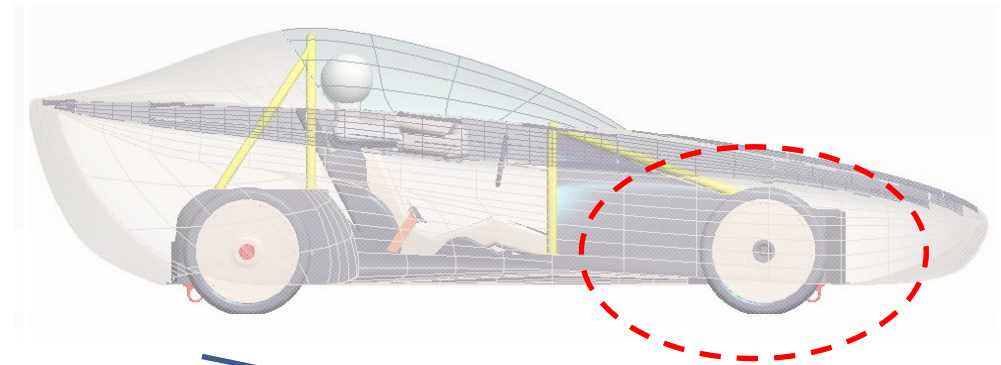
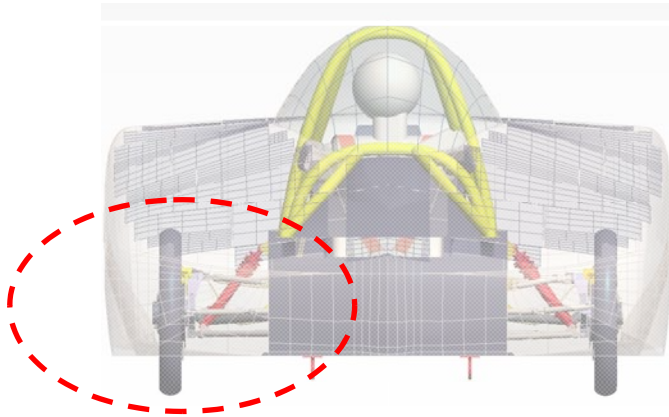


*Different turning radius  
need different angle*

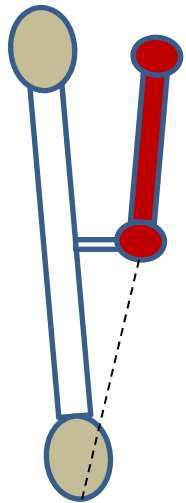




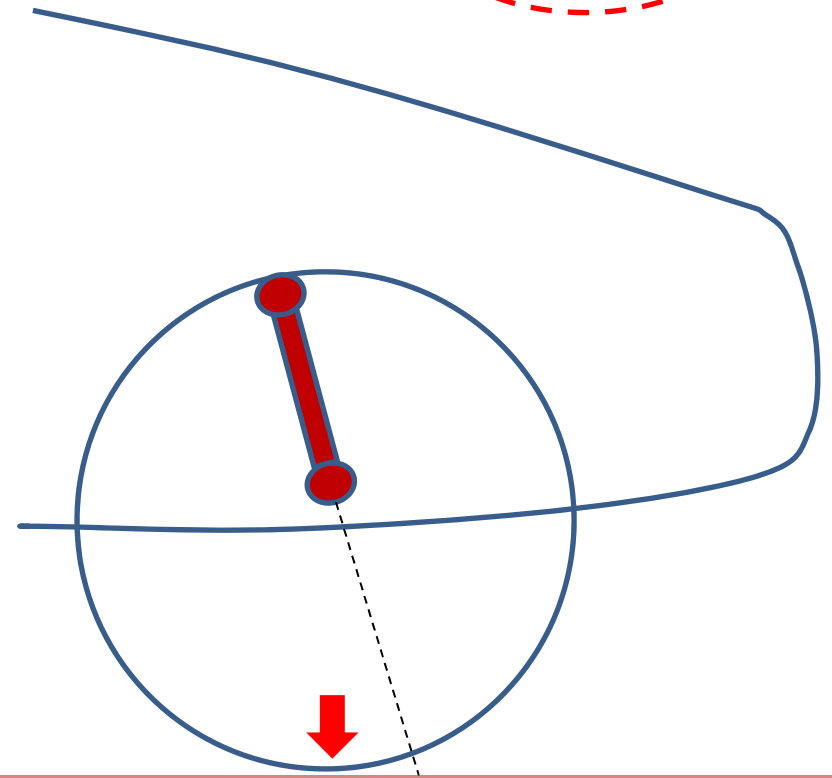
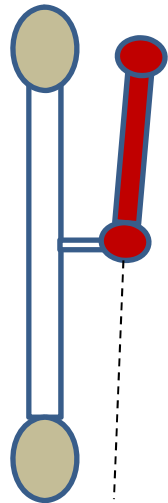
## Friction around wheel



*Angle setting  
for steady move*



*Gentle for tire  
and low friction*



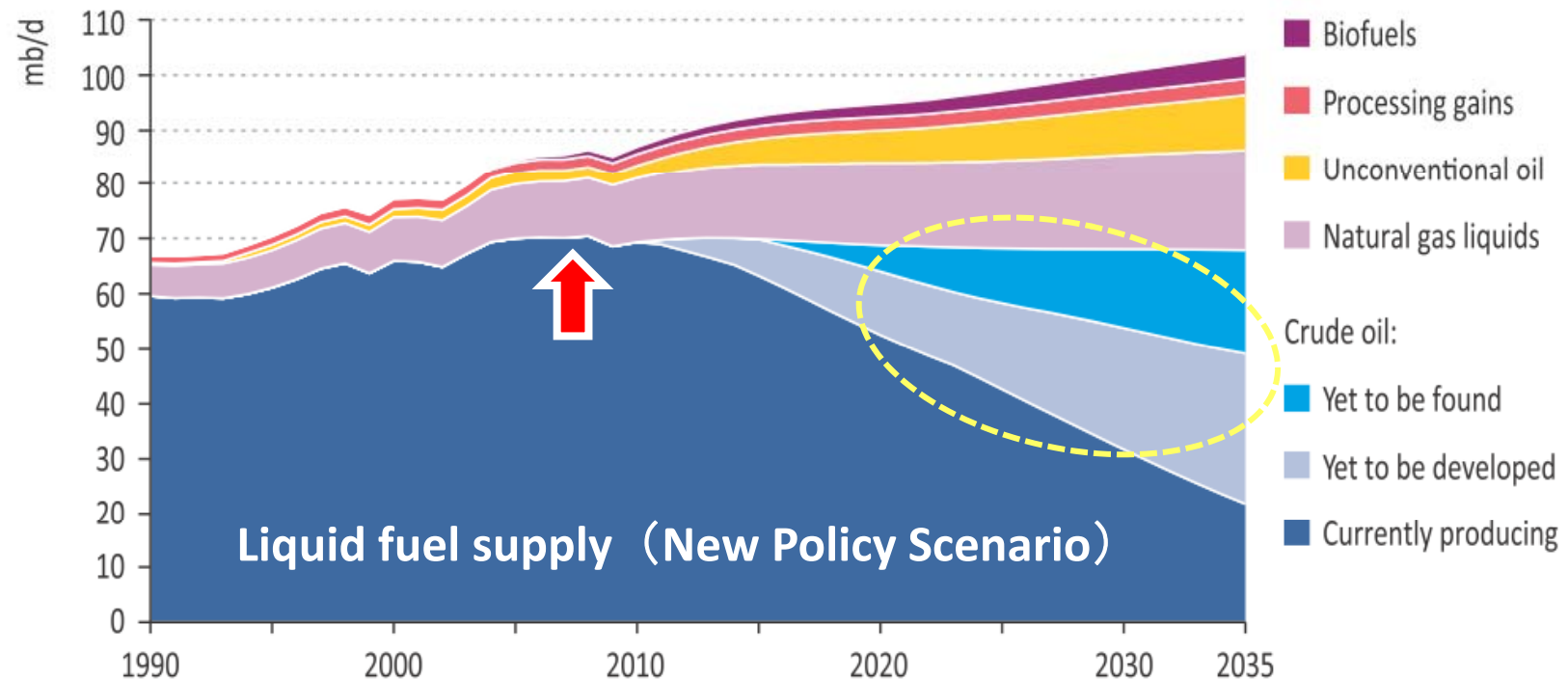


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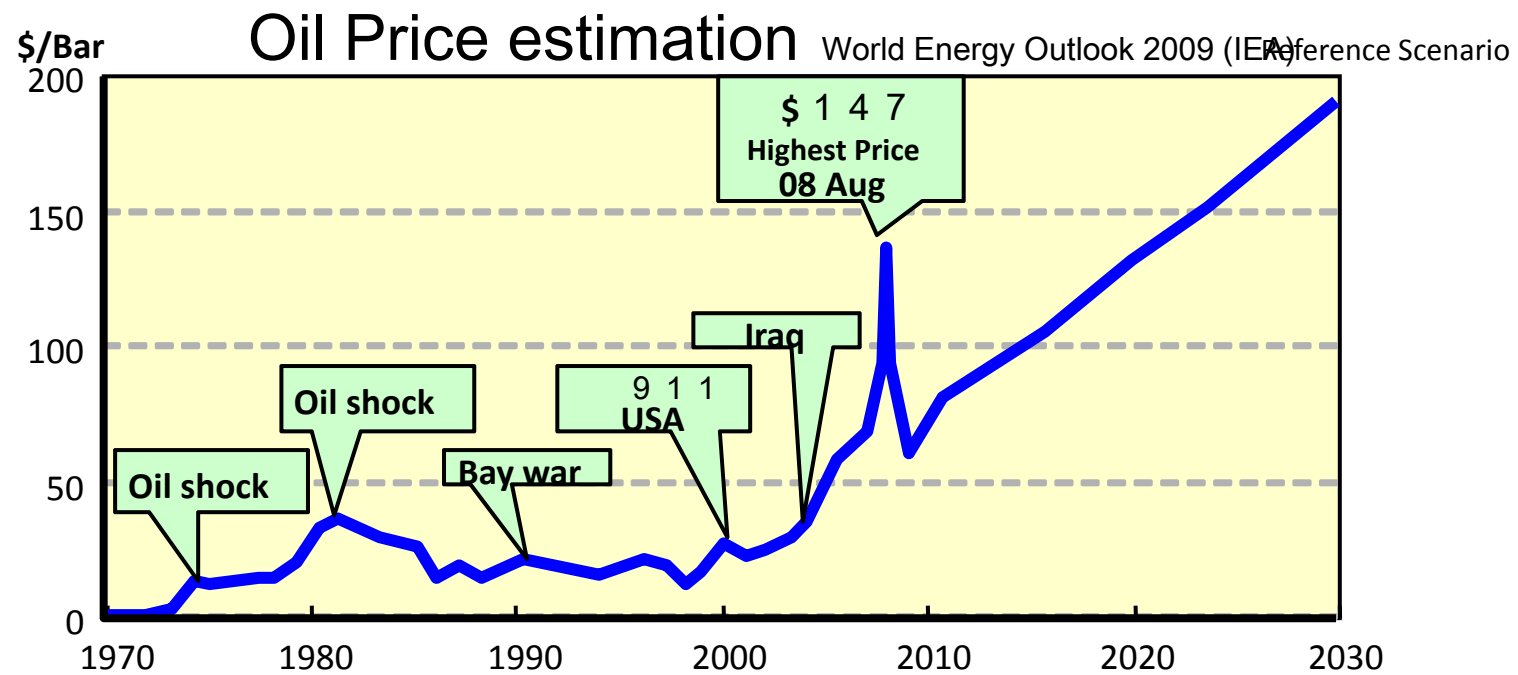


## We are facing big change of energy supply !



IEA World energy forecast (WEO2011)

- IEA recognized “ Peak Oil ” ( 9<sup>th</sup> Nov. 2010 )
- Without counting “ Yet oil ” , shortage of oil happens

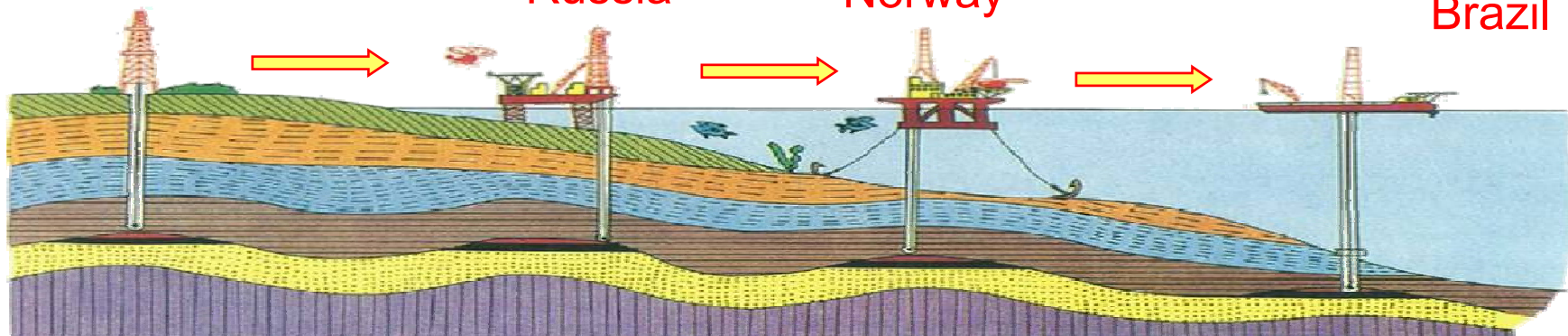


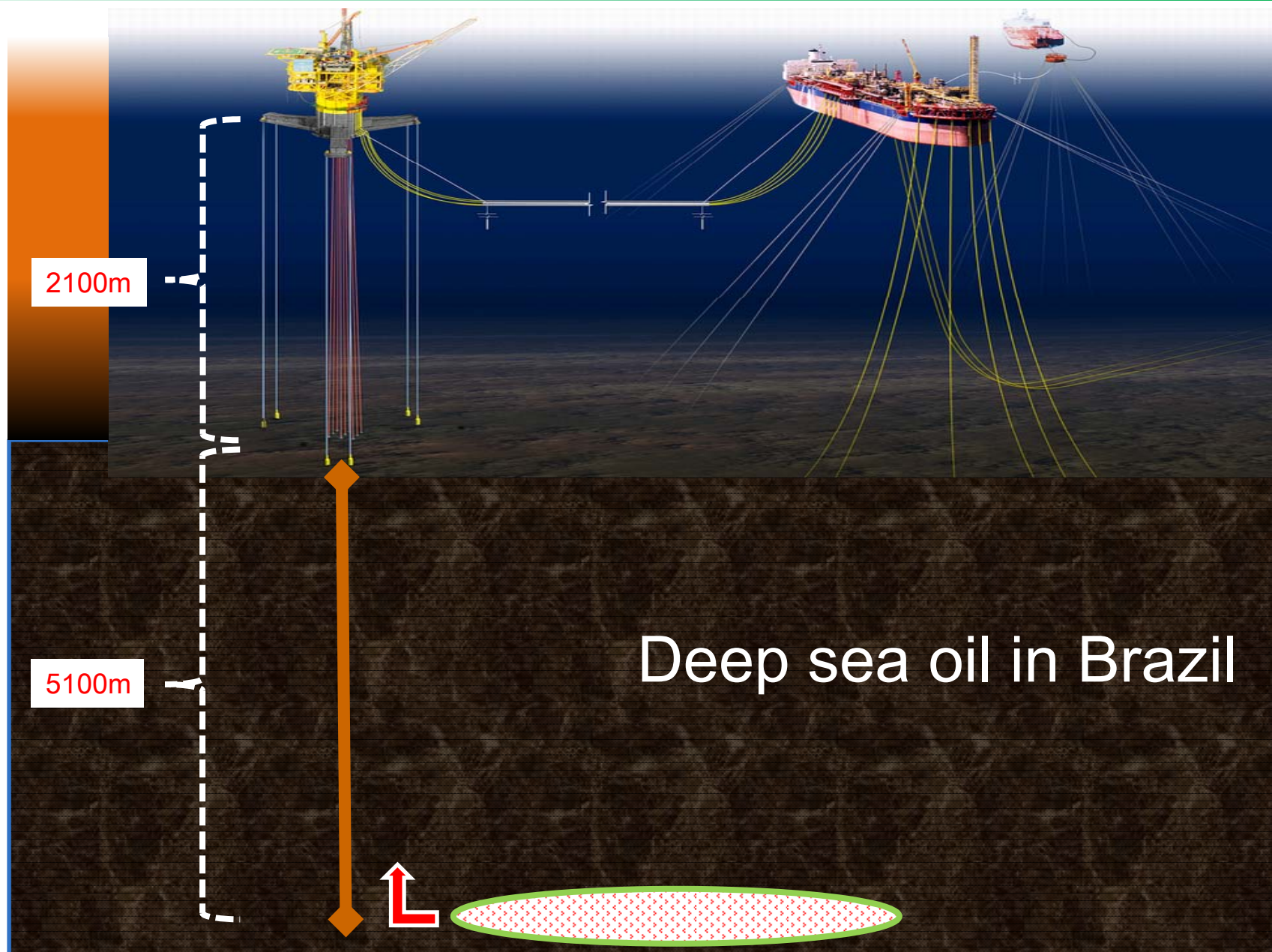
Middle east

Russia

Norway

Brazil

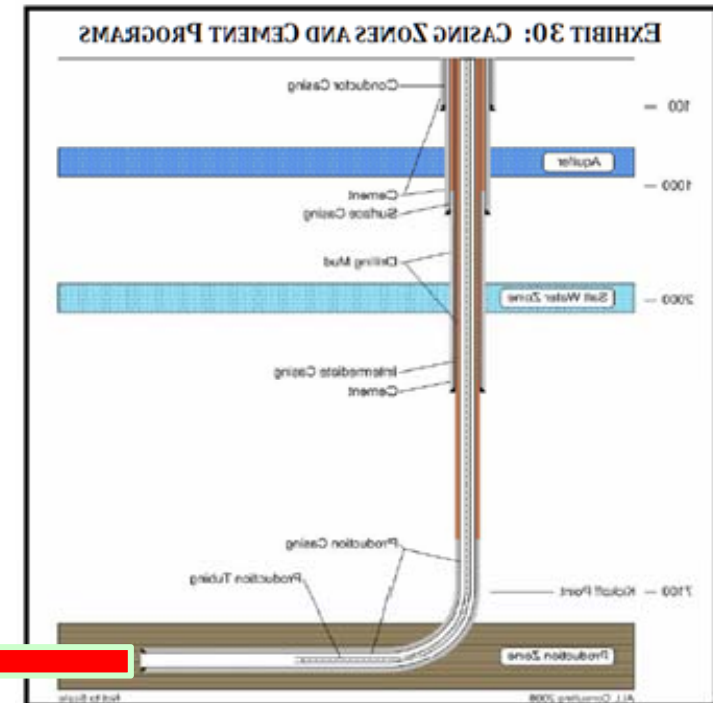
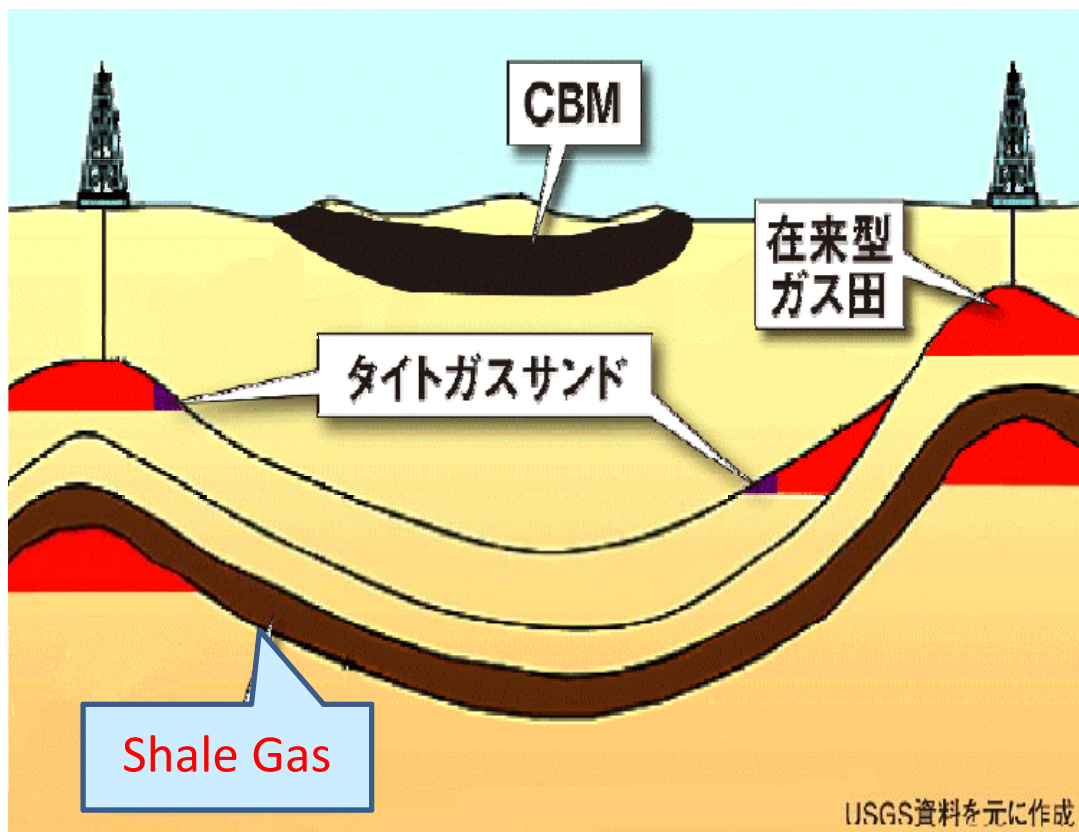


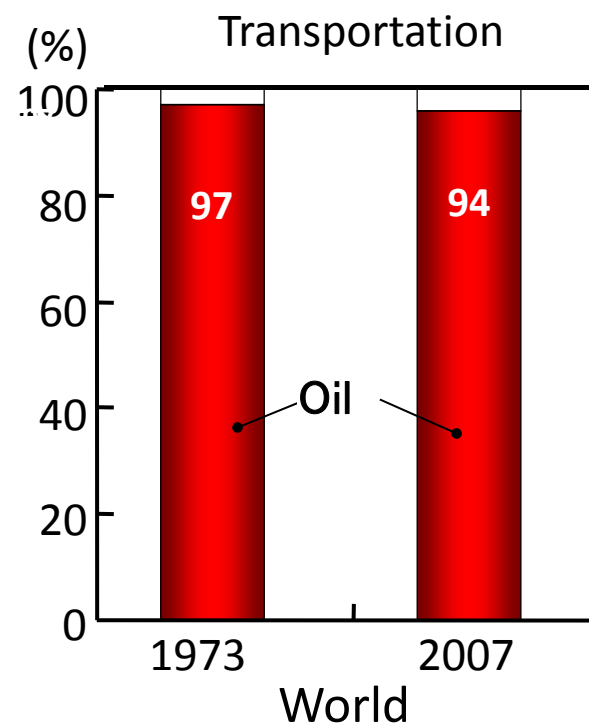
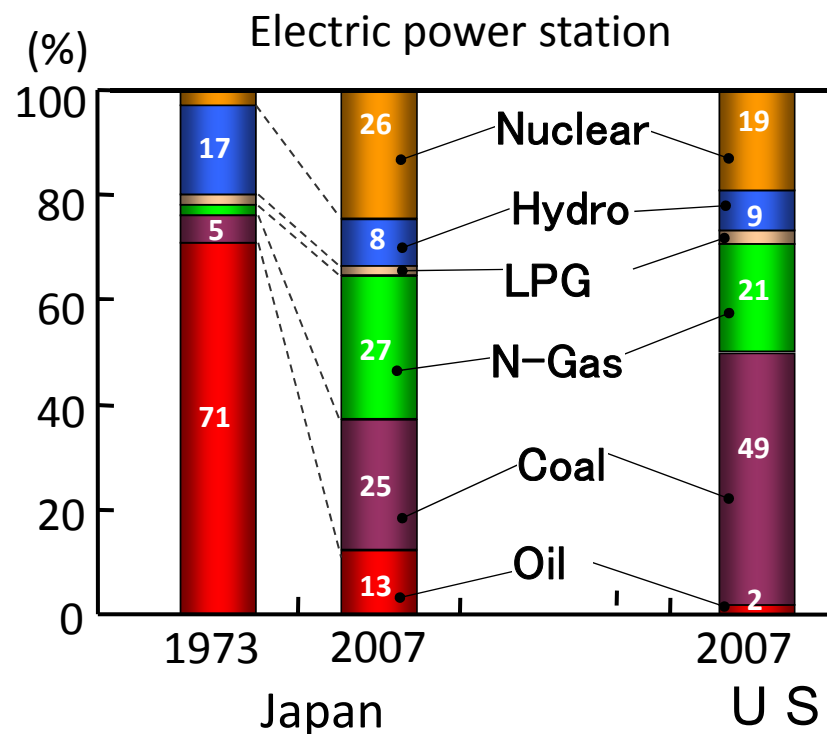






# New wave of energy from land ++++ Shale Gas

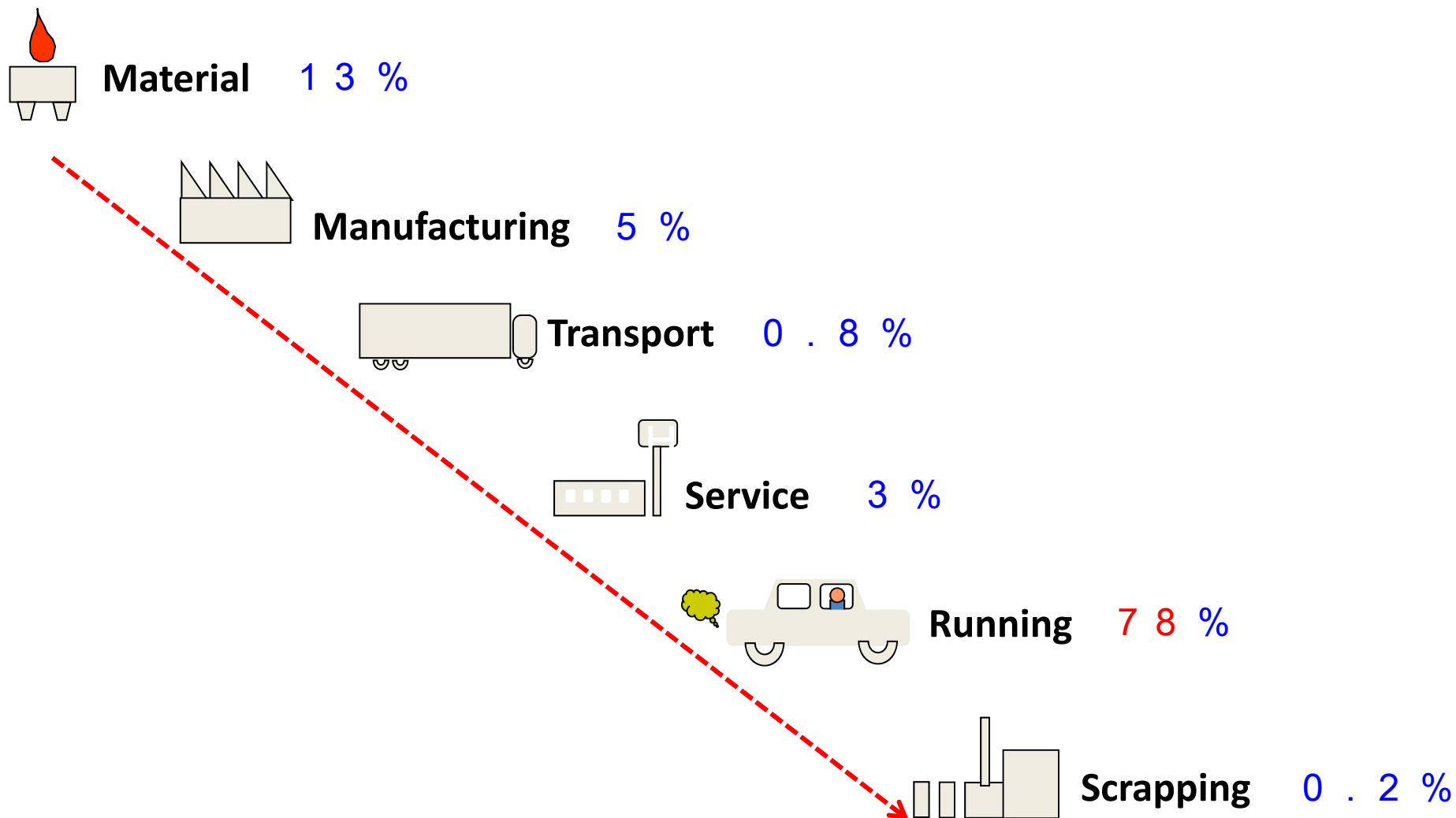




*Energy source for transportation needs to shift to hydrogen or electric step by step !*












## CO2 of vehicle ( Birth till scrapping )



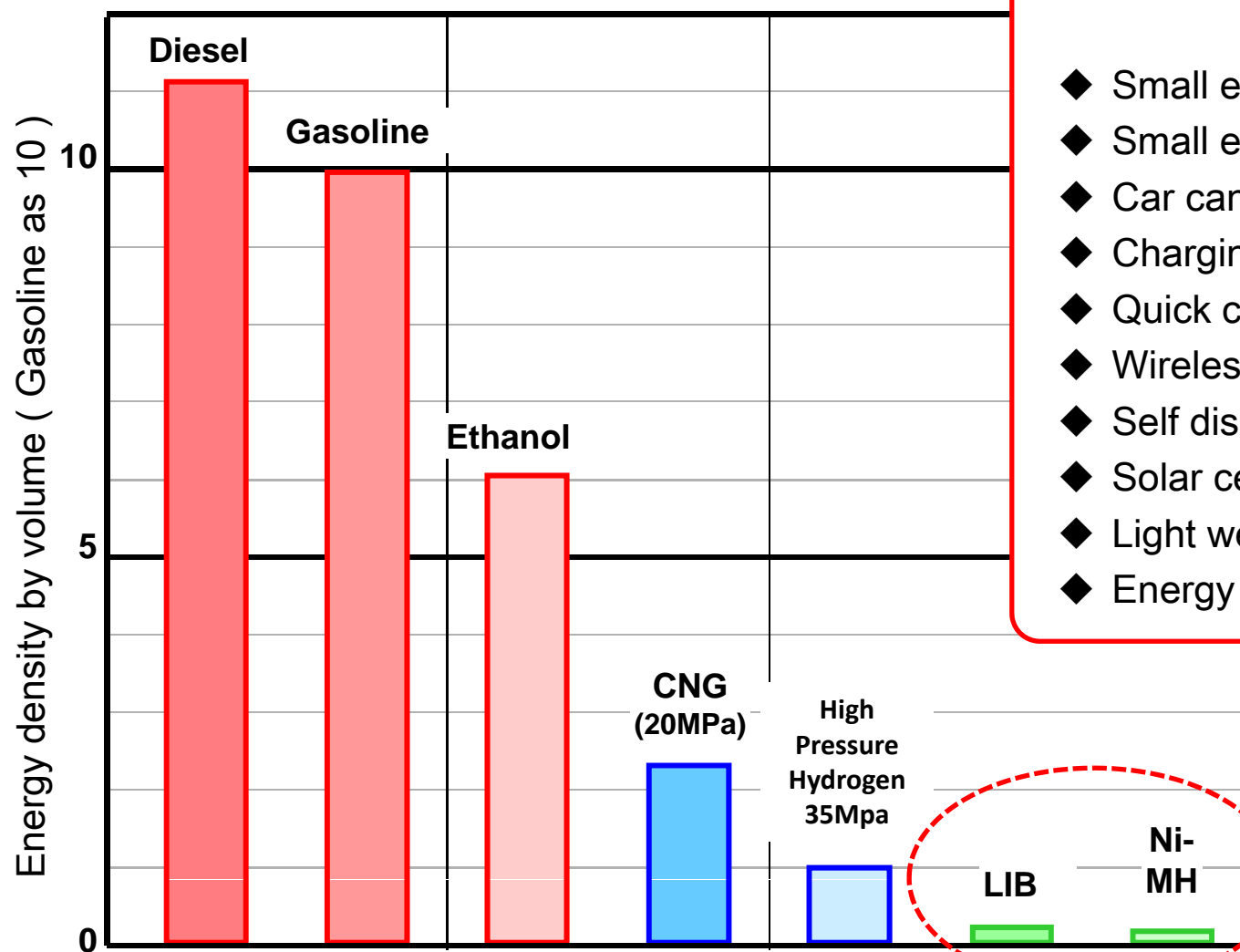




Internal combustion engine		Liquid fuel	
Hybrid electric vehicle		Electricity	
Plug in hybrid electric vehicle			
Electric vehicle			
Compressed natural gas		Gas fuel	
Fuel cell vehicle			



## Energy density by volume



### Key factors of technology !

- ◆ Small energy per volume
- ◆ Small energy per weight
- ◆ Car can carry small energy
- ◆ Charging needs many hours
- ◆ Quick charge
- ◆ Wireless charge
- ◆ Self discharging
- ◆ Solar cell charge
- ◆ Light weight of vehicle
- ◆ Energy management

Battery



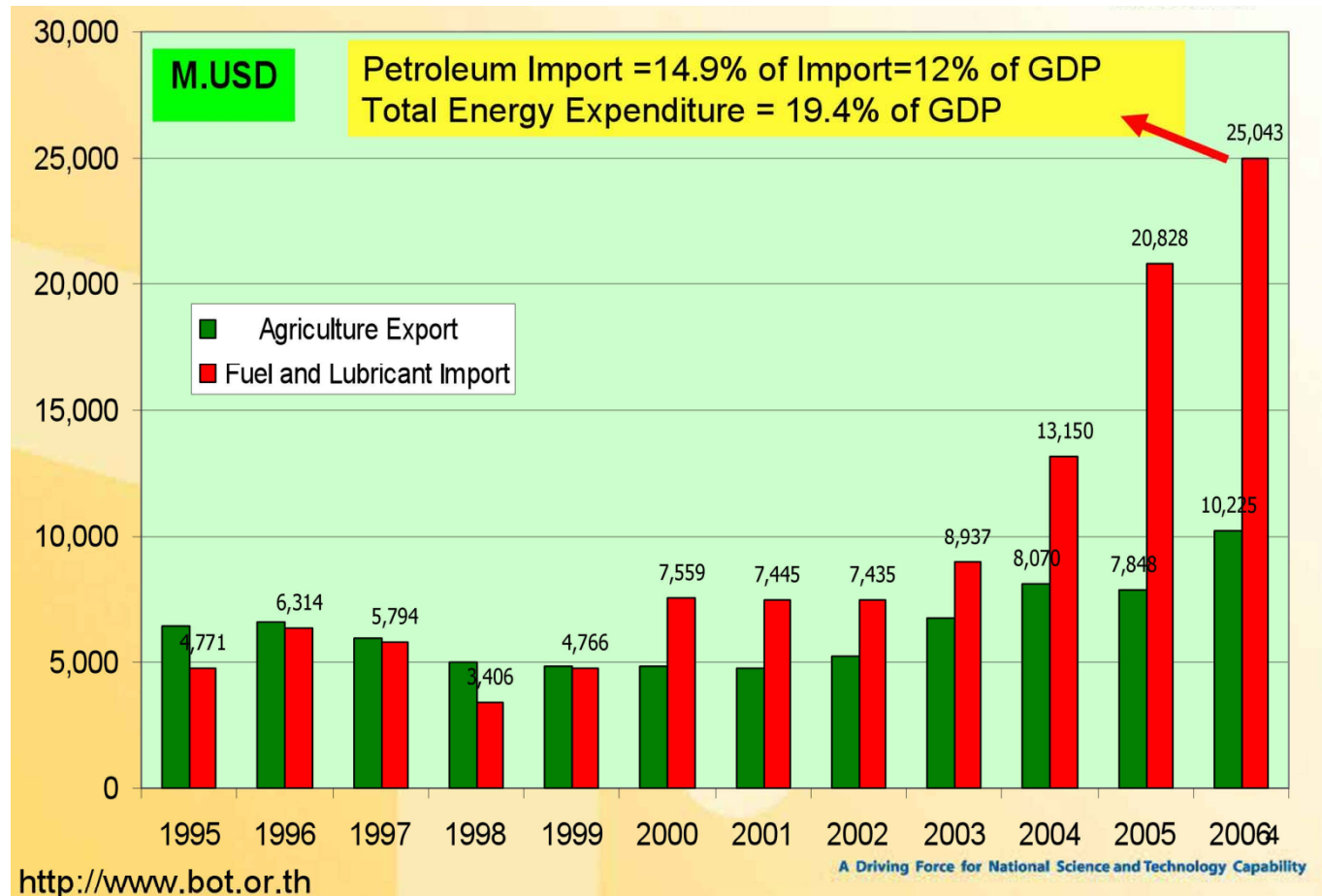
Roof top solar-cell can cover many points of Electric Vehicle.



**Solarcar = Solar-powered Electric vehicle !**



Thailand imports oil more and more  
than exporting agricultural products.



Solar power must be used for car also for home-life !

## Technical factor in employment of solar power to people's life or vehicle. ~ 1

- 1.Photo Voltaic
  - ◇ Sun-ray · · · · **【Radiation at location】 【Weather situation】 【Spectrum of sun-ray】**
  - ◇ P.V.technology · · · · **【Character of P.V.type】 【Character against Temp.】**  
**【 I - V curve】 【Moduling】**
- 2.Electricity storage
  - ◇ Lead/Acid · · · · **【Low cost】 【Tuff】 【Short life in cycle use】 【Power dencity】**
  - ◇ Litium · · · · **【High power density】 【High power rate】**  
**【need cost down】 【Charge/discharge manager is important】**
  - ◇ Super capacitor · · · **【High power rate】 = High power re-generation in braking**  
**【constant power control under big changing of I,V】**  
**【need cost down】**
- 3.Energy management
  - ◇ Peak power tracking for P.V.
  - ◇ Energy management of battery
  - ◇ Safety control cutting / connecting electric power
  - ◇ DC power driving ( mainly PWM control for high current)
  - ◇ Inverting lower DC power to 100 / 200 AC power
  - ◇ Balanced control of solar generation to storage power to output
  - ◇ Isolation / leakage control of electric power and EMI handling

#### 4.Motor

- ◇ DC brush · · · · 【Low cost】 【Low efficiency】 【Brush last short】
- ◇ Induction · · · · 【Tuff durable】 【motor driver necessary】 【start torque poor】
- ◇ DC Brushless · · · · 【high efficiency】 【motor driver necessary】  
【good torque】 【high cost】

#### 5.Electric commuter (including TukTuk or racer)

- ◇ vehicle design · · · · 《no description this time》
- ◇ specify vehicle · · · · 【type of vehicle】 【purpose of vehicle】 【area to cover】  
【number of passenger】 【pay load】 【start/crimb power】  
【max speed】 【distance per charge】
- ◇ battery spec · · · · 【type】 【volt / current / density】 【mounting】  
【charging method】
- ◇ specify motor · · · · 【type】 【rotation / torque / size / shape】  
【matching with traction system】



**Than you for your attention !**

**The Power of Dreams**



**HONDA**