SOCIO-ECONOMIC IMPACT ASSESSMENT OF FUTURE CSP DEPLOYMENT IN SPAIN USING AN EXTENDED SOCIAL ACCOUNTING MATRIX

Natalia Caldés Gómez. CIEMAT. natalia.caldes@ciemat.es
Ángeles Cámara Sánchez. Universidad Rey Juan Carlos. angeles.camara@urjc.es
Mónica Flores García. Universidad de Zaragoza. monicafl@unizar.es
Patricia Fuentes Saguar. Universidad Pablo de Olavide. pfuesag@upo.es
Marta Santamaría Belda. CIEMAT. marta.santamaria@ciemat.es

Abstract:

CSP technologies are likely to play a very important role in Spain's future energy mix. In order to assess if the existing and future support policies are justified on the grounds of social welfare, it is necessary to conduct an integrated analysis of its associated impacts.

The work presented here contributes to this goal by assessing the socio-economic impacts associated to CSP investments requirements in accordance to the Spanish Renewable Energy Plan 2011-2020. For this purpose, a 2008 Spanish Social Accounting Matrix with six renewable energy accounts is extended, and a multisectorial model is used to analyse the effects on the Spanish economy as well as on employment creation. Our results show that, in addition to environmental benefits, CSP investments positively impact those productive sectors hardly hit by the crisis, such as construction, metal and industrial installations.

JEL Code: C67, Q42, Q48

Key Words: Concentrated Solar Power, Social Accounting Matrix, Multisectorial Models.

1. Introduction

During the next decades, solar energy is likely to be one of the most promising sources of clean energy. This fact is especially relevant for some countries like Spain, where solar radiation is high and solar electricity generation potential is remarkable. At present, there are several solar thermal power technologies (parabolic trough, central tower, parabolic dish and linear Fresnel) and despite the fact that their commercial stage has recently started, their future potential decline in costs and technological advances are striking, as it has been highlighted in the International Energy Agency CSP roadmap (IEA, 2010).

CSP electricity generation cost is far from being competitive in the current power market. However, no one doubt that compared to fossil fuel technologies, renewable energies technologies –and CSP is not the exception-, bring various benefits to society that policy makers must take into account. One way to internalize their positive externalities and make renewable energy technologies more competitive in the power market is to put in place renewables support policies (for example, subsidies). Given the current scarcity of public money, an integrated impact assessment of these renewable technologies is necessary to analyse whether the public budgetary resources spent in subsidising the cost of renewable technologies are justified in terms of social welfare, considering not only their environmental benefits but also their contribution to increasing GDP and employment, reduction in foreign dependency as well as other impacts such as grid stability.

In this context, the work presented here represents one step forward towards conducting a CSP integrated assessment since it looks at socio-economic impacts associated to the deployment of solar thermoelectrical technologies according to the recently published Spanish Renewable Energy Plan - PER, from the Spanish *Plan de Energías Renovables* - (2010-2020). From a policy maker point of view, finding out what is the impact that any given project or plan will have on employment as well as economic stimulation is very relevant and even more during the current financial crisis.

With regards to the socio-economic impact assessment, and as Kulisic *et al.* (2007) noted, most of renewable energy feasibility studies accounts, at the most, for direct effects, underestimating social gain in terms of income and job creation. In the present work, in order to account for such impacts, a Spanish Social Accounting Matrix for the year 2008[1], whit six renewable energy accounts -one of them specific to CSP-, has been created in order to construct a multisectorial model to analyze the effects that investments required to meet the CSP PER 2011-2020 objectives would cause on the Spanish economy as well as on the employment.

The paper is structured in the following way: after this brief introduction, in the next section, a general overview of CSP past, present and possible future deployment in Spain will be presented. The following sections, 3 and 4, will focus in the methodological details, and the scenario that will be analyzed in the CSP impact assessments. In the section 5, results from the socio-economic assessment are shown. Finally, the last section will present the overall conclusions derived from the two assessments as well as present further lines of research that arise from this work.

2. CSP past, current and future deployment in Spain

With more than 600 MW of installed capacity by 2010, Spain is considered worldwide as the CSP technologies deployment Mecca. Partly due to past and current favourable Spanish regulatory scheme as well as due to optimum climatic conditions, a remarkable promotion of the solar thermal industrial activity has taken place in Spain. As stated by the Royal Decree (RD 661/2007), a 0.27€/KWh fare[2] for the electricity generated by solar thermal technologies, added to the possibility to construct mixed plants with gas (between 12% to 15% to compensate for any heat losses during the process), has generated a great interest for solar concentration technologies among investors and the Spanish industrial sector. Since the construction of the first CSP plant in 2006, a rapid increase of projects has taken place. As a result of it, by the end of 2010 total installed capacity reached 632MW, most of them parabolic trough (95%) but also some central receiver plants. Moreover, the recently approved Spanish Renewable Energy Plan 2011-2020 considers a solar thermal installed capacity of 4.800

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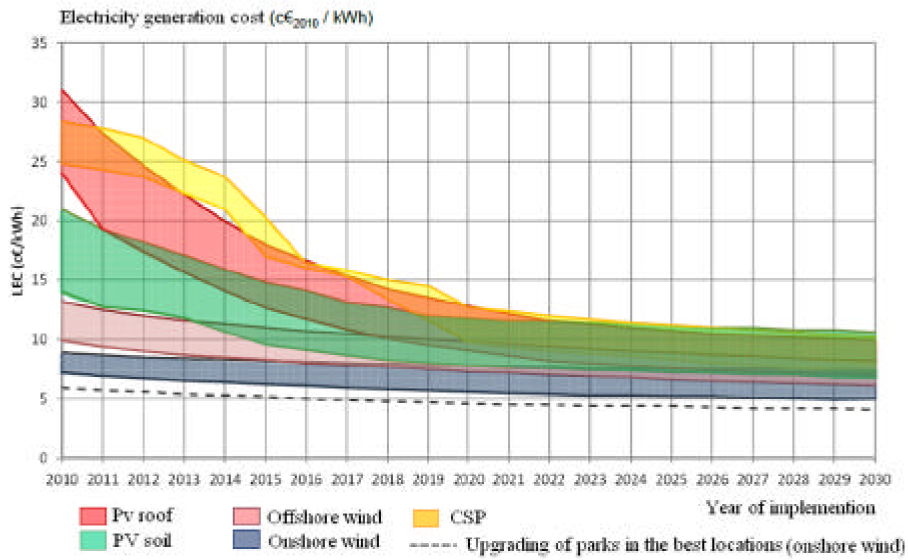
[1] Cámara et alia (2010).

[2] The RD 661/2007 established that solar thermal producers can choose between: [i] obtaining a fix fare of 0.27€/KWh for the energy or [ii] selling it in the electricity market, taking in the price paid for the energy in the market plus a 0.25 €/kWh premium - with a minimum turnover (considering the price of the market and adding the premium) guaranteed of 0.25 €/kWh and a maximum limit of 0.34 €/kWh.

MW by 2020. Its associated energy production amounts to 14.379GWh, which accounts for approximately 10% of the total RES (renewable energy sources) forecasted production by 2020.

As it is shown in figure 1, CSP electricity generation cost is higher than both fossil fuel technologies as well as renewable technologies.

Figure 1. Levelized electricity cost evolution of renewable technologies



Source: IDAE (2011)

Despite the foreseen reduction in costs in solar thermal production (A. T. Kerney, 2010; IDAE, 2011; IEA, 2010), and as for the most of renewable energy technologies, CSP is not yet cost competitive. However, compared to fossil fuel technologies, the various positive impacts on society's wellbeing associated to renewable energies, justify government intervention materialized in the various types of support policies in place.

Besides the common proven benefits associated to renewable energies – positive impacts on the environment and the economy, job creation as well as reduction in energy dependency- CSP technologies have additional ones that should be considered when designing support mechanisms. For example, CSP technologies (i) facilitate the operation of the power system when it is reinforced with storage and backed up with other fuels (as natural gas and biomass); (ii) its production pattern match the summer demand peaks; (iii) compared to other RES technologies, they retain a higher share of the total Value Added in Spain (as most components are manufactured nationally); and (iv) have placed Spain in a worldwide leadership position offering the possibility to become a potential exporter, of both technology and knowhow.

The following sections will then contribute to a CSP integrated analysis by evaluating, according to the PER 2011-2020, what is the foreseen CSP technology deployment impact on the Spanish Economy and, more particularly, in job creation.

3- Construction of a Social Accounting Matrix with CSP

The analytical framework used in this work is a multisectorial model based on a Social Accounting Matrix (hereafter SAM). A SAM is a database where all the goods and income transactions that are produced among the different agents -productive activities, productive factors, households, societies, public sector and foreign sector- in a given economy (national, regional or local) are registered for a specific period of time, usually a calendar year. Given that the SAM offers a description of the relationship between productive and institutional agents in the economy, it is a suitable instrument to study the functioning of the economy of a given area.

Table 1. Simplified structure of the SAM

	PRODUCTION	*PRIMARY FACTORS*	*RESIDENT SECTORS*	*CAPITAL ACCOUNT*	*FOREIGN SECTOR*
PRODUCTION	*Intermediate consumption*		*Private and public consumption*	*Gross capital investment*	*Exports*
PRIMARY FACTORS	*Gross value added*				*Wages and property income*
RESIDENT SECTOR	*Production taxes*	*Net resident income*	*Current and capital transfers*	*Taxes on capital*	*Current and capital transfers*
CAPITAL ACCOUNT		*Fixed capital consumption*	*Net resident financial capacity*		*Foreign savings*
FOREIGN SECTOR	*Imports*	*Wages and property income*	*Current and capital transfers*		

Source: Cardenete, Fuentes y Polo (2011).

Table 1 shows a SAM diagram with five blocks representing the five economy agents: productive activities, productive factors, resident sectors (households, companies and public sector), savings-investments and foreign sector. The SAM is a double-entry table where each row totals coincides with the totals of each column, because the resources obtained by each account, must coincide with their uses. The column totals are the total uses carried out by each account, and row totals reflects the source of the income of each account.

The SAM developed for this work is composed by 32 productive activities accounts; two Productive factors accounts (Labor and Capital factor); one account for Private Consumption, one for Savings-Investments; six accounts for Public Sector (that include direct, indirect, and payroll taxes), and one for Foreign Sector. As a result, the SAM diagram has 43 rows and 43 columns.

Table 2. Accounts of the SAM

Productive Activities	1- 32. Sectors
Primary Factors	33. Labour 34. Capital
Private Sector	35. Consumption
Saving/Investment	36. Gross Capital Formation (GCF)
Government	37. Employers' social security contributions 38. Net product taxes 39. Net production taxes 40. Employees' social security contributions 41. Direct Taxes 42. Public Sector
	43. Imports/Exports

Source: Own elaboration

The SAM can be divided into four submatrices, which are shown in Table 3. The *Intermediate Consumption submatrix* is composed of the rows and columns of productive sectors (32x32). It contains all the intersectorial relations, that is, each sector's expenditure on and income from intermediate consumption in other sectors.

Table 3. Structure of the SAM

	Productive Activities	Primary Factors	Private Sector	Saving/Investment	Government	Foreign Sector
Productive Activities	Intermediate Consumption	Final Demand				
Primary Factors	Primary Factors	Closure Sub-matrix				
Private Sector						
Saving/Investment						
Government						
Foreign Sector						

Source: Own elaboration.

The *Primary Factors submatrix* sets out payments to factors used by each productive activity. All the cells are zero except for the ones containing factors income, net product and production taxes, as well as imports.

The *Final Demand submatrix* provides information about the final uses of goods and services. The accounts in this submatrix are Consumption, reflecting household and other private consumption; Investment, composed of gross fixed capital formation and variations in stock; Public Sector, which includes public consumption (composed of the collective consumption expenditure and individual consumption expenditure of the public administrations, and non-profit institutions serving households) and, finally, Exports.

The *Closure submatrix*, that “closes” the circular flow of income by the interactions between factors matrix and final demand, and it is also the matrix hardest to build. Households receive their revenue from labour, from gross operating profit and from transfers, and Government receives its revenue from the different taxes and social contributions. This submatrix also contains Private, Public and Foreign Saving.

In order to assess the socio-economic impacts of CSP investments, the SAMER-08 has been extended as statistical support for the model. It contain 32 branches of activity, six of which relate to renewable energy (wind; hydropower; solar photovoltaic/thermal; solar thermoelectric; biomass/MSW/geothermal/biogas and biofuels). Compared to previous studies that have used SAM models, this work represents an added valued because of the decomposition of the energy production account into other technology specific accounts. Consequently, the SAMER-08 used in this work is an analytical tool that allows to model different energy policy scenarios.

The breakdown of the energy sector accounts is based on different types of data and it has been performed in two steps using information from different official sources: Secretary of State for Energy (SEE, 2009); Red Eléctrica de España (REE, 2009) and Institute for Energy Diversification and Saving of Energy (IDAE, 2011). To do this and complete the new rows, the first step has consisted on getting the consumption of energy from renewable sources distinguishing between primary (mainly for electricity generation) and final energy. Secondly, the new columns which reflect the expenditure structure of the new renewable technology sectors have been built using the investment as well as operation and maintenance cost data provided in the PER 2011-2020. Thus, once the new rows and columns are constructed, the matrix is completed. A more detailed description of the SAMER's construction can be found at Cámara *et al* (2010).

4- SAM Methodology

In Spain, there are various studies that attempt at assessing the socio-economic impact of CSP deployment using different methodologies and approaches (Izquierdo *et al*, 2010; Caldés *et al*., 2009; Deloitte, 2011; Cansino *et al*, 2011). The present work extends the current body of literature by using an "extended[3] SAM" model to estimate the impact in the Spanish economy associated to further investments in CSP plants in accordance with the PER 2011-2020. As previously mentioned, the SAMER-08 has been specially designed to analyse renewable energy policies, and more specifically, those policies that affect CSP technology deployment.

SAM models are linear models which use the information from a SAM to specify the multipliers of the model. Such multipliers are technical coefficients which can be interpreted as unitary requirements by produced unit, similar to the ones in the Input-

[3] It is called an "Extended SAM" because the original energy sector (as depicted in the official I-O tables) has been disaggregated into several energy technology sectors.

Output (IO) Model. Among others, the first applications of Social Accounting Matrices are found in Stone (1962) and in Pyatt and Round (1979), being first applied in the Spanish context by Kehoe *et al*. (1988). Pyatt and Round (1979) were the first to propose the fix-price multiplier set up that has been extensively employed since then.

Starting from the basic equation of linear models in an economy,

$$Y = AY + X \qquad (1)$$

Where A is the coefficients matrix -being its components a_{ij} the average expenditure coefficients that show the payments to account *i* per income unit of *j*- Y is a column vector of endogenous accounts and X a column vector of exogenous accounts. Solving this equation for X , the revenue of the endogenous accounts (which depend on the income of exogenous accounts) is obtained as follows:

$$Y = (I - A)^{-1} X = MX \qquad (2)$$

Where M is the Accounting Multiplier Matrix (equivalent to the Leontief inverse in the input-output framework) whose components m_{ij} gather the -direct and indirect- impact on the income of the endogenous account *i* because of an exogenous unit shock of income in endogenous account *j*.

5. Socio-economic impact of CSP investment under PER 2011-2020

5.1 Description of the analyzed scenario

In order to conduct the socio-economic impact assessment, the scenario analyzed is the one presented in PER 2011-2020. Table 4 shows the figures of CSP forecasted capacity installation along the period.

Table 4. Forecasted CSP capacity installation in PER 2011-2020

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Central receiver	17									
Parabolic trough	699	649	372							
Fresnel	30									
Disco		1	70							
New capacity installed (MW)	**746**	**650**	**442**	**250**	**280**	**300**	**300**	**350**	**400**	**449**
Cumulative capacity	1,378	2,028	2,471	2,721	3,001	3,301	3,601	3,951	4,351	4,800

Source: PER 2011-2020.

Note: From 2010 to 2014 there is a National Registry of PreAssignment (NRPA) –prerequisite for investors who want to benefit from the FIT system. According to NRPA data, 94% of total installed capacity by 2013 will be met with parabolic trough plants.

The main reference data that will be used to construct the analyzed scenario are the estimated future CSP energy capacity. Taking into consideration the existing capacity in 2008 as well as investment profile and production of a typical plant, the required new investment flows will be estimated and modelled.

Given the current and expected prevalence of parabolic trough plants, it has been assumed that all the foreseen capacity will be met with parabolic trough plants (in future revisions of this work such assumption will be modified to include other CSP technologies). According to PER data, out of the total installed capacity in 2013, 60% of the plants will have storage and 40% not. Due to the advantages associated to storage systems, it is assumed that from 2014 onwards, all new CSP plants will have storage systems. Another relevant assumption that will be revised in future versions of this work is that 100% of components and services required for CSP plants will be produced nationally.

In order to conduct the analysis, two reference plants with parabolic trough collectors have been considered. One of them has seven hours storage system, and other one, has no storage system. Following the current regulatory framework, 15% of total output is generated by natural gas. Cost data has been taken from IDAE (2011).

5.2. Application and results

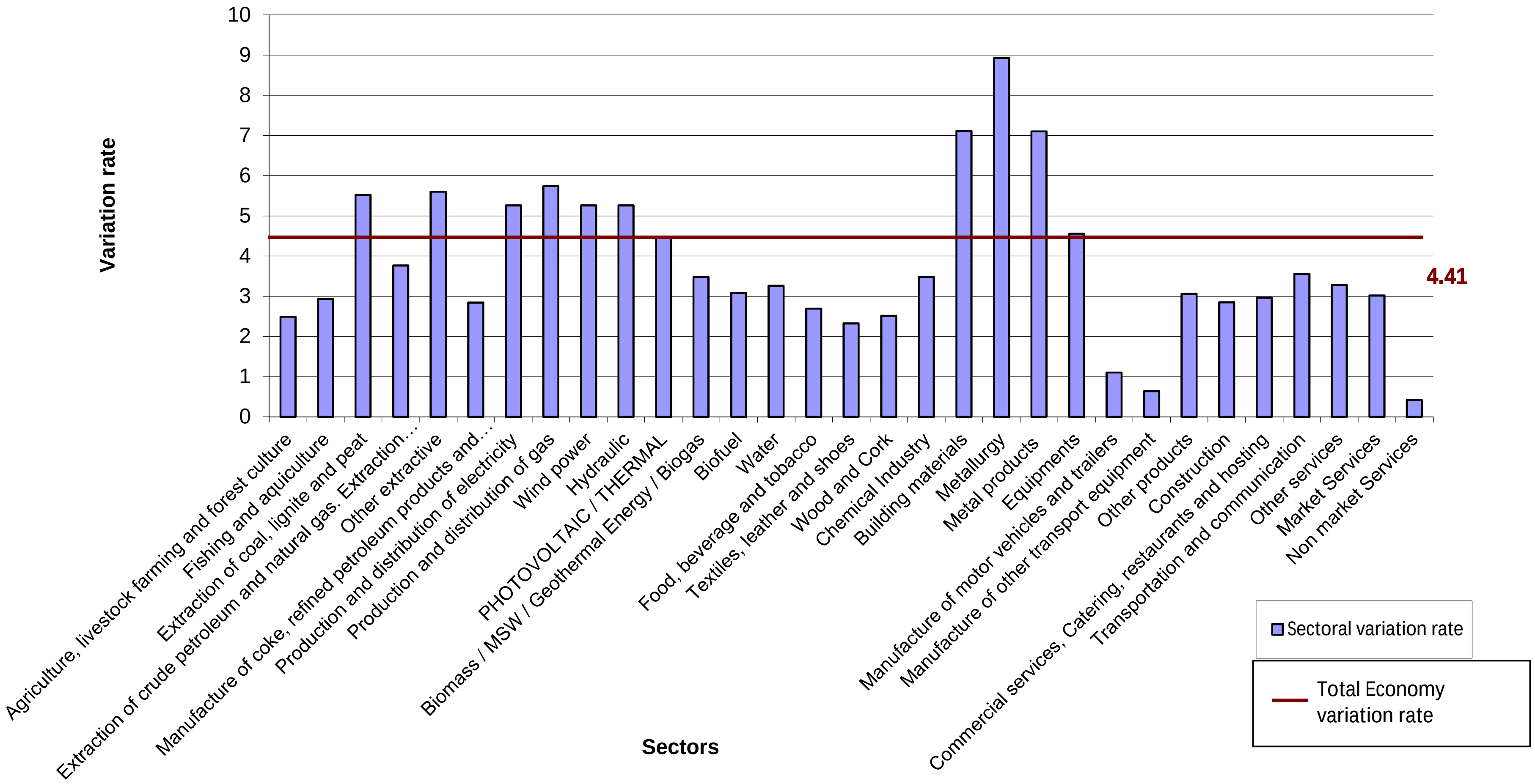
As previously said, the aim of this work is to enlarge the existing knowledge of CSP socio-economic impacts by using an expanded SAM model –based on the extended SAMER 08– to analyze the impacts on the economy (output and employment) that would be derived from the accomplishment of the PER 2011-2020 investment plans for CSP. In order to estimate such impact, a single investment shock in 2008 -which amounts the average annual investment on CSP plants along the period 2011-2020- will be simulated.

This exercise involves accepting the hypothesis that such investment will not alter the productive structure of the Spanish economy during the analyzed period. This is an important assumption and affects the robustness of the results since, despite the productive structure does not necessarily change from year to year, technical coefficients should be revised and modified at least after shorter periods than ten years. However, for the purpose of this study, this hypothesis seems adequate enough to approach the overall effect of such investment.

In order to estimate the impact on production (output), the simulation is performed considering three exogenous accounts: Investment (GCF) is considered exogenous since it is the injection to be evaluated. Similarly, Public Sector and External Sector are considered exogenous because of their special features (that is decisions determined by political criteria or outside of the economic system). Since present work is using a SAM model, the endogenous accounts are branches of production, Private Consumption, Labour and Capital.

Figure 2 shows that the effects that the investment shock would have on the different economic sectors´ output so that the percentage increase in output for each sector is presented in each column. It can be observed that the total impact on the productive economy (shown by the red line) is growing at 0.36%, being the most affected branches within the industry sector: Extractives, Energy, and Building Materials, Metallurgy, Metal products and Machinery. For all these branches, their output growth rate is above the average increase of the economy. One possible explanation is the productive structure of this sector that spends a large percentage of its expenses in the above mentioned branches of industry and energy sector (mainly gas and electricity). In turn, these branches have a heavy reliance on extractive industries so that an impact is observed in the latter sectors. Finally, it is worth mentioning the low impact generated on service industries. That is because, although some spending is done in these branches, is a very small percentage of the total. Considering that the inversion on CSP is going to take place along all the period, it could be said that in cumulative terms the impact on output due to increased capacity in CSP forecasted by PER will be 4,41%.

Figure 2. Increase in total and sectoral output generated by planned investment in Thermal Power for the period 2010-2020. (Rate of change)



Source: Own elaboration

Regarding the impact on employment, it has been assumed that the branches are only endogenous production sectors, and therefore it has been possible to work with a Leontief Model. Figures related to the impact on employment are collected in Table 5.

As a consequence of the CSP annual investment shock over the period 2008-2020, the total annual increase in employment would be 48.169 jobs. This figure includes direct employment (26.568 jobs, as indicated in CSP row) and indirect employment (in the rest of the economy, 21.602). The ratio of direct-indirect employment is approximately 1:1, which is similar to other renewable technologies. A significant portion of this growth is due to the construction phase. Unlike for the output impact assessment, different branches of services experienced an important increase in employment. Similarly, and as expected, other branches with a relevant employment growth are Metallurgy; Building materials; Metal products and Other extractive activities. The impact on employment has been estimated taken into account the average annual investment along the period 2011-2020. Considering the whole period, it could be said that in cumulative terms the impact on employment due to CSP increased capacity forecasted by PER will be 529,870 employees of one year of duration.

Table 5. Total employment impact (direct & indirect) of investment in CSP according to the PER 2011-2020

	Employment created due to CSP anual average investment	Employment due to CSP / Total employ in the sector [%]
Agriculture, livestock farming and forest culture	249	0,03%
Fishing and aquiculture	3	0,01%
Extraction of coal, lignite and peat	44	0,35%
Extraction of crude petroleum and natural gas. Extraction of uranium and thorium	2	0,19%
Other extractive	194	0,46%
Manufacture of coke, refined petroleum products and nuclear fuel	15	0,11%
Production and distribution of electricity (from conventional sources)	135	0,31%

Production and distribution of gas	33	0,35%
Wind power	1	0,31%
Hydraulic	0	0,31%
Photovoltaic / Thermal	0	0,20%
Solar CSP	26.568	99,97%
Biomass / MSW / Geothermal Energy / Biogas	0	0,13%
Biofuel	0	0,14%
Water	29	0,07%
Food, beverage and tobacco	46	0,01%
Textiles, leather and shoes	58	0,03%
Wood and Cork	392	0,12%
Chemical Industry	637	0,23%
Building materials	1.262	0,60%
Metallurgy	855	0,75%
Metal products	1.990	0,57%
Equipments	1.326	0,35%
Manufacture of motor vehicles and trailers	19	0,01%
Manufacture of other transport equipment	15	0,02%
Other products	349	0,16%
Construction	5.346	0,22%
Commercial services, Catering, restaurants and hosting	1.388	0,03%
Transportation and communication	1.728	0,16%
Other services	3.314	0,15%
Services for sale	993	0,05%
Services not intended for sale	1.178	0,03%
TOTAL EMPLOYMENT	**48.169**	**0,25%**

Source: Own elaboration

6. Conclusions

Despite their higher electricity generation costs, Concentrating Solar Power (CSP) technologies may play a very relevant role in the energy mix of Solar resource abundant countries like Spain. Compared to fossil fuel technologies and other renewable energy technologies, they bring various benefits to society that policy makers must taken into account when designing price support policies.

In this context, the work presented here has attempted to shed some light to this debate by estimating what are the socio-economic implications associated to future CSP investments in Spain as foreseen by the PER 2011-2020. To do so, a new Social Accounting Matrix (SAM) named SAMER-2008 has been built for this purpose. The main added value of this new analytical tool is that the energy sector has been disaggregated into 6 new renewable energy technology sectors, including CSP allowing to perform this analytical exercise as well as other policy scenarios simulations.

Our results show that, given the estimated investment requirements associated to a 4368 MW CSP increased capacity foreseen by the PER 2011-2020, the resulting average annual increase in the demand of goods and services would be 0,35% and the average annual increase in employment would be 48169 jobs (of one year of duration). During the whole period, in accumulative terms, compared to the 2008 situation, there would be an output growth of 4,41 % and an increase in employment of 529.870 new jobs of one year of duration. Similarly, one further positive result from the analysis, is that the sectors most affected by the CSP investments are some of the ones most hit by the crisis such as construction, building materials, etc.

In conclusion, results show that CSP investments in Spain have a positive and relevant socio-economic impact for both the National Economy and for employment creation in sectors that in the current economic crisis deserve special attention.

However, for a more complete integrated assessment, it would be required to include in the analysis other type of impacts (such as the environmental, energy dependence, cost of support policies, value of storage, etc) to be able to assess weather or not the cost of the current and future CSP support policies are justified on the grounds of social wellbeing.

Finally, from the work presented here there major lines of future research have been identified by the authors: (i) update and improvement of the data supporting the SAMER08, (ii) re-evaluation of the hypothesis supporting the model (such as the temporal patterns of investment of the plants, CSP cost variations, energy demand fluctuations, etc) and, finally, (iii) use new analytical models such a structural decomposition and, ultimately, a computable general equilibrium model.

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