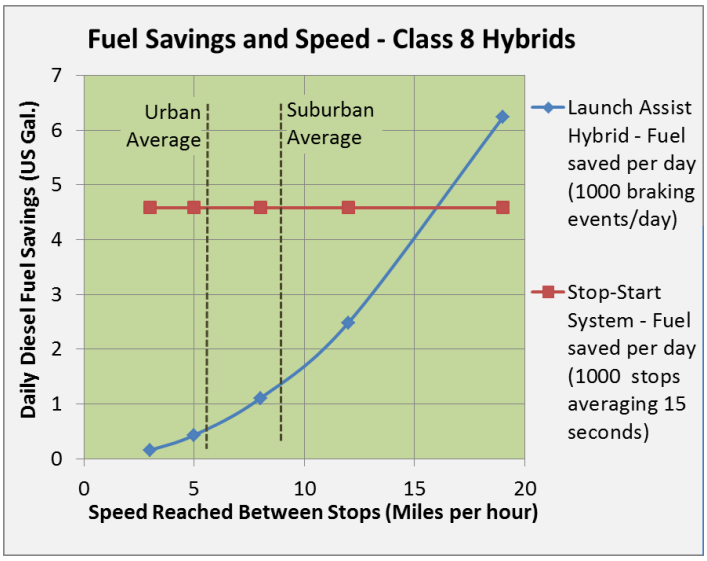
ENGINEERED EFFICIENCY FOR REFUSE COLLECTION VEHICLES

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, economic factors clearly justified the scope of this investment.

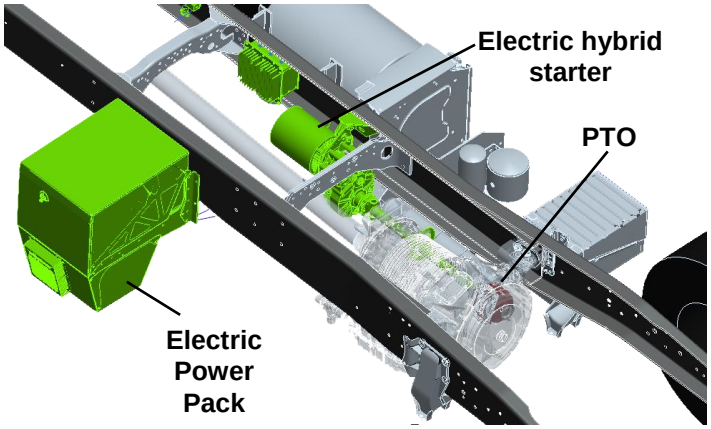
Almost all early developers set out to develop a common platform that would fit all vocational applications including cement trucks, dump trucks, large delivery vehicles, refuse collection vehicles (RCVs) and so on. The resulting products were variations on a common platform (generically called launch-assist) designed to harvest and store as much kinetic energy as possible while the vehicle is braking in order to reuse it to reaccelerate the vehicle.



As the graph in the previous column indicates, RCVs operate well below the speeds at which launch-assist hybrids can provide meaningful fuel savings. For the equipment to pay for itself, the vehicle had to reach at least 29 kph (18 mph) between stops and idle less than 25% of the time. Unfortunately, few vocational applications met these criteria, least of all RCVs who reach between 8 and 15 kph (5 and 9 mph) between stops when collecting and are immobile between 50% and 65% of their operating time.

THE EFFENCO ACTIVE STOP-START SYSTEM

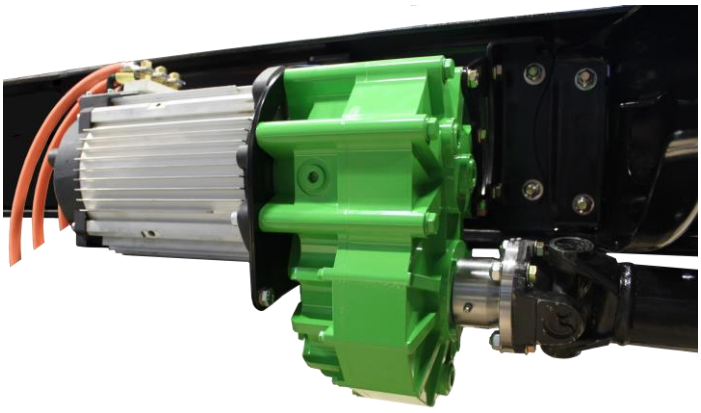
Effenco's Stop-Start hybrid system is designed to turn off the engine of RCVs when they are stationary and to provide energy to low power vehicle systems such as the bin lifts, transmission or HVAC systems when the engine is off. Since these vehicles spend a large proportion of their operating time immobile,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



Effenco Active Stop-Start System

Because of the high stopping frequency of RCVs, 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.

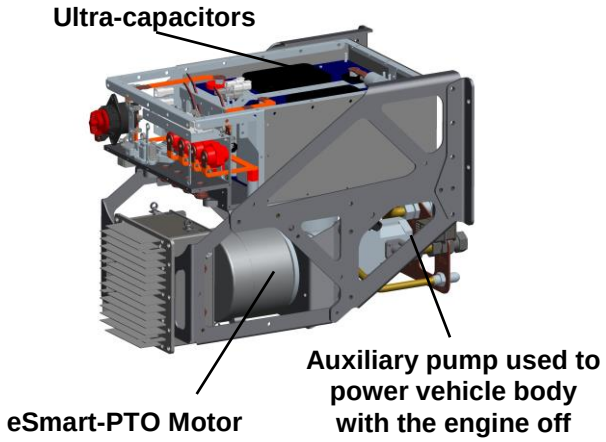
The system is engineered to be transparent to drivers. When the engine has been turned off by the system, the vehicle's transmission remains fully functional. The driver can change gear or simply stay in drive so the vehicle is ready to accelerate when the engine turns on. The system's PTO starter takes less than half a second 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 up to 35 kW to the starter and auxiliary loads. The power pack also includes Effenco's eSmart-PTO, a controllable electric motor-driven hydraulic pump which powers the hotel loads and body with the engine off. Without integration, the motor's controller is configured to simply deliver the same flow as the truck's transmission PTO pump. Through a software interface, it can also be configured by the body OEM to control flow, pressure or position allowing smoother and more responsive control and greater reliability to the body's operation.

Rail Mounted Power Pack



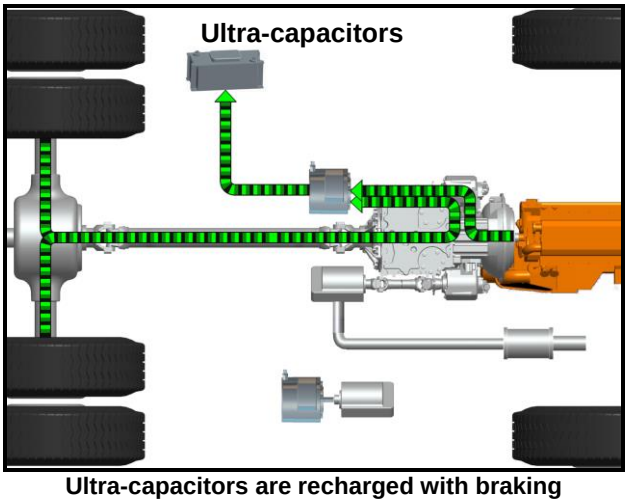
Power Pack Detail

The modular packaging of the Effenco Active Stop Start system makes it suitable for retrofit or factory installation.

ENGINE AND ENERGY MANAGEMENT

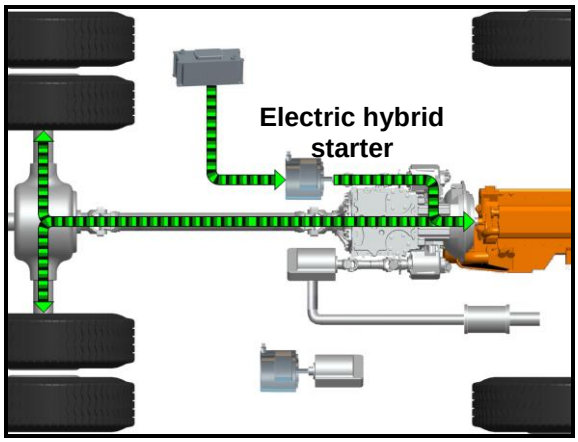
The electric hybrid starter can operate as a motor or a generator. In generator mode it harvests power while the vehicle brakes or if braking energy is insufficient by taking some power of the engine when it is at best efficiency point. The system is configured so that just the power pack reaches nears full charge by the time the vehicle reaches zero speed, maximizing available auxiliary power.

Charging Power Pack



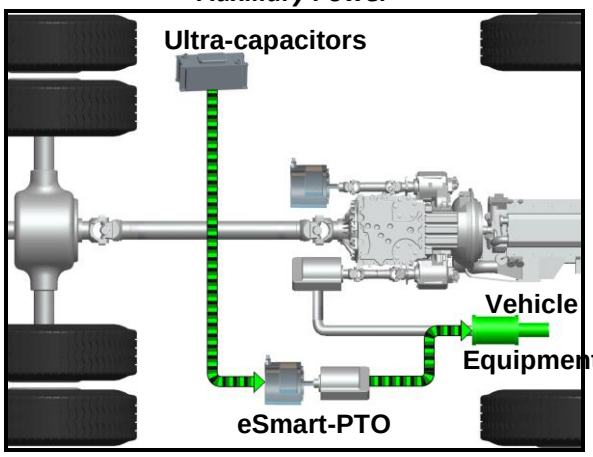
Ultra-capacitors are recharged with braking and/or engine power
(Energy goes from wheels and/or engine to system)

Automatic Restart



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

Auxiliary Power



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 internal combustion engine. The most exhaustive assessment of Effenco's system was carried out by New York City in their vehicle testing lab on an RCV. 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%**

Weight	**290 kg / 620 lbs**
Rail space (standard build)	**60 cm / 25 in.**
Brake life extension	**2 x**
Annual GHG reductions per vehicle	**15-30 tons**
Reduction of NOx, Particulates	**Proportional to fuel reduction**

IDLING AND ENGINE WEAR

Reducing idling time on internal combustion engines has benefits over and above fuel savings. Cummins Engines' presentation *Idling Myths: How Much is Enough* provides the a comprehensive review of the benefits of eliminating idle over and above simply saving fuel:

- *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 therefore come from reduced engine maintenance (including oil changes) and longer engine life. In several applications, lower engine hours will also increase the vehicle resale value.

REFUSE COLLECTION APPLICATIONS

Three case studies under real conditions are presented below in order to illustrate some of the benefits from adopting the Effenco Stop-Start Hybrid in refuse collection applications. The system reduces engine run time by 35% to 50% and thanks to the eSmart-PTO, a high proportion of bin lifts or arm cycles can be performed with the engine off. A new feature to be rolled out in early 2016 will also allow compacting without the engine.

It is reasonable to achieve annual savings in the range of $5000 to $9000 per year on RCV applications corresponding to payback periods from 36 to 48 months without factoring financial benefits for noise, NOx, particulate and carbon emissions.

CASE STUDY 1 – MUNICIPAL, LONDON, UK

The data for this case study comes from a vehicle operating on a municipal collection route in London. The vehicle is equipped with a 7.2 liter Volvo D7E290 engine and an Allison 3000 transmission, a Dennis Eagle Olympus rear loading refuse body and a Terberg Omni DEL Dual bin lift system. A summary of 8 days of operation in a northern borough of Greater London is detailed in the following table:

Day	Op. hours [h]	Immobile [h]	Max speed btw. stop [k/h]	Bin lifts with engine off	Fast Idle Reduction	Engine-off [h]	Engine hrs reduced	Fuel saved [L]
1	5.4	3.8	6.4	67%	58%	2.3	42%	10.3
2	6.4	4.8	7.7	62%	54%	2.7	42%	12.5
3	5.9	4.3	7.6	60%	57%	2.5	42%	11.3
4	8.8	6.0	6.5	65%	57%	3.5	40%	15.9
5	6.5	5.2	7.8	63%	52%	2.7	41%	12.7
6	6.5	4.8	7.3	58%	54%	2.7	41%	12.3
7	8.4	6.0	7.6	65%	57%	3.6	42%	16.3
8	6.9	4.8	6.6	68%	59%	2.9	43%	12.9
Av.	**6.8**	**5.0**	**7.2**	**64%**	**56%**	**2.9**	**42%**	**13.0**

CASE STUDY 2 – MUNICIPAL, EDMONTON, CANADA

The data for this case study comes from a fleet of five identical vehicles operated on municipal collection routes in Edmonton, Alberta. The vehicles are equipped with Cummins ISC 300, 8.3 liter diesel engines generating 860 ft-lbs of torque @1300 RPM / 300 HP @2000 RPM and Allison 3500 automatic transmissions.

The table below covers 40 days of operation between October 2014 and May 2015:

Vehicle	Distance travelled (miles/day)	Operating Hours per day	Immobile time per day	% operating time immobile	Engine hours eliminated per day	% operating time engine off	Number of stops per day	Fuel Reduction (%)
1	28.9	7.3	4.2	57%	3.0	41%	476	26%
2	54.7	7.9	4.1	52%	3.0	38%	427	18%
3	57.2	8.3	4.3	52%	2.9	35%	540	17%
4	55.2	7.6	4.0	53%	2.8	37%	509	17%
5	48.2	8.2	4.6	56%	3.2	39%	522	19%
Av.	46.6	7.9	4.3	54%	3.0	38.3%	500	19.7%

FOR ENQUIRIES

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