WHAT TO DO WITH A HYBRID DRIVE SYSTEM?

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Abstract: Do hybrid drive are the future? Limited resources of fossil fuels causing increasingly frequent questions about the future of propulsion systems. In this paper, on the basis of available information, was described the basic structure, types, and the potential benefits of multisources drive systems. The author's intention is to initiate a discussion which type of drive system: hydraulic, pneumatic, mechanical, electrical, is potentially the best solution to use in the future.

***Keywords**: Hybrid drive system, ecology, energy, efficiency.*

1. Introduction.

Drive systems of machines and vehicles with an accumulation of energy is one of the elements of environmental technology. In a fast-changing cyclically repeated external loads of working machines and vehicles drive systems provide a reduction of primary energy consumption, and therefore exhaust gases emissions. They also allow to recuperate a kinetic or potential energy. Generally, lower energy consumption of drive systems of machines and vehicles, can be obtain by [4]:

- increasing an efficiency of drive system components,
- appropriate matching of high-efficient zones of components of powertrain,
- use of multi-source (hybrid) drive system, allowing to recuperate a kinetic or potential energy.

To design rational drive systems there should be used above listed postulates. It requires knowledge from transformation, transmission, distribution and energy recuperation field and meet several additional requirements. This applies in particular:

- Knowledge of the characteristics of the load (energetic characteristic), including flow variables (linear and angular velocity, flow rate) and effort variables (power, torque, pressure). It could be represented as: operating point, load curves, area of work or cycle work, or in the spectrum of loads.
- Knowledge of an energy characteristics (energy efficiency or losses).
- Evaluation of an energy efficiency of alternative solutions of the drive system for the same load conditions.
- Problems solving connected with structures and components selection for the drive system.
- Problems solving connected with controls issues, in particular the synthesis of control systems.

In the literature, the concept of multi-sources (or hybrid) drive systems, is known for several decades [1], [2], [3], [4]. Research and development on these issues, from economic and technological reasons, were periodic- sometimes very intensive, sometimes weak activity. They were closely related with the fuel crisis. Nowadays R&D activity in this area is more and more connected with an environmental aspects.

"Keeping up" of energy source for variable load is characteristic for classic drive systems. It is directly connected with the energy efficiency of the system, which often reaches values even below 10%. It has a significant impact on the operating costs such as: fuel and lubricants consumption, or durability of the drive system. This applies in particular to internal combustion engines.

One of the ways to solve this problem is multisources (hybrid) drive systems, characterized by the cooperation of at least two energy sources, wherein at least one of them must be the secondary source of energy.

The concept of "primary source of energy" should be understood as a source of energy with constant parameters, providing energy to the system regardless of the changes taking place in the load. This may be for example a heat engine. The "primary source of energy" is characterized by irreversible energy flow- only from source to the system.

The term "secondary source of energy" (an accumulator) means a device for accumulating potential or kinetic energy. The battery stores the surplus and / or recoverable energy. The accumulation can be realized by electrochemical, hydraulic or mechanical batteries. Secondary source of energy is characterized by reversible work.

Due to the direction of energy flow and location of the sources, there are two types of structures of hybrid systems:

- series (fig.1),
- parallel (fig.2).

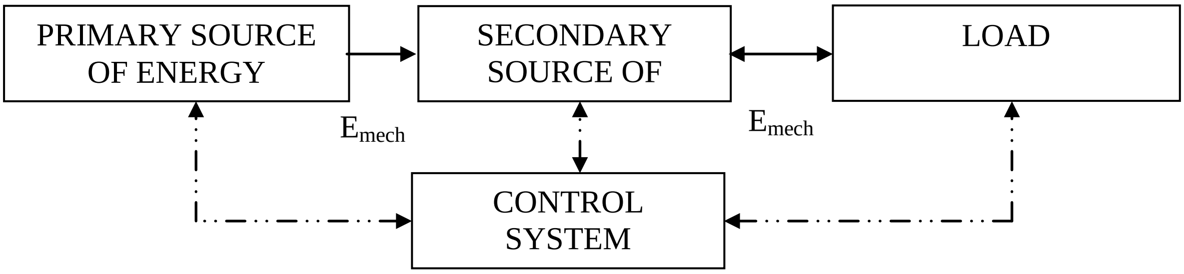

Fig. 1. Schema of series hybrid drive system.

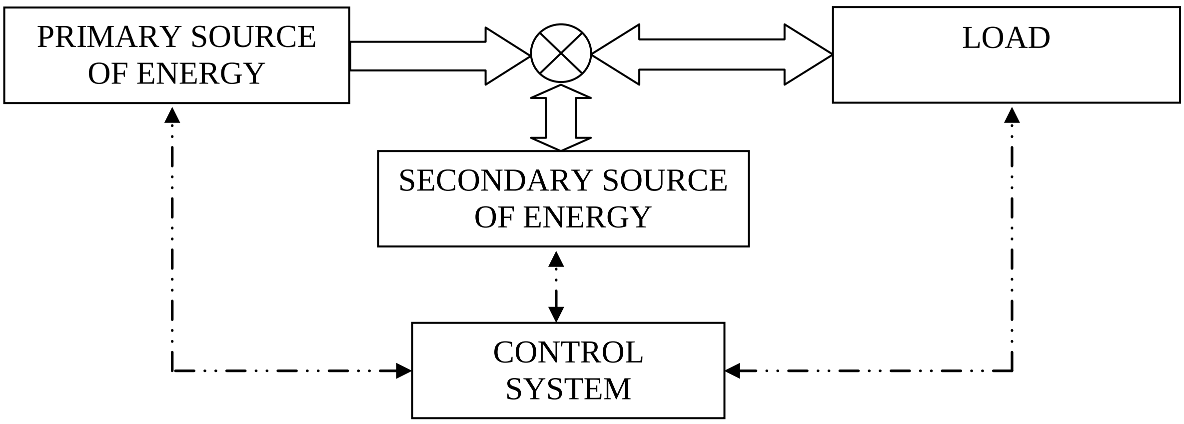

Fig. 2. Schema of parallel hybrid drive system [4].

There are many solutions of secondary sources of energy. The most widespread and historically oldest, is undoubtedly a mechanical press (serial system), in which the electric motor operates with power equal to the average power in the cycle. Increased energy demand is met from secondary sources of energy- in this case flywheel. When the press is in idling mode, flywheel gathers an energy supplied to the system by an electric motor. Other examples could be: the steam engine, compressor or IC engine, where the flywheel is used to stabilization of angular velocity [5].

Nowadays more and more companies propose a hybrid machinery and equipment of propulsion systems. Information on the details of construction and principles of their controls, is limited to the manual, because of trade secret or competition between companies. In some cases, the construction of hybrid machines is a result of experimental tests and an engineers intuition and their experience

2. Energy sources for hybrid vehicles

There are a few power sources for hybrid vehicles [5]:

2.1. On-board or out-board rechargeable energy storage system (RESS).

A rechargeable energy storage system or RESS is a system that stores energy for delivery of power and which is rechargeable. Production storage systems use electric rechargeable traction batteries, electric double-layer capacitors or flywheel energy storage [21].

2.2. Coal, wood or other solid combustibles.

Solid fuel refers to traditional types of combustible solid fuels like firewood and coal. While these fuel types are readily available (some of them actually grow on trees), not all of them are sustainable in the long term. Coal, for example, is a fossil fuel, and its use in the production of electricity is said to make it the largest contributor to the human-made increase in CO_2 in the atmosphere. The use of coal in solid fuel heaters is, however, increasingly uncommon. Types of solid fuel:

- wood,
- charcoal,
- peat,
- coal,
- hexamine fuel tablets,
- organic pellets.

2.3. Electricity, Electromagnetic fields, Radio waves.

Electricity is the set of physical phenomena associated with the presence and flow of electric charge. Electricity gives a wide variety of well-known effects, such as lightning, static electricity, electromagnetic induction and the flow of electrical current. In addition, electricity permits the creation and reception of electromagnetic radiation such as radio waves [5].

2.4. Compressed or liquefied natural gas.

Compressed natural gas (CNG) is a fossil fuel substitute for gasoline (petrol), Diesel fuel, or propane/LPG. Although its combustion does produce greenhouse gases, it is a more environmentally clean alternative to those fuels, and it is much safer than other fuels in the event of a spill (natural gas is lighter than air, and disperses quickly when released). CNG may also be mixed with biogas, produced from landfills or wastewater, which doesn't increase the concentration of carbon in the atmosphere [22].

CNG is made by compressing natural gas (which is mainly composed of methane [CH_4]), to less than 1% of the volume it occupies at standard atmospheric pressure. It is stored and distributed in hard containers at a pressure of 200–248 bar (2900–3600 psi), usually in cylindrical or spherical shapes.

2.5. Human powered e.g. pedalling or rowing.

Human powered transport includes walking, bicycles, velomobiles, row boats, and other environmentally friendly ways of getting around. In addition to the health benefits of the exercise provided, they are far more environmentally friendly than most other options. The only downside is the speed limitations, and how far one can travel before getting exhausted [5].

2.6. Hydrogen.

A hydrogen vehicle is a vehicle that uses hydrogen as its onboard fuel for motive power. Hydrogen vehicles include hydrogen fueled space rockets, as well as automobiles and other transportation vehicles. The power plants of such vehicles convert the chemical energy of hydrogen to mechanical energy either by burning hydrogen in an internal combustion engine, or by reacting hydrogen with oxygen in a fuel cell to run electric motors. Widespread use of hydrogen for fueling transportation is a key element of a proposed hydrogen economy [11].

2.7. Petrol or Diesel fuel.

Petrol and diesel are petroleum-derived liquid mixtures used as fuels. Though both have similar base product but have different properties and usage.

Petrol is a petroleum-derived liquid mixture consisting mostly of aliphatic hydrocarbons and enhanced with aromatic hydrocarbons toluene, benzene or iso-octane to increase octane ratings, primarily used as fuel in internal combustion engines. Diesel is a specific fractional distillate of petroleum fuel oil or a washed form of vegetable oil that is used as fuel in a diesel engine invented by German engineer Rudolf Diesel [8].

2.8. Solar.

Solar energy, radiant light and heat from the sun, has been harnessed by humans since ancient times using a range of ever-evolving technologies. Solar energy technologies include solar heating, solar photovoltaics, solar thermal electricity and solar architecture, which can make considerable contributions to solving some of the most urgent problems the world now faces

The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately 3,850,000 exajoules (EJ) per year.[6] In 2002, this was more energy in one hour than the world used in one year

2.9. Wind.

Wind is the flow of gases on a large scale. On Earth, wind consists of the bulk movement of air. In outer space, solar wind is the movement of gases or charged particles from the sun through space, while planetary wind is the outgassing of light chemical elements from a planet's atmosphere into space. Winds are commonly classified by their spatial scale, their speed, the types of forces that cause them, the regions in which they occur, and their effect.

3. Engine type.

3.1. Hybrid electric-petroleum vehicles

When the term hybrid vehicle is used, it most often refers to a Hybrid electric vehicle. These encompass such vehicles as the Saturn Vue, Toyota Prius, Toyota Camry Hybrid, Ford Escape Hybrid, Toyota Highlander Hybrid, Honda Insight, Honda Civic Hybrid, Lexus RX 400h and 450h and others. A petroleum-electric hybrid most commonly uses internal combustion engines (generally gasoline or Diesel engines, powered by a variety of fuels) and electric batteries to power the vehicle. There are many types of petroleum-electric hybrid drivetrains, from Full hybrid to Mild hybrid, which offer varying advantages and disadvantages [5].

3.2. Continuously outboard recharged electric vehicle (COREV).

Given suitable infrastructure, permissions and vehicles, BEVs can be recharged while the user drives. The BEV establishes contact with an electrified rail, plate or overhead wires on the highway via an attached conducting wheel or other similar mechanism (see Conduit current collection). The BEV's batteries are recharged by this process on the highway and can then be used normally on other roads until the battery is discharged. Some of battery-electric locomotives used for maintenance trains on the London Underground are capable of this mode of operation. Power is picked up from the electtrified rails where possible, switching to battery power where the electricity supply is disconnected.

3.3. Hybrid fuel (dual mode).

In addition to vehicles that use two or more different devices for propulsion, some also consider vehicles that use distinct energy sources or input types ("fuels") using the same engine to be hybrids, although to avoid confusion with hybrids as described above and to use correctly the terms, these are perhaps more correctly described as dual mode vehicles [5]:

- Some electric trolleybuses can switch between an on board diesel engine and overhead electrical power depending on conditions (see dual mode bus). In principle, this could be combined with a battery subsystem to create a true plug-in hybrid trolleybus, although as of 2006[update], no such design seems to have been announced.
- Flexible-fuel vehicles can use a mixture of input fuels mixed in one tank — typically gasoline and ethanol, or methanol, or biobutanol.
- Bi-fuel vehicle:Liquified petroleum gas and natural gas are very different from petroleum or diesel and cannot be used in the same tanks, so it would be impossible to build an (LPG or NG) flexible fuel system. Instead vehicles are built with two, parallel, fuel systems feeding one engine. While the duplicated tanks cost space in some applications, the increased range and flexibility where (LPG or NG) infrastructure is incomplete may be a significant incentive to purchase.
- Some vehicles have been modified to use another fuel source if it is available, such as cars modified to run on autogas (LPG) and diesels modified to run on waste vegetable oil that has not been processed into biodiesel.
- Power-assist mechanisms for bicycles and other human-powered vehicles are also included (see Motorized bicycle).

3.4 Fluid power hybrid.

Hydraulic and pneumatic hybrid vehicles use an engine to charge a pressure accumulator to drive the wheels via hydraulic or pneumatic (i.e. compressed air) drive units. In most cases the engine is detached from the drivetrain merely only to change the energy accumulator. The transmission is seamless.

3.5 Elctric-human power hybrid vehicle.

Another form of hybrid vehicle are human power-electric vehicles. These include such vehicles as the Sinclair C5, Twike, electric bicycles, and electric skateboards [5].

4. Environmental issues.

4.1. Fuel consumption and emissions reductions.

Start/Stop: In the NEDC (New European driving cycle) a fuel consumption reduction of 5-8 percent can be achieved with engine stop at vehicle standstill (fig. 3) [23].

Optimised operation: Engine operation with low engine load can be substituted by electric driving. Further, the combination of combustion engine and electric machine offers the possibility to shift the engine load point

Brake energy recovery: Recovery of the brake energy results in a fuel consumption reduction of 3-10 percent in the NEDC, depending on the layout of the hybrid powertrain, the maximum power of the electric machine and the efficiencies of the powertrain components

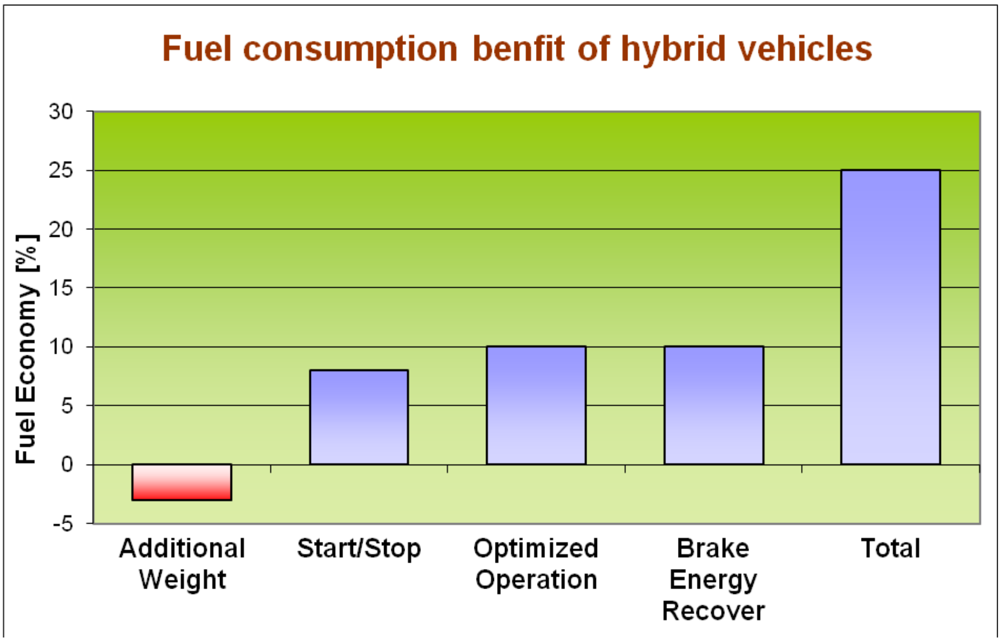

Fig.3 . Fuel consumption benefit of hybrid vehicles [23].

Figure 4 shows the simulated fuel consumption values for a conventional vehicle, the parallel hybrid and the parallel hybrid with fuel cell range extender.

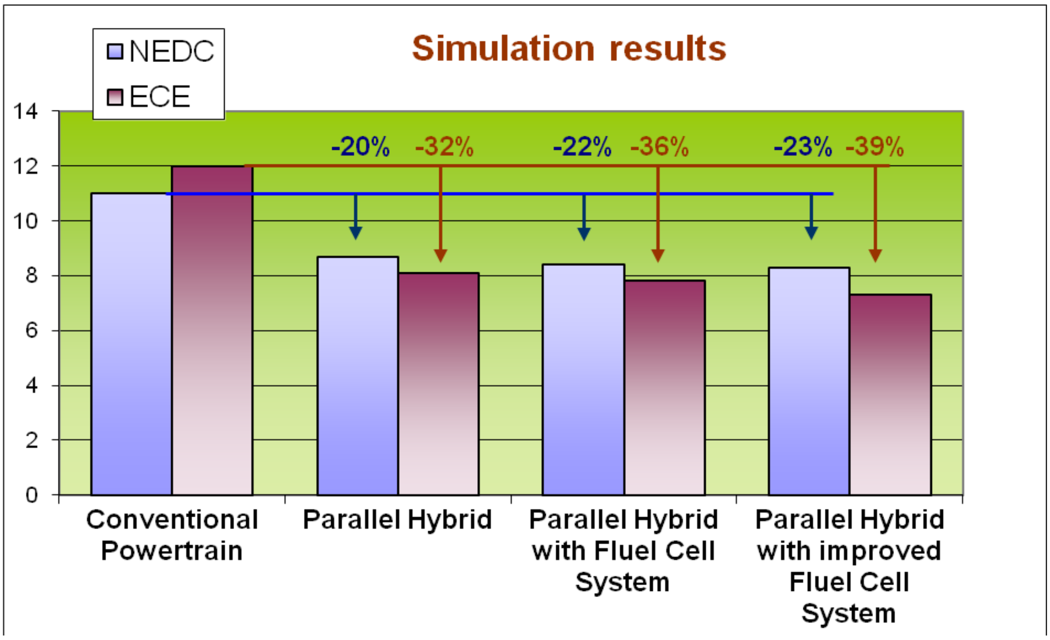

Fig. 4. Simulated fuel consumption values for a conventional vehicle, the parallel hybrid and the parallel hybrid with fuel cell range extender [23].

Hybridisation offers a big potential to reduce the fuel consumption especially in the ECE (urban part of the NEDC cycle) as all hybrid features – start/stop, electric driving and energy recovery – can be fully used.

4.2. Hybrid vehicle emissions.

Hybrid vehicle emissions today are getting close to or even lower than the recommended level set by the EPA (Environmental Protection Agency). The recommended levels they suggest for a typical passenger vehicle should be equated to 5.5 metric tons of carbon dioxide. The three most popular hybrid vehicles, Honda Civic, Honda Insight and Toyota Prius, set the standards even higher by producing 4.1, 3.5, and 3.5 tons showing a major improvement in carbon dioxide emissions. Hybrid vehicles can reduce air emissions of smog-forming pollutants by up to 90% and cut carbon dioxide emissions in half.

4.3. Environmental impact of hybrid car battery.

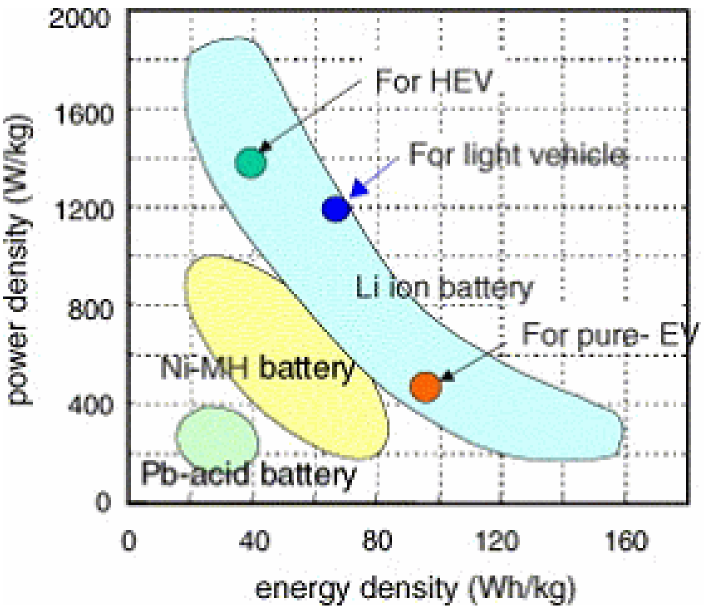

Fig. 5. Comparison of energy densities of rechargeable batteries [18].

Though hybrid cars consume less gas than conventional cars, there is still an issue regarding the environmental damage of the hybrid car battery. Today most hybrid car batteries are one of two types: 1) nickel metal hydride, or 2) lithium ion; both are regarded as more environmentally friendly than lead-based batteries which constitute the bulk of petro car starter batteries today. There are many types of batteries (fig. 5). Some are far more toxic than others. Lithium ion is the least toxic of the three mentioned above.[19]

The toxicity levels and environmental impact of nickel metal hydride batteries the type currently used in hybrids are much lower than batteries like lead acid or nickel cadmium. However, nickel-based batteries are known carcinogens, and have been shown to cause a variety of teratogenic effects.[20]

The Lithium-ion battery has attracted attention due to its potential for use in hybrid electric vehicles. Hitachi is a leader in its development. In addition to its smaller size and lighter weight, lithium-ion batteries deliver performance that helps to protect the environment with features such as improved charge efficiency without memory effect. The lithium-ion batteries are appealing because they have the highest energy density of any rechargeable batteries and can produce a voltage more than three times that of nickel–metal hydride battery cell while simultaneously storing large quantities of electricity as well. The batteries also produce higher output (boosting vehicle power), higher efficiency (avoiding wasteful use of electricity), and provides excellent durability, compared with the life of the battery being roughly equivalent to the life of the vehicle. Additionally, use of lithium-ion batteries reduces the overall weight of the vehicle and also achieves improved fuel economy of 30% better than petro-powered vehicles with a consequent reduction in CO_2 emissions helping to prevent global warming [19].

4.4. Raw materials increasing costs.

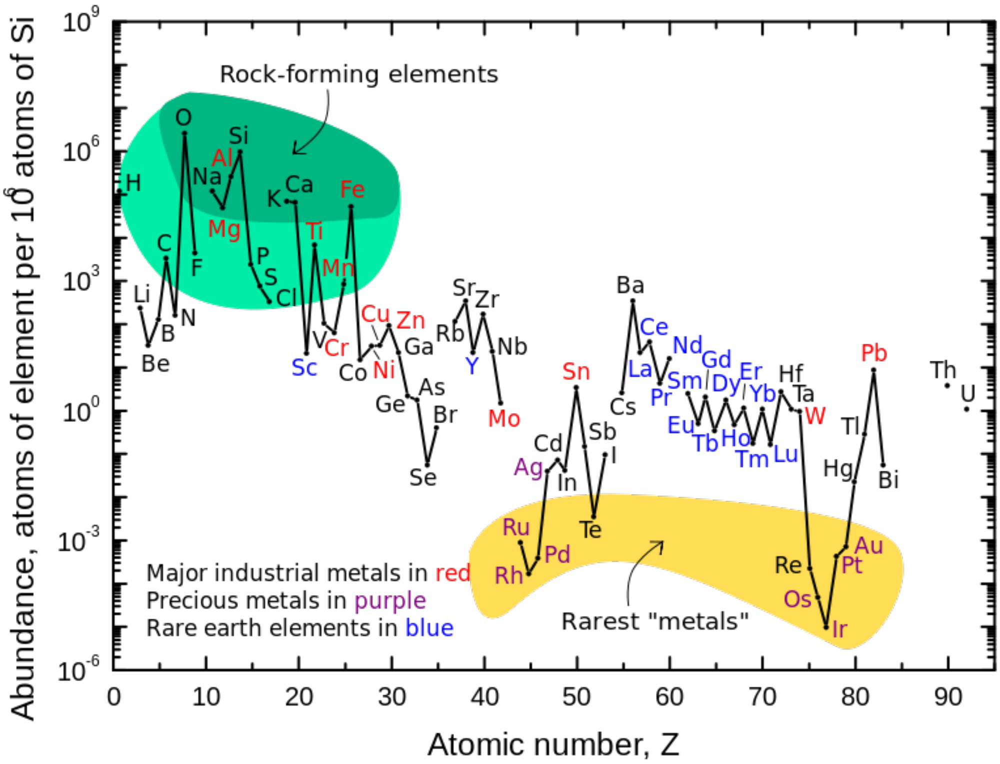

Fig. 6. Abundance of elements in the Earth crust per million of Si atoms [11], [12].

There is an impending increase in the costs of many rare materials (fig.6) used in the manufacture of hybrid cars [15]. For example, the rare earth element dysprosium is required to fabricate many of the advanced electric motors and battery systems in hybrid propulsion systems [15], [16]. Neodymium is another rare earth metal which is a crucial ingredient in high-strength magnets that are found in permanent magnet electric motors[13].

Nearly all the rare earth elements in the world come from China [14], and many analysts believe that an overall increase in Chinese electronics manufacturing will consume this entire supply by 2012 [15]. In addition, export quotas on Chinese rare earth elements have resulted in an unknown amount of supply [11],[14].

A few non-Chinese sources such as the advanced Hoidas Lake project in northern Canada as well as Mount Weld in Australia are currently under development; however, the barriers to entry are high [17] and require years to go online.

5. Conclusions.

So what we have to do? We have to planing future without oil.

With the price of crude hovering above $140 a barrel there is significant pressure to reduce and manage our energy consumption. Goldman Sachs has predicted that we will soon hit $200 per barrel [24].

Politicians and commentators are quick to offer solutions or attribute blame. However many of them deny the fact that in the not too distant future, supply will not be able to keep up with demand. Drilling cannot fix this and speculators are not to blame. Speculators are simply reading the markets. Making pariahs out of speculators is yet another way to avoid the reality of the energy problems we face. And drilling for oil in Alaska or off America's shores will further degrade the environment and do nothing to reduce the price of oil [24].

Even the much maligned government of China has put energy efficiency on the top of their agenda. Within the realm of today's technology it is entirely possible to achieve a 10% reduction in energy consumption. Although inflation is a real problem, there are some upsides to increased oil prices. The high price of oil exerts pressure to reduce consumption and research alternatives [24].

Although oil is still part of the energy equation, in the future we will have a more diversified energy economy that is much less dependent on oil. If we are to be weaned off of oil we will need to focus on energy in a methodical way. From a policy point of view we need incentives and disincentives in support of efficiency and alternatives. We need national and global energy strategies [24].

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