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Title

Environmental and Economic Assessment of Alternative Fuels and Power Trains on Aircraft Level

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Abstract

Air transportation plays a vital role in driving economic growth. However, the negative environmental effects of aviation, e.g. emissions and noise pollution, have become a major concern. The FUTPRINT50 project aims to address these concerns by designing a sustainable aircraft powered by a hybrid-electric powertrain. The goal is to have this aircraft carry 50 passengers over a distance of 800 km and enter into service (EIS) by 2035 or 2040. An all-electric aircraft of the described size would have the benefit having no in-flight emissions. The range would be limited by the low energy density of current and near-future battery technology. A hybrid-electric propulsion system could mitigate this drawback. By combining a traditional primary energy source with an electric powertrain, the aircraft's range could be increased while still reducing emissions compared to traditional aircraft. To achieve a truly sustainable hybrid-electric propulsion concept, alternative fuels must be considered to further reduce the environmental impact. This study compares the hybrid electric aircraft (HEA) designed in FUTPRINT50 to three purely internal combustion engine (ICE) powered aircraft regarding emissions and direct operating costs (DOCs). These aircraft will lack the benefits of the electric powertrain but will otherwise be designed considering the same technology levels. All three ICE-aircraft are designed with a different sustainable fuel. The design process is carried out using the open source SUAVE framework. The first aircraft, referred to as the Conventional Reference Aircraft 2040 (CRA2040), is an ATR42-like aircraft fueled with sustainable aviation fuel (SAF). Its design mission is 840 nautical miles with a payload of 5300 kg. The EIS between 2035 and 2040 of the CRA2040 allows for improved structural materials and engine technologies to be implemented. The second and third aircraft are similar to the CRA2040 in terms of technology levels and design parameters, but use hydrogen and methane as fuel, both stored as a cryogenic liquid LH_2 and LNG respectively. The fourth aircraft is the previously mentioned hybrid-electric design from the FUTPRINT50 project. It is a partial serial-parallel hybrid powered by SAF burnt in two gas turbines. Furthermore, 4 electric motors (2 as wing tip propellers) are installed. The three ICE-aircraft are compared to the HEA regarding their emissions (well to wing) and direct operating costs. Since all fuels shall be sustainable, only green hydrogen and renewable LNG (RLNG) are considered. Depending on the energy management strategy it is possible to significantly lower the NO_x emissions of the HEA compared to the CRA2040. The hydrogen and methane ICE-aircraft are expected to have lower NO_x emissions than the CRA2040 as well. However, the H_2O emissions will increase for both which is especially important in higher altitudes and regarding contrail formation. Burning hydrogen will result in zero CO_2- “tail-pipe-emissions”. This is not the case for methane and SAF. However, well-to-wing CO_2-emissions will be close to zero for both fuels depending on the feedstock. Due to potentially higher development and production costs as well as higher masses, the HEA is expected to have higher DOCs than the CRA2040. Both the hydrogen and methane fueled aircraft have a higher empty mass than the CRA2040, however the maximum take-off mass is close since both fuels have a higher gravimetric energy density than SAF. Hence, the DOCs for all three aircraft will be highly dependent on the fuel costs. Development costs for cryogenic fuel systems must further be considered when predicting the overall aircraft’s economics.