The potential of quinoa in Bolivia’s bioeconomy
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1. Introduction

This paper presents emerging findings from ongoing work in Latin America from SEI’s Bioeconomy Pathways Initiative. It discusses the quinoa biomass value web in Bolivia – its products and its commercial, financial and knowledge connections, then looks at challenges and ways forward for a sustainable quinoa sector in Bolivia.

The bioeconomy is a “social and complex societal transformation process” (Global Bioeconomy Summit 2018, p.2), in which the economy is based on the production, utilization and conservation of renewable biological resources (McCormick and Kautto 2013; Global Bioeconomy Summit 2018). Bioeconomy promotes further processing of biomass to include a range of agro-industrial and value-added products, including the use of agricultural waste and by-products (Raimondo et al. 2018). The concept of bioeconomy has emerged as a strategy to achieve sustainable development, including its economic, environmental, and social aspects (Bauer 2018; Gawel et al. 2019) although some scholars argue that the concept of bioeconomy was not automatically sustainable (Pfau et al. 2014). Only if certain criteria and practices such as the sustainability of the resource base, or a circular processes for material flows are met, one could assume that the concept of bioeconomy is also sustainable (Gawel et al. 2019).

Bolivia has potential to develop a bioeconomy due to its biocapacity. Bolivia’s biocapacity (the capacity of ecosystems to regenerate what people demand from its surface) is 12.6 global hectares, one of the highest in the world and almost three times larger than its ecological footprint (Global Footprint Network 2019). Bolivia also has a great biodiversity, and it is one of the twelfth most biodiverse countries in the world (Butler 2016). Despite a reduced expenditure in research and development within its national innovation system, there is still bioeconomy potential for biomass-based production and transformation, including biofuels and biomaterials (Ponce and Carrillo 2017). Until now, Bolivia’s bioeconomy of value-added basic products has mostly been developed for the food industry (8.7% of total Bolivian exports between 2010-2015 were from the food industry, higher than the regional average of 5.8%), silviculture and paper industry, and bioenergy (Rodríguez et al. 2017). Value-added basic products are those with some degree of processing, based from bio-based primary sectors (Rodríguez et al. 2017).

Quinoa is one of the seven priority crops in Bolivia, due to its potential to contribute to rural development. Bolivia is the second largest producer of quinoa in the world after Peru, with 67 000 tons produced in 2017 (FAO 2019). This is an increase of 94% compared with 2013, the International Year of Quinoa. However, productivity remains low at 600 kg per hectare in 2017, particularly if compared with Peru, which in the same year produced 1200 kg/ha (FAO 2019). In the altiplano, where quinoa grows, it is the main commercial and export crop, and therefore of utmost importance for the 70 000 smallholder farmers who cultivate it in smallholdings of between one and six hectares. Quinoa exports have on average made up 46% of the total production between 2010 and 2017 (MDRyT 2019), shipped mainly to the US (50%), France (8%), the Netherlands (7%) and Germany (5%) (IBCE 2018). Bolivia has also the greatest biodiversity of quinoa worldwide, with 6721 of the 16 422 quinoa accessions (Rojas et al. 2013). Quinoa is a versatile crop, with uses in the food industry, but also in the cosmetic and pharmaceutical industries. However, only 9% of the total quinoa biomass in Bolivia is transformed into other products, while the rest is commercialized as bulk seeds (CABOLQUI 2014).

The Bolivian government is promoting quinoa production through policy and regulation. A national policy was published in 2009 to promote quinoa as a productive crop (MDRyT 2009), and a national strategy to complement the policy was also published in 2010 (MDRyT 2010). In 2011, a law declared the production, industrialization, and commercialization of quinoa in domestic and international markets as a priority (Asamblea Legislativa 2011). The 2010 strategy also recognized the need for the involvement of research institutions, such as the Agriculture and Forestry Innovation Institute (INIAF), and more recently of the International Quinoa Centre (CIQ) (established by Law N° 395 in 2013) for the development of the quinoa sub-sector. The
government is particularly promoting quinoa real, an endemic white variety of quinoa which grows only in southern Bolivia and whose seeds are high in saponins and bigger than other varieties. Saponins are obtained as a sub-product of the beneficiado process but are currently mainly a waste stream. A regulating council for the designation of origin for quinoa real was established in 2013, and is currently pursuing the designation of origin status with the World Intellectual Property Organization (EFE 2019).

In this paper we explore the potential of quinoa in Bolivia’s bioeconomy. In section 2 we identify current and potential quinoa biomass uses in Bolivia, using the value web approach (see Virchow et al. 2016). Then we assess which key stakeholders and which relationships or links exist among them, and which are important for generating and diffusing new knowledge and innovations in the quinoa sector (See Lundvall 2010). Our assessment is based on the concept of the national innovation system, which highlights the need to understand the learning capacity, the financial support, and the businesses that generate and exchange knowledge in a particular context (Lundvall 2010; Scheiterle et al. 2018). We used the participatory Net-Map tool (See Schiffer 2007) to identify who was involved in the quinoa value web and how the actors are linked with each other, with an emphasis on commercial, financial and knowledge connections. In addition to a literature review, we carried out 14 interviews between October 2018 and April 2019 with Bolivian companies, experts, governmental and research institutions, and with the Chojñacota community in La Paz.

Section 3 discusses the challenges for the bioeconomy within the links explored in section 2, and in section 4 we draw some conclusions.

2. The quinoa biomass value web in Bolivia

Products and actors

The biomass-based value web approach captures the diversity of products that are derived from one biomass source, in this case the quinoa crop. It also identifies the different value chains, as well as the synergies among them, and can help to explore potential recycling and cascading processes (Virchow et al. 2016). The quinoa biomass value web in Bolivia is illustrated in Figure 1. Three categories of bioeconomy value-added products were used to group the diversity of goods obtained from quinoa (See Table 1):

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic products</td>
<td>Bio-based products directly derived from primary sectors (e.g. agriculture and agroindustry products; fishing, aquaculture and derived products; forestry and wood industry products)</td>
</tr>
<tr>
<td>Value-added basic products</td>
<td>Bio-based products with some degree of processing (e.g. products from the food industry; wood pulp and paper; natural fibres textiles and leather; biodiesel; bioethanol and other alcohols; solid bioenergy)</td>
</tr>
<tr>
<td>High value-added products</td>
<td>Bio-based products from manufacture sectors (e.g. bio-based chemicals; bio-based pharmaceuticals; bioplastics; bio-based cosmetics and perfumes)</td>
</tr>
</tbody>
</table>

The value web shows that Bolivia is currently producing bioeconomy products in the three categories in Table 1. The main bioeconomy “basic products” are the quinoa seeds and the saponins. Because quinoa is a cash crop, most of the seeds harvested are commercialized. Whereas the share of self-consumption and commercialization depends on each farmer, in Chojñacota farmers consume on average two or three of every 10 quintals (1 quintal is 46 kg) of the quinoa seeds they produce. After harvested and de-branned, seeds for commercial use go through an industrial process known as
In this process seeds are peeled, cleaned, and washed to free them from saponins, a chemical with a similar nature to soap found mainly in the husk that generates a bitter taste. One of the industrial interviewees mentioned that only 1% of their produced saponins is returned to farmers, who add it to their compost and then used as an organic fertilizer. After the beneficiado, quinoa seeds are selected based on colour and size, separating them in two main groups: those intended for export (mainly big, white, and with organic certification and traceability) and those for the domestic market. Around 90% of the total quinoa seeds are commercialized as seeds in bulk (CABOLOQUI 2014).

Beyond the seeds, other biomass from the quinoa plant is also used by farmers. These uses can also be categorized as “basic products”, and include fertilizer, from composting the leaves and stems; food and feed from the green leaves; and livestock feed from the bran (a sub-product of the artisanal de-branning process).

In the “value-added basic products” category, all the products identified are produced by the food industry from the seeds only, and after the beneficiado processing. These products include intermediate products, such as quinoa flakes and extruded seeds; and final products such as ready meals. One sub-product, quinoa protein concentrate, obtained from transforming a quinoa drink into instant powder, is currently commercialized as an input for breadmaking. A potential product for this category is natural food colourings, which could be obtained from the betacyanins from the red quinoa’s panicle and seeds.

Finally, in the high value-added products category, saponins are currently used mainly in the domestic cosmetic industry to produce toothpastes, shampoos, detergents, and cosmetics. One of our interviewees also mentioned that a small share (around a fifth) of their saponins is currently exported to the French cosmetic company L’Oréa to produce skincare products.

Figure 1. Quinoa biomass flows in the quinoa value web in Bolivia.

Source: Authors’ data.
with the rest of the saponins discarded as waste. Potential products in this category include those using quinoa saponins to produce oleanolic acid and nutraceuticals in the pharmaceutical industry, emulsifiers for the food industry, and bio-pesticides and fungicides for agriculture.

The value web approach was also used to identify the institutional components of the Bolivian quinoa innovation system. Table 2 shows the 32 institutions and organizations identified in the quinoa value web, grouped in seven clusters.

### Table 2. Clusters of actors in the quinoa value web. Source: own data. Clusters adapted from Poku et al. 2018.

<table>
<thead>
<tr>
<th>Clusters</th>
<th>Organizations</th>
</tr>
</thead>
</table>
| Development partners/donors | European Union  
DANIDA (Danish Development Organization)  
Sida (Swedish International Development Cooperation Agency)  
SDC (Swiss Agency for Development Cooperation)  
FAO (Food and Agriculture Organization of the United Nations)  
IADB – MIF (Interamerican Development Bank’s Multilateral Investment Fund) |
| Quinoa sub-sector    | Ayllus  
Farmers  
Farmers’ associations  
Beneficiadoras  
Small and medium-scale processors (domestic market)  
Large-scale processors (export market) |
| Industrial end-users | Markets  
Supermarkets  
Food industry  
Cosmetic industry |
| Government agencies  | Ministry of Rural Development (MDRyT)  
International Quinoa Centre (CIQ)  
Ministry of Production (MDPyEP)  
ProBolivia  
Servicio de Desarrollo de Empresas Públicas (SEDEM) |
| Research institutions| PROINPA  
Universidad Mayor de San Andrés (UMSA)  
Chemistry research institute (UMSA – IIQ)  
Agriculture and Forestry Innovation Institute (INIAF) |
| Financial institutions| Shareholders  
Banks |
| Other institutions   | Organic certifiers  
Regulating council for designation of origin  
Input suppliers  
CABOLOUI (Quinoa chamber of commerce)  
Food-product development consultants |

### The commercial links in the value web

As described in Figure 1, the main commercial product in the value web is seeds, therefore most of the commercial links identified correspond to the flow of quinoa seeds. The seeds are produced by farmers in the altiplano, processed in beneficiadoras, and then transformed or commercialized. Specific actors involved vary depending if the quinoa is organic or conventional. If organic, all actors involved need to comply with organic certification standards (e.g. avoidance
of synthetic chemical inputs, physical separation of organic and non-certified inputs and products) for growing, storage, processing, packaging, and shipping.

In Bolivia, quinoa grows mainly in the altiplano, an arid region between 3600 and 4000 meters above sea level with 200 days of frost per year, where quinoa is the main commercial and export crop. Production is distributed between three departments Oruro (42%), Potosí (39%), and La Paz (19%). There are no large-scale commercial quinoa plantations, as most of the land in the altiplano belongs to indigenous or peasant communities and therefore is collective land and can’t be sold (INRA 2012). Production is therefore done in farmers’ smallholdings of on average one hectare in La Paz, and between three and six hectares in Potosí and Oruro. Farmers in the altiplano are generally part of an ayllu, the traditional form of community in the Andes. Beyond the ayllu, quinoa farmers can also be organized in cooperatives, which generally belong to farmer’s associations. However, associativity is still limited, covering only around 20% of all quinoa farmers. The largest farmers’ associations are ANAPQUI (2500 members) and CECAOT (500 members). Because quinoa production is at small-scale its commercialization generally involves several intermediaries, including collectors and traders. Farmers’ associations minimize the use of intermediaries by having an integrated business model, from farmers through to processing companies.

Beneficiadoras companies are crucial for the commercial flows, as they select and classify the seeds (according to size and colour) and separate the saponins from the seeds. Most of the large-scale beneficiado plants (2800 to 3000 TM/year) are part of large processing companies or industrial complexes. Though medium and small-scale plants also exist. Large-scale plants use technology locally developed by the Centro de Producción de Tecnología Sostenible (CPTS), which maximizes the recovery of up to 95% of saponins (CPTS 2019) while reducing consumption of water by 70% and energy by 81% (Gamarra 2016).

After the beneficiado process, more than 90% of quinoa seeds are sold in bulk or in packages for retail markets. According to our interviews, only between 5% and 10% is processed into value-added products (see Figure 1). Processing companies can be focused on the domestic market or on external markets. Most of the conventional quinoa is destined for the domestic market and is processed mainly by small and medium enterprises.

Export-oriented processing companies are generally specialized in organic quinoa. This specialization requires following organic standards, and therefore traceability is required. These companies can establish commercial links with farmers in three ways:

- by purchasing quinoa from members, if buying from an association,
- buying from independent producers, or
- through an agreement with the ayllu.

Interviewees from large-scale companies (not associations) stated a preference to work with independent producers, mainly through loyalty schemes. Working directly with the ayllu was considered as their least preferred option, though it still happens (see Swebol’s example in Box 1). If a company is negotiating with an ayllu, this has to be done with the traditional authority, or tata-maico, a position that rotates annually. Decision-making requires consensus with all ayllu members, agreements can be changed according to circumstances (e.g. they can deliver less quantity if production is lower due to drought), and payments are in cash at the point of exchange.

The main buyers of quinoa seed exports are food companies in the US (50%), France (8%), the Netherlands (7%) and Germany (5%) (IBCE 2018). Between 2010 and 2017 quinoa seed exports made up on average 46% of the total production between 2010 and 2017 (MDRyT 2019). In 2019 an agreement between Bolivia and China was signed, and there are great expectations for this market among farmers and export-oriented processing companies. According to the interviewees,
the external markets prefer white quinoa varieties that have organic certification.

The main buyers of quinoa seeds in the domestic market are wholesale markets and retailers in the food industry, but government purchases are also important, particularly for medium and small-scale companies. The government buys quinoa seeds and value-added basic products (i.e. quinoa flakes, quinoa flour) for three subsidy programmes – prenatal and lactation subsidies, prenatal universal subsidies, and nutritional compliments for the elderly subsidies – that deliver quinoa products to beneficiaries. In 2017 purchases for these subsidies represented around 7% (4600 tons) of the national production of that year. In 2017, the Bolivian government purchased quinoa products from six different companies, including small, medium and large companies, and from cooperatives and associations as well as private companies.

Our interviews identified only two cases where saponins were being exported: from Andean Valley to France for the L’Oréal cosmetic line Kiehl’s, and AGRONAT’s exports of shampoo with quinoa saponins to Peru and Brazil.

**BOX 1. SWEBOL AND CHOJÑACOTA AYLLU**

Swebol Biotech AB S.R.L. is a Bolivian company that emerged from a research collaboration between Lund University (Sweden) and Universidad Mayor San Andrés (Bolivia). Swebol has patented a formula for a quinoa-based beverage, and the quinoa used is supplied by the Chojñacota ayllu in the northern altiplano. The agreement with the ayllu has no formal contract, as the ayllu does not issue an invoice; but prices were agreed beforehand, quantities depended on the annual production, and the payments were in cash upon delivery of the seeds.

**The financial links in the value web**

We found that most of the financial links with the Bolivian public sector were with international cooperation funds, which are mainly project-based. Therefore, the funding and involvement of project partner’s institutions has been restricted to the duration of the interventions. The most stable flows of funding are those from members to associations, from shareholders to their companies, and from the banking sector.

Domestic public funding was expected to support the quinoa national strategy, which includes production, industrialization and commercialization. But no specific budget for the quinoa strategy was identified, and according to the interviewee from the Ministry of Rural Development, the state has mainly concentrated on supporting farming, because quinoa industrialization or transformation into value-added products is limited to only 10% of production. A US$ 22 million national plan for quinoa was announced in April 2019, which will include domestic public co-funding, with financial support mainly from the International Fund for Agricultural Development (IFAD). No current financial support was identified for industrializing or transforming quinoa into value-added products. In previous years, the Ministry of Production had a project funded by the European Commission and administered by ProBolivia, which established a two-year (2012–2013) grant fund for micro and small enterprises, to co-finance processing plants for value-added products. The recipient projects included plants for quinoa beverages and biopesticides derived from quinoa husk (ProBolivia 2015). According to our interviews, these plants were not yet operational. The financial support for the commercialization was identified by most interviewees as limited, though partial funding (20–30% of the costs) from the chancellor’s office for participation in international food fairs was mentioned.

Among private actors, quinoa processors’ financial links are mainly with companies’ shareholders and commercial banking, though they have also received support from international cooperation.
For example, CABOLQUI, the Bolivian Chamber of Commerce of Quinoa Exporters (with 11 members representing 70% of quinoa seed exports) received funding from the Interamerican Development Bank’s Multilateral Investment Fund, for a project to improve sustainable production and traceability (FOMIN 2014).

**The knowledge and information links in the value web**

In the quinoa sub-sector in Bolivia innovation for value-added products has been limited, as is shown in its market share. Knowledge and information links among actors in the value web are crucial for knowledge generation and innovation.

In the food industry, our interviewees identified Andean Valley as a leader in terms of value-added product development. Most of the largest processing companies work with their own product development units, or consultants. The links between the food industry and research institutions are still limited, although two cases are exceptions. One is PROINPA, a non-profit research institute, which has also been identified by the food industry as leader in generating and sharing knowledge on quinoa biodiversity and its potential uses in different industries. The other was Swebol, which is a company set up as a result of a research collaboration (See Box 1).

For the high value-added products, knowledge is being generated in universities, in particular the chemistry research institute (IIQ) of the UMSA, which is currently working on the use of saponins for bio-pesticides. Though its links with the chemical industry is still limited, innovation in the development of machinery has also been identified, to adjust machinery to work appropriately in high altitude conditions.

Despite quinoa being a versatile crop with uses in various industries, in Bolivia the quinoa value web is mainly concentrated in commercializing seeds in bulk after the beneficiado process for export. The support for developing basic and high value-added products is currently very limited, with almost no financial public support, and with severe limitations in knowledge and information exchange among different actors.

### 3. Challenges for the bioeconomy in the quinoa value web

This section discusses the challenges and opportunities in the quinoa value web in Bolivia in terms of the development of the bioeconomy, including its economic, environmental, and social aspects.

**Commercial challenges**

Current developments in value-added products from quinoa in Bolivia have happened mainly in the food industry, though these are still marginal, utilize less than 10% of national production, and concentrate on the use of the seeds only. Though due to Bolivia’s quinoa biodiversity, there is potential to develop other uses for quinoa in the food industry and beyond. The further development of basic value-added products could provide an opportunity for use of those seeds that do not comply with current export market requirements (mainly using white, large varieties like quinoa real). In addition, residual quinoa biomass (stems and husks represent 71% of the total quinoa plant biomass) could also be used to produce thermal energy and replace fossil fuels (Salgado et al. 2018). Further development of high value-added products would also make use of saponins that are currently discarded and other chemicals that are underused.

Whereas policies highlight the importance of both domestic and external markets, some of the new policy instruments are encouraging commercial measures targeting mainly external markets. These measures, however, can threaten sustainability of the value web. For example, the
recently announced national plan promotes quinoa real, and organic certification (see CIQ 2019; COPROFAM 2019); and the government is pursuing an internationally recognized denomination of origin for quinoa real. Whereas these policies are responding to domestic demands, no consideration has been made for the potential impacts on biodiversity of promoting mainly one of the varieties of quinoa. For example, the external markets preference for quinoa real and other types of white quinoa have resulted in the loss of other varieties in different farmer communities. Farmer interviewees mentioned that today they only produce white quinoa, as it is the one that could be sold, whereas the other colour varieties are being “lost” because they are less commercial. Replacing varieties or other native crops, such as cañahua, for quinoa real has also been done for commercial purposes (see Meldrum et al. 2018). This can support more diversified livelihoods, but could also reduce capacity to adapt to climate change (Meldrum et al. 2018).

The promotion of organic certification, which guarantees access to external markets with better prices, is also changing environmentally sustainable cropping practices. According to our interviewees, those with a commitment to organic certification standards tend to prefer monoculture instead of having quinoa within a rotating crops system. Crop rotation is considered to be sustainable agricultural practices, so the transition towards monoculture could reduce the sustainability of the crop. Preference for monoculture can be partially explained because farmers are avoiding potential cross-contamination with synthetic chemical inputs from traditional quinoa rotation crops (e.g. potatoes), which may not necessarily be part of a certified organic value chain. Avoiding cross-contamination is important, as it can affect the ability to commercialize the quinoa into organic value chains.

The increase in quinoa production for commercial purposes can also threaten sustainability if the whole landscape is not considered. For example, the expansion of quinoa areas from 58,000 hectares in 2010 to 110,000 hectares in 2017 has happened mainly in the southern altiplano plains, causing use of the land to change from grazing areas for camelids to quinoa production, and increasing soil erosion (IRD 2011; Jacobsen 2011; Gandarillas et al. 2013; Kerssen 2015). Given the nature of current land ownership in the altiplano, further expansion may also happen in the remaining grazing areas owned by traditional communities. Considering the landscape in an ecosystem as fragile as the altiplano is crucial for a sustainable bioeconomy.

**Financing challenges**

There were limited funding flows for most of the actors engaged in the value web. Domestic public funding has mainly supported farming practices. Whereas the concentration of funding flows on the primary production is justified by the current status of the value web (concentrated on selling seeds), the diversification of markets through an increase of value-added products can be also highly relevant for farmers. According to the quinoa national strategy, further domestic financial support will also concentrate on farmers, with credit lines and insurance mechanisms.

Interviewees also mentioned that there are no public incentives for the development of value-added products, partially because the industrial leaders are mainly private companies and the current government’s position is concentrated in supporting farmers and farmers’ association companies, and not the private sector. However, whether or not they are developed by farmers’ association companies or private companies, a wider diversity of value-added products would require more diverse sources of funding. A bigger role for the public sector could also contribute to this process through public procurement of value-added products.

The lack of domestic public funding increases the relative importance of international cooperation, which could support the commercialization of quinoa value web products. However, international cooperation is retreating from Bolivia as it becomes a middle-income country (e.g. SDC will only be active in Bolivia until December 2019, and DANIDA ceased activities in 2018). Interviewees mentioned the reduced support experienced by sub-national chambers of commerce, who have been historically dependent on cooperation funds (e.g. DANIDA, SIDA, SDC).
Knowledge challenges

We found that information and knowledge exchange was limited among stakeholders in the value web. Most of the innovations in terms of value-added products in the food industry were produced within the processing companies or with consultants, with limited interactions with other research institutes or universities, or even other public institutions (e.g. INIAF, CIQ). Exchange among processing companies in other industries was not particularly explored, due to the limited development of other products based on quinoa biomass. This limited interaction with research institutes or universities is not exclusive of the quinoa value web: results of an innovation survey at the national level found a similar structure of exchange (See Foronda et al. 2018). More and better knowledge links on the bioeconomy are required between industry and universities or research institutes, so the knowledge generated by them is better utilized.

The CIQ could play a knowledge sharing coordination role, but there is still a need to strengthen the industrialization and commercialization sections of the value web. This could facilitate better knowledge and information exchange between public and private actors.

4. Conclusion

Given the biodiversity of quinoa in Bolivia there is potential to develop a sustainable quinoa bioeconomy, but the sector also faces significant challenges. While the food industry has started to use quinoa seeds for value-added basic products, this activity is still underdeveloped, with less than 10% of total production going beyond the commercialization of quinoa seeds in bulk. Beyond the use of the seeds, only the saponins, residues from the quinoa beneficiado process, have been used by industry, specifically for domestic cosmetics. However, this has also been highly limited to a few cases, with most of the industrial saponins being discarded as waste. In the agrochemical and pharmaceutical industries, the use of saponins is still in the research phase, and it will take some time to reach commercialization, although Bolivia could maximize its comparative advantage of having varieties with high levels of saponins. The use of saponins could contribute to the circular economy component of a sustainable bioeconomy concept, but more research and industrial application is required.

Any increase in the use of quinoa for value-added products will require public and private investment in research and development, as well as better links between industries and research institutions and universities. These links include national policies and funding supporting not only the agricultural production but also the industrialization and commercialization of quinoa. But there is also a need for policies and regulations to ensure that a landscape approach is used to promote sustainable practices, taking into account the environmental limits of land and water resources. Without such an approach, the potential increased support to the quinoa value web in the name of bioeconomy might not necessarily be sustainable, in particular if it only focuses on satisfying economic or commercial ends.
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