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## Executive summary

This document contains a review of European Union LIFE projects and greenhouse gas mitigation policies aimed at identifying transferability to SheepToShip LIFE. The results are conceptualized with the Multi-Level Perspective on socio-technological transitions.

# Index

**Abbreviations**

AFOLU – Agriculture, Forestry and Other Land Use

CAP – Common Agricultural Policy

EU – European Union

FAO - Food and Agricultural Organization

GHG – Greenhouse gas

IPCC – Intergovernmental Panel on Climate Change

LCA – Life Cycle Analysis

LCI – Life Cycle Inventory

PDO – Protected Designation of Origin

## Abstract

The European Union funded project “SheepToShip (StS) LIFE” aims to implement eco-innovations in the Sardinian dairy sheep product supply-chain in order to increase the chains environmental performance. The eco-innovations aim at lowering the sheep dairy products greenhouse gas (GHG) emissions by 20% by 2030. Reaching this goal, involves considerable socio-technical change on farm and dairy factory level. The implementation of these changes raises uncertainty about available possibilities from a governmental policy and governance perspective. In order to extend knowledge on possible innovations and policies for future developments in the sheep dairy product supply chain, this review firstly identifies best practices from LIFE projects as a state of art of innovations for the dairy sector. Secondly, exemplary policies coming from a government and governance perspective on GHG mitigation are reviewed, which accommodate scaling opportunities for eco-innovations. In order to conceptualize the reviewed approaches, the Multi-Level Perspective (MLP) on socio-technical innovation is used. Concludingly, best practices and policy are discussed together with governance for socio-technical innovations, which can facilitate further planning for socio-technical change towards an increase in environmental sustainability and to overcome barriers of adoption on farm and dairy factory level.

## 1. Introduction

Limiting climate change through GHG emission mitigation is one of the pressing issues of our time. The effects of climate change link directly to observable changes in the environment. Negative environmental changes may lead to resource conflicts but also environmental emergencies such as floods and droughts. An accumulation of negative developments may lead to sufficient land degradation, defined as loss of either biological productivity, ecological integrity or value to humans to cause mass migration movements (IPCC, 2019). In order to change this trend, GHG emissions need to be mitigated from the Agriculture, Forestry and Other Land Use (AFOLU) sector, as well as the sectors' environmental degradation needs to be limited. Uniquely positioned the agriculture sector has the potential to reduce the emissions it creates by adopting practices which enhance carbon sinks as well as to produce more efficiently through management optimization and energy saving measures. The European agricultural sector amounted to approximately 10 % of all European Union GHG emissions in 2017 (EUROSTAT, 2020).

Prospectively, the EU aims at a carbon net-neutral economy in the year 2050 (COM 773, 2018). The contributions of the dairy sector will need to be reduced to reach the climate neutrality envisioned by the EU. The emissions from the sheep dairy sector on Sardinia result mainly from the production of milk and cheese. The main dairy product with more than 50% of the sheep sector production is Pecorino Romano DPO (Vagnoni, 2015).

In order to reduce emissions in this sector a variety of mitigations strategies has been proposed. Productivity increases in the livestock (dairy) production systems contribute to the transition pathway to a carbon neutral future in line with United Nations climate targets (Hedenus et al., 2014). A productivity increase in terms in terms of a higher animal stocking rate may cause unintended effects, such as the decline in permanent pasture used for grazing, as more soy feed is imported and supplements extensive grazing. Therefore, a productivity increase needs to rely on feed which is rich in proteins and energy (e.g. cereals, legumes, soybeans) but preserves an extensive grazing system and protects against abandonment (Picasso et al., 2014). To achieve this effect a feasible option is to produce protein rich feed on farm. However, this could in return lead to a higher application of nitrogen-based fertilizers, which leads to an increase of $N_2O$ emissions (Hedenus et al., 2014). Hence, a limitation of fertilizer application is also necessary guarantee a reduction effect.

Nevertheless, a stark decrease of emissions can, according to Hedenus et al. (2014), only be expected if meat consumption would decrease equally to the increase in productivity of dairy ruminants. As a constant demand for meat would outweigh the productivity gains through different types of feed input and inhibit an efficiency driven reduction in head numbers. However, these scenario dynamics do not counteract the intent of productivity increase on farm level. To increase productivity Gerber (2013) provides an overview of the possibilities with a holistic review (900 articles) of technical innovation focused on the ruminant and livestock sector, focusing on non-$CO_2$ emission sources based on LCAs. The changes proposed are focused on the enteric fermentation process in ruminants, as well as manure management and changes in animal husbandry techniques (health and longevity of animals). Similarly, Domingo et al. (2014) collected measures specifically to the dairy production sector in Europe. The conclusions are presented in case studies from various European countries and focus on the following topics: nitrogen balance, introduction of leguminous plants on arable land, conservation agriculture, implementation of cover crops, manure storage improvements, manure spreading, biogas use at farm level, use of biomass for heating needs, photovoltaic installation, fuel reduction, electricity reduction, individual low carbon agri-environmental measure plan on farm level.

The recommendations for a productivity increase to farmers in the ruminant and dairy sector (Gerber, 2013; FAO, 2007), are also proposed by Vagnoni et al. (2017; Atzori et al., 2017) for the Sardinian production system. For the Sardinian dairy production system specifically, studies have been conducted for GHG mitigation to gain new insights into environmental and GHG performance on farm level (Vagnoni et al., 2015 & 2017). The recommendations are based on LCAs, which allow for the precise identification of GHG emissions by process and therefore, the derivation of strategies for mitigation by increasing efficiency in process innovating or through exnovation of practice or technology (Eckard et al., 2010; Marino et al., 2016). These LCAs for two products *Pecorino Romano* and *Pecorino di Osilo* (Vagnoni et al., 2017) led to the conclusion that, "the milk production phase represents by far the main environmental hotspot of the whole dairy life cycle (with a contribution to the total GHG emissions in general of about 90%)" (SheepToShip LIFE, 2018: 55). It was determined that for the production of one kilogram (kg) of Pecorino Romano 16.9 $CO_2$-eq kg and for one kg of Pecorino di Osilo 17.1 $CO_2$-eq kg is emitted (Vagnoni et al., 2017). In line with the LCA (Vagnoni et al., 2017) propose eco-innovations on farm level for the reduction of emissions, which occur during the enteric fermentation process in sheep rumen.

Hence, strategies for GHG mitigation focus on the adoption of eco-innovations in form of forage composition "to decrease methane production in sheep rumen" (Vagnoni et al., 2017: 1086). A further focus is put on an increase "of on-farm produced feed, especially forage legumes" (Vagnoni et al., 2017: 1086) by doing so achieving a limitation of soybean and other high protein feed imports. Ultimately, the recommendations include a change towards a "low-input and high-quality pasture acreage and adopting sustainable grazing management techniques" (Vagnoni et al., 2017: 1086). In detail, recommendations from the StS LIFE project include:

**Flock management**: monitoring of reproduction performance to increase fertility; monitoring of milk production; disease control/prevention; feed quality (use of forage legumes, feedstuff analysis to better balance sheep diet; feed blocks to improve digestibility of straw and cereal stubbles).

**Land use**: introduction of native self-regenerating legumes-grasses mixtures and Sulla (a biannual forage); low-input agricultural practices (minimum tillage, direct sowing, reduced use of fertilizers, etc.); soil and water analysis to better drive pasture fertilization (Vagnoni et al., 2019).

Adding to the recommendations which directly affect the management of sheep milk farms, it is ultimately preferable to decarbonize the overall power supply by using renewable energies. Furthermore, to lessen the use of pollutants cleaning agents and to implement a cleaner wastewater management system, to achieve significant improvements (Vagnoni et al., 2017)[1].

These innovations identified through StS LIFE project are considered to have the potential to significantly lower GHG emissions provided farmers adopt the practices on a broad scale. Although the innovations developed in the projects' process represent a considerable step towards a reduced environmental impact of the dairy production, not all novelties may suit every farms' needs or meet the willingness of a farmer to adopt new practices. In order to change the practices on farm level it is necessary to know which innovations are most likely to be adopted by farmers. Implementation of practices encounter barriers of adoption in the production system which ought to be overcome. Therefore, Jones et al. (2013) rated innovation on a farm level according to the preference of UK-farmers and their willingness to apply them by using a scoring matrix (worst to best, in terms of practicality) (see Figure 1). Jones (et al., 2013) research showed that 11 innovations have a mean practicality score above 0, making them susceptible to adoption in the UK ruminant production system. Even though, it can be assumed that similar preferences exist for Sardinian farmers as for tested innovations in the (Jones et al., 2013) as they concur with the FAOs (2007) general recommendations, it remains unclear which policy options are most suitable to ensure transferability to the EU, national and into the Sardinian rural development plan (Vagnoni et al., 2019).

[1] Solutions which were not deemed adequate were options for rumen modifiers and control, as well as genetic modifications and the increase of intensity of production (Vagnoni et al., 2017: 1085). Other options would include animal manipulation, plant secondary compounds (condensed tannins).

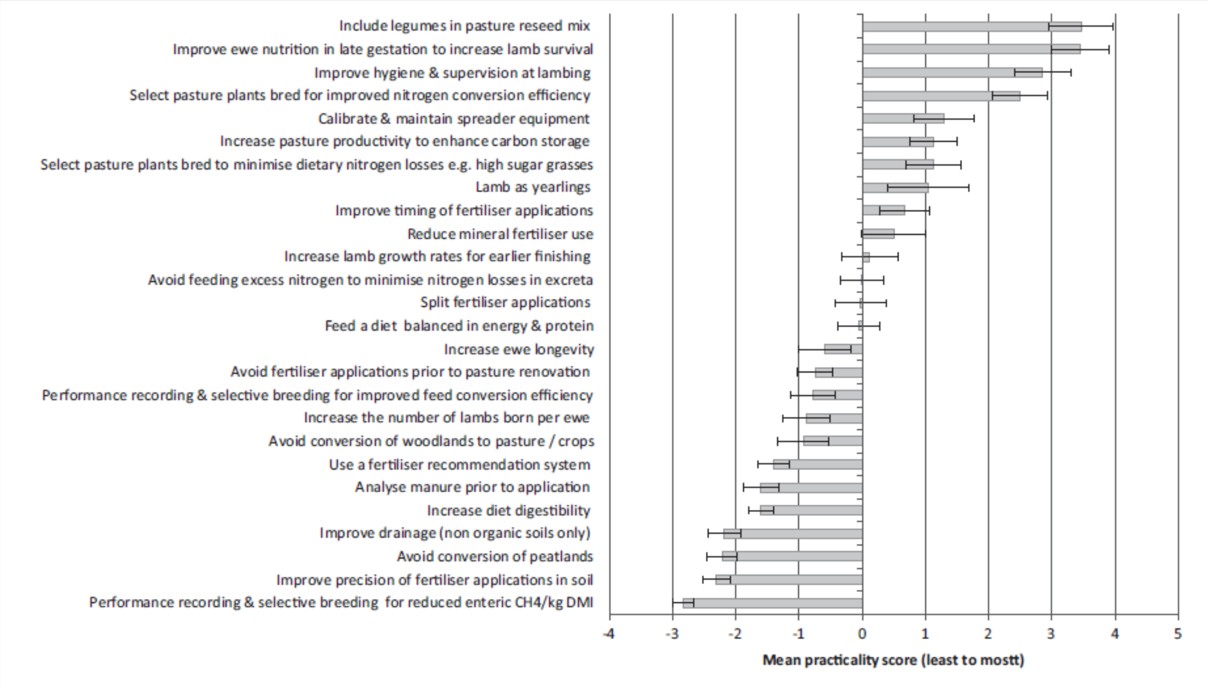


Figure 1: Mean estimates of the practicality scores across all farmers 26 mitigation measures. (The error bars represent 95% confidence intervals of the mean scores (Jones et al., 2013))

The transferability of these results to a much larger European agricultural system context is of course neither a given for the EU, nor for the Sardinian dairy sheep sector. Due to this uncertainty, this research intends to broaden knowledge on other available innovations and policy designs which promote scale up. Ultimately, the options are to be summarized in the Environmental Action Plan of the project. Therefore, the first objective of the research is to identify innovations, which are currently implemented by other LIFE projects in Europe, which deal with similar objectives as StS LIFE. This objective directly leads to the questions of which eco-innovations exist apart from the identified innovations by SheepToShip?

Furthermore, as a second objective this work sets out to identify potential policies, which lead to an adoption of innovation by farmers and a scale up of practices. Therefore, the question, accordingly is, what environmental policies exist to stimulate the process of innovation adoption? This is, what Environmental Programmes (policies) are currently applied or proposed in order to scale up adoption of innovations?

In order to better comprehend the ambition of innovations and the process of scale up, the use of a conceptual framework can help to increase understanding. Through a conceptualization of policy programs and LIFE projects, the framework provides a vocabulary and categories for analysis as well as for their discussion.

Therefore, the following chapters will discuss the themes laid out in this introduction. Chapter three describes the theoretical frame, the Multi-Level Perspective (MLP), in combination with current knowledge on adoption of innovation research specific to the Sardinian case. The fourth chapter describes first the method used for the literature review and is followed by a presentation of the results for the innovations implemented through LIFE projects and the current environmental policies applied to dairy farming. In the discussion section, the policies are debated in the context of governing the adoption of innovations in the frame of the MLP on socio technical transition.

## 2. Theoretical considerations

The outlined LCAs and derived recommendations become socio-culturally as well as politically relevant when they are conceptualized through a theoretical lens by which sense is attributed to an object or an action (Moon, 2014: 1172). By doing so LCAs raise an ontological viewpoint, which is best described as critical realism. This assumes reality exists, but its understanding is "basically flawed [by] human intellectual mechanisms and the fundamentally intractable nature of phenomena" (Guba & Lincoln, 1994: 110; Moon, 2014: 1170). Furthermore, social interpretations of the life cycle thinking recommendation raise epistemological questions on knowledge and its understanding. The questions are addressed by limiting epistemological uncertainty through a set-up of a Life Cycle Inventory (LCI) and the definition of a system boundary - cradle to gate[2] (von Bahr & Steen, 2004).

The considerations on ontological and epistemological underpinnings inform the choice of the theoretical framework which guides the analysis. The MLP on socio-technological transitions (Geels, 2004) is used as a mid-range theory to guide the analysis with the goal of understanding the innovations and LCA results in the context of a socio-technological development. For this purpose, it is important to note that "the different levels are not ontological descriptions of reality, but analytical and heuristic concepts to understand the complex dynamics of sociotechnical change" (Geels, 2002). At the three levels, activities conducted by social groups (re)produce links and elements and establish "sociotechnical configurations" to which people ascribe meaning and derive symbols (Geels, 2002). The next chapter highlights key aspects of the framework and how they are relevant for barriers of adoption

### 2.1. Multi-Level Perspective and barriers of adoption

Society relies on socio-technical systems in order to function. These systems "comprise a complex bundles of interacting material, social and institutional elements" (EEA, 2019: 24). This view encompasses value chains together with production and consumption, the extraction of resources and the management of waste and is not focuses solely on one industry or a sector. Together with infrastructure, culture, knowledge and politics the system is kept in a stable state which create "shared rules, practices and institutions (e.g. technical knowledge paradigms,

[2] The Life Cycle Inventory for this case is described in detail by Vagnoni et al., 2015 & 2017

habits of use, prevailing normality, cultural discourses, established practices of professional and regulatory regimes” (EEA, 2019: 24-25).

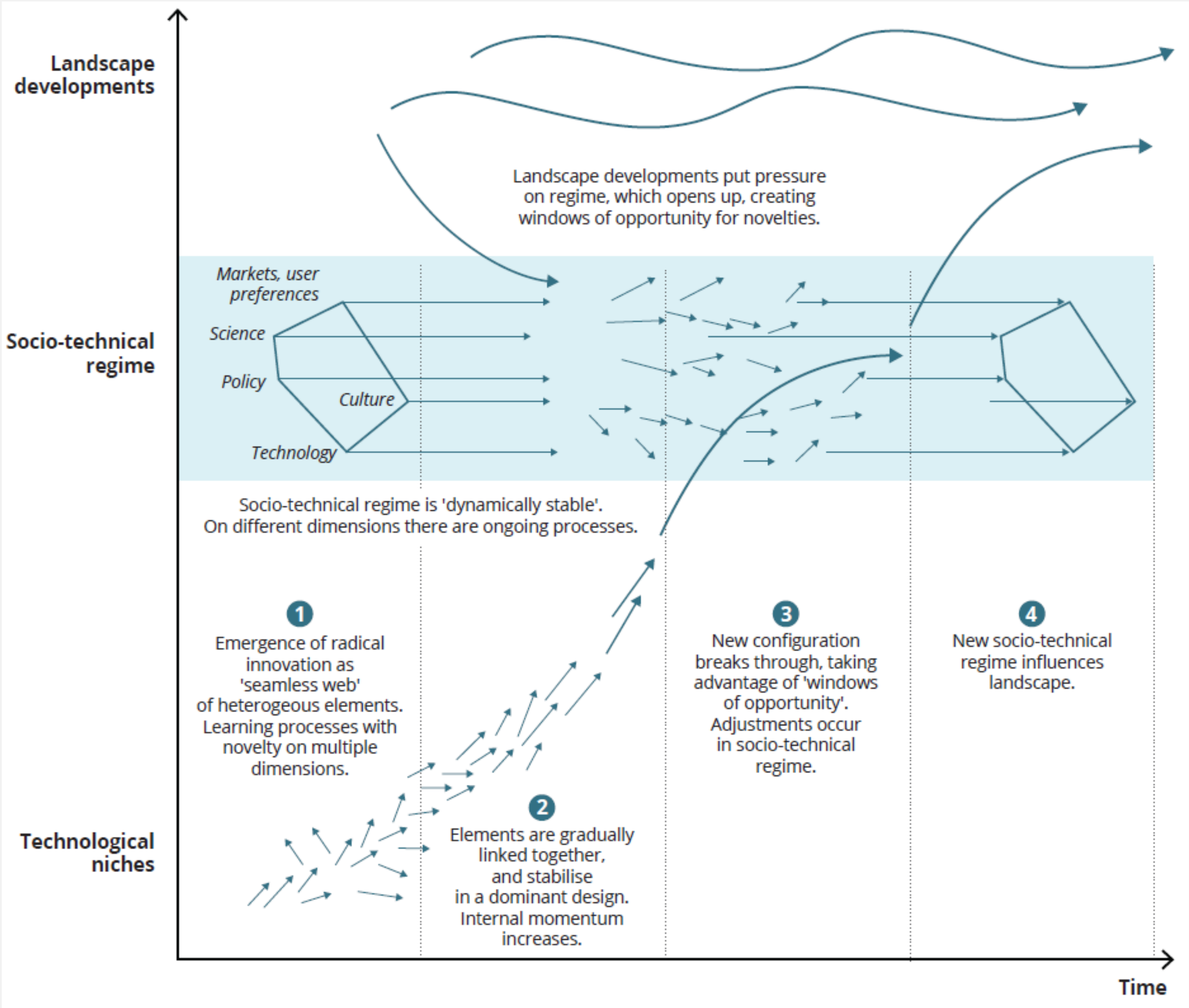


Figure 2: Multi-level Perspective on socio-technical transitions (EEA, 2018: 52, based on Geels, 2004)

In order to change socio-technical systems a long time horizon is necessary, as change of the overall system can occur slowly but at the same can be initiated on a small scale and an immediate manner. Therefore, the MLP perspective conceptualizes such transitions of socio technical systems (Figure 1) “as the outcomes of interactions between the micro (niches), macro (regimes), and meso (landscapes) levels” (Raven, Schot & Berkhout, 2011: 64). The three levels have their own characteristics and react to change on different time scales. *Landscapes* represent conceptually the external technological factors and “deep structural trends” (Geels, 2002: 1261) and are analyzed on an international spatial scale (Raven, Schot & Berkhout, 2011). However, Geels (2002) points out this can also be the “material context of a society e.g. material and spatial arrangements of cities, factories, highways and electricity infrastructure”. Landscapes consist of long-term trends such as demographic developments or political ideologies, but also external shocks such as recessions. However, landscapes remain influenceable through human agency through the aggregation of human action, nonetheless they cannot be influenced at will by actors (EEA, 2019). Change occurs in landscapes occurs slowly (over centuries) (Raven, Schot & Berkhout, 2011).

Socio-technical *regimes* consist of culture and symbolic meaning, techno-scientific knowledge, sectoral policy, markets and use practices, technology and infrastructure. Regimes are considered "rules that enable and constrain activities within communities" (Geels, 2002: 1261). These are often analyzed on the basis of national territorial boundaries (Raven, Schot & Berkhout, 2011).

*Niches* are on the micro level and can occur on a local scale (Raven, Schot & Berkhout, 2011) and are protected spaces for innovation. Niches represent the incubation place for radical innovations which are initiated and nurtured by entrepreneurs. Innovations which come out of niches force or adapt their way into regimes (over decades) and over time change them. This leads ultimately to a change in the landscape (Köhler et al., 2019). Raven, Schot & Berkhout (2011:64 ) postulate, however, that

> "there is no reason to conflate the MLP levels with specific territorial boundaries. The MLP levels refer to processes with different temporal dimensions and modes of structuration that could each have a variety of spatial positionings and reach. In niches, social networks are less extensive, less stable, expectations more fragile, and learning process are less institutionalized than in regimes, but such networks need not be exclusively local"

The elements of the system (outlined above) are interdependent to each other, making it difficult to effectuate change as the system is highly complex and may encounter itself in state of path dependence or a lock-in (EEA, 2019). These path dependencies are dependent on several barriers (for a comprehensive overview see Annex 1).

Particularly relevant for this analysis is the diffusion of innovations through niches, as the StS project aims to implement innovation in a niche and in the following scale up successful change to a broader level. Therefore, Smiths (2005) work on development of technological innovation finds entry. The adoption of new technology is defined as "social processes that present criteria against which [these] qualities are judged, and whether the technology represents a worthwhile means for satisfying a human need" (Smith, 2005: 108). In these social processes groups use "technological frames of references" to determine whether a technology is deemed applicable (positive) or avoidable (negative). The frames inform categories against which technology can be judged. This includes the goals, problems and, challenges which the technology addresses as well as "the problem-solving strategies appropriate for this challenge; the criteria for judging solutions; the knowledge and material resources the group can draw upon; and comparison against any existing technology practices" (Smith, 2005: 108). Furthermore, the adoption of innovations depends on the participation of actors and available resources (researches, manufacturers, investors, regulators, machinery, infrastructures) which will provide the socio-technical network for the role out of novel technology. This network provides "resources, markets, technical know-how, manufacturing capabilities, infrastructures, and legitimacy" (Smith, 2005: 109).

An actors' commitment to innovate is determined by the actors' interpretation of the performance qualities of the innovation. Hence, the more flexibility the technology allows in its interpretation the larger the chance to gain the support of an actor. Preferences, viewpoints and expectations of actors are possibly different depending on the "quality of the innovation or the value the actor has" (Smith, 2005: 108). An actor attributes their own meaning towards the technological innovation and may advocate for it or modify it for their own reference frame. For example, the focus can differ on speed, costs, profitability, reliability, adequacy of existing infrastructure, or emissions. The likelihood of the innovation becoming an accepted artefact rises when several viewpoints can be accommodated (Smith, 2005).

When a technological innovation is broadly implemented through a process of closure, it is hard to imagine that society has existed without it. Through the process the social relations form around the artefact and value and qualities are prescribed to it. The closure process may even lead to usages of the technology not anticipated by the original designer (Smith, 2005).

In order to facilitate the theoretically outlined change innovations need to be diffused at the local scale. One of the mechanisms by which the EU seeks to implement innovation in the, amongst others, agriculture sector is the LIFE programme. As outlined in the introduction the StS LIFE project seeks implementation of innovative practices in order to reduce GHG emissions. For this purpose, 20 dairy farms could be identified as willing to implement innovative procedures in milk production. These represent within the conceptualization the niches in which innovation can be test and learned lessons can be abstracted for policy insights. However, as displayed in Annex I (EEA, 2019), barriers for adoption were also identified context specific to the Sardinian dairy supply chain. Concu et al. (2020: 99) conducted research which pinpointed a barrier to "divergent attitudes among actors in the knowledge transfer chain […] towards several topics related to GHG mitigation and adaptation to climate change." The actors considered relevant for the adoption of innovation on a farm level were researchers and extension officers, as they provide input to the farm level and therefore create the structure and information to adopt innovations. However, with an input which is not focused on innovation on farm level due to "[…] different information and beliefs on the causes and effects of climate change [...]" (Concu et al, 2020: 99) adoption rates of innovations are suspected to be dampened (Concu et al., 2020). These results are especially relevant as they identified a structural leverage point to the StS LIFE projects' ambition to increase efficiency and to establish a "valorization of ecosystem services provided by pasture-based farms" (Vagnoni et al., 2019: 367). By increase the knowledge and awareness of stakeholders as well as the public behavioral and policy change is intended (Vagnoni et al., 2019)

In order for the proposed changes to leave the niches, the regime configuration, consisting in the political sphere of the Sardinian, Italian, and EU government may choose to act by promoting innovations through a sectorial policy towards the sheep dairy sector. The rural development plan is in this context of great significance due to its overall budget for a seven-year period of roughly 1,3 billion euro.

Further relevant plans, which the regional government has created for the environmental improvements, climate change mitigation and sustainability improvements, are on a Sardinian level:

- Assessorato dell'Industria della Regione Autonoma della Sardegna (2015). Energy and Environmental Plan 2015-2030
- Assessorato della Difesa dell'Ambiente della Regione Autonoma della Sardegna (2019) Regional Strategy for Climate Change Adaptation. N. 6/50
- Direzione Generale dell'Assessorato dell'Agricoltura e Riforma agro-pastorale (2014). Rural development programme Sardegna.

On European level:

- COM (2011) 112 final: "A Roadmap for moving to a competitive low-carbon economy in 2050".
- COM (2007) 2 final: "Limiting Global Climate Change to 2 degrees Celsius - The way ahead for 2020 and beyond".
- COM (2007) 354 final: "Adapting to climate change in Europe – options for EU action" Common Agricultural Policy (CAP).

The principal policies indirectly supported by the results include:

- Thematic Strategy for Soil Protection (COM (2006) 231 and COM (2006) 232).
- Nitrates Directive (91/676/CEE of the Council).
- 7th Community Environment Action Programme (EAP) (1600/2002/CE).
- EU Water Framework Directive (WFD, 2000/60/CE).

The adaption of proposed innovations needs a political process which evaluates the innovations and formulates a strategical implementation in the next decade. Therefore, the policies to achieve the laid out plans may be "stringent environmental regulation and pricing instruments […] to drive efficiency improvements, stimulate innovation, steer the direction of socio-technological change […], but catalyzing system change also requires policies that directly support innovation, experimentation, diffusion and networking, facilitate and drive structural economic change […]" (EEA, 2019: 40).

The theoretical discussion above contributes the background for the discussion on policies and projects which are reviewed. In order to increase structure and replicability of the research the next chapter outlines a literature review method.

## 3. Methodical aspects

In order to identify feasible policies and governance mechanisms for the dairy sector, a review on successful attempts for innovation implementation, can create an array of policy options for consideration. Therefore, a review as a state-of-the-art compilation of ongoing LIFE projects and environmental policies, as specified in the objective and research frame (below), is conducted. The reviews aim is to understand the mechanisms by which LIFE projects aspire to implement their innovation proposal on a larger scale and if available determine successes or failures through scientific literature about the projects. The cross-dissemination from project to project as well as government learning could benefit by comparing solutions to comparable problems.

The choice of a literature review as a method was taken because it increases reliability and validity of best practices of existing approaches to GHG reduction (Uriona & Grobbelaar, 2018). The projects are selected based on criteria concerning a) their comparability to the StS methodology (LCA-based) and b) treatment of the ruminant-, dairy-, milk sector. It is assumed that by limiting the search to these criteria, policy and governance strategies can be found to guide policy conclusions.

For the policies derived from environmental action plans and government programs a similar approach is taken, however, for both, policies and Life projects limiting criteria are selected based on their purpose of improving environmental and GHG performance for the ruminant and dairy sector.

In order to gather the projects and policies a combination of narrative literature and systematic literature review is used. Narrative literature reviews are often incomplete and hold biases of the author, whether intentional or unintentional concerning the choice of literature and its interpretation. Therefore, the narrative desk research is supplemented with a systematic search with a predetermined set of parameters (Uriona & Grobbelaar, 2018).

**Following search frame for LIFE projects was used:**

**Database:** LIFE project database[3],

**Period:** 2005-2019

**Open search query in LIFE database:** agroindustry, dairy, Life Cycle Assessment (LCA), spatial governance, agriculture, scale up, political communication, ruminant.

Only themes: industry production: agriculture – forestry; climate change mitigation; climate change adaptation.

**Considered documents:** Environmental Action Plans/Manual guides/after LIFE reports. Documents, which consider LCAs, are included to analyze the way the results are presented.

**Presentation of results:** Results will entail territorial scale, type of change envisioned (innovation, policy), strategy for innovation implementation (if applicable), communication strategy. If available, long lasting results of the projects are presented.

**Categories**: Project name, area, date goal, method, communication means, policy, governance scheme for scale up

**Following search frame for EPAs and environmental policies was used:**

**Search Engine:** Google Scholar

**Terms**: Environmental action plan + sheep/ruminant/dairy; climate change mitigation + sheep/ruminant/dairy

Time frame 2005 – 2019

**Presentation of results**: presentation of the identified environmental problem and the proposed solution in the EPA on relevant sectors

For presenting the policies it was decided to present the results concerning the principle underlying the policy approach. The categorization is based on the European Environmental Agencies Policy paradigm categorization:

**Categorization of results follows three broad clusters:** Market based, classic steering, interactive network governance.

[3] http://ec.europa.eu/environment/life/project/Projects/index.cfm

Table 1: Different policy paradigms (EEA, 2019)

| | Market Model (bottom-up), | classic steering (top down), | Interactive network governance |
|---|---|---|---|
| Characterization of relationships | Autonomous (government creates incentives and 'rules of the game', but let's autonomous actors choose freely) | Hierarchical, command-and-control (government sets goals and or tells actors what to do) | Mutually dependent interactions |
| Characterization of coordination processes | Incentives and price signals coordinate self-organizing actors through markets | Government coordinates through regulation, goals and targets | Coordination happens through social interactions and exchange of information and resources |
| Policy instruments | Financial incentives (subsidies, taxes) | Formal rules, regulations and laws | Demonstration projects and experiments, knowledge transfer policies, network management, vision building through scenario workshops, strategic conferences and public debates |

# 4. Results

## 4.1. LIFE projects

The presentation of results is conducted in form of a table found in Annex II.

Originally, the search yielded 66 results, out of which 7 resulted to meet the criteria for further analysis. Notable is that ultimately the successfulness of the projects could not be considered fully as most of them are still not completed or had no concise plan for an implementation on a larger scale and achieving high adoption rates. Analyzing the LIFE projects through a desk research could identify combining strategies which are used by LIFE projects.

**Agricarbon**

Cooperation with public administrations for the development of policies. Conservation agriculture adopted by the Spanish inventory and projections for emissions in the atmosphere of the UN (400000 hectares included as mitigating measure). Inclusion in the Energy Saving and Efficiency Action Plan 2011-2020 with (17,6 mio. euro) (INI 2009/2157).

**Carbondairy**

1. Delivery of environmental techniques and methods and modify existing techniques on farm level. 2. Promotion of a livestock raising system of "tomorrow" by assuring a feasibility on technical, economic, social and environmental level. 3. Start a national dynamic to promote the feasibility of the carbon plan. 4. creating a pathway to a milk production with low carbon impact and creating strategic partnerships on national level.
- Environmental diagnostic by means of software tool (CAP'2ER) based on an LCA approach. The consulting company ECEL and the local agricultural chambers undertook the diagnostic on farm sites. Participating farms: 3348.

**Cropsforbettersoil**

Technical seminars and conferences; national and international level on sustainable soil management, bio fertilization, organic agriculture in semiarid conditions, new methods to analyze soil characteristics. Awareness raising and dissemination, trade fairs (BioCultura) training material Cooperation with regional agricultural cooperatives.

**DairyClim**

Workshops, scientific meetings, agricultural fairs, conferences

**DOP - Demonstrative Model of a Circular Economy Process in a High Quality Dairy Industry**

Implementation of a circular economy of the value chain of the dairy sector (livestock rearing to production) of the participating farms and industry partners.

Forage4climate

Actions are directly focused on the regions, which are participating in order to implement the innovations directly (-on farm). Creation of indicators to recommend to the Sardinian ministries of agriculture and environment.

**MontadoAdapt**

Training courses, site visits, climate model for communication. Direct implementation of proposed innovations. Political action aspired on integrated land use techniques for national level.

**Render**

Awareness raising strategies (consumers, stakeholders), implementation of PEF Methodology at EU level to communicate to business consumers and stakeholders. Industry of nutrition and drinks knowledge transfer.

**TTGG – the though get going**

Implementation of the applied techniques in the production facilities of the cheeses.

## 4.2. Environmental policies

The policies are presented in the table 2. This includes a cluster on steering (green), market (red) and interactive network governance (yellow).

Table 2: Policies for innovation promotion

| Policy instrument | Title | Description |
|---|---|---|
| New Zealand/ICCC | | |
| Steering | Farm environment plan + audit (NZ: 4) | Farm plan for good practices, government audits implementation |
| Steering | Farm-level emissions limit (NZ: 5) | Limits set by government, limits not reached lead to penalty. Limits set flexible, depending on farm type and topography |
| Market | Farm-level methane quota system (NZ:6) | Cap on e.g. Overall methane levels-> farmer is allocated percentage of total amount -> overall methane level/percentage decline over time |
| Market | Processor-level trade scheme (NZ:10) | Processors are charged be ton of product with a fixed price. Lowering the price can be achieved by making the farms calculate their emissions and enforcing innovations. |
| Market | Processor-level emissions levy (NZ: 11) | Set price for emissions, allocation per processor, levy collected by government when allocation is exceeded, money paid out when allocation is undercut |
| Int. Network Governance | Negotiated Target (NZ: 12) | Participants set targets in the future and report on meeting them, government fines or pays the results |
| Bord Bia - Sustainability Dairy Assurance Scheme | | |

| | | |
|---|---|---|
| Market | Producer Standard | ISO 17065: 2012; Application to Quality Assurance Scheme with external auditor. Criteria: Producer Capability & Competence, Identification and Traceability, Animal Remedies, Animal Feeds and Water, Land Management, Specified Management Tasks: Dairy Animals, Animal Health and Welfare, Biosecurity and Pest Control, Housing Transport, Environment, Farm Personnel: Health, Safety and Social Sustainability, Dairy, Milking Parlor, Milk Storage & Collection, Milking Equipment, General Hygiene, Chemicals, Pesticides and Herbicides. Audit after 18 months. Result: Assurance Scheme can be used to communicate sustainable practices |
| California Climate Smart Agriculture (CalCAN) (2020) | | |
| Int. Network Governance | Healthy soils program (HSP) | Demonstration Projects. Demonstration farms in order to collect data and showcase conversation management practices that mitigate GHG emissions and increase soil health. Grants are awarded on application basis. 317 projects were funded with 17,8 Mio dollars. Reduced $CO_2$ 40,000 metric tons. |
| Int. Network Governance | Sustainable Agricultural Land Conservation Program | Protection of "at-risk" farmland. Planning grants to local government to improve farmland conservation planning and policy development |
| Int. Network Governance | Climate Smart Agriculture Technical Assistance Program | Funds for outreach, education, project planning and design, application assistance and project implementation. Funds are for technical assistance providers |

| | | |
|---|---|---|
| Ammonia Action Plan Finland | | |
| Steering | Direct payment under EU-Rural Development Plan (FI: 14) | Parcel-specific measure concerning injection of slurry into the soil. Payment of 40 €/ha. Result: at least half of total produces slurry was injected directly |
| Steering | Direct payment under EU-Rural Development Plan (FI: 16-17) | Acquisition of machinery for the injection of slurry, cooling manure channels and acquisition of manure treatment equipment |
| Steering | Environmental payments (FI: 18) | Balanced use of nutrients (54 €/ha/year), 86% of farms applied (2,06 mio. hectare) |
| Int. Network Governance | Payment to farm advisory services (FI: 19) | Training for advisors, materials for training, advice for crop farms on manure handling |
| Steering | Animal welfare payment (FI: 19) | Establishment of written animal welfare/feeding plan, 5564 farms applied. For grazing ruminants' records for grazing during pasture season, the practices outside pasture season and possibilities to extend grazing season. |
| Institute de l'elevage (idele), Cniel, Interbev, Confédéderation Nationale de l'Elevage, I4CE Institute for climate economics | | |
| Market | Label: Bas Carbone (Carbon Agri) | Indicator based label, established on the basis of an LCA (ISO 14044) and the CAP'2ER software tool for the assessment of GHG emissions on farm level. Participation is voluntary. Label project based financed. Individuals, collectives and enterprises have the chance to finance projects for individual farms and carbon reduction projects. |

## 5. Discussion

Finding adequate policies to overcome barriers to adoption (Concu et al., 2020; EEA: 2019, Annex I) of (eco-) innovation and introducing them into the regime configuration has resulted in a variety of approaches (Annex II & Table 2). Ultimately, the choice on policy lies with the political system and the regulatory authority. Furthermore, it depends on the implementation possibilities the regional or national level has .

The results of the LIFE projects and the reviewed policies are in the following discussed to the background of the MLP approach. Through the Bord Bio consumer standard no greater regime level effect, sufficient for a "greater" sustainability transition, could be achieved but only (on the voluntarily participating farms (Linton, 2019). Similar outcomes can be attributed to program-based approaches (Action plan to reduce ammonia from agriculture in Finland, California Smart agriculture programs) which provide funding, grants and subsidies for the promotion of a specific action or promote a sustainable practice. This type of supporting policy led to results in terms of money distribution and farms financed for adoption of practices (Table 2, description column). The financial incentives reviewed in the Finish case have led to a widespread adoption of practices, as for example the injection of slurry within 24 hours. This type of policy is also widely applied in the European regions development plans and is a characterized based as a traditional governmental steering policy to monetarily incentivize adoption of a practice otherwise unprofitable. If adopted to the Sardinian case this policy, could alter alter the regular functioning of the regime (function: provisioning of development plans) to allow for the innovation of novel measures such as a focus on eco-friendly production of pecorino. In terms of changing the configuration of the regime level these policies are however to be considered with caution from a MLP as they do not aim for change on a broader scale but rather to increase an individual indicator (e.g. nitrogen content decrease in soils and water through in-cooperation of slurry to prevent runoff). As soon as the policy is discontinued, and the payment seizes, the old behavior might return.

A regime changing policy could aim at introducing agricultural practices (agroforestry, conservation agriculture), which are in need of less manure fertilization in general. The California Smart Agriculture Programs seek to implement these approaches through the funding of the establishment of innovative farms with permanently changed practices. This is implemented however, not on a broad scale but for a limited number of farms. Applications in this scheme are based on innovative proposals for change and are rewarded with grants. Similarly, the French government recently introduced a label (Label bas carbone) in order to allow for financing of individual projects to offset greenhouse gases through the direct investment of individuals, companies and collectives. The label uses an LCA based software tool (CAP'2ER) to assess improvement potential in terms of efficiency but also through the increase of carbon sink uptake.

In the light of the MLP, the grant funded niche-farms serve as protected spaces for experimentation of changed farm management. Once an ecological, social and economically sustainable balance has been found the support is potentially no longer needed and the former niche has become part of a transformed regime constellation. This then entails new artifacts and social practices as Smith (2005) laid out.

In a sense LIFE projects aim at establishing a similar niche constellation for trial and error. When successfully implemented on farm level, it the projects ambition to enter the regime level knowledge through workshops, institutional meetings with European, country and regional policy makers. The creation of this knowledge on farm level is in jeopardy if supporting policies are not established in the follow up or the innovations are not economically feasible by themselves. Hence, to facilitate large uptake economically feasible innovations which create a win-win situation in terms of social and ecological benefits could be promoted through the long-term establishment of here termed “light house farms”; similarly, to the approach of the California Smart Agriculture Programs. Ones established these farms facilitate best practices to surrounding farms and act as nuclei for others to learn and adopt practices.

Furthermore, the policies proposed by the ICCC to the New Zealandian government rely on the inclusion of the agricultural sector in the carbon trading scheme. Under current conditions, agriculture is excluded in the European carbon trading mechanism. Therefore, the accounting for GHG and their capping on individuals farms seems unfeasible in the context. However, a revisiting of this policy is possible when agricultural emissions fall under the carbon trading scheme of the EU.

Looking forward to conceptualizing the MLP as a guiding heuristic for policy definition can be combined with a reflexive governance approach (transition management) (Voß and Bornemann 2011; Lopez et al., 2019). Enabling a governance search heuristic for innovations will need to be a prerequisite for a sustainability transition as it implies a constant search for innovations. In that sense “governance schemes that take socio-technical complexities into account, and yet retain a sense of which niche-regime-landscape reproduction processes are significant for transitions, and that target their policy attention on the key players accordingly, are more likely to generate effective transition policy” (Smith, Voß and Grin, 2010: 445).

Therefore, a mixture of policy approaches, which on the one side enables the adoption of innovation through financial support and includes a limiting element on environmental degradation, has a higher chance of promoting a change in the regime configuration permanently. In order to evaluate policies of a governance of socio-technical systems, a promising research agenda is to couple the policies with a System Dynamics (SD) model (TEEB, 2018). The SD approach can raise knowledge on independencies between individual parts of the system and plan for scenarios, the governance of socio-technical systems of innovations can provide insights towards the governance design.

Concludingly, the transferability of the LIFE projects as outlined in detailed in Annex II has its relevance in the sense that the workshops, scientific meetings and adoption by the regional government are legitimate exercises for promoting change. However, it appears that these activities rarely lead to a political buy in (with the exception of the Andalusian and French governments) and the action fades instead of stabilizing in a new regime configuration. An increase in communication activity and the beforehand identification of communication channels for the target group (e.g. how to reach farmers) remains a key factor in scaling up innovations.

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## Annex I: Lock-ins and barriers to change in socio-technical systems

### Economic and social barriers

- **Increasing returns**: Production costs for new technologies often drop significantly as output grows due to economics of scale and learning-by-doing, as well as network effects (Arthur, 1994). As a result established technologies can become the 'dominant design', enjoying significant price/performance advantages over newly emerging 'green' innovations.

- **Sunk costs**: Public and private investments in long-lasting assets such as transport infrastructure or power plants are often very substantial. Businesses and employees likewise make major investments in manufacturing plants, knowledge and skills, which are geared towards are particular modes of production

- **Jobs and earnings**: Disruptive innovations threaten established businesses and can lead to structural economic change leading to job losses and even impacting whole regional economies (e.g. in coal-mining areas). These effects are likely to create major resistance from workers, industry groups and unions.

- **Division of labor and specialization**: These produce investments in specific skills and knowledge aimed at optimizing aspects of the dominant design (rather than questioning the design as a whole). Cognitive routines and shared mindsets can blind actors to developments outside their focus (Nelson and Winters, 1982).

- **User practices and lifestyles**: These stabilize particular technologies. For example, the car has become embedded in mobility practices such as commuting to work, taking children to school, shopping and social visits. It is also embedded in cultural discourses and identity (e.g. prestige). Cognitive biases such as loss aversion, status quo bias and endowment effects can further deter lifestyle change.

### Political barriers

- **Sectoral policies (e.g. promoting standardization or protecting human health)**: These tend to create lock-ins because producers and consumers will make choices and investments based on them. Partly for this reason existing policies may favor incumbents, creating an uneven playing field.

- **Vested interests**: Changing policies is difficult because of active opposition to change from groups with vested interests (Geels, 2014), which is corporate political strategies to shape policies in their favor (Hillman & Hitt, 1999; Levy & Egan, 2003).

- **Distributional effects**: Policy change impacts different groups unevenly, creating political obstacles. For example, taxing necessities such as food, energy and mobility are likely to have regressive impacts and varying effects on urban and rural populations, young people and the elderly.

- **Globalization and jurisdiction**: The globalization of value chains and financial flows places significant constraints on the efficacy of territorially based policy instruments in national jurisdictions, particularly as domestic measures may lead to offshoring of production (and burden shifting).

- **Short-termism**: Electoral incentives can discourage politicians from introducing measures that are likely to be unpopular in the short term but deliver long-term benefits for society.

### System interlinkages

- **Rebound effects**: Increasing returns to adoption and technological innovation can lower the costs of goods and services, incentivizing increased consumption. As a result, the environmental improvements from green technological innovation may be (partly) counteracted by increasing consumption (e.g. resource use and emissions).

- **Burden shifting**: In increasing globalized systems, efforts to prevent an environmental or socio-economic problem in one location may results in substitution effects or relocation of production overseas.

- **Market failures**: The globalization of production-consumption systems into often highly disintegrated value chains means that consumer and producers (at different stages) are unaware of the socio-economic and environmental impacts of their choices and have limited influence over them. Externalities substantially weaken incentives for system change (European Environmental Agency, 2019: 25).