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Modelling the natural gas dynamics in the Southern Cone of Latin America

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HIGHLIGHTS

- We present an energy system model for natural gas in the Southern Cone region.
- We modelled a new approach for upstream gas extraction and processing.
- We use the TIMES_ConoSur gas & power optimization model from 2012 till 2030.
- We present an natural gas outlook in the Southern Cone for 6 regions.

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ABSTRACT

Natural gas plays an important role in the Southern cone energy system, and is expected to increase in primary supply in the future. This paper presents a new energy systems model for the Southern Cone region of Latin America, covering five regions (Argentina, Bolivia, South and Centre Chile, North Chile, and Brazil) with the aim to explore, up to 2030, the interplay between (i) the expected consumption of natural gas for electricity generation and end-use consumption (i.e. residential, commercial, transport and industry) in each country, (ii) the inter- and intra-country potential role as producer and consumer of natural gas, and (iii) the possible supply network of LNG and natural gas via pipeline and domestic production. It is found that, under a Constrained Investment Scenario, the gross domestic gas production of the Southern Cone from 2012 to 2030 could be 62 Tcf, whereas under an Unconstrained Scenario, it could rise to 75 Tcf. This highlights the economic potential of the unconventional gas resources of Argentina and projections of associated gas from the Campos and Santos basins in Brazil. However, accessing these resources poses financial challenges. Nonetheless, results clearly indicate significant potential for an increase in regional natural gas trade in the Southern Cone.

1. Introduction

Natural gas is a promising transition energy carrier between higher-carbon fossil energy and renewable energy resources due to its relatively low emissions of carbon dioxide and local air pollutants, comparatively low-capital cost utilisation technologies and abundant global reserves [1–3]. Typically, natural gas plays an important role supporting the balancing of power systems with higher penetration of renewables, as they are flexible and can react quickly to changes in renewable output or electricity demand [4]. Natural gas is also an important feedstock to produce other energy carriers such as hydrogen [5], electricity in power plants [6], biofuels [7] medium distillates [8] and even extra-heavy oils [9].

The future balance of natural gas in the Southern Cone (SC) – here defined as Argentina, Bolivia, South and Centre Chile, North Chile, and Brazil[1] – makes a timely study. On the supply side, three major new gas sources could alter energy system dynamics in the region: associated gas in Brazilian pre-salt fields (a major world petroleum frontier), unconventional gas (shale and tight) in Argentina, and imported liquefied natural gas (LNG). On the demand side, gas is becoming increasingly important to cope with the intermittency of variable electricity generation sources. This is particularly relevant

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[1] This simplification is due to the lack of available data for Uruguay and Paraguay and also to their relatively small amount of natural gas consumption.

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in Brazil where wind power generation is sharply increasing and new hydropower plants are mostly run-of-river [10].

Despite the important role that natural gas may play in the future Southern cone energy system, to date no models have been published that can adequately characterise the opportunities and challenges regarding natural gas in this region, including the competition with other energy vectors. While studies exist that characterise South America (or a coarse disaggregation thereof) as a region [11], and others that focus on single countries within or adjacent to the region [12–15], until now no spatially-resolved representation of the region has been produced. This paper provides this representation, enabling better characterisation of the pathways for gas infrastructure development. It also presents a novel way to characterise upstream resource extraction, which is an area that is often neglected in energy systems modelling.

Furthermore, the use of an integrated system analysis to clarify the role of natural gas in the region is of high relevance. As of today, natural gas plays an important but still limited role in integrating Argentina, Bolivia, Brazil and Chile, mostly through exports from Bolivia [15]. The potential for increasing this integration is large, as Argentina and Brazil develop their own production, and natural gas demand shows complementarities between the countries. In order to properly explore the potential role of gas in this region, the energy system of the Southern Cone is modelled herein, focusing on natural gas and its use in the electricity system, while representing the gas spatial infrastructure development pathways.

In order to convey these methodological novelties and region-specific insights, two core elements are presented in this paper: (i) a new TIMES model representing the natural gas system in the Southern Cone, from upstream to final use, and (ii) an outlook on the role of natural gas in the Southern Cone till 2030. The outlook was developed over two scenarios of available capacity investments, and brings insights on: the role of each region supplying and/or consuming natural gas for power generation and for end-uses, the international trade of natural gas, relevance of LNG, influence of unconventional gas in Argentina, and associated natural gas in Brazil.

The article is organised as follows: after this Introduction, a Background section presents previous relevant research focusing on systems modelling efforts that include some of the Southern Cone countries. This is followed by a description of the current situation with regards to natural gas in the region in order to provide a base year representation for the modelling, and to put the model development in context. Then the modelling methodology is presented in detail, segregated into downstream, midstream and upstream characterisations, followed by a description of the scenario analysis methodology. Finally, results are presented and discussed, leading to conclusions.

2. Background

Several global and regional studies have looked at the medium- and long-term role of natural gas within the energy system (i.e. from primary energy production, conversion into energy carriers such as electricity and end-use consumption). At global level, the ETP energy system model has been used to develop scenarios up to 2050 [16]. Also at the global energy system model ETSAP-TIAM was used to analyze how shale gas can impact on regional gas production, inter-regional trade, demand and price until 2050 [17].

The European Union (EU) research project REACCESS used the two energy system optimization models, TIAM (for the world) and PET – Pan European TIMES (for EU27+), to evaluate technical, economic and environmental features of existing and future energy corridors within Europe and between European countries and rest of the world. A detailed representation of the natural gas supply chain was modelled in PET, including re-gasification plants to take in account the liquefied natural gas imported by ships, seasonal exchanges within natural gas trade and a detailed import and trade matrix between EU countries and world supplying regions [18]. Other authors [19,20] used the PRIMES partial equilibrium energy system model to assess the decarbonisation of the EU energy system until 2050 concluding that the EU power sector can reduce its CO_2 emissions by 98% with respect to1990 levels by replacing coal and gas power plants with RES electricity and carbon capture and storage (CCS) gas plants. A more recent study [21] performed a multi model analysis (PRIMES, GEM-E3 and TIMES Pan EU) to explore the required EU wide energy system transformations to reduce Greenhouse Gas (GHG) emissions in 2050 to less 80% of 1990 levels.

At national level, the general equilibrium economic model EPPA was applied to study energy scenarios for natural gas exports from Russia [22]. Also, [22], through the use of PLEXOS model, evaluated future primary energy consumption in the Italian thermoelectric sector and the impact of different fuel and carbon price scenarios. A simulation model was used in [23] to assess investment decisions on natural gas trade in Colombia to increase short-term security of supply. A cost-benefit analysis was applied to evaluate Peru's liquefied natural gas export policy and found the policy's associated costs exceed the benefits [24].

Although some studies, as previously referred, exist for selected countries of the Southern Cone region (i.e. Brazil, Bolivia, Argentina, Chile, Uruguay and Paraguay), they do not undertake to an integrated analysis from the perspective of the energy system optimization, and do not consider the linkages among those countries. There are no public studies of natural gas integration for the Southern Cone region, although the Latin America Energy Organization (OLADE) has made some efforts to collect and represent data on natural gas international pipelines projects using a Geographical Information System (GIS). Studies using energy planning tools in the region have addressed only the electricity integration [25].

3. Natural gas in the Southern Cone

The Southern Cone region encompasses countries with highly varied energy landscapes, reflecting the different countries' economic structure and development, climatic conditions, population distribution and density, availability of primary energy resources, and the degree of coverage of transport and distribution system, to name but a few [26]. In this paper, the Southern Cone region corresponds to the group of countries: Argentina, Bolivia, Brazil, and Chile. The combined natural gas consumption represented 63% of the total natural gas consumption in South America in 2014[2] [27].

Natural gas has played an important role in diversifying the energy mix in the SC, with consistent market share increase since 2000 (except for Chile), as shown in Fig. 1. In the case of Argentina and Bolivia, natural gas is the main primary energy source. In the last 14 years, natural gas consumption in the Southern Cone increased 4.6% per year, mostly driven by the Brazilian market evolution that has increased consumption almost fourfold in that period [27,28]. There are significant differences in market size among the four SC countries, with Argentina and Brazil as major markets, consuming 1.848 TJ and 1.731 TJ respectively in 2014 [29,30], while Bolivia and Chile are substantially smaller consuming 133 TJ and 159 TJ, respectively in the same year [28,31]. Overall, the region relies greatly on gas and oil, but also on hydropower and biomass in the energy-mix.

[2] Other important consumers in the continent include Venezuela (20%) and Colombia (7%) [27].