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ENERGY COMMUNITIES: DECARBONIZATION AND DECENTRALIZATION OF THE ENERGY SYSTEM

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The European Commission's Clean Energy for All Europeans package confirms the leading role that citizens and communities will play in the future energy system. Energy communities are legal entities voluntarily integrated by individuals or companies, aligned with the objectives of sustainable development, allow partners to achieve energy, economic, environmental and social benefits that promote the expansion of renewable energies, improve energy efficiency, contribute to the decarbonization and decentralization of the energy system. The dual role of each member, shareholder and end user guarantees the advantages of energy communities: they create a sustainable environment, increase social development, control energy by its members, reduce costs, promote the use of clean energy, and help in the fight against climate change. In this field, this work presents a review of the state of the art of energy communities in Europe: the legal framework of the main countries, the activities and organizational forms, the types of renewable energy, a comparison of European success stories and Guide to project an energy community.

Keywords: energy communities; Renewable energy; Decarbonization; Decentralization

COMUNIDADES ENERGÉTICAS: DESCARBONIZACIÓN Y DESCENTRALIZACIÓN DEL SISTEMA ENERGÉTICO

El paquete “Energía limpia para todos los europeos” de la Comisión Europea confirma el papel destacado que desempeñarán los ciudadanos y comunidades en el futuro sistema energético. Las comunidades energéticas son entidades jurídicas integradas voluntariamente por personas físicas o pymes, alineadas con los objetivos del desarrollo sostenible, permiten a los socios conseguir beneficios energéticos, económicos, ambientales y sociales que fomentan la expansión de las energías renovables, mejoran la eficiencia energética, contribuyen a la descarbonización y a la descentralización del sistema energético.

El doble rol de cada integrante, accionista y usuario final garantiza las ventajas de las comunidades energéticas: crean un entorno sostenible, aumenta el desarrollo social, control de la energía por sus miembros, reducción de costes, impulsa el uso de energías limpias, y ayuda en la lucha contra el cambio climático. En este ámbito, este trabajo presenta una revisión del estado del arte de las comunidades energéticas en Europa: el marco legal de los principales países, las actividades y formas organizativas, los tipos de energías renovables, una comparación de casos de éxito europeos y una guía para proyectar una comunidad energética.

Palabras clave: Comunidades energéticas; Energías Renovables; Descarbonización; Descentralización

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1. Introduction

All human beings are responsible for climate change, and the devastating consequences represent a great threat to our security and prosperity (Takht Ravanchi et al., 2021). The integration of renewable energy sources (RES) and the increase of energy efficiency are crucial to decarbonize end-use sectors and the energy system as a whole (REN21, Renewables 2021 Global Status Report).

Europe, committed to the energy transition and aligned with the objectives of sustainable development, has an ambitious plan to decarbonize the energy system by 2050. (European Commission's Communication 'Energy Roadmap 2050'). The main intermediate objectives for 2030 establish a 32% share of RES in final energy consumption, a reduction in greenhouse gas emissions of up to 40% and an increase of 32.5% in the energy efficiency by 2030 (European Commission's Communication 'A Policy Framework for Climate and Energy in the Period from 2020 to 2030').

This strategy creates new opportunities for researchers, citizens, businessmen, and organizations in general; focused on the development of innovative energy supply systems. In this context, in 2019, the European Union (EU) revised its energy policy framework based on the Clean Energy Package for all Europeans proposed in 2016. EU countries have between 1 and 2 years to turn the new directives into national laws. Among them, it is important to highlight: the generation of energy from RES, energy efficiency measures, structure of the electricity market, security of supply regulation, and electricity governance (Clean energy for all Europeans package). Table 1 links the measurements with the official publication.

Table 1: Clean energy for all Europeans packages.

Energy performance in buildings	Directive (EU) 2018/844
Renewable energy	Directive (EU) 2018/2001
Energy efficiency	Directive (EU) 2018/2002
Governance of the energy union	Regulation (EU) 2018/1999
Electricity regulation	Regulation (EU) 2019/943
Electricity directive	Directive (EU) 2019/944
Risk preparedness	Regulation (EU) 2019/941
Agency for the Cooperation of Energy Regulator	Regulation (EU) 2019/942

The new directives aimed at transforming the energy sector towards a sustainable and accessible energy system for all, give the citizen the leading role, and in this sense, the energy communities are recognized for the first time within European legislation. In general, energy communities are parallel processes of energy transition and social innovation. On the one hand, they are decentralized energy projects based on renewable energies, which originate sustainable energy production and consumption practices. On the other hand, they are community-driven and consumer empowerment initiatives, generating a fundamental change in consumer behavior, moving from a “passive” role to an “active” role: energy prosumer, co-owner of renewable energy facilities and community energy participant (Van der Schoor T. et al., 2016).

In this matter, the objective of this work is to review the state of the art of energy communities in Europe with the aim of proposing a guide to design an energy community. The structure of

he work is as follows: Section 2 details the work methodology, section 3 the results and finally, section 4 presents the main conclusions.

2. Methodology

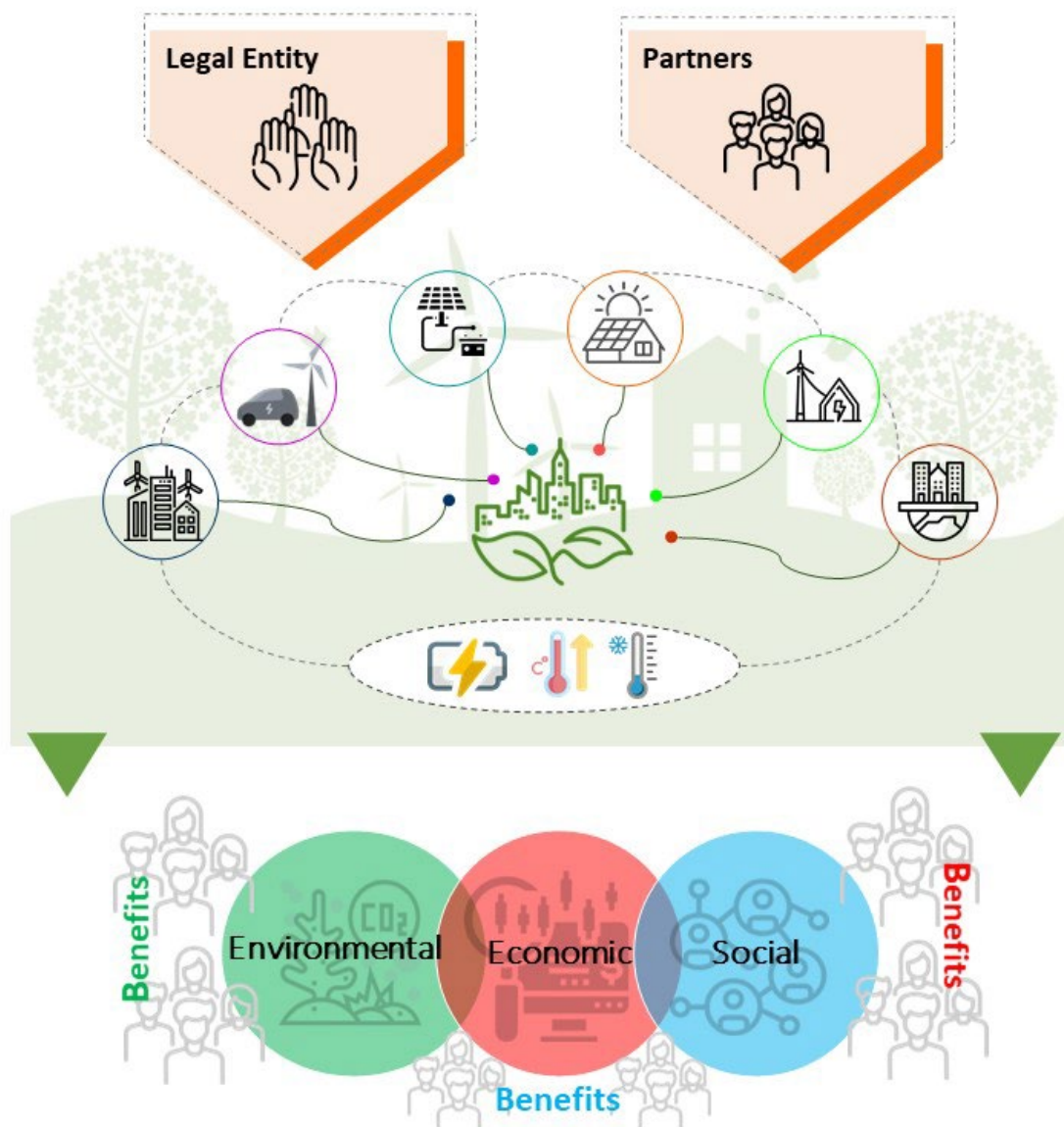
2.1 What is an energy community?

In European legislation there are two formal definitions of energy communities:

Citizen energy communities (CEC), which is included in the revised Internal Electricity Market Directive (EU) 2019/944 (European Parliament & Council of the European Union, 2019).

Renewable energy communities (REC), which is included in the revised Renewable Energy Directive (EU) 2018/2001 (European Parliament & Council of the European Union, 2018).

Figure 1. Pillars of renewable energy communities. Own elaboration



In CECs, shared energy can be generated with renewable sources and fossil origins, and the citizens of the community can be geographically distant.

The RECs are based on three pillars (Reijnders et al., 2020), see Figure 1:

1. That it be a legal entity, which, in accordance with applicable national law, is based on open and voluntary participation, is autonomous and is effectively controlled by partners or members that are in the vicinity of the renewable energy projects. These projects must be developed and owned by said legal entity.
2. That its partners or members are natural persons, SMEs (Small and medium-sized enterprises) or local authorities, including municipalities.
3. That its primary purpose is to provide environmental, economic or social benefits to its partners or members or to the local areas where it operates, instead of financial gain.

According to the renewable energy directive, Member States must provide an enabling framework that promotes and facilitates the development of renewable energy communities as a way to expand renewable energy. In fact, they are forced to consider the renewable energy communities when designing their plans to support renewable energy (REScoop.EU, 2019)

It is important to highlight that the geographical scope of the RECs maintains the link of having local communities organized "in the proximity" of the renewable energy projects that belong to and are developed by that community. In fact, their members are restricted and only allow natural persons, local authorities, and micro, small and medium enterprises whose participation does not constitute their main economic activity. They also cover a wide range of activities referring to all forms of renewable energy in the electricity and heating sectors (Roberts et al., 2019). The creation, configuration, and projection of a REC is a complex task. Indeed the International Renewable Energy Agency (IRENA, 2020) recommends taking into account the following points in order to achieve the success of such RECs:

- Identify optimal opportunities to make productive use of renewable energy and expand its benefits.
- Foster dialogue between community members to consolidate a shared purpose and take advantage of the group's knowledge and experience to carry out their initiatives.
- Invest in developing technical capabilities in renewable energy and financial knowledge necessary to develop business plans for the energy initiatives.
- Evaluate the possibility of associations.
- When working with partner organizations, communities should help their partners develop an understanding of local contexts, values, and needs.
- Communities can turn to other communities for inspiration and guidance.

2.2 State of the art of energy communities in Europe

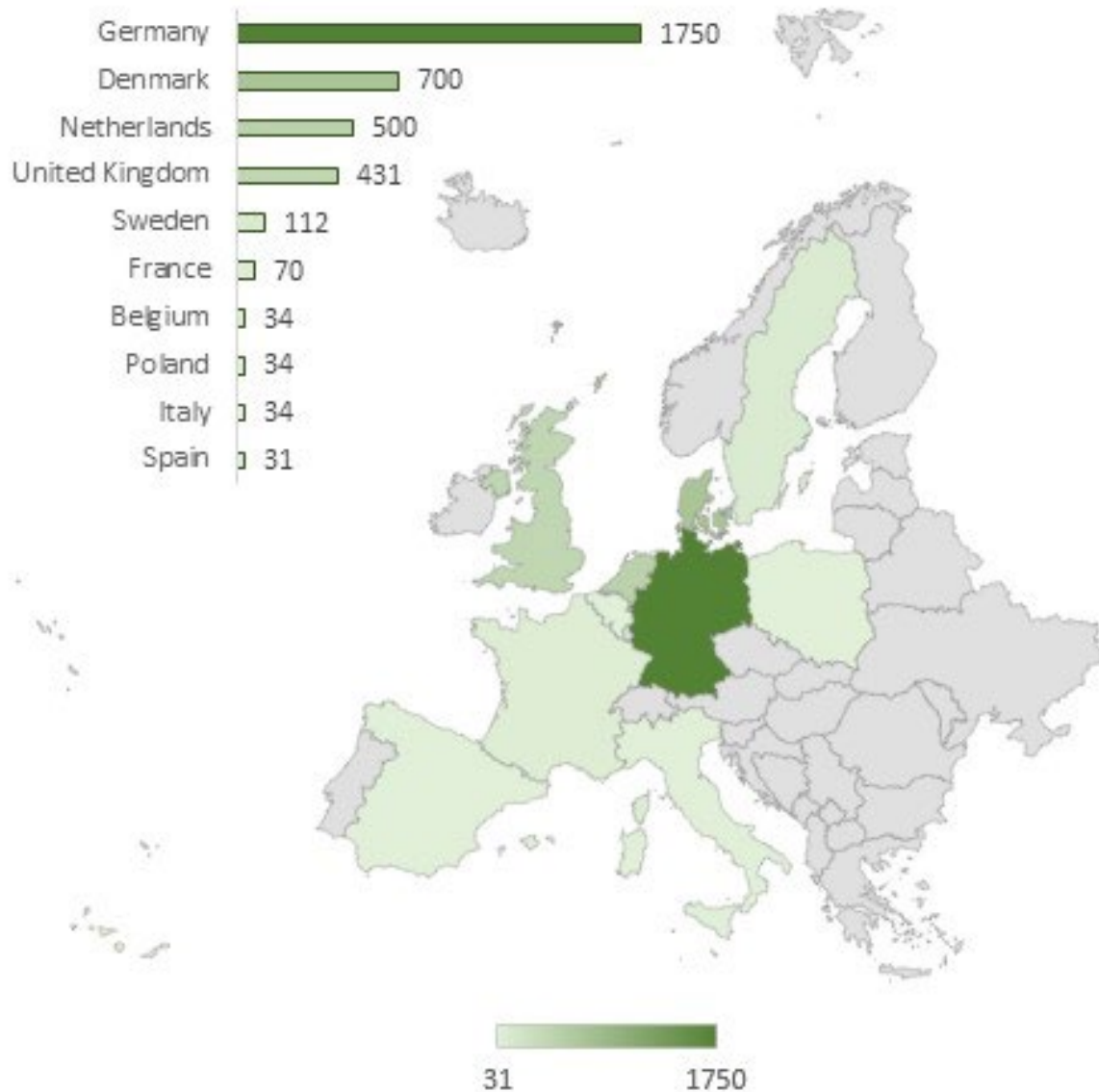
In Europe there are currently a significant number of community energy initiatives such as cooperatives, eco-villages, small-scale heating organizations, and other projects led by citizen groups, see Figure 2.

The countries with the most energy community initiatives are in North-Central Europe (Germany, Denmark, the Netherlands, the United Kingdom, Sweden, and France), countries committed to climate change (Reckien et al., 2018).

The statistics on this are not accurate. The EU-funded project called COMETS will investigate collective action initiatives (CAI) evolution and contribution in the energy transition efforts at

EU and national level in several countries: Spain, Norway, Italy, Belgium, Denmark, Estonia, Netherlands and Poland. (Curli B. et al., 2020)

Figure 2. Initiatives of energy communities in Europe. Own elaboration from: (REScoop MECISE, 2019, Hewitt Richard J. et al., 2019).



2.3 The legal framework of the main countries

The member states have adopted or are in the process of adopting regulatory measures with respect to energy communities, among the main countries it is important to highlight:

Germany is the European country with the most energy community initiatives, since 1990 the first wind cooperatives emerged and the Feed in Tariffs (FiTs) were introduced (Enzensberger et al., 2003), solar cooperatives began in 2005. The Renewable Energy Law (EEG) establishes energy community initiatives with at least ten natural persons who are voting members, in which at least 51% of the voting rights are held by natural persons residing in the project location. The government is considering introducing investment subsidies to reduce barriers to participation (Tounquet et al., 2019). However, representativeness and diversity

are insufficient, and the new generation is keen to participate in climate action (Radtke et al., 2021).

There is a long historic tradition for cooperative ownership in the Danish energy sector. Wind power plants owners must offer 20% shares to nearby residents, including the right to buy up to 50 shares for citizens living within 4.5 km of the project, therefore citizen participation is seen strengthened (Ronne et al., 2019).

The Netherlands in 2015 created a regulatory sandbox for Energy Cooperatives and Associations, who can operate in the electricity sector and must be based on renewable energies. 80% of the participants must be private final consumers. It is possible to operate a local microgrid for households, obtain an exemption from the electricity supply license requirement and special grid tariffs for a maximum period of 10 years, according to the Dutch Experimentation Decree of 2015. All members must be connected to the same medium or low voltage network of the system operator to which the request refers, and they have a deadline-period of 6 months after the concession to connect (Hannoset et al., 2019). The formation of these energy community initiatives relies heavily on citizen leadership, so policies aimed at increasing the number of community initiatives should target small groups and individuals with leadership potential, who could lead projects and explore synergies with broader community benefits (Ghorbani et al., 2020).

In the UK, the Office of Gas and Electricity Markets (Ofgem) introduced regulatory sandboxes that allow innovators to test new products, services and business models. Examples of sandboxes awarded include a test from Chase Community Solar, a community benefit society that has installed solar panels on homes owned by the Cannock Chase District Council; and peer-to-peer trading using blockchain technology backed by Repowering London, a community benefit society (Ofgem). In 1997 first wind coop established, in 2010 FiT and Renewable Heat Incentive (RHI) were introduced.

In France in 2001 FiT were introduced and first wind coops were established, increasing the new projects in 2016 (Dreyfus et al., 2018). The French Law on energy and climate of November 8, 2019 introduced the concept of "Renewable Energy Communities" that can produce, store, sell, and share renewable energy. They can operate in both the heating and electricity sectors if they are based on renewable energies. The main focus of the Law is collective self-consumption (Dreyfus et al., 2022).

The Spanish legal framework copies the rights, privileges and responsibilities of the EU directives for renewable energy and citizen communities. Subsequently, the Ministry of Ecological Transition introduced the concept of renewable energy community in Royal Decree-law 23/2020, of 23th June, which approved measures in the field of energy and in other areas for economic reactivation, by amending several articles of Law 24/2013, of December 26th, on the Electricity Sector (IDAE). Royal Decree 244/2019 completed Royal Decree Law 15/2018, expanding individual self-consumption to a group of people. A self-consumption installation can now be in more than one dwelling and surplus energy can be shared with nearby consumers located in other buildings or injected into the grid.

3. Result & Discussion

3.1 Success stories

Some initiatives of energy communities with different activities and objectives are shown in Figure 3.

Edinburgh Community Solar Limited, was created in 2013 in the United Kingdom. It currently has 683 members. Its main activities are the generation and supply of renewable electricity. The renewable technology used is solar energy, with a capacity of 2 MW and 1.5GWh generated per year. Its main objectives are help to deliver low-carbon initiatives for buildings that host their panels, as well as help other community groups that wish to tackle fuel poverty or reduce carbon emissions (Edinburgh Community Solar Co-operative).

Durzaam Ameland, was created in 2007 in Netherlands. Its main activities are the generation and supply of renewable energy, distribution (smart distribution network, derogation), energy efficiency (green lighting, school vision light system), public lighting, electro-mobility (public transport, gas and electric buses). The renewable technology is multiple: solar, smart energy grid, sustainable lighting, fuel cells, hybrid heat pumps, combined heat and power (CHP), hydrogen, and a natural gas filling station, with a capacity of 6 MW and a total production of 14.7 GWh. The main objective is to ensure that the island can largely meet its own energy needs in a sustainable way (Sustainable Ameland).

Som Mobilitat was created in 2016 in Spain. Its main activity is the electro-mobility. The main objective is the transition towards more sustainable mobility, accelerating local sustainable mobility, and reducing spending on individual mobility (Som Mobiliat).

3.2 Activities and types of renewable energies

Community energy initiatives expand their range of energy activities and services, from renewable energy generation to investments in electromobility services. Normally, small energy communities are linked to the generation of electricity from renewable sources. However, an increasing number of energy communities have taken on new roles as providers of energy and energy services (Caramizaru et al., 2020). Table 2 shows a summary of the main activities.

Table 2: Main activities of the energy communities (Caramizaru et al., 2020)

Activities	Target	Self-Consumption	Renewable Source
Generation	Sale of energy	No	Solar-wind power, hydro
Supply	Generate electricity and gas for sale, purchase or auction in the electricity markets	No	Solar-wind power, hydro, biomass etc.
Consumption and sharing	Produce electricity / heating for the community	Yes	Solar-wind power, hydro, biomass, geothermal etc.
Distribution	Ownership and/or management of community-managed distribution networks, such as local electricity networks or small-scale district heating and (bio)gas networks	No	Solar-wind power, hydro, biomass etc. (Ownership or management)

Electro-mobility	Operation and management of car sharing, car-pooling and/or charging stations	Yes	Solar-wind power
Other activities	Consulting services to develop initiatives CE	-	-

Figure 3. Edinburgh Community Solar Limited (1), Durzaam Ameland (2), Som Mobilitat (3). Own elaboration from: (Edinburgh Community Solar Co-operative, Sustainable Ameland, Som Mobiliat).



3.3 Guide to project an energy community

The following key points constitute a basic reference to project an energy community.

1. Analysis of the regulatory framework. Although European legislation incorporates directives about energy communities, the location of the project (and, therefore, the country) may include regulatory measures of various kinds such as financial, administrative, etc. In general, it is important to know:
 - Rights, privileges. and responsibilities
 - Regulatory requirements
 - Support programs and policies
 - Meet and lean on other successful communities
2. Selection of the type of energy community. Members should consider the goals and scope of the community to determine:
 - REC or CEC?
 - Activities to develop
3. Members: Among the members of the community there must be a governance framework for decision-making that allows the relationship with other partners, local authorities and others. Consider:
 - Voluntary participation of all members defining individual responsibility.
 - Include members with technical, financial and resource knowledge
 - Define structure in decision-making, normally by consensus of all members
4. Selection of the type or types of renewable energy: The type of projects will depend on the existing potential of the renewable resource as well as the different types of final consumption (electrification, heating, etc.). For example:
 - The study of the wind resource shows a high potential in the location. What would be the optimal location? Are the regulatory measures of the wind sector complied with?
 - The study of the solar resource shows a high potential in the location. What would be the optimal location? Is there space for its installation?

It should be noted that the study of optimal technologies must be carried out by experts in the field through a technical-economic analysis of the project.
5. Financing: Financing is a key point in the existence of the energy community, determine:
 - Ability of members to contribute to the community.
 - Existence of available external sources, whether public or private
6. Benefits: Determine the distribution of benefits either economically, socially or environmentally:
 - Economic: the income obtained in a community energy project can be distributed in different ways: based on the percentage of ownership, targeting vulnerable people (reduction in energy bills), investing in the community itself that benefits all residents local.
 - Social: creation of local employment opportunities, provision of education and technical training etc.

4 Conclusions

Climate change requires urgent measures, and the energy transition is the only way to reduce CO₂ emissions. The EU puts citizens at the heart of the energy transformation, giving energy ownership through energy communities.

Energy communities bring benefits to members and the wider community, being them economic, social and environmental: increases community value, creates new job opportunities, lower energy bills, increased awareness of climate issues and energy, promotes a culture of cooperation, creates energy independence and security of local supply, energy production with zero emissions, increases the share of renewable energy, reduces air pollution, among others.

Prior to the adoption of the Clean Energy for All Europeans Package, support from legislative frameworks for citizens and communities wishing to invest in energy projects was practically nil. The new EU legislation must be regulated in the member states to promote the creation of energy communities and integrate them into their energy systems.

The proposal for the creation of an energy community shows the six key points that must be taken into account in the decision-making process of its projection.

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Communication aligned with the Sustainable Development Objectives

