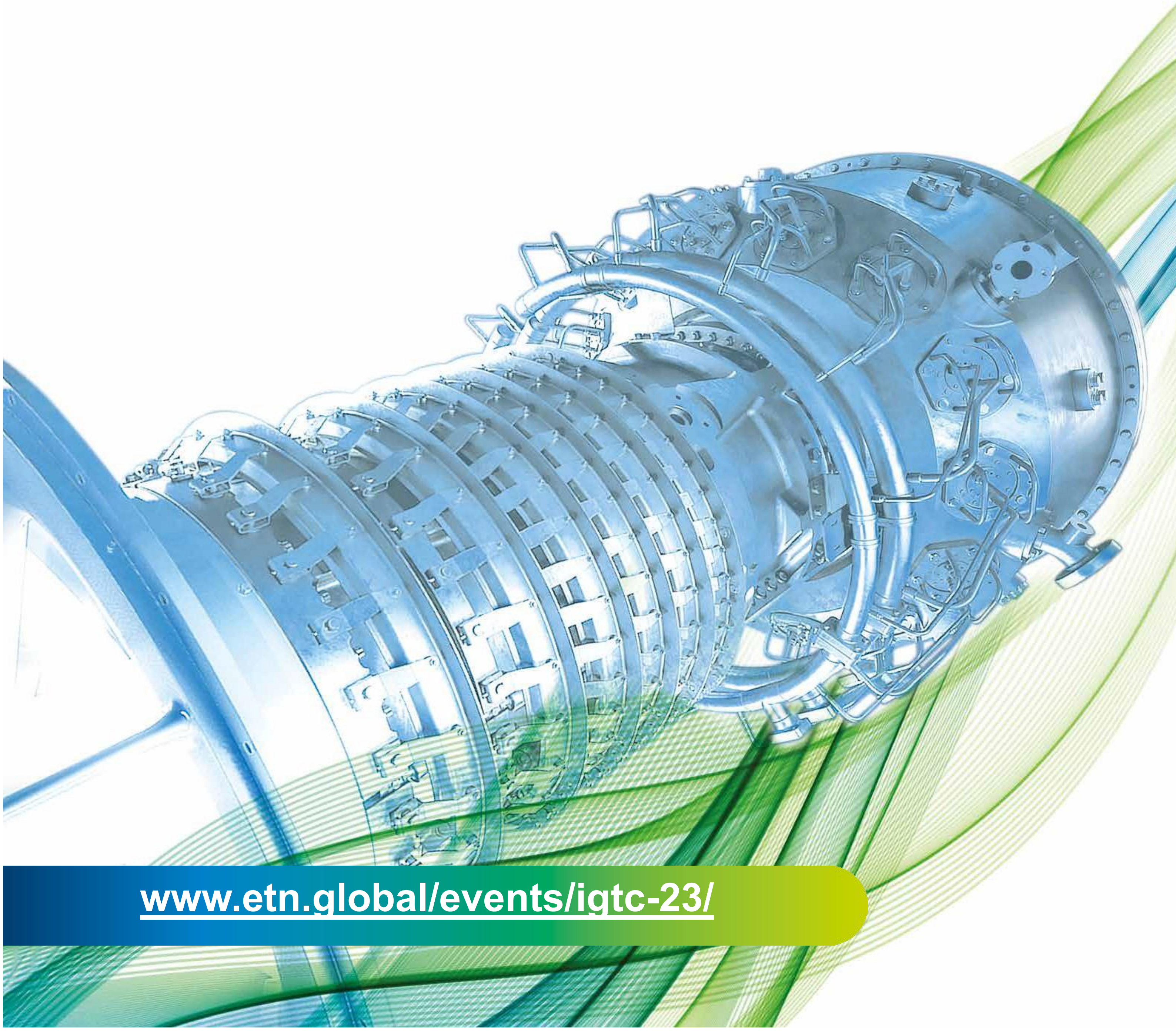
Dispatchable technology & innovations for a carbon-neutral society

11th IGTC, 10-11 October 2023, Brussels, Belgium

Abstracts



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Technical session 1: Low carbon solutions

Low-carbon alternative fuels for sustainable and secure gas turbine power generation: a review

Paper ID Number: 53-IGTC23

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Keywords: alternative fuels, biofuels, fuel flexibility, low-carbon, gas turbines

Abstract

Gas turbines (GTs) are known for providing flexible, reliable, and dispatchable power and, in line with global ambitions to mitigate climate change, can provide a fundamental contribution to achieve net-zero carbon emissions, thereby supporting energy and climate policies. In this regard, GT original equipment manufacturers (OEMs) are working to enable the low-carbon fuel flexibility of their commercially available GT fleets. The OEMs have demonstrated the ability of industrial GTs to operate with many gaseous and liquid fossil fuels, however, there is a growing need to shift towards renewable and sustainable alternative fuels to support the role of GTs in the future low-carbon energy system.

The current work presents a comprehensive review of the current status of alternative fuels (except hydrogen, which has already been covered extensively elsewhere) for industrial GTs and aims to identify the most promising low-carbon solutions. Several non-traditional fuels such as ammonia, biomass, or waste-derived fuels (e.g., biomethane and biodiesel) and alcohol-derived fuels (e.g., methanol, ethanol, dimethyl ether) are analysed, and a common framework is established to compare and contrast these fuels.

This review critically compares the thermophysical and chemical properties of the selected fuels (e.g., heating value, energy density, carbon intensity and chemical composition) with standard GT fuels. Subsequently, the viability of these fuels for power generation is investigated, discussing the main advantages and challenges. Additionally, potential barriers such as fuel purity requirements, emissions, combustion, and safety issues have been incorporated. The study considers aspects connected to fuel handling, transportation, and storage, highlighting the major constraints and technical challenges that might hinder the commercialization of solutions based on low-carbon fuels. The market maturity of each alternative fuel is also evaluated and several criteria (e.g., production methods, generation potential, retrofit capability) are considered to assess their competitiveness, with a particular focus on social acceptance and technology readiness level.

Finally, the study proposes the most promising alternative fuels that are economically, technologically, and environmentally viable resulting from the detailed comparison along with knowledge and experience gaps that must be addressed. Therefore, the present review could serve as a guide for the GT industry to lay the path of further alternative fuel research and development efforts to meet global energy transition and decarbonization goals.

Evaluation of the minimum NOx emission from ammonia combustion

Paper ID Number: 11-IGTC23

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Keywords: Ammonia, Combustion, Gas Turbines, Emissions, Carbon-free

Abstract

Ammonia (NH_3) is currently being actively investigated as a carbon-free alternative fuel, however, the fuel-bound nitrogen in NH_3 causes significant increase in NOx emissions during ammonia combustion. Different from conventional combustors designed for hydrocarbon fuels, it is still unclear what strategy and structure to use for ammonia-based combustor design therefore combustor suitable for ammonia combustion still does not exist. A useful benchmark and guideline to have when designing ammonia-based combustors is the theoretical minimum NOx emissions which could be achieved under ideal conditions for ammonia combustion. In this work, we will evaluate the minimum NOx emission for NH_3 combustion using different staged combustor strategies. Simulation will be conducted using chemical reactor network modeling to model different conceptual combustor strategies. The first strategy is the staged combustor is rich-quench-lean typed staged combustor. The scientific rational behind this strategy is to crack NH_3 in the first stage rich burn with low NO emission. In the second stage, the fuel rich exhaust could be further oxidated through secondary air injection. The second strategy is staged fuel injection. The scientific rational behind this strategy is to burn lean NH_3/air mixture in the second stage and inject NH_3 in the second stage to consume the NO produced in the first stage to achieve low NO emission. The last strategy will be investigated is partially cracked NH_3 and how such fuel pretreatment affects NO emission. In this way, we can find the theoretical minimum NOx emissions for different NH_3 combustion strategies and provide guidance on NH_3 combustor design with minimized NOx emission.

Field demonstrations of hydrotreated vegetable oil as biofuel for gas turbine decarbonisation

Paper ID Number: 50-IGTC23

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Keywords: Biofuel; Hydrotreated Vegetable Oil; Decarbonisation; Field Test; Emissions

Abstract

Hydrotreated vegetable oil (HVO), when derived from waste products such a used cooking oil, animal fats or forest residues, can offer significant lifecycle CO_2 emissions reductions (>90%) when compared with the equivalent fossil diesel or fuel oil. Given its similar properties to fossil diesel, it is often marketed in the transport sector as a drop-in replacement fuel, offering a decarbonised solution with minimal or no equipment changes by the user. However, there is only limited available evidence of the use of HVO to decarbonise liquid-fired or dual-fuel capable gas turbines (GTs).

Uniper has investigated the use of biofuels, and HVO in particular, as one pillar to achieve the goal of decarbonising its European power generation by 2035. After a detailed HVO analysis including the fuel specification, properties, availability, and suitability for use in selected gas turbine applications, three successful field demonstrations to replace fossil diesel or fuel oil with HVO have been undertaken in recent months, including the world's first demonstration of HVO in a gas turbine in July 2021 in Sweden. Subsequent GT field testing with HVO was conducted in March 2022 in Germany and in August 2022 in the United Kingdom.

This paper describes the preparatory work, testing, results, and further considerations associated with the use of HVO in the Uniper gas turbine fleet. For each gas turbine and site, a detailed study was first undertaken to determine the feasibility of replacing the existing fossil fuel with HVO. A test plan was also developed for each GT which served as the basis for performing a hazard identification (HAZID) workshop attended by technical specialists and site personnel. Each test plan included operation of the gas turbine on the existing fossil fuel to establish a baseline of performance and emissions. HVO was then delivered to each GT to demonstrate its ability to operate across a range of conditions including start-up, base load, part load, and shut-down. Key performance and emissions indicators (such as NOx and CO) were compared across fuels and operating conditions to ensure the suitability of HVO. In many cases, accredited emissions measurements showed improvements when using HVO.

As a result of these field tests, HVO is promising as a suitable low-carbon replacement fuel for fossil diesel and fuel oil in GTs. However, site conversion and long-term operational reliability require further evidence and consideration including costs, safe handling, material impacts, and storage.

Technical session 2:

Product sustainability, performance & reliability

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Assessing gas turbine fleet readiness for a low-carbon future

Paper ID Number: 49-IGTC23

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Keywords: -

Abstract

Invested parties in the power industry are investigating hydrogen as a replacement for carbon-containing fuels in gas turbines. It is important to understand the capability of current fleets to utilize hydrogen containing fuels, not just for 100% hydrogen but rather for any percentage inclusion, as part of a potential gas turbine fuel transition. These practical assessments will help in evaluating the costs and timing in completing the transition. This paper describes the authors work in evaluating the criteria important in existing fleet transition to hydrogen as well as case studies for specific fleets and units. The work delves into the fleet, site, unit, and component considerations. On a fleet level, topics discussed are commonality of components, fleet downtime and reliability, and site wide investment considerations. On a site level, unit to unit considerations and commonality are considered, as well as specific site to site variation in timing and investment. On a unit level, more detailed technical information around a unit capability is discussed, such as the hydrogen capability limits, hydrogen flow requirements, and component considerations such as the combustion system, hot gas path, fuel delivery and other systems impacted by the hydrogen fuel. This paper is intended to provide the reader a practical reference through general and case study assessment of the requirements around gas turbine transition to hydrogen-containing fuels. The report is an unbiased view as to the requirements and capabilities currently in the representative fleets studied.

The impact of hydrogen fired gas turbines on HRSGs

Paper ID Number: 42-IGTC23

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Keywords: -

Abstract

Global pressure on the use of traditional fossil fuels and the emission of greenhouse gases such as CO_2 is enormous. Consequently, the gas turbine (GT) industry is taking action. One of the key efforts of reducing CO2 emissions in gas turbines is to shift the use of natural gas (typically CH_4) to Hydrogen (H_2). The different gas turbine OEMs, as well as utilities and other users of gas turbines, are currently investigating the impact of firing H_2 in gas turbines. A lot less focus is given to its impact on other complementary equipment to gas turbines such as Heat Recovery Steam Generators (HRSGs), while a great deal of the global gas turbine fleet is connected with HRSGs. This paper will give insight into what the main impacts are of firing H_2 in gas turbines on HRSGs.

One of the side effects of firing hydrogen is typically the production of more nitrogen oxides (NOx). Current estimates show that gas turbines running on 100% hydrogen will produce roughly 40% more NOx than those running on natural gas. In countries where stringent NOx regulation applies, necessary design alterations or design preparations are necessary and are described in the full paper.

Secondly, the water dew point of the flue gas increases when firing hydrogen in the GT. This means that cold parts which are in contact with flue gas will form condensation quicker. When designing a new installation, it is necessary to engineer the insulation system to avoid the accumulation of liquid water and thus design for the hydrogen firing capability in advance.
Thirdly, firing H2 adds extra volume to the exhaust gas flow compared to firing natural gas. This (small) increase could create more flue gas side pressure drop, depending on the existing boiler design. This additional pressure drop needs to be within the limits of the design pressure drop to avoid an impact on the design performance of the unit or design pressure of the casing and ducting.

Last, but certainly not least, are the additional safety aspects that apply when firing H_2 in the gas turbine. This is specifically applicable when a gas turbine trip occurs. Such an event could, for instance, cause a collection of the H_2 gas in the 'attic' of the HRSG, since H_2 is significantly lighter than air/flue gas.

Additive manufacturing gas turbine high pressure nozzles: design and validation

Paper ID Number: 55-IGTC23

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Keywords: Additive Manufacturing, New Materials, Gas Turbine Vanes

Abstract

The application of nozzle sectors realized with additive manufacturing on Gas Turbine for the Industrial segment shows several advantages in terms of performances, reduction of production lead time and environmental impact.

The standard manufacturing process for turbine nozzles is the investment casting. This process is based on the creation of an equipment/tooling that requires, beside an important investment, a long development and qualification lead time. Moreover, any geometrical variation requires the tooling's modification, and therefore additional cost and time. These aspects make the investment casting process as robust as it is rigid and not very flexible in responding to the different needs of the market.

Additive Manufacturing offers a greater versatility as it does not require a specific equipment, developed only for a single component, and modifications can be implemented simply by updating the CAD model and the related printing and post-processing activities. Furthermore, especially for cooled nozzles, the additive allows to design more complex and efficient geometries and/or to optimize/tune the baseline geometry according to a specific customer need. Complexity of the nozzle design increases costs only marginally in additive manufacturing and geometry design of the Hot Gas Path components in additive can be produce even for those not producible today by standard process.

Baker Hughes (BH) has developed, and continues to optimize, proprietary additive alloys for Hot Gas Path components, for example NP110, a Nickel based super-alloy with excellent mechanical properties that make it suitable for cooled high-pressure gas turbine nozzles. The production process is completely internal to the company, including the printing, post-processing and machining operations. This "vertical capability" allows a greater control and management of production times.

The NP110 was selected for the first stage nozzle of the NovaLT12 and NovaLT16 high pressure turbine. The nozzles' design has been analysed following the same analytical verification process of casting nozzles: the oxidation, crack initiation and propagation, high cycle fatigue (HCF) and creep have been assessed to target the scheduled standard product scheduled maintenance policy.

As well as the simulation, the whole nozzle industrialization process was optimized to ensure that the additively manufactured parts target all the requirements.

A significant sample of nozzles has been assembled on NovaLTs’ internal prototypes and validated through stress tests made by multiple transient missions. Finally additional sectors have been assembled on a customer's NovaLT12 for a long-time field validation and monitored by borescope inspections.

The paper describes the design and validation steps, including the disassembly and detailed inspections, which demonstrates comparable behaviours between casting and additively manufactured parts.

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Technical session 3: Product sustainability, performance & reliability

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Rotor lifetime assessment: a reference report

Paper ID Number: 57-IGTC23

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Keywords: Additive Manufacturing

Abstract

A gas turbine rotor is a large complex structure, made of different stages of discs which are exposed to a range of temperatures and stresses during operation. Depending on the nature of its operation and the standard of its design, various damage mechanisms such as creep-fatigue, oxidation and corrosion act to limit the life of the gas turbine rotor. However, because of its nominally long design life less attention is traditionally paid at intermediate inspections to this highly critical part of the machine.

A large numbers of gas turbine rotors are expected to reach the end of their nominal design life in the coming years. Replacing a turbine rotor (or part of it) or sending a rotor for an inspection and overhaul requires some careful advanced assessment and planning. The consumed life of a turbine rotor can be different to that of its peers operating in different units, driven by the operational conditions.

Any rotor life model should be able to provide clear recommendations to the plant operator to run, repair or replace a turbine rotor (or part of it). This can only be achieved by an in-depth knowledge of damage mechanisms, materials data, and thermal transient modelling of the rotor combined with an assessment of confidence levels associated with the non-destructive techniques used to inspect it.

Initially, this paper focuses on rotor life definition, then it describes the lifetime assessment process in more detail. Some cross-references are made to integrity assessments of turbine rotors in flight engines. Finally, the gaps identified in current practices are discussed in the context of managing the uncertainties and improving the confidence in the rotor life assessment.

Given the issues discussed in this paper, it is greatly beneficial to the turbine community to run a collaborative rotor lifing program to establish a generic lifing protocol for gas turbine rotors. Therefore, ETN invites gas turbine owners and operators (including service providers and OEMs) to join this working group, to improve the awareness of the issues surrounding rotor integrity, working towards higher confidence in future gas turbine operation for older machines.

Validation of a lifing approach for a digital fleet of gas turbines

Paper ID Number: 32-IGTC23

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Keywords: Digital Twin, Digital Engine Modelling, Component lifing, Physics-based models, Flexible operation

Abstract

Gas turbines are being increasingly used outside of their original design intent due to a mixture of commercial and legislative reasons. For example, overfiring of engines for defined periods of time is becoming common place. There are a number of reasons why an operator may wish to overfire their engines; these include a requirement for additional power on a hot day or for grid code events. This poses a challenge for the lifing of industrial gas turbines as they can be subject to complex loads resulting from this flexible operation.

OEMs and operators have developed lifing strategies and tools which can account for this flexible operation. And OEMs have developed services that can allow operators to work their engines harder or extend the time between overhaul. These tools use a range of data sources and modelling techniques to predict component life. For hot gas path components it is necessary to consider degradation mechanisms such as fatigue, creep and their interactions. Physics based models, combined with operational data, are therefore required so that beyond intent operation can be predicted accurately.

This paper will present a lifing approach, for gas turbine hot section components, that has been embedded within our digital twin fleet to predict the initiation of damage under high temperature operation. The approach enables us to predict a material response for each component based on its recorded operational history. This paper will demonstrate how the lifing approach has been validated by predicting the life of notched bar tests, which are representative of the geometry of critical locations in a gas turbine. The paper will also contain details about how the lifing approach has been validated using ex-service components. The lifing approach has been applied more widely to an engine fleet and the paper will provide examples of how it is being used to substantiate our different services, for example: the overfiring of engines and flexible overhaul periods.

Novel laser cladding process for local TBC repair

Paper ID Number: 37-IGTC23

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Keywords: Thermal Barrier Coatings, Repair, Laser Cladding, Columnar Structure

Abstract

In laser-based additive manufacturing of Ni-based superalloys, significant progress has been made in recent years in terms of possible dimensions and geometric design, as well as in terms of improved mechanical characteristics. In the field of gas turbines, this enables now targeted repair and the realization of novel component designs by means of laser-based processes such as direct laser deposition or selective laser melting. In the case of ceramic materials, the necessary high processing temperatures and the lack of ductility of ceramics often lead to high local stresses and crack formation even in relatively small structures. This makes it difficult to build defect-free components and still restricts the range of applications.

In the field of gas turbine applications, however, there are microstructure requirements, particularly for ceramic thermal barrier coatings, which can in principle be met by laser-based additive manufacturing. Due to the high demands on the thermal shock resistance of the coatings, the presence of porous areas or segmentation cracks, for example, can not only be tolerated, but supports the function and lifetime of the coatings. In this contribution, a novel laser cladding process (Clad2Z) for the deposition of columnar structures is presented, which can be used for localized fabrication and repair of thermal barrier coatings [1]. The stability and durability of the so-prepared TBCs were investigated under realistic gradient conditions in burner rig tests. The durability and failure mode qualify the coatings as at least equivalent to conventional TBC systems.

[1] "Additive manufacturing of columnar thermal barrier coatings by laser cladding of ceramic feedstock" (DOI: 10.1002/admt.202200098).

Technical session 4:
Energy efficiency improvements

BTC – A new technology for high efficiency biopower in a decarbonised society

Paper ID Number: 35-IGTC23

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Keywords: BECCS, humid cycle, high-pressure gasification, fuel flexibility, MILD combustion

Abstract

To restrict climate change to 1.5°C, an enormous shift to renewable energy is needed, representing a growth rate of up to 1000 TWh of new production per year up to 2050. The past decade has seen a marked acceleration in the deployment of low-cost but variable renewable electricity generation. However, as this renewable energy can neither be easily stored or dispatched, the value of flexible, dispatchable and renewable energy is expected to be very high in the energy transition.

To meet this market need, a highly efficient power cycle is being developed by Phoenix Biopower. The process, called the Biomass-fired TopCycle (BTC), is introduced in this paper and its key attributes and process features are presented. The target for the BTC is a cost-efficient, dispatchable, scalable and fuel flexible product for renewable electricity and heat, with possible fuels range from various biomass waste feedstocks (e.g. residues), to gaseous fuels, like renewable methane or pure hydrogen.

The BTC is a humidified gas turbine cycle integrated with biomass gasification where substantial injection of steam, generated from gas turbine and gasifier waste heat, allow a high electrical efficiency without a steam turbine. As the BTC utilizes near-stoichiometric combustion, with air substituted by steam, the compressor size and work can be minimised, and plant efficiency maximised. The high concentration of water vapor in the exhaust gases provides for a high dew point where a flue gas condenser can efficiently recover both heat, for e.g. district heating production in combined heat and power (CHP) mode, and all process water required for the plant.

As part of the BTC development program, Phoenix Biopower is designing several critical systems which will be presented in the paper. First, a new biomass gasification system for high-pressure operation, high fuel-, load-, and output-flexibility and high biomass conversion rates. Second, a novel combustion technology capable of utilizing a fuel spectrum from biomethane to syngas and pure hydrogen with a single burner and ultra-low thermal NOx. Third, plant integration and operations with carbon dioxide capture technology to generate negative emissions from biomass. Other key development areas done in joint efforts with external partners, like the gas turbine. Test rigs are also critical in the development of BTC where fundamental behaviour and performance targets are verified. Initial results from an integrated "fuel to flame" rig, i.e., biomass gasification, clean-up and combustion, are shown.

The paper will finish with a commercial outlook on how BTC can contribute to a cost-effective energy transition.

Potential of a utility scale sCO_2 bottoming cycles for gas turbines: thermodynamic, carbon capture and preliminary economic performance assessment

Paper ID Number: 52-IGTC23

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Keywords: Gas turbines, sCO_2 cycles, energy analysis, industrial application, carbon capture

Abstract

The quick start-up time of gas turbines makes them a predilect technology to cope with the intermittency of renewables. Their high turbine inlet temperature conducts to efficiencies close to 40%, but also to a significant loss of energy due to the still hot flue gases (up to 700 °C). Despite the addition of a bottoming cycle, allowing to rise the total efficiency up to 60%, the high CAPEX of current steam technologies seems to discourage the smaller units (< 150 MWe). In general, most efficient steam cycles require heavy technological investments that only large-scale electrical productions can amortize. Nevertheless, the use of sCO_2 as a working fluid considerably contributes to more compact and simpler installations, and potentially represents a more affordable solution for smaller gas turbine units. Despite this theoretic potential, further research remains required to confirm this on real utility scale applications. Hence, this article not only intends to characterise the amount of power recoverable from different exhaust conditions, by means of supercritical CO_2 cycles, but also to apply it to a utility scale context. First, the advantages and limitations of different supercritical CO_2 cycles, convenient to recover heat from gas turbine flue gases, are presented. Depending on the source temperature, sCO_2 technologies can recover between 40% and 50% of the exergy content of the exhaust gas. For each cycle, performance maps are designed to link the temperature of the gas turbine exhaust with the maximal efficiency. The specific case of a Siemens SGT5 9000HL, coupled with a three-pressure steam cycle and with a sCO_2 cycle, is presented. Exergy diagrams are drawn to better understand the losses in the components and the differences between the two bottoming technologies. As already indicated in literature, the sCO_2 bottoming cycle remains less efficient than its steam counterpart. To exceed the steam performances, constraints on the sCO_2 cycles are needed that can be considered technically unrealistic. Nevertheless, the sCO_2 cycle still shows some clear advantages towards CAPEX reduction and flexibility. An extension to amine-based carbon capture is also studied to try to find out new configurations, enabled by sCO_2 cycles, aiming to reduce the carbon capture energy penalty while maximizing the plant efficiency.

Aspects of the GT inlet system that affect GT efficiency, including a focus on the correct application of power augmentation

Paper ID Number: 47-IGTC23

Authors:

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Keywords: -

Abstract

With the ongoing environmental and geopolitical concerns in this modern world, it has never been more important to consider and optimise the efficiency of gas turbine installations. Beit, to reduce carbon emissions or fuel consumption, increase power output or improve availability. The combustion air inlet system is one of the contributing factors that plays an important role in the efficiency of the gas turbine system. It has been recognised in recent years, with many papers already published, that reducing GT fouling by increasing the dust removal efficiency of the inlet system can offer a significant improvement to GT efficiency. The standard recommendation today is to upgrade to EPA rated filters, which are now available from most filter vendors.

The session to be presented here focuses on other, lesser discussed aspects of the inlet system that also contribute to improving the efficiency of the gas turbine, to ensure they do not get forgotten or overlooked and these will include; control of moisture to minimise unwanted side effects such as spikes in pressure loss, the role of and considerations for, hydrophobic and oleophobic properties of filters to reduce GT fouling or eliminate salt penetration, and the use and types of combustion inlet air cooling, with pros and cons and application advice.

Technical session 5:
Low carbon solutions

HYFLEXPOWER: Demonstration project of power-to-H_2-to-power advanced plant concept

Paper ID Number: 18-IGTC23

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Keywords: Power-to-X-to-Power, hydrogen, electrolysis, hydrogen combustion, energy storage, gas turbine

Abstract

H_2 combustion in gas turbines is expected to become the technology of choice for backing up intermittent renewable generation in deeply decarbonized energy scenarios. The HYFLEXPOWER project is the first-ever demonstration of a fully integrated power-to-H_2-to-power full scale installation in a pre-existing pilot plant within an industrial facility in Saillat-sur-Vienne, France. This paper provides a comprehensive summary of the successful development, installation, and demonstration of the power-to-H_2-to-power application in the pilot plant: production of green hydrogen via an electrolyser, storage of the hydrogen inside the plant and the re-electrification through combustion in a Siemens SGT-400 gas turbine up to 30 % vol in natural gas. It also provides an outlook on the next phase of the project to operate the pilot demonstration plant for carbon-free power generation with 100% hydrogen in 2023.

Hydrogen and hydrogen blended jet and recirculation stabilized combustion in a Turbec T100 micro gas turbine combustor

Paper ID Number: 43-IGTC23

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Keywords: Hydrogen Combustion, NOx and CO Emissions, Turbec T100, CFD RANS, Jet and recirculation stabilized combustion

Abstract

Hydrogen utilization in decentralized micro gas turbine (MGT) combined heat and power (CHP) systems gains great importance due to the transition towards renewable energy. The work at hand contributes to hydrogen usage in CHP by means of experimental and numerical studies.

An existing jet and recirculation stabilized DLR combustor - designed for synthetic gas - is operated and experimentally investigated with methane hydrogen blends up to pure hydrogen in a Turbec T100 MGT in cooperation with the University of Stavanger (UiS), Norway.

Focal points are emissions behaviour and practical usability of the combustion system concerning hydrogen utilization. A wide range of fuel compositions at all significant power levels of the machine are considered. CO and NOx pollutants are quantified for the combustor emissions behaviour. Different dilution air configurations are tested in order to get a picture of equivalence ratio influence for varying fuel compositions. Additionally, experimental results are used as validation data for numerical RANS-based CFD simulations in order to contribute insights for flow field and flame stabilization.

Comparison of numerical results and experiments furthermore focuses on CO and NOx emissions predictions, since no optical access is given in the MGT combustor. It is shown that the applied numerical approaches predict emissions quantitatively to a certain extent, which is crucial for further combustor design and optimization.

It is demonstrated that the jet and recirculation stabilized combustion system safely and reliably operates with a large range of hydrogen and hydrogen blended fuels over all relevant load points, with at the same time meeting European legal emissions requirements.

Decarbonisation of gas turbines with the H2R®

Paper ID Number: 16-IGTC23

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Keywords: Retrofit burner, Dry low emission, Renewable energy systems, Natural gas fuel, Hydrogen fuel

Abstract

Gas turbines play a key role in the balancing and stabilization of the grid in Europe, due to their high load flexibility and fast ramp-up. The demand for clean and low-carbon energy, however, increases significantly. As the market share of renewable, but variable, energy rises, the capacity of hydrogen as a storage medium for excess renewable energy is coming increasingly into focus. Its use as a fuel in existing deployed gas turbines, first within natural gas / hydrogen fuel blends during a transition period, later pure as a primary fuel, would enable the extended utilization of gas turbines while supporting the global decarbonization.

The company Crosstown Power GmbH has developed and validated the 'H2R® burner', a 100% hydrogen-capable retrofit combustion system for power plant gas turbines. This solution allows installed gas turbines to continue to operate in their existing infrastructure and as the fuel composition evolves, and to be ready for a CO_2-free electricity production. The H2R® operates with any proportion of Natural Gas and Hydrogen and therefore supports the energy transition.

The H2R® burner is a retrofit multi-tube cluster burner, scalable to target engines' capacity and thermal power, with an extended fuel flexibility from 0% to 100% hydrogen. Given its inherent modularity by design, it is able to accommodate a variety of fuels, mixtures and inerts. This burner design thus permits powerplant operation within their current infrastructure and facilitates the transition phase of fuels to blends or even pure hydrogen. Prototype burners have been developed, tested and validated in an atmospheric rig, particularly suited to the validation of gas turbine burners. Very low emissions have been achieved at all fuel compositions - hydrogen, natural gas and mixed fuels – and for a wide range of firing temperatures. Low emission levels at engine-relevant pressures are estimated, thereby fulfilling the current and expected emission regulations. Dedicated flashback tests have been extensively carried out, showing the good flashback resistance of the burner concept and its wide operational capability.

An overview of the burner validation results, the operational capability and overall current status will be provided in the final paper. Further considerations of validation and engine integration, as well as the next steps towards product launch will be discussed.

Design and cost optimization of carbon capture for H-class gas turbine

Paper ID Number: 36-IGTC23

Authors:

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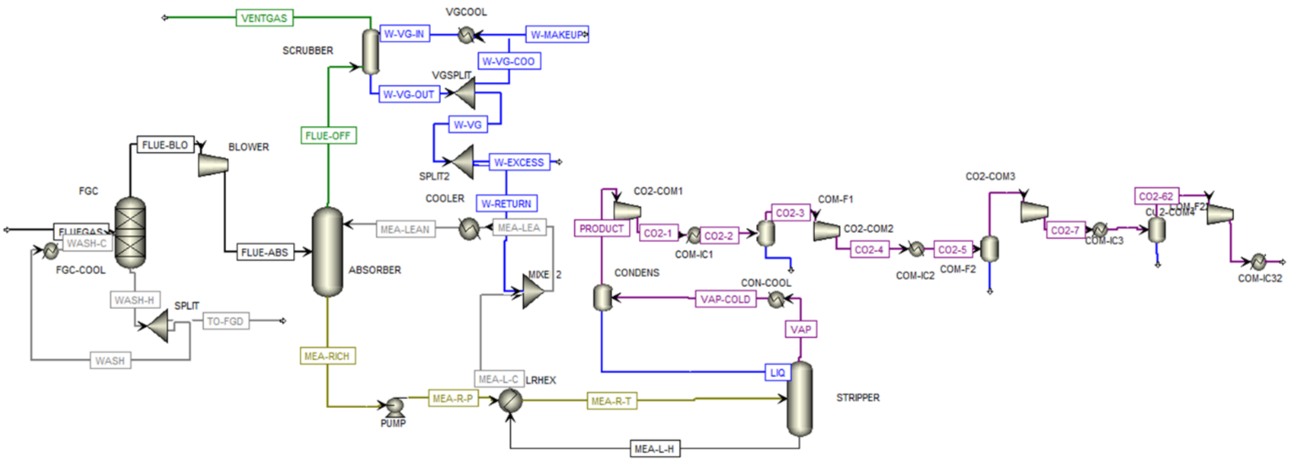
Keywords: amine-based Carbon Capture, H-Class turbine, process optimisation, Levelized Cost of Electricity, capture rate

Abstract

Carbon Capture and Storage (CCUS) applied to new-built CCGT is one of the strategies considered for decarbonizing power production. Today, amine-based absorption technologies are the most mature technologies to be deployed for short-term application. However, the main obstacles to the implementation of the CO_2 capture plant lie in the high capture costs encountered due the large volume of flue gas to be treated with diluted CO_2 concentration resulting in high CAPEX due to large equipment and high OPEX. Besides, to coordinate with electricity demand with the increasing share of renewable energy sources, CCGT-CCS plant should be able to operate in flexible mode with varying operating loads and frequent start-ups/shut-downs while minimizing residual CO_2 emissions during transient phases.

While a 90% capture efficiency at stable load conditions was long considered as the optimum capture rate, high capture levels are technically feasible if permitted by the plant design and solvent selection and seem to be the new target for the future Carbon Capture demonstration projects. Indeed, higher capture rates are considered as a most effective approach to reach carbon neutral power production and to compensate reduced CO_2 capture efficiency during transient phases.

Through modelling using Aspen, the objective of the present study is to highlight the impact of process optimisation on capture costs (CAPEX and OPEX) applied to a CCGT H-class turbine. The CO_2 capture plant is represented in the Figure below.



Flowsheet of the CO_2 capture plant for a CCGT class H-turbine simulated using Aspen plus V12.1 using 30 wt% MEA (2-ethanolamine) and 90% capture rate as base case.

The impact of several parameters (reboiler duty, absorber height and flue gas inlet temperature to absorber) to increase the capture rate has been studied and compared to the base case. Among these, the stripper’s reboiler duty had the maximum effect, in which by increasing the regeneration energy consumption (REC) we could reach to 98% capture rate however, the opex would increase dramatically by 50%. Based on the opex results it can be considered that an increase of REC could be reasonable until a 95% capture rate. On the other hand, the increase of the absorber height and decrease of inlet gas temperature could only increase the capture rate by 3%. However, in the case of the absorber height variation, the rise in the capex (+23%) and opex (+12%) illustrates that the increase of the absorber height is not the best route to a higher capture rate.

When selecting one solvent, determining the optimal configuration to increase capture rate > 90% while minimizing the impact on cost will be key.

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The evolving transformation of gas-fired power plants toward a sustainable and profitable generation system

Paper ID Number: 05-IGTC23

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Keywords: power market, profitability, product development, reliability, availability

Abstract

In the incoming power grid scenario, dominated by not-programmable renewable generation, gas-fired power plants will have to meet more stringent performance requirements and environmental constraints. Since many years, Ansaldo Energia has been implementing product development strategies aimed to assure new and existing power plants to be future-proof and sustainable, while maintaining the asset's value and profitability: to achieve these goals, customers are provided with new equipment, upgrades, and solutions to allow power plants to maintain their positioning in the dispatching arena.

In the Ansaldo Energia vision, the near-future gas-turbine power generation systems will be able to supply (or even draw) active or reactive power on the grid, and to fully participate in the capacity and grid-balancing services market, thereby maintaining their key role in the grid regulation and support.

Gas-fired generation evolution trends
During next years, the heavy-duty power generation development roadmap will therefore include a number of new or updated capabilities:

- increased plant flexibility and reliability: part-load performance, mainly in terms of efficiency and emissions, are getting a quite greater relevance, due to the actual plant operation profile.
- the ability to stack multiple revenue streams by promptly following the energy commodities and electricity markets.
- plant hybridization and operation optimization, by energy storage solutions.
- the increasing use of non-fossil fuels, such as (green) hydrogen and biofuels.
- resilience to extreme weather conditions: gas-fired plants will maintain a strategic role in the security of the power system.

With respect to the past, today gas-fired power plants operate in cycling mode by following the daily dispatching profitability and by supporting grid balance. In order keep their positioning in the merit-order and to keep dispatchability, both open-cycle and combined-cycle GT plants have to reduce operative costs (OPEX) and ensure availability.

OPEX are of course mainly related to fuel costs, where suitable long term purchase contracts are usually an effective way to ensure natural gas supply by avoiding the spot market instabilities.

Another relevant route to keep OPEX is to ensure plant's availability by larger maintenance intervals and optimized overhaul procedures. In the present cycling operation models, maintenance intervals are often constrained by the maximum allowable number of starts between hot parts inspections: a suitable optimized design components procedure is therefore required.

In addition, predictive maintenance digital tools can allow the optimal scheduling of engine overhauls: here the actual use of Ansaldo Energia Apex system is presented as an example.

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The role of combined cycle gas turbines as an energy storage solution in a hydrogen economy

Paper ID Number: 40-IGTC23

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Keywords: P2X2P, Hydrogen, Combined cycles, Optimization, Dispatch strategies

Abstract

The world is highly committed to a future with climate neutrality via a deep decarbonization of all sectors of the economy by including higher shares of renewable energy sources in the electric grid. At the same time, energy independence is becoming more relevant for many countries in Europe, especially those relying heavily on imported natural gas to power their fleet of thermal power plants. One solution that has been proposed, is the development of a hydrogen economy. Hydrogen has a well-established market, and it is currently produced mostly by reforming natural gas. However, hydrogen can also be used as an energy carrier, and produced from renewable sources via electrolysis. This is why many agencies and organizations are foreseeing a future with greater shares of hydrogen production and utilization. In this scenario, hydrogen can be produced with electrolysers, which main inputs are water and electricity, stored for a wide variety of timespans, and used as fuel in many applications, one of which is electricity production via Combined Cycles Gas Turbines (CCGT).

This study is set to explore the potential of a power plant layout in which CCGT units are complemented with hydrogen generation and storage systems. The layout is composed by a conventional CCGT, a fast-cycling electrolyser, and a compressed hydrogen storage system. This configuration is also known as power-to-gas-to-power (P2G2P/P2X2P). Depending on the scenario considered it can make use of already existing CCGTs, saving a great amount of capital investment. In this configuration, the hydrogen is produced and stored using electricity from the grid during low-price electricity periods. The stored hydrogen is then used within the same power plant by injecting it to the gas turbine, up to a certain hydrogen to natural gas concentration ratio. The fuel ratios explored in this study go from 0 to 100% hydrogen in the mix. The paper describes the components proposed for the layouts, e.g. gas turbines, electrolysers, etc. It also identifies optimized operational strategies, system sizing, and the markets in which systems like these would thrive. The dispatch strategy is determined using a mixed integer linear programming routine. The system sizing is established by running a set of simulation using genetic optimization algorithms. The different markets are explored by using historical data of different locations.

The performance of the power system was measured with technical, economic, and environmental KPIs. The indicators include LCOH, LCOE and CO_2 emissions saved. The results show that these P2G2P systems are a feasible alternative to provide energy storage and shifting. Moreover, these layouts also present a great opportunity for mothballed CCGTs which operation is no longer feasible under current electricity and natural gas markets. This study set the grounds for future investigations addressing different sources of electricity for hydrogen production, and different sources and end uses of hydrogen.

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Optimization of fully renewable power plants with seasonal storages: the role of green hydrogen & H_2-fired gas turbines

Paper ID Number: 38-IGTC23

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Keywords: seasonal storage, hydrogen-fired gas turbine, virtual power plant, H2 storage, optimization.

Abstract

Nowadays, net-zero carbonic emission objectives are in the agenda of many governments. Despite the ambitious goals, there is a lack of comprehension on the way these objectives shall be pursuit. While solar and wind energy sources remain two of the most promising renewable technologies already available to meet the climate targets (showing a continuously growing installed capacity worldwide), relying just on these ones is not technically feasible due to their intermittency and seasonality. For this reason, identifying long-term energy storage solutions to accommodate the excess renewable production, mitigate their intermittency and seasonality, will be essential for the future.

This work optimizes the design of a fully renewable power plant which aggregates the renewable production of several PV fields and wind farms located in his proximity, batteries, electrolysers, H_2 storages and H_2-fired gas turbines. The different units are operated synergically as a virtual power plant to meet the time-varying electricity demand of a region in Sicily for the whole year, without outages. The optimal design (i.e., components sizing) and operational management has been obtained by formulating the problem as a Mixed-Integer Linear Programming (MILP) model using the methodology developed by Politecnico di Milano [1] [2] [3].

The results show that the optimal configuration features a battery capacity sized for short-term balancing operations and green hydrogen storage systems (electrolyser + H_2 storage + H2 fired gas turbine) for long-term storage. Considering current prices, such solution has a Levelized Cost of Electricity (LCOE) of 220 €/MWh. However, if the costs projected for 2050 are considered, the cost of electricity is reduced to 123 €/MWh. The optimized management strategy of the aggregated system exploits the batteries for short-term (daily and weekly) operations, while the hydrogen-based storage is used as long-term seasonal solution to compensate seasonal variations in the renewable production.

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Optimization of gas turbine-based microgrids: an airport case study

Paper ID Number: 48-IGTC23

Authors:

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Keywords: microgrid, combined heat and power, distributed energy systems, MILP.

Abstract

Due to the requirement of reducing CO_2 emissions and fossil fuel consumption, it is essential to integrate renewable energy sources in the energy systems which provide electricity and heat to industrial and civil facilities (e.g., hospitals, schools, airports, etc.). Solar energy (PV) and wind are the renewable sources typically considered because of their availability and relatively lower cost of electricity. On the other hand, their intermittent nature poses the need of installing flexible dispatchable generators and/or energy storages (batteries and/or thermal energy storages). Thus, an energy management system is needed to aggregate and operate several units (generators and storages) in a synergic way with the objective of minimizing the total operating cost while providing energy to the final users with sufficient reliability. Due to the presence of different units, storage systems and uncertain renewable production, the rule of thumbs, design criteria and operating modes developed for conventional centralized energy systems are not applicable.

In the last ten years, Politecnico di Milano has developed a code for the systematic design optimization of aggregated energy systems [1] [2]. Given the expected hourly energy demand profiles of the final users, the PV and wind production potential of the site, the catalogue of available generators (PV panels, wind turbines, gas turbines, internal combustion engines, heat pumps, etc.) with their costs and performance curves, the code determines the optimal selection of units, their optimal sizes and their optimal operation considering capital and operating costs (including the carbon tax). The code solves the problem in a rigorous way, by formulating the combined design and operational optimization problem as a Mixed-Integer Linear Programming (MILP) model.

This paper is applied in collaboration with Nuovo Pignone to the optimization of the energy system for a medium size airport. The case study is constructed to represent an average airport serving about 71 million of passengers per year and located at middle latitudes (total annual average solar irradiance of about 1780 kWh/m2) with both electricity and heating demands. The electricity demand includes the airport services (critical demand), with an average load of 20 MW and a peak of 60 MW, and the charging stations for electric vehicles planned for 2030 (adjustable demand), considering an average of 7000 electric vehicles per day. The total annual heating demand is about 70 GWh/y, characterized by a peak of 30 MW. As a reliability requirement, the energy system must be able to meet the airport critical demand

in any circumstances, also in case of failure of one generator. The catalogue of generators includes PV panels, wind turbines, combined heat, and power (CHP) gas turbines, heat pumps, and boilers, while the catalogue of energy storage systems includes batteries and thermal storages.

The optimization is repeated for different scenarios, considering an off-grid location and a grid-connected location, and for different values of carbon tax/CO_2 emission targets.

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