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Strategic use of the underground in an energy mix plan: Synergies among CO_2, CH_4 geological storage and geothermal energy. Latium Region case study (Central Italy)

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HIGHLIGHTS

- Proposal of a methodology to evaluate the energy potential of the underground.
- Encourage a synergic use of different energy resources.
- Development of energy-mix scenarios, considering CO_2, CH_4 geological storage and geothermal energy.
- Results show that a synergic use of the underground improves the energy autonomy.
- CO_2, CH_4 geological storage and geothermal energy may significantly contribute to the CO_2 emissions reduction.

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ABSTRACT

In recent decades, the worldwide demand for energy has been increasing, with an associated rise in CO_2 emissions being observed. In such conditions, the development of "low carbon energy technologies" and strategic energy-mix plans is necessary, and an evaluation of the underground energy potential may be a useful step in developing these plans. This evaluation involves the synergic development of such technologies as: coal combustion in combination with CO_2 geological storage (CCS), natural gas geological storage (CH_4-GS) and geothermal energy (GE), especially in densely populated countries, such as Italy.

Currently, 13.7% of Italian energy demand is met by foreign providers. Most of the Italian regions have energy deficits, and the Latium Region (in Central Italy) represents one of those in the worst conditions.

This work proposes a methodology to develop energy-mix scenarios, starting in Latium, to identify areas that are potentially suitable for CCS, CH_4-GS and GE. Six geothermal systems and one CO_2/CH_4 storage potential area were identified.

Three main scenarios are proposed: (A) a combination of CH_4-GS with methane as cushion gas and GE; (B) a combination of CH_4-GS with CO_2 as cushion gas and GE; (C) a combination of CCS and GE. Scenario A results in a reduction of the regional energy deficit that ranges from 21.8% to 45.6%. In Scenario B, the regional energy deficit reduction ranges from 30.8% to 80.7% and the CO_2 emissions reduction ranges from 1.4% to 5.6%, supposing an injection of 20 years. Scenario C shows a decrease in the regional energy deficit that ranges from 15.9% to 22.1%, while the CO_2 emissions reduction ranges from 7.1% to 31.3%, over the same time period.

The proposed scenarios may be useful not only for the scientific community but also for policymakers as they identify the most reliable energetic strategies. Thus, this case study could be extended to the entire Italian territory with the ultimate goal of reaching energy autonomy in each region.

1. Introduction

In recent decades, the worldwide energy demand has increased far beyond a critical threshold, which indicates a need for an urgent development of a strategic energy mix plan to encourage low greenhouse gas (GHG) technologies and to discontinue large-scale CO_2 emissions.

A recent study published by the European Commission [1] shows that if the existing trends continue without any mitigation, by 2050, the CO_2 emissions will be unsustainably high: as high as 900–1000 ppm by volume.

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Nomenclature

CO_2 and CH_4 geological storage

G_{CO2}	mass estimate of saline formation CO_2 resource
G_{CH4}	mass estimate of saline formation CH_4 resource
A	geographical area of the storage site
h	gross thickness of saline formations of the storage site
φ	average porosity of entire saline formation over thickness h or total porosity of saline formations within each geologic unit's gross thickness divided by h
ρCO_2	density of CO_2 evaluated at pressure and temperature that represents storage conditions anticipated for a specific geologic unit averaged over h
E	CO_2 or CH_4 storage efficiency factor that reflects a fraction of the total pore volume that is filled by CO_2 or CH_4

Geothermal energy

W	thermal power (MW_{th})
P_{el}	electric power (MW_e)
η_{th}	thermal efficiency
η_{th-max}	maximum thermal efficiency
η_{th-r}	real thermal efficiency
T_{HS}	absolute temperature of the heat source (K or °R)
T_C	absolute temperature of the brine leaving the plant (K or °R)
T_0	absolute dead-state temperature (K or °R)
T_L	absolute temperature of the heat sink (K or °R)

Potocnik and the European Commission in 2007 [2,3] underlined the need to elaborate, at the European level, a Strategic Energy Technology Plan that focused on non-carbon or reduced-carbon sources of energy, such as renewable energy technologies, CO_2 Capture and Storage (CCS) technologies, and smart-energy networks, as well as energy efficiency and energy conservation.

Future scenarios extended to 2030 by the International Energy Agency (IEA) [4] show that an energy mix plan characterized by the integration of CCS in power generation, nuclear, renewable resources and natural gas could reduce the global CO_2 emissions from 27 Gt to 23 Gt (Fig. 1).

A useful first step in designing an energy mix plan may be the evaluation of the underground potential in terms of low carbon energy development, specifically:

(1) Coal combustion combined with geological storage of CO_2.
(2) Natural gas (CH_4) geological storage in natural reservoirs.
(3) Geothermal energy for power generation.

These technologies could coexist, especially in densely populated countries with high energy demand, such as Italy.

This work proposes a methodology that is aimed at the development of an energy mix plan and which starts in the Latium Region because it has one of the highest energy deficits in Italy.

The Latium underground was analyzed to identify potential suitable areas for CCS, natural gas storage and geothermal energy. In particular, the work focused on CO_2 and CH_4 storage in saline aquifers due to their wide distribution over Italian territory compared to the other reservoir types. In addition, conventional geothermal systems are the preferred option for geothermal energy exploitation because they have already been well-characterized during the 1970–1990s explorations.

These combined operations could allow for a new energy scenario according to the climate change mitigation models proposed by IPCC [5]. These models foresee that to produce a tangible reduction in CO_2 emissions, a mixture of several technologies is necessary, and furthermore, no technology is self-sustaining [6,7].

2. Proposed technologies

2.1. CO_2 geological storage

CCS is an emerging technology that is capable of reducing anthropogenic emissions of CO_2 into the atmosphere. A modern conventional power plant with CCS could reduce CO_2 emissions by approximately 80–90% compared to a conventional plant without CCS [6]. The IPCC estimates that the economic potential of CCS could be between 10% and 55% of the total carbon mitigation effort until the year 2100 [8].

CCS technology involves three distinct operations: the capture of the emitted CO_2 from industrial power plants (e.g., fossil fuel power plants, cement factories, oil refineries, biomass energy facilities), followed by the compression and transport of the CO_2 by a pipeline to the storage site and, finally, its injection into deep geological formations, where the CO_2 will be safely contained for long periods of time (hundreds to thousands of years).

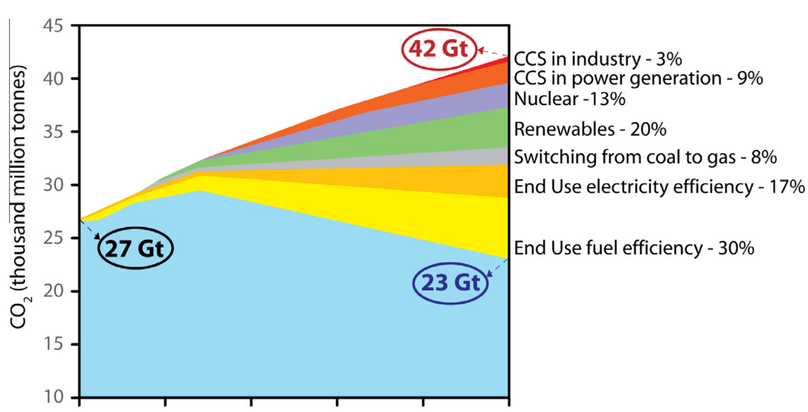

Fig. 1. Energy-related world CO_2 emissions, each wedge represents a strategy to reduce CO_2 emissions and the thickening of each reflects the estimated CO_2 reducing [4].