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Article

Between Research and Practice: Experts on Implementing Sustainable Construction

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Abstract: Despite documented political support for energy reduction measures in Switzerland's built environment, as well as high international regard for its construction and research sectors, design practitioners and researchers perceive a diverse set of challenges involved in the implementation of green development solutions. Grounded in Science and Technology Studies (STS), observations drawn from 31 semi-structured qualitative interviews conducted with Swiss building industry experts provide insight into the relationships between designers, researchers and public authorities. A series of examples from the empirical data show how regulatory frictions and the challenges of implementing construction strategies into diverse domestic and international working contexts are ameliorated.

Keywords: energy; construction; architecture; implementation; Switzerland; Science and Technology Studies (STS); stakeholders; experts; sustainability

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1. Introduction

While buildings play a central role in the cumulative effects the built environment has on rising worldwide emissions, it has also been repeatedly shown that the construction and design industries possess significant potential to mitigate the accelerating negative impacts of development through sustainable construction [1–3]. However, the complexity involved in methods of calculation and evaluation has encouraged a primary focus on energy and efficient resource use within much of current operational discourse [4]. Also, the process of attaining projected estimated energy-savings potentials has not always been adequately recognized as non-linear and highly influenced by diverse actors, and therefore often "ambitious targets fail to materialize into comprehensive strategies, effective instruments and transparent results" [5]. Finally, another growing concern indicated in the literature is that the narrower perspectives often associated with technology policy, with its focus on innovation linked to economic stimulation, as well as management policy with its emphasis on calculable losses, strongly shape how the regulation of sustainable development is being formed [6–8].

Within the field of Science and Technology Studies (STS) the design and construction of buildings have been argued as scientific practices, since "science is nothing but a space that obtains authority precisely from and through sporadic negotiations of its flexible and contextually dependent borders and territories" [9]. Subsequently, a central STS critique of sustainable construction implementation has been regarding the lack "appreciation of the social contexts of energy saving action and of the socially situated character of technical knowledge" [10]. Additionally, scholar Elizabeth Shove argues in her article, "Gaps, Barriers and Conceptual Chasms: Theories of Technology Transfer and Energy in Buildings", that notions of technical potential, the discourse of gaps and barriers, as well as the focus on technology transfer often create a problematic "web of taken-for-granted belief strong enough to encapsulate" the wide range of sectors affiliated with the design and management of the built environment and "elastic enough to span countries and continents" [10]. She suggests that by recognizing differing countries possess varied histories linked to alternate temporal patterns of development and actor networks, technological approaches to energy efficiency and the technologies themselves would be better understood as part of "unique socio-commercial" narratives that defy simple strategies of transfer. It is within this STS perspective of situated actor networks that the research presented in this article was formulated to develop a better understanding of the knowledge practices and concerns of Swiss experts linked to the implementation of energy efficiency measures and green development strategies [11,12]. Therefore, in alignment with Shove, it is critical to acknowledge that as an analysis of a single case country—Switzerland, universal claims about the building industries cannot be deduced from the set of interviews presented here. Rather, the aim in this article is to situate aspects of the socio-technical process of sustainable construction within a specific country context through: (1) in-depth interviews with a subset of heterogeneous research and design actors and (2) reflection on expert-reported challenges.

As a research site, Switzerland was chosen primarily because it is well known as a leader in environmental protectionism, but is also highly regarded internationally for its design and construction industries, in addition to housing a number of respected research and teaching institutions. Seen as a linguistic microcosm of Europe, but also recognized as sharing important parallel governance structures with much larger federal states, the overall transparency of the country's system of regulation, meant that all of the experts interviewed perceived to be working under an interconnected regulatory umbrella [13]. Thus, this location provided a unique opportunity to explore expert perceptions of the relationships between energy research, practice, and sustainable construction. Through semi-structured qualitative interviews, 31 experts were asked to reflect on their work in relation to industry trends. From these interviews "snapshots" of the state of sustainable construction implementation from experts working within the Swiss context were developed. Given the small sample size this study is considered as exploratory and intended to gage current trends within the research and professional practices implicated in sustainable construction implementation. Central questions of interest were: What constraints were most explicit to them? What were their concerns, how were they framed and what did this suggest about their working context and expertise? How for example, were regulatory and disciplinary institutions viewed? New types of knowledge integrated? Perceived challenges mediated? Subsequently, the article is structured as follows: after outlining the framework used to shape this research, key terms are defined. Next, relevant aspects of Switzerland are detailed, and an overview of the empirical work is presented. Lastly, findings drawn from the data that show how experts mediate diverse challenges linked to sustainable construction are discussed.

2. The Built Environment as a Socio-Technical Network

Although the spectrum of scholarship referenced as STS presents a variety of argumentation and terminology, all positions argue that artifacts can function as key actors and recognize that a diverse set of drivers both human and nonhuman mutually inform decision making. Primarily grounded in case studies, STS research has demonstrated sophisticated strategies for deconstructing: technical expertise in the tracking of disciplinary history, how knowledge practices function as social institutions, and the underpinnings of philosophical positioning through close observation of actual practices [14–17]. Of particular use in the analysis of socio-technical networks—which in this research centers on the relationships between sustainable construction implementation, research and professional expertise—is the notion of boundary work. Initially, the concept evolved out of the perceived need to establish and maintain scientific legitimacy [18,19]. However, other contemporary theorists alternatively posit that boundary work: functions as the interface "between communities with different views of what constitutes reliable or useful knowledge" [20]; is focused on linking knowledge practices with action [21]; occurs within social worlds not bounded by geography, but rather by the effective limits of communication [22–25]; and lastly operates in concert with "boundary objects" that sit between and facilitate "multiple translations" of meaning across different social worlds [24]. Fujimura's meta-concept of "standardized packages" [26,27] also serves as an "interface between multiple social worlds [28], but effectively scales up the concept of "boundary object" and emphasizes its links to activities of "fact and skill" stabilization rather than destabilization [14,29]. Fujimura's work in particular provided an accessible tool to conceptualize how sustainable construction and the expertise affiliated with it fit into a broader socio-technical landscape of built environment discourse. Specifically, unlike Star and Griesemer's narrower notion of "boundary objects" [30], "standardized packages" pool together several boundary objects such as concepts, technologies, and/or organizations [24]. Thus, the outcome is the production of a "less abstract, less ill-structured, less ambiguous, and less amorphous" workspace that is narrower, but not definitive [31]. For example this concept could be illustrated in diverse scenarios of sustainable construction: (1) as a bundle of technologies that are prescribed by a building standard (e.g., a building R value requirement that necessitates a particular insulation thickness and mechanical ventilation to achieve its performance); (2) by how discrete technologies can be prioritized over others within building subsidy programs (e.g., heat pumps or photo-voltaic panels); (3) by how the calculative assumptions embedded in a software modeling tool shape spatial design outcomes; (4) or how the development of certain building typologies can be encouraged or discouraged through lending practices, architectural competition processes, *etc.* Essentially, within the operational context of this study, this concept helped determine the selection criteria in finding experts to participate in a purposeful qualitative sample [28,32–34] of individuals linked to boundary objects implicated within standardized packages such as, for example boundary organizations which might include research institutions, public authorities or other knowledge transfer groups (See Figure 5) and also opened up the interview pool to include the perspectives of experts involved in planning projects and mobility infrastructure. Additionally, during the interview phase of this research, this concept informed which types of socio-technical relationships were pursued for discussion.

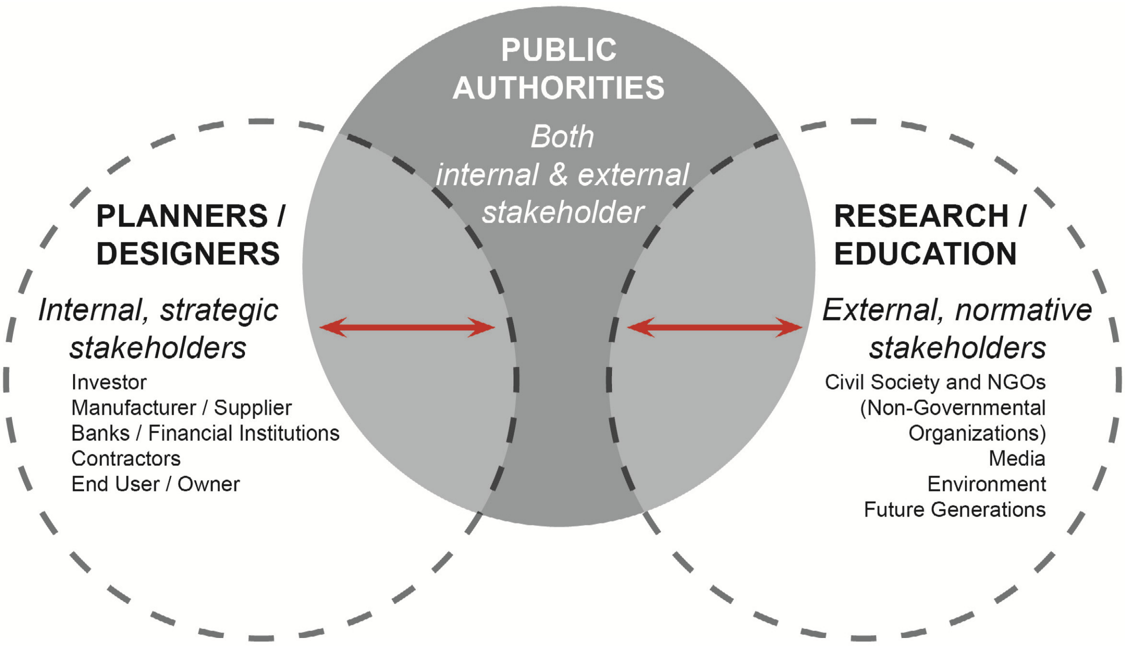
3. Key Terms

Since the terms "stakeholders", "experts and expertise", "sustainable construction", and "drivers and barriers" are frequently referenced, they are briefly outlined to indicate how they were used.

3.1. Stakeholders

The concept of stakeholders and their management references the organization of groups/individuals around specific focal issues, where a smaller group represents much larger groups of individuals [35] and reflects a greater mix of actors [36,37]. Sustainable construction is a suitable example of such a focal point as it is not a topic that is relevant to single individuals and organizations, but is globally important. In addition, critically acknowledged across the literature is that no single group can effectively change common praxis [38]. Rather, harnessing the interest and input of actor networks who are not directly involved in decision making processes but are both impacted and have the potential to impact others is an important aspect of an issue oriented conception of stakeholders [39,40]. According to Feige *et al.* [38], research conducted in the Swiss context has shown that in sustainable construction efforts, key stakeholders fall into three main categories where "internal, strategic stakeholders" are concerned with different phases of the project's life cycle, and "both internal and external stakeholders", as well as "external, normative stakeholders" represent an interest in all phases of a project's life cycle. In this view, "planners/designers" are indicated as functioning in a categorical role of "internal, strategic stakeholders", along with investors, manufacturer/suppliers, banks/financial institutions and end users/owners. "Researchers/educators" are designated as "external, normative stakeholders" beside civil society and non-governmental organizations (NGOs), the media, environmental groups and the interests of future generations. Lastly, this schema recognizes a diverse range of actors involved and creates horizontal links across the categories through the "main concerns" of each grouping such as "regulation", "knowledge", "corporate social responsibility", "economic feasibility", and "personal beliefs" which bridge the categories. Also, a distinction is provided in regard to technology between the interests of "planners/designers" and "researchers/educators", where the former group is focused on its "creative and efficient application", second to "knowledge" and the latter group emphasizes "knowledge", second to "technology" [41]. Experts who fell within the overlapping zones were targeted for interview (Figure 1).

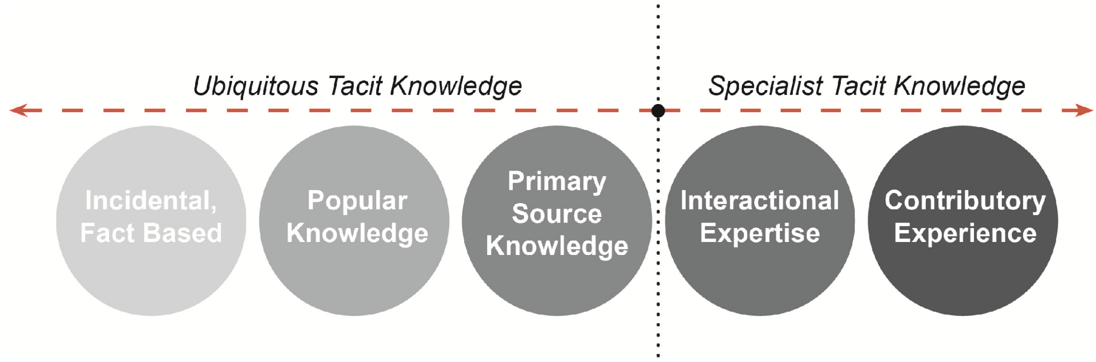
Figure 1. Key stakeholders and stakeholder types from Feige *et al.* [38].



3.2. Experts & Expertise

The term "experts" is not a neutral term that denotes social-cognitive capacities. Rather, "expertise" is explicitly recognized as context dependent knowledge that is social and performative [12,42]. Following STS relational theories, "expertise" references "one's position in a network of other actors rather than a substantive theory of expertise, in which the nature of expertise itself is the object of investigation" [12]. Specialist "expertise" range from individuals who have superficial knowledge of incidental facts to interactional expertise and contributory expertise (Figure 2). Interactional expertise involves specialist tacit knowledge of a subject beyond primary or book knowledge. Although those with interactional expertise would be considered "fluent" in a field, they would not qualify as having contributory expertise, which in this study meant being capable of actually performing design or research work. This notion is supplemented by meta-criteria of external and internal expertise. That is for example, external verification in the form of a professional degree, qualifications or publications and internal criteria such as standing within a professional community. In this study, the experts selected for interview held specialist, tacit knowledge linked to the research, design and implementation of sustainable construction and had externally verifiable qualifications.

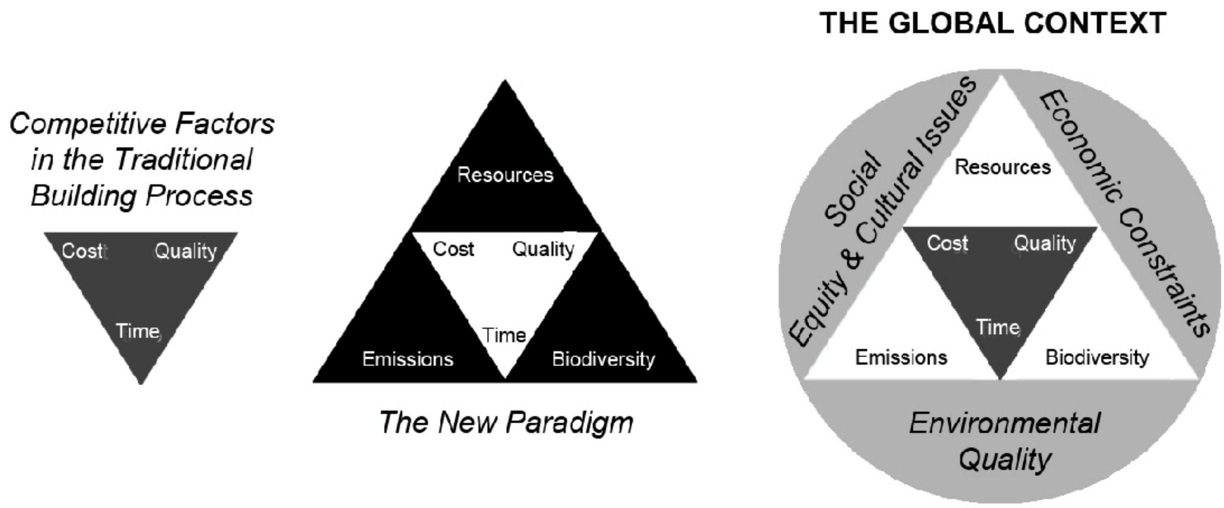
Figure 2. Specialist expertises from Evans and Collins [43].



3.3. Sustainable Construction

Common elements in definitions of sustainable construction have been found to involve energy consumption, reduction, and optimization; conservation of nature; the quality of the built environment and indoor health standards [44,45]. Although all concepts encourage more holistic perspectives, the scope of construction research is understood as explicitly artifact oriented, involving processes that begin prior to construction, though planning and design, construction, use, and eventual demolition [46]. Essentially by linking local building processes to broader, contextual concerns, such as resource protection, the construction agenda has been broadened by sustainability agendas. Critically, research framed by the term "sustainable construction" typically articulates technical concerns as distinct from economic, environmental and social "pillars" primarily referenced in planning focused frameworks, where technical concerns are a subset of economic priorities [44,47]. In relation to the interview sample it was considered an important selection criterion that interviewees were linked to complete or ongoing physical projects. In line with the understanding of experts and expertise, it was assumed that this indicated that interviewees respectively had direct experience in implementation issues (Figure 3).

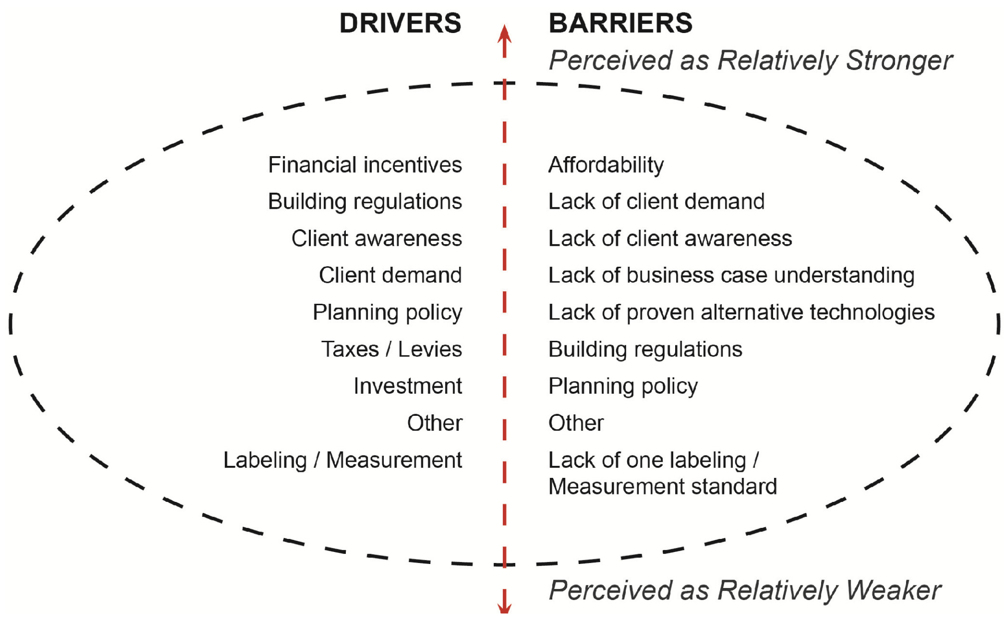
Figure 3. Sustainable construction contextualized from Bourdeau [48].



3.4. Drivers & Barriers

Institutions can take the shape of legislation or organizations that can manifest in habits, traditions and social practices. In the literature both formal and informal institutions have been identified as functioning as barriers to sustainable construction. Typically, the development of rule making is considered a key source of friction within the regulation of issue driven concerns such as sustainable construction, and can be precipitated by a combination of agency fragmentation and informational asymmetries. Informational asymmetries refer to "gaps" in the decision-making processes between key actor groups such as the building and real estate sectors; construction and management; construction and use; in addition to urban-scale planning and building project development [49]. As previously noted in the introduction, the concepts of gaps and barriers like information asymmetries have been argued within STS scholarship as oversimplifications of more complex processes. However, since pervasively used in working practice, it was considered relevant as interviewers to become familiar with these topics in order to recognize them, and subsequently redirect interviewees to focus on issues linked to specific boundary objects, the interaction between them and their experiences with the aim of teasing out possible relationships relevant to the notion of sustainable construction as examples of standardized packages. Drawing from current literature and 83 questionnaires, Pitt *et al.* [50] rank widely reported drivers and barriers of sustainable construction, highlighting which social, institutional and material actors are seen as more or less challenging (Figure 4). Next, relevant details regarding institutional and material actors in the Swiss context are provided.

Figure 4. Perceived Drivers and Barriers to Sustainable Construction from Pitt *et al.* [50].



4. Case Country Switzerland

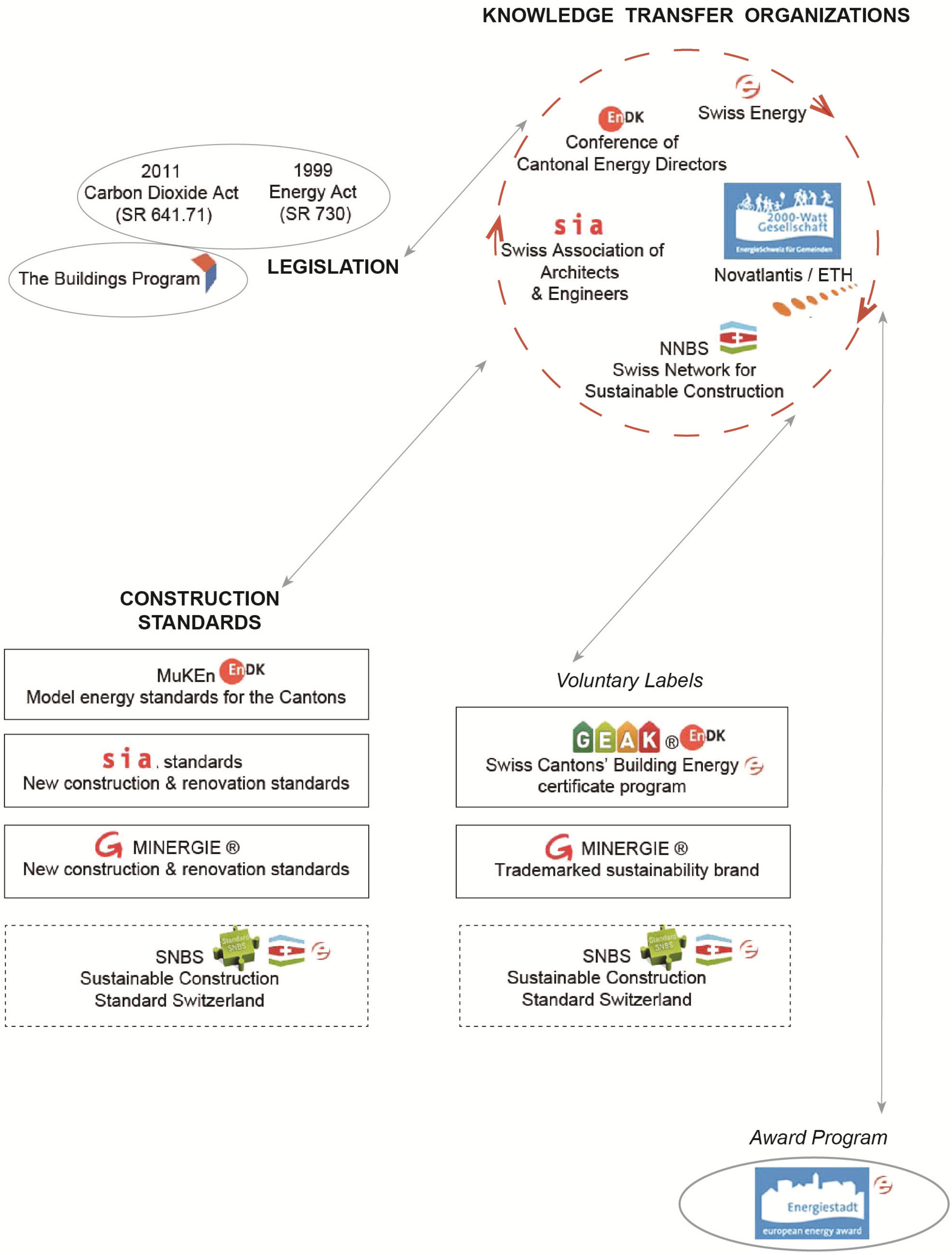
4.1. Federal Legislation

The radical shift in the Swiss building and design sectors was precipitated by the oil crisis in 1973, when the sharp increase in energy costs highlighted the poor quality of building construction and inefficient energy consumption linked in part to extremely low fuel costs [51]. Although territorial energy consumption, greenhouse gas intensity and emissions roughly match European consumption patterns per capita [52], the country heavily relies on imports for approximately 80 percent of its needed fossil fuels and other combustibles. Also, despite producing roughly 56 percent of its electricity domestically, additional imports are needed in the colder months due to greater demand [53]. Second only to the transport sector, the Swiss building sector has been identified as an important source of greenhouse gas (GHG), at 19.7 Mt of CO_2e [54], which includes indirect emissions from the consumption of electricity. Direct emissions accounted for 17.6 Mt of CO_2e in 2005 or 89 percent of building emissions. Hence, the building sector has become an area of intense focus, as it provides opportunities to further significantly reduce GHG emissions through primarily retrofits (6.1 Mt of CO_2e), but also by shifting to alternative heating systems (4.2 Mt of CO_2e), more efficient new construction (0.7 Mt of CO_2e), and LED lighting (0.3 Mt of CO_2e) [55]. Current energy policy outlined in the Swiss federal constitution that impacts the building stock identifies strategic sectors where energy reduction measures must be addressed. However, the respective cantons retain significantly more power in determining their implementation. This constitutional edict is supported by more detailed legislation in the form of the Energy Act and the Carbon Dioxide Act [56–58]. Figure 5 highlights the relationships between energy and emissions focused boundary objects: federal legislation, construction standards, knowledge transfer organizations and an award program.

The Energy Act explicitly outlines the responsibility of the cantons regarding energy consumption in the existing building stock and new construction, including specifications on, for example maximum allocations from non-renewable sources used for heating and hot water, and individual metering of heating and hot water [59]. Yet, the legislation says little about building performance standards with the exception that by 2030 targeted reductions in residential energy use should equal that of the year the Energy Act was enacted (1999).

The main impact of the Carbon Dioxide Act (CO_2 Act), first enacted in 2000 but revised in 2011, on the building industries is related to the provisionary tax affiliated with the law, which states that one third of the tax revenues, up to a maximum of 300 million CHF, must be used to reduce CO_2 emissions from buildings. This revenue is distributed to the cantons in two funding streams. The first source can be used to subsidize building envelope renovations, and the cantons are eligible to receive this money on the condition that all of the cantonal allocation programs are harmonized with each other. This falls under the name of the Buildings Program [51]. The second stream of funding can be used by the cantons to increase the use of renewable energy sources, implement heat recovery, and update or install other energy-saving technical installations in buildings. Individual cantons may be eligible for these monies if they already have energy-efficiency and energy-reducing subsidization programs in place [60].

Figure 5. Overview of key relationships: boundary objects linked to sustainable construction.



4.2. Construction Standards & Voluntary Labels

As stated previously, the Confederation provides guidelines for general spatial policy and energy laws; however, the explicit power to implement energy and building standards resides within respective cantons. Although this does introduce problems at the level of uniformity in development standards, steps have been made to coordinate the use of standards across cantons. The most prevalently used building standards originate from the Swiss Association of Architects and Engineers (SIA) and the Conference of Cantonal Energy Directors (EnDK), which are both organizations that function as key knowledge transfer groups. The EnDK also oversees a voluntary Cantonal building energy certificate program (GEAK), which provides potential buyers or renters transparent, comprehensible, building energy consumption information to inform their decision-making [61,62]. In addition, another widely used standard and labeling system is Minergie, a Swiss trademarked sustainability brand for new construction and renovations which outlines a baseline heat demand reduction to 90 percent or less of the limit of SIA standard 380/1 [58]. Both the SIA standards and those from the EnDK, the Model Energy Standards for Cantons or MuKEn, are legally binding only once a canton officially adopts them into law, and the policy aim is that each will do so at least in part [63].

Notably, revisions to the SIA standard have been made to reflect energy targets outlined in the MuKEn. Furthermore, several references are made in the MuKEn to Minergie, which although is not currently, directly mandated by law, is often cited as an eligibility requirement to qualify for federal building subsidies and bank loans. Frequently used as the primary benchmarking tool for Swiss politics, financing mechanisms, cantons, communities, private and public building owners, Minergie has been heavily marketed as combining energy efficiency in buildings with better comfort and added value. Since its development in 1994 by Ruedi Kriesi at the Swiss Federal Institute in Lausanne (EPFL), the label has become a widely used trademarked brand for new building construction and renovations, with a primarily technical focus on a combination of strategies that include controlled ventilation, selective double-glazing, external shading and insulation. Criticized as dimensionally simple approaches rooted in solutions that were once calculated manually, Minergie has not been without controversy concerning its potential restriction of architectonic expression and innovative non-standard solutions [64].

4.3. Knowledge Transfer Organizations

There is a range of active knowledge transfer organizations in Switzerland that are linked respectively to the federal government (Swiss Energy), the cantons (EnDK), professional groups (SIA, home to both architects and engineers) and the university system (Novatlantis). As mentioned in the previous section the EnDK and the SIA are also affiliated with construction standards, and the EnDK also supports the GEAK label. Swiss Energy is an extension of the Federal Office of Energy, and Novatlantis is part of the ETH domain, which is made up of the two Federal Institutes of Technology (ETH Zurich and EPF Lausanne), four research institutes (PSI, WSL, Empa and Eawag), as well as a strategic management body (the ETH Board) and an independent appeals body (the Internal Appeals Commission of the ETH). Lastly, although the Swiss Network for Sustainable Construction (NNBS) was still in its pilot phase during the time this research was conducted, it is mentioned here since it highlights the development of standardized package to support the production of sustainable construction. That is, the alignment between the boundary objects of a knowledge transfer group, existing labeling systems and construction standards from the SIA and Minergie [65,66]. Currently the existing groups create a patchwork of overlapping services, although Swiss Energy is the most comprehensive provider.

The Swiss Energy program was originally launched in 1990 as the "Energy 2000" program [67]. The initiative provides housing owners and managers informational services and functions as a platform that unites a range of activities within the field of renewable energy and energy efficiency under a single initiative. In addition to the building stock, the umbrella program focuses on renewable energy, transportation, industrial and service companies, electrical appliances, municipalities and towns, education and training, and communication. Managed by the Federal Office of Energy, the program intends to bridge the scope of energy and energy efficiency by fostering close working relationships between the federal government, cantons, communes and a range of partners located in both private and public sector industry, consumer and environmental groups.

Novatlantis takes a similar, but regionally, targeted approach. Based on the vision of the "2000-Watt Society" developed by the Swiss Federal Institutes of Technology (ETH), the ambition of the plan is to reduce the primary energy consumption per person in Switzerland from today's roughly 5500 Watts to 2000 Watts by 2050. To achieve this goal, Novatlantis takes findings from research within the ETH domains and aims for a coordinated, holistic approach to promote multi-scalar sustainable development [68]. Political support for the goals of the 2000-Watt Society continues to gain momentum, as evidenced in a 2008 referendum in the city of Zurich, where 76 percent of the population voted in support of integrating the plan into the city's constitution to significantly reduce energy consumption across policy sectors by 2050. Subsequently, the public approval of this approach has been acknowledged by the Swiss Federal Council, as shown by its continued inclusion in its Sustainable Development Strategy [69]. Also, the initiative has been further acknowledged through the national Energy City award program (Figure 5).

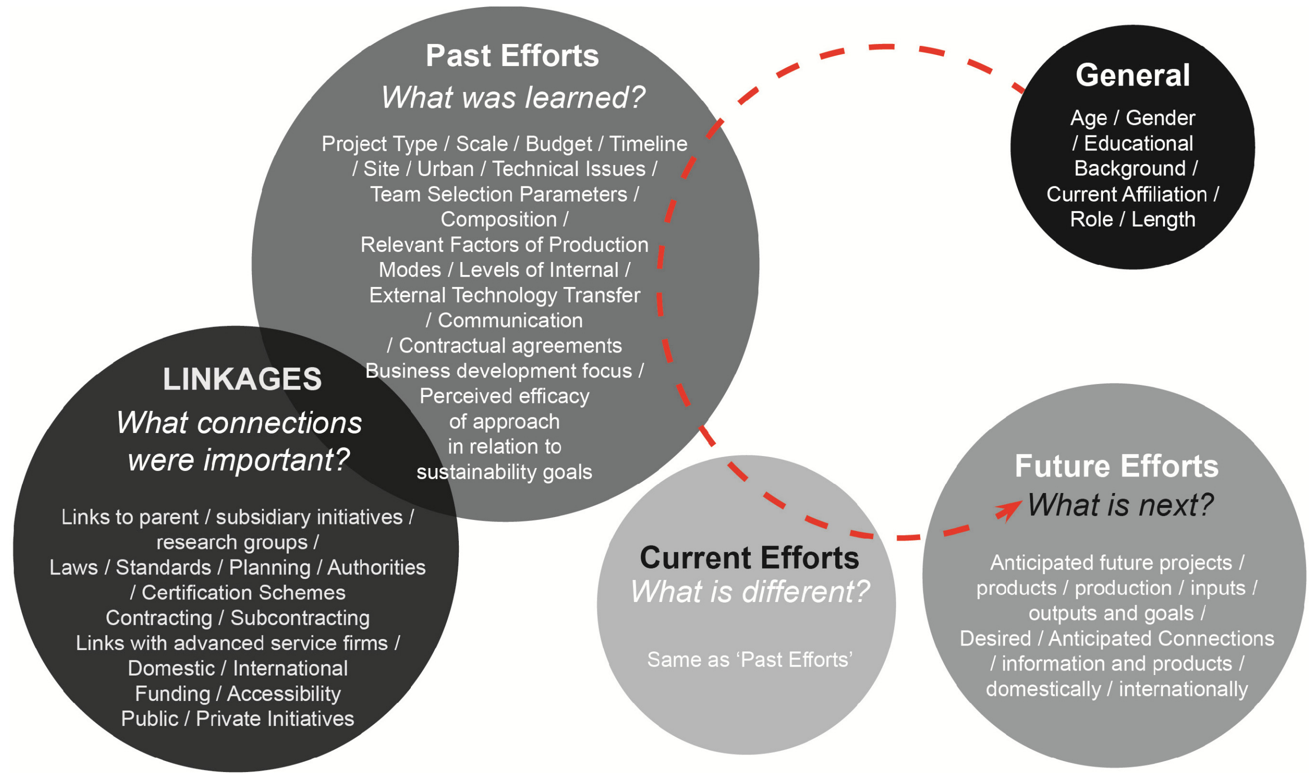
5. Empirical Work

5.1. Method

As stated in the introduction, Switzerland provides a unique opportunity to explore stakeholder perceptions of the relationships between energy research, practice, and sustainable construction. Through semi-structured qualitative interviews with experts having specialist tacit knowledge, observations regarding these relationships were developed. Central questions of interest were: What constraints were most explicit? What were their concerns, how were they framed and what did this suggest about their working context and expertise? How for example, were regulatory and disciplinary institutions viewed? New types of knowledge integrated? Perceived challenges mediated?

The SIA's official interdisciplinary trade publication, TEC21, for architecture, engineering and environmental concerns [70] was used to develop a pool of experts linked to implemented, sustainable construction projects in Switzerland within the last ten years. Additionally, contacts were gathered though relevant sustainability literature, websites within the ETH domain such as of the 2000-Watt Society, as well as the construction department websites of the largest cities located within the regions of Zurich, Basel, Geneva, and Lausanne. Interviewees were contacted via email and telephone at their primary place of practice, and 31 semi-structured interviews were conducted in person from February to June 2012. Each recorded qualitative interview lasted between 1.5 and 2 h and followed a discussion guide that was developed to encourage the interviewee to discuss the details of specific sustainable construction projects linked to implementation issues and the links between past, current and future efforts. Ample opportunities to deepen the conversation around project specific sustainable development implementation issues were available and encouraged by the experienced interviewer (Figure 6).

Figure 6. Discussion guide.



5.2. Summary Results

5.2.1. Interviews

First, to highlight the heterogeneous expertise represented in the interview sample, a description of each interviewee categorized by education is provided below. The two individuals indicated by asterisk (*), were qualified as both engineers and architects and therefore were counted twice to surpass the total 31 interviews by 2 counts (Table 1). Subsequently, in order to verify the perspectives represented in the interview sample, the external expertise of study participants were coded by education; by highest qualification; by practice and by position. This highlights that the interviews conducted captured the current views of Swiss experts with the following characteristics (Table 2):

Table 1. Descriptions of heterogeneous actors interviewed.

Group	Descriptions
A.	**By Education**
	*1. Architecture & Planning (*n *= 20) **
	- Architect, Planner, Educator
	- Architect, Planner, City Project Manager
	- Architect, City Project Manager
	- Architect, Research Scientist, Prototype Research & Design
	- Architect, Research Scientist, Software Developer, Educator, Prototype Research & Design
	- Architect, Firm Owner, Executive Director of Sustainability Knowledge Transfer Organization
	- Architect, Firm Owner, Federal Advisory Panel Participant
	- Architect, Firm Owner, Prototype Research & Design
	- Architect, Firm Owner, Cooperative Housing Construction Management
	- Architect, Firm Owner
	- Architect, Firm Owner
	- Architect, Firm Owner
	- Architect, Firm Owner
	- Architect, Firm Owner, Educator
	- Architect, Firm Owner, Educator
	- Architect, Senior Project Architect
	- Architect, Competition Design, Graphics
	- Architect, Energy Modeling
	*2. Engineering Specialty (*n *= 10) **
	- Engineer, Research Scientist, Educator
	- Engineer, Senior Research Scientist, Educator, Prototype Research & Design
	- Engineer, Senior Research Scientist, Educator
	- Engineer, Senior Research Scientist, Consultant
	- Engineer, Senior Project Manager
	- Engineer, Project Manager
	- Engineer, Communications Officer of Sustainability Knowledge Transfer Organization
	- Executive Director of Sustainability Knowledge Transfer Organization, Educator
	* Architect, Specialist in Building Physics, Technical Director of Certification Label, Educator
	* Architect, Engineer, Sustainability Consultant, Firm Owner
	*3. Other (*n *= 3)*
	- Senior Research Scientist, Consultant to City Mobility Planning, Energy Transitions
	- Director of Energy/Mobility Research Institute, Upcoming Executive Director of Sustainability Knowledge Transfer Organization
	- City Project Manager, Energy Award Program

Table 2. Interview breakdown.

Group	Interviewees	Men	Women	Total (*n*)	Percent
A.	**By Education**				
	1. Architecture & Planning *	16	4	20 *	60.6%
	2. Engineering Specialty *	8	2	10 *	30.3%
	3. Other	2	1	3	9.1%
		24	7	33 *	100.0%
B.	**By Highest Qualification**				
	1. Professional Degree	18	4	22	71.0%
	2. PhD	4	3	7	22.6%
	3. Other	2	–	2	6.4%
		24	7	31	100.0%
C.	**By Practice**				
a.	*Primary*				
	1. Design	15	3	18	58.1%
	2. Research	4	2	6	19.3%
	3. Management/Coordination of Research	4	–	4	12.9%
	4. Management/Coordination of Design	1	2	3	9.7%
		24	7	31	100.0%
b.	*Secondary*				
	1. Management/Coordination of Design	8	1	9	29.0%
	2. Education	8	–	8	25.8%
	3. Consultancy/Advisory	3	4	7	22.6%
	4. Other	4	–	4	12.9%
	5. Research	1	2	3	9.7%
		24	7	31	100.0%
c.	*Tertiary*				
	1. Other	13	3	16	51.6%
	2. Consultancy/Advisory	5	1	6	19.4%
	3. Education	2	3	5	16.1%
	4. Management/Coordination of Design	4	–	4	12.9%
		24	7	31	100.0%
D.	**By Position (Stakeholder Type)**				
	1. Planners & Designers	15	2	17	54.8%
	2. Research & Education	8	3	11	35.5%
	3. Public Authorities	1	2	3	9.7%
		24	7	31	100.0%

A. The sample reflects the views of experts trained primarily within the design disciplines of architecture and planning, as well as the engineering design disciplines, 60.6% and 30.3% respectively, with an additional 9.1% representing other types of training, specifically economics and geography. It is important to note that as indicated by asterisk (*), two the interviewees were qualified as both engineers and architects, therefore the total surpasses 31.

B. Grouped by highest qualification, 71% of the interview sample held a professional degree with 22.6% holding a doctoral qualification and 6.4% holding other types of qualifications, specifically a MBA and a Bachelor's Degree respectively.

C. (a) Parsed by practice, the primary activity of the interviewees mainly involved design work at 58.1 percent, followed by research activities at 19.3%, the management and/or coordination of research at 12.9%, and lastly the management and/or coordination of design at 9.7%.
(b) Assessed by secondary practice, the majority of interviewees engaged in the management and/or coordination of research at 29%, followed by education related activities at 25.8%, consultancy/advisory at 22.6%, other activities at 12.9%, and finally research related activities at 9.7%.
(c) Evaluated by tertiary practice, interviewees' responses were much more diverse with 51.6% reporting a range of activities unrelated to sustainable construction, followed by 19.4% indicating consultancy and/or advisory activities, 16.1% engaged in activities related to education, and 12.9% involved in managing or coordinating design.

D. Aggregated by stakeholder type, primarily planners and designers were represented at 54.8%, followed by the interests of research and education at 35.5%, and lastly by the public authorities at 9.7%.

5.2.2. Collated Responses of Interviews by Practice (Category C)

Under the practice category in Table 2, responses were collapsed around the activities of design and research and are shown in Table 3. This indicated that: (d) 67.7 percent of those interviewed were primarily involved in design, and design management and/or coordination activities, followed by the remaining 32.3 percent of the sample that was primarily involved in research, and the management and/or coordination of research. Next all responses from Category C were collated similarly with the exclusion of "other" activities as it was recognized that many of these activities occur simultaneously and that the hierarchy of tasks performed in practice are perpetually in flux. This aggregative method shows that when those interviewed engage in activities linked to sustainable construction: (e) 47.6 percent of those activities were related to design, and 17.8 percent were respectively participating in research; education; as well as consultancy and/or advisory work linked to knowledge transfer organizations. Yet critically, as highlighted in Tables 1 and 2 even within a small sample populated by primarily architects and engineers, a spectrum of practice is represented within these groups.

5.2.3. Challenges Linked to Technical Aspects of Sustainable Construction

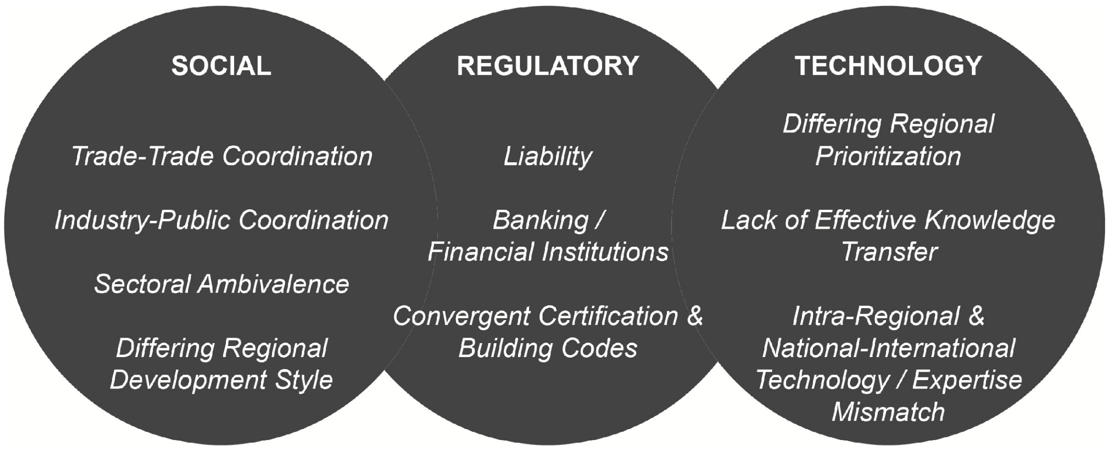
Though responses were broadly consistent with mainstream barriers of affordability; lack of client demand, awareness, business case understanding; and planning policy, additional challenges were unearthed around technical aspects of sustainable construction and were grouped by concerns that were social, regulatory and technology oriented. Social concerns related: to coordination issues between the construction sectors, between the construction sectors and the public consumer; to aspects of sectoral ambivalence; and to differing regional development styles. Regulatory challenges were connected to the perception of: liability; the influence of the banking industry on the direction of development; and the convergence of certification schemes and building codes. The last types of challenges were linked to specific technologies, resources and technological expertise. Specific concerns focused on: differing regional prioritization; lack of effective knowledge transfer; as well as intra-regional and national-international level mismatches (Figure 7). The comparison to existing barriers in the literature was considered useful, since it notably highlighted that, amongst the Swiss experts interviewed, the lack of proven technologies was never claimed as problematic, nor was the lack of a single labeling and/or measurement standard.

Table 3. Collated responses of interviewees by practice.

Group	Interviewees	Men	Women	Subtotal	Total (*n*)	Percent
C.	**By Practice**					
d.	*Primary Practice Responses Collated*					
	1. Design	15	3	18	21	67.7%
	+ Management/Coordination of Design	1	2	3		
	2. Research	4	2	6	10	32.3%
	+ Management/Coordination of Research	4	–	4		
		24	7	31	31	100.0%
e.	*All Practice Responses * Collated*					
	1. Design	15	3	18	34	46.6%
	+ Management/Coordination of Design	13	3	16		
	2. Research	5	4	9	13	17.8%
	+ Management/Coordination of Research	4	–	4		
	3. Education	10	3	13	13	17.8%
	4. Consultancy/Advisory	8	5	13	13	17.8%
		55	18	73	73	100.0%

* “Other” Responses Excluded.

Figure 7. Reported challenge linked to technical aspects of sustainable construction.



6. Discussion

Recognizing that in the design practices, research and teaching are often critical aspects of the practice, it was also assumed that our interview material would provide examples of how experts move between the viewpoints of internal and external stakeholders. Moreover, in fact, interviewees were clear that this movement was important: to integrating knowledge practices between the jurisdiction of cantons; across the trades to keep the estimated costs of construction down; or in the process of raising support for research and demonstration projects. For example, those whose primary practice was design or technical research reflected that their visible involvement in advisory positions to the canton or state through knowledge transfer groups was critical in shaping the direction of how sustainability aims were perceived by the public and ultimately, realized in practice.

In accordance with the STS notion of boundary work, the primary aim of the qualitative interview process was to unearth how the overlapping concerns of differing social worlds (e.g., architecture, engineering research, design, regulation, knowledge transfer groups, infrastructure, *etc.*) intersect with processes of sustainable construction implementation. By recognizing that implementation efforts are "an assemblage of policy-making, market processes, and professional and industrial practices," it was expected that a diversity of potentially conflicting perspectives would be present in the respective interviews, since the specificities of boundary objects or parts of standardized packages often diverged in material form, (*i.e.*, technical artifacts, tools or organizations), despite the fact that all the discussions were grounded in the energy narrative of the Swiss context [71].

The boundary objects of standards and knowledge transfer groups were most significant in the context of this study. Interviewees expressed varying degrees of concern regarding widely adopted labeling and certification schemes; however, knowledge transfer groups such as Novatlantis were viewed more or less positively concerning its promotion of multiple pathways to achieve sustainable construction goals and effectively engaging both the building sectors and the wider public. Essentially, the coordinated, but flexible approach in support of a range of sustainable solutions allowed the organization to effectively operate in concert with a variety of technical solutions. Additionally, programs supported by Swiss Energy, the EnDK and the SIA were also recognized as supporting sustainable construction efforts either through financial support or by providing technical guidelines.

However, interviewees' also highlighted other diverse vectors of knowledge transfer in the form of architectural and planning competitions, boundary processes in their own right, international research collaborations centered on construction projects, and international exchange amongst firms with multiple offices. For example an architect who worked as a city official in Basel argued that holding planning competitions was an efficient way to legitimize and promote its public process, while involving the "best" design talent and further refining the positioning of the city's green policy goals through verifiable construction outcomes. Other practitioners suggested that architectural competition processes introduced innovative concepts into the professional discourse and were a means to garner public support while diminishing the perceived risk of unconventional strategies.

Of those interviewed, an image of multi-headed expertise emerged: practitioners and researchers displayed multiple types of working competence in design, research, management, education and advisory activities. This is consistent with the group of experts that were targeted. As articulated earlier in this section, this finding could also be argued as a general reflection of the nature of disciplines being studied, which are typically conceptualized as 'problem solving professions' or alternatively, that these traits are evident in individuals working close to the borders of professional and research practices which intersect sustainable construction implementation efforts. Although too small of a research sample to substantiate here, the choice of the Swiss "close community setting" of experts as an object of study was carefully considered in relation to its geographic location, system of governance, dense multicultural pattern of urbanization and energy context, in addition to its strong history of design, construction and infrastructure development. No doubt, these combined factors have been central in the "forming and framing" of how these Swiss researchers and practitioners approach sustainable construction as Guy and Shove argue for the respective contexts of Finland, Sweden and Ireland [72].

6.1. Context Counts

It goes without saying that context counts. However, typically in the comparison of construction practices, differing working milieus also signify alternate institutional contexts that create challenges for coordination. It became clear in the organizational phase of this study that gaining access to experts in the German-speaking part of the country was a much more straightforward process than in the French-speaking part of the country. Despite this, with the exception of five interviewees, every person interviewed reported that their respective working practice spanned multiple cantons, and approximately one-third of the interviewees worked in both French and German-speaking areas. Additionally, sixteen of the interviewees reported international working experience linked to sustainability construction. In the case of Switzerland, where four national working language contexts exist under the same federal regulatory rubric, interviewing experts operating in varying regions of the country provided an opportunity to look at the activities of actors operating within differing linguistic contexts. Those working in multiple regions expressed the view that federal laws were interpreted differently by cantons in differing language areas, which is consistent with documented ethno-linguistic divisions in the organizational cultures of Swiss public space and political discourse [73] and highlights the interpretive flexibility of federal laws.

6.1.1. Domestic

As previously discussed Novatlantis functions within the ETH domain as a knowledge transfer organization that makes research findings more accessible to the public in an effort to attain the goals of the 2000-Watt Society. Originally launched in three test-pilot regions, Zurich, Basel and Geneva, regional approaches have since diverged [74–77]. As the fieldwork process progressed it was repeatedly reported by interviewees that the aims affiliated with the 2000-Watt Society were being prioritized differently in the French-speaking part of the country in comparison to the German-speaking areas. Specifically, variations in the working cultures of the German- and French-speaking sites have been significant enough to slow the momentum of the program's coordination efforts in predominantly French-speaking test regions, while continuing to gain increasing support in German-speaking areas. According to a city official in Geneva, the planning influence of neighboring France and the strong local presence of the United Nations (UN) subsidiary headquarters has encouraged the culture of French-speaking Switzerland to look more to Europe than internally. This highlights the critical link between boundary objects such as knowledge transfer groups and local actors.

Alternatively, described as healthy competitors, the neighboring primarily German-speaking cities of Basel and Zurich have provided the main successes of the 2000-watt society to date. Although the "push-pull" strategy is employed across all the program sites between—the ETH domain—on one side of the knowledge transfer group Novatlantis, and—businesses, as well as cities/cantons, and the public—positioned on the other, both cities have positioned their implementation strategies very differently. For example the city of Zurich has taken a top-down process, which has been led by the city mayor and supported by a strategic management team made up of Novatlantis and a steering committee of directors, which oversee 6 related taskforces that address the city's energy strategy;

stakeholder participation; design, integrated planning; environmental and health (HVAC); IT, Smart Grid; and facility management. Whereas in Basel, a much less formal bottom-up structure exists where the city has spearheaded efforts test a small fleet of hydrogen fueled vehicles, and also engages in several public-private partnerships focused on the concepts of smart grids, energy hubs, electricity storage, the utilizations of river water, building retrofit, PV integration, quick charging electric vehicles and natural gas driven hybrids. In these neighboring cities, differing organizational practices developed out of local conditions and play an important role in the type of sustainable development projects that are prioritized [78].

6.1.2. International

Numerous interviewees had previously or were currently working internationally. This highlighted another trend in how international working contexts shape and are shaped by design and research actors. Specifically, practitioners working internationally within the EU context underscored the challenges of working in what was perceived as more restrictive regulatory contexts such as Germany, as well as the importance of the economic strength and local expertise of the domestic labor market to support the implementation of atypical sustainable construction strategies. Alternatively, university researchers working within non-European, non-Western contexts raised a slightly different point on resource mismatch and international expertise. For example, efforts to demonstrate the applicability of strategies developed in Switzerland to attain Nearly Zero Energy Buildings (NZEB) in more humid East Asian climates ran into technology linked difficulties in the field. Specifically, two problems arose that were implementation related. First a certain type of cabling necessary for a technical assembly was not available and no comparable replacement could be found locally. Second, the lack of available local skilled labor created a significant challenge to installing, maintaining and repairing the technical assemblies proposed. In the first EU example, this caused practitioners to restructure their contractual agreements to reflect Swiss billing practices and opt only to work outside of Switzerland on more higher profile projects. In the East Asia example, since partnering universities and the local authorities supported the project work, the main reported focus here was to expand the design analysis to accommodate local construction practices. This example highlights how learning can occur on both sides of an object and that depending on how that object is grouped with another object—here an institutional—can encourage actors to pursue alternate subsequent actions.

6.2. Mediating Frictions between Regulation & Innovation

6.2.1. The Convergence of Standards

The perception that stable, proven technologies already exist was very strong amongst the experts interviewed. Therefore, the focus of perceived challenges centered on dissatisfaction with the specifics of building standards and financing mechanisms, which were perceived as steering development in a particular direction. As mentioned previously, efforts to harmonize cantonal standards have been underway for sometime, and none of the interviewees objected to this trend. Although the concern regarding the strength of the Minergie label seems to be at odds with this assertion, the following example clarifies the distinction that was frequently made by interviewees. Specifically for example, a researcher and former active practitioner found it problematic that owner requirements for bank financing included meeting the criteria for Minergie standards, which prescribed a specific bundle of technologies. The same interviewee also observed that originally he had assumed "superior solutions" would supersede lesser solutions, but now recognized that developing a local demand for construction assemblies that are deemed "risky" by lending institutions was a considerable challenge. According to Pitt *et al.* [50] interviewees should have perceived the presence of fewer, coordinated standards positively. However, this was not the case amongst the interviewees. Practitioners frequently expressed frustration over the convergence of building standards in Switzerland as restricting the exploration for alternative methods to reduce energy consumption and emissions. However, another expert raised the point that labels do have value especially in development contexts where sustainable construction knowledge is not high and benchmark values are needed.

Now much more than a voluntary label, Minergie plays a significant role in Switzerland's building code and the label combines several building technologies in the aim to reduce energy consumption. Specifically, the technical focus has been a combination of controlled ventilation, selective double-glazing, external shading and insulation. Although criticized by one researcher for reflecting dimensionally simple approaches rooted in solutions that were once calculated manually, the label continues to evolve, evidenced by its growing number of sub-labels. In a discussion with one of the lead technical consultants to the Minergie label, it was explained that although their group did not act as a general advisor to owners or the building sector, they would regularly be involved in demonstration projects. The aim behind their participation in these projects were not to highlight specific technologies that were considered appropriate for mass implementation, but rather it was an effort to work out complementary technical strategies with the design team, as well as verify the appropriateness of the standard. As one architect who participated in a museum demonstration project explained the benefit of collaborating with the technical group of the label was an opportunity to influence the logic of the standard. Again another example of mutual learning, but it also highlights what Fujimura describes as fact stabilization in the form of lending practices that support a particular bundle of technologies that Miniergie standards indirectly require to meet its performance criteria.

6.2.2. Liability

Liability was a consistent concern for researchers involved in sustainable construction projects. According to one interviewee, 'the researcher's dilemma' centered on when their oversight of a project should end. Although the oversight of construction drawings and construction are a critical part of achieving intended sustainability goals, typically financial liability and lack of construction management experience limits researcher involvement. In the interviews this presented itself in two types of responses—sectoral ambivalence and attempts to integrate into the normative system. In the former type of response, some firm owners expressed a lack of interest in discussing energy efficient strategies, one going so far as to refer to it as "boring". However, that particular interviewee, a business owner and educator had overseen the design and construction of multiple Minergie certified projects, which underscored that his expressed ambivalence was not for a lack of technical expertise.

In the latter type of integrative response, many of the researchers interviewed simultaneously worked in advisory or consultancy roles to industry, local and/or federal levels of government. Two specific examples are worth mentioning here. The first is an example of an architect researcher who created a spin off consultancy to distance his more practice-oriented liability from his host research institution, reduce the amount of trade-to-trade coordination necessary during bidding and construction, as well as retain specification development or oversight of the technology implementation. The second example is of a firm owner who worked with local train authorities to develop an alternative means of achieving a target level of insulation performance for service buildings housing technical installations. In both of these examples, interviewees explicitly varied their modes of practice and moved back and forth between the roles of internal and external stakeholders—that is between positions of design and research, where the role of technology is prioritized differently [6].

7. Conclusions

Coordinating the rapidly expanding body of literature on energy, its infrastructure, policy and climate change in an intelligible way with current industry practice and ongoing research on buildings, planning, sustainability and the built environment poses significant challenges [79]. As an exploratory, qualitative assessment, the concerns of Swiss development experts involved in sustainable construction efforts provide insight into understanding where frictions exist in the overlap between researchers, practitioners and public authorities that share similar green ambitions of implementing sustainable construction within a significantly broader landscape of actors.

Essentially, the framework of science studies was used as an approach to investigate practices linked to sustainable construction. Subsequently, in the process of adapting core STS perspectives such as "the heterogeneous and hybrid socio-technical character of technology and knowledge production; the mutual shaping of social and technology order"; and "the actor-oriented approach combined with critical constructivist perspectives" [28] additional information regarding the frictions experienced by local actors surfaced as a supplementary area of study. Specifically, Science and Technology Studies (STS) perspectives were used to strategically inform how sustainable construction can be conceptualized within a broader socio-technical network and instances where social affiliations supported technical choices in the Swiss context were highlighted. In particular, the notions of boundary objects and standardized packages were useful as constructs to identify experts affiliated with sustainable construction implementation efforts, structure the discussion goals for the interviews, and in the analysis identify relationships worthy of further study such as processes of negotiation involved in the development of building standards, and the workings of knowledge transfer groups. Centrally, the key contribution of the STS framework in this research area is its potential ability to expand the operational understanding of the architectural case study in ways meaningful to the concerns of sustainable construction implementation.

Unique to the Swiss context was the perception that domestically, there was not a lack of existing technologies and methods available to achieve sustainable construction and that converging building codes were a potential hindrance to atypical solutions. This latter challenge in particular highlights the notion of bundled boundary objects, which create standardized packages that although are not rigidly fixed provide:

> For a greater degree of fact stabilization than using boundary objects. Simultaneously, however, standardized packages are also similar to boundary objects in that they facilitate interactions and cooperative

work between social worlds and increase their opportunities for being transferred into, and enrolling members of, other worlds. They serve as interfaces between multiple social worlds which facilitates the flow of resources (concepts, skills, materials, techniques, instruments) among multiple lines of work [10].

In this exploratory study of Switzerland an effort was made to depict the socio-technical web that connects specific building technologies to building standards that are in turn, generated, supported and regulated by institutional practices though the use of in-depth expert interviews. The examples presented illustrated how complementary pathways for sustainable construction can be crafted out of separate tools, technologies and organizations. Similar to Shove's work with building experts, this study also underscores that:

> They [experts] do not have contextually disembodied technologies transferred upon them. Instead they acquire and develop knowledges which mesh with and which emerge out of local, culturally and temporally specific working environments [10].

These findings are consistent with Switzerland's steady success in sustainable development implementation efforts that are grounded in strong national traditions of resource protection, design, infrastructure, construction quality, and research, and are additionally supported by high standards of living. Therefore as a frontrunner in the process of operationalizing sustainability goals, further empirical casework on how sustainable construction is implemented, challenges mediated, circumvented and/or problem situations recast is warranted in the Swiss context to deepen the preliminary conclusions drawn here.

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Conflicts of Interest

The authors declare no conflict of interest.

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78. Anecdotally, one interviewee, who was a qualified mechanical engineer, researcher and educator, even went so far as to self-finance a building project, hire a design team and implement his prototype system of integrated building technologies. However, according to both the project architect, and the energy modeler the introduction of atypical construction details was still a strong source of friction between the design team and the construction trades in terms of perceived liability, schedule and cost.
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