

Who drives green innovation in the Nordic Region?

A change agency and systems perspective

Alberto Giacometti, Mari Wøien Meijer, Hilma Salonen

Who drives green innovation in the Nordic Region? A change agency and systems perspective

Alberto Giacometti,
Mari Wøien Meijer,
Hilma Salonen

Who drives green innovation in the Nordic Region? A change agency and systems perspective

Nordregio Report 2024:10

ISBN: 978-91-8001-097-9

ISSN: 1403-2503

DOI: <http://doi.org/10.6027/R2024:101403-2503>

© Nordregio 2024

Nordregio
P.O. Box 1658
SE-111 86 Stockholm, Sweden
nordregio@nordregio.org
www.nordregio.org

Authors: Alberto Giacometti, Mari Wøien Meijer, Hilma Salonen

Communication: Anne Katrine Ebbesen

Layout: Kotryna Juškaitė

Cover: Fredrik Ohlander / Unsplash.com

Nordregio is a leading Nordic and European research centre for regional development and planning, established by the Nordic Council of Ministers in 1997. We conduct solution-oriented and applied research, addressing current issues from both a research perspective and the viewpoint of policymakers and practitioners. Operating at the international, national, regional and local levels, Nordregio's research covers a wide geographic scope, with an emphasis on the Nordic and Baltic Sea Regions, Europe and the Arctic.

The Nordic co-operation is one of the world's most extensive forms of regional collaboration, involving Denmark, Finland, Iceland, Norway, Sweden, and the Faroe Islands, Greenland, and Åland. Nordic co-operation has firm traditions in politics, the economy, and culture. It plays an important role in European and international collaboration, and aims at creating a strong Nordic community in a strong Europe. Nordic co-operation seeks to safeguard Nordic and regional interests and principles in the global community. Common Nordic values help the region solidify its position as one of the world's most innovative and competitive.

The Nordic Council of Ministers is a forum of co-operation between the Nordic governments. The Nordic Council of Ministers implements Nordic co-operation. The prime ministers have the overall responsibility. Its activities are co-ordinated by the Nordic ministers for co-operation, the Nordic Committee for co-operation and portfolio ministers. Founded in 1971.

The Nordic Council is a forum for co-operation between the Nordic parliaments and governments. The Council consists of 87 parliamentarians from the Nordic countries. The Nordic Council takes policy initiative s and monitors Nordic co-operation. Founded in 1952.
Stockholm, Sweden, 2024

Table of contents

Preface	7
Executive summary	8
Laaja Tiivistelmä (Executive Summary in Finnish)	12
1. Introduction	16
PART I: Theoretical and conceptual overview	17
2. Theoretical overview	17
PART II: Methodological Framework	42
3. Conceptual framework	42
PART III: Empirical Study	47
4. Case Study 1: Innovation Dynamics in Wood Construction in Sweden and Finland	47
4.1. Introduction	48
4.2. Technological innovation	52
4.3. Historical overview of industrial development and technological innovation in wood construction	55
4.4. Institutional & public sector innovation	63
4.5. Systems perspective to innovation in wood construction	76
4.6. Conclusions: the roles of actors	83
5. Case Study 2: Nordic innovation systems dynamics in the protein shift	87
5.1. Introduction	87
5.2. The protein shift	89
5.3. Proteins: a cocktail of sustainability challenges	90
5.4. Sustainability narratives of the 'protein shift'	92
5.5. Technological innovation & industrial development in the protein shift	96
5.6. Institutional innovation and consumer behaviour	111
5.7. Systems perspectives on the protein shift	118
5.8. Conclusions: The roles of actors in driving change in the protein shift	125

PART IV: Cross-case analysis	128
6. Analysis	128
6.1. Innovative entrepreneurship	128
6.2. Institutional entrepreneurship	131
6.3. Social innovation and dominant narratives	134
6.4. Place-based leadership & place-less developments	136
6.5. Green Innovation in a context of 'transitions'	140
7. Conclusion	142
8. References	145
8.1. References Theoretical Overview	145
8.2. References case study: Innovation Dynamics in Wood Construction in Sweden and Finland	154
8.3. References case study: Systems perspectives on the protein shift	158
8.4. Interview list	162

Preface

This report is the outcome of the Systems Perspectives on Green Innovation (GRINGO) project, which aims at generating understanding, from a systems perspective, of the roles different agents play in driving 'green innovations', or innovations that facilitate the green transition. The study was carried out by Nordregio on behalf of the Nordic Thematic Group for Green, Innovative and Resilient Regions (2021–2024) to support the implementation of the Nordic Vision 2030 and its core goals

of increased competitiveness and sustainability.

To uncover the bottlenecks preventing industries or sectors from undertaking green transitions, we investigated the link between agency and innovation. In particular, we examined the role different agents and actors play in driving transition processes and how policies and framework conditions impact the green transition in various economic sectors and business ecosystems across the Nordic Region.

Executive Summary

This study focuses on exploring the relationship between agency and innovation. It examines the roles played by various agents and actors in steering the green transition, ranging from technological and institutional innovations to systems innovations. The discussion does not solely revolve around the impact of structures on agents or vice versa but also focuses on how agents instigate transformative change seen from various perspectives, both individually and in partnerships. The results of this study are presented in four parts, as follows:

PART I: Theoretical and conceptual overview:

Our theoretical overview of innovation examines the evolution of academic thinking and policy development concerning innovation systems, the long-running debate on the relationship between structures and agency and the role of 'place' or geography within these. We also explore the academic discussion surrounding the emergence of a new paradigm in innovation policies – so-called 'transformative innovation policies', which focus on steering science, technology and innovation in directions that facilitate 'transitions' and meeting the sustainable development goals.

At the centre of the structure-agency debate, we discover that efforts to define causality are

challenged by a significant knowledge gap in terms of the micro-processes at work behind systems innovations. More specifically, we identify the need for a more nuanced understanding of how agency plays out in these processes in relation to *structure*. Through empirical research, we aim to bridge this gap by observing different types of change agents and systems dynamics and, in so doing, figure out what innovation policies may be overlooking.

PART II: Methodological framework:

Borrowing from Grillitsch & Sotarauta (2020), we apply the 'trinity of change agency' framework to study the different forms of agency set in motion to drive innovation and path creation. This framework sets out three different types of agency at work individually and simultaneously. These include 1) '*innovative entrepreneurship*' building on an evolutionary tradition, focusing on entrepreneurship as an instigator of change and triggering industrial and economic transformation; 2) '*Institutional entrepreneurship*' building on an institutional tradition and focusing on institutional structures and risk-taking institutions in laying out new growth paths and 3) '*place-based leadership*', highlighting the role of multiple actors in pooling competences and resources to achieve individual or collective objectives.

PART III: Empirical Study:

The empirical study delves into change agency in green innovations from a sectoral perspective, exploring two specific cases. The first examines the use of wood-based products, technologies and construction systems in multi-storey constructions in Sweden and Finland. We reconstruct a historical sequence of events, developments and decisions deemed essential by experts in defining innovation and industrial path creation. While technologies seem to be the result of many years, if not centuries, of incremental innovations and political decisions (many of which are unrelated or only indirectly related to a specific technology), the case study reveals the presence of 'structural inertia' (understood as a general resistance to change within the system) in the construction sector, representing the main roadblock for the use of wood-based systems in modern multi-storey buildings. Nonetheless, key actors were eventually able to disrupt the market and institutional structures through the decisiveness of place-based 'champions' working closely together, in parallel to a process of systems integration and cross-fertilisation, in which different sectors shared knowledge, skills and labour force, leading to streamlined related processes, overcoming bottlenecks and increasing efficiency. These forces have seen the creation of a new, competitive market ecosystem.

The second case study focuses on the 'protein shift', by which we refer to innovation and industrial development processes aimed at

reducing the environmental impacts of protein food products/systems. Here, competing sustainability narratives represent a major factor influencing consumer behaviour and giving direction to systemic change. We observe a low degree of cross-fertilisation across interconnected but also largely disconnected industrial and scientific ecosystems. Instead, the protein shift involves multiple parallel developments, leading to increased diversification of protein food products, industrial processes and supply chains. Institutional leaders have been active on a place basis but more significantly at a national and EU level. Despite a lack of a well-defined societal discussion regarding appropriate development pathways, the protein shift is unlikely to solely rely on a series of individual solutions but will more likely depend on a multi-pathway approach considering diverse ethical, economic and cultural aspects, as well as the opportunities afforded by both old and new technologies and practices in improving sustainability in food and protein systems.

PART IV: Cross-case analysis:

The empirical evidence presented in this study sheds light on how innovation processes occur under the banner of 'green transitions' and the relevance of different types of agency to these processes. A key realisation is that different technological and sectoral innovations often occur under fundamentally different conditions, i.e., context matters. In some cases, the main driver for innovation (and new development paths) may be a policy push; in

others, a technology push (by private businesses) or a demand pull (by clients and consumers). Although the three types of agency are often simultaneously at work, case studies show that they may play different roles at any given time or place.

The current policy context and its orientation towards implementing the 'green transition' means that policy, regulation and public authorities at different territorial levels play a major role in setting directionality in innovation processes. Institutional entrepreneurship is evidenced not merely by, for example, public institutions adapting to emerging contexts (e.g., fixing market failures) but by actively shaping development processes. This challenges the assumption that the private sector is inherently innovative, consistently taking risks and pushing market boundaries. On the contrary, our empirical observations show that a substantial portion of private entities often resist change.

Although public-sector actors play a crucial role in advancing new agendas (e.g., the protein shift), public policy does not happen in a vacuum. It is usually a response to a broader social recognition of a problem (e.g., climate change) and the myriad of other concurrent developments in science and the marketplace. The institutional context, both the formal and informal rules in place, may enable or hinder agency: determining the essential preconditions such as well-functioning markets, appropriate regulatory frameworks and access to labour, knowledge and capital while itself continuously learning and adapting to these frameworks.

Our fieldwork revealed intense interactions across national, regional, technological and sectoral innovation systems. These are crucial for facilitating the green transition. Network-based (and often place-based) innovation requires all actors to embrace new ideas and welcome change. Nevertheless, the findings also point to the importance of an entrepreneurial perspective influenced by creative labour and opportunity recognition, as typified by Schumpeter (1942). Entrepreneurs, whether individuals or businesses, have the sensitivity to discern market opportunities, address technological gaps and assess the commercial viability of new products and solutions. Place-based leadership can be clearly discerned in the case studies in the way sub-national authorities, the private sector and academia actively contribute to overcoming challenges in established business ecosystems.

Bochma's understanding of proximities helps us disentangle the puzzle of how structure-agency relations play out on the ground. Beyond geography alone, Boschma (2005) refers to 'proximity' as the ability to understand, adopt and adapt to identify novelty, interpret and exploit new knowledge. While it is easy to see how geographical proximity enables knowledge spillovers and innovation in both case studies, cognitive proximity, as in interactions among like-minded individuals, regardless of physical distance, appeared to be more important in delivering technological innovations. However, systems innovations seemed to be more clearly

determined by institutional structures and the ability of different actors to exchange knowledge, collaborate to solve bottlenecks and enable path creation. Here, organisational, social and institutional proximities become particularly relevant in determining the closeness and influence between organisations, the nature of human interactions and the institutional arrangements. Different types of proximities converged more in the wood construction case than in the protein shift case, where developments are more geographically sporadic.

Conclusion:

Based on the empirical evidence, this study shows that systemic green

innovations are non-linear, highly complex and are the result of the sum of various individual efforts and collaborations. We realise that change emerges at the interface between key players via collaboration, knowledge exchange and trust-building. Although many actions are not intentionally aimed at producing systemic changes (with the possible exception of targeted policies), these are not random actions but aim at seizing emerging opportunities. Directionality in innovation and path-creation is, therefore, not the same in all cases and leadership may shift over time from one actor to another, be it public authorities, businesses, hybrid organisations or individuals.

Laaja Tiivistelmä (Executive Summary in Finnish)

Tämä tutkimus käsittelee toimijuuden ja innovaation välistä suhdetta. Painopiste on eri toimijoiden roolissa vihreän siirtymän suuntaamisessa teknologisista ja institutionaalisista innovaatioista rakenteellisiin innovaatioihin. Tutkimus laajentaa näkökulmaa rakenteiden vaikutuksesta toimijoihin tai päinvastoin myös siihen, miten eri toimijat edistävät perustavanlaatuisia muutosta eri kulumista yksin ja yhteistyössä. Tutkimuksen tulokset esitellään neljässä osassa:

OSA I: Teoreettinen ja käsitteellinen katsaus

Aloitamme innovaatiotoiminnan teoreettisella tarkastelulla ja kartoitamme innovaatiojärjestelmiä koskevan akateemisen keskustelun ja politiikan kehitystä, rakenteiden ja toimijuuden välistä suhdetta puntaroivaa pitkään jatkunutta väittelyä sekä "paikan" tai maantieteen asemaa näissä. Lisäksi tarkastelemme akateemista keskustelua liittyen innovaatiopolitiikan uuden lähestymistavan - niin sanotun "transformatiivisen innovaatiopolitiikan" - syntyyn. Se keskittyy tieteen, teknologian innovaatioiden ponnistelujen tietoiseen ohjaamiseen kestävän siirtymän ja kestävän kehityksen

poliittisten tavoitteiden saavuttamiseksi.

Syy-seuraus-yhteyden määrittämistä rakenne-toimijuusväittelyssä hankaloittaa merkittävä tietovaje rakenteellisten innovaatioiden taustalla vaikuttavista mikroprosesseista. Toisinsanoen on selvää, että tarvitaan entistä monisyisempää ymmärrystä toimijuuden vaikutuksista suhteessa rakenteeseen näissä tapahtumasarjoissa. Tämän empiirisen tutkimuksen avulla pyrimme osaltamme kuroma umpeen tätä aukkoa havainnoimalla erityyppisiä muutosagentteja ja järjestelmien välistä dynamiikkaa ja siten ymmärtämään, mitä osaluja innovaatiopolitiikka on mahdollisesti jättänyt huomiotta.

OSA II: Metodologinen kehys

Grillitschin ja Sotaraudan (2020) mallia lainaten sovellamme muutosagenttien kolminaisuuden käsitettä (trinity of change agency) kehyksenä tutkiessamme innovaatiotoimintaa ja erilaisia toimijoita, jotka edistävät polkujen luomista. Tässä kehyksessä esitetään kolme erilaista toimijuuden tyyppiä, jotka ovat toiminnassa sekä erikseen että samanaikaisesti. Nämä ovat 1) "innovatiivinen yrittäjyys", joka perustuu ajallisen kehityksen fokukseen ja keskittyy yrittäjyyteen

muutosvoimana, joka käynnistää teollisen ja taloudellisen murroksen; 2) "institutionaalinen yrittäjäyys", joka perustuu institutionaaliseen perinteeseen ja keskittyy institutionaalisiin rakenteisiin ja riskejä ottaviin virallisiin elimiin uusien kasvupolkujen luomisessa; ja 3) "paikkaperustainen johtajuus", jossa korostetaan useiden toimijoiden roolia osaamisen ja resurssien yhdistämisessä yksilöllisten tai yhteisten tavoitteiden saavuttamiseksi.

OSA III: Empiirinen tutkimus

Empiirinen tutkimus tarkasteli vihreisiin innovaatioihin liittyvää muutostoimijuutta sektorikohtaisesta näkökulmasta kahden tapaustutkimuksen kautta. Ensimmäisessä tarkasteltiin puupohjaisten tuotteiden, teknologioiden ja rakennusjärjestelmien leviämistä monikerroksisessa rakentamisessa Ruotsissa ja Suomessa. Koostimme historiallisten tapahtumien, kehityskulkujen ja päätösten sarjan innovaation ja teollisten kehityskulkujen edistämiseen liittyen asiantuntijahaastattelujen pohjalta. Vaikka teknologinen kehitys vaikuttaa olevan useiden vuosien, ellei jopa vuosisatojen, asteittaisten innovaatioiden ja poliittisten päätösten tulos (mistä monet eivät liity tai liittyvät epäsuorasti tiettyyn teknologiaan), tapaus paljastaa, että rakennusallalla vallitseva "rakenteellinen inertia" (eli järjestelmän yleinen muutosvastarinta) oli suurin este puupohjaisten järjestelmien käytölle nykyaikaisessa monikerroksisessa

rakentamisessa. Keskeiset toimijat ovat kuitenkin pystyneet horjuttamaan markkinoiden ja instituutioiden rakenteita paikallistason "mestareiden" päättäväisyyden tukemana ja tiiviin yhteistyön avulla, ja samalla järjestelmien integrointi- ja ristikkäisviljelyprosessien kautta. Näissä eri alat ovat tulleet yhteen jakamaan tietoa, taitoja ja työvoimaa, mikä on johtanut prosessien virtaviivaistamiseen, pullonkaulojen poistamiseen ja tehokkuuden lisäämiseen. Tämän tuloksena on luotu uusi, kilpailukykyinen markkinatalousekosysteemi.

Toisessa tapaustutkimuksessa keskityttiin "proteiinisiirtymään", jolla tarkoitetaan innovaatioita ja teollisia kehitysprosesseja, joilla pyritään vähentämään perinteisten proteiinipitoisten elintarvikkeiden ympäristövaikutuksia. Kilpailevien kestävyysnarratiivien merkitys on suuri tässä yhteydessä kuluttajien käyttäytymiseen ja systeemille muutokselle suuntaa antavana tekijänä. Tutkimuksessa panimme merkille, että toisiinsa kytkeytyneiden mutta myös pitkälti toisistaan irrallaan olevien teollisten ja tieteellisten ekosysteemien keskinäinen vaikutus on vähäistä. Sen sijaan proteiinisiirtymään liittyy paljon rinnakkaista kehitystä, joka on johtanut proteiinipitoisten elintarviketuotteiden, teollisuusprosessien ja toimitusketjujen lisääntyvään monipuolistumiseen. Institutionaaliset johtajat ovat olleet aktiivisia paikallisesti, ja vielä enemmän kansallisella ja EU:n tasolla. Huolimatta

asianmukaisia kehityskulkuja käsittelevän yhteiskunnallisen keskustelun mustavalkoisuudesta proteiinisiirtymä ei todennäköisesti ole riippuvainen yksittäisistä ratkaisuista vaan monipolkuisesta lähestymistavasta, jossa otetaan huomioon erilaiset eettiset, taloudelliset ja kulttuuriset näkökohdat sekä vanhojen ja uusien teknologioiden ja käytäntöjen tarjoamat mahdollisuudet parantaa elintarvike- ja proteiinijärjestelmien kestävyyttä.

OSA IV: Tapausten vertailu ja analyysi

Tämän tutkimuksen empiirinen aineisto valaisee innovaatioprosessin tapahtumakulkuja niin sanotuissa vihreissä siirtymävaiheissa ja sitä, miten tärkeitä erityyppiset toimijat ovat. Keskeinen oivallus on, että erilaiset teknologiset ja alakohtaiset innovaatiot tapahtuvat usein täysin erilaisissa olosuhteissa: asiayhteydellä on suuri merkitys. Joissakin tapauksissa innovaation (ja uusien kehityspolkujen) pääasiallinen ajuri voi olla poliittinen paine, toisissa taas teknologinen sysäys (yksityisten yritysten toimesta) tai kysynnän vetovoima (asiakkaiden ja kuluttajien toimesta). Vaikka nämä kolme toimijatyyppiä ovat samanaikaisesti toiminnassa, tapaustutkimukset osoittavat, että niillä voi olla eri rooli tiettyinä aikana tai tietyssä paikassa.

Nykyinen poliittinen toimintaympäristö ja sen suuntautuminen vihreän siirtymän toteuttamiseen tarkoittaa, että politiikalla, sääntelyllä ja eri aluetasojen viranomaisilla on merkittävä rooli innovaatioprosessien

suuntaamisessa. Institutionaalinen yrittäjäyys ei ilmene pelkästään julkisten instituutioiden sopeutumisessa uusiin olosuhteisiin (esim. korjaamalla markkinahäiriöitä), vaan myös niiden aktiivisesti kehitysprosesseja muokkaavassa työssä. Tämä kyseenalaistaa oletuksen, jonka mukaan vain yksityinen sektori on luonnostaan innovatiivinen, ottaa jatkuvasti riskejä ja venyttää markkinoiden rajoja. Sen sijaan empiiriset havaintomme osoittavat, että huomattava osa yksityisistä yrityksistä vastustaa muutosta.

Vaikka julkisilla toimijoilla on ratkaiseva rooli uusien ohjelmien edistämisessä (esim. proteiinisiirtymä), julkinen politiikka ei tapahdu tyhjiössä vaan usein heijastaa laajemman yhteiskunnallisen ongelman (kuten ilmastonmuutoksen) tunnistamista ja lukemattomia tieteen ja markkinoiden kehityskulkuja. Voimassa olevat viralliset ja epäviralliset säännöt voivat joko mahdollistaa tai estää toimijuutta, sillä ne määrittelevät keskeiset edellytykset, kuten hyvin toimivat markkinat, asianmukaisten sääntelyjen puitteet sekä työvoiman, tiedon ja pääoman saatavuuden samalla jatkuvasti oppien ja mukautuen.

Tapaustutkimuksemme toi ilmi, että kansallisten, alueellisten, teknologisten ja alakohtaisten innovaatiojärjestelmien välillä on tiivistä vuorovaikutusta, joka on ratkaisevan tärkeää vihreänsiirtymän helpottamiseksi. Verkostopohjainen (ja usein paikkasidonnainen) innovointi edellyttää, että kaikki

olennaiset toimijat omaksuvat uusia ideoita ja suhtautuvat myönteisesti muutokseen. Havainnot viittaavat kuitenkin myös yrittäjänäkökulman merkitykseen, johon vaikuttavat luova työ ja mahdollisuuksien tunnistaminen, kuten myös Schumpeter (1942) on todennut. Yrittäjillä, olivatpa he sitten yksityishenkilöitä tai yrityksiä, on herkkyyttä havaita markkinamahdollisuuksia, puuttua teknologisiin aukkoihin ja arvioida uusien tuotteiden ja ratkaisujen kaupallista elinkelpoisuutta. Paikkaperusteinen johtajuus ilmenee tapaustutkimuksissamme etenkin siinä, miten valtiollista tasoa alemmat viranomaiset, yksityinen sektori ja korkeakoulut osallistuvat aktiivisesti vakiintuneiden liiketoimintakosysteemien haasteiden voittamiseen.

Bochman käsite läheisyydestä ("proximity") auttaa meitä lähestymään kysymystä rakenteiden ja instituutioiden välisestä suhteista käytännössä. Boschma (2005) viittaa "läheisyyteen" pelkän maantieteen lisäksi kykynä ymmärtää, omaksua ja sopeutua, tunnistaa uutuuksia, tulkita ja hyödyntää uutta tietoa. Vaikka maantieteellisen läheisyyden mahdollistama tiedon leviäminen ja innovointi käy selvästi ilmi molemmissa tapaustutkimuksissa, kognitiivinen läheisyys, kuten vuorovaikutus samanhenkisten yksilöiden välillä fyysisestä etäisyydestä riippumatta, voi nousta tärkeämpään asemaan teknologisten innovaatioiden edistämisessä. Rakenteellisten innovaatioiden toteutumista näyttää kuitenkin määrittävän

selvimmin institutionaalisten rakenteiden ja eri toimijoiden kyky vaihtaa tietoa ja tehdä yhteistyötä pullonkaulojen ratkaisemiseksi ja uusien kehityskulkujen luomiseksi. Tässä yhteydessä organisatoriset, sosiaaliset ja institutionaaliset läheisyydet ovat erityisen tärkeitä määriteltäessä organisaatioiden välistä läheisyyttä ja vaikutusvaltaa, ihmisten välisen vuorovaikutuksen luonnetta ja institutionaalisia järjestelyjä. Erilaiset läheisyystyypit lähenivät toisiaan enemmän puurakentamisen kuin proteiinisiirtymän tapauksessa, jossa kehitys on ollut maantieteellisesti hajanaisempaa.

Päätelmät

Empiirisen aineiston perusteella tämä tutkimus osoittaa, että systeemiset vihreät innovaatiot ovat epälineaarisia, erittäin monimutkaisia prosesseja, jotka syntyvät erilaisten yksittäisten ponnistelujen ja yhteistyön tuloksena. Murros syntyy ensisijaisesti keskeisten toimijoiden välisessä vuorovaikutuksessa yhteistyön, tiedonvaihdon ja luottamuksen rakentamisen kautta. Vaikka monilla toimilla ei tarkoituksellisesti pyritä tuottamaan rakenteellisia muutoksia (suorat poliittiset toimet pois lukien), ne eivät ole sattumanvaraisia vaan niillä pyritään tarttumaan uusiin ilmeneviin mahdollisuuksiin. Suunnan määrittäminen innovaatioissa ja kehityspolkujen luomisessa ei siis käy aina samalla lailla. Johtoasema voi ajan myötä siirtyä toimijalta toiselle, oli kyseessä sitten viranomainen, yritys, hybridiorganisaatio tai yksilö.

1. Introduction

The green transition, a politically-willed process of economic, social and technological transformation, is perhaps the most revolutionary and profound process of systems innovation in current times. Shedding light on this colossal challenge requires a close overview of the historical evolution of the academic and policy discourse surrounding innovation, innovation systems and transformational innovation and economic policies. Furthermore, the intentional nature of green transitions poses the question: who or which factors should determine change and set directionality?

To answer this question, this study focuses on exploring the relationship between agency and innovation. It examines the roles played by various agents and actors in instigating green innovations and the more systemic process of the green transition. In other words, surveying not only technological and institutional innovations but also systemic innovations. The discussion does not solely revolve

around the impact of structures on agents or vice versa but rather focuses on how agents intentionally and unintentionally instigate transformative change individually and in collaborations from various perspectives.

The report is organised as follows: PART I introduces the theoretical and conceptual background for our study, taking a deep dive into the literature concerning innovation systems theory, the structure-agency debate and transitions. PART II sets out the methodological and conceptual framework based on the 'trinity of change agency' approach. This is followed by two extensive empirical case studies in PART III: *innovation dynamics in wood construction in Sweden and Finland* and *Nordic innovation systems dynamics in the protein shift*. PART IV provides a cross-case analysis, and finally, we conclude with a brief reflection on the dynamics observed when examining the role of agency in the green transition.



Photo: Karl Hornfeldt / Unsplash.com

PART I: Theoretical and conceptual overview

2. Theoretical overview

This theoretical overview explores the role of different agents in green innovation. It conceptualises the terms 'systems', 'innovation' and 'green' and reviews them in the context of the 'green transition'. We begin by considering 'systems' through the lens of innovation and its different manifestations and then expand upon place-based innovation, tapping into the extensive contributions of economic geography literature in innovation studies, as well as innovation-based green transition of economic and social systems, as understood within transition literature. These different interpretations of innovation offer insight into how policies have been framed and changed over time. Interpretations have evolved from understanding innovation

mainly as an economic driver, to acknowledging its systemic nature, to finally transcending purely economic aspirations and including social goals. We conclude with an overview of the current policy climate surrounding green transitions that emerges from the expected potential of innovation policy in addressing the complex societal and environmental challenges of today. This ambition for innovation policy has been translated into what is described as transformative innovation policies and missions-oriented innovation policies.

Innovation policy and economic development

At the end of the 20th century, Nelson and Winter (1977) conceptualised innovation policy as being forged

on two premises: The first rests on the indisputable premise that "technological advance has been a powerful instrument of human progress", and the second, more presumptuous premise, is that policy makers and key actors have sufficient knowledge to guide technology towards achieving "high priority objectives" in the future (Nelson & Winter, 1977, p. 38). However, then, as now, the situation is more complex. The same authors argue that "the key policy problem will be to augment or redesign institutions rather than to achieve particular resource allocation per se" (Nelson & Winter, 1977, p. 40). In 1977, Nelson and Winter recognise that innovation is not one single entity but can vary and is relatively complex within each economic sector. Innovation, Nelson and Winter write, is uncertain in an essential way and that the "explicit recognition of uncertainty is important in thinking about policy" (Nelson & Winter, 1977, p. 47). Furthermore, Schumpeter writes in 1942:

”

Every piece of business strategy acquires its true significance only against the background of that process and within the situation created by it. It must be seen in its role in the perennial gale of creative destruction; it cannot be understood irrespective of it or, in fact, on the hypothesis that there is a perennial lull"

(Schumpeter, 1942: 73)

The Austrian-German economist Joseph Schumpeter laid the foundation for modern theories

of business and entrepreneurship in the early to mid-20th Century. His work can be divided into two distinct phases: *Theory of Economic Development* (1934) and his later work *Capitalism, Socialism and Democracy* (1942). The first theory is concerned with an increasingly 'widening' understanding of innovation and innovative activity, whereby entry into a new industry is characterised by relative (technological) ease. It also involved entrepreneurs challenging established businesses within the industry through their new ideas, processes, or products, which led to a process of constant disruption (Schumpeter 1934 in Malerba & Orsenigo, 1995). By 1942, Schumpeter had 'deepened' his theory of innovation (Malerba & Orsenigo, 1995), launching the term 'creative destruction', aided by capitalism, whereby:

”

the process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism. It is what capitalism consists in and what every capitalist concern has got to live in."

(Schumpeter, 1942 (2010), p. 73)

Based on empirical findings, Malerba & Orsenigo (1995) argue that there is support for this 'deeper' understanding of innovation set out by Schumpeter in 1942. This is especially evident when seen in light

of innovation patterns in advanced economies in the 1990s, even though the nature of innovation activities varies across technologies and, therefore, the dominant technological regime. Moreover, *stability* emerges as a "feature of the patterns of innovative activity" as technological performance continues to be reliant on "a stable group of innovators", generally in larger businesses. This, Malerba & Orsenigo (1995) write, has implications for theoretical analysis and policy writing, as it demands greater emphasis on the necessary analysis of innovation activities as they unfold in a dynamic context. Regarding policy, they contend that policymakers should primarily be concerned with creating conditions for the aforementioned 'stable group of innovators' – i.e., stability – as a crucial complement to policies concerning innovation in new but smaller businesses.

Innovation theory and the subsequent institutional policy development must, therefore, recognise the nature of innovation as *evolutionary* and against the structural backdrop within which it dwells, as well as ensuring significant room for organisational complexity, according to these authors (Nelson & Winter, 1977; Schumpeter, 1942 (2010)). For innovation, it is essential that the time, institutions and organisation for which (and within which) policy is developed are also considered necessary tenets of knowledge for creating appropriate innovation policy instruments. If capitalism and innovation as the force driving economic growth forward are inherently evolutionary, as first identified by Karl Marx, policy and

institutions must follow: "capitalism, then, is by nature a form or method of economic change and not only never is but never can be stationary" (Schumpeter, 1942 (2010), p. 73). Moreover, capitalism is not merely conditioned within social and natural environments, but also comes from inventions, radical innovation, public sector innovation as well as innovation in goods and services (Schumpeter, 1942).

Innovation systems theory

Nelson and Rosenberg (1993, p. 4) define innovation as the new processes and product designs mastered and put into practice by businesses or that otherwise are commercialised. Cooke et al. (1997) critique this definition as too narrow, especially as it only considers productive companies and argue for a broader understanding of innovation. Innovation, they argue, implies a wider systemic concept, which comprises the ways in which actors, organisations and behaviour connect and the relationship between them. They maintain that "systemic innovation [...] implies the loose coupling of subsystems" (Cooke, Gomez Uranga, & Extbarria, 1997), which essentially means that a system of innovation is a system that encapsulates a myriad of other smaller systems and does not exist on its own. Moreover, innovation systems are "open, dynamic, and social" (Carayannis, Samara, & Bakouros, 2015, p. 107) and should not be considered separate from the interaction occurring between people. In this way, the use of 'systems' should be taken as explaining interactivity between actors rather

than solely as some form of linear knowledge transfer (Carayannis, Samara, & Bakouros, 2015; Lundvall, 1992 [2010]).

Innovation systems

The 'innovation systems' concept stems from the assumption that "innovations do not originate as isolated, discrete phenomena, but are generated by means of the interaction of a number of entities or actors/agents" (Saviotti, 1997, s. 180). In relation to emerging policies such as the European Union's smart specialisation strategies, Asheim (2019) further notes that limiting the understanding of 'entrepreneurial discovery' as a public-private effort ignores "the systemic nature of innovation as interactive learning involving a number of stakeholders". These actors and their interactions, Saviotti (1997: 180) writes, conserve certain features over time and, in many cases, behave as a whole. This applies to national, regional, sectoral, or technological innovation systems. Regardless of the level of aggregation, be it country, region, industrial sector, or technology, the key consideration under the systems approach "is that innovations are generated not only by individuals, organisations, and institutions but by their, often complex, patterns of interactions" (Saviotti, 1997, s. 180).

Asheim and Coenen (2006, p. 166) claim that a systems approach to innovation sheds light on the understanding that "innovations are carried out through a network of various actors underpinned by an institutional framework". Saviotti (1997) critiques traditional

growth theories for being largely a-institutional and emphasises that "institutional and organisational configurations are important determinants of economic development and growth" (Saviotti, 1997: 180). Therefore, Saviotti concludes that the "historical specificity and the institutional nature of national systems of innovation cannot be predicted or explained by traditional economic theories" (Saviotti 1997:180). As Nelson and Winter observe (1977), the role of normative institutions matters for innovation policy development and with regards to innovation systems, they are tightly interlinked through time, context and the agents that carry innovation systems forward.

Space and place in innovation theory

The role of space in innovation has been discussed in the literature for decades (Porter M. , 1998; Asheim & Coenen, 2005; Audrecht & Feldman, 1996; Freeman, 1995). With the increased pace of globalisation, however, the role of geography in innovation has been questioned. It is accepted that globalisation has played a significant role in levelling the global playing field (to a large extent) through free trade and better access to products, services and potential new partners (Friedman, 2005). Seen from a technological and sectoral/industrial systems lens, in the early 1990s, Carlsson and Stankiewicz (1991) wrote that innovation is essentially place-less. Friedman continued this argument and stated that globalisation meant the "end of geography as we know it", ultimately leading to "the death

of distance". This conclusion has been heavily debated since (Rodríguez-Pose & Crescenzi, 2008).

In their paper *On the nature, function and composition of technological systems*, Carlsson & Stankiewicz (1991) write that a country's development potential, as part of a wider technological system, is reflected by its economic growth – closely tying innovation theory to economic growth theories.

Technological systems of innovation are defined as "a network of agents interacting in a specific *economic/ industrial area* under a particular *institutional infrastructure* or set of infrastructures and involved in the generation, diffusion, and utilization of technology" (Carlsson & Stankiewicz, 1991, p. 111). These networks are defined by knowledge and competence rather than by goods and services and by technology and its techno-industrial area rather than by national borders. Technological systems bring with them institutional infrastructures, a regime/organisations that "support, stimulate and regulate the process of innovation and diffusion of technology" (1991, p. 109). By institutional structures, Carlsson & Stankiewicz mean "the normative structures which promote stable patterns of social interactions/transactions necessary for the performance of vital societal functions. Institutions reduce social uncertainty and prevent or mitigate conflicts between different value systems (...) Crucial for the survival and effectiveness of institutions is their legitimacy" (1991, p. 109). Although technological systems are conceptualised independently of

geographical boundaries, they are nevertheless characterised in relation to economic systems, formal and informal institutions, networks and proximity that are, in turn, largely place-bound.

Technological systems of innovation are closely linked to **sectoral systems of innovation**. A sectoral system of innovation is also a network of agents, but agents operating within specific technological areas and in a specific institutional context (Carlsson & Stankiewicz, 1991). Breschi and Malerba (1997) write that in sectoral systems of innovation, clusters of companies and industries are involved in the generation and diffusion of technologies, and that the knowledge flows between these actors and learning from the new technologies employed are at play. Relationships between and across industries are important factors for the analysis of sectoral innovation systems (Carayannis, Samara, & Bakouros, 2015).

Boschma (2005) corroborates both Carlsson and Stankiewicz', (1991) and Breschi and Malerba's (1997) arguments to some extent when examining the role of cognitive proximity vis-à-vis geographical proximity. He argues that as tacit knowledge knows no distance, it may be transmitted by other means than geographical location (Boschma, 2005). In this approach, geographical proximity has a stronger, complementary role when it comes to strengthening and building institutional or social proximity. The assumption is that if there is cognitive proximity, i.e., shared ideas and understandings,

geography plays a minor role (ibid). By 'proximity', Boschma refers to the ability to understand, adopt and adapt, to identify novelty, interpret and exploit new knowledge. Boschma's five proximity dimensions are geographical, cognitive, organisational, social, and institutional proximity. Boschma argues that both too much and too little 'proximity' are harmful to learning and innovation and that effective interactive learning and innovations require an absorptive capacity in businesses and institutions demonstrating openness to new ideas (Boschma, 2005). These proximities are mutually reinforcing when it comes to 'learning' as part of economic development (Hansen, 2015).

Audrecht and Feldman (1996) maintain that location matters, especially when it comes to transmitting tacit knowledge versus transmitting information, which in turn may explain why some industries have clustered geographically. Rodríguez-Pose and Crescenzi (2008) further argue that although rapid technological development supports the idea of the death of distance, globalisation implies changes, opportunities and threats and "not all territories across the world have the same capacity and tools to make the world an even playing field" (Rodríguez-Pose and Crescenzi, 2008, p. 372). Moreover, it is primarily in metropolitan areas that these different proximities (social, institutional, cognitive, organisational and geographical) coalesce (Rodríguez-Pose and Crescenzi, 2008). In relation to globalisation, the death of distance

and the capacity of a 'flatter world' only really work conceptually in a generalised macro-perspective and not in the more granulated details of regional and local development: "Paradoxically," Porter writes "the enduring competitive advantages in a global economy lie increasingly in local things – knowledge, relationships, and motivation that distant rivals cannot match" (Porter M. , 1998). Moreover, the role of proximity in terms of mutual understanding and absorptive capacity among and between actors to find novel niches matters (Boschma, 2005). Geographical dimensions still play a key role in economic analysis as key social institutions develop within the national, regional, and local space (Freeman, 1995). However, as we have seen, the transmittance of ideas and technology is not dependent upon these defined boundaries. This is particularly interesting in terms of the turn towards global missions to solve so-called: 'grand social challenges'. We will discuss this later in this report.

National innovation systems are a response to questions about the role of 'home ground' in relation to globalisation (Cooke, Gomez Uranga, & Extbarria, 1997). Freeman (1995) investigated this in relation to transnational and multinational companies. He writes that even if you cannot ignore the role of 'global' demands, there are still a vast number of products and services where local, regional and national institutions, climate and preferences play a key role. Moreover, these institutions, often considered a hampering factor in relation to innovation, are also the source of

change. As Freeman points out, the role of the nation, or the state, to be more accurate, has been around for centuries (1995). Friedrich List (1854) commented on the industrial catch-up between Germany and the United Kingdom in the 19th century, showing that learning from others by adopting and adapting good practices, relying on reverse engineering and creating training and education systems to support change in many instances was supported by the German government – as the government was the only actor and still often is the only actor, that can afford to fund massive social changes. Considering the grand societal challenges global society is currently facing, the state may well still seem to play this role. Or as a minimum, the state continues to play a key role in the policy design premises on which grand societal challenges are meant to be addressed.

Another interesting question that arises is the role of the region. More specifically, “whether the organisation of innovation within nations [is] evolving in new ways” (Cooke, Gomez Uranga, & Extbarria, 1997) and the extent to which the national level is the appropriate lens through which to analyse innovation and the role of globalisation. However, it is equally interesting to investigate the role of the region in addressing grand social challenges, e.g., the green transition through innovation. According to Cooke et al. (1997), **regional innovation systems** (RIS) define the ways in which innovation subsystems are connected. This is particularly of note when studying innovation processes, as the complexity and non-linearity of

such connections underpin national systems at a lower geographical level (Freeman, 1995; Cooke, Gomez Uranga, & Extbarria, 1997).

Considering the learning aspect, Asheim & Coenen (2005) conceptualised regional innovation systems as “regional clusters surrounded by supporting knowledge organisations through regional governance” (Asheim & Coenen, 2005, p. 11). They write that “in a globalising economy characterised by vertical disintegration and distributed knowledge bases, the important perspective ought to be the interdependences between regions and nations, where the deciding criteria must be the location of core activities (and not the whole value chain as such) and the relative importance of their connections to regional knowledge infrastructures” (Asheim & Coenen, 2005, p. 13).

Looking at the linkages between regional innovation systems and clusters, Asheim and Coenen (2005) view regions as sites for innovation and competitiveness in the globalising economy. They draw on the common rationale that territorial agglomeration provides the best context for an innovation-based globalising economy because of localised learning processes and ‘sticky’ knowledge grounded in social interaction (Asheim and Coenen 2005, p. 1174). At the same time, the authors acknowledge RIS to be embedded in national and global systems. In their words: “interacting knowledge generation and exploitation subsystems [are] linked to global, national, and other regional systems” (ibid. p. 1174).

In its focus on knowledge infrastructures and surrounding features this is linked to Cooke et al., (1997). For Cooke et al. (1997), "strengthening of regional level capacities" for promoting learning and innovation is crucial, as the key features of a regional innovation system revolve around financial capacity, productive culture (embeddedness) and institutionalised learning (access to knowledge), without which regional knowledge infrastructures cannot be supported. However, it must be differentiated and literature on regional innovation systems has built a significant empirical evidence-basis that challenges 'one-size-fits-all' models (Asheim & Coenen, 2005). According to Grillitsch and Hansen (2019), the interlinkages between innovation and economic geography studies have contributed to an increased understanding of 1) the spatial embeddedness of innovation processes and 2) how innovation systems approaches can inform regional policy and assist industrial development. A basic assumption is that preconditions for innovation and new industrial developments vary in different regions. Based on this, Grillitsch and Hansen (2019) note that literature increasingly focuses on the potential for differentiated pathways of innovation in different types of regions.

Grillitsch and Hansen (2019) write that the regional innovation systems approach has added to the substantial empirical evidence of regional differences. This has evolved into a proposal of regional typologies, which distinguishes between peripheral regions, specialised

regions and metropolitan regions, each of them with its "specific challenges and opportunities for regional development" (ibid). Regional typologies have been based on (1) actors and governance, (2) the strengths in radical versus incremental innovations and (3) RIS failures (ibid). The authors note that RIS failures have been the central argument for proposing new industrial path development (Grillitsch & Hansen, 2019).

Considering the learning aspect, Asheim & Coenen (2005) conceptualised regional innovation systems as "regional clusters surrounded by supporting knowledge organisations through regional governance" (Asheim & Coenen, 2005, p. 11). They write that "in a globalising economy characterised by vertical disintegration and distributed knowledge bases, the important perspective ought to be the interdependences between regions and nations, where the deciding criteria must be the location of core activities (and not the whole value chain as such) and the relative importance of their connections to regional knowledge infrastructures" (Asheim & Coenen, 2005, p. 13).

Looking at the linkages between regional innovation systems and clusters, Asheim and Coenen (2005) view regions as sites for innovation and competitiveness in the globalising economy. They draw on the common rationale that territorial agglomeration provides the best context for an innovation-based globalising economy because of localised learning processes and 'sticky' knowledge grounded in social interaction (Asheim and

Coenen 2005, p. 1174). At the same time, the authors acknowledge RIS to be embedded in national and global systems. In their words: "interacting knowledge generation and exploitation subsystems [are] linked to global, national, and other regional systems" (ibid. p. 1174).

In its focus on knowledge infrastructures and surrounding features this is linked to Cooke et al., (1997). For Cooke et al. (1997), "strengthening of regional level capacities" for promoting learning and innovation is crucial, as the key features of a regional innovation system revolve around financial capacity, productive culture (embeddedness) and institutionalised learning (access to knowledge), without which regional knowledge infrastructures cannot be supported. However, it must be differentiated and literature on regional innovation systems has built a significant empirical evidence-basis that challenges 'one-size-fits-all' models (Asheim & Coenen, 2005).

According to Grillitsch and Hansen (2019), the interlinkages between innovation and economic geography studies have contributed to an increased understanding of 1) the spatial embeddedness of innovation processes and 2) how innovation systems approaches can inform regional policy and assist industrial development. A basic assumption is that preconditions for innovation and new industrial developments vary in different regions. Based on this, Grillitsch and Hansen (2019) note that literature increasingly focuses on the potential for differentiated pathways of innovation in different types of regions.

Grillitsch and Hansen (2019) write that the regional innovation systems approach has added to the substantial empirical evidence of regional differences. This has evolved into a proposal of regional typologies, which distinguishes between peripheral regions, specialised regions and metropolitan regions, each of them with its "specific challenges and opportunities for regional development" (ibid). Regional typologies have been based on (1) actors and governance, (2) the strengths in radical versus incremental innovations and (3) RIS failures (ibid). The authors note that RIS failures have been the central argument for proposing new industrial path development (Grillitsch & Hansen, 2019).

The difference in innovation capacity between regional typologies lies mainly in the underlying preconditions and support systems for innovation and entrepreneurship (Grillitsch & Hansen, 2019). These are, for instance, the available knowledge generated by universities and research institutes and the possibility to apply or 'exploit' this in economic activity in industries and economic sectors. This often happens through intermediaries such as technological parks and incubators. Thus, apart from human capital and networks, other preconditions are necessary for turning knowledge into innovations applicable to markets or in practice more generally, such as knowledge intermediaries and entrepreneurial capital, which refer to both competence in business models and access to risk capital. Finally, the social and institutional contexts play a substantial role in shaping entrepreneurial activity (ibid.).

Metropolitan regions often host a number of universities and a range of education programmes and training opportunities. The scale and diversity of knowledge and entrepreneurship allow for the development of multiple related and unrelated industrial specialisations. Specialised regions, on the other hand, often experience some form of positive or negative 'lock-in', a self-reinforcing cycle stemming from their strong legacy and dependency on one or a few interrelated industrial activities, where support systems, knowledge and resources are concentrated in a few sectors (Grillitsch & Hansen, 2019). Nonetheless, this may strengthen their competitive advantage, although also weakening their position and ability to adapt when technologies or demand changes. Many peripheral regions have not reached a critical mass of high value creation and knowledge-intensive activities to be considered specialised in any one industry. In some cases, although support systems may be available, such as universities, these may not sufficiently trigger industrial development in the region. It may also be the case that innovative businesses are present in peripheral regions but rely on knowledge and networks from outside their regional location (ibid.).

In conclusion, we cannot easily differentiate between spatial sensitivity and spatial blindness; in many ways, innovation and innovation systems are too complex for compartmentalisation. A strict demarcation between the two would only shed light on certain aspects of the innovation system, depending

on our analytical starting point (structure-agency).

Structure-Agency: institutions, the public sector and entrepreneurs in innovation policy and theory

The literature on innovation systems generally contributes to an understanding of how innovations occur through networks rather than individuals and highlights the relevance of institutional frameworks. In this way, place-based approaches accept the territorial unit rather than the sector as the "lens through which to observe the ways in which different sectors or even clusters interact with the regional governance and innovation support infrastructures as well as the national and global levels" (Cooke et al., 1997 p. 476). Examining clusters and sectors and their interaction in place-based (or place-less) settings thus illuminates the role of different agents. Sotarauta & Suvinen (2021) suggest that to study and understand the different types of agency, we inevitably need to learn how they interlink, what "roles they play in relation to each other" – even outside a geographically bound space, as sectors and clusters do not necessarily rely on the same preconditions for development.

Agents and structures

The underlying theoretical basis in social and political sciences is split between those who argue that structures drive change and those who argue that agency is the change maker. Söderholm (2020) emphasises that the focus should be on the role of national and local framework conditions (structure) and not merely

on “individual heroes” (agency) (Söderholm, 2020, p. 9). Giddens’ structuration theory provides a more nuanced view by arguing that one cannot be understood without the other (Giddens, 1991). Understanding Giddens’ dualism of structures and agency, Jessop (2001) suggests that each should be bracketed to understand the emergence of structures and agency by analysing the position of structures and agents in relation to each other: by bracketing action in relation to structure and structure in relation to action. This would further point to the modalities of power. The dynamics between modalities of power are crucial for understanding how, e.g., policies (structures) and industries or businesses (agents) influence each other.

From the perspective of path development studies, Grillitsch and Sotarauta (2020) critique the “fundamental theoretical debate on structure and agency”, arguing that the “blind spot is the role of agency and its relation to structure”. They

note that both the evolutionary tradition in economic geography and studies stemming from the institutional theory provide little insight into the micro-level processes at work in shaping new development paths (Grillitsch and Sotarauta 2020). Therefore, the authors point out a need to build an evidence base to shed light on “what actors do to create and exploit opportunities in given contexts, why they do so in some places and not in others, and why the effects of such efforts differ between apparently similar places”. To address this gap, Grillitsch and Sotarauta (2020) suggest a conceptual framework using a more holistic approach to the analysis of agency and new regional economic development paths. This framework explains interactions between a wider range of intentional and unintentional actions. They argue that there are three types of agency at play in regional path development (Grillitsch & Sotarauta 2020), as presented in Figure 1.

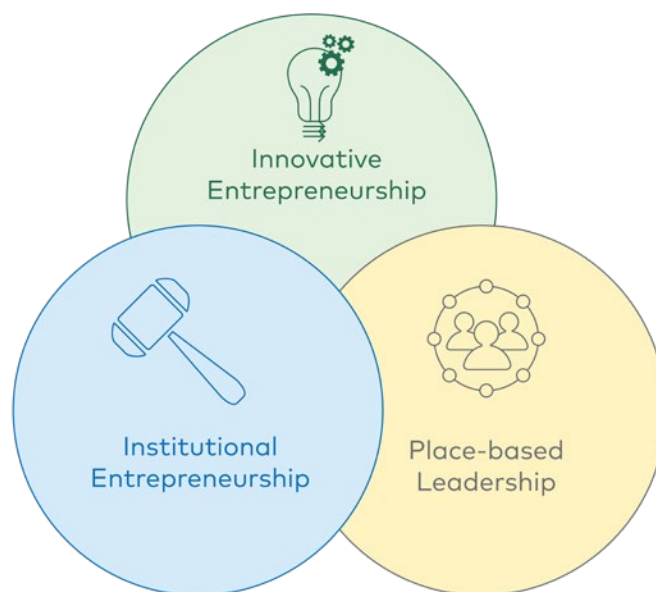


Figure 1: Trinity of change agency. Source: Adapted from Grillitsch, M. (2021). Re-design: Kotryna Juškaitė, Nordregio.

I. **Innovative entrepreneurship** whereby *entrepreneurship* is a key instigator of change by triggering industrial and economic transformation.

II. **Institutional entrepreneurship** demonstrating how new growth paths necessitate institutional change as they require opportunities and risk-taking institutional entrepreneurship. This is a *second type of transformative agency*.

III. **Place-based leadership** is crucial for the organisation and pooling of competences to achieve individual objectives and broad-based (regional) goals. It stems from the border leadership literature but is conceived within the framework of city and regional development literature. New development paths are not constructed in a vacuum but is the outcome of multiple actors efforts. Place-based leadership, is therefore, important to coordinate efforts. (Grillitsch & Sotarauta 2020)

This 'trinity of change agency', as Grillitsch & Sotarauta (2020) argue, better explains how "the three types of agency – separately and in combination – contribute to the emergence of regional growth paths". Therefore, the argument is not exclusively centred on whether structures influence agents or vice versa but also on how agents drive transformative change from multiple directions in a more or less chaotic process that leads to innovation or change within the entire ecosystem.

The entrepreneurial discovery process that leads to innovations occurs within a context, but context

is not static; it changes, and with it, the opportunities for innovators. Those on the side of 'structures' in the structure-agency debate settle precisely on the role of context in determining the possibilities for innovations to occur. The question is, therefore, whether the context (as in systems) change is the cause or consequence of innovations. Grillitsch & Sotarauta (2020) suggests that the concept of **opportunity space** is beneficial for examining reflexive and embedded agency as it can be seen as a mediator between the aspects outlined in the trinity of change agency and structure. An opportunity is the time and set of circumstances that make something possible. Opportunity space is identified by agents' deliberation of these possibilities in the future or for their future actions. In this sense, both actions and intentions reveal something about the apparent windows of opportunity. Agents reflect in a strategic way to decode the impact of their actions on the evolution of structures and vice versa: how structural changes also opens windows of opportunity for them 'to exploit' (Grillitsch & Sotarauta, 2020).

Furthermore, the concept of opportunity space extends previous ideas regarding the construction of regional advantage through an active policy approach, thereby establishing positive conditions for innovative entrepreneurship (Asheim et al., 2011; Tödtling et al., 2013). Opportunities are dynamic, evolving over time and show variations across different geographical areas. Moreover, the perception of opportunities and the ability to realise them vary not only across regions but also among

individuals within them. According to Grillitsch and Sotarauta (2020), opportunity spaces manifest at three levels (see Figure 2):

- **Time-specific opportunity space:** *determines what can be accomplished based on global knowledge resources, the institutions in place, market maturity and available technologies and resources at a specific point in time.*
- **Region-specific opportunity space:** *determines what can be achieved by considering the specific conditions in a particular area, e.g. in a region.*
- **Agent-specific opportunity space:** *denotes the opportunities, chances and abilities available or needed in individual agents to drive change based on their own experience, competences, networks, etc. (Grillitsch & Sotarauta 2020)*

OPPORTUNITY SPACE

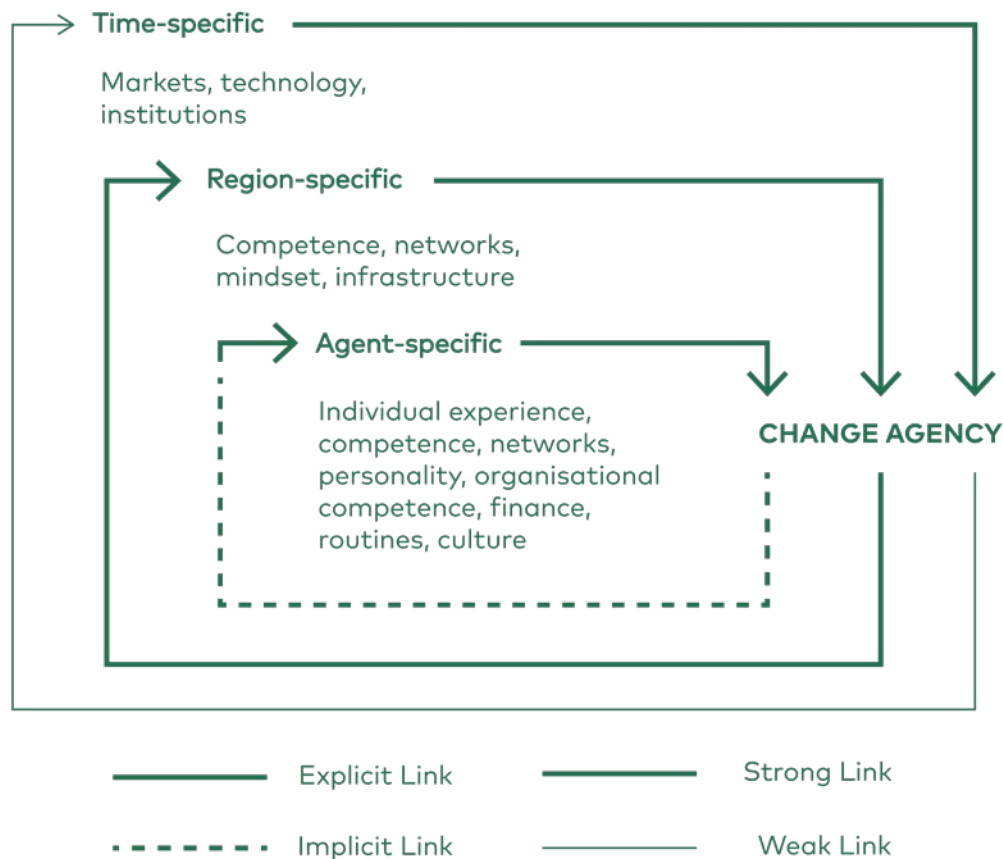


Figure 2: The various levels determining an 'opportunity space'. Source: Adapted from Grillitsch, M. (2021). Re-design: Kotryna Juškaitė, Nordregio.

In terms of the structure-agency debate, this demonstrates how structures at various levels can move forward and how these structures influence each other while explaining how things do not remain the same but are constantly moving. It also clarifies the interdependencies between structure and agency: how changes in structures and specific combinations can enable agents to act.

Entrepreneurs and agency

Schumpeter's theory of entrepreneurship laid the foundation for understanding creative labour and opportunity recognition. His thinking on innovation permeates his writings on entrepreneurship. In Schumpeter's early work, entrepreneurs were the only relevant and true economic change agent; the 'personification of innovation' (Hagedoorn, 1996). Schumpeter's early understanding of the entrepreneur as both an irrational and rational agent in search of new opportunities still stands up to reasonable scrutiny today. As Sotarauta and Suvinen (2021) write, "entrepreneurs have the will to realise something new to 'map unknown terrain, to move where no-one dared venture before". For Schumpeter, entrepreneurship is, in essence, creative labour (Hagedoorn, 1996).

In Schumpeter's later writings, the entrepreneur as the sole change agent, the "heroic creative labour of a single individual" (Hagedoorn, 1996, p. 891), disappears. This may be connected to an altered notion of innovation as an increasingly automatised

and routinised process due to the emergence of 'trained specialists' (ibid). In this depersonalisation process, entrepreneurial activities are increasingly attributed to businesses engaged in co-operative development, whether internally or with external partners. Innovation is seen as a solely endogenous factor in this process, whereas invention happens exogenously. The ability to commercialise inventions becomes the main output. Innovative entrepreneurs, whether understood as single individuals or as businesses, engage in the search for new economic opportunities even if these entail risks (Sotarauta and Suvinen, 2021), exploiting both existing and new possibilities. In this way, Hagedoorn (1996) notes that "entrepreneurship is not a magic phenomenon or a *deus ex machina* but primarily an endogenous factor that combines the application of innovative capabilities based on tacit knowledge [and] firm specific skills and organisational learning" (Hagedoorn, 1996, pp. 893). It is driven by "(...) competition, change, learning, climate, communications, processes, social interaction between individuals and other external factors" write Carayannis et al., (2015), pointing to Schumpeter's later writings on entrepreneurship where skills are seen as an element in a larger, co-operative structure.

Entrepreneurship and innovation processes are inherently hard to define, being based on uncertainty and the ability to creatively exploit ideas. However, the pursuit of a distinctive theory of entrepreneurship continues.

According to Phan (2004, p. 617), this ongoing search for a cohesive theory is in part due to the "phenomenological nature of extant work", which in turn seems tied to our contemporary understanding of entrepreneurship as closely related to entrepreneur psychologies, network economics and innovation. These prevailing understandings of entrepreneurship are also often associated with context, whether organisational, sociological or as a typology of certain behavioural patterns (Phan, 2004).

Yet the definition of who and what an entrepreneur is depends very much on our language, interpretation of the world and the way we frame the concept of 'entrepreneur'. Capturing who entrepreneurs are cannot be separated from the context in which they operate (Ramoglou, Gartner, & Tsang, 2020). Due to the many constantly changing contexts, it is clear that a theory of entrepreneurship must consider external factors, e.g., institutional structures and context, culture, the political economy, etc. (Carayannis et al., 2015). Moreover, seeking a specific entrepreneurial identity is entirely the wrong approach as it presupposes an individual trait, or even specific genetics in some cases and neglects that "entrepreneurs exercise a widely held human potential" (Ramoglou, Gartner, & Tsang, 2020, p. 4). As previously stated, entrepreneurship is creative labour.

Entrepreneurship is, according to Ramoglou et al., tied to human agency: humans do not simply respond spontaneously to external triggers but rather exercise their agency

when responding to "entrepreneurial opportunities" (2020, p. 3). By refraining from conflating the factual (i.e. outcome) from a conceptual (i.e. language and semantic) understanding of entrepreneurs, it becomes clear that entrepreneurs are those who exercise their agency at the opportune moment. They do not necessarily harbour 'deeply held secrets' but are simply able to reframe old ideas in new ways within their given context: "worldviews are not rooted in genes, but in grammar", according to Ramoglou et al. (2020, p. 4). Moreover, this may happen on a variety of levels, perhaps even leading to the need for an understanding of innovation and agency based on a multilevel analysis (Phan, 2004).

The understanding and conceptualisation of entrepreneurship in policy and practice impacts entrepreneurs' ability to act. According to Sotarauta and Suvinen (2021), entrepreneurs require certain preconditions, such as capital, well-functioning capital markets, legal arrangements and skilled labour. This may demand a strategic approach to policy making beyond fixing 'market failures' and resource allocation: one that sets a course where co-creation and co-shaping of the economy occur in tandem with key market actors. This is an example of what Grillitsch and Sotarauta (2020) refer to as the second type of agency – institutional entrepreneurship – which entails moulding institutions to become risk-taking and opportunity-oriented entities with the intentional objective of influencing new industrial development or path creation.

But even here, the framing of opportunities also plays a central role and relates back to the importance of context: institutional infrastructures matter. Entrepreneurial discoveries and their enabling, depend on the ability of actors to work together on optimising both formal and informal institutions (Sotarauta & Suvinen, 2021). Seen in the light of the structure-agency debate, it is clear that change agents are necessary, both to enable and ensure change in a constantly and mutually reinforcing mechanism. It is systemic.

Institutions and the rules of the game

According to Rodríguez-Pose (2013), institutions “abandon the more rationalistic ‘game-theoretic’ approach of the new institutional economics and embrace a position in which institutions not only shape, but also are shaped by the environment” (2013, p. 1037). Although institutions share common features across territories, they are, to a significant extent, place-specific (ibid.). Institutions are commonly understood as “the rules of the game in a society; and more formally, as the humanly devised constraints that shape human interaction” (Rodríguez-Pose, 2013; North, 1990). In other words, the interplay between formal institutions (rules, laws and organisations) and informal institutions (norms, values, routines), as well as path dependencies, generate a distinct institutional environment in a particular territory (Gertler, 1997; Rodríguez-Pose, 2013). Path dependency and ‘lock in’ are often seen in relation to innovation capacities: here, historical

institutionalism (i.e., sequences and time) dominates, as innovation is seen to be recreated in the same framework from whence it came (Wøien Meijer & Peters, 2021). History is full of examples of path dependencies, path disruptions and path creation (Lema, Nordensvård, Urban, & Lüktenhorst, 2014).

Rodríguez-Pose (2013) adds that place-based institutional arrangements are often more successful at local and regional scale than national level, as the latter can ‘be too distant and detached’ to mobilise actors and organisations effectively. Development strategies and innovation policy need to be tailored to regions’ distinct contexts and institutional arrangements to ensure legitimacy.

Institutional legitimacy, however, depends on the ability of institutions to work as a ‘glue for collective action’ through their ability to ‘reduce uncertainty and transaction costs’ (Boschma, 2005, p. 68). This requires striking the balance of institutional proximity. Boschma (2005) argues that “institutions are enabling or constraining mechanisms that affect the Having said this, it is not easy to describe how an level of knowledge transfer, interactive learning and effective institutional structure may overcome these (thus) innovation” (Boschma, 2005, p. 68). Too much proximity may cause inertia due to fewer new ideas and a lack of novelty, while insufficient proximity leads to the development of silos: lack of social cohesion and common values between actors and weak formal institutions. Cooke et al., (1997) adhere to the same

principles: "innovation and learning are closely interlinked. There can be no change without previous learning (...)" (Cooke, Gomez Uranga, & Extelbarria, 1997, p. 485). For Rodríguez-Pose and Crescenzi (2008): "Local innovative activities not only allow better local economic performance but also produce localised knowledge spillovers whose beneficial effects depend not only on proximity relationships but also on the presence of local institutions (or social filters) enabling their absorption and translation into further economic growth" (2008, p. 383).

In the context of change agency, Rodríguez-Pose (2013) argues that both "formal and informal institutions help territories to adjust and react to change, generating a degree of 'adaptive efficiency' that highlights the willingness and capacity of local actors to adopt new knowledge and to engage in innovative and creative activities" (2013, p. 1039). He adds that institutions are a key factor in determining the learning capacity of a region and, thereby, its ability to adapt to changes (Morgan, 1997 in Rodríguez-Pose, 2013). However, Rodríguez-Pose (2013) also notes contradictions and challenges in building institutional arrangements, as there is seemingly no clear agreement as to which informal or formal institutions are more relevant in driving economic development, nor no simple way to measure this. What is clear, however, is that mutual understanding is key to ensuring 'adaptive efficiency' and change. However, redesigning or augmenting institutions beyond resource

allocation (Nelson & Winter, 1977) to ensure their ability to respond to the evolving nature of innovation (Carayannis, Samara, & Bakouros, 2015) remains a problem.

Institutional innovation in the public sector

Three main periods can be distinguished in the literature on the role of the public sector in innovation (Kattel, 2015, pp. 9-19). First is the Schumpeterian period, where "innovations and the public sector are related to a larger theory of how evolutionary change takes place in societies" (Kattel, 2015, pp. 9-19). Second is the organisational-theory period, where similarities between innovation occurring in the public sector and in private companies can be discerned (usually found in early organisational theory (Wilson, 1989; Kattel, 2015). Finally, the autochthonous-theory period concerning the trend to "disassociate public and private-sector innovations" (Kattel, 2015, pp. 9-19), returns to the origins.

However, the role of the public sector in innovation and by extension vis-à-vis markets, has been widely debated throughout recent history. In economic theory, the Austrian and Chicago schools of thought placed much emphasis on rational choice and the role of the consumer, embracing monetarism and rejecting Keynesianism, also in macroeconomics. However, when considering markets, capitalism, and competitiveness, it is difficult not to invoke the role of the state. Porter (1990) writes in his article *The Competitive Advantage of*

Nations that "national prosperity is created, not inherited" and that in an increasingly globalised world, nations, or rather countries, have become more, not less, important (Porter M. E., 1990, p. 74). As the accumulation of knowledge continues to drive competitive advantage, it has become clear that the fundamental structures of a society and country, such as culture, values, institutional structure, history and economics, contribute to competitiveness (Porter M. E., *The Competitive Advantage of Nations*, 1990). Moreover, "the home nation takes on growing significance because it is the source of the skills and technology that underpin competitive advantage" (Porter, 1990, p. 79).

In more recent years, the state's role in correcting market failures has re-emerged in the debate. There is a host of literature on market failures and the role of the state in correcting them to minimise the negative externalities of these failures. Considering the role of state interference in economics, the state is often viewed as offering false life support or as a source of "institutional drag". However, Mariana Mazzucato (2020) argues that we cannot reduce the role of the state into a patchwork of bandages covering market failures. Rather, the state ensures that the institutional framework creates a favourable environment by reducing the risk of market failures, by taking the hits in a 'risky bump landscape' of innovation and economic growth.

In her book *The Entrepreneurial State*, Mazzucato attempts "to debunk this idea that the private

sector has all this risk-taking embedded in it; there are many private companies that do not take risks and are perfectly happy with the status quo" (Mazzucato M. , 2013). She proposes the creation of entrepreneurial ecosystems, thus redefining the relationship between the public and private sectors. This requires public sector innovation, releasing bureaucratic culture from its inflexible organisational structures and their subsequent inertia. Civil servants should instead be trained to frame policy from a more strategic perspective rather than merely fixing 'market failures': setting a course for co-creating and co-shaping the economy together with market actors. This represents Grillitsch and Sotarauta's (2020) approach, the second type of agency – institutional entrepreneurship – outlined earlier. Mazzucato (2020) raises the criticism that the bar for conceiving a risk-taking environment within bureaucratic structures is currently very low, perhaps due to a relatively risk-averse public sector. An emerging policy practice centred on pre-emptive considerations, where learning through mistakes is not encouraged, may be to blame. This is arguably impeding development. Mazzucato (2021) furthermore argues that the public sector must invest in its own capabilities and not succumb to so-called 'brochurism', in which the 'sexiest brochure' or PowerPoint presentation produced by for-profit consultancies take precedence and where facts and expert knowledge are easily relegated. This increased strategic or entrepreneurial institutional role is

called for by Mazzucato (2013; 2021) and Grillitsch and Sotarauta (2020) to facilitate the establishment of institutions as a driving force for change through transformative and mission-oriented innovation policies. Seen from an entrepreneurial perspective, Sotarauta and Suvinen make it abundantly clear that “by definition, institutional entrepreneurs work to change the rules of the game” (Sotarauta & Suvinen 2021). At sub-national levels, increased pressure falls upon regional actors and governance structures through Smart specialisation (S3) and other far-reaching policy goals, emphasising the importance of continuously developing institutions (Morgan, 2017). Investigating whether governance structures have changed since the introduction of S3 and how policies reflect the increased focus on green technologies is of interest. Exploring this informs us of existing policy feedback loops and institutional thickness, the role of partnerships and whether the regions involved are ‘learning’ and adapting to an evolving regional innovation system. Moreover, taking the region as a starting point reinforces the relevance of a spatial dimension in innovation policy.

Innovation policy and transitions in innovation systems

For decades, innovation policy served as a sub-category of economic policy, driving businesses and organisations to become more innovative (Freeman, 1995). However, in the current policy climate, innovation is moving beyond this somewhat one-dimensional conceptualisation. This is particularly

evident in the development of the EU-wide concept of smart specialisation (see, e.g., Foray, 2014). Smart specialisation goes beyond the mere consideration of innovation in businesses and organisations and focuses on co-operation, leveraging competitive advantages within regions and an overall levelling of the innovative playing field in Europe. Innovation, Freeman explained in 1995, must be seen in relation to employment and economic growth, as it impacts both.

Smart specialisation (S3) is, in many ways, the European Union’s response to ‘new industrial innovation policies’ (Asheim B. , 2019; Radošević, 2017). This ‘new industrial policy’ brings novel approaches to industrial innovation development, whereby ‘discovery processes’ for new specialisations seek economic diversification and path creation. Policy making is thus an endogenous process based on the acknowledgement that nobody possesses a full overview of the economy (Asheim, 2019). The new industrial policy, expressed through S3, aims to fulfil the EU’s 2020 objectives of a smart, inclusive and sustainable economy (Asheim, 2019) and receives European Regional Development Funds ex-ante.

Apart from economic development, however, the policy and academic debate has increasingly focused on the potential for innovation policy in solving societal challenges. According to Grillitsch et al. (2019), “the orientation towards grand societal challenges can be seen as a new wave or paradigm for innovation policy”. This will be

addressed in more depth below.

Transition in innovation systems theory

Transitions help explain the complexity of systems innovations, encompassing not only the emergence of new technologies but the necessary changes in “markets, user practices, policy, and cultural discourses as well as governing institutions” (Coenen et al., 2012: 968). Innovations that require changes – or transformation – in the interlinked social and technical systems are referred to as ‘*socio-technical transitions*’.

Four different schools of thought have contributed to transition studies literature: strategic niche management (Kemp, Schot, & Hoogma, 1998); transition management (Rotmans, Kemp, & van Asselt, 2001; Loorbach, 2007), which can be seen as precursors to the multi-level perspective approach (Geels F., 2002; Geels & Schot, 2007); technological innovation systems (Bergek, et al., 2008; Hekkert et al., 2007; Hekkert et al., 2020), with their sectoral/industrial approach (Breschi & Malerba, 1997; Carlsson & Stankiewicz, 1991) and finally, territorial variants (Asheim & Isaksen, 1997; Lundvall, 1992 [2010]). All these branches concur that change in complex sociotechnical systems is channelled through *socio-technical transitions* (Cedergren et al., 2022)

Coenen et al. (2012, p. 968), stress that transition analyses are particularly useful in addressing the “structure-agency duality via evolutionary long-term trajectories of socio-technical change.” Literature on innovation systems in relation

to sustainability transitions has generally centred around emerging new technologies, whereas literature on the multi-level perspective has, instead, “oriented toward reconstructing historical processes of sectoral change” (Coenen, Benneworth, & Truffer, 2012, p. 968)., Coenen et al. (2012) argue that both of these traditions have largely overlooked the geographical dimension and the socio-spatial dynamics in which transitions occur. However, the more recent shift towards the transformative capacity of innovation and innovation policy has established new bridges between innovation studies and economic geography (Grillitsch & Hansen, 2019).

Building from a multi-level perspective approach, Geels’ seminal paper published in 2002 introduces the idea that large-scale technological transformations result from an evolutionary and continuous process of technology substitution that occurs at different levels (Geels F., 2002). This process results in the shift – or transition – “from one *sociotechnical regime* to another one” (Cedergren et al., 2022). The ‘green transition’, addressed later in this paper, is a prime example of a large-scale transformation, which requires not only technological innovations but an overhaul of both formal and informal institutions. Louiseau et al. (2015) at the European Environmental Research Partnership suggest that the green transition requires several aspects of transformation, including organisational support, market conditions, governance frameworks, technologies and political will.

The latter is considered crucial: without it, addressing vast societal challenges proves difficult. However, the growing urgency to tackle these societal challenges, including environmental ones, has pushed policy makers towards incorporating transition thinking, or transformative policy, into innovation and industrial policies.

Transformative Innovation Policy

According to Grillitsch et al. (2019), "the orientation towards grand societal challenges can be seen as a new wave or paradigm for innovation policy". Hekkert et al. (2020) stress that for decades, innovation policy was aimed primarily at repairing market failures, first by investing in R&D and later by addressing failures in national innovation systems and strengthening networks. A new wave of innovation policy – *Transformative Innovation Policy (TIP)* - explicitly centres on the "mobilisation of science, technology and innovation for meeting societal needs" (Grillitsch et al., 2019). Building on transition studies and socio-technical transitions theory, TIP provides directionality to innovation

efforts. Also referred to as system innovation policy, this new approach implies system-wide transformation (ibid.).

TIP is rapidly emerging as a new innovation policy approach that drives for change, particularly in addressing major societal challenges (Grillitsch & Hansen, 2019) such as climate change, biodiversity loss, ageing population, poverty, hunger, etc. Transformative innovation policy essentially provides directionality and concentrates policy and financial efforts on innovations that offer solutions for social challenges. This represents a major shift, at least in discourse, from previous innovation policy generations, which focused primarily on economic growth (Hekkert et al., 2020). A substantial example is Horizon Europe, the EU research & innovation framework programme for 2021–2027, which has allocated EUR 95.5 billion towards five 'missions', including some of the most pressing contemporary societal challenges: adaptation to climate change, climate-neutral and smart cities, soil health and food systems, healthy oceans and waters and cancer (see Info Box 1).

Info Box 1: Horizon Europe: an interpretation of Mission Oriented Innovation Policy

The Horizon Europe missions reveal one possible interpretation of the Mission-Oriented Innovation Policy (MOIP) approach by operationalising the principle of discovering willing problem-solvers instead of specific solutions. For example, within the mission of building climate-resilient regions, the emphasis is on inclusive governance via resource pooling and mobilising actors. This entails the co-design, co-production and co-assessment of policies, improving access to education and information, strengthening sustainable local economies and targeting funds. As a result, all European citizens, communities and regions should become better placed to tackle climate disruptions as the innovation pathways and local transformative solutions developed in target regions and cities spread and increase in scale (European Commission, 2020a).

The Horizon Europe Missions target their resources on capacity-building and creating enabling conditions under which new experiments may take seed and grow. Instead of structuring policy based on a linear cause-effect solution, the MOIP framework defines criteria and characteristics for the end result (European Commission 2020a and 2020b, Mazzucato M., 2019).

The proposed Missions involve specific targets, e.g. supporting 200 European communities and regions, scaling up 100 successful community innovations of climate resilience as “deep demonstrations”, and establishing 100 climate-neutral cities that will transform into innovation hubs. Despite these numbers, evaluating the success of these missions will leave plenty of interpretative room to manoeuvre due to the broad criteria and characteristics of the sought-after end results. Emphasis on strengthening networks and engaging a wider range of stakeholders, as well as targeting financing in a more coordinated manner, suggests that previous waves of innovation policy (focusing on R&D funding, repairing system failures and network building) remain active parts of new innovation policies. The Horizon missions thus entail not only developing new directions but also executing established approaches or instruments more effectively. However, the extent to which a change in directionality results in discovering innovative policy instruments has yet to be seen. So far, the Horizon Europe Missions have adopted a more incremental approach, rather than introducing ground-breaking measures.

TIP has been closely connected to the movement towards exploring new economic pathways or industrial path creation, which reinstates geography's relevance in innovation. Binz et al. (2016) and Steen and Hansen (2018, s. 191) define a new industrial development path as a “set of functionally related firms and supportive actors and institutions that are established and legitimised beyond emergence and are facing early stages of growth and developing new processes and products” (in Sotarauta & Suvinen 2021). Grillitsch and Asheim (2018) offer three alternative routes this might take: upgrading, diversification and the emergence of new regional industrial paths. All of these imply transformative processes but distinguish between incremental processes (upgrading), changing the fundamental structure

of the local economy by establishing new industries (emergence) and ‘diversification’ representing a middle way or combination of the two.

In the context of a ‘Green Transition’, upgrading may imply a change in industrial paths through scaling “the hierarchy of global production networks by introducing green services and products” or by supporting “major changes in the existing industry due to the adoption of new green technologies and/or the introduction of new environmentally friendly business models (renewal)” (Sotarauta & Suvinen, 2021). As for diversification, it will require a move towards “new green industries by applying existing knowledge and competencies” (ibid.). Finally, emergence implies “the creation of new green industries which do not draw on the knowledge bases of existing regional industries.” (ibid.)

Societal challenges and mission-oriented-innovation policy (MOIP)

Directionality in innovation policy has ignited a heated debate in academia. The main division is between *mission-oriented innovation policy (MOIP)* and *broad-based innovation policy (or Foundational Innovation Policy)*. Supporters of MOIP believe it is an effective approach to concentrating efforts and mobilising actors in to solving societal challenges, while advocates for broad-based innovation policy argue that narrowing the scope risks rejecting other possible alternatives or focusing on erroneous missions.

MOIP is a subtype of transformative innovation policy, as missions define the end goal of a transformative process. Mazzucato, a primary advocate of the mission approach, defines MOIP as:

”

... systemic public policies that draw on frontier knowledge to attain specific goals or 'big science deployed to meet big problems'. Missions provide a solution, an opportunity, and an approach to address the numerous challenges that people face in their daily lives."

(Mazzucato M. , 2018)

The OECD further describes them as:

”

... systemic public policies that draw ... a coordinated package of policy and regulatory measures

tailored specifically to mobilise innovation in order to address well-defined objectives related to a social challenge, in a defined timeline""

(OECD, 2020)

Mazzucato refers to the success of policy in generating the ICT revolution and the welfare state as examples where the efforts require bold ambitions (missions) and strategic thinking (ibid.). She claims that the internet, biotech, nanotech and green tech revolutions would not have happened if nation states had merely taken an observant or passive role (Mazzucato M. , 2021). Mazzucato believes that the green transition and addressing the Sustainable Development Goals (SDGs) also demands this type of approach: "it requires rethinking the tools for policymaking, whether we look at procurement policies, grants, loans, subsidies – these are all different types of levers governments have" (Mazzucato, Kattel, & Roll, 2020). However, she also believes that the way these tools are applied needs to be rethought "to foster transitions, be it the green transitions or other types of investments and activities that are required to solve the 17 SDGs" (ibid).

Mazzucato also raises concepts such as public value and purpose. "If an economy has a purpose, then it has a direction, so, how do we talk about directionality of the economy?" she asked in a lecture at the Creative Bureaucracy Festival (2020). Public purpose links to the role of targeted public missions. Public missions do not need to single

out an individual sector or technology but rather can encourage and foster activity in all related industries or sectors that may require incentive support. In other words, a mission can be targeted. However, "solution-picking" policies are not required for bottom-up activity across organisations or to support sectors in their problem-solving activities in order to meet these public mission goals (Mazzucato, Kattel, & Roll, 2020). Although opponents of mission-oriented innovation policies claim that these limit alternatives, their aim is to support the emergence of diverse ideas and technologies.

Mazzucato (2021) explains that MOIP can be operationalised by identifying 'the problem' as the starting point and then supporting any sectoral or industrial innovations that work towards this predefined end. This would mean, for example, to "turn the SDGs, these 17 broad goals, into targeted missions, like getting 90% of the plastic out of the ocean or having 100 carbon neutral cities across Europe, or social ones, like fighting knife crime" (ibid.). Furthermore, policy instruments, such as industrial strategies, procurement, or loans and grants to stimulate bottom-up experimentation across businesses and organisations, are shaped to solve the (already) set problems. Mazzucato argues that this differs from common industrial policy strategies that often simply choose the top five industries to be funded, for example.

Green transition as a policy goal/mission-oriented concept

In the context of transition

literature, a 'green transition' is merely another example of socio-technical transitions (Cedergren et al., 2022). As understood in MOIP and TIP, green transitions solve one or several 'grand societal challenges', such as climate change, biodiversity loss, eutrophication, etc. Beyond academic discourse, a green transition exists as a policy goal with varying interpretations. In general, it implies moving from a non-green (unsustainable) 'present' to a green (sustainable) 'future', which inevitably requires change in the social, economic and institutional systems.

At the core of green transition as a policy goal lies a "green economy", which Jacobs (1991) conceptualises as "an economic context in which prosperity and social equality increase while pressures on the environment and ecological damage simultaneously decrease" (in Cedergren, et al., 2022). In relation to development or industrial policy, we can talk of green path development. UNEP (2011: 16) describes green path development as "industrial development around products, solutions, or technologies that 'reduce carbon emissions and pollution, enhance energy, and resource efficiency, and prevent the loss of biodiversity and ecosystem services'" (in Sotarauta & Suvinen, 2021). The European Green Deal, which is the EU's new 'growth strategy', is set to accelerate and trigger a green transition and transform "the Union into a modern, resource-efficient and competitive economy", characterised by climate neutrality and reduced pollution, a competitive economy and

green technology and sustainable industry and transport (European Commission, 2020)

Setting aside policy ambitions, the concept of 'green' is a highly dynamic one that may well change in just a few years (Tanner et al., 2019). Moreover, framing 'green' in terms of traditional exponential 'growth' leading to resource depletion and waste production while also linking it with human well-being and economic development is no longer sustainable (Altenburg & Rodrik, 2017). The concept of green transition is often linked with the concept of 'green growth', whereas innovation is understood in terms of economic development. Green growth is the capacity to create sustainable growth through innovation for new and improved services, processes, and goods, writes Annala & Teräs in 2017. Ambec (2017) furthermore states that when preconditions are fulfilled, green growth leads to economic competitiveness. These involve the ease of facilitating patent and technology transfers in industrial policy, high levels of technological absorption capacities in industries, and finally, flexibility in green innovation policy instruments, e.g., taxation policies (Ambec, 2017, p. 47). However, they are highly context-specific and dependent, contingent on the role of public policies and financial infrastructure and on the role played by 'proximity'

in driving industrial green transitions (Altenburg & Pegels, 2012)

Conceptualising 'green' in the framework of the existing economic system can, therefore, quickly become limiting (Wøien Meijer & Peters, 2021). According to Altenburg and Rodrik (2017), radical new techno-institutional systems are necessary. The commitment to Agenda 2030 and the SDGs has transformative power, but conflict about goals may result in 'halfway solutions' if there is little or no guidance on balancing conflicting issues (e.g., housing vs. area protection). New policy foundations, such as the SDGs, may reform, in turn, both the formal and informal institutional structures if afforded the chance (Wøien Meijer & Peters, 2021).

Structuration theory establishes frameworks wherein agents and structures, under certain circumstances, have the potential to mutually influence each other, propelling society forward. As Asheim (2019) notes, new industrial innovation policies are generally built on the assumption that "no single agent has a total overview of the economy". Therefore, to study innovation in green transitions, we need to examine change agency and identify where change is initiated, who and what triggers it and who or what leads the process of path creation.



Photo: Nazarin Babashova / Unsplash.com

PART II: Methodological Framework

In this section, we briefly describe our methodology and our approaches to

the study of change agency in green innovation in the Nordic Region.

3. Conceptual framework

We use Coleman's boat (Figure 3) to guide our interpretation of macro-micro-macro interlinkages – in other words, how structures (macro-level) influence agency (micro-level) in a mutually reinforcing way (Coleman, 1986; Giddens, 1991). This helps us ground our theory of change agency by understanding social change and change processes as dependent on changing institutions, values,

visions, and attitudes. In relation to sustainable development, for example, macro may refer to the threats of climate change. This, in turn, conditions micro-level attitudes, leading to individual action, the development of the SDGs or other climate action, which in turn has an impact on economic pathways and the severity of the climate crisis.

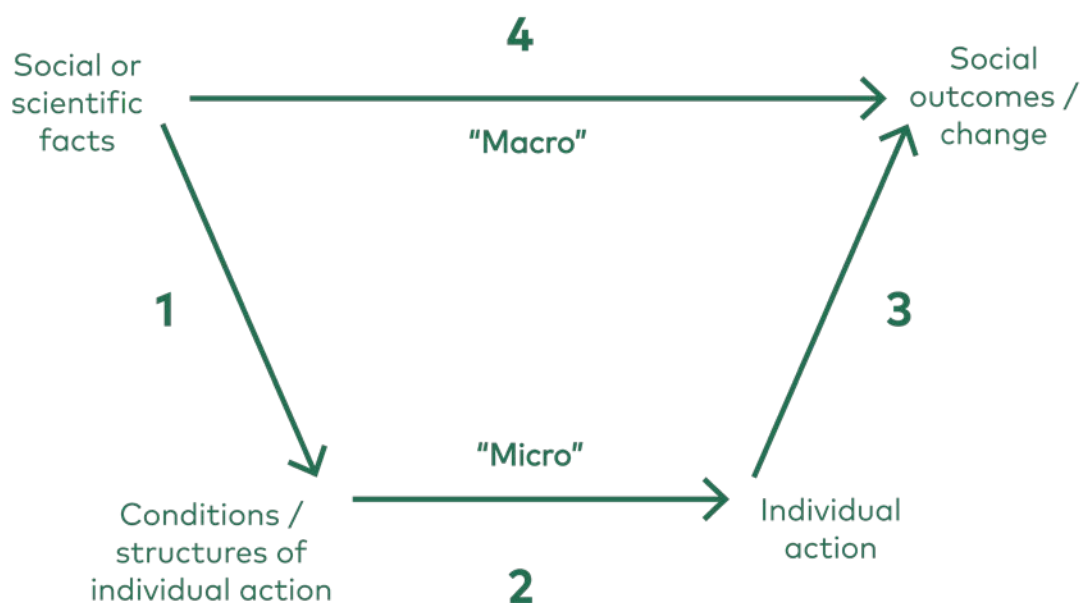


Figure 3. Coleman's Boat, authors' interpretation.

The boat explained: In relation to innovation within green transitions, individual actions link to system behaviour. This is partly because green transitions are catalysed by attitude and value changes that involve trust and/or social influence. Attitudes and values affect macro-level change, which in turn influences micro-level behaviours, change and eventually governance structures through institutional entrepreneurship. So, for example, influence type 1 (Figure 3) indicates social or scientific facts, such as e.g., climate change's impact on society. Influence type 2 represents the impact on the conditions/structures of individual action. Influence type 3 shows the process of individual action impacting social outcomes (Coleman, 1986, p. 1331). Finally, we would like to add a double arrow as a fourth type of influence, showing how social outcomes may

impact the development of social and scientific conditions and vice-versa on the macro scale, implying general shifts in attitudes – resulting in, e.g., establishing the newfound development of problem-solving mission-oriented policies to solve grand social challenges.

The limitation of the methodology based on Coleman's Boat includes risks common to all qualitative methods, i.e., the lack of tangible, empirical results and the need to carefully review the credibility of results at every stage of analysis. While we acknowledge this limitation, we ground our conceptual framework on this model. Although the directionality and causality of influence tend not to be linear but complex, Coleman's boat helps simplify and visualise how transformative action (individual level) and policies (structural level)

influence and strengthen/weaken each other. This is observable in, for example, many contemporary social issues (e.g., the civil rights movement, women's rights etc.). The interlinkages between agency and structures are charging transformations, while the institutionalisation of norms and values is driving green transitions and manifesting in individual action and policy change.

Having established how we conceptualise our ontological basis of social change in the relationship between structure-agency, we take a closer look at how this might work

within the framework of innovation. Building on Grillitsch and Sotarauta's theory of Trinity of Change Agency (2020), we see how, depending on the overall social conditions, variables and outcomes might change (Figure 4). Depending on the context and actors involved, the process, directionality of influence and outcomes of change agency vary. Moreover, this acknowledges the complex interlinkages between agency and structure in contributing to social change, or in this case, green transitions.

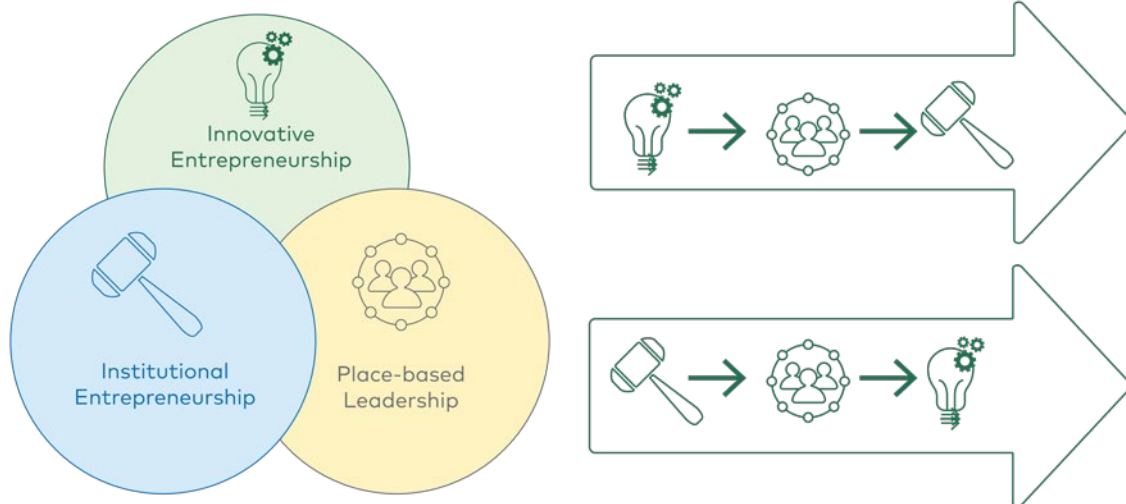


Figure 4: Trinity of Change and the role of agency in generating outcomes. Source: Adapted from Grillitsch, M. (2021). Re-design: Kotryna Juškaitė, Nordregio.

The 'Trinity of Change Agency' does not happen in a vacuum but is surrounded by various actors who may impact change. Grillitsch and Sotarauta (2020) suggest that these three forms of agency "[...] contribute in their own way to constructing and exploiting opportunity spaces, thereby continuously forming and shaping regional growth trajectories".

We also follow their assumption that despite similar preconditions regions do perform differently and that this may be rooted in the types of agency that exist and their ability to exploit opportunity spaces (Grillitsch & Sotarauta, 2020).

To complement the traditional view of actors in terms of formal role or organisation, we apply 'the

roles in change agency' proposed by Sotarauta et al. (2020, p. 96), which involves both the formal and informal roles of actors in change processes and in driving innovation. These include support actors, vision brokers, critics and mentors,

in addition to core place-leaders, institutional entrepreneurs and innovative entrepreneurs (Sotarauta et al., 2020, p. 96). In our empirical study, we will consider who these actors are in relation to the sectors chosen for our case studies.

Table 1: The roles in change agency. Source: Sotarauta et al., (2020, p. 96)

The role	Characteristics of the role (within the game metaphor)
Institutional entrepreneur	Initiates divergent institutional changes and actively participates in their implementation and is willing to take risk in doing so - <i>works to change the rules of the game.</i>
Innovative entrepreneur	Actively seeks new economic opportunities and is willing to take financial and personal risk – <i>exploits the existing, emerging and possible games and simultaneously changes them.</i>
Visionary	Breaks away from what already exists and has the imagination and the ability to see the big picture - <i>imagines new games.</i>
Support actor	Encourages change by supporting the process by loosening up facilitation, coordination and/or providing change efforts with resources - <i>does not play the game but helps the players and those who make/change the rules.</i>
Mentor	Typically, an actor who coaches and advises other actors and especially institutional entrepreneurs and leaders as well as entrepreneurs throughout the process but is not actively engaged in the change process - <i>teaches others to play better or to change the rules more effectively.</i>
Critic	Plays the role of the devil's advocate by asking cunning questions that force the other actors to re-examine their assumptions and hold them against other criteria - <i>does not work for the game or improve the ways it is played but indirectly helps the players to improve their game.</i>
Place leader	An actor having a position to assess a path development process from a more comprehensive angle than the other actors, and mobilise and pool resources, competencies and powers – <i>makes it all possible, provides a generic direction for a game.</i>

Methodological approach

Assuming a systemic nature of innovation in which no single agent has the monopoly of change, we find it relevant to use agency as a

starting point to explore the concept of green innovation in the context of regional development. This allows us to gain further insights into the role and collaborative efforts employed

by actors in enabling the green transition. Finally, this also sheds some light on the way in which the green transition may come to fruition through the complexity of actor-structure interactions.

The study included the following methodological approach:

- Theory and conceptual overview: desk study of innovation literature, concepts and policy evolution based on ongoing academic discourses.
- Methodological framework: based on the change agency approach.
- Empirical study: qualitative sector-based case studies based on 1) semi-structured interviews (selected following leads from the knowledge overview and by utilising the snowball method) and 2) knowledge overview combining a variety of sources (i.e., academic literature, policy documents and grey literature, e.g., reports, journalistic articles, websites, company reports, etc.). An overview and a conceptualisation of key terms at a case level were also conducted.
- Cross-case analysis in relation to the key theoretical.

The cases were selected based on the following criteria. Following our decision to focus on the concept of agency and the complexity of actor-structure interactions in green innovation, we decided to focus on sectors instead of specific regions. This has allowed us to capture a more

complete picture of the multiple and changing roles of various actors during the process of systemic innovation, where a certain region or city, for example, may be proactively involved at a certain stage and less so at another. This approach also allows us to appreciate the relevance of place in technological, institutional, social and systems innovations.

We chose to focus on wood construction and the protein shift due to fast developments and innovation happening within these sectors, and their particular relevance in Nordic countries. We interviewed 14 people for Case study 1 and 8 people for Case study 2 between Autumn 2022 and Spring 2023 (for a detailed list see 8.4.). We also conducted fieldwork in Västerbotten region in Sweden, and Midtjylland region in Denmark in relation to the first and second case, respectively.

We recognise a number of limitations to our empirical study related to the limited number of interviews and the reliance on informants partial or subjective views in recollecting the historical sequence of events and identifying the relevant actors and factors in determining agency in the sectors development. This study, however, does not claim to seek an objective certainty of events but rather an understanding of aspects that carry the most weight to experts in the field. Furthermore, the case is limited by having only two cases, and therefore cannot claim to cover all possible manifestations of green innovation. For this, we need further research.



Photo: Skellefteå kommun / Unsplash.com

PART III: Empirical Study

This section presents two case studies examining the role of agency in green innovations from a sectoral point of view. This includes 1) a case study on *'Innovation dynamics in*

wood construction in Sweden and Finland' and 2) a case study on *'Nordic innovation systems dynamics in the protein shift'*.

4. Case Study 1: Innovation Dynamics in Wood Construction in Sweden and Finland

4.1. Introduction

Wood is undoubtedly one of the oldest building materials and a key resource historically in the Nordic countries. As Andersson (2020 p. 57) puts it: "employing renewable, locally sourced, and strong yet light material, wooden houses have dominated the single-family housing

market in Sweden for centuries". In Sweden, the oldest surviving wooden buildings date from the 13th century (Swedish Wood, access: 02/10/2022). Given this background, it may seem slightly odd to talk of innovation and 'green innovation', in particular, in wood in the construction sector. However, as we see from Figure 5,

wood construction has followed a long and winding road, composed of many setbacks and opportunities, to arrive at its current state. As a consequence of devastating fires in cities throughout Europe in the 1700–1800s, wooden buildings started to be considered a hazard, leading to a ban on multi-storey wood buildings. Finland (then part of the Russian Empire) banned wooden buildings of more than two storeys in 1856 (Suikkari 2007) and Sweden followed suit in 1874 (Swedish Wood, access: 02/10/2022). After more than a century-long moratorium, multi-storey wood buildings are experiencing a renaissance. The previous negative association to wooden buildings as fire hazards has been replaced by a more positive outlook, where wood is seen as a means to 'greening' the construction sector.

The construction and life cycle of buildings are associated with 39% of global carbon emissions, of which about a third comes from building materials production (Rasmussen et al., 2021). In addition, the industry uses significant amounts of energy and mineral and metal resources during the construction and use phases of buildings (ibid.). Reducing the carbon footprint of the sector has, therefore, garnered considerable attention from policymakers. Novel regulations are being introduced to trigger and accelerate the transition of the industry towards low-impact practices and solutions. From January 2022, new regulations in Sweden and Finland require 'climate declarations' for all new buildings, which is a step

in the right direction for setting limit values on new construction projects' carbon emissions. These challenges represent an opportunity for the forestry industry, as building in wood significantly cuts the carbon footprint of construction. Assuming that wood is harvested from sustainably managed forests (although this is an increasingly contested issue), wood construction appears to be the most sustainable option for the Nordic countries. The processing and production of wooden building materials use less energy-intensive industrial processes than the extraction and production processes of cement and steel. Additionally, wood can store carbon over the lifetime of the building and possibly beyond since wood elements are easily reusable and recyclable. After two decades of slowly creating a market for multi-storey wood construction (MSWC) in the Nordic Region, these advances are now expected to rapidly expand and capture a sizeable market share over the coming years.

In 1994–95, Sweden introduced the new Building Codes (BBR), which effectively annulled any restrictions on wood construction (Smart City Sweden 2020). This legislative reform, however, was not purely motivated by the opportunities offered by wood materials in construction. Instead, it was part of a legislative harmonisation process required for EU accession (Andersson, 2020 p. 61). This sudden shift in the 'rules of the game' generated high expectations within the forestry and wood industries (Interview 4.1). However, it

soon transpired that developments progressed at a slower pace than expected. After over a century of cement and steel prevalence in the construction industry, a wide knowledge and skills gap surrounding the construction of tall wood buildings was evidenced, as well as a need for a more profound cultural and systemic change in relation to their viability. However, the experience garnered by the wood industry and building companies over the last 25 years and by engineers, architects, planners, regulators, academia, banks and insurance companies, has allowed this 'sub-sector' to find a foothold in the market, gradually increasing its market share to approximately 20%, and thus creating a solid foundation for further rapid expansion over the years to come (Interviews 4.1, 4.2, 4.8). National and sub-national authorities have also played a substantial role in promoting wood building by setting ambitious targets, mobilising stakeholders and funding and, most importantly, by taking risks and leading by example in public building and apartment block construction. Moreover, several decades of sustained urbanisation processes and an increased social focus on environmental sustainability since the early 2000s have proved beneficial to the wood construction industry (Interviews 4.1, 4.2, 4.3). In line with these trends, wood strategies have increasingly focused on climate goals, capitalising on this new momentum.

Following EU accession in 1995, key promoters of wood construction in Finland increased their advocacy

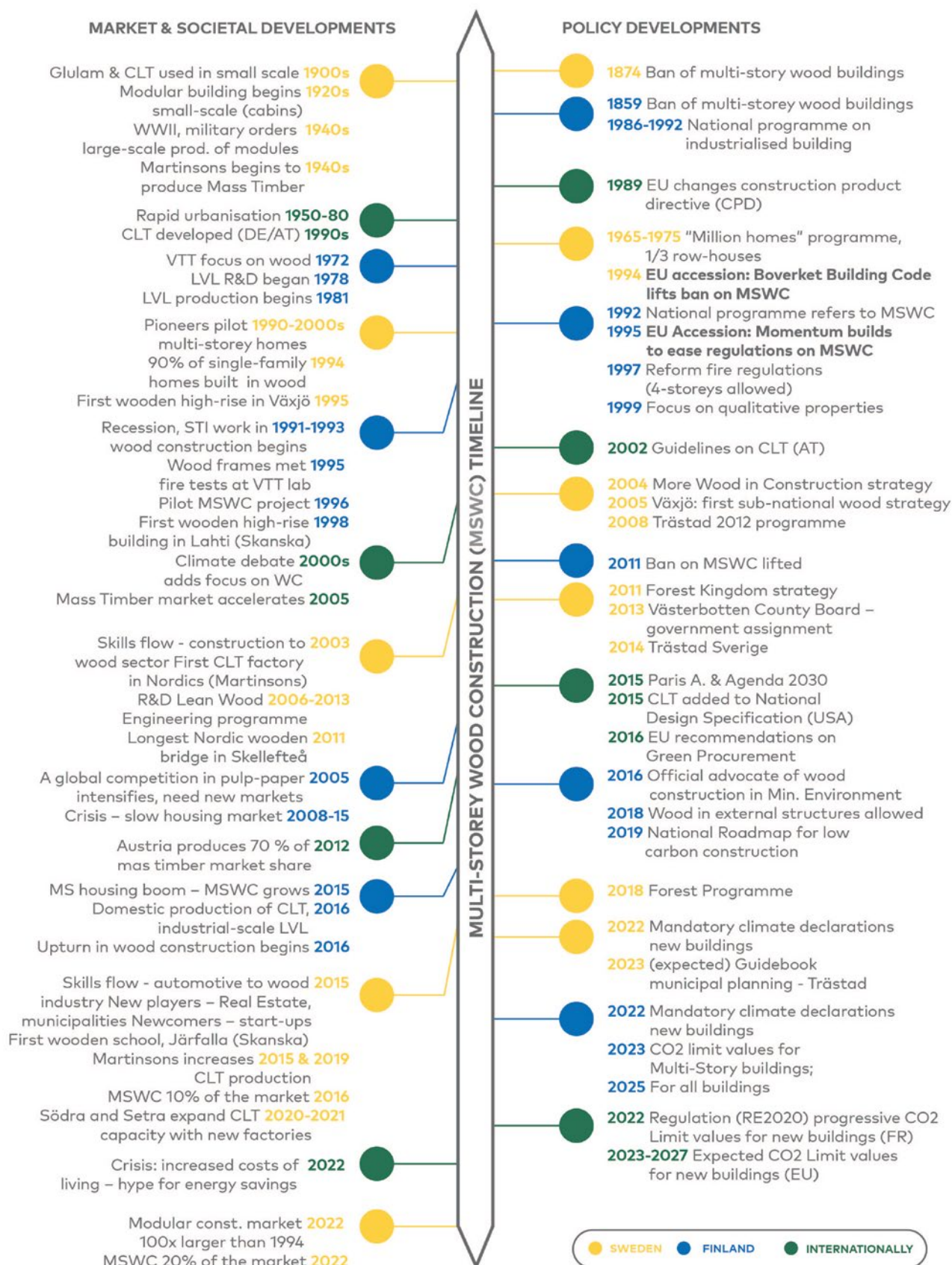
for building with wood. However, restrictions on the height of MSWC and fire safety regulations were only lifted gradually. From 1986 onwards, changing governments have initiated several policy and research programmes to support increased knowledge of material science and structural engineering using wood. These national strategies also set ambitious goals for expanding wood construction, with several municipalities taking the lead by building schools and other public facilities, thus generating demand, construction experience and incentivising private sector investment. While many of these government programmes generated substantial knowledge and expectations in the forestry and wood industries, direct market creation has faced considerable resistance. Negative perceptions, regulatory barriers and the dominance of the concrete industry have, until recently, relegated MSWC to a marginal position. Compared to Sweden, construction processes have remained underdeveloped, relatively inefficient and thus expensive. The question of timing has also been less favourable to Finland than to Sweden, as urbanisation and demographic trends have stagnated over recent decades. Despite three decades of constant political support, these factors have notably hampered wood construction actors' efforts to gain a foothold in the market. Under these difficult conditions, the role played by a small number of 'champions' has been key, such as the various policy mechanisms and

methods wielded by larger cities to motivate and compel constructors to choose wood. Today, the MSWC market share remains at around 5% but is expected to increase over the coming years (Paavola 2019).

Regulation, policy stimulation and technological innovation were not the only instigators behind the rise of modern high-standard wood buildings. Incorporating wood construction into the market has required the creation of a new 'sub-industry' and business ecosystem. These efforts have led to an overhaul of the entire system, from altering business practices, spatial planning

systems and industrial processes to readjusting the organisation of the construction sector, their supply chains, business models and financial strategies, as well as promoting an overall cultural change within the industry. Co-operation between multiple public, academic and private actors from different sectors has been pivotal in shifting cultural values, setting common goals, formulating new policy incentives and building trust between all partners. This trust underlies and enables the industry to make significant yet risky investments.

Figure 5: Timeline Multi-storey wood construction (MSWC) – key industry and policy developments, Design: Kotryna Juškaitė, Nordregio.



4.2. Technological innovation

Technological innovation in modern wood construction derives from material science and structural engineering: from testing the properties of different types of materials and wood products in relation to stability, vibrations, fire safety, acoustics, energy efficiency, etc. Moreover, technical and technological innovations also include industrial processes, architecture and design tools, transport and supply chain innovations. Significant efforts have centred around developing efficient building systems and the industrialisation of construction (The Lean construction method). As a part of the 'green agenda', there is an increasing focus on designing new assembly-and-disassembly methods and taking the life cycle of buildings, their transformation over time and their 'end-of-life' into account. We will focus more specifically on building systems and industrialisation processes in the following.

There are several different construction techniques and systems that can be employed when building with wood. Important variables relate to the degree of prefabrication and the types of wooden products and material combinations used. Conventional construction generally implies that work is carried out primarily onsite, using traditional materials and with a low level of industrialisation. In many high-income economies, however, conventional construction also implies the use of industrialised or prefabricated building elements. Prefabricated (or prefab) elements, such as frames, columns and slabs, are

produced in a factory and assembled onsite. To varying degrees, most buildings in industrialised economies now have portions of their structures manufactured in a factory setting. Although wood is a traditional construction material, multi-storey wood buildings are still very much an outlier in the market. Nonetheless, innovation in wood construction has propelled the industrialisation process forward, including modular systems for prefab volumes production and specific wood-engineered products for creating prefab frames and other building elements. According to Nord (2008), there are approximately three levels, or methods, of prefabrication in the production of multi-storey wood buildings: 1) onsite construction using pre-cut components, 2) assembly onsite using prefab timber elements and 3) assembly onsite using prefab and pre-assembled timber volumes.

In Sweden, about 97% of all wooden frame multi-storey buildings were partially or completely prefabricated by 2020 (Swedish Forest Agency 2020). In modular systems, most components are prefabricated offsite and assembled onsite to produce building volumes resembling human-sized LEGO. Prefab modular construction can manufacture complete ready-made rooms or sections of apartments, including electrical installations, heating, plumbing and air-conditioning systems, in a factory setting (Manninen 2014). Other systems use prefab frames and building elements similar to conventional construction but replace concrete-steel elements

with structural wood-engineered products or mass timber such as glue-laminated timber (Glulam), cross-laminated timber (CLT) and laminated veneer lumber (LVL). (See **Info Box 2** for definitions).

Each different building system and wood product has its own application, advantages and disadvantages. Wood is a light, structural material with a low or almost negative carbon footprint and is widely available in the Nordic countries. Modular wood construction relocates most of the construction phase offsite to a factory setting. Systematising the work in a factory has numerous advantages. It provides a dry and predictable working environment while minimising possible climate or site accessibility problems and reduces public disruption around the construction site. It also allows for a targeted strategy and improved co-ordination of the work, involving fewer sub-contractors, as more workers are employed directly at the factory instead of providing services onsite. Finally, it radically reduces the duration of work onsite, making it possible to assemble a high-rise building in the span of a few months. All of these benefits combined result in lower production/construction costs. Given these indisputable advantages, the growth of the modular wood construction industry is now comparable to the advance of electric cars, growing from a EUR 20 million industry to almost EUR 100 million in the space of a few years (Interview 4.2). A more commonly recognised disadvantage is that deploying prefab modules limits the

flexibility of architectural design (Interviews 4.1, 4.6; Brege et al., 2013). However, this may be less related to the technical possibilities afforded by modular systems and more to inherent transport restrictions (as lorries are restricted in the shape and size of units they can carry) or to decisions made at the design stage before fully considering the modular systems' option, rendering it too late in the process (as modules can potentially be built in any shape). In any case, modular construction is a prime alternative when speed and cost efficiency are prioritised over architectural expression, e.g. to rapidly increase hospitals, care homes, schools, or affordable homes provision in municipal or regional settings. Modular construction has proven extremely effective in delivering high volumes efficiently in a competitive and cost-efficient environment (Interview 4.2).

The introduction of engineered wood products has added versatility to the use of timber in construction, enabling larger structures that are light, structurally sound and energy efficient. One expert view is that CLT represents a radical innovation in the sense that it enables the construction of large wooden buildings while facilitating designs similar to conventional ones, requiring no major deviations in the design process (Interviews 4.1, 4.11) and thus making the innovation decisively less disruptive.

As the market expands, focus is shifting from exclusively building with wood-base systems to also incorporating hybrid construction systems and materials: mixed

wood products, wood with steel, concrete, recycled materials, or new innovative materials. For example, non-bearing walls can be made from lighter, material and space-efficient alternatives instead of structural materials such as CLT. Combining building systems is also a possibility, as in the case of the SARA Cultural Centre in Skellefteå, which was built using a glulam frame combined with CLT modules for the hotel units.

Finally, several experts interviewed agree that aside from the development of novel construction systems, the industrialisation of wood construction represents a major breakthrough, allowing building to scale, higher production volumes and a move from a niche market segment to direct competition with the conventional construction industry. By applying the principles of 'lean construction' and 'lean

manufacturing', industries have optimised the workflow in production facilities, enabling them to cut costs and produce in higher volumes. Lean manufacturing or 'lean production' is a methodology or practice first applied in post-war Japan by automobile company Toyota, aimed at increasing productivity via continuous production system improvements. It maximises value by minimising 'waste', both in terms of material resources and superfluous processes, activities, work and time in the production system. Lean construction employs these principles to ensure greater efficiency in the building process, thus saving valuable time. Lean construction centres on limiting or reducing all work phases that do not produce added value for the customer, e.g., by decreasing waiting times at the construction site (Rakennuslehti 2016).

Info box 2: Terms and concepts

Engineered wood products or mass timber: "are made by glueing wood, veneers, panels, strands or fibres together to form pillars, elements or modules that can be used in building family houses, multi-storey buildings or other constructs, such as bridges" (Manninen 2014). CLT, Glulam and LVL are all examples of engineered wood products.

Glued laminated timber (Glulam): "Glued laminated timber comprised of multiple layers of timber bonded together with an adhesive to form structural beams." (Ramage et al., 2017)

Cross Laminated Timber (CLT): "Cross-laminated timber comprised of multiple layers of wood panel bonded together, [crosswise], perpendicular to one another with an adhesive to form a uniform wood panel with structural properties." (Ramage et al., 2017). "The result is a construction element that is transversely rigid and durable in relation to its low weight. It enables large spans and rational methods for rapid assembly" (Martinsons 2015).

Laminated Veneer Lumber (LVL): "Laminated veneer lumber comprised of multiple layers of thin wood bonded together with an adhesive to form structural elements, such as beams." (Ramage et al., 2017).

Prefabricated (prefab) construction: A construction technique in which building components, elements or volumes are manufactured offsite in a factory setting and then transported and assembled onsite. The degree of prefabrication varies between building systems, from the manufacture of components only to the offsite assembly of more complex elements and volumes. Modular construction allows for the most advanced form of prefabrication.

Modular construction: A form of prefabricated building system in which a building is manufactured offsite in repeated sections called modules or volumes. Modules usually consist of ready-made ceilings, walls and floors, resembling human-sized LEGO and can include all internal components including electrical installations, heating, plumbing and air-conditioning systems. The structural frame is usually built using pillars and beams or tile-type flatpacks. (Puuinfo.fi).

Flat pack house: A prefab house constructed out of pre-cut components produced offsite, often employing a timber frame system. Unlike modular houses, these are transported disassembled and do not include paint, plumbing or fittings.

Lean manufacturing or 'lean production': A methodology or practice first applied in post-war Japan by automobile company Toyota, aiming at increasing productivity via continuous improvements in the production system. It maximises value by minimising 'wastes', both material and in terms of superfluous processes, activities, work and time spent in the production system.

4.3. Historical overview of industrial development and technological innovation in wood construction

Prior to 1994: the emergence of prefab modular houses

The technological innovation process that has facilitated multi-storey building construction in wood is not a linear train of events. It did not originate with legislative change or the adoption of a national strategy. The solid legacy of woodworking and the industrialisation of the wood industry, particularly in Northern Europe, has resulted in the amassing of a vast amount of knowledge and skills, generating further advanced technologies in terms of machinery, building systems, products and applications. The century-long

moratorium on multi-storey wood buildings in Sweden, Finland and most other countries did not prevent companies from building single-family houses and larger structures, such as barns or event halls, in wood. Indeed, by the early 2000s, 80 % of all single-family houses in the Nordic countries were made of wood (Manninen 2014), with 90% in Sweden (Näringsdepartementet, 2004). Engineered wood products or mass timber was also utilised in construction, although on a lesser scale. However, the degree of industrialisation and technological development varied significantly between countries and companies, as well as the type of technologies, materials and building systems used. In addition, experience of building MSWC was mostly non-existent.

Modular construction

In Sweden, modular construction in wood can be traced back to the 1920s, when a handful of companies started producing modules, mostly as temporary structures (Interview 4.2). In the 1940s, modular construction received a sudden boost as a result of World War II, as the military sought a quick solution to accommodating the large number of soldiers mobilised to guard the national borders. Companies with experience in modular construction were requested to urgently mass-produce modules for barracks. This enabled them to generate the skills and industrial capacity necessary for high-volume production, which in turn facilitated the rollout of prefabricated construction to the market as part of the rapid post-war urbanisation in the 1950s. A second, even more defining moment for modular construction was the introduction of the Million Homes Programme (Miljonprogrammet), where the Swedish government set a goal of building one million homes within the space of ten years (1965–1975). Although this programme is, for the most part, associated with high-rise concrete apartment blocks, around one-third of its houses were, in fact, single-family homes. Another third consisted of low-rise buildings, many built in wood from prefabricated modules or 'flatpacks' (Interview 4.2). The then-ongoing urbanisation and increased demand for holiday homes ensured continuous development of modular construction in the following decades. The scale of this demand enabled companies to increase capacity and industrialise modular construction.

These proved key preconditions for the later development of multi-storey modular buildings when regulatory barriers were abolished in 1994.

In pre-war Finland, prefabricated building was mainly limited to sporadic experimentation and the industrialisation of construction took place later than the industrialisation of other sectors. An urgent need to build more homes arose as part of the reconstruction and urbanisation following the war. This, combined with rapidly increased industrialisation (in part due to the demands placed on Finland in the form of war reparations to the Soviet Union), led to a surge in prefabricated building from the 1950s onwards. The first experiments in scaling up prefabricated techniques addressed industrial production facilities, followed by office buildings from the 1970s onwards. However, with regard to apartment buildings, the construction sector has proven much more reluctant to costly experiments and development has been slower. A change in zoning laws in 1959 represented a major breakthrough in prefabricated apartment building by allowing the planning of whole residential areas instead of singular blocks and creating more favourable conditions for mass production. The 1970s saw a record number of residential homes constructed in Finland as urbanisation accelerated. From the 1950s onwards, the traditional construction industry also re-organised internally, created common standards and reinforced its strong hold on the market. (SBK säätiö 2009)

Engineered wood products (mass timber)

By the time Sweden, Finland and other EU member countries altered their building codes, allowing for MSWC, engineered wood products were already in industrial production, albeit on a relatively small scale. After a few arguably unsuccessful attempts to introduce engineered wood products in the construction market, a renewed interest took shape in the 1990s, first in Germany and Austria and later in Sweden, Norway and Finland. The renaissance of mass timber use began in Germany and Austria, focusing primarily on single-family homes, while the main target in the Nordic Countries became apartment buildings. According to one expert, the initial failed attempt to introduce engineered wood products in the 1980s may be connected back to a business model which targeted flagship projects, such as large event venues and stadiums, instead of ordinary housing (Interview 4.2). Swedish company Martinsons is an exception, as they had consistently supplied mass timber to the housing market, which may go some way to explaining why they survived, while many other companies ceased mass timber production (Interview 4.2).

Post 1994 onwards: A new market for Multi-Storey Wood Construction (MSWC)

Context by 1994: Baseline for MSWC

The wood industry's long heritage in Sweden and Finland provided a strong basis for the development of MSWC. However, due to the

aforementioned moratorium on wood construction, direct experience of large multi-storey building in wood was almost non-existent. Prior to the legislative reforms of 1994, there was little or no available research on using wood as framing material in larger buildings (Nord 2008). This dearth of experience plagued all aspects of construction, from structural engineering and building systems to fire safety standards and regulations, ventilation, acoustics and energy efficiency in MSWC. There was limited knowledge and a lack of skilled labour across relevant sectors. With no built stock as reference points for new buildings, banks and insurance companies struggled to assess risks. Despite these challenges, the lifting of the ban on MSWC, combined with policy initiatives to develop wood construction and the decisive steps taken within the wood industry, all led to a rapid process of experimentation, knowledge creation and technological innovation, followed by a process of systematisation and industrialisation.

Piloting and Experimentation

As wood re-emerged as a feasible material for large-scale constructions, a handful of pioneering companies began an intensive process of experimentation, piloting and testing building systems, both modular and traditional systems featuring structural wood-engineered products or mass timber, i.e. Glulam, CLT and LVL. During this **first phase of development**, those involved were mostly large companies with a pre-existing industrial capacity and the financial

resources for R&D. In Sweden, Moelven and Lindbäcks, among other companies producing prefabricated modular houses in wood, invested in knowledge and capacities to develop building systems for tall buildings (Interview 4.2). These companies' experience in producing modules for single-family homes on an industrial scale proved a considerable asset in developing modules for multi-storey buildings. Although 90% of prefabricated homes were built of wood in the 1990s, the majority were 'flat pack houses' rather than modular and were constructed from pre-cut components, transported onsite disassembled and excluded paint, plumbing and fittings. Building multi-storey homes from modules coupled with extremely efficient assembly processes was, therefore, a true game changer: the market for modular MSWC grew a hundredfold, from EUR 2.5 million in 1994 to approximately EUR 125 million today (Interview 4.2). However, various companies have followed their own distinct development paths. While Moelven has targeted private customers, offering a wide variety of choices, other companies, such as Boklok, the Skanska-IKEA joint venture, apply a more rigidly defined model, comparable to IKEA furniture, with only a narrow selection of options available (Interview 4.2). Martinsons', on the other hand, invested in building systems development, using mass timber frames in multi-storey buildings. This process introduced a first wave of skilled labour into the wood industry, sourced primarily from the construction industry. One of our interviewees is an example of this

trend: he was recruited by Moelven directly from the construction sector to help develop their building systems (Interview 4.2).

Prior to 1994, Swedish universities and institutes had little relevant infrastructure or research programmes dedicated to wood construction (Nord 2008). Based on dialogue with the forestry industry, academia and policymakers, significant R&D was initiated within a 'triple-helix' framework. A major research programme was launched in 1996, aimed at increasing the basic knowledge of timber utilisation in larger structures (ibid.) A project stemming from this was the Cross-Laminated-Timber Consortium (Massivträkonsortiet), which brought together representatives from the wood industry, building contractors, consultants, and universities. Massivträkonsortiet contributed to generate knowledge of product properties, the development of timber frame systems, fire-safety solutions, noise reduction and moisture issues. The programme also resulted in several prototype buildings and handbooks for using timber in larger structures. As one of the participants in this consortium, Martinsons "learnt more about process flow and production management for structural elements" (Nord 2008).

In 2006, the Lean Wood Engineering programme (2006–2009) was launched, aimed at developing industrialised timber frame construction and industrial wood components and systems. With a budget of SEK 36m, co-funded in equal parts by Vinnova, Sweden's Innovation Agency, industry partners

and three universities (Linköping University, Luleå University of Technology and Lund University), the programme endeavoured to increase academia-industry cooperation with academic, industry-related and financial goals. The programme also included several PhD candidates who formulated their research around pertinent issues: the calculation and testing of structurally sound frame design and examining fire safety, acoustics and sound insulation and moisture issues. The programme envisaged an expansion in related research and education, increased co-operation between companies and improved R&D financing. The 'research' component of the programme centred on developing businesses and processes, with less focus on products, whereas the 'development' element of the programme explored industrial wood construction and manufacturing (Kunskapsförmedlingen 2022; Stehn 2022). Subsequently, similar smaller-scale projects have involved many of the same companies and aimed at increased co-operation between academia and industry, e.g., the programme launched in 2014 by Luleå Technical University examining the productivity and industrial development of wood construction in Sweden (Träbyggnadskansliet 2014).

Industrialisation of wood construction: from onsite to factory-setting

In the wake of the pioneer companies' success in developing construction systems for multi-storey buildings, a **second wave of development** commenced. Industries began actively focusing on the industrialisation

of wood construction by applying lean manufacturing principles to systematise the workflow. In the process, companies invested in the infrastructure and equipment necessary for scaling up production. A second wave of skilled labour made its way into the sector, this time sourced from the automotive industry (Interview 4.2). Experience in automotive production lines was particularly useful, argues one expert, as there are many similarities in the way trucks and building modules are assembled.

According to several experts, the **industrialisation** of wood construction is perhaps the most important **innovation** in the industry, enabling the emerging 'sub-sector' to move from piloting-phase and niche market placement to mass-production and sizable inroads in the overall construction market. Industrialisation also entails relocating parts of the construction process offsite to the factory. Offsite construction offers many benefits. As one interviewee puts it: "offsite construction can lower the construction time and costs, but also change the habits and processes that were less efficient" (Interview 4.1). According to one expert:

"while the technical innovations were developed over a hundred years ago, streamlining the production, the workflow and lean production, to get the volumes needed for a full building offsite, has changed the game" (Interview 4.2).

However, the degree of construction industrialisation varies depending on the choice of building systems. For

instance, mass timber frames (beams, columns, slabs) mimic conventional concrete and steel building frames and thus rarely require any major changes to the architectural design. Modular construction, on the other hand, requires changing the entire process, from architecture and design to building and assembling and entails transferring a major part of the work offsite (Interview 4.1).

Despite the many benefits of relocating offsite and systematising the construction process to factory procedures, progress has been slow, as the learning process and the design of new systems and protocols have required much time, effort and investment (Interview 4.1). The transition also necessitates new players entering 'the game' and thus challenges older established practices and business relations built up over time. Moving offsite radically changes the organisation of work in construction projects, which has led to re-adjustments for the actors involved and in their contractual conditions, as well as opening up new networks, partnerships, and trust relations (Interview 4.1).

Emergence of a new market: a bumpy road

Despite the initial hype generated by legislative change and national and regional level strategies, the market for MSWC did not immediately experience the desired boom. The goals of reaching 30% of all multi-level construction to be built in wood frames in a decade's time in Sweden (2005 strategy) (Lindblad 2020) and 10% in Finland by 2015 (2011 programme) (Laapotti 2020) proved

overly optimistic while severely underestimating the weight of structural inertia within the industry. Today, 15–20% of new multi-storey buildings are built in wood in Sweden (Interviews 4.2, 4.3). In Finland the figure is less than 5% (although 40% of public buildings are now constructed in wood) (Paavola 2019; Laapotti 2020). The slower-than-expected market growth indicates the strength of an already firmly established construction sector based on concrete and steel, which has significantly invested in production infrastructure while accumulating skills, experience and networks that operate within well-defined parameters. The status quo is also reinforced by clients' familiarity with concrete construction, e.g., municipalities and other public actors responsible for regulating and implementing standards for new developments. Moreover, some unrealistic expectations may also stem from a simplified understanding of the nature of industrial transformation, where change takes time and requires systemic thinking.

Industrial MSWC has slowly begun to overcome the structural inertia in the construction sector, but market penetration has also required new forms of financing, risk-taking and novel business models. In the earlier stages, pioneering companies circumvented traditional actors, including contractors and banks, rather than challenging them directly. Lindbäcks, with its origins in the construction sector, was the first company to build multistorey residential wood buildings using volumes (modular construction) in

1994 (Nord 2008). As Lindbäcks has also a real estate company, they were in a position to create demand for themselves (interview 4.2).

Moelven, on the other hand, has nearly a century of modular single-family home-building experience. They developed their own capacities and production system to build multi-story buildings in wood, first in Norway, then in Sweden, similarly circumventing construction companies reluctant to take on the risk of new solutions. Similarly, Swedish Derome AB, founded in 1946, is active in the timber value chain and has developed a lightweight framing system (A-hus) and modular construction. The company has realised many projects through its own development and real estate company (Nord 2008).

Martinsons was established in 1939 as a sawmill and later began producing glulam. Despite a dormant period in the mass timber market (prior to the aforementioned legislative changes), Martinsons expanded, becoming both a supplier of building elements and a wood housing company (Nord 2008). Following the 1995 regulation changes, Martinsons entered the building industry and created its own construction company, Martinsons Byggsystem AB, effectively taking over the entire building process. They provided everything needed on the construction site, from consulting to plumbing (Interview 4.2). More recently, Martinsons has been acquired by Holm, a forestry company, further consolidating elements of the supply chain under a single roof. Holm now controls the

source material, its processing, mass-timber products, building elements fabrication and, on many projects, the overall design and construction of new buildings (Interview 4.9).

In addition, several companies with origins in the forestry industry, such as Stora Enso, Setra, Södra, amongst others, also began the production of timber products and created their own building systems, thus moving prefabrication of building elements further down the supply chain (replacing intermediaries). For example, Södra Building System developed a truss system that is offered directly to contractors (Bengtsson, 2003 in Nord 2008).

As the market share for wood construction continues to expand, circumventing established contractors is becoming less necessary, as many of them now have the requisite experience in wood building. Instead, the wood industry is working closer with construction companies (Interview 4.2). On the contrary, the many conservative construction companies that have resisted change are now feeling the pressure and see the need to build their own capacities to build in wood. This trend is likely to accelerate as new regulations are on their way to set limit values on emissions of new buildings, making wood a favourable choice (Interview 4.5). Going forward, construction companies will inevitably become part of a larger transformative process by which changes in parts of the system will impact several other parts, including relations with other companies and subcontractors (Interview 4.1).

Market development of engineered wood products (mass timber)

The post-war period in Sweden saw a number of companies setting glulam into production, of which three still exist today: Martinsons, Setra and Glulam of Sweden AB (Suomen liimapuuyhdistys ry and Puuinfo Oy 2014). The market for glulam and mass timber products experienced a period of decline and stagnation during the 1980s and 1990s. However, by the early 2000s, the market for mass timber products had recovered, first in Austria and Central Europe, then in the UK and France and to a lesser degree in Canada and Australia (Manninen 2014). Within a decade, the demand for glulam had almost doubled to approximately three million cubic metres in Europe (and to roughly 5 million cubic metres globally), most of which was produced in Germany, Austria and Finland (Manninen 2014). Production of CLT began in the early 2000s (Manninen 2014). Swedish-Finnish company Stora Enso established their CLT factories in Austria, whereas Martinsons built the first CLT factory in Sweden in 2003. Shortly after, Södra and Setra followed suit and established their own CLT factories in Sweden. Despite the 2008 economic crisis and uncertain housing markets, CLT production continued unabated. As demand continued to increase, new factories were established in several countries, e.g. Monnet Seve in France (2013) and Cross Lam Kuhmo Ltd in Finland (2014), among others. The production of LVL in Finland began in 1981 but took decades to scale up, with MSWC targeted investments only made after 2016.

The material properties of LVL make it a competitive option for mid-height apartment and office buildings (Lazarevic et al., 2020). Today, there are also several factories in the Baltic countries producing mass timber and modular houses targeting the Nordic market.

Economy and market conditions

The efficiency of the industrialisation processes has succeeded in creating a viable market in Sweden, to the point that building a multi-storey apartment building from wood today is approximately 15–20% less expensive than using concrete and steel (Laapotti 2020). In Finland, where the market is not yet self-sustaining, the situation is often the opposite (ibid.). To enable the processes in Finland to achieve the same level of efficiency as their Swedish counterparts and reduce the cost of wood construction, demand would have to be considerably stronger. Unfortunately, due to the lack of expert knowledge and wood construction process management know-how, the price remains high and demand low. In essence, this is the vicious cycle plaguing the sector in Finland, stemming from the concrete industry's century-long competitive domination and its close ties to construction companies (Interview 4.1, Laapotti 2020). The rigidity of the existing system also means that the process flow in every project must remain broadly similar, even if the end product is different. Consequently, the customer must decide to build with wood at a very early stage so that the process can be adapted to incorporate it. If the

decision is taken during the initial stages, the process is efficient. However, if the plans are sufficiently well-advanced, the industry may find it difficult to provide a viable offer.

Broader market conditions have likewise impacted the growing market, especially in Finland during the 2000s. In particular, the 2008 economic crisis and subsequent prolonged economic downturn cooled the Finnish housing market and glulam export markets (Manninen 2014). Although CLT continued to increase its market share despite the crisis, production was still on a smaller scale than glulam (Manninen 2014). Sweden's housing market was not significantly affected during the financial crisis in 2008. On the contrary, the housing deficit inherited from previous decades, coupled with a growing population, meant that demand continued to increase. In Finland, a combination of a slowing construction pace and declining populations across many regions has also played a role in the sluggish development of wood construction.

Beyond the role of private actors

The emergence of multi-story wood construction is not merely reliant on companies challenging the status quo, taking risks and circumventing traditional industries. There are other important drivers of change, notably the national government, first in its position as regulatory authority and second as an enabling entity: defining strategies and assigning funding to support the development of the sector. Moreover, municipalities have also played a major role in pushing the adoption of wood as a possible

building material alternative in the market by spearheading development and assuming the inherent risks through the construction of public buildings and publicly-financed housing developments. The following chapter focuses on the role of the state, sub-national authorities, and institutional innovation.

4.4. Institutional & public sector innovation

Legislation

The first and crucial institutional innovations enabling MSWC were the legislative changes previously prohibiting the use of wood products in buildings taller than two storeys. In 1989, the EU implemented a Construction Products Directive (CPD) aimed at removing any technical barriers to trade in construction products between member states, in line with the EU common market (Railio 2014; Elspecta AB). The rationale was to move from material-based to function-based standards, which eliminated barriers to wood construction despite not specifically supporting it. Regardless of the material used in construction, the new legislation decreed that buildings have to meet standards for fire safety, energy efficiency, acoustics, accessibility and other 'functions'. The original directive, which has since been replaced with a more harmonised regulatory framework, left much room for interpretation and freedom of implementation for individual member states. Nevertheless, it has served as an important milestone for other regulatory changes

implemented at national level over the following years. (Interviews 4.1, 4.3, 4.6)

With Sweden's accession to the EU in 1994, the Swedish National Board of Housing, Building and Planning (Boverket) evaluated the Swedish rules and regulations and decided to harmonise them with the EU CPD. The new regulations came into effect with the first issue of the Building Codes of Boverket (BBR), in which detailed technical requirements were substituted with requirements based on the function of the end product. The regulation would set "the minimum function or property required but not in detail how to accomplish the function" (Nord 2008). The consequence was that the use of wood was no longer forbidden in larger structures as long as the 'functions' were met. For instance, no matter the material used, buildings are required to be capable of withstanding fire for 90–120 minutes before collapse (Interview 4.1, Andersson, 2020 p61). In practice, this represented a total lifting of the ban on MSWC in Sweden.

In Finland, legislative changes were more gradual. Following the first legislative ban against two-storey wooden houses with fireplaces in the mid-1800s, fire regulations continued to restrain wood construction in apartment buildings, even after Finnish EU accession. However, increased global competition persuaded policymakers to revise established regulations in favour of new approaches (Tolppanen et al., 2013). A hybrid model gradually emerged as new function-based regulation did not fully replace material-based restrictions. The

fire safety regulation was reformed over the years, eventually allowing a wider selection of building materials in increasingly higher multi-storey buildings. From 2011, five-to-eight-storey tall buildings were allowed under the regulation (Paavola 2019). In 2018, further simplifications to the regulations were enacted, allowing unprotected wood in interior and exterior surfaces of residential buildings of up to 16 storeys (using automatic fire extinguishers) (Lazarevic et al. 2020).

New and upcoming legislation: Climate declarations and limit values on carbon emissions:

If we fast forward to the current situation, a new policy push is underway to reduce the environmental footprint of the construction sector, which indirectly favours wood construction. From January 2022, all new construction projects of over 100 m² in Sweden must issue a climate declaration (with a number of notable exceptions). The Swedish National Board of Housing (Boverket) defines:

"A climate declaration describes the building's climate impact, as calculated based on the greenhouse gas emissions from the construction stage. The construction stage comprises the extraction of raw materials, manufacture of construction products, work at the construction site and transport". (Boverket Website: Accessed 31-10-2022)

The Swedish government tasked Boverket with developing and managing a climate regulation

database and registry to assist the climate goals in construction. These two elements target climate impact at the construction stage, i.e. relating to building permits for new buildings. During the first phase, Boverket's tasks included developing an open database to calculate the climate impact of buildings and a registry of this data (both launched in January 2022). As part of this assignment, they also focused on information campaigns and developing a more holistic plan of action to reduce the climate impact of buildings overall, which would not be limited to the construction phase but consider the whole life cycle of buildings. The next steps include setting limit values for emissions in new buildings, to be in place by the latest in 2027 (although possibly already by 2025) and gradually enforcing stricter values by 2035 and 2043 (Boverket Website: Access 31-10-2022; OneClick 2022). In addition to the climate declaration, there are several other voluntary certification schemes currently in use (OneClick 2022).

The realisation that optimising energy efficiency in new buildings will soon reach its maximum level of efficiency and minimal level of emissions led regulators in Finland to shift their focus to reviewing emissions during the building's whole life-cycle, starting with public procurement. Finland followed the European Commission's decision to publish voluntary recommendations regarding green procurement in office buildings construction in 2016 (The Ministry of Environment 2022). In 2017, the Ministry of the Environment began the process of measuring

the climate impact of buildings and preparing the ground for setting future emissions limit values. The national low-carbon construction roadmap from 2019 suggested the introduction of a climate declaration for multi-storey buildings from 2020, followed by setting limit values for multi-storey buildings from 2023 and for all buildings from 2025 (Bionova 2017). The final version of the roadmap covering the period up to 2030 will be published with the new Zoning and Building Act in 2024. Voluntary measures currently in place include a policy for assessing public buildings (acknowledging life-cycle emissions), some of the current regional cities' and municipalities' agendas and international and national sustainability certification for buildings. All of these elements contribute to Finland's goal of reaching carbon neutrality by 2035, with some cities, such as Helsinki, hoping to achieve this aim as early as 2030 (OneClick 2022; The Ministry of Environment 2022).

Even before the climate declaration regulations imposing limit values are fully in place in Sweden and Finland, a building's carbon footprint may become a marketing tool for real estate companies, predicts one expert (Interview 4.1). The expert notes that this happened when the requirement for energy declarations in new buildings introduced in the early 2000s in Sweden. Real estate companies soon began adding the energy consumption profile of new apartments to their marketing strategies. As national actors develop procurement criteria for low-carbon buildings and introduce low-carbon

roadmaps, these initiatives are also likely to benefit wood construction, as wood is considered a low-carbon building material (Lazarevic 2020). In addition, climate declarations are, in turn, likely to encourage broader regulatory pressure in relation to the climate impact of buildings, with the EU expressing interest in implementing the Nordic climate declaration model across Europe (Interview 4.14).

An area of contention surrounding the upcoming limit values for carbon emissions regulations in new buildings is the methodology and criteria used for calculating these emissions and whether these should be limited to the construction phase or the whole life cycle of the building. For the moment, the argument appears to lean towards taking the entire life cycle of a building into account, including the production of building materials and elements, construction stages, use duration, end-of-life stages and possibly further potential uses for building elements beyond their designated end-of-life cut-off point. Life Cycle Assessments (LCA) represent new opportunities for wood construction, as wood requires significantly less energy-intensive industrial processes, is a carbon-capturing material and, being notably lighter, takes significantly lower energy to transport than heavy materials, e.g. cement and steel, and is easily recyclable. (Rasmussen et al., 2021). Another issue under scrutiny is whether pre-existing structures should be included in LCAs. Avoiding demolition and repurposing older buildings normally results

in significantly lower emissions compared to new 'sustainable' buildings. However, companies tend to prefer demolition, although more for financial than technical reasons. (Interview 4.11).

National strategies in Sweden

Sweden's first effort to introduce a policy directly promoting wood construction began with the 2002 decision to appoint a national coordinator to carry the groundwork for formulating a national strategy. This resulted in the 'More Wood in Construction' (Mer trä i byggandet) strategy, adopted in 2005 (Näringsdepartementet, 2004). This strategy set a target that within the following 10–15 years, 30% of all new buildings would be constructed with wood-frames (Lindblad 2020). Although it has proved difficult to reach this target, it nonetheless represents an important step in generating broader debate and mobilising public and private actors. The strategy was based on analyses of the current state, trends and emerging needs of the forestry and construction sectors (Interview 4.1). Discussions were held between industry, ministries and municipalities, revealing important structural transformations already underway in construction and highlighting some of the existing systemic barriers facing the introduction of more wood products into the sector. This groundwork also led to the selection of Skellefteå (in Västerbotten), Växjö (in Småland) and Falun (in Dalarna) as pioneering municipalities, spearheading the implementation of the strategy

(Interview 4.1). Together with local authorities, a list of short-term and long-term objectives and activities were formulated, including research and pilot projects in collaboration with the industry to increase knowledge production and better inform the sector. The Ministry of Industry also appointed a co-ordinator to assist in implementing the listed activities. (Interview 4.1).

The first 2005 strategy was framed from a regional development perspective based on the industrial legacy and growth potential across several Swedish regions (Interview 4.1). The strategy also introduced the concept of wood construction as a political climate strategy (Andersson 2020). However, the original link to environmental sustainability was initially inadequate, only gaining prominence in later versions. In 2011, the strategy was replaced with a broader national strategy titled: 'The Forest Kingdom – with values for the world', launched by the Minister for Rural Affairs. "The 'Forest Kingdom' strategy aimed at increasing the economic development potential of rural areas while also seeking new export markets for the timber industry" (Andersson, 2020, p. 61). The 2018 strategy has also boosted wood construction, although its main focus is bioeconomy and developing forests as a national resource (Interview 4.8). Updates to the national strategy have added the political commitments of the Paris Agreement and UN Agenda 2030 to frame it more directly as a climate strategy (Interview 4.1). On a more general level, forest sector representatives experience a shift

in Swedish forest and wood policies away from the needs of industries to an emphasis on climate issues (Interview 4.6). More recent policy discussions have also centred on social sustainability (Interview 4.1). This coincides with the introduction of the 'Just Green Transition' concept in the EU Green Deal, which brings to the fore discussions of social justice or 'fairness' in industrial transformations. The shifting foci in the different iterations of the strategy also reflect the political landscapes under which they were formulated and the areas of priority for the government in power at that time. The 2011 strategy, which concentrated heavily on industrial development, was formulated by a right-leaning government coalition of four parties, whereas the 2018 strategy, which emphasised nature conservation, was formulated by a Social Democrat and Environmental Party coalition (Interview 4.8).

The efforts that began with the implementation of the strategy were followed in 2008 by a national four-year programme called 'Trästad 2012' (Wood City 2012), which has since continued in cycles with slightly different emphases (Interview 4.8). Trästad 2012 involved seventeen municipalities and was aimed at fostering large-scale production of MSWC. Under the programme, participating municipalities developed their own projects and activities focusing on themes relevant to their own specific contexts. Municipalities in North Sweden focused on CO₂ calculations and climatic stress in the construction phase; municipalities in mid-Sweden

focused on cost-efficiency via standardisation; municipalities in the Southeast focused on environmental targets and municipalities in the Southwest focused on ways to increase the use of wood in public construction, particularly in improving public procurement competences (NTT WoodNet 2012). The experience gaps that were uncovered between municipalities and the programme's diverse focus proved to be particularly useful for knowledge transfer between all involved partners.

Building on the Trästad 2012 programme, Trästad Sverige (Wood City Sweden) has since continued as a platform and a meeting hub for several projects, bringing together over 60 members from municipalities, relevant ministries, architects, and construction companies. In 2016, the association received state funding and a professional director was recruited to lead the organisation (instead of relying on municipal politicians leadership). The main objective of the networking activities is to support regions and municipalities in compiling a wood-building strategy by assisting them in implementing related regulations and legislation via the digital platform Wood First. In addition to promoting knowledge of wood construction, the platform facilitates open dialogue on wood building, involving various stakeholders and enabling them to have direct contact, e.g. with the Ministry of Housing (currently within the Ministry of Industry)

and between industry actors and municipalities (Interviews 4.6, 4.8).¹ In addition, Wood City Sweden, has developed a roadmap for Swedish politicians and municipal planners who want to better support wood construction and who may need both strategic and practical guidance in relation to tasks such as planning or public procurement. The project also aims to support wood construction by connecting it to other areas or urgent societal needs: for example, utilising wood for social housing is an effective way to produce comfortable homes at scale and speed or add more living space on top of, or to, existing buildings (Interview 4.6).

Coinciding with the establishment of Trästad in 2013, the County Administrative Board of Västerbotten was given a government mandate to work with other interested municipalities to develop wood construction in a cost-effective way, increase knowledge and encourage other municipalities to realise the national climate goals. Västerbotten's County Governor is the acting chair of Trästad (Trästad Sverige web).

The Swedish government has also supported wood construction in more indirect ways by enabling construction firms to develop skills and increase modular construction capacity. State intervention, such as the order for mass-produced barracks during the Second World War and the housing stock increase generated by the Million Homes Programme between 1965–1975 were

¹ Disclaimer: this case study was written during early 2023 and does not consider changes to the budget and mandate to Trästad Sverige made by the current government.

major catalysts paving the way for MSWC development (Interview 4.2). Today, the central government insists on impartiality, so publicly procured buildings remain 'material-neutral' in line with function-based regulations. However, state authorities have continued to support the development of the forestry and wood sectors, not least by financing Trästad Sverige, as well as investing in R&D. The influence of climate policies is more indirect but nonetheless significant, particularly the new legislation aiming at cutting carbon emissions within the construction sector. Wood construction advocates are also critical of the state's perceived impartiality given that the Swedish government is a shareholder in Cementsa, the main cement industry in Sweden, LLKB, an iron-ore mining company and SSAB, a steel company, as well as supporting the forest industry, which also represents a large economic sector (Interview 4.6). Furthermore, as MSWC was banned for over a century, state intervention is now required in the form of policy support, stakeholder engagement and funding to rebuild the construction market 'from scratch'.

National strategies in Finland

Since the mid-1980s, Finland has encouraged wood construction in the form of government strategies and support programmes (Saarnivaara 1998). The first set of state-funded initiatives focused on various areas, from technological innovation to architecture and urban planning and aimed at solving issues that would render wood a less risky building

material (Siikanen 2008; Metsä Group 2013; Tolppanen 2017). As a part of a series of programmes proposed by the government to alleviate the effects of the early 1990s recession, the state, the forest industry and the Finnish Funding Agency for Technology and Innovation (now Business Finland) initiated financial support packages in the fields of science, technology and innovation. Although these did produce practical knowledge and led to regulatory reforms, these R&D programmes were not in themselves enough to establish a wider market base for wood construction.

In the 2000s, other official housing strategies also encouraged the use of wood. In response to EU-wide trends, Finnish national strategies have begun to emphasise the qualitative properties of housing rather than a mere quantity increase (Purdy 2010). Global competition in the paper and pulp markets compelled the forestry industry to find new product outlets, which in turn led to increased state support for wood construction development and represented an opportunity for the forestry sector. Strategic programmes drafted in the 2000s have noted MSWC's increased market share and set a provisional target of 10% use in new housing stock by 2015 (compared to just 1% in 2011). However, the initial policy goals in Finland, as in Sweden, have proved overly ambitious, with little notable increase in activity in the industry between 2011 and 2014. Despite this, government programmes did contribute to an expansion of the theoretical knowledge available and

led to regulatory reform (including the appointment of an official wood construction advocate at the Ministry of the Environment), as well as the implementation of several pilot projects, which have resulted in a small market share increase (Lazarevic et al. 2020; Saarnivaara 2022). According to one interviewee, the research programme's focus on material properties neglected relevant broader areas such as wood construction processes and solutions (Interview 4.13). Nonetheless, these programmes have proven impactful in terms of shifting attitudes, adjusting building regulations and affecting municipal planning processes. Despite the modest results, ambitions remain high: the most recent wood building strategy aims at capturing a 20% market share by 2025 and a 50% share in all publicly procured buildings (Paavola 2019).

The strategic and R&D elements of these state programmes have paved the way for wood construction by creating more favourable conditions for knowledge exchange and improved regulatory frameworks. However, this in itself is not enough to address some of the deeper structural barriers, including resistance from strong lobby groups of established actors with their close ties to the construction sector. As long as sectoral development relies on pilot projects, wood construction will continue to bear the brunt of high costs due to inefficiency and insufficient skills. Finland's first wooden high-rise apartment building in Lahti, 1998, remained the only one of its type for several years, as

the high construction costs incurred discouraged construction company Skanska from continuing with other wood construction projects (Mölsä 2021). In short, policy-making alone is not enough to overcome some of these barriers.

Sub-national strategies: Sweden

The groundwork undertaken in the Swedish national wood construction strategy encouraged regional and municipal authorities to draft their own responses (Interview 4.1). 'More Wood in Construction 2005 and Växjö' was the first published municipal strategy (Interview 4.1). The updated strategy (2013) has set an ongoing target for the municipality and the city's municipally owned companies that 25% of all new buildings must be constructed with wood frame, rising to 50% by 2020 (Växjö Municipality 2013). Similar regional strategies were proposed to support local industry in key forestry regions such as Småland, Västerbotten and Dalarna. In addition to wood construction strategies, several municipalities now have individual climate strategies setting goals for carbon neutrality or are affiliates of the network of Swedish Climate Municipalities (Interview 4.7).

In Småland, the Växjö municipal strategy was aligned with the broader strategic regional goals (2012), whereby the county worked towards assuming leader status among Europe's wood regions by 2020 (ibid.). The coupling of regional and municipal strategies with the national strategy generated a domino effect involving the participation of cluster organisations, interest groups

and private actors. (Interview 4.1). Given the clearly defined political stance, "construction companies in Växjö realised that in order to win project competitions and gain a competitive advantage, they needed to learn how to construct from wood" (Interview 4.1). As a result, the wood construction industry has broadened its competences, competition has increased, and new innovations are underway (Interviews 4.1, 4.2). This, in turn, has led to private and public actors jointly "apply[ing] for money from European regional funds and research organisations to support their activities" (Interview 4.1).

It should be noted that the practical and policy undertakings leading to a published strategy and official platforms often begin at a much earlier stage. Before the first national wood construction strategy was adopted in Sweden, wood building was already expanding in Växjö, coinciding with the lifting of the MSWC ban. In 1994, Värendshus built a three-story house using wood frames, and shortly after, in 1995, Sweden's first modern five-storey wood-frame building was built as a model case study in Växjö (Wälludden). The municipality also set in place related academic research before adopting its timber-building strategy. (Lindblad 2020; Tina Wik Arkitekter 2023).

In Skellefteå, the municipal strategy was first adopted in 2014, but intense work aimed at fostering wood construction had started as early as the introduction of the new national building codes. After a period of economic stagnation in the 1990s, which also affected the forestry

industry, the changes in legislation were seen as a golden opportunity by the chair of the municipal council at the time, Lorentz Andersson (Interview 4.7). Despite the lack of a formal strategy, the municipality took the audacious decision to build wooden apartment buildings in 1995 and the longest wooden structure bridge (at the time) in 2011, which was later surpassed by an even longer one in 2022 (Interview 4.7; LTU 2011; Byggvärlden 2022). Local actors' willingness and ability to co-operate facilitated numerous partnerships, and the forest industry and local authorities aligned their visions to incentivise industrial development. At the time, the focus was primarily on adding value to the forestry industry to generate economic activity, support local businesses and create new jobs. From the early 2000s onwards, the municipality began placing orders for wooden buildings, as well as establishing a strategic co-operation with research and academia, i.e. RISE, Luleå University of Technology and Umeå University, including investing in a university campus for education and research in Skellefteå (Interview 4.7). The county-level strategy continued these initiatives by supporting proactive individuals and creating close links between public authorities and local businesses. The county of Västerbotten has been at the forefront of supporting wood construction since the 2000s when Lorentz Andersson was appointed governor of the County Administrative Board and was given a special mandate by the national government to act as chairman of the National Timber

Construction Strategy. Emphasising the importance of individuals in developing the market, Andersson was awarded the King's Medal for "his outstanding contribution to society" in 2008. Skellefteå's wood construction strategy was eventually published in 2014, setting out a systematic and clear path for future development. This coincided with the broader societal focus on climate and sustainability goals, which became a central pillar of the wood industry's agenda (Interviews 4.7, 4.8; Skogsindustrierna 2008).

Many of the municipalities originally involved in Trästad 2012 began planning for wood-based construction projects as early as 2006. Today, around 180 municipalities in Sweden have constructed tall wooden buildings, and the number is increasing, including several large-scale projects. A prime example is Frostaliden in Skövde, where blocks containing 150 wooden apartments, several of which are six storeys high, are currently underway. Another example is Välle Broar in Växjö, which represents Sweden's largest ongoing wood construction project, where an entire district has been built in wood (Ekholm 2011). Skanska erected the first school built entirely from wood in Northern Sweden in Järfalla in 2015 (Woodnet 2014).

Policy Tools

Beyond strategic level engagement, municipalities also deploy more practical instruments such as spatial planning, zoning, building permits and public procurement to steer development. These contain significant potential to support

wood construction (Interview 4.12). In the Swedish context, municipal planning is, for the most part, grounded in political decisions, housing development programmes or more general building plans, occasionally also taking developers' suggestions onboard (Lindblad 2020). The decisions reached are then set in train by the municipalities through 'procurement processes' or 'land allocation processes'. These procedures are used to identify and select (via competition) suitable developers to engage in development projects (Lindblad 2020). Municipal plans, however, can be rigid and slow to adapt to changing circumstances. Nonetheless, they pose significant potential for lifting barriers to innovation in wood construction. Building height restrictions stipulated in zoning regulations are a common obstacle, often favouring height in metres over the number of storeys. This would appear to disadvantage certain types of wood construction as wood beams and slabs are thicker than their concrete equivalent, thus increasing the overall height in relation to the same number of storeys. In many cases, this means that choosing wood as the main construction material implies a one-storey reduction to the building. As developers will generally try to maximise the gross constructed area, wood-based alternatives are often ruled out due to financial cost-benefit considerations. Updating and revising municipal planning and zoning regulations can, therefore, generate considerable new market opportunities (Interview 4.2).

Finally, another instrument often used by municipalities is 'land development agreements'. The legislation allows municipalities a certain leeway in defining the specific conditions and requirements for more detailed planning based on existing internal policy documents and targets (Lindblad 2020), e.g. setting carbon emissions limit values based on climate targets (Interview 4.6). Via land allocation agreements, municipalities can favour wood construction in upcoming project proposals. For example, when formulating its 2005 strategy, Växjö municipality explicitly stated that it would actively use land allocation and land development agreements as a method to increase and define new areas for wood construction, e.g., Torparängen. This also formed the basis for discussions between developers and contractors willing to work with wood (Lindblad 2020). In Skellefteå, the city stipulates that housing areas should be 'attractive' and 'sustainable', which can be greatly assisted by the widespread use of wood (Interview 4.7). These slightly more vague aspirations are often used by municipalities, as the Building and Planning Act restricts directly favouring wood construction and limits the insertion of specific technical requirements such as material specifications in land development projects (Lindblad 2020). Thus, sub-national agreements are possible in municipal land development, as it is the owner (the municipality) who sets the terms and conditions for the land-use outcome.

In Finland, municipal planning

has thus far been the most influential tool in supporting multi-storey wood construction, particularly in scaling up production volumes and processes, leading to increased knowledge sharing and experience across the board. This has generated useful knowledge of best practices and solutions and has enabled the wood construction sector to access market sectors formerly dominated by the concrete and steel industries. For example, Jyväskylä has initiated wood construction zones, and this practice has been replicated by Turku, Vantaa and, more recently, Helsinki (Interview 4.12). Zoning can prove to be an effective measure for cities and municipalities to impact climate emissions. This can take the form of mandatory carbon footprint assessments of city-owned projects or making Life Cycle Assessments compulsory in land sale competitions, as is the case in Helsinki (OneClick 2022). Most importantly, the new 2016 Procurement Act allowed Finnish municipalities and cities to use public procurement processes to support wood construction, as the use of wood can be one of the stipulated criteria when calling for proposals. Other methods include insisting on a building's carbon footprint specifications as part of the public procurement process, which may favour wood as a material (especially if the municipality already has a carbon neutrality strategy), allocating and reserving prime building sites for wood construction projects, or invoking emission-reduction goals when granting building permits (Mölsä 2021; Ympäristöministeriö 2022b).

'Green procurement' is perhaps an even more powerful tool for steering development to include broader municipal interests. The term green procurement simply refers to the use of public procurement to advance the green agenda and environmental sustainability. Public procurement includes all contracts entered into by public authorities for the provision of buildings, hospitals, care homes, meals in schools and other services. Again, while unable to set technical requirements directly, municipalities can impose regulatory standards that include climate impact assessments or weight stipulations to avoid wood construction being outcompeted during the bidding phase. This has been a crucial instrument in boosting timber construction development, where municipalities have favoured its use in schools, sports and event venues and municipally-owned housing projects. For instance, Skellefteå in Sweden finances a significant share of all 'green financed' developments (Interview 4.6). Since 2016, Finnish municipalities have been able to make 'green investments' in environmentally friendly projects in the form of affordable loans or leases. The majority of these projects have been schools or day-care centres constructed in wood (Puu-lehti 2017). By investing in timber construction, municipalities have helped expand the market sector by encouraging the industry to experiment, to learn and broaden experience while stimulating supply-chain expansion and, most importantly, by assuming and sharing some of the risks involved.

Governance and soft approaches

Aside from administering public policy tools, municipalities also play an important role in the day-to-day co-ordination of industry, research, civil society and different actors to encourage and facilitate the implementation of new ideas, projects and knowledge of different issues. Normally, the contractor shoulders the financial risks in any given construction project. Unsurprisingly, most companies, therefore, adopt a cautious approach, choosing to remain within their area of expertise, where they can most accurately calculate costs, time spent and assess all involved risks. However, innovative projects, such as wood building, imply uncharted territory and greater risk taking. Establishing common ground and trust among key stakeholders is a prerequisite for tackling these new ventures. Careful management and sharing of risk 'ownership' has been a key success factor in enabling more ground-breaking projects, such as the Sara Cultural Centre in Skellefteå (Interview 4.4).

Lindblad (2020) suggests that there is evidence of even bolder changes in municipal governance. The author notes that in Växjö, private companies, research institutions and other actors have become more directly involved in the building and planning processes surrounding proposed wood-building solutions. One specific example is the formal partnership established between Växjö municipality, developers and university partners around land allocation agreements (ibid.). These forms of partnerships have also

been created in the Vallen, Pelarsalen and Torparängen districts, with the intention of supporting research of these processes (ibid.). Skellefteå municipality provides another example, where it is responsible for co-ordinating the Wood Innovation Cluster. Established in 2017, it brings together regional representatives and wood-building experts from industry, research and the municipality. It aims to co-ordinate strategic efforts for the industry within the region and to conduct research, education and experimental activities (Interview 4.7; Skellefteå.se 2023). One important development has been the T2 College, established in 2016 as a joint venture between industry, municipalities and upper secondary schools with the aim of developing and creating conditions for industrial skills and training in the region.

Finally, municipal marketing and branding have also proved effective in overcoming regulatory barriers. For instance, Malmö and Växjö have supported wood construction in more subtle ways, such as using images featuring wood construction and its benefits in development site presentations, thus influencing architects' proposals (Interview 4.6). Similarly, the increased focus on green cities has generated a desire to create positive examples among Swedish planners, architects and engineers (Andersson 2020). Municipalities such as Skellefteå and Växjö have, from an early stage, initiated study tours under the umbrella concept 'wood house safaris' (Andersson 2020). These are intended to generate knowledge and experience for a broad range of participants, such

as real estate developers, engineers, building contractors, architects, planners, politicians and researchers (ibid.). Another subtle way of nudging contractors to choose wood, one practised by Skellefteå, is requesting a justification for the choice of materials in new projects. The municipality then invites contractors to a workshop with researchers to identify solutions to possible problems that might arise through wood construction (Interview 4.7).

On the flip side, there are a number of critical issues pertaining to the sometimes ambiguous role played by public institutions. Authorities and industry partners can struggle with conflicting legislation and policy goals, e.g. free competition and material-neutrality versus carbon-neutrality goals and wood strategies. The principle of material neutrality may have affected the willingness of some Finnish and Swedish municipalities to act in ways that favour wood or any other alternative with a lower carbon footprint. At the same time, some believe that the approach of not picking 'winners' (e.g. wood) triggers other innovations that utilise different types of products and hybrid materials. Furthermore, the lack of technical specifications, i.e., wood, in bidding processes, which directly contradicts the municipalities' stated policy goals of increasing wood construction, can generate confusion among developers regarding the expectations and criteria used in the selection of winning projects. For example, in an evaluation of the land allocation process used by Växjö municipality in the Torparängen area, which had been

designated for wood construction, both developers and private citizens were critical of possible elements of subjectivity within the procurement process (Lindblad 2020). Despite the evaluation process set in place, developers struggled to interpret the municipality's expectations (ibid.). There also seemed to be some misunderstanding of who the client was exactly, as the municipality saw itself as a "seller of land", whereas the developers saw it as "a buyer of a building solution". In other words, municipalities may lack experience in designing processes and setting clear criteria for evaluating proposals in a structured and objective way. This can be observed in the somewhat ad-hoc approaches and bases for decisions that municipalities resort to when selecting winning bids.

4.5. Systems perspective to innovation in wood construction

According to one expert: "in the construction industry, we have product and process innovations but also systemic innovations" (Interview 4.11). Systemic innovations "include organisational and 'actor-role' innovations", which, according to the expert, describes the essence of systems integration where separate systems and sub-systems become interconnected in new ways (Figure 6). Technologies transcend and cross-fertilise sectors towards new ends, and novel actors emerge, as well as new ties between actors and supply chains. Meanwhile, established players can change roles, adapting to new conditions and exploring new opportunities (ibid.).

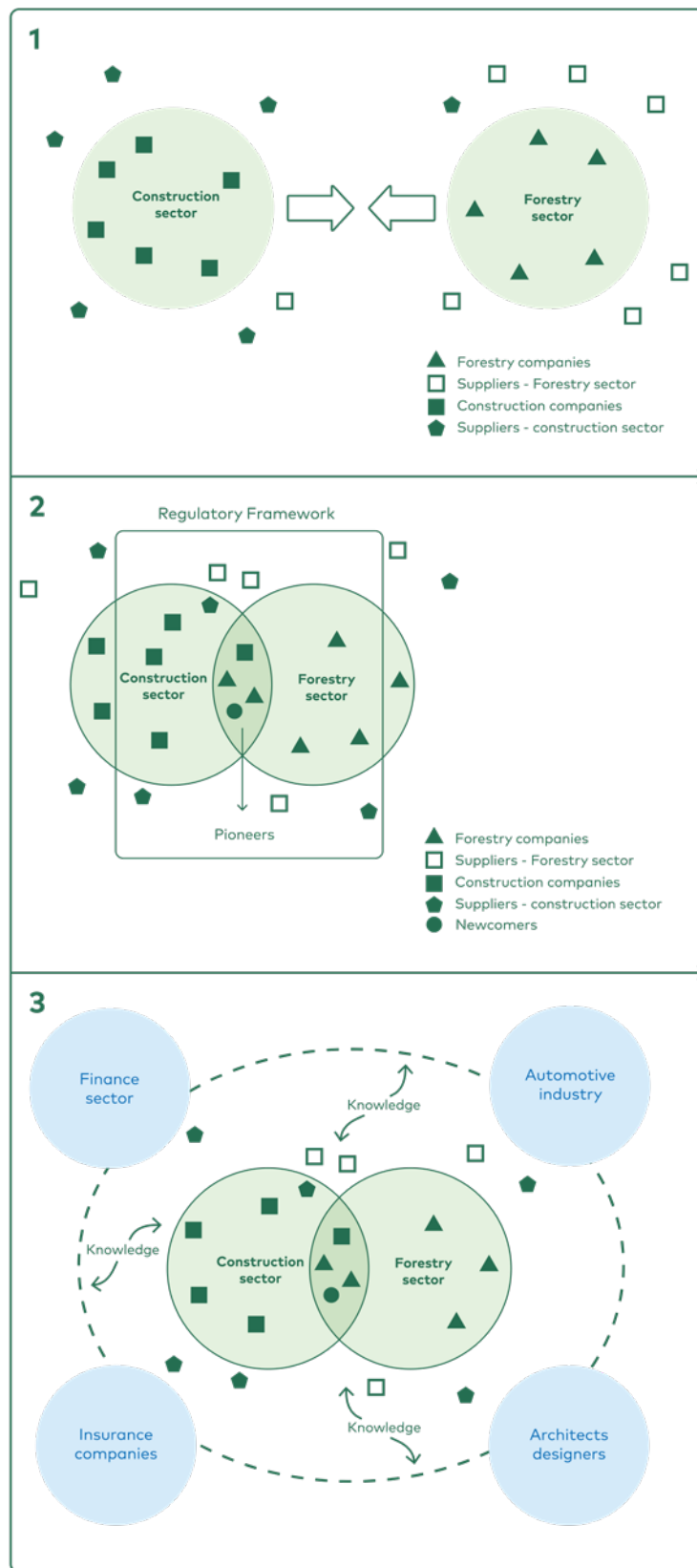


Figure 6: Systems integration of construction and forestry sectors & cross-fertilisation with other sectors. Source: Authors. Design: Kotryna Juškaitė, Nordregio.

Barriers to wood construction discussed in previous chapters point towards structural inertia, which cannot be disrupted without systemic changes to overall construction, forestry and other related sectors: from legislation and policy to market conditions, funding structures, governance and co-operation and finally a profound behavioural and cultural change. For over a century, building systems based on concrete and steel have maintained an unchallenged dominance, where established actors and lobby groups have had little or no competition in the marketplace (Interviews 4.1, 4.11). Over time, material suppliers, construction companies, real estate companies and other players along the supply chain have welded together a strong, mutually dependent relationship, making it difficult for even powerful industries such as forestry to pry open these links. The unchallenged status quo was reinforced by large investments, well-established supply chains, successful business models, funding mechanisms designed for a specific type of construction, a long tradition of established practices and vast accumulated knowledge. Therefore, the well-functioning status quo offers no specific incentive to established actors to enter a new playing field: one which entails risks, new knowledge, new investments, new business models and a re-organisation of the construction process and partnerships. For some, introducing wood as a construction option represented a leap into the unknown. Added to that, the infant wood construction industry, still taking baby steps but nonetheless

experimenting and solving all types of challenges, be they technical, regulatory, financial, or cultural, appeared far too utopian or unrealistic to capture and expand a niche market. At a systemic level, the effects of structural inertia are visible in very tangible forms: for example, the reluctance and sluggishness of actors such as banks and insurance companies to offer more flexible financing options that take different building processes into consideration. Although this is now changing, the emergence of multi-storey wood building has only become possible through the involvement of a handful of pioneering companies and municipalities that bypassed the established actors and processes, built the first pilot schemes and gradually created competing business ecosystems. Investing in technological innovation and knowledge-building, facilitating co-operation across sectors, academia, policymakers and public authorities is thus an enabler of systemic change. In what follows, we will discuss some of the issues that facilitate or hamper systemic change.

Knowledge building

Co-ordinated knowledge building efforts are vital because the lack of information about wood as a construction material is one of the major barriers hindering the development of the sector. As seen in Ch.4, there have been several efforts at national level in both Sweden and Finland, including several research programmes, since the beginning of the 1990s, and state funding has allowed a more detailed examination of practical problems

such as acoustics and fire safety and facilitated the testing of different construction systems (Interview 4.1). However, most advances in engineered wood products or solving the associated technical problems have been made either by the pioneering companies themselves or through their own funding. In addition to these examples of technical research, changing the current education system through which many civil engineers, planners, architects and constructors gain their expertise remains an important but complicated task. Unless otherwise well-informed, these actors still expect wood to behave similarly to steel, which can lead to unfavourable experiences that reinforce negative stereotypes about wood as a material (Interview 4.3). The notoriously expensive publicly procured wooden music hall in Lahti has long served as an example of the perils of wood construction (Mölsä 2021).

In addition to technical research, the wood industry collectively has played an important role in generating awareness, for example, by creating open standards. In the future, construction companies could continue to make it easier for customers to arrive at cost estimations by setting prices more clearly to reflect the real costs of building in wood (Interview 4.13). Resource banks featuring exemplary solutions or templates for alternative co-operation agreements based on life-cycle thinking could be another way of using knowledge and experience to direct public resources more efficiently (Paavola 2019). Efforts to synchronise business

practices have been complicated by the fact that all the Nordic countries (not to mention the other EU members) continue to have and follow their own construction standards and regulations (Interview 4.3).

Perceptions

Since wood is still considered a novel material and a more widespread knowledge of it is sorely lacking, anything that goes wrong with wooden buildings can quickly become newsworthy, reinforcing possible negative stereotypes. Therefore, some experts favour safer projects such as multi-storey apartment blocks (compared to tall, experimental buildings) as the best strategic approach to increasing market share (Interview 4.11). As an example of negative perceptions, Finland's key breakthrough in wood construction experiments gave mixed results. In 1995, the fire laboratory of the Technical Research Centre of Finland (VTT) succeeded in exposing wooden frames to fire for over an hour, which led to the green-lighting of a three-storey apartment building in Helsinki. However, the final costs of this pilot project escalated far beyond the initial estimates, leading to the sacking of the construction company's CEO and a more general scepticism towards wood as a material (Rakennuslehti 2016). Behavioural factors influencing stakeholder ecosystems have considerable influence and come in many shapes and sizes. In addition to common fears associating wood with fire hazards, mould and moisture, public opposition may also be swayed by fears of deforestation or

unsustainable forest management. This is especially true outside the Nordic countries, where deforestation of primary forests remains common (Interview 4.11). However, standard forest management practices in the Nordic countries are also increasingly alleged to be unsustainable. To combat some of the negative associations common to wood construction and the industry, advocates posit a wide spectrum of factors that should be taken into consideration, including broader societal values, perceptions and attitudes towards the material (both real or imaginary), planning systems and public procurement, general rules and legislation, certification schemes, timber industry supply options (material-wise) and their search for new markets and the attention of architects. 'Wood house safaris' is one such initiative in Växjö and Skellefteå municipalities, intending to challenge the inertia posed by negative perceptions and fears. Beyond simply increasing awareness, these safaris are an effective way of selling the idea of 'success', which can hopefully form a self-reinforcing cycle in which new projects and investments are attracted to examples of previous success stories and narratives.

Networks

Overcoming structural inertia and wood's successes in gaining a foothold in the construction market over decades is closely tied to building and relying on both formal and informal networks and actors. Many failures can often be traced back to a lack of support systems. One of the most concentrated efforts to build

networks and increase cross-sectoral co-operation in Sweden has been the platform established by Trästad Sverige, discussed in Ch. 4. During periods where no state funding has been available, active members have themselves kept the momentum going. Again, this underscores the importance of the role of active regional players. Regional and local representatives were closely involved in Trästad Sverige from the beginning, including the governor of the county administrative board of Västerbotten, who also chaired the board of Trästad Sverige.

Place-based developments

Driving industrial transformations on a national level is often too great an undertaking to fully succeed. Local, place-based initiatives can prove more effective in mobilising local businesses and other actors and creating common ground. Geography generally determines regions' industrial legacy, the resources available, the knowledge and skills present, the established networks at hand and the 'tacit knowledge' or more implicit societal norms or 'ways-to-do-things'. This local level represents a more 'human scale' where people know each other and have built relationships based on trust. Skellefteå and the broader Västerbotten region serve as a good example, with many pointing to the short distance (metaphorically) between people in the industry, local authorities and the university as being a crucial element in bringing them together to focus on common goals and define practical paths to achieve them. For instance, this was the municipality that commissioned

the first wooden multi-storey building as early as 1995, the same year the new building codes entered into force. At the same time, Martinsons, the local wood company revived the production of Mass Timber products, began pilot projects and made long-term investments. Moreover, place-based developments are often the result of the capacity of individuals to mobilise change. In Skellefteå, one visionary politician was a significant figure in pushing for change. Skellefteå's ability to tap into its specific strengths, resources and historical roots has been a decisive factor in its success in promoting wood construction. As owner of Skellefteå Kraft, a large energy company, Skebo, the municipal housing company and co-owner of Kommuninvest, a bank that offers 'green loans' with low interest rates, the municipality is centrally placed to effect change on numerous levels. In addition, as is common across Sweden, much of the land is also municipally owned. Skellefteå municipality is, therefore, in a position to lead by example and has constructed many of the city's buildings, including public schools, event venues and parking lots, as well as apartment buildings in wood. By working with the county's strong industrial forestry legacy, the city has been able to provide a less interventionist and more organic approach to wood construction policies (Interview 4.7).

Development can also be driven at an industrial far remove, as is the case in Finland, where urban areas have become forerunners, again highlighting the role that zoning and local sustainability goals can take

in supporting wood construction (Interview 4.12; WoodJoensuu 2022). Place is also relevant when assessing the environmental footprint of construction, as material proximity determines related transport emissions. In addition to reviewing the sustainability of material itself, it is essential to assess, e.g. which materials are available locally and if these are durable under local conditions. For example, the sustainability of wood construction in Iceland, where most construction materials are imported, should be evaluated differently than in the forest regions of Sweden and Finland (Palmadottir at a panel debate during the Icelandic Democracy Festival, Fundur fólksins, 2022).

On the other hand, global perspectives and national and international level networks also play a key role as they allow actors to transcend the limits of geography. Since joining the EU, Region Västerbotten has found it easier to gain allies in Brussels than in Stockholm. As one local civil servant explained, actors and networks in the region have benefitted hugely from expanding co-operation and connecting value chains across international borders (Interview 4.10).

Funding structures

As a nascent industry or sub-sector, wood construction is (or was in the case of Sweden) a formerly market outlier, which in turn affected the possibility of accessing necessary funding. In addition, the lack of building experience, at least in the early phases, was deemed too risky for insurance companies and thus

incurred higher fees for wood-based projects. The common financial structure used by banks can also be problematic for wood construction projects because the work phases are structured and organised differently. Normally, banks make payments to constructors at different stages of the building process, e.g. foundations, framing and completion of the interiors and exteriors, as each concluded phase can be used as a value guarantee for finished work. Wooden building on the other hand, especially modular building systems, takes place for the most part offsite in a factory and is then rapidly assembled onsite. Standard loan structures can effectively restrain small and medium-sized companies lacking the necessary cash flow to invest in the entire building process from A to Z. In Sweden, municipalities have been able to circumvent these funding problems by applying for 'green loans' from Svenska Kommuninvest, which is a collectively owned investment bank by the municipalities and supports their interests. Municipally led projects that classify as 'Environmental Buildings' in accordance with the 'Miljöbyggnad' certification scheme can be drawn down at notably lower interest rates (Interview 4.7). In general, however, the wider banking sector has been slow to adapt. And although many companies have found ways around these financial obstacles, increases in wood building construction call for a more systematic change in banks' funding structures in relation to the sector (Interview 4.2).

Cost-effectiveness

In the early days of wood construction, insufficient networks

and lack of experience rendered it less cost-effective than traditional construction methods. This is a situation facing many emerging industries, where contractors will continue to favour cost-effectiveness over sustainability (Interview 4.11). The differences in market conditions between Sweden and Finland can be partially traced back to the lack of systemic efforts to invest in research, development and innovation in Finland. In the 1960s, Sweden set aside a portion of all salaries, earmarked the money specifically for research and used these funds to establish Bygghälsöfundersrådet, which today finances research for hundreds of millions of SEK annually. A similar initiative in Finland was rejected (Rakennuslehti 2016). Finnish construction companies have struggled to develop efficient construction processes and, therefore, face higher costs to a much greater extent than their Swedish peers. As the timeline for building and erecting prefabricated buildings is predictable, increased experience and know-how should lessen the burden of perceived risks of wood construction over time. Another important factor to consider would be the collation of risk analysis data, which forms the basis for many financial and insurance decisions (Interview 4.6).

Systems changing

One expert compared operating in the construction market to training an army (Interview 4.2). Both processes are carried out in a highly similar way, so that any new or additional components must be carefully assessed and aligned with existing

parts of the system. Since most new endeavours imply a risk of not meeting the pre-fixed and calculated price for the customers, companies tend to avoid new solutions, even if these might prove more efficient in the long run. However, there are signs of change on the horizon. Some construction companies are becoming more involved in wood construction because they identify a clearly growing market demand. This new involvement entails establishing more domestic factories for mass timber products and modular units but also allowing new players and start-ups to fill existing market gaps with innovative products and solutions, leading to a further rapid increase in volumes. As the market grows, all involved processes become more cost-effective. As the same expert puts it, "you just need to shake the ketchup bottle a bit and it all comes out at once" (Interview 4.2). But who is actually responsible for shaking the bottle? In this scenario, municipalities play a key role in co-ordinating action and establishing ties between key players. However, the municipal governance and planning systems can function both as barriers and useful instruments for achieving change. Planning systems and zoning regulations have, for the most part, been based on conventional construction systems, which represents a problem for certain wood construction alternatives. To enable wood construction to compete on a levelling footing with conventional construction, planning systems have had to be adapted. Indeed, in some of the successful cases outlined above, municipalities have used public procurement and

planning systems strategically to favour wood construction and circumvent systemic barriers.

4.6. Conclusions: the roles of actors

This case study shows that the development of the wood construction sector is complex and causality cannot be attributed to single actors or decisions but to the sum of many and varied efforts. Change originates at the intersection of key players, where co-operation functions as a catalyst and trust forms the glue that binds them. The fact that there is no "golden ticket", no singular innovation, event, or driver that explains the longer gestation of multi-storey wood construction implies that the nature of innovation differs from other types of ground-breaking innovations. For instance, the smartphone had an immediate global effect, rapidly replacing and rendering obsolete previous technologies and products, profoundly transforming the industry, the way we communicate and society at large. However, there is no rush to adopt timber as a construction alternative or to render established building systems obsolete, nor should we expect a societal impact of the same magnitude as with the smartphone. However, albeit at a slower pace, wood construction does appear to have the potential to profoundly transform the construction industry in certain parts of the world, including the Nordic countries (Interview 4.11). This will not mean a complete divergence from existing building systems and actors but will disrupt current business ecosystems and business

models and add diversity to existing market options. In short, this is a case of systems innovation rather than a product or technological innovation alone.

In this study, we have identified a number of key moments or events in history that have triggered major developments in the form of technological innovation or in building capacity and knowledge. From the contracts issued by the Swedish military in the 1940s, the Million Home Programme in the 1960s–70s, the rapid post-war urbanisation processes (and reconstruction in the case of Finland), to more recent changes in legislation, first enabling multi-storey building in wood and the more recent climate declarations and limit-values set on emissions. The state, both in Sweden and Finland, has enabled technological development by funding and supporting R&D programmes and setting strategies for development. All these events, past and present, highlight the strong influence of state policy and legislation in boosting the wood construction market. This despite the fact that the state originally halted development for a century via the prohibition on MSWC imposed in the late 1800s.

Accession to the EU and the associated legislative harmonisation has also triggered important changes on many fronts, even if unintentionally. The EU has played a significant role in setting environmental goals, as well as underpinning more soft approaches, such as the voluntary recommendations for green procurement in office construction.

However, once the rules of the game have changed, the role of the

national and supra-national level becomes less prominent, whereas sub-national authorities play a more practical role in supporting development in several ways. Selected municipalities reacted quickly to the legislative changes and expanded local industrial and economic competitive advantages. Their closer proximity to business networks and other community actors allowed them, often informally, to create momentum and a common vision around these new opportunities. Establishing trust relations with businesses was key: taking risks, investing in new infrastructure and working towards securing a place in the new market niche. By participating in knowledge creation projects (e.g. Trästad 2012) and commissioning the first pilot buildings, municipalities have also assumed a more entrepreneurial role. And by providing 'green finance', municipalities have stimulated market creation and supported companies in their efforts to expand capacity and experience.

The private sector plays a more direct role in industrial development: from exploring and investing in product development, designing new building systems and piloting them, to finally producing materials, building elements and erecting finished buildings. However, the private sector is heterogeneous and includes many actors along the supply chains. Only a handful of these can be considered risk-taking pioneers, whereas the majority, at least in the early development stages, are part of the establishment and can be resistant to change or are more comfortable with the status

quo. These include contractors, real estate companies, banks and insurance companies. With regard to the pioneering companies, some have come from outside the established business ecosystem (wood industry), while others have emerged from inside the construction sector itself. However, no matter their starting point, all the companies have had to circumvent existing actors, supply chains and business and finance institutions in order to improve and broaden their market access.

R&D has been an essential mechanism for progress, whether within academia, the industry or in partnership. The public sector and academia were quick to recognise the importance of funding large-scale R&D programmes for knowledge development and the value of creating triple helix partnerships to solve technical and systemic challenges. Academic and education programmes have also been successful in generating awareness of the benefits of wood construction.

Banks and insurance companies have acted more as a deterrent, being slow to adapt and unwilling to offer novel solutions to the nascent industry, which, requires substantial risk capital and support given its outlier status within the market. Finally, changing values within society have increased pressure on policymakers and the industry to deliver the sustainability goals and the green agenda. These values have also had a positive effect on the perceptions of modern wood buildings, being seen as both status symbol and emblematic of urban renewal.

Changing roles of actors

When examining the role of different actors, it is important to recognise their evolution over time. For example, authorities have moved beyond their normal administrative tasks to become drivers of development and entrepreneurial processes. Municipalities have learnt to navigate legislation and favour wood construction despite material neutrality demands. When entering new market segments or engaging in new parts of the supply chains, private companies have also proved that they can evolve. For instance, to overcome the well-established actors' resistance or financiers' reluctance to support their ventures, pioneer companies have transformed themselves from being solely wood industry players to becoming construction companies, or vice versa, or have simply established parallel companies to deliver supplementary services, e.g. design and consulting. This has proven an invaluable process for building new capacities and facilitating the movement and exchange of knowledge and professionals across industries. As a result of these multitudes of changes, business ecosystems have been vitally transformed.

In short, the systemic nature of industrial transformation means that no single interest group, no matter how powerful, nor one single factor can be said to bear responsibility for driving change. Systems barriers are embedded within the interlinkages between actors, nodes in the supply chains and the overall industry's organisation. Structural inertia stems from long traditions and

practices, network gaps, insufficient knowledge, experience and skills and the inherent risks involved in developing a new industry. In such a situation, even major legislative and policy shifts may not automatically lead to an upsurge in demand, as wood companies quickly realised after their initial optimistic reception to the 1994 regulative reforms. Instead of waiting for transition to occur by itself, actors were forced to directly support the fledgling industry

by establishing new partnerships and finding creative ways to increase market access. One method has been to support wood construction 'champions', thus creating a new customer base with the help of successful pilot projects, which in turn creates more demand. All in all, change emerges precisely at the intersection of key players where co-operation is paramount to boosting systems innovation.



Photo: Alex Kotomonov / Unsplash.com

5. Case Study 2: Nordic innovation systems dynamics in the protein shift

5.1. Introduction

In this case study, we explore the role of (change) agency in the 'protein shift' in the Nordic Region. To meet the carbon neutrality and other goals of Agenda 2030, the food system and the protein sub-system need to undergo major transformations. Many processes to stimulate this transition have already been set in motion on different fronts. These include changes to the broader regulatory frameworks and policies to support innovation and investment, as well as efforts to raise awareness among consumers.

The role of agency is dispersed across the value chains and is in many ways driven by sectoral agency through endogenous innovations. EU policy development plays a significant role in shaping the broader context within which these innovations emerge and businesses

operate. However, as we shall also see, sustainability narratives impact the actions of both businesses and policymakers – depending on how 'green' innovations are defined. Indeed, far from there being consensus on the rationale for a protein shift, there is instead a highly complex and heated debate about its ethical, sustainability, economic, cultural, societal and geographical implications. Disagreements touch on the very foundations of 'the problem' but also on what the solutions and outcomes of the transition should be. These competing visions make paving the way for a coherent policy framework more cumbersome. Therefore, investigating the potential for innovation for a protein shift will inevitably involve a discussion about the different views and contrasting narratives on sustainability and the ethical challenges that arise.

Competing narratives play a key role in guiding public opinion and investments. They also shape the regulatory and policy measures adopted by authorities.

The protein shift in the Nordic Region presents a potential new array of technological, policy and social innovations. With dynamic systems of innovation, Nordic countries and regions are in a favourable position to seize the opportunities for new business developments and avenues while responding to the sustainability goals. Considering the ongoing trends within the industry in the Nordic countries, the protein shift can be described as a process of diversification rather than a replacement of conventional food products and farming practices. While this diversification process is clearly generating economic opportunities for some regions and municipalities, a question mark hangs above the benefits for rural areas, as innovations seem to be emerging from areas closer to research centres or university campuses located in and around urban centres,

rather than conventional farms – for now. Another question mark surrounds what alternative protein products' business structure will look like and how the benefits will be distributed, as large and well-established corporations appear to be gaining more control over R&D and absorbing start-ups and SMEs that offer innovative technologies and products.

This case study first addresses how the "protein shift" or "protein transition" is defined and framed by competing narratives. Second, it dives into the technical aspects surrounding industrial development and technological innovation in the protein production space. Third, the case study moves on to the role of institutional norms and consumer behaviour and what roles these play in pushing the protein shift in new directions. And finally, the case elaborates on the systems perspectives and the interplay between policy and regulation, entrepreneurial agency and place-based developments.

Info Box 3: Key terms

** Many terms are emerging related to protein products, sources of proteins, novel or traditional. Many of which are used interchangeably by different academic strains or actors, yet often having different meanings. For clarity, we list and define some of these key terms here.*

Alternative proteins refers to protein products deriving from plants or animal cells or by means of fermentation, which are specifically aimed at replacing animal-sourced protein. The term is often used interchangeably with similar terms, yet not meaning the same, such as unconventional proteins, meat analogues, and 'novel protein food products' (NPFPs).

Animal sourced protein foods (ASPFs) refers to foods that derive from animal sources, including eggs, dairy, meat and fish.

Bioavailability is the degree to which the body can absorb and utilise nutrients from ingredients contained in a particular food source.

Conventional proteins are, generally, referred to food products that have been traditionally a **global** staple source of protein, including animal sourced protein foods (ASPFs) and plant sourced protein foods (PSPFs). However, staple foods also vary based on cultural context.

Cellular agriculture is the biotechnological process used to grow agricultural products (meats, milk, egg white protein) from cell cultures instead of livestock.

Cultivated meat: Also known as cultured, in-vitro, or clean meat. It is genuine meat grown through culturing animal cells (cellular agriculture) instead of in a living animal.

Meat analogues or **alternative meat** products are products designed to simulate meat products and meant as meat substitutes, including both land and marine animal products. **Plant-based meat** is a type of meat analogue created from plant-based ingredients.

Novel protein food products (NPFs) refer to foods that have not been considered a global staple source of protein until recently, or that are heavily processed and transformed for human consumption. These include e.g., powdered protein supplements, second generation meat analogues, insect-based foods, cell-cultured meat.

Plant sourced protein foods (PSPFs) are proteins that exist in unprocessed or minimally processed plant tissue, e.g., legumes and pulses.

Protein shift or protein transition is the dietary transition away from resource-intensive protein sources with negative environmental impact, to sources with a lower environmental footprint and better health profile.

Unconventional proteins in this case study refer to protein sources that have not been used traditionally in Nordic diets such as insects, but also to innovative uses of micro-organisms (via fermentation) and mycelia. This also covers innovations in plant-based and animal-based protein production that has resulted in meat analogues and cultured meat. The definition of conventional and unconventional protein sources and food products consumed is largely context and culturally dependent.

Sources: Clayton et al., 2018; European Medicines Agency, n.d.; (Good Food Institute, n.d.); Mayer Labba et al. 2020; Katz-Rosene et al., 2023; Khan, 2022.

5.2. The protein shift

Increased awareness of the different but interlinked sustainability and societal challenges has generated support for a regime change in the food systems. Within the protein sub-system, this process is referred to as the 'protein shift' or 'protein transition'. To be better able to

understand the implications of the protein shift, the potential of innovation, the roles of different actors and the spatial/territorial dimension, we must first be cognisant of 1) the sustainability challenges and 2) the changes proposed. This section addresses these two aspects.

5.3. Proteins: a cocktail of sustainability challenges

The global food system is facing several different and interlinked challenges relevant to several sustainable development goals (SDGs) and different industries. More specifically for the protein sub-system, sustainability challenges can be grouped into five main topics, including i) food insecurity, ii) malnutrition and ill health, iii) unethical production practices, iv) climate change and biodiversity decline; and v) disruptions in social, economic and cultural prosperity (Katz-Rosene et al., 2023).

The first challenge is to feed a growing global population: this is expected to increase food demand by 35% to 56% by 2050, compared to 2010 levels (van Dijk et al., 2021). Satisfying this growing demand without major environmental consequences will require a regime shift in the food system. Protein production, more specifically, stands out as a major challenge, with Animal Sourced Protein Foods (ASPFs) alone contributing to 14.5% of global GHG emissions (Béné & Lundy, 2023). Livestock is also linked

to deforestation and biodiversity loss in many parts of the world.

Plant Sourced Protein Foods (PSPFs) account for up to 60% of protein consumption worldwide (Clayton et al., 2018). Yet, there are significant geographical differences ranging from ~80% reliance on PSPFs in Asia (except China) and Sub-Saharan Africa to ca. ~60% of total protein intake coming from ASPFs in the US and Canada (ibid; see Figure 7). It is in the excessive meat-consuming Western societies where the market for 'alternative proteins' and 'meat analogues' (products intended to directly substitute meat) have gained the most traction. However, these geographical differences may partly have less to do with culture and more to do with wealth – as there is a direct correlation between developing countries' economic growth and a "shift to a more Westernized diet reliant on animal products" (Clayton et al., 2018). The problem with this trend is that "Western dietary patterns cannot be sustained if practised by the entire world's population" (Katz-Rosene et al., 2023).

People Are Eating More Protein than They Need - Especially in Wealthy Regions

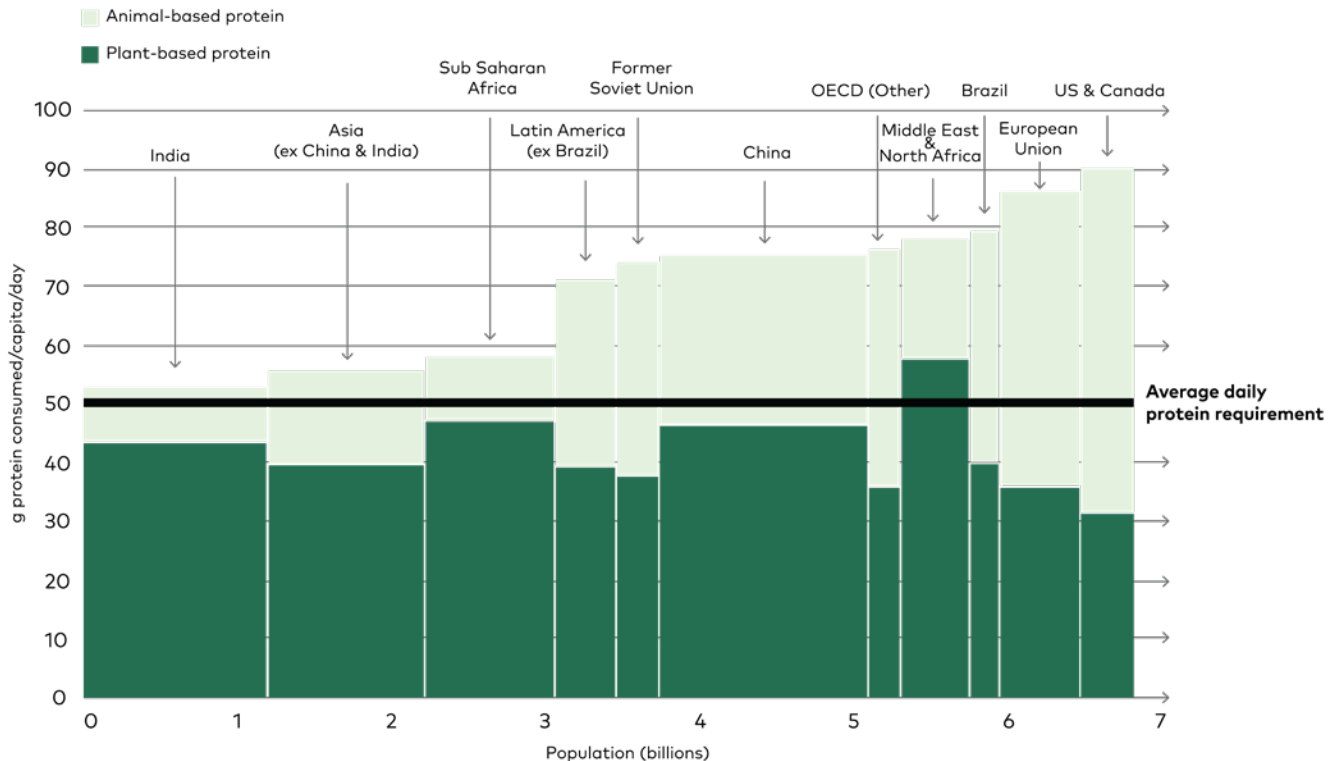


Figure 7: Per capita daily protein consumption by world region and protein source (plant-based vs. animal-based). Source: Adapted from World Resources Institute (in Clayton et al., 2018). Re-design: Kotryna Juškaitė, Nordregio.

A second challenge is connected to malnutrition. Over a third of the global population suffers from health issues related to food and diet (Katz-Rosene et al., 2023). There are more than 1.9 billion overweight people in the world, while at the same time, close to 700 million people "suffer from underweight, stunted growth, or 'wasting'" (World Health Organization, 2019 in Katz-Rosene et al., 2023). Protein-rich products are both a contributing cause and a means to tackling this 'double burden'

(ibid.). While excessive consumption of ASPFs is associated with increased risks of stroke, type-2 diabetes and other diseases, increasing protein-rich foods is a necessary element in battling nutrient deficiency (Béné & Lundy, 2023). However, physiological needs are not only determined by quantity but also by the quality and type of proteins (Interview 5.2). The human body cannot synthesise all types of amino acids² and is unable to digest and obtain nutrients from all types of foods. Therefore, diet

² Amino acids are organic compounds that serve as the building blocks of proteins. Essential amino acids are those that the human body cannot produce and must come from the food we eat. Non-essential amino acids are naturally synthesised in the body.

needs to consist of a variety of food products to ensure a balanced and adequate amount and type of proteins consumed (Clayton et al., 2018).

Furthermore, ethical questions surrounding protein sourcing constitute a third and highly contentious challenge. These include several issues ranging from the harmful effects of production systems on the natural environment to animal rights and welfare, workers' wellbeing, decent employment and inclusiveness, as well as concerns about genetic engineering. According to Katz-Rosene et al. (2023), many people oppose practices that transgress their personal ethical boundaries, such as intensive animal farming, genetic manipulation or cellular agriculture.

Finally, the way the transformation of the food system is affecting many communities' and individuals' livelihoods in terms of economic prosperity, the cultural and social fabric is another significant challenge often overlooked in climate policies. While many developments, be they technological, regulatory or behavioural, are presented as positive for society and the environment, they will inevitably lead to a "range of outcomes resulting in a set of winners and losers, particularly between urban and rural inhabitants, between rich and poor and between the owners and users of intellectual capital" (Katz-Rosene et al., 2023).

5.4. Sustainability narratives of the 'protein shift'

Support for the protein shift emerges from the increased awareness of sustainability challenges. However,

narratives are often built on one-sided or partial accounts of the different environmental, social and economic challenges. Generally, the protein shift is referred to as "the transition from a heavy red-meat consuming world to a more plant-based food system" (Béné & Lundy, 2023). There are many sustainability and health benefits of a shift from meat to plant, particularly legumes, as they have a higher protein content and lower use of fertilisers (as they fix their own nitrogen) compared to other types of crops (Blom, et al., 2022). Nonetheless, Mayer Labba et al. (2020) argue for a broader definition of the protein shift, conveying a more impartial account of the complex array of factors and sustainability implications that are at stake when inducing a systems change in the food sector. They define the 'protein shift' as:

”

a large-scale change in dietary patterns from use of protein from resource-intensive sources with negative environmental impact and large climate footprint, to sources with a lower climate and environmental footprint and a better health profile"

(Mayer Labba, et al., 2020).

With this broader definition of the protein shift, Mayer Labba, et al. (2020) intentionally avoid prescribing specifically what the alternatives should be and instead point to the sustainability and health challenges that ought to be addressed. This opens up a more

nuanced discussion of all the positive and negative factors, the plant-based or other products marketed as alternatives or 'green', as well as the opportunities that exist within livestock or aquaculture industries to make improvements (Interview 5.2).

For instance, one expert points out that many plant proteins are not necessarily healthy as they have a high salt content and low 'bioavailability' of iron and zinc (Interview 5.8). Another expert emphasises that there is a transparency gap surrounding the bioavailability of alternative protein products in the market, which is the extent to which the human organism can absorb and utilise nutrients from food ingredients (Interview 5.2). Therefore, consumers cannot be certain that they benefit from the nutritional contents stated on product labels.

The same expert also recognises the inefficiencies in conventional food industries. For example, a very large percentage of fish caught by Swedish fisheries goes to the production of biogas despite being perfectly fit for human consumption (Interview 5.2). Thus, the expert argues, a more holistic approach to sustainability is needed to address the challenges within the existing industries in tandem with developments in other supply chains and scientific fields. This is echoed by one of the co-founders of the Ocean Cluster in Iceland, who notes that "the world is now wasting around 10 million metric tonnes of perfectly good side streams of fish, because people don't know any better"; side streams which comprise all the remaining part of the fish once the filet has been extracted (Norden-

Estonia, 2023). He also notes that this waste contains what "probably (is) the best proteins in the world". Therefore, there may be a huge untapped potential for using seafood side streams while making the industry much more circular (ibid.).

Contextual differences are highly relevant. This becomes abundantly clear when zooming in on Western societies and, more specifically, the Nordic countries. Amilien and Notaker (2018) highlight the need to study food culture and consider the link between place, time and identity. In their thorough research on Nordic food traditions, they emphasise that traditions are ever-changing in response to innovations, wealth and influence from abroad. Indeed, Nordic cuisine and diets have significantly evolved over the centuries (Amilien & Notaker, 2018). Moreover, the authors also point to the relevance of territory in food production, as natural conditions vary significantly, from mountains, forests, valleys, fjords and lakes to plains and open moors, as well as from north to south, continental, or coastal (ibid.). For instance, "as a food-exporting country, Denmark has the highest percentage of arable land, while a main food export from Norway is fish" (Amilien & Notaker, 2018). However, they recognise that from a consumption point of view, geography plays a smaller role than it did in the past, given that increased wealth coupled with technological advancement has resulted in globalised food chains. From a production point of view, geography continues to matter significantly, although technology and climate change have also enhanced food

production in Nordic countries. Globally, contextual differences can be striking, for instance, between Western societies, overfed on red meat and countries where more meat consumption would be beneficial to the population. Therefore, context is key when designing any course of action. Indeed, while reducing meat consumption is recommended in Western societies, Béné & Lundy (2023) note that "large benefits [can be achieved] from modest increases in meat in the diets of the poor in sub-Saharan Africa" (Béné & Lundy, 2023).

Geography also significantly influences food production dynamics, particularly in crisis preparedness and food security. Recent global events, such as the war in Ukraine, the energy crisis and lessons from the COVID-19 pandemic underscore the importance of this relationship. A recent report to the Ministry of Agriculture and Food and the Ministry of Trade and Fisheries by the Office of the Auditor General of Norway states that "it is objectionable that arable land is not managed in a fully sustainable manner", pointing out that high-quality arable land is often repurposed for different uses. Furthermore, the report underscores the inadequacies in preparedness levels to address significant disruptions in access to food and feed (Office of the Auditor General of Norway, 2023, p. 9). Although Norway is almost entirely self-sufficient in meat, eggs and dairy, the building blocks on which this production depends are almost entirely imported. Increased production of high-quality and protein-rich crops for feed could increase self-sufficiency, the Auditor

General writes. However, while economic measures for stimulating such production are important, these measures need to be adapted to increase production (Office of the Auditor General of Norway, 2023).

Policies seeking changes in the production systems are difficult to implement, even incrementally in existing food production systems. Béné & Lundy (2023) argue that the protein shift involves "conflicting and painful trade-offs between economic, ethical, societal and environmental objectives and priorities". Because of these trade-offs, the 'protein question' is often presented as a 'wicked problem', a black-and-white argument, where the sustainability debate is pushing us to believe that there are only two opposing and irreconcilable flanks: "on one side, the pro-livestock supporters who advocate for protecting the meat industry and its activities and, on the other side, the pro-alternative-protein advocates who push for a replacement of red meat by other, more "sustainable" sources of protein" (Béné & Lundy, 2023). This has created a battle of narrative and counter-narrative, where the challenges described do not represent "reality as it is (i.e., complex, nuanced and often ambivalent)", but instead frame the problem by cherry-picking evidence that suits and strengthens the narrative's argument (ibid.). Béné & Lundy (2023) conclude that the current debate leads to a fallacious lock-in situation, preventing society from seeing the full picture and preventing us from entering a more constructive and solutions-oriented discussion.

Despite the lack of consensus, Katz-Rosene et al. (2023) explain that advocates on various sides of the debate offer very material pathways on how to conduct the protein shift, and these are worth analysing in detail. They identify three meta-narratives, understood as the path towards protein sustainability, with which like-minded actors associate. These three meta-narratives are constructed by identifying how different actors frame the problem (across sustainability challenges) and the course of action they propose. These sustainability challenges include i) food insecurity, ii) malnutrition and ill health, iii) unethical production practices, iv) climate change and biodiversity decline, and v) disruptions in social, economic and cultural prosperity. We summarise the three meta-narratives as follows:

1. The **'modernising protein'** meta-narrative centres around technological innovation and improved production processes as the main "mechanism for achieving sustainability in the global food system". Sustainability is to be achieved via the intensification of agriculture and aquaculture, improved efficiency by solving the technological deficiencies of existing production systems and improving the nutritional profile of protein foods (including ASPFs, PSPFs and Novel Protein Food Products [NPFs]) through, e.g., gene editing. Ethical challenges, including feeding the growing population and achieving high standards of animal welfare and workers' conditions, are

considered solvable via the implementation of technology, scientific knowledge and improved legislation. Precision agriculture, vertical farming, robotics and automation technologies are some of the ways of achieving efficiency and can also alleviate heavy or dangerous work for workers and improve animal welfare. Complementary technologies such as methane capture, feed additives and bioengineering can reduce GHG emissions even further. (Katz-Rosene et al., 2023)

2. The **'reconstituting protein'** meta-narrative seeks to achieve the sustainable food system transition by reducing animal protein consumption. The key concerns raised are the inefficiency of ASPFs production, animal mistreatment and the health risks of excess meat consumption. Advocates highlight the realistic possibility of feeding the global population via enriched PSPFs and NPFs. Members of this coalition deem the consumption of ASPFs and their consequences for the environment, health and animal suffering unnecessary and unjustifiable, given the availability of alternatives. Advancements in biotech, particularly cell-culture meat, are seen by some members of this coalition as a disrupting factor rendering conventional livestock farming obsolete. (Katz-Rosene et al., 2023)
3. The **'regenerating protein'** meta-narrative favours restoring "human-nature relationships within protein production and

consumption practices as a means of achieving sustainable development within the global agri-food sector". Industrialisation and globalisation of agri-food systems are considered the main causes of the problem. Sustainability is to be restored by "protecting the food sovereignty rights of pastoralists and locally-oriented food producing communities" and by prioritising locally sourced, seasonal and whole foods. Proponents advocate restoring traditional knowledge and production methods, such as permaculture, pasturing of livestock (e.g., rotational grazing), mixed animal-crop production and hunting. Community-oriented food production should result in healthier and more nutritious naturally-produced foods by eliminating the use of harmful pesticides and heavily processed products and growing animals by means of holistic and regenerative agriculture (including a series of management practices that nurture and restore soil health, capture carbon, protect the climate, water resources and biodiversity). Regenerative agriculture is considered a 'natural' and thus ethical way of growing food, both plant and animal. Consumption of animal proteins is highlighted as a natural part of human nutrition, and its removal is considered undesirable as it can lead to health problems, alter agricultural landscapes and have harmful socio-economic consequences. (Katz-Rosene et al., 2023)

From a policy perspective, what is critically relevant in relation to these three distinct meta-narratives is that they lead to different conclusions and recommendations about the type of measures that should be implemented and what the outcomes of a transformed food system and protein sub-system should be. The opportunities for innovations (technological, institutional-regulatory and behavioural-societal) will, therefore, be influenced by the manner in which these meta-narratives steer the societal and political debate and how this, in turn, is translated into actions by decision-makers, businesses and society. However, in order to move the debate forward and design pathways that are sensitive to the multi-dimensional challenges facing food systems, it should be necessary to avoid the black-or-white framing of the problem and allow for an open discussion about the negative and positive aspects of different agriculture and industrial processes and practices. In line with Katz-Rosene et al., (2023), the answer to increasing the resilience of the agri-food system and achieving the protein shift lies not in single solutions but in embracing multiple pathways. In turn, this would create a favourable playground for innovations to emerge from multiple scientific and industrial fields and from distinct cultural and geographical contexts.

5.5. Technological innovation & industrial development in the protein shift

The growing focus on the protein shift has expedited technological

innovation and industrial development in the production of conventional proteins, both PSFPs and ASFPs and unconventional proteins or NFPs and along their supply chains.

Some of the technologies used for the production of alternative protein products, like extrusion, have been in existence for a considerable time, for example, in the plastics industry, but also in the food sector, which has texturised soy proteins since the 1960s. However, a new wave of incremental innovations leading to a wider range of applications of extrusion has emerged in response to the sustainability agenda. Fermentation is another technology that is experiencing a second wind, given its millennial-long presence in food culture. Precision fermentation is frequently applied to efforts in developing mycoprotein, the main ingredient in the products sold by larger companies such as British company Quorn. Other innovations have also experienced a more recent surge, such as those used for cellular agriculture, which is used to produce cultivated or cultured meat and other animal-based products from cell cultures instead of livestock.

The type of technological and industrial development in the alternative proteins sector seems to follow certain patterns. In many cases, the type of product developed depends on the type of knowledge base available to the producers. Depending on the input factor, whether grass, fungi or pulses, the companies developing alternative protein products tend to lean either on analytical knowledge or

synthetic knowledge. By analytical knowledge, we refer to basic knowledge development, e.g., basic science, whereas with synthetic knowledge, we refer to already existing knowledge being used to solve practical issues. These two knowledge bases are both typical for innovation and product development in general, and they affect the type of activities and products a company produces (Zukauskaitė & Moodysson, 2016). The type of knowledge base chosen or available influences companies' choices of future partners. For instance, businesses aiming to develop ground-breaking new products tend to choose universities or academics as natural partners, whereas those developing and improving existing products may find different types of partners (ibid) in similar or relevant industries.

Zukauskaitė and Moodysson (2016) identified three distinct paths in the Swedish food sector based on these two knowledge bases: Extension (extending the existing developments in a linear way), renewal (related and new, yet incremental, innovation) and path creation (disruptive and novel innovations). Their paper focuses on the results of institutional influences on company activities and actors. These two paths can be discerned in a recent mapping of alternative protein businesses in the Nordic and Baltic regions (Wøien Meijer, 2023). There is a clear case of path extension and path renewal in many of the larger, established companies working with a specific set of ingredients (often pulses or legumes), such as BeanIt, owned by the Finnish company

Härkis and the Raisio Group, while smaller companies and startups are paving the way for ground-breaking innovations and path creation, such as Finnish company Solar Foods

The mapping also showed a distinction between knowledge bases, i.e., synthetic or basic knowledge, as applied to the aforementioned firms. In general, working with novel and disruptive food development requires a greater set of specific scientific knowledge and a greater degree of transformation, such as working with new technologies for optimising various forms of microorganisms (e.g., fungi and yeast) (Wøien Meijer, 2023). Such 'basic science' technologies are seen in, e.g., the use of precision-fermentation processes for the development of alternative proteins and these processes are often codified in documents (e.g., patents). Protein development processes based on synthetic knowledge seem to be more mechanised and 'traditional', using existing technologies such as wet or dry extrusion processes (i.e., to "solve the problem" of increasing plant-based options in a company's product portfolio).

5.5.1. Diversification of options: protein sources, products and standards

The protein shift is leading to a diversification of options in terms of the source of the protein, food products and production standards. Common sources of plant protein used in meat substitutes are legumes such as soy, peas, fava beans and, more recently, even grass. One example is the Danish company Biomass Protein, which is changing the value and use of grass, challenging the value we put on relevant supply chains (see Box 4).

Many novel foods find their protein source in insects, fungi, micro-algae and micro-organisms. All these add to the conventional PSFPs and ASFPs, which, despite remaining the 'same' product, are also diversifying in the way they are marketed based on the production standards and inputs used. For instance, improvements within the animal industry to reduce their environmental footprint allow for marketing conventional products as 'greener' via, but not exclusively, certification schemes.

Info Box 4: Biomass Protein, Denmark

Biomass Protein, based in Denmark, focuses on green biorefining. At the start of its journey in 2017, the focus was on developing fodder protein using fermentation processes. Following a pilot project in 2019, the company recognised the potential for commercial expansion and attracting investment. In 2020, Biomass Protein shifted operations to produce proteins from grass for human consumption, which is now its core business.

A crucial technological breakthrough was key to facilitating the use of grass membranes by separating juice from proteins. The juice contains RuBisCo, an enzyme found in plant leaves and a major component of soluble plant proteins. Researchers

acknowledge the potential of RuBisCo as a beneficial food additive, but its industrial applications and purification procedures in emerging plant-based food products remain under-explored. By employing a membrane filtering system, Biomass Protein separates the "green protein" from white proteins. The green protein is not bioavailable to humans. The white protein has diverse applications within the food industry, such as egg white substitutes, foam formation and specific functionalities for various food products. The company believes that its white proteins derived from grass production could offer valuable applications in the plant-based food segment, complementing existing options such as beans and soy.

With an abundance of grass available, utilising its protein content could contribute to diversifying food production. Biomass Protein works closely with local farmers who supply the raw material and leverages their expertise in grass harvesting and optimal utilisation. The company recognises the enduring availability of grass and the potential value it holds as a protein source.

Source: Interview 5.1; Wøien Meijer (2023)

As discussed earlier, product development is achieved both by means of technological innovation and via the application of existing knowledge in new ways. Indeed, many new products in the market do not require new technologies per se but rather an upgrade in their nutritional content by adapting the ingredient list in existing products, such as adding a protein extract in powder form to granola bars. Nonetheless, there are a number of technological developments relevant for product development along the supply chain, from biotechnology and DNA modification for seed development to a complete set of practices and digital technologies used in primary production, including precision agriculture. These technological developments are also necessary in the secondary industrial production processes needed for the transformation of raw materials to produce more elaborate products, such as meat substitutes – or meat

analogues and real in-vitro meat, also known as cultured meat and cultivated meat.

In the following sections, we will examine several ongoing developments leading to a diversification of the options available, ranging from production processes and industrial practices to different types of protein sources.

Product development of meat analogues

Meat analogues are products designed to simulate meat products and intended as meat substitutes, including both land and marine animal products. This differs from products such as bean burgers, which may serve as a direct replacement but do not simulate meat in the same way. Apart from replacing the source of protein, the central idea with meat analogues is to achieve a result that most closely replaces meat in terms of texture, flavour and function. The expectation is that by achieving

these characteristics, consumers would pick analogues rather than the 'real thing', as this would not require major changes in people's habits. The protein can be sourced from plants, fungi, microorganisms or insects, but they generally combine a mix of different ingredients, including fats, carbohydrates and fibre (Clayton et al., 2018).

The processes for producing meat analogues vary depending on the input factor used (e.g., soy) and specific company choices. A key part of the process, and a major challenge, is to achieve the desired texture – one most closely resembling real meat. Extrusion is the most common process to achieve Textured Vegetable Protein (TVP) ingredients in the form of chunks, flakes, mince or shreds. The result of this process is an intermediary product that needs further processing before becoming a meat analogue, such as burger patties or sausage-like products. However, since the 1960s discovery of extrusion technology for texturising soy protein, there have been no significant breakthroughs in the technology, but incremental innovations leading to improvements or refining existing techniques have been developed (Interview 5). Despite these advances, knowledge gaps still exist. According to one scientist working with product development, "even if manufacturers know how to set up extrusion to make fibrous high moisture meat analogues, nobody really knows what the mechanisms are for fibre formation" (Interview 5.8).

Despite extrusion being a well-proven technique, only a few companies use extrusion

commercially in Europe (Interview 5.8). One example is Organic Plant Protein, a company producing TVP ingredients in Denmark, who apply a dry texturing process in which the dry protein concentrates from peas and fava beans are subjected to a series of physical processes, including mixing, hydration, kneading, heating and shaping.

The raw material or inputs used in extruders are either 'protein concentrates' with 55–65% protein content, high in dietary fibres, or 'protein isolates' with 80–90% protein content, low in dietary fibres (Interview 5.5). These can be wet or dry and have different advantages and disadvantages. Climate impact is one key advantage of using dry concentrates. Wet extrusion has emerged more recently in the past 10 to 15 years. Products made with wet extrusion are generally seen as performing better in terms of texture and taste, and there is a broader range of raw materials available for the process (Tzvia, Negro, Kalfagianni, & Hekkert, 2020). However, wet extrusion also poses challenges in terms of complexity, cost and sustainability. It requires more energy and yields different output characteristics, requiring freezing after processing (Interview 5.5).

TVP ingredients can then be utilised by food product manufacturers or chefs to produce the final product by adding other ingredients to achieve the desired flavour and result. Although this final step is the responsibility of the next company in the chain, Organic Plant Protein has taken the initiative to employ a chef who tests the usability

of their TVP products and educates customers on how to cook with them. This shows that TVP products can still be considered a novelty for many actors in the food sector.

The primary production and extraction of the raw material (i.e., concentrates and isolates) is a whole different chapter, which depends on the input factors and their availability in different countries. Generally, this part of the process lies with other companies than those in charge of producing TVP products. For instance, Organic Plant Protein purchases the pea and fava bean concentrates as these are available in the Nordic and Baltic Region. The company is also exploring the potential of utilising concentrates extracted from other foods also common to the region, such as pumpkin seeds, sunflower seeds and rapeseed (Interview 5.5).

Protein extraction

There are several well-established methods for protein extraction from food sources, particularly plants, including alkaline extraction, isoelectric precipitation, salt-based extractions, ultrafiltration/diafiltration and dry fractionation technologies (Hewage et al., 2022). However, these methods have many drawbacks, such as protein denaturation (alterations in the biological, chemical and physical properties) and generate significant amounts of wastewater, high usage of chemicals, high production costs and low yields (ibid.). This is particularly problematic for plant-based proteins, as the extraction methods can lead to a loss in their techno-functional properties, which are critical for food applications.

Some of the key functionality traits include: "solubility, fat and water-binding capacity, foaming capacity and stability, emulsion capacity and stability, gelation, film-forming capacity and viscosity" (Hewage, et al., 2022). Some of the factors that impact the techno-functional properties of plant proteins are pH and ionic strength of the solvent, temperature, among others. For example, extremely high temperature and pH results in poor nutritional and functional properties (ibid.).

In addition, plants contain antinutritional factors (ANFs) that reduce protein digestibility, which again vary depending on the method employed for protein extraction. Wet extraction methods have the advantage that they result in higher protein concentration (>85%) and lower ANF content (75%–96% lower), whilst dry methods tend to result in lower protein concentration and higher accumulation of ANFs (Amin, Petersen, Malmberg, & Orlien, 2022; Harvard T.C Chan School of Public Health, 2022). However, dry methods offer other benefits, not least their lower environmental impact (Interview 5.5) and efficacy in dissociating protein and other cellular compounds, i.e., starch, leaving no chemical residues, having minimal impact on the techno-functional properties and loss of insoluble protein (Hewage, et al., 2022). Novel technologies, although still in their infancy, show promise in overcoming some of these challenges, including enzyme-assisted extraction, deep eutectic solvent (DES) extraction, reverse micelles extraction, microwave-assisted extraction, ultrasonic-

assisted extraction and subcritical water extraction (Hewage, et al., 2022).

Several of the companies observed in the Nordic countries apply dry methods, such as Ausumgaard, who extract protein from grass and Vestjyllands Andel, from plant and fish (i.e., starfish, shrimp waste), both located in Denmark. Vestjyllands Andel employs Spin Flash Dryers, which are widely used for a range of different applications, including agrochemicals, ceramics, food and feed products, inorganic and organic chemicals, pharmaceuticals, pigments and dyestuffs and waste products (SPXFLOW, n.d.). It is a patented process, offering a faster and highly energy-efficient alternative to, e.g., spray drying. The system is quite simple. There is a feed system in which the product is broken down by an agitator before it is sent to a drying chamber using a twin feed screw. The powder from the drying chamber is subsequently collected in a filter bag.

Different processes of protein extraction occur following fermentation or when sourcing from microalgae, which mainly involves air drying. Furthermore, protein-rich foods can be consumed without the need to undergo significant transformational processes. Plants, meat, mushrooms, seaweeds and even insects can be consumed in their natural form with little or minimal transformation.

Fermentation

Fermentation is a versatile process that uses microorganisms to produce alternative proteins. It has been used for millennia to preserve

food, create beverages and enhance nutritional value. There are three types of fermentation: traditional, biomass and precision fermentation. Traditional fermentation changes food through microbial digestion, while biomass fermentation efficiently produces protein-rich food using rapid-growing microorganisms. Precision fermentation programmes microorganisms to produce specific ingredients. Fermentation plays a vital role in the alternative protein landscape by optimising plant-based products and aiding cultivated meat production. It offers advantages such as efficiency, waste reduction and the creation of animal-free components. Advancing fermentation requires innovation in target selection, strain development, feedstock optimisation, bioprocess design and end-product formulation. Further exploration and optimisation of fermentation processes and bioreactor designs are essential for unlocking its full potential. Harvesting biomass or isolating specific target molecules can yield ingredients for alternative meat, egg, or dairy production (GFI 2023).

One company applying precision fermentation is Solar Foods, based in Finland. Solein, the company's key product, is produced by fermenting a single-cell organism, a microbe, utilising air and electricity as the primary resources. The result is a protein-rich powder that can be further utilised in food product development. With a protein content of 65–70%, Solein's macronutrient composition resembles that of dried soy or algae. It contains essential nutrients such as iron, fibre, B vitamins and all nine essential amino

acids required by the human body. The bioprocess of Solar Foods is twenty times more efficient than photosynthesis and 200 times more efficient than meat production. This opens a wide range of possibilities for the food industry, offering nutritious and sustainable options for the future. (Solar Foods, n.d.).

Macroalgae

In Europe, seaweed biomass is a flexible and multi-purpose resource utilised across several sectors, including the food and feed industries (Kuech, Breuer, & Popescu, 2023). To some extent, seaweed is used for its protein content, but it is also found in food supplements due to the high concentration of antioxidants in the form of vitamins and Omega-3. Seaweed is also indirectly relevant in the protein shift in the form of feed supplements, which have shown promising results, both in facilitating growth and reducing methane emissions from cattle (Katz-Rosene et al., 2023). While the aim here is mainly to reduce emissions rather than provide alternative proteins to cattle, the innovation is primarily considered a method for reducing the environmental footprint of conventional animal-based products. The Swedish start-up company Volta Greentech has recently established the first on-land commercial scale production of *Asparagopsis* seaweed specifically for this purpose (Giacometti, 2021). In 2022, the company launched the world's first 'methane-reduced beef' to the market in collaboration with retail giant Coop and food company Protos and in summer 2023, the product became available in selected stores

in the Stockholm area. According to tests conducted by the company, the algae-based supplement reduces methane emissions from animals by approximately 70–90% (Volta Greentech, 2023).

Microalgae

Microalgae are versatile microorganisms with immense potential for various industries and applications. In Europe, many companies employ microalgae biomass in the food and feed industries (Kuech, Breuer, & Popescu, 2023). The use of microalgae as a nutritional source has long been recognised and widely utilised in animal nutrition, particularly in aquaculture. Fishmeal, a protein ingredient commonly used in aquaculture feed, plays a crucial role in production costs. However, the declining availability and increasing price of fishmeal pose sustainability and growth challenges to the aquaculture industry (Roy & Pal, 2015). Consequently, there is a need to partially or completely substitute fishmeal with alternative protein sources. Currently, microalgae are being successfully employed worldwide as a viable alternative protein source in place of fishmeal (Roy & Pal, 2015).

Fungi-based

Mycoprotein, or fungi, are another protein alternative. Their filamentous structure, similar to muscle tissue, offers a texture that, to some extent, resembles meat (Food Business News, 2020). Fungi provides significant environmental advantages compared to meat production, including the ability to use agri-food waste as a substrate (Chezan, Flannery, & Patel,

2022), although the EU Novel Foods directive may impose restrictions on using inputs predefined as 'waste' (Wøien Meijer, 2023). Fungal protein also has a favourable nutritional profile with high fibre content and low saturated fat levels, making it a relatively appealing choice compared to meat (Chezan, Flannery, & Patel, 2022).

One example of a mycoprotein-based Swedish company is Mycorena in Gothenburg. Mycelium, which is the underground network of roots found beneath mushrooms, serves as the foundation for Mycorena's flagship products and has a neutral taste and texture that resembles that of meat. Mycelium presents a whole new ballgame in protein production, reducing the amount of space, water and time needed. The fungi grow to 10,000 times its size in approximately 48 hours when cultivated.

The use of fungi as a base for alternative protein products is not a recent development. The British company Quorn has been using fungi in their products for decades. The expiration of Quorn's extensive list of patents in 2015 opened up new opportunities for fungi-based businesses across Europe. However, it is worth noting that Quorn never marketed its products explicitly as fungi-based. Therefore, there is much work ahead to promote or raise awareness of fungi-based foods to overcome prejudice about their safety. In contrast to Quorn's approach, Mycorena focuses on developing a food ingredient rather than exclusively offering products based exclusively on fungi for direct sale to the consumer. They believe that by positioning themselves

as an input factor provider in the food chain, they can have a more significant impact in a long-term perspective in diversifying the food market (Wøien Meijer, 2023).

Insect-based protein

Insects have gained attention as a novel ingredient in high-value food products. In the last ten years, researchers have been investigating the potential of edible insects as an innovative ingredient in high-value products as a substitute for conventional protein sources (Gravel & Doyen, 2020). Food experts who speculate about the future acknowledge that as society becomes more focused on sustainability, insects will be increasingly embraced as an alternative source of protein. However, it is important to note that the insects that have been extensively studied and are easily raised may not necessarily be the most sustainable, widely accepted, or enjoyable options in terms of taste (Wang & Shelomi, 2017). According to Gravel and Doyen (2020), insect proteins can serve as functional ingredients in food preparation. To integrate insect proteins into large-scale industries, further research is required to optimise processing techniques and achieve the best balance between cost-effectiveness, functionality, taste and sustainability, all while ensuring consumer safety.

According to a review undertaken by Wang and Shelomi (2017), the black soldier fly (*hermetia illucens*) is a highly efficient converter of various organic materials, including food waste and manure, into insect biomass. This review highlights the advantages of black soldier flies,

such as their ability to grow and be harvested without dedicated facilities, their low pest potential and their good nutritional composition (42% crude protein and 29% fat). However, the review also discusses their higher saturated fat content compared to other insects and the challenges posed by social stigmas and legal restrictions surrounding their consumption as human food, as it is primarily currently used in animal feed. There are several companies in the Nordic Region working with black soldier flies, including Danish ENORM and Norwegian companies Invertapro and Ecoprot (Wøien Meijer, 2023).

Cellular agriculture: Cultivated meat

A whole different field of research and industrial development is focused on cellular agriculture, which is a biotechnological process used for growing meats (i.e., beef, pork, poultry and seafood) and other animal products (i.e., milk and egg white protein) from cell cultures instead of using livestock (Khan, 2022). Unlike meat analogues, cultivated meat, also known as cultured, in-vitro, or clean meat, is real meat that is made from the same animal cells grown artificially through cellular agriculture instead of a living animal (Clayton et al., 2018). "Cultivated meat is made of the same cell types that can be arranged in the same or similar structure as animal tissues, thus replicating the sensory and nutritional profiles of conventional meat" (Swartz & Bomkamp, n.d.). Cellular agriculture is a resource-efficient process that reduces inputs to a fraction, in comparison to

animal-grown meat, reduces waste and eliminates the need for vast pasture lands and crops devoted to feeding animals (Clayton et al., 2018). Nonetheless, it is important to note that cell-cultured meat production still requires some contact with animals, where living or even extinct animals can be involved in the process. These products mainly target meat-eaters and flexitarians, offering an alternative to conventional meat.

The process of producing cultivated meat consists of three key steps: stem cell extraction, proliferation and differentiation (Interview 5.4). Figure 8 provides a visualisation of this process. First, biopsies are carried out to extract stem cells from the animal. Then, the stem cells proliferate inside a bioreactor, also known as a cultivator, which is a vessel or tank that provides the controlled conditions that enable cells to grow and replicate. Replacing the function of the animal's body, the bioreactors provide the environment with the correct temperature and oxygen levels and is where cells are fed with "an oxygen-rich cell culture medium made up of basic nutrients such as amino acids, glucose, vitamins and inorganic salts and supplemented with growth factors and other proteins" (Swartz & Bomkamp, n.d.). Finally, differentiation consists of shaping and providing a structure to the mush of cells by means of scaffolds, to achieve a similar structure to animal tissue (Interview 5.4). Similar processes are now being developed to create milk and other animal products (Swartz & Bomkamp, n.d.).

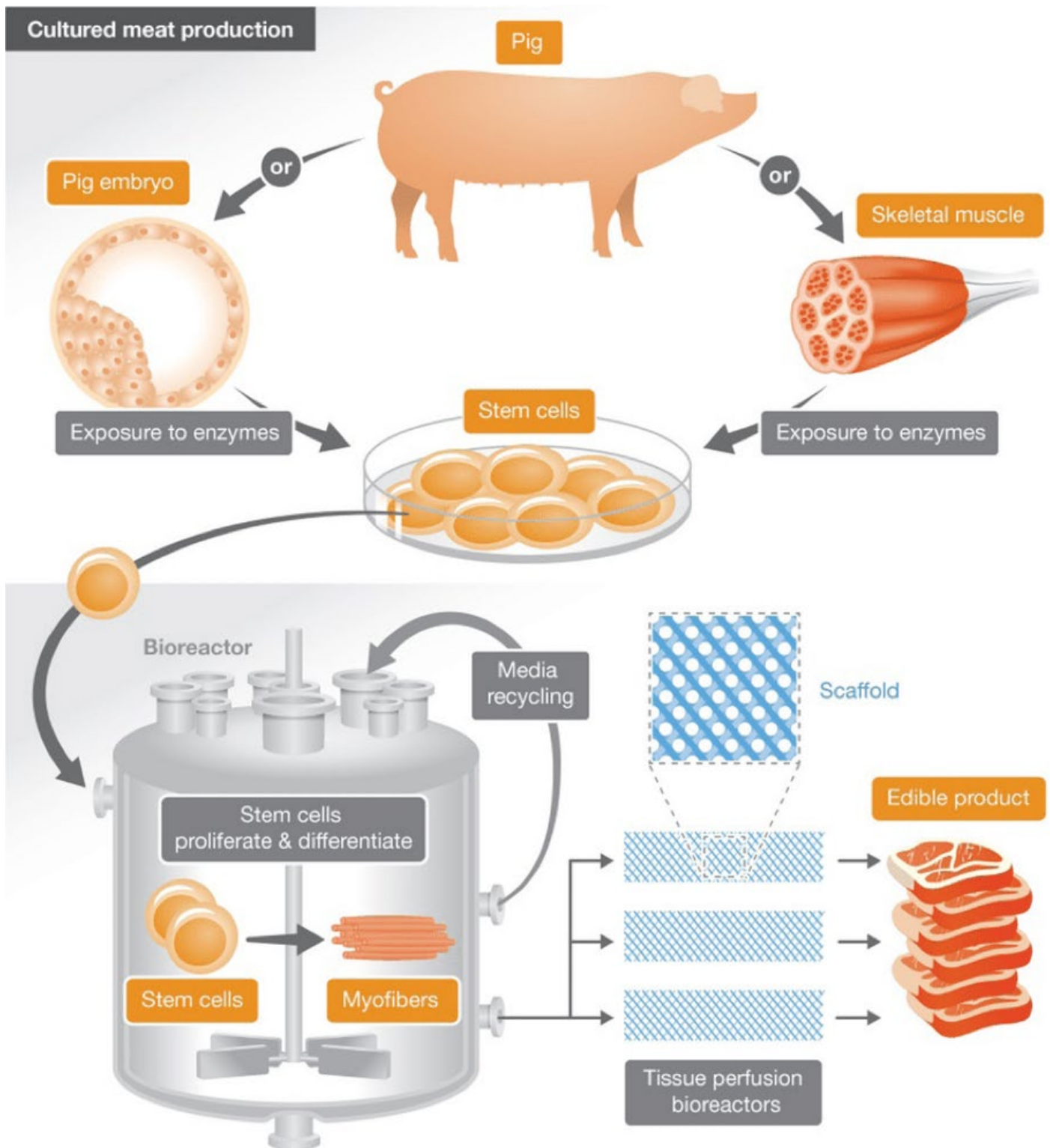


Figure 8: Cultivated pork production process. Source: (Tuomisto, 2018)

Technological innovation in cell agriculture can be seen as the accumulative result of different knowledge bases converging as a source of innovation and development (Zukauskaitė & Moodysson, 2016, p. 592). According to Swartz & Bomkamp (n.d.) of the Good Food Institute, a global think tank on alternative protein, cell agriculture builds on decades of knowledge from a variety of fields, including stem cell research, tissue engineering, chemical and bioprocess engineering, fermentation and cell culture research. Animal tissue cultivation outside the animal body was first achieved in 1907 by Ross Granville Harrison, an American zoologist, who isolated frog nerve cells and cultured them in an external medium (Seedtable, 2022). Granville Harrison's culture technique has since been vital to many biological applications in cancer research, the development of polio vaccines (ibid.) and in developing the cultivated meats for food purposes industry.

Fast-forwarding to the year 2013, Dutch scientist Mark Post presented the first cultivated meat burger on live television. Immediately after, four pioneer companies were established to further develop the technology, with more than 150 companies having emerged since, developing new technology or

solutions for improving the value chain (Swartz & Bomkamp, n.d.). One such company is the Tallinn-based Gelatex, a materials company which has made significant breakthroughs with the structural aspects of cultivated meat production (see Box 5). In 2020, Singapore became the first country to approve the sale of cultivated meat, and in June of 2023, Eat Just and Upside Foods became the first companies accredited to commercialise their products in the USA (The Economist, 2023). These companies are not alone. As one expert explained, many companies are ready to scale up, but investors are hesitant, waiting for someone else to take the lead (Interview 5.4). In the meantime, experimentation is building expectations, such as the most recent 'mammoth meatball' created by Australian start-up Vow Food, made by mixing DNA extracted from ancient mammoth remains with that of elephants (The Economist, 2023). While such Frankenstein-like attempts may be successful in generating media hype, the success of cell ag will eventually depend on its ability to penetrate the regular food market and make products accessible to the regular consumer. The challenge will be to overcome the barriers to simultaneously scaling up and cutting costs.

Info Box 5: Gelatex, Estonia

Gelatex, based in Tallinn, Estonia, is a specialised materials company focused on nanofibre production. Their venture into cell-cultured meat began in 2020, leveraging the applicability and technology transfer from their existing products, which were initially developed for the medical equipment industry. Their nanofibres have

demonstrated high efficiency and have been extensively tested in the pharmaceutical sector. However, what was once deemed too futuristic and economically unviable now appears to be within reach due to the potential for economies of scale. The sustainability drive in the food tech market is bringing previously unimaginable products closer to reality. As one interviewee puts it, "We have all the necessary pieces; now we just need to assemble them." (Interview 5.4).

Gelatex is not a producer of cell-cultured meat per se. It specialises in creating complex 3D scaffolding and microcarriers to be used by companies producing cell-cultured products, enabling the scaling up of cell-cultured meat production and achieving the desired texture. The microcarriers provide attachment points for the parent cells to proliferate inside bioreactors. At the same time, scaffolding solution aids in the development of muscle tissue that closely resembles conventional meat products in terms of texture, appearance and taste.

In addition, Gelatex's technological innovation, known as HaloSpin™, represents a breakthrough in scalable, continuous and cost-effective nanofibre material production on an industrial scale. In contrast to the slower, costlier electrospinning technology, HaloSpin™ enables more efficient production at higher speeds and results in a more porous material that mimics natural cell structures better than alternative solutions. This increases cell adhesion rate, reduces production costs and also provides an experience that more closely resembles conventional meat.

Source: Wøien Meijer (2023)

Molecular farming practices and gene editing

Molecular farming is also developing, and we have seen that certain plant proteins can be used in the development of pharmaceutical products and medicine. The production of such proteins and metabolites (a factor in metabolism) is what is termed "molecular farming". Crop plants are a novel source of molecular medicine, but also low-cost and relatively simple to cultivate (Singh, A. et al., 2021). Plants have a long history of medicinal use, and molecular farming points to new innovation pathways. According to Singh et al. (2021), molecular farming can enable crop plants to become a source of enzymes, growth factors, plasma proteins and vaccines, to name but a few products.

Developments in crop plant production can also contribute to diversified food production. According to the Innogen Institute in Scotland, crop plant innovation using synthetic biology and gene editing can contribute to this shift and "create a niche-market sector populated by small companies delivering benefits to markets that are not of interest to the major agro-biotechnology multinational companies" (Innogen Institute, n.d.). For example, crop plants can be used in high-value protein production. In the Nordic Region, the Icelandic company ORF Genetics works with molecular farming, sourced specifically from barley crops, to produce growth factors for cultivated meat. Growth factors are a costly part of cell-based meat production, but using

barley seeds for molecular farming can reduce these costs significantly due to barley's ease of cultivation (Cell-based Tech, 2020). These crop diversifications grounded in newer scientific developments may help diversify the protein market over time, either directly through the crop itself or indirectly through, e.g., growth factors.

From a food security perspective, the extensive knowledge of plants already at our disposal could lead to more "efficient crop production" (Tait & Barker, 2011). Europe can become a frontrunner, also with regard to molecular farming, due to the preponderance of highly fertile agricultural land across the continent. There are, however, challenges: competing sustainability narratives, discussions on the role of science and technology in molecular farming, particularly in relation to the use of gene editing and genetic modification and the role of regulation, e.g. should the technology or the product deriving from the technology, be subjected to regulation? (Tait and Barker, 2011).

Innovation in conventional protein foods supply chains

In addition to the work of developing alternative proteins, significant innovations are ongoing across the supply chains for conventional proteins to improve sustainability. These include a wide range of practices, some enabled by technological innovation (e.g., AI in precision agriculture) and many that do not require technological innovations per se but rather the implementation of 'good practices' based on existing knowledge

and improved standards. These processes are not mutually exclusive, and the implementation of existing knowledge often goes hand-in-hand with the application of modern technologies. The aim of innovation here is not to develop novel food products but rather to enhance the efficiency and sustainability of existing industries and supply chains.

One promising mechanism for reducing the environmental impacts of conventional food products is to implement new technology and state-of-the-art scientific knowledge. This can be achieved at both farm and commodity level (Katz-Rosene, Heffernan, & Arora, 2023). At a farm level, technologies such as sensors, drones, AI and other monitoring technologies, data analysis and precision agriculture can all help maximise the use of inputs (i.e., water, fertilisers, pesticides, etc.) and minimise the leakage of nutrients into the water streams (Randall, Vestergård, & Wøien Meijer, 2020). Some of these technologies may also be applied to improving animal wellbeing. In addition, biodigesters are becoming increasingly popular, as they can break down manure and other organic residues into organic fertiliser and capture methane gas, which is then burnt to generate electricity. Furthermore, new developments in breeding, bioengineering, feed additives, etc., can help reduce the environmental footprint of the livestock industry at a commodity level. For instance, feed additives could have a significant impact in cutting methane emissions if made available to more cattle farms.

Many practices based on traditional knowledge have attracted renewed attention, such as permaculture, pasturing of livestock (particularly rotational grazing), mixed animal/crop production and other practices applied in combination under the umbrella concepts of regenerative or holistic agriculture. These offer many benefits: revitalising ecosystems, enhancing biodiversity, soil improvement (including carbon capture), animal welfare, health, and protecting many communities' livelihoods dependent on traditional activities. Proponents of these practices argue for changing carbon emissions' accounting by taking the entire carbon cycle into account. A wealth of accumulated research on regenerative agriculture supports the potential for enhancing carbon sequestration in the soil through better management practices. One flagship venture is the MULTA project,³ led by the Finnish Meteorological Institute, which is developing a verification system for carbon sequestration aimed at policy makers and markets. The key argument here is not whether animals generate emissions or not but how specific management practices may be able to offset emissions by enabling carbon to be returned to the soil and plants. Finally, many advocates are opposed to common misconceptions regarding traditional techniques as being 'primitive' or 'less efficient', pointing out that these methods can help reverse some of the worst effects of industrial agriculture, reconnect consumers to producers and achieve more positive results in efficient ways

(Katz-Rosene, Heffernan, & Arora, 2023). Although some proponents of the regenerative protein narrative who favour reinstating traditional knowledge may harbour anti-industrialisation views, not all are anti-innovation. Indeed, many traditional practices can be used in combination with, or even enhanced by, high-tech solutions.

5.5.2. Final remarks on technological innovation and industrial development

To conclude this section on technological innovation, it is vital to highlight that innovation takes place across multiple areas, from conventional industries and products to new industrial processes and alternative products. It is worth noting that, in a practical sense, many of these developments occur largely independently of each other. In other words, research groups and businesses developing novel products rarely intersect (Interview 5.8). As a result, there is still a great deal of unexplored potential in combining different knowledge bases and technologies to improve the quality and taste of alternative proteins or to reduce costs. Many companies developing cell ag are increasingly considering the potential of hybrid meats to cut production costs by combining cultivated animal protein with plant protein (The Economist, 2023).

Another example of cross-fertilisation between knowledge bases can be found in the 'Like:meat' project conducted by the Research Institutes of Sweden (RISE) in

³ <https://www.bsag.fi/en/projects/stn-multa-research-consortium/>

partnership with two major industry partners, namely Lantmännen, a large Swedish agricultural co-operative that owns many food brands such as AXA, Kungsörnen and Norwegian conglomerate Orkla, with Swedish and international subsidiaries. The project aimed to overcome some of the current challenges faced by meat analogue products, including the low bioavailability of iron and zinc and other issues with digestibility, by combining extrusion with fermentation (RISE, n.d.). Fermentation helps reduce anti-nutritional factors and oligosaccharides (which cause physical discomfort). It can also facilitate extrusion by improving protein quality and reducing the starch content of protein concentrates, and it improves taste by reducing the aftertaste of legumes (ibid.). At first, the project's lead scientist noted that the two industry heavyweights were uninterested in pursuing fermentation but became strong advocates midway through the process as they became more aware of the possibilities it offered (Interview 5.8).

These examples show that there is still much room to explore combining and utilising different technologies and protein sources. Finally, achieving the sustainability of the protein system overall requires innovations and improvements across several industries and scientific fields and at every step in the supply chains. Indeed, developments in primary, secondary and tertiary production are all complementary in promoting

the protein shift.

5.6. Institutional innovation and consumer behaviour

In addition to technological innovation, there is a widely accepted argument that changing consumer behaviour is essential for creating a more sustainable food system. To this end, many interest groups are active in generating awareness and creating a support base in society. Public sector initiatives have also been set in motion to guide consumers. Many countries have developed national dietary recommendations which suggest a moderate consumption of red meats and generally more balanced diets. In a similar vein, the new Nordic Nutrition Recommendations (NNR) suggest that people should consume:

”

[...] a predominantly plant-based diet rich in vegetables, fruits, berries, pulses, potatoes and whole grains, ample amounts of fish and nuts, moderate intake of low-fat dairy products, limited intake of red meat, white meat, processed meat, alcohol, and processed foods containing high amounts of added fats, salt and sugar”⁴

(NCM, 2023, p. 105).

The NNR document also suggests that proteins from plants or fungi could help replace a significant portion of animal proteins in Nordic

⁴ Considering both the environment and human health (NCM, 2023).

diets without reducing the intake of recommended essential amino acids (NCM, 2023). However, Hartman and Siegrist (2017) argue that consumer awareness of environmental impacts is still limited and there is considerable reluctance to switch to alternative protein products, be they plant-based, insects or cultured meat. The EU's Farm to Fork Strategy states that, in general, "European diets are not in line with national dietary recommendations" and points out that the environmental footprint of food systems could be significantly reduced if consumers were to follow them (European Commission, 2020). Instead, about 20% of the food produced in the EU is wasted and negative lifestyle issues such as obesity are on the rise, with over half the adult population being considered overweight (ibid.). This may imply that the increasing demand for protein is less an issue of technology or physiological need and more an issue of wealth and habit. Indeed, Clayton et al. (2018) note that despite major work already achieved in product development and in generating awareness, the main factors that determine consumers' choices remain resolutely price, taste and convenience. To this, we might add that behaviour and willingness to alter consumption patterns are also directly influenced by where individuals position themselves in relation to the debate on sustainability and ethical food systems. Nevertheless, the fact that the 'protein shift' is firmly on the agenda demonstrates that something is changing. Vegetarian and vegan

diets have existed for decades, even centuries, but the increased focus on extreme weather events and the tangible effects of climate change have incentivised many new adherents. Growing consumer awareness has contributed to a gradually expanding market creation for alternative protein products. Especially in wealthier countries where meat has been the main source of protein for many years, the appetite for alternatives has grown more rapidly (McKinsey & Company, 2019). So far, Europe has been the largest market for meat analogues, with Germany, France, the Netherlands, the United Kingdom, Italy and Sweden the primary consumers (Béné & Lundy, 2023). At EU level, the market for plant-based meat and milk alternatives has seen annual growth of 14% and 11%, respectively, in the period 2013–2017 (Blom, et al., 2022). More recently, this trend is beginning to unfold in developing markets (McKinsey & Company, 2019), with Asia the fastest-growing market (Béné & Lundy, 2023).

According to Béné & Lundy (2023), the market for meat alternatives is projected to have an annual growth rate of 15–18% in the period 2020–2025 and reach annual sales of USD 12 billion and USD 17 billion by 2025 and 2027, respectively (Béné & Lundy, 2023). Indeed, the positive market outlook, supported by strong social media marketing campaigns, has generated significant interest among investors (McKinsey & Company, 2019). Many new businesses are rolling out new technologies, ingredients and innovative food products that more

and more resemble the mouthfeel of animal products (McKinsey & Company, 2019). Béné & Lundy's research reveals, on the one hand, that "the meat industry in both high- and lower-income countries, is rapidly changing "and, on the other, "that those changes have been driven -and continue to be driven- by markets forces and powerful actors". Consequently, they believe it relevant to analyse the structure of the meat industry over recent decades to better understand its future structure (Béné & Lundy, 2023). Although there will most likely be an increased mix of options in protein products, the industry will nonetheless continue to be controlled by large corporations.

The increased popularity of alternative protein products should not necessarily lead to the conclusion that the market for animal-based products is in decline. Long-term trends show otherwise. The value of meat production worldwide has steadily ballooned from around USD 65 billion in 1961 to USD 366 billion in 2014 (Béné & Lundy, 2023). While the livestock industry has been preoccupied with the potential threat of environmental policies to meat consumption, the attitudes of many of the larger corporations with a stake in the meat industry have changed somewhat (Interview 5.6). Indeed, R&D in alternative protein products is, to a significant extent, in the hands of some of the corporations that have controlled much of the global meat industry for decades. Most transnational meat-and-dairy and fast-food corporations are heavily invested in acquiring existing plant-based substitute companies or in developing their own (Béné &

Lundy, 2023). Bene and Lundy (2023) list a number of examples:

”

Cargill, for instance, invested in the lab grown meat company Aleph Farms, join ventured with the pea protein firm Puris, and later introduced its own plant-based meat substitute; JBS purchased Bio.Tech. Foods (a Spanish lab grown meat firm) in 2022 while investing another US\$100M in developing lab grown meat. Other major agri-food TNCs who invested in alternative protein include Nestle who acquired Sweet Earth in 2017, Unilever who acquired The Vegetarian Butcher in 2018, Kerry Group who acquired a majority stake in Ojah (a Dutch company specialized in the production of plant-based ingredients), or Hormel who acquired Skippy and Justin's, two peanut firms, in 2016 (Howard et al., 2021). Not to forget McDonald of course who ventured with Beyond Meat to develop their "McPlant" plant-based patty."

(Béné & Lundy, 2023)

McKinsey & Company (2019) observe that most fast-food chains now offer vegetarian variants of their most popular menu items. Therefore, although the emergence of alternative proteins may threaten the meat industry, major corporations are not missing out on the chance to profit from them. On the contrary, one expert noted that while many companies within the meat industry – also in the Nordic countries - initially opposed protein alternatives, they have now changed tack and view

them as a new promising market segment rather than a potential threat (Interview 5.6).

5.6.1. Policy and regulatory implications on the protein shift

Given that social awareness alone is insufficient to generate substantial behavioural change, additional measures are needed to effect the protein shift. The EU's increasingly ambitious climate and environmental policies have the potential to generate sizable action and perhaps even regime change in food systems in general. The Common Agriculture Policy (CAP) for the period of 2023–2027, approved in 2021, established that 5% of arable land must be devoted to the benefit of biodiversity as a pre-condition for farmers receiving subsidies (European Commission, 2021). Moreover, the nature restoration law approved in the summer of 2023 by the EU Parliament is expected to have even further impacts on agricultural activity by committing more areas to biodiversity restoration. Furthermore, the EU Farm to Fork Strategy sets targets to reduce the use of pesticides and fertilisers, increase organic agriculture and commit to mitigating the impact of the protein 'sector' (European Commission, 2020). As the strategy states:

"To help reduce the environmental and climate impact of animal production, avoid carbon leakage through imports and to support the ongoing transition towards more sustainable livestock farming, the Commission will facilitate the placing on the market of sustainable and innovative feed additives. It will examine EU rules

to reduce the dependency on critical feed materials (e.g. soya grown on deforested land) by fostering EU-grown plant proteins as well as alternative feed materials such as insects, marine feed stocks (e.g. algae) and by-products from the bio-economy (e.g. fish waste)" (European Commission, 2020)

To pursue these goals, the EU Horizon Europe programme has allocated EUR 10 billion for investment in R&D in the fields of food, bio-economy, natural resources, agriculture, fisheries, aquaculture and environment and to increase the application of digital technologies and nature-based solutions in the agri-food sector (Euro Funding, n.d.). This funding is intended to help develop and test solutions, overcome bottlenecks and create new market opportunities (ibid.). One beneficiary of this programme is the Swedish company Mycorena (see earlier chapters). Along with the Austrian start-up Revo Foods, it has received a EUR 1.5 million grant for its venture project to reinvent 3D-printed food using customised mycoprotein (Mycorena, 2023).

However, regulation can sometimes be barriers and slow innovation, and may even backfire by negatively affecting the local market, such as that of commodity crops. One example is legume cultivation in Sweden. Over time, it has experienced waves of expansion and contraction as a direct result of policy and regulatory shifts. A recent report by the Swedish Board of Agriculture shows that the production of legumes dropped dramatically in Sweden to a total area of just under 10,000 ha. as a result of widespread deregulation

in the early 1990s (Blom et al., 2022). By the late 1990s, production had rapidly expanded again to 60,000 ha. due to agricultural support schemes introduced as part of Sweden's accession to the EU (ibid.). Changes to the Common Agricultural Policy in 2005 cut support for protein crops and resulted in a new drop to 25,000 ha., but the tide soon turned again, and production grew steadily to reach its peak of 65,000 ha. in 2016, mainly as a result of increased demand for organic milk (ibid.). Since then, production has fallen again to around 50,000 ha. in 2021, partly due to tightening regulations prohibiting the use of chemical plant protection agents in areas designated for organic production (ibid.). Therefore, there are reasons to be cautious when drawing conclusions about the possibilities of increasing sustainability in the food sector with the new wave of regulations emerging from the EU if these are not paired with additional measures to help markets absorb the impacts and adapt.

In terms of innovation, the EU Novel Food Regulation is of key importance, influencing the type and speed of technological advances in food technologies. In 1997, in response to the need for standardised food laws and concerns raised by the public regarding unregulated imports of genetically modified soy, the European Commission introduced the Novel Food Regulation (Tzvia et al., 2020). This regulation established a complex and costly authorisation process for introducing new foods and ingredients into the EU market, particularly those that had not been widely consumed in the block prior

to 1997. As this applies to various potential raw materials used in meat substitutes, it has posed a significant obstacle for companies wanting to experiment with certain ingredients (Tzvia, 2020, p. 222). However, experimentation has prevailed and companies are still able to innovate based on known input factors (i.e., existing sources of protein).

According to interviews, the Novel Food Regulation is a necessary but sluggish institution (Interviews 5.4; 5.7). The sheer time spent on filing novel-food applications incentivises product perfection to avoid having to go through the process twice but also generates a reluctance to create entirely new products with new ingredients. The regulation has also proven to be somewhat rigid in relation to innovation. For example, feed used for growing fungi needs to come from uncontroversial sources. In other words, working with other actors, such as bakeries or other foodstuff producers, to capitalise on waste streams as feed for fungi is not automatically approved. This is because the definition of 'waste' suggests that fungi feeding on waste resources might not be safe.

At national level, there are various policy initiatives to help create industrial change and enable the protein shift. The Swedish Food Production Strategy 2.0 (Livsmedelstrategin 2.0), for instance, is intended to provide a long-term strategy that supports all aspects of Swedish food production, and it is the first of its kind to include the entire food production chain (Regeringskansliet, 2023). It envisages increased sustainable food production that contributes to

more jobs and sustainable growth across the country, to conscious consumption with the aim of providing consumers with “better preconditions for making conscious choices” (Regeringskansliet, 2023). To this end, there is an increasing number of funding programmes investing in R&D in alternative proteins. Vinnova, the Swedish innovation agency, has funded many projects aimed at supporting innovation and development in the local alternative products industry. Similarly, the Swedish Agency for Regional Growth is working in a missions-oriented way with key actors to change the food system as part of the government’s food production strategy (Tillväxtverket, 2023).

In 2021, Vinnova, with a total budget of SEK 20 million, launched a call for projects to boost innovations that would enhance Swedish processing of plant-based raw materials and create conditions for development along the entire plant-based value chain (Vinnova, 2021). One example is Like:meat, mentioned previously, where Vinnova funding supports local actors in all stages of development, from basic laboratory research through piloting phases to scaling up for industrial processing (RISE, n.d.). By involving some of the largest industrial players in Sweden, the venture is likely to ensure that R&D product development can have a market impact – as these actors have the resources and capacity to introduce new products. Indeed, Lantmännen, one of the industry players involved, has already announced that it will establish a factory for producing

protein isolates (Interview 5.8). More recently, in 2023, Vinnova opened up for any relevant stakeholder to contribute and influence the design of ‘Programme A: new recipe for the food system’, which intends to help Sweden “meet the system and policy challenges that hinder innovation and change in the food area” and where the protein shift has been selected as one of five priority focus areas (Vinnova, 2023). In addition to this general input call, 51 organisations have become more actively involved in addressing the five selected themes. In the protein shift focus area, the task force comprises a mixture of non-profit, research and private actors, including Axfood, Djurens Rätt, Hasta Eco AB, Damn Gott/Chou, KTH, Millow AB, RISE, the World Wildlife Fund and Swedish consumers (ibid.). At the end of 2023, several projects were awarded a grant by Vinnova to further elaborate on the protein transition and food systems (Vinnova, 2023).

Country-wide strategies, such as the Swedish one, do not currently exist in Denmark and Norway, but food strategies are in place at local and regional levels. Denmark and Norway both have funding bodies that target the development of bioeconomic and agricultural innovation, namely Bionova and Nofima in Norway and the Food and Biocluster in Denmark, and goals to strengthen R&D for food production have been drawn up (Innovation Norway, 2023; Innovationsfonden, 2023). In Denmark, regional farmer co-operatives such as Vestjyllands Andel are making great strides in diversifying and innovating their product portfolio, both by supporting

new ventures, e.g. in grass protein production and using marine proteins found in starfish (Interview 5.3), as well as entering partnerships with other regional actors such as Ausumgaard and BioMass Protein. They informed us that Vestjyllands Andel is now reacting to the increased demand for locally sourced protein to reduce dependency on global value chains. In other words, sustainability narratives play a role in influencing market actors. In Norway, initiatives have also been taken by partnerships between waste management companies and alternative protein production companies, such as the inter-municipal waste management company IRIS and the larvae production company ECOPROT (Wøien Meijer M., Forthcoming).

Furthermore, it is important to note that efforts to support the protein shift exist within a broader political, institutional and regulatory context, where longstanding legislation, the organisation of public administration and industrial policy traditions, as well as the political mood music of any given time, all serve as the background from which innovations may emerge. For instance, RISE is a well-established network of research centres in place all across Sweden, with a mission to support the innovation and competitiveness of Swedish industry and business. RISE comprises over 130 testbeds and demonstration environments for new technologies, products and services and works closely with industry, academia and the public sector. Therefore, the institute has a central role to play where there is demand for applied science and product development,

including (but not exclusively) the development of novel food products. National research councils and funding bodies operate under a similar logic by supporting research based on broader societal needs and trends without necessarily 'picking winners'. Research funds may also target certain developments or industries more directly, such as the project calls from Vinnova described earlier. However, targeted support for certain developments may be too short-lived to effectively help in the initial steps of research development or to incentivise market development or may be discontinued if over-reliant on market trends or the political mood. As one expert recalls, there was a large wave of research investment in the 1980s with Nestlé, Unilever and other major players putting many resources into meat analogues, which resulted in rapid development that later stagnated, probably for market reasons (Interview 5.8). More recently, although the Swedish funding bodies have allocated increased resources towards the development of alternative protein products, this funding stream seems to be slowing down again.

5.6.2. Final remarks on institutional innovation and consumer behaviours

Social awareness and consumer behaviour have played an important role in pushing for political action and have expanded the market for alternative proteins and innovative and ethically produced foods. It has also urged regulators to establish stricter sustainability standards in conventional agriculture. Change agency in the protein shift is clearly coming from society, not merely

through altered consumption behaviour, but also through pushes for ambitious regulation, for instance, around biodiversity protection, which in turn is directly impacting agricultural land use for certain crops.

However, increased awareness and demand do not appear to lead to one single behavioural pattern but to multiple varied ones, as consumer choices are also influenced by other factors, such as habit, culture, purchasing power and convenience, as well as where individuals position themselves in relation to the wider debate about sustainability and ethical food systems.

To ensure a more stable framework embedded in sustainability issues, more ambitious policy measures are necessary to induce a more profound transformation of the food system. So far, however, legislation and policy measures have mostly focused on improving practices and incentivising innovation rather than introducing punitive measures to restrict animal-based products, such as outright bans or targeted taxes. Whether such measures are desirable is beyond the scope and purpose of this study.

5.7. Systems perspectives on the protein shift

The protein shift is essentially a case of systems innovation. However, the extent to which the food system will change as a result of ongoing technological and product innovations or regulation remains unclear. While innovations are actually occurring across all parts of the system, these remain incremental

for the moment and they necessarily eliminate other existing innovation structures. Indeed, the alternative proteins segment in food production represents a case of both new and old practices meshing together, as well as traditional and modern businesses. However, a complete transformation of the food system, in which protein sub-systems are embedded, would require radical innovation within the regulatory framework, major technological regime changes, re-organisation of business structures and global food trade, financial models and, most importantly, a process of socio-cultural engineering. However, some fundamental structures seem to go largely unchallenged. Dominant transnational corporations in today's food systems are rapidly appropriating the market for alternative protein products, meaning that even if a greater diversification of protein products is achieved, overall business structures would remain relatively unchanged on a global scale. However, if we zoom in on different territories, the production of plant proteins and other novel food products may induce new economic opportunities at a more local level.

In terms of primary production, it has yet to be seen whether developments in both technology and regulation will significantly challenge conventional agriculture and livestock farming practices or whether meat and dairy consumption will be radically reduced. This pertains both to consumer behaviour and consumer demand, which largely depends on price and convenience.

A range of other factors, such as culture, tradition, territory, resources and available production means, are also important elements to consider. This shows the complexity of transformations, the role of consumer agency and the need for innovation and systems perspectives across the board. Farming structures have already undergone substantial transformation in Europe over several decades, including increasing farm size and reducing manual labour. However, these changes have much more to do with common market competitiveness and the design of subsidy schemes than with the sustainability agenda. Indeed, intensive agricultural practices are unlikely to grind to a halt anytime soon despite strong lobbying efforts against them. On the contrary, the needs of an ever-increasing global population coupled with declining manual labour demographics in agricultural production merely reinforce this industrial intensification. However, significant improvements over time are nonetheless likely to happen in terms of efficiency, animal welfare, and reduction of the environmental footprint, due to consumer pressure and tighter regulations. For example, the increased use of technologies in precision agriculture may yet serve as a way to support a 'positive' and 'green' narrative based on intensification.

5.7.1. The role of innovation and agency in protein supply and value chains

It is clear that new developments in the food technology industry do

not appear out of nowhere but are the product of the involvement of several actors together with strong institutional drivers to create, renew and extend innovation pathways. The pooling of powers, resources and competences – or different types of agency – and the application of both new and traditional knowledge and practices – is enabling the protein shift.

Companies within the alternative proteins segment build on pre-existing knowledge and operate within the conditions of an existing market. Systems innovation is evidently tied to companies taking on risk in developing new products or adapting existing products and their business models. This happens in co-operation with the research community that can bring new technologies and new knowledge to the table or that can support businesses in applying existing knowledge in new ways or as a response to new market opportunities. Moreover, this also occurs in a context where institutional frameworks are being adapted to encourage change – and by doing so, opening new opportunity spaces for entrepreneurs to explore. Taking the climate movement and the increased popular demand for alternatives, we can also clearly discern structure-agency dynamics in the food technology sector, where innovation and institutions are co-dependent (Tzvia, Negro, Kalfagianni, & Hekkert, 2020; Zukauskaitė & Moodysson, 2016).

New technology and practices in both farming and agriculture, endogenous developments in

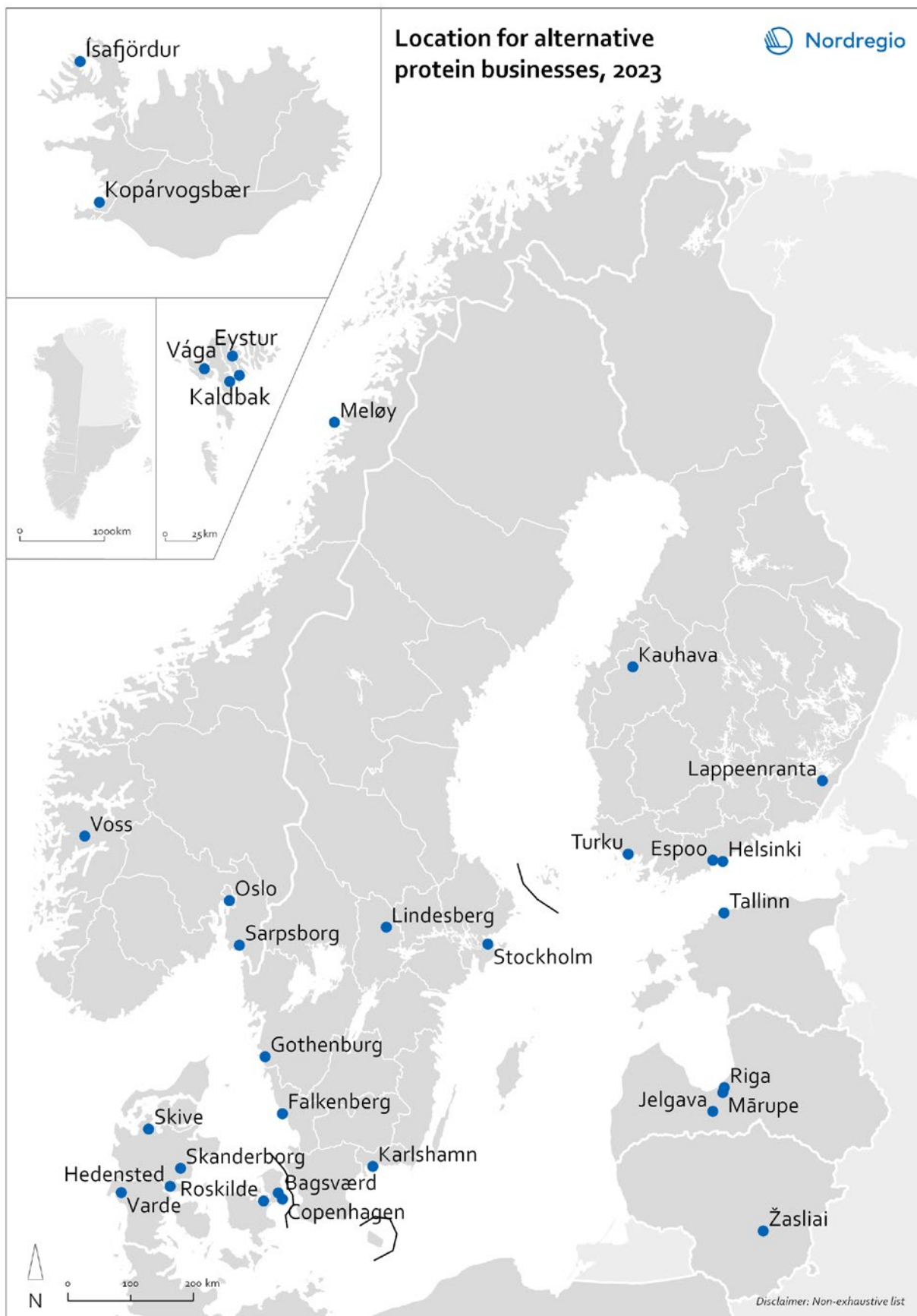
existing industrial processes, new techniques, new processes, new products, new food ingredients and the basic science driving the protein shift are all elements that encourage new directions in the food system. The role of agency in this innovative space is evident: Without sectoral pioneers or sectoral actors taking a leap of faith and innovating in technique, processes and products would be much slower. It is a bottom-up process, aided by the broad financial frameworks available to innovation and business, as well as the increasingly accessible green financing opportunities. A more general societal awareness of the impact of individual choice is also an important enabler for new market creation in sustainable options. In the Nordic Region, it is clear that the space within which the protein shift is unfolding is conducive to risk taking and innovation, albeit challenged by sluggish regulatory and legislative processes and a slower move towards extracting plant proteins and developing PSPFs, compared to, e.g. Germany, which has a large and established market.

However, demand in the Nordic countries could easily be absorbed by international suppliers. But the winds are changing, and companies in Denmark and Sweden are starting to catch up (Interview

5.6). This arguably demonstrates that the market for alternative proteins is maturing in Sweden. Indeed, Växtbaserat Sverige, an industry umbrella organisation, states that plant-based foods have increased by 15% to 30% annually over the past five years for their members, giving a promising outlook for the future (Blom et al., 2022). A scientist working with product development at RISE notes that it is mostly large companies that have requested support in developing new PSFPs, whilst smaller companies and ventures may do this work in-house despite being limited by their own capacities (Interview 5.8). A different interviewee points out that small companies can be nimbler and more open to change: They can generate new ideas and encourage diversity, but larger companies retain greater capacity to scale up, have more know-how, logistics and links throughout the supply chain and can cut costs more effectively making new products affordable for everyone (interview 5.6)

5.7.2. The role of place in protein development

Multi-actor involvement in pooling actions, resources and competences often occurs in a specific institutional context and place-based business ecosystem.



Map 1: Location of alternative businesses in the Nordic and Baltic regions, 2023. This list is not exhaustive. Map: Maria Bobrinskaya, Nordregio in Wøien Meijer (forthcoming).

The role of these various factors can be observed in the thirty-six cases mapped in Wøien Meijer (2023), (see map 1). The role of "place" matters, but less so in connection to specific typologies such as rural or urban qualities than in relation to different forms of "proximity". Based on the type of company, product and location, it may seem that the proximity to specific qualities in a place, such as university facilities or a highly specialised labour force is important. In these cases, it is clear that the existing knowledge bases available to the companies in these areas shape the company's trajectory and, therefore, their ability to innovate, change and learn (Wøien Meijer M. , Forthcoming). In three specific cases, it seems that existing food production companies or raw material networks were important, as were existing infrastructures. Other cases reveal the importance of knowledge 'proximities', such as Solar Foods and its connection to the University of Lappeenranta in Finland, the Estonian company Gelatex's roots in the University of Tartu and its current location in the Estonian capital Tallinn and the links between BioMass Protein and the University of Aalborg in Denmark (Wøien Meijer M. , Forthcoming). The latter also has a direct connection to its location as it relies on local suppliers of grass. However, company development has been decisively connected to the university and their researchers' skills and scientific competencies, e.g. in learning how to extract white proteins from green proteins.

From a regional perspective, the location of alternative protein

businesses seems to be less relevant in relation to access to raw materials than to existing networks or competences in the surrounding area. Nonetheless, these two are often interlinked as networks can emerge at the intersection of different actors in the supply chain.

At the same time, food supply chains are now extremely globalised, which means that there is a complex interplay between place-based and global dynamics in food production and trade. This adds a higher level of complexity to the design of policies to promote development, be it for technological innovation or improving food system sustainability. For instance, Sweden would need to increase its production of legumes by 8,000 ha. to replace current imports and an additional 140,000 ha. to replace imported soybeans, primarily used for feed (Blom et al., 2022). Yet legume production in Sweden has declined from 65,000 ha. to under 50,000 ha. between 2016 and 2021 (ibid.). Increasing production would require greater profit margins compared to other crops, but also increases in the domestic legume processing industry and demand for PSPFs. However, this is difficult to achieve due to the price and quality of imported soybeans. Therefore, achieving the protein shift is dependent on both the ability to upscale place-based developments and react to changes on the global stage.

5.7.3. The role of narratives and the key actors supporting them

As previously laid out, the meta-narratives built around the societal debate play a significant role in

shaping the path towards the protein shift, thereby influencing the actions of decision makers, businesses and individuals. Of particular note is the often black-and-white debates that emerge when food comes under discussion. Supporters of the protein shift do not necessarily all subscribe to the same views on sustainability within the food systems but may offer alternative paths on how to conduct this process. Likewise, it is important to pay attention to both supporters and detractors of change (and what they may stand to gain or lose).

This brings to the fore the debate between pro- and anti-livestock interest groups and some segments of society. Defenders of the livestock industry are many. Major transnational agri-food corporations (TNCs) such as JBS, Tyson Foods, Cargill and Smithfield have invested billions of dollars in the sector, and thus, it is unsurprising that they have exerted significant efforts in defending their interests. There are also many other pro-livestock actors, including many smallholders, academics and professionals (Béné & Lundy, 2023). On the opposing side are the many international environmental or conservation organisations and global experts that advocate for a drastic reduction in ASFPs production and consumption (ibid.). In addition, there is an increasing number of players proactively promoting alternative protein-based systems in several countries, such as Germany, South Korea, the United Kingdom and the Netherlands (Béné & Lundy, 2023). Several universities and think tanks in the Netherlands are particularly

vocal in advocating for transition in the protein shift debate.

Looking beyond the pro- and anti-livestock 'battle', Katz-Rosene et al. (2023) point out that adherents to a 'modernising protein' narrative based on scientific and technological advancement include not only major corporations within the conventional food systems, manufacturers of agriculture equipment and fertiliser companies, but also 'a range of sustainability policy associations' (Katz-Rosene et al., 2023). Advocates for 'reconstituting protein' or a transition to alternative proteins, both PSPFs and NFPFs, "include venture capitalist firms and food tech entrepreneurs which have invested or launched high-profile novel protein food products" and associations that support the development of new markets for NFPFs, such as the Good Food Institute and RethinkX (ibid.). In contrast, advocates for 'regenerating protein' include mostly pastoralists and a range of small-scale producers based on regenerative or holistic agriculture and other traditional practices. In Figure 9, Katz-Rosene et al. (2023) map a number of organisations and interest groups and position them according to the narrative and pathway they adhere to (modernising protein, reconstituting protein and regenerative protein). Here, it is possible to observe that certain actors and interest groups clearly subscribe to one of the three narratives, while others have overlapping views across narratives. For instance, small-scale producers are threatened by large corporations, while some of them are also threatened by potential measures discouraging the

conventional protein foods market: as a result, it is clear that markedly support the regenerative protein sphere. The Savory Institute, also placed within the same sphere, is perhaps the strongest voice in favour of regenerative practices in animal farming, which both opposes those seeking alternatives, but also supports intensive farming practices. Many within the vegan and vegetarian communities are in favour of replacing meat consumption and

using technology to develop novel foods, some of which are, in fact, highly processed products. However, others within this community are in favour of 'natural products' (as in not heavily processed and produced using more traditional processes). Thus they are situated in an overlapping position between modernising and reconstituting protein spheres, but also close to the regenerative protein sphere.

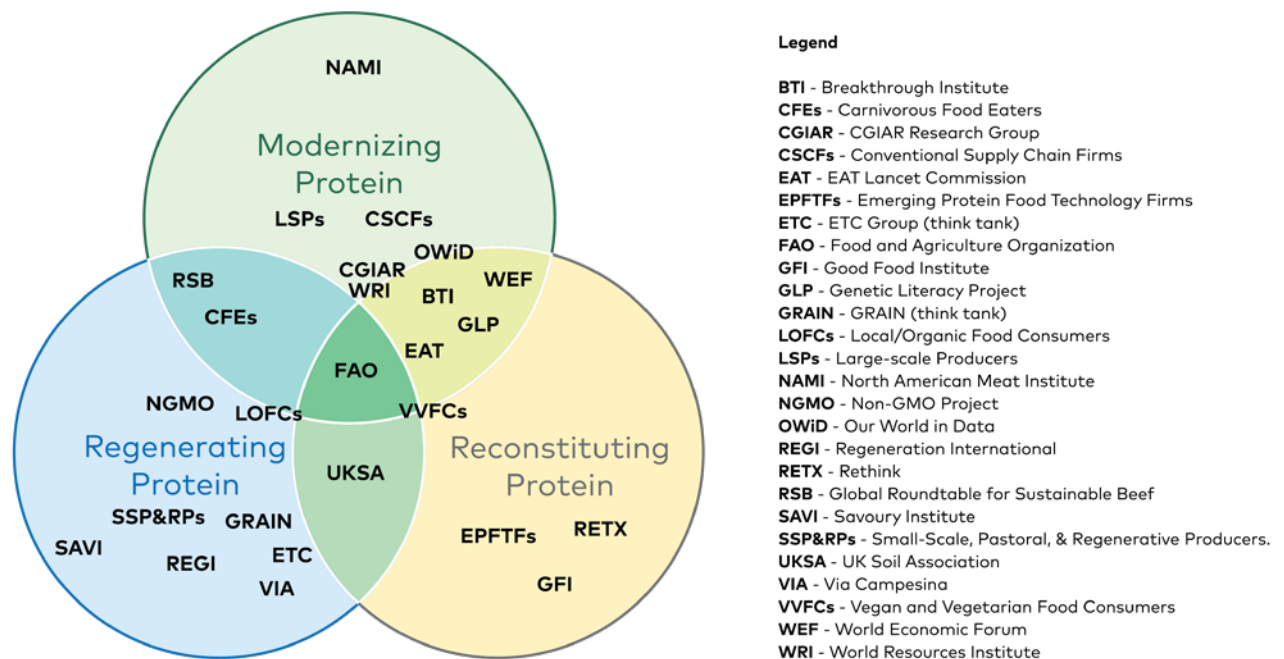


Figure 9. A Representative Sample of Meta-Narrative Coalition Leanings. Source: Adapted from Katz-Rosene et al., (2023) Re-design: Kotryna Juškaitė, Nordregio.

These meta-narratives and the black-and-white debate heavily influence the direction the protein shift is taking. This tug of war between the various factions of actors in the protein shift will ultimately be decided by those who manage to bridge the three

meta-narratives and communicate their policy "imaginaries", ideas and constructs to a wider audience. This also depends on the relative weight these agents carry on the global stage.

5.8. Conclusions: The roles of actors in driving change in the protein shift

This case study presented a general overview of the role of agency in the protein shift as one example of 'green innovation' in the food sector. The food system is built on several interlinked sub-systems in several different industries and is found in many parts of the world. Assuming a holistic view when studying innovation systems in the protein shift requires analysing simultaneous processes in interlinked and separate industrial ecosystems, each with its own historical traditions and development path consisting of different companies, supply chains and networks, as well as the application of different equipment, technologies and practices. Similar to the energy sector, the protein shift is leading to a process of industrial and resource diversification, which in combination could play a part in addressing sustainability challenges.

The processes leading to the diversification of products and protein sources used for food and feed, as well as the many developments in industrial and production processes, reveal that innovation is taking place in all parts of the value chains across many industries and scientific fields. However, the protein shift is certainly not moving in a single direction, nor is it co-ordinated by a single player: it is evolving in multiple directions at once and involves a myriad of different actors, who intentionally or unintentionally, aware or unaware, all contribute to the transformation of food and protein systems. New start-ups and companies play an important role by using cutting-edge technologies, such as in cell ag and

precision fermentation, as well as applying known technologies, such as extraction or extrusion of plant proteins or from fish waste. At the same time, existing companies also continue to play an important role in incremental innovation within primary production and processing industries. As old and new practices are meshed together, academia and research actors are at the centre of these developments. Indeed, scientists are often found spearheading the development of new technologies for protein production themselves, either by creating their own companies or being indirectly involved in new ventures.

From a regional perspective, geographical proximity seems to be a relevant factor in many new businesses, start-ups and other developments. Yet this may have more to do with the business ecosystem and access to knowledge and competences in the area rather than access to raw materials, given the extremes to which food supply chains are now globalised. Indeed, local development's reliance on global food chains is undeniable, and any place-based action aimed at contributing to the protein shift is inevitably bound to developments in the global sphere. One point of uncertainty revolves around the future business framework for alternative protein products and the distribution of the benefits. This concern arises from the increasing control of research and development concentrated in the hands of a handful of established global corporations as they absorb start-ups and small to medium-sized enterprises with inventive technologies and products.

Within the Nordic countries, the innovation and start-up ecosystem appears currently to be extremely dynamic in relation to new products and technologies surrounding the protein shift. However, a similar pattern to the wider global trend is also visible, where major companies and corporations have a greater capacity for R&D investment and in scaling up innovations and, therefore, eventually absorbing the smaller players.

Innovation in alternative protein sources and protein-rich products appears to be insufficient in addressing the environmental challenges. While the growing global population is an important factor in increasing the demand for protein-rich products, the increased intake of proteins as a total share of people's diet seems to be less related to 'need' but to food preference or habit and purchasing power. Furthermore, plant-based products are already a main protein source, which means food innovations (e.g., meat analogues) seem to be more relevant in helping consumers make different choices without significantly changing their habits (mentally) than in filling a technological gap (since plant proteins, such as fava beans or peas, do not necessarily need to be processed into new products to obtain the protein). Indeed, an important finding of this study is that the role of consumer behaviour should be more carefully assessed. While it is true that the general shift in values and awareness has generated innovation and a market pull for alternative protein products, caution should be advised in concluding that this automatically leads to increased

sustainability. Overconsumption of proteins, high levels of food waste and the fact that alternative protein products also have an environmental footprint go some way to explaining this.

Technological innovations need additional measures to reduce the protein intake, such as regulation, taxation and more profound efforts to influence people's overall preferences and choices. EU and national regulations and strategies have been an important driver, and a new wave of ambitious regulations from the EU have the potential to generate substantial change. However, there is as of yet no regulation directly banning or disincentivising the consumption of conventional protein products, so novel food products do not occupy an enviable market position for the moment. Policies, however, have other softer but more substantial ways of incentivising innovation, not to mention financial incentives, R&D funding and securing a permanent ecosystem of innovation with test beds, incubators and a whole range of support instruments. The highly globalised nature of the food system makes it less predictable as to whether policies will generate sufficient change locally without simply transferring the problems to third parties or other countries.

All in all, the way the protein shift will be shaped in coming years seems to be largely dependent on the way different sustainability narratives are able to convince consumers, businesses and decision-makers to take action and, more complicatedly, what type of action. Indeed, even those in favour of the

sustainability agenda may not agree on the specifics regarding the path towards the protein shift or the problem formulation. This is closely related to the multi-dimensional nature of the debate, including various ethical, sustainability, economic, cultural, societal and geographical considerations. Therefore, rather than directing radical support towards one narrative, a multi-pathway approach may seem a more realistic way to appease the

different interest groups, while at the same time improving the overall sustainability of the food and protein systems. In practice, this means that technological innovations, in combination with tighter regulation, will continue to deliver solutions for the intensification of food production and the diversification of protein food products in the market, while at the same time, traditional practices may well experience a renaissance.



Photo: Skellefteå Kommun / Unsplash.com

PART IV: Cross-case analysis

6. Analysis

This study has sought to use empirical evidence to provide some ideas on how innovations processes occur under the so-called 'green transitions'. In this section, we analyse our empirical evidence on the basis of the theoretical debate presented in PART I. Hence, this chapter is devoted to analyse the role of innovative entrepreneurs, institutional entrepreneurship, and place-based leadership in 'green innovations' and in setting directionality (see Figures 1, 2).

The relevance of singling out 'green innovations' from other, more general, 'innovations' is because the former are politically willed and specifically aimed at addressing the environmental crisis. This is what Grillitsch et al. (2019), among other authors, argue is characteristic of the new wave of innovation policies – Transformative Innovation Policy (TIP) - explicitly mobilising science,

resources and innovation efforts to meet societal challenges. Different cases of technological or sectoral transformative innovation occur from fundamentally different starting points, where innovations (and new development paths) are triggered either by a policy push, a technology push (by private businesses) or a demand pull (by clients/consumers). Empirical evidence gathered from our case studies in distinct industries, countries and regions shows that there is no black-and-white distinction of which particular actor is responsible for instigating change. The fact that there are policies that specifically target green innovations and transitions says as much about pull-push forces as the innovations that occur without the need for a policy push. However, regulations and policies are generally not the starting point of a transition, as they tend to be the result of a

broader process of societal problem recognition and a myriad of scientific and product developments. These are often ignored when tracing the chronological order of events, as there is often no precise moment, actor or action that can be attributed as the starting point of everything. Instead, it is the sum of related and unrelated actions by different agents that lays the groundwork. This can suddenly take on new meaning once a window of opportunity opens, effected by a regulatory change, for instance, although other changes may also play a part.

Green innovations also require a demand pull unless legislation demands the use of a specific technology or resource (e.g., via quota schemes) or by providing no alternative (e.g. by introducing bans or penalties that would push other options out of the market). In the case studies presented above, regulation and policy goals play an important role in boosting green innovation but do not, for the moment, rule out other options. However, in the wood construction case, we found evidence of more indirect ways of excluding alternatives: not necessarily conspicuously favouring wood buildings in new development programmes, but by municipalities setting ambitious carbon emissions requirements and/or by hinting what desired design features in newly developed areas could include. Similarly, in the protein shift case, conventional protein products are not being brushed aside, but there are examples of municipally or publicly owned schools that are trying to reduce their overall meat and dairy consumption by introducing more

varied diets in their meal offers, while at the same time encouraging local companies to provide innovative food products. This underscores the soft power and influence that many municipalities have in the Nordic countries, where there is much room for manoeuvre despite the parameters set out by national and supra-national authorities.

These direct and indirect, intentional and unintentional ways of pushing for change suggest that there is a need to adapt our traditional structure-agency debate understanding and adopt a more systemic understanding of innovation processes. It is evident that the current policy agenda represents a major change in the 'structure' – the rules of the game. From international agreements, such as the Paris Agreement and Agenda 2030, the EU Green Deal and Horizon Europe at EU level, to national legislation and sectoral policy and sub-national development strategies comes a substantial and clear message from the authorities: the economy needs to go 'green'. However, examining in detail the micro-processes leading to individual innovations or sectoral transformations reveals a much more complex and chaotic picture of who the drivers are, the roles the different actors play and their interactions. While changes in legislative and regulatory efforts entail systems change, exploring new economic pathways or industrial path creation is a multi-level and multi-actor process.

6.1. Innovative entrepreneurship

The Schumpeterian understanding of entrepreneurship as the exercise

of creative labour, opportunity recognition and idea exploitation rings true in our case studies. We recognise the ability of entrepreneurs, be they individuals or businesses, to identify windows of opportunity and take clear steps to avail of them, including solving technological bottlenecks, exploring the commercial viability of new products and solutions, developing a business model, etc. This does not necessarily mean, however, that entrepreneurs are gazing fixedly into a crystal ball, but proves their agility in applying existing knowledge and ideas to emerging opportunities occasioned by contextual changes for instance, in novel ways. Our empirical evidence supports this conclusion. Wood construction is not new, but changing contexts, both in terms of legislative and societal demands, brought new opportunities, which businesses were quick to identify and exploit. Many innovations have taken place, but mostly in incremental ways. Thus, in our first case study, the well-established companies assumed the pioneering role in developing new solutions for multi-storey wood building, as they had sufficient resources and built capacity to embark on costly investments. Start-ups, on the other hand, have played a greater role at a later stage by addressing technological and market gaps in relation to innovative materials – complementary to the industry.

In other cases, however, exploiting market opportunities does involve the application of unique trade secrets, patents and breakthrough innovations. This is more clearly visible in the protein shift where the holders of such "secrets" or

new knowledge are often scientists, some of whom chose to become entrepreneurs themselves or work in tandem with existing businesses to exploit the knowledge they hold. We could, therefore, identify two distinct paths in which companies exploit knowledge when conducting product development. Either they apply analytical knowledge (basic science) or synthetic knowledge, as in existing knowledge used to solve immediate problems. One pertinent observation in the protein case study is that larger and well-established companies tend to use synthetic knowledge, as in known processes and inputs used for imitating meat, including soy, peas and beans, whereas smaller start-ups and scale-ups more often work with basic science in laboratories, with niche products and radical or disruptive technologies such as precision fermentation and cellular agriculture. This can also be seen reflected in the backgrounds of those engaged in protein development. In companies such as BioMass Protein, ORF Genetics, Gelatex, Solar Foods and Mycrorena, the founders and their staff seem to primarily consist of natural scientists, whereas in contrast, business entrepreneurs are behind companies such as the Swedish fish-substitute start-up Hooked Foods and the pea-based company Bärta. That being said, these companies do not work in a vacuum and all interconnect with relevant knowledge brokers to gain the skills and insights needed for the development and marketing of their products.

Therefore, at least in the early phases, large and small businesses appear to contribute to the protein

shift in different ways: One contributes new knowledge through more radical products and inventions, and the other instigates endogenous change, improving and adapting existing products and commercialising and scaling-up production. However, this reality appears to be changing, as transnational companies, many of which have a dominant stake in the traditional food sectors' value chains, are now establishing or absorbing much of the R&D activities related to novel protein food products, thus securing their stake in emerging market niches. This suggests that once new ingredients and products become part of the standard offering on supermarket shelves, new products and innovations become systematised and controlled by larger companies.

In relation to change agents, both smaller and larger companies have a role to play in creating the conditions and contexts for the protein transition. As part of exploiting niche markets, smaller companies face a prerogative to diversify their path creation and, as such, contribute to creating a more dynamic technological, sectoral or regional market. Smaller companies in the protein sector are creating new pathways or extending existing ones. Beyond product development processes, which is a key role for entrepreneurs, it would be wrong to assume that business entrepreneurs are the sole instigators of systems transformation. In the cases under review, innovative entrepreneurship cannot be seen as wholly separate from institutional and place-based developments, as well as the more network-based processes

of innovation in which businesses engage in co-operative development with multiple actors.

It is clear from both case studies that entrepreneurs are currently capitalising on the favourable political context within which they find themselves, as well as their ability to be part of the solution to significant societal challenges (institutional demand). The political winds in Denmark in favour of finding alternative protein sources to diversify their pork production have clearly created a positive context that works in favour of protein businesses and start-ups, such as BioMass Protein. Likewise, the explicit regulatory developments pushing for a substantial cut in carbon emissions in the construction sector send a clear signal to businesses in favour of wood-based solutions. Moreover, the roles of different actors cannot be explained in a simple structure-agency relationship whereby the changes in structures enable businesses to conduct the creative labour on their own, but rather by public authorities, scientists, as well as other intermediate actors such as science parks or cluster organisations becoming involved in co-development and driving forward processes of system innovation and industrial path creation together.

6.2. Institutional entrepreneurship

What is the role of the state and public authorities when it comes to green innovation? We identify a wealth of examples of institutional innovation in our case studies, not only from the Schumpeterian understanding of public institutions as simply

'adapting' as part of the evolutionary change taking place in society at large but also in line with organisational theory and institutional entrepreneurship in which the public sector is understood to have a more proactive and intentional role in building competitive advantage. By shaping the baseline structures and pushing for politically-willed developments, public institutions are not merely fixing market failures but actively engaging with innovation processes and setting a direction towards economic prosperity or environmental sustainability, for example (path creation). In the wood construction case, the removal of bans or restrictions on multi-storey building in wood are clear examples of fixing market failures. Nor did the state authorities stop with these first-step measures, but continued by setting out a clear development path: from nursing innovation and the creation of a market niche by drafting ambitious strategies for development to more directly influencing paths by establishing R&D programmes and funding networks to support development (e.g. Wood City Sweden). At the sub-national level, certain municipalities and regions took an even more prominent role in fuelling innovation systems by mobilising local actors and enabling the flow of knowledge and learning, as well as boosting market expansion by using their role as a major client to purchase public buildings made of wood. In some cases, municipal engagement goes even further. Skellefteå municipality has directly spearheaded building new schools and other municipally funded projects utilising public procurement as one tool for supporting the wood

construction industry in the region.

However, we observed that municipalities' ability to act varies significantly based on key contextual differences. While both Skellefteå and Växjö municipalities lie within the same country (Sweden) and are thus subject to identical legal frameworks and baseline conditions, Skellefteå has a more dominant position in controlling development, thanks to its substantial financial resources, land ownership and a local housing company under its control. Växjö, on the other hand, finds itself in a less privileged position, although still possibly better off than other municipalities at home and abroad. Nevertheless, both municipalities represent successful examples of pushing forward industry development. What is interesting here is that local authorities, as institutional entrepreneurs, have had to adopt different strategies to foster change by adapting to their own specific regional conditions. In some cases, institutional entrepreneurship can take the form of a single person, a visionary with strong leadership capacity. For instance, the chair of the municipal council of Skellefteå and governor of Västerbotten Region at the time pushed for wood construction at a very early phase, even before a national strategy was in place. Achieving sustainability or innovation was not the main goal per se, but rather shaping the economic development path of the region after years of decline within the manufacturing industries. The city's success in advancing wood construction can be attributed to its capacity to leverage unique strengths, resources and historical roots. In this sense, the public official

took the entrepreneurial discovery process upon himself.

Institutional entrepreneurship at local level has also revolved around circumventing national regulation, i.e. the material neutrality principle established in Sweden's building codes, to support desired developments. This has been made possible through the help of other softer tools, such as presenting the type of architecture envisaged in a certain area, in combination with more blunt instruments such as public procurement (without directly demanding specific material use).

Institutional entrepreneurship also takes place in the form of new organisations, hybrid structures or networks aimed at pushing certain developments. The creation of Wood City Sweden (which the former governor of Västerbotten has chaired) provides an example, first in the form of a project and then an association of municipalities and regions formed specifically to address the bottlenecks in the market of wood buildings. Another example is the creation of the Wood Innovation cluster led by the municipality of Skellefteå to bring together market, science and public sector actors to co-ordinate innovation actions. The relevance of such hybrid structures corroborates Grillitsch and Sotarauta's (2020) conclusion that multi-actor involvement, as well as the right institutional drivers to renew, create or extend existing innovation paths are key to pooling powers, resources and skills. What is interesting to note is the role individuals assume in multi-actor partnerships is not necessarily dependent on the institutions they represent but more on the character

of the person. For instance, individuals can act as leaders, visionaries, mentors, critics or 'vision brokers', regardless of their formal position or employer. Individuals, in effect, can change employer yet remain connected to, or influential for, a specific development by 'wearing a different hat' or representing a different 'actor'.

In the protein shift case study, it is clear that there is a general societal megatrend pushing urgently in relation to climate change. This is reflected in political policies at supranational, national and local levels. The EU Green Deal and Horizon, the Farm to Fork strategy and the CAP are all increasingly adopting mission-oriented objectives to steer development and innovation towards increasingly sustainable production systems. On the one hand, tighter regulation aims to reduce the negative externalities of pollution, emissions and loss of biodiversity by setting limits on land use and the use of fertilisers and, on the other, through boosting innovative solutions by allocating substantial funding for R&D and innovation. VINNOVA, Sweden's innovation agency has put these ambitions into practice at a national level by funding R&D on novel foods and plant proteins, for example. While this mission approach in some specific funding programmes may lead to 'picking winners', our overall view is that many of these investments are actually 'picking the losers', as in choosing whom not to fund older industries and technologies based on their negative impact on society and the environment. However, neither are these alternatives (and competing developments), such

as conventional concrete and steel construction systems or livestock farms being directly banned or restricted: often, they do not need additional funding, as they are already well-positioned within the market. Indeed, in the latter case, we find EU-level agricultural subsidies that benefit both sustainable and unsustainable farming (although the CAP is increasingly setting requirements for subsidies in line with the sustainability goals).

The substantial impact of public policy and more active institutional entrepreneurship challenges the notion that the private sector is inherently innovative, takes risks and pushes the boundary of existing markets. While a number of pioneers have taken steps to challenge the status quo, such as investing in multi-storey wood construction and developing novel food products, a large portion of private entities not only remain within their comfort zones but also actively resist change. In the construction sector, resistance is evident across the entire supply chain, from contractors to banks and insurance companies. Similarly, in the food sector, traditional corporations and food-producing companies have, for the most part, resisted change. Nonetheless, once it has been demonstrated that a promising market for wood buildings or alternative protein products genuinely exists, many companies, including those who initially resisted change, rapidly pivot and follow the trends. However, as we have also seen, public actors are also in place, promoting and pushing new agendas. Therefore, the concept of the 'entrepreneurial state' is perfectly

applicable in these case studies. Without the active involvement of the state and sub-national authorities, private actors might have struggled to make significant progress.

Moreover, institutional entrepreneurship also occurs beyond the realm of public institutions in the form of normative institutional and societal behaviour changes. Altering consumer patterns and demand is another form of institutional entrepreneurship that challenges the baseline conditions, or rules of the game from the societal side - thus creating a market for new businesses and new products. Innovation is, as are most things, discourse and language dependent: what we say and how we frame it matters. Indeed, the clearly evident change in values, as well as the meta-narratives identified for and against certain building materials or food products, have been important determining factors in the development of new market niches. We will address this more informal dimension of institutional innovation in the next section.

6.3. Social innovation and dominant narratives

As innovations and entrepreneurial discovery processes exist within a social context, social change determines the scope of the opportunities that facilitate the emergence of these innovations. However, it is not always clear whether social change is the cause or the effect of innovations. Our empirical evidence shows that the reality is more chaotic. Given that many actors are focusing on '*green innovation*' specifically, as opposed

to other innovations, it suggests that the political and social context is prepared for innovations which are specifically situated within the 'green' sphere. This may suggest further that policy initiatives follow societal change and can, therefore, be seen as a policy response to climate concerns. This does not necessarily imply that society has changed its opinion on any given matter, but at least that a sufficient critical mass pushing for new policy initiatives has been reached. Society is not homogenous. Whilst some voices may become louder many others remain silent either due to lack of awareness, indifference or because the issue at stake is too complex for simplistic opinions.

In the protein shift case study, we have seen that there are at least three meta-narratives comprising a myriad of different actors with related views associated with the protein shift or sustainability within the food industry. Disagreements around the problem definition exist, which in turn impacts the choice and form of solutions. Moreover, the manifestation of different dominating discourses can be identified in various communities and although this may bode well for mutual understanding and common problem-solving approaches, it can also act as a brake on the development of alternative solutions (as we saw in the case of excessive cognitive proximity). The potential for innovation, be it technological advancements, institutional-regulatory changes or shifts in behavioural-societaldynamics, hinges on the impact of these overarching narratives on societal and political

discourse. The translation of these narratives into action by decision-makers, businesses and society shapes innovation opportunities. For example, product developers innovating in the food space target different consumer groups based on these groups' perceived values. Yet it remains unclear whether changing values will lead to radical regime change, with one technology/product category dominating the market, or a case of multiple technological 'regimes' with diversified market offerings that meet the demands of social groups with different values. What is clear is that dominating meta-narratives have an impact on the push-and-pull forces manifested in consumer choices, policy decisions and what businesses offer.

The wood construction case witnessed a similar situation, where broader social support for sustainability has led to an increase in the use of wood materials, even though it remains highly unlikely that other materials will be simultaneously phased out. Although the role of social innovation, behaviour and perceptions seems to have a more direct impact on the protein shift, where individual consumer choice plays a central role, these factors are also observable in the multi-storey wood construction path creation. Changing social values appear to have impacted the perception of modern wooden structures where they come to represent both a renewed elevated status and revitalisation of urban areas. However, fear of fire and mould also act as deterrents to development, more so for investors, contractors and other players in the value chain, such as banks and

insurance companies, than the final consumer. Uncertainty remains an important threat to change. Similarly, as in the protein case study, we see that competing narratives continue to vie for attention, e.g. the juxtaposition of concerns regarding wooden structures and deforestation with narratives emphasising sustainability and health benefits. Pilot projects have an important role to play, especially at a time when a dominant narrative is being challenged, as they create a space for an alternative narrative to unfold. In the wood construction case, one such pilot project is the architecturally ambitious high-rise SARA Kulturhus in northern Sweden.

Narratives are connected to people's perceptions of different vying alternatives and, ultimately, to choices that people and institutions make (or which are available to them). It is particularly interesting that the debate is often couched in black-and-white terms when the answers to the concerns about sustainability and ethics often lie in an extended grey zone.

6.4. Place-based leadership & place-less developments

When analysing the role of a place in innovation systems, a fundamental question arises: how do we define the system? Defining the system depends on what represents the most appropriate level of aggregating the relevant actors, resources and series of conditions that define a system of innovation. The literature suggests different alternatives, including **national, regional, technological and sectoral innovation systems**. The key differences are whether the emphasis

is placed on the geographical dimension and physical boundary that encloses the system or on the networks and connections between relevant actors, regardless of location. In practice, the most relevant way to aggregate the system often depends on the industry, sector and technology that we are investigating, as well as the ways actors and value chains are organised. To disentangle this riddle, we will avail of Boschma's (2005) understanding of proximities to analyse our empirical findings. For Boschma, 'proximity' refers to the ability to understand, adopt and adapt, to identify novelty, interpret and exploit new knowledge. This occurs across five dimensions, namely **geographical, cognitive, organisational, social and institutional proximities**. These dimensions of proximity may or may not exist simultaneously and may become more or less relevant depending on the type of innovation and phase of development. Moreover, proximities can either produce positive effects by aiding the flow of information and path creation or negative effects by hindering the influx of new ideas, causing technological, institutional and behavioural lock-ins that resist change and innovation.

Geographical proximity, the colloquial understanding of proximity, is relevant to national and especially regional innovation systems. Geography generally determines regions' industrial legacy, the resources available, the knowledge and skills, the established networks, the institutional structures, as well as 'tacit knowledge' or more implicit societal norms or 'ways-

to-do-things'. This is especially prominent in the case of wood construction, where the industrial legacy and proximity to resources have produced a positive lock-in, allowing traditional forestry regions to lead the innovation processes in wood construction. Localised knowledge spillovers became useful when structural change, in the form of changed legislation, enabled new developments, as in companies developing new solutions for multi-story wood construction. Under new dynamic networks, innovation and transformational changes emerge and grow as there is a short 'distance' between key players across public institutions, companies, municipalities and academia. This short distance can refer to geographical proximity in place developments, such as in Skellefteå or Växjö, but also cognitive proximity across longer distances via intensive collaboration.

In the case study on protein transitions, we see that the role of a "place" also matters less so in connection to specific typologies such as rural or urban qualities but more in relation to different forms of proximity. Based on the type of company, product and location, it appears that the proximity to specific qualities in a place is important, such as access to university facilities or a highly specialised labour force. In these cases, the existing knowledge bases available to the companies in these areas shape that company's trajectory and, therefore, their ability to innovate, change and learn (Boschma, 2005; Hansen, 2015; Zukauskaitė and Moodysson, 2016).

However, there is a dual situation. While start-ups tend to stay close to universities or large university cities, the suppliers of input factors (raw materials) are internationally based, possibly due to the spatially blind nature of some of the proteins (e.g., larvae, yeast, fungi and commodity crops). However, in some cases, geographical proximity to biomass suppliers is highly beneficial. In one observed case, the company is situated between a university town and a rural area.

Furthermore, case studies revealed many examples of 'too little' geographical proximity, where actors were compelled to bring skills, resources and markets closer to each other in order to succeed in furthering their ventures. However, other cases also revealed examples of 'too much' proximity, leading to a myopic, inward-looking environment where cross-fertilisation is rare and inefficient. For example, some companies and scientific networks focusing on a specific protein food category or industrial process may largely work alone and ignore the opportunities for cross-learning. In the construction sector, innovation via the use of wood materials was limited during the century-long moratorium on tall wooden buildings, thus enabling the consolidation of concrete and steel construction systems and value chains. Strong cognitive and organisational proximity produced a lock-in situation making it extremely difficult for newcomers offering disruptive alternatives to enter the market. The extent of this difficulty led 'disruptors', at least in the early stages of development, to

circumvent existing actors and value chains and create parallel avenues to enable market penetration.

Cognitive proximity, which is more associated with like-minded people with common understanding and ideas and less with physical distance, is therefore key to enabling technological innovation to emerge, evolve and spread. The important condition here is that these actors are willing and able to stay in close communication, share knowledge and advance science, even if dispersed across large geographical distances. One example is the partnership between Polarbröd and the fungi company Mycorena, located in the north and south-western part of Sweden, respectively. Drawing on the potential to close the resource loop and encourage circular economy practices, the two companies work together to minimise waste by feeding waste streams to fungi despite being located far apart. However, capitalising on fungi is currently halted by the definition of waste in EU regulations. This is a good example of co-operation toward a common goal but also demonstrates the potential of geographical proximity.

While the industrial legacy rooted in very specific places has played an important role in the wood construction case, it is also clear that intensive cross-fertilisation between companies working with the development of new building systems and products has taken place mostly across the Nordic countries and central Europe, (although also more recently in the Baltic countries, North America and to a much lesser extent, globally).

The substantial work carried out in Germany and Austria in developing mass timber products proved useful for companies and scientists in the Nordic countries, where the forestry industry and wood construction markets are highly developed. It is interesting to note that while industrial development requires close geographical proximity amongst different types of actors (i.e., private, public and academia), technological breakthroughs, independent of industrial development, are less determined by place and more by like-minded companies and professionals learning from each other across borders and industrial sectors. Moreover, significant knowledge exchange has occurred between municipalities, e.g., across Swedish regions that are particularly keen to boost sustainable construction, including in more urban regions where the forestry industry has less or no direct presence. Here, cognitive proximity precedes geographical proximity, although the national level remains an important dimension, as municipalities across Sweden operate under the same national rules.

Excessive cognitive proximity may also limit the opportunity for alternative or hybrid options (e.g., construction systems and materials), a situation which undercuts systems innovation. Many argue that the protein debate is largely one-sided and in the wood construction conversation, some actors have been described as 'wood Taliban', a title inferring a certain degree of partiality.

The case studies have also revealed evidence of the role of

organisational proximity, understood as the extent to which relations are shared in an organisational arrangement within and between organisations (Boschma, 2005). One obvious example is the substantial extent to which the Skellefteå municipality administration can drive action by owning its own energy company, by co-ordinating the multi-actor Wood Innovation Cluster and through access to funding via the investment bank Svenska Kommuninvest, which is jointly owned by a large number of Swedish municipalities. This demonstrates strong relations within and between organisations and the power this affords the municipality to exert influence on other actors. There is also evidence of organisational proximity emerging from the recently established consortium following the Vinnova call for 'recipes for the future', in which the project consortium has been tasked with establishing an innovation platform for where actors can connect.

Organisational proximity is also, and often, closely related to **social proximity**, which refers to the extent to which economic structures are embedded in social contexts (Boschma, 2005). Relations between agents at the very lowest level (microlevel) are important here, as they bring trust, the "Nordic gold", to the table. At local level and particularly in regions with small populations, the 'human factor' is of utmost relevance, as individuals representing different organisations know or are at least acquainted with each other and have built trust relationships that can make supporting new innovative action

more efficient and faster. Skellefteå municipality and the broader region is a clear example of this phenomenon where the (social) distance between stakeholders is said to be 'one phone call' away. Interestingly, cultural proximities, including values and ethics – as we have seen in the protein case – do not belong in this category but rather to the category of institutional proximity. Also of note here is the role of agents and trust in the development of new products and services in the protein space: innovation in start-ups and scale-ups is dependent on social proximity to enable the exchange of tacit knowledge (Boschma, 2005). This is closely connected to the intersection of place, time and identity.

Finally, the fifth dimension of proximity is **Institutional proximity**: a general condition relevant, in one form or another, to all the observed processes. Institutional proximity concerns the ways relationships between actors and innovation are determined by the institutional environment.

There is a clear connection to the national innovation system in the development of the wood construction sector, where the interlinkages between regulation, national policy and R&D programmes with existing companies throughout Sweden, as well as industry organisations, have all played a significant role in boosting innovation and market development. The more sporadic nature of the same development in Finland has been one of the main barriers to up-scaling the wood construction industry there. Although much of the necessary knowledge came from abroad, and

the fact that these developments did not happen in isolation, the role of national innovation systems has been nonetheless crucial. In the protein case, however, the presence of national innovation systems is much less apparent and developments in different industrial and technological strands have emerged more sporadically. Instead, we notice a close interlinkage between scientists and companies that focus on these developments, e.g. cell agriculture or protein alternatives internationally, which have not been particularly determined by national regulatory frameworks, with the exception of certain market creations where first Singapore and later the USA have granted permits to sell cultured meat in the market. However, institutional arrangements do play a role; hence the role of geography, particularly in the form of R&D funding programmes geared towards food systems change.

More generally, Nordic countries are well placed to advance the development of protein systems, with well-functioning innovation systems, a high ranking on human development indices, more rigorous regulations and governments recognising the importance of working towards a more sustainable future. These well-functioning and dynamic institutional environments, in combination with a society that shows a high degree of openness towards innovation, enable businesses and scientists not only to lead technological innovation processes but also gives them the confidence to pilot and launch them. Institutional arrangements at local and regional levels can be even more

impactful in supporting or halting innovation. This is more clearly the case in wood construction, where municipal strategies, local spatial planning systems and tools, as well as the closer relationships between key actors, determine the capacity to pool resources and drive change.

6.5. Green Innovation in a context of 'transitions'

A final relevant theme to this analysis is transition: more specifically, the green transition. A fundamental presumption that we need to take into account is that we are studying the role of agency in green innovation in a policy context that intends to produce profound transformations in our economic and social systems. Not only innovation policies but also the overarching policy frameworks at EU level, which are then transposed to national and sub-national levels, are all designed with the explicit intent of changing the status quo. Moreover, the changes are not just any changes but are specifically aimed at addressing major societal challenges, including the environmental crisis. This context is a key starting point for this analysis, as studying innovation under a policy context-oriented towards maintaining the status quo would obviously produce entirely different results.

Transitions, or transformational innovations, require changes in the interlinked social and technical systems, understood as '*socio-technical transitions*'. Transformational policy activates different agents to drive innovation, be it technological, social, entrepreneurial or institutional innovations and be they incremental

or radical, intentional or unintentional. The sum of all these actions will produce systems change.

Geels' (2002) argument that technological transformation results from a process of technological substitution is evidenced in the empirical case studies, although only partially. Literature on sociotechnical transitions emphasises the inherent challenges in these processes, often marked by resistance from influential entities in politics, business and social structures. Overcoming the significant inertia within sociotechnical systems demands more than just technological innovations or alterations in consumer behaviour: it calls for far-reaching and interlinked innovative actions. For this reason, sociotechnical transitions may follow diverse pathways, with the complete system transformation being just one option. It is common for transitions to commence by enhancing or expanding existing systems rather than dismantling them outright (Geels 2002; Geels 2012; Araujo 2014; Geels et al. 2018; Sorrell 2018).

The sectors studied in our case studies follow this pattern whereby new technologies, processes, products and behaviours lead to diversification and incremental change rather than full regime change. Many innovations are also not intended to replace the function of existing products but to transform the processes needed to achieve the end results. For instance, an apartment building or a sausage will fulfil their intended purpose, no matter how they are produced. Yet major change can be achieved through new building processes such as modular technologies or by

means of Mass Timber structures in the case of construction, or the feed used in animal farms, animal welfare standards, crop cultivation technologies, fertilisers and pesticides used in the case of meat production. The resulting differences are significant in terms of environmental footprint, efficiency, organisation of labour, costs, etc.

There are a number of innovations that can potentially lead to radical change, such as cultivated meat or precision agriculture. However, we have not found evidence that these can completely substitute existing products and practices, but nonetheless may lead to a more diversified market and set of practices.

When it comes to institutional structures, the green transition has required substantial transformations in governance structures, particularly the role of public authorities in supporting sectoral development, organisational change, generating new market conditions and assuming a leading role in path creation. The same can be said of social innovation, as it is primarily societal awareness that has triggered change in the political and market spheres. Yet, our case studies show that awareness of environmental issues does not necessarily lead to consumer behaviour that can be considered sustainable. For example, when it comes to consumer choice in selecting an apartment, the decision is mostly guided by convenience, location and price rather than the construction materials or energy efficiency of the building.



Photo: Joel Klassen / Unsplash.com

7. Conclusion

The empirical results of the two sectors investigated in this study show that the development of green innovations and transitions are non-linear and highly complex and that the influence of and between agents is multi-directional. Causality cannot be attributed to single actors or decisions but rather to the sum of different individual efforts working together. Directionality and causality become even more blurred the more one examines the micro-processes that determine key decisions (policies, legislation and private and public investment) and the relationships

between actors. However, we acknowledge that change emerges precisely at the interphase between key players, where co-operation is the catalyst and the means for knowledge exchange and learning and trust is a key condition for putting knowledge into action. Figure 10 helps visualise the process of systems innovation resulting from the sum of actions of all relevant actors in our case studies, which intentionally and unintentionally exploit the knowledge that is continuously circulating among them.

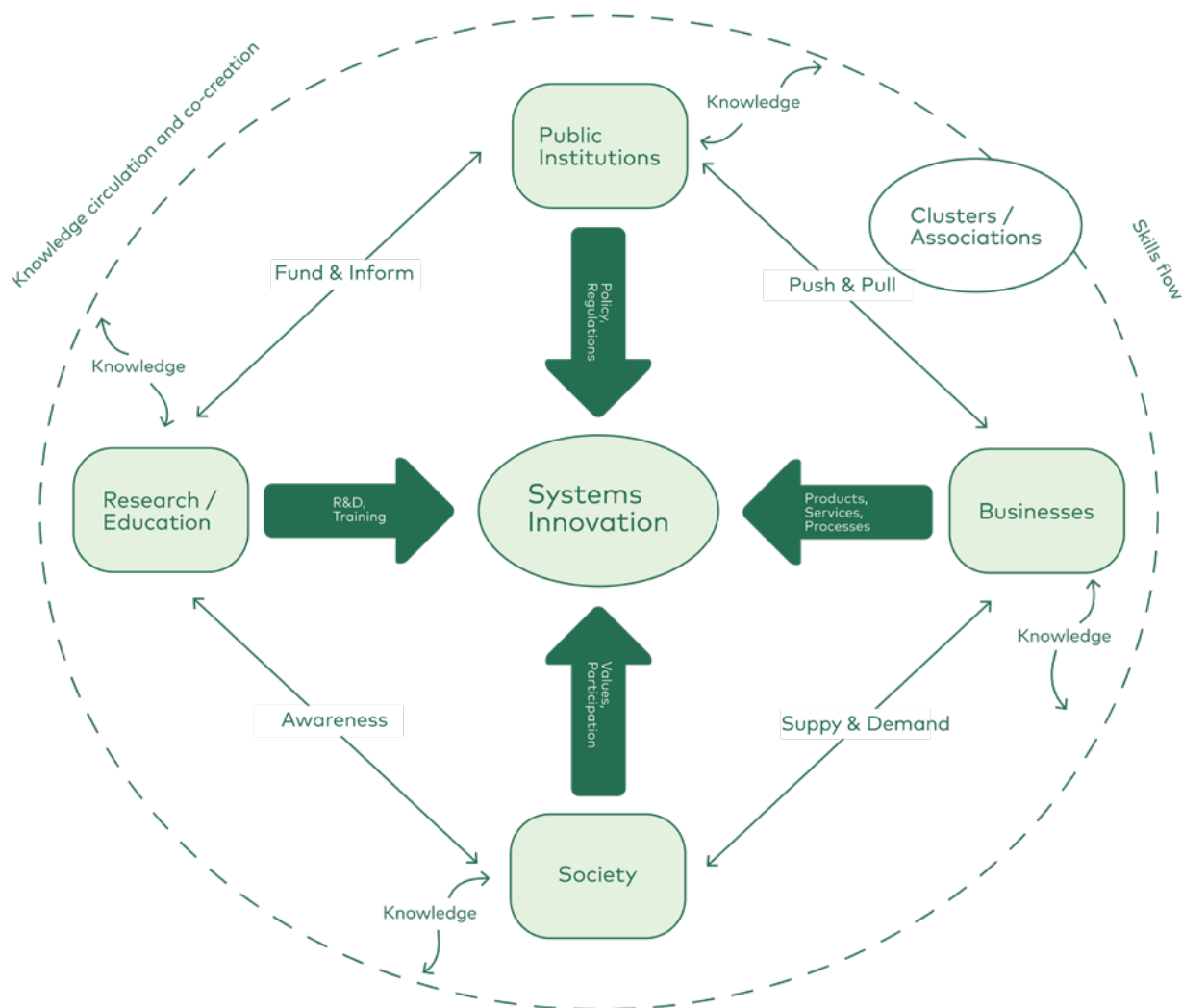


Figure 10: Systems' innovation as a product of multiple agents' simultaneous actions. Source: Authors' re-interpretation of existing frameworks in innovation systems literature.

However, the complex and non-linear nature of systems innovation does not mean that directionality is irrelevant. While many actions unintentionally lead to systems change, most of these are not random but have a specific purpose. Businesses engage in new activities in search of new economic opportunities: although not necessarily with the aim of changing 'the world' they inevitably contribute to processes of structural change. Policies and regulation

are more intentionally designed to address systemic issues, including systems innovation and economic path creation. However, directionality does not unfold in the same way in every context. Different actors and institutions can assume the role of change agents/leaders. For instance, the state and local authorities can play a more general role in setting the framework for new green developments and financing the green transition through, e.g., research

grants geared towards tackling problems rather than supporting one specific technology. Regulations can act both as a gatekeeper and a door opener. They encourage innovation by guiding private actors towards new opportunities and at the same time determine 'exnovation', meaning the path towards abandoning specific technologies, processes or products that are deemed 'unwanted'. Moreover, in certain cases, authorities become more than administrative units, setting the rules of the game by taking a more active role in pursuing a course of action, mobilising stakeholders, co-ordinating actions and addressing practical bottlenecks. In other cases, the business and scientific community play a more prominent role in leading systems innovation.

When it comes to place-based developments, identifying the formal and informal roles of individuals who act as 'champions' is relevant, even as they move between jobs, from private to public sectors and vice versa. The changing roles of different actors can be seen at an institutional level when either public, private, academic or hybrid entities are activated and assume a leading role. Companies can also mutate and change their market position by entering new market segments or expanding their presence along supply chains. Companies often create sister

companies if suppliers of related products and services are missing, or when existing partner companies resist change, or more simply to cut costs, reduce intermediaries and increase efficiency. Finally, actors setting directionality can also change over time. While authorities can play an important role at a given point in time by changing the rules of the game, they may become less relevant at a later stage. Similarly, businesses can at one moment resist new developments yet subsequently change their attitudes and even lead to market creation or expansion. This also holds true for complementary actors. For example, risk-averse financial capital tends to be reluctant to support new ventures until these are proven viable, although here, we can also observe that context matters.

Returning to the structure-agency debate, agency is, in effect, the conductor of change. However, context (structure) provides the preconditions to enable or halt agency, such as functioning markets, appropriate regulatory frameworks and access to labour, knowledge and capital. In the Nordic countries, a major enabler of change is the so-called 'Nordic gold' or trust, understood as the high degree of trust placed in authorities and individuals prevalent throughout society.

8. References

8.1. References Theoretical Overview

Amin, A., Petersen, I., Malmberg, C., & Orlén, V. (2022). Perspective on the Effect of Protein Extraction Method on the Antinutritional Factor (ANF) Content in Seeds. *Food Science & Technology*, 604-612. doi:10.1021/acsfoodscitech.1c00464

Altenburg, R., & Rodrik, D. (2017). GREEN INDUSTRIAL POLICY: Accelerating structural change towards wealthy green economies. In T. Altenburg, & C. Assmann, *Green Industrial Policy: Concept, Policies, Country Experiences*. (pp. 2-20). Geneva: United Nations Environmental Program.

Altenburg, T., & Pegels, A. (2012). Sustainability-oriented innovation systems - managing the green transformation. *Innovation and Development*, 2(1), 5-22.

Ambec, S. (2017). Gaining competitive advantage with green policy. *Green Industrial Policy - Concept, policies and country experiences*, 38-50.

Amilien, V., & Notaker, H. (2018). Health and Nutritional Perspectives on Nordic Food Traditions—An Approach Through Food Culture and History. In B. Andersen, E. Bar, & G. Wirtanen, *Nutritional and Health Aspects of Food in Nordic Countries* (pp. 1–31). Academic Press. doi:doi:10.1016/B978-0-12-809416-7.

Annala, K., & Teräs, J. (2017). *Synthesis report*. Nordic working group for green growth – innovation and entrepreneurship 2013-2016. Stockholm: Nordregio. Retrieved from <http://norden.diva-portal.org/smash/get/diva2:1092495/FULLTEXT01.pdf>

Araujo, K. (2014). The emerging field of energy transitions: Progress, challenges, and opportunities. *Energy Research and Social Science* 1: 112–121

Asheim, B. (2019). Smart specialisation, innovation policy and regional innovation systems: what about new path development in less innovative regions? *The European Journal of Social Science Research*, 32(1).

Asheim, B. T., & Coenen, L. (2005). Contextualizing Regional Innovation Systems in a Globalizing Learning Economy: On Knowledge Bases and Institutional Frameworks. *Paper no. 2005/5*.

Asheim, B. T., & Coenen, L. (2006). Contextualising regional innovation systems in a globalising learning economy: On knowledge bases and institutional frameworks. *The Journal of Technology Transfer*, 31(1).

- Asheim, B. T., & Isaksen, A. (1997). Location, Agglomeration and Innovation: Towards Regional Innovation Systems in Norway. *European Planning Studies*, 5(3).
- Audrecht, D. B., & Feldman, M. P. (1996). R&D Spillovers and the Geography of Innovation and Production. *The American Economic Review*, 86(3), 630-640.
- Béné, C., & Lundy, M. (2023). Political economy of protein transition: Battles of power, framings and narratives around a false wicked problem. *Frontiers in Sustainability*, 4(1098011). doi:10.3389/frsus.2023.1098011
- Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the Functional Dynamics of Technological Innovation Systems: A Scheme of Analysis. *Research Policy*, 37(3).
- Binz, C., Truffer, B., & Coenen, L. (2016). Path creation as a process of resource alignment and anchoring – industry formation for onsite water recycling in Beijing. *Economic Geography*, 92(2), 172–200.
- Blom, S., Edström, F., Eklöf, P., Johnsson, B., Markensten, T., & Stenberg, M. (2022). *Ökad odling av baljväxter till livsmedel och foder – Möjligheter och utmaningar*. Swedish Board of Agriculture (Jordbruksverket).
- Boschma, R. (2005). Proximity and innovation: a critical assessment. *Regional Studies*, 39(1), 61-74.
- Breschi, S., & Malerba, F. (1997). Sectoral Innovation Systems: Technological Regimes, Schumpeterian Dynamics, and Spatial Boundaries. *Systems of Innovation: Technologies, Institutions and Organizations*, 1, 130-156.
- Breschi, S., & Malerba, F. (1997). Sectoral systems of innovation: technological regimes, Schumpeterian dynamics and spatial boundaries. In C. (Edquist, *Systems of Innovation*. London: Pinter.
- Carayannis, E. G., Samara, E. T., & Bakouros, Y. L. (2015). *Innovation and Entrepreneurship: Theory, Policy and Practice*. New York: Springer.
- Carlsson, B., & Stankiewicz, R. (1991). On the nature, function and composition. *Journal of Evolutionary Economics*, 1, 93-118.
- Cedergren, E., Tapia, C., Sánchez Gassen, N., & Lundgren, A. (2022). 'Just Green Transition' – key concepts and implications in the Nordic region. *Nordregio discussion paper 2022:2*. DOI: 10.6027/WP2022:2.1403-2511. 'Not Just A Green Transition'-project. Stockholm: Nordregio.
- Cell-based Tech. (2020, Aug 21). *Cell based tech weekly – Plant molecular farming*. Retrieved from Weekly reports: <https://cellbasedtech.com/2020/08/cell-based-tech-weekly-plant-molecular-farming>
- Chezan, D., Flannery, O., & Patel, A. (2022). Factors affecting consumer attitudes to fungi-based protein: A pilot study. *Appetite*.

Coenen, L., Benneworth, P., & Truffer, B. (2012). Toward a spatial perspective on sustainability transitions. *Research Policy*, 968-979.

Coleman, J. (1986). Social theory, social research, and a theory of action. *American Journal of Sociology*, 91(1), 1309-1335.

Cooke, P., Gomez Uranga, M., & Extbarria, G. (1997). Regional innovation systems: Institutional and organisational. *Research Policy*, 26, 475-491.

Euro Funding. (n.d.). "From farm to table". Healthier and more sustainable food system, <https://euro-funding.com/en/blog/from-farm-to-fork-healthy-and-sustainable-food-system/>. Retrieved 11 05, 2023, from Euro Funding.

European Commission. (n.d.). (D. Reform, Producer) Retrieved 1 25, 2022, from https://ec.europa.eu/reform-support/what-we-do/green-transition_en

European Commission. (2020). *A Farm to Fork Strategy for a Fair, Healthy and Environmentally-Friendly Food System*. Brussels. Retrieved from <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0381>

European Commission. (2020). *Farm to Fork Strategy: for a fair, healthy and environmentally-friendly food system*. (COM/2020/381 final). Brussels.

European Commission. (2020). *The European Green Deal: Striving to become the first climate-neutral continent*. Retrieved from EU

Commission: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en#:~:text=To%20overcome%20these%20challenges%2C%20the,and%20no%20place%20left%20behind

European Commission. (2020a). *Proposed Mission: A Climate Resilient Europe Prepare Europe for climate disruptions and accelerate the transformation to a climate resilient and just Europe by 2030*.

European Commission. (2020b). *Proposed Mission: 100 Climate-neutral Cities by 2030 – by and for the Citizens*. Report of the Mission Board for climate-neutral and smart cities.

European Commission. (2021). *Common Agriculture Policy 2023-2027*. Retrieved from https://agriculture.ec.europa.eu/common-agricultural-policy/income-support/greening_en

European Medicines Agency. (n.d.). *Bioavailability*. Retrieved from Glossary: <https://www.ema.europa.eu/en/glossary/bioavailability>

Freeman, C. (1995). The 'national system of innovation' in historical perspective. *Cambridge Journal of Economics*, 19, 5-24.

Geels, F. (2002). Technological Transitions as Evolutionary Reconfiguration Processes: A Multi-Level Perspective and a Case-Study. *Research Policy*, 31.

Geels, F., & Schot, J. (2007). Typology of Sociotechnical Transition Pathways. *Research Policy*, 36(3).

Geels, F. (2012). A socio-technical analysis of low-carbon transitions: introducing the multilevel perspective into transport studies. *Journal of Transport Geography* 24: 471–482.

Geels, F. W., Schwanen, T., Sorrell, S., Jenkins, K., Sovacool, B. (2018). Reducing energy demand through low carbon innovation: A sociotechnical transitions perspective and thirteen research debates. *Energy Research & Social Science* 40: 23–35
Gertler, M. (1997). The invention of regional culture. In R. Lee, & J. Willis, *Geographies of Economies* (pp. 47–58). London: Arnold.

Giacometti, A. (2021). *Fredrik, Leo and Angelo: Cutting up to 4% of global emissions by feeding cows with seaweed*. Nordregio. Retrieved from <https://nordregioprojects.org/blog/2020/04/29/fredrik-leo-angelo/#/home>

Giddens, A. (1991). Structuration theory: past, present and the future. In C. Bryant, & D. Jary, *Giddens' theory of structuration: A critical appreciation* (pp. 201 - 221). London: Routledge.

Giddens, A. (1991). Structuration theory: past, present and the future. In C. Bryant, & D. Jary, *Giddens' theory of structuration: A critical appreciation* (pp. 201-221). London: Routledge.

Good Food Institute. (n.d.). *Fermentation*. Retrieved from Good Food Institute Europe: <https://gfiEurope.org/fermentation/>

Gravel, A., & Doyen, A. (2020). The use of edible insect proteins in food: Challenges and issues related to their functional properties. *Innovative Food Science & Emerging Technologies*, 59.

Grillitsch, M., & Asheim, B. (2018). Place-based innovation policy for industrial diversification in regions. *European Planning Studies*, 26(8), 1638-1662.

Grillitsch, M., & Hansen, T. (2019). Green industry development. *European Planning Studies*, 27:11, 2163-2183. doi:10.1080/09654313.2019.1648385

Grillitsch, M., & Sotarauta, M. (2020). Trinity of change agency, regional development paths and opportunity spaces. *Progress in Human Geography*, 44(4).

Grillitsch, M., Hansen, T., Coenen, L., Miörner, J., & Moodysson, J. (2019). Innovation policy for system-wide transformation: The case of strategic innovation programmes (SIPs) in Sweden. *Research Policy*, 48(4), 1048-1061. Retrieved from <https://doi.org/10.1016/j.respol.2018.10.004>

Hagedoorn, J. (1996). *Innovation and Entrepreneurship: Schumpeter Revisited*. Industrial and Corporate Change, 3(3).

Hansen, T. (2015). Substitution or overlap? The relations between geographical and non-spatial proximity dimensions in collaborative innovation projects. *Regional Studies*, 49(10).

Hartmann, C., & Siegrist, M. (2017). Consumer perception and behaviour regarding sustainable protein consumption: A systematic review. *Trends in Food Science & Technology*, 11-25.

Harvard T.C Chan School of Public Health. (2022, January). *Are anti-nutrients harmful?* Retrieved from The Nutrition Source: <https://www.hsph.harvard.edu/nutritionsource/anti-nutrients/#:~:text=Though%20certain%20foods%20may%20contain,any%20potential%20negative%20nutritional%20effects.>

Hekkert, M. P., Janssen, M. J., Wesseling, J., & Negro, S. O. (2020). Mission-Oriented Innovation Systems. *Environmental Innovation and Societal Transitions*, 34.

Hekkert, M., Suurs, R., Negro, S. O., Kuhlman, S., & Smits, R. (2007). Functions of Innovation Systems: A New Approach for Analysing Technological Change. *Technological Forecasting and Social Change*, 74(4).

Hewage, A., Olatunde, O., Nimalaratne, C., Malalgoda, M., Aluko, R., & Bandara, N. (2022). Novel Extraction technologies for developing plant protein ingredients with improved functionality. *Elsevier: Trends in Food Science & Technology*, 129, 492-511. doi:<https://doi.org/10.1016/j.tifs.2022.10.016>

Innogen Institute. (n.d.). *Application of synthetic biology and gene editing to agricultural crops*. Retrieved from Regulatory challenges: <https://www.innogen.ac.uk/regulatory-challenges/application-synthetic-biology-and-gene-editing-agricultural-crops>

Innovation Norway. (2023). *Bionova - tilskudd til bioøkonomi og klimatiltak*. Retrieved from Grønn omstilling: <https://www.innovasjon Norge.no/tjeneste/bionova-tilskudd-til-bioekonomi-og-klimatiltak>

Innovationsfonden. (2023). *Innorapporten: Danske succeser. Innovative svar på komplekse udfordringer*. Innovationsfonden. Retrieved from <https://innovationsfonden.dk/sites/default/files/2023-06/Innorapporten%202023.pdf>

Jessop, B. (2001). Institutional re(turns) and the strategic-relational approach. *Environment and Planning A*, 33, 1213 – 1235. doi:10.1068/a32183

Kattel, R. (2015). What would Max Weber Say about Public-Sector Innovation? *NISPAcee Journal of Public Administration and Policy*, 8(1), 9-19. Retrieved from <https://doi.org/10.1515/nispa-2015-0001>

Katz-Rosene, R., Heffernan, A., & Arora, A. (2023). Protein pluralism and food systems transition: A review of sustainable protein meta-narratives. *Elsevier*, 161. doi:10.1016/j.worlddev.2022.106121

Kemp, R., Schot, J., & Hoogma, R. (1998). Regime Shifts to Sustainability through Processes of Niche Formation: The Approach of Strategic Niche Management. *Technology Analysis & Strategic Management*, 10(2).

Khan, A. (2022). *An Introduction to Cellular Agriculture*. CellAgri.

- Kuech, A., Breuer, M., & Popescu, I. (2023). *Research for PECH committee - The future of the EU algae sector*. Policy Department for Structural and Cohesion Policies, European Parliament. European Parliament.
- Lema, R., Nordensvärd, J., Urban, F., & Lüktenhorst, W. (2014). *Innovation Paths in Wind Power - Insights from Denmark and Germany*. Discussion Paper.
- Loorbach, D. (2007). *Transition Management New Mode of Governance for Sustainable Development Transitiemanagement*. PhD Thesis. Rotterdam: Erasmus Universiteit Rotterdam.
- Louiseau, et al. (2015). Implementing the green economy in a European context: Lessons learned from theories, concepts and case studies. *Partnership for European Environmental Research*.
- Lundvall, B.-Å. (1992 [2010]). *National Systems of Innovation: Toward a Theory of Innovation and Interactive Learning*. (Vol. Second Edition). Anthem Press.
- Mac Monagail, M., Cornish, L., Morrison, L., Araújo, R., & Critchley, A. (2017). Sustainable harvesting of wild seaweed resources. *European Journal of Phycology*, 52(4), 371-390.
- Malerba, F., & Orsenigo, L. (1995). Schumpeterian patterns of innovation. *Cambridge Journal of Economics*, 19, 47-65.
- Mayer Labba, I., Karlsson, A., Sandberg, A., Cederberg, C., Nadeau, E., Undeland, I., . . . Landberg, R. (2020). *A healthy and sustainable protein shift in Västra Götaland region*. Gothenburg: Chalmers University of Technology, Swedish University of Agriculture (SLU), Research Institutes of Sweden (RISE).
- Mazzucato, M. (2013). *The Entrepreneurial State: Debunking Public vs. Private Sector Myths* (Vol. 1st Edition). London: Anthem Press.
- Mazzucato, M. (2018). *Mission-Oriented Research & Innovation in the European Union: A problem-solving approach to fuel innovation-led growth*. European Commission: DG for Research and Innovation. Luxemburg: Publications Office of the European Union.
- Mazzucato, M. (2019). *Governing Missions in the European Union*. European Commission.
- Mazzucato, M. (2021, Aug 21). *Mission Economy: A Moonshot Guide to Changing Capitalism*. Youtube. Retrieved from <https://www.youtube.com/watch?v=-uTNPSCaMmU>
- Mazzucato, M., Kattel, R., & Roll, K. (2020, Oct 1). *Innovation, Public Policy and Public Value: New Masters in Public Administration*. *Creative Bureaucracy Festival*. Retrieved from <https://www.youtube.com/watch?v=GMuTR1aemRs>
- McKinsey & Company. (2019, August). *Alternative proteins: The race for market share is on*. *Agriculture Practice*, pp. 1-11.
- Morgan, K. (1997). *The Learning*

Region: Institutions, Innovation and Regional Renewal. Regional. *Regional Studies*, 31, 491-503.

Morgan, K. (2017). Nurturing novelty: Regional innovation policy in the age of smart specialisation, *Environment and Planning. Politics and Space*, 35(4).

Mycorena. (2023, 01 25). *Mycorena Receives €1.5 Million EU Funding for Cutting-Edge Technology to Develop 3D Printable Mycoprotein*. Retrieved from Mycorena: <https://mycorena.com/mycotalks/mycorena-receives-15-million-eu-funding-for-cutting-edge-technology-to-develop-3d-printable-mycoprotein>

Nelson, R., & Rosenberg, N. (1993). Technical innovation and national systems. In R. Nelson, *National innovation systems: A comparative analysis* (pp. 3-21). New York Oxford: Oxford University Press.

NHO Mat og Drikke. (2020). *Vil styrke forskning og innovasjon i matproduksjon*. Retrieved from NHO Mat og Drikke: <https://www.nhomd.no/politikk/forskning-og-utvikling/2020/vil-styrke-forskning-og-innovasjon-i-matproduksjon/>

Nofima. (2023). *Nofima*. Retrieved from Nofima: <https://nofima.no/>

North, D. (1990). *Institutions, Institutional Change and Economic Performance*. New York: Cambridge University Press.

OECD. (2020). *Mission-Oriented Innovation: Tackling society's grand challenges*. Retrieved from OPSI - Observatory of Public Sector

Innovation: <https://oecd-opsi.org/projects/mission-oriented-innovation/#:~:text=What%20is%20mission%2Doriented%20innovation%3F&text=A%20mission%2Doriented%20innovation%20policy,challenge%2C%20in%20a%20defined%20timeframe>.

Office of the Auditor General of Norway. (2023). *Matsikkerhet og beredskap på landbruksområdet. Dokument 3:4 (2023-2024)*. Oslo: Riksrevisjonen. Retrieved from <https://www.riksrevisjonen.no/globalassets/rapporter/no-2023-2024/matsikkerhet-og-beredskap-pa-landbruksomradet.pdf>

Phan, P. (2004). Entrepreneurship theory: Possibilities and future directions. *Journal of Business Venturing*, 617-620. doi:DOI: 10.1016/j.jbusvent.2003.09.001

Porter, M. (1998). Clusters and the new economics of competition. *Harvard Business Review*, 76(6), 77-90.

Porter, M. E. (1990). The Competitive Advantage of Nations. *Harvard Business Review*, March+April, 74-91.

Porter, M. E. (2000). Location, Competition, and Economic Development: Local Clusters in a Global Economy. *ECONOMIC DEVELOPMENT QUARTERLY*, 14(1), 15-34.

Radosevic, S. (2017). Assessing EU Smart Specialisation Policy in a Comparative Perspective. In S. e.

Radosevic, *Advances in the Theory and Practice of Smart Specialisation*, (pp. 2-36). Amsterdam: Elsevier Science Publishers.

Ramoglou, S., Gartner, W. B., & Tsang, E. W. (2020). "Who is an entrepreneur?" is (still) the wrong question. *Journal of Business Venturing Insights*.

Ramström, G. (2018). Coleman's boat revisited. Causal sequences and the micro-macro link. *Sociological Theory*, 36(4), 386-391.

Randall, L., Vestergård, L., & Wøien Meijer, M. (2020). *Rural perspectives on digital innovation: Experiences from small enterprises in the Nordic countries and Latvia*. Stockholm: Nordregio. Retrieved from <https://norden.diva-portal.org/smash/get/diva2:1429460/FULLTEXT02.pdf>

Regeringskansliet. (2023). *En livsmedelsstrategi för jobb och hållbar tillväxt i hela landet*. Retrieved from Landsbygds - och infrastrukturdepartementet: <https://www.regeringen.se/regeringspolitik/en-livsmedelsstrategi-for-jobb-och-hallbar-tillvaxt-i-hela-landet/>

RISE. (n.d.). *Like: meat project*. Retrieved 11 04, 2023, from <https://www.ri.se/sv/vad-vi-gor/projekt/likemeat>

RISE. (n.d.). *New and healthier products pushing the protein shift*. Retrieved from What we do: <https://www.ri.se/en/our-stories/new-and-healthier-products-pushing-the-protein-shift>

Rodríguez-Pose, A. (2013). Do Institutions Matter for Regional Development? *Regional Studies*, 47(7).

Rodríguez-Pose, A., & Crescenzi, R. (2008). Mountains in a flat world: why proximity still matters for the location of economic activity. *Cambridge Journal of Regions, Economy and Society*, 1(3), 371-388.

Rotmans, J., Kemp, R., & van Asselt, M. (2001). More Evolution than Revolution: Transition Management in Public Policy. *Foresight*, 3(1).

Roy, S., & Pal, R. (2015). Microalgae in aquaculture: a review with special references to nutritional value and fish dietetics. *Proceedings of the Zoological Society*, 1-8.

Saviotti, P. (1997). *Innovation Systems and Evolutionary Theories*. In C. Edquist, *Systems of Innovation: Technologies, Institutions and Organisations* (pp. 180-199). Routledge.

Schumpeter, J. A. (1942 (2010)). *Capitalism, Socialism and Democracy*. New York, London: Routledge.

Seedtable. (2022, October). *Cultivated Meat. Problems Worth Solving. (#1)*. Retrieved from <https://www.seedtable.com/>

Singh, A. et al. (2021). Transformation Techniques and their role in crop improvement: A global scenario of GM crops. In P. Singh, A. Borthakur, A. Singh, A. Kumar, & K. Singh, *Policy*

issues in genetically modified crops: A global perspective (pp. 515-542). Academic Press. doi:<https://doi.org/10.1016/C2019-0-02566-6>

Solar Foods. (n.d.). Retrieved 06 10, 2023, from Solar Foods: <https://solarfoods.com/>

Sorrell, S. (2018). Explaining sociotechnical transitions: A critical realist perspective. *Research Policy* 47: 1267–1282

Sotarauta, M., & Suvinen, N. (2021). The many roles of change agency in the game of green path development of the North. *European Urban and Regional Studies*, 28(2).

SPXFLOW. (n.d.). (SPXFLOW) Retrieved 06 15, 2023, from SPXFLOW: <https://www.spxflow.com/anhydro/products/spin-flash-dryers/>

Steen, M., & Hansen, G. (2018). Barriers to path creation: the case of offshore wind power in Norway. *Economic Geography*. 94(2), 188–210.

Swartz, E., & Bomkamp, C. (n.d.). *The science of cultivated meat*. Retrieved from Good Food Institute: <https://gfi.org/science/the-science-of-cultivated-meat>

Tait, J., & Barker, G. (2011). Global Food Security and the Governance of Modern Biotechnologies. *EMBO Reports*, 763-768. doi:<https://doi.org/10.1038/embo.2011.135>

Tanner, A., Lourenco, F., Moro, M., Iversen, E., Østergaard, C., & Park, E. (2019). *Regional Distribution of*

Green Growth Patents in four Nordic Countries: Denmark, Finland, Norway and Sweden. Technical University of Denmark. Retrieved from https://backend.orbit.dtu.dk/ws/portalfiles/portal/167481794/gonst_wp3_report_distribution_of_green_patents_2019.pdf

Tanner, A., Lourenco, F., Moro, M., Iversen, E., Østergaard, C., & Park, E. (2019). *Regional Distribution of Green Growth Patents in four Nordic Countries: Denmark, Finland, Norway and Sweden*. Technical University of Denmark. Retrieved from https://backend.orbit.dtu.dk/ws/portalfiles/portal/167481794/gonst_wp3_report_distribution_of_green_patents_2019.pdf

The Economist. (2023, December 12). Will lab-grown meat ever make it onto supermarket shelves? *The Economist*.

Tillväxtverket. (2023). *Ny innovativ mat*. Retrieved from Tillväxtverket: <https://tillvaxtverket.se/tillvaxtverket/omtillvaxtverket/detharartillvaxtverket/varauppdrag/nyinnovativmat.4071.html>

Tuomisto, H. L. (2018). The eco-friendly burger. *EMBO reports*. doi:10.15252/embr.201847395

Tzvia, M., Negro, S., Kalfagianni, A., & Hekkert, M. (2020). Understanding the protein transition: The rise of plant-based meat substitutes. *Environmental Innovation and Societal Transitions*, 35, 217-231.

Vinnova. (2021). *The good and sustainable everyday food of the*

future - Innovations for support for Swedish processing of plant-based raw materials. Retrieved 11 04, 2023, from Vinnova: <https://www.vinnova.se/en/calls-for-proposals/food-from-the-future/innovations-to-support-for-protein-shift/>

Vinnova. (2023, November 22). *The Protein Revolution*. Retrieved from Vinnova: <https://www.vinnova.se/en/p/the-protein-revolution/>

Vinnova. (n.d.). *A new recipe for the food system*. Retrieved 11 04, 2023, from Vinnova: <https://www.vinnova.se/en/m/sustainable-food-systems/follow-and-contribute-to-a-new-recipe-for-the-food-system/>

Volta Greentech. (2023). *Volta Greentech*. Retrieved 08 15, 2023, from Press release: Launch of Lome Beef at Hemköp. Probably the most climate-friendly beef on the planet: <https://www.voltagreentech.com/>

Wang, Y., & Shelomi, M. (2017). Review of black soldier fly (*Hermetia illucens*) as animal feed and human food. *Foods*, 6(10).

Wilson, J. (1989). *Bureaucracy: What Government Agencies Do and why they Do it*. New York: Basic Books.

Wøien Meijer, M. (2023). *A mapping of alternative protein businesses across the Nordic-Baltic Region*. Copenhagen: Nordic Council of Ministers.

Wøien Meijer, M., & Peters, O. (2021). Nordic Industrial Green Transition: A literature review. *NORCE Samfunn*, Report no. 20/2021.

Zukauskaite, E., & Moodysson, J. (2016). Multiple paths of development: knowledge bases and institutional characteristics of the Swedish food sector. *European Planning Studies*, 24(3), 589 - 606.

8.2. References case study: Innovation Dynamics in Wood Construction in Sweden and Finland

Bionova Ltd. (2017). Tiekartta rakennuksen elinkaaren hiilijalanjäljen huomioimiseksi rakentamisen ohjauksessa.

Boverket. Climate declaration for new buildings. Website: [Boverket.se](https://www.boverket.se). Access 31-10-2022

Byggvärlden, 2022. Skellefteå bygger bro i trä. Available at: <https://www.byggvarlden.se/skelleftea-bygger-bro-i-tra/>

Ekholm, T., 2011. Trästad 2012 utvecklar byggbranschen. Byggnyheter.se 4th June 2011. Available at: <https://www.byggnyheter.se/20190804/5720/trastad-2012-utvecklar-byggbranschen>

Elspecta AB. 89/106/EEC. Website. Available at: <https://elspecta-ab.com/en/?layout=edit&id=7>

The European Commission, 2016. Green Public Procurement.

Available at: https://ec.europa.eu/environment/gpp/news_archive_en.htm

Finnish Government (Valtioneuvosto), 4th June 2021. Rakennuksen ilmastoselvityksen asetussuunnitelma lausunnoille – tavoitteena yhdenmukainen ja luotettava vähähiilisyysarviointi. Available at: <https://valtioneuvosto.fi/-/1410903/rakennusten-ilmastoselvityksen-asetussuunnitelma-lausunnoille-tavoitteena-yhdenmukainen-ja-luotettava-vahahiilisyysarviointi>

Kunskapsförmedlingen, 2022. Lean Wood Engineering. Website. Available at: Lean Wood Engineering—Kunskapsförmedlingen (<https://kunskapsformedlingen.se/projekt/lean-wood-engineering/>)

Laapotti, S., 2020. Rakennetaanko puusta vai rahasta – puu taipuisi moneen, mutta rahayhtälö sakkaa. University of Tampere 07.12.2020. Available at: <https://www.tuni.fi/unit-magazine/artikkelit/rakennetaanko-puusta-vai-rahasta-puu-taipuisi-moneen-mutta-rahayhtalo-sakkaa>

Lindblad, F. (2020) Växjö Municipality's Planning Strategy to Increase the Construction of Wooden Multi-Family Buildings. Sustainability 2020, 12, 4915. DOI: 10.3390/su12124915

LTU, 25.8 2011. Nordens längsta snedstagsbro i trä invigd. Available at: <https://www.ltu.se/research/subjects/Trateknik/2.39050/Nordens-langsta-snedstagsbro-i-tra-invigd-1.82355>

Martinsons (2015) Martinsons invests SEK 80 million in Cross Laminated Timber production line. Cision News. Web-article: <https://news.cision.com/martinsons/r/martinsons-invests-sek-80-million-in-cross-laminated-timber-production-line,c9864685>

Manninen, H. (2014). Long-term outlook for engineered wood products in Europe. European Forest Institute.

Metsä Groupin Viesti 4/2013. Published on Nov 28, 2013. Available at: https://issuu.com/metsagroup/docs/mg_viesti_4_2013/52

Mölsä, S., 30.8. 2016. 50 vuotta kehitystyötä: VTT ja Tekes ovat monen rakennusalan menestystarinan takana. Rakennuslehti. Available at: <https://www.rakennuslehti.fi/2016/05/vtt-ja-tekes-ovat-monen-rakennusalan-menestystarinan-takana/>

Mölsä, S., 2021. Analyysi: Puurakentaminen on liian kallista, siksi sen edistämiseksi siirryttiin pakkoon. Rakennuslehti 25th March 2021. Available at: <https://www.rakennuslehti.fi/2021/03/analyysi-puurakentamista-on-edistetty-yli-25-vuotta-mutta-vasta-pakko-tuotti-tulosta/>

Nord, T. (2008). Prefabrication Strategies in the Timber Housing Industry: Case studies from Swedish and Austrian markets. Luleå University of Technology. Technical Report: 2008:16 - ISSN: 1402-1536

Näringsdepartementet (2004). Mer trä i byggandet: Underlag

för en nationell strategi att främja användning av trä i byggandet. [More Wood in Construction strategy]. Ds 2004:1

NTT Woodnet (2012). Vad händer efter Trästad 2012? Access: 27, October 2022. Website: https://www.woodnet.se/article/view/429632/vad_hander_efter_trastad_2012

OneClick, October 2022. Construction carbon regulations in Europe. Review & best practises.

Paavola, H., 2019. Puurakentamisen ohjelman kehittävä arviointi. Witmill and Ministry of Environment. Available at: <https://valtioneuvosto.fi/-/1410903/puurakentamisen-ohjelman-valiarviointi-puurakentamisella-jovahva-tuki-mutta-kunnianhimon-tasoa-varaa-nostaa>

Palmadóttir A., Arkitekt FAÍ sap arkitektar. 2022. Panelist at: The climate villain goes green – the role and responsibility of the construction industry to reduce its emissions. Icelandic Democracy Festival, Fundur fólksins, 2022 Sustainable Construction project.

Purdy, Sirpa 2010. Suomalainen moderni puuasuntorakentaminen 1990- ja 2000 -lukujen vaihteessa. Tapausesimerkinä Niiralan Kulma Oy:n modernit puuvuokratalot Kuopiossa. Master thesis. University of Jyväskylä.

Puu-lehti, 2017. Opas julkisiin hankintoihin. Available at: https://puutuoteteollisuus.fi/images/pdf/Julkkis_sivuittain_LOW.pdf

Railio, J., 2014. Construction Products Regulation (CPR) applies also to HVAC products. Rehva Journal March 2014. Available at: 10-11_CPR_RJ1402_WEB.pdf (rehva.eu)

Ramage, M.H.; Burrridge, H.; Busse-Wicher, M.; Fereday, G.; Reynolds, T.; Shah, D.; Wu, G.; Yu, L.; Fleming, P.; Densley-Tingley, D.; et al. (2017) The wood from the trees: The use of timber in construction. Renew. Sustain. Energy Rev. 68, 333–359.

Rasmussen, F.N.; Andersen, C.E.; Wittchen, A.; Hansen, R.N.; Birgisdóttir, H. (2021) Environmental Product Declarations of Structural Wood: A Review of Impacts and Potential Pitfalls for Practice. Buildings, 11, 362. <https://doi.org/10.3390/buildings11080362>

Saarnivaara, V-P., 1998. User-oriented industrialized construction as a strategic target in Finland.

SBK-säätiö, 2009. Tehdään elementeistä: Suomalaisen betonielementtirakentamisen historia

Siikanen, Unto 2008. Puurakentaminen. Helsinki: Rakennustieto.

Skellefteå.se, 2023. Wood Innovation Cluster. Available at: skelleftea.se/trainnovationsklustret

Skogsindustrierna, 19.11. 2008. Lorentz Andersson dubbad till träriddare. Available at: <https://news.cision.com/se/skogsindustrierna/r/lorentz-andersson-dubbad-till-trariddare,c394357>

Smart City Sweden, 2020. Wooden construction – The future in Urban Planning. Available at: <https://smartcitysweden.com/wooden-construction-the-future-in-urban-planning/>

Stehn, L., 2022. Lean Wood Engineering. Available at: https://www.ltu.se/cms_fs/1.51998!/lars%20stehn_lwe.pdf

Suikkari, R., 2007. Paloturvallisuus ja kaupunkipalot Suomen puukaupungeissa – historiasta nykypäivään. Licentiate Thesis. University of Oulu.

Suomen liimapuuyhdistys ry and Puuinfo Oy, 2014. Liimapuukäsikirja Osa 1. Libris Oy.

Swedish Forest Agency (2020) Market Statement 2020 – SWEDEN. UNECE Timber Committee Market Discussion 4-6 November 2020 Geneva, Switzerland

Swedish Wood. Wood in the construction process. Website: <https://www.swedishwood.com/building-with-wood/construction/building-with-wood/> Access: 02/10/2022.

The Ministry of Environment (Ympäristöministeriö), 2022a. Vähähiilinen rakentaminen ("Low carbon construction"). Available at: <https://ym.fi/vahahiilinen-rakentaminen>

The Ministry of Environment (Ympäristöministeriö), 2022b. Puun käyttö julkisessa rakentamisessa: Hankintaopas. Ympäristöministeriön julkaisuja 2022:25. Available at: https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/164407/YM_2022_25.pdf?sequence=4

Tina Wik Arkitekter, 2022. Wälludden I. Website. Available at: <https://tinawikarkitekter.se/wordpress/walludden-i/>

Tolppanen, J., Karjalainen, M., Lahtela, T., Viljakainen, M., 2013. Suomalainen puukerrostalo – Rakenteet, suunnittelu ja rakentaminen. Opetushallitus.

Träbyggnadskansliet 2014 <https://trabyggnadskansliet.se/kunskap/2021/pressmeddelande-industriellt-byggande/>

Växjö Municipality (2013). Växjö the modern wooden city: Växjö Municipality's Wood Construction Strategy.

Wood Joensuu, 2022. Puurakentaminen. Website. Available at: <https://woodjoensuu.fi/teemat/puurakentaminen/>

Woodnet, 2014. Sveriges första guldklassade skola helt i trä. Available at: <https://www.woodnet.se/article/view/430348/sveriges-forsta-guldklassade-skola-helt-i-tra>

8.3. References case study: Systems perspectives on the protein shift

- Amin, A., Petersen, I., Malmberg, C., & Orlén, V. (2022). Perspective on the Effect of Protein Extraction Method on the Antinutritional Factor (ANF) Content in Seeds. *Food Science & Technology*, 604-612. doi:10.1021/acsfoodscitech.1c00464
- Amilien, V., & Notaker, H. (2018). Health and Nutritional Perspectives on Nordic Food Traditions—An Approach Through Food Culture and History. In B. Andersen, E. Bar, & G. Wirtanen, *Nutritional and Health Aspects of Food in Nordic Countries* (pp. 1–31). Academic Press. doi:doi:10.1016/B978-0-12-809416-7.
- Asheim, B. T. (2007). Differentiated knowledge bases and varieties of regional innovation systems. *Innovation: The European Journal of Social Science Research*, 20(3), 223–241.
- Béné, C., & Lundy, M. (2023). Political economy of protein transition: Battles of power, framings and narratives around a false wicked problem. *Frontiers in Sustainability*, 4(1098011). doi:10.3389/frsus.2023.1098011
- Blom, S., Edström, F., Eklöf, P., Johnsson, B., Markensten, T., & Stenberg, M. (Jordbruksverket). *Ökad odling av baljväxter till livsmedel och foder – Möjligheter och utmaningar*. Swedish Board of Agriculture (Jordbruksverket).
- Cell-based Tech. (2020, Aug 21). *Cell based tech weekly – Plant molecular farming*. Retrieved from Weekly reports: <https://cellbasedtech.com/2020/08/cell-based-tech-weekly-plant-molecular-farming>
- Chezan, D., Flannery, O., & Patel, A. (2022). Factors affecting consumer attitudes to fungi-based protein: A pilot study. *Appetite*.
- Euro Funding. (n.d.). “From farm to table”/Healthier and more sustainable food system, <https://euro-funding.com/en/blog/from-farm-to-fork-healthy-and-sustainable-food-system/>. Retrieved 11 05, 2023, from Euro Funding.
- European Commission. (2020). *A Farm to Fork Strategy for a Fair, Healthy and Environmentally-Friendly Food System*. Brussels. Retrieved from <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0381>
- European Commission. (2020). *Farm to Fork Strategy: for a fair, healthy and environmentally-friendly food system. (COM/2020/381 final)*. Brussels.
- European Commission. (2021). *Common Agriculture Policy 2023-2027*. Retrieved from https://agriculture.ec.europa.eu/common-agricultural-policy/income-support/greening_en
- European Commission. (2023). *European Innovation Scoreboard*. Retrieved from Research and

Innovation: <https://research-and-innovation.ec.europa.eu/statistics/performance-indicators/european-innovation-scoreboard-en#european-innovation-scoreboard-2023>

European Commission. (2023). *European Innovation Scoreboard. Country profile Sweden*. Brussels: European Commission DG Research and Innovation. Retrieved from https://ec.europa.eu/assets/rtd/eis/2023/ec_rtd_eis-country-profile-se.pdf

European Medicines Agency. (n.d.). *Bioavailability*. Retrieved from Glossary: <https://www.ema.europa.eu/en/glossary/bioavailability>

Giacometti, A. (2021). *Fredrik, Leo and Angelo: Cutting up to 4% of global emissions by feeding cows with seaweed*. Nordregio. Retrieved from <https://nordregioprojects.org/blog/2020/04/29/fredrik-leo-angelo/#/home>

Good Food Institute. (n.d.). *Fermentation*. Retrieved from Good Food Institute Europe: <https://gfieurope.org/fermentation/>

Gravel, A., & Doyen, A. (2020). The use of edible insect proteins in food: Challenges and issues related to their functional properties. *Innovative Food Science & Emerging Technologies*, 59.

Hartmann, C., & Siegrist, M. (2017). Consumer perception and behaviour regarding sustainable protein consumption: A systematic review. *Trends in Food Science & Technology*, 11-25.

Harvard T.C Chan School of Public Health. (2022, January). *Are anti-nutrients harmful?* Retrieved from The Nutrition Source: <https://www.hsph.harvard.edu/nutritionsource/anti-nutrients/#:~:text=Though%20certain%20foods%20may%20contain,any%20potential%20negative%20nutritional%20effects>.

Hewage, A., Olatunde, O., Nimalaratne, C., Malalgoda, M., Aluko, R., & Bandara, N. (2022). Novel Extraction technologies for developing plant protein ingredients with improved functionality. *Elsevier: Trends in Food Science & Technology*, 129, 492-511. doi:<https://doi.org/10.1016/j.tifs.2022.10.016>

Innogen Institute. (n.d.). *Application of synthetic biology and gene editing to agricultural crops*. Retrieved from Regulatory challenges: <https://www.innogen.ac.uk/regulatory-challenges/application-synthetic-biology-and-gene-editing-agricultural-crops>

Innovation Norway. (2023). *Bionova - tilskudd til bioøkonomi og klimatiltak*. Retrieved from Grønn omstilling: <https://www.innovasjon Norge.no/tjeneste/bionova-tilskudd-til-bioekonomi-og-klimatiltak>

Innovationsfonden. (2023). *Innorapporten: Danske succeser. Innovative svar på komplekse udfordringer*. Innovationsfonden. Retrieved from <https://innovationsfonden.dk/sites/default/files/2023-06/Innorapporten%202023.pdf>

Katz-Rosene, R., Heffernan, A., & Arora, A. (2023). Protein pluralism and food systems transition: A review of sustainable protein meta-narratives. *Elsevier*, 161. doi:10.1016/j.worlddev.2022.106121

Khan, A. (2022). *An Introduction to Cellular Agriculture*. CellAgri.

Kuech, A., Breuer, M., & Popescu, I. (2023). *Research for PECH committee - The future of the EU algae sector*. Policy Department for Structural and Cohesion Policies, European Parliament. European Parliament.

Mac Monagail, M., Cornish, L., Morrison, L., Araújo, R., & Critchley, A. (2017). Sustainable harvesting of wild seaweed resources. *European Journal of Phycology*, 52(4), 371-390.

Mayer Labba, I., Karlsson, A., Sandberg, A., Cederberg, C., Nadeau, E., Undeland, I., . . . Landberg, R. (2020). *A healthy and sustainable protein shift in Västra Götaland region*. Gothenburg: Chalmers University of Technology, Swedish University of Agriculture (SLU), Research Institutes of Sweden (RISE).

Mayer Labba, I., Karlsson, A., Sandberg, A., Cederberg, C., Nadeau, E., Undeland, I., . . . Landberg, R. (2020). *A healthy and sustainable protein shift in Västra Götaland region*. Gothenburg: Chalmers University of Technology, Swedish University of Agriculture (SLU), Research Institutes of Sweden (RISE).

McKinsey & Company. (2019, August). Alternative proteins: The race for market share is on. *Agriculture Practice*, pp. 1-11.

Mycorena. (2023, 01 25). *Mycorena Receives €1.5 Million EU Funding for Cutting-Edge Technology to Develop 3D Printable Mycoprotein*. Retrieved from Mycorena: <https://mycorena.com/mycotalks/mycorena-receives-15-million-eu-funding-for-cutting-edge-technology-to-develop-3d-printable-mycoprotein>

NHO Mat og Drikke. (2020). *Vil styrke forskning og innovasjon i matproduksjon*. Retrieved from NHO Mat og Drikke: <https://www.nhomd.no/politikk/forskning-og-utvikling/2020/vil-styrke-forskning-og-innovasjon-i-matproduksjon/>

Nordren-Estonia. (November 2023). *Norden Estonia YouTube channel*. Hämtat från https://www.youtube.com/watch?v=KR4AZYAtJew&ab_channel=NordenEstonia

Nofima. (2023). *Nofima*. Retrieved from Nofima: <https://nofima.no/>

proteinreport.org. (2023, May 11). *Gelatex Awarded 760,000 Euro Grant to Develop Edible Microcarriers for Industrial Cultured Meat Production*. Retrieved from Protein Report: <https://www.proteinreport.org/newswire/gelatex-awarded-760000-euro-grant-develop-edible-microcarriers-industrial-cultured-meat>

Randall, L., Vestergård, L., & Wøien Meijer, M. (2020). *Rural perspectives on digital innovation: Experiences from small enterprises in the Nordic countries and Latvia*. Stockholm: Nordregio. Retrieved from <https://norden.diva-portal.org/smash/get/diva2:1429460/FULLTEXT02.pdf>

Regeringskansliet. (2023). *En livsmedelsstrategi för jobb och hållbar tillväxt i hela landet*. Retrieved from Landsbygds - och infrastrukturdepartementet: <https://www.regeringen.se/regeringens-politik/en-livsmedelsstrategi-for-jobb-och-hallbar-tillvaxt-i-hela-landet/>

RISE. (n.d.). *Like: meat project*. Retrieved 11 04, 2023, from <https://www.ri.se/sv/vad-vi-gor/projekt/likemeat>

RISE. (n.d.). *New and healthier products pushing the protein shift*. Retrieved from What we do: <https://www.ri.se/en/our-stories/new-and-healthier-products-pushing-the-protein-shift>

Roy, S., & Pal, R. (2015). Microalgae in aquaculture: a review with special references to nutritional value and fish dietetics. *Proceedings of the Zoological Society*, 1-8.

Seedtable. (2022, October). Cultivated Meat. *Problems Worth Solving*. (#1). Retrieved from <https://www.seedtable.com/>

Singh, A. et al. (2021). Transformation Techniques and their role in crop improvement: A global scenario of GM crops. In P. Singh, A. Borthakur, A. Singh, A. Kumar, & K. Singh, *Policy issues in genetically modified crops: A global perspective* (pp. 515-542). Academic Press. doi:<https://doi.org/10.1016/C2019-0-02566-6>

Solar Foods. (n.d.). Retrieved 06 10, 2023, from Solar Foods: <https://solarfoods.com/>

SPXFLOW. (n.d.). (SPXFLOW) Retrieved 06 15, 2023, from SPXFLOW: <https://www.spxflow.com/anhydro/products/spin-flash-dryers/>

Swartz, E., & Bomkamp, C. (n.d.). *The science of cultivated meat*. Retrieved from Good Food Institute: <https://gfi.org/science/the-science-of-cultivated-meat>

Tait, J., & Barker, G. (2011). Global Food Security and the Governance of Modern Biotechnologies. *EMBO Reports*, 763-768. doi:<https://doi.org/10.1038/embo.2011.135>

The Economist. (2023, December 12). Will lab-grown meat ever make it onto supermarket shelves? *The Economist*.

Tillväxtverket. (2023). *Ny innovativ mat*. Retrieved from Tillväxtverket: <https://tillvaxtverket.se/tillvaxtverket/omtillvaxtverket/detharartillvaxtverket/varauppdrag/nyinnovativmat.4071.html>

Tuomisto, H. L. (2018). The eco-friendly burger. *EMBO reports*. doi:[10.15252/embr.201847395](https://doi.org/10.15252/embr.201847395)

Tzvia, M., Negro, S., Kalfagianni, A., & Hekkert, M. (2020). Understanding the protein transition: The rise of plant-based meat substitutes. *Environmental Innovation and Societal Transitions*, 35, 217-231.

Vinnova. (2023). *Konkreta förslag till Sveriges livsmedelsstrategi*. Retrieved from Hållbara matsystem: <https://www.vinnova.se/m/hallbara-matsystem/konkreta-forslag-till-sveriges-livsmedelsstrategi/>

Vinnova. (2023, November 22). *The Protein Revolution*. Retrieved from Vinnova: <https://www.vinnova.se/en/p/the-protein-revolution/>

Vinnova. (n.d.). *A new recipe for the food system*. Retrieved 11 04, 2023, from Vinnova: <https://www.vinnova.se/en/m/sustainable-food-systems/follow-and-contribute-to-a-new-recipe-for-the-food-system/>

Vinnova. (n.d.). *The good and sustainable everyday food of the future - Innovations for support for Swedish processing of plant-based raw materials*. Retrieved 11 04, 2023, from Vinnova: <https://www.vinnova.se/en/calls-for-proposals/food-from-the-future/innovations-to-support-for-protein-shift/>

Volta Greentech. (2023). *Volta Greentech*. Retrieved 08 15, 2023, from Press release: Launch of Lome Beef at Hemköp. Probably the most climate-friendly beef on the planet: <https://www.voltagreentech.com/>

Wang, Y., & Shelomi, M. (2017). Review of black soldier fly (*Hermetia illucens*) as animal feed and human food. *Foods*, 6(10).

Wøien Meijer, M. (2023). *A mapping of alternative protein businesses across the Nordic-Baltic Region*. Copenhagen: Nordic Council of Ministers.

Zukauskaitė, E., & Moodysson, J. (2016). Multiple paths of development: knowledge bases and institutional characteristics of the Swedish food sector. *European Planning Studies*, 24(3), 589 - 606.

8.4. Interview list:

8.4.1. Case study: Innovation Dynamics in Wood Construction in Sweden and Finland

Sweden

- Interview 4.1: RISE
- Interview 4.2: Independent Consultant – industry expert
- Interview 4.3: Swedish Wood (Svenskt Trä)
- Interview 4.4: White Arkitekter
- Interview 4.5: Swedish National Board of Housing, Building and Planning (Boverket)
- Interview 4.6: Trästad Sverige (Wood City Sweden)

- Interview 4.7: Skellefteå Municipality
- Interview 4.8: Västerbotten County Administrative Board
- Interview 4.9: Martinsons (Holm)
- Interview 4.10: Region Västerbotten

Finland

- Interview 4.11: Aalto University
- Interview 4.12: University of Helsinki
- Interview 4.13: Independent, former director of Business Finland

Nordic

- Interview 4.14: Nordic Council of Ministers

8.4.2. Case study: Systems perspectives on the protein shift

- Interview 5.1: Biomass Protein
- Interview 5.2: Chalmers University of Technology
- Interview 5.3: Danish Marine Protein - Vestjyllands Andel
- Interview 5.4: Gelatex
- Interview 5.5: Organic Plant Protein
- Interview 5.6: RISE - A
- Interview 5.7: Mycorena
- Interview 5.8: RISE - B

