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Disputed dams: Mapping the divergent stakeholder perspectives, expectations, and concerns over hydropower development in Iceland and Switzerland

Guillaume Voegeli [a,*], David C. Finger [b,c]

[a] Institute for Environmental Sciences, University of Geneva, Uni Carl Vogt, Boulevard Carl-Vogt 66, 1205 Genève, Switzerland
[b] Sustainability Institute and Forum (SIF), School of Science and Engineering, Reykjavik University, Menntavegur 1, Nauthólsvík, 101 Reykjavik, Iceland
[c] Energy Institute, Johannes Kepler University, Linz, Austria

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ABSTRACT

The evaluation of the stakeholders' perception of new hydropower projects is essential for assessing public acceptance, ensuring local involvement, and identifying feasible and desirable changes towards sustainable development. This study uses the concept of *causal diagrams* (CD) to identify the individual perspectives of stakeholders of two new hydropower projects, one in Switzerland (Val d'Ambra project) and one in Iceland (Hvammvirkjun project). For this purpose, semi-structured interviews with relevant stakeholders were conducted, which were then categorized into 5 interest groups. Using the software Atlas.ti, we identified and sequenced the perceived causality of impact pathways of the two projects. The results are exposed in two series of 10 topical causal networks, and two aggregated diagrams. For each case, CDs expose the complexity of multi-sequenced causalities between elements of a very heterogeneous nature, as expected and reported by stakeholders. This approach enables the identification of inter- and intra-group conflicting perspectives, and perceived uncertainties, concerning both subjectives matters along with much more tangible and predictable aspects. Our method enables the identification of areas where further research or better transfer of information between stakeholders is required. It also exposes how hydropower impacts can differ in time and space, when in one case study, intracommunity tensions and conflicts were identified at the earliest project stage, along with psychological distress of some local residents. Based on the presented CD, we conclude that this method can facilitate communication and problem-solving in complex social-environmental situations amid multiple stakeholder categories, which heterogeneity should not be underestimated.

1. Introduction

For decades, large hydropower infrastructure projects have been at the centre of public debates. Fostered on the one side by the benefits that could be expected from renewable and cost-efficient electricity production, a reserve of freshwater, flood and drought protection, but also by the emblem of development they represent, hydropower and dams have also largely been criticized and opposed on grounds of concerns regarding their ecological and socio-economic consequences, and inadequate distribution of potential benefits among the population [1–3]. Indeed, the damming of rivers for electricity production represents the biggest contributor to renewable and cost-efficient energy production worldwide [4–6]. The construction of hydropower infrastructures can enhance economic development and generate new job opportunities on the local scale [7]. As such, hydropower currently represents the dominant source of power in multiple countries [8]. These include many European countries, such as Switzerland, Austria, Norway, and Iceland [9,10], where hydropower is supported by low-carbon initiatives and policies [11,12]. On a worldwide scale, new hydropower projects are being planned and implemented at a growing rate, and this tendency is assumed to continue in the coming decades [13].

Nevertheless, large hydropower facilities require the construction of massive infrastructures, frequently criticized for the recurrent significant cost and time overrun in the sector [14–17]. These large hydropower infrastructures lead to the flooding of large parts of the land and

* Corresponding author.
E-mail addresses: guillaume.voegeli@unige.ch (G. Voegeli), Davidf@ru.is (D.C. Finger).

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natural habitats, destroying at the same time the local ecosystems [18], along with the livelihood and housing of affected people [19,20], and in some cases become a net emitter of greenhouse gases due to decay processes affecting flooded biomass [21,22]. Furthermore, hydropower has also been reported to jeopardize natural freshwater systems by disrupting the stream connectivity and altering the natural flow of water and sediments [23–25], with consequent repercussions for both the riverine ecosystems [26,27] and the communities living downstream [28,29]. While these undesired ramifications can be partly mitigated through legal or technological means [30,31], mitigation measures can hardly remedy all the concerns of local stakeholders regarding the impacts of new hydropower projects. Indeed, the occurrence and severity of impacts largely depend on contextual settings [32], which can result in complex interactions between biophysical and socio-economic aspects [33,34] and differ in time and space [35]. Consequently, every new infrastructure project should undergo a holistic impact assessment with a strong integration of stakeholders to ensure that local variables are fully included [36], while at the same time assessing the potential causal interactions between impacts, which can take place in multiple spatial and temporal frames.

To undertake such an assessment, we propose an innovative approach based on causal diagrams (CD), a type of conceptual modelling, which is part of the available sustainability assessment (SA) tools [37]. Using CD techniques, we aim at exposing the miscellaneous perceptions of key stakeholders regarding the causality of consequences expected from new hydropower projects. We applied our method to two planned hydropower projects, one located in the Swiss Alps, the other in Southern Iceland. A clear representation of the causal relation resulting from hydropower implementation, and differing in nature, time and space, is expected to enable the identification of the roots of concerns and expectations of stakeholders, including shared or conflicting perspectives. An investigation into the causal relations also highlights how anticipated consequences can be perceived differently by the people concerned. Finally, by comparing two projects, this paper also enables us to identify the common sources of conflicts and consensus around hydropower plants in development.

2. Two case studies: hydropower projects in Switzerland and Iceland

In the frame of this study, we have applied interview-based diagram techniques on two planned hydropower projects in countries dominated by hydroelectricity production, namely Switzerland and Iceland. Indeed, hydropower accounts for approximately 60% of the domestic electricity production in Switzerland [38] and more than 70% of the Icelandic electricity production [10]. Both countries are currently investigating possibilities to increase their respective hydropower capacity [39–41], although the purpose of this impetus is different for the two. In that perspective, we selected two hydropower projects at the planning phase for this study, as they can be seen as representing the current evolution of the hydropower sector for both countries. Below, we present the details of the considered projects, including some contextual elements of each national energy sector accordingly.

2.1. Pump and storage hydropower project in the Swiss Alps – Val d'Ambra II

In May 2017, voters in Switzerland decided in a national referendum in favour of a phase-out of nuclear energy, calling for new options to produce electricity in line with the national carbon–neutral and renewable energy policy [42]. At the same time, the potential for new hydropower implementation is rather limited [41] and would most likely raise concerns to protect the last remaining wilderness areas of the country. In this context, the project Val d'Ambra II (VdA), which was originally proposed in 2003 by the local electricity company, was frozen in 2016 by local authorities due to environmental concerns, five years after its approval in 2011.

Located in the Val d'Ambra valley (Fig. 1, Table 1), in the Southern Swiss Alps (Ticino), VdA would be built upstream of an existing hydropower storage facility. The project location is characterized by a narrow valley, making access difficult but at the same time protecting its pristine state. With a glacier-free 20 km^2 watershed, the average natural water flow is relatively limited. Accordingly, the project would function as a pump and storage facility, by storing water from the downstream reservoir during low-energy demand periods and releasing it to provide power during high-energy demand periods.

2.2. Run-of-river hydropower project in Iceland – Hvammsvirkjun, on the ûjorsá river

Due to its remote location, the Icelandic electricity market and power grid are limited to its national boundaries. In the last decades, the main purpose of new electricity production projects in Iceland was developed to support the growing demand of the industrial metallurgy sector [45]. Currently, this sector directly consumes approximately 80% of the domestic electricity [46], making Icelandic electricity consumption per capita seven times larger than the average European consumption per capita [47]. The installation of new hydropower infrastructure has, however, also raised environmental awareness and concerns from the local population, as man-made infrastructures are impacting on the wilderness, degrading the attractiveness of pristine nature, and subsequently may jeopardize the local tourism, a growing industry at the national scale [48].

We selected the Hvammvirkjun Project (HVP) as a typical project representing the ongoing development of hydropower infrastructure

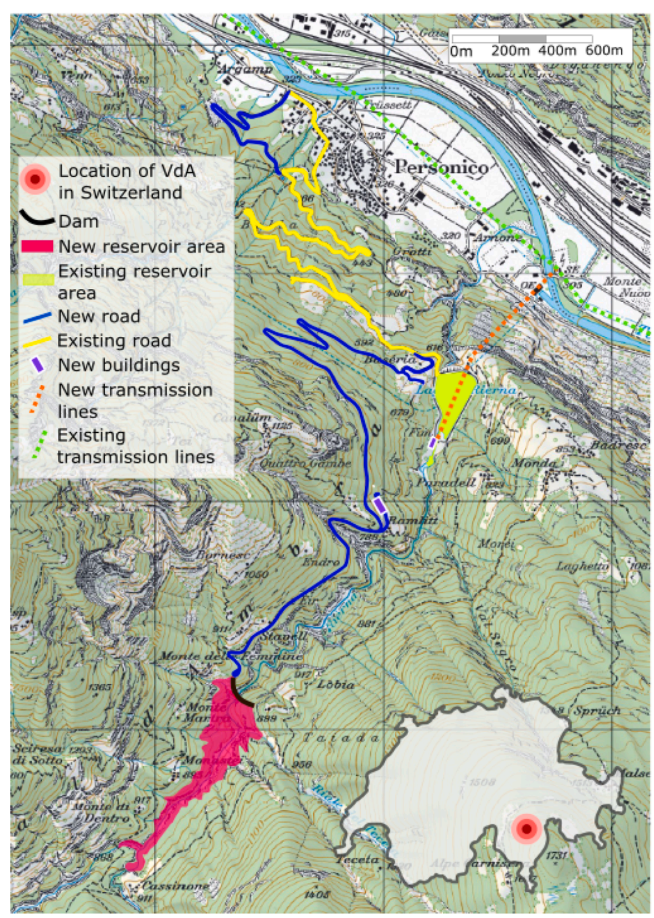

Fig. 1. Main external VdA projected infrastructure. Drawn by the authors based on PUC Val d'Ambra and Swiss Confederation [43,44].

Table 1
Technical specificities of VdA and HVP projects.

	VdA (Switzerland)	HVP (Iceland)
Maximum height of dam	86 m	18 m
Total length of dam (crest)	180 m	350 m (main dam) 150 m (downstream dam) Total: 5′000 m (including dikes)
Storage capacity in reservoir	3 hm^3	12 hm^3
Surface of reservoir	0.09 km^2	4 km^2
Yearly averaged water flow	1.1 m^3/s	352 m^3/s
Installed power capacity	50 MW	95 MW
Expected yearly production	111 GWh	720 GWh
Expected yearly consumption for pumping	136.6 GWh	No pumping unit
Length of new road	3′300 m	3′500 m (new road) 2′450 m (replacement of flooded road)

(Fig. 2, Table 1). HVP is planned to be a run-of-river power plant, with a reservoir the function of which is to redirect the river flow towards the turbines, enabling only relatively limited water storage capacity. Located along the ûjorsá River, HVP would be an additional infrastructure on a river that has already been dammed upstream with several large storage facilities.

The ûjorsá River is the longest river in Iceland. At the location of the HVP project, the river marks the boundary between two municipalities. While the village of the southern municipality is located out of sight of the river, the village of the northern municipality is located close to the river, next to the location of the project. Surrounding lands are mainly used for agriculture by local farmers, and are crossed by one of the main roads towards the highlands, the central Icelandic wilderness area.

3. Method

As demonstrated above, hydropower installations can result in a very large diversity of impacts. In this study, we use semi-structured interviews and causal diagrams (CD) to assess the sustainability of these two hydropower case studies, as presented in this section.

3.1. Sustainability assessment to approach hydropower impacts

Sustainability is a normative concept [51] usually defined on the basis of sustainable development, as described by the Brundtland Commission [52]. Developed as an answer to the increasing evidence that the current trend is not sustainable in the long term, for socio-economic and biophysical reasons.[53] Sustainable development has progressively become a key guiding policy principle [54] and led to the emergence of sustainability science [55] in recent decades. As a new policy goal, sustainability requires that steps towards this goal must be assessed. Sustainability assessment (SA) tools have therefore been developed for this aim [37]. The SA common three-pillars approach and other conceptions have largely been debated [53,56], making its current definition rather broad and generic [57]. This has led to the development of numerous tools, leaving practitioners and decision-makers with equally manifold methodological choices and implications. Ideally, SA tools should enable the integration of nature-society systems, multiple temporal perspectives and various spatial scales [37]. In addition, SA tools require the use of a contextual approach as close to the concerned people as possible [53], as they are likely to have crucial insights, but also because their perceptions define what is feasible and can be judged positive in terms of change.

Conceptual modelling is a specific integrated SA tool with essential and innovative features to fulfil such requirements. Compatible with multiple approaches (e.g. flowcharts, diagrams, etc.), this qualitative tool enables to simplify complex situations by visualizing the problem and finding out the flows, causal relationships, points of strength and weaknesses [58]. This approach eventually identifies where changes can be made for increasing efforts and steps towards sustainability at the project scale [37]. Other SA tools and approaches to assess hydropower have already been applied and even flourished recently [59], including institutional protocols [60], multi-criteria approaches [61] or local stakeholder analysis [19]. However, most of the applied approaches rely on impact checklists, resulting from an arbitrary choice [62] and at the same time disregarding the existing interactions between biophysical and social impacts [33,35].

3.2. Application of CD to assess hydropower impacts

In the scientific literature, the term "impact" is usually used as a synonym for "effect", or "change". An impact refers to the significant

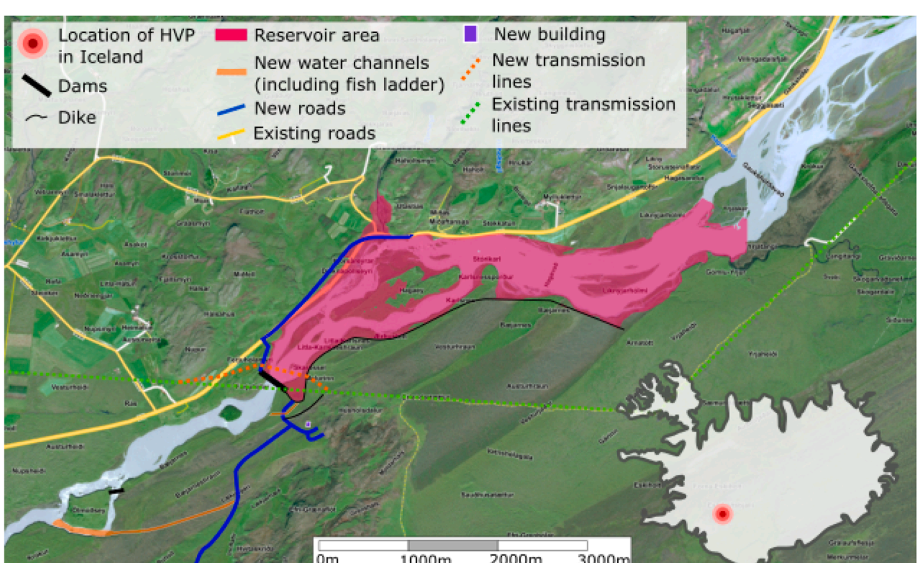

Fig. 2. Main external HVP projected infrastructure. Drawn by the authors, based on National Land Survey of Iceland and National Planning Agency (Iceland) [49,50].

influence of one phenomenon on another. In the frame of this research, the potential implementation of a hydropower project is therefore expected to induce a series of impacts on the surrounding ecological, social or economic environment. For any influenced element, the influencing phenomenon consists of a cause. Influenced elements could further influence other elements, and therefore form an impact pathway. Finally, it is notable that impacts are not only objective and quantitatively measurable effects, but can also have a subjective or qualitative form (e.g. psychological reactions experienced by people exposed to a changing situation).

Based on the recognition that large infrastructure physical intervention can result in such consecutive biophysical and social consequences [34], and that profound causes of undesirable impacts can be identified through the tracing of such impact pathways [63], causal diagrams (CD), a declination of conceptual modelling, have been introduced to improve the rigor, clarity, and conciseness of the expression of causality in impact assessments [64]. Applied to investigate stakeholder perceptions [65–67], ex-post evaluation of environmental impacts [63], or social consequences of hydropower [68], CD proved to be a manifold concept. Intrinsically holistic, CD techniques can support the identification of hidden and therefore disregarded causal relationships between impacts, but also assess cumulative and indirect effects [69,70], making them a valuable support tool for decision-makers [71].

Conceptually, CD has two basic components: i) Elements and ii) Causal links [72]. Elements represent ideas or phenomena, and links represent causalities or influences between two elements. Together, they form a system. Based on a systemic and holistic perspective [73], two main assumptions support CD: i) Interlinkages exist between elements and ii) Any influence on one element induces further influences on the other connected elements [69]. Adapted from Perdicoúlis & Piper [74], we constructed CD around 3 essential features (Fig. 3): i) Elements, forming the fundamental items of the system. They are grouped under common themes; ii) Causality, which connects elements on a one-to-one basis, is represented by arrows, starting from the influencing element, pointing toward the influenced one; iii) Effects, which are placed in the middle of arrows and give details on each causal relation.

Elements are directly adapted from the framework elaborated by Voegeli et al. [75]. Based on an extensive literature review, they illustrate the impact pathways of hydropower implementation using CD. They define two orders of elements: i) First-order elements, which represent the direct implications of the physical process of damming a river to produce power, and the core characteristics of the facility (Table 2), and ii) Second and higher-order elements, which represent aspects impacted by this hydropower implementation (Table 3). First and second orders are assembled in 4 and 10 topical groups, respectively.

Table 2
Presentation of the first-order elements for diagram construction, adapted from Voegeli et al. [75].

List of first-order elements		
	Groups (I-IV) and elements (a-m)	Definition of elements
I.	Built infrastructure	
a.	**Dam infrastructure**	*Physical parts to store water and conduct it to the turbines*
b.	**Power generating infrastructure**	*Infrastructure to produce power (e.g. building, turbines and generators)*
c.	**Side infrastructure**	*Logistic parts (e.g. access road and transmission lines)*
II.	Reservoir impoundment and water dynamics	
d.	**Storage of water**	*Volume of water stored in reservoir*
e.	**Flooded area**	*Part of land permanently flooded*
f.	**Artificial waterbody**	*Surface of flat water in the reservoir*
g.	**Modified and diverted river flow**	*Artificial debit created by released water*
III.	Financial aspects	
h.	**Construction costs**	*Costs involved in the construction of the infrastructure*
i.	**Operation costs**	*Costs involved in the operation and maintenance of the infrastructure*
j.	**Public subsidies**	*Perceived financial support (e.g. from authorities)*
k.	**Resource rent**	*Financial contribution for exploitation of natural resources*
IV.	Workforce and material	
l.	**Construction material**	*Material used or removed for the construction of infrastructure*
m.	**Workforce required**	*Human workforce for the construction and operation of infrastructure*

3.3. Semi-structured interviews

This research is essentially based on the investigation of stakeholder perspectives, to be mapped using CD. The first step of this process was the identification of key stakeholders. For both VdA and HVP, we identified the potential participants based on the following process: First, we used personal contacts and available contact information to establish a primary list of potential stakeholders (power company, government department, interest associations, NGO, etc.). Second, we systematically and explicitly asked all the participants (both from the primary list and those identified later) about potential further contacts and support in our investigation process. This non-probabilistic sampling approach was necessary to enlarge the number of participants and the representation of miscellaneous interests in this research. It also enabled the support of some key stakeholders for recruiting others, the former acting as "guarantor" of the researcher's approach and decreasing his "outsider" status, making stakeholders more disposed to be interviewed.

Specifically, in the interview process of VdA, the first participants indicated that an informal primary consultation process was organised during the earlier planning stage of the project, in the mid-2000 s. We managed to contact 11 of the 12 original participants, 6 of which accepted to participate, in addition to two new key stakeholders. In the case of HVP, we identified 32 key stakeholders in total. 16 of them accepted to participate. Besides stakeholders who did not accept to participate in this study, it is also worth mentioning that some stakeholders could simply not be contacted, due to various reasons (e.g. no personal contact information).

For both VdA and HVP cases, the research for new participants stopped when interviewed participants only suggested key stakeholders who had already been interviewed or contacted. Overall, the number of key stakeholders for both projects remains relatively low, especially for VdA. One reason could be the early stage at which this latter project was stopped.

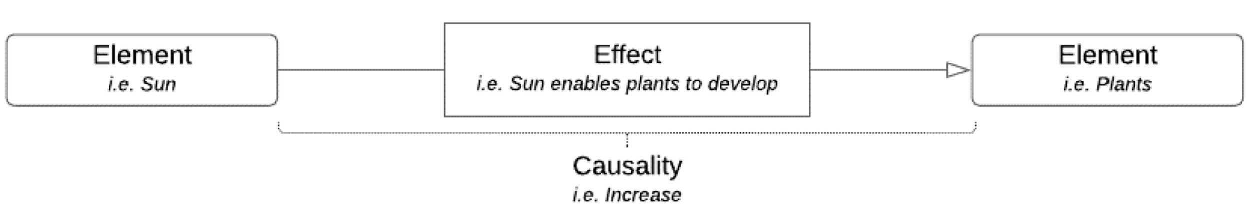

Fig. 3. Main features of the CD, adapted from Voegeli et al. [75].

Table 3
Presentation of the second and higher-order elements for diagram construction, adapted from Voegeli et al. [75].

List of ***second and higher-order elements***

	Groups (A-J) and elements (1–35)	Definition of elements
A.	Functional and aesthetic aspects of landscape	
1.	**Surface and quality of agricultural land**	*Areas used for agriculture, pasture and maintained as such by humans*
2.	**Surface and quality of natural habitats**	*Areas with natural biotope suitable to sustain natural biological communities*
3.	**Surface and quality of urban habitats**	*Areas covered by built environment (e.g. cities, villages, roads)*
4.	**Sites for extraction of building material**	*Areas used for extraction of material (e.g. quarries) and landfills*
5.	**State of cultural and heritage sites**	*Areas or artifacts of cultural importance or considered as heritage*
6.	**State of river channel**	*Areas covered by riverbed and surrounding banks and lands*
7.	**Visual quality of landscape**	*Areas with valuable features from an aesthetic perspective*
B.	Ecosystems and biodiversity	
8.	**Species migration**	*Migration of species along the stream (e.g. fish, invertebrates, algae)*
9.	**Quality of upstream and reservoir ecosystems**	*Quality of biotope and biological community upstream the facility, including the reservoir*
10.	**Quality of downstream ecosystems**	*Quality of biotope and biological community downstream the facility*
11.	**Biodiversity**	*Quantity, diversity and endemicity of species*
C.	Water quality	
12.	**Sedimentation of reservoir**	*Sediment filling process in reservoir*
13.	**Quality of water in reservoir**	*Water specificities in reservoir & upstream the facility (e.g. sediments, temperature)*
14.	**Quality of water downstream**	*Water specificities downstream the facility (e.g. sediments, temperature)*
D.	Climate	
15.	**Greenhouse gases (GHG) emissions**	*Greenhouse gases emitted by the facility*
16.	**Climate change**	*Implications of the facility regarding climate change*
17.	**Local climate**	*Implications of the facility for climate on the local scale*
E.	Economic and financial aspects	
18.	**Economic activity at regional and national level**	*General economic context & factors, along with related implications of facility*
19.	**Local economic activity**	*Economic context & factors on the local scale*
20.	**Profitability of project**	*Capacity of the facility to be profitable*
21.	**Public finances**	*Finances of the local or national public sector*
F.	Natural hazards & risks	
22.	**Risks related to natural hazards**	*Risks related to the occurrence of natural hazards artificially or naturally induced*
23.	**Risks induced by infrastructure**	*Risks linked to the infrastructure (e.g. artificial lake, dam collapse)*
G.	Public health	
24.	**Human health**	*Implications for human health (e.g. disease, psychological distress)*
25.	**Physical injuries and fatalities**	*Physical implications for humans (e.g. deaths, injuries)*
H.	Social cohesion and acceptance	
26.	**Displacement of people**	*Forced or volunteered movement of people*
27.	**Employment**	*Implications for the quantity and quality of jobs*
28.	**Level and distribution of local incomes**	*Distribution and general level of revenues within local people*
29.	**Social identity and culture**	*Traditional rite and practice, cultural identity and cohesion within local people*
I.	Power services	
30.	**Balancing and ancillary services**	*Capacity to provide regulation services on the power grid*
31.	**Generation of electricity**	*Capacity to generate electricity*
J.	Non-power services	
32.	**Flood control**	*Capacity to hold water for the prevention of occurrence of flood events*
33.	**Water supply and irrigation**	*Availability of water for field irrigation, domestic and industrial use*
34.	**Transport and communication**	*Implications for access to specific areas and communications between people*
35.	**Tourism and recreational activities**	*Attractiveness of areas and facility for the practice of recreative activities*

Interview partners were then classified into 5 categories, based on their affiliation groups and institutions (Table 4): (a) Local representatives, including the local officials, (b) Representatives of the governmental administration, (c) Project promoters (power company), (d) Representatives of environmental NGOs and (e) Academics and researchers. Unfortunately, no identified representative of the governmental administration for VdA accepted to participate in this study.

We conducted an individual semi-structured interview with each participant, to understand their perception of the above-described hydropower project. By "perception", we mean the concerns and expectations from the power project, as well as the associated feelings, fears, and hopes of each participant, based on their discourse. The semi-structured interview is a type of interview that provides both the researcher and the interviewee with a degree of relative flexibility during the interview (e.g. order of questions, flow of discussion). Researchers usually have a list of topics, which they then try to fit into the discussion, rather than forcing the interviewee to follow a specific pre-defined arrangement of questions [76]. This type of interview was most suitable for this research as stakeholders frequently focused their answers on their specific interests. Since this study aims to describe the links between the elements (see Tables 2 an 3) it was essential to let interviewees intuitively and freely explain their perceptions of the impact pathways related to the hydropower project in which they were involved. A pre-set rigid list of questions regarding the elements might have influenced the interview and led to biased answers.

Before each interview, the list of elements was sent to the participants, including an explanation of the aim of the study. During the interviews, the following aspects were discussed: i) relevance of the list of elements to evaluate hydropower projects (e.g. missing elements, redundant ones) and ii) perception of the manner each element could be affected or affect another, because of the expected impacts from the concerned project. The role of the list of elements was to provide participants with a reference frame during the interview. If requested, additional detailed information about each element was provided and elements were explained in case of misunderstandings or misinterpretations. This element list was also used as a starting point for discussion, and supported the interviewer in feeding it. Finally, it also helped in framing the interviews and facilitated the analysis process. The interviews typically lasted 90 minutes but time could vary between 50 min and 120 min.

3.4. Building CD based on stakeholder's interviews

After the interview it was transcribed and analysed using the software package Altas.ti [77], which essentially allows the user to structure the qualitative analysis and identify recurrent aspects through a labelling system. On this basis, we identified each reported causal relation between elements. Comprehensive CDs were then developed, by merging individual perspectives. For each causal relation, we specified the number and categories (see Table 4) of participants having reported this relation. Similarly, effects were set as a result of a synthesis and standardization process. Finally, each relation was attributed to a direction of change according to individual perceptions. Classified into six groups

Table 4
Number, affiliation and position of interviewees for each project.

Participants and individual information for each project					
Project	Organization or affiliation		{Short form}	Position or specialization	Number
VdA (Switzerland)	a.	Local representatives	**{Lo}**	Mayor	1
				Ex-mayor and representative of landowners	1
				Representative of local interest group	1
	c.	Power company	**{Pc}**	Board members	2
	d.	Environmental NGO	**{En}**	Representatives	2
	e.	Academics and researchers	**{Ac**	Energy economics specialist	1
	Total interviewees				*8*
HVP (Iceland)	a.	Local representatives	**{Lo}**	Mayor	1
				Representatives of local interest group	2
				Local citizens (non-affiliated)	2
	b.	Governmental administration	**{Ga}**	National energy authority representative	1
				Planning agency representative	1
				Tourist board representative	
				Institute for natural history representative	1
	c.	Power company	**{Pc}**	Board member	1
				Project manager	1
	d.	Environmental NGO	**{En}**	Representatives	2
	e.	Academics and researchers	**{Ac}**	Aquatic and river life specialists	2
				Tourism specialist	1
	Total interviewees				*16*

(Table 5), the direction of change defines the influence of one element on another. An increase [I] in causality means that the relation increases the quantity, quality or intensity of the targeted element. A decrease [D] reports the opposing effect. If a relation was explicitly deemed weak or of minor importance, we used the lowercase letters [i] and [d]. In some cases, participants explicitly indicated the absence of a relation between two elements, which we specified as [0]. In other instances, participants perceived a relation but expressed a certain degree of uncertainty regarding the change to be expected, which we defined as [U].

Table 5
Directions of change.

	Symbol		Direction of change	Definition
1.	[I]	–[I]–▷	Increase	An increase (e.g. quantity, quality, intensity) to the influenced element is perceived.
1a.	[i]	· · [i] · · ▷	Minor increase	Only a limited increase (e. g. quantity, quality, intensity) to the influenced element is perceived.
2.	[D]	–[D]–▷	Decrease	A decrease (e.g. quantity, quality, intensity) to the influenced element is perceived.
2a.	[d]	· · [d] · · ▷	Minor decrease	Only a limited decrease (e. g. quantity, quality, intensity) to the influenced element is perceived.
3.	[U]	–[U]–▷	Undefined change	Causality is perceived, but the direction of change is uncertain.
4.	[0]	–[0]–▷	No change	No influence between two elements is perceived and explicitly expressed
5a.	[I/i]	··[I/i]···▷	Inconsistent increase	Perception of an increase with inconsistent importance among participants
5b.	[D/d]	·[D/d]···▷	Inconsistent decrease	Perception of a decrease with inconsistent importance among participants
6.	[.../...]	–[.../...]–▷	Conflicting direction	Perception of a relation with conflicting direction of change among participants

While directions of change from groups 1 to 4 [I, i, D, d, U, 0] were adequate to define each relation at the individual level, they are unsuitable for the consolidated diagrams, as they cannot reflect conflicting perspectives. In that aim, we used hybrid directions of change (i.e. [I/i] and [D/d]), when the importance of the relation was differently perceived among participants. To handle and represent conflicting perspectives (e.g. a relation is considered a [D] by one participant and a [0] by another), we specified the conflicting perspective in the direction of change (e.g. [D/0]). In Fig. 4, we present the visual representations of all the causality features explained above.

4. Results

In the first part of the interview, participants were asked to evaluate the relevancy of the elements for assessing one of the two projects. A very large majority of participants confirmed the list was suitable and extensive enough for that aim. Some participants considered some of the elements as superfluous, but required no modification of the list as exhaustiveness was seen preferable. Finally, one participant (VdA) considered that the element *water quality downstream* could have been split up into several elements to assess the diversity of hydrological aspects affected by hydropower plants downstream. However, because of the already high diversity of aspects present in the list, this participant did not require any modification of the list. The list remained therefore unmodified.

Based on 8 (VdA) and 16 interviews (HVP), we identified 86 and 143 aggregated causal relations, respectively, all structured around 10 topical CD for each project, which were set accordingly to the topic groups of elements (Table 3). We present first the CDs for VdA (Figs. 5–14) and subsequently the CDs for HVP (Figs. 15-24). Stakeholder categories (short form, cf. Table 4) are specified for each commented causal relation, using "{}". In the final part, we present a CD focusing on the inter-group causal relations exclusively, which enables a comparison of both VdA and HVP projects on this basis.

4.1. *Causal diagrams of VdA, Switzerland*

4.1.1. *Functional and aesthetic aspects of landscape – Fig. 5*

The impacts of VdA on the land cover was highlighted by all stakeholder categories. The reservoir would flood agricultural land {Lo; Pc}

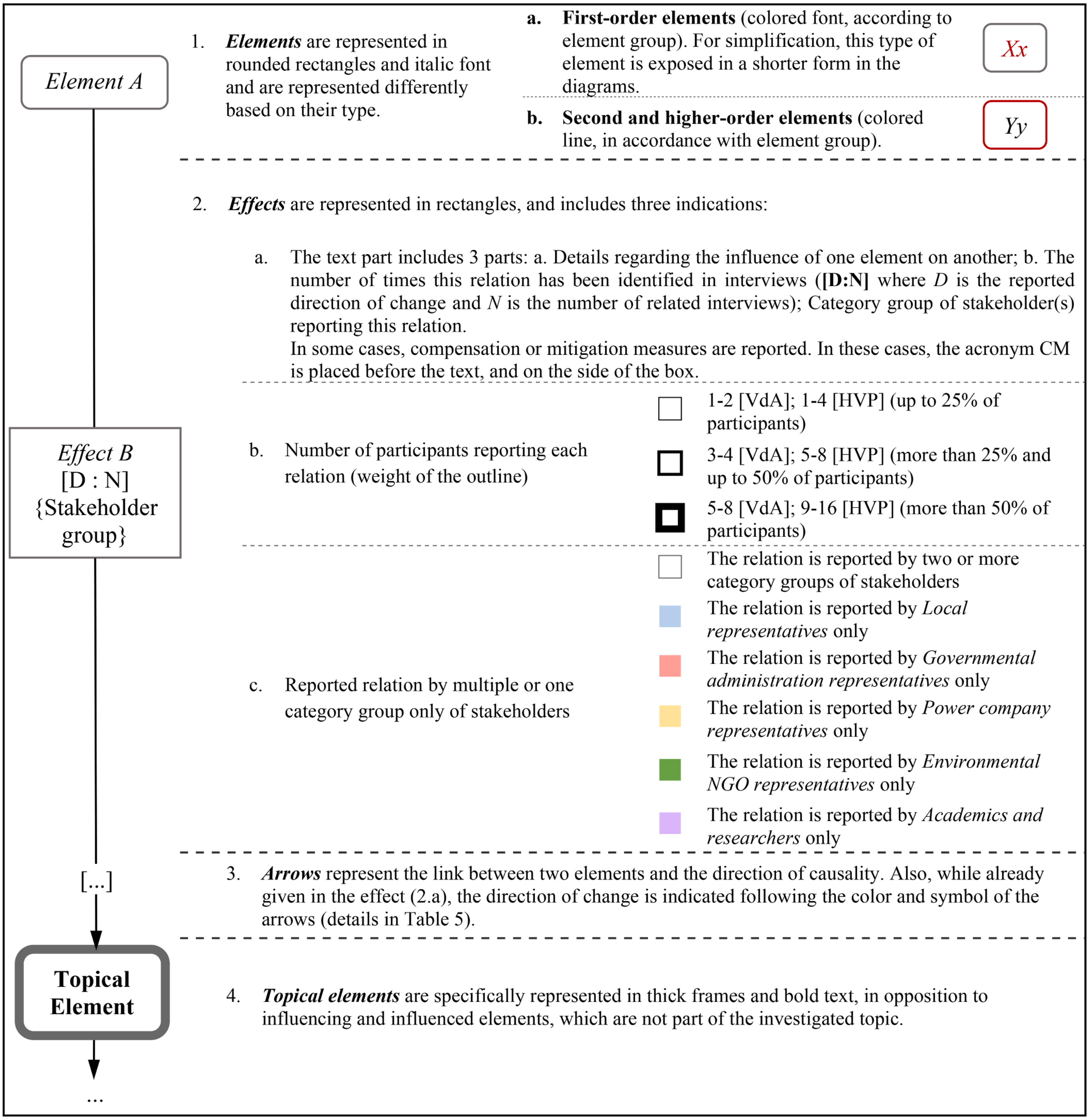

Fig. 4. Visual representation of elements and links featured in CD.

and pristine area {Lo; En}. While the flooding would be limited to a small area {Lo; Pc}, the infrastructure would be built traditional hiking paths and natural habitats, cut the valley in half, facilitate the access leading to enhanced forest exploitation {En} and increase the local urbanisation {En; Ac}). Increased local urbanisation was also reported due to new workers coming for the construction phase {Lo}. Besides, a control flow downstream and better access to water would improve natural habitats {Lo}. Changed natural habitats would have an impact, although undefined, on ecosystems {Lo; Pc} and biodiversity {Pc}. The impact of VdA on the landscape brings a very various set of expectations. The dam is predicted to damage {En}, improve {Ac}, change the landscape {Lo; Pc}, or being hardly visible {Lo; Pc}. The reservoir could either deteriorate {En}, improve {Lo}, or simply change the landscape {Lo; En}. The project could increase the need for new quarries and deposit sites {Lo; Pc; En}. While the controlled flow could improve the river channel downstream {Pc}, the river channel at the reservoir site would remain unchanged due to rocky sides {Lo} and trapped sediments would not be able to compensate for riverbed erosion downstream {En}. VdA is not expected to force people to move away {Lo; Pc; En; Ac}. Finally, while the reservoir itself could be used as a recreational fishing area {Lo; Pc} or attract recreationists {Pc}, the damaged landscape could also reduce local tourism {En}.

4.1.2. *Ecosystems and biodiversity* – Fig. 6

VdA could affect fish migration due to the construction of a new dam {Lo; En}. However, its impact is limited due to the presence of another

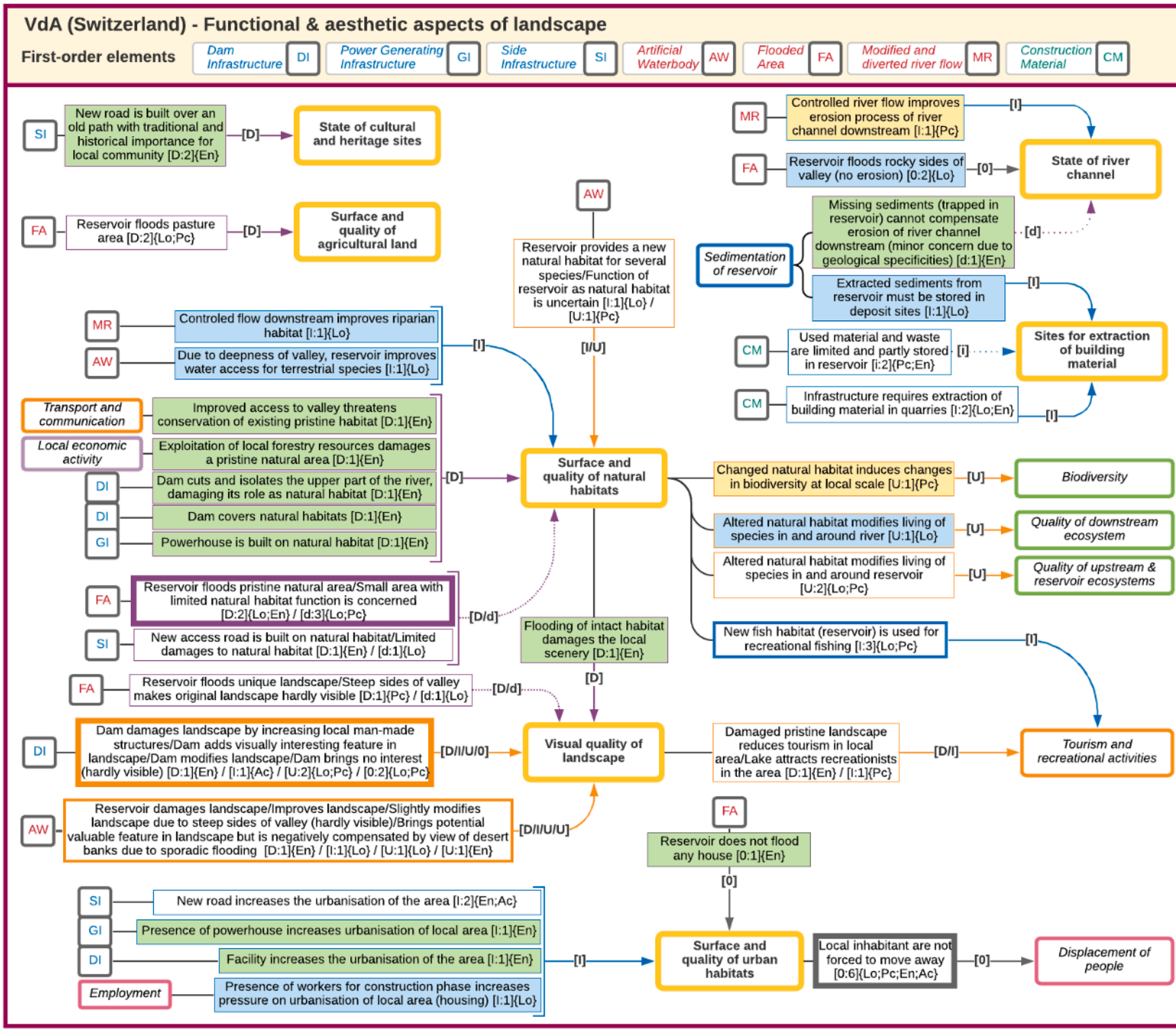

Fig. 5. Functional and aesthetic aspects of landscape – VdA, Switzerland.

dam downstream {En}. The fish migration is recognized as essential for aquatic species {En}. In the case of VdA, the existing downstream dam downstream was perceived as minoring the problem {En}, or even discarding it completely {Lo}. One stakeholder considered the forest exploitation as beneficial for the ecosystems upstream {Lo}. The impact of a controlled river flow generated different perspectives among stakeholders, ranging from damages {En} and improvement {Pc} to uncertain changes {Lo}. The changed natural habitats are expected to have an impact on ecosystems {Lo; Pc} and local biodiversity {Pc}, although these effects were not defined. Finally, a degraded ecosystem would lead to a decrease in local biodiversity {En}.

4.1.3. *Water quality* – Fig. 7

The effect of stored water from VdA on the water quality downstream is perceived as insignificant {Lo}. While the process of storing water itself would induce sedimentation in the reservoir {Lo; Pc}, this issue could be minored by the natural low sediment content of the water {Pc}. Subsequent siltation of the reservoir would lead to a decrease in the storage volume {Lo; En (limited issue)}. Trapped sediments are also expected to induce additional costs for removal and require deposit sites {Lo}, while a lack of sediments downstream would slightly affect the erosion of the river channel downstream {En}.

4.1.4. *Climate* – Fig. 8

The construction of the infrastructure would increase GHG emissions due to the machinery {Lo}, although such emissions are also viewed as be negligible compared to the size and lifetime of the infrastructure {Lo; Pc}.

4.1.5. *Economic and financial aspects* – Fig. 9

The local economy could experience a boost by the new presence of workers for the construction phase {Lo; Pc}, but also thanks to improved access facilitating local forestry {Lo; En; negligible for another En}. The VdA project in its current state is also reported as blocking the development of another smaller hydropower plant project that would present some economic benefits at the local scale {Lo; En}. Reduced tourism and recreational activities would be slightly damaging for the local economy {Pc}, if not insignificantly {Lo}. Locals are not expected to benefit from improved access to electricity {Lo; En}.

A change in the local economy would have no impact on the local incomes, except a slight damage for the local tourism-related employment, and a positive impact on the renewal of forest resources {Lo}. On

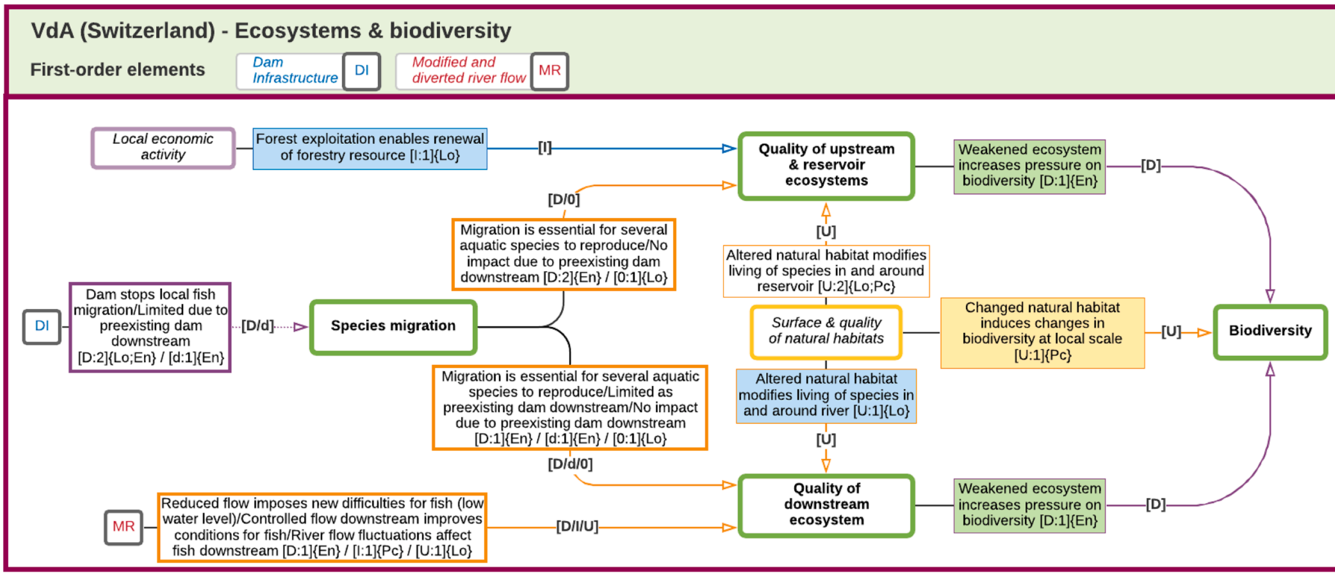

Fig. 6. Ecosystems and biodiversity – VdA, Switzerland.

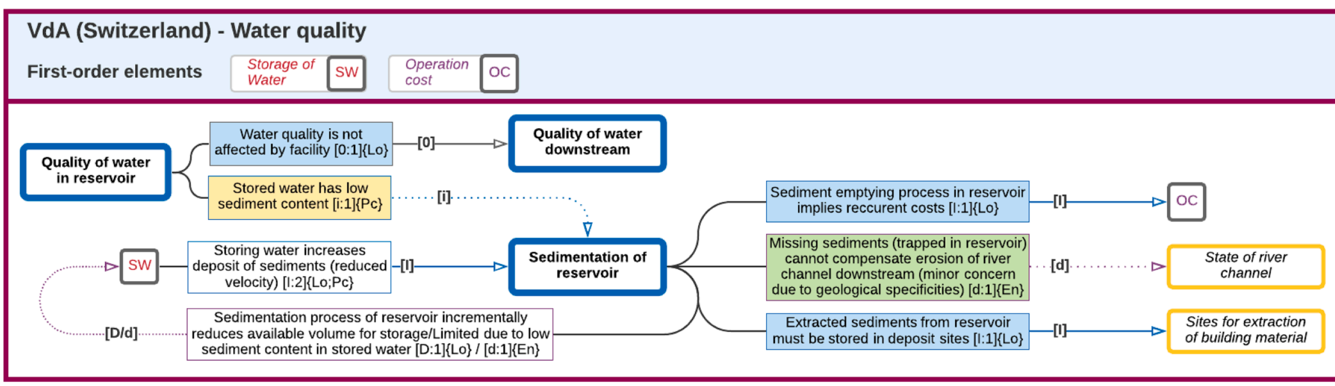

Fig. 7. Water quality - VdA, Switzerland.

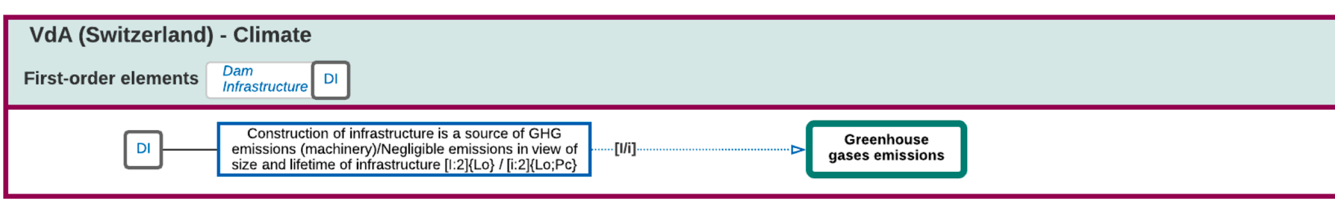

Fig. 8. Climate - VdA, Switzerland.

the other side, increasing local forestry could damage a pristine natural area {En}. All participants consider the provision of power balancing services as being the primary source of profitability for VdA, although it could be minored by a limited capacity {En}. However, construction costs could put this profitability at risk, and potential profits would not benefit to the local community {En}. For 6 participants, the profitability of the project is mainly questioned by the current low-price volatility on the power market {Lo; Pc; En}. VdA is a public-owned company project. Therefore, its financial results would directly impact public finances. The hydropower tax, imposition system and expected outcome is perceived differently among the stakeholders, also within the {Lo} category. One {Lo} expects the project to generate a new tax-based income, which could bring support from the local population. Such tax could also benefit the local community {Lo; Pc}. The existence of this tax is however questioned for a pump - storage facility {En}, and if existent, could only benefit to the cantonal (state) level {Lo; Pc}. The provision of balancing services is expected to support further integration of new renewable capacity {Pc; Ac}, although such support could be limited {En}. The net production of electricity of VdA is expected to be very low {Pc; En}, but could still optimize local hydropower potential as a renewable source {Lo; Ac}.

4.1.6. *Natural hazards and risks* – Fig. 10

VdA would be able to hold a small flood {Pc}, but could also increase the risks linked to natural hazards {Lo}. The risk for the infrastructure to collapse is mainly considered residual {Lo; Pc; En; Ac}, while consequences following such event would be limited, due to no infrastructure directly downstream, and the limited storage capacity {Lo}. As a result, the local community would experience only limited distress {Pc}, or no distress at all {En; Ac}.

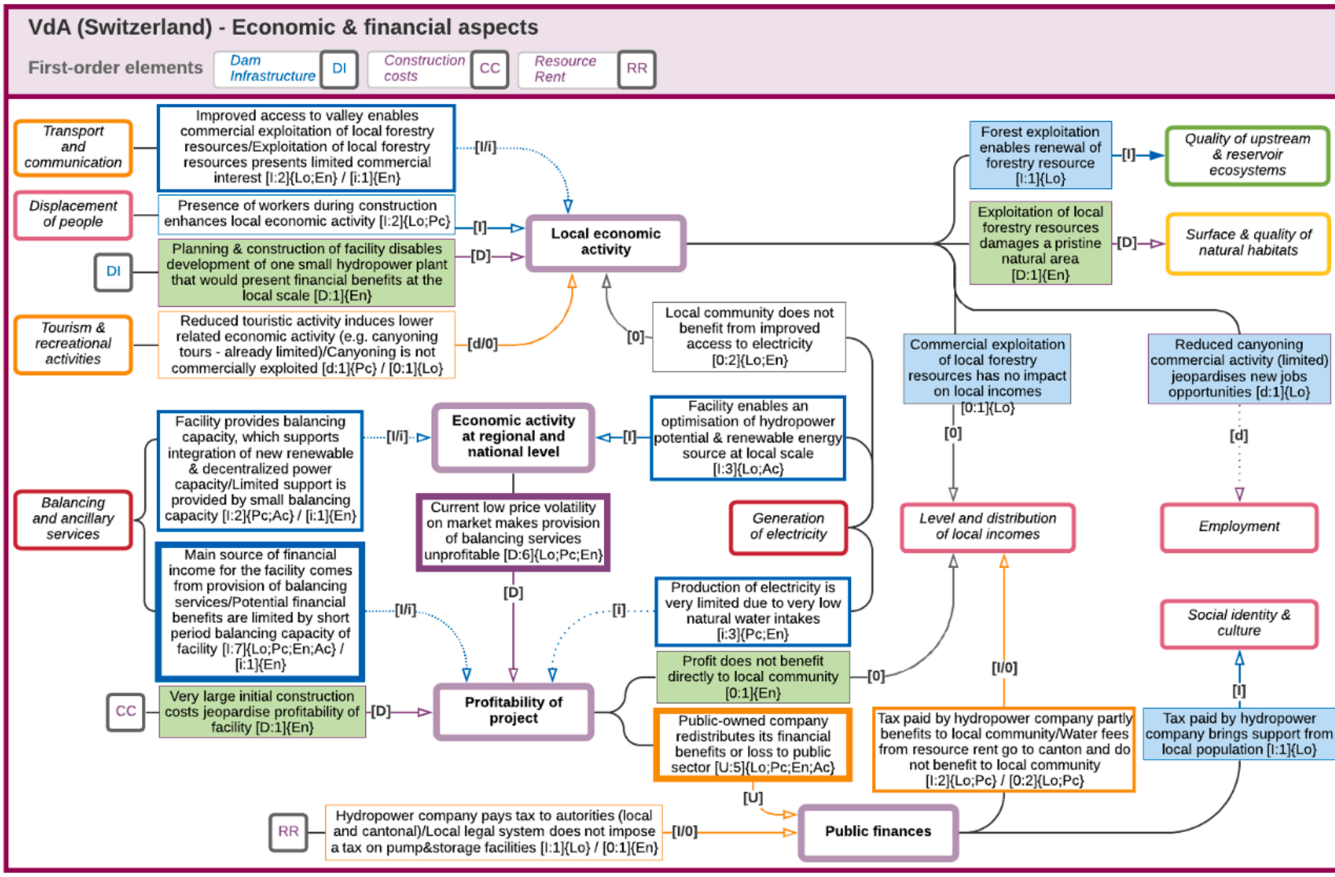

Fig. 9. Economic and financial aspects - VdA, Switzerland.

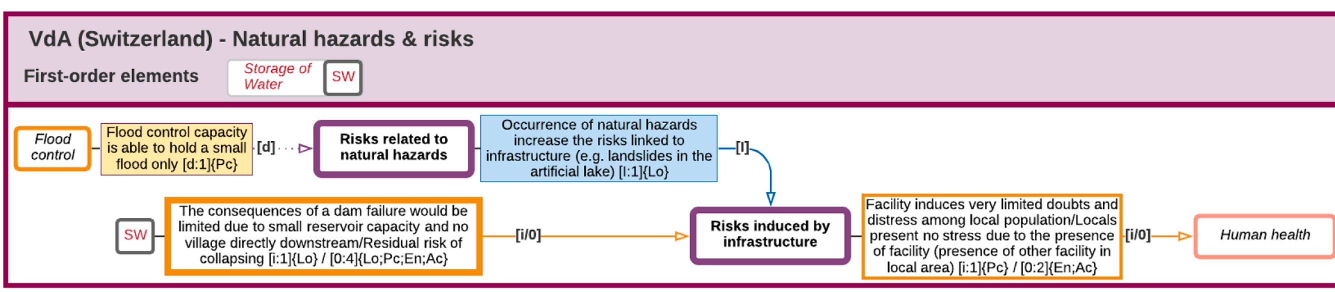

Fig. 10. Natural hazards and risks - VdA, Switzerland.

Fig. 11. Public health - VdA, Switzerland.

4.1.7. *Public health* – *Fig. 11*

Besides the minimal distress of local population regarding the potential presence of VdA {Pc; no distress for En; Ac}, the construction phase would induce a risk for workers, although equivalent to professional standards {Lo; Ac}.

4.1.8. *Social cohesion and acceptance* – *Fig. 12*

Regarding employment, seven stakeholders expect VdA to afford new jobs during the construction phase, but very few in the long term. These new jobs are also expected to attract newcomers in the local community {Lo; Pc}, which could then boost the local economic activity. Changes at this level could adversely jeopardize a few touristic-related jobs, and the newly enabled forestry activity could bring no

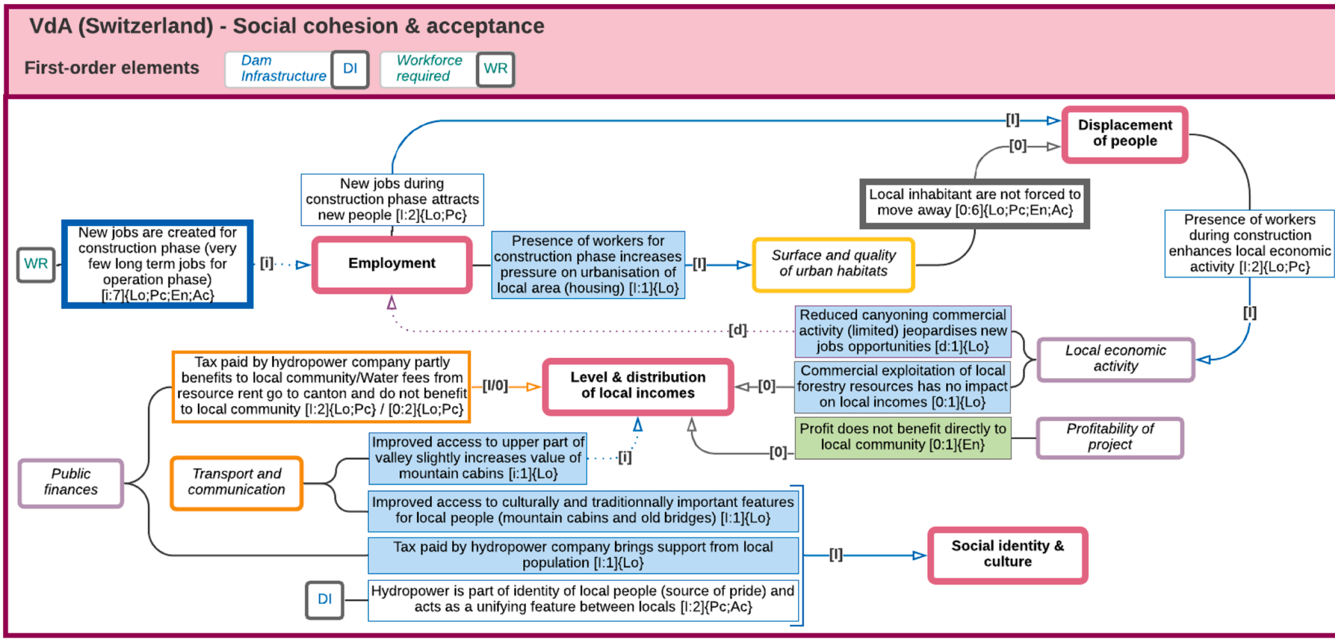

Fig. 12. Social cohesion and acceptance – VdA, Switzerland.

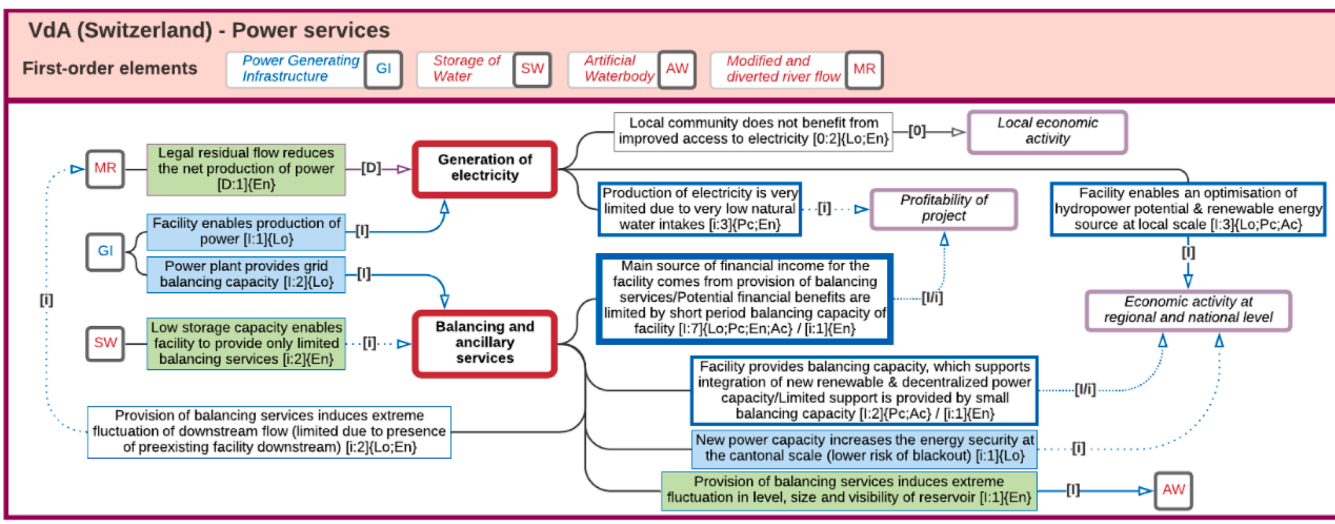

Fig. 13. Power services – VdA, Switzerland.

positive effect for local incomes {Lo}. New workers would also induce a higher pressure for the development of local urban areas {Lo}. Six stakeholders from all categories do not expect people to have to move due to the project. As noted above, the beneficiary of the hydropower tax is not expected to be the same among the stakeholders. However, if allocated to the local community, this tax would bring support from the local population, while improved access to mountain cabins and local cultural artifacts would improve local incomes, and community identity and culture, respectively {Lo}. Finally, hydropower is seen as a source of unification and pride for local communities {Pc; Ac}.

4.1.9. Power services – Fig. 13

While VdA is expected to provide both a valuable generation of electricity and provision of balancing services {Lo}, the project could suffer from residual water flow and limited storage capacity for this aim {En}. The project would not benefit the local population in terms of access to electricity {Lo; En}. Nevertheless, VdA could optimize the local hydropower potential {Lo; Pc; Ac}. All participants foresee the profitability of VdA as related to the provision of balancing services. However, the limited capacity of the project could restrain its profitability {En}, and, additionally, could only provide a limited support for the further implementation of renewable power {En}. The project is expected to bring slightly more energy security at the cantonal level {Lo}. Finally, the provision of balancing services would generate some significant fluctuation of reservoir level and visibility {En}, as well as fluctuation in downstream river flow, although this aspect would be mitigated due to an existing dam, downstream {Lo; En}.

4.1.10. Non-power services - Fig. 14

For seven stakeholders, VdA would require the construction of a road, which would then improve access to the valley, and, for five of them {Lo; Pc; En}, could then be used for local tourism. This same road would also enable the commercial exploitation of forest resources {Lo; En; negligible for another En}, would improve access to locally important heritage features {Lo}, and could even increase the value of remote mountain cabins {Lo}. At the same time, the road could also constitute a

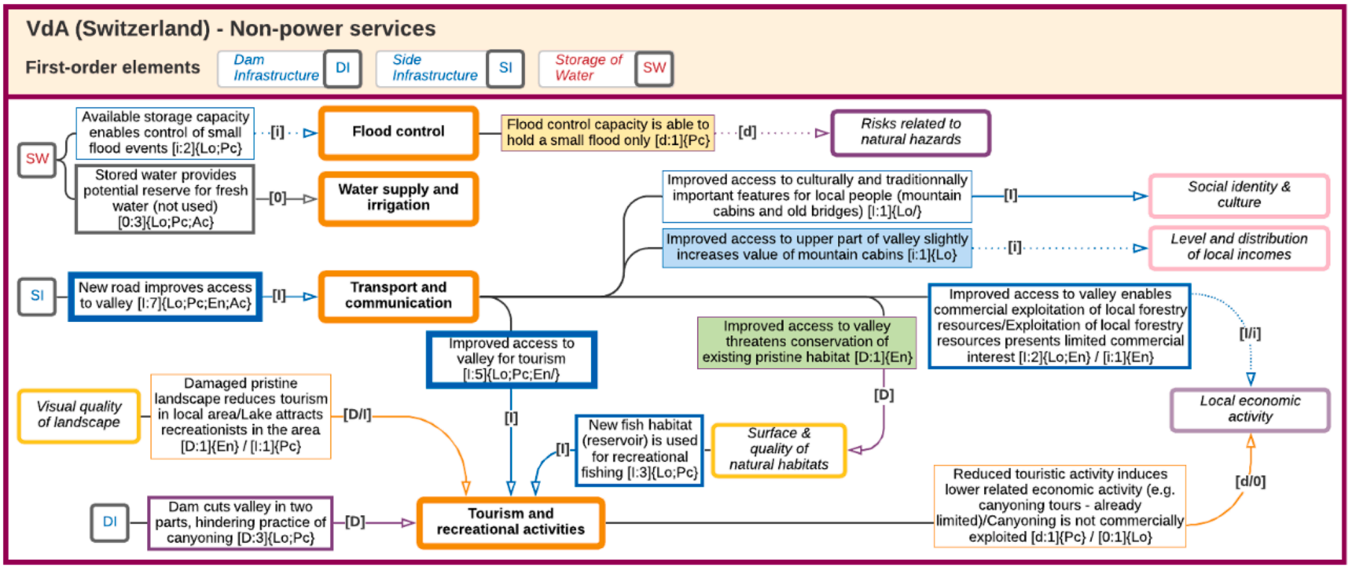

Fig. 14. Non-power services – VdA, Switzerland.

threat toward the pristine state of the valley {En}. The visual interest of the project is perceived either positively {Pc} or negatively {En}, impacting the local tourism accordingly. Furthermore, the new reservoir could be used for recreational fishing, while the dam itself would hinder the practice of canyoning {Lo; Pc}. Regarding the latter, its limitation would have slightly negative {Pc}, or no impact at all {Lo} on the local economic activity. As a water storage facility, VdA would able operators to hold a small flood, and affect the risks related to natural hazards accordingly {Lo; Pc}. It would also provide a potential, although yet unrequired new source of freshwater {Lo; Pc; Ac}.

4.2. *Causal diagrams of Hvammsvirkjun, Iceland*

4.2.1. *Functional and aesthetic aspects of landscape* – Fig. 15

HVP is located in an agricultural area, and most participants expect the project to flood some agricultural land {Lo; Ga; Pc; En; Ac}, although some stakeholders consider that only a limited area is concerned {Ga; Pc; En} and would be physically compensated {Lo; Pc; Ac}. While the farming activity itself is expected to be unaffected {Pc}, the value of farmlands could be reduced {Lo} but would be financially compensated {Ga; Pc; En; Ac}. Through its infrastructure, reservoir, and modification of river flow, HVP is expected to have negative consequences on natural habitats, due to habitat coverage and dried floodplains {Pc}. Concerns are expressed regarding the dried floodplains leading to dust storms, slowing down water in the reservoir, creating an area of still water, and converting land through the construction of a new road {Lo}. Furthermore, the flooding of bird nesting areas {Lo; Pc} and the conversion of natural floodplains into new agricultural land – a mitigation measure for farmers – also raise concerns {Lo; Pc; Ac}. The changes in the river channel brought rather negative concerns for the natural habitats {Lo; Ac; uncertain for En}. Although HVP is primarily perceived as damaging the natural ecosystem due to flooding and aquatic disturbances, the new reservoir could constitute a new habitat for fish adapted to slow-flowing water {Pc}, and accordingly could be used for recreational fishing {En}. The river channel is also expected to be affected by the infrastructure and changed water quality {Lo}, sediment removal processes {Ac}, dried riverbed downstream {Lo; Pc; En; Ac}, eroded riverbed upstream {Lo; Ga; En}, and the sedimentation in the reservoir {Lo; irrelevant for Ga}. HVP would require some building material and increase the need for new quarries {En}, although part of it would be directly extracted from the riverbed {Lo; Pc; Ac}, and could be used as construction material in the future {Pc}. Nothing in the HVP project is perceived as improving the landscape. To its best, the project would have a limited visual impact. Among the HVP consequences, the presence of the dam, the reservoir, the transmission lines, the reduced river flow downstream, the replaced road, the powerhouse and required new quarries are perceived as damaging the visual landscape. However, stakeholders from all groups also relativized some of those visually intrusive features, mainly due to the pre-existing presence of man-made infrastructures in the area, and planned mitigation measures. Nevertheless, the damaged landscape would negatively impact the local tourism and be seen as a loss of local cultural heritage {Lo; Ga; pc; En; Ac}. Some existing urban area would also be lost or damaged {Lo}, although no residential areas are expected to be flooded {Lo; Ga; Pc; En}. On the other side, new workers during the construction phase {Lo} and the infrastructure itself {Lo; Ga} are expected to increase the urbanisation of the area. While no inhabitants would be forced to move away {Ga; Pc}, changed landscape and loss of agricultural land could encourage people to leave the area {Lo; Ac}. The impact of HVP on local cultural heritage generates various considerations {Important for Lo; minor for Pc; negligible for Lo; Ga}. Overall, the project's consequences on natural habitats, agricultural, heritage, and urban areas, along with visual changes, are all considered as damaging the local social identity and culture.

4.2.2. *Ecosystems and biodiversity* – Fig. 16

All stakeholder groups perceive HVP as a threat towards fish migration, notably the presence of the dam for the upstream migration of salmon. However, other limiting-migration aspects from the project are acknowledged, such as lower river flow and velocity {Ac}, presence of turbines for downstream migration {Lo; Ga; En; Ac}, and presence of rocks and dikes as affecting geese population {Lo}. For some of these impacts, mitigation measures are acknowledged by stakeholders, such as residual water flow {Ga; Pc}, fish ladder {Lo; Ga; Pc; En; Ac}, and fish-friendly turbines {Ga; En; Lo}. The efficiency of the two latter mitigation measures was, however, questioned {Lo; Ac}. Reduced capacity of salmon to migrate would damage both the upstream and downstream ecosystems {Lo; Ga; En; Ac}. The upstream ecosystem is expected to be damaged by the disturbance of aquatic habitats {Lo; Ac}, the flooding of existing terrestrial habitats {Lo; Pc; En}, and a change in the local water temperature {Lo}. However, an increase in nutrients and higher water temperature in the reservoir would benefit the reservoir ecosystem {Ga}. Regarding the ecosystem downstream, a reduction of the river flow could have deleterious consequences {En; minor for Pc}. Other harmful impacts would result from flushing events {Ac}, facilitated

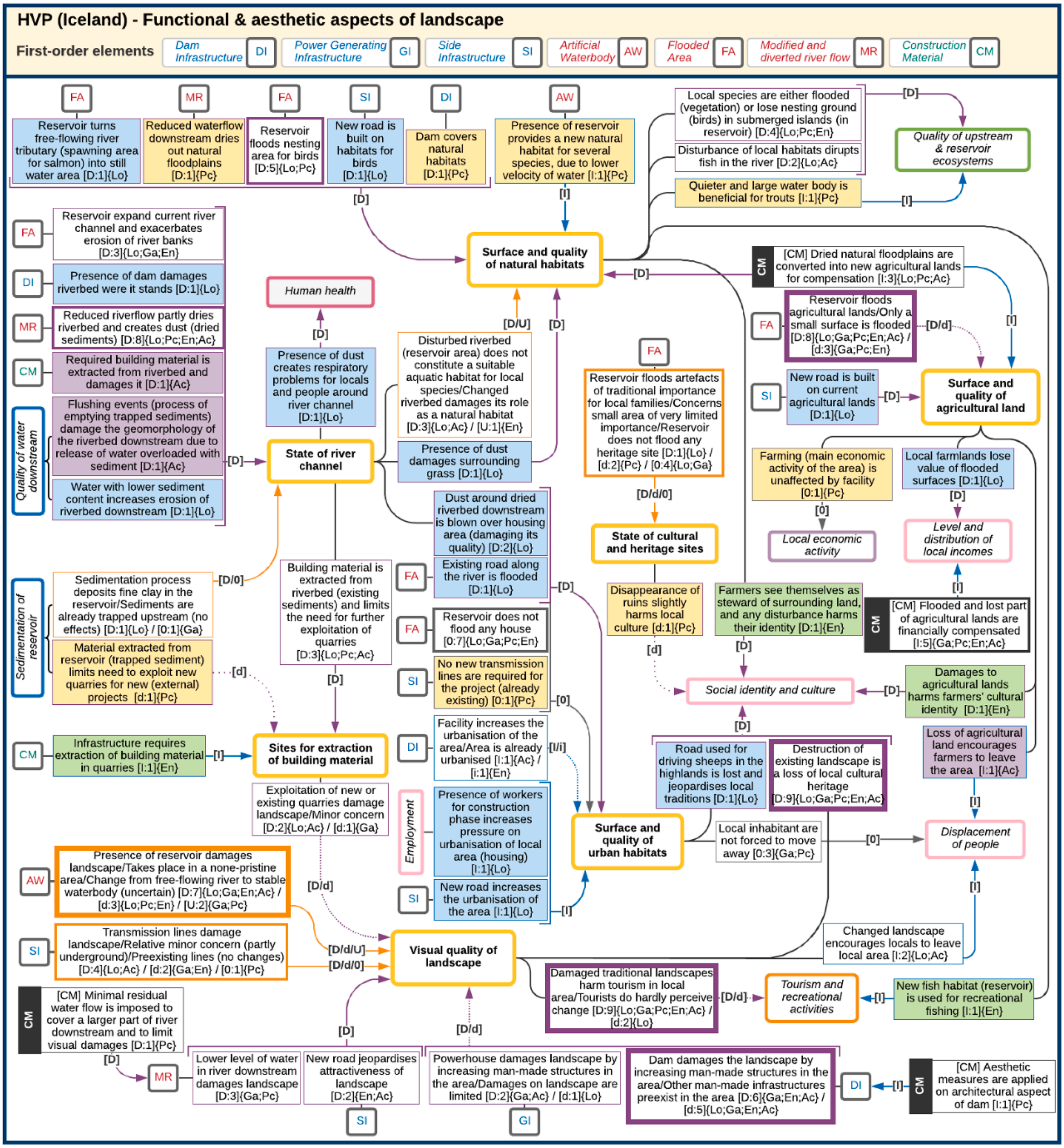

Fig. 15. Functional and aesthetic aspects of landscape – HVP, Iceland.

access to a currently isolated and pristine island due to lower river level {Lo; Ga; Pc}, and reduced nutrient content in water {En; Ac}. On the other hand, the reduced quantity of sediments is seen as positive due to the excessive natural rate {Ga; En}. The expected changes in the water temperature could also damage the ecosystem {En; contradicted by Ac}. Both impacted reservoir and downstream ecosystems are expected to have similar consequences. Deteriorated ecosystems are foreseen as presenting a threat to the local salmon {Lo; Ac; insignificant for En}. Reduced number of salmon would also be damaging for the identity of local communities and local tourism, as salmon is of major cultural importance for local communities {Lo; Pc; En}, and recreational fishing is practiced by recreational fishers in the area {Lo; Pc; En; Ac}. This latter view was not shared by two stakeholders, who consider that local recreational fishing is already limited, and only the experience of fishing in the wilderness is threatened {Ga}. In addition, the affected reservoir ecosystem could reduce commercial fishing {Ga} and local egg gathering tradition {Lo}.

4.2.3. Water quality – Fig. 17

The process of storing water is expected to increase the sedimentation of reservoir {Lo; Pc; En; Ac} and the water temperature {Ga; no change for another Ga; Ac} with subsequent benefits for local aquatic

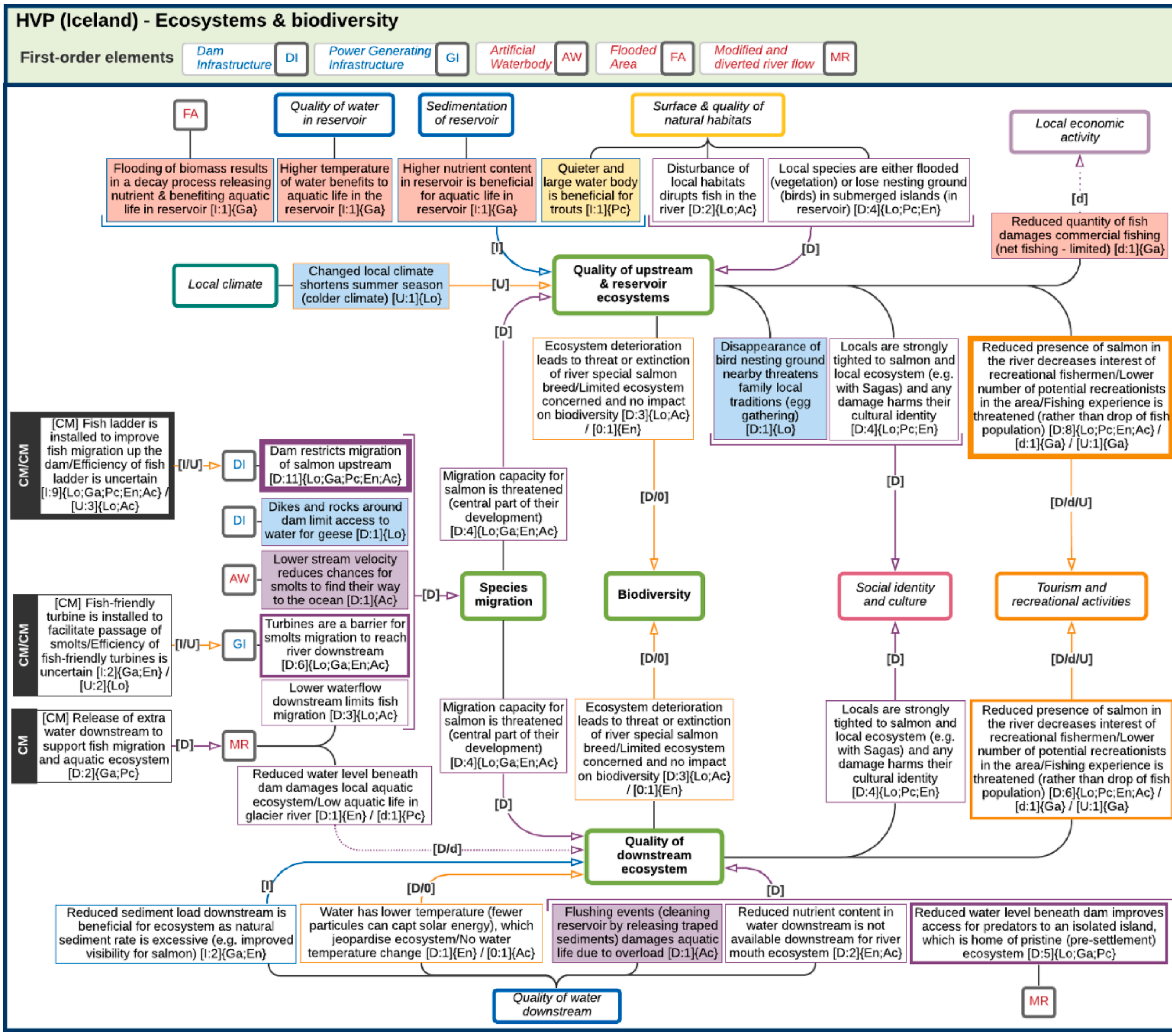

Fig. 16. Ecosystems and biodiversity – HVP, Iceland.

life {Ga}. No impact for the water downstream is expected {Pc; Ac}. Thanks to the upstream storage of sediments by other facilities, stakeholders expect the sedimentation of the reservoir to be limited {Lo; Ga; Pc; Ac}, while its occurrence is expected to reduce the capacity and lifespan of the reservoir {Lo; Ga}. To counter this process, flushing events could also be used, although turning the water downstream muddy, with deleterious impacts for the riverbed and the aquatic life downstream {Ac}. One stakeholder expects a higher nutrient rate in the reservoir to improve the aquatic life {Ga}. Overall, the change in sediment rate for the water downstream brings miscellaneous perceptions among stakeholders, from positive {Lo; Ga}, uncertain {Ga; En} to negative consequences {Lo}. This diversity of perception is then reflected in the consequence of a changed sediment rate for the downstream ecosystem, which is expected to either suffer {En; Ac} or benefit {Ga; En} from reduced sedimentation rate, as the current one is excessive. As a side consequence, change in the water temperature is expected, with deleterious impacts for the ecosystem {En; no change for Ac}. The riverbed in the reservoir could be affected by the deposit of fine clay {Lo; no impact for Ga}, and missing sediments could increase the erosion of the riverbed downstream {Lo}. Finally, the deposit of sediment in the reservoir is parallelly expected to be exploited, for external construction projects {Pc}.

4.2.4. Climate – Fig. 18

Both the construction phase {Lo} and the decay process of flooded biomass {Lo; Ga; En} are expected to emit GHG, although some stakeholders also consider the flooded area to be limited {Pc; En; Ac}, and the GHG emissions due to the construction phase to be limited compared to the lifetime of the infrastructure {Ac}. For several stakeholders, the presence of the reservoir, as a large body of glacial water, could reduce local temperatures and increase the presence of fog {Lo; Ga; Pc; En}. For two other stakeholders, however, this effect would be entirely overshadowed by the extreme Icelandic weather {Ga; Pc}.

4.2.5. Economic and financial aspects – Fig. 19

At the local scale, the economic activity is expected to suffer from reduced tourism {Lo; Ga} and reduced sale of fishing permits {Lo; Pc; En; Ac}, although the latter is parallelly considered a small activity in the area {Ga}. One stakeholder also expects commercial fishing to be reduced, though it is already a limited activity {Ga}. However, the dam

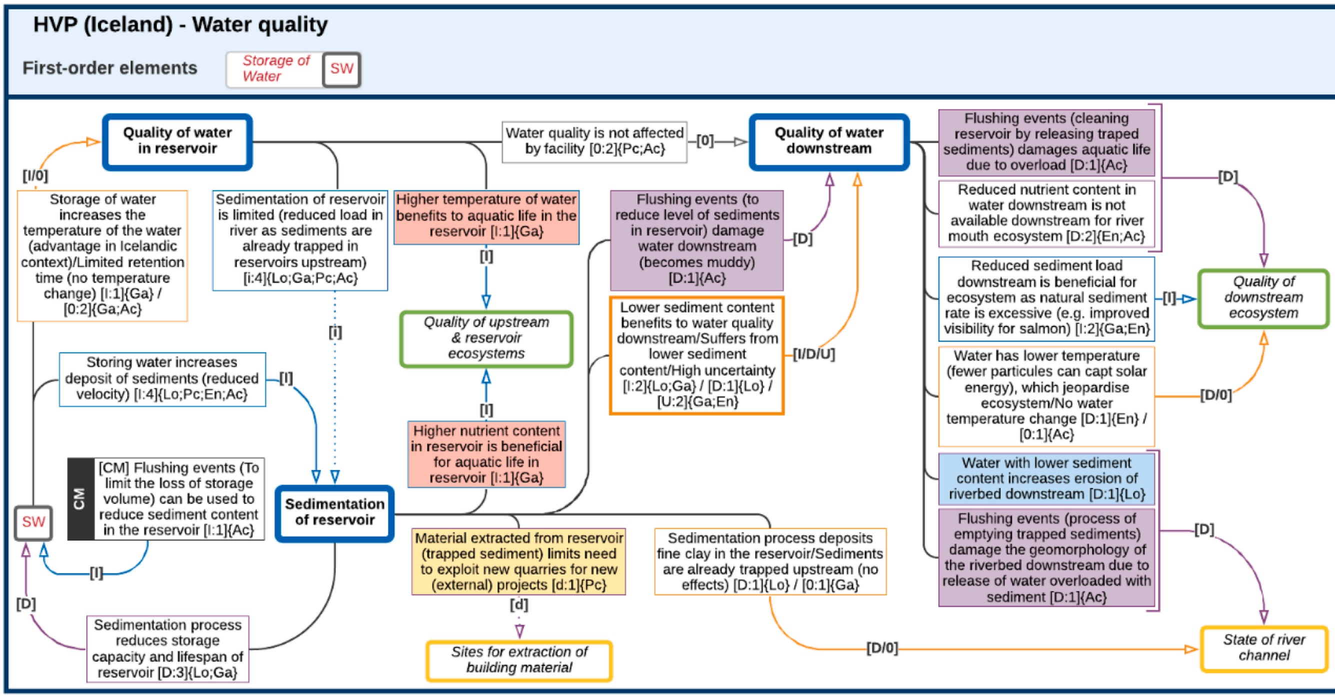

Fig. 17. Water quality – HVP, Iceland.

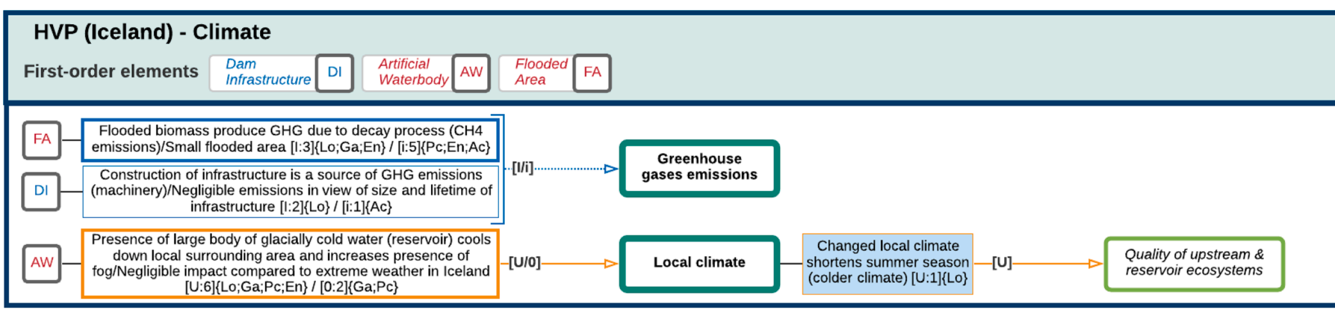

Fig. 18. Climate – HVP, Iceland.

itself could provide a new touristic attraction {Ga; Pc} and new workers for the construction phase could also enhance the activity {Pc; En}, though only a few businesses would be concerned {Lo}. No impact from HVP towards farming {Pc}, improved local access to electricity {Lo; Ga} nor financial gain for locals from enhanced economic activity are expected {Lo}. HVP perceived as a touristic attraction {Ga; Pc} is opposed to an expected reduced tourism-based economic activity {Ga; En} among stakeholders. Furthermore, the hydropower tax is based on the location of the powerhouse. Therefore, it would be unevenly distributed among local communities, leading to an unbalanced distribution of financial benefits from water exploitation {Lo; Ga; Pc; Ac}, although some participants foresee a compensation for lost land {Lo; Pc} and increased tax income from potential new jobs {Pc}.

At the national scale, HVP is expected to increase the supply of renewable power {Lo; Pc}, along with a slight improvement of the national energy security {Pc; En}. However, this new source of electricity supply is also considered unnecessary by several stakeholders {Lo; Ga; En; Ac}, due to the current overproduction at the national level. The production of power is perceived as the main source of profitability for the project {Lo; Pc}, and its benefits would be distributed to the public sector {Ga}, although this distribution could be uneven among local residents {Lo}.

4.2.6. *Natural hazards and risks* – Fig. 20

HVP is expected to be able to hold a small flood {Lo}, but not large ones {Pc}. Its presence could in addition increase the magnitude of some extreme flooding events {Lo; Ga}. Besides, the risk of a dam collapse dam is foreseen as residual {Lo; Pc}. If occurring, it would only have limited consequences due to the small storage capacity {Ga; Pc}, and the absence of inhabited areas downstream {Pc}, although putting the energy supply at risk {Ga}. An exacerbated flood event could, however, induce physical injuries for some people downstream {Lo}.

4.2.7. *Public health* – Fig. 21

The presence of dust and damaged local land are both expected to have a deleterious impact on the health of local people, creating respiratory issues {Lo} and psychological distress {Lo; En}, respectively. The planning phase itself is perceived as creating psychological distress among local residents {Lo; Ga; limited for Pc}. During the construction phase, a higher risk of accident could result from work {Lo; Ga} and increased local traffic {Lo}, and a higher presence of tourists around the infrastructure once built {Pc}. An exacerbated flooding event could involve injuries of people downstream {Lo; contradicted by Pc}.

4.2.8. *Social cohesion and acceptance* – Fig. 22

A majority of stakeholders foresee an increase of short-term job as

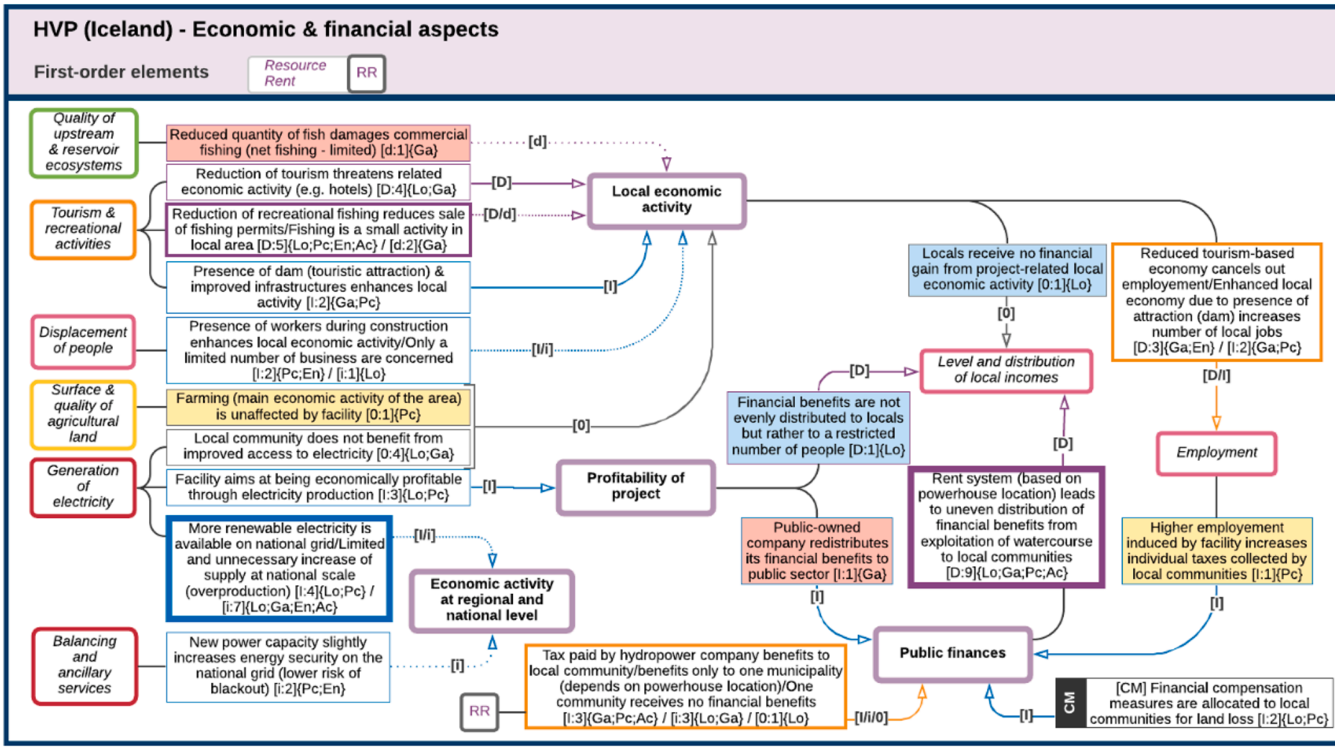

Fig. 19. Economic and financial aspects – HVP, Iceland.

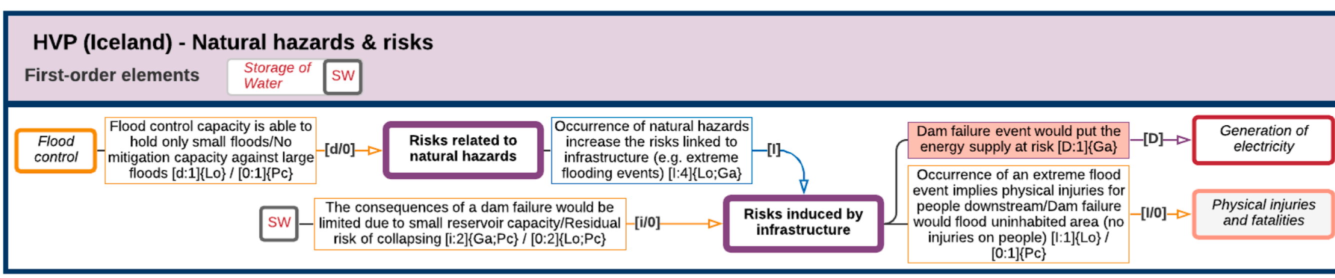

Fig. 20. Natural hazards and risks – HVP, Iceland.

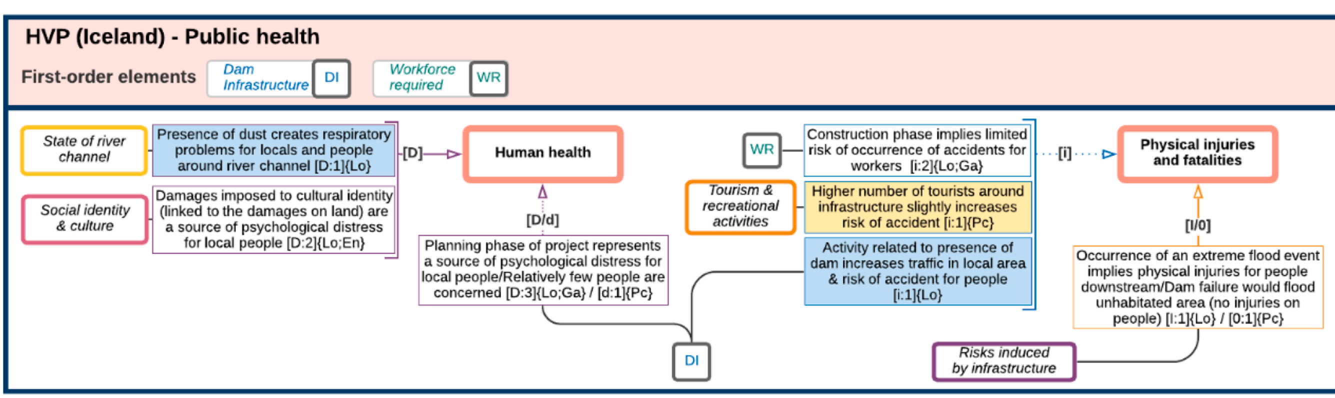

Fig. 21. Public health – HVP.

resulting from HVP, which would increase the income of a few locals {En}, the amount of collected taxes {Pc}, the urbanisation of the area {Lo} and attract newcomers {Lo; Pc; En}, who could, in turn, enhance the local economic activity {Pc; moderately for Lo; En}. The local level of employment is also perceived as related to the touristic activity, which might be impacted negatively {Ga; En} or positively {Ga; Pc} by HVP. Uneven distribution of hydropower rent {Lo; Ga; Pc; Ac} and financial benefits {Lo}, reduced recreational fishing {Lo; Ga; Ac} and loss of farmland value {Lo; compensation of lost value for Ga; Pc; En; Ac} are all perceived as reducing the level and distribution of local incomes.

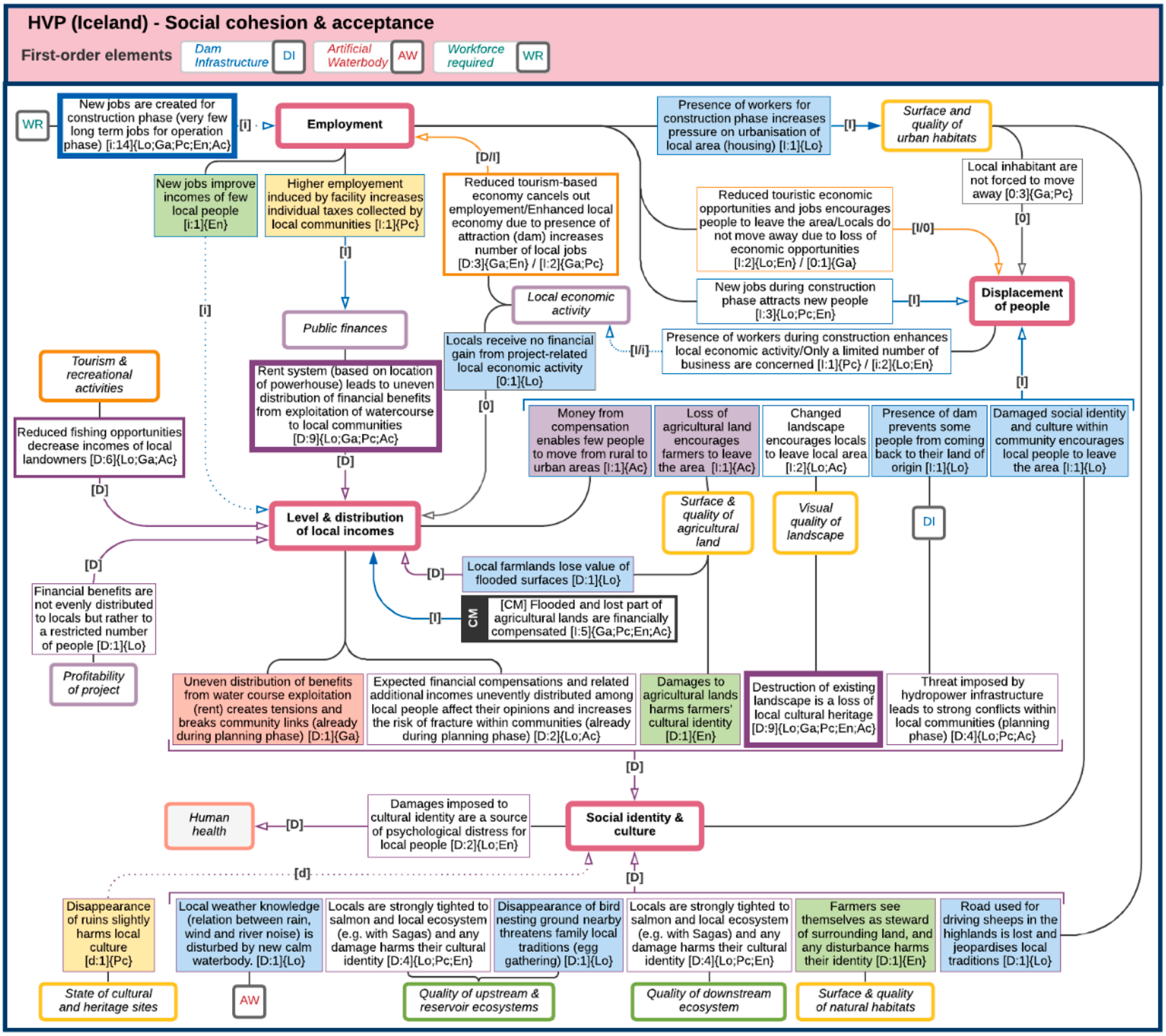

Fig. 22. Social cohesion and acceptance – HVP.

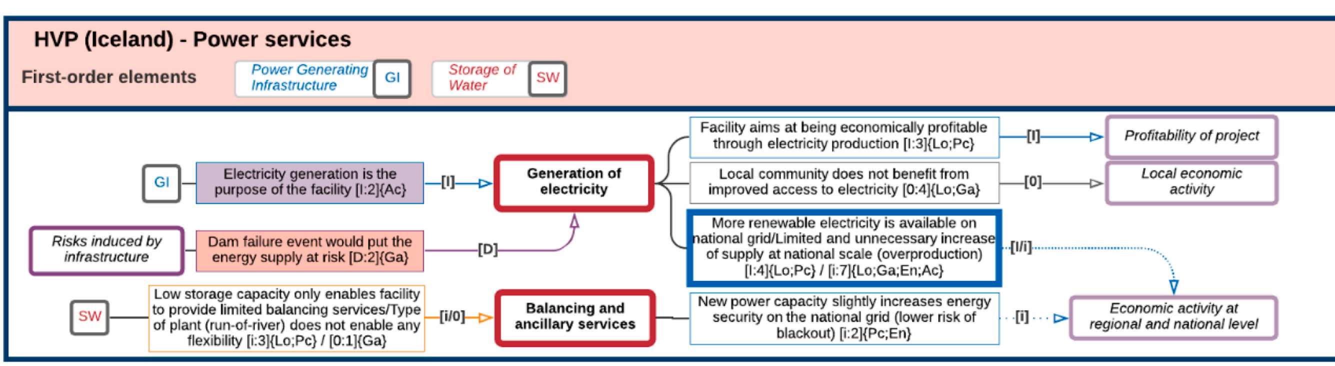

Fig. 23. Power services – HVP.

The uneven distribution of compensation {Lo; Ac} and financial benefits {Ga}, along with the threat of the project itself {Lo; Pc; Ac} create tensions and conflicts within local communities, already at the planning phase. Besides, locals have been reported maintaining close relations with their surrounding environment. Therefore, damaged agricultural and natural areas {En}, harmed existent landscape {Lo; Ga; Pc; En; Ac}, threatened ecosystems {Lo; Pc; En}, flooded existing road {Lo}, disturbed local weather knowledge {Lo}, and to a certain extent, flooded

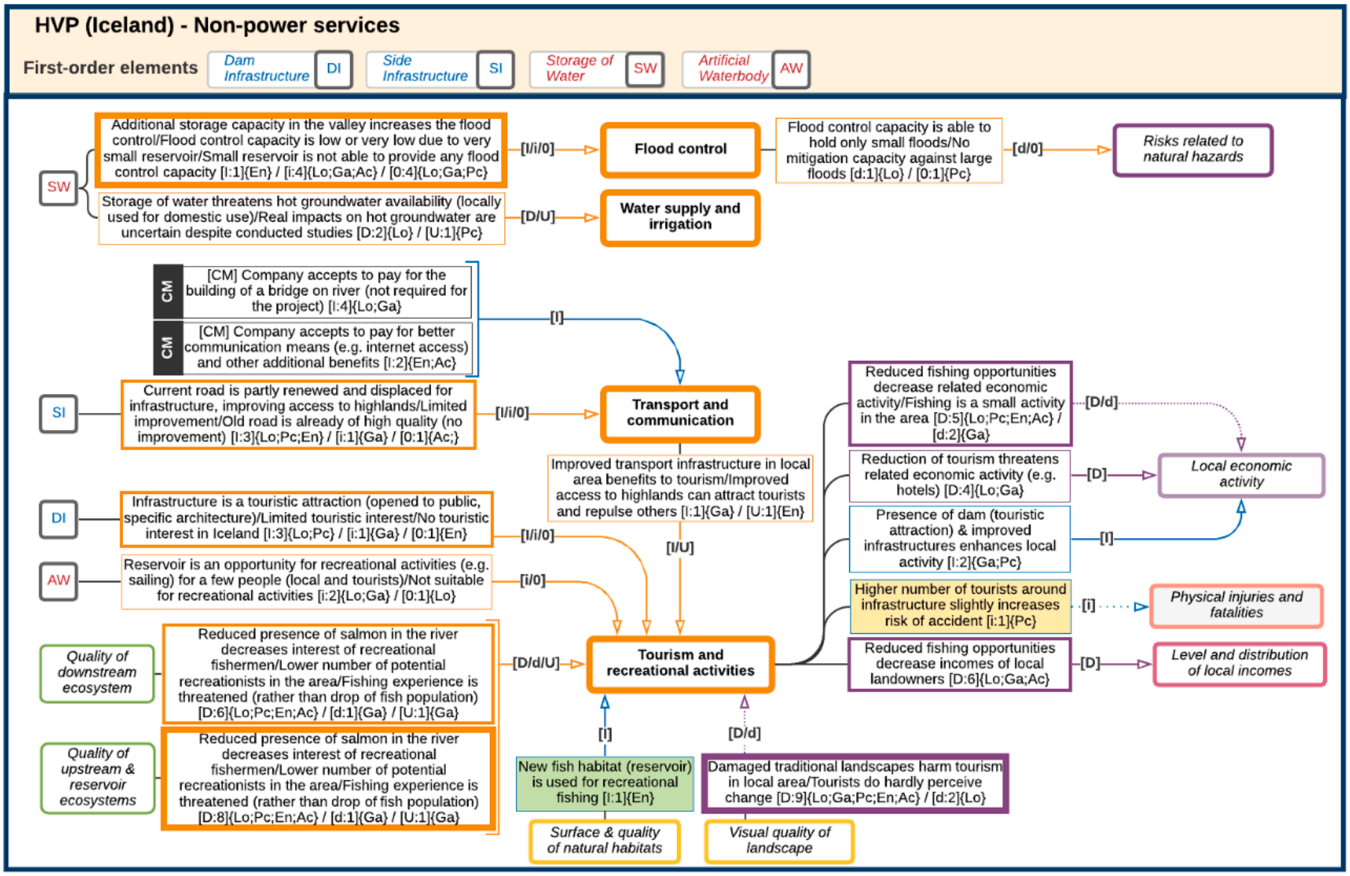

Fig. 24. Non-power services – HVP.

ruins {Pc} are all perceived a threat from HVP towards the local identity and culture. Harmed social identity and culture could act as a source of distress among locals {Lo; En}, and encourage people to leave the area {Lo}. While local inhabitants are not expected to be forced to be displaced {Ga; Pc}, the financial compensation {Ac}, loss of land {Ac}, changed landscape {Lo; Ac}, presence of infrastructure {Lo} and reduced economic opportunities {Lo; En; contradicted by Ga} could all further encourage local people to leave the area.

4.2.9. Power services – Fig. 23

HVP is aimed at producing electricity {Ac} and would be profitable using this mean {Lo; Pc}. The limited storage capacity would only enable HVP to provide limited power balancing services {Lo; Pc; none for Ga}. The project would also bring more renewable power on the grid {Lo; Pc}, although the relevance of this aim is questioned by several participants {Lo; Ga; En; Ac}, as the current national production in Iceland is already sufficient. Finally, the project could moderately increase the national energy security {Pc; En}, but no improved access to electricity is expected at the local level {Lo; Ga}.

4.2.10. Non-power services – Fig. 24

The non-power services brought high conflicting perspectives among participants. First, HVP is expected to provide either higher flood control capacity {En}, limited flood control capacity {Lo; Ga; Ac} or even none {Lo; Ga; Pc}, with accordingly limited {Lo} or no influence {Pc} on the prevention of natural hazards. Hot groundwater could be threatened by the project {Lo}, although this threat is made uncertain by conducted studies {Pc}. Stakeholders also have different expectations regarding the new road, as it could improve the access to the highlands {Lo; Pc; En}, slightly improve it {Ga}, or not improving it at all {Ac}. The promise to build a bridge {Lo; Ga} and improve the side infrastructures in the area {En; Ac}, both being unrequired for the project, were reported. Local tourism could benefit from this new infrastructure {Ga; uncertain for En}, from the reservoir as a new recreational fishing spot {En} and other activities {Lo; Ga; contradicted by another Lo}, and from the HVP infrastructure itself as a touristic attraction {Lo; Pc; moderated for Ga; contradicted by En}. On the contrary, the damaged traditional landscape would harm local tourism {Lo; Ga; Pc; En; Ac; limited for Lo}, along with a reduced presence of salmon {Lo; Pc; En; Ac; limited and uncertain for Ga}. Accordingly, stakeholders see the consequences of affected tourism on the local economic activity. Finally, while more tourism could mean more risk of accident {Pc}, a reduction of fishing opportunity would also mean a reduction of local income of landowners through the sale of fishing permits {Lo; Ga; Ac}.

4.3. Comparison of VdA and HVP

For this last part, we built an aggregated CD of both projects based on uniquely perceived causal relations between topical groups. For simplification issue, we do not specify the direction of change, but simply expose the synthetized effect of each relation between groups of elements. Groups of elements are placed identically in both CDs, to facilitate the comparison of cases. Colours used in the relations refer to the causal group of each reported relation to ease understanding. We also add two additional visual features for these two additional CDs (Table 6).

Regarding VdA (Fig. 25), stakeholders expected changes regarding the new access road, enabling local forestry and facilitating access to a pristine habitat. Extreme fluctuation within both the reservoir and in the river flow downstream are also foreseen as resulting from the project. Interviewed stakeholders also reported hydropower as a local source of pride. While these aspects were specific to VdA, HVP (Fig. 26) raised on

Table 6
Additional visual features for aggregated CD.

Additional features for aggregated CD	(grey box)	The causal relation between two elements is reported in both VdA and HVP
	(*)	The synthetized effect is not equally reported by stakeholders (conflictual perspective)

its side particular concerns regarding the changes in the sedimentation and nutrient rate in both the reservoir and water downstream, along with consequences on local ecosystems. Also specific for HVP is the presence of salmon in the river, to which local residents confer a considerable importance, with potential influence on both the local economy and culture. Comparatively, the changes in the natural habitats, agricultural lands and local landscape seems to bring many more concerns for the local community compared to the reported apprehension for VdA. Finally, only HVP stakeholders reported impacts of the project in the local community during the early planning stage. Indeed, concerns and expectations of local residents linked to the project have reportedly led to the appearance of tensions and conflicts within local community, resulting in higher psychological distress for concerned people.

On the other hand, both projects also include some similar expectations and concerns as reported by stakeholders. In both cases, new jobs are expected during the construction phase, attracting newcomers, with benefits for the local economy. Concerns are also expressed regarding the flooding of land, although no house is expected to be destroyed. Consequently, no stakeholder expressed any concern regarding any forced displacement of local residents. While the primary purpose of both projects is the generation or storage of electricity, participants do not expect any advantage of this kind for the local residents. Finally, in both cases, we observe a certain degree of uncertainty and conflicting views between stakeholders regarding the beneficiaries of the hydropower tax.

5. Discussion

Based on the framework established by Voegeli et al. [75], we used a

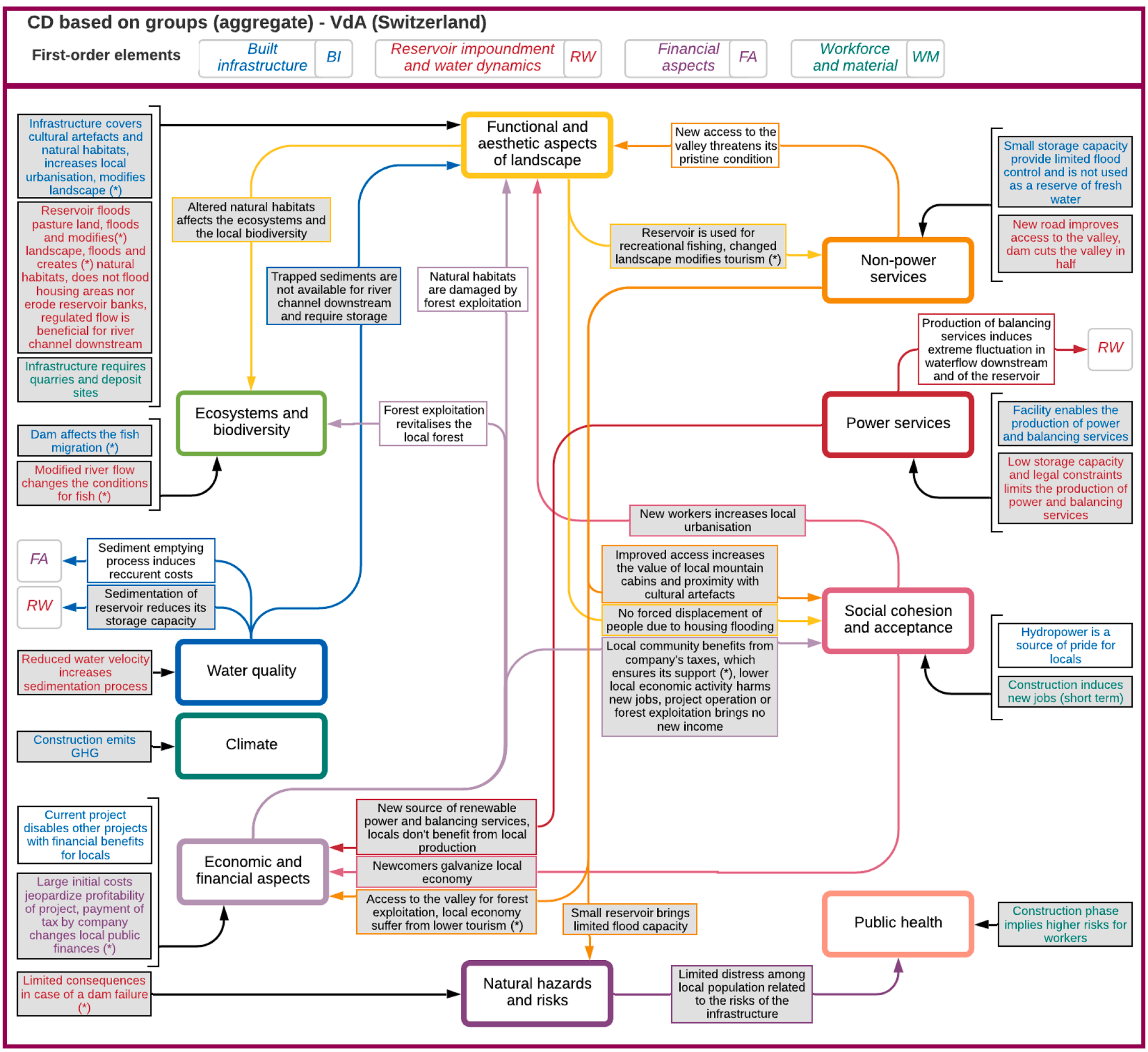

Fig. 25. Aggregated CD – VdA.

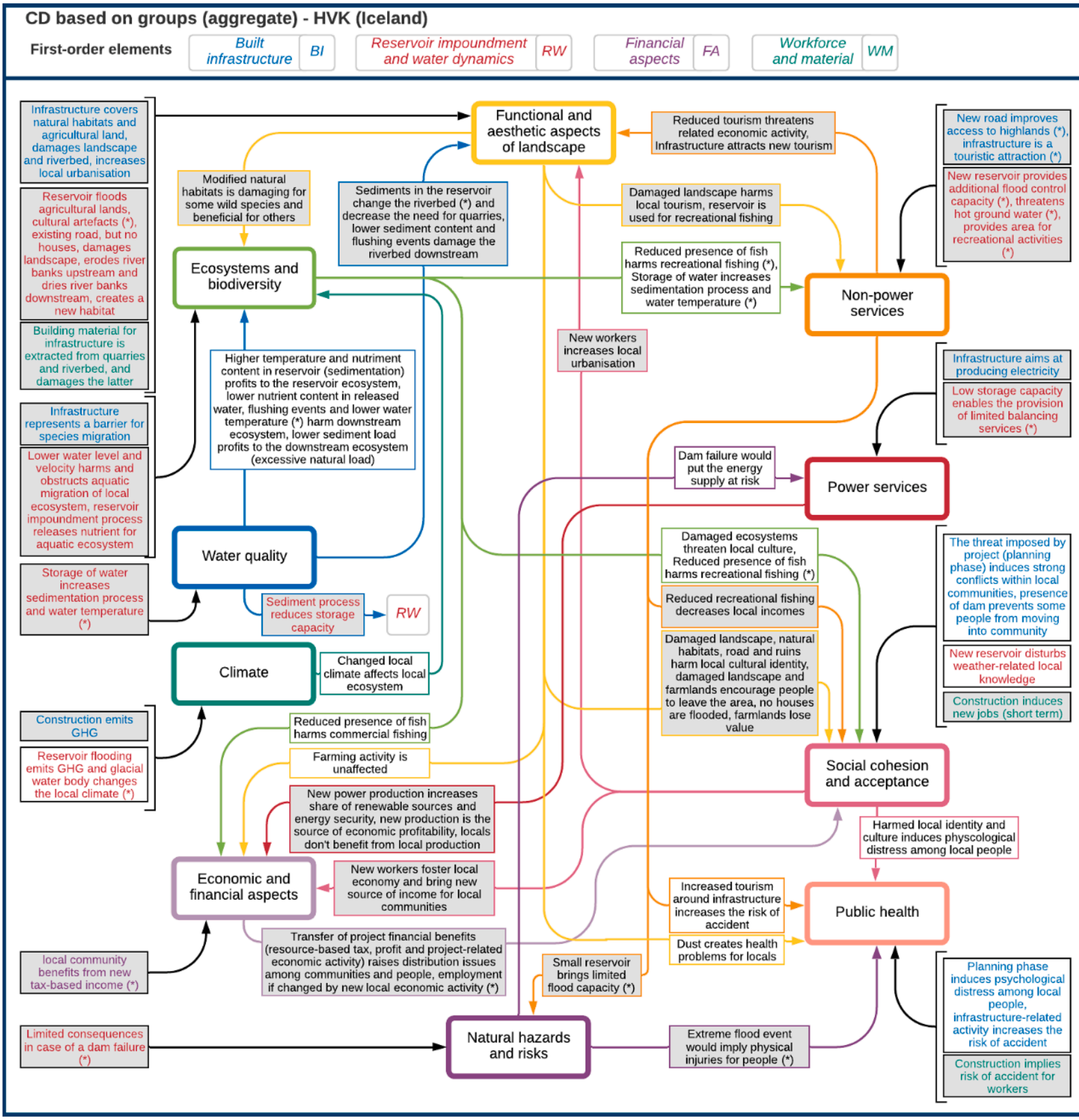

Fig. 26. Aggregated CD – HVP.

SA approach employing CD to synthetize the perceptions of stakeholders for two different hydropower projects, both located in hydro-dependent countries (Switzerland and Iceland). The CD techniques applied to semi-structured interviews enable the exposition of the complete causal sequences of perceived concerns and expectations, as reported by stakeholders. As presented in the last part of the results, CD is a flexible tool that can be modulated to adapt the scale of investigation. In our research, we first detailed the causal interactions perceived in each topical group, then presented an aggregation version, focusing on causal relations between topical groups. This approach enabled us to acquire a more straightforward view of each project, as perceived by interviewed stakeholders, and facilitate the comparison of their concerns and expectations.

We cannot discard strategical behaviour during the interview process, such as minimization of effects, expression of uncertainty, or certainty when uncertainty remains. Based on individual perspectives, this research leaves room for individual misconceptions, misunderstandings, or ideological clashes. Nevertheless, reported contradicting causal relations between stakeholders and expressed uncertainty represent an integral part of the results, as they highlight aspects that could require further research or larger dissemination of information. Those results also stress the core facets of the project that eventually drive conflicting views among the stakeholders.

In this research, the number of participants could arguably be considered limited, and unbalanced between projects (8 for the Swiss case and 16 for the Icelandic case). However, as both projects were in an early development stage, only a narrow group of stakeholders was available for participation (sufficiently informed, participation in public debates or consultation process, etc.). Indeed, we quickly reached the point where new participants would only recommend already interviewed or contacted stakeholders, subsequently so that we had to stop the research process for new participants. Accordingly, it can certainly be argued that most of the relevant existing key stakeholders at the current stage of both projects were interviewed.

Interviewees were presented with a pre-defined list of elements to structure the conduction of semi-structured interviews. The use of a pre-defined list could act as a formatting frame for the stakeholders to express their perceptions. However, this approach was necessary to enable a relevant comparison between projects and was aimed at facilitating the merging process of individual diagrams. During interviews, participants were invited to comment, discard or add new elements to adequately represent their perceptions. All participants considered that the list was extensive enough to assess the projects, although some would ideally have restrained or slightly extended it. In the results we can observe that two elements from the pre-existing list are not represented: ii. Public subsidies and ii. Climate change, as no participant explicitly mentioned a relation between them and any other element during the interviews. Besides, the presentation of the consolidated individual effects in the CD is the result of rephrasing and synthetizing efforts from the original participants' quotes. Although required during the consolidation process, this stage certainly results in an additional formatting process applied to the individual perceptions of causal relations. Finally, to avoid overinterpretation during the analysis, we did not develop logical deductions by interpreting individual perceived causal relationships. Consequently, final complete impact pathways are in some instances showing some incoherencies (e.g. 6 VdA participants expect no forced displacement of people, but only one explicitly acknowledged that no house would be flooded).

Ideally, the conduction of a common workshop with all participants would support the confirmation of the elaborate CDs (approval, addition or deletion of exposed causal relations), distinguish the degree of uncertainty affecting some aspects, and also assist the dissemination of information among stakeholders. Unfortunately, such a workshop could not be conducted within the scope of this study, mainly due to time constraints and distances between some stakeholders.

6. Conclusion

This study investigates the concerns and expectations of key stakeholders using Casual Diagrams (CD) for two independent hydropower projects: i) Val d'Ambra II, in the Swiss Alps, and ii) Hvammsvirkjun, in Southern Iceland. Both projects are at the developing stage, although currently interrupted for further legal clarifications by cantonal (Switzerland) and national authorities (Iceland). This article explores the potential of CD in investigating the expectations and concerns of key stakeholders regarding the impacts of hydropower projects. For this purpose, we identified and interviewed 8 stakeholders for Val d'Ambra II and 16 for Hvammsvirkjun.

CD techniques enable to unveil the complete causal sequences of impact pathways on multiple scales. In this research specifically, CD expose the intense interactions between biophysical and socio-economic aspects, according to the concerns and expectations stakeholders reported regarding two distinct hydropower projects. In the results, we were able to expose issues perceived by a majority of stakeholders, but also less largely shared, although not necessarily less important ones. In parallel, the results highlight to what extend stakeholders may have divergent perspectives on aspects that appear very tangible and predictable. For instance, in the case of VdA, two stakeholders expect the tax to be collected by local communities, while two other stakeholders of the same categories expect the tax to exclusively benefit the cantonal level (state). The visual mapping of individual perspectives also supports the identification of conflicting perspectives between stakeholders of different groups, but also within groups. For instance, undesirable impacts of both investigated hydropower projects are not systematically and uniquely reported by stakeholder categories that could be expected to have a more "anti-dam" perspective (e.g. environmental NGO), while benefits of both projects are not recurrently and only reported by stakeholder categories assumed to have rather "pro-dam" perspectives (e.g. power company). By emphasizing the conflicting perspectives between and within stakeholder groups (e.g. within a local community), CD can be used to track down the starting points of such conflicting perspectives. These can for instance be an ideological clash, a lack of information or some remaining uncertainties, which would require further scientific research or legal clarification.

Our results therefore support the overcome of simplistic expectations of coherent intra-group perceptions, and advocate for a more in-depth investigation of the multiplicity of intra-group perspectives. The findings finally highlight how by anticipating stakeholders' perceptions, a project can in some cases cause a series of socio-economic impacts already at the planning stage, especially on the local level.

Such results hold central importance for decision-makers, as they can reveal unexpected foreseen impacts, but also shortcomings in the transfer of information, misunderstanding or ideological clashes between key stakeholders. In addition, the anticipation of stakeholder perceptions can help avoid or mitigate fractures and tensions within local communities. Accordingly, our results advocate for the conduction of an impact analysis as early as possible in the planning of such infrastructures. Using CD for impact analysis can also guide decision-makers in the identification and elaboration of temporally and spatially relevant mitigation measures to counter undesirable effects.

The CD approach is in line with the recommendations made by Gibson [53] and Ness et al. [37] to ensure a valuable application of a sustainability assessment. Indeed, the results enable us to identify what changes are unanimously perceived as a positive or negative step towards sustainability by the concerned people. Furthermore, our findings highlight the complexity of this goal, as one particular step can be considered as either a positive or negative step towards this goal.

Finally, these conclusions emphasize the value of conducting stakeholder workshops for hydropower development projects. Indeed, such an event facilitates the discussion of direct and indirect concerns and expectations among local stakeholders, but can also act as an essential step towards the dissemination of information among stakeholders and the identification of sources of uncertainty. Furthermore, such an event could be used to evaluate and focus on the most important causal relations identified through the CD. This approach could prove to be an extremely valuable tool for decision-makers, by guiding them on priority issues on the one hand, but also by supporting them in improving good practice on the other hand.

Declaration of Competing Interest

The authors 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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