ENGINEERED EFFICIENCY FOR VOCATIONAL TRUCKS

HYBRIDS AND THE KINECTIC ENERGY MYTH

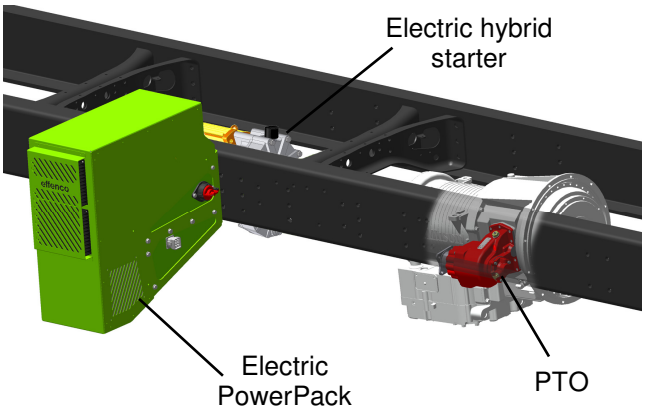
Over the last fifteen years, tens of millions of dollars have been invested in developing hybrid systems for Class 6 to 8 trucks. Because the average truck consumes 18 times more fuel per year than the average passenger vehicle, it made economic sense to do so.

To minimize development costs, a common commercial strategy was to develop a one size fits all solution that would apply to all vocation applications from cement trucks to terminal tractors to bucket trucks. Almost all early hybrids were therefore variations on a common platform which involves harvesting as much kinetic energy as possible while braking and using the energy to reaccelerate the vehicle after a stop. To deliver bankable fuel savings, most such systems require duty cycles in which mean speeds between stops are at least 32 kph (20 mph) and idle time is less than 25% of the vehicle's operating hours. Few vocational applications meet these criteria.

Terminal tractors, for example, perform a lot of stop and go cycle during a day and typically stop from speeds that are barely faster than walking pace. From such speeds, very little kinetic energy can be harvested and used to generate fuel savings. Furthermore, they stay immobile between 40% and 65% of their operating time during which a kinetic energy hybrid system provides no value.

THE EFFENCO STOP-START HYBRID SYSTEM

Effenco's Stop-Start hybrid system is designed to shut down the engine of terminal tractors when they are stationary and to provide alternative energy to low power vehicle systems such as the transmission, fifth-wheel or HVAC systems. Since these vehicles spend a large proportion of their operating time immobile, the Effenco Stop-Start technology creates value by reducing engine operating hours and corresponding fuel consumption, emissions and maintenance.

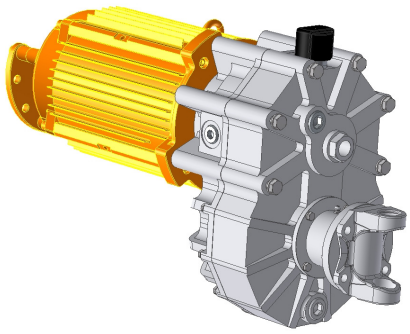


Effenco Stop-Start Hybrid System

Because of the high stopping frequency of terminal tractors, the system is equipped with a powerful electric hybrid starter linked to the engine through a constant mesh PTO connection. The system uses this starter to restart the engine and does not add any load or wear to the existing electric starter and batteries.

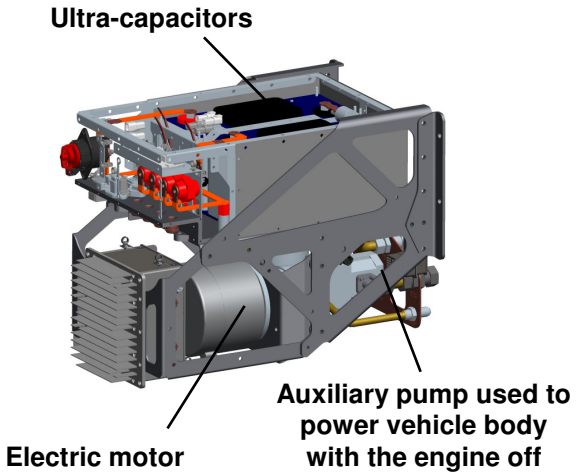
The system is engineered to be transparent to drivers. When the engine has been turned off by the system, the vehicle's transmission remains fully functional. The driver can change gear or simply stay

in drive so the vehicle is ready to accelerate when the engine turns on. The system's PTO starter takes less than 400 ms to take the engine from a stop to idle speed making the vehicle as responsive as it would have been if the engine had been running.



Hybrid Electric Starter

An electric power pack powers the hybrid starter with ultra-capacitors designed to provide more than 1 million high power charge and discharge cycles. The Effenco PowerPack also includes an electric motor-driven hydraulic pump which allows the vehicle's equipment to operate with the engine off. The displacement and rated power of this pump are sized to match performances and cycle time of the original equipment design.

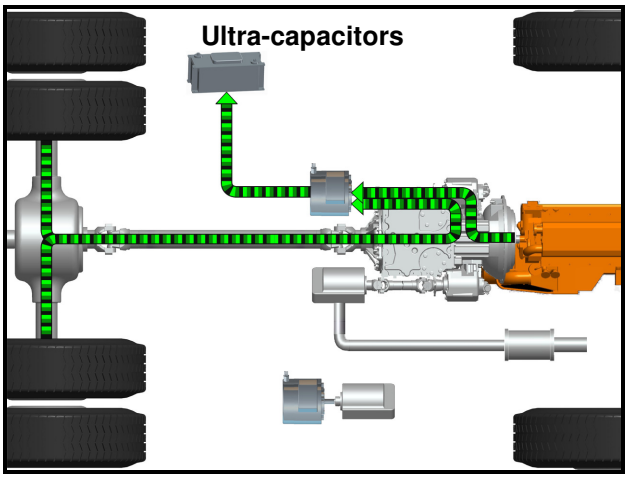


The Effenco PowerPack

ENGINE AND ENERGY MANAGEMENT

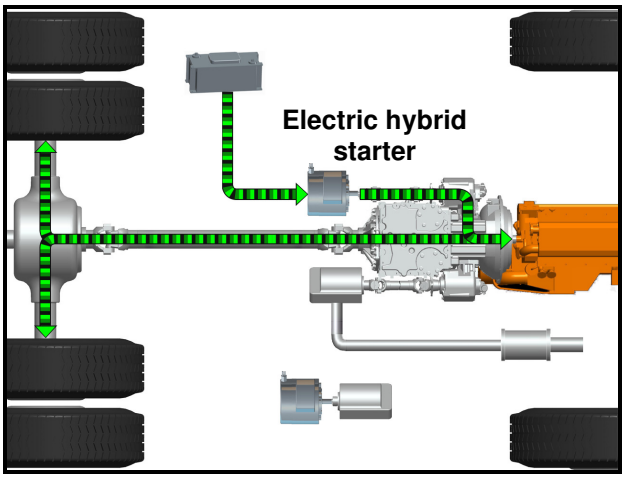
The electric hybrid starter can operate as a motor or a generator. In generator mode it harvests power while the vehicle brakes or if braking energy is insufficient by taking some power of the engine when it is at best efficiency point.

Charging PowerPack

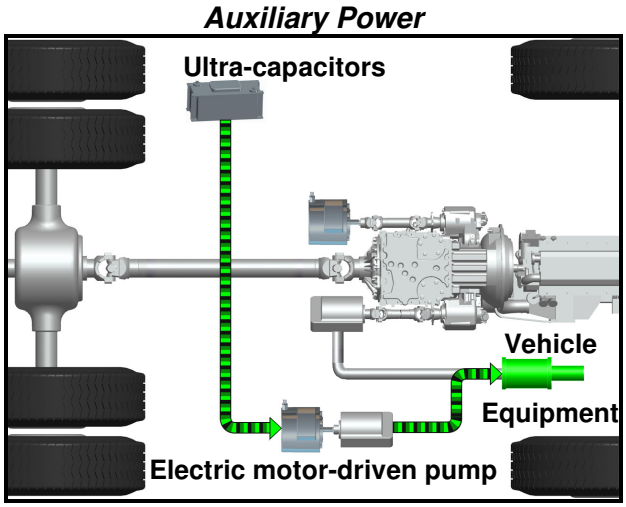


Ultra-capacitors being recharged with braking and/or engine power
(Energy goes from wheels and/or engine to system)

Automatic Restart



Engine restart and vehicle launch with the electric hybrid starter
(Energy goes from the system to the engine and wheels)



Pump powers vehicle equipment with engine off

FEATURES AND BENEFITS OF THE SYSTEM

The Stop-Start hybrid system creates value by virtually eliminating the idle and low power operation of the combustion engine. The most exhaustive assessment of the performance of Effenco's system was carried out by New York City in their Vehicle Testing and Analysis Facility on a refuse truck. The duty cycle was defined by New York City and represented a city averaged cycle. The results are summarized below:

Fuel savings	**30%**
Engine hours reduction	**48%**
Idle time eliminated	**92%**

Additional features are described in the table below:

Weight	**290 kg / 640 lbs**
Rail space (standard build)	**50 cm / 20 in.**
Suitable for retrofit installation	**✓**
Suitable for factory installation	**✓**
Brake life extension	**2 x**
Annual GHG reductions per vehicle	**15-30 tons**
Reduction of NOx, Particulate	**Proportional to fuel reduction**

IDLING AND ENGINE WEAR

Reducing idling time on internal combustion engines has benefits over and above fuel savings. The engine manufacturer Cummins produced some of the most compelling material to support the reduction idle time in the presentation Idling Myths: How Much is Enough (R. Somerville), most of which was not related to fuel savings:

- *Idling is the most inefficient mode - emissions*
- *Fuel contamination of lube oil is high at idle*
- *Cylinder wall wear is accelerated by "wash down"*
- *Short term idling actually "over cools" the engine*
- *Engine life can be reduced by up to 20%*
- *500 hrs of idling = 64000 miles of wear (road transport equivalent)*
- *Noise emissions*.

Part of the benefit of the eliminating idle will be in the form of reduced engine maintenance (including oil changes) and longer engine life. Lower engine hours will also increase the vehicle resale value.

TERMINAL TRACTOR APPLICATIONS

Effenco has worked with several terminal tractor operators to log real application data from vehicles' CAN J1939 network at ports and other logistics hubs. The range of relevant operating data is as follows:

- Idle fuel rates: 2 to 3.5 liters/hour in neutral
- Annual use: 3000 to 5000 hours
- Aggregate immobile time: 35% to 60% of operating hours

It is reasonable to achieve savings in excess of USD 10,000 per year on such applications corresponding to payback periods from 18 to 42 months for terminal tractor applications assuming no monetary value for the reduction of noise, NOx, particulate matter and carbon emissions.

CASE STUDY 1 –PORT APPLICATION

The data for this case study comes from a vehicle operating in a North American container port with an annual capacity exceeding 1 million TEUs. A sample of 10 days is detailed in the following table:

Day*	Op. hours [h]	Distance [km]	Fuel used [L]	Stops	Max speed btw. stops [k/h]	Idle Time [%]	Fuel at idle [L]	Fuel at idle [%]
1	4.6	25.9	27.9	122	9.8	55%	5.7	20%
2	17.1	86.4	90.8	377	10.2	60%	22.6	25%
3	17.6	99.1	91.9	358	9.6	54%	19.3	21%
4	28.9	147.4	144.9	639	9.7	58%	34.4	24%
5	9.6	49.9	47.0	172	9.7	58%	10.4	22%
6	19.3	89.1	98.0	358	10.3	65%	24.8	25%
7	21.4	109.9	118.2	506	9.9	58%	28.3	24%
8	13.4	76.4	72.1	323	9.5	51%	14.0	19%
9	17.4	128.3	104.5	508	10.4	44%	14.5	14%
10	31.9	186.4	180.1	678	10.4	53%	36.0	20%
Av.	**18.1**	**99.8**	**97.5**	**404**	**9.9**	**56%**	**21.5**	**22.0%**

The reference to ***Day*** in the table should be interpreted as continuous usage periods as some exceed 24 hours in length. The fuel savings from adopting the Effenco Stop-Start Hybrid in port applications will vary from 18% to 25% depending on the size of the port installations. Between 40% and 55% of the vehicle's engine hours will be eliminated.

CASE STUDY 2 – WHOLESALE LOGISTICS CENTER

The data for case study 2 comes from a vehicle operating in a wholesale logistics facility. As in case study 1, ten continuous days of operation are shown in the following table:

Day	Op. hours [h]	Distance [km]	Fuel used [L]	Stops	Max speed btw. stops [k/h]	Idle Time [%]	Fuel at idle [L]	Fuel at idle [%]
1	11.6	48.9	58.8	562	10.2	70.3%	21.3	36.3%
2	15.2	70.6	80.8	827	8.5	61.4%	25.5	31.6%
3	19.7	85.2	104	1085	8.2	61.5%	37.0	35.6%
4	15.6	72.7	85.0	915	8.5	59.3%	27.5	32.3%
5	13.4	57.7	71.0	776	7.6	57.5%	23.8	33.6%
6	15.7	75.3	83.6	864	8.2	57.0%	26.1	31.2%
7	10.7	44.7	58.7	589	9.6	68.9%	19.0	32.5%
8	11.6	50.1	61.3	594	10.1	70.0%	21.2	34.6%
9	14.3	69.6	77.2	865	8.1	56.1%	24.1	31.2%
10	15.9	72.5	82.1	942	7.6	56.7%	26.1	31.8%
Av.	**14.3**	**64.7**	**97.5**	**802**	**8.7**	**61.3%**	**21.5**	**33.1%**

As expected, the mean speed between stops is slower and the number of stops is greater in the case of the inland logistics application. This also leads to higher fuel savings potential (25% to 32%) and a greater proportion of engine hours eliminated 45% to 60%.

FOR ENQUIRIES

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