Summary

Terminal equipment contains all kinds of equipment that can handle and transport cargo, in many cases in containers, "horizontally" from ship to stacking yard. Millions of these containers are transported all over the world, making over 200 million trips every year between seaports with container terminals. Examples of terminal equipment are the straddle carrier, terminal tractor and reach stacker. The operations of terminal equipment are characterized by start-stop operations and, in many cases, by lifting cargo. Reliable and efficient handling with low energy consumption is crucial, because the competition between container terminals is fierce. Moreover due to higher energy prices energy economy is becoming more and more an issue. Therefore, energy management by hybridization and further electrification using energy storage systems is an important development in terminal equipment.

For terminal equipment, three different kinds of propulsion systems can be mentioned: conventional (driven by an Internal Combustion Engine), fully electric and diesel-electric hybrid. Diesel-electric hybrid vehicles can be seen as a mixture of an ICE-powered automobile and a fully electric vehicle. Hybrid propulsion systems can be classified into four different kinds: series hybrid, parallel hybrid, series-parallel hybrid and complex hybrid. A major point in which hybrid electric vehicles (HEV's) can differ is the size of the electric motor (EM) and ICE. A vehicle can be dominated by the ICE or by the EM. A subset of the HEV's is the so-called plug-in HEV, which is characterized by the feature that the batteries can be recharged from the electric power grid. The main benefits of hybridization and electrification of terminal equipment are: the possibility of regenerative braking; the downsizing of the ICE; higher efficiency of the ICE due to operating at its maximum operating point; and allowing the ICE to stop under vehicle stop conditions. The different energy sources which can be distinguished are: batteries, fuel cells, ultracapacitors, ultra-batteries and flywheels. They all differ in specific energy and specific power. The hybridization of energy sources can combine the advantages of two (or more) different energy sources.

The goal of energy management is to minimize the fuel or energy consumption of the hybrid or fully electric terminal equipment. Energy management can be external as well internal. External energy management methods concern the charging frequency of the batteries, the discharge pattern, charging pattern and battery swop. These methods have implications on the energy consumption, battery lifetime and required battery weight.

Internal energy management is caused by control strategies. The highest control layer of a vehicular drive train, termed the Energy Management Strategy (EMS), plays an important role in an effective usage of the drive train components and has as most important task to constantly control the amount op power supplied by the ICE and the battery, while they work together to meet the power demand. The energy management strategies can be classified in heuristic, optimal and sub-optimal control strategies. The former class of controllers represents the state of the art in most hybrid vehicles.

Plug-in hybrid electric vehicles (PHEV's) have their own energy management strategies. A fully charged PHEV operates in charge-depleting mode (CD-mode) until the battery is depleted to a target

state of charge (SOC), at which the vehicle switches to a charge-sustaining mode (CS-mode), using the engine to maintain the target SOC. PHEV's can be categorized as range-extended, engine-dominant blended or electric-dominant blended. If the vehicle could make intelligent predictions about the upcoming cycle, the greatest fuel savings strategy would be to adaptively switch between the engine-dominant and electric dominant blended approaches.

One of the main disadvantages of fully electric vehicles is the relative short range compared to diesel-electric hybrid vehicles and conventional vehicles. It can be said that when the cycle distance enlarges, the advantage of hybrid vehicles becomes larger compared to fully electric vehicles.
It is mostly advantageous to keep the battery weight as low as possible, because large batteries bring in a higher rolling resistance. But if the structural weight of the vehicle compared with the battery weight is low, it is even more advantageous to use batteries with a low weight. Therefore, for vehicles with a low own weight it is more advantageous to use a hybrid propulsion system than a fully electric one.
Fully electric terminal equipment has the advantage of zero fuel consumption. One kWh of electrification brings in about € 0,23 per tank. Unfortunately, this profit is been undone by the extra purchase costs of the battery. Therefore, being economical with the battery is very important.
If a short charging time is required, a hybrid electric vehicle is preferred above a fully electric vehicle. Because of the long charging time of fully electric terminal equipment, the amount of this equipment has to be larger than the amount of diesel-electric hybrid terminal equipment or there must be extra batteries.
Drained or nearly drained batteries also can be simply switched with fully charged batteries. This saves much charging time and results in a longer battery life.

Because of the many advantages of hybridization such as regenerative braking, less fuel consumption, a long driving range and the lack of real disadvantages, hybridization would be a good possibility for all terminal equipment. The costs and weight of the batteries are reasonable or even low. The purchase costs are higher, because of the complexity and the battery. But due to the decrease in fuel consumption and the possible subsidy or decrease in penalties, these costs will be earned back.
Fully electrification is still not recommended for all terminal equipment. Reasons for that are the very long required charging time, the high battery costs and the high battery weight. Only automatic guided vehicles (AGV's) and small forklift trucks have good possibilities. The high battery weight of AGV's has not much effect because of the very high structural weight of an AGV. The charging time for fully electric AGV's is also reasonable.
There are already many fully electric forklift trucks (especially small ones). The advantage is the very reasonable charging time of about 3 hours. A disadvantage however is the high battery costs compared with the costs of a forklift truck itself.