

University of Wales Trinity Saint David

Wales Institute of Science and Art



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

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Alexander Cook

2104599

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1. Introduction

This report subject will be centred on the components of the Energy Recovery System (ERS) in a Formula 1 car and the Fédération Internationale de l'Automobile's (FIA) push to making the sport more sustainable. From the 2014 Formula 1 season onwards F1's governing body the FIA updated the technical regulations, this meant that the new cars would be fitted with 1.6L V6 turbo hybrid engines. The hybrid part of the new engines would be under the form of an Energy Recovery System, this is an electrical system that works alongside the internal combustion engine and drivetrain to generate electrical energy and then use that energy to produce more power and make the cars more sustainable.

1.1 Aims

In this report we will introduce each component of the ERS and explain how they work individually. In addition, we will see how these components work in unison to produce more power all while being more sustainable and make these modern Formula 1 cars hybrids. Furthermore, we will investigate the potential of this technology to trickle down into road cars.

1.2 Objectives

This will allow us to understand the function of the ERS and its potential to create more sustainability in motorsport and moving forward in road cars.

2. Overview of modern Turbo Hybrid Formula 1 engines

The post 2014 Formula 1 engines come in the form of a compact 4 stroke 1.6L turbo charged 90-degree V6. It should also be noted that these engines are hybrids, meaning that some of the power generated comes from electrical components working with the internal combustion engine. This is an incredibly high revving engine with a maximum Revolutions Per Minute (RPM) of 15 000, to put that into perspective your average road car has a maximum RPM of 5500 to 6500. With these engines being so high revving along with them using hybrid technology they can produce a lot of power. These exact numbers are highly classified by the engine manufacturers, but we know that the power output of a modern F1 car is in region of 1000 horsepower.

3. The components of the ERS

3.1 The MGU-H

The Motor Generator Unit Heat (MGU-H) is an electrical motor. Therefore, if you supply it with electricity it will spin. As well as this it is also a generator, this means that if you spin it, it will create and supply electrical energy. It is called Heat because it is part of the turbo charger assembly and uses the waste heat energy from the turbo charger to produce its electrical energy. The MGU-H is mounted between the turbine and compressor, more commonly known as the hot and cold sides of the turbo as shown in figure 1. This assembly is then seated in the “V” of the internal combustion engine. The waste heat energy from the internal combustion engine spins the turbine and as a result the shaft connecting it to the MGU-H which in turn generates electrical energy. That energy can then be stored in the battery or used by the other components of the ERS including the MGU-H itself, therefore it is also a motor. The MGU-H uses the electrical energy to solve the problem of turbo lag by spinning the compressor allowing the turbo to spool instantly upon acceleration. The MGU-H can also be used to effectively increase the brake thermal efficiency increasing the sustainability of these F1 engines. Furthermore, from a technical point of view the MGU-H is not very restricted by the technical regulations its allowed power output and energy production is free however ‘the mass of the MGU-H may not be less than 4KG’ and ‘the rotational speed of the MGU-H may not exceed 125,000rpm (Fédération Internationale de l’Automobile, 2022)’.

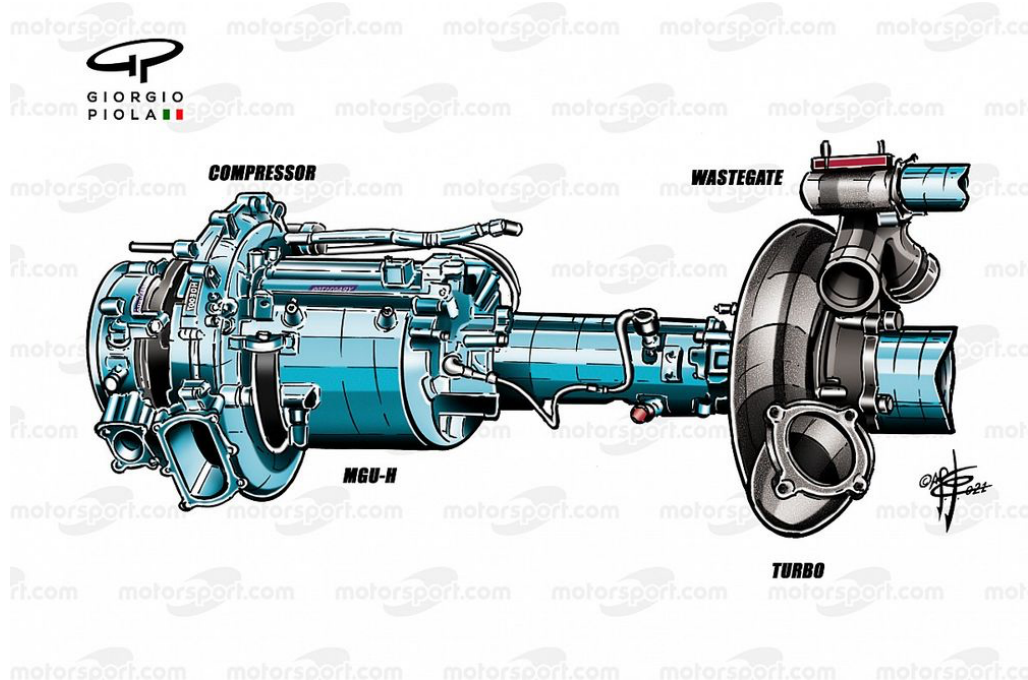


Figure 1 - MGU-H and turbo assembly

3.2 The MGU-K

The Motor Generator Unit Kinetic (MGU-K) is very similar to the MGU-H in the way that it is also a motor and a generator at the same time. It is an electric motor 'connected to the crankshaft through the timing gears (Fagnan, 2016)' that sits on the left-hand side of the internal combustion engine, under the exhaust. The MGU-K recovers the lost heat energy that occurs during the braking phase and converts it into electrical energy that can then be stored in the batteries or used by the MGU-K as a motor to put more power back into the crankshaft. This component however is heavily regulated. Article 5.3.3 of the 2022 Formula 1 Technical regulations states that 'the mass of the MGU-K may not be less than 7kg', that 'the power of the MGU-K may not exceed 120 kW' and 'the rotational speed of the MGU-K may not exceed 50,000rpm (Fédération Internationale de l'Automobile, 2022)'.

3.3 The Control Electronics

The control electronics (CE) consists of two parts, K and H respectively associated with the MGU-K and MGU-H. The CE takes the energy produced by the MGUs and converts it into energy that can be stored in the batteries, it can then do the exact opposite and transfer that stored energy back to either MGU where it is then used to power the motors and therefore create more horsepower. The CE is the link between both MGUs and the batteries. The performance of the CE relies on its efficiency and because of this it needs to be thermal efficient.

3.4 The Energy store

The Energy store (ES) is an assembly of lithium-ion batteries that sit under the control electronics unit. They are used to store the energy produced by both the MGU-H and MGU-K, the Energy Store then supplies these components with the energy they require to create more power by spinning the turbo charger or the crankshaft respectively. However, these batteries are restricted by the Technical Regulations on how much energy they can store and deploy at one given time. As stated by (Mitchell-Malm, 2021) the battery can deploy 4 MJ per lap to the MGU-K, but it can only harvest 2MJ per lap from said component. 'These interactions make the relevant components extremely heat sensitive. The thermal management of the battery is therefore very important (Mitchell-Malm, 2021)'.

4. How each component of the ERS work together

The Energy Recovery System is major part of the turbo hybrid Formula 1 engines, making up to 120kW of extra power. This is equivalent to 161bhp.

The ES harvests energy from the MGU-H which in turn is converted by the CE into energy that can be stored in the batteries. The MGU-H can then later use this energy to spin the turbo charger eliminating the effects of turbo lag. 'There is no regulated limit to the amount of energy that can be harvested from the MGU-H. The battery can also supply an unlimited amount of power to the MGU-H' (Mitchell-Malm, 2021).

Moving on to the communications between the MGU-K and the Energy Store, this is more heavily regulated. As shown in figure 2, the Energy Store can only harvest 2MJ of energy per lap from the MGU-K while it can supply 4MJ/lap back to it, producing 120kw of power at the crank.

In addition, the MGUs can also power each other making the system incredibly efficient. With Formula 1 being at the peak of motorsport, they are constantly seeking to push the boundaries and make the Power Units as efficient as possible. Therefore, heat thermal efficiency is a main priority, the MGUs are at their highest levels of efficiency when the energy harvested by the MGU-H is being directly deployed by the MGU-K without passing through the batteries.

Figure 2 gives a good representation on how each system of the ERS works together to produce more power all while keeping carbon emissions down and making these engines more sustainable.

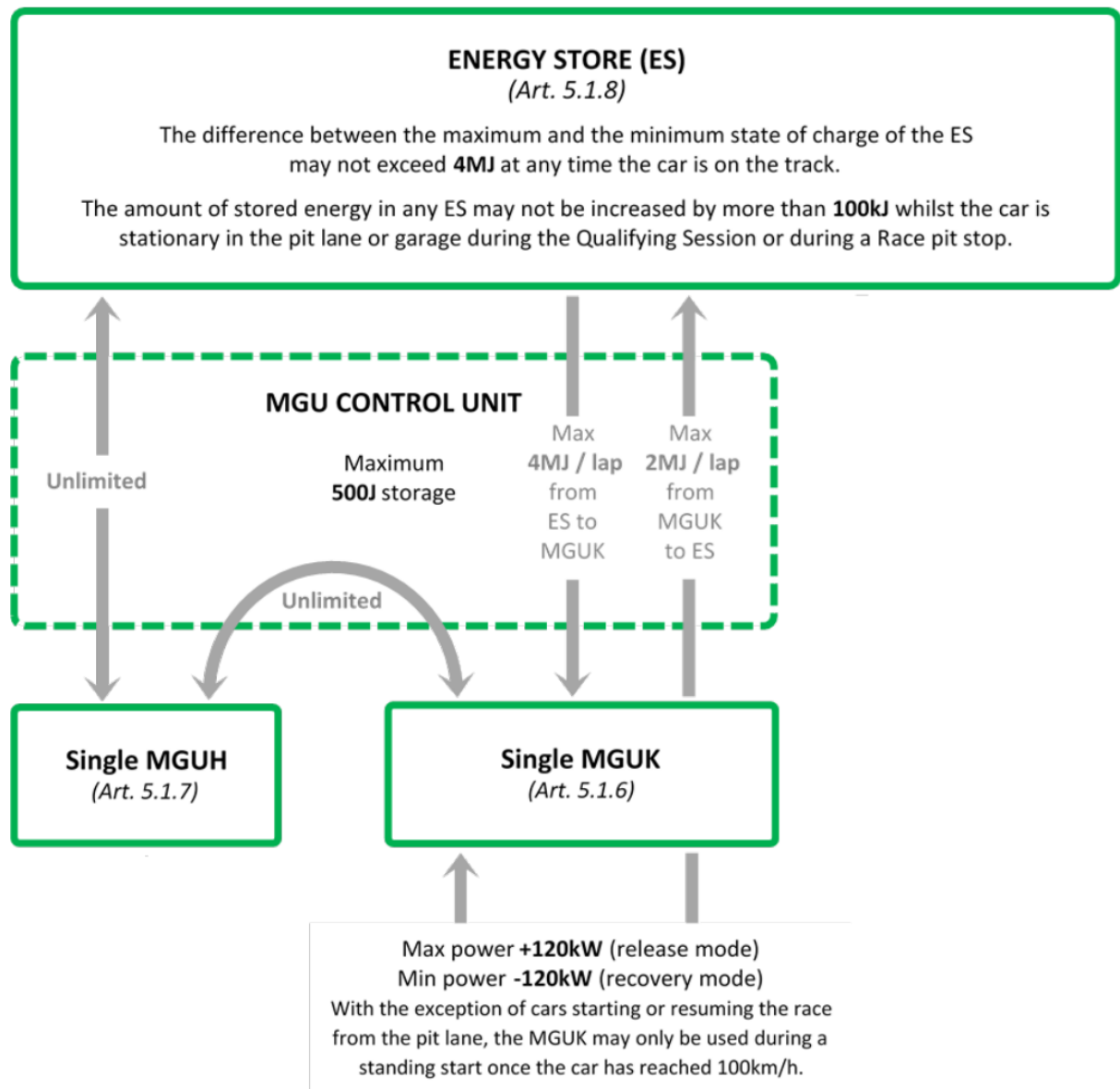


Figure 2 - ERS energy flow

5. This technology is becoming more common in road cars and making way for a more sustainable future

There are various examples of Formula 1 technology making its way down into road cars, more commonly we are starting to see it used by performance brands linked with F1 teams to develop similar technology for road cars. A good example is AMG who are the performance division of Mercedes-Benz and are currently working alongside Mercedes AMG Petronas Formula 1 Team to develop an iteration of the MGU-H that they are starting to introduce into their performance road cars. In an interview Hywel Thomas, Managing Director at Mercedes AMG High Performance Powertrains stated: "This type of electric turbo charger is not yet common in road cars, but what we have learnt from Formula 1 is that they can increase your break thermal efficiency and therefore increase your sustainability. For those reasons it is beginning to crossover to road cars, and we've had some great conversations with AMG who are starting to consider this type of technology" (Thomas, 2022).

Mercedes and AMG are not the only manufacturers to be introducing this technology into their cars. 'Manufacturers such as BMW and Renault have already integrated ERSs in internal combustion engine vehicles (Gabriel-Buenaventura & Azzopardi, 2014)'. Renault also being an engine manufacturer in F1 shows that these teams are playing a big part in the development of road cars.

Moreover, this is helping push Internal Combustion Engine Vehicles (ICEVs) towards a more sustainable and brighter future. 'ERSs for ICEVs may be considered one of the best carbon cutting measures for the automotive sector (Gabriel-Buenaventura & Azzopardi, 2014)'.

Furthermore, six out of ten of the current F1 teams are also car manufacturers with three of these teams being one of the four engine suppliers. This will have a big effect on this hybrid technology becoming more common in road cars along with it influencing the future sustainability of cars.

6. Conclusion

The ERS is a complex and thoroughly engineered system, showing that it has lots of potential for future development whether it is in Formula 1, other motorsport categories or road cars. This hybrid system is a way of creating a sustainable future for F1 which will then hopefully influence the consumer market. The F1 regulations will change for 2026 increasing the power output of the ERS to almost three times as much as the systems we have now, thereby proving that the pinnacle of motorsport is constantly looking into developing its technology and working towards a more sustainable future. Moving forwards, we can already see that this technology is making its way into our day-to-day road cars, more and more companies seem to be taking on the task of integrating this technology into their cars. From what we can understand F1 is set on what direction they are heading in. However, only time will tell if an iteration of the ERS is the answer to a greener future for standard cars.

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