COLLECTIF 55+
se réinvestir

La voiture électrique et la révolution des transports : les fondamentaux de la mécanique

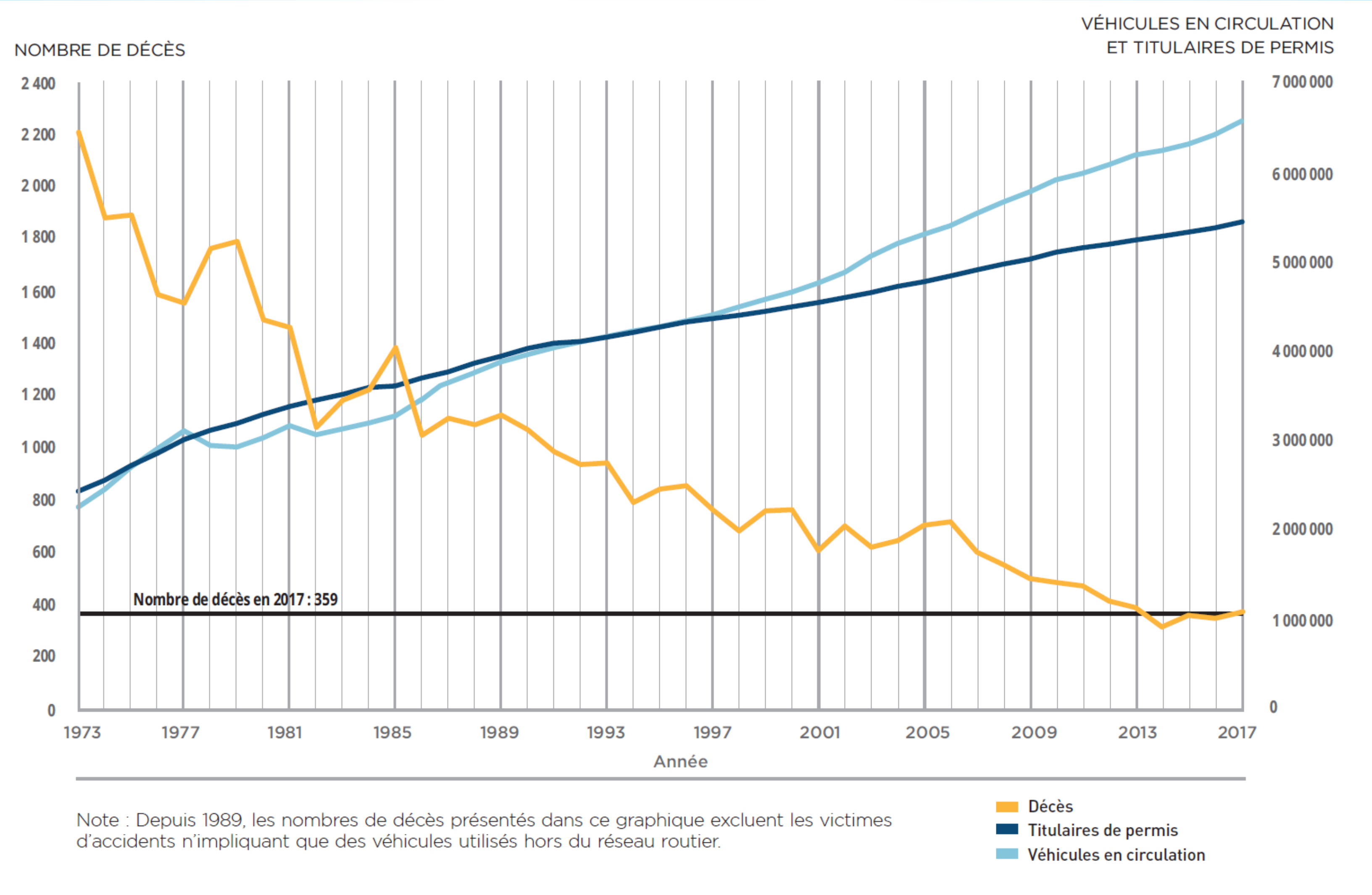
Bernard Drouin, 28 février 2019

Les voitures électriques

- **Les autos depuis 1960**
- **Les éléments fondamentaux.**
  - ✓ Le rendement des moteurs thermiques.
  - ✓ La conduite en ville.
  - ✓ La conduite sur autoroute.

- **La génération de l'électricité.**
  - ✓ Les centrales thermiques.
  - ✓ Les gros ont-ils plus de chance?

- **Conclusion**

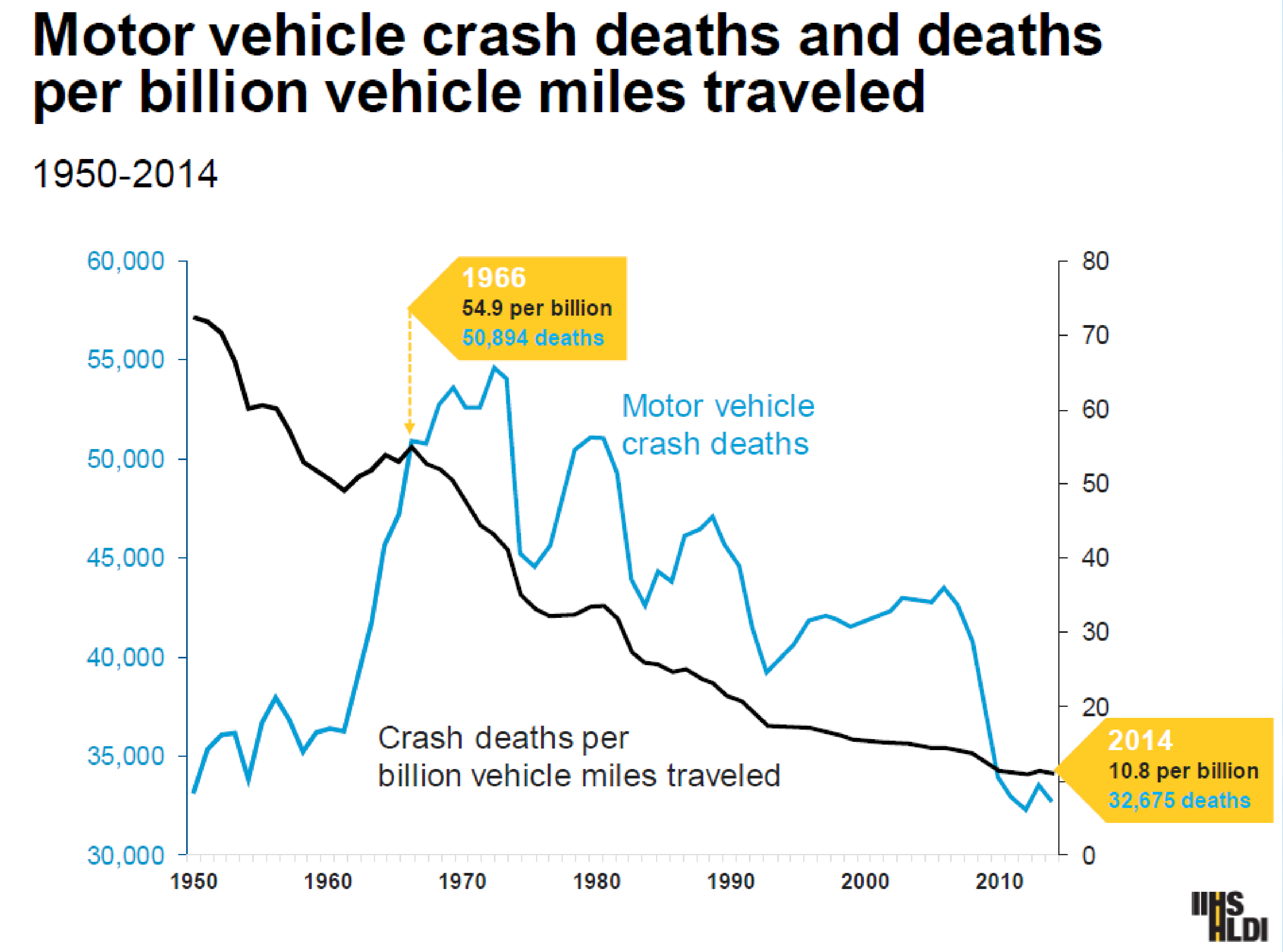


Aux USA on a 11,4 morts sur les routes par 100 000 habitants. Si on applique le même ratio au Québec, on aurait 950 morts et non 359 morts.

https://saaq.gouv.qc.ca/fileadmin/documents/publications/bilan-routier-2017.pdf

https://en.wikipedia.org/wiki/Motor_vehicle_fatality_rate_in_U.S._by_year

Les traumas



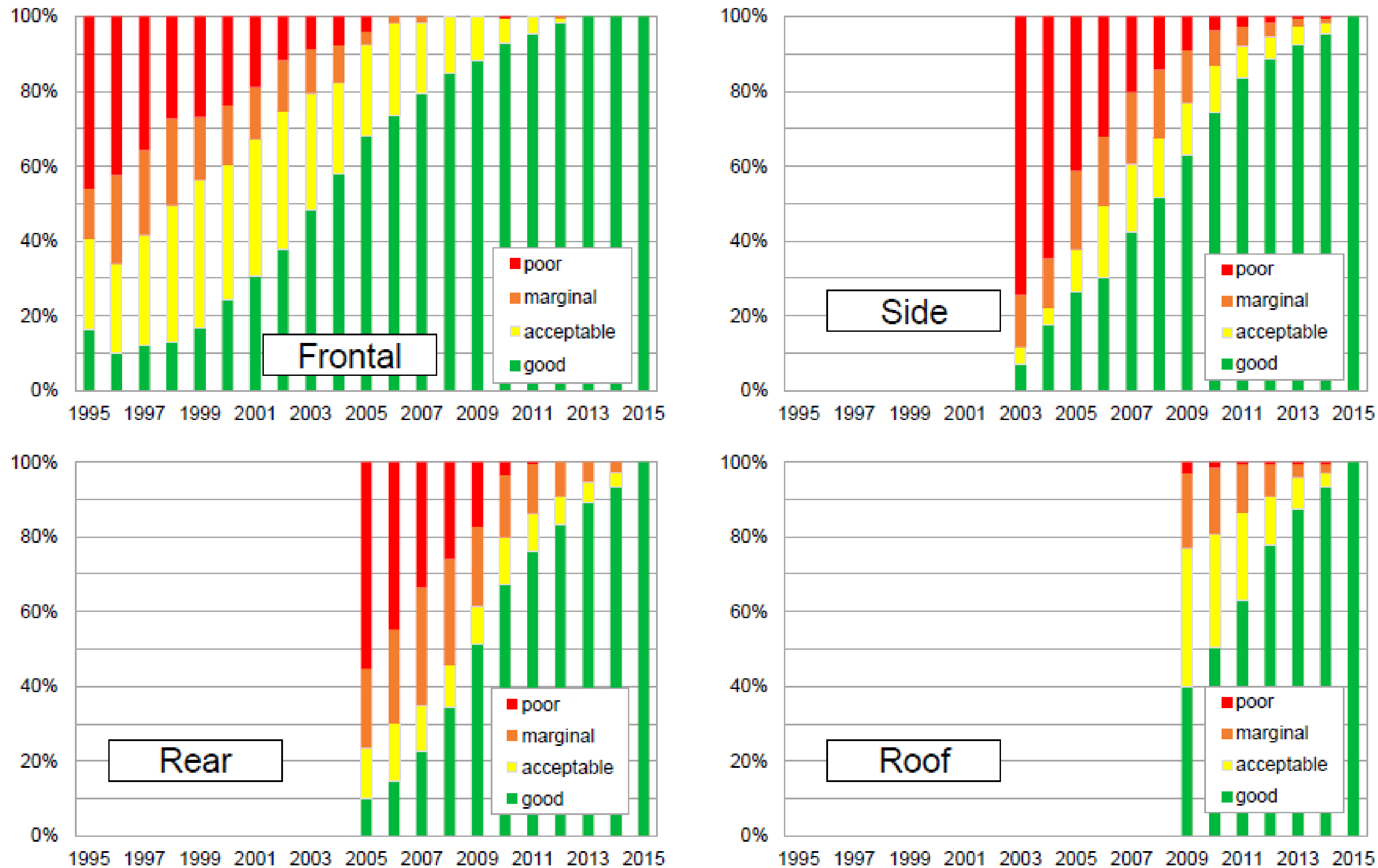
http://www.iihs.org/iihs/topics/t/crash-testing-and-crashworthiness/presentations/bytag

http://www.autoexpert.ca/fr-ca/actualites/les-coussins-gonflables-et-les-pretensionneurs?mid=200805&nid=740

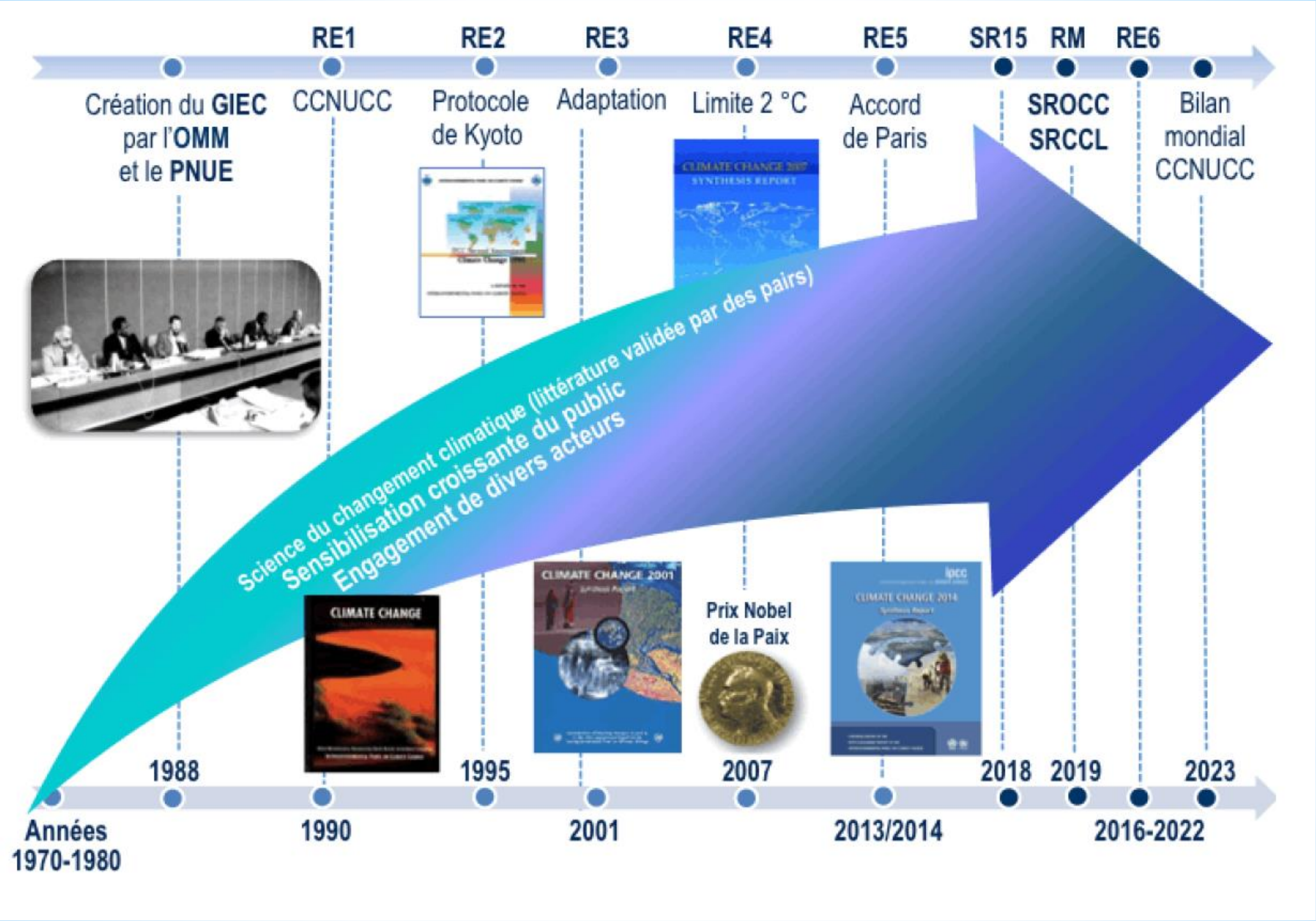
Les traumas

Crash protection ratings by model year

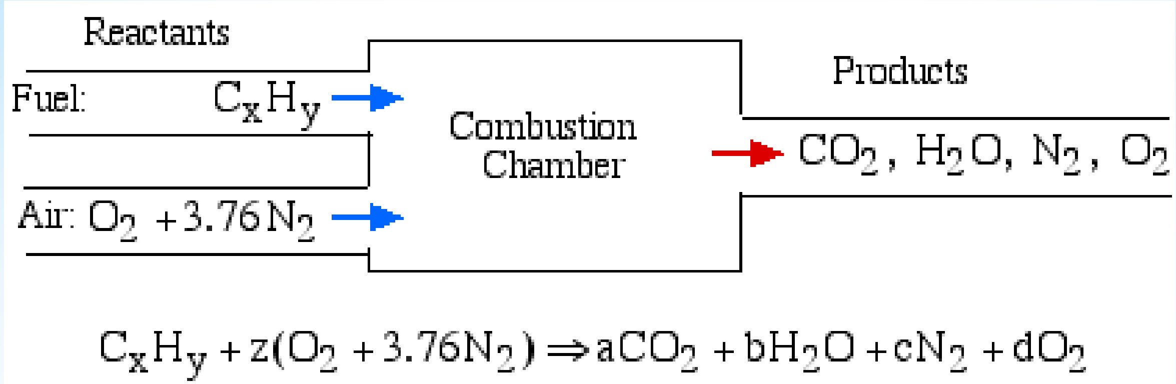
Improvements: Beginning in 1995

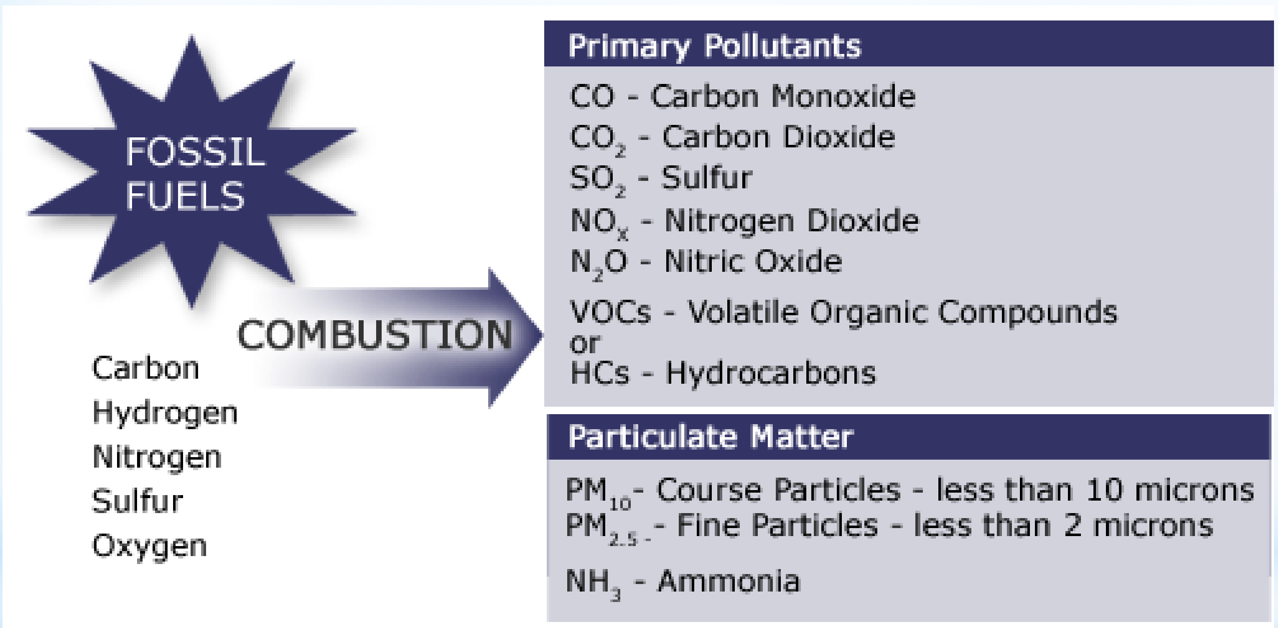


http://www.iihs.org/iihs/topics/t/crash-testing-and-crashworthiness/presentations/bytag



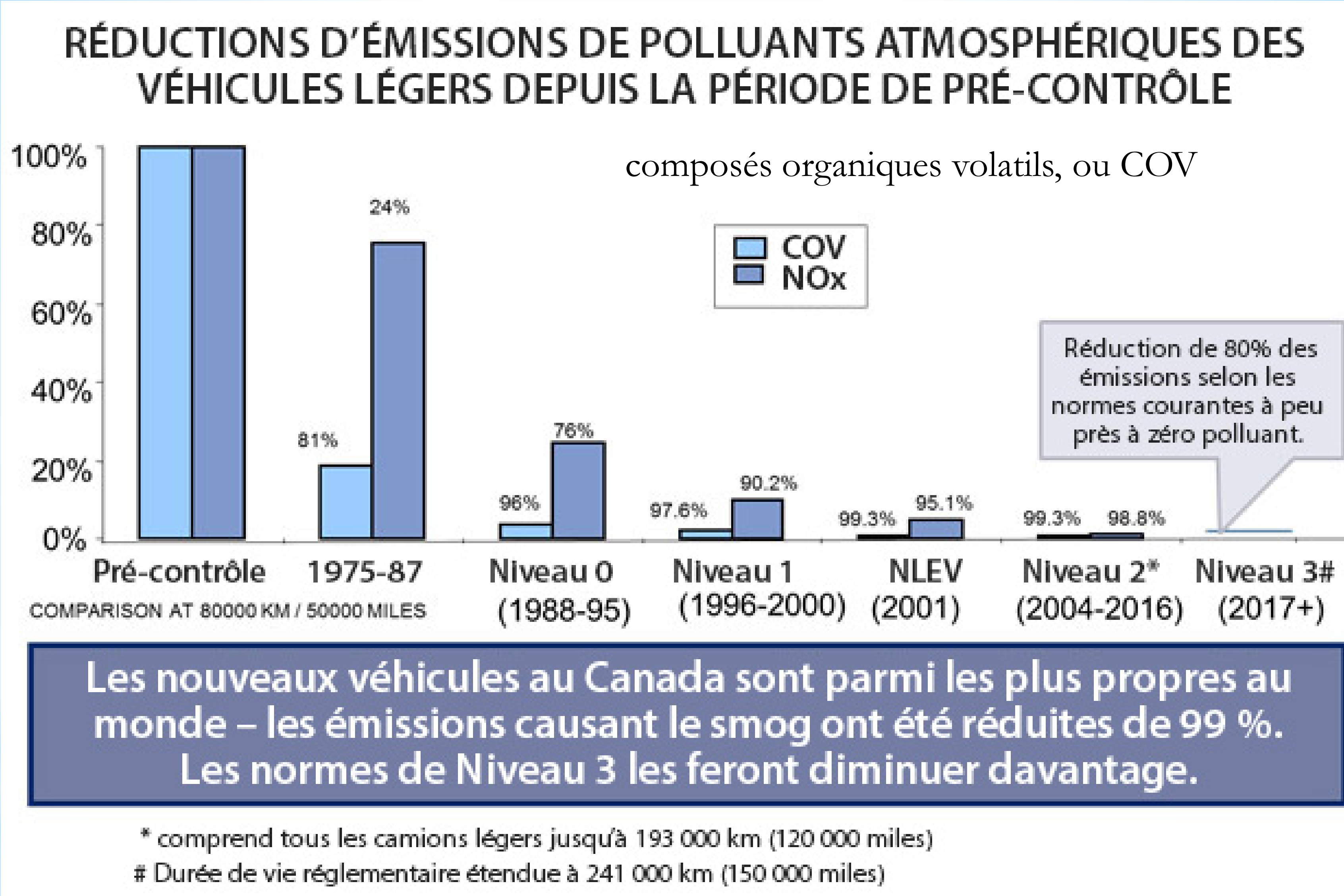
Le GIEC et le sixième cycle d'évaluation





https://www.ohio.edu/mechanical/thermo/Applied/Chapt.7_11/Chapter11.html

https://www.e-education.psu.edu/egee102/node/1951

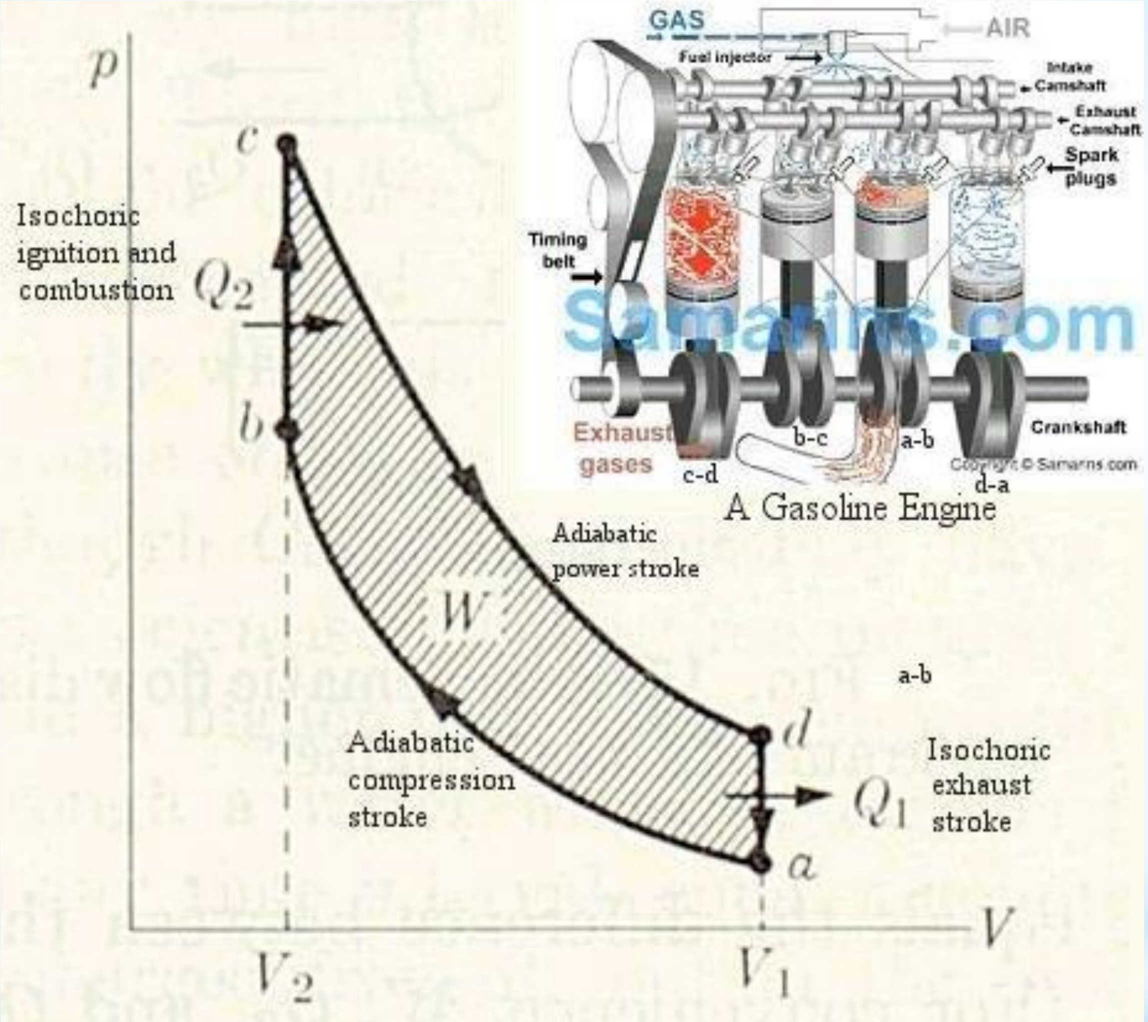


composés organiques volatils, ou COV

https://www.cvma.ca/fr/dossiers-prioritaires/environnement/les-emissions-des-vehicules/

Les fondamentaux

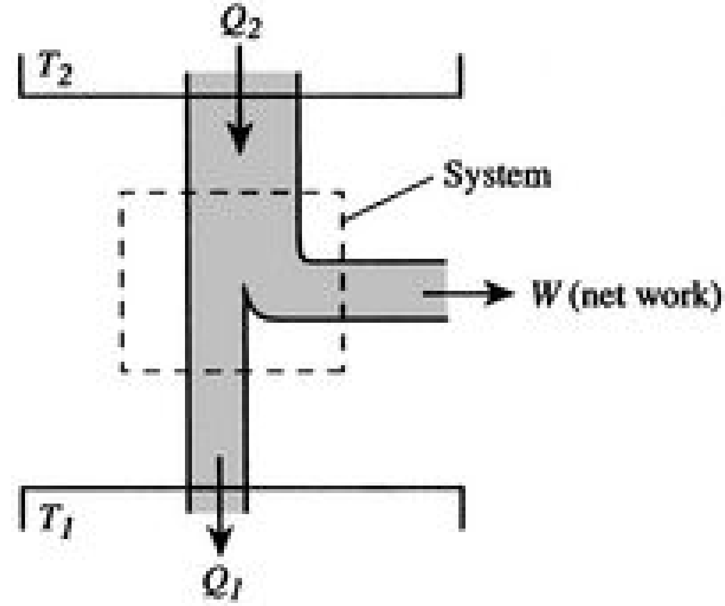
Le rendement des moteurs thermiques



p-V diagram of the gasoline engine

http://universe-review.ca/I13-23-gasoline.jpg

$$\eta = 1 - \frac{T_1}{T_2}.$$ **Carnot cycle efficiency.**



$$\eta = 1 - \frac{293}{400} = 1 - 0{,}73 = 0{,}27 = 27\%$$

http://web.mit.edu/16.unified/www/SPRING/propulsion/notes/node25.html

η_e overall engine efficiency [-]

Table 4 Comparative Data for Motor Vehicle Engines[g]

Engine Type	CR	Peak N (rpm)	bmep (kPa)	bp/D (kW/liter)	bp/W (kW/kg)	bsfc (g/kWhr)	η_e (%)
Spark Ignition							
Motorcycles							
2-stroke	6.5–11	4500–7000[e]	400–550	20–50	0.17–0.40	600–400	14–18
4-stroke	6–10	5000–7500[e]	700–1000	30–60	0.18–0.40	340–270	25–31
Passenger cars							
2-stroke	6–8	4500–5400	450–600	30–45	0.18–0.40	480–340	17–18
4-stroke	7–11[c]	4000–7500[f]	700–1000	20–50	0.25–0.50	380–300	20–28
Rotary	8–9	6000–8000	950–1050	35–45	0.62–1.1	380–300	22–27
Trucks (4-stroke)	7–8	3600–5000	650–700	25–30	0.15–0.40	400–300	16–27
Diesel							
Passenger cars[a]	12–23[d]	4000–5000	500–750	18–22	0.20–0.40	340–240	23–28
Trucks—NA[b]	16–22	2100–4000	600–900	15–22	0.14–0.25	245–220	23–33
Trucks—TC[b]	15–22	2100–3200	1200–1800	18–26	0.14–0.29	245–220	—

[a] Exclusively IDI in United States. 2-stroke and 4-stroke DI may be used in other countries.

[b] NA: naturally aspirated, TC: turbocharged. Trucks are primarily DI.

[c] U.S. average about 9.

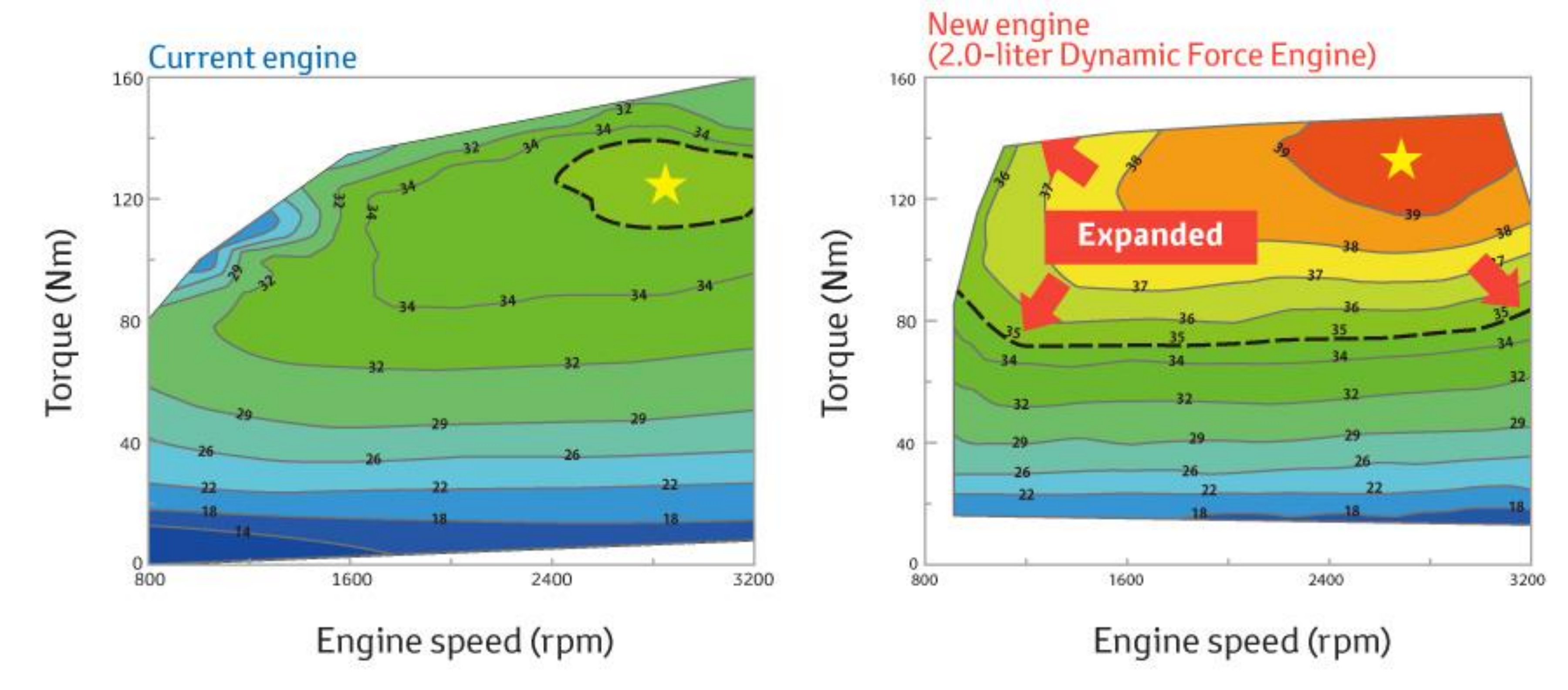
[d] U.S. average about 22.

[e] Many modern motorcycle engines have peak speeds exceeding 10,000 rpm.

[f] Production engines capable of exceeding 6000 rpm are rare.

[g] Adopted with permission from Adler and Bazlen.[3] Design trends to be read left to right.

Mechanical Engineers' Handbook: Energy and Power, Volume 4, Third Edition.
Edited by Myer Kutz



Toyota Gasoline Engine Achieves Thermal Efficiency Of 38 Percent

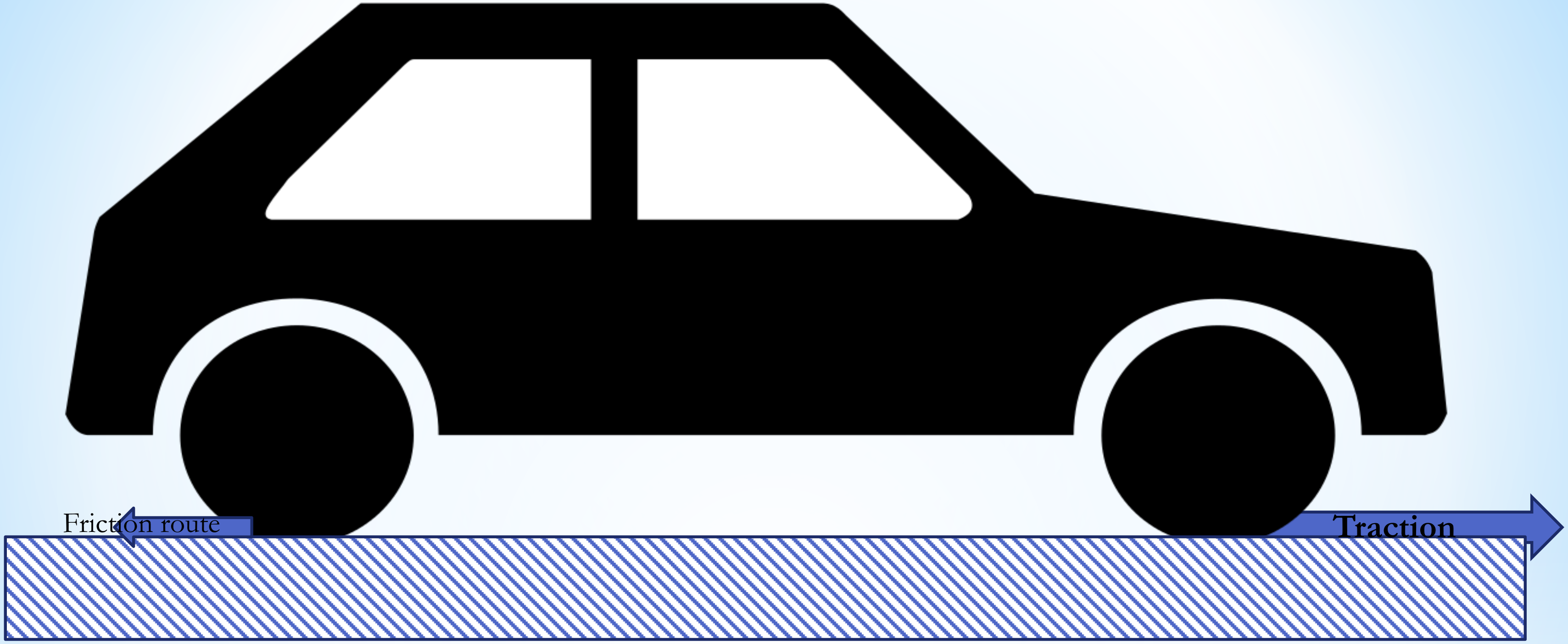
By the end of 2023, Toyota intends to install TNGA-based powertrain units in approximately 80 percent of Toyota vehicles sold annually in Japan, North America, Europe, and China, thereby reducing CO_2 emissions from Toyota vehicles by 18 percent or more2.

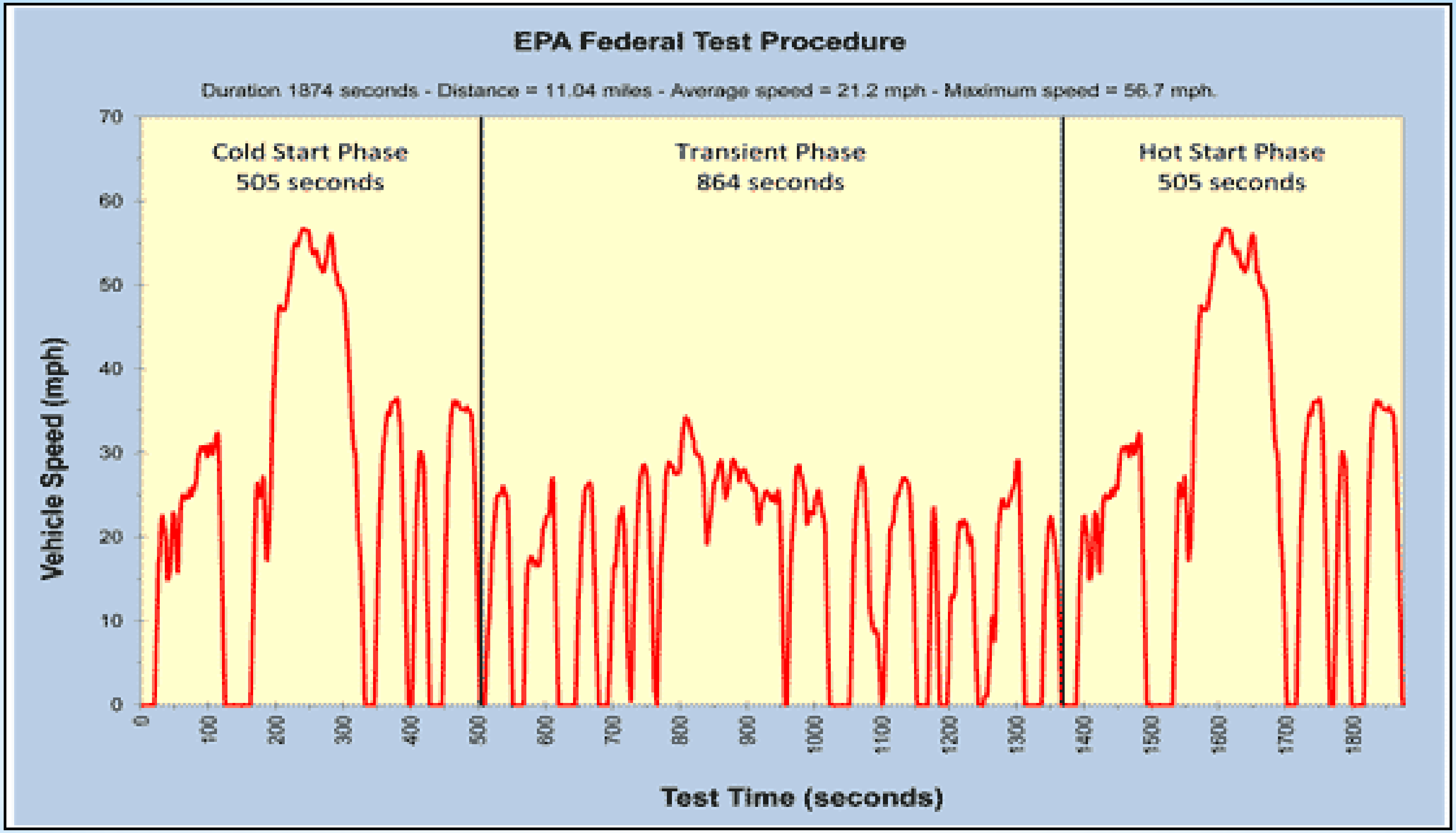
http://media.toyota.ca/fr/categories/innovation-and-advanced-technology
http://media.toyota.ca/releases/toyota-announces-new-powertrain-units-based-on-tnga

Les fondamentaux

La conduite en ville

Auto qui accélère





City: Represents urban driving, in which a vehicle is started with the engine cold and driven in stop-and-go rush hour traffic.

http://www.fueleconomy.gov/feg/fe_test_schedules.shtml

$$K = \text{Énergie cinétique} = \frac{1}{2}mv^2; kg\frac{m^2}{s^2} = kg\frac{m}{s^2}\ m = Nm = Joule$$

$$m = Masse\ de\ l'automobile(kg)$$

$$v = Vitesse\ de\ l'automobile\left(\frac{m}{s}\right)$$

Exemple: Si on accélère de 0 à 50 km/h (14 m/s), quelle énergie dépense-t-on

$$\Delta \boldsymbol{K} = \frac{\mathbf{1}}{\mathbf{2}}\boldsymbol{mv}^{\mathbf{2}} = \frac{\mathbf{1}}{\mathbf{2}}\mathbf{1500}\left(\mathbf{14^2}\right) = \mathbf{147000}\ \boldsymbol{Joules}$$

$\acute{E}nergie\ en\ kWh$

$$\Delta K = \frac{1}{2}mv^2 = \frac{1}{2}1500\ (14^2) = 147000\ Joules$$

Si moteur électrique, en assumant un rendement de 100%

$$1kWh = 1000\frac{J}{s}.1h.3600\frac{s}{h} = 3600000J = 3600kJ$$

Hydro 2016: Les 30 premiers kWh par jour 0,0571 $

$$\frac{147\ kJ}{3600kJ}6¢ \cong 0,25¢$$

Donc cette accélération de 0 à 50 km/h a coûté ~ 1/4¢

Age yr	BMR Basal metabolic rate BMI = 22.0[a]		BMR MJ/d	Physical activity level (PAL)[b] Males MJ/day						BMR MJ/d	Physical activity level (PAL)[b] Females MJ/day					
	Ht (m)	Wt (kg)	Male	1.2	1.4	1.6	1.8	2.0	2.2	Female	1.2	1.4	1.6	1.8	2.0	2.2
51-70	1.5	49.5	-	-	-	-	-	-	-	4.9	6.0	6.9	7.9	8.9	9.8	10.9
	1.6	56.3	5.8	7.0	8.2	9.3	10.4	11.5	12.7	5.2	6.2	7.3	8.3	9.3	10.4	11.4
	1.7	63.6	6.1	7.3	8.6	9.8	11.1	12.3	13.6	5.4	6.5	7.6	8.7	9.8	10.7	12.0
	1.8	71.3	6.5	7.8	9.1	10.4	11.7	13.1	14.4	5.7	6.9	8.0	9.1	10.3	11.4	12.6
	1.9	79.4	6.9	8.3	9.6	11.1	12.4	13.8	15.2	6.0	7.2	8.4	9.6	10.8	12.0	13.2
	2.0	88.0	7.3	8.8	10.2	11.7	13.2	14.7	16.1	-	-	-	-	-	-	-
>70	1.5	49.5	-	-	-	-	-	-	-	4.6	5.6	6.5	7.4	8.3	9.3	10.2
	1.6	56.3	5.2	6.3	7.3	8.3	9.4	10.4	11.5	4.9	5.9	6.9	7.8	8.8	9.8	10.8
	1.7	63.6	5.6	6.7	7.8	8.9	10.0	11.2	12.3	5.2	6.2	7.2	8.3	9.3	10.3	11.4
	1.8	71.3	6.0	7.1	8.3	9.5	10.7	11.9	13.1	5.5	6.6	7.7	8.7	9.8	10.9	12.0
	1.9	79.4	6.4	7.6	8.9	10.2	11.4	12.7	14.0	5.8	6.9	8.1	9.2	10.4	11.5	12.7
	2.0	88.0	6.8	8.1	9.5	10.8	12.2	13.5	14.9	-	-	-	-	-	-	-

$$\frac{6x10^{6}\,{}^{J}/_{jour}}{4200\,{}^{J}/_{Calorie}} \cong 1430\,\frac{Calories}{Jour}\ hommes;\ \frac{5x10^{6}\,{}^{J}/_{jour}}{4200\,{}^{J}/_{Calorie}} \cong 1200\,\frac{Calories}{Jour}\ femmes$$

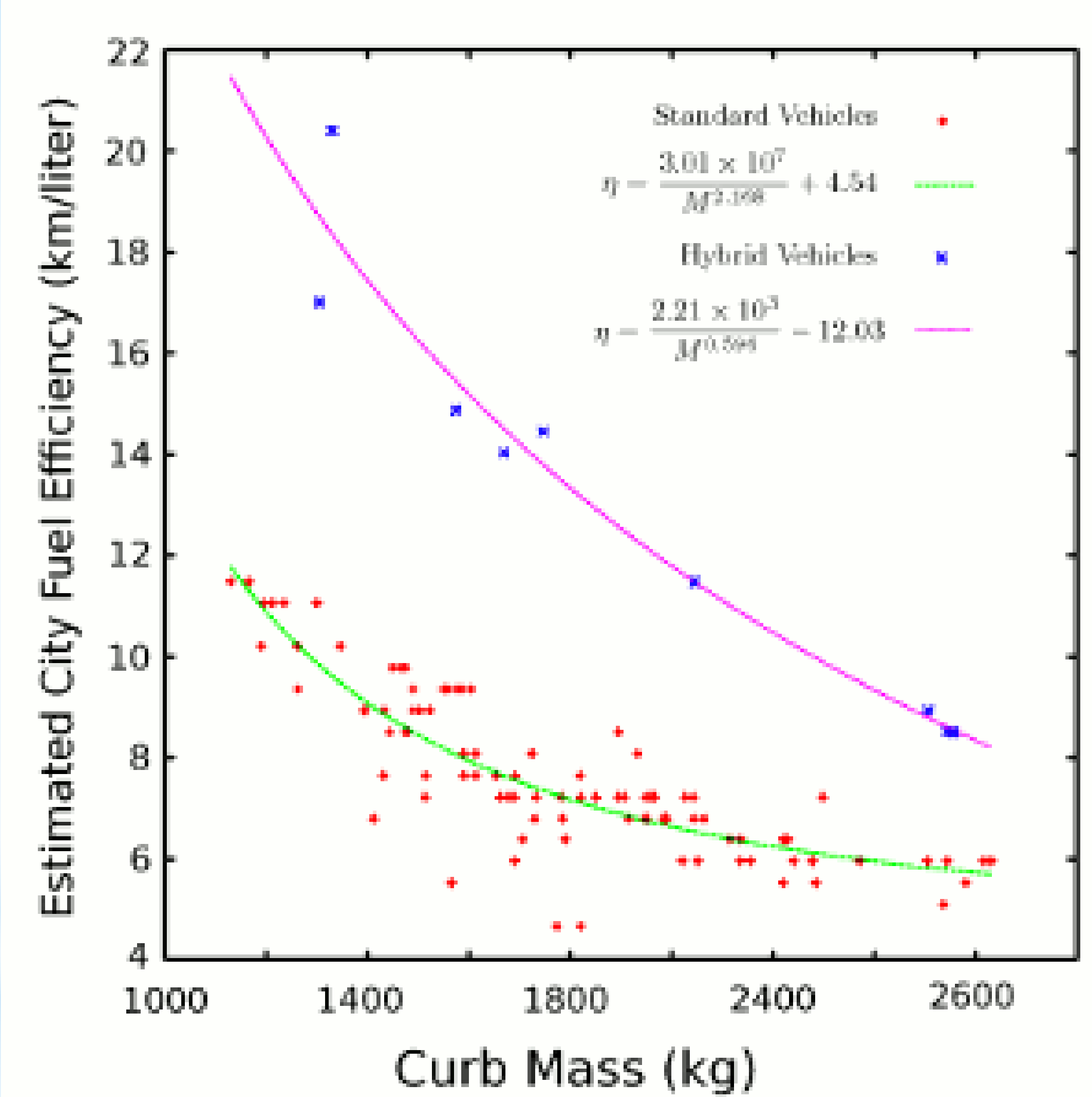
https://www.nrv.gov.au/dietary-energy

Aliments	Mesure	Poids	Énergie	Énergie	Protéines
		g	kcal	kJ	g
Sucres et sucreries					
Sucres, miel et substituts					
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Garnitures et tartinades					
Garniture au chocolat, consistance épaisse	30mL	39	135	564	2
Garniture aux fraises	30mL	43	110	458	tr
Garniture ou tartinade, caramel écossais	30mL	42	105	438	1
Garniture pour tarte aux cerises, en conserve	30mL	25	29	121	tr
Tartinade au chocolat et noisettes (Nutella[MC])	30mL	38	203	848	2

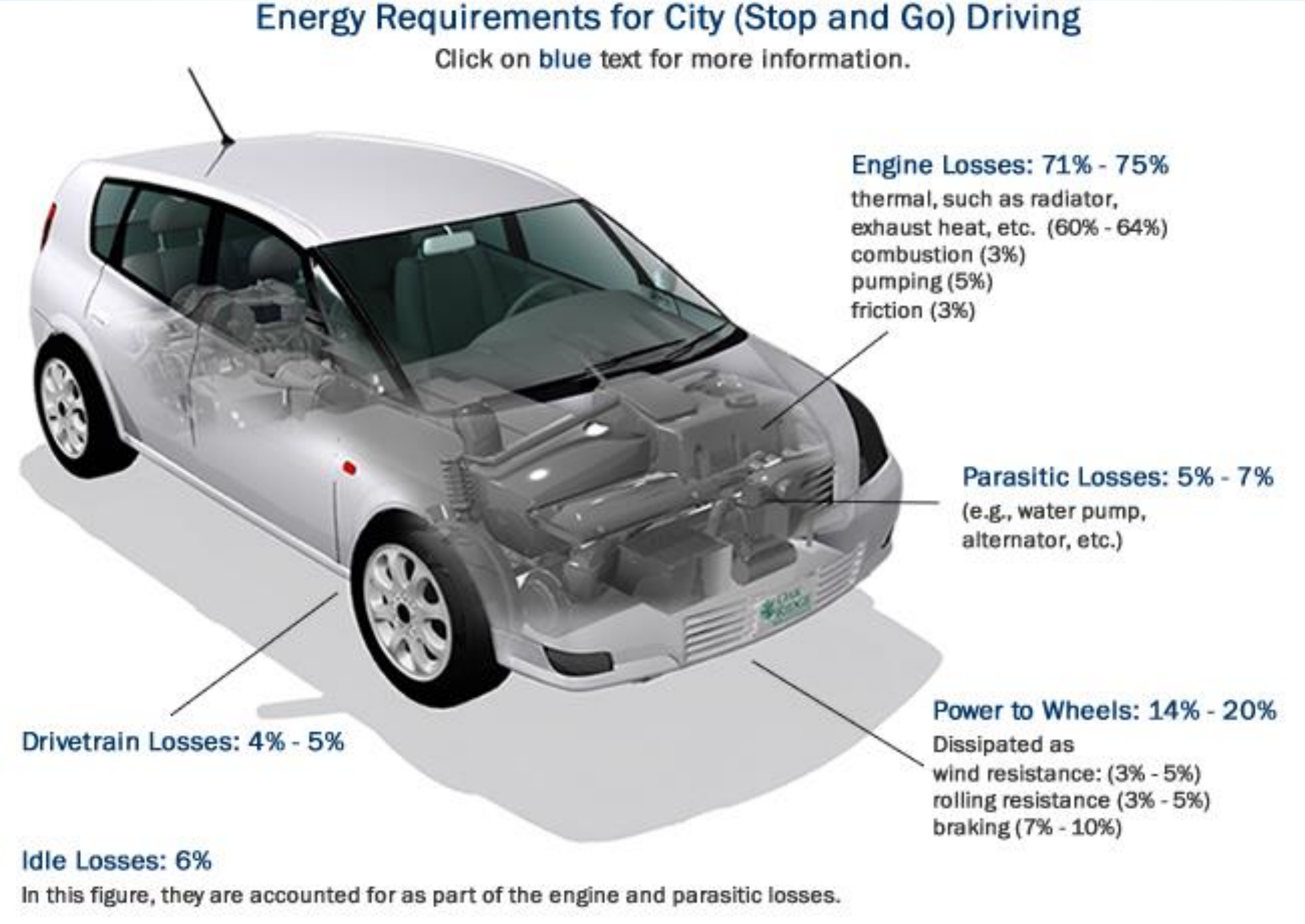
$$Si\ humain = 100W, \gg \frac{147000J}{100\frac{J}{s}} \gg 1470s \approx 24{,}5\ minutes$$

Pour 38 g de Nutella, on obtient 848 kJ ~ 5,8x 147kJ). Ceci signifie que l'énergie est disponible. Le problème c'est la puissance donc la vitesse à laquelle on peut déployer l'énergie.

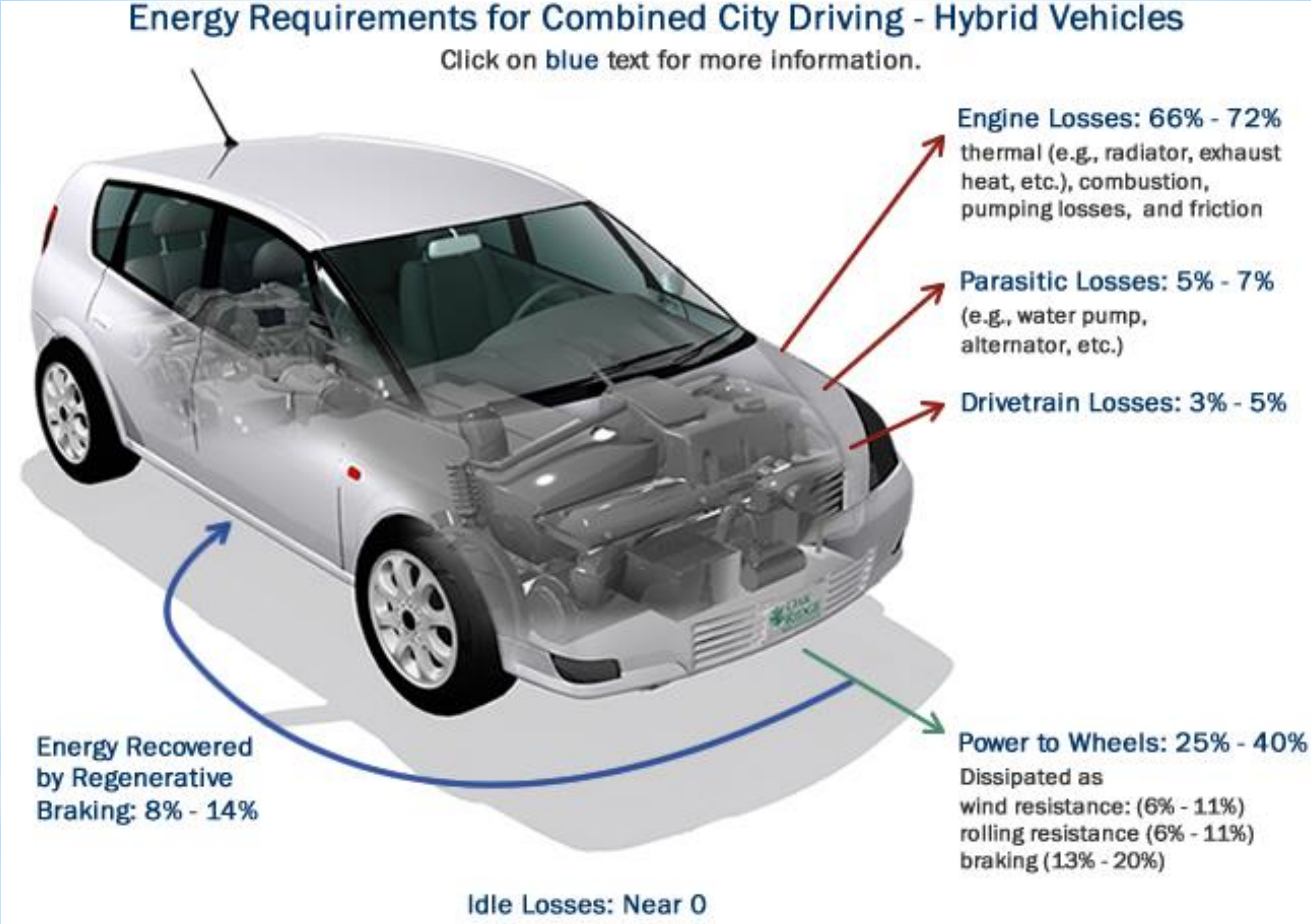
http://www.hc-sc.gc.ca/fn-an/alt_formats/pdf/nutrition/fiche-nutri-data/nvscf-vnqau-fra.pdf



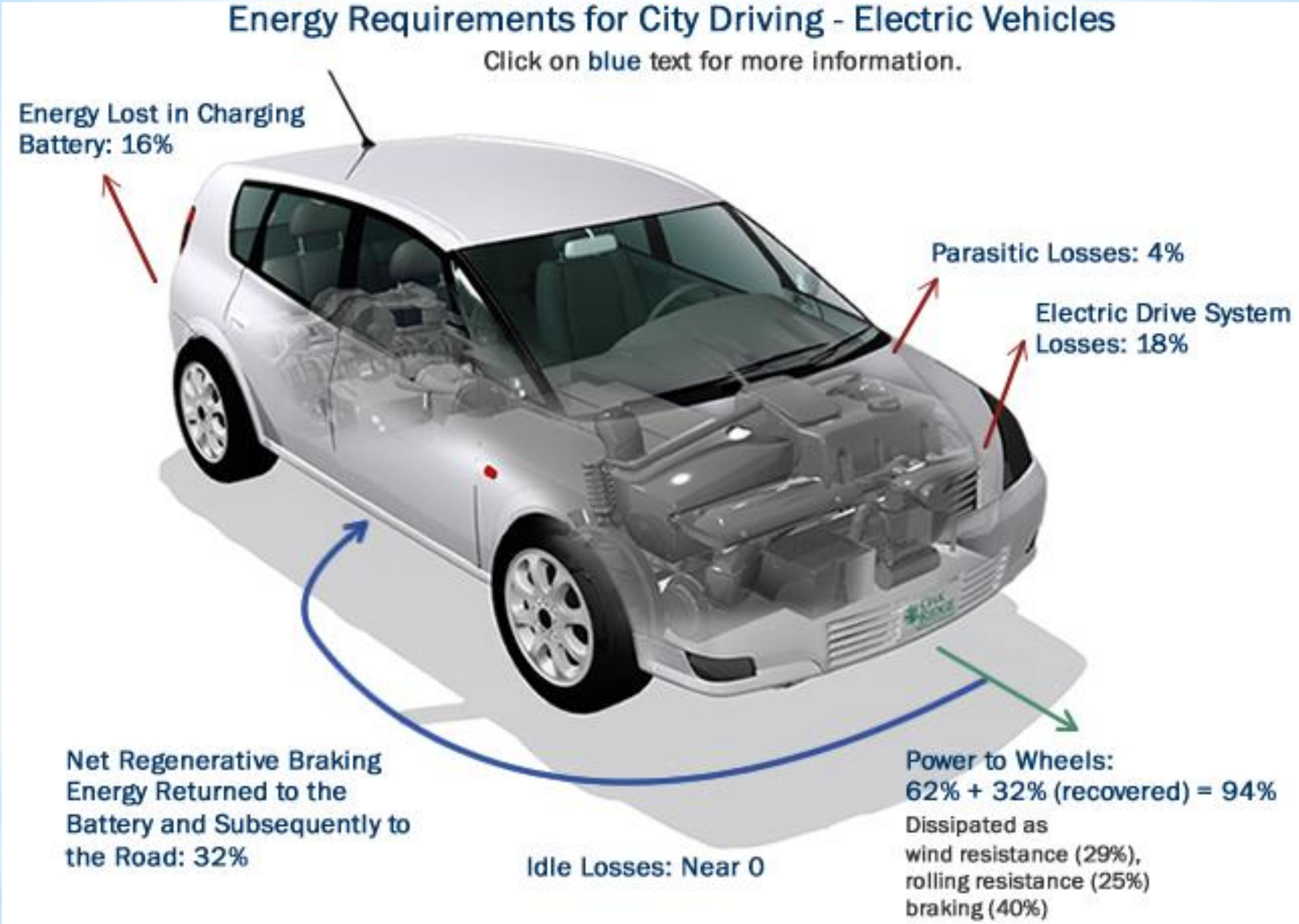
http://large.stanford.edu/courses/2010/ph240/danowitz1/



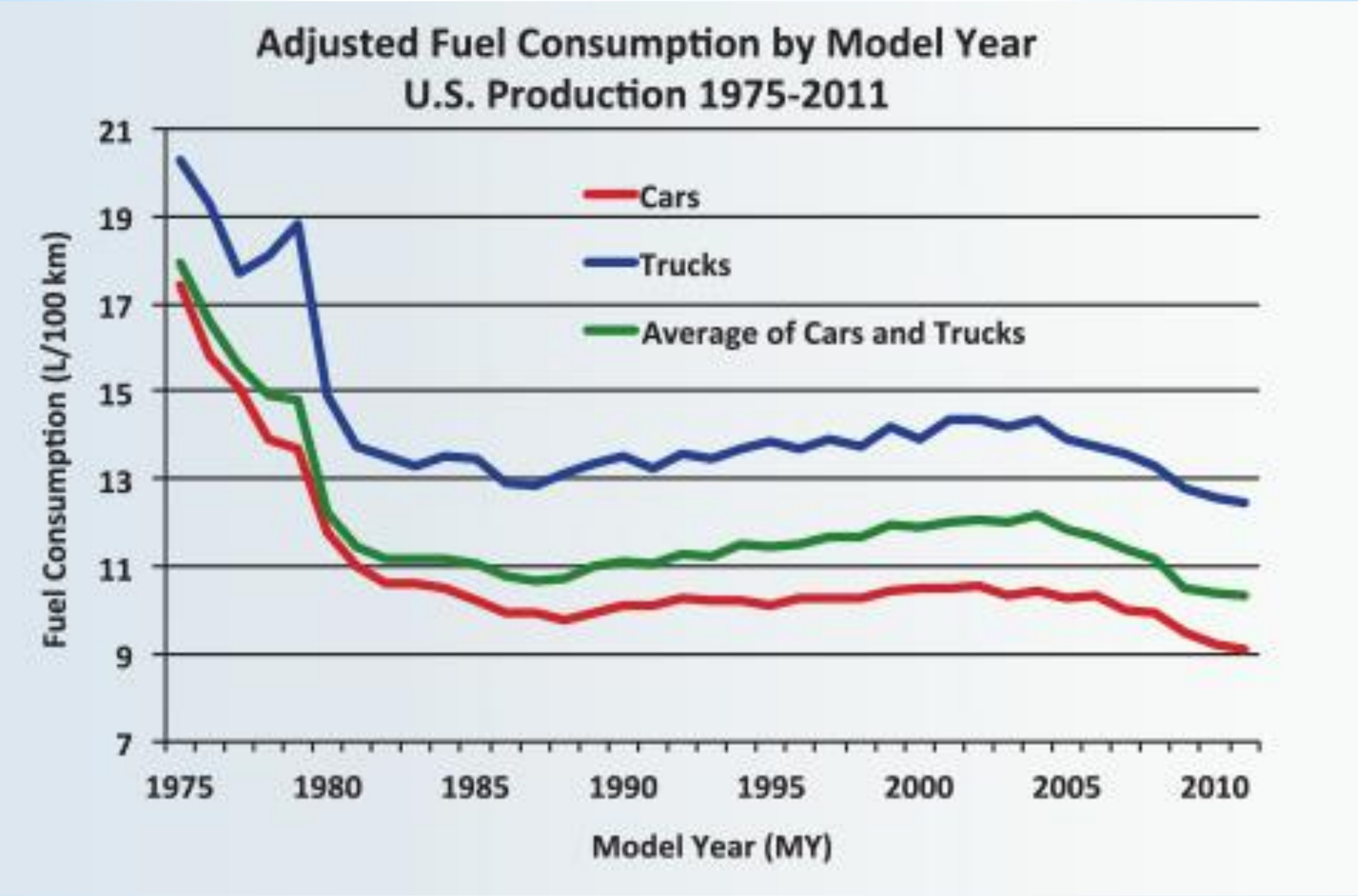
https://www.fueleconomy.gov/feg/atv.shtml



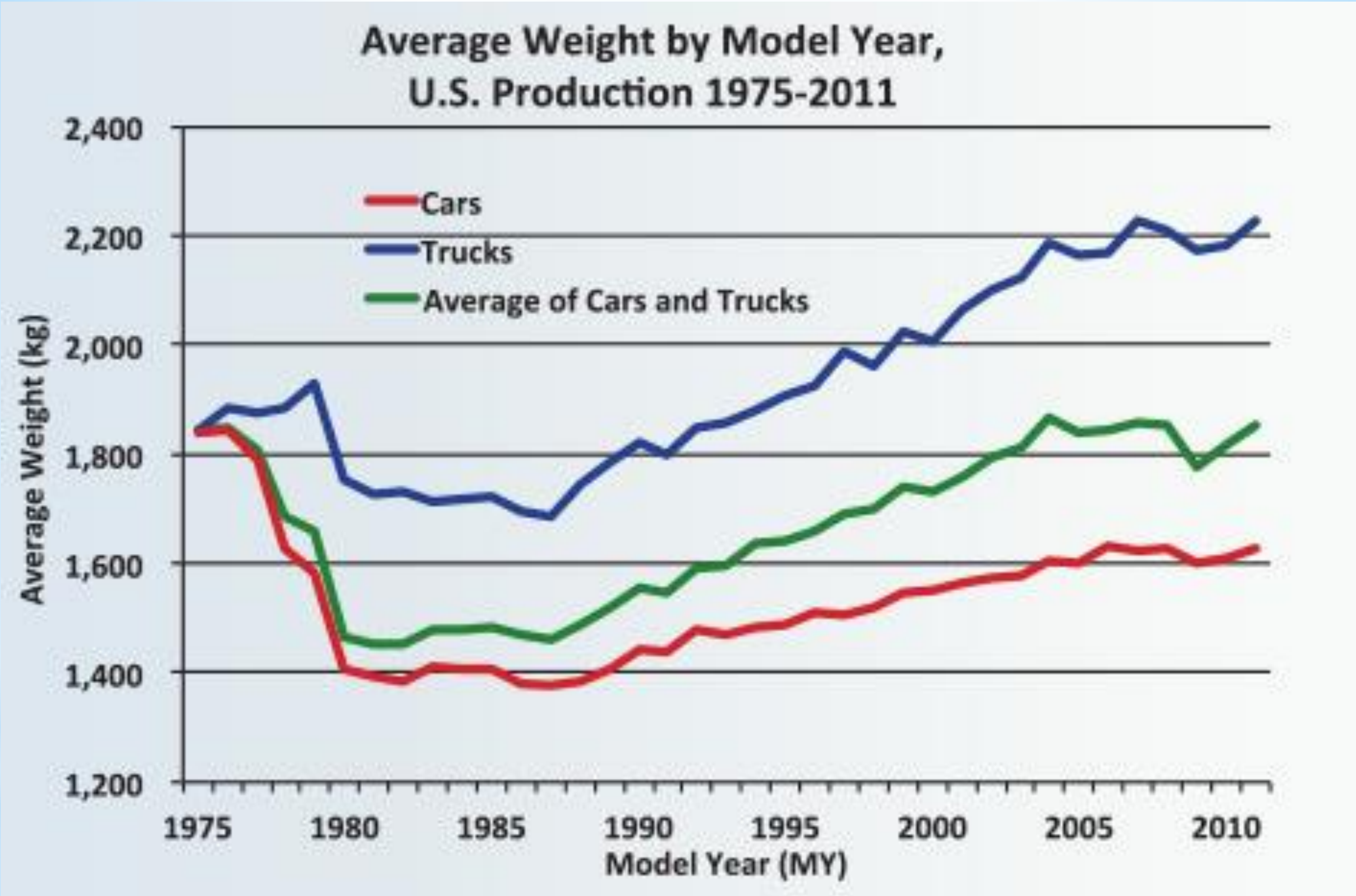
https://www.fueleconomy.gov/feg/atv.shtml



https://www.fueleconomy.gov/feg/atv.shtml



http://www.nrcan.gc.ca/energy/efficiency/transportation/cars-light-trucks/buying/16755

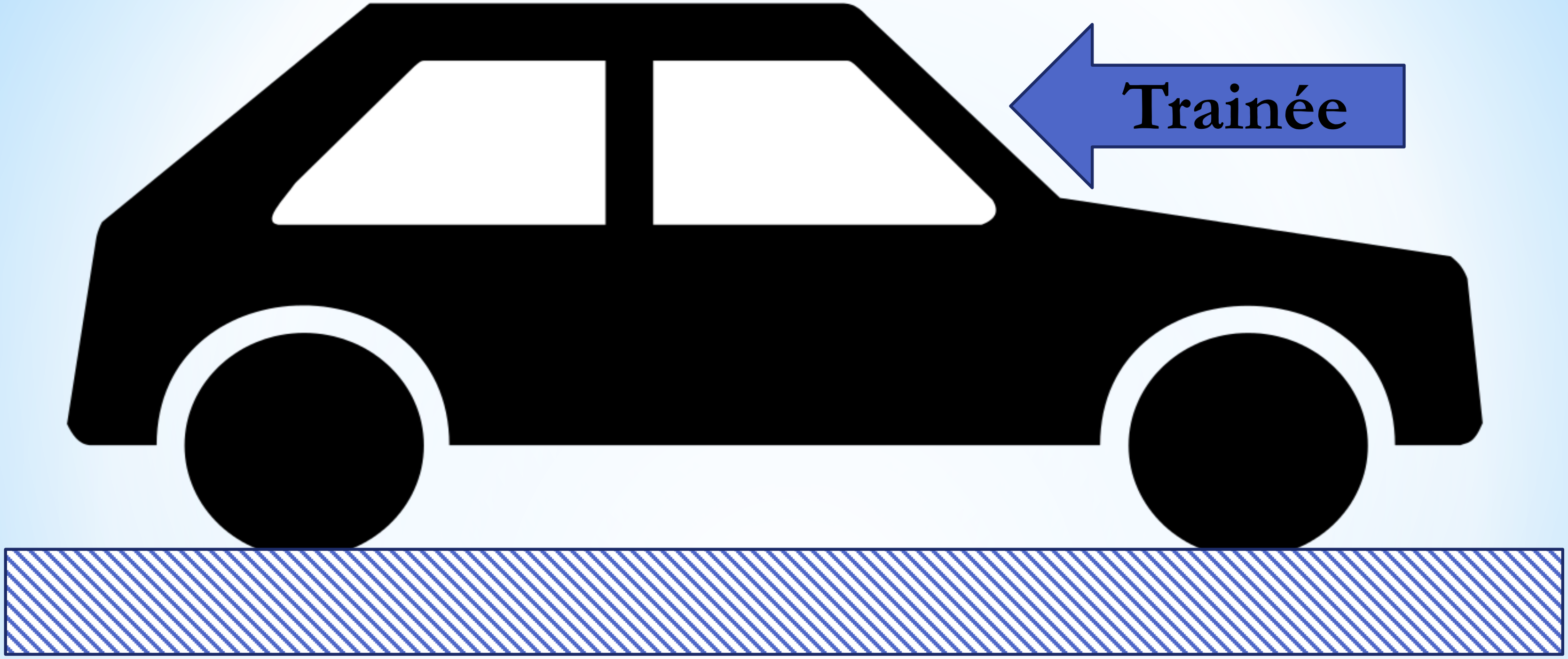


http://www.nrcan.gc.ca/energy/efficiency/transportation/cars-light-trucks/buying/16755

Les fondamentaux

La conduite sur autoroute

Auto à traction avant à vitesse constante



$$T = \frac{1}{2}\rho C_D A V^2;\ \frac{kg}{m^3}\frac{m^2}{s^2}m^2 = \frac{kg.m}{s^2} = N$$

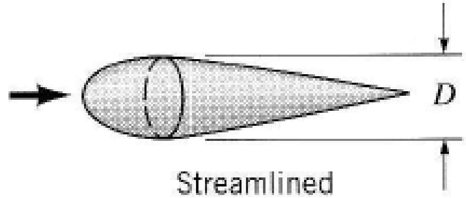
$T = trainée\ en\ Newton$

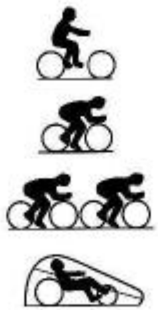
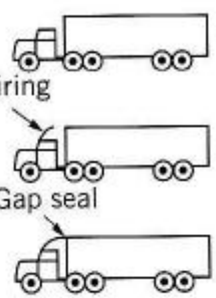
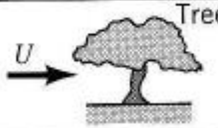
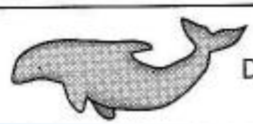
$\rho = Densité\ de\ l'air\ en\ \frac{kg}{m^3}$

$C_D = Coefficient\ de\ trainée$; sans unité

$A = Surface\ frontale\ en\ m^2$

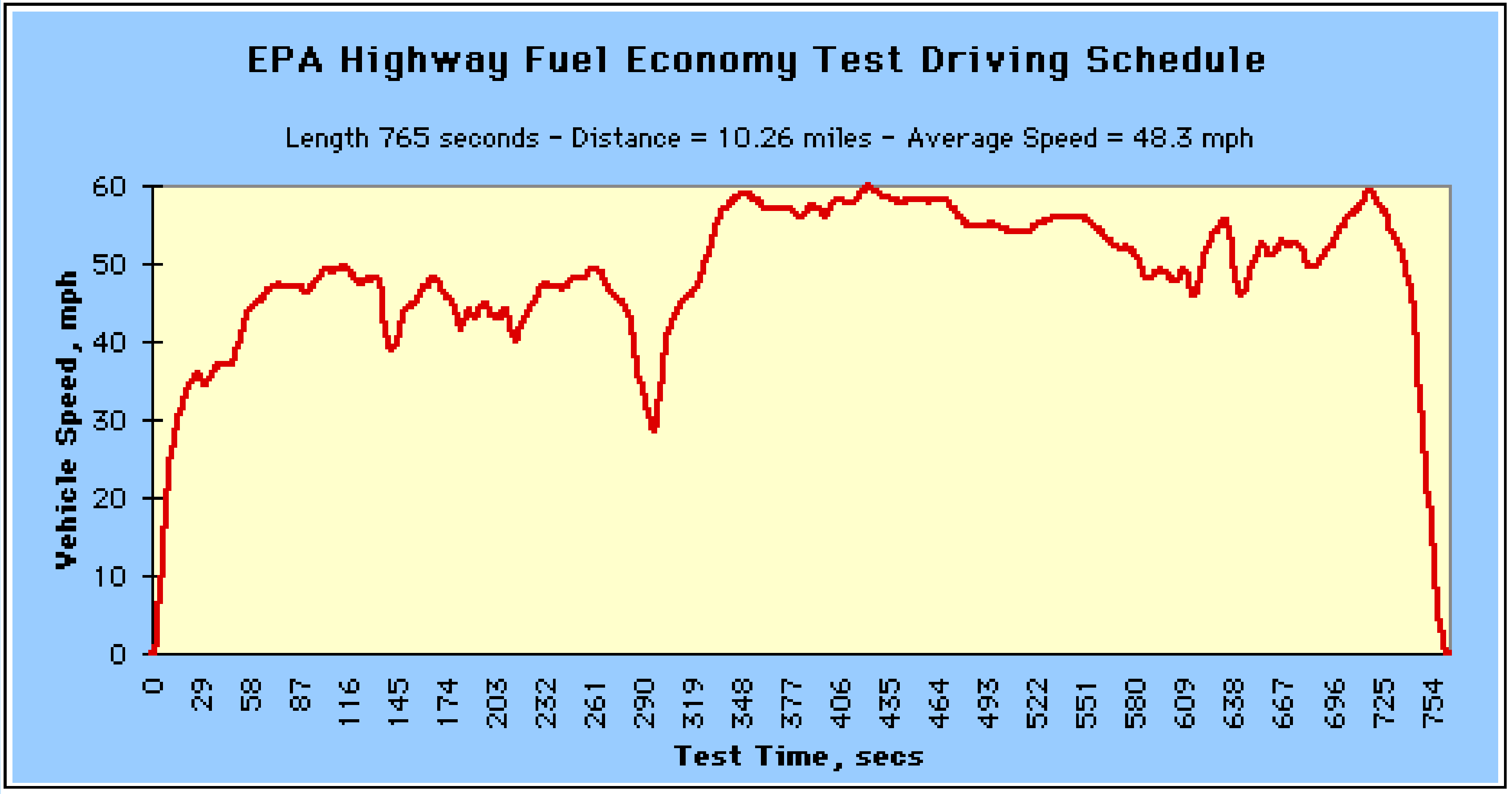
$V = Vitesse\ en\ \frac{m}{s}$

 Streamlined body	$A = \frac{\pi}{4} D^2$	0.04	$Re > 10^5$

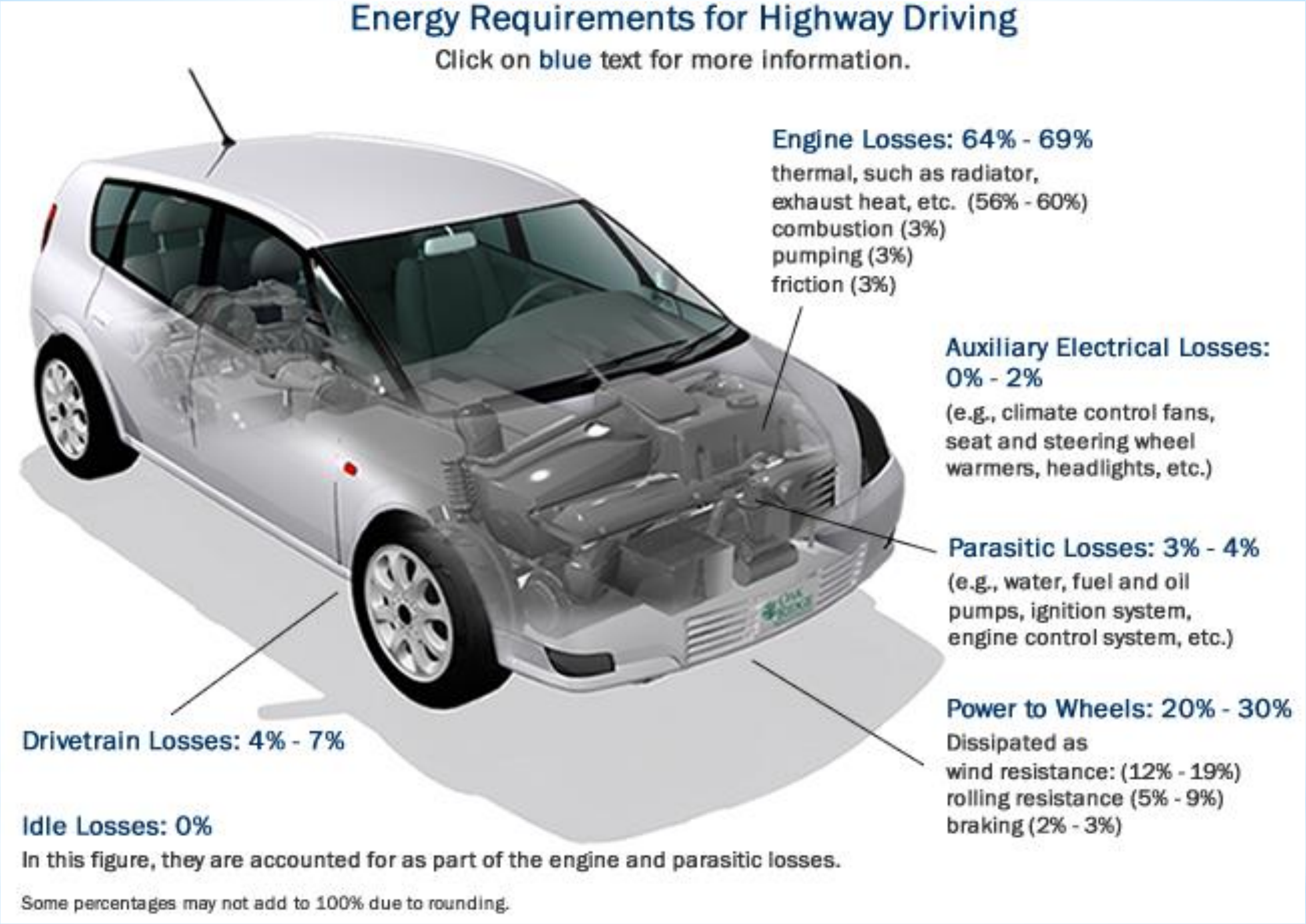
Bikes 		
Upright commuter	$A = 5.5\ ft^2$	1.1
Racing	$A = 3.9\ ft^2$	0.88
Drafting	$A = 3.9\ ft^2$	0.50
Streamlined	$A = 5.0\ ft^2$	0.12
Tractor-trailor tucks 		
Standard	Frontal area	0.96
With fairing	Frontal area	0.76
With fairing and gap seal	Frontal area	0.70
 $U = 10$ m/s $U = 20$ m/s $U = 30$ m/s	Frontal area	0.43 0.26 0.20
 Dolphin	Wetted area	0.0036 at $Re = 6 \times 10^6$ (flat plate has $C_{Df} = 0.0031$)

https://upload.wikimedia.org/wikipedia/commons/d/d9/T77_Advertising-2.jpg

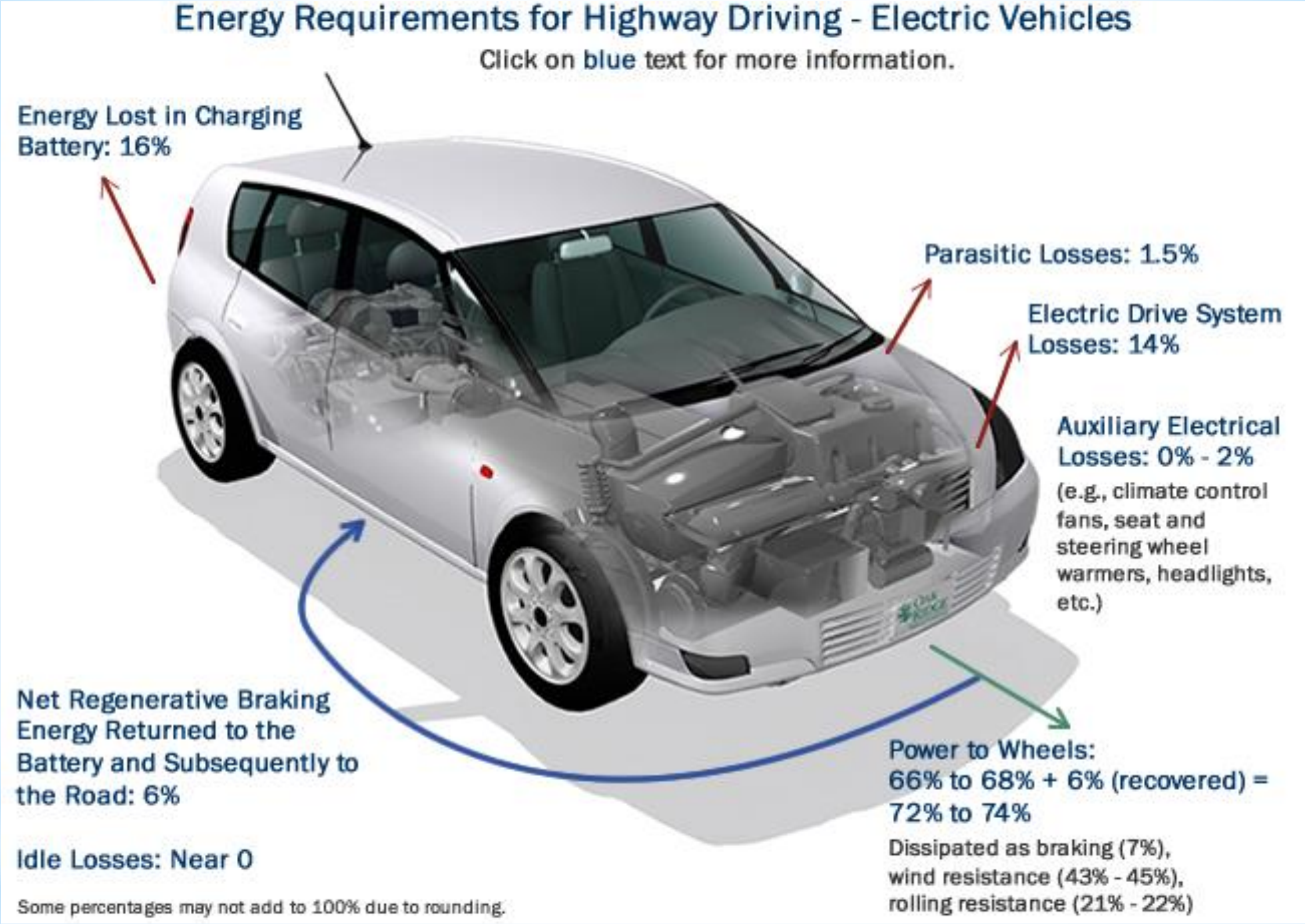
https://upload.wikimedia.org/wikipedia/commons/9/9c/Hummer_H2_.jpg



Highway: Represents a mixture of rural and Interstate highway driving with a warmed-up engine, typical of longer trips in free-flowing traffic.



https://www.fueleconomy.gov/feg/atv.shtml


Energy Requirements for Highway Driving - Electric Vehicles
Click on blue text for more information.
Energy Lost in Charging Battery: 16%
Parasitic Losses: 1.5%
Electric Drive System Losses: 14%
Auxiliary Electrical Losses: 0% - 2%
(e.g., climate control fans, seat and steering wheel warmers, headlights, etc.)
Net Regenerative Braking Energy Returned to the Battery and Subsequently to the Road: 6%
Power to Wheels: 66% to 68% + 6% (recovered) = 72% to 74%
Dissipated as braking (7%), wind resistance (43% - 45%), rolling resistance (21% - 22%)
Idle Losses: Near 0
Some percentages may not add to 100% due to rounding.

Type de Carburant	Densité énergétique spécifique (MJ/kg)	Densité énergétique volumétrique (MJ/L)	CO_2 produit par combustion (kg/kg)
Bois ((C6H10O5)n)	16 – 21		1,88
Méthanol (CH3-OH)	19,9 – 22,7	15,9	1,37
Éthanol (CH3-CH2-OH)	23,4 – 26,8	23,4	1,91
Biodiesel	37,8	33,3 – 35,7	~2,85
Huile de tournesol (C18H 32O2)	39,49[5]	33,18	2,81
Méthane (CH4)	55 – 55,7	(liquéfié) 23,0 – 23,3	2,74
Dihydrogène (H2)	120 – 142	(liquéfié) 8,5 – 10,1	0,0
Charbon	29,3 – 33,5	39,85 - 74,43	~3,59
Essence	45 – 48,3	32 – 34,8	~3,30
Gazole (Diesel)	48,1	40,3	~3,4
Gaz naturel	38 – 50	(liquéfié) 25,5 – 28,7	~3,00
Uranium-235 (235U)	77 000 000	(Pur)1 470 700 000	0,0
Fusion	300 000 000		0,0
Batterie au plomb	0,108	~0,1	(~600 cycles)
Lithium ion	0,54 - 0,72	0,9 - 1,9	300-500 cycles)
Lithium-Ion-Polymer	0,65 - 0,87	(1,2 * Li-Ion) 1,08 - 2,28	300-500 cycles)

Un réservoir d'essence de 60 L peut potentiellement donner 60L * 35 MJ/L ~ 2000MJ ce qui correspond à environ ½ tonne de TNT. (1 tonne de TNT ~ 4000 MJ)

https://fr.wikipedia.org/wiki/Carburant

https://fr.wikipedia.org/wiki/%C3%89quivalent_en_TNT

$Ex.$ Honda Civic $C_d A = 0{,}654;\ V = 100\frac{km}{h} \gg v = 28\frac{m}{s}$

$$T = \frac{1}{2}C_D A\rho V^2 = \frac{1}{2}0{,}654 * 1{,}2 * \ 28^2 \ = 307N$$

Si la vitesse est constante, La traction doit être de 307N

Le système mécanique doit fournir au minimum le travail

$$W = Fd = 307 * 250000 \ = 77MJ$$

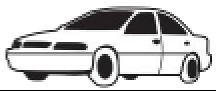
$Ex.$ *Honda Civic* $C_d A = 0{,}654, V = 100\frac{km}{h} \gg v = 100\frac{km}{h} x1000\frac{m}{km} x\frac{1}{3600}\frac{h}{s} = 27{,}7\frac{m}{s}$

$$T = \frac{1}{2} C_D A \rho V^2 = \frac{1}{2} 0{,}654 * 1{,}2 * 28^2 = 307N$$

$Si\ la\ vitesse\ est\ constante, La\ traction\ doit\ être\ de\ 307N$

Si la résistance de l'air représente 1/7 (~15%) de la dépense énergétique, ceci signifie que le besoin en énergie fournie par l'essence pour vaincre la résistance de l'air sera au minimum 77,4MJ* 7= 542MJ. Puisque l'essence génère 35MJ/litre, on aura besoin de 542MJ/35MJ/L soit 15 litres pour 250 km soit 6 L/100km.

A



VOITURES

MARQUE / MODÈLE	CATÉGORIE	CYLINDRÉE (L)	CYLINDRES	TRANSMISSION	CARBURANT	CONSOMMATION (L/100 KM)			$ PAR AN	ÉMISSIONS DE CO_2 (g/km)	INDICE DE CO_2	INDICE DE SMOG
						VILLE	ROUTE	COMBINÉE				
CIVIC COUPE	C	1,5	4	AV	X	7,5	5,9	6,8	1 333 $	158	8	3
CIVIC COUPE	C	1,5	4	M6	X	7,7	5,7	6,8	1 333 $	158	8	3
CIVIC COUPE	C	2,0	4	AV	X	7,8	6,0	7,0	1 372 $	163	8	3
CIVIC COUPE	C	2,0	4	M6	X	8,5	6,1	7,4	1 450 $	173	7	3
CIVIC COUPE Si	C	1,5	4	M6	Z	8,4	6,2	7,4	1 687 $	173	7	3
CIVIC HATCHBACK	L	1,5	4	AV	X	7,7	6,0	6,9	1 352 $	162	8	3
CIVIC HATCHBACK	L	1,5	4	AV7	X	7,9	6,6	7,3	1 431 $	170	7	3
CIVIC HATCHBACK	L	1,5	4	M6	X	8,0	6,2	7,2	1 411 $	167	8	3
CIVIC HATCHBACK SPORT	L	1,5	4	AV7	Z	7,9	6,6	7,3	1 664 $	170	7	3
CIVIC HATCHBACK SPORT	L	1,5	4	M6	Z	8,0	6,2	7,2	1 642 $	167	8	3
CIVIC SEDAN	M	1,5	4	AV	X	7,4	5,6	6,6	1 294 $	153	8	3
CIVIC SEDAN	M	2,0	4	AV	X	7,8	6,0	7,0	1 372 $	163	8	3
CIVIC SEDAN	M	2,0	4	M6	X	8,5	6,0	7,4	1 450 $	172	7	3
CIVIC SEDAN Si	M	1,5	4	M6	Z	8,4	6,2	7,4	1 687 $	173	7	3

$Ex.$ $Nissan\ Leaf$; $C_d A = 0{,}725, V = 100\frac{km}{h} \gg v = 100\frac{km}{h} x 1000\frac{m}{km} x \frac{1}{3600}\frac{h}{s} = 27{,}7\frac{m}{s}$

$$T = \frac{1}{2} C_D A \rho V^2 = \frac{1}{2} 0{,}725 * 1{,}2 * \ 28^2 = 341N$$

Dans le cas d'une Nissan Leaf électrique, pour le trajet Qc-Mtl, (250 km à 100km/h) on devra dépenser pour vaincre la résistance de l'air 341 N * 250000= 85MJ. Si la résistance de l'air représente 1/2,2 (45%) de la dépense énergétique, ceci signifie que l'énergie fournie par la batterie pour vaincre la résistance de l'air sera de 85MJ* 2,2 = 188MJ. Puisque 1 kW-h = 3,6 MJ, ceci représente 52 kW-h, soit 21 kW-h/ 100 km. Ceci équivaut à 5,4 L d'essence soit 2,2L/ 100km.

Marque ModèleCaractéristiques Note de bas de page2	Carb	Ville/Route/Comb kWh/100km Ville/Route/Comb L_e/100 km	$/an	CO_2 (g/km)	Indice de CO_2	Indice de smog	Autonomie (km)	Temps de recharge (h)

NISSAN LEAF

Marque ModèleCaractéristiques	Carb	Ville/Route/Comb	$/an	CO_2 (g/km)	Indice de CO_2	Indice de smog	Autonomie (km)	Temps de recharge (h)
M, 80 kW, A1	B	17,0 / 20,7 / 18,6 1,9 / 2,3 / 2,1	484 $	0	10	10	172	6

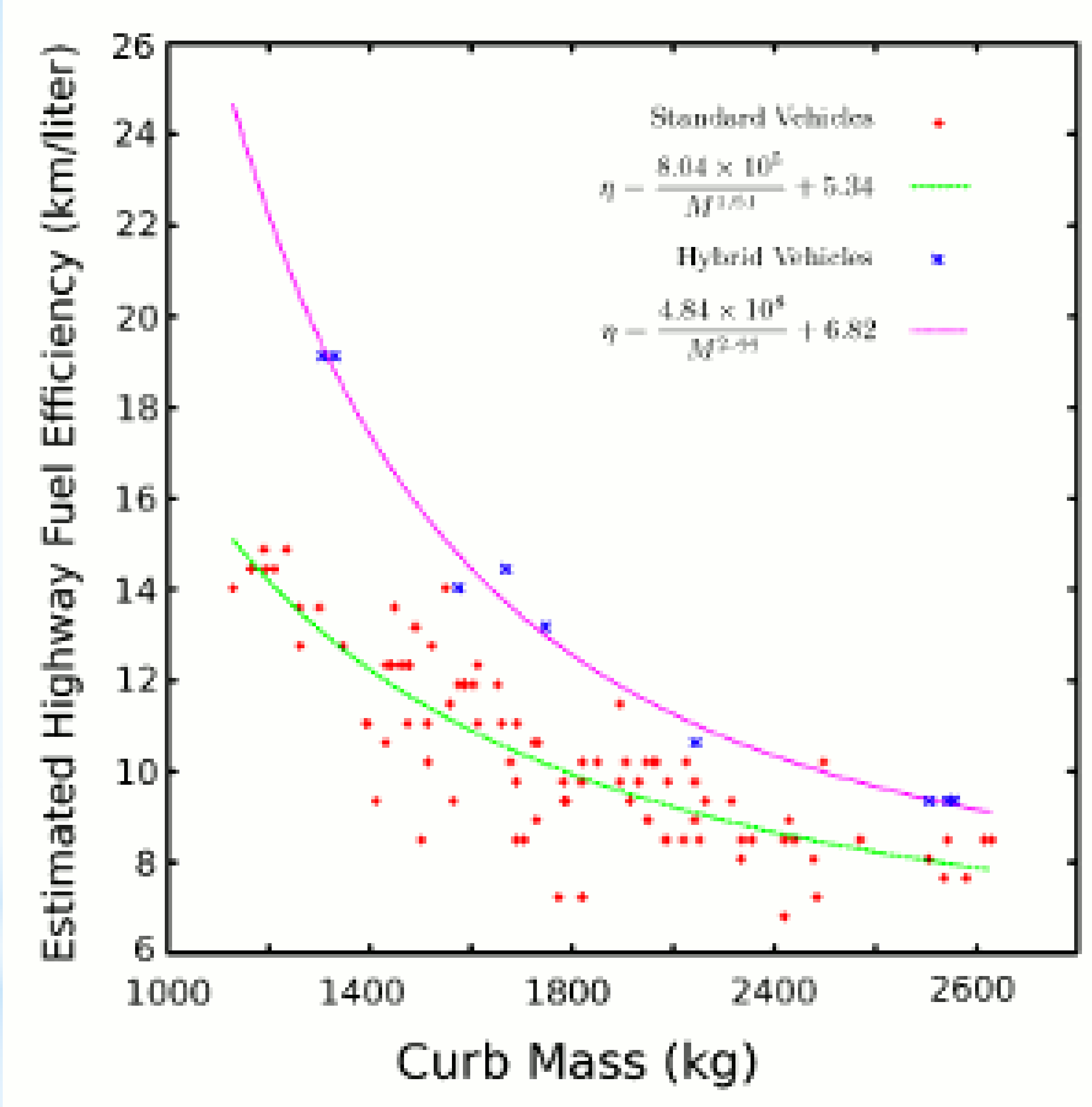
https://www.rncan.gc.ca/energie/efficacite/transports/voitures-camions-legers/achats/20238

Énergie pour accélérer de 0 à 100 km/h

Par opposition à l'énergie nécessaire pour parcourir toute la distance Qc-Mtl, l'énergie pour accélérer est négligeable.

$$\Delta K = \frac{1}{2} m v^2 = \frac{1}{2} 1500 \left(28^2\right) = 588000\, Joules \sim 0,6\ MJ$$

Ainsi, on a besoin de 0,6MJ pour passer de 0 à 100 km/h et on a besoin de 77 MJ pour parcourir la distance Qc-Mtl à 100km/h.



http://large.stanford.edu/courses/2010/ph240/danowitz1/

2017

Rank	Team n°	Team name	Country	Organization	Institution type	Competition category	Energy type	Best attempt (mpg (us))
1	1	Alerion Supermileage	Canada	Universite Laval	University	Prototype	Gasoline	2713.1
2	23	BYU SMV	United States	Brigham Young University	University	Prototype	Gasoline	1708.9
3	36	Mater Dei Supermileage 2	United States	Mater Dei High School	School	Prototype	Gasoline	1550.7

2713 miles per us gallon

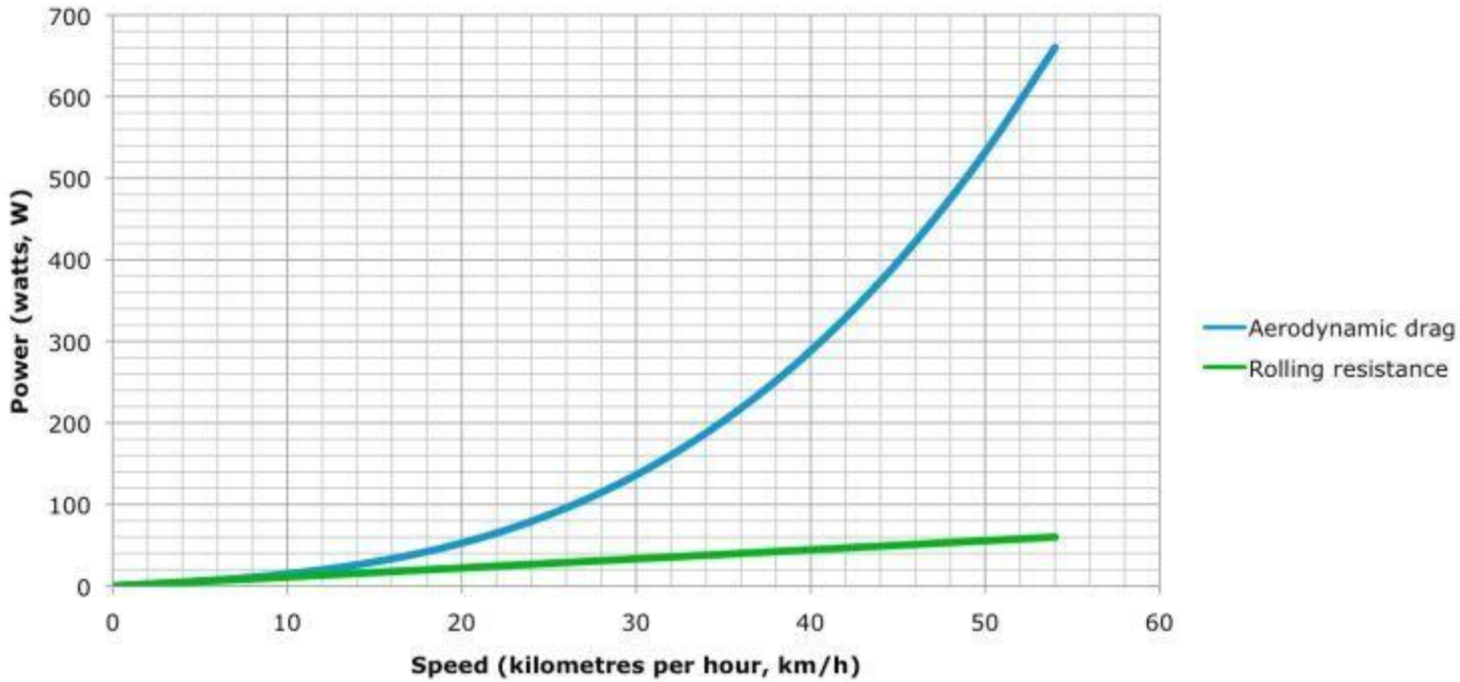
=0,09L/100km

Cd=0,07

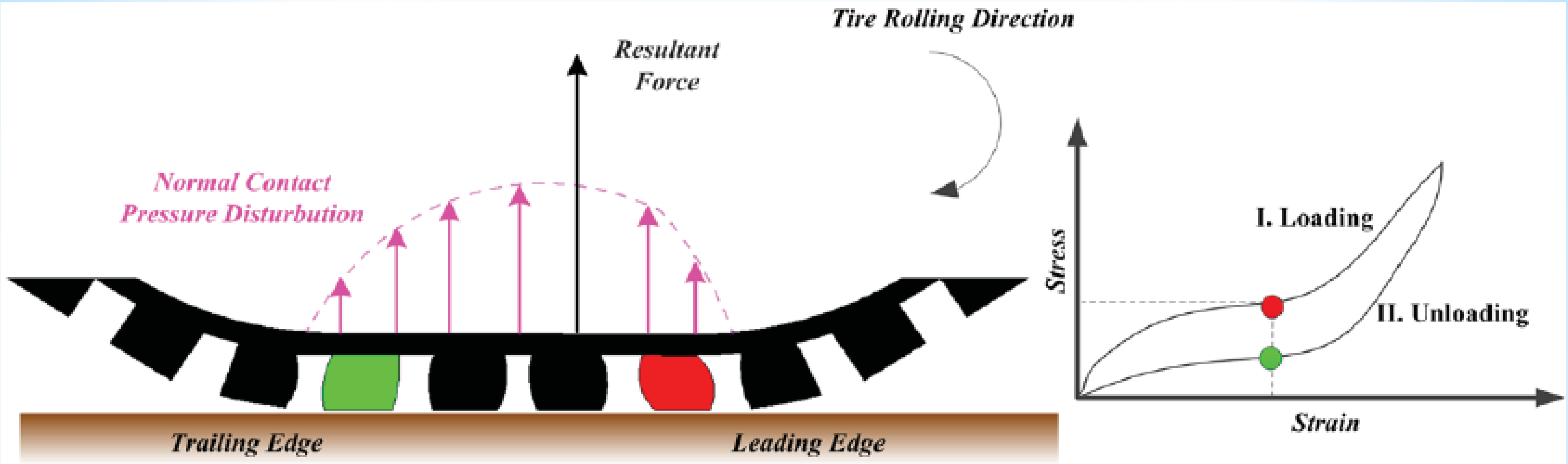
We are thrilled to share that we earned 1st place for the first time at the Shell Eco-Marathon Americas for our battery-electric prototype vehicle! It got colder and windier with each of our attempts, but we managed to improve on each consecutive one. Final attempt: 296 mi/kWh, or 9,977 MPGe.

0,02 L/100km

We're proud to have the most fuel efficient electric vehicle in the country, and look forward to showing it off (and the incredible trophy) when it returns to Duke!

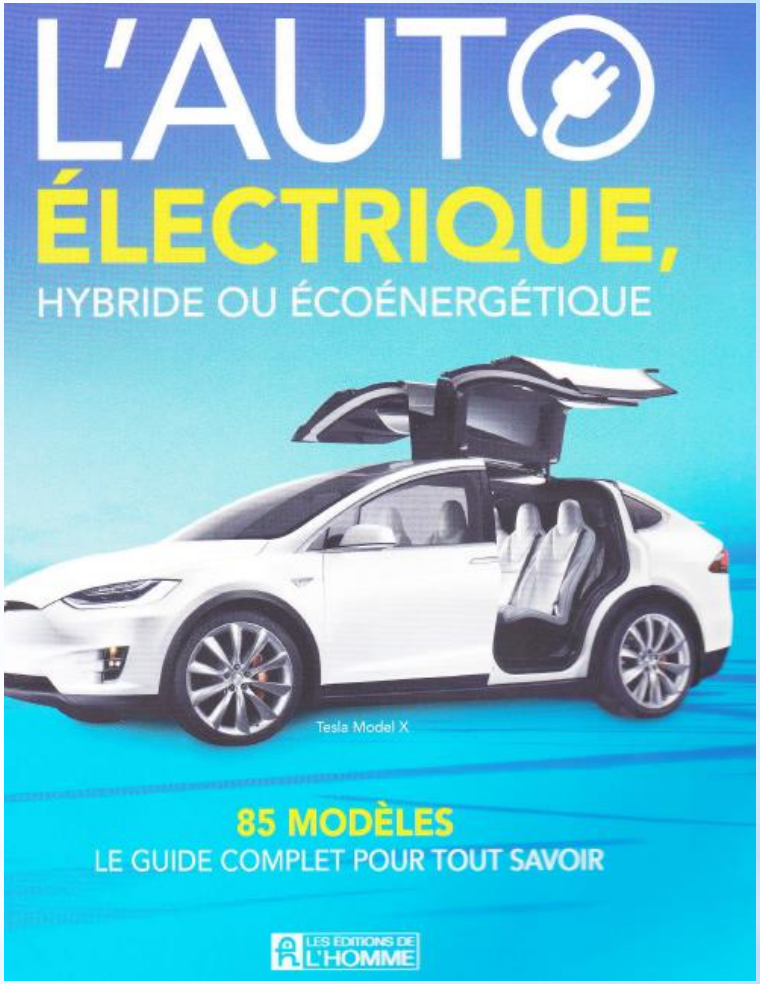


https://www.sciencelearn.org.nz/images/1658-power-needed-to-counter-aerodynamic-drag-and-rolling-resistance



https://www.researchgate.net/publication/266620763_A_laser-based_sensor_system_for_tire_tread_deformation_measurement/figures?lo=1


DANIEL BRETON JACQUES DUVAL PIERRE LANGLOIS
L'AUTO ÉLECTRIQUE
... ET PLUS !
LES ÉDITIONS DE L'HOMME


L'AUTO ÉLECTRIQUE,
HYBRIDE OU ÉCOÉNERGÉTIQUE
Tesla Model X
85 MODÈLES
LE GUIDE COMPLET POUR TOUT SAVOIR
LES ÉDITIONS DE L'HOMME

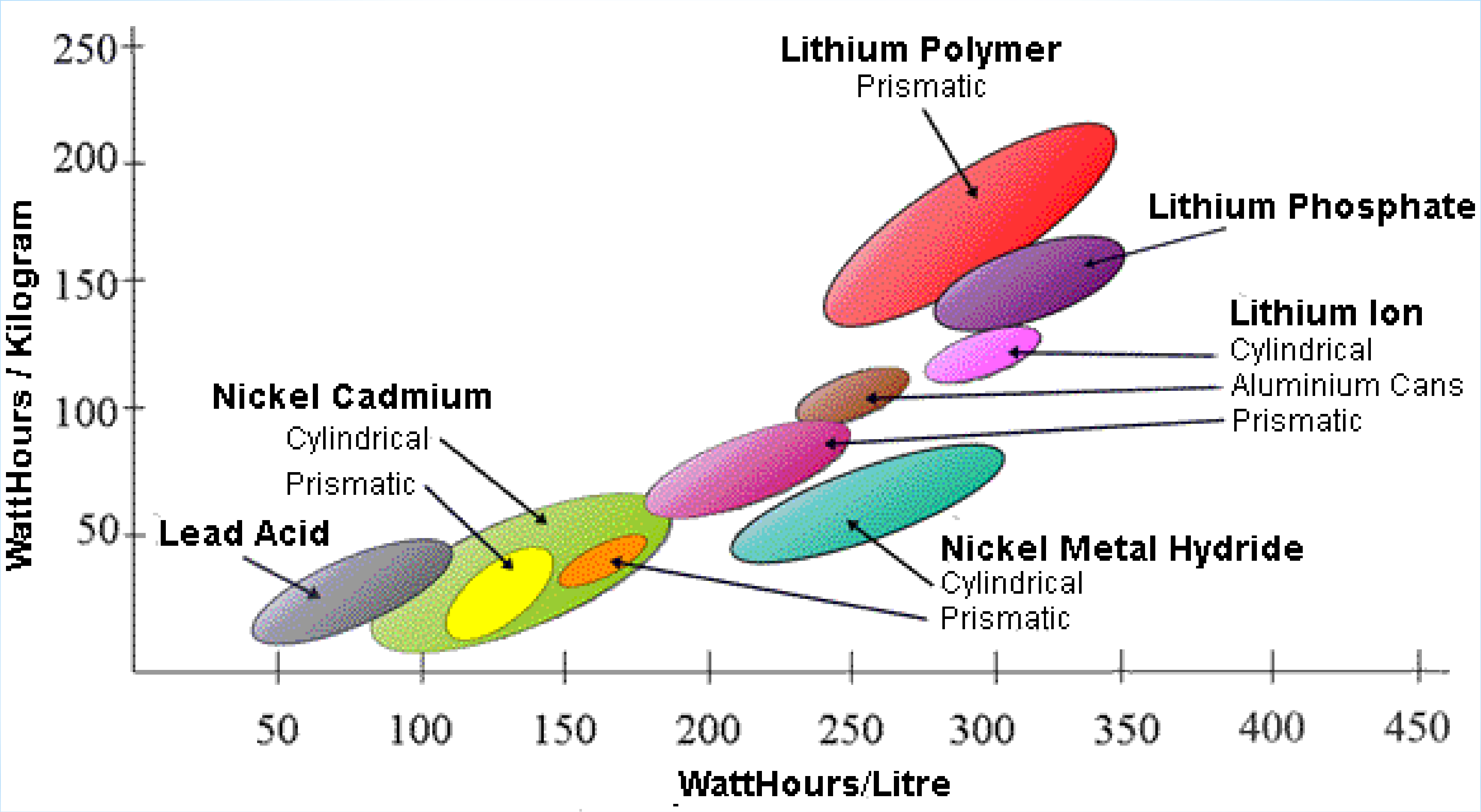
Batterie lithium-ion.

TOUTES LES BATTERIES NE SONT PAS NÉES ÉGALES

PIERRE LANGLOIS

Dans le texte qui suit, nous exposerons les principales caractéristiques des diverses batteries que l'on trouve sur le marché pour les véhicules.

IMPORTANT : Lorsqu'on caractérise la durée de vie des batteries en nombre de cycles de recharge, on considère des recharges profondes (plus de 80 % de la capacité de stockage), et la limite correspond au moment où la batterie a perdu 20 % de sa capacité initiale.



http://www.mpoweruk.com/chemistries.htm

Nissan Leaf

Type	Laminated lithium-ion battery
Voltage	**403.2V** [1]
Nominal voltage	**360V** [2]
Total capacity	**24 kWh**
Power output	Over 90 kW
Energy density	140 Wh/kg
Power density	2.5 kW/kg

$$En\ électricité, P = VI; \gg I_{max} = \frac{90kW}{400V} = 225A$$

http://www.electricvehiclewiki.com/Battery_specs

Battery Type	Year	Cost ($/kWh)
Lead acid		256.68
Li-Ion	2016	145[27]
Li-Ion	2014	200–300[28]
Li-Ion	2012	400[30]
Li-Ion	2012	500–600[29]
Li-Ion	2012	520-650[31]
Li-Ion	2012	689[31]
Li-Ion	2010	750[33]
Li-Ion	2012	752[31]
Li-Ion	2013	800–1000[32]
Nickel Metal Hydride		350[35]
Nickel Metal Hydride	2013	500–550[32]
Nickel Metal Hydride	2004	750[34]

https://en.wikipedia.org/wiki/Electric_vehicle_battery

La capacité des batteries dans les voitures électriques

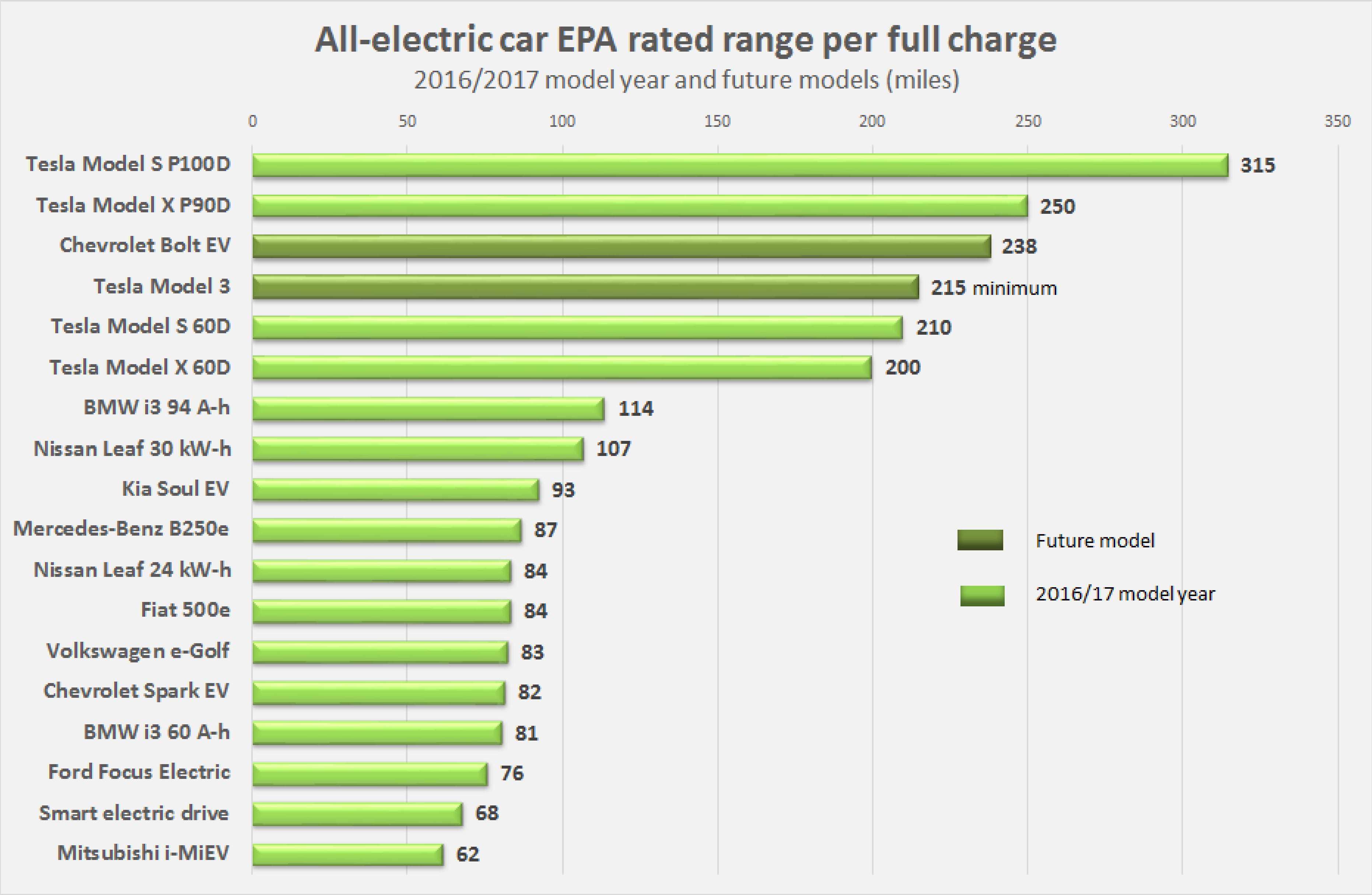
Bolt (60 kWh; 320 km) = 60 * 3,6 MJ= 216 MJ

Puisqu'un litre d'essence représente 35 MJ

cela signifie que la Chevrolet Bolt a une réserve d'énergie

correspondant à 216MJ/35MJ/L = ~ 6 L.

https://en.wikipedia.org/wiki/Electric_vehicle_battery

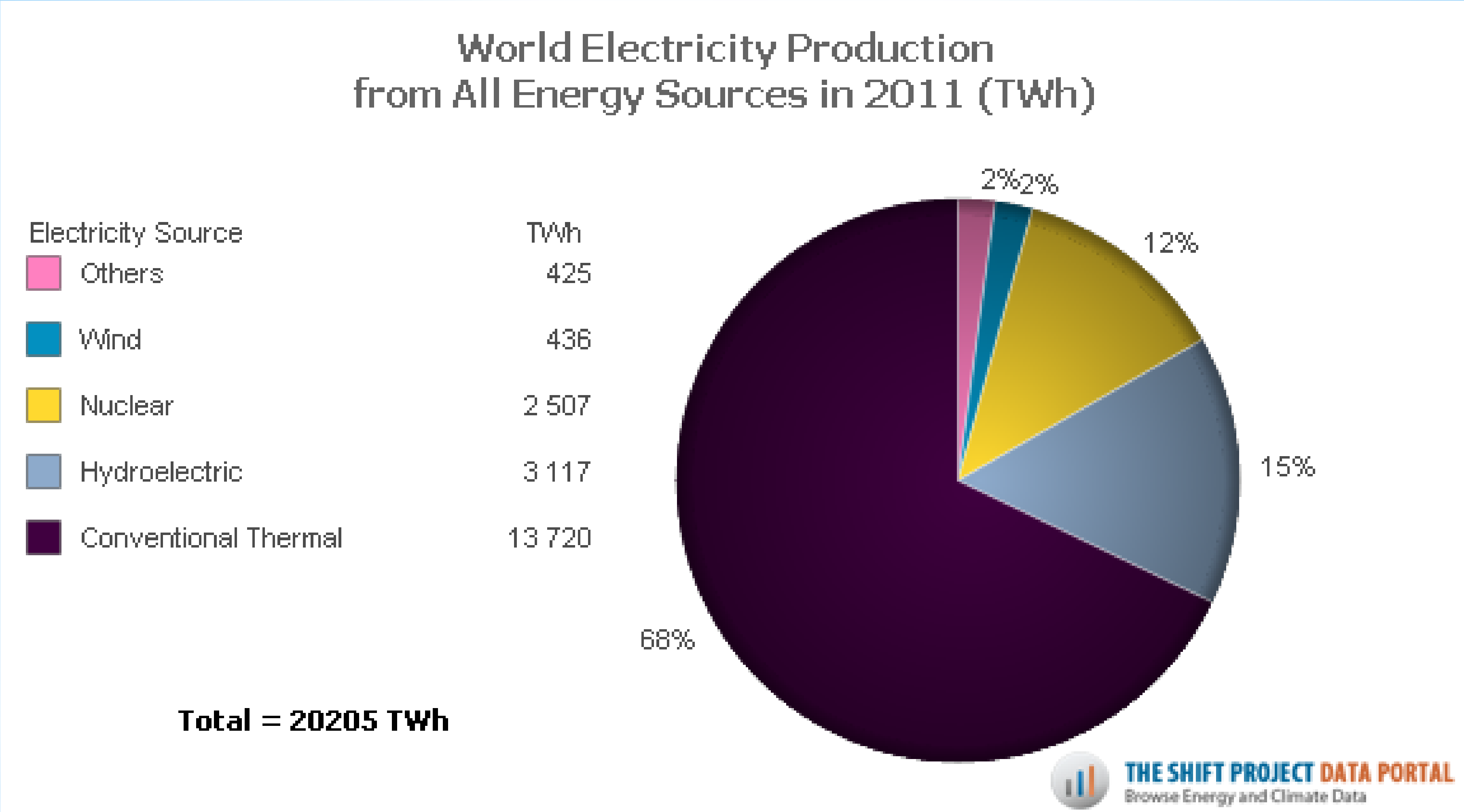


https://en.wikipedia.org/wiki/Battery_electric_vehicle

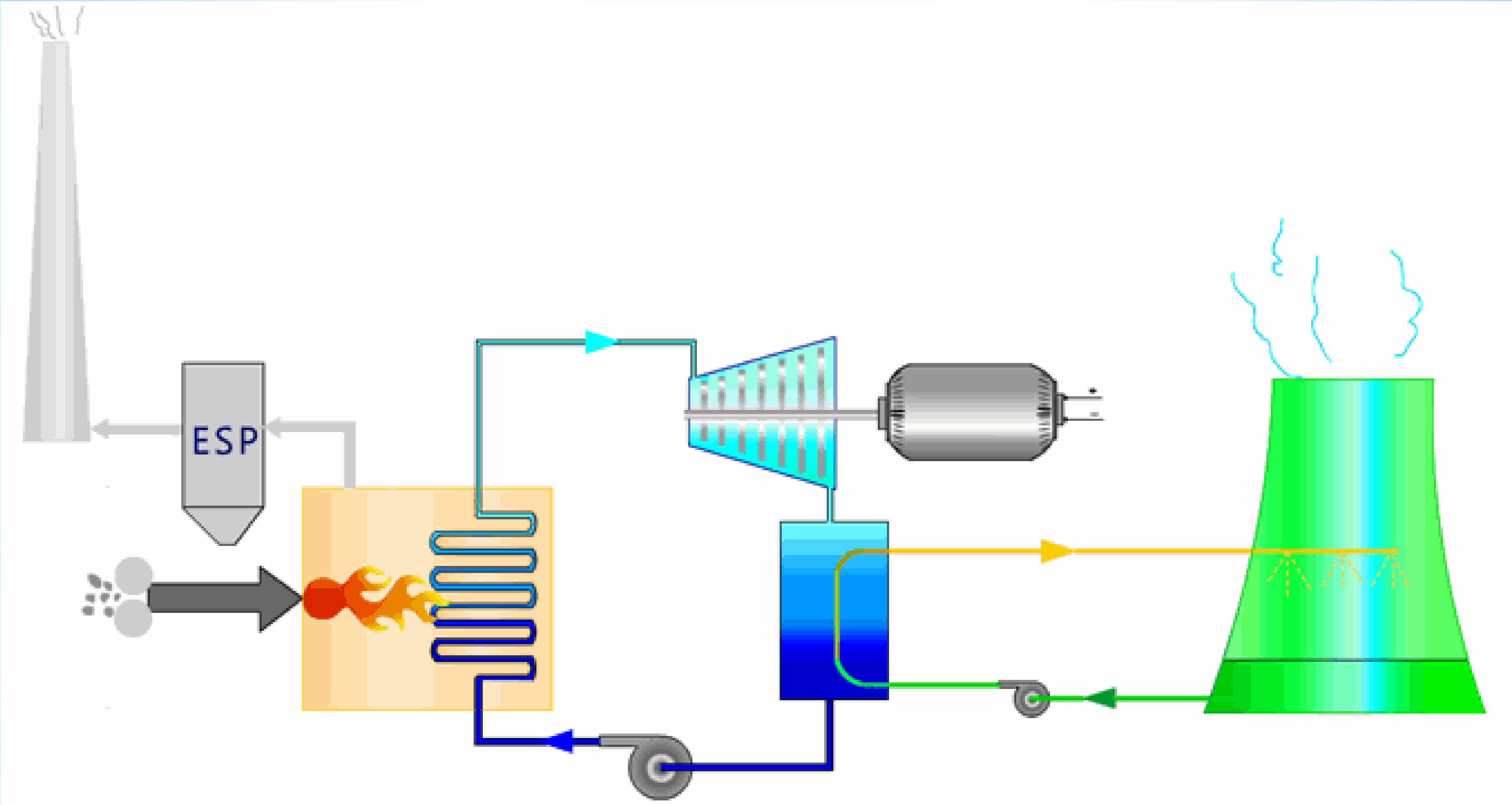
Battery Type	Year of Estimate	Cycles	Miles	Years
Li-Ion	2016	>4000[37]	1,000,000[37]	>10[38]
Li-Ion			100,000[39]	5[39]
Li-Ion			60,000	5
Li-Ion	2002			2-4[40]
Li-Ion	1997	>1,000[41]		
Nickel Metal Hydride	2001		100,000[42]	4[42]
Nickel Metal Hydride	1999	>90,000[43]		
Nickel Metal Hydride			200,000[35]	
Nickel Metal Hydride	1999	1000[44]	93,205.7[44]	
Nickel Metal Hydride	1995	<2,000[45]		
Nickel Metal Hydride	2002	2000[40]		
Nickel Metal Hydride	1997	>1,000[46]		
Nickel Metal Hydride	1997	>1,000[41]		
Lead acid	1997	300–500[41]		

https://en.wikipedia.org/wiki/Electric_vehicle_battery

La génération de l’électricité



http://www.tsp-data-portal.org/Breakdown-of-Electricity-Generation-by-Energy-Source#tspQvChart



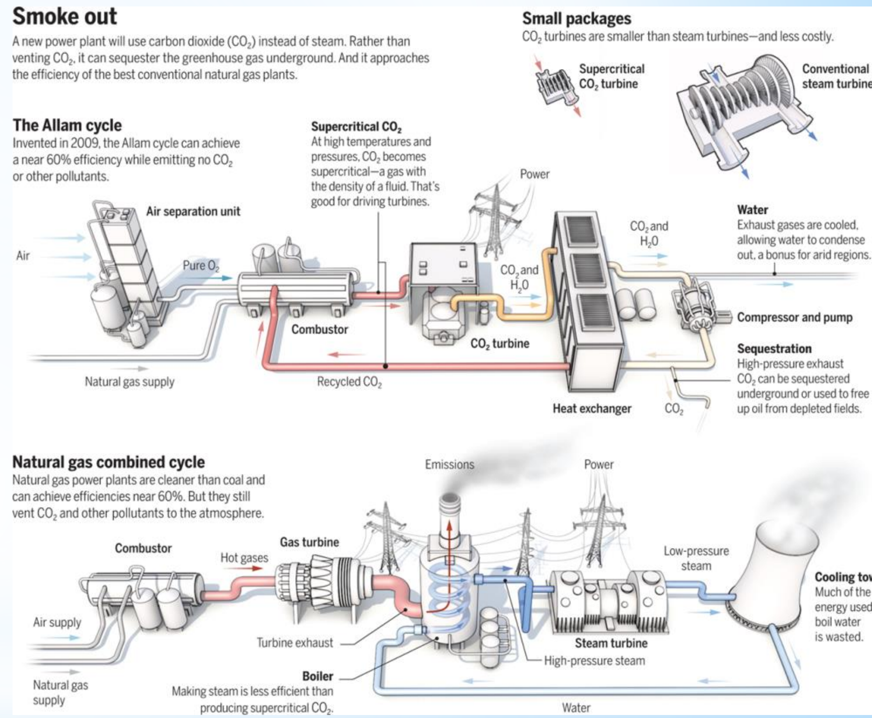
http://www.learnengineering.org/2013/01/thermal-power-plant-working.html

Wind, solar, and innovative fossil fuel plants can all deliver energy without carbon emissions. But they can't address a continuing threat to climate: existing fossil fuel plants, which still generate two-thirds of the world's electricity. If humankind has any hope of sticking to a temperature rise of 2°C or less, as nations pledged to do in the 2015 Paris accords, carbon capture and storage (CCS) systems must be bolted onto these plants—and quickly.

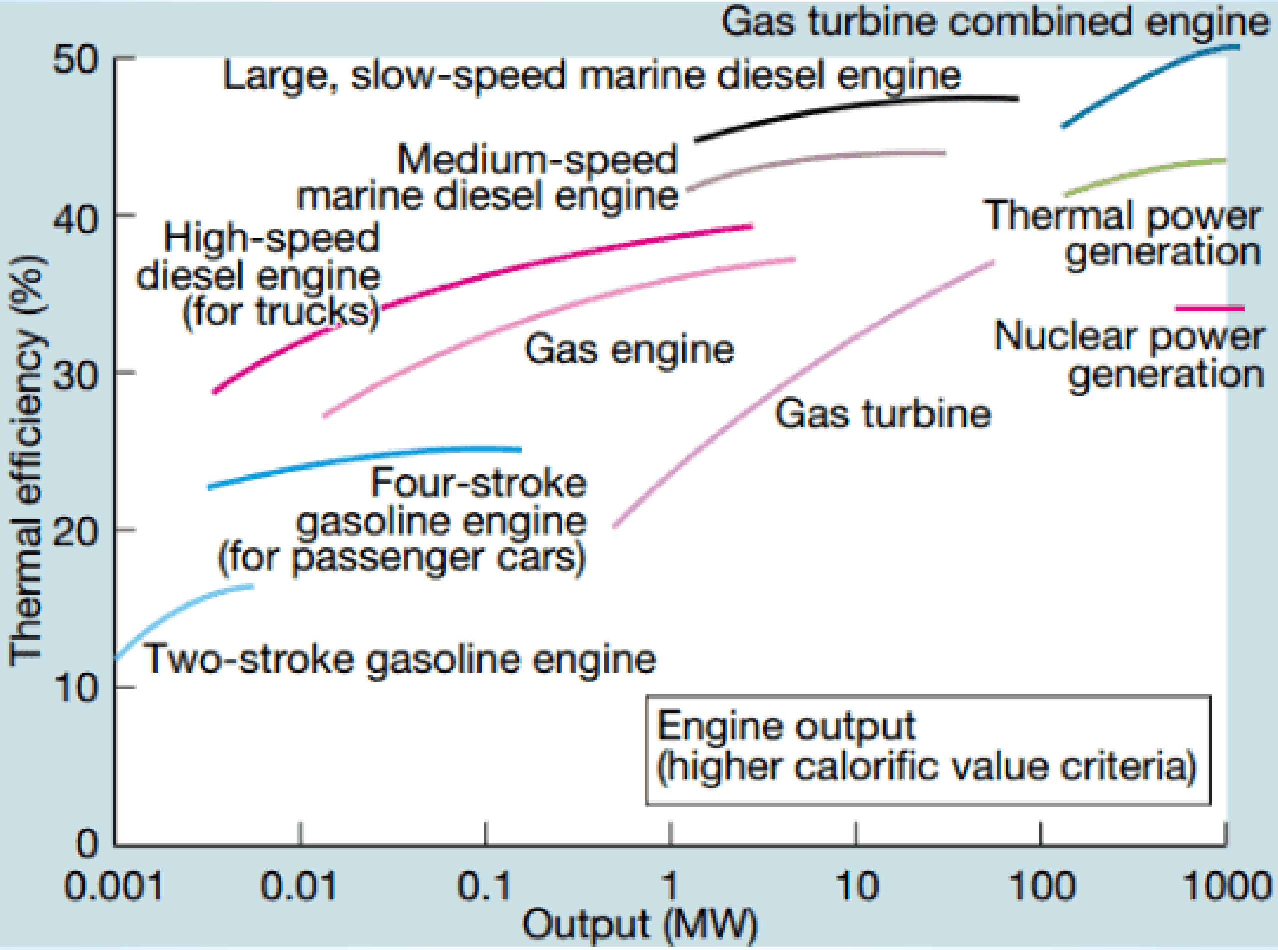
Petra Nova captures 1.6 million tons of carbon dioxide (CO_2) per year, equivalent to taking 350,000 cars off the road.

Cleaning up coal—
cost-effectively

Fossil power, guilt free
Science 26 May 2017:



Ce que l'on entend dans les médias:
Les voitures électriques sont rechargées par des centrales au charbon. Il n'y a pas de gain de rejet de CO2

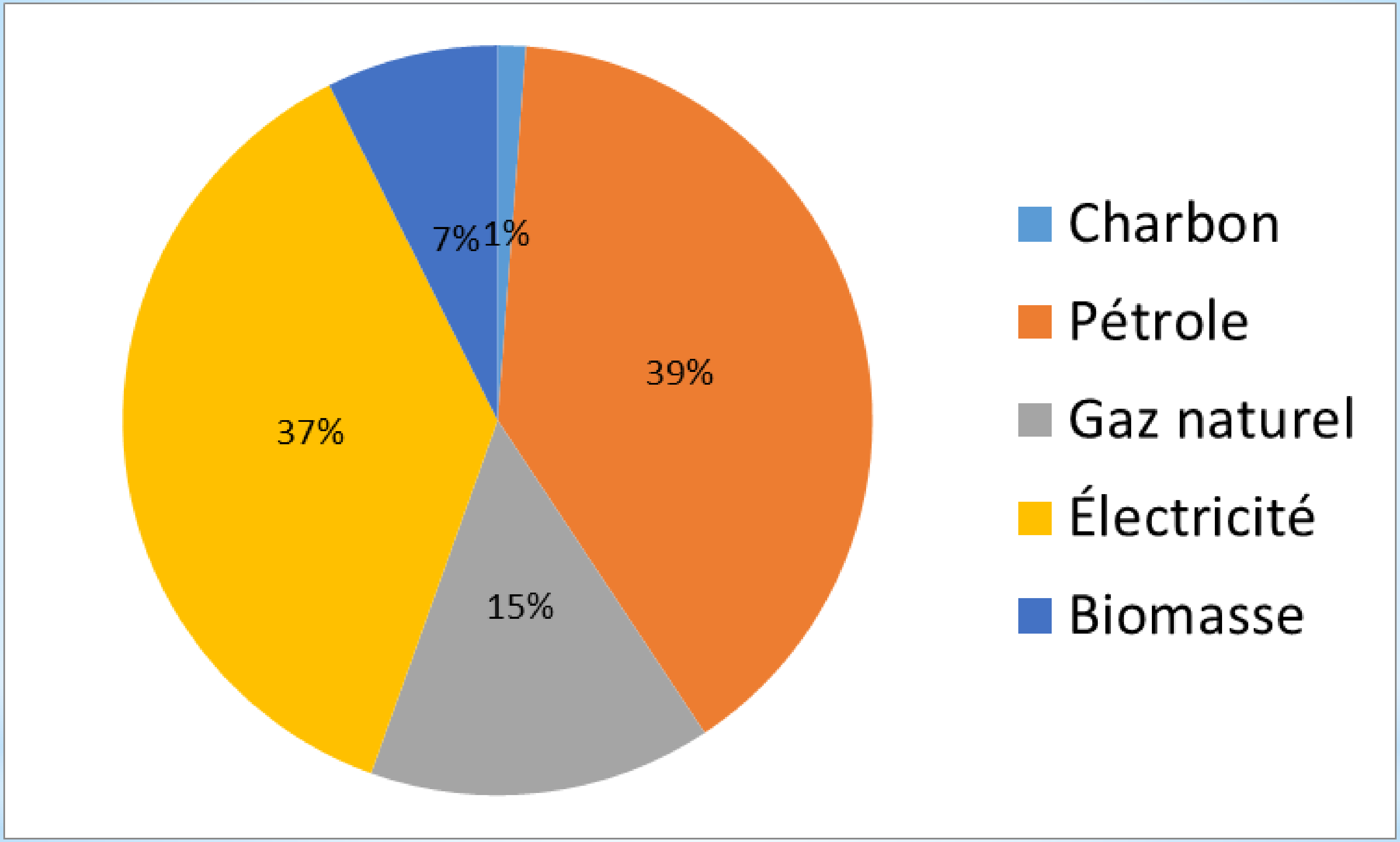


https://www.nuclear-power.net/nuclear-power-plant/turbine-generator-power-conversion-system/theory-of-steam-turbines-thermodynamics/thermal-efficiency-of-steam-turbine/

At the heart of the plant will be the latest Siemens gas fired power plant turbine generation: the SGT5-8000H. Its output is equivalent to that of 22 jumbo jet engines, and it weighs as much as an Airbus A380 with full fuel tanks. …provide an electrical output of more than 600 megawatts (MW). …
the electrical efficiency of the power plant will be about 61,5 percent

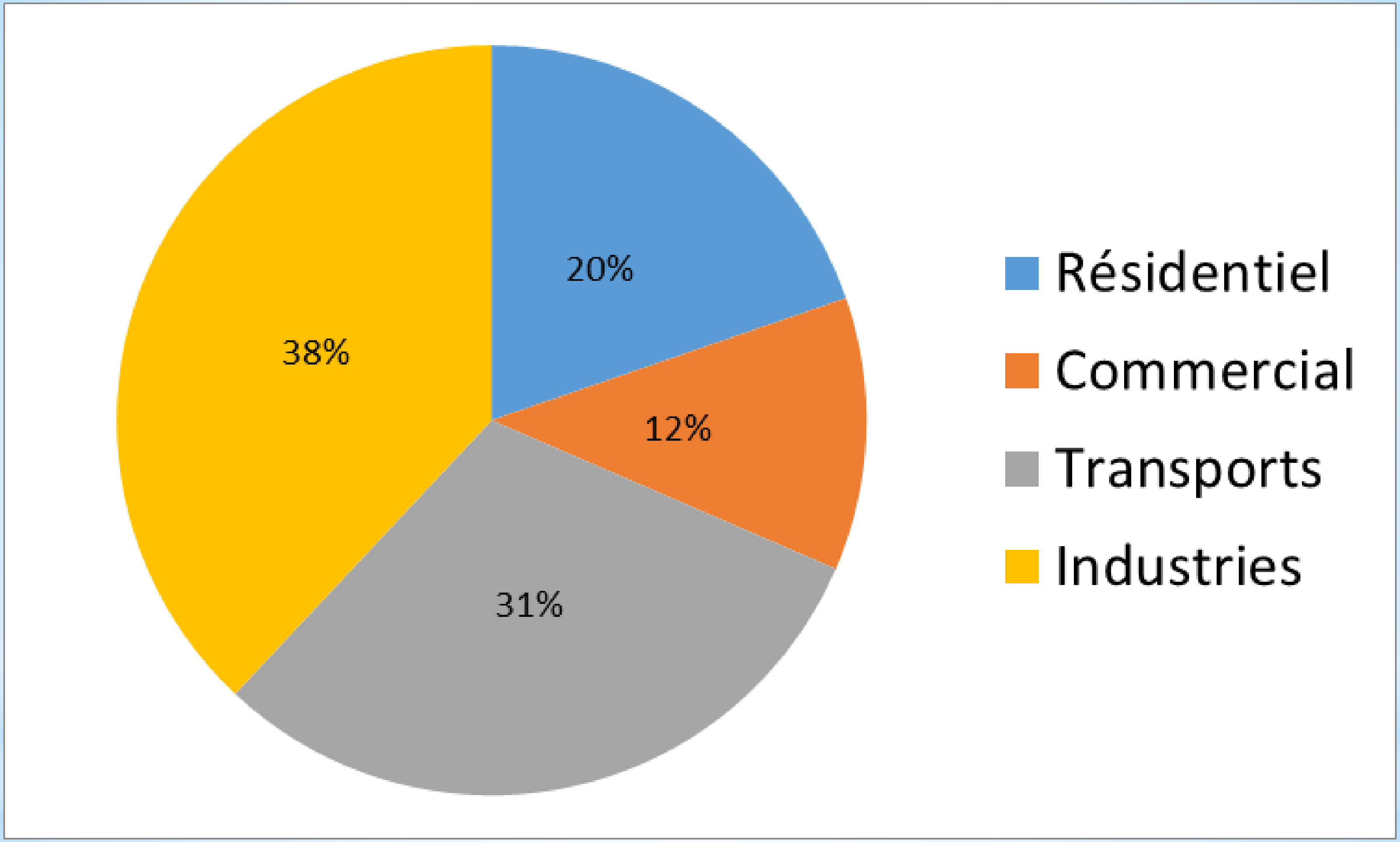
https://www.siemens.com/innovation/en/home/pictures-of-the-future/energy-and-efficiency/sustainable-power-generation-the-worlds-most-efficient-combined-cycle-power-plant-goes-online-in-2016.html

Sources d'énergie au Québec 2013



https://mern.gouv.qc.ca/energie/statistiques/statistiques-consommation-forme.jsp

Utilisation de l'énergie au Québec 2013



https://mern.gouv.qc.ca/energie/statistiques/statistiques-consommation-forme.jsp

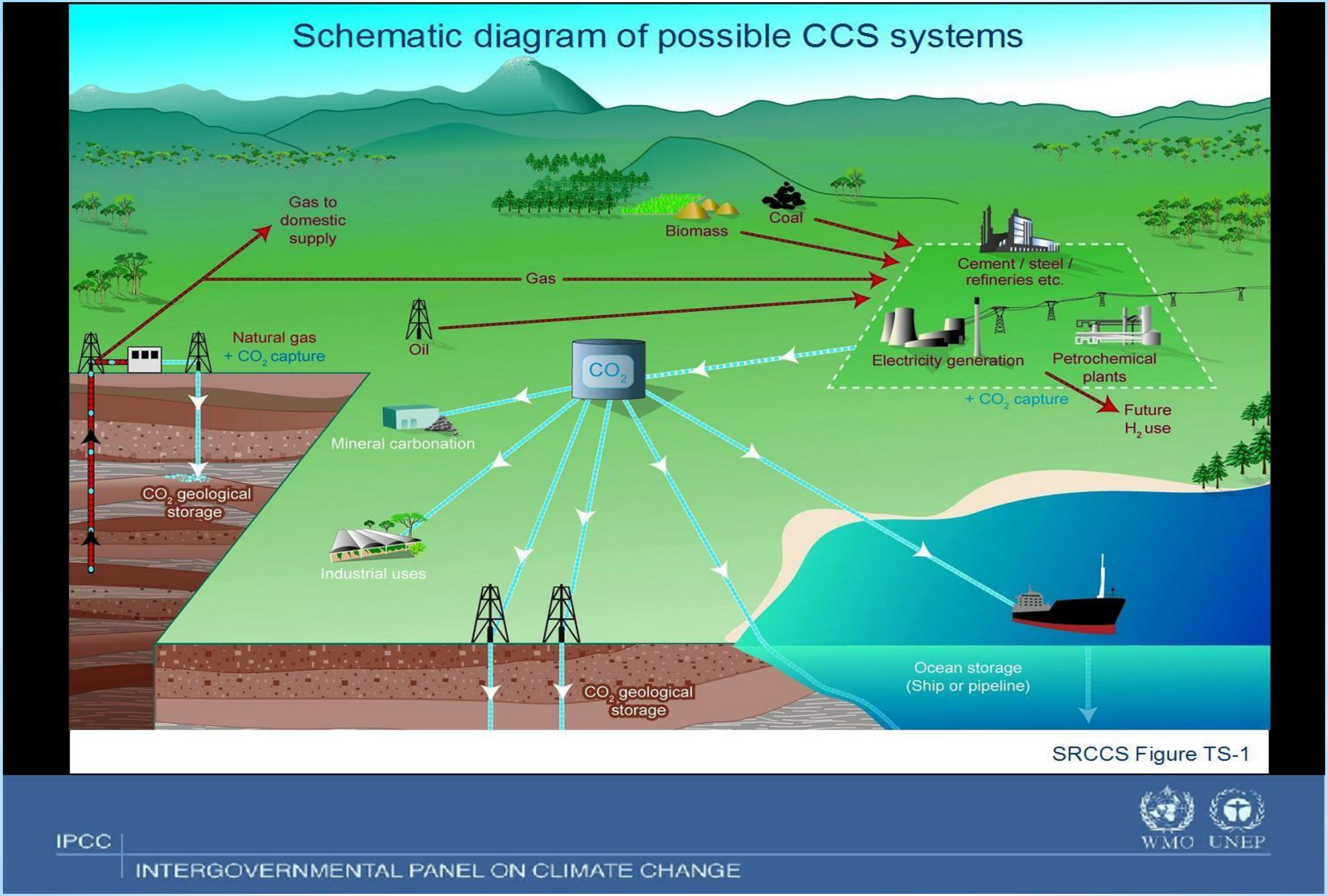
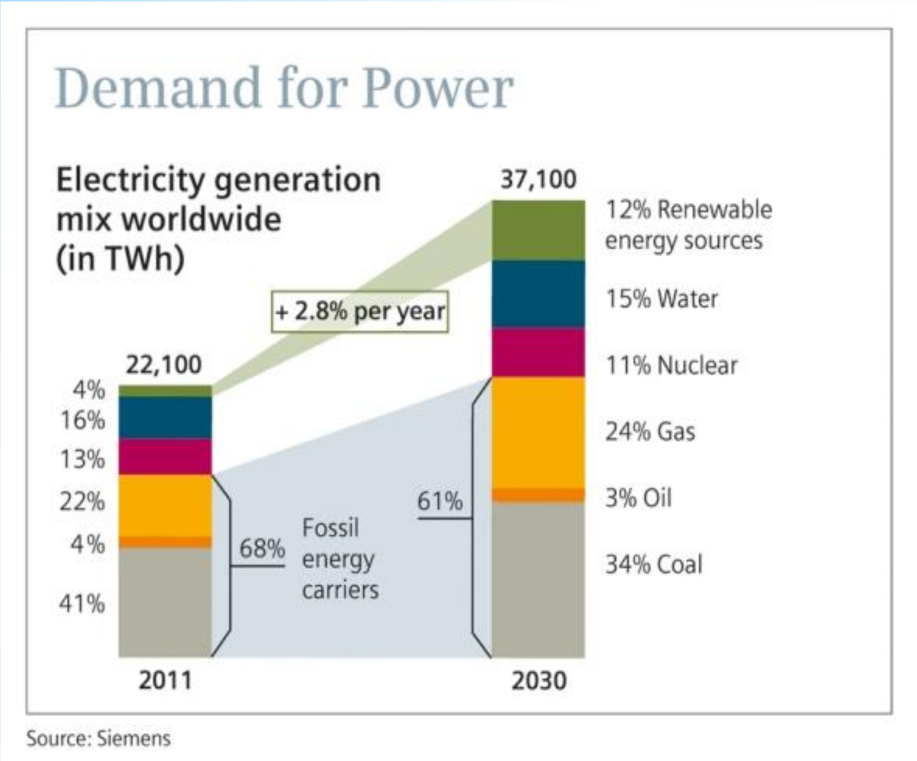
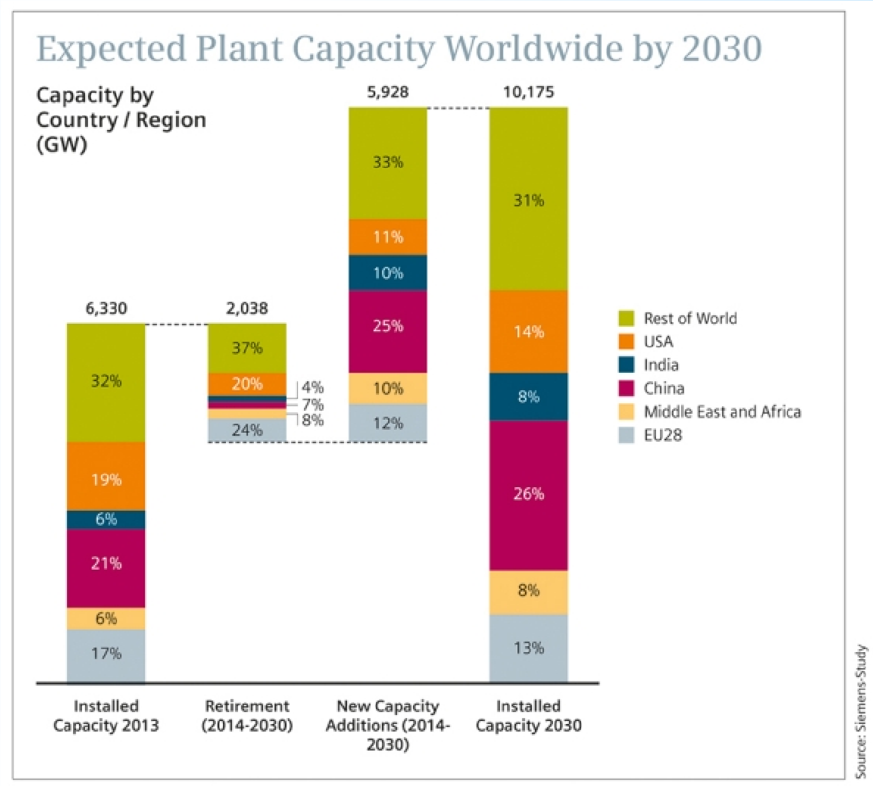


Figure TS.1. IPCC Special Report Carbon Dioxide Capture and Storage

MERCI



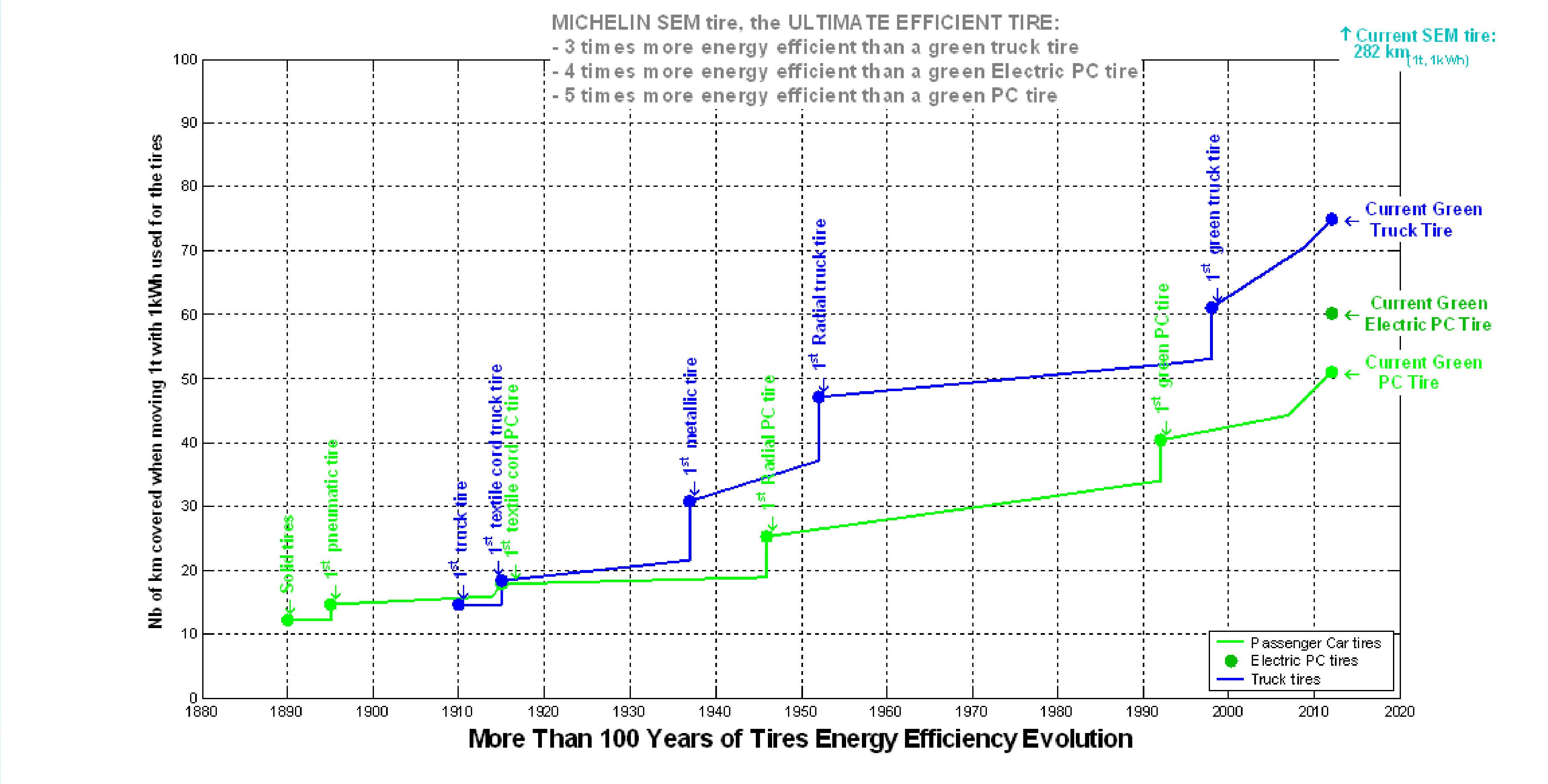


https://www.siemens.com/innovation/en/home/pictures-of-the-future/energy-and-efficiency/sustainable-power-generation-facts-and-forecasts.html

	Power output	Frequency	Gross efficiency
SGT5-8000H	450 MW	50 Hz	> 41%
SGT6-8000H	310 MW	60 Hz	> 40%
SGT5-4000F	329 MW	50 Hz	41.0%
SGT6-5000F	250 MW	60 Hz	39.3%
SGT5-2000E	187 MW	50 Hz	36.2%
SGT6-2000E	117 MW	60 Hz	35.2%
SGT-800 (54.0 MW)	54.0 MW(e)	50/60 Hz	39.1%
SGT-800 (50.5 MW)	50.5 MW(e)	50/60 Hz	38.3%
SGT-800 (47.5 MW)	47.5 MW(e)	50/60 Hz	37.7%
SGT-750	39.8 MW(e)	50/60 Hz	40.3%
SGT-700	32.8 MW(e)	50/60 Hz	37.2%
SGT-600	24.5 MW(e)	50/60 Hz	33.6%
SGT-400 (15 MW)	14.3 MW(e)	50/60 Hz	35.4%
SGT-400 (13 MW)	12.9 MW(e)	50/60 Hz	34.8%
SGT-300	7.9 MW(e)	50/60 Hz	30.6%
SGT-100 (5.4 MW)	5.4 MW(e)	50/60 Hz	31.0%
SGT-100 (5.1 MW)	5.1 MW(e)	50/60 Hz	30.2%
SGT-A65 TR DLE	53.1 MW(e)	50 Hz	42.0%
SGT-A65 TR DLE with ISI	63.5 MW(e)	50 Hz	43.2%
SGT-A65 TR DLE	54.0 MW(e)	60 Hz	42.5%
SGT-A65 TR DLE with ISI	61.8 MW(e)	60 Hz	43.4%
SGT-A65 TR WLE with ISI	66.0 MW(e)	50 Hz	41.5%
SGT-A65 TR WLE with ISI	65.7 MW(e)	60 Hz	41.1%
SGT-A35 RB 50Hz (38 MW)	37.4 MW(e)	50 Hz	38.7%
SGT-A35 RB 50Hz (34 MW)	33.2 MW(e)	50 Hz	37.5%
SGT-A35 RB DLE 50Hz (34 MW)	32.5 MW(e)	50 Hz	37.3%
SGT-A35 RB 60Hz (38 MW)	36.6 MW(e)	60 Hz	39.7%
SGT-A35 RB 60Hz (34 MW)	32.2 MW(e)	60 Hz	38.5%
SGT-A35 RB DLE 60Hz (34 MW)	31.9 MW(e)	60 Hz	38.3%
SGT-A30 RB (32 MW) DLE	32.1 MW(e)	50/60 Hz	39.3%
SGT-A30 RB (30 MW) DLE	29.9 MW(e)	50/60 Hz	37.5%
SGT-A30 RB (27 MW) DLE	27.2 MW(e)	50/60 Hz	36.4%
SGT-A05 AE (6.6 MW) w/ case steam	6.6 MW(e)	50/60 Hz	41.2%
SGT-A05 AE (5.4 MW)	5.4 MW(e)	50/60 Hz	32.3%
SGT-A05 AE (4.0 MW)	4.0 MW(e)	50/60 Hz	29.7%

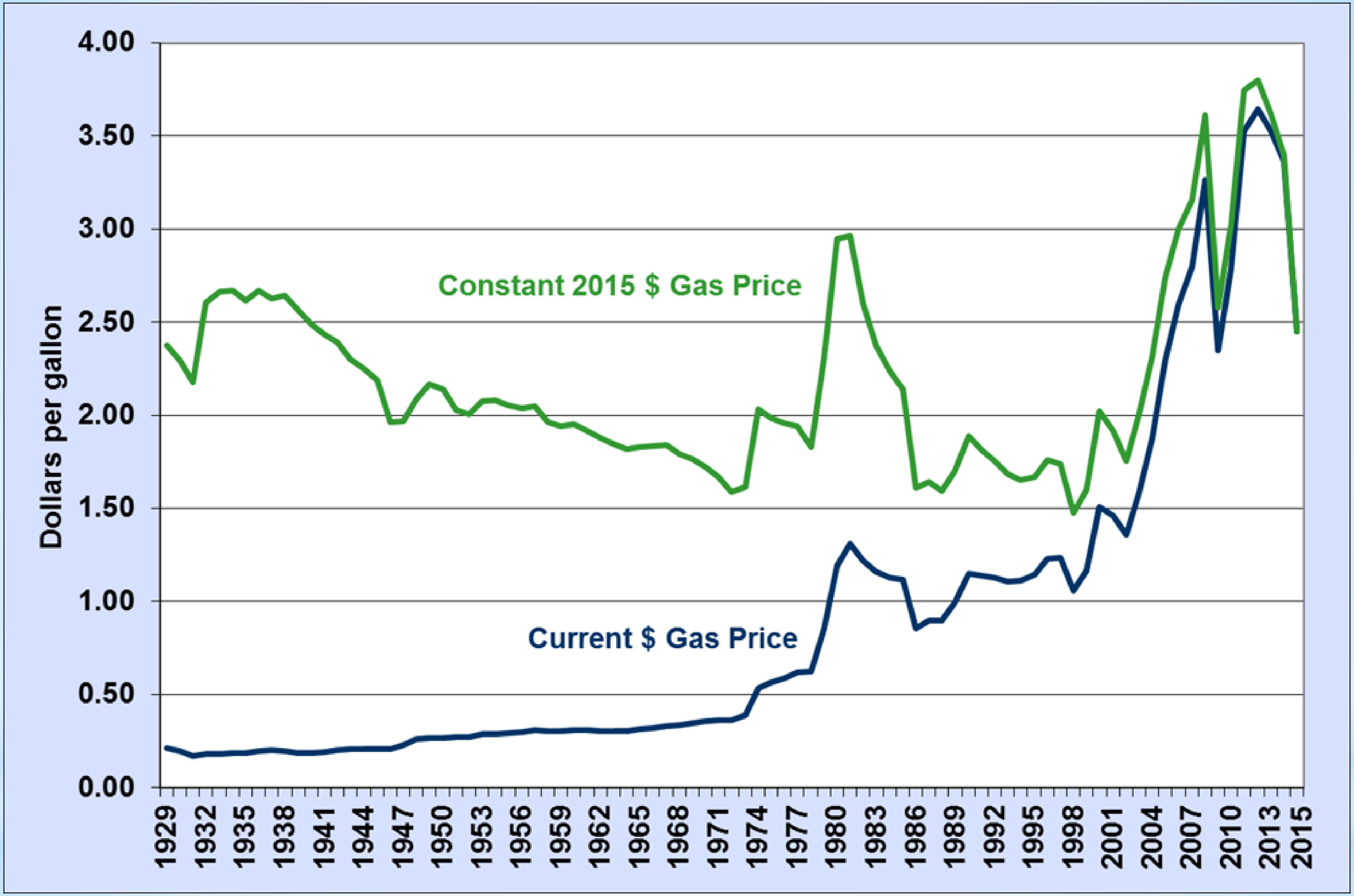
We power the world with innovative gas turbines

Siemens gas turbine portfolio

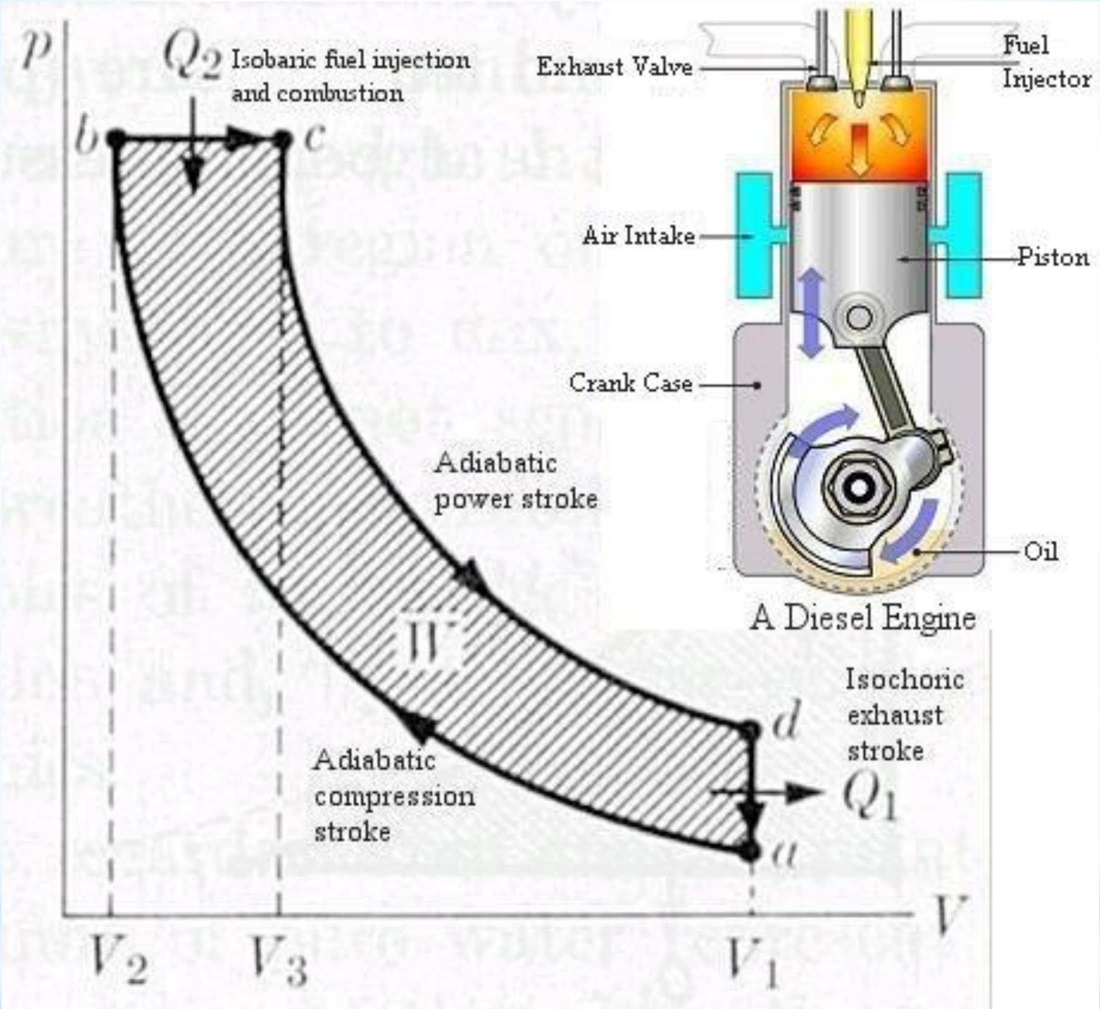


ULTIMATE ENERGY TIRE 1 tank out of 5 is used for the tires on PC vehicles, 1 out of 3 for trucks... and much more for a Shell Eco-marathon vehicle, up to 70%! For the Shell Eco-marathon, Michelin has developed the ultimate energy-efficient tires that are 5 times more energy-efficient than the best tires available for standard passenger cars.

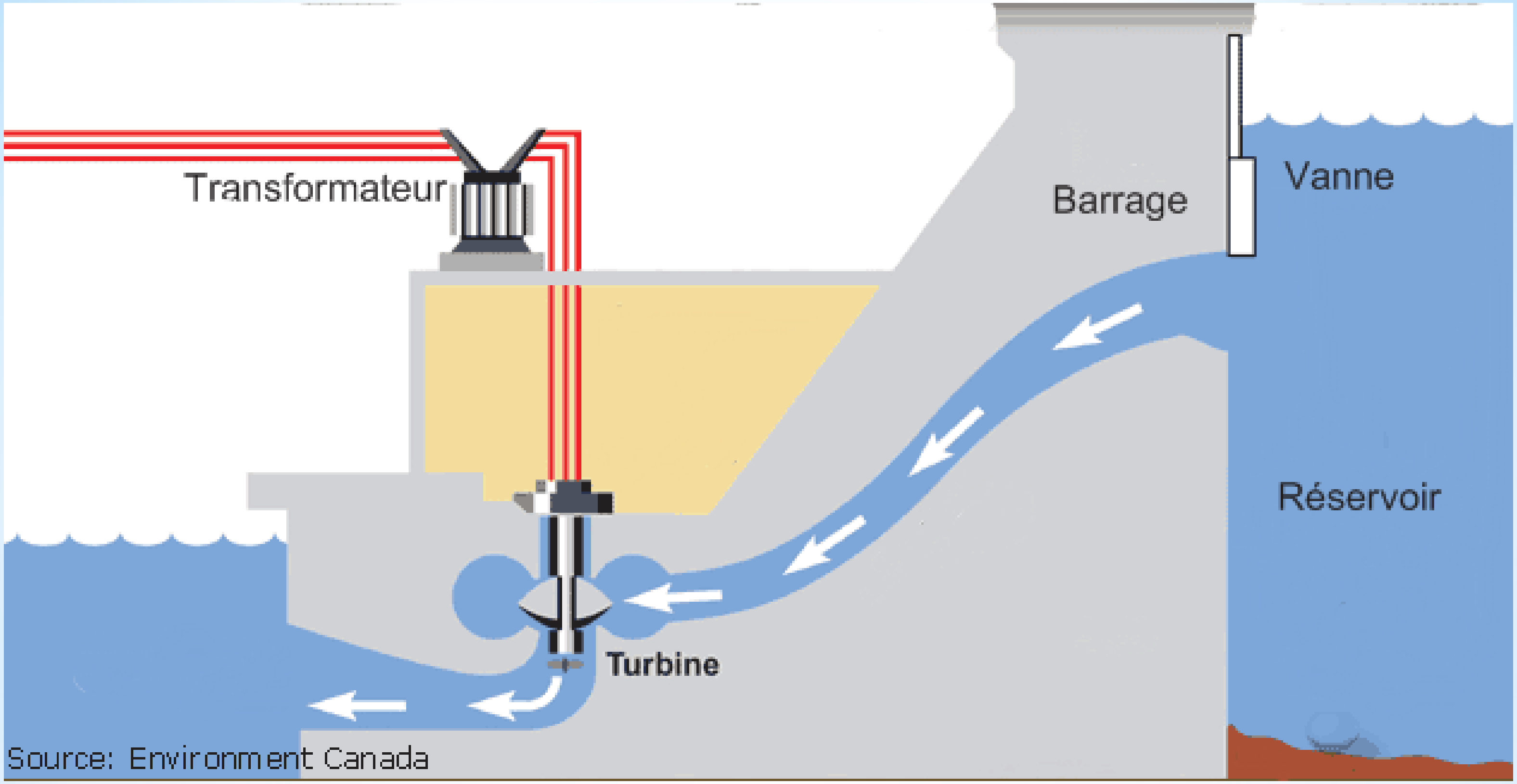
http://thetiredigest.michelin.com/michelin-ultimate-energy-tire



https://www.energy.gov/eere/vehicles/fact-915-march-7-2016-average-historical-annual-gasoline-pump-price-1929-2015



p-V diagram of the diesel engine



http://kidiscience.cafe-sciences.org/articles/comment-produit-t-on-lelectricite-partie-ii/

ENERGY

Turbines can use CO_2 to cut CO_2

Turbine efficiency can be boosted by replacing steam with CO_2

By 2030, as an article in Science highlighted in May 2017, improved energy efficiency alone could reduce greenhouse gases by up to 50 percent by 2030.

Bolt

Electric drive unit, (200 hp [150 kW] 266 lb-ft of torque [360 N-m])
Battery, 60 kWh (320 km), Propulsion, Lithium-ion, Rechargeable Energy Storage System
Charge cord, 120-volt, portable
Charger, 7.2 kW high-voltage
Battery, 12-volt with Rundown Protection
Brakes, 4-wheel antilock, 4-wheel disc

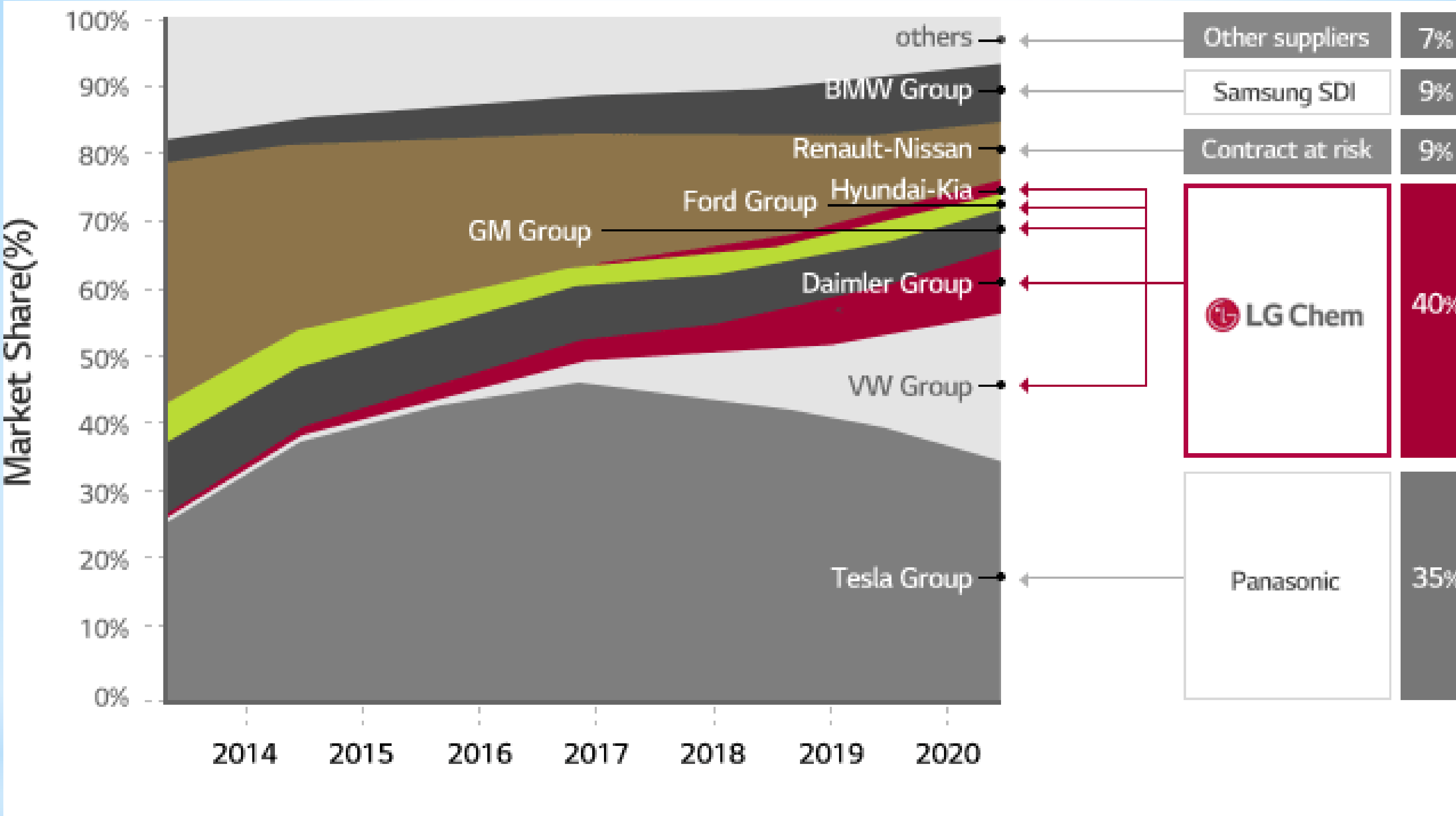
Nissan Leaf

Moteur électrique synchrone à CA de 80 kW
Batterie au lithium-ion de 30 kWh (172 km)
Batterie au lithium-ion de 24 kWh (135 km)
Chargeur embarqué de 6,6 kW
Système de chauffage hybride
Câble de recharge portable à régime lent (110-120 volts)
Port de recharge rapide: disponible sur modèle 30 kWh
Poids total - kg (lb) 1 481 (3 265) 1 518 (3 347)

Résumé du travail de Pierre Langlois

Type	Énergie spécifique (Wh/kg)	Cycles profonds	Commentaires
Plomb	30-50	300	
Nickel-hydrure métallique (NiMH)	60-120	500	Toyota hybride
Lithium-ion (Li-ion)			Pas bonne pour forts courants
Li-ion-Phosphate de fer (LFP)	90-120	1000-4000	
Li-ion Nickel Cobalt-Aluminium (NCA)	200-260	500	Tesla
Li-ion Nickel Manganese cobalt (NMC)	130-220	1000-2000	Fabriquée par LG Chem; BMW, GM, Ford, Chrysler, Renault, Mercedes, Volvo et éventuellement Tesla
Li-ion Titanate (LTO)	57-90	10000	
Li-métal polymère (LMP)	100		Maintenue à 80°C

L'auto électrique, … Éditions de l'homme, chapitre portant sur les batteries par Pierre Langlois



http://www.lgchem.com/global/vehicle-battery/car-batteries-Different/product-detail-PDEB0002