A COMPREHENSIVE TAXONOMY OF NUCLEAR NON-ELECTRICAL MARKETS. APPLICATION TO THE MARKET PERSPECTIVES FOR FRANCE

Martin Leurent, I-tésé, CEA, Université Paris Saclay, 91191 Gif-sur-Yvette, Laboratoire Genie Industriel, CentraleSupélec, Université Paris-Saclay, Grande Voie des Vignes, 92290 Chatenay-Malabry, France, +33(0)1 69 08 80 48 martin.leurent@cea.fr
Camille Cany, I-tésé, CEA, Université Paris Saclay, 91191 Gif-sur-Yvette, Laboratoire Genie Industriel, CentraleSupélec, Université Paris-Saclay, Grande Voie des Vignes, 92290 Chatenay-Malabry, France, +33(0)1 69 08 39 57, camille.cany@cea.fr

Overview

The adoption of the universal Paris agreement to combat climate change, in December 2015, roots the global movement to switch to low-carbon economies. To be in line with decarbonisation targets, most energy mixes must undergo transformations with country-specific energy transition pathways. As a low carbon energy source, nuclear power could be part of the solution. Nuclear power plants (NPP) are usually solely dedicated to power generation although they could contribute to satisfy a wider range of energy services. Markets such as district heating, seawater desalination, industrial process heat applications or hydrogen production represent economic, environmental and strategic new potentials for nuclear operators.

The aim of this article is twofold. Firstly, thanks to a literature review, we propose a comprehensive taxonomy of non-electrical markets that may be targeted by NPPs worldwide, based on the extensive classification offered by the IAEA (2002). The objective is to provide stakeholders and policy makers with an accurate tool to identify relevant non-electrical markets for nuclear energy to help fulfil their goals. Secondly, the analysis focus on the French case and its transitional period from 2030 onwards. We address the opportunities and challenges for the deployment of nuclear towards new markets, focusing on the cogeneration of low-temperature heat and hydrogen.

In France, due to a long-standing policy based on energy security, the power system is characterised by a high nuclear penetration. It supplied 77% of the total production in 2014 (RTE, 2015). Even though this share is to be reduced to 50% from 2025 onwards (French Government, 2015), there is a potential for NPPs to help achieving the energy transition goals through non-electrical applications. On the one hand, nuclear cogeneration of low-temperature heat could help achieving the EU 2030 climate and energy goals (European Commission, 2012) and reduce the carbon footprint of the heat sector in France. Considering the technological improvements carried out these last years in heat piping insulation, it is now feasible to envisage heat transport over quite long distances, exceeding 100 kms, with affordable losses. District heating networks are expanding in France, thus increasing the size of the potential market for nuclear cogeneration. On the other hand, with the expected growth of hydrogen markets (OECD/IEA, 2015), producing it thanks to NPPs represents a twofold opportunity. First, it allows producing low-carbon hydrogen. Second, through hydrogen cogeneration, NPPs could contribute fostering the integration of intermittent renewable sources whose share is intended to reach 27% by 2020 and 40% by 2030 in accordance with the EU goals (European Commission, 2012 and French Government, 2015). Addressing the hydrogen market could be promising given its multiple outlets, as an energy carrier or a chemical product, and future specific position within the energy system (OECD/IEA, 2015). In such systems, the NPPs could provide additional flexibility to the power system through its power use: it would be operated as a baseload and, instead of reducing the plant load when requested by the power system, the outputs could be used to produce hydrogen or low temperature heat.

Methods

At first, we conduct a thorough literature review over the last 15 years to provide a situational analysis of the development of nuclear non-electrical markets worldwide. Thanks to a developed taxonomy based on IAEA (2002), we establish a ranking of potential markets to be targeted. Second, the ranking guides us to explore the new potential markets to be addressed by nuclear in France, for the short-term transitional period from 2030 onwards. After market potentials being sorted out, we decide to deepen the analysis on the most promising markets. These are low temperature heat and hydrogen. The potential for nuclear as a new player in these markets is estimated by comparing the forecast demand to the forecast supply in terms of volumes and target costs to be achieved. It allows assessing opportunities and challenges for these markets. Finally, policy recommendations are formulated.

Results

The worldwide review of current nuclear non-electrical markets allows us to construct a comprehensive taxonomy and rank markets from the reachable ones to the more prospective ones. The taxonomy considers the specific clients' needs, including the heat temperature range, the market development phase with the associated Technology Readiness Level and the expected environmental features. The economics of non-electric nuclear applications are strongly related to those of nuclear power production for generating electricity. Indeed, operating with a cogeneration mode signifies reducing the electricity output. This represents the cost of opportunity associated to the decision of producing the side-product.

Most of the French low temperature heat comes from burning gas, fuels or other hydrocarbons, and hardly from wood or renewable sources. Excess heat recovery from industry, geothermal heat pumps or cogeneration plants is still marginal (ANCRE, 2015). Thus, the use of low-carbon heat from nuclear cogeneration would have the immediate effect of diminishing the carbon emissions of the French industry. Alongside, the French industry needs for low-temperature heat constitute a significant and reachable market: about 20% of its low-temperature heat cumsumption could be provided by nuclear cogeneration, relevant sectors being the food-processing industry, chemistry and paper mill. For each specific site, an economic assessment of nuclear cogeneration of low-temperature heat is needed in order to determine whether this option is economically competitive compared to other alternative technologies. First results indicate that the profitability, i.e. when the net present value (NPV) proves to be positive, depends strongly on the relative price of the heat compared to electricity, the amount of heat sold and the distance between the NPP and the customer (Jasserand, 2015). The key criterion being the distance, results highlight the importance of thinking the geographical synery between district heat networks, nuclear cogeneration and alternative heat sources such as excess heat recovery from industries.

As regards hydrogen, the production consists in a captive and a merchant production. The 2016 world estimated demand is around 73 millions of tonnes, with 84% of it as a captive use. Refining activities and ammonia production are the biggest consumers with a contribution of around 90% of total demand (SBC Energy Institute, 2014). The new uses of hydrogen as an energy carrier for mobility and energy storage, comprising power-to-power, power-to-gas and power-to-fuel applications will boost the demand in the next 15 years. To meet the demand, almost all the production comes from fossils with 48% of it coming from natural gas. Thus, the development of electrolysis process coupled to NPPs, including the High-Temperature Steam Electrolysis process, will contribute reducing the carbon footprint of hydrogen (OECD/IEA, 2015). Moreover, in the transitional period, the increase of wind and solar will benefit from the introduction of a novel flexible power demand (i.e. the hydrogen production through electrolysis). Instead of reducing nuclear load factors which would decrease down to 40% for proactive renewable developments, we recommend that nuclear industry takes advantage from these changes to contribute to the hydrogen market. The current French nuclear annual available energy already offers a great potential. Indeed, it could already contribute to supply hydrogen for the equivalent of 15% of the current French fleet of passenger light-duty vehicles. The amount of available energy is expected to grow with the intermittent renewable share increase. The cost of hydrogen depends on the available annual electricity, the available hourly power profile, the cost of electricity and the utilization rate of electrolyzers. Results enhance the importance of the business model to produce economically competitive hydrogen.

Conclusions

This article establishes a comprehensive taxonomy of non-electrical markets for NPPs, based on the classification offered by the IAEA (2002). It has been used to weigh the pros and cons of applications for the French case, and thus allowed to identify the most promising markets for the short-term transitional period. Firstly, the potential for nuclear cogeneration to competitively provide low-temperature heat to industries and district heating networks is addressed through the identification of the relevant markets and the assessment of the NPV of a single project. Secondly, the potential for nuclear as a new player in the low-carbon hydrogen market is investigated. Non-electrical applications of NPPs could help achieving the political goals of the European Commission and the French Government in terms of energy efficiency and decarbonization. Future works will focus on developing a generic method to assess the economics of nuclear non-electrical applications, including the socio-technical stakes, such as regulation or social acceptance factors, that are also influencing the development of nuclear technologies. Such a method would be useful to stakeholders and policy makers for decision-making.

References

ANCRE, 2015. Cogénération nucléaire: Intérêts et potentiels d’une offre de chaleur basse température pour l’industrie française.

Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

French Government, 2015. LOI n° 2015-992 du 17 août 2015 relative à la transition énergétique pour la croissance verte, 2015-992.

IAEA, 2002. Market Potential for Non-electric Applications of Nuclear Energy (technical reports series No. 410)Vienna.

Jasserand, 2015. Initial Economic Appraisal of Nuclear District Heating in France. Proceeding Glob. Paper 5392.

OECD/IEA, 2015. Technology Roadmap. Hydrogen and Fuel Cells.

RTE, 2015. Le bilan prévisionnel de l’équilibre offre-demande d’électricité en France.

SBC Energy Institute, 2014. Hydrogen-based energy conversion. More than storage: system flexibility.