Turbocharger

Defining characteristics	*Narrative*
General	Modern light- and heavy-duty road vehicles are predominantly powered by internal combustion engines (ICEs) running on energy-dense fuels such as petrol[90] or diesel. In an ICE, combustion of a fuel-air mixture inside engine cylinders generate a motive force that drives the vehicle's powertrain and releases heat energy and exhaust gases through the vehicle's exhaust manifold and finally to the environment. Essentially, engine performance is related to the composition of fuel-air mixture, ideally 14.7 parts of air to 1 part of fuel by mass, obtained from synergistic operation of air-supply and fuel-supply sub-systems. Past methods for optimising fuel-air mixtures include fuel modifiers[91] to increase cylinder compression ratios, whilst current trends in combustion management focus on dynamic control over air supply and/or fuel supply systems. A practical method for increasing air and by extension oxygen supply to engine cylinders is forced air induction with superchargers or turbochargers. The latter piece of technology, which evolved from mechanically driven superchargers, exploit the heat and pressure energy contained in vehicle exhaust gases to improve compression ratio resulting in higher power output, improved fuel economy and lower emissions of GHGs and particulate matter (Saidur et al, 2012; Berggren and Magnusson, 2012). With environmental concerns gaining traction on the global policy agenda, and environmental standards driving technological innovations on several fronts, turbochargers[92] are arguably one of the most important technologies for the automotive industry. For manufacturers, the use of turbochargers enables reduction of engine cylinder volumes and weight without reducing engine power produced (Galindo et al. 2013; Jinnai et al., 2012; Uchida, 2006)
Siting and land use	Bolted to the exhaust manifold of vehicle engines

[90] gasoline (in the US)
[91] Products added directly to fuel included lead (now outlawed in many countries), catalysts and other commercial formulae
[92] A well established technology in the diesel industry, especially on heavy duty vehicles

Design (components) and Operation	A turbocharger is a device that serves to pump extra air into a vehicle's combustion chambers during the downward stroke phase of the combustion cycle. It is composed of a shaft with turbine wheel attached at one end (inlet) and compressor wheel at the other (outlet) assembled within a centre housing and rotating assembly (CHRA), and waste gate valve in some designs. The CHRA also contains a bearing system supporting the shaft and protecting the turbine from damage when operating at very high speeds. As exhaust gas from engine cylinders pass through the turbocharger inlet, latent heat and pressure energy spin the the turbocharger turbine, which moves the compressor that shares a common shaft with the turbine. In turn, the compressor draws in ambient air, accelerates it to a high velocity raising its pressure in the process and dispatches this pressurised mass of air through an intercooler to the intake manifold where a correspondingly greater mass of air is fed into engine cylinders on each intake stroke.[93] The sharp increase in intake air pressure, commonly referred to as boosting is limited by the engine displacement, engine speed, throttle valve opening, and the size of the turbocharger.[94] A pressure sensor installed in the intake manifold monitors and transmits air pressure proxy variables to the engine control unit (ECU) which actuates a waste gate (by-pass valve) when air pressure exceeds a pre-programmed threshold, thus regulating exhaust gas flow to turbines.[95] Exhaust gas diverted through the waste gate not only depresses turbine speed (i.e., degree of boosting) but also protects the turbine from possible damage. Interposed between the compressor and intake manifold, an intercooler is an auxiliary heat exchange device that cools down compressor air discharge before it reaches the intake manifold.[96] A concomitant pressure drop of compressed air circulating within the intercooler leads to denser air being transported to the intake manifold.
Cost	In new vehicles, the cost of turbocharging systems is inseparable from the vehicle cost which itself is strongly correlated to performance-related specifications such as volumetric displacement, top speed, range, acceleration, tailpipe emissions, and brand name as well. Thus, indicative costs of a 1,300 and 1,600cc vehicles fitted with direct injection technology lies between 19,000 and 22,000 Euros, with corresponding powertrain specific costs of 50.9 and 67.3 Euro/kW (Thiel et al, 2010). Assuming, a retrofit strategy is adopted by policy-makers/owners, the cost of a turbocharging unit approximates the market price of key component parts, and professional fees of engineer carrying out retrofit. At this point, a conservative estimate of direct injection retrofit cost falls within the range 850 to 1,800 Euros.
Supporting infrastructure	High quality roads
Advantages	Improves fuel economy of passenger vehicles by up to 30–50% (Saidur et al, 2012; Berggren and Magnusson, 2012) Enables engine downsizing without loss of performance (Jinnai et al., 2012)

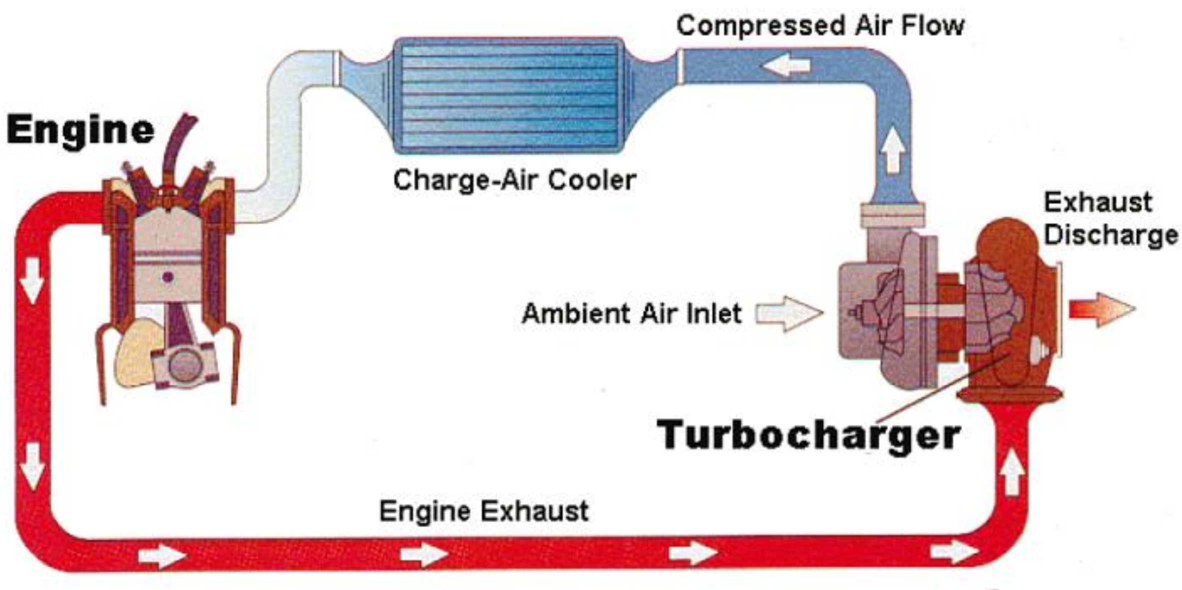
[93] In effect, pumping air under higher pressure into the combustion chamber proportionally increases the density of intake fuel-air mixture resulting in greater power generated per engine cycle, compared to naturally aspirated engines.

[94] Large turbochargers have higher inertia, creating lag at low speed. On the other hand, small turbochargers spin more quickly, but may not have the same performance at high acceleration. To this effect, complex configurations are sometimes deployed to take advantage of the performance characteristics of large and small wheeled turbines

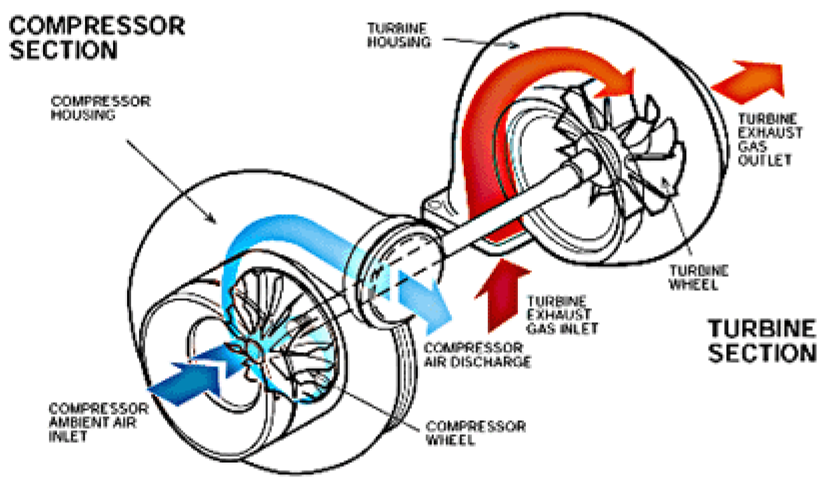
[95] The ECU directs various sub-systems of the vehicle by actuating certain key components and monitoring performance through a feedback from multiple sensors. In particular, it measures electric signals proportional to manifold air pressure during operation to determine dynamic response characteristics of the engine switch on/off the waste gate signal valve.

[96] The lowering of intake fuel-air mix temperature is a precaution taken against damage of engine components by overheating and pre-ignition. Air is also less dense, and contains less oxygen at higher temperature.

	Reduces particulates for diesel engines (Saidur et al, 2012) Low cost and high adaptability (Berggren and Magnusson (2012)
Disadvantages /Challenges	Poor transient response during low speed acceleration (Jinnai et al, 2012), although this shortcoming can be overcome by reducing the size of turbine and compressor wheels, or more revolutionary designs such as the variable geometry turbocharger, VGT (Saidur et al., 2012).
Abatement potential	Greenhouse emissions reduction attributable to fuel economy of turbocharged engine (Saidur et al, 2012; Jinnai et al., 2012) is mediated by a complex function of engine make, fuel type, fuel quality vehicle loads and driving patterns. CO_2 emissions reductions derived from literature range between 65 and 108gCO_2/km (Sullivan et al., 2004; Zhao et al. 1999).
Level of penetration	Unknown. Likely very small except for big cylinder motorcycles.



Source:
http://www.marine-knowledge.com/wp-content/uploads/2013/10/Turbocharger-Working.png



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