DEEP
DECARBONIZATION
PATHWAYS

DEEP DECARBONIZATION PATHWAYS IN EMERGING COUNTRIES

Estimating net job creation in long-term decarbonization scenarios for Brazil through employment factors

BRAZIL

Carolina Grottera, Giovanna Ferrazzo Naspolini, Vinicius Lima Dias

NOVEMBER 2021

Universidade Federal Fluminense

CENTRO CLIMA
CENTER FOR INTEGRATED STUDIES ON CLIMATE CHANGE AND THE ENVIRONMENT - COPPE / UFRJ

IDDRI

Citation

Carolina Grottera, Giovanna Ferrazzo Naspolini, Vinicius Lima Dias (2021). *Deep decarbonization pathways in emerging countries*, *estimating net job creation in long-term decarbonization scenarios for Brazil through employment factors*. Deep Decarbonization Pathways (DDP) Initiative-IDDRI. Paris.

The report is available online:
https://ddpinitiative.org/wp-content/pdf/DDP_BIICS_jobs_BRA.pdf

Contact

Henri Waisman, henri.waisman@iddri.org
Carolina Grottera, carolinagrottera@id.uff.br

Financial support from

The report "Estimating net job creation in long-term decarbonization scenarios for Brazil through employment factors" is financially supported by the International Climate Initiative (IKI) of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) as part of the "Climate Action After Paris" project (nr. 18_I_326).

Editing: Marta Torres Gunfaus, Anna Pérez Català, Henri Waisman.
Layout: Ivan Pharabod.

DEEP DECARBONIZATION PATHWAYS IN EMERGING COUNTRIES

Estimating net job creation in long-term decarbonization scenarios for brazil through employment factors

Carolina Grottera (coordinator)
Assistant Professor (Economics Department, Federal Fluminense University - UFF)
carolinagrottera@id.uff.br

Giovanna Ferrazzo Naspolini
PhD candidate (Energy Planning Department, Federal University of Rio de Janeiro – UFRJ)
gnaspolini@ppe.ufrj.br

Vinicius Lima Dias
Research assistant (Economics Department, Federal Fluminense University - UFF)
viniciusdias@id.uff.br

Overview and objectives 3

Methodology 5

Data bases 5

Calibration to IMACLIM-BR and DDP-BIICS dashboard 7

Detailment of key sectors 9

Employment factors in the base year 9

Results 11

Aggregate results 11

Sectoral results, future trends and policy recommendations 12

Next steps 20

References 21

Appendix 22

BRAZIL

Overview and objectives

The Deep Decarbonization Pathways (DDP) initiative is a collaboration of leading research teams, aiming to help governments and non-state actors make choices that put economies and societies on track to reach a carbon neutral world by the second half of the century.

The DDP-BIICS project aims to have a far-reaching transformative impact. In Brazil, it will contribute to the formulation of new, more ambitious climate policies and measures, in order to significantly impact the GHG emissions curve up to the middle of the century, exploring the following policy questions:

I. What are the possible pathways that Brazil can take in harnessing climate action while meeting economic and social development objectives? What is the degree of ambition beyond current NDC levels that fosters radical transformation towards net-zero emissions in the second half of 21st century in Brazil?

II. Which specific measures are needed in order to set this pathway, namely short to medium-term ones, and the enabling conditions for their implementation? What are the links between these measures and other development objectives?

III. What are the economy-wide implications of these specific measures? Can we expect unwanted outcomes on specific sectors or agents? If so, how can transition policies contribute to attenuate them?

IV. What are the optimal strategies to mobilize key stakeholders, even in a context of moderate or low political will? How can we accelerate climate action through capacity building in order to mainstream mitigation and climate resilience into development strategies?

V. How can we enhance planning capabilities and policy instruments in order to support such ambition level? What are the barriers, financing needs and viability of proposed actions, and how international cooperation can make a difference?

As noted in point (iii) above, one of the key objectives of the DDP-BIICS project is to shed light on the economy-wide implications of the transition to a low carbon economy. Socioeconomic impacts of the energy transition occur as a by-product of investment in new infrastructure or new activities. The so-called economic multiplier effect means the extent to which increased investment propels economic activity increasing GDP or jobs, for example, more, or less, than investment itself.

An emblematic case refers to the transition to renewable energy sources, which notedly tend to require higher upfront investment than fossil-fuelled thermal power plants, subsequently offset by lower O&M costs, leading to decreased lifetime overall costs (ECLAC/CGEE, 2020). The deployment of renewables will therefore reveal to mean a higher increased capital investment with potentially more production and jobs along their supply chain (SAGET; VOGT-SCHILB; LUU, 2020) than an economy reliant on traditional energy technologies investment. Positive impacts relate to jobs, income and GDP created by increased economic activity as a consequence of investment. Negative impacts relate to socioeconomic losses (GDP, jobs etc.) in polluting sectors, such as coal mines and thermal plants that would have a relatively less relevant role in low-carbon or zero-carbon world. Gross impacts, in this context, are the effects created by the chosen set of technologies for infrastructure expansion, whereas the net impacts consider also the net gains and losses, which can be analysed by building and simulating hypothetical scenarios in which such effects can be captured and quantified.

Nonetheless, the economy-wide models typically applied to undertake this kind of analysis often overlook such net impacts. This occurs because computable general equilibrium models (CGE) operate at the sectoral aggregation level, with little emphasis on the technology level. This hinders a more detailed analysis able to consider the employment intensity of different activities within a given sector.

This study will contribute to a more detailed analysis of the net employment creation in the long-term scenarios developed for the Brazilian economy under the scope of the DDP-BIICS project. It will build on the use of bottom-up, sectoral models with technological detail coupled with the CGE model, as explained below.

Since 2010, CentroClima has developed a series of models to better address the need to provide reliable insights and analysis on long term mitigation policy scenarios. Those models can be separated in two categories: Bottom-Up (BU), or sectorial models, and Top-down (TD), or macroeconomic models. In the BU category we can cite energy optimizing models (as Message and Matriz, which are Markal-type models), and simulation models (developed in ad-hoc excel sheets or LEAP).

Current bottom-up models comprise Matriz, an energy supply optimizing model developed by CEPEL (Electrical Energy Research Centre); Transport-Energy-Emissions Multi-Tier Analysis (TEMA) model for freight and passenger transportation; and ad-hoc spread sheets for industry, waste and the agriculture, forestry and land use (AFOLU) sector. They are integrated through a core model, the computable general equilibrium model (CGE) Imaclim-BR (described in LE TREUT (2020)).

This study will use the outputs of each BU model and/or the DDP-BIICS country sheets (dashboards) to estimate employment factors at the technology level, and subsequently incorporate them in the Imaclim-BR model at the sectoral level.

Methodology

DATA BASES

This study used data from two national databases to reconcile the National Accounts system and official employment statistics in Brazil. PNAD-C[1] is the Continuous National Household Sample Survey, a sampling survey carried out quarterly by the Brazilian Institute of Geography and Statistics (IBGE[2]) that synthesizes primary socioeconomic data regarding Brazilian households at the national level. It provides information for household members regarding employment in all its forms (e.g., formal and informal contracts, self-employed workers, entrepreneurs, domestic workers, etc.). RAIS[3] is the Annual List of Social Information, a national-level database convening information companies and entities provide regarding their employees under formal contracts. Every entity is legally obligated to fill the RAIS declaration and submit it to the Ministry of Economy once a year. Unlike PNAD-C, RAIS is not a sample survey but an observational one. Hence, it is considered the best source for information related to formal jobs in Brazil.

CNAE[4] is the National Categorization of Economic Activities, a list of codes and their corresponding denominations following international standards, the official classification of economic activities used by IBGE. The CNAE code was used to categorize workers activities in the RAIS database. The PNAD-C survey applies the CNAE *Domiciliar,* a reduced version of the original CNAE. The following paragraphs describe the data treatment process and the main variables extracted from each database.

Microdata from PNAD-C and RAIS was extracted for the first quarter from 2012 to 2019 using the programming language R and the software RStudio. The choice of the periods for both extractions is due to the need of reconciling with both the DDP-BIICS Dashboard (which considers 2019 as default) and the IMACLIM-BR model base year calibration (2015). Further details are provided in section 2.2. Historical data will also be used to develop some key assumptions to support scenario projections (more details in section 4).

The variables from PNAD-C used for the extractions and groupings were:

I. Position and job category (of the main job): indicates the type of employment relationship, categorised in 10 different types, as detailed in **Table 1** (VD4009);
II. CNAE *Domiciliar* code, indicating the economic sector or activity to which the worker belongs (V4013)
III. Household sample weight (V1028);
IV. Average monthly wage (VD4016)

1 Portuguese acronym for *Pesquisa Nacional por Amostra de Domicílios Contínua*
2 Portuguese acronym for *Instituto Brasileiro de Geografia e Estatística*
3 Portuguese acronym for *Relação Anual de Informações Sociais.* In this study, we consider the CNAE 2.0, the most recent version of CNAE.
4 Portuguese acronym for *Classificação Nacional de Atividades Econômicas*

The data was then grouped by job category and CNAE *Domiciliar* code to allow reconciling with the National Accounts Systems used in the model calibration (more details in section 2.2)[5].

The variables from RAIS used for the extractions and groupings were:

I. CNAE code, indicating the economic sector or activity to which the worker belongs (cnae_2)
II. Average monthly wage (valor_remun_media_nominal)

Informing the RAIS is mandatory - all legal entities with employees must report information concerning their workers on an annual basis. Since each registry of the RAIS represents a single occupation, there is no need to apply sampling weights to obtain the survey universe. Therefore, the data was directly grouped by job category and CNAE Domiciliar code to allow reconciling with the National Accounts Systems used in the model calibration.

The totals from RAIS and PNAD-C under the two categories they intersect are similar and match tabulations from SIDRA/IBGE[6] and CAGED[7], which makes both the data extracted from PNAD-C and RAIS consistent and reliable.

As PNAD-C carries out information for the whole Brazilian population and reports all types of employment (both formal and informal labour), it was chosen as the main source to extract the required data. We are interested in all jobs in the Brazilian economy, and there are some key sectors for our analysis in which informal labour prevails, for example, agriculture and cattle ranching. **Table 1** summarises each of the aforementioned databases' types of data based on the job category as considered in PNAD-C.

However, as mentioned before, the RAIS survey considers the original CNAE classification, which is more comprehensive than the CNAE *Domiciliar* taxonomy. Therefore, data from RAIS was used to complement and validate information gathered from PNAD-C. Further details are provided in section 2.2.

5 *Workers with undefined or poorly defined occupations would have their CNAE code returning "0000" (they account for a negligible share of observations). Since PNAD-C covers all the population, there is also data for people out of the workforce, which includes not only the unemployed population but also elderly, retired, and children. These would have their CNAE code, employment relationship and salary variables returning as "NA" and were not accounted for in the data treatment.*

6 *Sistema IBGE de Recuperação Automática.*
7 *Cadastro Geral de Empregados e Desempregados (CAGED).*

Table 1 - Job categories considered in PNAD-C and RAIS surveys

Employment Relationship	Type	PNAD-C	RAIS
Private sector formally contracted worker	Formal	✓	✓
Private sector worker without a formal contract	Informal	✓	
Domestic worker formally contracted (housekeeper)	Formal	✓	
Domestic worker without a formal contract (housekeeper)	Informal	✓	
Government formally contracted worker	Formal	✓	✓
Government worker without a formal contract	Informal	✓	
Military and Public servants	Formal	✓	
Employer	Formal	✓	
Self-employed	Informal	✓	
Auxiliary family workers	Informal	✓	

Source: the authors based on PNAD-C and RAIS

CALIBRATION TO IMACLIM-BR AND DDP-BIICS DASHBOARD

The IMACLIM-BR 2015 model calibration relies on an Input-Output Table (IOT). It comprises product-by-product dimensions and was estimated under the industry technology assumption (i.e., each industry has its specific way of production, irrespective of its product mix) to be more specific in determining the GHG emission factors of economic sectors.

The IMACLIM-BR calibration procedure relies on economic, energy, and prices databases, called "hybridisation". The objective is to reconcile economic activities and their physical flows in the energy sector, articulating macroeconomic constraints with engineering representations of the energy system. **Table 2** presents the IMACLIM-BR 2015 aggregation, illustrating its 40 economic sectors.

A series of manipulations of the IOT original data allows a better representation of energy flows, incorporating data from the energy balance into the economic system in IMACLIM-BR sectors. The Supply and Use tables required for such manipulations come from the National Accounts System (SCN, in the Portuguese acronym), published by the IBGE. The National Classification of Economic Activities (CNAE) categorises all economic activities and products in the SCN.

The CNAE code is the link between PNAD-C and RAIS databases and the IMACLIM-BR sectoral aggregation. IBGE provides dictionaries to bring into consonance the PNAD-C/CNAE *Domiciliar* and RAIS/CNAE databases. Harmonizing PNAD-C and RAIS economic activities with those from IMACLIM-BR is the first step of the calibration. Since RAIS considers the CNAE 2.0, it presents an excellent match with the SCN, while PNAD-C relies on a more aggregated level (CNAE *Domiciliar*).

However, none of them counts on disaggregated data for oil refining products as considered in the IMACLIM-BR sectors (gasoline, diesel and other refining products).

The ratio of products from refining production in the Supply table are applied as shares to estimate the jobs and average wage on PNAC-D database, allowing to handle such incompatibility. The allocation of gasoline, diesel, and other fossil fuels are inherent to the energy sector. However, in IMACLIM-BR, naphtha is comprised in the Chemical industry, together with a share of the total ethanol consumption (non-energetic use).

In IMACLIM-BR hybridisation, a similar rationale is behind the construction of the Natural Gas sector by disaggregating the Oil & Gas sector in the IOT.

Table 2- IMACLIM-BR 2015 sectoral aggregation

ENERGY	AFOLU	INDUSTRY	TRANSPORT	SERVICES
Coal	Planted Forest	Cement	Freight: Road	Water, sewage, and drainage
Crude Oil	Sugar Cane	Iron and Steel	Freight: Rail	Education
Natural Gas	Soy	Mining and Palletisation	Freight: Air	Health
Refining (Other Fossil Fuels)	Rest of Agriculture	Non-Ferrous and other Metals	Freight: Water	Composite - Other Services
Other Biofuels	Cattle	Chemical	Passenger: Road	
Diesel	Rest of Livestock	Bovine meat	Passenger: Rail	
Biodiesel		Rest of Food and Beverages	Passenger: Air	
Gasoline		Textiles	Passenger: Water	
Ethanol		Pulp and Paper		
Electricity		Ceramics		
		Construction		
		Other Industry		

Source: Grottera et al. (2021)

The same applies to Other Biofuels, which correspond to a share of charcoal production from the Forestry activity. **Table 3** shows how these rationalisations are applied to PNAD-C statistics to harmonise it with IMACLIM-BR calibration requirements.

Regarding Biofuels production, Forest restoration and Transport services (water, air, and rail modals), RAIS conveniently presents the same level of aggregation that IMACLIM-BR. Therefore, to harmonise PNAD-C to these economic sectors in IMACLIM-BR, the shares observed in each of these aggregates in the RAIS database parameterise the disaggregation of such economic activities.

Table 3 presents the sectoral shares from IMACLIM-BR, SCN, and RAIS applied to disaggregate the PNAD-C employment factors. It worth mention that the Native Planted Forest sector is not comprised in the original in IMACLIM-BR calibration. Still, it is present in the DDP-BIICS dashboard and relevant to our analysis, particularly to the strategy of the deep decarbonisation scenario.

The reconciliation of employment data from PNAD-C reckons 2015 and 2019 to be compatible with IMACLIM-BR and the DDP-BIICS dashboard, respectively. The Supplementary Material comprises the full results of the compatibilization. The following section describes the procedure and data to further specify some activities at the technology or subsector levels.

Table 3 - Shares from IMACLIM-BR, SCN and RAIS to PNAD-C compatibilization (2019)

PNAD-C	IMACLIM Hybridisation	Jobs	Total labour income
Oil and gas extraction	Oil	86%	86%
	Natural gas	14%	14%
Ethanol	To chemical industry	11%	11%
Forestry	Other biofuels	32%	32%
PNAD-C	SCN	Jobs	Total labour income
Oil refining	Gasoline	22%	22%
	Diesel	30%	30%
	Naphtha to the chemical industry	2%	2%
	Other fossil fuels	46%	46%
PNAD-C	RAIS	Jobs	Total labour income
Biofuels	Ethanol	97%	96%
	Biodiesel	3%	4%
Forestry	Planted Forest	92%	94%
	Native Planted Forest	8%	6%
Rail and subway transport	Freight rail	49%	41%
	Passenger rail	51%	59%
Air transport	Freight air	3%	3%
	Passenger air	97%	97%
Water transport	Freight water	93%	95%
	Passenger water	7%	5%

Source: the authors based on PNAD-C, RAIS, SNC and the IMACLIM-BR matrix

DETAILMENT OF KEY SECTORS

POWER SECTOR

Table 4 presents secondary data regarding direct jobs in different phases of deployment and operation for power generation technologies. This allowed a better detainment of job creation in the base year for three IMACLIM-BR sectors: Electricity (O&M), Construction (Construction phase) and Other industry (Manufacturing for power generation).

AUTOMOTIVE INDUSTRY

Jobs in the automotive industry manufacturing were also detailed directly from RAIS. The categories used were:

- Manufacture and assembly of motor vehicles (CNAE code 29001) and
- Manufacture of cabins, bodies, trailers and parts for motor vehicles (CNAE code 29002)

EMPLOYMENT FACTORS IN THE BASE YEAR

At least one indicator was built in the form of an employment factor for each IMACLIM-BR sector (**Table 5**). An employment factor is defined as the number of jobs or amount of work generated per unit of production capacity (CAMERON; VAN DER ZWAAN, 2015). In our case, we consider both physical and monetary units, according to data availability and the nature of each sector. The DDP-BIICS project dashboard gathers a synthetic representation of the scenarios with quantitative indicators to highlight specific policy areas of interest. It convenes the evolution of these indicators up to 2050, making them adequate to estimate the job creation in each sector in the assessed period. In other cases, the sectoral model sheets provided better approximations and were therefore favoured.

An employment factor as such is an imperfect indicator to expand estimates for job creation in long-run scenarios up to 2050. Nonetheless, once the adequate adjustments and caveats take place, it can be considered a reasonable proxy for this kind of exercise. These aspects are discussed in the section *Conclusion and next steps*.

Table 4 - Direct employment factors for the main phases of deployment for power generation technologies

		Jobs		
	Construction years	Construction phase (jobs years/MW)	Manufacturing (jobs years/MW)	O&M (jobs /MW)
Coal	4	4,4	1,5	0,15
Natural Gas	2	1,3	0,9	0,1
Fuel oil	2	1,4	0,1	0,1
Diesel oil	2	1,4	0,1	0,1
Nuclear	10	19,6	1,3	1,2
Biomass	2	14,0	2,9	1,55
Sugar cane bagasse	2	-	2,9	-
Hydro	5	7,4	2,5	0,2
Small hydro	3	31,3	5,5	1,6
Wind - onshore	3	7,7	3,3	0,6
Wind - offshore	3	19,3	11,0	0,4
Solar PV (Centralized)	2	18,0	11,5	0,5
Solar PV (Distributed)	1	27,4	11,5	11,3
Concentrated Solar Power (CSP)	3	10,0	7,2	1,3

Obs: Cogeneration plants in the sugar-alcohol sector do not add a significant amount of direct jobs, as this activity is linked to sugar and ethanol production.

Table 5 - Employment factors for IMACLIM-BR sectors

	IMACLIM-BR sector	Selected indicator and unit	Source
1	Coal	Coal production (million tonnes)	DDP-BIICS dashboard - Economy-wide
2	Crude Oil	Oil & Gas production (EJ)	DDP-BIICS dashboard – Economy-wide
3	Natural Gas	Oil & Gas production (EJ)	DDP-BIICS dashboard – Economy-wide
4	Gasoline	Gasoline production (ktoe)	Supplementary sectoral sheet (Energy sector)
5	Diesel	Diesel production (ktoe)	Supplementary sectoral sheet (Energy sector)
6	Refining (Other fossil fuels)	Fuel oil and LPG production (ktoe)	Supplementary sectoral sheet (Energy sector)
7	Ethanol	Ethanol production (litres)	Supplementary sectoral sheet (AFOLU)
8	Biodiesel	Biodiesel production (litres)	Supplementary sectoral sheet (AFOLU)
9	Other Biofuel	Fuel wood and charcoal (ktoe)	Supplementary sectoral sheet (Energy sector)
10	Electricity		
	Generation	Added installed capacity (MW)	Supplementary sectoral sheet (Energy sector)
	Transmission and distribution	Electricity consumption (TWh)	DDP-BIICS dashboard - Power Sector
11	Planted Forest	Area - Planted forest (ha)	Supplementary sectoral sheet (AFOLU model)
12	Native Planted Forest	Area - Native forest (ha)	Supplementary sectoral sheet (AFOLU model)
13	Sugar Cane	Tonnes (t)	Supplementary sectoral sheet (AFOLU model)
14	Soy	Tonnes (t)	Supplementary sectoral sheet (AFOLU model)
15	Rest of Agriculture	Tonnes (t)	Supplementary sectoral sheet (AFOLU model)
15	Cattle	Animal heads	Supplementary sectoral sheet (AFOLU model)
17	Rest of Livestock	Animal heads	Supplementary sectoral sheet (AFOLU model)
18	Cement	Physical production/sectoral output (Mt)	DDP-BIICS dashboard - Energy Intensive Industry
19	Iron and Steel	Physical production/sectoral output (Mt)	DDP-BIICS dashboard - Energy Intensive Industry
20	Mining and Pelletization	Rest of energy intensive industry sectoral GDP (million USD - 2015)	DDP-BIICS dashboard - Energy Intensive Industry
21	Non-Ferrous and other Metals	Physical production/sectoral output (Mt)	DDP-BIICS dashboard - Energy Intensive Industry
22	Chemical	Rest of energy-intensive industry sectoral GDP (million USD - 2015)	DDP-BIICS dashboard - Energy Intensive Industry
23	Bovine meat	Total animal production (Mt) - only cattle meat (beef and veal)	DDP-BIICS dashboard - AFOLU
24	Rest of Food and Beverages	Light Industry Sectoral GDP (million USD - 2015)	DDP-BIICS dashboard – Economy-wide
25	Textiles	Light Industry Sectoral GDP (million USD - 2015)	DDP-BIICS dashboard - Economy-wide
26	Pulp and Paper	Rest of energy-intensive industry sectoral GDP (million USD - 2015)	DDP-BIICS dashboard - Energy Intensive Industry
27	Ceramics	Rest of energy intensive industry sectoral GDP (million USD - 2015)	DDP-BIICS dashboard - Energy Intensive Industry
28	Construction		
	Power generation infrastructure	Jobs - construction (Job/MW)	Supplementary sectoral sheet (Energy sector)
	Rest of construction	Light Industry Sectoral GDP (million USD - 2015)	DDP-BIICS dashboard – Economy-wide
29	Other Industry	Light Industry Sectoral GDP (million USD - 2015) - auto industry and manufacturing for power generation deducted	DDP-BIICS dashboard – Economy-wide
	Auto industry	Annual car sales (Mio veh/year)	DDP-BIICS dashboard - Passenger transportation DDP-BIICS dashboard - Freight transportation
	Manufacturing for power generation	Jobs - manufacturing (Job/MW)	Supplementary sectoral sheet (Energy sector)
30	Freight road	Transport activity (Gtkm)	DDP-BIICS dashboard transport freight
31	Freight rail	Transport activity (Gtkm)	DDP-BIICS dashboard transport freight
32	Freight Air	GHG emissions from air freight transport ($MtCO_2$)	DDP-BIICS dashboard transport freight
33	Freight water	Transport activity (Gtkm)	DDP-BIICS dashboard transport freight
34	Freight pipeline	Oil & Gas production (EJ)	DDP-BIICS dashboard - Economy-wide
35	Passenger road	Public transport activity (pkm/per capita/year)	DDP-BIICS dashboard transport passenger
36	Passenger rail	Public transport activity (pkm/per capita/year)	DDP-BIICS dashboard transport passenger
37	Passenger Air	Passenger air transport activity (pkm/per capita/year)	DDP-BIICS dashboard transport passenger
38	Passenger water	Public transport activity (pkm/per capita/year)	DDP-BIICS dashboard transport passenger
39	Water, sewage and drainage	Services sectoral GDP (millions USD - 2015)	DDP-BIICS dashboard - Economy-wide
40	Education	Services sectoral GDP (millions USD - 2015)	DDP-BIICS dashboard - Economy-wide
41	Health	Services sectoral GDP (millions USD - 2015)	DDP-BIICS dashboard - Economy-wide
42	Composite (Other Services)	Services sectoral GDP (millions USD - 2015)	DDP-BIICS dashboard - Economy-wide

1. Electricity generation is disaggregated into 27 technologies: Hydroelectricity; Nuclear; Natural gas (combined cycle gas turbine); Natural gas (open cycle gas turbine); Coal (national); Coal (imported); Fuel oil; Diesel oil; Other non-renewable; Small hydro; Bagasse (sugar cane); Biomass; Wind – onshore; Wind – offshore; Solar PV (Distributed); Solar PV (Centralized); Concentrated Solar Power (CSP)

2. Vehicles are disaggregate into:

Passenger: Liquid ICE (Internal Combustion Engine); Gas ICE (Internal Combustion Engine); BEV (Battery Electric Vehicle); PHEV (Plug-and-Hybrid Electric Vehicle); FCEV (Fuel-Cell Electric Vehicle). Freight: Heavy Goods Vehicle (HGV) and Light Commercial Vehicle (LCV). For each, the following Technologies apply: ICE LF (Internal Combustion Engine, Liquid fuels); ICE CH4 (Internal Combustion Engine, Methane, Natural gas, Biogas); BEV (Battery Electric Vehicle (full electric cars); PHEV (Plug-in Hybrid Electric Vehicle; Dual engine: rechargeable electric motors and ICE) and FCEV (Fuel-Cell Electric Vehicle; Electric engine powered by hydrogen-based electricity)

Results

AGGREGATE RESULTS

This study provides a framework for an analysis of employment factors of a decarbonisation pathway to Brazil. **Table 6** presents general results to employment factors calibration to 2019. The services sector is dominant in jobs position, corresponding to 69% of total jobs in 2019, followed by the Industry sector (17%). The energy sector employs the fewest workers (1%). However, it presents the highest mean wage of the economy, reaching R$ 4,247, which is 209% higher than the economy-wide mean wage (R$ 2,036).

An analysis considering a distinction between formal and informal jobs is needed to evaluate the social disparities in the labour market. **Table 7** convenes the detailed results for the base-year calibration taking this distinction into account.

As expected, the mean wages for formal jobs are higher than for informal positions in all sectors. All economic sectors offer formal mean wages more elevated than the economy-wide mean wage. Formal positions are dominant in the energy sector, illustrating its high level of skilled labour. Consequently, it is translated into the total labour income from formal jobs, corresponding to 95% of the energy sector's total.

Conversely, the opposite occurs in the Agriculture. Informality is predominant (79%), and mean wages are the lowest compared to the other sectors. The disparity between formal and informal wages is economy-wide and reflects in the total labour income.

Table 6 - Aggregate results of employment factors calibration for 2019

Economic sector	Jobs (thousand)	Total labour income (million R$)	Mean wage (R$)
Energy	554 (1%)	2,353 (1%)	4,247
Agriculture	8,318 (9%)	9,098 (5%)	1,094
Industry	15,477 (17%)	28,908 (15%)	1,868
Transport	4,014 (4%)	8,270 (4%)	2,060
Services	63,437 (69%)	138,263 (74%)	2,180
Total	91,800	186,893	
Economy-wide mean wage (R$)			2,036

Source: the authors

Table 7 - Detailed results of employment factors calibration for 2019 - Distinction between formal and informal jobs

Economic sector	Jobs (thousand)		Total labour income (Millions of R$)		Mean wage (R$)	
	Formal	Informal	Formal	Informal	Formal	Informal
Energy	460 (83%)	94 (17%)	2,224 (95%)	129 (5%)	4,834	1,374
Agriculture	1,715 (21%)	6,603 (79%)	3,793 (42%)	5,305 (58%)	2,212	803
Industry	8,551 (55%)	6,925 (45%)	20,557 (71%)	8,351 (29%)	2,404	1,206
Transport	1,754 (44%)	2,260 (56%)	4,300 (52%)	3,970 (48%)	2,451	1,757
Services	35,823 (56%)	27,614 (44%)	97,555 (71%)	40,709 (29%)	2,723	1,474
Total	48,304	43,496	128,429	58,464	2,659	1,344

Source: the authors

SECTORAL RESULTS, FUTURE TRENDS AND POLICY RECOMMENDATIONS

ENERGY SUPPLY: THE ENERGY TRANSITION AND ITS POTENTIAL FOR NET JOBS CREATION

The diffusion of non-conventional renewable energy has been following an exponential curve globally (GRUBB; DRUMMOND; HUGHES, 2020), a result of steep cost reductions (SAGET; VOGT-SCHILB; LUU, 2020). In Brazil, renewable energy harbours nearly half the jobs within the energy sector (non-electric). In power generation plants, it accounts for the massive majority of jobs (e.g., hydropower, biomass). Such technologies are more labour intensive on average than fossil-fuelled power generation, as shown in **Table 4** and various studies (FRAGKOS; PAROUSSOS, 2018; IRENA, 2019; OCHS; GIOUTSOS, 2017; SAGET; VOGT-SCHILB; LUU, 2020)

According to ECLAC (2021), the expansion of the power system comprises on-site effects, observed during construction and installation phases, with large short-term impacts (e.g., 1 to 3 years), and the operation and maintenance phase, yielding smaller impacts, but for the entire life span of plants (over 25 years on average). However, the socioeconomic effects of such an expansion span the whole economy, reaching far more sectors than the electricity generation sector itself (DINIZ, 2019; MILANI et al., 2020). Indirect effects, occurring along power plants' supply chain, account for the majority of job creation, particularly if most plant components are produced

Table 8 - Sectoral results: Energy supply

	Total jobs	Share of informality	Average wage (R$)
Coal	4,554	21%	2,207
Crude Oil	108,679	5%	7,916
Natural Gas	32,098	7%	5,754
Gasoline	7,370	3%	7,442
Diesel	10,181	3%	7,442
Refining (other fossil fuels)	15,513	3%	7,442
Ethanol	71,333	3%	2,420
Biodiesel	2,405	3%	3,490
Other Biofuel	103,498	69%	1,057
Electricity (G+T&D)	198,485	6%	3,838
Generation (G)	50,482		
Hydropower	20,215		
Nuclear	2,288		
Natural Gas (CCGT)	980		
Natural Gas (OCGT)	701		
Coal (national)	259		
Coal (imported)	217		
Fuel oil	147		
Diesel oil	76		
Other non-renewables	-		
Small hydro	1,125		
Bagasse (sugar cane)	0		
Biomass	16,393		
Onshore wind	1,719		
Offshore wind	5,789		
Solar PV (distributed)	1		
Solar PV (centralized)	573		
Solar CSP	-		
Transmission and Distribution (T&D)	148,002		

nationally (FÜLLEMANN et al., 2020; MILANI et al., 2020). These can be verified in **Table 10**, which shows the jobs associated with power generation and transmission infrastructure in the Construction sector and manufacturing for power generation within the rest of the industry.

Indeed, the supply-chain effects comprise direct plant suppliers, such as component industries (e.g., wind turbine producers, motors manufacturers, solar panel manufacturing and assembling, biomass thermal-plant boilers, steam turbines). In addition, services directly related to the plant include, for instance, financial and legal services and engineering consulting. Component manufacturing normally demands iron and steel products, glass, electronics, chemicals, among others (ECLAC, 2021). **Box 1** lists the main job requirements in renewable energy value chains according to skill levels.

While distributed solar PV still accounts for a negligible share of power supply, it accounts for a significant share of jobs created both in the construction and manufacturing sectors (see **Table 10**). Indeed, PV is the NCRE technology with the highest employment multipliers for manufacturing and installation (**Table 4**). Prospects for increasing distributed solar PV in the coming decades imply effects over energy access, the dynamisation of the local economies, fostering micro-entrepreneurship and the creation of further construction and installation jobs. Nonetheless, the industrial development regarding PV supply chain is still challenging in Brazil, since PV cells manufacturing plants have a high upfront investment, requiring

Box 1- Main occupations in selected renewable energy sub-sectors by skill level

Equipment Manufacture and Distribution

- R&D Engineers (computer, electrical, environmental, mechanical) (H)
- Software Engineers (H,M)
- Modellers (prototype testing) (H,M)
- Industrial Mechanics (M)
- Manufacturing Engineers (H)
- Manufacturing Technicians (M)
- Manufacturing Operators (L)
- Manufacturing Quality Assurance Experts (H,M)
- Certifiers
- Logistics Professionals (H,M)
- Logistics Operators (L)
- Equipment Transporters (L)
- Procurement Professionals (H,M)
- Marketing Specialists (H,M)
- Sales Personnel (H,M)

Project Development

- Project Designers (Engineers) (H)
- Architects (H) (small projects)
- Atmospheric Scientists and Meteorologists (H)
- Resource Assessment Specialists and Site Evaluators (H)
- Environmental Consultant (H)
- Lawyers (H)
- Debt Financier Representatives (H)
- Developers/Facilitators (H,M)
- Land Development Advisor (H)
- Land Use Negotiator (H)
- Lobbyist (H)
- Mediator (H)
- Environmental and Social NGO Representatives (H,M)
- Public Relations Officer (H)
- Procurement Professionals (H,M)
- Resource Assessment Specialists (H)

Construction and Installation

- Engineers (civil, mechanical, electrical) (H)
- Project Managers (H)
- Skilled Construction Workers (Heavy Machinery Operators, Welders, Pipe-fitters etc.) (M)
- Construction Labourers (L)
- Business Developers (H)
- Commissioning Engineer (Electrical) (H)
- Transportation Workers (L)

Operation and Maintenance

- Plant managers (H)
- Measurement and Control Engineers (H)
- Welders (M)
- Pipe Fitters (M)
- Plumbers (M)
- Machinists (M)
- Electricians (M)
- Construction Equipment Operator (M)

Cross-cutting and enabling activities

- Policy Makers and Government Office Workers (H,M)
- Trade Association and Professional Society Staff (H, M,L)
- Educators & Trainers (H)
- Management (H,M,L)
- Administration (H,M,L)
- Publishers and Science Writers (H,M)
- Insurer Representatives (H,M)
- IT Professionals (H,M)
- Human Resources Professionals (H)
- Other Financial Professionals (Accountants, Auditors and Financers) (H)
- Health and Safety consultants (H,M)
- Sales and Marketing Specialists (H,M)

(H) High skill; (M) Medium skill; (L) Low skill

Source: ILO (2013)

quite a large-scale demand to be financially attractive. Currently, competition with imported products, particularly from China, still undermines investment[8] (SEBRAE, 2018).

In this study, we adopted a conservative assumption that cogeneration plants in the sugar-alcohol sector do not add a significant amount of direct jobs, as this activity is linked to sugar and ethanol production. However, cogeneration still fosters jobs in the manufacturing sector. According to SORIA et al. (2015), the widespread use of sugar cane bagasse cogeneration has led to developing a national component industry that currently provides 100% of biomass-fired thermal plants' content. Moreover, the main components of solid biomass electricity are mostly the same as traditional thermoelectric utilities', for instance, boilers, steam turbines and motors (ABDI, 2012). Therefore, the expansion of forest-based biomass for power generation – combined with gradually replacing fossil sources – may benefit enormously from this consolidated production chain in Brazil.

TRANSITIONING AWAY FROM COAL: LOCATIONAL IMPACTS AND THE COMMUNITIES' NEEDS MUST BE TAKEN INTO ACCOUNT

As the energy worldwide moves towards low-carbon paths, there is a group of workers that currently make up a large part of the energy workers that may not be left behind – the coal, oil and gas industries workers. Phasing-out coal power plants is crucial for attaining long-term climate targets but can negatively impact entire communities that are economically reliant on coal mining and coal-fired power-plants (SAGET; VOGT-SCHILB; LUU, 2020). The main challenge resides in the fact that such jobs will most probably be located in different areas and may not replace jobs lost in the same communities. As a matter of fact, the solar and wind largest resource potentials are not necessarily concentrated in the same areas as coal mines and thermal plants (ECLAC, 2021). The Brazilian federal government aims set to phase out all subsidies for the national coal industry by 2027. While the impact of such a measure is expected to be enormous throughout the coal production chain, the sector workers are not being taken into account.

International experience from countries undergoing the transition away from the coal industry, such as Canada, Germany, Spain and Chile, suggest that endorsing the views and needs of coal workers and communities results in better defined and more feasible goals for the transition plans (DIEESE, 2021). On social, environmental and economic levels, it is also worth noting lower hospitalization rates due to the unhealthy nature of the coal activity, reduction of local pollution and emissions, soil recovery, increased competitiveness rates of regions when they are restructured towards other economic activities, reconversion of old industries and higher local GDP due to the increase of investments (DIEESE, 2021).

According to (DIEESE, 2021), it is worth noting some peculiarities of the coal industry in Brazil, such as: (a) workers are usually better paid in this industry in comparison with other activities in the cities they live in; (b) cities and municipalities with strong coal-related activity are usually small and low-density populated areas, which makes it harder for national job or income policies to work effectively; (c) coal mining is typically generational, with many workers being the second or third generation of their family working in the industry.

Alternatives to address the transition away from coal include programs and policies to subsidize the reinsertion of the recently discharged workers, free courses and qualification degrees for these workers and their families, also while they are still working in the coal industry, earlier retirement plans, long-lasting unemployment compensation, temporary basic income for affected families and businesses and the restructuring of the economic activity of affected areas.

Finally, the federal and local governments will need to work on easy-to-access financing solutions for these communities, which may include the articulation with development banks and agencies as well as private banks to finance new businesses and industries in the given region. As the international experience suggests, it is possible to redirect sectoral subsidies to creat-

8 According to CEPAL (2021), PV modules are assembled and inverters and system balance equipment are produced nationally.

ing a fund to support the transition of these workers and communities (DIEESE, 2021) . On a local level, policymakers must work on detailed plans interconnected with national or international plans, creating committees and task forces with the participation of the community to accompany the workers, monitor and regulate the new activities and the ceasing of the older coal activity.

EXPLORING SYNERGIES BETWEEN OFFSHORE WIND GENERATION AND THE OIL AND GAS SECTOR

Regarding the relocation of workers from the oil & gas sector, a clear synergy with the renewable energy sector may be explored. The expertise acquired throughout the years by oil and gas workers, while aligned with many of the skills required for offshore renewable energy, specifically wind power, is still uncharted territory in the renewables industry. The usage of such expertise could be valuable to this emerging industry.

There are several technical skills that are commonly found in the oil and gas offshore industry which could also serve the offshore wind industry, such as: geological and marine engineering, offshore construction workers, offshore Health, Safety and Environment (HSE) specialists, subsea engineers and divers, geological and environmental surveyors, and quality assurance and control professionals for activities such as coating, welding, foundation and cable installation. Besides that, other competencies from professionals from the oil industry would be valuable additions to the wind sector: the complex offshore supply chain logistics, ocean and meteorological data analysis and environmental surveying.

As means of preparing the industry and its workers towards this transition in Brazil, apart from possibly creating policies for the utilisation of deactivated or soon-to-be decommissioned platforms structure for wind farms installation, both sectors could work on standardised training certifications, creating similar job structures and positions so workers could move easier. Additionally, it is possible to create policies to prioritise former oil offshore workers for wind offshore industry positions. Finally, governments must also support and find ways of funding local communities which will be impacted by the deactivation of these industries – most of these regions suffer from devastating economic impacts when oil production ceases, by means of either preparing them to be absorbed by the wind industry or to transition to other renewables or sectors.

AGRICULTURE, LAND USE AND FOREST (AFOLU)

The employment impacts of specific AFOLU decarbonisation pathways are still poorly represented in the literature, requiring further research to investigate how climate and sustainable development objectives interact (SVENSSON et al., 2021).

Table 9 presents the sectoral results of the AFOLU sector. Soy and sugar cane crops are presented apart from the Rest of Agriculture, given their relevance to exports and biofuel production. The cattle sector is also isolated from the Rest of Livestock given its predominance in the ranching sector and high methane emissions content. Commercial planted forest and native forest restoration are also critical sectors for the Brazilian decarbonization strategy that is strongly reliable on forest activities stimulation.

Table 9 - Sectoral results: AFOLU

	Total jobs	Share of informality	Average wage (R$)
Planted Forest	187,591	69%	1,057
Native Planted Forest	26,992	69%	853
Sugar Cane	289,472	22%	1,527
Soy	443,410	56%	2,614
Rest of Agriculture	4,281,938	87%	805
Cattle	2,086,051	78%	1,380
Rest of Livestock	1,002,940	80%	947

The AFOLU sector pays the lowest average wages in the economy, as presented in **Table 6**. It is necessary to increase the engagement of the rural population to overcome the low level of wages by supporting entrepreneurial initiatives that can provide competitive green services while enhancing the quality of jobs.

The establishment of smaller enterprises in rural areas with low smallholder participation, as biofuels-related crops (sugar cane), dynamic exported-oriented sectors (soy), and forestry activities, can promote better quality jobs in agriculture value chains. In addition, a shift towards the production of high-value fruits and vegetables would provide greater opportunities for smallholders and family farmers and healthier diets for the population at large (SAGET; VOGT-SCHILB; LUU, 2020; SVENSSON et al., 2021).

Biofuels- related crops

Sugar cane production seems to have a more specialized production system given its lower share of informality. However, this is not reflected in the sector´s average wage compared to the soy sector. It is worth mentioning that both sectors present higher average wages than the rest of agriculture, especially soy.

Conversely, the forestry sectors present high informal employment rates, still below the average of the rest of agriculture, but still higher than sugar cane and soy. Commercial forests and native vegetation restoration represent the most fomented economic sector in the decarbonization scenario.

Commercial forests (including integrated crop-livestock-forest systems)

Commercial forests, such as eucalyptus and pine, are critical carbon removals, either in the form of homogeneous forests or through integration in crop-livestock-forest systems. The surface of planted forests is expected to reach 19.5 Mha in 2050 in a deep decarbonization scenario. This area considers the demand from all sectors: energy (charcoal and firewood), industry (pulp and paper, and others), and pellets production for exports.

Native forest restoration

Fostering reforestation and restoration of 30 Mha in 2050 with native species in public and private areas is also relevant, removing 417 $MtCO_2eq$ by 2050 and going beyond the area considered in the NDC target (12 Mha by 2030). It can be made possible with government support, international funds, payment for environmental services programs, and forest offsets allowed through the cap-and-trade system imposed on the industry.

The growth of the forest sector is 50.3% higher in DDS in comparison to CPS. It is mandatory that instruments to foster decent rural employment be considered in the development strategy to this sector. Saget et al. (2020) point that it is necessary to strengthen social capital and farmers' organization to ensure increased inclusion and knowledge sharing among the workers. In addition, market-based instruments, such as payments for ecosystem services, can direct efforts to enhance quality jobs. It allows providing cash or training to landowners and communities living in protected areas in exchange for services that protect the environment (SAGET; VOGT-SCHILB; LUU, 2020).

In Brazil, mechanisms introducing payments for environmental services can attract private investments to restore native forests and compensate forest producers for maintaining forest stocks. Law No. 14,119/2021 makes provision for these payments and considers modalities such as compensation for reduced emissions from deforestation and degradation (REED+), green bonds, and Quotas for Environmental Reserve (CRA) (BRAZIL, 2021). In addition, changes proposed in the Forest Concessions Law (Law No. 11,284/2006) can streamline contracts and make concession processes viable (BRAZIL, 2006).

Also, projects that combine environmental conservation and social protection for low-income populations from the Amazonian region and indigenous people are key to sustainable forest activities. They promote employment creation and higher income for families living in protected areas in return for environmental services provision (SAGET; VOGT-SCHILB; LUU, 2020).

The *Bolsa Verde* program provides a conditional cash transfer for ecosystem conservation as part of Brazil's extreme poverty fight plan. The program also aims to promote citizenship and improve the living conditions and incomes of the extremely poor. Another program, *Bolsa Floresta*, seeks to generate employment and income from sustainable natural resources use (Law No. 3.135 State Policy on Climate Change; complementary Law No. 53 State System for Protected Areas) (AMAZONAS STATE GOVERNMENT, 2007a, 2007b). With more than 8,500 participating families in 15 conservation units covering 10 million hectares in 2013, it is one of the largest PES programs in the world (SCHWARZER; VAN PANHUYS; DIEKMANN, 2016). The program rewards indigenous peoples for their conservation work in tropical forests, provides sustainable production training and support, and strengthens community associations (SAGET; VOGT-SCHILB; LUU, 2020).

Livestock

Finally, the cattle and rest of livestock sectors also present a high share of informal jobs. The sector considers the recovery of an additional 60 Mha from degraded pasturelands associated with increased productivity of the cattle herd reduces emissions from enteric fermentation in DDS. Cattle ranching intensification has the most significant mitigation potential, pointing to a challenge to promote jobs creation and increase the average wages in the sector while fostering intensification production.

Despite its extensive pasturelands area, Brazil pursues a high content of jobs per cattle head (9.8 jobs/thousand heads) when contrasted with other major cattle ranching countries, such as Argentina (8 jobs/thousand heads), USA (5 jobs/thousand heads), and Australia (14 jobs/thousand heads). On the other hand, an analysis considering the number of jobs per area of pastureland ranks Brazil in the lowest position (0.01 jobs/ha) followed by Australia (0.11 jobs/ha), USA (2.07 jobs/ha), and Argentina (5.65 jobs/ha).[9]

9 Pastureland area according to FAO-UN (2021). Jobs data by USDA-NASS (2021); Australian Government (2021); Fundácion FADA (2020). Cattle head data by USDA (2021); Argentina (2020); MLA (2020).

A transition cannot be just without targeted policies to help producers, farmers, agricultural workers, and consumers reap the benefits while at the same time reducing GHG emissions. An effective strategy for the livestock sector must include improving the land efficiency of cattle ranching (e.g., through intensification).

Occupational safety and health play a key role in ensuring decent work in agriculture. By replacing arduous and poorly paid work on the field, advancements in technology could also generate better quality jobs. Technological change and the sustainable intensification of the sector would imply an important transformation in skills for agricultural workers. A strategy to create employment locally is to reskill agricultural workers according to territorial development strategies. The private sector also plays a critical role in providing information to narrow any relevant skills mismatch (SAGET; VOGT-SCHILB; LUU, 2020).

EFFECTS OF AUTOMATION, DIGITALISATION AND THE SHIFT TOWARDS ELECTROMOBILITY IN THE INDUSTRIAL AND TRANSPORTATION SECTORS

There are many trends to be observed in the upcoming years for energy transformation in Brazil. Most of them relate to digitalisation and the upsurge of a market for electric mobility.

As for digitalisation, for the decade it is expected a lot of progress in the computational analysis capabilities, fast and cheapest data transfers and connectivity, facilitation for the implementation of new operational standards and increased system operative efficiency. The energy sector is also predicted to fluctuate towards active smart grids, which are highly automated, subdivided into subsystems providing greater efficiency and controllability.

Frey and Osborne (2017) suggest that automation will likely affect a number of roles across the mobility ecosystem. The type of positions among most susceptible to automation include drivers and industrial truck operators, traffic technicians and transportation inspectors and highway maintenance workers.

To a lesser extent, auto mechanics, urban planners and drivers or workers related to services within urban areas could also be potentially affected by automation and digitalisation. On the other hand, as previously discussed, there will be a higher demand for professionals to work on electric mobility, namely specialists in urban mobility and professionals to install and maintain the infrastructure of charging stations and underlying services, highlighting the surge of required professionals to work in smart grid networks and system services (payments and traffic management, for example).

Existing analyses estimate that the number of jobs in car manufacturing may decrease in the future with an uptake in electromobility. Indeed, the manufacturing processes are much simpler in battery-electric cars than those with internal combustion engine (ICE) vehicles, while the manufacturing for plug-in hybrid vehicles is more labour-intensive[10]. Therefore, the net impact upon car manufacturing jobs will depend partially on the role of hybrid vehicles. Employment in the sector will also be impacted by productivity gains from digitalisation and robotisation, which will take place throughout the industry (AIE, 2020).

Nonetheless, estimates show that more jobs can potentially be created in the electricity value chain than lost in automotive manufacturing. Most of the new jobs will be downstream and are associated with the installation, operation and maintenance of charging points. They include the production of batteries and chargers, the sales of electrical equipment, the installation, connection to the grid, operation and maintenance of the chargers, associated grid reinforcements and civil and road work, as well as production of necessary additional electricity. These jobs are high skill and entirely new to the automotive sector.

The maintenance of chargers is the most job intensive segment on the electromobility value chain, followed by battery cell manufacturing. With the exception of the latter, these jobs are local and cannot necessarily be automatised, therefore helping SMEs tap into new areas of value creation and employment and driving local economic dynamism (AIE, 2020).

The advent of electrification and digitalisation will bring a reorganisation of value creation along the entire supply chain. Digitalisation is set to trigger substantial

qualitative changes to employment, for example, a positive shift in employment requirements for IT. In all of the job clusters and areas investigated, the shift to electric mobility, automation and digitalisation will result in a substantial need for training and further training in terms of digital skills and expertise. Consoli et al. (2016) provide evidence that green jobs use more intensively high-level cognitive and interpersonal skills compared to non-green jobs. Green occupations also

10 An assessment for the European car manufacturing industry estimated that, with respect to component manufacture, labour requirements are 70 percent higher for the production of a conventional powertrain than for the production of a powertrain for an electric vehicle (BAUER; RIEDEL; HERRMANN, 2020).

Table 10 - Sectoral results: Transport

	Total jobs	Share of informality	Average wage (R$)
Freight road	1,657,857	49%	2,274
Freight rail	26,314	4%	3,158
Freight Air	2,362	3%	4,424
Freight water	74,023	42%	2,855
Freight pipeline	2,781	0%	1,425
Passenger road	2,146,060	66%	1,724
Passenger rail	27,882	4%	4,230
Passenger Air	71,369	3%	5,077
Passenger water	5,462	42%	1,834

Table 11 - Sectoral results: Industry

	Total jobs	Share of informality	Average wage (R$)
Cement	235,665	32%	2,039
Iron and Steel	123,788	5%	3,215
Mining and Pelletization	283,696	21%	2,683
Non-Ferrous and other Metals	59,453	6%	2,523
Chemical	357,366	12%	3,485
Bovine meat	486,669	9%	1,662
Rest of Food and Beverages	1,358,601	35%	1,708
Textiles	587,208	61%	1,170
Pulp and Paper	178,208	20%	2,100
Ceramics	286,125	32%	1,587
Construction (P+R)	4,872,171	72%	1,572
Power generation and transmission infrastructure (P)	81,687		
Hydropower	34,918		
Nuclear	0		
Natural Gas (CCGT)	0		
Natural Gas (OCGT)	0		
Coal (national)	0		
Coal (imported)	0		
Fuel oil	0		
Diesel oil	0		
Other non-renewables	0		
Small hydro	3,330		
Bagasse (sugar cane)	0		
Biomass	71		
Onshore wind	12,739		
Offshore wind	0		
Solar PV (distributed)	16,004		
Solar PV (centralized)	14,625		
Solar CSP	0		
Rest of construction (R)	4,790,484		
Other Industry (A+P+R)	4,437,548	34%	3,058
Auto industry (A)	533,629		
Manufacturing for power generation (P)	34,095		
Hydropower	11,797		
Nuclear	0		
Natural Gas (CCGT)	0		
Natural Gas (OCGT)	0		
Coal (national)	0		
Coal (imported)	0		
Fuel oil	0		
Diesel oil	0		
Other non-renewables	0		
Small hydro	585		
Bagasse (sugar cane)	186		
Biomass	15		
Onshore wind	5,460		
Offshore wind	0		
Solar PV (distributed)	6,710		
Solar PV (centralized)	9,344		
Solar CSP	0		
Rest of manufacturing (R)	3,869,823		

exhibit higher levels of standard dimensions of human capital such as formal education, work experience and on-the-job training.

With the transformation of the energy sector, demand and opportunities in various fields will be created and will increase over time. As observed by GIZ (2021), Brazil is not preparing professionals to adapt to such changes, namely the emergence of non-conventional renewable energy and distributed resources, electromobility and digitalisation. There is little to no offerings of undergraduate, graduate, professional qualification courses or even elective or mandatory subjects in universities, colleges and professional schools. A large share of the engineering curricula and other courses that could prepare professionals for the energy transformation are currently outdated. There is an urge to incorporate aspects of smart grids, urban mobility, storage and generation of renewable electricity into graduation courses and professional schools alike, with greater integration and multidisciplinarity.

Next steps

This study combines the output of a modelling exercise and national employment data for Brazil from two official sources to provide a comprehensive picture of net job creation in long-term scenarios in Brazil. Departing from outputs from the DDP-BIICS project, we identified several indicators that could be used as a proxy for sectoral employment factors. In addition, we resorted to secondary data and literature to further detail key segments at the industry (e.g., automotive industry) or technology (e.g., power generation technologies) levels.

These employment factors will be used to expand net job creation up to 2050 in two different scenarios from the DDP-BIICS project: the Current Policies Scenario (CPS) and the Deep Decarbonization Scenario (DDS). A set of preliminary results can be found in the Annex. We highlight, however, that these results still require some finetuning. For now, they fail to incorporate some of the major trends described foreseen to take place in key sectors, as discussed in section 3.2 (e.g., shift to electromobility, digitalisation, etc.). Other aspects, such as productivity gains and decreasing informality, which will occur irrespective of the aforementioned trends, must also be embedded within the projections.

References

- ABDI. *Avaliação das Perspectivas de Desenvolvimento Tecnológico para a Indústria de Bens de Capital para Energia Renovável (PDTS-IBKER)*. ABDI - Agência Brasileira de Desenvolvimento Industrial, 2012. Retrieved from: <https://www.ie.ufrj.br/images/IE/grupos/GIC/publica%C3%A7%C3%B5es/2012.%20Kupfer%20et%20al%20(Coords).%20Relatorio%20Final%20PDTS%20IBKER%20(1).pdf>. Accessed: 9 oct. 2021.
- AIE. *Powering a new value chain in the automotive sector* - the job potential of transport electrification. Brussels: European Association of Electrical Contractors, 2020.
- AMAZONAS STATE GOVERNMENT (2007a). *Complementary Law 53/2007* - Amazonas State System for Protect Areas. Retrieved from: <https://sapl.al.am.leg.br/media/sapl/public/normajuridica/2007/844/844_texto_integral.pdf>. Accessed: 9 oct. 2021.
- AMAZONAS STATE GOVERNMENT (2007b). *Law 3,135/2007* - Amazonas state Policy on Climate Change. Retrieved from: <https://online.sefaz.am.gov.br/silt/Normas/Legisla%E7%E3o%20Estadual/Lei%20Estadual/Ano%202007/Arquivo/LE%203135%2007.htm>. Accessed: 9 oct. 2021.
- ARGENTINA. *Existencias bovinas por provincia* - marzo 2020. Gobierno de Argentina, mar. 2020. Retrieved from: <https://www.argentina.gob.ar/files/existenciasbovinasporprovinciamarzo2020xlsx>
- AUSTRALIAN GOVERNMENT. *Livestock Farm Workers*. Australian Government - Job Outlook, , 2021. Retrieved from: <https://joboutlook.gov.au/occupations/livestock-farm-workers?occupationCode=8415>
- BAUER, W.; RIEDEL, O.; HERRMANN, F. *Employment 2030*: Effects of electric mobility and digitalisation on the quality and quantitity of employment at Volkswagen. Stuttgart: Fraunhofer Institute for Industrial Engineering IAO, 10 nov. 2020. Retrieved from: <https://www.volkswagenag.com/presence/stories/2020/12/frauenhofer-studie/6095_EMDI_VW_Summary_um.pdf>. Accessed: 9 oct. 2021.
- BRAZIL. *LAW 11,284 / 2006*. Retrieved from: <http://www.planalto.gov.br/ccivil_03/_ato2004-2006/2006/lei/l11284.htm>. Accessed: 9 oct. 2021.
- BRAZIL. *Federal Law 14,119 - 13th January 2021*. Retrieved from: <https://www.in.gov.br/en/web/dou/-/lei-n-14.119-de-13-de-janeiro-de-2021-298899394>. Accessed: 10 oct. 2021.
- CAMERON, L.; VAN DER ZWAAN, B. Employment factors for wind and solar energy technologies: A literature review. *Renewable and Sustainable Energy Reviews*, v. 45, p. 160–172, maio 2015.
- CONSOLI, D. et al. Do green jobs differ from non-green jobs in terms of skills and human capital? *Research Policy*, v. 45, n. 5, p. 1046–1060, jun. 2016.
- DIEESE. *Carvão mineral*: Experiências internacionais na busca por uma transição energética justa para o setor carbonífero no sul do Brasil. Dieese – Departamento Intersindical de Estatística e Estudos Socioeconômicos, 2021.
- DINIZ, T. B. *Impactos econômicos e regionais dos investimentos em geração de energia elétrica no Brasil*. Instituto Escolhas, 24 jul. 2019. Retrieved from: <https://www.escolhas.org/wp-content/uploads/2020/04/PB_06_Tiago-Barbosa_Impactos-economicos-e-regionais-dos-investimentos-em-geracao-de-energia-eletrica_Brasil.pdf>
- ECLAC. *Opportunities for a more sustainable and low-carbon post-pandemic recovery in Latin America and the Caribbean*: Energy Transition in LAC. ECLAC - Economic Commision for Latin America and the Caribbean, 2021.
- ECLAC/CGEE. *Performance indicators associated with low-carbon energy technologies in Brazil*: evidence for an energy big push. Economic Commission for Latin America and the Caribbean (ECLAC)/Center for Strategic Studies and Management (ECLAC), 2020.
- FAO-UN. *FAOSTATS*. Food and Agriculture Organization of the United Nations, 2021. Retrieved from: <https://www.fao.org/faostat/en/#country/>
- FRAGKOS, P.; PAROUSSOS, L. Employment creation in EU related to renewables expansion. *Applied Energy*, v. 230, p. 935–945, nov. 2018.
- FREY, C. B.; OSBORNE, M. A. The future of employment: How susceptible are jobs to computerisation? *Technological Forecasting and Social Change*, v. 114, p. 254–280, jan. 2017.
- FÜLLEMANN, Y. et al. Hire fast, fire slow: the employment benefits of energy transitions. Economic Systems Research, v. 32, n. 2, p. 202–220, 2 abr. 2020.
- FUNDACION FADA. *El 22% del empleo nacional viene de la agroindustria*. Fundacion FADA - La Fundación de Agropecuaria para el Desarrollo de Argentina, 5 oct. 2020. Retrieved from: <https://fundacionfada.org/informes/el-22-del-empleo-nacional-viene-de-la-agroindustria/>
- GIZ. *Profissões do Futuro na Área de Energia e Implicações para a formação profissional*. Cooperação Alemã para o Desenvolvimento Sustentável por meio da Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, feb. 2021.
- GROTTERA, C. et al. *Hybrid Input-Output tables for Brazil at year 2015*. v. 1, 22 fev. 2021.
- GRUBB, M.; DRUMMOND, P.; HUGHES, N. *The shape and pace of change in the electricity transition: Sectoral Dynamics and indicators of progress*. UCL Institute for Sustainable Resources, 2020.
- ILO. *Investment in renewable energy generates jobs*. Geneva: International Labor Organization, 2013.
- IRENA. *Renewable Energy and Jobs*: Annual Review 2019. International Renewable Energy Agency, 2019.
- LE TREUT, G. *Description of the IMACLIM-Country model*: A country-scale computable general equilibrium model to assess macroeconomic impacts of climate policies.CIRED - Centre international de recherche sur l'environnement et le développement, sep. 2020.

- MILANI, R. et al. Promoting social development in developing countries through solar thermal power plants. *Journal of Cleaner Production*, v. 246, p. 119072, feb. 2020.
- MLA. *Fast Facts - Australia's beef industry 2020*. MLA - Meat & Livestock Australia, 2020. Retrieved from: <https://www.mla.com.au/globalassets/mla-corporate/prices--markets/documents/trends--analysis/fast-facts--maps/2020/mla-beef-fast-facts-2020.pdf>
- OCHS, A.; GIOUTSOS, D. *The Employment Effects of Renewable Energy Development Assistance*. European Union Energy Initiative Partnership Dialogue Facility, out. 2017.
- SAGET, C.; VOGT-SCHILB, A.; LUU, T. *Jobs in a Net-Zero Emissions Future in Latin America and the Caribbean*. Washington D.C. and Geneva: Inter-American Development Bank and International Labour Organization, 2020.
- SCHWARZER, H.; VAN PANHUYS, C.; DIEKMANN, K. *Protecting people and the environment. Lessons learnt from Brazil's Bolsa Verde, China, Costa Rica, Ecuador, Mexico, South Africa and 56 other experiences*. Geneva: International Labor Office, 2016.
- SEBRAE. *Cadeia de valor da energia solar fotovoltaíca no Brasil*. SEBRAE, 2018. Retrieved from: <https://www.sebrae.com.br/Sebrae/Portal%20Sebrae/Anexos/estudo%20energia%20fotovolt%C3%A1ica%20-%20baixa.pdf>. Accessed: 9 oct. 2021.
- SORIA, R. et al. Hybrid concentrated solar power (CSP)–biomass plants in a semiarid region: A strategy for CSP deployment in Brazil. *Energy Policy*, v. 86, p. 57–72, nov. 2015.
- SVENSSON, J. et al. A low GHG development pathway design framework for agriculture, forestry and land use. *Energy Strategy Reviews*, v. 37, p. 100683, set. 2021.
- USDA. *United States and Canadian Cattle*. USDA - United States Department of Agriculture, 25 aug. 2021. Retrieved from: <https://downloads.usda.library.cornell.edu/usda-esmis/files/474299142/v405t7614/wd376v46t/uscc0821.pdf>
- USDA-NASS. *USDA-NASS Farm Labor Report*. United States Department of Agriculture - National Agricultural Statistics Service, 2021. Retrieved from: <https://www.nass.usda.gov/Charts_and_Maps/graphics/data/QtrWorkers_Data.txt>

Appendix

DETAILED RESULTS FOR SCENARIOS PROJECTIONS (PRELIMINARY)

	2020		2030		2050	
	CPS	DDS	CPS	DDS	CPS	DDS
Total formal jobs	46.612	46.612	60.451	60.642	90.880	90.993
Total informal jobs	42.139	42.139	52.587	52.777	79.051	81.039
Total	88.750	88.750	113.038	113.419	169.930	172.033
Labour income – formal	123.931	123.931	161.743	162.117	243.187	242.549
Labour income – informal	62.527	62.527	78.915	79.133	116.992	118.212
Total labour income	186.458	186.458	240.658	241.250	360.179	360.761
Average wage	2.101	2.101	2.129	2.127	2.120	2.097
% informality	47,5%	47,5%	46,5%	46,5%	46,5%	47,1%

Figure 1. Energy supply

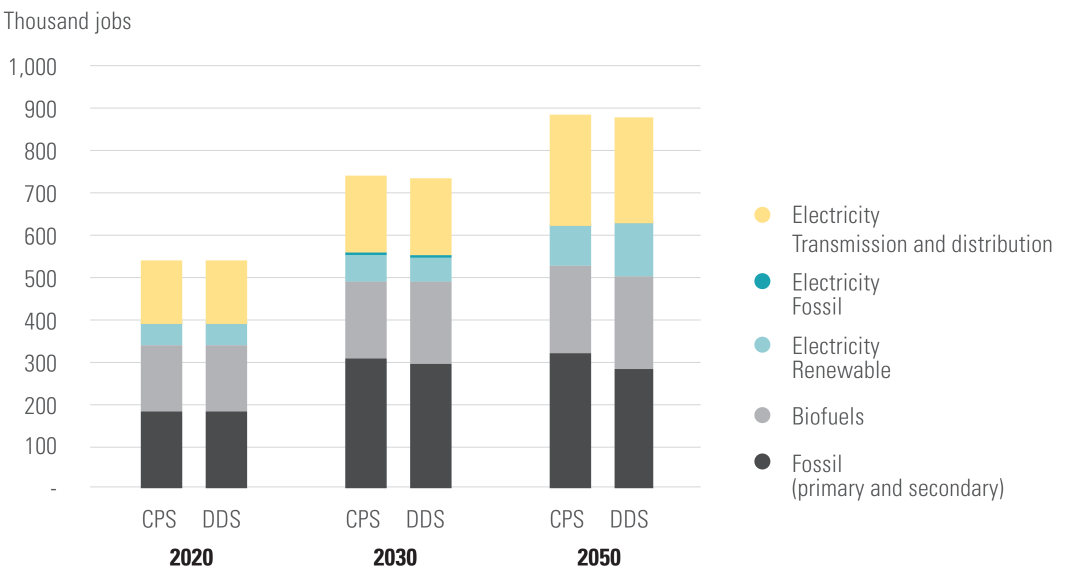


Figure 2. AFOLU

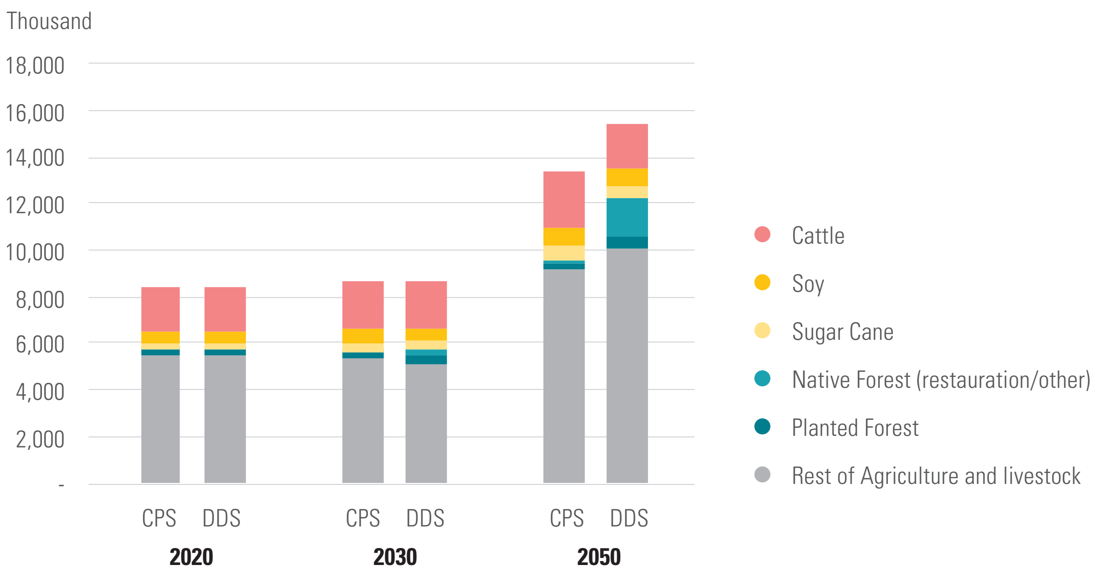


Figure 3. Industry

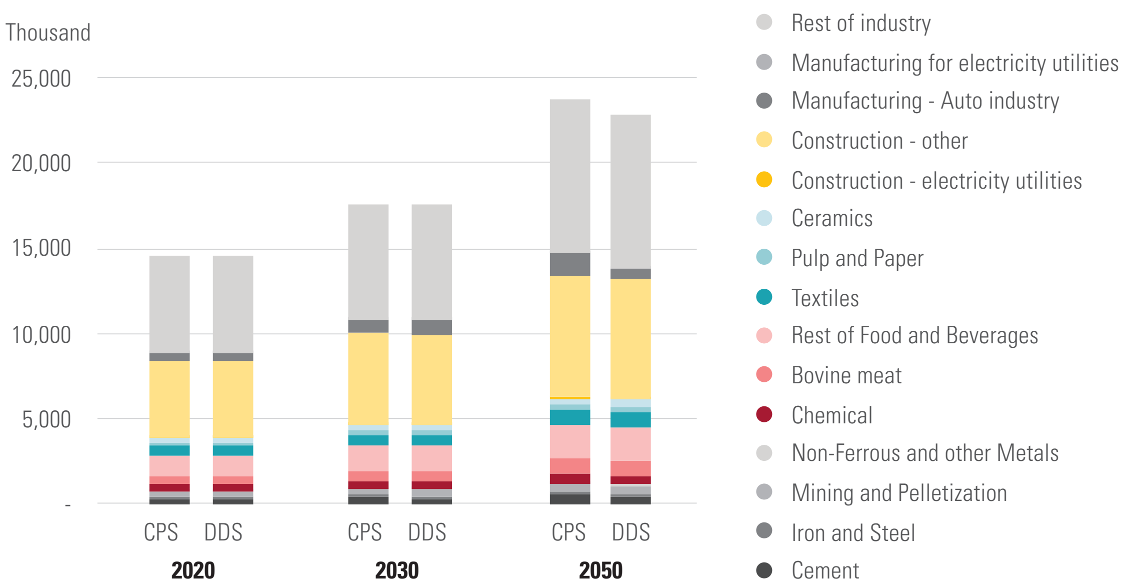
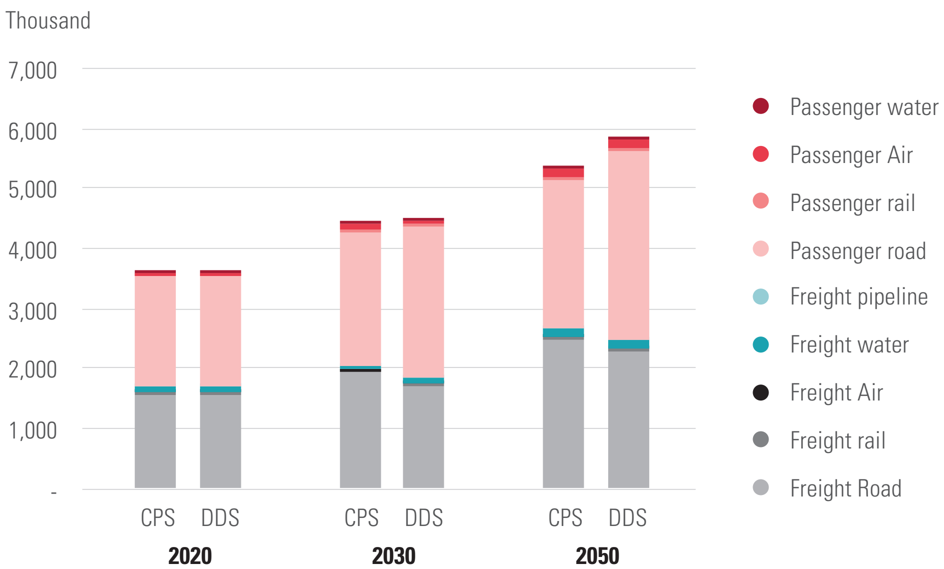


Figure 4. Transportation



DDP

The DDP is an initiative of the Institute for Sustainable Development and International Relations (IDDRI). It aims to demonstrate how countries can transform their economies by 2050 to achieve global net zero emissions and national development priorities, consistently with the Paris Agreement.. The DDP initiative is a collaboration of leading research teams currently covering 36 countries. It originated as the Deep Decarbonization Pathways Project (DDPP), which analysed the deep decarbonization of energy systems in 16 countries prior to COP21 (deepdecarbonization.org). Analyses are carried out at the national scale, by national research teams. These analyses adopt a long-term time horizon to 2050 to reveal the necessary short-term conditions and actions to reach carbon neutrality in national contexts. They help governments and non-state actors make choices and contribute to in-country expertise and international scientific knowledge. The aim is to help governments and non-state actors make choices that put economies and societies on track to reach a carbon neutral world by the second half of the century. Finally, national research teams openly share their methods, modelling tools, data and the results of their analyses to share knowledge between partners in a very collaborative manner and to facilitate engagement with sectoral experts and decision-makers.
www.ddpinitiative.org

IDDRI

The Institute for Sustainable Development and International Relations (IDDRI) is an independent, not-for-profit policy research institute based in Paris. Its objective is to identify the conditions and propose tools to put sustainable development at the heart of international relations and public and private policies. IDDRI is also a multi-stakeholder dialogue platform and supports stakeholders in global governance debates on the major issues of common interest, such as actions to mitigate climate change, protect biodiversity, strengthen food security, and to manage urbanisation. The institute also participates in work to build development trajectories that are compatible with national priorities and the sustainable development goals.
www.iddri.org