***CIRCULAR ECONOMY FOR THE ENERGY TRANSITION: WHAT TRANSFORMATION OF TERRITORIAL ENERGY SYSTEM?***

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## Overview

Circular economy (CE) is a decisive strategy to conciliate economic development and environment [1]. This resonates particularly with the development of future energy systems which have to evolve in order to secure the supply of energy in a world where resources are getting more and more scarce while reducing its impact over the environment and over climate [2]. Fostering the analysis of CE in all aspects of our society is primordial, first to understand the effects of its application and then to foster its implementation [3]. In France, CE was introduced in 2015 in its law with the objective to reduce wastage of resources and to close-the-loop [4]. In addition, energy policy was declined towards its territories with the objective of developing its local available resources[5]. In 2015, the legislation also gives the French regions the necessary competences to implement the energy transition of their own energy system [6]. Thereby, the SUD PACA region, has redefined its objectives concerning the decarbonization of its territory, targeting by 2050, a neutral carbon scenario and a transition to a CE. Thus, in order to analyze the impact that these policies might have, a TIMES-$SUD_{PACA}$ bottom-up optimization model was developed. The aim of this study is to understand the implications and impacts of the application of a CE perspective for the decarbonization of this energy system.

## Methods

The modelling of the Region SUD energy system is developed under the TIMES framework under the IEA's Energy Technology System Analysis Program (ETSAP). TIMES is a bottom-up model generator using a partial equilibrium under a linear optimization paradigm, with an objective to satisfy the exogenous demand of energy services at the lowest possible discounted cost for the development of the energy system in a time period and under constraints defined by the user. In order to better integrate specific characteristics of each of the territories of the SUD PACA region, the energy system is broken down into nine zones or sub-systems, which represent the Vaucluse, Alpes-de-Haute-Provence, Hautes-Alpes, Bouches-du-Rhône, Alpes-Maritimes and Var departments. The latter three have been separated into two zones: high-energy demand zones and low-energy demand zones. In this way the TIMES-$SUD_{PACA}$ model allows a rich detailed representation of each energy system of each zone of the region. This representation includes, for each zone: primary available energy resources; transformation, transportation and distribution processes with their respective technical-economic costs (including the electrical interconnection between the region and the rest of France); and end-use energy demands. The region can withdraw electricity and natural gas from the French networks. Demand is represented in five different sectors along with their respective associated energy services: transport, residential buildings, tertiary buildings, industry, and agriculture. Furthermore, the TIMES-SUD PACA model includes potential technologies that could be developed, and are specifically available according to the geographic location of each zone of the SUD PACA region. With respect to the circular economy, the principal technologies are methanation that use carbon dioxide from biomass reforming and from syngas and biogas purification with biogas to produce biomethane that can be injected into the gas network. It is also possible to give a second life to electric vehicles batteries for storing electricity from solar production, and the use of other waste products for the production of energy. With this detailed representation, it is also possible to show the flow of commodities through the different transforming processes to finally satisfy the energy demand depicting in this way the Reference Energy System (RES) of Region SUD. From the model the evolution of the structure of the energy system is discussed for each zone: the investment needed for this evolution; the operating cost of the developed technologies; the energy flows among the represented technologies; the energy consumed by type of commodity; and the related emissions. The time horizon is 2050 and the reference year 2017.

The analysis follows three scenarios: 1) *Reference-scenario* takes into consideration the developments stablished in the region; altogether with policies already implemented before 2017. It also contemplates the evolution of the energy system over the last years in order to project its possible evolution to 2050. The development of fossil fuels is constrained to have a maximum activity level as in 2017. Moreover, there are no further constraints for emissions; it does not promote any energy, and does not consider other efforts to reduce energy consumption that those who were already engaged. 2) *SRADDET-scenario* integrates the objectives proposed by the region in terms of renewable energy production. The development of the supply side is constrained according to the Planning, Sustainable Development and Territorial Equality Regional Scheme. 3) *CE-scenario* studies the development of the energy system promoting the recovery and reuse of resources in order to identify how the decarbonization of the energy system of the region can be achieved with a CE perspective.

## Results

Preliminary results show that, after 2040, in the *reference-scenario* fossil fuels are used mainly to produce electricity to cover some of the consumption at peak hours and during some periods of the night. Renewable electricity production comes mainly from solar energy, representing around 80% of the total local production in 2050. In the *SRADDET-scenario,* there is no use of fossil fuels for regional electricity production after 2030. Here biogas replaces the use of oil that was used in the *reference-scenario* to cover peak demand. Hence helping the development of clean non-intermittent energy solutions that accompany the production coming from technologies depending on climate conditions, seems key to help the decarbonization of the supply side. Moreover, the electricity coming from the French electric network has been reduced in 50% and only represents 15% of the total electricity consumed in the region. In the demand side, for the reference scenario, electricity consumption has increased in around 10% with respect to 2017. In general, the use of fossil fuels in the region has decreased in 12% by 2050, being the transport sector the responsible for most of this consumption representing 43% of energy demand. This shows that, it is imperative to push for the development of alternative energies that can be used to cover energy demand in the transport sector. For the habitat sector in the *SRADDET* scenario, the use of fossil fuels just represents around 15% of the total energy demand of the sector, which means a reduction of more than 50% with respect to 2017 and 35% with respect to the reference scenario in 2050. This fossil fuel use comes mainly from the use of natural gas for heating and water heating production. There has been an increase in use of heat coming from heat network, representing in 2050 7% of the total energy demand, (1% in 2017). This heat is issue mainly from the use of biogas. Hence, one interesting alternative to further decarbonate this sector seems to develop power-to-gas technologies to produce bio methane, that can be used to replace the use of natural gas, and develop a further use of local resources. The industry still consumes fossil fuels, but its use has decreased in 42% with respect to 2017. Some of the fossil fuels use has been replaced with blended gas, representing 23% of the energy demanded of this sector in 2050. The transport sector consumes mostly fossil fuels, electricity represents 9% of its energy demand and hydrogen 1%. This also reinforces the idea that developing an hydrogen market seems to be a strong alternative in order to help the further decarbonation of the energy system of the SUD PACA region. The *CE-scenario* (still under analysis) has the purpose of studying how the application of CE strategies can help the decarbonization of the energy system of the region. In particular, promoting the development of recovery solutions can push a deeper decarbonization compared to the *SRADDET-scenario* where heat coming from heat network showed already an important development that, in addition, can help to reduce final energy consumption due to increase efficiency of the system. Moreover, implementing policies to foster the development of bio gas that altogether with the use of $CO_2$ to produce bio methane seems to be an important alternative to have a deeper decarbonization of the region SUD's energy system.

## Conclusions

The energy transition of the region has some difficulties to overpass in order to reach first the objectives proposed in the *SRADDET* and then its reduction of carbon emissions in order to reach its complete decarbonization. Current trends of energy consumption show that energy demand might increase in 2050, and that renewable energy production might not fulfill the proposed objectives. The application of circular economy strategies can help to get some insight on how the decarbonization of energy system of the region SUD can be achieved while maximizing the use of resources. Specially the use of methanation technologies to use $CO_2$ altogether with biogas to produce biomethane can help to substitute the use of natural gas in the habitat sector.

## References


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