



An integration-monitoring approach to the development of sustainable technology and innovation: The case of University Technology Transfer Offices

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ABSTRACT

Using an integration-monitoring theoretical framework, which assesses the alignment of internal and external perspectives along with performance evaluation, this research demonstrates how suitable political, regulatory, and societal contexts, effective stakeholder engagement, and an active role for middle managers (even in the absence of a clear mandate) are essential for embedding sustainable goals in the development and public transfer of sustainable technologies and innovation. The proposed integration-monitoring framework is applied to the case of university Technology Transfer Offices (TTOs) to explore how they can strengthen sustainability-oriented innovation systems. Additionally, it examines the role of TTOs in promoting economic development and commercializing new technologies and innovations while integrating socio-environmental sustainability dimensions. Two university TTOs, one in the USA and one in Spain, were studied using a two-level analysis. This analysis reflects on the understanding and integration of social and environmental sustainability in their activities and evaluates a framework for monitoring their sustainability-oriented efforts. Importantly, this study highlights a fundamental lack of assessment and performance evaluation indicators in the development of sustainable technologies, even in the case of institutions that have fully embraced sustainable innovation goals. The proposed framework and findings from this research can extend beyond the TTO context, providing insights applicable to other organizations tasked with the development and public diffusion of sustainable innovative technologies.

Introduction

Over the past few years, there has been increasing acknowledgment of the importance of sustainable development. The introduction of the Sustainable Development Goals (SDGs) [1] has garnered significant attention from governments, policymakers, researchers, and professionals worldwide, placing sustainable development at the forefront of their agendas [2]. In fact, the development of technologies and innovation for sustainable development has evolved, with a number of sets of themes becoming central and giving the field a definite identity. Of these themes, the most commonly-studied are the development of energy technologies, energy resources, emission reduction and fossil fuels [3,4].

Three key interrelated areas can be identified that allow innovation

for sustainable development: new management practices, new technologies, and new policy approaches. In terms of new technologies, technological innovation can be highly instrumental, especially for the energy sector. However, despite the impact on sustainable development that these technologies can have in different sectors [5,6], there is still a lack of consistent applications for the purposes of assessing the economic, environmental and social performance applied to different types of technologies [6,7] and the inclusion of performance evaluation perspectives with which to develop a better understanding of how technology and innovation can generate profit as well as positively impact society [8,9].

The evaluation of new technologies has concentrated mainly on technical, economic and environmental aspects [10–14], leaving aside more social aspects, such as social acceptance [15], heritage

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conservation [16], or the positive impact on the quality of life of the beneficiaries. However, some positive experiences have shown the importance of addressing technological, commercial, organizational, and societal innovation uncertainties [17,18]. For instance, [19] shows that a combined strategy of responsible ownership and sustainable technology commercialization strengthens the focus on the SDGs. Likewise, [20] demonstrates that value chain design that works for those at the bottom of the pyramid meets social needs, creates new social relationships, and can maximize the adoption of long-term green solutions; [21] integrate sustainability factors into technology diffusion models; and [22] demonstrates the viability of a combination of technosocio-enviro-economic parameters for the assessment of integrated renewable energy systems. Nevertheless, these experiences are particular to the cases being designed, making it difficult to extend them to different types of innovations and technological developments. For this reason, and building on the experiences discussed, this study will focus on exploring the roles of organizational (internal managerial), external relational (stakeholders), and performance assessment processes that contribute to the successful development of innovative sustainable technologies [8]. While conducted within the context of University Technology Transfer Offices, the findings are applicable to any technology bureau responsible for the development and public diffusion of sustainable innovations, including energy and other technologies.

The innovation system approach offers an avenue for linking new technologies and sustainability [23]. The concept provides a suitable analytical framework for understanding the implications of transitioning from an economy-oriented paradigm to one that is sustainability-oriented. The traditional innovation systems approach involves actors that transform research activities into useful processes, products, and services [24]. The fundamental principle underlying innovation systems is that innovation is a relational, interactive and cumulative process that requires alliances between producers and users [25]. Therefore, universities possess immense potential in fostering such alliances within this context.

Universities, as centers of knowledge and innovation, have a crucial role to play in promoting sustainability through their traditional core activities of research, education, and outreach [26]. The challenge of sustainability has led to the expansion of these traditional missions [27] and the establishment of different collaboration mechanisms to manage their innovation ecosystems, [28] leading universities to partner with government, industry, and civil society in order to drive sustainable transformation. Sustainable innovation studies suggest that these alliances and different mechanisms [29–31] help improve innovation outcomes and positively impact the development of sustainable innovation [32–34].

In summary, universities are change agents for sustainability-oriented innovation systems in different cultures and contexts [35]. In this study, we focus on the economic development and commercialization missions [34] carried out by Technology Transfer Offices (TTOs), which should facilitate the transition of sustainable technologies from academic research to broader societal use. These university units are suitable for the study of sustainable technology and innovation from the early stages and from the perspective of sustainability-oriented innovation systems. We found little empirical work in the context of systems-level innovation [8,36], especially at the institutional level. Consequently, a proper theoretical view of TTOs as central actors who not only promote technological diffusion but also embed socio-environmental goals influencing the sustainable development of technologies is still lacking and this is why this study has an exploratory nature and is conducted using an inductive/deductive approach. A micro-foundational approach is required to further elucidate sustainable innovation initiatives [8]. For these reasons, we propose an integration-monitoring framework to enhance sustainable assessment practices within the innovation landscape within TTOs. That can be broadly applied not only to one particular sector.

Our framework aims to explore and assess sustainable technology

from both a practical and institutional perspective. By highlighting TTOs as pivotal players in technology commercialization and sustainable development, we hope to demonstrate how institutional practices and assessments can strengthen sustainability-focused technological advancements. This framework is valid not only in the context of TTOs but also for all institutions interested in promoting sustainability.

The paper is organized as follows: Firstly, we present the literature on Sustainability-oriented innovation systems and Sustainable Innovation. Secondly, we explain the methodology and the techniques used in the analysis. Thirdly, we present the results of our study. Finally, we discuss the results and offer some conclusions and propose some future research.

Literature review

The mainstream study of innovation for environmental and social benefit is nascent, yet it has grown rapidly [36]. Given the multidisciplinary nature of sustainability and innovation processes, different approaches and constructs have been proposed for their conceptualization and operation [8,37]. Fig. 1 shows a summary of some of the main concepts proposed by the literature to conceptualize and operationalize sustainability and innovation processes. This study is based on the approaches of sustainability-oriented innovation systems and sustainable innovation.

Sustainability-oriented innovation systems

Altenburg & Pegels [25] introduced the concept of Sustainability-oriented innovation systems as “*networks of institutions which create, import, modify and diffuse new technologies that help to reduce environmental impacts and resource intensity to a level commensurate with the earth’s carrying capacity*”. Sustainability-oriented innovation systems incorporate the principles of sustainable development into the traditional concept of innovation systems. Several key characteristics distinguish sustainability-oriented innovation systems from traditional innovation systems. These include a focus on sustainability challenges, a participatory approach that involves multiple stakeholders, a systemic perspective that considers the interactions between different actors, and a long-term perspective that considers the social, economic, and environmental dimensions of sustainability.

Sustainability-oriented innovation systems have mainly been explored in the context of businesses and recognized as sustainability-oriented innovation (SOI) [36]. Hansen et al. [38] define SOI as “the introduction of a new or improved product or service that leads to environmental and/or social benefits over the prior version’s life cycle”. SOI has gained significant attention in recent years, with several studies analyzing SOI at the small and medium-sized enterprise level, at the sectoral level and at national level [39]. Lessons learned from SOI literature are twofold; firstly, there is a link between individual-level managerial values of universalism and the organizational-level phenomena of sustainability-oriented exploration and diversification [40]; and secondly, SOI activities and practices can be identified in the context of operational optimization, organizational transformation and systems building [36].

The presence of strong leadership, effective communication among stakeholders, the availability of financial resources, and the presence of supportive institutional frameworks can contribute to the development of sustainability-oriented innovation systems. Moreover, these systems also require the development of new governance structures that enable collaboration and coordination among stakeholders, as well as the creation of new knowledge and technology transfer mechanisms. Universities are the institutions that can fulfill this new role as ‘transformative institutions’ engaged in co-creating social, technical and environmental transformations [27]. Within universities, the TTOs are mainly responsible for this transformative role and this is the reason why they are the foci of this study.

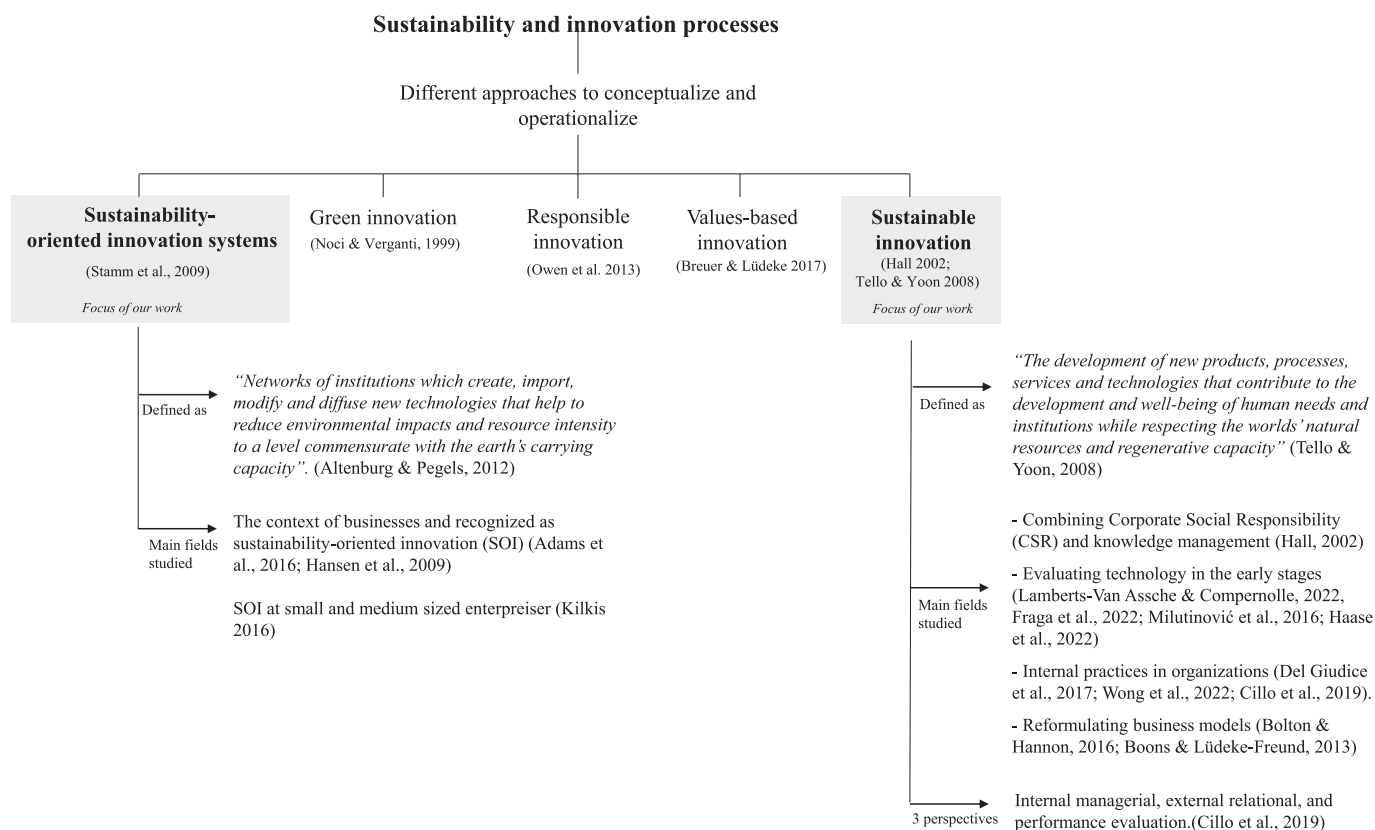


Fig. 1. Literature framework. Approaches to conceptualizing sustainability-oriented innovation systems.

Sustainable innovation

The concept of sustainable innovation can be defined as “the development of new products, processes, services and technologies that contribute to the development and well-being of human needs and institutions while respecting the world’s natural resources and regenerative capacity” [41]. It explores not only technological and environmental considerations but also the dynamics of social change [42]. Specifically, extant literature has focused on Corporate Social Responsibility (CSR) and knowledge management. These two topics are combined, with an emphasis on the energy sector, in order to incorporate more sustainable corporate practices and this increases the need for the combination of internal and external knowledge in the generation of sustainable innovations.

Some recent studies focus on evaluating technology in the early stages. In Lamberts-Van Assche and Comperolle [43], this is done by developing practical guidance to implement techno-economic assessments for carbon capture and utilization technologies including economic and environmental indicators. Another study on a similar topic is by Fraga et al. [44], in which a cost-benefit analysis of sustainable drainage systems was developed following the principles of low impact development. However, these proposals concentrated mainly on the environmental impact of the outcomes and less on social benefits. Measuring sustainability and quantifying the social dimension of sustainability are difficult tasks [45]. Several challenges can arise from such multifaceted sustainability requirements [46].

Other studies that emerge from the scientific literature have explored the role of internal practices in organizations. New managerial and organizational capabilities are required to innovate for sustainability purposes [47]. Therefore, recent studies have focused on exploring specific practices and perceptions within organizations. For example, Wong et al. [48] studied employees working in the oil and gas industry to understand their perceptions about the technologies needed and carbon policies in the transition to net-zero energy. However, there is

still a lack of fundamental evidence about the factors that enable sustainable practices [8].

Sustainable innovation can be studied from three major perspectives [8]: internal managerial, external relational, and performance evaluation. The internal-managerial perspective analyzes strategies, practices, structures, resources, capabilities and processes to support environmental and social aims in innovation. The external-relational perspective focuses on organizations as embedded in a broader context related to regulatory and social governance as well as value chains and socio-technical regimes. The performance evaluation perspective attempts to go beyond traditional financial performance measures and to develop a better understanding of how innovation can produce profit as well as positively affect society.

Universities, especially TTOs, exhibit organizational dynamics and behaviors similar to businesses and can be studied from the same three major perspectives: internal managerial, external relational, and performance evaluation [8].

Sustainability-oriented innovation is closely linked to the broader concept of sustainable innovation, and for this reason they can be treated as similar concepts. Both refer to the development of innovations that contribute to sustainability in general. They encompass a broad range of innovations that have the potential to reduce negative environmental impacts, enhance social equity and inclusion, and support economic growth and development. On the other hand, sustainability-oriented innovation systems refer to the institutional frameworks, financing mechanisms, policies, and processes that support the development, transfer mechanisms and diffusion of sustainability-oriented innovation and sustainable innovation-

Technology transfer offices oriented to sustainable development

The technology transfer process involves the dissemination or absorption of novel technologies, applicable knowledge, or the outcomes

of their implementation, which culminate in the creation of new products, processes, or services. This multifaceted process engages a variety of participants, including industries, individuals, institutions, and other entities, all playing critical roles in the diffusion of technology [49,50]. The nature of the technology being transferred—whether tangible elements, such as products and hardware, or intangible, like knowledge and software—varies according to the application's nature and purpose, thereby influencing the transfer's flow and objectives, shaped by the goals of the interacting parties [51].

Various models of technology transfer have been developed, the efficacy of which is measured by tangible outputs, like new products or patents, and intangible results, such as enhanced capabilities, underscoring the dynamic and outcome-oriented nature of technology transfer [50,51].

The potential to harness technology transfer as a tool for sustainable development is evident in the need to design strategies that address global challenges related to sustainability. TTOs can effectively support the role of the university as a transformative institution within their sustainability-oriented innovation systems [27,50], especially promoting sustainable innovation from R&D. Although the role played by technology transfer in the promotion of sustainable development has been widely dealt with in the literature [50,52], studies on how TTOs encourage sustainability in their transfer processes are limited. Studies focus on understanding the institutional effects of TTOs on university social responsibility [49] and the impact of TTOs in influencing sustainable development in their context [53] or in a particular sector [54,55]. Moreover, Sieg et al. [56] introduce some sustainable development principles addressed by innovation support programs implemented by a TTO.

Based on the revised extant literature, this research proposes an integration-monitoring framework that offer a unique approach to evaluate TTOs in terms of their contributions to sustainable technologies and innovations. By incorporating internal, external, and performance-evaluation perspectives, we assess how effectively these entities can meet socio-environmental sustainability goals in their different contexts.

Methods

This study used an exploratory approach to assess the extent to which TTOs' activities align with socio-environmental sustainability goals. We used a qualitative and inductive/deductive approach, which was operationalized through the case study research strategy. By using this approach, the authors sought to generate findings through evidence-based research [57–59].

The methodological strategy followed has been as shown in this section: 1) case selection strategy, 2) data collection, 3) data analysis.

Case selection strategy

Two universities were selected as our case studies due to their extensive research experience and recognition as agents of change within their respective contexts. Their geopolitical environments also play a significant role in shaping their specific strategies. They provide two transparent, observable and complementary examples of the phenomenon under study. They were selected based on the following criteria:

- (i) They constitute suitable institutions to explore the proposed research questions;
- (ii) They have well-structured Technology Transfer Offices (TTOs) that belong to the main university's innovation office/function
- (iii) They are located in geopolitical contexts that would shape their particular strategies; and
- (iv) They are top-tier institutions in their own context.

A brief description of the selected universities is shown in (Appendix

A). Our findings are that there is no differentiation in the treatment of technologies on the basis of their area of application in either TTO. For example, technologies related to the energy sector are treated the same as those related to the health sector.

Data collection

Our case studies are structured around research questions that utilize qualitative evidence obtained through two distinct data-collection techniques: (i) the collection and analysis of strategic and organizational documents, websites, newsletters, etc. and (ii) in-depth interviews with persons responsible for making decisions in the TTOs. The data collection process was approved by the Ethics Committee of the leading research institution conducting this study.

A thorough review of documentation related to the organization of the centers was conducted, with the aim of understanding the nature of their work, the different tasks they undertake, and their main sources of funding, among other things. Relevant documents were found on the web in both English and Spanish. The collection and analysis of documents was instrumental in triangulating the interviews.

In-depth interviews were carried out with innovation managers at the selected TTOs [60], especially at the operational level, i.e., coordinator, head of department, innovation and commercialization manager, technology licensing manager. The main selection criteria for interviewees were that they were in a leadership position and had more than 5 years of experience. Six interviews were conducted: 4 with women and 2 with men. The interviews were conducted during 2022, both in person and virtually using the Microsoft Teams applications. They lasted around 40 and 60 min, and were audio recorded with prior permission and assurance of confidentiality. Audio data were carefully transcribed word-for-word by a professional transcriber for subsequent analysis.

Two pilot interviews were conducted with innovation experts so as to guarantee the reliability of the interview questions. The feedback from the pilot interviews assisted the research team in optimizing the final interview questions. The main selection criteria for interviewees were that they were in a leadership position within their respective TTOs and had more than 5 years of experience. During the interviews, what was discussed were questions covering the main purpose of the unit, the expected outcomes, stakeholder identification, the socio-environmental challenges and the activities developed around different social and environmental issues.

Data analysis

The analysis of the documents and interviews was inspired by the approach used by Cillo [8]. Three perspectives were considered for the purposes of exploring how TTOs are currently integrating and monitoring socio- and environmental sustainability: internal managerial, external relational, and performance evaluation. A list of variables was defined to analyze the data collected from the documentation review and the in-depth interviews.

The documents and interviews were analyzed on the basis of the variables mentioned above (Table 1). The research team further verified the quality of text data. The transcripts were analyzed using the NVivo (released in March 2022) [61]. A combination of inductive and deductive reasoning approaches was employed. The analysis began with a deductive coding system using the elements of the literature review and the interview guide while creating additional new nodes inductively from emerging interview data [62,63].

Results

In this section, a detailed discussion of the main results of the current study are provided.

Table 1
Perspectives, themes and variables analyzed.

Perspectives	Definition	Themes	Variables
Internal Managerial	Characteristics, strategies and practices for managing innovation activities	Unit purpose and main outcomes	Organizational structure Unit function Products/outcomes Manager profile Perception and concerns concerning environmental and social dimensions
External Relational	Way the unit collaborates and engages with stakeholders regarding socio-environmental dimensions	Stakeholder engagement and socio-environmental issues	Stakeholder identification Stakeholder engagement (practices, activities and mechanisms) Origin of actions
Performance Evaluation	How the unit reports its results	Reporting unit results	Indicators used Reporting impacts Benefits

Purpose of TTOs and consideration of environmental and social dimensions

The first theme discusses how the TTO understands itself and its position in relation to the social and environmental dimensions of sustainability. The main results are summarized in Table 2.

The **TTO at University A (TTO-A)** is responsible for intellectual property protection, review and support. The main unit aims to commercialize academic inventions from the university all around the world. It recognizes itself as a service for allowing Principal Investigators (PIs), including graduate students and faculty, to gain experience in commercialization.

Some of the most important functions of this unit are:

- Determination of the commercial potential and evaluation of the novelty of technologies
- Assessment of the possibility of capturing intellectual property and finding a market
- Definition of the type of intellectual property to use
- Promotion of intellectual property in the university
- Search for companies to take inventions developed within the university and develop them into products
- Assist PIs in obtaining access to reagents and materials outside the university
- Fulfillment of all the government compliance and reports related to grants and intellectual property, as well as report what is agreed

Table 2
Summary of purpose and main outcomes of TTOs.

TTO-A	TTO-B
Aims to commercialize academic inventions from the university to the world Considers that socio-environmental impacts are NOT criteria with which to evaluate viability or impact of a technology Understands that ethical and environmental considerations are specific to regulatory issues in knowledge areas (e.g. biology)	Promotes and facilitates R&D with a perspective of use in society Is actively concerned for a positive socio-environmental impact of technology and a policy of diversity and inclusion Ensures that innovation is socially and environmentally responsible in order to maximize use of public resources Considers ethical considerations of high concern and manages them by a University Ethics Committee Transfers research results properly so as to ensure viability of a business model (rather than over-reliance on openness)

upon when the university accepts money from foundations or any other organization.

Unlike other TTOs, this focuses on marketing. Its work is supported by other offices, such as the Office of Sponsor Programs that is in charge of receiving the specific requirements from private companies needed to work directly with a researcher through a contract.

Regarding the consideration of environmental and social dimensions, the main interest of this unit is to determine the commercial potential of inventions and discoveries, and focus on the commercialization of what the faculty are inventing, so they can equally encourage and support all technologies.

Some areas of knowledge offer more opportunity to focus on environmental sustainability; however, the environmental impact is not one of the criteria for the assessment of the viability of a technology. If the technology is good for the environment, that is a bonus which would cause people to embrace it even more. As one of our interviewees (EA2) argued: *...we don't currently have the focus on sustainability, but we don't penalize it either.*

With respect to other social aspects, the university encourages diversity, inclusion and other issues related to social sustainability. But specifically, TTO-A does not work on or develop programs to support or engage any particular kind of invention, technology or stakeholder. Recruitment processes do not focus specifically on diversity and inclusion either. Although that is not necessarily a priority, there are people in the TTO who would like it to be, as reported by one of our interviewees (EA1): *That's what should have been happening. Right? Because, again, we have a funnel issue. If we're not getting those exposures from female scientists. Right? We probably should be more vocal about it. And it's something we want to do and we're conscious.*

The unit is concerned about the negative effect that open access practices could have on both the quality of publications and patentability. The worry is that people are publishing more often, more quickly and without rigorous peer review. Another of the reflections noted from the interviews highlights an ethical issue. In general, there are regulations in each area of knowledge, although these are more defined for certain areas, such as biology, but not in others, such as computer science.

This TTO's main concern about the incorporation of sustainability-related criteria into their work is the fear that if they only focus on addressing sustainability, it could be merely subjective. Taken to an extreme, this focus would be a disservice to society because universities would not be commercializing publicly-funded research.

The mission of the **TTO at University B (TTO-B)** is to promote and facilitate R&D from the perspective of use. Its main objective is to have research results transferred and used by society, companies or institutions. This unit has two sections. The first is responsible for generating matches between companies and institutions with researchers (promotion). The second function is the protection and exploitation of results (transfer). Its most important functions are:

- Identification of innovation "challenges" and interests of companies, and public and private institutions
- Mapping companies with R&D resources
- Search for researchers who can contribute to the identified challenges
- Marketing of the technological offerings of the university
- Study the university's internal R&D offerings: projects, researchers, etc.
- Facilitating of relationships between researchers, companies and other institutions
- Management of protection and industrial protection rights
- Analysis and valorization of research results
- Assessment of innovation results and determination of the most appropriate type of protection: patents, software, knowhow, registrations, creation of start-ups, etc.

- Licensing of industrial and intellectual property assets
- Definition of the most convenient business or financing of model for internal developments
- Training of researchers in business generation, intellectual property, grant applications and investment search
- Reviewal of contracts and confidentiality agreements
- Promotion of the creation of start-ups based on research results

TTO-B is supported by an institutional innovation program that aims to connect all university services and units involved with companies. It has been operating as an independent unit for 5–6 years and was previously part of the Innovation, Research and Technology Transfer Support Unit. This latter office was responsible not only for technology transfer activities but also for research management, including grants, projects, contracts with companies, and consulting.

As regards the consideration of environmental and social dimensions, according to the member of this TTO, innovation must be responsible, making the very most of the knowledge from the resources received by the university, which are mainly public, as illustrated by one of our interviewees (E08): ... *the university is using public resources, the public wants these public resources to be used to generate knowledge that helps to solve things paid for by taxes.*

The environment is a dimension that is increasingly being incorporated into innovation. However, it relies on the discretion of the researchers. As concerns the social dimension in innovation, there is an awareness that it is mandatory to think about the value chain and involve intermediate and end users. The TTO is concerned about how to approach and incorporate social innovation. However, at a technical level, any type of innovation result that comes along is encouraged. There is no policy that mandates favoring or financing a particular group or knowledge area.

The University Ethics Committee is the body in charge of managing ethical issues. However, the reputation of the institution is important and if there is a possibility that this reputation could be damaged, the person in charge will act in favor of the university, without the need for an explicit policy.

One of the apparent concerns raised is the proper transfer of research results to ensure that valuable outcomes are able to generate a viable sustainable business model. There is a growing concern regarding the over-idealization of openness and its actual impact.

Stakeholder engagement in socio-environmental issues

The second theme analyzes the actions that the TTOs perform to engage stakeholders and contribute to sustainable development [64–66] (Table 3). We identify the stakeholders associated with the TTOs and discuss the social and environmental issues that the TTOs address with them.

In **TTO-A**, there is constant engagement and interaction with different stakeholders develops in multiple ways. Although different methods are used to reach out to them, it is generally a passive process.

Table 3
Summary of stakeholder engagement and socio-environmental issues.

TTO-A	TTO-B
Stakeholders do not need to be committed to sustainability or SDG goals There are no active programs on diversity and inclusion Focus on environmental impact depends on knowledge area (e.g., physical sciences) Any concerted action toward environmental and social goals is mainly a response to “major forces” (e.g., federal grants)	Stakeholder mapping is a common activity Promotion of interdisciplinary research to address social-environmental issues Concern regarding local development context Internal policies that benefit diversity and inclusion (in particular participation of women or end-users) . Use of public funds requires that the outcomes do not cause harm to the environment or people

Connections emerge from a structured base or program, evolve more organically, or emerge as stakeholders reach out to the unit with demands.

Stakeholders are generally defined as internal or external. Internal stakeholders include faculty, staff, students, people on the campus, and other offices in the university, and external stakeholders are mainly partners, such as companies, and other tech transfer offices.

Stakeholders involved in the activities of the TTOs are also classified as interested parties and supporters. The first group refers to those parties involved in intellectual property agreements. These are mainly graduate students and faculty, clinicians, outside companies, and other institutions and organizations. This stakeholder network depends on how broadly the faculty choose to collaborate with others. The second group are those supporting the activities of the TTOs. They can be other offices in the university, such as the Conflict-of-Interest Office or Sponsored Research Office, agencies in the region, venture capital firms, The Leading Association in Technology Transfer AUTM and peers in other tech transfer offices with whom the faculty have collaborated on projects.

As far as stakeholders and sustainability are concerned, TTO-A does not make a point of looking for partners dedicated to sustainability, rather they are looking for partners that want to support, move forward and have good relationships with the investigators. However, some initiatives involving stakeholders and sustainability were identified (Table 4).

As regards the social dimension, TTO-A is not actively working on or developing programs to promote diversity or inclusion. However, some projects require the support of an ethics committee to ensure the inclusion of patients from different backgrounds. Even so, in some particular cases they work harder to ensure that people from under-represented backgrounds have an opportunity to be involved and awarded. Additionally, they encourage women to participate in some grants whose purpose is to promote women in science.

Table 4
Actions carried out by TTO-A to address socio-environmental issues.

Issues	Stakeholders involved	Practices and Actions	Origin
Diversity and inclusion	Patients Underrepresented backgrounds	Ethics committees Increase visibility: Ensure their presence in awards and recognitions	Federal funds Internal
	Women	Encourage women to participate in funding opportunities for women	Financier: Foundations or sponsors
Education	Undergraduate students	Provide talks about biomedical innovations, technology transfer, etc.	University program
Openness	Faculty	Support groups that develop open-source software or code	Federal grants
Environmental impact	University partners	Generate agreements with innovations aimed at better use of resources, care for the environment	Area of knowledge (physical science)
	Faculty	Support applications for grants that inquire into the sustainability of a proposal.	Funder

Furthermore, some members participate in talks with undergraduate students about biomedical innovations, technology transfer, etc. when it is required by another University office or program. In terms of openness, TTO-A supports those groups that develop open-source software or code when it is required by federal grants.

The focus on the environmental impact depends, in some cases, on the area of knowledge. For instance, physical sciences are more likely to focus on green energy and sustainable technologies. This is different than in the life sciences, where questions specifically addressing sustainability are not being asked. However, there are some grants that inquire into the environmental sustainability of a proposal, and in this case the unit supports these faculties.

In summary, the actions identified are driven primarily in response to two “major forces”: (1) the push by federal agencies to incorporate some ethical issues for diversity impact, thus widening the scope of innovation, and (2) the fact that companies that involved in innovation understand the value of diversity.

On the other hand, stakeholder mapping is a common activity at TTO-B, and among the most important stakeholders are the researchers. This unit studies the projects that researchers are working on, as well as the R&D activities of the university. Companies are also important stakeholders, and the unit identifies them by searching for those that have received funds for innovation development, as well as by defining sectors of interest and contacting companies directly to raise funds as needed. Furthermore, sometimes it is the companies that approach the university. Relationships are maintained with all types of companies, with an attitude of ‘the more the better’, as reported by one of our interviewees (EB3): *Because we believe that everyone fits into this theme of innovation.*

Other stakeholders that complement the work carried out by TTO-B include university spin-offs, hospitals, patient associations and technological institutes. Yet another group of stakeholders is the supporters, including other transfer offices when research is performed in collaboration with other universities, consulting firms that assist with contacting companies and accessing public procurement of innovation, the local city council, the defense sector, the local innovation agency, local business associations and other research institutes of the university.

When working with external stakeholders, one of the most important challenges for TTO-B is to reach co-ownership agreements with other universities in different contexts, as some cultural differences can reduce protection opportunities.

In terms of sustainability, the section that is considered to have the greatest impact on social and environmental aspects is that of promotion, because this section has the capacity to define key sectors of interest, such as health or the environment. As in TTO-A, the transfer section receives the final results and gives the same priority to all of them without considering the characteristics associated with the people with whom contact is made.

To address socio-environmental challenges, TTO-B promotes interdisciplinarity as one of the mechanisms by which more diverse solutions may be obtained (Table 5). Therefore, the TTO favors a forum in which researchers from different disciplines face the same “challenge”.

From the social dimension, TTO-B is committed to the local context and is concerned about local industry. Therefore, it favors the creation of start-ups and encourages innovation development to remain at the local or national level in order to increase the absorption capacity of local industry.

As regards diversity and inclusion, especially gender equality, the internal goal is to maintain a gender balance, both in terms of the staff and the events it organizes. As for the promotion of innovation, TTO-B has a joint program with the health sector in which an additional 5 % is granted to proposals that include the gender perspective, have balanced teams and two female PIs. Likewise, when projects include end users, such as companies, patients, or citizens, through the use of specific tasks and from the early stages, they receive a better score.

In education, TTO-B works together with other units of the university

Table 5
Actions carried out by TTO-B to address socio-environmental issues.

Issues	Stakeholders involved	Practices and Actions	Origin
Interdisciplinarity	Researchers	Encourages conversation between different research groups in the construction of solutions to challenges posed by companies	Internal
Local commitment	Local productive sector	Encourages transactions with neighboring companies and institutions	Internal
	Local business sector	Supports the generation of local technology-based companies	Internal
	Small businesses	Promotes collaboration in innovation projects	Funders
Gender equality	Women	Ensures the presence of women at our own events	Internal
	Research with a gender perspective	Evaluation criterion grants an additional 5 % to research that:Includes the gender perspective (when applicable)Uses gender-balanced teams (60–40)Leads by two females PIs	Internal and joint program with hospitals
Education	Students	Actively participates in training programs	Internal
Opening	Researchers	Actively participates in the design of new ways of assessing outreach activities	Internal
Collective engagement	Researchers, citizens and end users	Provides a better evaluation of projects that include end users with specific tasks and from the early stages	Internal
Ethics	Companies	Modifies and defines the use of certain technology (when necessary)	Internal
Environmental impact	Companies and researchers	Hosts matching events with companies that work in environmental issues, e.g., circular economy	Internal
	Researchers	Declares that no harm will be caused to the environment or people	Public funding

to participate in training or outreach actions when necessary. Additionally, the unit supports the university in the design of new ways of valuing outreach activities performed by researchers.

In terms of ethical issues, the Ethics Committee ensures good practices in the field of research. However, if necessary, the unit adjusts the terms of a license; for instance, the unit has modified and defined the use of certain technology to prevent its use as an instrument to cause harm. Although there is no explicit policy formulated, the person responsible watches over the reputation of the institution.

With regard to the environmental dimension, for several years public

funding has required a declaration that the results of the research will not cause harm either to the environment or people. This is done through a checklist or general questions asked of the researchers. Likewise, some of the “Matching events” carried out have been aimed at working specifically on environmental issues, such as the circular economy.

On the whole, the university’s thematic lines can be prioritized through TTO-B. However, the actions mentioned are mostly driven by the requirements of funders, especially those from Europe.

Reporting the results and impact of TTOs

The third theme provides a summary of the mechanisms used in the TTOs to define their impact and report or monitor their activities relating to the social and environmental dimensions (Table 6).

According to the members of **TTO-A**, the main impact of the office is twofold. Firstly, they are working to get technologies out the door and make an impact in the world. Secondly, since there is not enough funding from the federal government, they find partners to move technologies forward. Among the main results of the office, the following are highlighted:

- Generation of income through the commercialization of academic inventions
- Creation of a bridge between academic discoveries and the marketplace
- Increase in the competitive advantage of the U.S. economy
- Facilitation of the PI’s further research and access to resources
- Development of academic inventions into products
- Finding partners to act as PIs

One key point is that **TTO-A** does not focus on revenue. The university is primarily looking to create economic development impact.

In terms of reporting, the results of **TTO-A** are measured primarily through a set of metrics promoted by AUTM. These metrics include the number of inventions, the disclosures, the patents that have been successfully prosecuted, the start-ups formed and the agreements negotiated. Although the unit has an internal scorecard, it does not currently have any sustainability-related questions focused on measuring the social or environmental impact.

In the case of **TTO-B**, some of the main results and benefits of the office are:

- Establishment of formal relationships with companies and institutions through collaborative R&D projects, consulting services, doctoral theses, graduate theses, training courses, postgraduate training, internships, etc.
- Generation of direct connections with different agents in the environment: companies, clinicians, innovation managers in public administrations, etc.
- Creation of start-ups
- Development of a public search engine tool for the purposes of accessing knowledge at the university: projects, spin-offs, patents, research lines, publications, doctoral theses, etc.
- Development of a website for the exchange of needs and expressions of interest

- Generation of revenue through licensing and other commercialization agreements
- Hosting of matching events to make connections between the needs of companies and the R&D on offer at the university
- Connection between the work of researchers and the specific needs of companies
- Obtaining of resources to increase the Technology Readiness Levels (TRLs) of research results
- Provision of financing for start-ups
- Provision of financing for preparatory actions and other grants for innovation projects
- Generation of research indicators and preparation of annual research reports

One of the major outcomes for **TTO-B** is the generation of connections; however, it is difficult to measure this in terms of KPIs. The **TTO** does not have sustainability-related indicators in its performance evaluation assessment. For this reason, the unit is working on other ways of measuring the impact and results of activities that go beyond the traditional methods. For instance, it plans to study the social impact of one of its programs within the health sector with the support of a social sciences institute at the university. It is also actively participating in the design of other means of assessing the research and innovation activities of researchers.

TTO-B presents indicators linked to the university’s innovation activity for the purposes of reporting the results; for instance, the number of patents filed and approved, the number of patent licenses, the software licenses, the income generated by collaboration with companies, etc. Furthermore, **TTO-B** has designed some indicators for internal control, such as, the number of matching events between companies and researchers, etc. Additionally, **TTO-B** collects and reports all university research indicators beyond its activity through annual reports.

Discussion and conclusions

Several important considerations can be derived from the findings of this study. Firstly, it demonstrates an evident alignment of values underpinning sustainability and issues developed by the **TTOs** being studied, which support the role of universities as transformative institutions [27] to fulfill their mission of promoting sustainable technology and innovation. Several socio-environmental issues addressed by the **TTOs** have been identified, but there are still clear opportunities for improvement, such as capturing the impacts of their interventions in the outcomes, technology assessments, and innovation results of the **TTOs**. Furthermore, this study shows that the integration-monitoring approach decomposed in the internal managerial, external relational and performance evaluation perspectives is an effective method with which to understand the development of sustainability-oriented innovations in specific organizational settings and applicable to other offices responsible for promoting sustainable development, as will be summarized next.

In terms of an *internal managerial perspective*, both universities are aware of sustainability and sustainable goals and accept them as desirable outcomes. For example, in University A, SDGs represent something to aspire to even though active programs are being developed in order to, at least partially, achieve these goals (e.g., diversity and inclusion) and are mainly driven by middle managers. In University B, these goals are institutionalized, that is, integrated into the managerial structure of the organization (e.g., innovations cannot be socio-environmentally detrimental) and driven top-down at the managerial level. The reason for this difference is the political and social context in which they operate; **TTO-A** operates in a context in which sustainable innovation is a desirable goal, but it is not institutionalized either in the mission or in the processes of the organization.

In terms of the *external relational perspective*, it is possible to reflect on the alignment of existing practices and what is needed for the further

Table 6
Reporting results of **TTOs**.

TTO-A	TTO-B
Performance metrics do NOT include sustainability-related assessment items	Performance metrics do NOT include sustainability-related assessment items yet, but the unit is working on other ways to measure the impact and results of activities beyond the traditional methods

integration of socio-environmental issues. At University A, the TTO is more reactive to the industry demands and regulations than to the socio-environmental impact. In contrast, there is a greater commitment to gender equity at University B and a greater synchronization between the priorities of the region, the local priorities, the university, and the TTO itself. Similar to the previous case, the explanation for this difference can be understood in terms of the socio-political context in which TTO-A and TTO-B operate. In the first case, industry regulations are institutionalized, while the socio-environmental impact is not. This is the opposite situation in the second case, which demands, as found, a greater commitment to sustainable and societally-oriented goals.

As far as the *performance evaluation perspective* is concerned, no measures were found for monitoring actions related to the socio-environmental dimensions in either of the two cases. This is particularly surprising in the case of University B, at which the internal managerial outcomes are attuned to sustainable goals. Still, this is consistent with the review of the extant literature, which suggests that the development of measures for socially desirable outcomes is still under debate [9].

The role of middle-managers

This research sheds light on the key role of middle-managers in driving sustainability-related goals both when objectives are still in the development stage (e.g., by actively focusing on women in University A) or by enforcing intended goals when they are already embedded in the organizations' norms and processes (e.g., explicitly avoiding the use of some technologies to cause harm to the environment or people in University B).

The findings here widely confirm the importance of middle-level managers, institutional support, and mechanisms for capturing impact as necessary components to accelerate the transition of a university to a transformative institution with an active role in implementing sustainable development. In this sense, partnering with other institutions that work with stakeholders or on challenges they are interested in supporting is a good opportunity. Furthermore, policies at the institutional level require close monitoring and active involvement.

From the interviews, it becomes clear that middle-level managers have a significant role in linking top managers' initiatives and organizational strategies into real practices. The interviews consistently described them as highly proactive, committed to an issue that interests or concerns them, and willing to connect with others.

From this perspective, it is also possible to discuss how work agendas are defined. Organizational and individual factors have consequences for internal agendas and outcomes. The first case (University A) reflects an agenda directly related to the objective of each unit, open to individuals and institutions inside and outside the university, and driven primarily by funders or sponsors. In the second case (University B), the university has the power to set an agenda, but it is driven by sustainability and European Union policies. It is also highly influenced by the local ecosystem.

The role of universities and their associations

The TTOs in question operate within their respective university contexts, which in turn operate in governmental, private and social environments. For this reason, the TTO in University A differs greatly from that in University B in terms of sustainability goals, stakeholder engagement and expectations with respect to socio-environmental issues. TTO-A is not concerned about sustainability goals, but simply about complying with regulations issued by either the university or government agencies. This stage of organizational change (in this case toward sustainability) has been called "basic" [67]; that is, the organization only meets industry regulations. On the other hand, TTO-B is actively concerned about the positive socio-environmental impact of technology, which reflects the university-favorable political context

toward sustainability. This TTO is in an "engaged" stage of organizational change; that is, the organization is quite aware that sustainability involves far more than compliance [67].

For these TTOs to move toward a change in sustainability, institutional theory suggests that even though it is important that the TTOs change their internal processes, it is even more so that the environment surrounding them should change; that is, the universities in which they operate and the social environment at large must first change so the TTOs will not only strive to obtain resources and satisfy customers but also to obtain institutional legitimacy as well as political power [68]. In this institutional perspective, the environment (the universities and their social contexts) provides an approximate vision of how the organizations (TTOs) should behave to obtain social legitimacy [69].

The previous discussion highlights the important role played by the universities if their internal TTOs, wish to move further into a sustainable model of operation. At the same time, university associations or consortiums, such as the Association of American Universities (AAU) [70], the European University Association (EUA) [71] and the European School of Sustainability Science and Research (ESSSR) [72], also have a role to play in promoting the adoption of policies toward sustainability to their members. At the university level, achieving social legitimacy is also an important goal that will extend to their internal TTOs.

Stakeholder relationships

Formal and informal connections between TTOs and individuals, groups, or entities inside or outside their universities are essential for building and strengthening sustainability-oriented innovation systems. The results suggest that engaging stakeholders effectively allows both TTOs to operate more holistically and with greater accountability.

TTOs can plan how to engage stakeholders strategically in shaping the development of sustainable innovations by fostering collaboration, knowledge sharing, and inclusive decision-making processes. TTOs, either on their own or in partnership with other units within the university, can identify and classify stakeholders according to their sustainability-related goals so that they can effectively contribute to the development of sustainable innovation from different roles and stages of research and innovation. Stakeholder theory proposes numerous ways of identifying and classifying stakeholders that allow them to be managed and connected to different missions of the university [73,74], leading to effective and sustainable outcomes that are supported by the wider community and ecosystem. Ultimately, this also contributes to the wider acceptance of research outcomes.

Political and regulatory context

In terms of the political and regulatory context, University A is within a context based on private financing and has a broad and highly specialized network of stakeholders concerned with positively impacting the economic development of the city and the country. It also has a larger organizational structure which is highly connected (internally or externally); this, in turn, allows the TTOs to be better connected and to have an extensive support network, which permits a greater degree of specialization. In terms of sustainability, there is little emphasis on environmental impact; however, there is a greater awareness of inclusion and diversity. In University B, the emphasis is more on the impact on society. Although this may partly be due to university goals, it is certainly unavoidable due to political and governmental politics and regulations. Its units also have broader objectives since they have more functions. In this case, the influence of both the European context and the SDGs is evident.

Funders hold the primary responsibility for evaluating and funding innovation, and their requirements have had a significant impact on the observed changes. Regulations also play a crucial role in shaping these criteria. For instance, there has been a shift at the European level from funding policies focusing on industrial competitiveness to others that

target societal challenges, which is evident in the alignment of the internal and external policies of University B. It would be worthwhile examining how the policies and mechanisms used by public agencies to finance and support research and innovation affect sustainable innovations.

The need for sustainability –oriented assessment

Moreover, and what constitutes a very important and surprising finding, this study has discovered a surprising lack of sustainability-related assessment items, even in institutions such as University B that have officially embraced and institutionalized sustainability and SDGs. Universities could develop a proposal of possible indicators or a monitoring approach which bears in mind the framework of Responsible Research and Innovation (RRI) [75]. It is important to confirm the potential aspects of assessment before indicator selection for a well-designed monitoring framework; therefore, social and environmental dimensions may be considered along with RRI dimensions. This finding suggests that performance monitoring may constitute the hardest step for institutions, even for those that have fully and formally embraced SDGs.

Research contributions and future research

In conclusion, this study contributes to the sustainable innovation research literature, and more specifically to the study of TTOs, as follows:

- Firstly, using an integration-monitoring theoretical framework, decomposed in the internal managerial, external relational and performance evaluation perspectives, this study explores the role and processes of a little studied unit, the goal of which to promote innovation: Technology Transfer Units (TTOs) in universities.
- By comparing the operations of two TTOs operating in different universities and political-societal contexts, this research finds that the political regulatory and societal context, as well as a proper engagement of stakeholders, are key for the institutionalization of sustainable-oriented goals.
- The key role of middle managers in the operationalization of sustainable-oriented goals, even in the absence of a clear mandate, is made evident.
- This study shows there is a clear need to develop performance evaluation indicators, even in institutions which have fully embraced sustainable innovation goals.

The above results suggest an important research agenda to build

Appendix A

Table A1

Basic features of selected case studies.

	University A	University B
Location	United States	Spain
Type	Public state-related research university	Public
Year founded	1787	1968
Students (2021–2022)	approx. 33,800	approx. 30,700
	Undergraduates: 24,600	Undergraduates: 21,900
	Postgraduates: 9,200	Postgraduates: 7,500
Academic staff (2021–2022)	approx. 14,200 employees	approx. 4,000 employees
	5,700 faculty	2,500 faculty and research associates
	700 research associates	1,500 staff
	7,800 staff	
Budget (2023)	USD 2.470 million	USD 442 million

(continued on next page)

upon. In particular because both the integration-monitoring approach and the findings for this research can be applied to any other institution tasked with the development and public diffusion of sustainable energy technologies and other innovations.

As a future line of research, the results underline the need to compare institutions and cases, not directly, but in the context of their stage of maturity and context (e.g., regulatory, private funding). A framework similar to that developed by [76,77] for RRI is a good example of the development of an approach adapted to social and environmental dimensions at an institutional level.

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CRedit authorship contribution statement

Hannia Gonzalez-Urango: Writing – review & editing, Writing – original draft, Validation, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Enrique Mu:** Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Carmen Corona-Sobrino:** Writing – review & editing, Validation, Software, Investigation, Formal analysis, Data curation.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Hannia Gonzalez-Urango reports financial support was provided by Polytechnic University of Valencia. Hannia Gonzalez-Urango reports a relationship with Polytechnic University of Valencia that includes: employment and funding grants. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Table A1 (continued)

	University A	University B
Academic Ranking	51–100	401–500
Technology Transfer Office (TTO)	Staff: 17 Director/Senior managers: 6	Staff: 7 Director/Senior managers: 3

Source: Institutional archives and Shanghai ranking.

Data availability

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to restrictions i.e. their containing information that could compromise the privacy of research participants.

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