Opinion

Low-carbon development pathways in Brazil and 'Climate Clubs'

Emilio Lèbre La Rovere*

Edited by Karin Bäckstrand, Domain Editor, and Mike Hulme, Editor-in-Chief

Brazil occupies a unique position among the major greenhouse gas (GHG) emitting countries due to its low per-capita energy-related GHG emissions (2.4 tons CO_2 in 2014), attributable to abundant clean energy sources. Recently, deforestation in Brazil has slowed considerably, to the point where forestry has ceased to be the major source of emissions. Brazil has reduced its overall GHG emissions by 41% from 2005 to 2012, and its total GHG emissions per capita decreased from a high in 2004 of 14.4 tCO_2e to an estimated 6.5 tCO_2e in 2012. Brazil faces the challenge of building upon its historically low energy-related GHG emission levels through new decarbonization strategies, while pursuing higher living standards for its population. There is a huge potential to further reduce national GHG emissions through the implementation of a wide spectrum of mitigation measures. While several observers from the scientific community have a different view, Brazilian government considers that the country has been playing both a pioneer and a leader role in ambitious climate action, including the submission of a quite ambitious intended nationally determined contribution, and a constructive role played in COP21, joining the High Ambition club at the end of the negotiations. Several motivations exist for Brazil joining other 'climate clubs' focusing on innovative financial mechanisms and sustainable energy and forestry technologies.

How to cite this article:
WIREs Clim Change 2017, 8:e439. doi: 10.1002/wcc.439

CLIMATE CHANGE MITIGATION POLICY IN BRAZIL

Brazil occupies a unique position among the major greenhouse gas (GHG) emitting countries due to its low per-capita energy-related GHG emissions (2.4 tons CO_2 in 2014), attributable to Brazil's abundant clean energy sources. The sources of major emissions have historically been concentrated in agriculture, forestry, and other land use (AFOLU), and are related mostly to deforestation, crop growing, and livestock. Recently, deforestation in Brazil has slowed considerably, to the point where forestry has ceased to be the major source of emissions. Thanks to reduced deforestation, Brazil has reduced its overall GHG emissions by 41% from 2005 to 2012, and its total GHG emissions per capita decreased from a high in 2004 of 14.4 tCO_2e to an estimated 6.5 tCO_2e in 2012.

Brazil faces the challenge of building upon its historically low energy-related GHG emission levels through new decarbonization strategies, while pursuing higher living standards for its population. Average annual income per capita in 2005 was only

*Correspondence to: emilio@ppe.ufrj.br

Energy Planning Program (PPE), Institute of Graduate Studies and Research in Engineering (COPPE), Federal University of Rio de Janeiro (UFRJ), Head of the Center for Integrated Studies on Climate Change and the Environment (CentroClima), Rio de Janeiro, Brazil

Conflict of interest: The author has declared no conflicts of interest for this article.

$4767. Inequality, as evidenced by Brazil's uneven income distribution, is a major problem. Brazil has made some progress in reducing income inequality in the last decade, thanks to the government consistently increasing the minimum wage faster than the inflation rate and social transfer programs (e.g., *Bolsa Família*). They decreased the Gini coefficient from 0.57 in 2005 to 0.53 in 2013, but inequalities are still a leading concern: in 2013, 15.5 million people in Brazil were living below the poverty line, of whom 6.2 million were living in extreme poverty.[1] Inequality between regions is also a problem; reducing these is the object of some regional incentive programs.

Brazilian government considers that the country has been playing both a pioneer and a leader role in ambitious climate action due to the following actions:

a Pioneering efforts from Brazil include:

- hosting in Rio de Janeiro the United Nations Conference on Environment and Development (UNCED) in 1992, thus being the first country to sign the United Nations Framework Conference on Climate Change (UNFCCC);

- being the single non-Annex I country to present a proposal for the Kyoto Protocol, based upon the principle of historical responsibility in the building up of global temperature, and on the establishment of a Clean Development Fund (through penalties on noncompliance) that eventually has led to the creation of the Clean Development Mechanism (CDM), as one of the flexibility mechanisms of the adopted Kyoto Treaty.

b Leadership moves from Brazil in climate action include:

- jumping ahead of non-Annex I countries in the announcement of voluntary mitigation targets prior to COP15 in 2009, in Copenhagen, departing from the G-77 and China previous position of refusing any mitigation commitments; and announcing a 2020 target that would imply a decline in absolute level of GHG emissions compared to 2005 (2 $GtCO_2e$ in 2020 against 2.1 $GtCO_2e$ in 2005);

- Sharply curbing down of economy-wide GHG emissions, allowing to comfortably meeting the 2020 targets (total GHG emissions nearly stable around 1.2 $GtCO_2e$ from 2010 to 2014, against the 2020 target of 2 $GtCO_2e$);

- Announcement of an intended nationally determined contribution (iNDC) at COP21 with an ambitious target of economy-wide 37% GHG emission reduction in 2025 and 43% in 2030, related to the level recorded in 2005 (only the EU target is comparable in terms of absolute GHG emission reduction levels).

Several observers from the scientific community (for example, Hochstetler and Viola) [2]have a more critical view in relation to Brazil's leadership role in multilateral climate negotiation as being in some issues and sometimes progressive, in other issues and other times spoiler. The degree of ambition of Brazilian iNDC may also be questioned as the bulk of the emissions reduction effort has already been achieved from 2005 to 2012 (41% against the target of 43% in 2030). However, it is undeniable that Brazilian commitment, unlike the targets set by China and India, involves a substantial absolute reduction of economy-wide GHG emissions compared to a past year (2005) and the record of reducing annual GHG emissions by 1 billion tons CO_2e/year is impressive.

Brazil might be interested in joining an alliance of climate pioneers for a number of reasons, including, inter alia:

- Access to international financial resources and to innovative financial schemes allowing to foster the tapping of mitigation opportunities.
- Playing a leader role in the deployment and export of mitigation technologies, both in the energy (e.g., biofuels) and forestry (monitoring and control of deforestation, planted forests, REDD+ projects) sectors.
- Current membership in BRICs initiatives, as the new development bank prioritizing investments in low carbon infrastructure.
- Support of strategic actors, such as the ministries of Foreign Affairs and Environment, corporate coalitions, and notably at the subnational level, including a number of municipalities belonging to the C-40 (chaired by Rio de Janeiro's mayor from 2012 to 2016).

BRAZILIAN LOW CARBON DEVELOPMENT

According to the recent Mitigation Actions, Plans and Scenarios (MAPS) study for Brazil, including inputs of key Brazilian experts from government, business sector, and civil society,[3] there is a huge potential to reduce national GHG emissions through the implementation of a wide spectrum of

mitigation measures, including: energy efficiency, renewable energy sources, low-carbon agriculture and cattle raising techniques, transport modal shifts, methane capture in the waste sector (landfills and sewage treatment stations), and reforestation with native and fast growth species. Large part of these mitigation measures are of low cost, such as those in the agriculture and cattle raising sector, energy efficiency, and increased utilization of renewable energy sources such as hydropower and sugarcane ethanol. Adopting these measures can result in a significant level of additional mitigation in relation to current governmental efforts. If other measures are made viable, such as restoration of the Atlantic Forest, large-scale production of charcoal from planted forests, significant increase in intercity freight and urban passenger rail transport, it would be possible to reach in 2030 the level of 1 billion tCO2e, 25% lower than in 1990 and a 49% reduction from 2005, a higher ambition than in the iNDC. More importantly, besides other environmental cobenefits, this deeper mitigation pathway can contribute to an increase in economic growth, a decrease of unemployment rate, and to an increase in average annual household income, with the largest gain for the poorest families, contributing to a small improvement in the distribution of wealth, depending on the way in which they are implemented.

There are various barriers, both economic and financial, as well as noneconomic (legal, regulatory, and institutional) for implementing such a high ambition mitigation pathway, and different means of overcoming them. Such means include microeconomic instruments and command/control tools, as well as innovative financial mechanisms to fund the higher upfront costs of mitigation measures.

There are clear signs that the previous cycle of economic growth in Brazil has been exhausted, as indicated by the current economic crisis. After the adjustment policies to be implemented in 2015–2016, a new economic growth cycle must be sustained upon other basis. There is a wide consensus among Brazilian economists that a new development strategy should focus on higher investments in infrastructure. Therefore, given the huge potential of renewable energy resources in Brazil, a positive synergy emerges between the investment in low carbon infrastructure and the starting of a new virtuous development cycle.

This strategic vision of Brazilian objectives informs the requirements of 'climate clubs' that may be of interest to Brazil:

- The goal pursued by forging an alliance would be of GHG emissions mitigation contributing toward economic transformation and growth.
- It should supply ways and means to overcome the implementation gap, mainly through innovative financial mechanisms and technological development.
- Sectoral priorities would be AFOLU, renewable energy, and energy efficiency.

Table 1 illustrates Brazilian sectoral priorities for the case of mitigation technologies in the energy sector. This sector is crucial as it has now become the main driver of future increase of GHG emissions in Brazil, as population and gross domestic product (GDP) growth push energy demand up in transport, industry, agriculture, and buildings. Moreover, increasing in the long term the already high share of renewables in the energy mix is quite a challenge due to the difficulty of building new hydropower plants in the very fragile ecosystems of the Amazon region (where the bulk of the remaining potential to be tapped is located). The deployment of wind, solar, and particularly biomass (ethanol and bagasse from sugarcane) will thus be increasingly important to contain the increase of GHG emissions from burning fossil fuels up to 2030 and sustain a lower carbon energy development path in the long term. This way, GHG emission reductions in other sectors (mainly in AFOLU) may offset the growth of energy-related emissions up to 2030 and allow for meeting the iNDC targets.

The Brazilian iNDC falls within the range of the two Additional Mitigation scenarios of IES-Brasil (AM1 and AM2). According to the vision of nearly 100 experts involved in the IES-Brasil study, and considering the assumptions of a fast economic growth rate up to 2030, achieving the Brazilian iNDC targets in the Energy Sector appears to be feasible. Moreover, if implemented through the adoption of appropriate public policies, the Brazilian iNDC can contribute to sustainable economic growth and improved social development while simultaneously reducing GHG emissions in Brazil.

Brazilian participation in climate clubs helping its efforts to remove the barriers to higher penetration of renewable energy (hydropower and sugarcane products, but also biodiesel and other biomass sources, wind and solar energy) and energy efficiency would thus be of utmost interest. Such clubs might help not only in the implementation of the iNDC but also to its review toward a higher ambition, pushing it toward the level of IES-Brasil AM2 scenario.

TABLE 1 | Comparison between Brazilian iNDC and IES-Brasil Scenarios

	2010	2030 iNDC-Brasil	2030 AM1	2030 AM2
Total GHG emission reductions (compared to 2005)	40%	43%	35%	49%
Total energy supply (Mtoe)	268.8		520.8	533.6
% Renewable energy	45%	45%	46%	49%
% Renewable energy without hydropower	32%	33%	35%	38%
% Sugarcane products + biodiesel	18%	18%	22%	22%
% Sugarcane	17.5%	16%*	21%	21%
% Hydropower in the National interconnected grid	83%	66%*	69%	71%
Total power generation (average GW)	68.9		131.4	130.1
% Renewable power generation	86%		85%	87%
% Hydropower	75%		61%	63%
% Sugarcane products + other renewables	11%	23%	25%	24%
Total power generation/GDP (av MW/billion R$ 2005)	25.3		23.7	23.0
% of 2010	100		94	91
Improvement of 'electricity productivity' (related to 2010) (or efficiency gains in the electricity sector, in the iNDC)	—	10%	6%	9%

Not in the iNDC but presented in the Brazilian President speech at the UN General Assembly in September, 2015.
GDP, gross domestic product; GHG, greenhouse gas; iNDC, intended nationally determined contribution.
Source: IES-Brasil, 2015.[3]

CLIMATE CLUBS FOR BRAZIL

For being attractive to Brazil, a climate club must provide the means to scaling up the investment in sustainable infrastructure, including additional financial resources and guarantees, and/or technological cooperation capable to trigger the deployment of sustainable energy technology. If a single climate club cannot deliver both kinds of incentives, might also be explored the idea of multiple climate clubs.

Follows a discussion of three examples of climate clubs supplying these incentives: a Positive Carbon Pricing Club, a Sustainable Energy Technology Club, and a Sustainable Forestry Club.

A Positive Carbon Pricing Club

Hourcade et al.[4–6] have developed an innovative financial mechanism to bridge the gap between available savings in a world flooded by a rapid expansion of liquidity and investment in low carbon infrastructure. The Brazilian government adopted this idea and in a submission to COP20 Workstream 2 in Lima, suggested that 'The Conference of the Parties should provide a clear political signal of its willingness to recognize the social and economic value of early and additional mitigation activities under the UNFCCC and to translate their verified results into units of convertible financial value, for the purpose of attracting investments and further promoting the implementation of national sustainable development policies by Parties.'[7] This submission was not adopted in Lima, but Brazil was able to include in the last version of the Paris Agreement a sentence where the Conference of the Parties '*recognizes the social economic and environmental value of voluntary mitigation actions and their co-benefits to adaptation, health and sustainable development*.'[8] It could be the cornerstone of financial mechanisms to scale up the support to a low-carbon transition in Brazil and other non-Annex 1 countries. To do so, Annex 1 countries should commit to an amount *of public guarantees on low-carbon investments assessed in function of an agreed social, economic and environmental value of mitigation activities*. According to Espagne,[9] this Positive Carbon Pricing Club fulfills the four conditions established by Nordhaus[10] for a climate club definition. Moreover, this club might encompass other members besides states (as in the original definition by Nordhaus). Its benefit comes by a guarantee supplied to an emission reduction that may be induced by a corporate project, and even by a change in behavior within a household, in exchange of the agreed social value of carbon (SVC). As Espagne[9] puts it, '*This boost of value, the SVC, stems from a political compromise between the players of a club. It is therefore not a market price, but rather what one would call a notional price. This*

SVC serves as an anchor for the financial aid offered to a club's player. This way, a low-carbon project could be partially financed through certificates of emission reduction, highlighted at the level of this SVC. The financial sector would accept these certificates as loan repayments, insofar as their value would be guaranteed by the national public power.'

Brazil has been struggling to increase investment in low carbon infrastructure such as railways, waterways, ports, and hydropower plants. Current investment rates are below 16% of GDP (15.5% in 2005), and do not reach the 18–21% required in the fast economic growth and additional mitigation scenarios explored by IES-Brasil. The government has been trying to establish public/private partnerships (PPPs) to fund these investments, with mixed results. International knowledge exchange and cooperation provided through a climate finance club might help to get the right conditions in place when designing the tenders to attract private capital into sustainable infrastructure. Moreover, such a climate club might help to integrate in this effort subnational actors such as state governments and municipalities, who often lack the capacity to leverage the finance required to face the needs of building up sustainable cities and infrastructure.

Alternatively, Brazilian Treasury has increased the capital of the National Development Bank (BNDES), the main funder of long-term investment in the country. However, according to international accounting rules, this operation increases public debt and the country's risk, as accounted by international risk assessment agencies. If carbon emission reductions would be valued at the international level as financial assets, and guaranteed by Central Banks from a climate club of countries, it would slacken this constraint.

A Sustainable Energy Technology Club

In Brazil, renewable energy accounted for 45% of total energy supply in 2010 (49% in 1990, 41% in 2000), and a huge potential of renewable energy remains to be tapped, with a potential increase in this share of renewables (see Table 1). Hydropower development was boosted by the creation of Eletrobras in 1964. In 2010, 75% of total electricity consumption in the country was supplied by hydropower. In 2030, it would contribute 61–66% (see Table 1). Wind energy has recently taken off at a fast pace (more than doubling the installed capacity in 2014, from 2.2 to 4.9 GW, with a 2030 projection in the range of 25 to 30 GW). Solar energy is at an incipient stage of deployment, but recently approved regulations can remove some of the barriers to decentralized PV power generation. Potential for PV installed capacity in 2030 is estimated between 16.5 and 18.5 GW (IES-Brasil, 2015). Renewable charcoal produced from fast-growing planted forests (eucalyptus and pinus) is already an important energy source for the pig iron and steel production. There is potential to more than double current planted forest area in 2030 (from 6 to 12–14 million hectares). Since 1975, Brazil has been using increasing volumes of ethanol from sugarcane as a car fuel. In 2010, ethanol production was of 27 billion liters, and sugarcane products (including bagasse) were able to contribute 17.5% of total energy supply. Production of second generation (2G) biofuels looks very promising in Brazil. The first two plants for ethanol production from sugarcane bagasse, using 2G technology for enzymatic hydrolysis of cellulosic materials, have reported yields of 24,800 L/hectare per year (against current average of 6800 with conventional technology). Biodiesel is blended to diesel oil at 7% currently, but it could reach 15% in 2030, tripling production thanks to the use of palm oil as feedstock, besides soybeans and waste.

International cooperation can accelerate technology development and speedup the deployment of renewables both in Brazil and abroad. Brazil has been trying to promote the production of biofuels in other countries, in order to make ethanol a global commodity. In the Technology Needs Assessment (TNA) to the UNFCCC, Brazil has included a section on its potential to share renewable energy technology with other parties. Brazilian government has already indicated the intention to join the International Solar Alliance launched by the Government of India prior to COP21.

A Sustainable Forestry Club

Brazil has produced a remarkably successful record in sharply cutting deforestation by 80% in the Amazon from 2004 to 2010, allowing for a substantial reduction in the country's GHG emissions (see Table 1). Half of this reduction is attributed to stricter enforcement of laws and regulations, and half to making the access of farmers to soft credit from public banks conditional upon compliance to the Forest Code and environmental permits. Despite this success, the war is not over, as illustrated by Amazon deforestation increase of 16% in 2014. The main challenge remains to make cost-effective to keep the tropical forest in place, through the development of new technologies and markets for forest products. Besides REDD+ activities, the Amazon Fund

managed by the National Development Bank (BNDES) is also supporting pilot projects with this goal, thanks to the financial support supplied mainly by Norway and complemented by Germany and international NGOs.

Considerable experience has been accumulated in Brazil in the field of AFOLU, including:

- Early warning systems for forest clearance and fire dectection, using satellite imagery;
- Inventory of GHG emissions from land use change;
- Enforcement of Forest Code laws and regulations;
- Good practices in sustainable funding to farmers by public banks;
- Pilot projects for forest protection and sustainable use, including REDD+ activities;
- Low-carbon agricultural practices, such as low tillage, biological fixation of nitrogen, and agroforestry schemes;
- Forest plantations, both of fast-growing species for commercial purposes and for native forest restoration (mainly in the Atlantic Forest).

This experience can be shared with other forest countries. The Amazon Fund is already supporting projects abroad, in neighboring Amazon countries. This initiative might be extended to Southeast Asia and African countries as well. Therefore, Brazil would have a strong interest in joining a Climate Club focusing on sustainable forestry, not only to find new ways to keep deforestation under control in the country, but also to share its experience with other forest countries.

CONCLUSION

Brazil has achieved an impressive reduction in its overall GHG emissions since 2005, submitted a quite ambitious iNDC, and played a constructive role in COP21. There is a growing awareness in the country of the opportunities to foster development though the building of low carbon infrastructure and mitigation projects. Giving the high endowment of forests and renewable energy sources, Brazil is well placed to play a leadership role in these fields, as illustrated by its recent achievements in the deployment of sustainable energy and forestry technologies. One of the key conditions for Brazil to play this role is the availability of financial resources to meet the upfront costs involved in the transition to a lower carbon economy. Therefore, several motivations exist for Brazil joining not only a High Ambition club (as it already happened in COP21), but also a number of other climate clubs focusing on innovative financial mechanisms and sustainable energy and forestry technologies. Besides the examples identified in *Climate Clubs for Brazil* section, and the International Solar Alliance launched by India, one can also mention the joint EU/Brazilian initiative in COP21 of proposing a Sustainable Development Mechanism to succeed CDM as a booster of mitigation projects, included in Article 6 of the Paris Agreement.

Given the strong attachment of Brazil's Foreign Affairs Ministry to multilateralism, a key condition for Brazil joining these clubs would be a clear linkage with UNFCCC. Other conditions would include the ability of the clubs to provide goods such as knowledge exchange and additional financial resources for mitigation actions.

A number of strategic actors in Brazil may be useful partners to help implementing and facilitating these climate clubs, such as:

- The Ministry of Foreign Affairs must be involved in all climate clubs to ensure an appropriate linkage to UNFCCC and the alignment of the clubs with the general orientation of the Brazilian foreign policy; it is also worth mentioning that the new minister is breaking with traditional multilateralism, paving the way to a Brazilian participation in minilateral climate clubs.
- The Ministry of Finance (Fazenda), the Central Bank, the National Treasury, the ministry of Science, Technology and Innovation (MCTI) and the National Development Bank (BNDES) would need to be involved in clubs targeting enhanced climate finance, and existing financial institutions such as the Future Stockchange (BMF), and the Green Stockchange (Bolsa Verde) may be useful partners of these clubs.
- The Ministry of Environment, the National Institute of Spatial Research (INPE), the Brazilian Enterprise of Agricultural Research (EMBRAPA), and BNDES would be key partners of a climate club focusing on sustainable forestry.
- The Ministry of Mines and Energy, its Energy Planning Agency (EPE), MCTI, BNDES, the Technological Center on Bioenergy (CTBE), Petrobras and Eletrobras would be useful partners of a Sustainable Energy club.

Other actors might be involved in one or more of these clubs, such as the cities belonging to the C-40, some states, and corporate coalitions, such as the Brazilian Coalition for Climate and the Forests.

The political feasibility of the climate clubs presented here depends on a number of factors, as for climate clubs in general. For example, one may refer to Brandi et al.,[11] as this discussion goes beyond the scope of this paper that has focused on the potential Brazilian participation in climate clubs that might foster its low carbon development and the conditions to be met by such climate clubs.

ACKNOWLEDGMENT

This paper summarizes a work prepared for the study 'Pioneer's Alliance for Climate Action' jointly coordinated by DIE—German Development Institute and WI—Wuppertal Institute. The author thanks the financial support provided by DIE under the Klima Dialog project and the technical support from WI to the research performed.

FURTHER READING

La Rovere EL, Dubeux CBS, Pereira Jr. AO, Wills W. Beyond 2020: from deforestation to the energy challenge in Brazil, Climate Policy—Special issue: Low carbon drivers for a sustainable world, 2013, v.13, n.01, pp. 70:86.

La Rovere, EL, Gesteira CM. Brazil, in Pathways to deep decarbonization, DDPP 2014 report, SDSN-IDDRI-COPPE/UFRJ.

La Rovere E., Gesteira CM, Grottera C, Wills W. Pathways to deep decarbonization in Brazil. DDPP 2015 report, SDSN-IDDRI-COPPE/UFRJ, December, 2015.

REFERENCES

1. Brazil, Ministério do Desenvolvimento Social—MDS. Data Social 2.0. Available at: http://aplicacoes.mds.gov.br/sagidata/METRO/metro.php?p_id=4 (Accessed September 24, 2015.
2. Hochstetler K, Viola E. Brazil and the politics of climate change: beyond the global commons. *Environ Polit* 2012, 21:753–771. doi:10.1080/09644016.2012.698884.
3. IES-Brasil. "Economic and Social Implications of GHG Mitigation Scenarios in Brazil up to 2030." Report of the Mitigation Action Plans and Scenarios (MAPS) project in Brazil, 2015.
4. Hourcade J-C, Aglietta M, Perrisin-Fabert B, Espagne E. The low carbon transition between the animal spirits of finance and the fault lines of the world economy. In: Sirkis, A, Hourcade J-C, Dasgupta D, Studart R, Gallagher K, Perrisin-Fabert B, Veiga JE, Espagne E, Stua M, Aglietta A. *Moving the trillions: A debate on positive pricing of mitigation actions*. CIRED; 2015, 22–36.
5. Hourcade JC, Aglietta M, Perrissin Fabert B. Transition to a low-carbon society and sustainable economic recovery. A monetary-based financial device. CIRED concept note, 2014. Available at: http://www.centre-cired.fr/IMG/pdf/concept_note-2.pdf. (accessed October 2015).
6. Hourcade JC, Perrissin Fabert B, Rozenberg J. Venturing into uncharted financial waters: an essay on climate-friendly finance. *Int Environ Agreements: Polit Law Econ* 2012, 2:165–186. doi:10.1007/s10784-012-9169-y.
7. Brazil. Views of Brazil on accelerating the implementation of enhanced climate action. Positive incentives for the promotion of early and additional action: recognizing the social and economic value of mitigation activities. Brazilian submission to COP20, November, 2014.
8. COP21,UNFCCC. Adoption of the Paris Agreement, Decision 1/CP.21, 2016, paragraph 108, FCCC/CP/2015/10/Add.1.
9. Espagne E. Climate clubs and COP21: Foes or allies? In: Sirkis A, Hourcade J-C, Dasgupta D, Studart R, Gallagher K, Perrisin-Fabert B, Veiga JE, Espagne E, Stua M, Aglietta A. *Moving the trillions: A debate on positive pricing of mitigation actions*. CIRED; 2015, 145–157.
10. Nordhaus W. Climate clubs: overcoming free-riding in international climate policy. *Am Econ Rev* 2015, 105:1339–1370.
11. Brandi C, Berger A, Bruhn D. *Between Minilateralism and Multilateralism: Opportunities and Risks of Pioneer Alliances in International Trade and Climate Politics*. Bonn: German Development Institute/Deutsches Institut für Entwicklungspolitik (DIE); 2015.

