energies

MDPI

Editorial

Advanced Research on Internal Combustion Engines and Engine Fuels

Zongyu Yue * and Haifeng Liu *

State Key Laboratory of Engines, Tianjin University, No.92 Weijin Road, Nankai District, Tianjin 300072, China
* Correspondence: zongyuyue@tju.edu.cn (Z.Y.); haifengliu@tju.edu.cn (H.L.)

Abstract: Internal combustion (IC) engines serve as power devices that are widely applied in the fields of transport, engineering machinery, stationary power generation, etc., and are evolving towards the goal of higher efficiency and lower environmental impacts. In this Editorial, the role of IC engines for future transport and energy systems is discussed, and research directions for advancing IC engine and fuel technologies are recommended. Finally, we introduce the 14 technical papers collected for this Special Issue, which cover a wide range of research topics, including diesel spray characteristics, combustion technologies for low- and zero-carbon fuels, advanced combustion mode, fuel additive effects, engine operation under extreme conditions and advanced materials and manufacturing processes.

Keywords: internal combustion engine; fuel; renewable energy; carbon neutral; Special Issue

check for updates

Citation: Yue, Z.; Liu, H. Advanced Research on Internal Combustion Engines and Engine Fuels. *Energies* **2023**, *16*, 5940. https://doi.org/10.3390/en16165940

Received: 3 August 2023
Accepted: 9 August 2023
Published: 11 August 2023

1. Introduction

Internal combustion (IC) engines have driven the development of human civilization and global economic growth, serving as a power device that is widely applied in the fields of transport, engineering machinery, stationary power generation, etc. The current global stock of passenger cars is around 1.19 billion, and the number of commercial vehicles totals 249 million, of which almost 99% are powered by IC engines, accounting for 81.3% of the oil demand in the transport sector [1]. Following that, maritime and aviation vehicles, which are also primarily powered by combustion engines, account for 7.9% and 7.1% of the transport oil demand, respectively [1]. Overall, the transport sector, including road, railway, aviation and shipping vehicles, accounts for 25.5% of global energy consumption [2] and contributes 16.2% of total global greenhouse gas (GHG) emissions as the fourth-largest source of emissions following industry (29.4%), agriculture, forestry and land use (18.4%) and construction (17.5%) [3]. Therefore, IC engines are a leading source of GHG emissions, and significant effort is needed to reduce their carbon footprint.

2. Current Status and Trends in IC Engine and Fuel Technologies

2.1. Progress in IC Engine Technologies

Since its conception in the late-19th century, the IC engine has undergone a continuous and rapid evolution and is now a complex assembly of numerous advanced technologies. To meet the ever-stringent emission regulations, tremendous effort has been dedicated to research and development aiming at an improvement in combustion efficiency and reduction in pollution emissions. The main harmful emissions generated from IC engine exhaust include particulate matter (PM), nitrogen oxide (NOx), carbon monoxide (CO) and unburnt hydrocarbon (UHC). Figure 1 presents the trends in the US federal emission limits on PM, NOx and non-methane organic gas (NMOG) emissions for light-duty fleet vehicles [4], which have been tightened significantly since their adoption in 1994. Over the past 40 years, including in the pre-regulation age, the emission levels of these harmful pollutants from IC engines have been effectively reduced by 100–1000 times. Taking the

PM emissions of passenger vehicles as an example, the level of PM emissions from engine tailpipes (1.9 mg/km for EPA Tier 3 and 4.5 mg/km for Euro VI-d) was found to be at least 10 times lower than that generated from tire and brake wear (>50 mg/km [5]), indicating that the PM emissions from the daily operation of IC engine vehicles (ICEVs) and battery electric vehicles (BEVs) are comparable [6], and ICEVs are even favored in terms of PM emissions when taking the upstream production of fuel/electricity into account. Indeed, a recent study revealed that the direct PM emissions from an EV are comparable or even higher than those from an ICEV depending on the material of the brake pads [7]. Also, the current emission standards for heavy-duty diesel vehicles in the US, which have been in place since model year 2010, limit NOx at 0.20 g/bhp·h, while in comparison, the NOx emissions generated from US electricity generation in 2020 totaled 0.237 g/bhp·h [8]. With the continuous advancement in combustion technologies as well as catalysts and after-treatment systems, it is possible to further reduce the harmful emissions of IC engines by more than 90% from today to realize the goal of near-zero emissions. For example, the use of selective catalytic reduction can lead to extremely low NOx emissions [9].

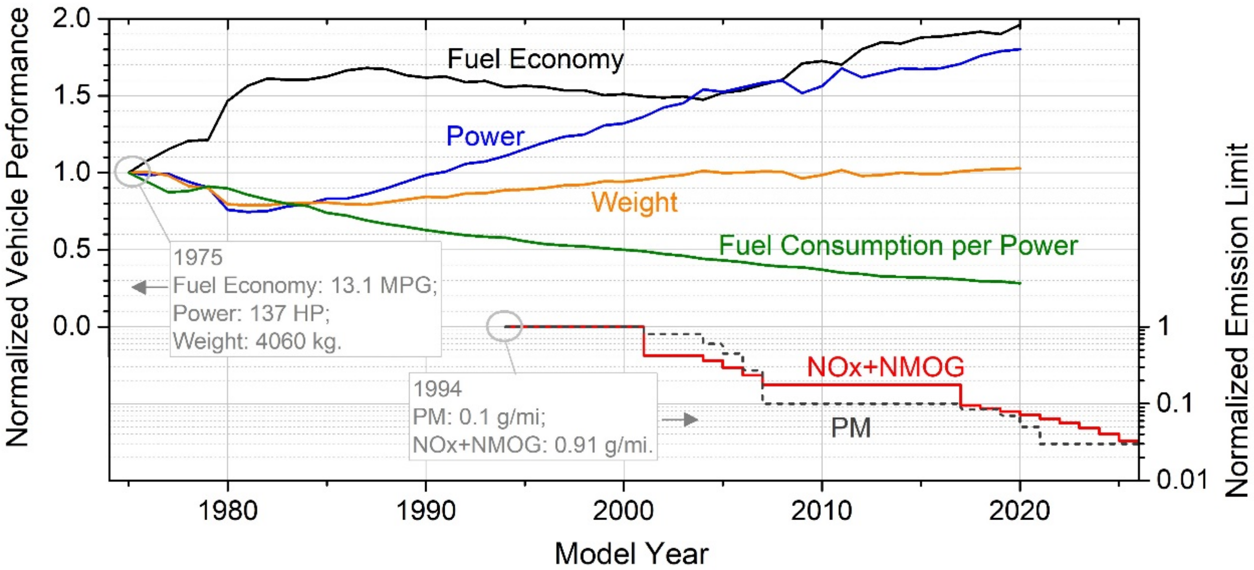

Figure 1. Trends in vehicle performance [10] and federal fleet average emission limit [4] for light-duty vehicles in US market.

Regulations have also been employed to promote IC engine technologies with higher thermal efficiency to achieve lower fuel consumption and lower carbon dioxide (CO_2) emissions, driven by concerns about fossil fuel depletion and more recently global warming, in addition to the demand by customers for lower operation costs. Figure 1 presents the trends of vehicle performance over the past 45 years in the US light-duty vehicle market, including sedans, wagons, sport utility vehicles (SUVs), vans and pickup trucks, which are predominantly powered by IC engines [10]. Although the vehicle fuel economy declined from model year 1985 to 2005 due to the rapidly growing demands for greater horsepower and vehicle weight (size), it has increased significantly for the past 15 years despite the continuous growth in horsepower and vehicle weight (size). More importantly, the fuel consumption per power unit has steadily decreased, which is attributable to the development of advanced engine technologies such as turbocharging, gasoline direct injection (GDI), variable valve timing (VVT), stop–start systems, cylinder deactivation, hybridization, etc. Similar advancements in IC engine technology and vehicle fuel economy have also been seen in the heavy-duty sector in various countries and regions. For example, China's Weichai launched a heavy-duty diesel engine with a record-breaking brake thermal efficiency (BTE) of 50.25% [11] in 2020.

2.2. Diversity of IC Engine Fuels

The fundamentals of IC engine operation can be concisely summed up as the Carnot cycle with a high-temperature reservoir supplied by fuel combustion, meaning that any substances that can efficiently burn inside the cylinder are eligible candidates for IC engine fuels. Indeed, the search for alternative fuels for IC engines has been a major research direction in both academia and industry. Natural gas is the most commonly used fuel for IC engines besides conventional gasoline and diesel and is employed for light-duty and heavy-duty road transportation, maritime operations and power generation. Natural gas mainly consists of methane, and a gasoline engine can be easily adapted to run on natural gas. For instance, many taxis in China are equipped with an additional gas cylinder in the trunk so they can run on either gasoline or natural gas to lower the operation cost. The share of natural gas in today's transport energy is still less than 5% [2], but it is projected to grow quickly in the future. Ethanol is another alternative fuel employed in the market and is mostly seen in the form of blendstock for gasoline with a blending ratio of 10%, i.e., E10 sold at American and Chinese gas stations. There are also "flex-fuel" vehicles [12] that can run on ethanol–gasoline with an ethanol content of up to 85%. Other candidates, such as methanol, dimethyl ether (DME) and polyoxymethylene dimethyl ether (PODE), are all promising fuels for IC engines and have been demonstrated to provide even better efficiency and lower emissions compared to conventional fuels.

The search for alternatives to today's petroleum-based fuels is of great significance not only due to concerns about fossil fuel depletion, but also because low-carbon or carbon-neutral transport can be enabled if the fuel is derived from bio-mass or clean primary energy such as wind, hydro and solar electricity. Biofuels mainly refer to ethanol, biodiesel and hydrotreated vegetable oil (HVO) and are mostly blended with fossil fuel at a low blending level, e.g., E10 gasoline, as mentioned above, as well as B5 and B20 (biodiesel blends with a blending level of <5% and <20%, respectively). HVO is considered a key driver of biofuel production growth since it can be produced utilizing waste and residue feedstock, and it has several favorable metrics as an IC engine fuel, such as flexibility as a "drop-in" fuel, good cold-start properties and a low aromatic content for low PM emissions. Nonetheless, biofuel only accounts for <4% of today's transport energy [2]. On the other hand, hydrogen can be produced from water electrolysis, and it can be used directly as fuel for IC engines [13] or as feedstock for further synthesis of hydrocarbons such as methane, methanol and diesel with carbon from carbon capture and storage (CCS) technology [14]. Ammonia is another hydrogen-based fuel receiving growing interest due to its higher energy volume density and being free of carbon. The water electrolysis hydrogen and the fuels that are derived from it are collectively called "electro fuels" or "e-fuels" and can achieve zero- or net-zero carbon emissions with good compatibility with IC engines.

Except for natural gas, ethanol and biodiesel, the use of alternative fuels in IC engines is mostly seen in laboratories, and petroleum-based fuels still account for more than 90% of transport energy produced worldwide [2]. It is worth noting that the growth of alternative fuels in the transport fuel market is not limited by IC engine technologies. In fact, several advanced combustion technologies have been proposed to achieve fuel flexibility [15–18], and the use of alternative fuels provides benefits in thermal efficiency improvement and pollution emission reduction [19]. The lack of a cost-effective production method and sustainable source of feedstock for fuel synthesis at a large scale, as well as incompatibility with current storage and distribution facilities, are among the major issues that prohibit the wide application of these fuels. However, as renewable energy continues to grow in popularity and fuel synthesis technologies mature, biofuels and e-fuels are projected to take up a large percentage of transport energy in the future. From a long-term perspective, the use of low-carbon or zero-carbon emission fuels, together with the advancement in IC engine technologies, offers a great opportunity to lower the carbon footprint of world transportation [20].

2.3. Advanced IC Engines for Low- and Zero-Carbon Emissions

Despite the trend of electrification, IC engines will continue to dominate in road transport as well as other transport sectors in the coming decades, as shown in the projections made by several prestigious research organizations in Figure 2. In 2030, around 60% to 90% of sold light-duty passenger vehicles will be equipped with IC engines, including ICEVs, HEVs and PHEVs. In the approach to 2050, the trend of electrification is expected to continue, but the share of IC-engine-equipped vehicles is forecast to remain above 50%. The progress of electrification in the heavy-duty vehicle sector is much slower, with more than 92% vehicles predicted to be powered by IC engines in 2030.

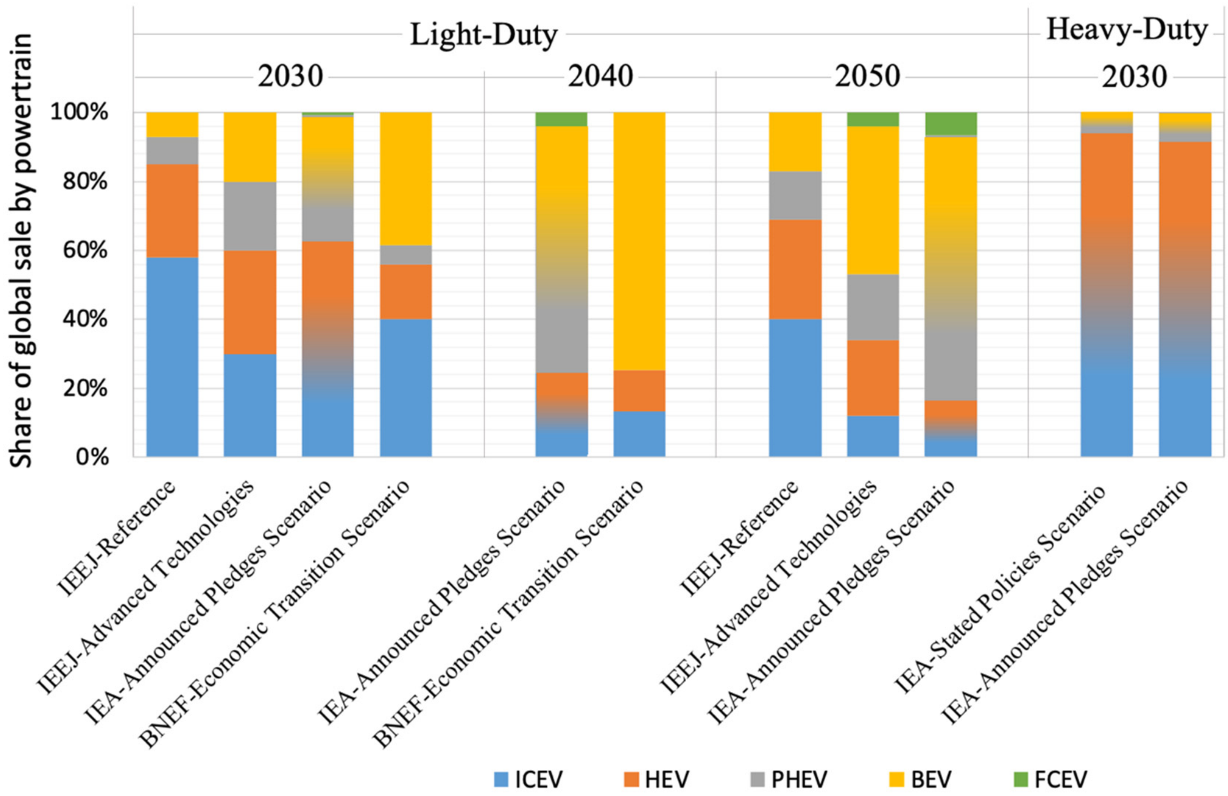

Figure 2. Share of global sales for light-, medium- and heavy-duty vehicles predicted by various organizations [21–23]. Color gradients indicate lumped items.

In the meantime, IC engines have great potential to play an essential role in future distributed renewable energy systems. It is generally accepted that the transition from fossil fuel to renewable energies such as solar and wind power is a prerequisite to achieving carbon neutrality. However, these renewable energies are intrinsically intermittent and unstable, causing problems in providing a reliable power source and requiring the development of advanced energy storage technologies that store energy in various forms, e.g., hydrogen and e-fuels, pumped hydro, compressed air, batteries, superconducting magnets, flywheels and supercapacitors [24], instead of direct integration in the public grid. These technologies can be used as a reserve to supplement electricity generation during renewable energy downtime. Fuel energy storage, i.e., e-fuel, has significant advantages over the other options in energy density and storage capacity [25], making it an ideal solution for long-term, large-scale storage and long-distance trade of renewable energy. In this sense, the IC engine is a competitive option for an energy conversion device in a distributed energy system with fuel energy storage due to its fast response, high durability, high efficiency, low cost and great compatibility with varying fuels. The use of IC engines powered by renewable e-fuels for transport and power generation in distributed energy systems is thus a promising option to facilitate the scaling up of renewable energy deployment.

Therefore, it is imperative we continue investing in research and development activities for IC engine technologies. Many studies have suggested the potential of IC engines in helping us reach zero emissions [9,26–30]. Promising research areas include, but are not limited to, the following:

1. Renewable fuels such as hydrogen, ammonia, methanol, etc., have distinct characteristics compared to petroleum fuels, and thus require dedicated combustion technologies and engine designs [31–33]. Also, the fuel properties that enable high engine efficiency need to be accounted for when developing new fuels and new engine technologies in conjunction [19,34].
2. Inspired by the concept of homogeneous charge compression ignition (HCCI) [16], many advanced combustion technologies have been proposed to improve thermal efficiency by means of controlling the evolution and stratification of the in-cylinder thermodynamic state as well as mixture and reactivity distribution, such as gasoline compression ignition (GCI) [35], reactivity-controlled compression ignition (RCCI) [15], partially premixed combustion (PPC) [18,36], etc. Lean combustion technologies are often used to increase combustion efficiency and lower heat loss, and the lean operation limit can be extended via turbulent jet ignition (TJI), high-tumble in-cylinder flow, etc.
3. Numerical simulation has become an imperative tool in the course of engine research and design, providing an in-depth understanding of the multiphysics, multiscale and multiphase process of IC engines and significantly reducing the development period duration and cost [37,38]. In addition, artificial intelligence is an emerging technique aiming to further strengthen the capability of numerical and diagnostics tools beyond their original limits [39–41].
4. Gas exchange and management systems are effective measures used to control the in-cylinder process. Exhaust turbocharging can be used to increase charge density and dilution, with two-stage and variable geometry turbocharging (GVT) offering variability on demand [42]. Exhaust gas recirculation (EGR) can be used to control in-cylinder temperature, heat loss and pollutant emissions [43]. Variable valve systems can prevent the use of throttle to reduce pumping loss and also enable the Miller cycle with an expansion ratio larger than the compression ratio to improve the thermal efficiency [44].
5. Engine aftertreatment technologies such as diesel oxidation catalysts (DOCs), selective catalytic reduction (SRC), diesel particulate filters (DPFs), lean NOx traps (LNTs), passive NOx adsorbers (PNAs) and so on can enable near-zero pollutant emissions of IC engines. These technologies often have a high conversion efficiency in the steady state, and future efforts will be focused on the cold-start and transient conditions that require engine aftertreatment system-level optimization [45].
6. Electrification of IC engine components has been a major trend in attempts to achieve flexibility and intelligence. Numerous control variables need to be controlled and optimized simultaneously, and advanced control algorithms and hardware are required to fulfill the full potential of engines [46].
7. A hybridized powertrain system consists of an IC engine, motor and battery. They are predicted to have a considerable share of the future market, as seen in Figure 2, because such a system has great potential to improve overall fuel economy and to avoid the issues associated with BEVs. A major challenge in IC engine design is the flexibility of performance under a wide range of speeds and loads, which causes the specific fuel consumption and pollutant emissions weighted under real driving conditions to be significantly higher than the values achieved under an optimally designed regime. With the assistance of a motor, the operation range of IC engines can be narrowed and optimized to achieve highly efficient and clean conditions. This requires an IC engine specifically designed for HEVs so the potential of hybrid powertrain systems can be fully explored [47].

8. Other technologies, such as thermal barrier coating, wasted heat recovery, low friction techniques, water injection, novel engine cycle and thermal management can all contribute to the improvement in engine efficiency to varying degrees [48,49].

3. Conclusions and Recommendations

IC engine technologies have been continuously advanced in the past decades and still have great potential for further improvements towards the goal of zero emissions. The IC engine will remain a major player in the future transport sector because of its technical maturity, high efficiency, reliability and its fuel diversity. In the near future, petroleum fuels will still be the main energy carrier for transport vehicles, and IC engine technology will be further advanced to improve its thermal efficiency and lower its carbon emissions. In the long term, renewable synthetic fuels such as e-fuels and biofuels will be phased in to facilitate the progress towards zero emissions. For future renewable energy systems, the IC engine is a promising option as an energy conversion device due to its fast response, high durability, high efficiency, low cost and great compatibility with varying fuels. Therefore, it is imperative we continue improving IC engine technologies to reduce their petroleum consumption and GHG emissions, which will be key to achieving carbon neutrality.

With the aim of promoting efforts towards engine research, this Special Issue of *Energies* on the subject of "Advanced Research on Internal Combustion Engines and Engine Fuels" is dedicated to sharing recent progress and findings from the engine research community. A total of 14 technical papers have been selected through a rigorous review process and published in this Special Issue, with topics covering a broad range of research areas related to engine and fuels, i.e., diesel spray characteristics [50], combustion technologies for low- and zero-carbon fuels [33,51–55], advanced combustion mode [33,52,54,56], fuel additive effects [55,57], engine operation under extreme conditions [58,59] and advanced materials and manufacturing processes [60–62]. With this Special Issue of *Energies*, we hope to encourage greater efforts to engage in this field to further advance technologies for IC engines and fuels.

Funding: The authors would like to acknowledge the financial support from the National Natural Science Foundation of China through project no. 52006154 and project no. 51921004.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. OPEC. World Oil Outlook 2021. 2021. Available online: https://woo.opec.org/index.php (accessed on 22 July 2022).
2. International Energy Agency. World Energy Outlook 2020. Paris. 2021. Available online: https://www.iea.org/reports/world-energy-outlook-2021 (accessed on 22 July 2022).
3. Ritchie, H.; Roser, M. CO_2 and Greenhouse Gas Emissions. Our World in Data. 2017. Available online: https://ourworldindata.org/CO2-and-other-greenhouse-gas-emissions (accessed on 22 July 2022).
4. Rodriguez, J.F.; Cheng, W.K. Analysis of NOx Emissions during Crank-Start and Cold Fast-Idle in a GDI Engine. *SAE Int. J. Engines* **2017**, *10*, 646–655. [CrossRef]
5. Grigoratos, T.; Gustafsson, M.; Eriksson, O.; Martini, G. Experimental investigation of tread wear and particle emission from tyres with different treadwear marking. *Atmos. Environ.* **2018**, *182*, 200–212. [CrossRef]
6. Winkler, S.L.; Anderson, J.E.; Garza, L.; Ruona, W.C.; Vogt, R.; Wallington, T.J. Vehicle criteria pollutant (PM, NOx, CO, HCs) emissions: How low should we go? *npj Clim. Atmos. Sci.* **2018**, *1*, 26. [CrossRef]
7. Woo, S.-H.; Jang, H.; Lee, S.-B.; Lee, S. Comparison of total PM emissions emitted from electric and internal combustion engine vehicles: An experimental analysis. *Sci. Total. Environ.* **2022**, *842*, 156961. [CrossRef]
8. United States Electricity Profile 2021. Available online: https://www.eia.gov/electricity/state/unitedstates/ (accessed on 22 July 2022).
9. Reitz, R.D.; Ogawa, H.; Payri, R.; Fansler, T.; Kokjohn, S.; Moriyoshi, Y.; Agarwal, A.; Arcoumanis, D.; Assanis, D.; Bae, C.; et al. IJER editorial: The future of the internal combustion engine. *Int. J. Engine Res.* **2020**, *21*, 3–10. [CrossRef]
10. The 2020 EPA Automotive Trends Report. Available online: https://www.epa.gov/sites/default/files/2021-01/documents/420r21003.pdf (accessed on 1 August 2023).

11. Weichai Launches a 50% BTE Diesel Engine. Available online: https://dieselnet.com/news/2020/09weichai.php (accessed on 26 July 2022).
12. Delavarrafiee, M.; Frey, H.C. Real-world fuel use and gaseous emission rates for flex fuel vehicles operated on E85 versus gasoline. *J. Air Waste Manag. Assoc.* **2018**, *68*, 235–254. [CrossRef]
13. Luo, Q.-H.; Hu, J.-B.; Sun, B.-G.; Liu, F.-S.; Wang, X.; Li, C.; Bao, L.-Z. Experimental investigation of combustion characteristics and NOx emission of a turbocharged hydrogen internal combustion engine. *Int. J. Hydrogen Energy* **2019**, *44*, 5573–5584. [CrossRef]
14. CIMAC (2020)—White Paper 2: Zero and Net Zero Carbon Fuel Options. Available online: https://www.cimac.com/cms/upload/Publication_Press/Strategy_Group_Publications/CIMAC__White_paper_2_Zero_and_Net_Zero_Carbon_Fuel_Options_Jan2020.pdf (accessed on 1 August 2023).
15. Reitz, R.D.; Duraisamy, G. Review of high efficiency and clean reactivity controlled compression ignition (RCCI) combustion in internal combustion engines. *Prog. Energy Combust. Sci.* **2014**, *46*, 12–71. [CrossRef]
16. Yao, M.; Zheng, Z.; Liu, H. Progress and recent trends in homogeneous charge compression ignition (HCCI) engines. *Prog. Energy Combust. Sci.* **2009**, *35*, 398–437. [CrossRef]
17. Musculus, M.P.; Miles, P.C.; Pickett, L.M. Conceptual models for partially premixed low-temperature diesel combustion. *Prog. Energy Combust. Sci.* **2013**, *39*, 246–283. [CrossRef]
18. Noehre, C.; Andersson, M.; Johansson, B.; Hultqvist, A. *Characterization of Partially Premixed Combustion*; SAE Technical Paper 2006-01-3412; SAE: Warrendale, PA, USA, 2006.
19. Szybist, J.P.; Busch, S.; McCormick, R.L.; Pihl, J.A.; Splitter, D.A.; Ratcliff, M.A.; Kolodziej, C.P.; Storey, J.M.; Moses-DeBusk, M.; Vuilleumier, D.; et al. What fuel properties enable higher thermal efficiency in spark-ignited engines? *Prog. Energy Combust. Sci.* **2021**, *82*, 100876.
20. Liu, H.; Ampah, J.D.; Zhao, Y.; Sun, X.; Xu, L.; Jiang, X.; Wang, S. A Perspective on the Overarching Role of Hydrogen, Ammonia, and Methanol Carbon-Neutral Fuels towards Net Zero Emission in the Next Three Decades. *Energies* **2022**, *16*, 280. [CrossRef]
21. IEA. *World Energy Outlook 2022*; IEA: Paris, France, 2022. Available online: https://www.iea.org/reports/world-energy-outlook-2022 (accessed on 1 August 2023).
22. IEEJ. IEEJ Outlook 2023. 2023. Available online: https://eneken.ieej.or.jp/data/10974.pdf (accessed on 1 August 2023).
23. BloombergNEF. Electric Vehicle Outlook 2023. 2023. Available online: https://about.bnef.com/electric-vehicle-outlook/ (accessed on 1 August 2023).
24. Beaudin, M.; Zareipour, H.; Schellenberglabe, A.; Rosehart, W. Energy storage for mitigating the variability of renewable electricity sources: An updated review. *Energy Sustain. Dev.* **2010**, *14*, 302–314. [CrossRef]
25. Yao, J.G.; Bui, M.; Mac Dowell, N. Grid-scale energy storage with net-zero emissions: Comparing the options. *Sustain. Energy Fuels* **2019**, *3*, 3147–3162. [CrossRef]
26. Yu, X.; Sandhu, N.S.; Yang, Z.; Zheng, M. Suitability of energy sources for automotive application—A review. *Appl. Energy* **2020**, *271*, 115169. [CrossRef]
27. Zhao, F.; Chen, K.; Hao, H.; Liu, Z. Challenges, Potential and Opportunities for Internal Combustion Engines in China. *Sustainability* **2020**, *12*, 4955. [CrossRef]
28. Senecal, P.; Leach, F. Diversity in transportation: Why a mix of propulsion technologies is the way forward for the future fleet. *Results Eng.* **2019**, *4*, 100060. [CrossRef]
29. Kalghatgi, G. Is it really the end of internal combustion engines and petroleum in transport? *Appl. Energy* **2018**, *225*, 965–974. [CrossRef]
30. Leach, F.; Kalghatgi, G.; Stone, R.; Miles, P. The scope for improving the efficiency and environmental impact of internal combustion engines. *Transp. Eng.* **2020**, *1*, 100005. [CrossRef]
31. Liu, H.; Ampah, J.D.; Afrane, S.; Adun, H.; Jin, C.; Yao, M. Deployment of hydrogen in hard-to-abate transport sectors under limited carbon dioxide removal (CDR): Implications on global energy-land-water system. *Renew. Sustain. Energy Rev.* **2023**, *184*, 113578. [CrossRef]
32. Liu, H.; Zhang, X.; Zhang, Z.; Wu, Y.; Wang, C.; Chang, W.; Zheng, Z.; Yao, M. Effects of 2-ethylhexyl nitrate (EHN) on combustion and emissions on a compression ignition engine fueling high-pressure direct-injection pure methanol fuel. *Fuel* **2023**, *341*, 127684. [CrossRef]
33. Sun, X.; Li, M.; Li, J.; Duan, X.; Wang, C.; Luo, W.; Liu, H.; Liu, J. Nitrogen Oxides and Ammonia Removal Analysis Based on Three-Dimensional Ammonia-Diesel Dual Fuel Engine Coupled with One-Dimensional SCR Model. *Energies* **2023**, *16*, 908. [CrossRef]
34. Yue, Z.; Som, S. Fuel property effects on knock propensity and thermal efficiency in a direct-injection spark-ignition engine. *Appl. Energy* **2021**, *281*, 114221. [CrossRef]
35. Liu, H.; Mao, B.; Liu, J.; Zheng, Z.; Yao, M. Pilot injection strategy management of gasoline compression ignition (GCI) combustion in a multi-cylinder diesel engine. *Fuel* **2018**, *221*, 116–127. [CrossRef]
36. Cui, Y.; Liu, H.; Wen, M.; Feng, L.; Ming, Z.; Zheng, Z.; Fang, T.; Xu, L.; Bai, X.-S.; Yao, M. Optical diagnostics of misfire in partially premixed combustion under low load conditions. *Fuel* **2022**, *329*, 125432. [CrossRef]
37. Yue, Z.; Reitz, R.D. An equilibrium phase spray model for high-pressure fuel injection and engine combustion simulations. *Int. J. Engine Res.* **2019**, *20*, 203–215. [CrossRef]

38. Zhu, H.; Battistoni, M.; Ningegowda, B.M.; Rahantamialisoa, F.N.Z.; Yue, Z.; Wang, H.; Yao, M. Thermodynamic modeling of trans/supercritical fuel sprays in internal combustion engines based on a generalized cubic equation of state. *Fuel* **2022**, *307*, 121894. [CrossRef]
39. Zhao, F.; Ruan, Z.; Yue, Z.; Hung, D.L.; Som, S.; Xu, M. Time-sequenced flow field prediction in an optical spark-ignition direct-injection engine using bidirectional recurrent neural network (bi-RNN) with long short-term memory. *Appl. Therm. Eng.* **2020**, *173*, 115253. [CrossRef]
40. Yue, Z.; Zhu, H.; Wang, C.; Li, Z.; Wang, H.; Yao, M.; Reitz, R.D. Artificial neural network models for phase equilibrium predictions under engine trans/supercritical spray conditions. *Fuel* **2023**, *339*, 127425. [CrossRef]
41. Cui, Y.; Liu, H.; Wang, Q.; Zheng, Z.; Wang, H.; Yue, Z.; Ming, Z.; Wen, M.; Feng, L.; Yao, M. Investigation on the ignition delay prediction model of multi-component surrogates based on back propagation (BP) neural network. *Combust. Flame* **2022**, *237*, 111852. [CrossRef]
42. Feneley, A.J.; Pesiridis, A.; Andwari, A.M. Variable Geometry Turbocharger Technologies for Exhaust Energy Recovery and Boosting-A Review. *Renew. Sustain. Energy Rev.* **2017**, *71*, 959–975. [CrossRef]
43. Yao, M.; Zhang, Q.; Liu, H.; Zheng, Z.Q.; Zhang, P.; Lin, Z.; Lin, T.; Shen, J. *Diesel Engine Combustion Control: Medium or Heavy EGR?* SAE Technical Paper 2010-01-1125; SAE: Warrendale, PA, USA, 2010.
44. Yan, B.; Wang, H.; Zheng, Z.; Qin, Y.; Yao, M. The effects of LIVC Miller cycle on the combustion charac-teristics and thermal efficiency in a stoichiometric operation natural gas engine with EGR. *Appl. Therm. Eng.* **2017**, *122*, 439–450. [CrossRef]
45. Joshi, A. Review of Vehicle Engine Efficiency and Emissions. *SAE Int. J. Adv. Curr. Prac. Mobil.* **2022**, *4*, 1704–1733. [CrossRef]
46. Norouzi, A.; Heidarifar, H.; Shahbakhti, M.; Koch, C.R.; Borhan, H. Model Predictive Control of Internal Combustion Engines: A Review and Future Directions. *Energies* **2021**, *14*, 6251. [CrossRef]
47. Li, L.; Zheng, Z.; Wang, H.; Wang, X.; Sun, H.; Li, J.; Yao, M. *Thermal Efficiency Enhancement of a Turbocharged Diesel Engine Dedicated for Hybrid Commercial Vehicle Application*; SAE Technical Paper 2022-01-7053; SAE: Warrendale, PA, USA, 2022.
48. Wang, Z.; Shuai, S.; Li, Z.; Yu, W. A Review of Energy Loss Reduction Technologies for Internal Combustion Engines to Improve Brake Thermal Efficiency. *Energies* **2021**, *14*, 6656. [CrossRef]
49. Liu, H.; Wen, M.; Yang, H.; Yue, Z.; Yao, M. A Review of Thermal Management System and Control Strategy for Automotive Engines. *J. Energy Eng.* **2021**, *147*, 03121001. [CrossRef]
50. Arai, M. Interpretative Review of Diesel Spray Penetration Normalized by Length and Time of Breakup (Similarity Law of Diesel Spray and Its Application). *Energies* **2022**, *15*, 4926. [CrossRef]
51. Jin, C.; Sun, T.; Xu, T.; Jiang, X.; Wang, M.; Zhang, Z.; Wu, Y.; Zhang, X.; Liu, H. Influence of Glycerol on Methanol Fuel Characteristics and Engine Combustion Performance. *Energies* **2022**, *15*, 6585. [CrossRef]
52. Toledo, E.; Guerrero, F.; Amador, G.; Toledo, M. Experimental Assessment of the Performance and Fine Particulate Matter Emissions of a LPG-Diesel Dual-Fuel Compression Ignition Engine. *Energies* **2022**, *15*, 9035. [CrossRef]
53. Enomoto, H.; Nakagawa, R. Reduction in CO Emission from Small Reciprocating Engine Operated with Wood Gasifier by Mixture LHV Changing. *Energies* **2023**, *16*, 2563. [CrossRef]
54. Wen, H.; Yu, Y.; Li, J.; Xu, C.; Jing, H.; Shen, J. Numerical Investigation on the Influence of Injection Location and Injection Strategy on a High-Pressure Direct Injection Diesel/Methanol Dual-Fuel Engine. *Energies* **2023**, *16*, 4518. [CrossRef]
55. Niu, K.; Yao, B.; Xu, Y.; Zhang, H.; Shi, Z.; Wang, Y. Study on Chemical Kinetics Mechanism of Ignition Characteristics of Dimethyl Ether Blended with Small Molecular Alkanes. *Energies* **2022**, *15*, 4652. [CrossRef]
56. Wang, X.; Zhao, H. Modelling Study of Cycle-To-Cycle Variations (CCV) in Spark Ignition (SI)-Controlled Auto-Ignition (CAI) Hybrid Combustion Engine by Using Reynolds-Averaged Navier–Stokes (RANS) and Large Eddy Simulation (LES). *Energies* **2022**, *15*, 4478. [CrossRef]
57. Cisek, J.; Leśniak, S.; Borowski, A.; Przybylski, W.; Mokretskyy, V. Visualisation and Thermovision of Fuel Combustion Affecting Heat Release to Reduce NO_x and PM Diesel Engine Emissions. *Energies* **2022**, *15*, 4882. [CrossRef]
58. Li, Z.; Wang, Z.; Mo, H.; Wu, H. Effect of the Air Flow on the Combustion Process and Preheating Effect of the Intake Manifold Burner. *Energies* **2022**, *15*, 3260. [CrossRef]
59. Zhao, L.; Zhang, Y.; Pei, Y.; Zhang, A.; Ameen, M.M. Numerical Optimization of Spray-Guided Spark Assistance for Cold Idle Operation in a Heavy-Duty Gasoline Compression Ignition Engine. *Energies* **2023**, *16*, 637. [CrossRef]
60. Hasan, A.O.; Essa, K.; Gomaa, M.R. Synthesis, Structure Characterization and Study of a New Kind of Catalyst: A Monolith of Nickel Made by Additive Manufacturing Coated with Platinum. *Energies* **2022**, *15*, 7575. [CrossRef]
61. Alshwawra, A.; Swerih, A.A.; Sakhrieh, A.; Dinkelacker, F. Structural Performance of Additively Manufactured Cylinder Liner—A Numerical Study. *Energies* **2022**, *15*, 8926. [CrossRef]
62. Chybowski, L. Study of the Relationship between the Level of Lubricating Oil Contamination with Distillation Fuel and the Risk of Explosion in the Crankcase of a Marine Trunk Type Engine. *Energies* **2023**, *16*, 683. [CrossRef]