sanedi
South African National Energy Development Institute (SOC) Ltd.

# Sustainable mobility
# Energy Efficiency

SA National Energy Development Institute

GREEN TRANSPORT

Carel Snyman
carels@sanedi.org.za

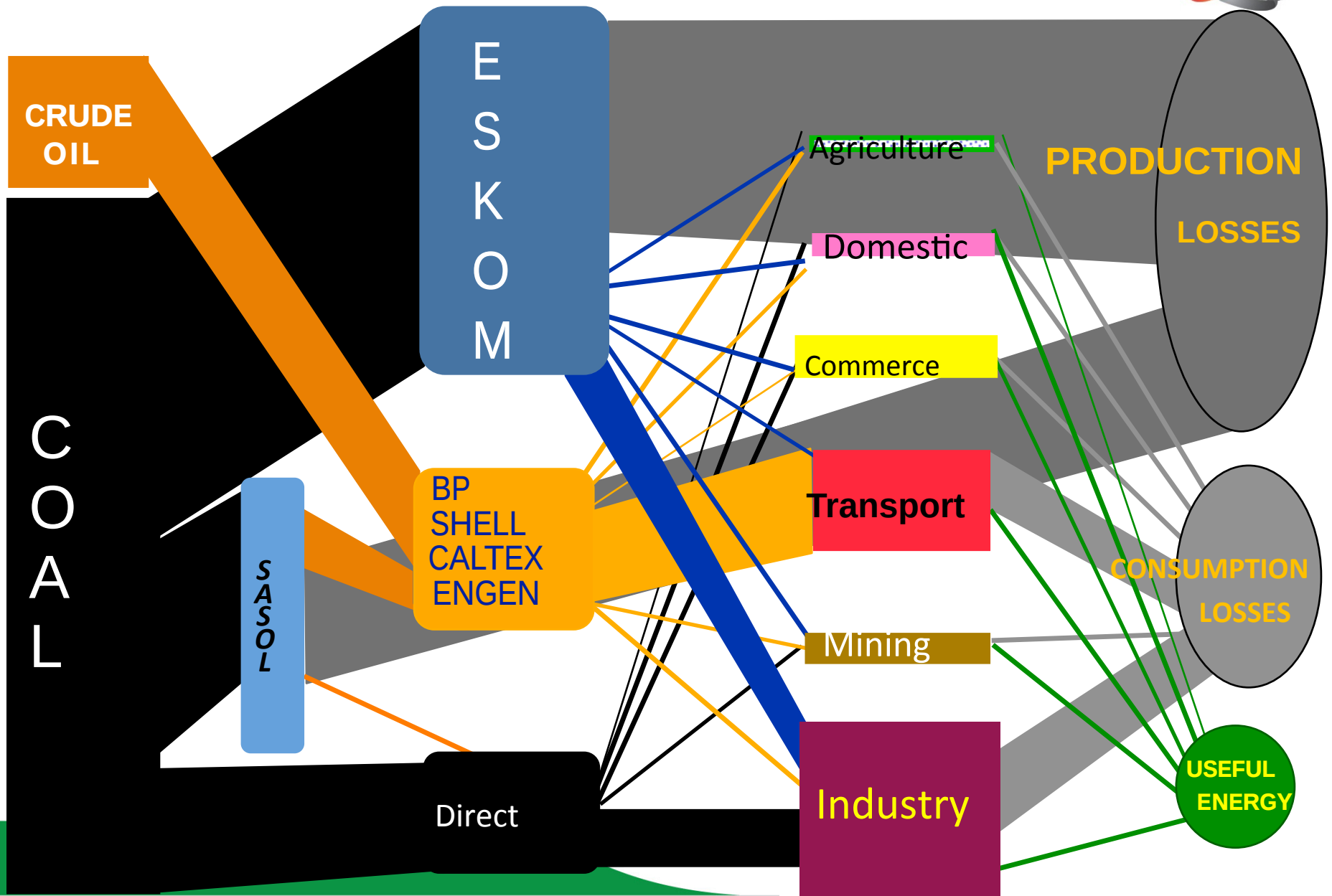
# **SANEDI**: Green Transport

- Developing **energy solutions** in Transport considering:
  - the energy used and
  - the technologies applied
- to do work - moving people and freight
- "Green" is lean and clean

(energy efficiency and reducing energy emissions)

- ✓ move away from paying forex for imported energy and
- ✓ develop local energy supply sources
- ✓ stimulating local industrial development and job creation

# South Africa's energy balance

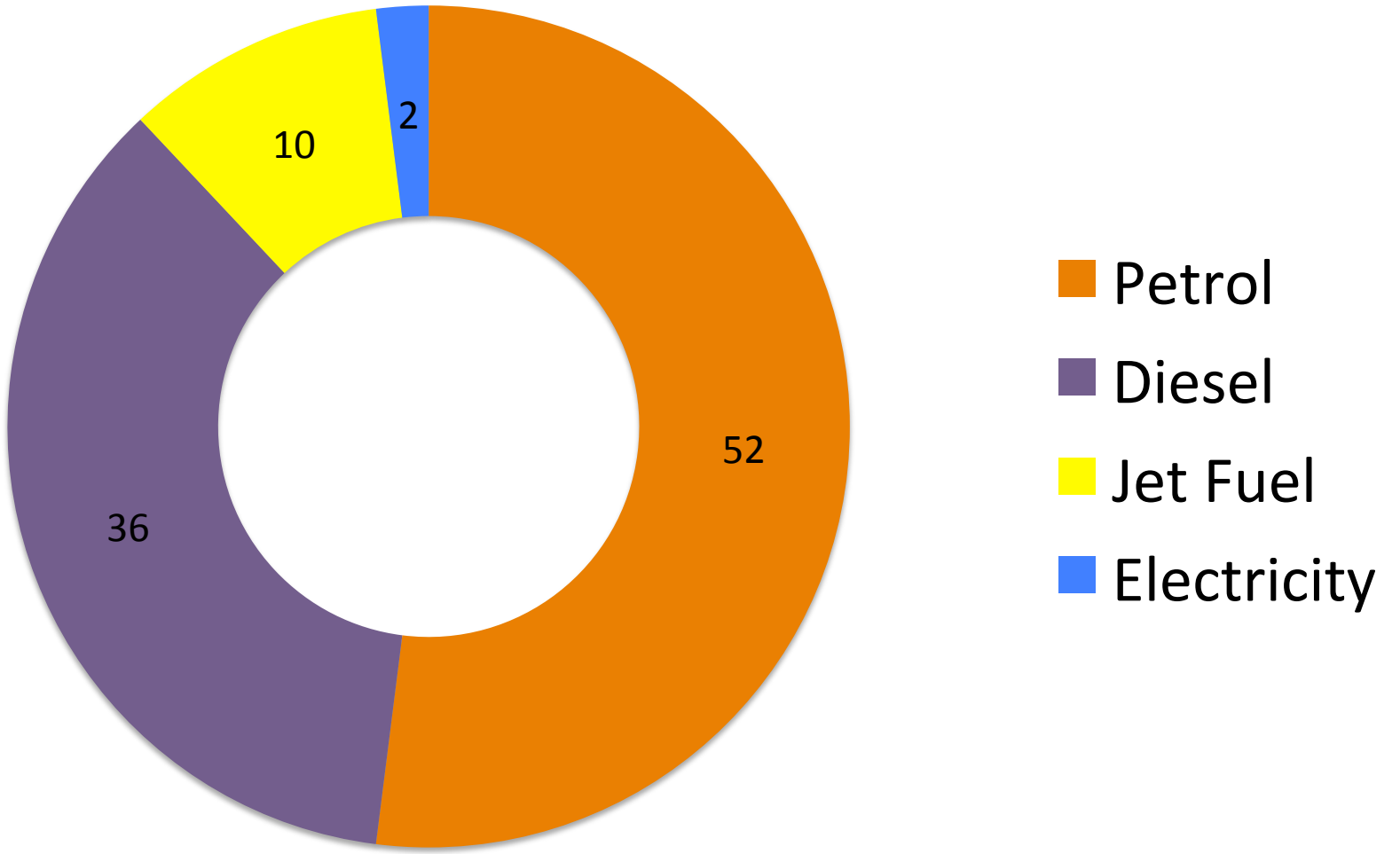


# South Africa's energy demand

| Economic Sector | 2010 | 2050 |
|---|---|---|
| Industry | 37 | 34 |
| Mining | 8 | 4 |
| Agriculture | 3 | 3 |
| Commerce | 7 | 7 |
| Residential | 11 | 8 |
| Transport | 34 | **44** |

DoE

# Transport energy use



# Focus is on:
## Urban Mobility
## City Commuting

Integration

Pathways

Technology

+

Energy

sanedi
South African National Energy Development Institute (SOC) Ltd.

# Technology

ENERGY INNOVATION FOR LIFE

# My Car

A bad technology choice!

Limit = 60km/h

Need only 14s

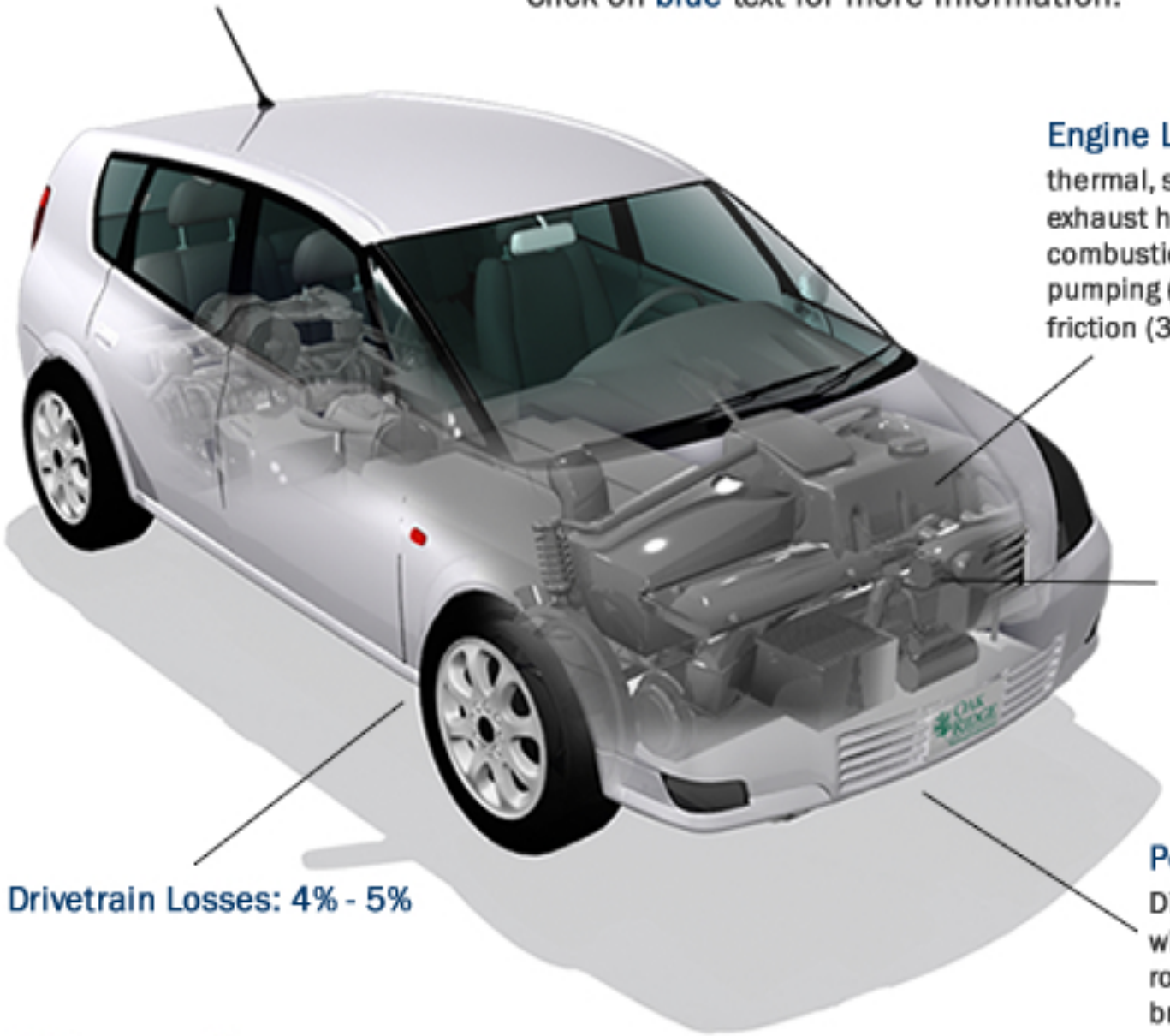
Need only 150km

40kg$CO_2$/100km

400kg can do

# Energy Requirements for City (Stop and Go) Driving

Click on blue text for more information.



**Engine Losses: 74% - 75%**

thermal, such as radiator, exhaust heat, etc. (63% - 64%)
combustion (3%)
pumping (5%)
friction (3%)

**Parasitic Losses: 6% - 7%**

(e.g., water pump, alternator, etc.)

**Drivetrain Losses: 4% - 5%**

**Power to Wheels: 14% - 16%**

Dissipated as
wind resistance: (4%)
rolling resistance (4% - 5%)
braking (6% - 7%)

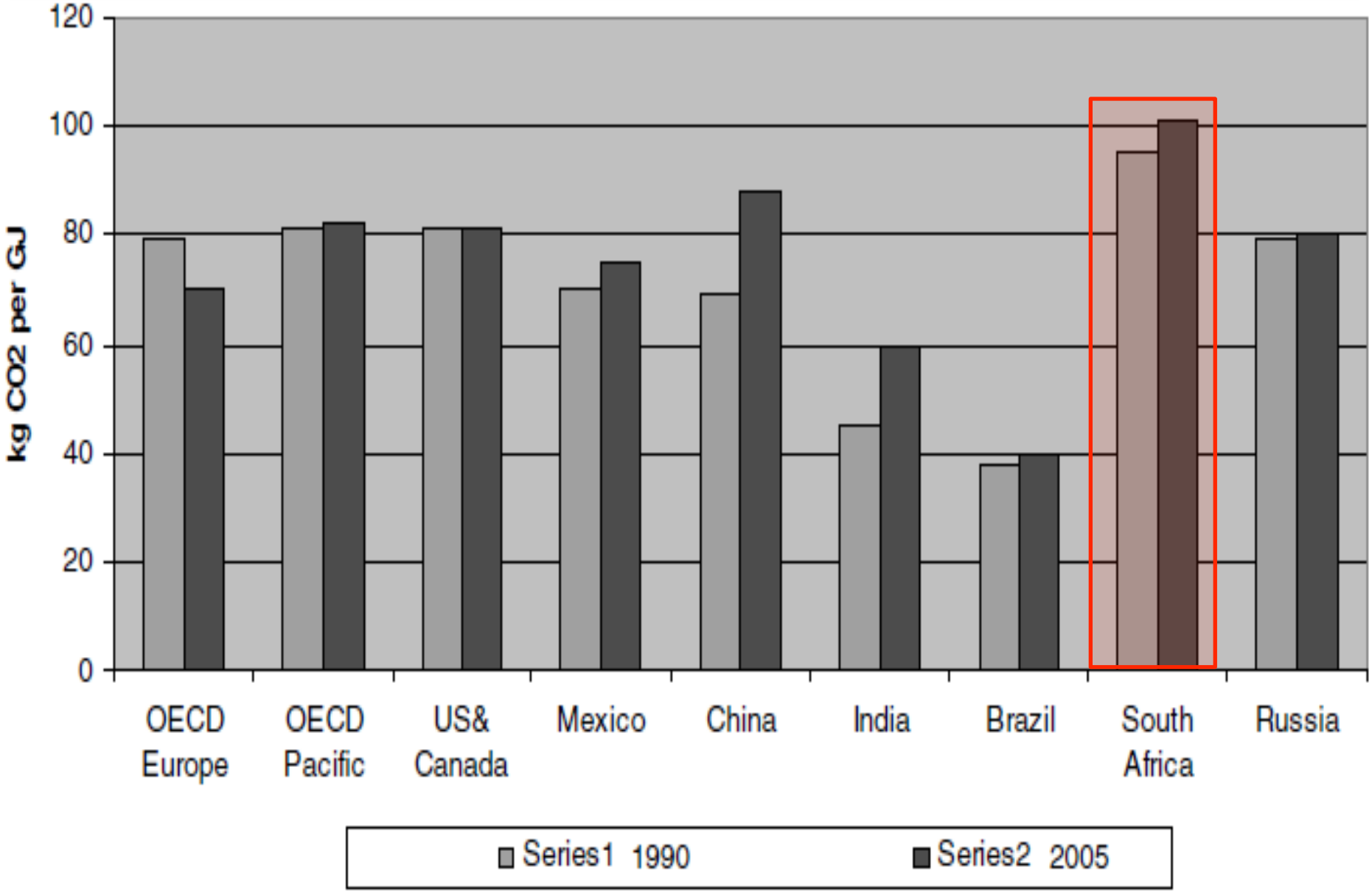
**Idle Losses: 6%**

In this figure, they are accounted for as part of the engine and parasitic losses.

| Oil Well | Refinery | Distribution | Petrol Car | (W→W)η |
|---|---|---|---|---|
|  |  |  |  | 15% |
| 96% | 90% | 97% | 18% | |

| Coal Mine | Synfuel Plant | Distribution | Petrol Car | |
|---|---|---|---|---|
|  |  |  |  | 7% |
| 97% | 40% | 97% | 18% | |

# Carbon Intensity of the Final Energy Mix



# Measures of transportation work

- **Work = People x kilometres = P.km**
- P.km/MJoule - **Efficiency**
- P.km/$CO_2$ - **Carbon Emissions**
- P.km/Rand - **Cost** (Forex)
- P.km/Hour - **Time**
- P.km/$m^2$ - **Space**

# Road: Modes & energy performance

| Mode | Energy | Number | % | Load Capacity | Unit / 100km | MJ/P.km MJ/T.km | $gCO_2$/P.km $gCO_2$/T.km |
|---|---|---|---|---|---|---|---|
| Car | Petrol | 4'455'038 | 57% | 1.4 | 9.0 | 2.19 | 153.77 |
| | Diesel | 184'407 | 2% | 1.4 | 7.0 | 1.90 | 119.60 |
| SUV | Petrol | 442'621 | 6% | 1.4 | 14.0 | 3.40 | 239.20 |
| | Diesel | 279'222 | 4% | 1.4 | 11.0 | 2.99 | 187.94 |
| LCV | Petrol | 1'103'608 | 14% | 0.5 | 13.0 | 8.84 | 621.92 |
| | Diesel | 700'265 | 9% | 0.5 | 10.0 | 7.60 | 478.40 |
| MCV | Petrol | 5'991 | 0.1% | 2.5 | 33.0 | 4.49 | 315.74 |
| | Diesel | 131'425 | 2% | 2.5 | 25.7 | 3.90 | 245.58 |
| HCV | Diesel | 198'134 | 3% | 15 | 38.0 | 0.96 | 60.60 |
| MBTaxi | Petrol | 260'577 | 3% | 14 | 15.0 | 0.36 | 25.63 |
| | Diesel | 13'976 | 0.2% | 14 | 11.7 | 0.32 | 19.93 |
| Bus | Diesel | 30'033 | 0.4% | 25 | 33.0 | 0.50 | 31.57 |

# Road: Modes & Energy Impacts

| Mode | Energy | Number | % | Vkm/ year | MP.km MTkm | Mlitre | GJ | % GJ | MTon $CO_2$ |
|---|---|---|---|---|---|---|---|---|---|
| Car | Petrol | 4'455'038 | 57% | 24'000 | 149'689 | 9'623 | 327 | 35% | 23.02 |
| | Diesel | 184'407 | 2% | 24'000 | 6'196 | 310 | 12 | 1% | 0.74 |
| SUV | Petrol | 442'621 | 6% | 24'000 | 14'872 | 1'487 | 51 | 5% | 3.56 |
| | Diesel | 279'222 | 4% | 24'000 | 9'382 | 737 | 28 | 3% | 1.76 |
| LCV | Petrol | 1'103'608 | 14% | 25'000 | 13'795 | 3'587 | 122 | 13% | 8.58 |
| | Diesel | 700'265 | 9% | 25'000 | 8'753 | 1'751 | 67 | 7% | 4.19 |
| MCV | Petrol | 5'991 | 0.1% | 45'000 | 674 | 89 | 3 | 0.3% | 0.21 |
| | Diesel | 131'425 | 2% | 25'000 | 8'214 | 843 | 32 | 3% | 2.02 |
| HCV | Diesel | 198'134 | 3% | 70'500 | 209'527 | 5'308 | 202 | 22% | 12.70 |
| MBTaxi | Petrol | 260'577 | 3% | 50'000 | 182'404 | 1'954 | 66 | 7% | 4.67 |
| | Diesel | 13'976 | 0.2% | 50'000 | 9'783 | 82 | 3 | 0.3% | 0.20 |
| Bus | Diesel | 30'033 | 0.4% | 40'000 | 30'033 | 396 | 15 | 2% | 0.95 |

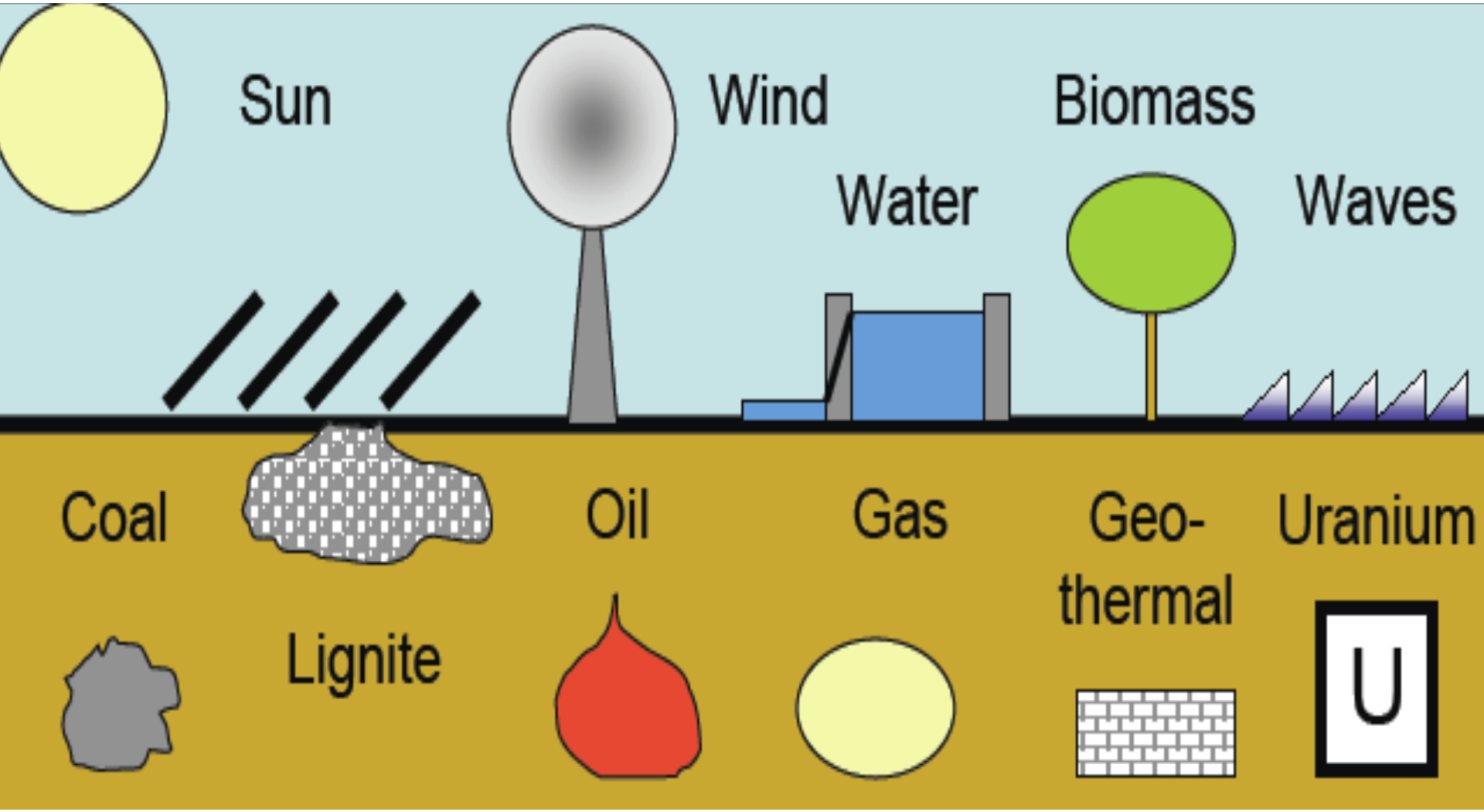
sanedi

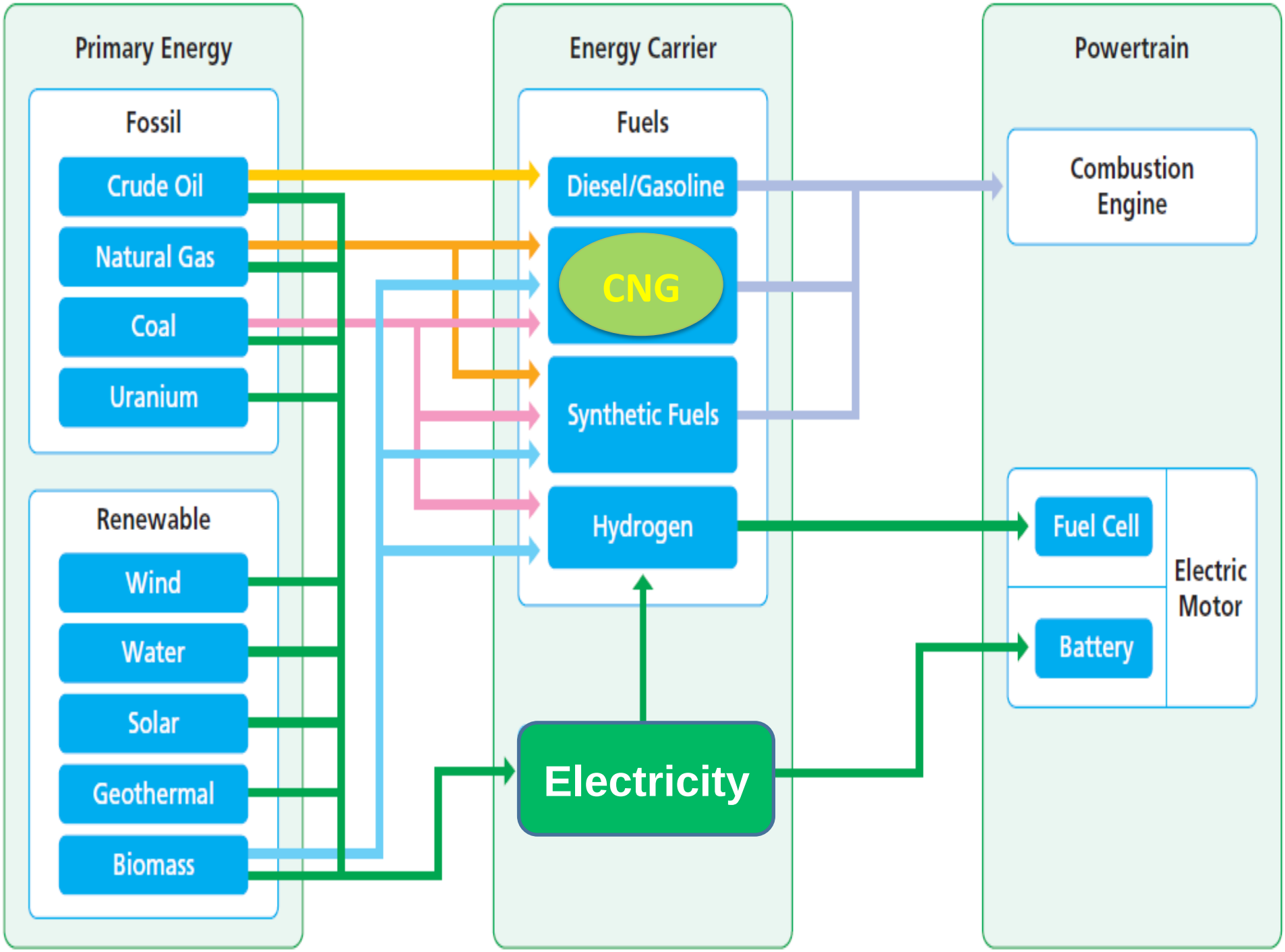
South African National Energy Development Institute (SOC) Ltd.

# Energy

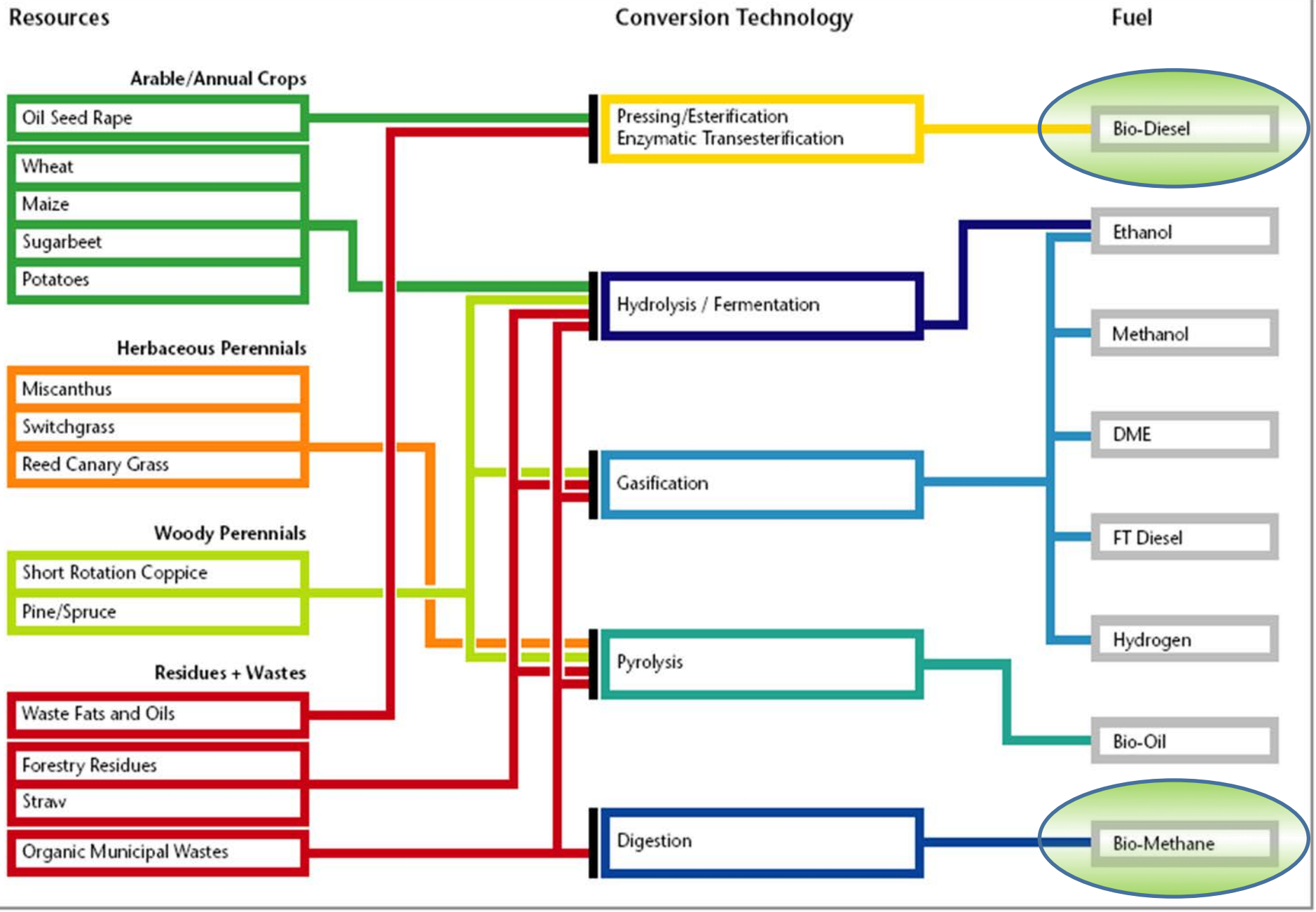
ENERGY INNOVATION FOR LIFE

# Energy


Sun
Wind
Biomass
Water
Waves
Coal
Oil
Gas
Geo-
thermal
Uranium
Lignite
U

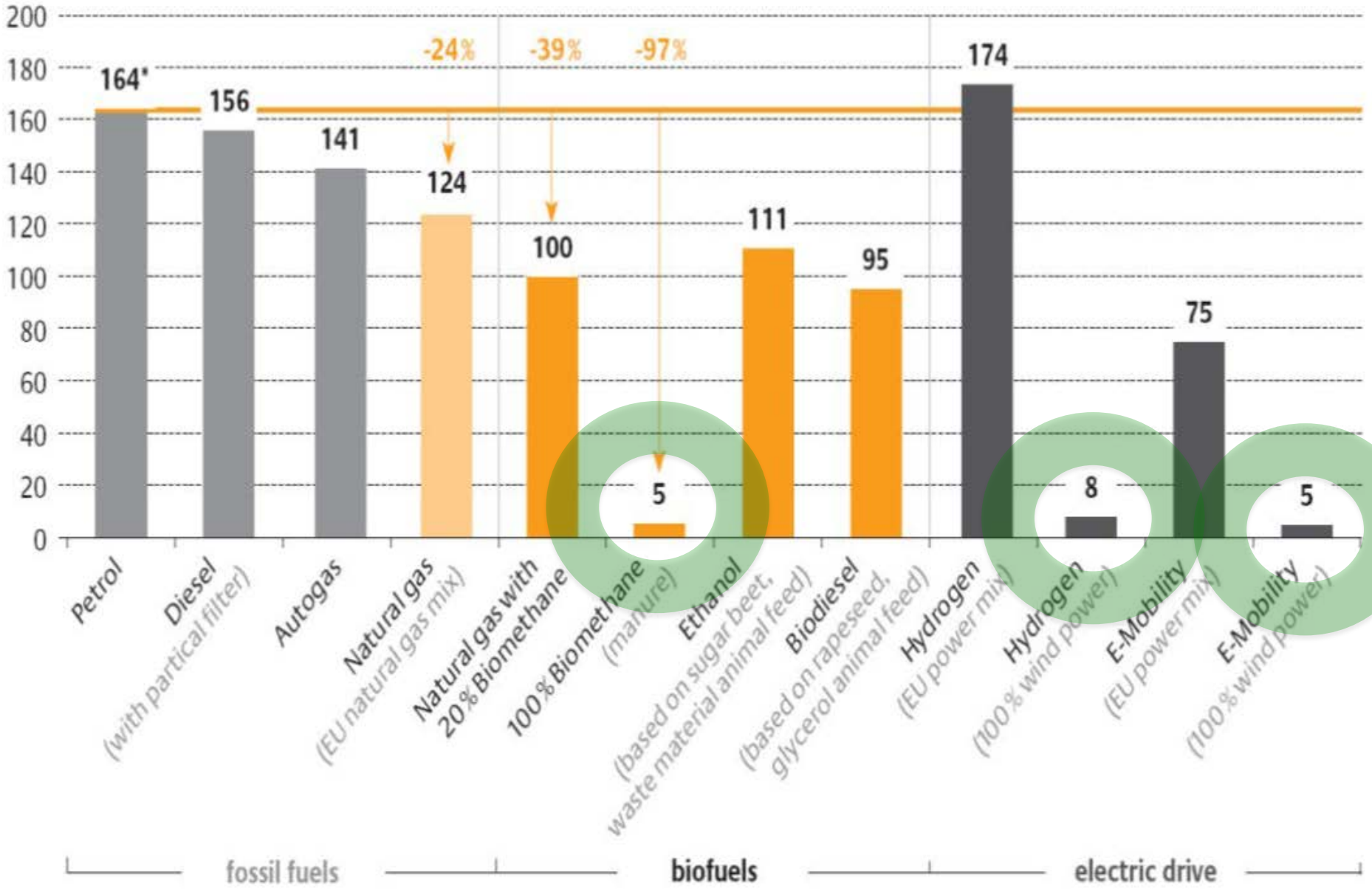

Primary Energy
Fossil
Crude Oil
Natural Gas
Coal
Uranium
Renewable
Wind
Water
Solar
Geothermal
Biomass
Energy Carrier
Fuels
Diesel/Gasoline
CNG
Synthetic Fuels
Hydrogen
Electricity
Powertrain
Combustion Engine
Fuel Cell
Battery
Electric Motor

# Potential Biofuel Pathways




Source: Adapted from **E4tech 2003**

# Well to Wheel GHG emissions in $gCO_{2eq.}/km$




* reference vehicle: gasoline engine (induction enginge), consumption 7 l per 100 km

# How much energy/hectare/year?

Photosynthesis: 2% of 20'000GJ/ha and cultivation period ➔ 400GJ/ha/yr

Processing: 50-135GJ BioFuels/ ha/yr (BioEtOH, BioDiesel, BTL)

Distribution & Combustion: 35% (Fuel to Wheel)

18-47GJ/ ha/year

**Solar beats Biomass 40-100 times!**

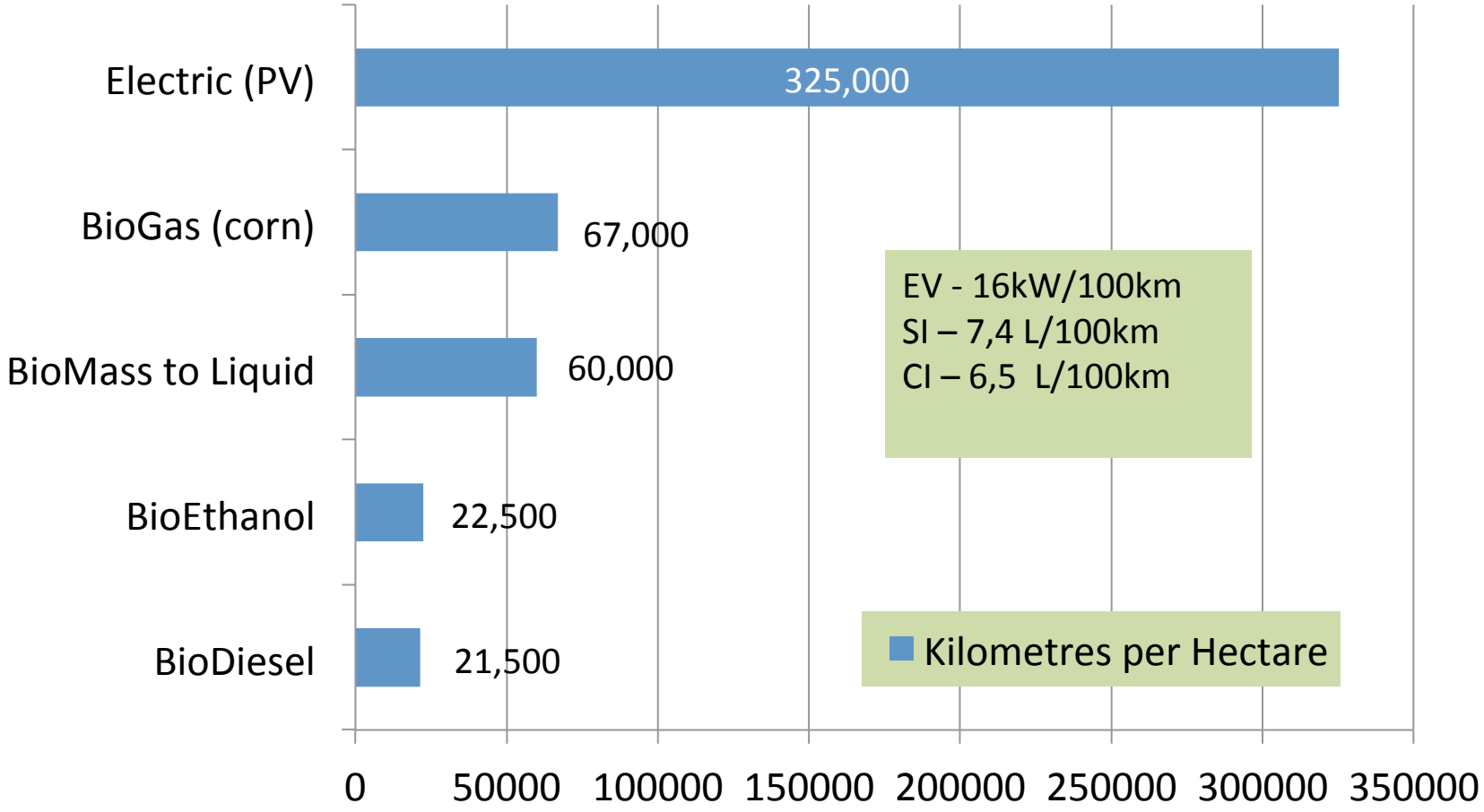
PV Cell to grid: 10% efficient ➔ 3'600GJ/ha/yr

Inverter {dc ➔ ac} 90% efficient 3'050GJ available for car battery

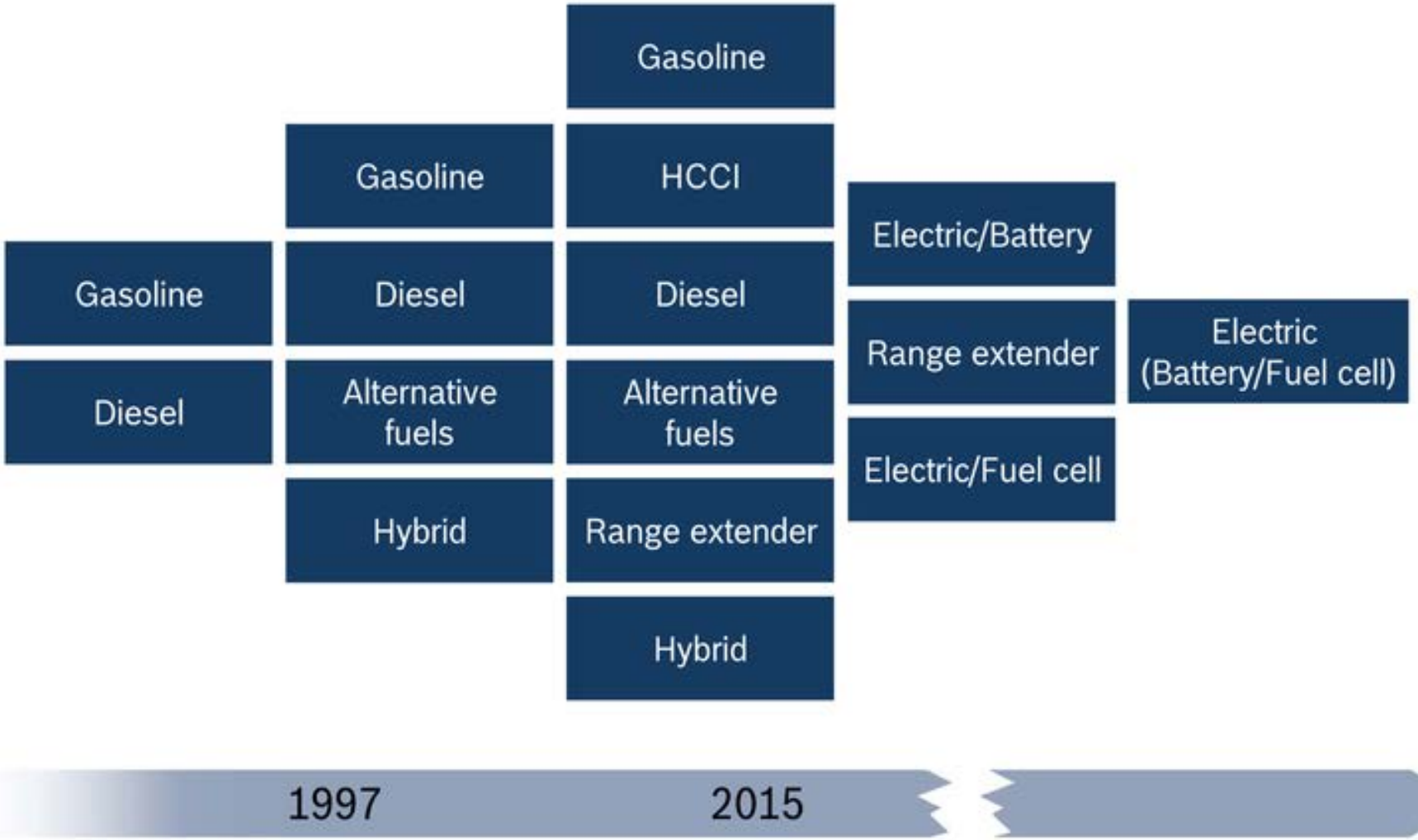
From battery to wheel: 60% efficient

1'800GJ/ ha/year

## Kilometres per Hectare



# Drivetrain technologies for passenger cars – timeline



(W→W)η

**Oil Well** → **Refinery** → **Distribution** → **Petrol Car**


96%


90%


97%


18%

**15%**

---

**Coal Mine** → **Synfuel Plant** → **Distribution** → **Petrol Car**


97%


40%


97%

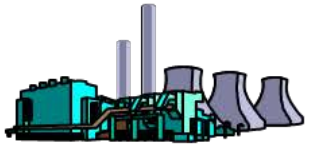

18%

**7%**

---

**Coal Mine** → **Power Station** → **Distribution** → **Electric Car**


97%


35%


95%


75%

**24%**

---

**Solar Farm** → **Distribution** → **Electric Car**


95%


75%

**71%**

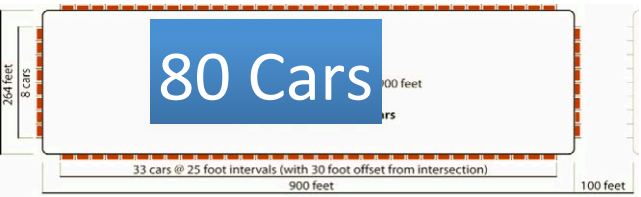
# City Car in Motion

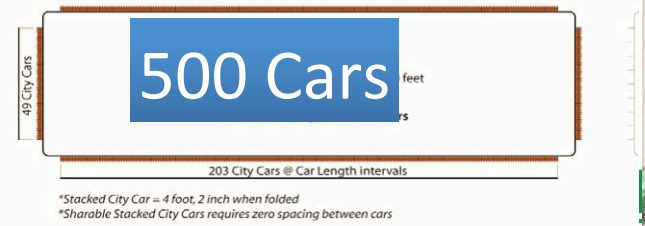
Mobility
(Shared Use)

# City Car at Rest

Energy Storage Device
(Renewable Friendly)

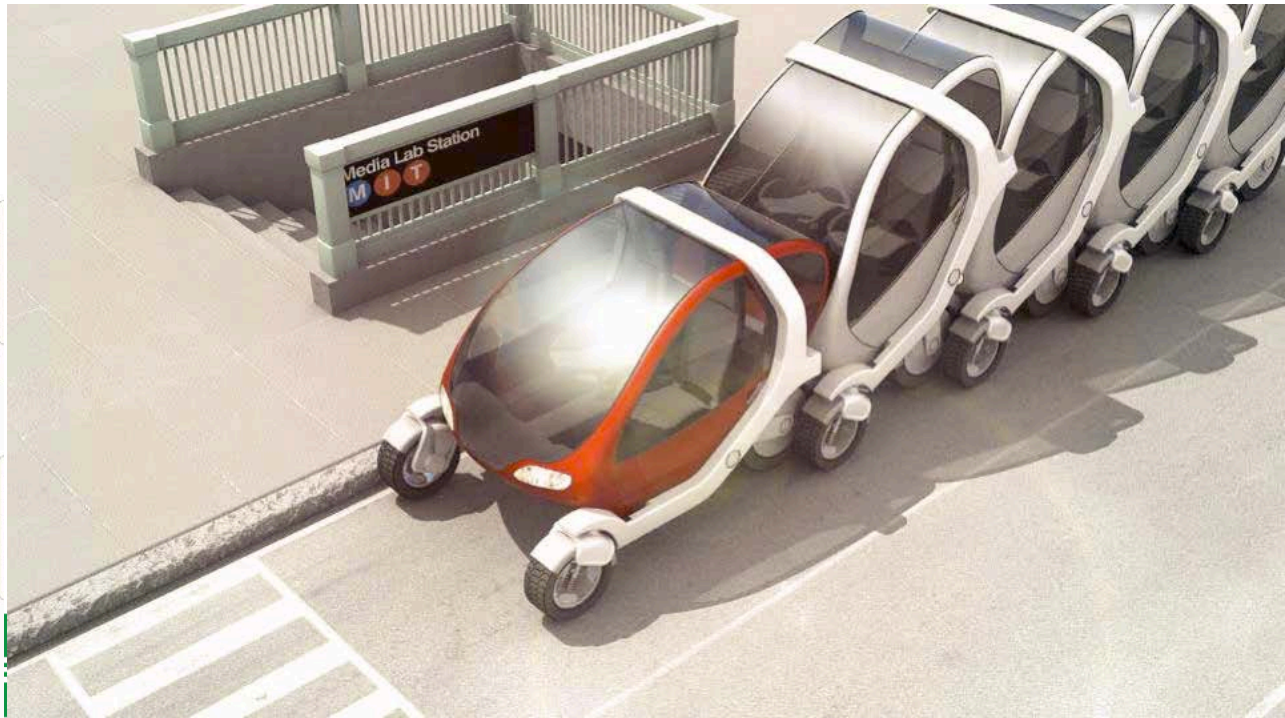
## City Car to Typical Car Parking Ratio = 6.25 : 1




*Stacked City Car = 4 foot, 2 inch when folded
*Sharable Stacked City Cars requires zero spacing between cars

City Car to Typical Car Parking Ratio = 6.1 : 1



# Performance: Person.km/Energy Unit

| Urban Commutes | |
|---|---|
| Electric Rail | 255 |
| Trolleybus | 123 |
| Diesel bus | 33 |
| Light motorcycle | 25 |
| Smart For 2 cdi | 20 |
| Prius | 20 |
| *e*Commuter | 60 |

Individual

Public

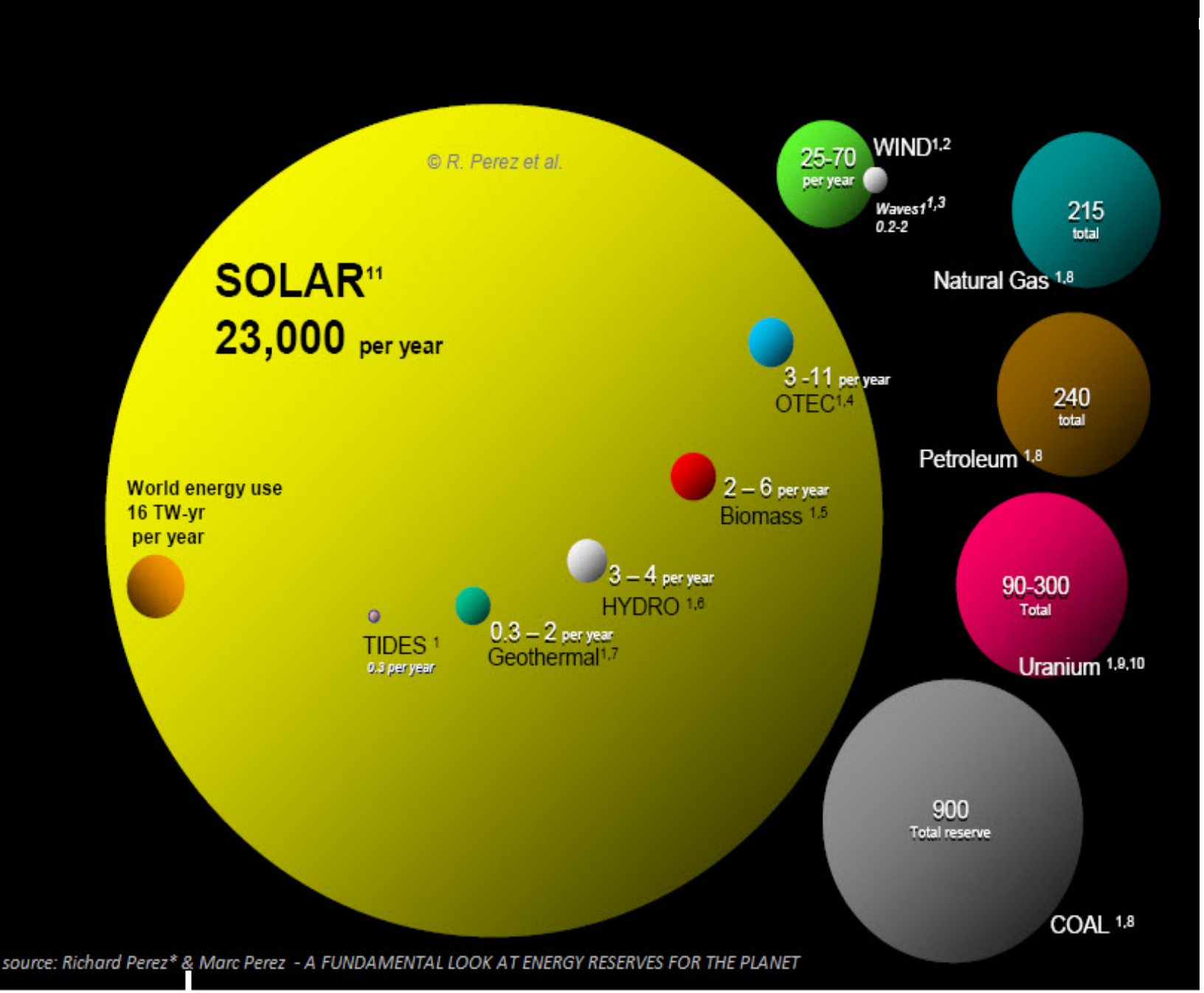
Transport!

# Cost, Energy and Pollution

| For 100km: | Petrol Car | Electric Car | |
|---|---|---|---|
| | | Normal | Off-peak & Small Car |
| Price/Unit | R 14,00 | R 1,33 | 60c |
| Units | 10 litres | 15 kWh | 5 kWh |
| Energy | 320 MJ | 54 MJ | 27 MJ |
| Cost | R 140,00 | R 20,00 | R3,00 |
| GWP | 45kg | 39kg | 13kg |

# Home & *e*Commuter

| Appliance | For Every Day | | |
|---|---|---|---|
| | Wh/d | MJ/d | Cost |
| Kitchen | 8'577 | 31 | R 8,58 |
| Rest | 7'720 | 28 | R 7,72 |
| Outside | 2'780 | 10 | R 2,78 |
| Total | **19kWh** | 69 | R 25 |
| | Use of petrol or electricity | MJ/d | Cost |
| *p*Car 9L/100km | 7,2 L 80km/day | 205 | R 100 R14/L |
| *e*Car 15kWh/100km | **12 kWh** 80km/day | 43 | **R 16** R1,33/kWh |
| *e*Com 5kWh/100km | **4 kWh** 80km/day | 14 | **R 5** R1,33/kWh |




Perspective

*Comparing finite and renewale planetary energy reserves )Terawatt-years).*
*Total recoverable reserves are shown for the finate resources.*

**TW.yrs**

# SURFACE AREA REQUIRED TO POWER THE WORLD

## WITH ZERO CARBON EMISSIONS AND WITH SOLAR ALONE

www.landartgenerator.org

BOXES TO SCALE WITH MAP

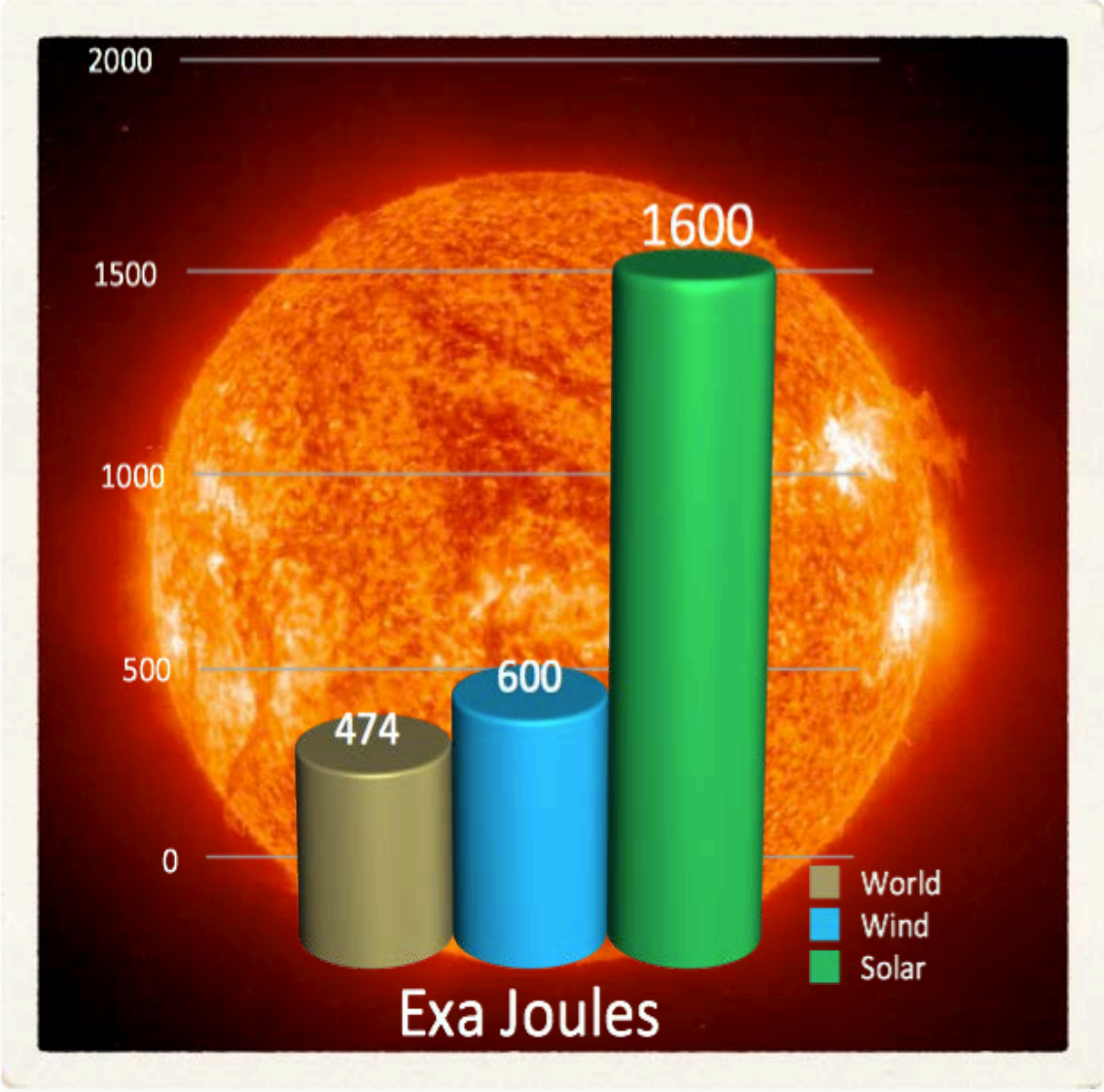
- 1980 (based on actual use)
  207,368 SQUARE KILOMETERS
- 2008 (based on actual use)
  366,375 SQUARE KILOMETERS
- 2030 (projection)
  496,805 SQUARE KILOMETERS

*Required area that would be needed in the year 2030 is shown as one large square in the key above and also as distributed around the world relative to use and available sunlight.*

- Areas are calculated based on an assumption of 20% operating efficiency of collection devices and a 2000 hour per year natural solar input of 1000 watts per square meter striking the surface.
- These 19 areas distributed on the map show roughly what would be a reasonable responsibility for various parts of the world based on 2009 usage. They would be further divided many times, the more the better to reach a diversified infrastructure that localizes use as much as possible.
- The large square in the Saharan Desert (1/4 of the overall 2030 required area) would power all of Europe and North Africa. Though very large, it is 18 times less than the total area of that desert.
- The definition of "power" covers the fuel required to run all electrical consumption, all machinery, and all forms of transportation. It is based on the US Department of Energy statistics of worldwide Btu consumption and estimates the 2030 usage (678 quadrillion Btu) to be 44% greater than that of 2008.
- Area calculations do not include magenta border lines.

LAND ART GENERATOR INITIATIVE

# Energy from the SUN




- Average = 80km per day
- Small electric commuter:

  5kWh/100km = 4kWh/day
- PV electrical energy
  - 5kWh per day
  - 1kW array = 5 x 200W panels
  - 10m$^2$
- PV cells cost – R30’000, once-off, for 25 years
- PV life = 500’000km
- 6c/km (no increase!)

# Solar powered electric bus

- Adelaide Australia – “Tindo” after the Aboriginal word for "sun”
- World's first 100% solar-recharged electric transit bus
- Seats 27
- 35kW electric motor
- 262kWh ZEBRA sodium nickel chloride batteries


11,480kg vehicle, top speed of 75km/hr and an estimated operation range between fast charges is 200km

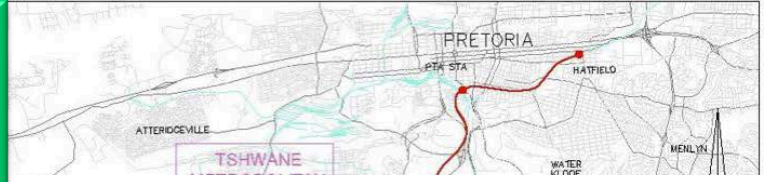
sanedi
South African National Energy Development Institute (SOC) Ltd.

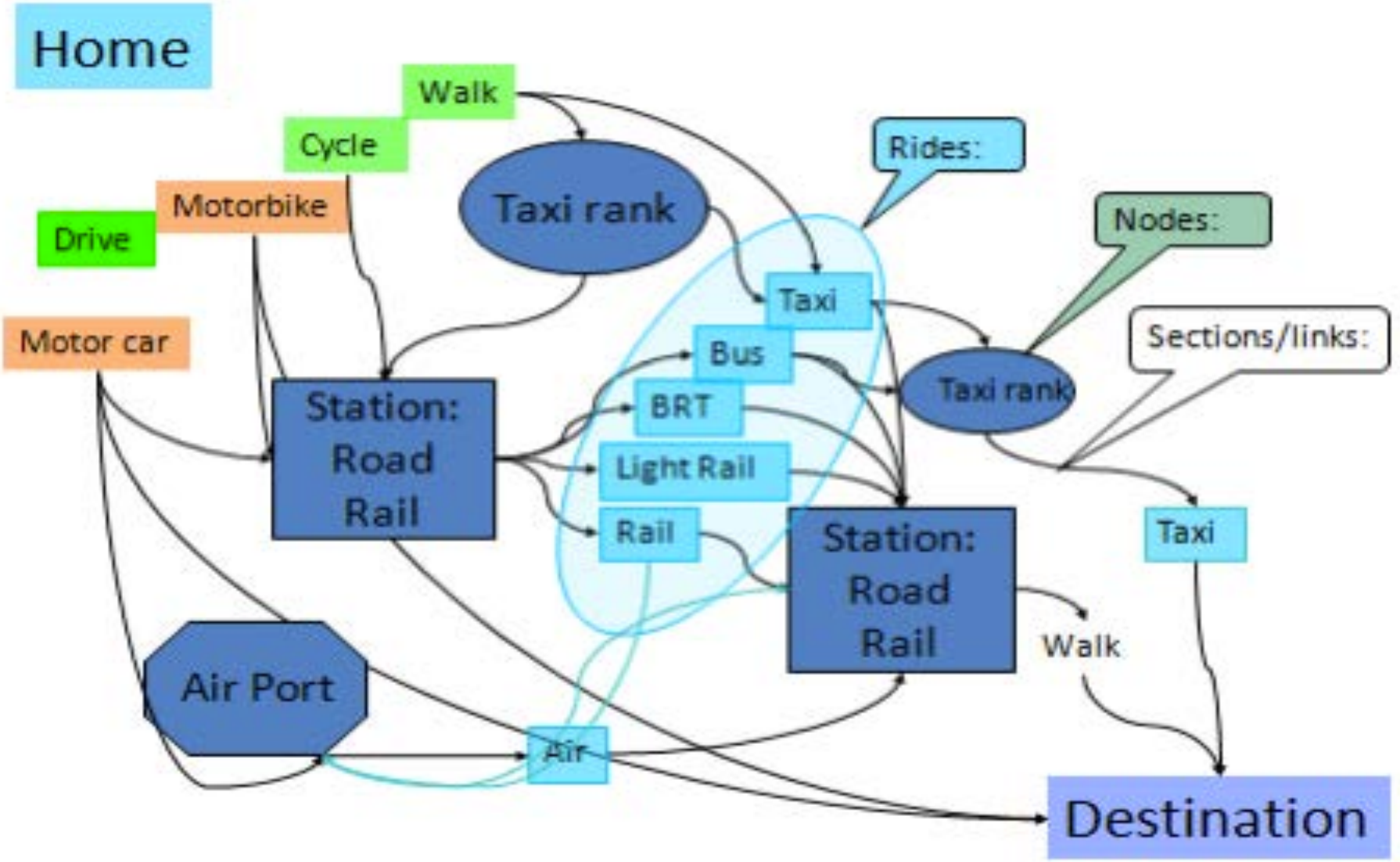
# PATHWAYS

# &

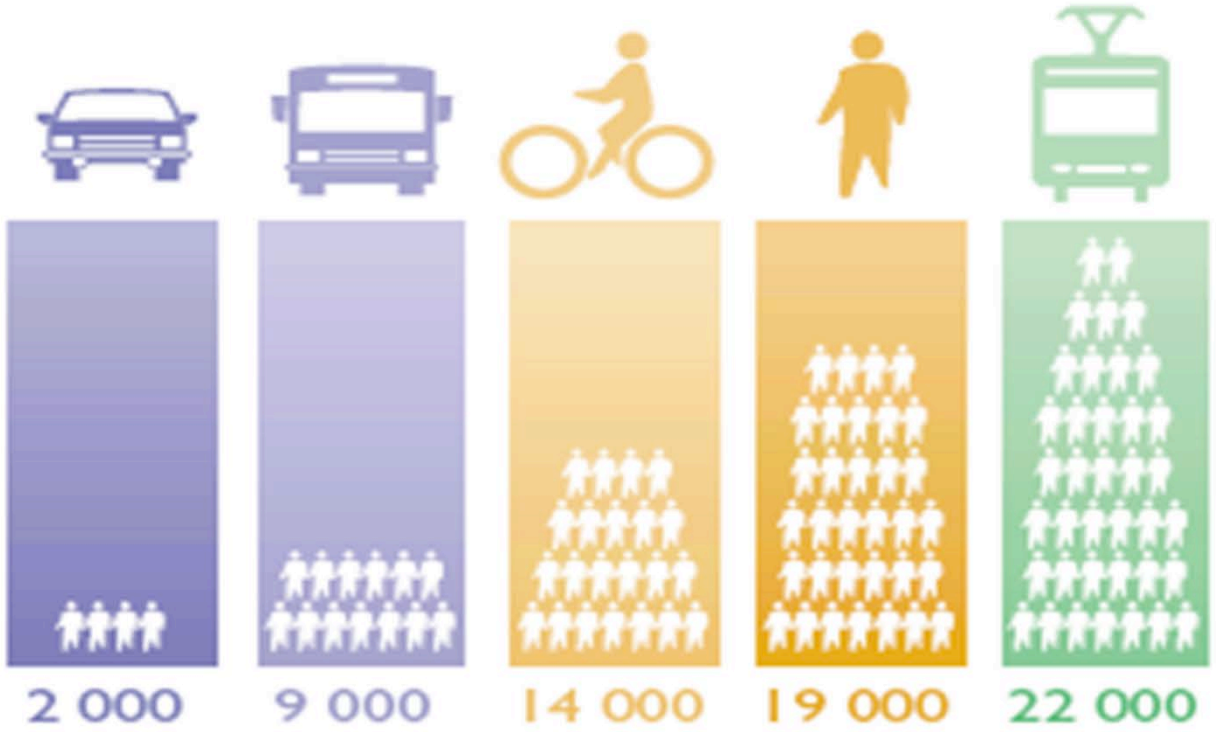
# Putting it all Together

# Ways of the Modes



# Space used by modes




Private cars are by far less efficient than the other modes of transport in town without taking into account the space they take up for parking

*Source: Botma & Pependrecht, Traffic operation of bicycle traffic, TU Delft, 1991*

# Shared *Integrated* Solar eCom




autolib'

# World Largest Public Service EV Car-Sharing Scheme

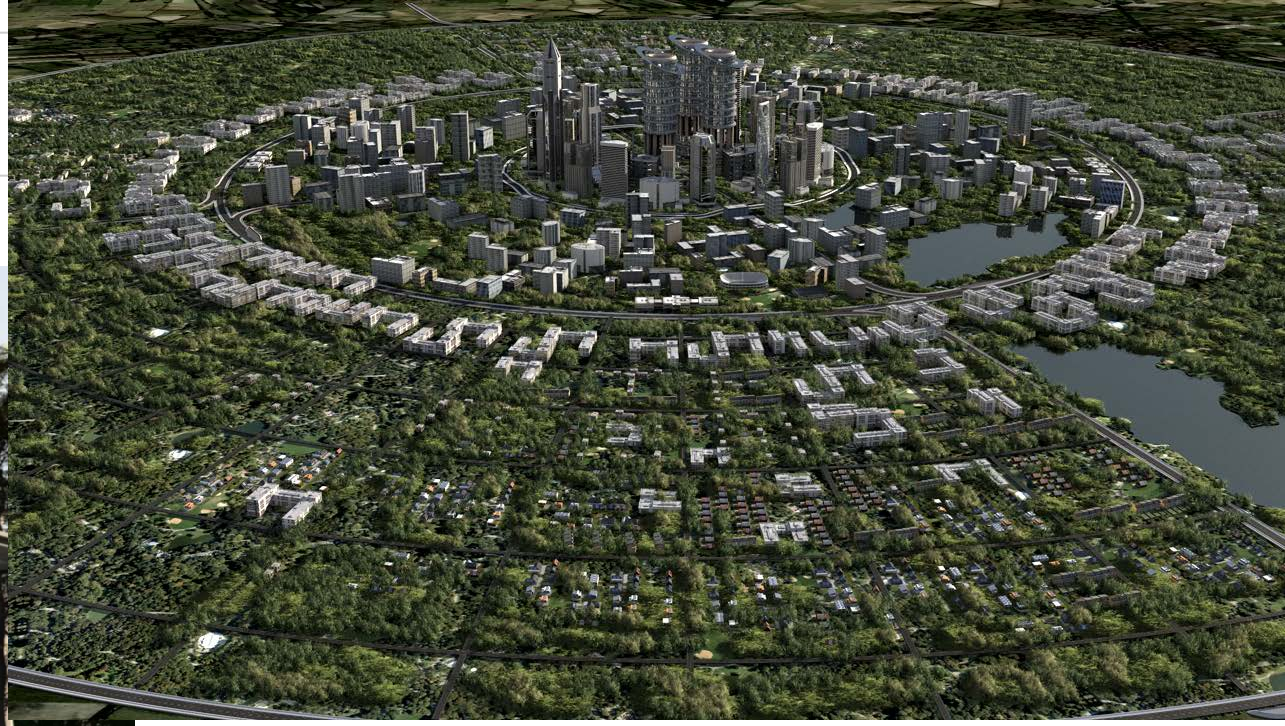
- 3,000 Electric Vehicles
- 1,100 Stations
- 6,600 Charge Points

# Global EV Solution

- Batteries
- EV Cars
- On-Board Equipment
- Self-Service Kiosks
- Charging Stations
- Information System
- 24/7 Customer Support



# Siemens City



## Solar Charging for Home & Car


# Cost of Ownership - variables

| Inputs | |
|---|---|
| Interest Rate | 9% |
| Inflation | 6.5% |
| *Vehicle prices* | |
| Petrol | R297'000 |
| Electric | R270'000 |
| Battery | R180'000 |
| Battery life in car | 150'000 |
| Annual km | 15000 |
| *Consumption rates in traffic* | |
| Petrol Car | 10 |
| Electric Car | 15 |

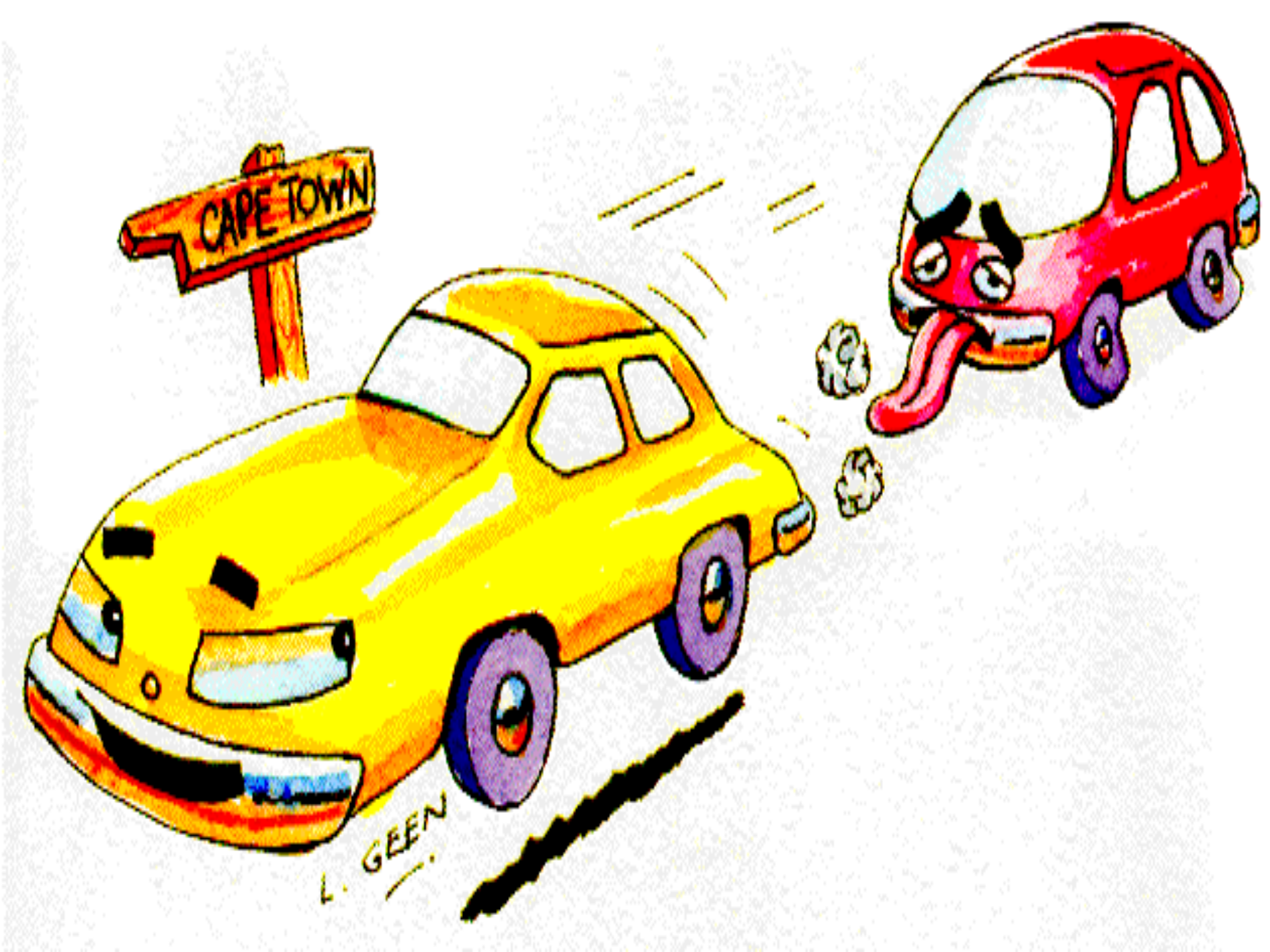
| *Energy prices and trends* | |
|---|---|
| Petrol per Litre | R13.00 |
| Ave over last 10 yrs | 20% |
| Electricity per kWh | R1.20 |
| Ass annual increase | 10% |
| *Value lost in 5 years* | |
| Petrol | 45% |
| Electric & Battery | 40% |
| Electric | 40% |
| Battery | 60% |
| *Value lost in 10 years* | |
| Petrol | 80% |
| Electric & Battery | 75% |
| Electric | 60% |
| Battery | 75% |

# Cost of Ownership - 5year calcs

| 5 | Petrol Car | | EV & Battery as unit | | Car & Battery separate | | |
|---|---|---|---|---|---|---|---|
| Years | Car | Energy | Car | Energy | Car | Battery | Energy |
| Payment (Yr) | (R70'052) | | (R106'139) | | (R63'683) | (R1'500) | |
| Energy cost/ yr | | (R19'500) | | (R2'700) | | | (R2'700) |
| Year | | | | | | | |
| 1 | (R70'052) | (R19'500) | (R106'139) | (R2'700) | (R63'683) | (R1'500) | (R2'700) |
| 2 | (R70'052) | (R23'400) | (R106'139) | (R2'970) | (R63'683) | (R1'500) | (R2'970) |
| 3 | (R70'052) | (R28'080) | (R106'139) | (R3'267) | (R63'683) | (R1'500) | (R3'267) |
| 4 | (R70'052) | (R33'696) | (R106'139) | (R3'594) | (R63'683) | (R1'500) | (R3'594) |
| 5 | (R70'052) | (R40'435) | (R106'139) | (R3'953) | (R63'683) | (R1'500) | (R3'953) |
| Residual values | R163'350 | | R270'000 | | R162'000 | R72'000 | |
| | (R179'163) | (R117'892) | (R256'040) | (R13'537) | (R153'624) | R43'111 | (R13'537) |
| **NPV** | **(R297'056)** | | **(R269'577)** | | **(R124'050)** | | |

# Cost of Ownership – 10year calcs

| 10 | Petrol | | Electric & Battery | | EV only | Battery | |
|---|---|---|---|---|---|---|---|
| Years | | | | | | | |
| Payment (Yr) | (R70'052) | | (R6) | | (R63'683) | (R0) | |
| Energy cost/yr | | (R19'500) | | (R2'700) | | | (R2'700) |
| Year | | | | | | | |
| 1 | (R70'052) | (R19'500) | (R106'139) | (R2'700) | (R63'683) | (R1'500) | (R2'700) |
| 2 | (R70'052) | (R23'400) | (R106'139) | (R2'970) | (R63'683) | (R1'500) | (R2'970) |
| 3 | (R70'052) | (R28'080) | (R106'139) | (R3'267) | (R63'683) | (R1'500) | (R3'267) |
| 4 | (R70'052) | (R33'696) | (R106'139) | (R3'594) | (R63'683) | (R1'500) | (R3'594) |
| 5 | (R70'052) | (R40'435) | (R106'139) | (R3'953) | (R63'683) | (R1'500) | (R3'953) |
| 6 | | (R48'522) | | (R4'348) | | | (R4'348) |
| 7 | | (R58'227) | | (R4'783) | | | (R4'783) |
| 8 | | (R69'872) | | (R5'262) | | | (R5'262) |
| 9 | | (R83'846) | | (R5'788) | | | (R5'788) |
| 10 | | (R100'616) | | (R6'366) | | | (R6'366) |
| Residual values | R59'400 | | R112'500 | | R108'000 | R45'000 | |
| | (R250'404) | (R332'005) | (R363'980) | (R29'450) | (R190'632) | R24'607 | (R29'450) |
| **NPV** | **(R582'409)** | | **(R393'430)** | | **(R195'475)** | | |


CAPE TOWN
L. GEEN

# Who needs to stop and charge or a plug and wires?



# Thank you for your attention!

## Any questions?

Carel Snyman +27 10 201 4830
carels@sanedi.org.za