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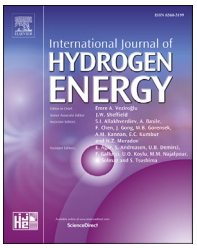

Review Article

Low to near-zero CO_2 production of hydrogen from fossil fuels: Status and perspectives

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ABSTRACT

At present, practically all industrial production of hydrogen either directly or indirectly (e.g., through electricity generation) relies on fossil fuels (mostly, natural gas and coal) and, according to many projections, this trend will continue in the foreseeable future. As a result, hydrogen plants are and will remain a major source of CO_2 emissions to the atmosphere, with potentially adverse consequences to our planet's ecosphere and climate. In view of these negative trends, there is an urgent need to substantially reduce or even completely eliminate CO_2 emissions from fossil fuel-based hydrogen production processes in order to underscore environmental advantages of hydrogen as an ecologically clean fuel. The main technological approaches to low to near-zero CO_2 production of hydrogen from fossil fuels can be classified into three main groups: (1) coupling hydrogen plants with CO_2 capture and storage systems, (2) dissociation of hydrocarbons to hydrogen and carbon, and (3) integrating hydrogen production processes with non-carbon energy sources such as nuclear and solar energy. The objective of this paper is to overview and analyze the current status of existing and emerging technological options and solutions to drastically reducing the amount of CO_2 emissions from fossil fuel-based hydrogen manufacturing plants. A near-to-mid term outlook for low to near-zero CO_2 hydrogen production from fossil fuels in the light of new technological trends is examined in this paper.

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List of Abbreviations

AC	activated carbon
AGR	acid gas removal
APC	Air Products and Chemicals, Inc.
CB	carbon black
CCS	carbon capture and storage
CMD	catalytic methane decomposition
CNT	carbon nanotubes
DLR	Deutsches Zentrum für Luft-und Raumfahrt e.V. (Germany)
DOE	US Department of Energy
EOR	enhanced oil recovery
ESA	electric swing adsorption
GWP	global warming potential
HPC	heteropolycompounds
HTGR	high-temperature gas-cooled nuclear reactor
IEA	International Energy Agency
IGCC	integrated gasification combined cycle
INL	Idaho National Laboratory (USA)
MDEA	methyl diethanol amine
MEA	monoethanolamine
MOF	metal organic frameworks
NETL	National Energy Technology Laboratory (USA)
NG	natural gas
NGCC	natural gas combined cycle
NRC	National Research Council (USA)
NTP	non-thermal plasma
OPM	oxygen-permeable membrane
PSA	pressure swing adsorption
SER	sorption-enhanced reforming
SMR	steam methane reforming
TCD	thermocatalytic decomposition
TSA	temperature swing adsorption
UV	ultra-violet
UOP	Universal Oil Products
VRR	volumetric reactor receiver
VSA	vacuum swing adsorption
WGS	water gas shift

Hydrogen production plants as a major source of CO_2 emissions

Currently, practically all industrial manufacturing of hydrogen (globally, about 60 million metric tons per year [1]) is based on fossil fuels (mainly, natural gas and coal) either directly (i.e., using them as a feedstock and process fuel) or indirectly (i.e., through the use of fossil fuel-generated electricity). The main industrial sources of merchant hydrogen are as follows:

- Steam methane reforming (SMR) (globally, about half of all H_2 produced)
- Partial oxidation and autothermal reforming
- Steam-oxygen gasification of coal
- Refineries and chemical plants (including chlor-alkali process) off-gases
- Water electrolysis
- Other minor sources (plasma pyrolysis, residual oil and biomass gasification, etc)

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