EXAMINING CHALLENGES IN THE INTRODUCTION OF SUSTAINABLE GREENHOUSES IN MOROCCO:

INSIGHTS FROM INTERNATIONAL TECHNOLOGY TRANSFER

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Abstract

The increasing water scarcity and the greater EU costs of horticultural production are pushing Morocco in innovating its food sector by transitioning to a more sustainable horticultural production. Sustainable high-tech greenhouses, in particular, is a promising technology for the generation of greater yield for export and reduction of resource use. Moroccan horticultural leader companies and some universities have already adopted the technology, which is currently diffused on a niche level.

Nevertheless, the ambitious implementation of Sustainable greenhouses does not come without problems in various aspects of construction and adoption. The technology is facing multiple challenges from the high initial investment required to the lack of a water and energy infrastructure capable to sustain its operations. Most local companies and growers are struggling with the adoption of the technology and are suffering the consequences of increasing water prices and taxation. Similarly, the lack of an alignment among the different market players and the lack of a governmental long-term vision is limiting the instance of goal-oriented subsidies. This shows that there are a complex series of factors that might hamper a technology's large-scale diffusion. Consequently, this research aims with the use of the Building Blocks framework by Ortt & Kamp (2022), to explore the barriers to different market applications of Sustainable Greenhouses and formulate niche introduction strategies to overcome the obstacles and reach large-scale diffusion in the Moroccan market. The use of the framework is taken into consideration the socio-technical system from a company perspective. The result of the study is a list of seven building blocks, which must be analysed to develop an ‘ad-hoc’ niche introduction strategy. However, if any of the building blocks are incomplete or incompatible, a barrier to large-scale diffusion is formed, hampering the diffusion of technological innovation. Yet sometimes the state of the barrier does not provide enough pieces of information for the development of a niche strategy. Thus, the investigation of the other seven influencing conditions is required to individuate the cause of the barrier, by providing important information to formulate a specific niche introduction strategy.

Previous research conducted with this study is often solely used to analyse the technological concept without fully considering that the same technologies might encounter different market applications. Nonetheless, when analysing sustainable greenhouse, multiple market applications must be considered. For the specific case of this study, three different market applications of sustainable greenhouses were revealed: sustainable greenhouses for tomato production, sustainable greenhouses for soft-fruits production and sustainable greenhouses for herbs production. Because the differences within internal components and running operations might lead to different obstacles to large-scale diffusion, the analysis requires the adaptation of the framework to develop a singular Building Blocks analysis for each market application.

In addition, this research focuses on examining the process of international technology transfer from the Netherlands to Morocco. The motivation behind this transfer is the increasing impossibility of European countries in growing food during winter due to the war in Ukraine. Previously, profit margins were limited, and now with higher energy prices, they are almost non-existent. Consequently, there is a strong push from the Netherlands to transition local production to Morocco by implementing Sustainable greenhouses. This study employs stakeholder analysis and a two-sided perspective to shed light on the varying opinions of researchers, growers, technology providers, and governmental actors from both countries. What is more, it uses, for the first time, the TIS framework in the case of international technology transfer to assess the barriers and influencing factors affecting the large-scale diffusion of three different types of sustainable greenhouses.

The research continued, with the development of tailored Niche introduction strategies per each market application. These strategies aim to overcome the barriers and prepare sustainable greenhouse companies to diffuse on the Moroccan national level. To illustrate, there have been identified multiple barriers to large-scale diffusion such as the high initial investment costs, the lack of a skilled workforce, the potential customers sceptically and the lack of a final product market. To overcome these obstacles, this study proposed to Moroccan companies some niche introduction strategies. For instance, the development of a network of knowledge share and knowledge development through showing or the establishment of a shared long-term vision from the government.

The paper progresses by reflecting on the analytical capacity of the adapted Building Block framework and gives some suggestions for improvements. It firstly reflects on the use of the adapted framework for the evaluation of the different barriers per market application. Then it discusses the implementation of a yardstick of judgement to develop an objective guideline for the future framework users so that the building block/influencing conditions status evaluation would be more impartial. To conclude it highlights the possibility of another useful adaptation could be the implementation of another building block, specific for sustainability as the lack of it could be an obstacle to diffusion and a key element to be considered toward the ecological transition.

The paper concludes by discussing the findings for each research question, and how the evidence, from the study, shows that there is an international push toward the adoption of more advanced horticultural technologies in Morocco. Similarly, from the gathered data, it is perceived that prevalently foreign countries would be benefiting from Morocco's technological shift. The technology adoption is facing an increased push after the war in Ukraine and the subsequent shrinkage in the profit margin for local food production. These findings raise the question of whether the introduction of Sustainable greenhouse technology is sustainable as it appears to be or whether this technological implementation might just be another example of green colonialism. Finally, the study addresses its limitations and gives some recommendations for further research.

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List of Abbreviations

Abbreviation	Explanation
B2B	Business to business
B2C	Business to consumer
IE	Industrial ecology
MKTA 1	Market application 1
MKTA 2	Market application 2
MKTA 3	Market application 3
NIS	Niche introduction strategies
NL	Netherlands
RQ	Research question
SG	Sustainable greenhouse
SUB-Q	Sub research question
TIS	Technological innovation system

Chapter 1: Introduction

1.1 Background

Since the 18th century, there has been unprecedented agricultural land expansion and development of agricultural technological innovation (Ramankutty et al., 2018). According to Mbow et al. (2019), the food supply globally has grown by 30%, with the increasing use of fertilisers and water for crop irrigation. At the same time, the food sector is facing an increasing urgency in increasing its crop production supply as the global population increases in demand. In fact, by 2050, it is predicted that the global population will reach 9.7 billion, with over 70% of people living within urban areas (Beacham, 2019). Hence why, there will be a diminishing trend of agricultural land available as it will be lost with the expansion of urban areas and infrastructure development (Lotze-Campen et al., 2008). The current crop, production and distribution system supplies its products at an affordable price. Nevertheless, it is having a disastrous hold on the environment, due to the increasing use of pesticides and herbicides used, which are making the soil incapacitated of growing plants without even more fertilizer (Despommier, 2010). This would develop more and more “dead” zones (areas with degraded soil) across the globe.

One solution lies in Sustainable High-tech Greenhouses (SG). This technology could play a key role in boosting crop yield per unit area of land and securing a stable crop supply (Beacham, 2019). This innovation is an indoor type of farming, which allows controlling the key parameters for efficient crop growth, like solar radiation, temperature, light intensity and humidity (Achour et al., 2021). According to Abakkanavar et al., (2015), “You can completely control the climate, as there are no external influences. This will allow a producer to make the exact product the consumer wants.” The introduction of Sustainable Greenhouses could provide increased crop security, boost water savings and decrease pesticide use (Giuliano Vox, 2010) for the production of multiple horticultural crops such as tomatoes, cucumbers and soft fruits.

Unfortunately, Sustainable greenhouses might not be a solution for some countries. This is because among the multiple benefits the technology presents some challenges to be born too. For instance, according to Yasmine Achour et al. (2021), “The high cost of implementing sustainable technologies represents a major challenge toward the diffusion of sustainable greenhouses”. Another example of a limiting factor could be the lack of a skilled labour force and the lack of forming institutions (Y. Achour et al., 2021). However, in the case of some countries like Morocco, there is a growing goal to spread on the national level Sustainable Greenhouses (SG). Yet, an effective way to diffuse the technology on a national level is still in its exploratory phase, resulting in the insolvency of many companies.

This is because every time a breakthrough technology is introduced in a new market, there are several difficulties to be overcome in the technology diffusion from a niche market to the national landscape. Among the existing body of literature regarding breakthrough technology diffusion Ortt (2004) provides an interesting view in one of his studies, where he analyses the patterns of pre-large scale diffusion phases of breakthrough technology and divides it into two different stages. The first analysed stage is the innovation phase, which goes from the development of the technology to its market introduction (Ortt, 2004), throughout this phase research institutes and universities play a central role. Once the product has been introduced within the market, the technology adaptation phase starts, this is the most critical stage due to the complex interaction among many factors which may hamper the technology's large-scale diffusion (Ortt, 2010). If the breakthrough technologies manage to overcome the adaptation phase (also called the pre-diffusion phase), it can start large-scale diffusion. However, most of the time organisations struggle in overcoming the market adaptation phase, resulting in an

organisation's “extinction” or dilatation of the market diffusion time (Ortt, 2010). Thus organisations need to develop a clear company direction and strategy not to end up bankrupt. One of the tools developed for companies to steer innovative technologies in the market is the use of niche introduction strategies. These strategies are not universal, but they have to be developed after having explored the environment around the companies to analyse the conditions that have caused the market formation (Ortt & Kamp, 2022). To do so, Ortt and Kamp (2022) in the paper: ‘*A technological innovation system framework to formulate niche introduction strategies for companies prior to large-scale diffusion’;* have developed the TIS framework made by seven building blocks and seven influencing conditions. Through the analysis of the 14 components, it is possible to investigate the context around innovation to understand the ‘scope and timing’ of the niche introduction strategies that fit the market around an innovation.

To conclude, this study is conducted with the use of the Technological Innovation System framework (TIS) (Ortt & Kamp, 2022). Thus, firstly, the barriers to large-scale diffusion for **three different market applications** of Sustainable greenhouse technology (SG) are going to be analysed. Then the factors influencing the barrier formation are identified. Consequently, tailored’ niche introduction strategies are developed. The research specifically targets Morocco due to its national interest, governmental efforts in promoting technology diffusion, and the growing environmental pressures necessitating a shift in current agricultural practices. Moreover, for the first time, the TIS framework is going to be used to analyse the case of technology adoption within the Moroccan landscape, caused by a **technology transfer** from one country to another. More specifically, from the Netherlands to Morocco. Additionally, the scarcity of literature on developing niche introduction strategies for sustainable greenhouses in Morocco makes this case study an ideal choice.

1.2 Research Objective

The research aims at investigating which are the barriers, from a company perspective to the large-scale diffusion of Sustainable high-tech Greenhouses (currently a market niche) in Morocco. Furthermore, the influencing factors affecting these barriers would be evaluated to gain a deeper understanding of the Moroccan socio-technical landscape. Finally, some niche introduction strategies aimed at accelerating the transition are developed. To do so, the TIS framework by Ortt & Kamp (2022) is applied and adapted to carry out the analysis for the same technology but for three different market applications and to investigate the case of national technology adoption through technology transfer from the Netherlands to Morocco.

1.3 Knowledge gap

While it is present a wide literature regarding the technological advances within Sustainable Greenhouses, the body of literature on SG diffusion is not abundant. Among the technological diffusion studies different frameworks are used, some examples are: the Multi-Perspective Analysis (MLP), or a combination of Econometrics and Agent-Based Modelling (ABM). The first one was in a study conducted by Berkers et al. (2011), where he analyses the transition pattern of the greenhouse as a horticultural method in the Netherlands, within a 50 years timeframe (1930-1980). Greenhouses are analysed as a niche innovation which is struggling to enter the existing regime (Berkers et al., 2011). It is noticeable how within this study, the pattern of diffusion of greenhouse technologies starts from universities to then diffuses on a greater scale. The second study was conducted by Schreinemachers et al. (2009), who examines the diffusion of Greenhouses in North Thailand. This is a more empirically oriented type of research. It starts by stating that because of the “lack of transferable land titles that could serve as mortgage collateral” the higher part of Thailand has a smaller amount of Greenhouses than the lower part of the country. Hence it analyses the diffusion of Greenhouses in the higher part of Thailand if mortgage collateral would not be required. Thus,

the study evaluates the constraints to adoption and gives an evaluation of the ecological and economic impacts related to the expansion of Greenhouses. There have been conducted some studies on the diffusion of technological components within Sustainable Greenhouses. A case example is the one carried out by Van Der Veen et al. (2015) which analysed the diffusion of combined heat and power within the Dutch GT, within a six years timeframe (2003-2009). This research dives into the institutional, cultural and economic factors that have influenced the diffusion of this technology within the Dutch market. Additionally, it gives an overview of the company's decision-making process to facilitate governmental policy-making. A further study, regarding winter greenhouse diffusion, was conducted by Wu et al. (2013). This author analysed the importance of network building among farmers and the local government, for a successful diffusion of innovation in China. The study's main takeout is the outline of how farmers' leadership is key to facilitating greenhouse technology diffusion. To conclude, the ones outlined are the main findings for the diffusion of Greenhouses on a national scale. It is noticeable, how no scientific research was found that analyses the diffusion pattern of Sustainable High-tech greenhouses from a company perspective in Morocco. A key point is as managers play a key role in the diffusion of technology. Therefore, this study can help in providing **relevant scientific insights** to sustain sustainable greenhouse companies throughout their pathway to diffusion in Morocco. What is more, this study **fills up three more research gaps**. The first one is the **lack of scientific literature research** on sustainable greenhouse diffusion with the use of the TIS framework (Ortt & Kamp, 2022). **Thus no research investigates** the building blocks / influencing conditions and develops some niche introduction strategies from a company perspective for sustainable greenhouses in Morocco. The second one is the expansion of the framework area of relevance by investigating and filling up the gap for lack of analysis of the technology adoption in Morocco for the case of Sustainable greenhouse **technology transfer from one country to another**. The third one is the **lack of literature investigating** the development of sustainable greenhouses in Morocco.

1.4 Research Question and Sub-questions

To accomplish the research objective and fill up the knowledge gap, the following research question has been drafted:

How can Sustainable Greenhouses, for horticulture, diffuse on a large-scale in Morocco?

With the aim of answering the main research questions, the following sub-questions will have to be evaluated:

I. *What could be the barriers hampering the large-scale diffusion of Sustainable Greenhouses in Morocco?*

The aim of this sub-question is to investigate with primary and secondary data collection which are the barriers to large-scale diffusion for the different sustainable greenhouse market applications in Morocco. The analysis is carried out with the TIS framework by Ortt & Kamp, 2022.

II. *What is the status of the influencing conditions that are impacting the incomplete building blocks?*

The purpose of this sub-question is to gain a clearer understanding of the factors impacting the barrier formation to large-scale diffusion of sustainable greenhouse market applications in Morocco. To do so the TIS framework by Ortt & Kamp(2022) is applied.

III. *What could be the potential niche introduction strategies to be adopted by Sustainable Greenhouses companies to overcome these barriers?*

To answer this sub-question the niche introduction strategies, intended to overcome the barriers and allow the large-scale diffusion of sustainable greenhouses in Morocco, are formulated.

IV. *How effective is the TIS framework in the analysis of the context around Sustainable Greenhouses companies?*

The aim of this final sub-question is for the author to evaluate the analytical capacity of the TIS framework (Ortt & Kamp, 2022) for the carry of this study.

1.5 Relevance for the industrial ecology field

This conducted research regarding Sustainable high-tech greenhouse diffusion in Morocco detains a remarkable Industrial ecology relevance in the domain of sustainable horticulture. This section critically analyses the technology's implications, as different strengths and areas of improvement have been identified.

Within the positives, it is noteworthy mentioning the sustainable horticultural statement: 'produce yield more with fewer resources'. According to Ghanem Hafez (2015), the urge of Morocco to satisfy the growing population's needs is putting at stake the country's limited natural resources. The problem for which, the current methods of horticultural production are playing an important role in the depletion of these resources (Dosseto et al., 2011). Thus, the introduction of sustainable greenhouses may help in limiting environmental depletion while increasing the yield (Vourdoubas et al., 2016). Besides this, this study could help the reader understand the need to innovate in the horticulture sector by providing insights coming from researchers, company managers and governmental actors. Additionally, the collected data can serve as a foundation for some following industrial ecology studies that may aim at identifying potential synergies between sustainable greenhouse companies and other industrial sectors, which could lead to the future development of a more sustainable agricultural system in Morocco.

Nevertheless, as is going to be shown in Chapter (3) it is the coexistence and collaboration of internal/external technologies and complementary infrastructures that contribute to the sustainability of greenhouses. Thus, sustainability is not only about the 'box' itself but within the development and efficiency within the know-how and complementary products and services. For instance, as mentioned by Giuliano Vox (2010) high-tech greenhouses have a high energy requirement to ensure the smooth running of operations. Therefore, Morocco is heavily reliant on non-renewable energy operations rather than detaining a diversified portfolio of renewable energy sources (K Houssini et al., 2021). The sustainability of high-tech greenhouses could be put at stake. Hence why, to ensure the diffusion of sustainable greenhouses rather than only high-tech greenhouses, complementary services and products need to be developed alongside technological adoption.

In conclusion, **this study is of utmost relevance for the industrial ecology field** because it critically evaluates, the secondary and the primary data collected from both Moroccan and Dutch actors, to identify the barriers and the factors causing the barriers to diffusion of Sustainable Greenhouse technology in Morocco. Thus, through this analysis, it is possible to evaluate the current state of the complementary infrastructures around technological innovation. Finally, if sustainable infrastructures and services will have to be developed alongside the diffusion of sustainable technology on the national level or if the adoption of this sustainable innovation cannot be achieved within the national landscape.

1.6 Relevance for society

This study regarding the Sustainable high-tech greenhouses diffusion in Morocco holds notable societal relevance in the field of sustainable horticulture. By critically evaluating the technology's implications, different strengths and areas of improvement have been identified.

On the one hand, the introduction strategies of sustainable greenhouses may be beneficial for society. The worsening of the environmental conditions and the stronger pressure on the national water resources are posing increasing pressure on the Moroccan agricultural sector (Hafez Ghanem, 2015). Thus, according to Giuliano Vox. (2010), the adoption of sustainable greenhouse could help in the reduction of energy/water use and waste generation. Therefore the technology could be used to reduce the environmental impacts related to horticulture in Morocco (Giuliano Vox, 2010). More specifically, Hafez Ghanem (2015) stated: 'Innovation within the horticultural sector in Morocco can help rural development through youth and women economic inclusiveness'. Finally, the technology's introduction can help in achieving the country's objective to reduce its dependence on food imports (Hafez Ghanem, 2015).

On the other hand, there are some crucial aspects to be borne in mind. Firstly, if the country aims to increase horticultural production for local use and export, although the production with sustainable greenhouses might limit the depletion of water resources, the widespread diffusion of the technology might not limit the increasing water pressure. Secondly, trade-offs have to be considered. For example, the energy requirement of sustainable greenhouses might increase Morocco's reliance on non-renewable energy sources, which might limit the system's sustainability (K Houssini et al., 2021). Similarly goes for need waste management centres, because of the huge quantities of waste the sustainable greenhouse production process generates (Giuliano Vox, 2010). Thirdly, to enhance rural development, socio-economic factors like knowledge share and capital investments (e.g. subsidies) need to be assured to ensure the economic inclusiveness of small/medium-sized growers.

To conclude, **this study is relevant for society** because it critically assesses, the primary data collected from Moroccan and Dutch actors, to identify the barriers and the factors causing the barriers to diffusion of Sustainable Greenhouse technology in Morocco. Finally, it is going to be discussed if sustainable greenhouse technology is the 'real' solution for Moroccan society or if the society needs another type of technological implementation.

1.7 Relevance for the Industry

The reason why this study is relevant for the industries is because of the Technology Innovation System (TIS) framework. The peculiarity of the TIS developed by Ortt & Kamp (2022), is the development of an introduction strategy from a company perspective. Companies that aim to scale up from a niche level to the national level, would have to take into account multiple actors and factors that may hamper their goal of diffusion. Thus, this research helps company managers in understanding the context around sustainable greenhouses. Furthermore, all the gathered insights are collected with the use of a systemic perspective, meaning that the data collected comes not only from one type of actor but from a 'melting pot' of researchers, growers, managers, governmental institutions and so on. This will help the reader in analysing the situation from different perspectives, while also assisting the researcher in developing the right scope, timing and niche introduction strategies that fit the Moroccan context.

Thesis structure

After having explained the topic's relevance, this paragraph briefly outlines the study structure. Firstly, in Chapter 2 the methodology is depicted. Then Chapter 3, through a literature review

the author highlights the context around the innovation and dives deeper within the Building Block analytical framework. Whilst, Chapter 4, is an introduction to the analysis because the stakeholder analysis presents the different relevant actors involved in the research and technology diffusion/transfer. The study continues with the analysis part in Chapter 5, where an in-depth study is carried out for the building blocks and influencing conditions for the three different market applications. Chapter 6 presents the niche introduction strategies that companies would have to adopt to overcome the barriers depicted in the previous chapter. After having concluded the analysis, the author reflects on the analytical capabilities of the TIS framework in Chapter 7 and gives some suggestions for improvements. Finally, the study concludes with Chapter 8, by answering the main research questions, briefly mentioning the international interest regarding sustainable greenhouse diffusion in Morocco, considering the limitations and giving some recommendations for further research.

Chapter 2: Methodology

This study, with the aim of answering the main research question and the four sub-questions, is divided into two different research phases. This chapter explains how the research process is outlined.

2.1 The research process

Because the aim of this research is the one of exploring the topic in-depth and gain insights, it is necessary a structured and systematic process to answer the Main Research Question and the subsequent Sub-questions. To reach this goal, an exploratory type of research has to be carried out, this according to Bhatterchejee (2012), is conducted in new areas of inquiry where the goal is to collect as much data as possible regarding a determinate phenomenon, problem or behaviour. Such a research project can be an important component of research design, which used in the most appropriate manner will help in developing a general strategy that will be used to collect and analyse data. This case study methodology involves the investigation of a case in depth, with the use of multiple data, such as: semi-structured interviews, literature research and observations. Therefore, most of the data collected is qualitative, from Dutch / Moroccan organisations, gained to generate, as deep as possible, a perspective of the current Moroccan landscape.

In the following sections, it is explained the process that has been followed to answer the research questions.

2.2 The phases to answer the research questions

The research is divided into two co-related but different phases, named: Phase 1 & Phase 2 (Figure 1). The two phases aim to address the sub-questions to answer the main research question:

How can Sustainable Greenhouses, for horticulture, diffuse on a large-scale in Morocco?

Phase 1

The methodology followed for this first data-gathering phase, takes an iterative approach that involves a **cyclical process** of evaluation and adjustment aimed at enhancing its effectiveness over time. This phase aims at conducting semi-structured interviews with relevant actors and in-depth literature reviews to gather relevant data. This process has been supported by the LDE Centre for Sustainability “Interdisciplinary thesis lab 2022-2023: Sustainable Horticulture”. The project consisted of lectures and/or excursions on a two weeks basis. The focus of these weeks was to encourage knowledge exchange among the different research centres between the Netherlands and Morocco, regarding Sustainable greenhouse technology. The author's dedication to the project enabled him to gain a comprehensive understanding of the practical aspects of sustainable greenhouse development and the concerns of the various stakeholders involved. Additionally, the presence of diverse actors created an engaging environment for exchanging ideas and opinions, which proved crucial in collecting the initial information necessary for the identification of the most suitable Niche Introduction Strategies. During the interview process, questions were improved on the information gained from the previous ones. This allowed a refinement of the interview questions making sure that the data gathered is always straight on point and accurate. Additionally, continuous improvement permits compensation of the knowledge gap in the literature review. To provide efficient and straight-to-the-point interviews initial desk research is needed. However, the desk research could provide only an initial basis to start conducting the interviews, which have to be constantly evaluated and adjusted. Moreover, the already

existing literature review is not enough for itself. Meaning that the data gathered from the interviews could be implemented in the literature review chapter. The data collected was constantly evaluated to determine whether further interviews or literature research is needed. Thus, the data collection system of this research did not follow a linear process but a circular one, as shown in Figure (1).

This phase aimed at answering the following sub-questions:

Sub-question 1: What could be the barriers hampering the large-scale diffusion of Sustainable Greenhouses in Morocco?

This first sub-question is tackled with the use of the TIS framework (Ortt & Kamp, 2022), in which all the different actors and factors are classified within the building blocks and their influencing conditions. The data collection is firstly supported by a literature review, to gain a perspective from the already conducted research on the current state of diffusion of Sustainable Greenhouses and the identified barriers limiting a further expansion of the technology on the national level. The data collected has been collected from a cautious analysis of literature, reports and other publications (Check Section 2.4). The initial idea gained from the literature regarding the status of the building block would allow the author, to lay the basis for the following semi-structured interviews with relevant actors. However, the status of the building blocks was depicted prevalently by the data collected by the primary research and backed up where possible by the desk research. Just at the end of the analysis of the building blocks, one graph for each market application is presented to show the reader the status of the building blocks (e.g. complete, partially incomplete or incomplete) for each market application. In each of the last two cases, a barrier to large-scale diffusion is formed. To ensure **clarity and consistency** throughout the research process it was necessary to develop clear guidelines for the status identification of the TIS components. Respectively, in the case if a building block is complete it is presented under the colour green, meaning that this building block is not a barrier to the technology's diffusion. If the building block is partially incomplete it is shown under the colour yellow, meaning that this building block may still limit the diffusion of the technology on the national level. Finally, if the building block is incomplete it is depicted with the colour red, meaning that this building block is a barrier to the technology's diffusion.

In conclusion, this question is answered in Chapter (5).

Sub-question 2: What is the status of the influencing conditions that are impacting the incomplete building blocks?

A comparable approach to the previous one is employed to address this third sub-question. Once the status of the seven building blocks has been established, an analysis of the influencing conditions is required to gain more information regarding the reason behind a barrier formation allowing the author to identify the optimal niche introduction strategy. This necessitates the identification of the status of the influencing conditions, which was accomplished through the use of a literature review and semi-structured interviews, much like the method employed, in the second sub-question, to analyse the status of the building blocks. Similarly, the visual representation of the influencing conditions for each sustainable greenhouse market application is presented at the end of the analysis to show the status of the factors (e.g. complete, partially incomplete or incomplete). To ensure **clarity and consistency** throughout the research process it was necessary to develop clear guidelines for the status identification of the TIS components. More specifically, in the case if an influencing condition is complete it is presented under the colour green, meaning that this factor is not a barrier to the technology's diffusion. If the influencing condition is partially incomplete it is shown under the colour yellow, meaning that this component may still limit the diffusion of the technology on the national level. Finally, if the influencing condition is

incomplete it is depicted with the colour red, meaning that this factor is a barrier to the technology's diffusion.

This question is answered in Chapter (5).

Sub-question 3: What could be the potential niche introduction strategies to be adopted by Sustainable Greenhouses companies to overcome these barriers?

To address this sub-question, it is essential to incorporate the findings from all previous sub-questions. A comprehensive analysis of the results is required to devise optimal niche introduction strategies (NIS) for sustainable greenhouses in Morocco. The final strategies aim at completing the TIS building blocks and influencing conditions, preparing the technology to spread on the national landscape. The used data for the formulation of the introduction strategies were the solutions gathered from the Moroccan and Dutch interviewees, the results of the building blocks and influencing conditions analysis carried in Chapter (5), the paper: '*Ten niche strategies to commercialize new high-tech products*' of Ortt et al., (2015) and the author consideration and field-experience. Additionally, where no specific NIS exists the author, based on his experience has developed some relevant strategies to overcome the barriers to the sustainable greenhouse market applications large-scale diffusion in Morocco.
To conclude, at the end of the Niche introduction strategies analysis is presented a visual representation of the building blocks and influencing conditions status after the implementation of each niche strategy for sustainable greenhouse market application 1 (MKTA1).

This sub-question is addressed in Chapter (6).

Phase 2

Despite the first phase of the research process, this stage of the methodology follows a **linear approach** that aims at answering the research question regarding the usefulness of the TIS framework (Figure 1). Discussing how it has been used to develop NIS for sustainable greenhouses in Morocco. This phase is strictly dependent on the previous one, in fact, it can be only carried out after having gained experience from the iterative approach used in the first phase, which is based on a literature review and semi-structured interviews. Moreover, the reflection is focused on the strengths and weaknesses of the framework, in relation to the answer to the main research question and its relevance for the technology transfer from one country to another analysis. The aim of this phase is to provide an objective evaluation of the framework and identify its areas of improvement. To conclude, this phase aims at enhancing the effectiveness of the framework to ensure its continued relevance for future studies.

In this phase the following sub-question is answered:

Sub-question 4: How effective is the TIS framework in the analysis of the context around Sustainable Greenhouses companies in Morocco?

As mentioned, the answer to this sub-question is gained through the reflection on the experience gained with the use of the TIS framework for the development of NIS in the case of technology transfer from the Netherlands to Morocco. This sub-sub-question is answered within Chapter (7).

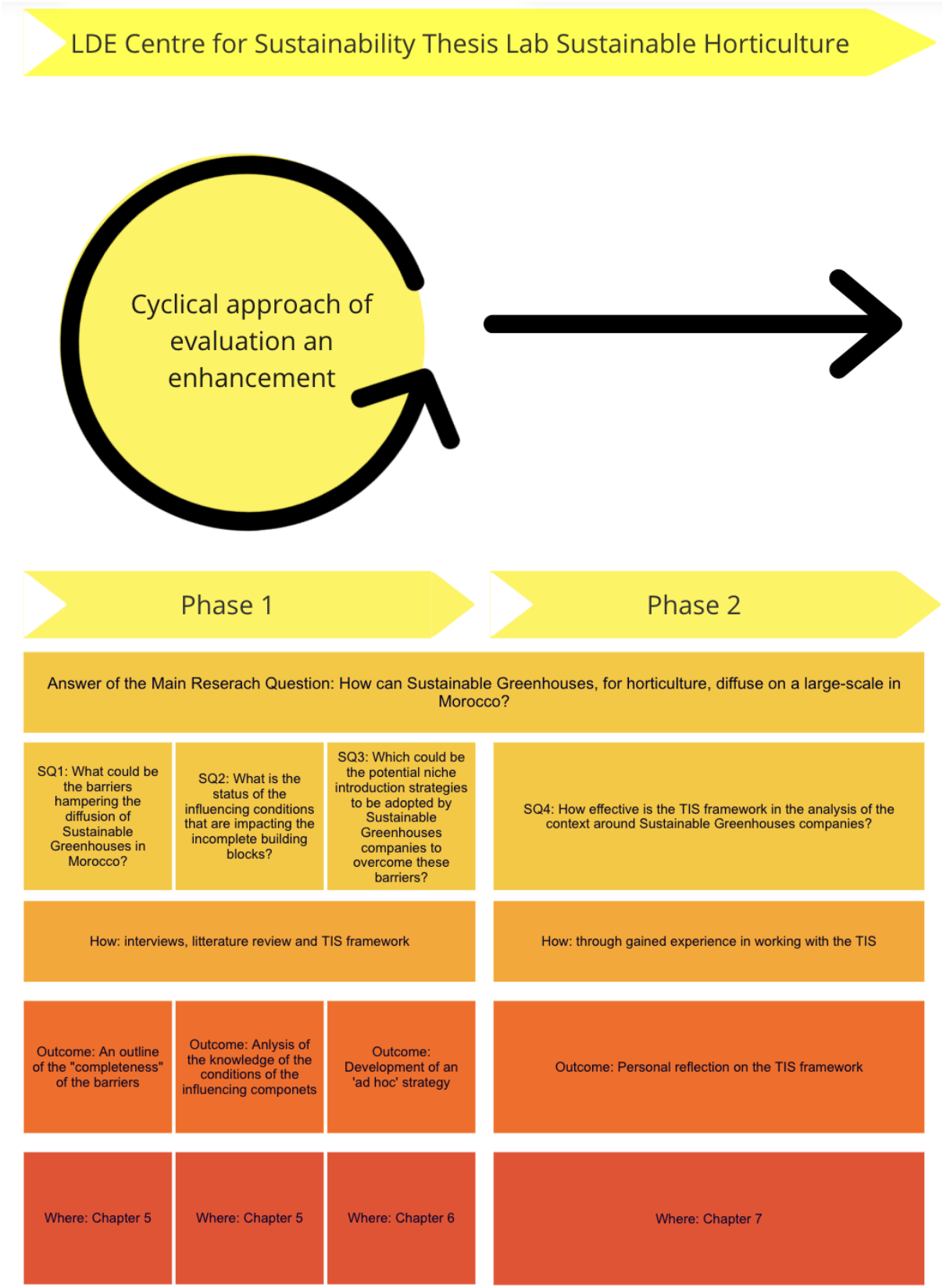


Figure 1: Research flow diagram

2.3 Primary Research

The primary mode of data collection for this research project is carried out with the use of primary research. This research method is a key component of this study as it provides the most up-to-date information that is used to draw the conclusion. According to the literature (Bhattarcherjee 2012) one of the most effective methods of data collection is the interview. According to Bhattarcherjee (2012), interviews are a set of questions to be asked. These could be structured (closed-ended) or unstructured (open-ended) or, like in this case, semi-structured. This last type of interview allows the author to have higher flexibility in topics during the conversation, diving into subjects that otherwise would be left untouched.

The interview process is carried out throughout most of the duration of the research project. Starting from the strong foundation provided by the initial secondary research, the interviews are used to capture the various perspectives and experiences of the participants. A part of the interviewed actors have been gathered with the help of the Centre of Sustainability, some of them through word-of-mouth and others through personal research on online platforms (e.g. LinkedIn).

The role of the Centre of Sustainability in gathering primary information for the development of this project cannot be overstated. The centre played a crucial role not only through the numerous lectures and excursions organized by relevant project stakeholders but also through the 'in situ' visit to Morocco. This trip allowed the author to gather data from a wide range of stakeholders to develop a broader perspective, key for the analysis of the barriers. Therefore, interviews have not been the only method of primary data collection used for this study.

Throughout the carry of this study, the author plays the role of the interviewer. Especially in this case, this role was of **greater complexity for the author** as he had to 'navigate' among different cultures, languages, and diversity of the technology innovation system. Moreover, the interviewer must establish a comfortable environment to allow the actors to share their knowledge. This has been done by the interviewer, by introducing himself in the first place, explaining the purpose of the interview and making sure that the participant understands the questions. Simultaneously the interviewers need to ensure that there is no misinterpretation of the answers and that no information is lost. As well as maintaining the confidential information of the interviewed participants.

The strength of this research is the care in **maintaining a systemic perspective** throughout the duration of the data collection and data analysis period. Additionally, the author took extra care in the selection of the interview participants. These two points have been achieved three in ways. Firstly, the interviewed actors are not part of only one stakeholder group, but they are **diverse in backgrounds and perspectives**. Thanks to the Stakeholder analysis conducted in Chapter (4), it was possible to identify the actors playing an important role in **the technology transfer** that had to be interviewed. These are researchers, growers, managers, entrepreneurs or governmental actors. Secondly, the interviewed actors come from both nations: the Netherlands and Morocco. This was done to **not have a one-sided** perspective. Thirdly, the author has put major efforts into maintaining an impartial role, presenting all the gathered pieces of information in the most neutral way possible and not influencing the interviewed actor in their response.

The data was collected from a total of 17 actors, these are grouped in two different tables depending on their state relevance (Table 1 for the Moroccan actors, Table 2 for Dutch actors). It is noticeable how the actors were named according to the role (e.g. researcher, governmental actor, grower or company manager). This was done to facilitate the reader in the study of the building blocks and influencing conditions, and more importantly to **highlight the differences in opinion** among the actors that cover different roles and different nations.

For instance, a grower's opinion regarding a specific barrier might be different from a researcher's one.

Table 1: List of the Moroccan interviewed actors

Interviewee	Specialization
Moroccan Researcher 1 (MR1)	Professor and Researcher within the field of horticulture at the University of Hassan II in Agadir, Morocco. This person is the coordinator of the in-campus start-up incubator and played a central role in the building of the demonstration greenhouse by HortiXS.
Moroccan Researcher 2 (MR2)	This actor works as coordinator of crop production research unity, at the same time he is a researcher for the Moroccan National Institute for Agricultural Research and plays an important role within the Regional Centre of Agricultural Research Agadir.
Moroccan Gov-act. 1 (MGOV1)	This actor is the head of the division and evaluation and planning of the water resources for the Souss-Massa region - Agence du Bassin Hydraulique de Souss-Massa.
Moroccan Gov-act 2 (MGOV2)	Regional director of ONSSA Souss-Massa - The national office for sanitary safety and security of alimentary products. This office cares about respect for the international standards set by the importing countries.
Moroccan Gov-act 3 (MGOV3)	Director of a 20 years old horticultural incubator in the area of Agadir, which aims at encouraging the foundation of start-ups and the development of innovative and original projects within the Horticultural sector.
Moroccan Gov-act 4 (MGOV4)	This actor is the Head of the Regional Office of Agriculture of Souss-Massa region and coordinator of the regional green strategy.
Moroccan Grower 1 (MG1)	This person with his decades of experience is the technical director of APEFEL (Moroccan grower association), furthermore, this actor is the adviser of the Minister of Agriculture in Morocco and the adviser of ONUDI of the African countries.
Moroccan Grower 2 (MG2)	This actor is the owner and manager of a 5-hectare greenhouse farm, specialising in the production of green beans for export to the EU.
Moroccan company 1 (MC1)	Sales and marketing responsible at a company based in Agadir region, for tomato export to the UK. This company is one of the major leaders in tomato export, selling tomatoes from over 35 different growers in the area.
Moroccan Company 2 (MC2)	This actor has over 20 years of experience working within greenhouses, and for 5 years is working as a technical advisor for many horticultural groups. The biggest grower this actor works with has over 100 hectares of greenhouses for tomato production and 150 hectares for citrus production.

Moroccan Company 3	This actor is the unit manager for the biggest family-owned exporter and producer of horticultural products in Africa. The unit managed is of 140 hectares of tomato, grown within metallic canary greenhouses with soilless production technology.

Table 2: List of the Dutch interviewed actors

Interviewee	**Specialization**
Dutch Researcher 1 (DR1)	This person in the last 6 years has been working as the founder and Coordinator of AgriFood Hub at Leiden Delft Erasmus (LDE) Centre for Sustainability. This actor has major knowledge regarding the collaboration between the two countries and plays a major role in the push toward the knowledge share and diffusion of sustainable greenhouse technology in Morocco.
Dutch Researcher 2 (DR2)	This researcher is the director of a Major Dutch Company, involved in the development of horticultural traineeship programmes and targeted consultancy to improve companies' functionality. This actor is majorly involved in the research process conducted within the company's facilities and knowledge shared with Moroccan Actors.
Dutch Grower 1 (DG1)	This actor with over 20 years of experience, of which 4 in Agadir, has been the key account manager for a Dutch company producer of biological pest control solutions. Moreover, this person in Morocco was responsible for educating growers in the correct use of these solutions enabling them to export their horticultural products to the EU.
Dutch Company 1 (DC1)	This actor has knowledge of Sustainable Business and Strategy development. This person currently works within one of the most important banks in the NL as the consultancy for business development for the African continent. Moreover, this actor is the CEO of an organisation that enhances stakeholder management and innovation among international parties.
Dutch Company 2 (DC2)	This entrepreneur with 20 and more years of experience, is the founder and CEO of a company that builds greenhouses all over the world. This actor has been in close touch with Moroccan growers and companies and has built some greenhouses in the Agadir area.
Dutch Company 3 (DC3)	This entrepreneur the director of a Major Dutch Company, is involved in the development of horticultural traineeship programmes and targeted consultancy to improve companies functionality. This actor is majorly involved in the business plan development for horticultural companies.

The questions asked of the interviewed actor were changing according to their degree of knowledge. In fact, different questions were asked depending if the actor was a researcher, a grower or a company manager. Furthermore, the questions had to be adapted according to the interviewee's answers, for instance asking for clarifications or to further dive within a mentioned topic. Below are presented the steps used to conduct an interview.

Firstly, the anonymity of the collected data and its following use was specified. Then a question regarding the actor's knowledge and experience within Sustainable Greenhouses in the Moroccan context is asked. Secondly, some of the following open questions were asked:

1. In your opinion what are the current obstacles to the diffusion of SG in Morocco?

2. What is the aim of this collaboration between the Dutch and Moroccan governments/ institutions?

3. How strong is the collaboration among the SG companies themselves and the research institute / the government?

Usually, these questions were followed by some barrier and influencing conditions-specific questions, to evaluate the status of the TIS building blocks and their influencing factors (Appendix E)(Ortt & Kamp, 2022).

Building block type of question

1. Is the Dutch/Moroccan production system able to produce large quantities of Sustainable Greenhouses with sufficient quality and performance?

2. As far as you know are there any regulations that may slow down or encourage the diffusion of the technology in Morocco?

Influencing condition type of question

1. Do you believe that the Moroccan growers have enough knowledge of the technology: in terms of resource use, knowledge of the crops grown and know-how on how to run a Sustainable Greenhouse?

2. How does the current competition in the horticultural sector affect the spread of the technology?

The interview concluded by asking about the potential solutions to the barriers of diffusion mentioned. Then by thanking the interviewee and asking if he/she knew any other relevant actor that might be interested and relevant to be interviewed.

As mentioned, the anonymity of the interviewees is preserved. To ensure it and to facilitate the writing process, the author has made **the assumption** that all the interviewed actors are males, thus they are referred to as he/him.

Before the analysis of the building blocks in Chapter (5) a stakeholder analysis is presented in Chapter (4), where are listed the interviewed actors both from the Dutch and Moroccan sides. It is important to note that the interviewees in most of the cases were conducted in English, although the ones in Morocco in the minor part were conducted in French and Arabic. This element has to be taken into account when analysing the limitations of this interview process. However, to ensure the **author's transparency** on the data collected the interview transcript is provided in Appendix **(**E and F). What is more, to facilitate the reader, to **each building block and influencing condition has been assigned a colour** with which the relevant parts are highlighted in the interview transcript.

To conclude, all the data collected from the interviews is further validated by the use of secondary research data collection, discussed in the following paragraph.

2.4 Secondary Research

Throughout this research process, secondary data analysis has been used. This is the use of data previously collected by some other studies (Bhattacherjee, 2012). Secondary data has been collected from a **cautious analysis of literature, reports and other publications**. This

type of research has been fundamental especially for the initial stages of the research process, to develop as effective as possible questions for the primary research process. According to Bhattarcherjee (2012), secondary research could be either internal or external. The first one involves the use of data coming from an organisation. Whilst the second one is the use of data coming from external sources (e.g. reports or publications).

For the development of this research project, both internal and external resources are used. Nevertheless, the external ones play a greater role in the gathering of information for Sustainable Greenhouses. Information and data are gathered from all the available research reports and publications. Moreover, because Morocco is an Arabic and French-speaking country, there were a lot of publications in these languages. This is an important factor to be considered during the data-gathering process. To conclude, the use of this data collection system provides a strong background and context for the study.

Chapter 3: Literature review

This chapter is of utmost importance for the reader because it will first help in understanding the general context around the socio-technical system. Secondly, the explanation of the TIS framework and Niche introduction strategies will guide the reader in understanding the framework used. Then the overview of the sustainable greenhouse technological components, structures and market applications, is fundamental to give the reader a basic understanding of what the technology comprehends and how it differs between the different market applications. Through the understanding of these elements, the reader will have the ability to maximise the understanding of the analysis of the study, carried out in Chapters 5 and 6. Moreover, in case the reader would like to further dive within the context of the framework / sustainable greenhouses, some further information's are presented in Appendix (A; B; C; D).

3.1 The Technological Innovation System Framework

The Technological Innovation System (TIS) framework was developed by Ortt and Kamp in the early 2000s. The unique aspect of this framework is that it combines the vision of both the socio-technical system and strategic management fields, deepening the understanding of the niche strategy to adopt (Ortt & Kamp, 2022). Additionally, this framework can capture the dynamics of the key technological, social and institutional actors and factors, that have a direct impact on the diffusion of the technology within the Landscape. These reasons help in exploring how new radical technological innovations can be introduced, from a company perspective rather than government policy. The developed framework is formed by seven technological Innovation System Building Blocks and seven influencing conditions, as shown in Figure (2). According to Ortt & Kamp (2022) "Each of the building blocks, once missing, incomplete, or incompatible with the other blocks or the innovation, forms a barrier to large-scale diffusion." This barrier could be overcome by adapting the influencing conditions with a specific niche strategy. Scholars have found that niche strategies are an important step in developing a market for new products. They can help organisations in overcoming or removing the barriers that prevent market formation (Ortt et al., 2015). In line with Cooper et al., (1986) new organisations aiming to introduce themselves within a highly competitive market, have a greater degree of success if they enter a market niche.

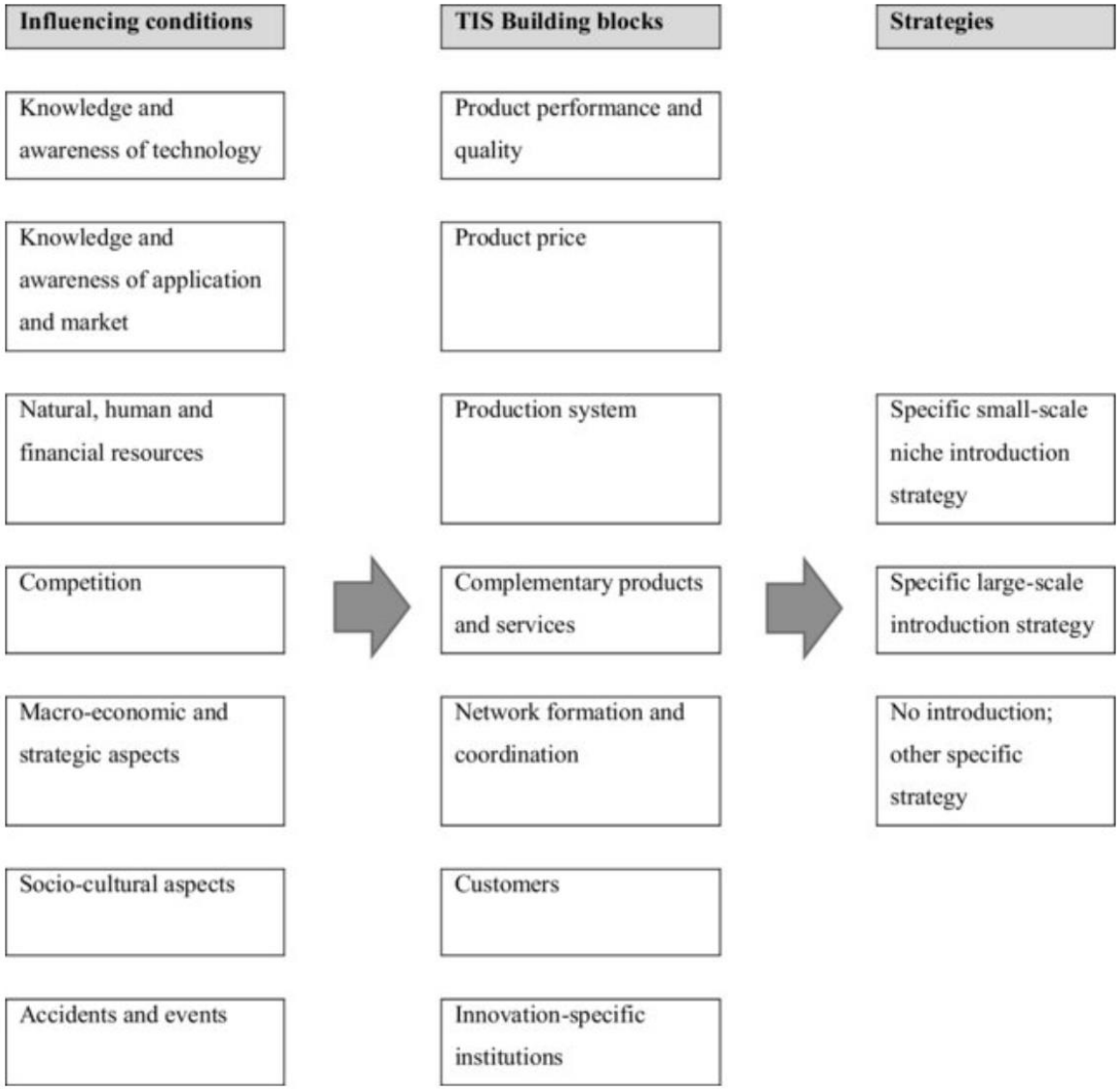


Figure 2: Technological innovation system framework to formulate Niche introduction strategies (Ortt & Kamp, 2022)

The TIS framework developed by Ortt and Kamp (2022) aids in evaluating the current practices within the regime during the adaptation phase, hence when the innovative technology has not started to diffuse on a large-scale yet. When a breakthrough innovation has to be implemented within the market, there are multiple actors and factors which have to be considered, the main ones are highlighted within the TIS system. An objective analysis has to be carried out for the technology, to understand which building block is missing or incomplete, as if it is, it would generate a barrier to large-scale diffusion. Once the barrier is identified, it has to be developed an 'ad-hoc' strategy to overcome it. Once all the barriers are solved, the company can prepare for technological diffusion on the national level. A case example, in the paper of Ortt and Kamp (2022), is the one of Dual-Clutch transmission technology (DCT), a transmission that is able to put one gear into position while the other is still functioning. Because the building block "knowledge of the technology" was incomplete, the DCT was applied to a niche market: the racing car market. This allowed the author to conduct further research and development on the technology while solving the blockage of the building block.

To conclude, the TIS framework has helped in delivering a detailed investigation of the socio-technical context around a company that aims to diffuse, in this case, Sustainable Greenhouses on the Moroccan market, to then develop the right introduction strategies for the innovation, capable to complete all the TIS building blocks and prepare for a large- scale diffusion on the national level.

Both the building blocks (Table 3) and the Influencing conditions (Table 4) are summarized below:

Table 3: Building blocks by Ortt & Kamp (2022)

Building Blocks	Overview
Product performance and quality	It refers to how well a technology or product can meet its intended function or purpose, while also satisfying user needs and expectations in terms of quality. These characteristics are crucial factors that can determine the success or failure of a technology or product in the market. For instance, if the quality of a product is poor, the users will be unhappy, thus the demand of the product may decrease.
Product price	The cost of purchase and use of a product could be financial and non-financial.
Production system	It relates to the methods and processes used to manufacture, assemble, and distribute a technology or product. In fact, these have a significant impact on the adoption and success of a technology or product. An efficient production system can help to reduce production costs, increase productivity, and ensure consistent product quality. Meanwhile, an inefficient production system can lead to higher production costs, decreased productivity, and lower product quality. Limiting the large-scale diffusion of the technology.
Complementary products and services	It refers to the entire innovation process from development to disposal. This building block can impact the speed of success of an innovation. In fact, when they are too expensive or inefficient they may hamper the large-scale diffusion of an innovation. For instance, an electric car might face a limited adoption if there are no charging stations.
Network formation and coordination	It is identified as the interactions among the different actors in the innovation system, like suppliers and producers. An effective interrelationship and a common vision among the different stakeholders would facilitate the diffusion of the innovation. Indeed this would generate a strong value chain as well as greater access to resources. Nevertheless, without effective coordination between them, the large-scale diffusion might be blocked.
Customers	It relates to the potential individuals or organisations that might purchase the technology. Identifying potential customer segments and their needs is crucial early on in the development process. Failure to involve customers during development can lead to

	customer-related issues that hamper diffusion, such as lack of means or knowledge, uncertainty, and difficulty integrating new technologies into existing practices and routines.
Innovation-specific institutions	It is a key factor as institutions, such as laws, government policies and regulations, play a significant role in regulating the development of technological innovation. Long-term supporting regulations can increase certainty for organisations, boosting the diffusion of innovation. Additionally, partnerships could be used to support the development of an innovation.

Table 4: Influencing conditions by Ortt & Kamp (2022)

Influencing conditions	**Overview**
Knowledge and awareness of technology	This influencing condition regards the knowledge of the customers of the product, the production system and complementary products. In addition to the awareness required to produce, repair, use and maintain the technology. A lack of knowledge and awareness of the technology will hamper TIS formation.
Knowledge and awareness of application and market	This influencing condition refers to the customer's knowledge of which application and how the innovation can be used. It relates to the market structure and market applications used too. The use of market analysis, learning by doing and testing can be ways to expand this knowledge
Natural, human and financial resources	This influencing condition represents the availability of natural, human and financial resources needed to allow the diffusion of the technology. The lack of these might hinder the diffusion of breakthrough innovation.
Competition	This condition refers to the competitors of breakthrough technology. The competitors might be old technologies or other new technological competitors. The chaotic network formed among these competitive alternatives may hamper the technological diffusion of technological innovation. This might increase uncertainty and hinder the diffusion of innovation
Macro-economic and strategic aspects	These factors pertain to economic recessions or economic growth that can hamper or facilitate the TIS formation.
Socio-cultural aspects	This factor refers to the norms and values held by the technology adopters in the TIS. These elements are more informal than the laws and regulations but have an important impact on the formation of the TIS.
Accidents and events	This influencing condition refers to accidents in production or product failure, or outside the TIS to wars or natural disasters.

3.2 The niche introduction strategies

The TIS framework is focused on the adoption phase, which occurs when a breakthrough technology has been proven to function but has not yet been widely diffused. Organizations can use this framework to develop niche introduction strategies (NIS) with the ultimate goal of forming a market for the technology. To determine which NIS to adopt, it is necessary to study the influencing conditions that affect the building blocks of the technology. By understanding these conditions, it is possible to identify the causes of any barriers to adoption. With the help of a specific NIS, it may be possible to overcome any incomplete building blocks and their causes, as described by Ortt and Kamp (2022).

Different causes require different NIS. For instance, as explained in the paper of Ortt et al. (2015), a lack of customer spending power could be solved by providing a cheaper version of the innovation that more individuals could afford. Therefore, organisations with an attentive understanding of the core and influencing factors could pick the most appropriate NIS.

There is a wide range of NIS that could be used by companies during market formation. Ortt et al. (2015) give a list of the ten main ones, which are summarized in the Table (5) below:

Table 5: Niche introduction strategies by Ortt et al. (2015).

Specific Niche Introduction Strategies	**Overview**
Demo and develop niche strategy	It involves introducing innovations in a targeted way, to specific groups or markets, before scaling up to a wider audience. This strategy reduces the risks of large-scale diffusion, by gaining stronger approval from key actors.
Redesign niche strategy	This technique aims at developing a simpler version of the innovation so that it is affordable for a wider range of people. Thus increasing the chances of adoption of the innovation. Moreover, this strategy could be used to adapt the characteristics of the product to match the needs of a specific market segment.
Stand-alone niche strategy	It is about positioning the innovation as a stand-alone solution that does not need any other complementary technology. This could be useful when complementary technology is too expensive or too hard to obtain. Thus by presenting the innovation with this strategy, it would be more likely to successfully diffuse.
Hybridization niche strategy	It aims at combining the introduction of innovation with an already existing technology. Thus, the innovation would have to be designed in a way to allow conjunction and compatibility.
High-end niche strategy	This strategy is also known as ‘skimming’. This strategy is widely used by organisations that want to diffuse an idea of exclusivity of the innovation. This is often done by applying a premium price to the product sold. Sometimes this approach is used by companies to test the market before developing a cheaper version of the product.
Educate niche	It involves sharing knowledge regarding the innovation with

strategy	potential actors and customers. The goal is to make sure what the capabilities of the proposed innovation are, and that is used at its fullest potential, in order to reduce costumers' skepticism.
Lead user niche strategy	It would consider spreading the innovation among 'lead user', thus customers with recognizable knowledge within the field of the innovation. The organisation would be receiving some feedback from these 'lead user', hence they could implement it to further develop the innovation.
Explore multiple markets niche strategy	It aims in identifying the most successful market application by testing the available ones. This process will help the organisation in understanding the most successful application of the innovation. Subsequently, it could be sold mostly within that field, to increase the revenues.
Subsidized niche strategy	This strategy seeks in gaining financial support from governments. This is often done by organisations that consider their innovation significantly valuable to society.
Geographic niche strategy	The goal of this strategy is to introduce the innovation in a specific geographical region, as due to the presence of resources and suppliers the diffusion of the technology might be greater.

3.3 An Introduction to Sustainable Greenhouses

Among the different methods, Greenhouse systems are one of the technologies used in agricultural production to improve crop growing conditions (Giuliano Vox et al., 2010). This technique involves growing crops within structures that are covered by a transparent material to protect them from unfavourable weather conditions (Krishna Nemali, 2022). Greenhouse technology is well known for its numerous market applications, unique architecture, and wide usage. This technology generates a controlled microclimate that can be adapted to meet the specific needs of crops.

However, greenhouse systems consume large amounts of resources, leading to significant waste production. This has led to concerns that modern agriculture practices, including greenhouse systems, are undermining the value of preserving natural resources associated with sustainable horticulture (Aerni, 2009). In response, many scholars have focused on improving sustainability within greenhouse systems by developing resource-conserving systems that reduce energy, water, and agrochemical consumption, as well as waste generation. These sustainable greenhouse systems are built on cultivation techniques, equipment management, and constructive materials aimed at reducing environmental impact (Giuliano Vox, 2010).

3.4 Sustainable greenhouse technological components, structures, and market applications.

The technological components of Sustainable Greenhouses

Sustainable high-tech greenhouses are a distinct category of greenhouses that emphasize sustainability, made possible through the integration of an extensive technological system. To thoroughly examine the technological components, an overview of the technological elements is required, which can be summarized into three distinct pillars: External technologies, SG-

specific technological elements and infrastructure technologies. The first two components are inherent to the technology of SG. External technologies are identified as already existing technologies surrounding the SG processes, which make SG possible. SG-specific technologies are those directly related to the SG. Whilst, the third element analyses the technologies that provide SG with the necessary infrastructural appliances. It is the coexistence and collaboration of these three pillars that contribute to the sustainability of greenhouses. The ones listed are the general components that must be within each sustainable greenhouse. However, the singular components and infrastructural characteristics vary depending on the market application of the technology.

It is important for the reader to have an overview of the technological elements within a Sustainable high-tech greenhouse to better understand the TIS analysis. Because one of the barriers could be triggered, for instance, by the lack of know-how for a technological element; or the lack of infrastructural technologies to support the energy/water demand of the innovation. An overview of the technological elements is presented in Figure (3), in case the reader wants to know more about the singular technologies more information could be found in the Appendix (D). The data collected for this map comes from Giuliano Vox et al.'s work in 2010.

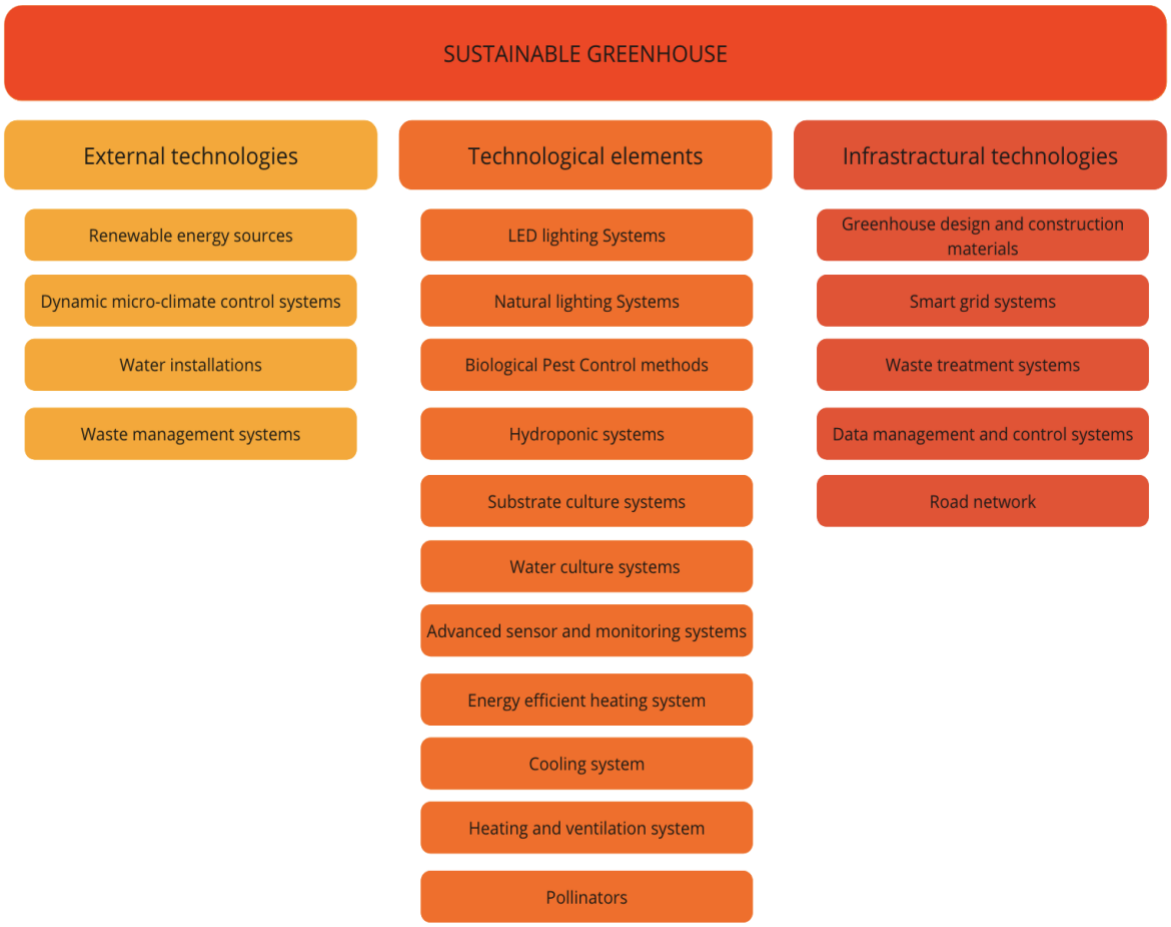


Figure 3: Technological map

Sustainable Greenhouses Structures

It is evidently clear from the technological map, how the greenhouse design, components and cover material properties have a great impact on the greenhouse efficiency. The choice of these components depends on the purpose of the greenhouse. For instance, some of them might be more suitable for seasonal crops and others might be used for a year-round

production. This paragraph analyses some types of commercial greenhouses, like Venlo greenhouse, Canarian Greenhouse and Plastic film Greenhouse.

This section is essential for the reader as within the TIS building block and influencing conditions the different types of greenhouse structures are going to be mentioned several times. For example, a competing technology for a Moroccan grower to Sustainable (Venlo) Greenhouse, could be buying more land and building a Canarian greenhouse instead. Thus the reader needs to have a foundation of the different structures.

The Venlo Greenhouse

This greenhouse with its components and operations could be considered the Sustainable Greenhouse per excellence. In fact, it uses a metallic frame covered by rigid plastic or glass material (Figure 4). It is distinguished as it has only one glass pane placed in glazing bars between the gutter and ridge (Von Elsner B. et al., 2000). Because of their standardization are easier and cheaper to build than other wide-span greenhouses. This type of greenhouse has been widely researched by the literature and there have been produced an incredible amount of components to maximise their efficiency. A key advantage of this structure is the roof ventilation, achieved with the opening of the windows on the ceiling.

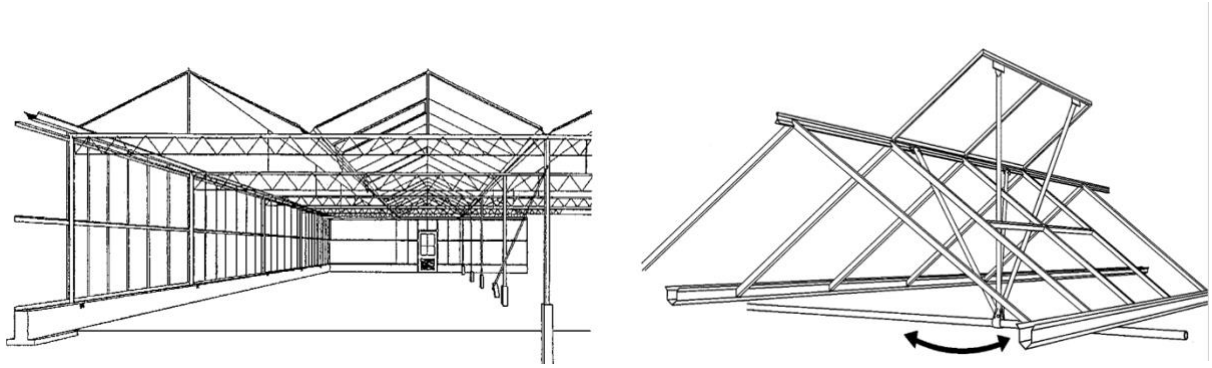


Figure 4: Venlo type greenhouse (Von Elsner B. et al,., 2000)

Plastic film Greenhouse

This greenhouse could be sustainable in components and operations, but it is cheaper to build and it requires greater maintenance in the long run. (Interviews: DR2, DC2) It is extensively used in countries with warmer climates, most of the time with a wooden frame to support the structure. These greenhouses are a cheaper alternative than common glasshouses. This is because among its benefits it has some disadvantages. For instance, the high maintenance required for the substitution of the plastic film or the inadequate ventilation (Von Elsner B. et al., 2000). The tunnel greenhouse (Figure 5) or the plastic pitched roof greenhouses are the most common examples.

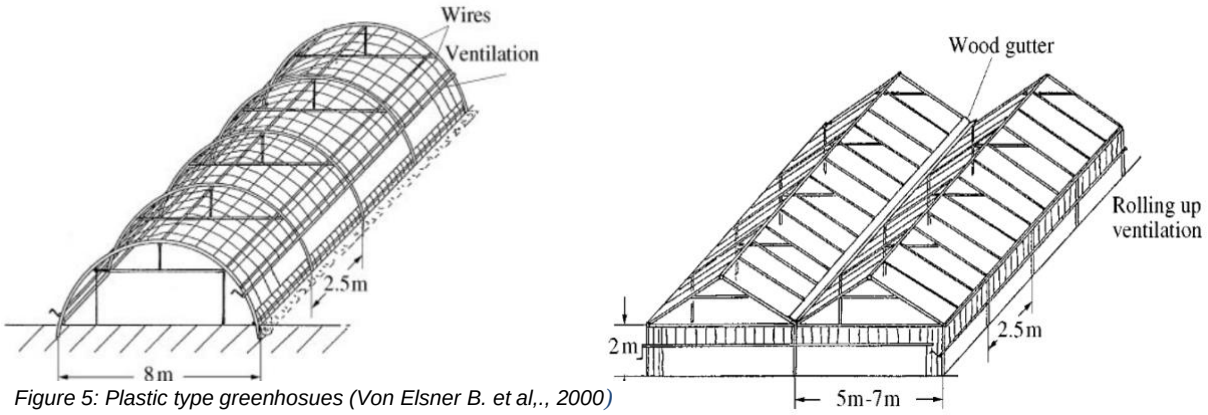


Figure 5: Plastic type greenhosues (Von Elsner B. et al,., 2000)

Canarian Greenhouse

This is the *most common type* of greenhouse built in Morocco, it is considered a low-technology greenhouse and highly water-intensive (Stanghellini et al., 2017). These were first developed for the cultivation of bananas. The typical design comprises a wooden frame, covered by a two-layered iron network that encloses plastic sheets (Stanghellini et al., 2017) (Figure 6). Unfortunately, this type of greenhouse does not have effective ventilation and water discharge systems in place. The only means of ventilation is through the side walls, which require manual opening, while insect nets are used to keep pests out. However, these structures present some advantages, such as good wind resistance and cheap building costs.

Figure 6: Amir Zoubi (2023), Canarian greenhouse Photograph. Self-published

Market applications of Sustainable greenhouses

The market applications are necessary for the reader as this technology is highly versatile in structures and internal operations, for this reason, it can be applied within horticultural production on a wide range of market applications. However, **in the TIS analysis**, the introduction of such technology for a market application rather than another may present some more barriers to diffusion. For instance, some market applications may present a greater barrier within the *Network formation & Coordination building block*, due to a greater lack of unskilled labour caused by harsher working conditions.

High-tech greenhouse for tomato production

The most widespread use of greenhouses is for tomato production. This is because it offers multiple advantages over traditional open-field cultivation. The covering material usually used is glass, heated with combined heat and power, thermal screen control, indoor temperature control and CO2 fertilization control (Maureira et al., 2021). The growing technique requires trellising technique and knowledge to promote the crop vertical growth and pruning techniques for fruit development. For this reason, the structure of this type of greenhouse needs to be particularly high (4-6 meters) and the crops must be planted farther away from one another (Peet et al., 2005). Additionally, to sustain the weight of the crop the greenhouse must possess a trellising system, like overhead cables. The irrigation system within these greenhouses employs drip irrigation (whilst soft-fruit production may use overhead sprinkles). Because tomatoes are more susceptible to certain types of pests a specific knowledge of disease management it is needed to allow this crop to thrive, as well as the correct pruning technique (Peet et al., 2005).

Figure 7: Greenhouse for tomato production (Greenhouse Growe, 2023)

High-tech greenhouse for soft-fruit production

In contrast with the previously discussed greenhouse types within these ones, the crops grown are usually stacked up to each other to maximise space utilization. Meaning that there is not extensive use of trellising systems. What is more in greenhouses for soft fruit production there are no netting systems or trellsing systems designed to support the pruning of the crop. To conclude, as already mentioned to irrigate the crops overhead sprinkles are often used (Peet et al., 2005).

Figure 8: Greenhouse for flower production (Depositphotos, 2023)

High-tech greenhouse for herbs production

Often herbs are considered high-value crops as they must maintain the desired flavour and odour. The structure of these greenhouses is not very high as the crops do not develop in height (Peet et al., 2005). In fact, it is common to see these crops grown in vertical structures or some specifically designed containers. Usually, these crops are grown in soilless systems such as hydroponic or aeroponics (Sathyanarayana, 2021). Due to the higher humidity tolerance of herbs, there is a reduced need for extensive ventilation in the crop, resulting in fewer ventilators being necessary.

Figure 9: Greenhouse for herbs production (Produce Business, 2023)

3.5 Literature review conclusion

The aim of this chapter was to provide the reader with a comprehensive understanding of the Sustainable Greenhouse context. It is possible to state, after the conducted research, that a Greenhouse is sustainable when it is built with the planet in mind. This is done with the combination of highly advanced technological elements (outlined in the technological map) and design that maximises the resources and operations. Furthermore, the problems that could be solved with the introduction of these innovations are many and they go from food security to the socio-economic development of the country.

Moreover, among the multiple advantages Sustainable Greenhouses have a wide spectrum of market applications. This is because the technology can be used by different companies with a great variety of business models and technological components. However, SG technology although the various amount of benefits that it brings, finds extensive use only in a few nations worldwide. Leaving the rest of the world, to the use of highly unsustainable cultivation practices. This is because there are some general challenges which may limit the diffusion of the technology on a national scale.

Now that there has been conducted extensive literature research on the topic, the analysis part of the research will start in the following chapter by illustrating the involved actors in the technology diffusion. Just as a reminder, the aim of this research is to develop some niche introduction strategies for sustainable greenhouse companies in Morocco. It is important to emphasize two aspects. Firstly, how this study focuses on a **company perspective**, and the development of the suggested strategies comes from all the gathered information from a series of dynamic actors which interact to diffuse sustainable greenhouse innovations on a national scale. Currently, there is a **lack in the literature** regarding sustainable greenhouse diffusion in Morocco, and more specifically there is **no study that analyses the barrier** to the diffusion of sustainable greenhouses from a company perspective in Morocco. Secondly, how currently the sustainable greenhouse innovation is diffused only on a niche level in Morocco, located in the Souss-Massa region of Agadir (shown in Chapter 4.2, Table 5). For these above-mentioned reasons, the study is conducted with the use of the TIS framework, which aids the author to develop the best way to overcome the barriers preventing companies to go bankrupt before reaching large-scale diffusion.

Chapter 4: The Actors in the Technological Innovation System: A Closer Look

This chapter aims to give a visual representation and a clear overview of the different interactions, influences and interests of the stakeholders that are playing a role for the diffusion of Sustainable greenhouses in Morocco. Moreover, **this chapter it is of major importance** because the reader needs to have an unequivocal understanding of three points. Firstly, how different actors from different stakeholder groups have different perspectives/roles in the diffusion of innovation. Secondly, how the author has managed to interview actors from each stakeholder group in order to have as in-depth and as impartial TIS analysis as possible. Thirdly, how this research embraces for the first time with the use of the TIS framework a case of technology transfer from the Netherlands to Morocco.

To conclude, this chapter presents the stakeholder analysis of the relevant actors from Morocco and the Netherlands. This is followed by an overview of some of the technology providers/growers currently in business in the Moroccan landscape.

4.1 Stakeholder analysis of the technology transfer

The stakeholder ecosystem is comprised of various actors who hold diverse interests. In the context of Morocco's goal to enhance its food self-sufficiency by adopting sustainable greenhouse practices, multiple perspectives must be taken into account. While some groups may be in favour of the change, others will be less enthusiastic. In this section, the author aims to provide an overview of the key actors involved or affected by the transition to sustainable greenhouses. The author's objective is to facilitate the reader's comprehension of the case study analysis through the comprehension of the actor chain. This paragraph is backed by the **primary data collection** and **validated by the papers** of el Khinifri, 2017; Stanghellini et al., 2017.

According to the information presented in Figure (10), there are a total of 23 actors involved in the project, belonging to 5 distinct areas: research and development, government institutions, public/civil society, businesses, and innovation. The actors are sourced from both the Netherlands and Morocco, as both countries have expressed interest in promoting the diffusion and development of innovation. The strong interest from the Dutch government, in diffusing sustainable greenhouses, has led to a collaboration of many governmental institutions. In fact, the Dutch Ministry of Foreign Affairs has commissioned the project for the creation of a Centre of Excellence (CEH) in Agadir and its operalization, the Netherlands enterprise agency (NEA, a governmental agency that is part of the Dutch Ministry of Foreign Affairs) is financing it, the Agricultural department of the Dutch embassy in Morocco is working as an intermediate and insurance of a smooth collaboration between the two countries (el Khinifri, 2017; Stanghellini, 2017). All these international governmental organisations are working hand-in-hand with the Moroccan government and with its ministry and offices, but more in particular with the Ministry of Agriculture, Agence du Bassin Hydraulique and the Office for food security and Safety (ONSSA). Multiple Dutch universities and research centres, like the one of Wageningen University and Leiden-Delft-Erasmus (LDE), are implementing wide knowledge sharing with the Complex Horticulture d'Agadir (CHA) (Stanghellini, 2017). This actor is the greenhouse research institute of the Institut Agronomique et Véterinaire Hassan II (IAV-Hassan II), which is an engineering university in Rabat, Morocco (el Khinifri, 2017). This centre received a great amount of funding from the Moroccan government and the Dutch government, to encourage research and development within the greenhouse field. From

the Moroccan side there are some other actors, like the association of the growers, named APEFEL, this association manages the Centre of Technology Transfer (CTT) (el Khinifri, 2017; Stanghellini, 2017). Similarly, to the CHA, this centre serves as a demonstration of the innovations and as a training centre. With all of the knowledge and investment within the field, with as an initiator of the CHA, there has been founded the Centre of Excellence in Horticulture in Agadir (CEH)(el Khinifri, 2017). This centre is a combination of knowledge of all the different actors and factors, which will help as a starting point for the diffusion of sustainable greenhouse innovation within the national Moroccan food (industry) market. The APEFEL as well as the consumers, the local communities and the supermarkets have been included as key stakeholders in the public/civil society as they want food security and an improved lifestyle that could be brought with innovative agricultural practices. These last 4 actors play an important role in the diffusion of innovation on a national scale.

In Figure (10) are shown which actor can influence other actors' decision-making. This could be done through some formal relationships among them, or through some informal decisions that may influence certain groups of actors. The interests, objectives and resources of each actor are summarized in Table (6). Further diving into the stakeholder analysis shown in Figure (10), it is noticeable how some of the actors are grouped within four categories: technology supply, technology demand, food supply and food demand. This is explained by Ortt & Kamp (2022), “The market is made by multiple actors from both the demand and supply. All of which makes up for a dynamic network of agents interacting in a specific area/field involved in the diffusion of the technology”. For the first two groups, it is meant the supply and demand of the sustainable greenhouse technology itself. Whilst the second one is the supply and demand of the horticultural products that will be produced from the greenhouses. This was done for the reader, to better identify the roles of these stakeholders. The technology supply actors are those stakeholders that contribute to the building and knowledge share of Sustainable greenhouses, these have direct monetary interests in the diffusion of the technology. Whilst on the technology demand side there is, firstly the CEH which is the centre of the technology diffusion and research. Secondly, the stakeholder that has a detains a greater demand are the growers (APEFEL) they need new technologies to enhance their productivity and reduce their environmental impacts. This is because, the growers are the final receiver of the technology, as they might decide on whether to implement it in their farming practices or not. Moving toward the food supply, it is noticeable from Figure (10), that the growers are added to this group. This is because, with the implementation of the breakthrough technology, they will be using it to produce horticultural products, which will be sold to the national and international markets fulfilling the national and international food demand. The producers could be directly interlinked to the wholesale market or indirectly if they decide to sell the products through auctions or some international food processing industries. In any case, the final products would be sold to the supermarkets and/or the general public; both of these actors make up for the food demand category. However, it is important to notice that the horticultural products could be sold on the national or international market only after being sampled and checked by the ONSSA Office of food safety and Security.

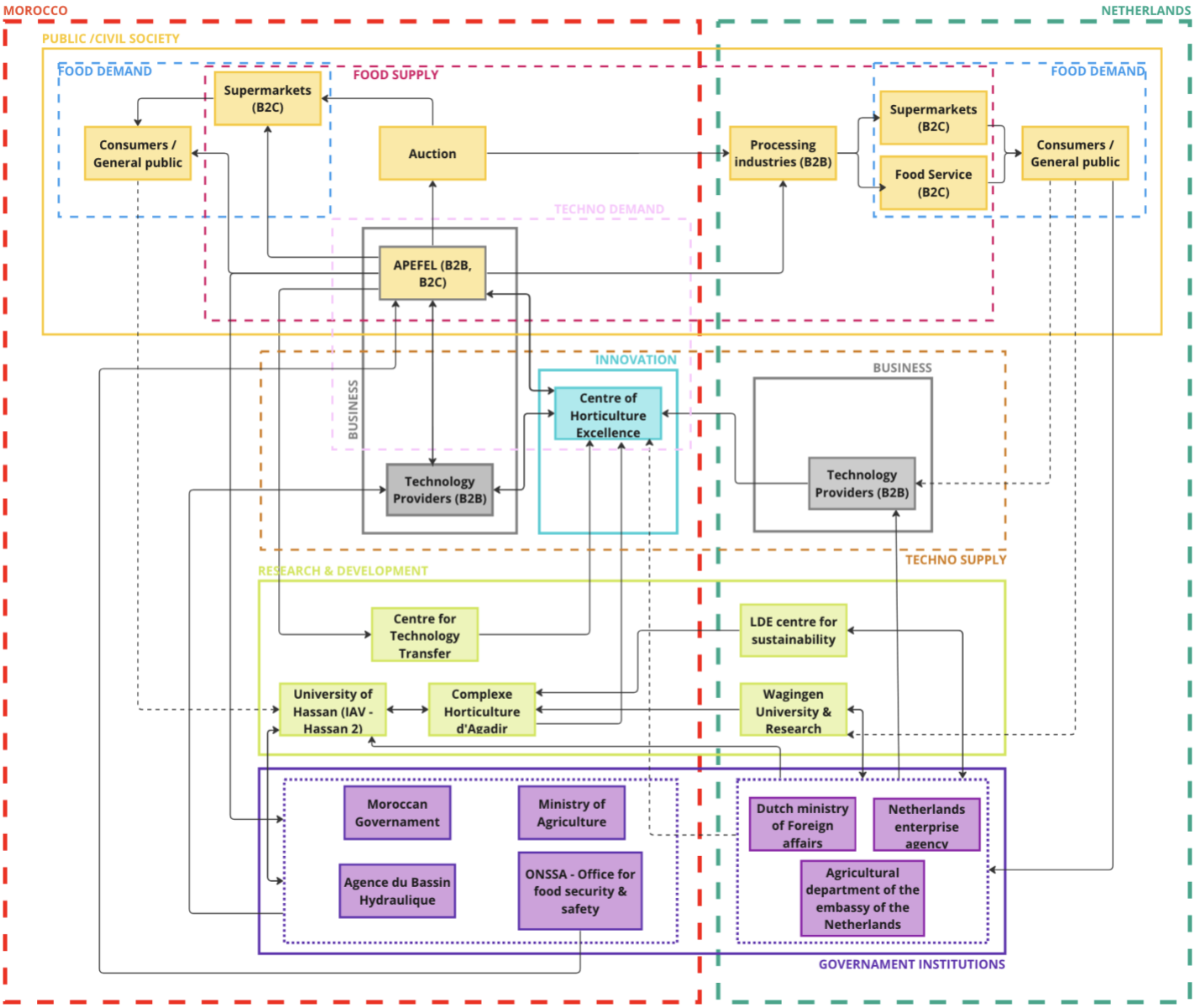


Figure 10: Moroccan and Dutch actors involved in the technological diffusion.

Table 6: Table listing the different actors rapresented in the stakeholder anlsysis with theri interests, objectives and influences by some primary research data collected and by the papers of el Khinifri, 2017; Stanghellini et al., 2017

Actor	Domain	Interests	Objectives	Resources / Influences	Supply /Demand
Moroccan Government	Government institution	Guarantee safe food supply; increase work availability and economic growth.	SG can aid in achieving a continuous, domestic supply of food. Food safety will be safeguarded. Increase the number of jobs through SG installations.	Laws, policies, tax money, information, regulations.	/

Agence du Bassin Hydraulique	Government institution	Guarantee safe water supply; ensure water availability.	SG could be an ally in the depletion of water resources.	Policies, tax, money, regulations, information.	/
Moroccan Ministry of Agriculture	Government institution	Ensures the agricultural development of Morocco.	Aims at ensuring innovation among the growers, social equity, reducing depletion of resources, help entrepreneurial activities.	Laws, policies, tax money, information, regulations.	/
ONSSA - The national office for sanitary safety and security of alimentary products.	Government institutions	Ensure that the exported and imported products fit within the laws and legislation.	The introduction SG will lead to more products produced that will conform to national and international norms.	Regulations , information.	/
Dutch Ministry of Foreign Affairs	Government institution	Create a robust link among the partners involved.	Increase their economic influence on the Moroccan region and reduce the amount of energy used for food production in the Netherlands	Law and policy making abroad, supply of goods, sanctions.	/
Agricultural department of the embassy of the NL	Government institution	Ensuring a smooth running of the operations between the two nations.	Wants to improve the international relationships of the Netherlands.	Diplomatic relations with other countries	/
NEA	Government institutions	Investing in the development of the technological institution to facilitate the diffusion of SG.	Making the right investment decision, by ensuring results in the operations.	Money, information.	/
CHA	Research & Development	Gain more knowledge about certain topics.	Research and manufacture the new agricultural technology to sell.	Lobbying, innovation through technology, knowledge.	/
IAV-Hassan 2	Research & Development	Gain more knowledge about certain topics.	Research the technological possibilities to increase food production.	Lobbying, education, empowering people, knowledge.	/

APEFEL	Public / Civil society	Making the interests of the growers and private actors, increasing their earnings.	To help the growers in developing the best national and international market strategy, and increase their production with the implementation of SG.	Lobbying, empowering growers.	Technology demand and Food supply
CTT	Research & Development	Gain more knowledge about certain topics, and spreading it among other actors.	Educate current and next generations of professionals.	Lobbying, innovation through technology, knowledge.	/
WUR	Research & Development	Develop a research programme in collaboration with the CHA.	Increase the knowledge sharing among the country, and definition of the WUR interventions in the execution of the research programme.	Lobbying, education, empowering people, knowledge.	/
Leiden-Delft-Erasmus centre for sustainability	Research & Development	Develop a research programme in collaboration with the CHA, and guide Moroccan institutions toward a more sustainable transition.	Increase the knowledge sharing among the country, and definition of the WUR interventions in the execution of the research programme.	Lobbying, education, empowering people, knowledge.	/
Consumers /General public	Public / Civil society	Satisfying their needs for a good quality of life	SG can increase quality of life through vegetation, i.e. air quality, fresh and affordable produced products.	Large amount of people, purchasing power, public involvement.	Food demand
Auction	Public / Civil society	Making more profits by selling produced products.	Have a stable supply of food and reach as many customers as possible. They encourage the diffusion of technology to have more food to be sold.	Provision of goods and services to Morocco, the Netherlands and other foreign countries.	Food supply
International Processing	Public / Civil society	Increasing their profits by selling	Have a stable supply of food and	Provision of goods and	Food supply

Industries		food.	reach as many customers as possible. They encourage the diffusion of technology to have more food to be sold.	services to Morocco, the Netherlands and other foreign countries.	
Supermarkets / Food Service	Public / Civil society	Having a wider range of products to sell	Purchasing good quality products for less.	Purchasing power, public involvement, advertising.	Food demand and Food supply
Moroccan Technology providers	Business	Learning more about the new technological innovation and making more profits.	Increase knowledge about SG, have a stable supply of food and reach as many customers as possible.	Investments, knowledge sharing and advertising.	Technology supply
Dutch Technology providers	Business	Making more profits by selling tech items/services.	Are in favour of the implementation of SG in Morocco	Provision of goods and services to Morocco, monetary exchanges.	Technology supply
CEH	Innovation	To work as a base to spread the gained knowledge from this collaboration within the whole of Morocco.	Combining international knowledge and technology to develop the Moroccan horticultural industry.	A large number of investments, and knowledge.	/

4.2 Morocco's Pioneering Companies in Sustainable Greenhouse Adoption

As it is shown from the stakeholder analysis there is a growing need in Morocco, encouraged by the national and the European government, to diffuse on a large-scale more sustainable food production technologies. Currently, sustainable greenhouses are diffused only on a niche level, more precisely within the Souss Massa region. However, there are a growing number of start-ups within the horticultural sectors, which are bringing new advancements in the field. In 2017, Duroc, a Moroccan company built over 14 greenhouses for the production of tomatoes in the area of Agadir (Duroc n.d.). It is important to notice that not all the greenhouses possessed by the company are high-tech some of them are Canarian Type greenhouses, this company follows a B2C (Business to Consumer) business model. Hortisud is another Moroccan company also located in Agadir, which instead of the producer is a technology provider (Hortisud n.d.). These companies produce and develop innovative irrigation components for greenhouse companies, therefore it follows a B2B (Business to Business) business model. Another technology provider is Agrembal, this company is specialised in the production of pollinators, steel components and seeds. However, it does produce early vegetables and citrus fruits, which are mostly exported (Agrembal n.d.). This company follows a B2B approach as both the technology and the horticultural products are sold directly to other

businesses. Nevertheless, there are still a lot of producers which keep on using low-tech greenhouses for their production, an example is Atlas Berry, a Moroccan company, that produces soft fruits (e.g. strawberry, blueberry). This company follows a B2C business model. As is shown, from the stakeholder analysis there is a strong collaboration with international companies (in this case Dutch companies) that aim to export and sell their technology, knowledge and expertise to Moroccan companies/research centres. An example is HortiXS, which has built some research greenhouses for the IAV-Hassan 2 university (one of 12.000m2 at the CEH) and it is currently delivering another showcase of sustainable high-tech greenhouse in Agadir. This Dutch company follows a B2B business model, as works as a technology seller to national/international companies. This shows how national universities are also exploring the technology and the best market applications for the technology in Morocco. To conclude, it is clear how the niche position of the technology is located in the Agadir area in the Souss-Massa region in Morocco.

The found Moroccan companies/growers/technology providers are summarized in the following Table (7).

Table 7: Table listing the main Moroccan companies

Who?	**Where?**	**What?**	**Business model**
Duroc	Agadir, Souss-Massa region, Morocco	Tomato production	B2B
HortiSud	Agadir, Souss-Massa region, Morocco	Irrigation technology provider	B2B
Agrembal	Agadir, Souss-Massa region, Morocco	Multi-component technology provider/producer	B2B
Atlas Berry	Agadir, Souss-Massa region, Morocco	Soft-food production with low-tech greenhouse	B2B
Azura	Agadir, Souss-Massa region, Morocco	Tomato /Herbs production	B2B
AdNature	Agadir, Souss-Massa region, Morocco	Tomato / Citrus production	B2B

It is **important to notice** that currently, the sustainable greenhouse technology in Morocco finds its applications only within a highly located geographical area in the country, and only by some leader companies in the sector. Besides this, it is statable that even if on a **niche level** the use of this technology is growing. Nevertheless, **it was not found**, by the author, any scientific literature exploring such an entrepreneurial ecosystem in Morocco.

Chapter 5: Barriers to sustainable greenhouse diffusion in Morocco

To refresh the reader this chapter aims at answering the following sub-questions:

> *What could be the barriers hampering the large-scale diffusion of Sustainable Greenhouses in Morocco?*
>
> *What is the status of the influencing conditions that are impacting the incomplete building blocks?*

Firstly, it is presented the list of the interviewed actors, and sources of primary research, from multiple perspectives and experiences. Secondly, the TIS building blocks analysis is carried out, concluding at the end of the paragraph with an analysis and a visual representation of the building blocks' status for each market application. Thirdly in the same way it is depicted the analysis of the influencing conditions. The chapter concludes with the representation of the interactions of the influencing conditions and building blocks per market application.

5.1 The TIS building block analysis

To refresh the reader with the use of the TIS framework, developed by Ortt and Kamp (2022), it is taken into consideration the socio-technical system from a company perspective. The result of the study is a list of seven building blocks, which have to be analysed to develop an 'ad-hoc' niche introduction strategy. However, if any of the building blocks is incomplete or incompatible, a barrier to large-scale diffusion is formed, hampering the diffusion of technological innovation.

Below are described and analysed the building blocks and the influencing conditions for Sustainable Greenhouse diffusion in Morocco, which are causing the incompleteness of the building blocks. The analysis is carried out with the help of literature research and the gained insights from the different interviewed actors.

As already mentioned within Chapter (2), in the analysis below it is explicitly said from which stakeholder group the gained data comes. Data was collected from a total of 17 actors, these were grouped in two tables with a detailed explanation of their role and relevance (Chapter 2, Table 1 for the Moroccan actors, Table 2 for the Dutch actors). To facilitate the reader, a brief overview of the interviewed actors with the according abbreviations is proposed below (Table 8 & Table 9). It is noticeable how the actors were named according to their role (e.g. researcher, governmental actor, grower or company manager). This was done to facilitate the reader in the study of the building blocks and influencing conditions, and more importantly to highlight the difference in opinion among the actors that cover a different role and different nation. For instance, a grower's opinion regarding a specific barrier might be different from a researcher's one. Moreover, where possible, the insights presented within the building blocks and the influencing conditions will be backed up by the data collected from the desk research.

Table 8: List of abbreviation of interviewed Moroccan actors.

Interviewee	Abbreviation
Moroccan Researcher 1	MR1
Moroccan Researcher 2	MR2
Moroccan Gov-act. 1	MGOV1
Moroccan Gov-act 2	MGOV2
Moroccan Gov-act 3	MGOV3
Moroccan Gov-act 4	MGOV4
Moroccan Grower 1	MG1
Moroccan Grower 2	MG2
Moroccan Company 1	MC1
Moroccan Company 2	MC2
Moroccan Company 3	MC3

Table 9: List of abbreviation of interviewed Dutch actors

Interviewee	Abbreviation
Dutch Researcher 1	DR1
Dutch Researcher 2	DR2
Dutch Grower 1	DG1
Dutch Company 1	DC1
Dutch Company 2	DC2
Dutch Company 3	DC3

To conclude, as a quick reminder for the reader, the analysis is based on qualitative research, and it was made an assumption (Chapter 2) that all respondents are referred to as male to ensure their anonymity and to facilitate analysis.

5.2 The building blocks analysis

This paragraph entails the first of a three-step process for the analysis of Sustainable Greenhouse Diffusion: the analysis of the building blocks.

The analysis of each building block is structured in the same way for each one of them. Firstly, it is presented the definition of the building block as provided by the paper of Ortt & Kamp, 2022. This is followed by the analysis of the status of the building block, this is done with the insights gained by the interviewee's knowledge and literature research.

For each building block at the end of the analysis, a summary table of the gained insights is presented. The table is structured in the following way: in the first column the barrier for the building block is presented, in the second column the barriers are explained, in the third column a summary of the primary and secondary data gathered that back up the mentioned barrier are shown. It is important to mention, that for the secondary data presented in the third

column if the data is in **bold** its because the paper mentions a barrier specific to the case of Morocco, if it is not in bold it is a paper that mentions this barrier on a global scale.

As mentioned in the methodology chapter (Chapter 2), at the end of the analysis of the building blocks / influencing conditions, one graph for each market application is presented to show the reader the status of the building blocks / influencing conditions (e.g. complete, partially incomplete or incomplete) for each market application. Additionally, to ensure **clarity and consistency** throughout the research process it was necessary to develop clear guidelines for the status identification of the TIS components. Respectively, in the case if a building block is complete it is presented under the colour green, meaning that this building block is not a barrier to the technology's diffusion. If the building block is partially incomplete it is shown under the colour yellow, meaning that this building block may still limit the diffusion of the technology on the national level. Finally, if the building block is incomplete it is depicted with the colour red, meaning that this building block is a barrier to the technology's diffusion.

To ensure the **author's transparency** on the data collected the interview transcript is provided in Appendix **(**E & F). What is more, to facilitate the reader, to **each building block and influencing condition has been assigned a colour** with which the relevant parts are highlighted in the interview transcript. The chosen colours are shown in the Table (10) below.

Table 10: List of assigned colours to each building block and influencing condition

Influencing conditions	**Building blocks**
Knowledge and awareness of technology	Product performance and quality
Knowledge and awareness of application and market	Product price
Natural, Human and Financial resources	Production system
Competition	Complementary products and services
Macro economic and strategic aspects	Network formation and coordination
Socio-cultural aspects	Customers
Accidents and events	Innovation specific institutions

This analysis of the building blocks is elaborated below:

Product performance and quality

The product performance and quality building block relates to whether or not the technological innovation, in this case, sustainable high-tech greenhouses, have enough quality and performance if compared to its market competitors. This building block could be a barrier if this technology is unable to meet companies' requirements (Ortt & Kamp, 2022).

According to a Dutch company manager (DC3) the introduction of sustainable high-tech greenhouses within the Moroccan market 'leads to a 40% improvement in production performance if starting from a Canarian type greenhouse'. The increase of intensive horticulture and the first effects of climate change (e.g. droughts, soil erosion and water scarcity) bring agreement to the interviewee on the importance to innovate and to make better use of their resources (DC1). It is important to notice how actors from different stakeholder

groups agree on the improvements that the introduction of this higher technology would lead to the Moroccan horticultural market. For instance, DR2 has stated: 'Sustainable greenhouses have enough quality and performance to satisfy the growing needs in Morocco, and by investing in such technology companies are making an investment looking at 15 years ahead'. Another Dutch company (DC2) continued declaring: 'that the challenges to overcome for crop production in Morocco are: water use reduction, pesticide reduction and increase productivity and yield quality. To overcome these obstacles, it is key to invest in plastic/glass greenhouses with sophisticated climate control elements, irrigation and water disinfection equipment. However, a Moroccan bean grower (MG2) after the statement: 'I would rather have half a hectare with Dutch technology than 5 hectares with mine'; has mentioned that the high performance brought by this technology would not make up for the higher costs related to the higher energy requirements for the specific crop the actor is growing. Therefore, in case of implementation of such technology, the grower would have to change the crop grown. Lastly, sustainable greenhouses would help produce products of higher quality (DC2).

To conclude, it is noticeable how the product performance and quality building block **is not a barrier** to the large-scale diffusion of Sustainable High-tech greenhouse technologies in Morocco.

Table 11: product performance and quality obstacles

Obstacles	Explanation	Source
Higher maintenance costs /harvesting costs	The maintenance costs of an SG are higher than a Canarian greenhouse.	**(MG2; MC2)**
High energy requirements.	The technology to sustain its operation is highly energy intensive	**(DC3)**
Not suitable for all market applications	Due to the high running costs it might not be always profitable	**(MG2)**

Product price

The product price building block involves the financial and non-financial costs to integrate the innovation, these could be the time, switching costs, depreciation and costs to find a new product or supplier (Ortt & Kamp, 2022).

Although the technology for sustainable high-tech greenhouses has been on the worldwide market for a while now, the high infrastructural costs and the multitude of its technological components (such as sensors and climate control systems) can sharply impact the upfront costs compared to the current canary greenhouses used in Morocco. According to the interviews conducted with a wide range of stakeholder groups from both the Netherlands and Morocco, the first barrier that was always mentioned, that is preventing many companies from adopting this technology, was the high-initial investment costs. In an interview with Dutch Researcher 1, it was stated 'If a Moroccan grower would decide to implement a new technology, or even a new component, in most of the cases he would not have enough money to make a full installation'. Similar if not identical statements were given by other Dutch companies (DC1, DC2, DC3) and especially by a wide range of Moroccan actors like a Moroccan Researcher (MR2) and one Moroccan Company (MC1). Likewise, some Moroccan governmental actors (MGOV 1 & 3) highlighted the gravity of this problem. Among the reasons for the high investment costs, there is the high switching costs, therefore the time scale period in which the grower would not be able to produce because of implementing the new technology

(DC3). What is more, after the covid pandemic there has been an increase in the materials costs, and this would have an impact on the price of the technology according to multiple actors (DC3, MG1, MGOV3). In particular, the Moroccan Grower 1 has put major emphasis on this issue, as if a component breaks it has to be imported from the EU, making it more expensive not only in monetary terms but because of the production time lost too. Here, although both sides are enthusiastic about this collaboration, it is evident a difference in thought between the Dutch actors and the Moroccan actors. For instance, the Dutch companies (DC2) want to encourage the diffusion of their own produced technology in Morocco, this is because 'of a strong economic interest from their side' (MG1). However, especially the Moroccan researchers (MR1, MR2) have put major evidence on the need to develop cheaper alternatives, as stated 'to adapt the technology to our reality' (MR2), which might not have the same efficiency as the imported technology but could be a good starting point for production improvement (MR1). According to MC2, another barrier within this category is the long return on investment time of the introduction of glass or plastic greenhouses. The first one, for example, is '30% more expensive and the return on investment is seen after 5 years. Whilst for the plastic the ROI is of 3 years'. According to DC2, DR2 the plastic greenhouse would be the best solution for Morocco. However, this comes at higher maintenance costs, not only of the outside plastic layer that has to be changed every 3 years (DC2, DR2) but because sustainable greenhouses have higher running costs (MC2). It is important to mention, how according to DC2, DR2, DR1, DC, and MR1, one of the reasons why Moroccan companies/growers are not making the monetary investment is because they are still profitable in the short-run with the current technology, and if they had to choose whether to implement a new technology they would rather purchase more land as it is cheaper. However, as mentioned this cannot work in the long run, for three main reasons. Firstly, as outlined by the MGOV4 it is now prohibited for the growers/companies to increase their land area expansion. Secondly, according to MG2, there is an increase in the costs of the resources and an increase in resource use (according to MGOV1 the increase in water use is caused by the first effects of climate change). Thirdly as stated by the DG1: there has been an increase in taxation within the horticultural sector. There are still margins of income, however, if these are compared with the ones from 15 years ago there is a big difference. This is why it is important to innovate. At the same time, these mentioned increased costs and reduced profit margins make the medium / smaller size growers/companies without any monetary capabilities to invest in innovation and implement new technological innovations, such as sustainable greenhouses. In fact, as quoted by DR2 ' 1% of the entrepreneurs in Morocco has the possibility to an immediate shift to high-tech greenhouses, for the rest 99% there are no financial capabilities to do so'. The same exact statement was made by a Moroccan researcher (MR2). In this case, the solution would be to access finance, however, a Dutch actor responsible for banking investment in the North African region (DC1), has highlighted the difficulty for medium-sized companies to get such funds to adopt sustainable greenhouses. It was stated 'For a Medium sized Moroccan grower it would be required a 40% own equity and 60% of loans, to get such an investment. The issue is that these sized growers do not have such equity'. Similarly, the actor (DC1) continued 'Banks do not understand agriculture, and they hardly invest in it, because they know that the profits come from one season crop. Or African banks do not have experience with these types of investments so they do not know how to finance them and how to monitor them. So in sum, growers on a side are not able to show or to demonstrate the banking industry their historical figures and the banking system is not able to translate them towards financing opportunities (DC1).

According to the Dutch technological providers sustainable high-tech greenhouses would be a valuable investment for different types of market applications. However, according to MGR2 and MR1, the high investment needed to invest within these technologies would be justified not for all market applications, for instance, it would not be worth making such an investment to grow beans as the company would not be competitive in the market anymore (MGR1). Nevertheless, if a Moroccan company decides to invest in this type of technology, it is to export the product abroad and not remain on the local market. Another price barrier is related not to

the adoption of sustainable greenhouses but reflects the end price of the final horticultural product produced. According to MC2, this is because 'due to the switch of technology there is going to be an increase of the costs of production, in maintenance and harvesting costs, therefore, the costs of the crops are going to be higher'. But this price increase is caused by an increase in product quality as well (DR2).

To conclude, it is evidently clear that the product price building block **is a barrier** to the large-scale diffusion of Sustainable high-tech greenhouses in Morocco. The high-initial investment needed to implement such technology would be a hustle for any grower. In fact, as MC2 said 'Even a medium-big grower with 6 hectares Canarian greenhouses would be able to convert only 2% to sustainable greenhouse technology'. Finally, there have been mentioned two solutions from researchers from both the Dutch and Moroccan side, one is the inclusion of cheaper technologies and the other to implement the change gradually (DR2).

Table 12: Product price building block barriers

Barrier	Explanation	Source
Product price is higher because the technology is imported	The importation costs have an impact on the final price	**(DC2; MGOV3)**
Rising price of materials	After covid the price of the materials have risen	**(DC3; MG1; MGOV3)**
High-initial investment costs	The investment costs required to build a SG are very big	**(DC1; DC2; DC3; DR2; MR2; MGOV1; MGOV3; MC2)** (Long et al., 2016; moons et al., 2015)(**Kalpakian et al., 2014)**
Long term Return On Investment (ROI)	The return of investment is of minimum 3 years	**(DC2)** (Long et al., 2016; van der Veen, 2015)
Hard access to finance to cover the switch in technology	There is a lack of government fundings	**(DC1)**
Higher maintenance costs /harvesting costs	The maintenance costs of an SG are higher than a Canarian greenhouse.	**(MC2; MC3)**
The cost of the final product is going to be higher	Increase in expense and increase in quality	**(DR2; MC2)** (Long et al., 2016)
Higher taxation for horticulture	Could be a barrier or an incentive to diffusion	**(DG1)**

Production system

The production system building block refers to the challenges related to the production processes and practices that can allow the delivery of high-quality products in large quantities. The lack of such a system can be an obstacle to the diffusion, in this case of sustainable greenhouse technology (Ortt & Kamp, 2022).

As a result of the conducted interviews none of the technologies related to sustainable high-tech greenhouses is produced in Morocco. Therefore, most of these technological elements have to be imported from Europe (DC1, DC2, DR2). According to DR2 in most cases, apart from shipment costs, at the beginning of the technological diffusion should not be a problem to import the components from abroad but 'at some point, Morocco would have to develop its own value chain cluster'. This is important because when a component breaks the company could speak with its partner nearby, which is supplied by an international supplier that has ventured out its technology (DR2). The expectation, in line with DC1, is that when the sustainable greenhouse industry starts developing within the country, areas where the production and supply of components are developed so that growers could buy their components locally. The same interviewed actor, DC1, mentioned the case of Etiopia, where once the diffusion of a similar technology started a service delivery model with storage and warehouses was developed. This element is extremely important, according to DC3, especially when a component breaks rather than when it's installed in the first place. Because the timeframe of action is limited as the problems should be fixed as quickly as possible or it could result in production loss. In fact, it was stated: 'Sometimes when a component breaks within my greenhouse I must have a technician come to substitute within 30 minutes'. Yet DC3, a technology supplier, had an opposing opinion to this. This actor firmly believes that once the technology diffusion starts, Morocco would be able to produce steel construction materials, aluminium parts for glazing, glass and some other components. However, for the more sophisticated components like software, drive mechanisms, pumps, and drip irrigation they will still have to be imported from the Netherlands. As it is stated: 'As long as there will be only a few greenhouses 80% of the value of the greenhouse investment has to be imported. When the market for high-tech greenhouses will grow, the share of imports can decrease to 30%'. On the Moroccan side, stakeholders are not that happy to be technology dependant from other countries, as a matter of fact, DR2 said that 'it is not it is not possible to continue importing the technology from EU as it would cost a lot not only on the import itself but for its maintenance too'. Suggesting the development of Moroccan technology since the beginning of the diffusion. Whilst, a Moroccan grower (MG1) suggests a more moderate approach, to first import the technology from Europe to support the initial diffusion as 'currently there are no companies that produce such components in Morocco' to then develop 'new companies in Morocco so that the import of the technology from EU will be reduced'. In any case, both Moroccan growers (MG1 & 2) were fully aware of the economic interests of the Dutch technology providers, it was mentioned by DG2 'It is very easy to have a connection with Dutch companies as they show me everything and it is easy to communicate with them. Even if sometimes they try to sell me things, but I will only buy what I really need, so I do not fall for their tricks'. A confirmatory statement regarding this comes from a Dutch researcher too (DR2): 'Although many Dutch companies would not like that as it would not be profitable for them, at some point Morocco would have to develop its own national value chain cluster'.

To conclude the production system building block **is a partial barrier** to the technological diffusion of sustainable high-tech greenhouses in Morocco. Even if the diffusion of such technology has already started within the nation in some of the incubators in Morocco there are not yet companies that care about the development of technological components for these greenhouse technologies (MG3). Even if the encouragement of young-entrepreneurial activities was considered as one of the main goals of a governmental actor (MG4), where in the conducted interview stated 'it is necessary to try to encourage young people to start new companies within the horticultural sector'.

Table 13: Production system building block barriers

Barrier	Explanation	Source
EU centralized supply chain	Most of the components	**(DC2; DC1; DR2; MR2;**

	come from abroad	**MG1; MC2)**
Lack of a service delivery model /national value chain cluster	There is a lack of a production system within the country	**(DC1; DC3; DR2)**

Complementary products and system

This building block regards the complementary products and system to sustainable high-tech greenhouses. These elements support the development, diffusion, adoption, use, repair, maintenance and disposal of the technology. This building block is a barrier when these aspects are missing or too expensive (Ortt & Kamp, 2022).

The main barrier that has been highlighted by a wide range of actors for the diffusion of the technology that fits within this building block category is the lack of infrastructure to deliver water and energy to sustainable high-tech greenhouses.

Firstly, the water infrastructure is analysed. Regarding the development of this infrastructure, there have been some small misalignments between the declared statements from the actors of the two nations. From the Dutch side (DC1, DC3, DG1) it was defined as a major (if not complete) lack of the water infrastructure in Morocco to sustain the diffusion of sustainable greenhouses. Nevertheless, from the Moroccan side, the information did not match the Dutch one. Starting from Moroccan Researcher 1, who has mentioned that the water infrastructure in the Souss-Massa region is highly enough developed to sustain the diffusion of sustainable high-tech greenhouses. However, only in the rural areas outside the Souss-Massa region, the infrastructure is not as highly developed. It is important to notice how the Moroccan Governmental actor 1, repeated a similar statement of the MR1. Furthermore, the MGOV1 went on to add that ‘the government is working in the development of dams and water infrastructure across the whole nation’. However, currently, still according to the MGOV1, 30% of the farmers in the region have no access to the water infrastructure. In this case, to solve the problem, no direct action is taken by the government but by some farmer's associations, as declared by MGOV1: ‘where the water infrastructure is lacking, there are some farmers associations, which are subsidized by the agricultural department to build a common water network to ensure water delivery to the farmers’. To conclude, a further statement from a Moroccan company (MC1) that highlights the lack of water infrastructure was given: ‘Currently, there is a good water infrastructure in the area of Souss-Massa, but it lacks in many other areas, in fact in some cases the private sector takes action more than the government to build these infrastructures’. This statement highlights another misalignment between the declaration of what the government says (MGOV1) and what is the day-to-day reality.

Figure 11: Amir Zoubi (2023), Water collection system in Morocco, Photograph. Self-published

Figure 12: Amir Zoubi (2023), Electric grid in Morocco Photograph. Self-published

Moving toward the analysis of the barrier for the energy infrastructure, the diffusion of sustainable high-tech greenhouses would require a sharply greater amount of energy to ensure the correct running of the operations. According to a Dutch company manager (DC3) in the case of Morocco, companies would not use a great amount of energy for lightning, but the electricity requirement would be high for humidification and/or ventilation technologies. This raises another issue, the lack of national natural resources. In fact, for instance, the current gas pipeline system, especially during winter times, has to stand the energy demand when gas is going to be needed for night heating (DC3, DG1).

Regarding the after-life facilities and services, Moroccan Grower 2 has stated: 'The plastic coverage of the greenhouses was used for 5 years and then he did not know what it was done with it once changed'. The other Moroccan grower (MG1) declared that sometimes the old plastic coverage was used as land coverage to not make grow any undesired herbs inside the greenhouses. None of them has mentioned the existence of after-life facilities.

On the positive side, all of the different actors (MR1, DG1, DC1), despite the country have agreed on the excellence and high level of development of the Moroccan road network. In particular, DG1 has stated 'the road infrastructure in Morocco is even better developed than some European countries'.

Beside this, a strong system of collaboration among the Moroccan companies and universities is established supporting the development and formation of working actors in the adoption and maintenance of high-tech greenhouses (MR1, MG2).

To conclude the complementary products and system building block it **is a barrier** to the diffusion of Sustainable high-tech greenhouse technology in Morocco. However, the horticultural production in Morocco is located in some selected areas (the Souss-Massa region and Rabat areas) which are overall enough-served by the mentioned services to not limit the start of the diffusion of the technology.

Table 14: Complementary products and services building block barriers

Barrier	Explanation	Source
The energy network/water network	The lack of infrastructures may hamper technological diffusion	**(DC1; DC3; DG1; MR1; MC1; MGOV1)** (Long et al., 2016; Giuliano Vox 2010; Van der Veen, 2015)
Increasing water pressure		**(DC3; MR1)**
Lack of natural energy resources	There is a heavy reliance on imported fossil fuels	**(DC3; DG1)**
Lack of people that know	There is not a network	**(DC3)**

how to repair the technology	established among the people that know how to repair SG	(Moons et al., 2015)
Energy efficiency for climatization technology		**(DC3)**
Lack of after-life facilities		**(MG2)** (Giuliano Vox, 2010)

Network formation and coordination

An efficient and highly coordinated network of actors for the distribution of supply, assembling of components, producing and distributing is crucial to novel technology diffusion. A lack of coordination among the actors may hamper the technology's large-scale diffusion (Ortt & Kamp, 2022).

To enhance the diffusion of the sustainable high-tech greenhouse on the national level it is necessary the formation of a network among three actors: the universities, the companies (growers/technology providers) and the government (Wu et al., 2013).

Firstly, it is going to be critically evaluated the barrier that is preventing the existence of a collaborative environment among the different horticultural companies. During the interview with a Dutch Company Manager (DC3), it was stated that the collaborative environment in Morocco is different from the one in the Netherlands. In Morocco 'most of the growers are internally focused so they do what they do and sharing knowledge is not that common' , whilst in the Netherlands all growers from any company have access to all types of data (DC3). Therefore, the manager believes that there is a 'mistrust' between the growers in Morocco'. Similarly, a Dutch Grower, commented that in Morocco there is competition for the product's retail price (DG1). However, for the Moroccan actors, the competition is not as big as it's described by the Europeans. In fact, a Moroccan Company Manager declared: 'Currently for the smaller-medium growers there is no competition and there is a lot and continuous knowledge share. But for the greater corporations, the confidentiality comes in, therefore there is not much knowledge share among them' (MC2). This was confirmed as well by two Moroccan Growers saying that at least once a month they were meeting with other growers to discuss how to improve their horticultural practices (MG1 & 2). Thus, it is possible to state that there is a strong network established among the small-medium sized growers, but not as strong collaboration among the big exporting companies. Nevertheless, the Dutch Company Manager 3 emphasized how big producers need to cooperate to have more exporting power: 'With time a big Association has to be developed, that has direct contact with retailers in Europe and that can export directly their high-quality product to Europe and make a decent amount of profit on that' (DC3). This is because now 'there is no Moroccan grower association for the EU, and this is a barrier for technological diffusion' (DC3). Another important element is the lack of collaboration between the smaller growers and the bigger ones. These last ones, because of their greater capital, hold the workers with assembling and production knowledge making it harder for smaller companies to find actors providing certain services (MR2).

Secondly, the collaboration between companies and universities is assessed. Regarding all the Moroccan stakeholders there is a great collaboration, aimed at offering training courses for workers (MR1). In fact, with a continuous system change some companies encourage their workers to follow some managerial or even technical courses within some associated institutions. 'There has been established a collaboration among the companies and the university to ensure training and consultancy' this was stated by an actor studying within the IAV Hassan II universities and an actor covering a high-level position within a greenhouse

company (MC1). Similarly, it is done by a company manager that has emphasised the importance of formation, and how the company has encouraged him to follow some formation courses to improve farm managing skills (MC2).

Thirdly, it is examined the collaboration between the companies and the government. The lack of a goal alignment between the Moroccan companies and the Moroccan government is one of the greatest barriers within this building block. A Moroccan grower, when talking regarding the export of products from Morocco to the EU, has mentioned as the greatest challenge the lack of clear agreements that 'change when with a change of government' (MG1). This forms a barrier within the coordination of a communicative network among Moroccan companies, preventing them from being united and exporting under one unique association. The grower has continued by stating: 'Currently a common objective is lacking, even because many times the growers objective (APEFEL) and the government objective do not match' (MG1). When some governmental actors were interviewed the misalignment of goals and challenges to the diffusion of the technologies were clear. For instance, at the questions of the main barriers that were preventing the companies to adopt sustainable greenhouse technologies, two governmental actors (MGOV1, MGOV3) presented the costs as a barrier, but according to one actor (MGOV4), there was no barrier related to the costs. It is important to remind the reader, that the cost barrier was the one most mentioned among the Moroccan / Dutch growers, companies and researchers. Moreover, it was stated by MGOV4 'That once a technology is subsidized, no more action from the government is taken and the adoption of this technology is left to the market'. A similar statement was made by MGOV1. However, during the conducted interview, one Moroccan grower was not asking only for technology subsidization but for a governmental acknowledgement 'that from 2015 to 2022 the costs of production have doubled' (MG1).

Fourth, it is surveyed the collaboration between the government and the universities.
Multiple times by the governmental actors it was brought up the importance of the co-operation with the universities. Especially when talking about start-up development, MGOV4 said: 'It is of great importance the collaboration among this organ and the universities in bringing new ideas and encourage young people to start new companies within the horticultural sector'. Another example is the one of MGVO1, which is working closely with IAV Hassan II University to help form young people. This is done with investments and the building of incubators. However, during an interview with the director of an agricultural incubator in Agadir, it was declared that there were no start-ups for horticultural technology suppliers or new component producers but only within the software part (MGOV3). Nevertheless, the author had the chance to speak with some students from the University of IAV Hassan II and all of them seemed enthusiastic about the network and collaborations of their university with the local government.

Fifth, the network formation and coordination between the Moroccan and the Dutch actors is analysed. A strong network to ensure the smooth diffusion of sustainable greenhouse technology in Morocco is very important, especially during the early stages of technological diffusion. This is because, as previously mentioned, most of the technological components (and technical knowledge) are imported from the EU (DC1 & 2; MR2; MC2, MG2). One Moroccan governmental actor regarding the collaboration has mentioned 'the cooperation is welcome, but it is needed co-ordination to bring the international actors together toward the same objective'. The importance of this collaboration was highlighted as well by the growers: 'Dutch companies are surely playing an important role in the encouragement of the diffusion of the technologies and that most farmers and companies are open to gain knowledge and expertise regarding the thing they do not know'. Consequently, it is noticeable how a good and strong network has been already established between Dutch and Moroccan companies and institutions.

To sum up, the network formation and coordination building block **is partially a barrier** to the diffusion of Sustainable high-tech greenhouse technology in Morocco.

Table 15: Network formation and coordination building block barriers

Barrier	Explanation	Source
Lack of collaboration among the different companies		**(DC3; DG1; DC2)** (Wu et al., 2013) (Van der veen, 2015)
Workers sent from the NL	The lack of workforce in Morocco, implies the 'import' of knowledgeable workforce from the EU	**(DC3)**
Lack of alignment among the companies and the government	There is a need of goal-oriented subsidies	**(MG1; MGOV4)** (Wu et al., 2013)
Lack of network formation to enter the EU market	There is no Moroccan grower association	**(DC3)**
Lack of skilled /unskilled workforce	There is a lack of people that know how to repair the technology	**(MR1&2; MC2)** (Moons et al., 2015)
Lack of young entrepreneurial start-ups	There is a low number of start-ups that aims at producing components	**(MGOV3)**

Customers

For the diffusion of breakthrough technology, customers with the need for the innovation, that are aware of it, aware of its benefits and with the willingness to acquire it have to be identified. The lack of a customer segment will hinder the diffusion of technological innovation (Ortt & Kamp, 2022).

In the case of sustainable high-tech greenhouse technology, the potential costumers for Morocco are growers and companies that want to export their produced products to the international market (DR2, DC3). However, according to the interviews, not many growers see the long-term advantages of adopting such technology. The CEO of a Dutch technology provider organisation has mentioned as the first barrier to the diffusion of sustainable greenhouses is the lack of a long-term perspective from the growers (DC2). This statement was made based on the provider experience and how the actor noticed that ' for the Moroccan growers Canarian greenhouses are still profitable for the short run, and a change in technology would mean for them a ROI of 3 years'. Even another Dutch company manager has confirmed this by stating: 'Most of the time Moroccan growers see sustainable greenhouses just as a too high starting investment cost' (DC3). The same issue was raised by a Dutch researcher that said that many growers do not feel the need to change as they do not feel the rising water pressure, therefore they do not care about the future as they want to 'eat now' (DR2). However, another Dutch researcher has highlighted the fact that this lack of long-term perspective is majorly present for smaller growers, that want to keep on serving the local market. Whereas the bigger growers that want to export the products abroad are more open to technological change. Regarding this, the Dutch company manager 3 explained: 'With the introduction of Sustainable Greenhouses there's going to be a sort of a shift where some growers decide to go into high-tech greenhouses and some growers decide to remain in their current way of growing, those last ones will provide for local markets'. Thus, the potential customers within

the early-stage diffusion of the technology are growers that want to enter the European market. In favour of this statement, is Moroccan Company 1 that suggested: 'big growers are keen to adopt sustainable greenhouses, but regarding the smaller growers there is a price barrier as the technologies are quite expensive to implement'. It was already mentioned the monetary barrier for some growers in the analysis of the other building block, but here it is important to highlight how this barrier prevents the spread of the technology. In fact, a small-medium-sized grower during an interview replied jokingly: 'I would rather have half a hectare with Dutch technology than 5 hectares with mine (Canarian type greenhouse)' (MG2). Meaning that the want to innovate is present within smaller companies too.

Another barrier found within this building block is the hesitancy toward new technology. The Dutch researcher 2 believes that there is a lot of skepticism among the Moroccans regarding the adoption of such technology. Similarly goes for Moroccan researcher 1, who was in touch with many different Moroccan growers, and he has noticed how the wrong use of the technology increases the scepticism of certain growers toward the adoption of new technologies. This is one of the reasons for the building of the demonstrative greenhouses to show the growers how to use the technology and to reduce their skepticism. It is important to highlight, for the reader, how many times every single actor interviewed throughout the carry of the study has mentioned **the importance of showing.** One Moroccan grower (MG1) has underlined how the growers are not skeptical but 'hesitant regarding the adoption of new technology, that is why the CTT (Centre for technological transfer) was built, to show the growers the greenhouses, we bring them here and we show them the technology, the yield and we convince them to adopt this technology'. This actor declared that the growers trust this centre because it is a centre owned by the growers, as stated: 'We give to the growers the real answer to their questions. If the technology does not work, we will tell them that it does not work, we have no reason to lie to them because this centre is owned and funded by farmers'. Regarding the grower's hesitancy toward the technology acceptance, the director of an incubator (MGOV3) has explained how throughout his career when any technological innovation had to be diffused people were skeptical. This actor made the example of the diffusion of drip irrigation in Morocco, where the centre has worked in the development of training sessions through showing, and that now this technology is widely diffused. Very similar statements were made by other governmental actors, for instance, MGOV4 declared: 'Some of the growers might not believe in the benefits of sustainable greenhouses, but this is not because they are not open. But because if it is shown to them that such technology can bring certain positive impacts in their yield they will surely invest money in there'. Thus, there is a lot of skepticality from Moroccan companies regarding the adoption of the technology. However, this skepticism is dictated solely by a lack of knowledge about the technology, a barrier that could be overcome by showing.

The lack of a market for horticultural products is another barrier that prevents customers from adopting this technological innovation. As mentioned, many growers want to switch toward sustainable high-tech greenhouses because they want to penetrate the international market, as exporters. This is because, if you are getting a ROI of 3-5 years on the investment, is because you want to produce higher quality products, that confirm the international safety standards and regulations, which can be sold in the European market (DC2 & 3; DR2). Yet here another barrier comes in, according to DC3, which is the limitation in the number of products a Moroccan grower could sell to the EU market. The Dutch actor spoke once with a grower that has said: "I can produce more but I cannot sell it in the European market, so why shall I make such an investment" (MG1). This retail barrier might make things more unclear for Moroccan growers making them reluctant to invest in new technologies. The tomato and cucumber quota was mentioned by all the Moroccan companies and how you had to pay a gut if you exceeded it (MC1 & 2). This quota is the main concern of any grower, 'I am scared that there is a lack of market, that although I produce a lot of products because of the quota I am unable to export them' (MG1). For this reason, the same grower mentioned that the best solution would be to increase local consumption. Lack of final product market

It is worth mentioning that for some market applications like bean production, it is not worth the adoption of a sustainable greenhouse, otherwise the grower would not be competitive in the market (MG2). Whilst for some market applications (e.g. soft fruits and herbs), it would be suggested for a Moroccan grower to build some costumes relations before the adoption of the technology and to develop a strong scale and distribution channel (DC1). In any case, this relates as well to the production of tomatoes, 'as it is necessary to be sure that there is a market established for this product, otherwise, growers/companies would make an investment ending up selling the same quantity of products' (MC1).

To conclude, the customer building block is incomplete therefore **it is a barrier** to the large-scale diffusion of Sustainable high-tech greenhouses in Morocco.

Table 16: Customers building block barriers

Barrier	Explanation	Source
Lack of long-term perspective from the growers		**(DC2; DR2; DR1; DC3)**
Skeptical regarding the technology	The growers are hesitant toward new technologies	**(DR2; MR1; MG1; MGOV3; MGOV4; MC2)** (Long et al., 2016)
Supply chain to final costumers	There is a lack of market for some horticultural products	**(DR1; DC3)** (Moons et al., 2015)
Lack of final product market	For some products a quota by the importing countries is established	**(DG1; DC3; DC1; MG1; MC1; MC2)** (Moons et al., 2015)

Innovation specific institutions

These institutions are fundamental for large-scale diffusion. There must be governmental standards, policies, laws and regulations that support the diffusion of the technology. If there is a lack of these large-scale diffusion is impossible (Ortt & Kamp, 2022).

Before it was highlighted the barrier formed for the lack of a collaborative network among the government and the growers. Within this building block analysis are presented the other institutional barriers that are limiting the diffusion of sustainable high-tech greenhouses in Morocco. The first barrier mentioned was the lack of long-term vision from the government, indeed MG1 highlighted that the laws and regulations should be constant with time and they 'should not change with a change in government'. This is because currently 'the Moroccan government possess enough funds to support the diffusion of sustainable greenhouses' but it is lacking a clear direction, which many times is not shared by both the government and the growers (APEFEL) (MG1). What is more, the statement made by MG4 'once a technology is subsidized, no more action from the government is taken and the adoption of this technology is left to the market' implies the lack of communication among these two actors. Even if according to another governmental office 'the lack of water is bringing people together, in fact, there is a growing debate with actors from different groups like APEFEL and the agricultural department' (MGOV1).

Another barrier within this building block is the lack of real and strong economic support from the government to the companies to encourage the adoption of the technology. In line with the information gathered by the interview with MGOV1 & 4, it is up to the national committee the

final decision on which technological components have to be subsidized, and it is up to the Agricultural Department the funding management. However, currently the allocated funds, according to a Moroccan medium size grower (MG2) 'are not enough to change technologies. The current findings are related to water irrigation and the building of the greenhouse, this last one is 1.000 euros'. It is clear how these fundings are not going to help the small-medium size growers to adopt sustainable greenhouses. Regarding the funding for a more sustainable irrigation method, Moroccan governmental actor 1 mentioned that they are trying to push this technology through subsidization. However, it was only found later in an interview conducted with a company (MC1) that the subsidy for irrigation technology covers only 30% of the total final costs of adoption. A further issue within the technology subsidization is the lack of knowledge from smaller-medium sized growers 'on how to get an investment or apply for funding' (MR1). Even MG2 has mentioned how the actor personally knew some farmers that 'did not know how to go through the bureaucratic process to ask for these fundings'. The grower continued stating that luckily many governmental offices have been established to help the growers to fill up the papers to ask for funding (MG2, MC2). This last statement was confirmed by the Moroccan incubator (MGOV3). Of which director raised another issue, which is the slowness of the bureaucratic process (MGOV3 & 4). The clearest example of the lack of financial support was brought up by MC2 who has stated 'in some cases the private sector takes action more than the government to build infrastructure'. This could be confirmed as well by the governmental institution (MGOV1), where it was mentioned that growers sometimes do not get the money directly but firstly 'they have to make the investment themselves to then get it refunded'. On the other hand, the MGOV4 mentioned the importance of trying to encourage the young generation to start new companies in the horticultural sector, this should be done by improving 'an easier bureaucratic procedure to allow and facilitate farmers to start their companies because right now is hard for them to get help from banks' (MGOV4).

An example of regulations that might limit the diffusion of more sustainable water technologies in Morocco, is the lack of enforcement to respect the water resources. It was outlined by Moroccan researcher 1 how there is a 'massive decrease in the groundwater level by 2 meters per year, and how the price of water has gone up to make it stop'. Regarding this regulation, there is a strong misalignment between the statements of companies and growers, if compared to the statement of governmental actors. These last ones emphasize how the building of many desalination plants, was aimed at the reduction of the underground water pressure. However, the desalinated water price is 5 dirhams (50 cents) per meter cube, while the cost of the underground water is 3.2 dirhams (32 cents) per meter cube (MGOV1 & 4). More specifically the taxation from the government for the 1-meter cube of groundwater is 0.2 dirhams (0.02 euros) and the growers pay 3 dirhams of energy to pump it (MGOV4). Therefore, the introduction within the water balance of desalinated water does not encourage Moroccan companies and growers to use it. This is because the water coming from the ground level is cheaper therefore to maximise their profit margin companies prefer to use this one (MG2, MC2). To conclude, this regulation is preventing the growers to introduce sustainable greenhouse technologies to try to reduce water use and maximise profits.

To conclude the Innovation specific institution **is a barrier** to large-scale diffusion for sustainable high-tech greenhouse technologies in Morocco.

Table 17: Innovation specific institutions building block barriers

Barrier	Explanation	Source
Lack of governmental vision on the long term	The general governmental vision keeps on changing, there is no clear objective	**(DR1; MR1)** (Long et al. 2016)

Lack of enforcement to respect the water resources	The laws are not strict	**(DC2; MC1)**
Increase in taxation		**(DG1; MG1)**
lack of collaboration with the EU for the reduction of export barriers	The quota is not going to be increased	**(DC3)**
Lack of clear indications to farmers on how to get the loan	There is a lack of direction on how to apply for the funding	**(MR1; MG2) (Kalpakian et al., 2014, p. 73)**
Slow bureaucracy	The time required to get the fundings is too long	**(MG2; MG3; MG4)**
lack of a real and strong economical support to encourage the switch	Lack of strong and effective subsidization to transition to this technology	**(MG1; MG2; MGOV 1&4)**(Van der veen, 2015)
Lack of representation for smaller growers	The smaller growers are left to themselves	**(MGOV3)**
Lack of collaboration among the growers and the government	Some of the goals and objectives are not shared by both actors	**(MG1; MGOV4)** (Wu et al. 2013; Long et al., 2016)
Low investment in innovation	Technological development is not highly financed	**(MGOV3)**

The Sustainable Greenhouse market applications and building block status in Morocco

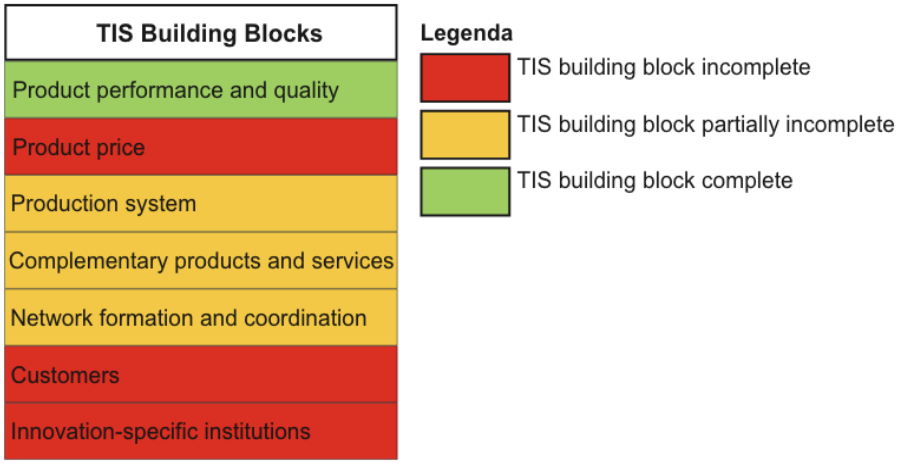
Throughout the interview process, most of the interviewees mentioned that there were three market applications suitable for Sustainable Greenhouses in Morocco. Thus, within this paragraph, a one-by-one analysis of the barriers with a subsequent overview of the building block status per each different type of Sustainable high-tech Greenhouse technology is done.

Market application 1: The first market application is Sustainable Greenhouse for vegetable production, more particularly for tomato production. This market application finds its greatest employment in the Souss-Massa region, where tomatoes are mainly produced for export.

Table 18: Analysis of the building blocks for market application 1

Product Performance & Quality
This building block is complete because the increased costs of running the greenhouse would be justified by a major increase in the final yield. This technology finds the highest level of performance within this market application.
Product Price
Currently most of the farmers do not have the financial capabilities to support the high initial investment costs and long-period ROI. These are caused by the high importing costs and the increasing price of the materials. Additionally, the lack of subsidies make the financial collection harder. However, for this type of SG the costs are more justifies by the increase in yield and of better quality, allowing the company an easier penetration in the international market.

Production System
The technology components are fully imported from the EU, however, due to its geographical proximity and the strong cluster developed among the nations. It should not be a major limiting factor if with time a national Moroccan value chain cluster is developed. Especially for this type of SG it is easier to have the components as it is the most widespread type of market application. What is more, Morocco detains the most favourable conditions for the growth of tomatoes, making it cheaper the purchase of some components. For instance, for this technology it could be used a plastic coverage rather than a glass coverage.
Complementary products and services
This market application is strongly prevalent in the Souss-Massa region, where the water and energy infrastructure is present. According to the Moroccan governmental actors only 30% of the farmers are not directly linked to the infrastructure in this area (MGOV1). Beside this, the lack of national energy resources might be a minor general barrier. For this type of SG there is a very low lack of unskilled labour force, but a fairly high lack of skilled operators (1 person every 20 hectares, MC3). Making this a minor barrier for technology diffusion, as there are enough services and infrastructures to support the initial diffusion of this type of Sustainable greenhouses.
Network Formation & Coordination
Especially for this technology there is a strong competition among the big exporting companies. This is because each company wants to penetrate the market by its own, trying to sell the more products at the cheapest price. Thus, the lack of collaboration within SG for tomato production companies and the government may strongly hamper the diffusion of the technology. On the other side, the strong collaboration with the universities for both the Moroccan companies/growers and the Moroccan government plays an important role in the knowledge and awareness spreading of the technology. Additionally, another important role in the establishment of strong collaboration is done by the EU, which is interested in shifting the production to Morocco (analysed later in the Macro-economic condition).
Customers
This building block is incomplete because of three reasons: Firstly, as a Moroccan company manager mentioned: “People are enemies of what they do not know” (MC2), the only way to overcome the initial skepticality toward this technology is to ‘show, show and show’ the benefits of it. Secondly, the presence of a quota for the export of tomatoes and the constantly increasing regulations for safety and standard make it a ‘tight’ final product market. Leaving the early technology adopters unsure of whether they might have their tomatoes left unsold. Thirdly, there was a lack of communications with medium sized growers and the government for the development of SG adoption subsidies.
Innovation-specific institutions
The laws imposed by the government, such as no further land expansion, can surely encourage diffusion. However, the misrepresentation of smaller growers, the slowness of bureaucracy and the lack of clear indications may prevent the adoption of such technology on a national scale. After the conduction of interviews with medium growers and big companies, it was clear that smaller actors that wanted to transition with this technology were not collaborating with the government for the development of goal-oriented subsidies. Leaving the technology adoption to big exporting companies that possess the financial capabilities and major influential power in the development of the regulations.

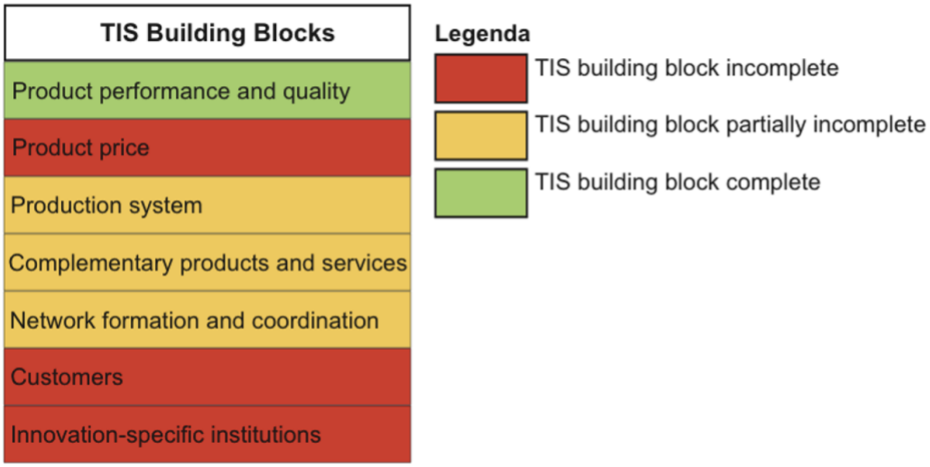


Market application 2: The second market application is a Sustainable Greenhouse for soft fruit production, more particularly for blueberries and raspberries. This market application finds its greatest employment in the Rabat region.

Table 19: Analysis of the building blocks for market application 2

Product Performance & Quality
This building block is complete because: 'The change to this type of technology is of leads to a 40% improvement if they start from the Canarian type of greenhouses' (DC3). SG would increase the yield and the quality of the produced products. The technology possess enough quality in performance and operations for this type of Sustainable Greenhouse.
Product Price
This building block is incomplete because, although the high-initial investment costs for this market application could find justification because of the higher-value crops that are produced. Most of the growers and companies do not possess the financial capabilities for its adoption. What is more, for this type of Sustainable greenhouse the unskilled workforce is paid the most. This is because of the extra fatigue required for the harvesting operations.
Production System
This building block is partially incomplete, as the technology components are fully imported from the EU, however, due to its geographical proximity and the strong cluster developed among the nations it should not be a major limiting factor if with time a national Moroccan value chain cluster is developed. However, it is important to note that the developed cluster is not built primarily for this type of SG technology, however the companies might dispose of these technological components too.
Complementary products and services
This building block is partially incomplete because this market application is strongly diffused in the Souss-Massa region and in the Rabat area. In the first one there has been a strong investment in the water and energy infrastructure, the second area is not as well served. However, the lack of national energy resources might be a minor barrier to technology diffusion. Another limiting factor specific for this type of Sustainable greenhouses is the lack of unskilled workforce, which because of the harsher working conditions prefer other jobs. As for the other types of Sustainable greenhouses there is a lack of skilled workforce.
Network Formation & Coordination

This building block is partially incomplete because there is not as strong commitment from the Moroccan government to spread this technology for soft fruit production. Similarly, the collaboration with the EU, on one side is aimed at wide-spreading Sustainable greenhouses for tomato production, on the other to increase their profits by selling more technologies. However, this market application may benefit from both strong collaboration with the universities, which play an important role in the knowledge and awareness spreading of the technology. In any case, these type of Sustainable greenhouse companies could take advantage from the already established network for the other technology. What is more, the competition among soft-fruit producers was not mentioned as a barrier by the interviewers.
Customers
This building block is incomplete firstly because of the lack of a final product market: 'I think the production of soft fruits could be possible, but I feel like the market is almost saturated' (DC1). Therefore, before switching to this technology major emphasis should be put on the building of costumers relations to ensure the development of a strong sales and distribution channel. Another barrier to overcome is the hesitancy of the growers, which because of the lack of knowledge of the benefits and running operation are skeptical toward the adoption.
Innovation-specific institutions
This building block is incomplete as the laws imposed by the government, such as no further land expansion, can surely encourage diffusion. However, the misrepresentation of smaller growers, the slowness of bureaucracy and the lack of clear indications may prevent the adoption of such technology on a national scale. Leaving the technology adoption to big exporting companies that possess the financial capabilities and major influential power in the development of the regulations.

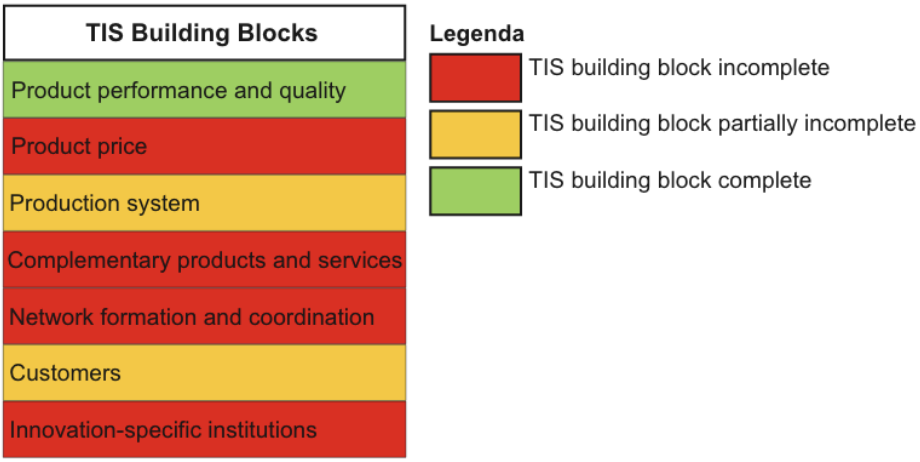


Market application 3: The third market application is Sustainable Greenhouse for herbs production. This market application would be supplying both the national and international markets.

Table 20: Analysis of the building blocks for market application 3

Product Performance & Quality
This building block is complete because this type of greenhouse will help the companies to produce more better-quality products that fit within the requirements of international export.
Product Price

This building block is incomplete as the price barrier to technological switch for these types of Sustainable greenhouses is the greatest. This is because the current horticultural practices allow the growers to produce a relatively good yield of herbs. What is more, although herbs can be considered a relatively high-medium value crop the high-initial investment cots might not justify the technological switch for this market application.
Production System
This building block is partially incomplete because the technology components are fully imported from the EU, however, due to its geographical proximity and the strong cluster developed among the nations. It should not be a major limiting factor if with time a national Moroccan value chain cluster is developed. However, it is important to note, that for this market application, the interior of the greenhouse would be strongly different.
Complementary products and services
This building block is incomplete because this type of market application is strongly diffused in the Atlas area. In this one, because in more rural, not as big investments are made for the building of a water and energy infrastructure, this might be a major barrier to the implementation of this technology. Similarly to the other type of SG there is a lack of skilled labour force, even if it is easier to this market application to find unskilled labour force.
Network Formation & Coordination
This building block is incomplete because there is not as big interest from the government in the establishment of a strong network within this company category. What is more, the product is mostly produced for local use by medium scale growers. The few times the product is produced for export, is by big exporting companies which have as a main source of income tomato production. However, this market application may benefit from strong collaboration with the universities, which play an important role in the knowledge and awareness spreading of the technology.
Customers
This building block is partially incomplete as for all types of Sustainable greenhouse technologies there is to overcome the skepticality barrier of the growers. However, for this specific case, there is no lack of a final product market, in fact a strong national and international market is already established.
Innovation-specific institutions
This building block is incomplete because the laws imposed by the government, such as no further land expansion, can surely encourage diffusion. However, the misrepresentation of smaller growers, the slowness of bureaucracy and the lack of clear indications may prevent the adoption of such technology on a national scale. Leaving the technology adoption to big exporting companies that possess the financial capabilities and major influential power in the development of the regulations.



5.3 The influencing conditions analysis

Knowledge and awareness of the technology

This influencing condition regards the knowledge of the customers of the product, the production system and complementary products. In addition to the awareness required to produce, repair, use and maintain the technology. A lack of knowledge and awareness of the technology will hamper TIS formation (Ortt & Kamp, 2022).

‘الناس أعداء ما جهلوا‘ (People are enemies of what they are ignorant of). This is a famous Arabic idiom that was cited by MC2 during an interview, to demonstrate how the lack of knowledge generates hesitancy and reluctance toward the adoption of new technologies.

Due to the large amount of information gathered for this influencing condition, the analysis is divided per topic into five paragraphs to facilitate the reader.

This first paragraph evaluates the level of knowledge share, firstly between the Netherlands and Morocco then the cluster developed between Moroccan universities and Moroccan companies. Some of the Dutch stakeholders have highlighted how Moroccans do not have enough knowledge on how to operate sustainable greenhouse technology (DR1, DR2). Therefore, according to a Dutch researcher (DR2): ‘we cannot just build the greenhouses for the Moroccans as they would not know how to use them in the best possible way’. This statement found truth in the words of Moroccan researchers too (MR1, MR2): ‘People do not have the knowledge on how to use such technology’. To overcome the lack of knowledge regarding Sustainable high-tech greenhouse technology in Morocco, a strong network has been established with the Netherlands (DR1, MR1). The two countries' connection has started with a cluster development, ‘more specifically with the involvement with local universities and the development of the centre of excellence in Agadir’ (DR1). According to the Moroccan Researcher (MR1) ahead of this project at the University of Hassan II, the main goal of this university is to share knowledge and connect the different actors in different fields. This is very important, to enhance the adoption of the technology, as MR1 has been in direct contact with a wide variety of growers in Morocco; and the actor has noticed how there is a lack of knowledge for the use of the technology, in fact, he stated that “many times happen that the farmers use the technology in the wrong way” (MR1). A statement that finds disagreement with what was expressed by a governmental actor (MGOV1) which believes that ‘Moroccan farmers have a good understanding of the technology and knows well how to use it’. The situation is not true for either big exporting companies nor for small-medium growers. An example of that is the statement of MC1: ‘The growers are not recycling the water due to the lack of knowledge on how to use that type of technology’. The same governmental actor (MGOV1) declared how once the technology has been implemented, the government does

not check the correct use of it with the individual growers. This leaves one wondering whether the state is aware of the real level of knowledge among the farmers. However, the universities are working as an intermediate in the knowledge share among the Netherlands and the Moroccan companies. For instance, many Moroccan company managers are following some formation and development courses (MC1, MC2, MC3). It is important to notice how all of these actors work within a major exporting company, suggesting that the knowledge share is limited to big growers. This is said because the medium-sized grower (MG2) mentioned that he was benefiting more from the knowledge share gained from his peers rather than the one gained from the University of Agadir.

It is of major importance to explain to the reader the importance of **Showing**, for the diffusion of Sustainable High-tech greenhouses in Morocco. According to Dutch researchers, the aim of the collaboration between the two countries, and the main goal of the Moroccan Universities is 'to show what installation do what and what effect do they have'(DR2). For Dutch Company Manager 1 (DC1): 'to practically demonstrate and educate toward the effectiveness and the advantages growers/companies could have with the adoption of the technology'. The showing of the technology should be done with help from 'the universities and 'innovative' companies so that the growers would be encouraged to switch' (DC2). For this reason, Moroccan Researcher 1, has highlighted the importance of the Hassan II on-campus demonstrative greenhouse built to show the growers in practice how the technology works and that the growers with its implementation could increase their yield (MR1). Similarly, it is done by the CTT (centre for technological transfer) by APEFEL, where the MG1 has again underlined the importance of showing. In fact, this same actor stated that: 'Most Moroccan growers are not skeptical but they are hesitant, that is why we have built the CTT, to show them the greenhouses, we bring the growers here and we show them the technology, the yield and we convince them to adopt this technology. The growers trust us because we give them the real answer to their questions. If the technology does not work we will tell them that it does not work, we have no reason to lie to them because this centre is owned and funded by farmers'. If Moroccan medium growers do not go to CTT to see the technologies, they will go to their peers. An example is the one of MG2, that has declared that sometimes some growers come to his greenhouses to see his technologies. The importance of showing and knowledge gain as a tool for technological adoption finds agreement in the words of Moroccan company managers too: ' A Moroccan farmer would purchase a higher tech greenhouse only after he knows perfectly how to run it and how to fix it'. It is noteworthy the experience of the DG1, that has worked in Agadir for 4 years with the aim of spreading knowledge and teaching the Moroccan growers' pest management control techniques. This actor stated: 'When I was working in Morocco, the first two / three years it was for knowledge transfer and making the system understandable. I was explaining how the tools were working, how to use them and how to analyse the collected data. I have to say that when I was working in there changing the mindset of the growers was the most difficult part because people were used to a certain system and I was telling them to change the way they have always been doing things. So people are afraid because they do not understand how the technology works and do not have any experience with it. This is valid for any technology you implement. People have to get familiar with it, knowing how to use it by showing it'(DG1). To conclude, all of the stakeholders from both the Netherlands and Morocco firmly believe that the key thing is **not to talk about the technology but to show it** (DR2).

In the previous paragraphs, there has been emphasized the importance of showing the network developed between companies and universities. Here is examined the knowledge share among the different Moroccan companies. As previously mentioned in the network formation and coordination building block, there is a misalignment between the Dutch actors and the Moroccan actor's statements. For instance, a Dutch company manager stated that 'most of the growers are internally focused so they do what they do and sharing knowledge is not that common'(DC3). However, for the Moroccan actors, the competition is not as big as it's described by the Europeans. In fact, a Moroccan company manager declared: 'Currently

for the smaller-medium growers there is no competition and there is a lot and continuous knowledge share. But for the greater corporations, the confidentiality comes in, therefore there is not much knowledge share among them' (MC2). This was confirmed as well by two Moroccan growers saying that at least once a month they were meeting with other growers to discuss how to improve their horticultural practices (MG1, MG2). Thus, it is possible to state that there is a strong knowledge share established among the small-medium-sized growers, but not as a strong one among the big exporting companies.

A limiting factor for the knowledge share is the limited knowledge of English among the Moroccan growers. In fact both the Dutch researchers (DR1&DR2) have presented this as an obstacle to diffusion in the short run because most of the terms used for these technologies are in English. This at the same time might hamper the communication among the Dutch and the Moroccan stakeholders. However, on the positive side, all the Moroccan growers have a very good knowledge of French, which might facilitate communication with international actors (DC3). What is more, according to the DR1&2 and DG1, currently there has been a switch toward English in schools as 'Morocco would like to increase its independence from France', therefore in 10/15 years, this is not going to be a barrier anymore. In fact, all of the Horticulture students met by the author during his interview process have a high English level. Moroccan stakeholders provided similar statements regarding the knowledge of English within the country. For instance, the MG2 had a very good knowledge of English however the actor stated that 'many of his peers do not speak any English'. Similarly, for some governmental actors (MGOV1, MGOV3, MGOV4), most of them were not speaking in English but communicating with the author through a translator. Another limiting factor is the lack of knowledge to go through the bureaucratic process. This problem was mentioned by MG2 that has stated: ' that many farmers do not know how to go through the bureaucratic process to ask for these funds'. The same statement was made by MR1. However, according to MG2 and MGOV4, some offices have been already established to help the growers to fill up the papers.

To conclude, the knowledge and awareness of technology have ***a big impact*** on the following building blocks:

- *Production system:* The technology is currently fully imported because there is a lack of know-how on how to build sustainable greenhouse components locally.
- *Complementary products and services:* Need to improve the water energy infrastructure.
- *Network formation and Coordination:* There is a lack of people that know how to repair the technology, additionally there is no knowledge share among the different companies and there have to be 'imported' the workers to build the greenhouses from the NL.
- *Customers:* all the potential customers are skeptical regarding the adoption of the technology because of the lack of know-how.

Table 21: List of the knowledge and awareness factors influencing the building blocks

Limitations	Explanation	Source
Limited knowledge of English	Most of the technical terms used are in English	**(MR1; MG2; MC2; DR1, DR2; DC1; DC2; DC3)** (Long et al. 2016; Wu et al., 2013)
Lack of knowledge share among big growers	There is no communication among big companies due	**(MC2; DR1; DC1; DC3)**

	to confidentiality	(Wu et al., 2013; Van der Veen, 2015; Van der Veen, 2015; Moons et al., 2015)
Lack of experience to go through the bureaucratic process	Many farmers lack of knowledge on how to ask for funds or subsidies	**(MR1; MG2; MGOV3)** (**Kalpakian et al., 2014)**
Lack of follow up help by the government	The government does not check for the right and most effective use of the subsidized technologies.	**(MGOV1; MGOV4)**
Lack of know-how on running a high-tech greenhouse	There are not many people with the know-how/skills to run a sustainable greenhouse	**(MR1; MR2; MC1; MC2; DR1; DR2; DC1)** (Wu et al., 2013)

Knowledge and awareness of application and market

This influencing condition refers to the customer's knowledge of which application and how the innovation can be used. It relates to the market structure and market applications used too. The use of market analysis, learning by doing and testing can be ways to expand this knowledge (Ortt & Kamp, 2022).

Since the beginning of the interview process, it was noticeable how there was a strong alignment of the products that have to be grown in Morocco within Sustainable high-tech greenhouses. When the question regarding which was the most suitable market application for this technology in Morocco, was asked to Dutch actors the responses were: tomatoes, soft fruit, cucumber, bell pepper, herbs and beans (DR1 & 2, DC1 & 2 & 3, DG1). The same answer was given to the majority of the Moroccan actors, which have demonstrated great knowledge of what to grow with Sustainable greenhouses. This could be confirmed by multiple statements by a wide range of Moroccan stakeholders like MC2: 'In Morocco, we are growers since always, we are not stupid when we talk about knowledge on what crops have to be grown'. Another example of a critical assessment of whether the implementation of Sustainable greenhouses would help a Moroccan grower to better penetrate the international market was given by MG2. This is a medium-scale bean grower and he has clearly stated that: 'the crops that I produce are not highly profitable to a level that would allow me to switch to higher technology'. This was confirmed by a Moroccan researcher too (MR1). Demonstrating, how it is present a critical eye and knowledge of the technology market application in smaller growers too. It was noticeable, how a strong alignment and awareness of the best market application for the technology was given by the Moroccan governmental actors too (MGOV1, MGOV2, MGOV3). Furthermore, another governmental actor responsible for the safety and security of exported and imported products (MGOV2), has mentioned how the growers are always kept up to date with the new international market regulations. This is done 'with the help of seminars and the collaboration with APEFEL' (MGOV2). During the interview with the Moroccan bean grower (MG2), the author had the chance to verify the grower's knowledge of the always-changing international market regulations. Undoubtedly, the grower was fully aware of which beans could be sent to the packing facility and which ones would have not reflected the EU regulations.
At the same time, each Moroccan researcher, grower and company manager was fully conscious of which technology had to be applied in the first place to improve their production. These were: heat insulation, water management and monitoring sensors (MR2). Similar elements were mentioned by the Dutch Company 2. To conclude, during the interviews, it was very clear that the main market application for sustainable greenhouses in Morocco should be

Tomatoes. On the Dutch side, it's convenient to shift the tomato production to Morocco, as after the war in Ukraine it is unprofitable to produce them in the Netherlands (DC1). While on the Moroccan side, it's clear how the actors are proud of their knowledge of how to grow tomatoes and how their country resembles the perfect conditions to grow them (MC2). Thus, on one side, there is an economic advantage for the Netherlands (MG1) (especially Dutch growers and technology providers), on the other it is a good opportunity for Morocco to innovate and make better use of their resources (DC1). However, the market currently presents some sort of limitation that may hamper the diffusion of the technology, as already mentioned in the customer building block, which is the lack of a final product market. According to DG1, 'European protectionism limits the Moroccan in the export due to the quota set, so if you have these limitations, it's harder for farmers to make the investment in a new technology'. This was confirmed by a Moroccan grower (MG1) too: 'I am scared that there is a lack of market, that although I produce a lot of products because of the quota I am unable to export them' (MG1). For this reason, the same grower mentioned that the best solution would be to increase local consumption. However, this does not seem like an option for big Moroccan exporting companies, which have stated (MC2): ''In Morocco, we produce to export not to feed the population. Even with a change in technology, this would be done only to export more and sell to the EU. This is because agriculture is the most important sector for Morocco, and we cannot stop producing'. Nevertheless, this retail barrier might make things more unclear for Moroccan growers making them reluctant to invest in new technologies.

To conclude, Moroccan people presented a good knowledge on what is the best market application for sustainable greenhouse technologies and their market limitations. Thus, the knowledge and awareness of application and market influencing condition is ***complete and compatible***, thus it does not hamper the diffusion of Sustainable high-tech greenhouse technology through the formation of a barrier.

Table 22: List of the knowledge and awareness of application and market factors influencing the building blocks

Limitations	Explanation	Source
Lack of final product market	For some products a quota by the importing countries is established	**(DG1; DC3; DC1; MG1; MC1; MC2)** (Moons et al., 2015)

Natural, human and financial resources

This influencing condition represents the availability of natural, human and financial resources needed to allow the diffusion of the technology. The lack of these might hinder the diffusion of Sustainable High-tech greenhouses (Ortt & Kamp, 2022).

Firstly, the natural resources are analysed. It has been stated by Moroccan Grower 1 that there has been an increase in the price of the natural resources necessary to build a greenhouse. Thus, at the moment, it is more expensive even to build a Canarian-type greenhouse. According to MG1 and MGOV3, the price increase is caused by increased material costs after the pandemic and because most of these materials (and technologies) are imported from the EU. The share of imports can decrease over time if the market of sustainable greenhouses would grow in Morocco (DC2). Leaving to the country the production of 'steel construction, aluminium parts for glazing and the glass' (DC2). However, as already mentioned in the production system building block, the Moroccan stakeholders are not that happy to be technology dependant from other countries, as a matter of fact, DR2 said that 'it is not it is not possible to continue importing the technology from EU as it would cost a lot not only on the import itself but for its maintenance too'. Suggesting the development of Moroccan technology since the beginning of the diffusion, with the quote: 'to adopt the technology to our

reality'. Therefore, using local technologies and local materials. This is because both of the Moroccan growers (MG1 & 2) were fully aware of the economic interests of the Dutch technology providers. Nevertheless, currently, Morocco is lacking one of the most important natural resources: water. This was said, during an interview, by the head department of the water institute of the Souss-Massa region (MGOV1), that has stated: 'Morocco is currently facing a double problem: the increase of water use in agriculture and the facing of the first effects of climate change on the nation'. This is increasing the water stress levels and decreases the groundwater level by 2 meters every year (MR1). The head of the regional office of agriculture (MGOV4) said that the only way to overcome this problem is 'to find the right balance between the produced products and the exports as Moroccan cannot put much weight on their water resources'(MGOV4). Thus, the introduction of sustainable high-tech greenhouses, with their water-management technologies, could help in decreasing the water pressure.

Secondly, human resources are examined. According to the interviews, there is a lack of two types of human resources: the skilled and the unskilled workforce. Regarding the first one, there is a complete misalignment between the statements of Dutch and Moroccan actors. The first ones believe that there is a complete lack of knowledge on the technology (DR1, DR2), whilst according to some Moroccan actors there are some technicians, but they are not enough. For instance, DC2 stated that: 'currently there is only one person that has enough knowledge, one engineer or technician, for 20 hectares. This is not enough, to manage well the whole area, more people are needed'. Another example is the one of DC3, this actor is the unit manager of 140 hectares of greenhouse production. Moroccan researcher 2 has mentioned how 'big companies keep for themselves the people with the know-how regarding the technology, leaving the smaller growers with a lack of workers'. Thus, bigger companies, because of their greater capital, hold the workers with assembling and production knowledge making it harder for smaller companies to find actors providing certain services (MR2). Hence it could be statable that there is competition among companies for the people with knowledge too. Regarding the lack of unskilled labour, this is only for some market applications. For instance, MR1 and MC2 both declared that there is a lack of unskilled workers depending on the season and on the crop grown (e.g. for soft-fruit production, although is the better-paying one). This is because harvesting the yield is a hard job and many people refuse to do it. For this reason, to overcome this problem some growers, like MG1, are hiring women as pickers because as MR2 stated: 'despite males, the female pickers work much harder without complaining'.

Thirdly the financial resources are evaluated. As already mentioned in the product price building block, according to DR2 and MC2, 99% of Moroccan companies do not possess enough financial capabilities for immediate technological adoption. Therefore, it is needed help through subsidization from the government to encourage the growers toward technology adoption. According to MG1: 'Currently, the Moroccan government possess enough funds to support the diffusion of this type of technology'. However, due to the lack of a shared objective among the growers and the government, subsidies sometimes do not reflect the real needs.

In conclusion, the analysis of the Natural, human and financial resources influencing conditions, it is statable that this factor has ***an influence*** on the following building blocks:

- *Complementary products and services and innovation-specific institutions:* The lack of natural resources such as water or gas (or renewable energy) will lead the government to build the right infrastructure to enable technological diffusion.
- *Product price & Customers:* If there is natural resource scarcity the price of the materials will rise, similarly a lack of workers with the know-how would make them more expensive for companies to hire them. This has a great impact on the financial resources needed by the customers to adopt the innovation.

Table 23: List of the natural, human and financial resources influencing the building blocks

Limitations	Explanation	Source
Lack of people with knowledge on running operations	There are not many people with the know-how/skills to run a sustainable greenhouse	**(MR1; MR2; MC1; MC2; DR1; DR2; DC1)** (Wu et al., 2013)
Lack of unskilled labour	For some market applications there are no pickers	**(MR1&2; MC2)**
No subsidization and the high initial investment needed	Lack of right subsidizations from the government	**(MG1, MGOV4, MGOV3)**
Lack of natural resources (water)	The lack of water is incentivizing the innovation	**(MGOV1; DR2; DC3; DG1)**
Increase in price of materials	Due to import and post-pandemic	**(MG1; MGOV3; MC2; DC2; DC3, MR2)**

Competition

This condition refers to the competitors of breakthrough technology. The competitors might be old technologies or other new technological competitors. The chaotic network formed among these competitive alternatives may hamper the technological diffusion of Sustainable high-tech greenhouses. This might increase uncertainty and hinder the diffusion of innovation (Ortt & Kamp, 2022).

It has been already highlighted in the analysis of the network formation and coordination building block, that despite what the Dutch stakeholders believe (that the competition is extended among smaller growers too)(DC3, DC1), there is strong competition only among the big Moroccan exporting companies (MC2, MC3, MG1, MG2). This is because 'most of the growers are internally focused' (DC3) and especially because there is 'a lot of confidential data which cannot be shared among the 3 main companies in Morocco' (MC3). This strong competition represents a barrier to the diffusion of sustainable high-tech greenhouses for three main reasons. Firstly, it is preventing the companies from establishing a strong network of knowledge sharing between them (DC3). Secondly, as previously mentioned, it inhibits their exporting power: 'The lack of a Moroccan grower association for the EU represents a barrier for technological diffusion. As with an exporting association, Moroccan companies could sell their high-quality products together and make a decent amount of profit on that' (DC3). Thirdly, without a grower association for the EU, Moroccan companies would have a dispersed influential power on the establishment of new quotas or guts for EU export (DC3). This last one limits the diffusion of the technology with the increase of market uncertainty (DG1; DC3; DC1; MG1; MC1; MC2).

The competition among companies is not the only challenger to sustainable greenhouse diffusion. This is because there is strong competition with some other practices. It should be emphasized how the author, mentioned 'practices' rather than 'technologies'. The reason is that no interviewed actor has mentioned 'Canarian greenhouses' as a possible competitor to sustainable greenhouses, all of them recognized the need either to innovate or either change practices to produce more. For instance, a common practice that Moroccan growers/companies are adopting to produce more yield is to purchase more land. According to DC1: 'in Morocco, the number of people per square km is quite low, therefore the land prices

are quite low. So that makes it also easier to buy more land and expand production instead of improving their production methods'. Therefore, if Moroccan farmers had to choose whether to implement a new technology they would rather purchase more land as it is cheaper. However, this cannot work in the long run because, as outlined by the MGOV4 it is now prohibited for the growers/companies to increase their land area expansion. What is more, there is an increase in the costs of the resources and in resources used, as confirmed by MG2 and MGOV1.

The only technological competitor to the adoption of a fully sustainable high-tech greenhouse, are small improvements to Canarian-type greenhouses (DC2). The same exact statement was made by Dutch researcher 2 and by Moroccan company 2, who has continued stating that: '1% of the entrepreneurs in Morocco has the possibility to an immediate shift to high-tech greenhouses, for the rest 99% there are no financial capabilities to do so. For them, it is important to make the change slowly, bit by bit'. A gradual change rather than a full change provides the companies with two benefits. Firstly, it would reduce the investment risks. Secondly, and most importantly, it would help companies to gain more knowledge and experience on the technology. Thus, DR2 kept on suggesting that for some companies the best option would be to 'build 1 hectare of higher technology greenhouse to learn how to use them first'. This statement found truth and application, in the interview conducted with a Moroccan Unit Manager (MC3), that works for a major Moroccan grower. In fact, within MC3's company in 2014 there have been built 1.2 hectares of sustainable high-tech greenhouses to learn how to use it. To conclude, for DR2 the adoption of step-by-step improvements would speed up the diffusion of sustainable greenhouses in Morocco, as companies would be able to 'understand which is the component that could have the greatest impact at the lowest cost'.

On the positive side, according to a Moroccan technical advisor (MC2), the growing competition among technology producers and distributors will help the diffusion of sustainable greenhouses in Morocco. This is because there are more international companies that sell the same components for cheaper.

To conclude, the competition influencing condition have ***a low influence*** on the following building blocks:

- *Network formation & Coordination:* The competition among different companies might influence the diffusion of knowledge.
- *Production system:* With a lower adoption of the technology, there will be a slowdown in the development of a national technology because there is going to be less demand.
- Innovation Specific institutions: A great number of technological competitors may shift the governmental focus on subsidization for some other technologies.

Table 24: List of the competing factors influencing the building blocks

Limitations	**Explanation**	**Source**
Competition with low land costs	Farmers prefer to purchase more land rather than investing in innovation	**(MR1; DC1; DC3, MGOV4)**
Competition with small technological improvements	Researchers' advice this as the best solution for diffusing the technology	**(MC2; DR2; DC2; MC3)**
Competition among big companies/exporters	Lack of knowledge share network	**(DC3; DG1; DC2)**

Macro- economic and strategic aspects

These factors pertain to economic recessions or economic growth that can hamper or facilitate TIS formation (Ortt & Kamp, 2022).

As is going to be explained in the Accidents and events influencing conditions, the economic recession that European countries are facing due to the pandemic and war in Ukraine is encouraging horticultural production in Morocco (DC1, DG1). Especially the war in Ukraine, according to DC1, is playing an important role in the technology transfer from the Netherlands to Morocco. The war has caused an increase in gas prices in the EU, making it unsustainable for European to grow crops like tomatoes in greenhouses during winter times. The Dutch actor continued stating, that especially in the Netherlands a lot of energy is required to heat the greenhouses in winter, diminishing the profit margins to a minimal level. Thus, Morocco due to its geographical proximity and need to innovate could be a good alternative for food production during winter times (DC1). However, Moroccan actors are not unaware of the economic interests of the Europeans, an example of that was the statement of MG1: 'There is an economic interest in moving the production from Europe to Morocco'. What is more, according to DR1, Morocco is facing economic growth. Also, the MGVO3, clearly stated that 'Morocco is facing an economic growth and that will encourage the diffusion of high-tech plastic greenhouses, in fact in around 40 years' time there is going to be a full switch to this type of technology'. The horticultural innovation is trying to be encouraged by the Moroccan government with subsidies and regulations (MGOV4), however, does not always reflect the real needs of the medium growers (MG1) but more the ones of big exporting companies.
Additionally, economic growth, according to another Moroccan governmental actor (MGOV4) is encouraged by the 'Green Morocco Plan' but also by the cooperation between the two countries which, however, requires co-ordination to bring the actors together toward the same objective. Moroccan growers, despite what some Dutch actors might believe, are very open to knowledge gain and being taught how to use new technologies by international actors (MG1). Yet, the Moroccans, thanks to their experience in horticulture, know exactly what technologies they need and are aware that the European technology providers are in Morocco for economic interests (MG1, MG2). Interest has been confirmed by a Dutch researcher too (DR1). This makes the Moroccan want to invest and develop their own technologies, as was stated by MR2: 'The case of high-tech greenhouses have to be adapted within the Moroccan context, it would be better to develop a cheaper local technology: 'to adopt the technology to our reality'. However, as mentioned in the production system building block, according to a Dutch technology provider (DC2): 'As long as there will be only a few greenhouses 80% of the value of the greenhouse investment has to be imported. When the market for high-tech greenhouses will grow, the share of imports can decrease to 30%'. Thus, it will be hard for Morocco to be fully technologically independent, at least until a national value chain cluster is developed (DR2). What is more, currently Morocco invests only 0.7% of its GDP in innovation, according to MGOV3, and this might slow down the development of local technology in the short run. Being aware of this
a Moroccan grower (MG1) suggests a more moderate approach (than the one proposed by the MR2), to first import the technology from Europe to support the initial diffusion as 'currently there are no companies that produce such components in Morocco' to then develop 'new companies in Morocco so that the import of the technology from EU will be reduced'. This approach on the one hand is positive for the country, as it would not limit the export and the economic growth. On the other hand, this would increase horticultural practices and limit the reduction of water consumption within the country. For this reason, for the same Moroccan grower (MG1), no horticultural product should be produced or exported but rather knowledge on how to grow some types of crops. This strong statement has found agreement according to the grower within a wide range of actors, but also some contrasting opinions by some other Moroccan companies (MC2).

It is clear that on the international level, there is strong support for the adoption of the technology. However, on the national level, although the intentions are very similar, the reality

differs. This is because, as already stated in the Innovation-specific institutions building block, the bureaucracy within the country is very slow (MG2; MG3; MG4) and the subsidies made available do not reflect the real needs of the companies (DR1; MR1).

In conclusion, the macro-economic and strategic aspects influencing condition have **an influence** on the following building block:

- Innovation-specific institutions: Morocco lacks a long-term vision, what is more, the bureaucracy within the country is slow and the subsidies do not reflect the real needs of the growers.

Table 25: List of the macro-economic and strategic aspects influencing the building blocks

Incentives/limitations	Explanation	Source
War in Ukraine	Forcing the EU to move the winter production to nearby countries	**(DC1; DG1; MG1)**
International co-operation	The NL is encouraging the diffusion of the technology	**(MG1; MG2; DC1; DR2; MR2)**
Lack of governmental vision on the long term	The general governmental vision keeps on changing, there is no clear objective	**(DR1; MR1)** (Long et al. 2016)
Slow bureaucracy	The time required to get the funding is too long	**(MG2; MG3; MG4)**

Socio-cultural aspects

This factor refers to the norms and values held by the technology adopters in the TIS. These elements are more informal than the laws and regulations but have an important impact on the formation of the TIS (Ortt & Kamp, 2022).

The conducted analysis has already mentioned some of the socio-cultural aspects that are a strong limiting factor for the diffusion of Sustainable high-tech greenhouses in Morocco, however in this paragraph the author will analyse them one step further.

The most mentioned socio-cultural limit for the diffusion of technology in Morocco, according to the Dutch actors is the skepticality toward what is new. For instance, a Dutch researcher (DR2) has mentioned the 'great skepicism that is around the Moroccan people'. However, particularly a Moroccan grower (MG1), did not like at all the word skeptical, insisting that Moroccan people are not skeptical at all, but they are hesitant. This hesitancy is generated by the lack of knowledge, for this reason, it is important to show them the new technology rather than to talk about it (MG1). Similarly, a Moroccan company manager, as already mentioned, stated: 'People are enemies of what they are ignorant of'. Thus, this hesitancy is caused, according to the Moroccan people, only by the lack of knowledge, not the refusal to innovate. However, the author has identified some other indirect reasons for this hesitancy to innovate. One of these, as already mentioned in the customer building block, is the lack of the final product market. The quota on tomatoes is limiting companies with financial capabilities from adopting sustainable greenhouses, as they might be unable to export a greater yield. Thus, preventing them to get the full benefits of the technology adoption. This was stated by, for example, MG1: 'I am scared that there is a lack of market, that although I produce a lot of products because of the quota I am unable to export them' (MG1).

A further reason, that is increasing hesitancy, is the age of the potential technology adopters. This problem was mentioned by a Moroccan governmental actor (MGOV4): 'One of the biggest challenges for Moroccan agriculture is that most of the growers are people of high age, therefore it is necessary to try to encourage young people to start new companies within the horticultural sector'. It is harder for older growers to change the way they have been doing things. This has been confirmed by a Dutch grower (DG1), that was working on knowledge share in Morocco for 4 years. The actor stated: 'I have to say that when I was working in there changing the mindset is the most difficult part because people are used to a certain system and now you tell them to change'. Whilst nowadays the younger generation is being trained within universities in the use of new technologies and firmly believes in their adoption (MR1). Besides this, it is important to highlight, that not all growers are not adopting the technology because they are hesitant. For most of them, the biggest barrier to overcome is the price. A Moroccan grower (MG2) has mentioned that he 'would rather have half a hectare with Dutch technology than 5 hectares with mine' but he could not adopt it for the lack of financial resources.
Throughout the interview process, it was clear that the skepticality was limited only to the smaller-medium-sized growers. As Dutch researcher 1 has mentioned: 'There are two different types of growers the big ones and the smaller ones. Both of them are part of the APEFEL group, although some growers might be more involved than others'. The ones that were more involved, within APEFEL but also within the universities were the bigger growers. These, as communicated by MC1 are keen to adopt technological improvement because they are fully engaged within the knowledge share environment and are fully aware of the technological advantages the technology would bring. A key example is the one brought by MC3, where his company has built over a hectare of sustainable greenhouses, and it is currently building a greenhouse with a closed-water management system.

Another limiting factor brought up by a Dutch company manager and confirmed by a Dutch researcher is the lack of long-term mentality among the growers (DC2, DR1, DR2)(This limiting factor was already mentioned in the customer building block). It was stated 'for the Moroccan growers Canarian greenhouses are still profitable for the short run, and a change in technology would mean for them a ROI of 3 years'(DC2). The same issue was raised by a Dutch researcher that said that many growers do not feel the need to change as they do not feel the rising water pressure, therefore they do not care about the future as they want to 'eat now' (DR2). As already seen, this lack of long-term mentality is more present in smaller growers, that are less involved in the knowledge share process. Thus, their lack of long-term mentality is caused by: a lack of economic resources, older age and preferability to purchase more land rather than investing in new technologies. An example of the desire to innovate but a lack of resources is the one of the medium-sized Moroccan bean Grower 2 (just mentioned before). Whilst, regarding the lack of long-term perspective due to the older age of the growers, DR1 has mentioned that: 'one way to bring the long-term perspective to the growers, is to train young people in the use of the technology'.

To conclude, the sociocultural aspects play ***a strong influence*** on the following building blocks:

- Customers: The hesitancy of the customers limits the adoption of new technologies.
- Network formation and Coordination: The lack of knowledge sharing among big companies limits the establishment of a strong network.

Table 26: List of the socio-cultural factors influencing the building blocks

Limitations	Explanation	Source
Moroccan growers are skeptical regarding the new technology	People are enemies of what they are ignorant of.	**(MR1; MG1, MGOV3; MGOV4; MC2; DG1; DR2)** (Long et al., 2016)

Lack of long-term perspective from the growers	There is a strong 'eat now' mentality	**(DC2; DR2; DR1; DC3)**
Lack of pressure for water saving	Moroccan companies do not feel the lack of water	**(DR2; MC2)**
Personal ability of the growers (e.g. age, education level)	Most of the growers are old age, thus more resistant to change	**(MGOV4; DR1)**

Accidents and events

This influencing condition refers to accidents in production or product failure, or outside the TIS to wars or natural disasters. These factors may hinder or encourage TIS formation (Ortt & Kamp, 2022).

According to Moroccan Grower 1: 'there is a strong economic interest on the Dutch side for the implementation of Sustainable high-tech technologies in Morocco'. Similar statements were given by Moroccan grower 2 that said: 'It is very easy to have a connection with Dutch companies. Even if sometimes they try to sell me things, I will only buy what I really need, so I do not fall into their tricks'. This urgency to penetrate the Moroccan horticultural market was explained by Dutch company 1, that due to the war in Ukraine, it is now unsustainable to keep on growing food during the winter in the Netherlands. This is because already before the war the profit margins were limited, now with higher energy prices, barely existent. For this reason, DC1 has confirmed the statement of MG1 by saying: 'There is an economic interest in moving the production from Europe to Morocco'. However, both the Moroccan growers and researchers agree that the Netherlands is surely playing an important role in the diffusion of the technology (MG1). At the same time, as DC1 mentioned, another event that is encouraging the diffusion of innovation is water scarcity. This is also why it is a good opportunity for Morocco to innovate to make better use of their resources (DC1). The MGOV4 declared that: 'Morocco is one of the first countries to be highly affected by water scarcity, but this problem is going to be more common in the coming years worldwide. In fact, it is important to find the right balance between the produced products and the exports as we cannot put too much weight on our water resources'. On the same line, there was the statement made by MG1: 'Morocco should not produce and export any horticultural products because there is a lack of water in the country. Morocco should produce the technology and export the knowledge on how to grow some types of crops but not produce any.' However, the big exporting companies do not agree with this. The case example is the statement made by MC2: 'we cannot stop producing because of the lack of water'. To conclude, both international influence and water scarcity are encouraging the diffusion of sustainable greenhouses in Morocco. However, it should be of prior importance to find the right balance between the produced products and the exports as we cannot put too much weight on our water resources (MGOV4).

In conclusion, the accidents and events influencing condition is ***complete and compatible***, thus it does not hamper the diffusion of Sustainable high-tech greenhouse technology through the formation of a barrier.

Table 27: List of the accidents and events influencing the building blocks

Incentives	Explanation	Source
War in Ukraine	Forcing the EU to move the winter production to nearby countries	**(DC1; DG1)**

Dutch economical interest	The NL is encouraging the diffusion of the technology	**(MG1; MG2; DC1)**
Lack of water	This factor could push water saving technology implementation	**(MGOV4; MG1; MC2)**

The status of the Sustainable Greenhouse influencing factors in Morocco

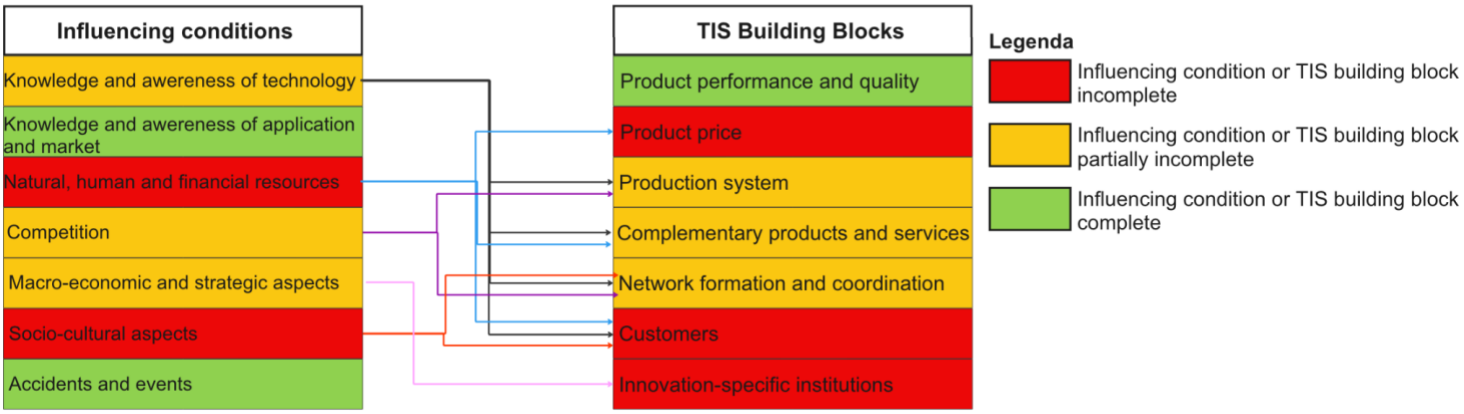
Within this paragraph, a one-by-one analysis of the influencing conditions with a subsequent overview of the status and their influence on the building blocks is depicted.

Market application 1: The first market application is Sustainable Greenhouse for vegetable production, more particularly for tomato production.

Table 28: List of the influencing conditions analysis for market application 1

Knowledge and awareness of the technology
This influencing condition is partially incomplete, in fact despite the knowledge on technology is currently very limited. A lot of work is being done by universities and especially big exporting companies to comprehend and invest in research and development for this type of Sustainable greenhouses. The greater obstacle is to share knowledge among the medium-small growers that do not take part in the knowledge share and to enhance the knowledge share among the big exporting companies.
Knowledge and awareness of application and market
This influencing condition is complete because the Moroccan growers have a very strong knowledge of the tomato crop, additionally, they are perfectly aware that they would get a greater profit margin if the technology would be used for this market application. Therefore, the Moroccan growers know the benefits of the implementation of this technology.
Natural, human and financial resources
This influencing condition is incomplete. Firstly, there is a lack of natural resources, to build the greenhouse technological components have to be imported, which due to the pandemic and war, are sold at a rising price. Secondly, there are scarce human resources as there is a lack of people with the know-how to run a greenhouse. For this technology there is only 1 person every 20 hectare with sufficient knowledge (MC2). However, for this technology is easier to find unskilled labour. Thirdly, there is a lack of financial resources as the implementation of this technology requires a great amount of initial investment capital, which many companies do not have.
Competition
This influencing condition is partially incomplete. This is because although many growers might prefer to buy more land rather than implementing Sustainable greenhouses, this type of technology for this market application is prevalently located within the Souss-Massa region which is more densely controlled. For this reason, harder to purchase it and get away with it. Thus, the competition with buying more land in this case is quite low. However, there is a quite strong competition, also among big companies, small technological improvements with short ROI. What is more is strong competition among the different big companies, which limits the knowledge share.
Macro-economic and strategic aspects

This influencing condition is partially incomplete, because the diffusion of this type of sustainable greenhouses is highly incentivised by the EU companies, which after the war in Ukraine, have a very limited profit margin on the yield, especially during winter. However, it is not complete because there is a lack of alignment on the national level, between the companies and the government.
Socio-cultural aspects
This influencing condition is incomplete as most of the growers that want to switch toward this innovation within this market application are big growers with a limited skepticality (Which represents only 1% of the growers). All the other growers are hesitant because they do not know anything about the technology and they are used with their old way of production.
Accidents and events
This influencing condition is complete as the diffusion of sustainable greenhouse technology is highly incentivised by the EU companies, which after the war in Ukraine, have a very limited profit margin on the yield, especially during winter. Another factor that plays an important role in the incentivisation is the lack of water, which limits the production and the spread of unsustainable horticultural practices and proposes Sustainable greenhouses as a solution.

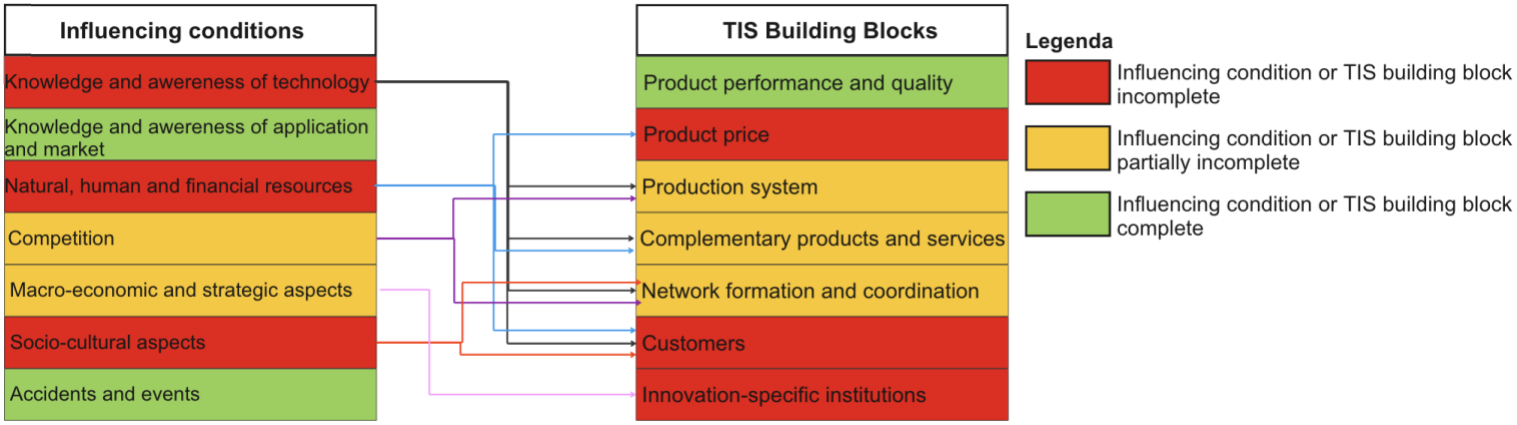


Market application 2: The second market application is a Sustainable Greenhouse for soft fruit production, more particularly for blueberries and raspberries.

Table 29: List of the influencing conditions analysis for market application 2

Knowledge and awareness of the technology
This influencing condition remains incomplete due to limited knowledge on Sustainable greenhouse technology, particularly regarding its application in tomato production. Furthermore, governmental efforts are not primarily focused on promoting knowledge acquisition specifically for sustainable greenhouses in tomato production. However, it should be noted that some companies already have experience and knowledge in operating sustainable greenhouses, albeit on a smaller scale, for the production of soft fruits. While there are differences in system and operational knowledge, there is potential for knowledge transfer and adaptation based on their existing operations.
Knowledge and awareness of application and market
This influencing condition is complete, this is because Moroccan growers have a fairly good

knowledge of how to grow this crop, they are currently aware that with the implementation of this technology, their ROI might be longer than the one for tomato producers. Additionally, there is no quota for the soft-fruit market.
Natural, human and financial resources
This influencing condition remains incomplete for several reasons. Firstly, there is a shortage of both skilled and unskilled labour force, as the work associated with Sustainable greenhouse technology is physically demanding and requires specialized skills. Secondly, there is a scarcity of natural resources, particularly in terms of importing the necessary technological components for building the greenhouses. Factors such as the ongoing pandemic and conflicts can lead to increased prices and limited availability of these resources. Thirdly, the technology itself demands a higher capital investment, primarily due to the higher labour costs associated with operating the Sustainable greenhouses. As a result, many companies lack the necessary capital for a technological switch, especially considering the lower profit margins involved. These factors collectively contribute to the incomplete nature of this influencing condition, hindering the widespread adoption of Sustainable greenhouse technology.
Competition
This influencing condition is partially incomplete, as it is not a solution to purchase more land for this market application. In fact, the production is mostly located within the Souss-Massa region and Rabat area, these agricultural centres are highly controlled making it harder for growers to illegally expand their horticultural area. However, a very common practice, also among big companies, is to make small technological improvements with short ROI. There is not as big competition among companies.
Macro-economic and strategic aspects
This influencing condition is partially incomplete. The diffusion of sustainable greenhouses is highly incentivized by the EU government and companies, which after the war in Ukraine, have a very limited profit margin on the yield, especially during winter. However not any specific effort is put to incentivize the diffusion of this type of sustainable greenhouses. In any case the technology would still benefit by the established network from other types of sustainable greenhouse diffusion.
Socio-cultural aspects
This influencing condition is incomplete. Due to the lack of knowledge, there is a high skeptically toward the adoption of this technology The product produced within this market application is for an international market only, therefore it is produced by big exporters. This is the 1% of the total growers the other 99% is hesitant.
Accidents and events
This influencing condition is complete because the lack of water in the country requires an incentivization of diffusion of this type of sustainable greenhouses.

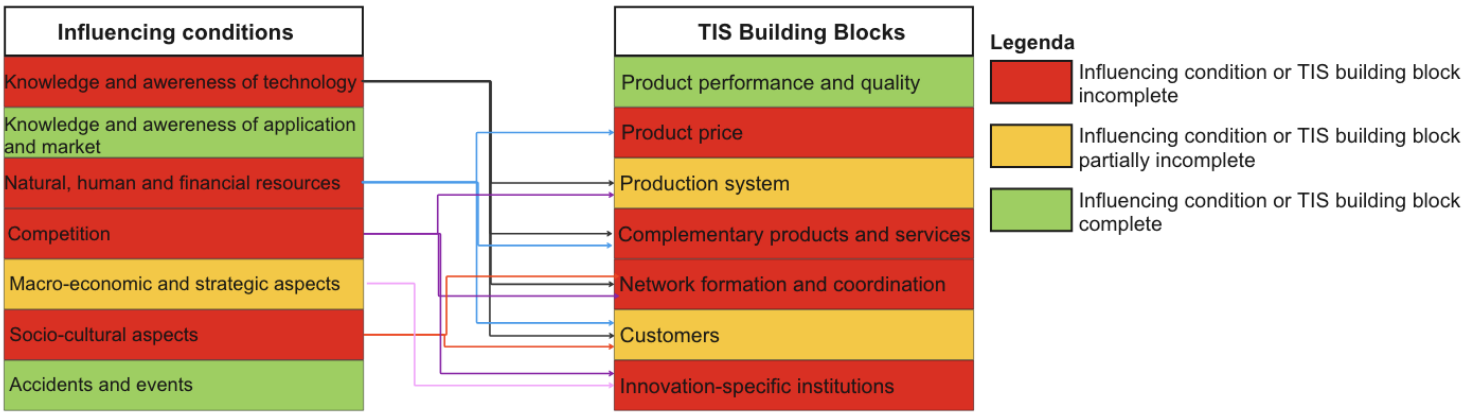


Market application 3: The third market application is Sustainable Greenhouse for herbs production.

Table 30: List of the influencing conditions analysis for market application 3

Knowledge and awareness of the technology
This influencing condition is incomplete because knowledge on the technology is still scarce. There is some work being done to maximise it for the other market applications especially but not particularly for this one. However, this technology could use the knowledge exchange network established by other technologies. The greater obstacle is to share knowledge among the medium-small growers that do not take part in the knowledge share.
Knowledge and awareness of application and market
This influencing condition is complete as it addresses a market niche that is aware about the technology and its market capabilities, this is because growing herbs, such as mint, have always been in the Moroccan culture. Additionally, Moroccan people are currently aware that with the implementation of this technology, their ROI might be longer than the one for tomato producers. On the positive side, there is a big local consumption for this crop.
Natural, human and financial resources
This building block is incomplete as there is a lack of human resources, more specifically there is a lack of skilled labour force with knowledge of running operations. This market application is less labour-intensive than the second one, hence why it is more accessible for the unskilled labour force. The natural resources required to build greenhouses are expensive. The profit margin for this market application with the adoption of sustainable greenhouses would be lower than for the other market applications.
Competition
This influencing condition remains incomplete for several reasons. Firstly, considering the specific market application in the Atlas region, characterized by its rural nature, there is a reduced emphasis on land expansion regulations. As a result, many growers may opt to invest in purchasing more land instead of adopting new technology, such as Sustainable greenhouses. This preference could lead to the establishment of Canarian type greenhouses or the utilization of open-air irrigation methods. Secondly, the high initial investment required for implementing Sustainable greenhouse technology poses a significant challenge, making gradual

implementation a strong competitor for technological adoption. The competition in this market application is more pronounced, which may influence the government's perspective and effectiveness in providing long-term subsidies. However, it is worth noting that there is a lack of competition among companies in terms of the final product market, which presents a potential advantage for market growth and expansion.
Macro-economic and strategic aspects
This influencing condition is partially incomplete. The diffusion of sustainable greenhouses is highly incentivized by the EU government and companies, which after the war in Ukraine, have a very limited profit margin on the yield, especially during winter. However not any specific effort is put to incentivize the diffusion of this type of sustainable greenhouses. In any case the technology would still benefit by the established network from other types of sustainable greenhouse diffusion.
Socio-cultural aspects
This influencing condition is incomplete. As mentioned, this product is grown prevalently in the Atlas region by small-medium growers of greater age. These potential technology adopters are more resistant to change because more used to their ways of growing, making it very hard for technological change. Moreover, for the growers that would be willing to adopt this technology they would still be skeptical because do not know how to use this technological innovation.
Accidents and events
This influencing condition is complete. This is because, although not primarily for this type of sustainable greenhouses there is a more general incentivisation by EU companies to move the product production. What is more, another factor that plays an important role in the incentivisation is the lack of water for horticulture, which in the Atlas area is prevalently dependent from underground water resources.



Chapter 6: The niche introduction strategies

The goal of this chapter is to answer the third sub-question:

What could be the potential niche introduction strategies to be adopted by Sustainable Greenhouses companies to overcome these barriers?

To achieve this, the chapter is divided into two parts. The first one is specifically related to Moroccan companies and will elaborate on the Niche Introduction Strategies (NIS) previously introduced in Chapter (3), and their order of introduction. Additionally, where no specific NIS exists the author, based on his experience has developed some relevant strategies to overcome the barriers to the sustainable greenhouse market applications large-scale diffusion in Morocco. These strategies, developed by the author are in **bold and underlined (**Table 31). The second part is developed to give specific strategical suggestions to the Moroccan government to support the diffusion of the technology. This is because, although there is a strong push toward implementation from the government, an *innovation-specific institution* barrier exists.

The used data for the formulation of the introduction strategies were the solutions gathered from the Moroccan and Dutch interviewees, the results of the building blocks and influencing conditions analysis (Chapter 5), the paper: '*Ten niche strategies to commercialize new high-tech products*' of Ortt et al., (2015) and the author consideration and field-experience.

The Chapter conclusion presents a visual representation of the building blocks and influencing conditions status after the implementation of each niche strategy for sustainable greenhouse market application 1 (MKTA1).

Table 31: List of the NIS by Ortt et al., (2015) and of the NIS developed by the author

NIS from Ortt et al., (2015) paper	**NIS developed by the author**
Demo and Develop NIS (DD)	**Gradual implementations NIS (GI)**
Educate NIS (ED)	**Network creation NIS (NTW)**
Redesign NIS (RD)	**Infrastructure & Service NIS (INS)**
Subsidized NIS (SUB)	**Common market NIS (CM)**

Part 1: NIS for companies

This section presents the NIS that Moroccan companies would have to adopt to overcome the barriers to sustainable greenhouse large-scale diffusion in Morocco. As explained, the high product price and the resulting lack of customers were the main barriers. The main influencing factors were the lack of natural, human and financial resources; and the lack of know-how. Similarly, the present socio-cultural factors.

The chapter is structured in the following way. Firstly, a table at the beginning of each NIS is presented. In the first column, there is the name of the niche strategy and by which interviewee it was proposed. In the second column are presented the barriers and influencing conditions that will be impacted by the NIS. Then a short description of the relative NIS is presented. To conclude, it is shown with an **(X)** for which sustainable greenhouse market application the NIS is relevant. The more **(X)** the more the strategy is relevant for the market application.

To conclude, a visual representation of the status of the building blocks and influencing conditions for the sustainable greenhouse market application 1 (MKTA1)(Sustainable greenhouse for tomato production) is presented for each NIS at the end of the Chapter. It has been chosen this market application because it was the most mentioned by the interviewees.

Demo and develop (DD) and Educate (ED) niche strategies

<table>
<tr><th>Niche-strategy</th><th colspan="2">Barriers</th><th>Description</th><th colspan="2">Relevant to:</th></tr>
<tr><td rowspan="2">Demo and Develop niche strategy (DD)/ Educate niche strategy (ED)</td><td>Influencing factors</td><td>Building blocks</td><td rowspan="4">Showcase the demonstration greenhouses within universities and innovation centres to generate interest, knowledge on the know-how, spread awareness and proof the efficiency of the technology.</td><td>MKTA 1</td><td>(X)(X)</td></tr>
<tr><td rowspan="2">Knowledge and awareness of the technology (KNWA)</td><td>Customers</td><td rowspan="2">MKTA 2</td><td rowspan="2">(X)(X)</td></tr>
<tr><td rowspan="2">(DR2; DC1; DC3, DG1; MR1; MR2; MGOV1; MGOV3; MC3) (Ortt et al., 2015)</td><td>Complementary products and services (CPS)</td></tr>
<tr><td>Human resources</td><td rowspan="2">Network formation and Coordination (NTWC)</td><td rowspan="2">MKTA 3</td><td rowspan="2">(X)</td></tr>
<tr><td>Socio-cultural aspects</td></tr>
</table>

This niche strategy is based on literature and interviewees solutions. To recap, as explained in Chapter (5), the influencing factors contribute to the barrier formation as they limit the acceptance of the technology by the potential customers, and limit the network and services formation and delivery. The best way to overcome the lack of know-how regarding Sustainable greenhouses is to validate and prove (DR1). Thus, not only to educate but also to demonstrate and prove, through showing (DC1). This is already done, on a very small scale, by some universities and research centres (e.g. IAV Hassan II), which are firstly, offering some short formation courses (followed by MC1, MC2). Secondly, use the on-campus sustainable high-tech demonstration greenhouse to show them in practice how the technology works and how it could increase the company's yield (MR1). Thirdly, the building of a start-up incubator to encourage young entrepreneurship (MGOV4, MR1). This NIS is the first one that has to be implemented as bringing change in the sociocultural aspects, thus overcoming hesitancy, requires a long-time frame (DG1). Alongside this NIS, big companies with their R&D and universities have to adopt the following niche strategies.

Redesign (RD) and Gradual implementations (GI) niche strategies

<table>
<tr><th>Niche-strategy</th><th colspan="2">Barriers</th><th>Description</th><th colspan="2">Relevant to:</th></tr>
<tr><td rowspan="2">Redesign niche strategy (RD)</td><td>Influencing factors</td><td>Building blocks</td><td rowspan="2">It entails the collaboration of actors in the development of cheaper SG alternatives (or</td><td>MKT A1</td><td>(X)</td></tr>
<tr><td>Natural</td><td>Product price</td><td>MKT</td><td>(X)</td></tr>
</table>

(MR1; MG1; MG2; MGOV3; MC2; MC3) (Ortt et al., 2015)	Resources	Customers	components), easier to produce with local natural resources to improve production.	A2	
	Competition	Production system		MKT A3	**(X)**
	Knowledge and awareness of the technology	Network formation and Coordination			

This niche strategy is based on literature and interviewees' solutions. To recapitulate, the influencing factors define the above-shown barrier formation by the increased costs of natural resources and the lack of locally-developed innovation that might reduce the components costs of adoption. To reduce the price of the technology and encourage local technological production, it would be required to develop some local technological components with similar quality and performance (MR2). Thus, in the long-run limit the import of technological components. The development of these should be done by big companies and universities (MR1). This NIS would be key in reducing the product price because these technologies would not be imported (MGOV3). Furthermore, the development of cheaper alternatives could help market applications that have a lower profit margin to adopt them (MG2).

Niche-strategy	**Barriers**		**Description**	**Relevant to:**	
<u>Gradual implementations niche strategy (GI)</u>	Influencing factors	Building blocks	A step-by-step implementation is feasible for 99% of the growers. The growers will talk and show the improvements and speed up the national SG adoption.	MKT A1	**(X)(X)(X)**
	Knowledge and awareness of the technology	Product price		MKT A2	**(X)(X)**
(DR2; DC2; MC2; MC3)	Socio-cultural aspects	Network formation and Coordination			
	Financial resources	Customers		MKT A3	**(X)(X)**

This niche strategy is based on literature and interviewees' solutions. According to MR1: '1% of the entrepreneurs in Morocco has the possibility to an immediate shift to sustainable greenhouses, for the rest 99% there are no financial capabilities to do so'. Therefore, to overcome the price barrier and the lack of know-how the best solution would be to make gradual technological implementations. Relating to many interviewees this would make technological adoption faster, as growers will be showing to other growers the technologies they have implemented and the advantages they have noticed. However, when making these step-by-step implementations, there is to understand which component could have the greatest impact at a lower cost. Thus, growers would have to calculate the ROI for each improvement and make their decision based on their individual cases, according to MR1 they would be: water recycling, climate control, and ventilation. Another way for the 1% of the companies, is to convert only 1 hectare to sustainable greenhouses to learn how to use it first (MC3, DR1). The following NIS can help the companies in the immediate adoption of SG or

for the gradual implementation of the technology. Bigger companies have a greater influence on the technologies to be subsidized, however, is the government that detains most of the power.

Subsidized (SUB) niche strategy

Niche-strategy	Barriers		Description	Relevant to:	
Subsidized niche strategy (SUB)	Influencing factors	Building blocks	Make the right use of the right subsidies to speed up the SG diffusion. These could help in building CPS or convince some potential customers in investing in SG.	MKTA 1	**(X)(X)**
	Financial resources	Product price		MKTA 2	**(X)(X)**
(DC1; MR1; MG2; MG1; MGOV3; MC2) (Ortt et al., 2015)	Macro-economic factors	Costumers			
	Socio-cultural aspects	Complementary products and services		MKTA 3	**(X)**
		Innovation specific institutions			

This niche strategy is based on literature and interviewees solutions. To restate, the influencing factors impact the above-mentioned barriers because the lack of goal-oriented subsidies limits the adoption of the technology. As it is going to be discussed in Part 2, it is necessary that the Moroccan government has a fixed long-term perspective to transition to more sustainable horticulture with the diffusion of SG in Morocco. Currently, there is a lack of strong subsidies to support technological change. Thus, it would be necessary to find an agreement with medium/small and big growers, which could be the best technologies to subsidize. For instance, MR1 suggests putting on finance water management and climate management technologies. Similarly, mobilization of funding should be done to help startup-ups to scale up (MGOV3). Moreover, an efficient help-service system has to be created alongside the subsidies to allow growers that are unable to go through the bureaucratic process to apply for them (MC2). Besides this, it has to be developed an after-subsidy programme to ensure the correct use of the implemented technologies by especially older growers.

Network creation (NTW) niche strategy

Niche-strategy	Barriers		Description	Relevant to:	
Network creation niche strategy (NTW)	Influencing factors	Building blocks	A network of knowledge share among the different stakeholders has to be established. For international	MKTA 1	**(X)(X) (X)**
	Knowledge and awareness of the technology	Customers		MKTA 2	**(X)(X)**

(MR1; MG1; MG2; MGOV2; MC2)	Human resources	Network formation and Coordination	market penetration and SG technological knowledge diffusion.		
	Socio-cultural aspects	Complementary products and services		MKTA 3	**(X)**
	Competition				

This niche strategy is based on literature and interviewees' solutions. To illustrate, the influencing conditions have a repercussion on the above-mentioned barriers as the lack of a strong network limits the knowledge share among the different actors. The competition among the big growers and the lack of shared vision with the government, is generating a barrier to knowledge share and network collaboration among the different actors. The aim of this NIS is to develop a network of knowledge sharing among the different actors, to make them understand that they are not competitors (MG1, MR1). This will be possible with the help of institutions and the need for the establishment of a national value chain to penetrate the international market. What is more the network will be made stronger once SG (or SG components) will be implemented within a slightly wider landscape, as growers will start talking about their improvement in production. This would help in reducing the skepticality of the growers and reduce the competition among them. The establishment of a strong collaborative network will help in developing more efficient complementary products and services, this is why the following NIS would have a greater impact after the establishment of a strong collaborative network.

Infrastructures and Service (INS) niche strategy

Niche-strategy	**Barriers**		**Description**	**Relevant to:**	
<u>Infrastructure and Service niche strategy (INS)</u>	Influencing factors	Building blocks	The development of water and energy infrastructure in the whole of Morocco, can provide the demand for the resources necessary for the operation of the SG.	MKT A1	**(X)**
	Natural resources	Complementary products and services		MKT A2	**(X)(X)**
(MR1; MG2; MGOV1; MC1)		Network formation and Coordination			
		Costumers		MKT A3	**(X)(X) (X)**

This niche strategy is based on literature and interviewees solutions, and it is going to have a greater impact with the successful implementation of the NTW and SUB niche strategies. The limiting factor determining the incompleteness of the Complementary products and services is the lack of a water and energy infrastructure on the national landscape. With this NIS it will be necessary for the Moroccan government to apply a plan of diversification of the water portfolio. Currently, some effort is already being put into building several water desalination centres across the country (MGOV1). However, at the moment (due to a lack of governmental support) it is up to companies to build the water infrastructure necessary to satisfy the demand

for SG operations (MC1). Thus, the establishment of a strong network and ad-hoc subsidization can help the adoption companies of this NIS.

Common market (CM) niche strategy

Niche-strategy	Barriers		Description	Relevant to:	
Common market niche strategy (CM)	Influencing factors	Building blocks	The generation of a national market can help the spread of SG on the national landscape and the establishment of a strong network among companies and faster development of CPS.	MKT A1	**(X)(X)**
	Socio-cultural aspects	Product price		MKT A2	**(X)**
(DC3; MG1; MC1; MC2; MC3)	Competition	Customers			
	Knowledge and awareness of the technology	Network formation and Coordination		MKT A3	
		Complementary products and services			

This niche strategy is based on literature and interviewees' solutions. Some of the growers do not make a switch toward sustainable greenhouses due to the lack of a final product market (e.g. quota on tomatoes). This is a customer barrier. Thus, with this NIS, thanks to the establishment of a strong collaborative network (with the NTW and INS), Moroccan growers would have to make a national association, that has direct contact with retailers in the international market and that can export directly their high-quality products and make a decent amount of profit on that (DC3). In the establishment of an association, it is important to not end up making an investment and selling the same amount of products (MC1, MC2). Furthermore, this would help in achieving a stronger network of collaboration with international customers making it easier to reach the desired requirements (MC3).

The influences between the different Niche Introduction Strategies

This section based on the data collected from the interviews explains to the reader why the NIS will have to be adopted in the presented order and what is the reasoning under the connection of the presented strategies. By implementing the NIS in the presented order their efficacy will be maximised. This is because the adoption of a certain NIS at a certain moment could facilitate the future implementation of another NIS. Figure (13) shows how the different NIS influence each other and how that promotes a positive mechanism that will encourage the technology adoption. More specifically it is shown how the adoption of the Demo and Develop and Educate niche strategies would encourage knowledge generation to overcome the hesitancy in companies and encourage the SG technology (or components) adoption. Thus, some company managers/growers would be learning through *showing* and decide to adopt Sustainable greenhouse technology or components.

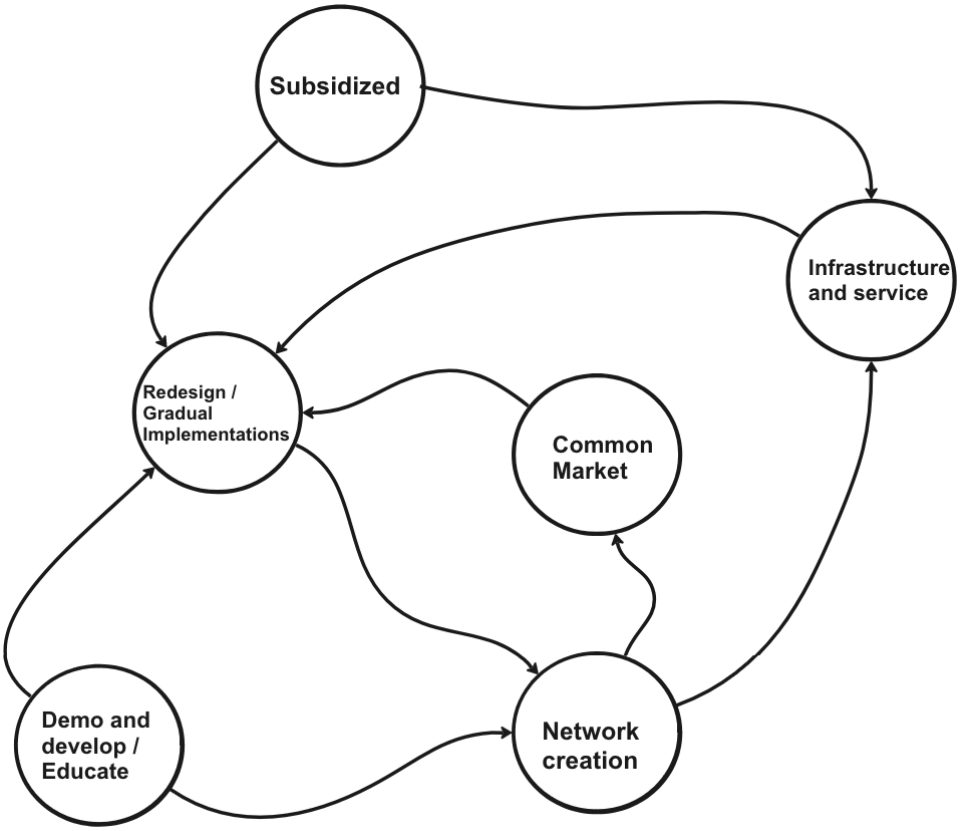


Figure 13: Visual rapresentation of the influences between the NIS developed by Ortt et al., (2015) and the author.

This would lead to the establishment of a network through the Network creation niche strategy. An initial connection among the actors is established by the DD/ED niche strategies, where many growers meet within the universities and exchange knowledge and information. A stronger network, however, is going to be established through the NTW strategy with the implementation of this technology by the market innovators (the first growers to implement the Sustainable greenhouse technology). This is because once they have implemented the technology, the neighbouring growers are going to be curious regarding the technological implementation and if convinced by its benefits decide to implement it. It is important for the success of the NTW niche strategy the implementation of the Redesign and Gradual Implementation niche strategies. As explained within the analysis in Chapter (5) the biggest barrier to the technology adoption is the high initial investment costs. Nonetheless, with the implementation of these strategies, the collaboration between universities and local technology providers can help reduce the price of the technology by encouraging local production and the development of affordable, high-quality technological components. These with the gradual implementation of the technological components, depending on the growers' needs and ROI terms, would make Sustainable greenhouses more affordable and speed up the large-scale diffusion. The government could help by speeding up the adoption of locally developed technology by introducing and spreading awareness alongside universities regarding some goal-oriented subsidies. To do so, the establishment of a strong network among the growers (NTW niche strategy) is essential for effective communication with governmental offices and the development of shared goals. A strong communicative network among the growers themselves and with the government can help in the valorisation and development of water/energy infrastructures were lacking (INS niche strategy). For instance, especially in the case of a Sustainable greenhouse for herbs production the development of an infrastructure to sustain the technology function and operations, would encourage its diffusion. Finally, the development of a strong network especially among big exporting companies would foster innovation with the generation of a common market. The Common

market niche strategy comprehends the formation of a national value chain and national exporting association that has direct contact with retailers in the international market and that can directly export their high-quality products and make a decent amount of profit on that.

Part 2: How to overcome the governmental barrier

As previously explained the NIS are usually adopted by companies (Ortt et al., 2015). However, according to Wu et al., (2013) to enhance the diffusion of the sustainable high-tech greenhouse on the national level it is necessary the formation of a network among three actors: the universities, the companies (growers/technology providers) and the government. Hence why, the author, had to develop some different strategies for the Moroccan government, to overcome the *innovation-specific institutions* building blocks barriers. The data gathered from the Dutch/Moroccan interviewees and the author's personal reflection are used to develop the following strategies.

Considering the Niche introduction strategies developed in Part 1, it seems reasonable to state that Moroccan companies should put major effort into the transition toward Sustainable Greenhouses. To do so, effective communication and a shared objective between companies and the government (MG1) are crucial to accelerate the diffusion of technology.

However, it is not solely the responsibility of companies to initiate action; it is essential for the government to develop a long-term vision. Considering the pressing water scarcity and expansion of agricultural practices, the government needs to include Sustainable greenhouse technology within their plan for more sustainable horticulture. What is more, it would be necessary to simplify the bureaucracy, making it easier for growers to access financial resources (MGOV3, MGOV4, DR1). This is currently a major issue, especially for small/medium-sized growers. Furthermore, it is necessary to collaborate with small/medium/big companies to identify the most important technologies to subsidize (MG1; MGOV4). A follow-up programme to technology adoption to ensure the correct use of the technology, especially for small/medium growers (MGOV1, MGOV4). Furthermore, improving the water portfolio by making it as diverse as possible to limit the depletion of resources is also essential (MC1). It should be ensured that farmers integrate desalinated water and other water resources too, for instance by increasing the price of groundwater. It is critical for the government to ensure respect for the land expansion limit set. Uncontrolled land expansion poses a significant barrier to technology adoption and contributes to resource depletion. If these strategies, **suggested by the Moroccan interviewees and elaborated by the author's reflection**, would be adopted by the Moroccan government the adoption of the NIS from companies would have greater results and the transition toward Sustainable Greenhouses would be accelerated.

Example of Applications of the NIS for Sustainable Greenhouse for tomato production

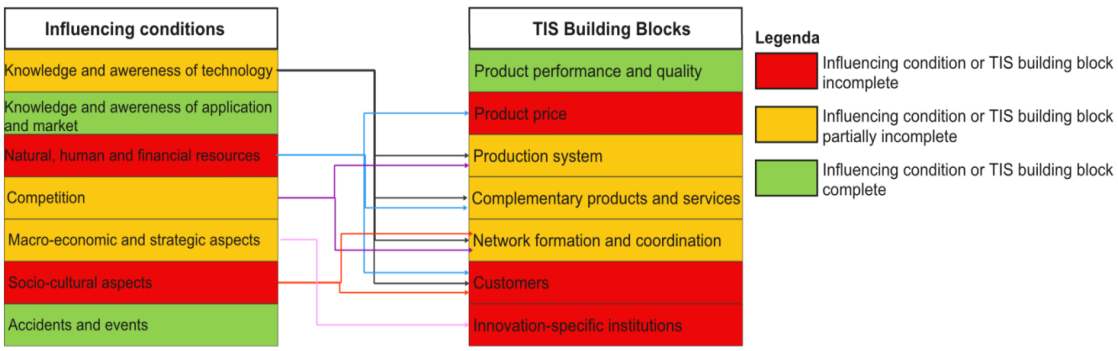


Figure 14: Building blocks and influencing conditions status of Sustainable greenhouses for tomato production before NIS adoption.

This section visually presents to the reader the gradual implementation of the Niche introduction strategies to overcome the barriers to Sustainable greenhouse market applications large-scale diffusion in Morocco. Due to time constraints, the application of the strategies is depicted only for Sustainable greenhouses for tomato production (Market application 1). As shown in Chapter (5), Figure (14) represents the status of the barrier and influencing condition for this specific market application prior to the adoption of the Niche introduction strategies. Once the Demo and Develop and Educate strategies have been implemented the Knowledge and awareness influencing condition is turning complete (Figure 15). In fact, this NIS aims at solving primarily the lack of know-how which is increased by showing to the customers how the technology works and what benefits they could gain from its implementation. The Customer's building block is influenced by the knowledge factor, due to the fact that many growers do not implement the technology because hesitant about its benefits and because of the lack of knowledge about its function and operations. This results in partially solving the customer's building block.

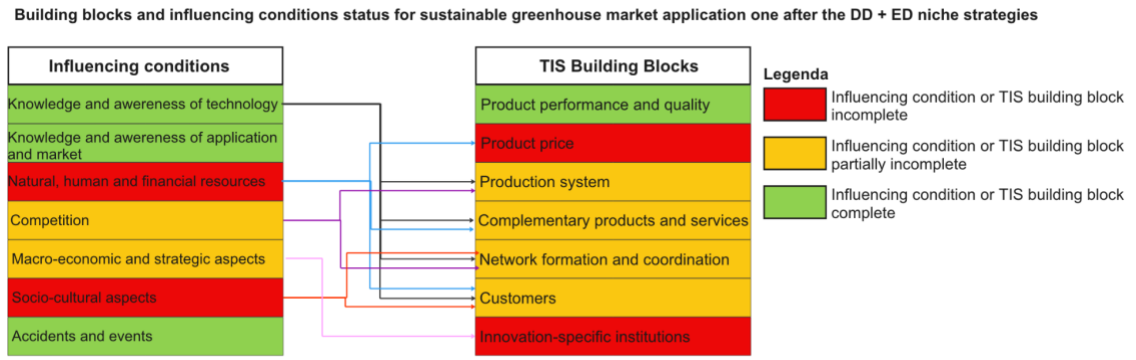


Figure 15: Building blocks and influencing conditions status of Sustainable greenhouses for tomato production after DD + ED NIS.

The implementation of the Redesign and Gradual implementation of niche strategies impact two influencing conditions (Figure 16). Firstly, the Natural, human and financial resources. The development of a locally produced Moroccan technology, adapted to Moroccan conditions and available resources, limits the costs related to imports and exploitation of locally scarce resources necessary for building greenhouses. Therefore, with the Redesign niche strategies the costs of the technology are going to be lower because it won't have to be imported and because some cheaper alternatives could be developed. Similarly, for this influencing condition, the Gradual implementation niche strategy plays a key role. In fact, by encouraging the small/medium growers to gradually implement (depending on the ROI) the locally developed technology or the imported one, more growers would be available to switch to Sustainable greenhouses. By partially solving this influencing condition, the product price will not be a challenging barrier to overcome.

The Sociocultural aspects are significantly influenced, particularly by the Gradual Implementation niche strategy, as it allows for a gradual introduction of economically feasible components in greenhouses. This approach enables farmers to overcome skepticism towards unfamiliar technologies by gradually implementing and learning from their experiences. Consequently, this strategy contributes to the resolution of the *network formation and coordination* building block.

For instance, if a grower adopts water management technologies while a neighbouring grower implements climate management technologies in their respective greenhouses, over time a network for exchanging knowledge can be established. This gradual and collaborative approach fosters the sharing of experiences and expertise among growers, enhancing the network formation and coordination within the industry.

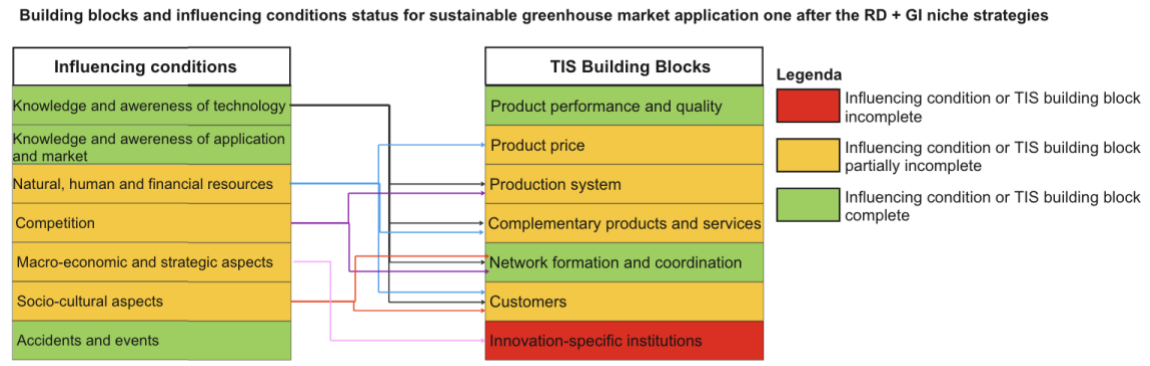


Figure 16: Building blocks and influencing conditions status of Sustainable greenhouses for tomato production after RD + GI NIS.

By introducing the Subsidized niche strategy and some of the presented governmental strategies the Macro-economic and strategic aspects influencing condition gets solved (Figure 17). The niche and governmental strategy will aim at speeding up the bureaucracy and encouraging the development of a shared governmental long-term vision for bringing sustainability within Horticultural practices. Moreover, the Subsidized niche strategy, helps in fostering innovation by developing and providing goal-oriented subsidies for growers. By solving this condition, the *Innovation specific institutions* building block gets partially solved.

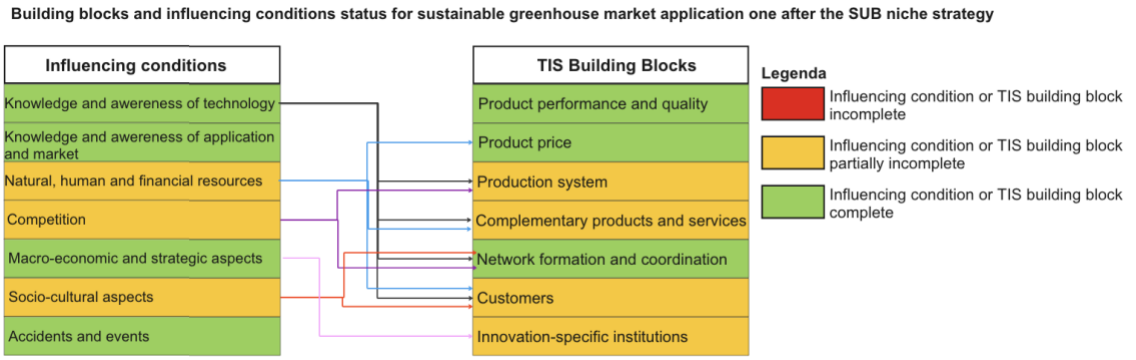


Figure 17: Building blocks and influencing conditions status of Sustainable greenhouses for tomato production after SUB NIS.

The implementation of the Network Creation niche strategy is intended to address the Socio-cultural aspects influencing condition (Figure 18). Although the introduction of the DD + ED niche strategies partially addresses this condition, establishing a robust cooperative network facilitates the rapid dissemination of knowledge among growers. Furthermore, this NIS promotes collaboration among companies and enables effective communication with the government as a unified entity. While the establishment of a strong network does not directly resolve a specific building block, it greatly enhances the likelihood of success for future niche introduction strategies.

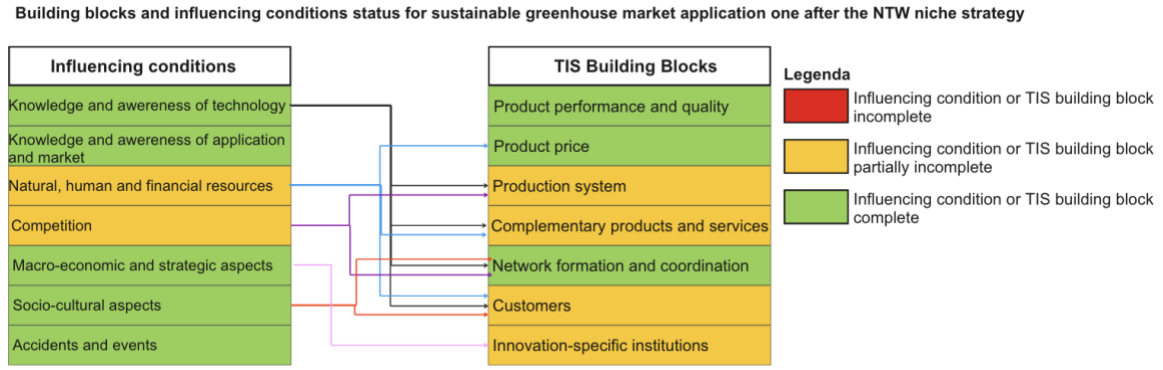


Figure 18: Building blocks and influencing conditions status of Sustainable greenhouses for tomato production after NTW NIS.

The introduction of the Infrastructure and Service niche strategy aims at solving the *Natural, human and financial resources* building block (Figure 19). This is not as an important strategy for Sustainable greenhouse for tomato production diffusion, because the production of this crop is located mostly within the Souss-Massa region which is extensively connected by a relatively good water and energy infrastructure to support the technology operations. However, the application of such strategy could help in this case in the maintenance operations of the infrastructure and to complete its expansion in the region. The solving of this influencing condition for this market application aims at solving the *complementary products and services* building block.

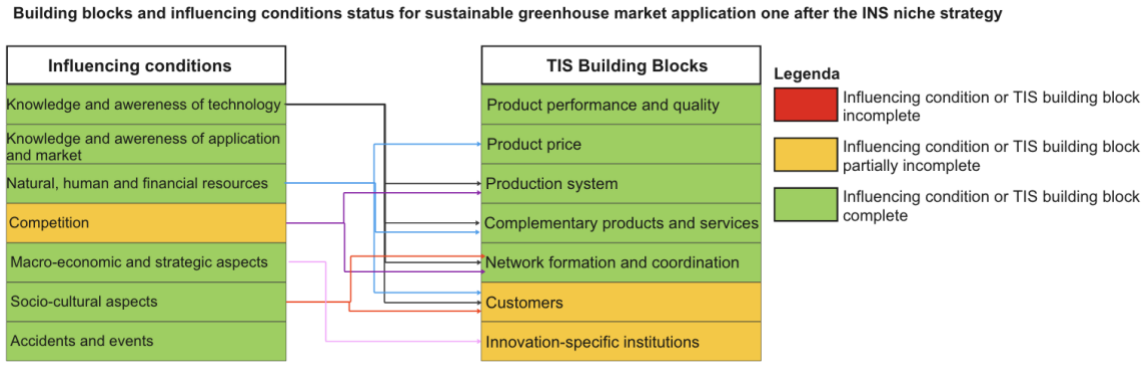


Figure 19: Building blocks and influencing conditions status of Sustainable greenhouses for tomato production after INS NIS.

Finally, the introduction of the Common market niche strategy targets the *competition* influencing condition. Especially for such market application, there is growing competition regarding the quantity and the price of the product sold to the international market. This limits the diffusion of the technology as it limits the knowledge share among the market application 1 company. By introducing the Common market strategy Sustainable greenhouse companies can collaborate in the development of a national value chain and of an association under which it is possible to export the produced products together on the international market increasing their profit margin. What is more, by having developed a common market for tomato production, the hesitancy toward the adoption of Sustainable greenhouse technology will be decreasing. Due to the growing interest from Moroccan companies to expand their market influence, not being limited by the quota (last point for which the Moroccan government needs to take action by entering into negotiations with foreign governments). As Figure (20) by solving the competition condition, *the customer* building blocks for this market application gets solved.

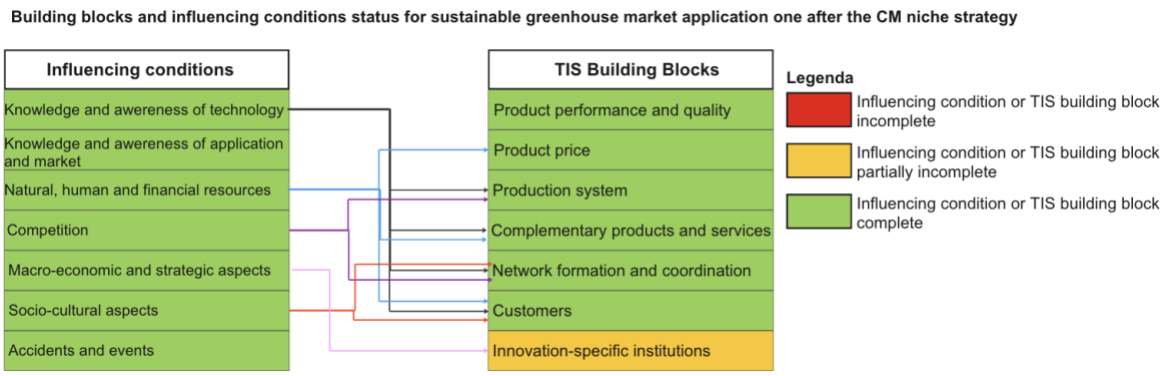


Figure 20: Building blocks and influencing conditions status of Sustainable greenhouses for tomato production after CM NIS.

It can be noticed how the application of the presented NIS is not enough for the Sustainable greenhouse companies for market application 1 to solve all the TIS barriers and achieve nationwide diffusion. This is primarily due to the need for governmental intervention in addressing the *Innovation-specific institutions* barrier. The Moroccan government would have a crucial role to play in implementing the Subsidized niche strategy developed for companies, particularly considering that the implementation of the technology for this market application might pose greater challenges for smaller and medium-sized growers. By providing financial support and economic incentives the government can help overcome the institutional barrier that hinder the widespread adoption of Sustainable greenhouse technology. Additionally, the government's involvement in knowledge dissemination, capacity-building programs, and policy reforms can contribute to creating an enabling environment for technology diffusion. Therefore, the collaboration between Sustainable greenhouse companies and the government becomes vital to effectively address the TIS *innovation-specific institutions* building block and ensure the successful diffusion of the technology at a national scale in Morocco (Figure 21).

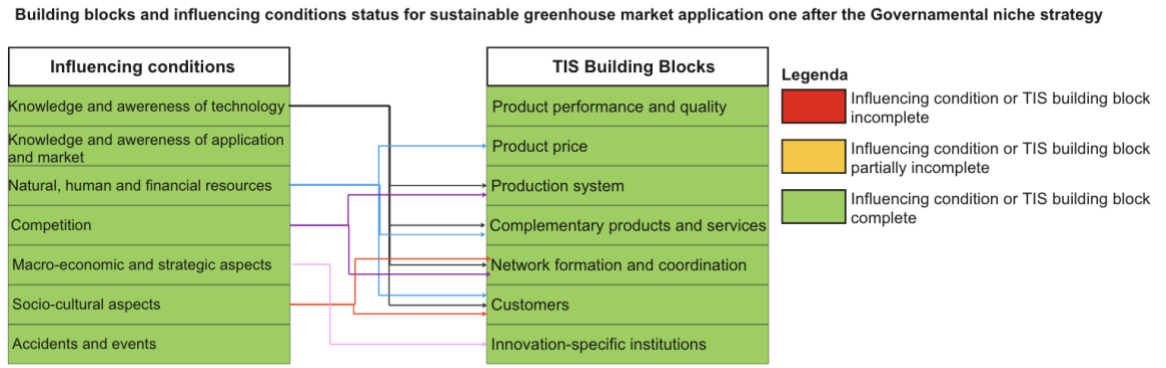


Figure 21: Building blocks and influencing conditions status of Sustainable greenhouses for tomato production after government interventions.

Chapter 7: Reflection on the application of the TIS framework

In this chapter is going to be answered the fourth and last sub-question:

How effective is the TIS framework in the analysis of the context around Sustainable Greenhouses companies in Morocco?

To answer this sub-question, the chapter is divided into two sections. The first one, presents the author's reflection on the use of the building block framework for the same technology, in this case, for sustainable greenhouses but for three different market applications. The second one raises a more general reflection on the strengths and trade-offs of the TIS.

TIS for the same technology but for different market applications

As mentioned in Chapter (3) the TIS framework by Ortt and Kamp (2022), provides companies and scholars the tools to comprehend the dynamics of technological innovation within a broader system perspective. Thus, it investigates the complex interactions between actors and factors to understand how a breakthrough technology emerges, develops and diffuses within the socio-technical context (Ortt & Kamp, 2022). Nevertheless, in some cases, the framework is used to analyse the technology for one market application only. Sometimes this is because the innovation could not be used for more than one market application, like in the case described in the paper of Ortt and Kamp (2022) for Dual-Clutch technology (DCT). However, in some cases, like for Sustainable Greenhouses (SG) or for Photovoltaic cells (PV) the technology could be applied in different markets. For instance, PV panels gather energy for residential rooftops and even power transportation.

Sustainable Greenhouse is another technology for which TIS analysis **requires different market applications.** Although the technology is the same, the internal structure of the greenhouse changes so does its relative operations. This leads to a different type of knowledge of operations required, a different type of production system within the greenhouse, a different type of product price and final product profit margin and a different availability of the components. Thus similarly, for how has been carried out for Sustainable greenhouses, due to the dynamicity and complexity of the socio-technical system the same technology may have different barriers for two or more market applications, hence requiring two separate TIS. Thus, as shown in Chapter (5), depending on the market applications the influencing conditions can have a greater/smaller hold on the building blocks, leading to the formation of a stronger or lower barrier to technological diffusion. To refresh the reader, it could be made the example of a Sustainable greenhouse for tomato and herbs production (Market applications1 & 3). In the case of Sustainable greenhouse for tomato production, there is a stronger network established among companies and growers and there is a greater push by the government and international actors in the establishment of a strong network of knowledge share to boost the diffusion of the technology. This is not happening at the same degree for Sustainable greenhouses for herbs production. In fact, the establishment of a knowledge share network for this market application would be an indirect advantage from the building of the same network for the same technology but for a different market application. This is because, for this last market application, there is a greater hold from the governmental actor which has not as a main priority the diffusion of Sustainable greenhouses within this market application. What is more, for a sustainable greenhouse for herbs production, it would be harder the establishment of a stronger network of the necessary components to ensure the running of operations. This is due to economies of scale and the lack of governmental push for this market, which may impose an extra limit or challenge to the availability of specific technological components. The differences in the factors and the status of the *network formation and coordination* building block is a noteworthy example of how for this study it was necessary to include the TIS analysis for more market applications and how each sustainable greenhouse market application has unique characteristics, requirements and challenges to be borne.

A further point, regarding the importance of different TIS for different market applications, relates to the **generalizability** of the results. If this research would have been conducted for the case of Sustainable greenhouses for Tomato production only, the reader could have generalized the results for other market applications underestimating the presence of a barrier. Whereas, with the TIS analysis for the three different market applications, not only a tomato producer, but even a Moroccan herbs grower can get a more specific understanding of the status of the barriers for the market application he is interested in. Additionally, the evaluation of the barrier for the different market applications has led to the development of specific NIS, of which some of them might be more relevant for some technology applications rather than others (as shown in Chapter 6). Thus, the **specificity** rather than generalizability of the NIS allows a more efficient allocation of time and resources. Finally, due to the delicate Moroccan environmental situation, the analysis of different market applications highlights the author's interest in the reader (especially if is a Moroccan grower) understanding if the technology is the best solution for their specific case.

Here are going to be discussed the **advantages and disadvantages**, of the use of the building block framework, for the same technology but for different market applications. Firstly, are going to be analysed the positives aspects. In this specific case, the TIS has been used to analyse Sustainable greenhouses for three different market applications. This allowed the researcher to interview a wider range of stakeholders, coming from different backgrounds and perspectives. Hence to gather enough data to frame a wider picture of the technology and the socio-economical aspects around it. For instance, if the author, would have limited the study for SG for Tomato production then he would have not interviewed MG2. Preventing the data collection process to gather information regarding the lack of unskilled labour and the lack of subsidies targeted for small/medium growers. However, the analysis of innovation under different market applications also has disadvantages. One of them could be the inability to further dive within the research due to certain limiting factors, such as time. For example, in the NIS due to some limiting factor (e.g. time and space), it is shown the barrier status only for the most important market application for Sustainable greenhouses. Moreover, gathering data for multiple market applications can be complex, as some of them might be less popular, hence slowing down the data collection process. Although in some cases, some data collected could be applied to multiple market applications, the author many times has to face some trade-offs as is not always feasible to address the different market applications simultaneously. Even though, as mentioned, the investigation of multiple market applications allows the entail of a greater picture, sometimes it can be complex to engage with a diverse set of stakeholders. Especially in the case of this study, where there have been interviewed at least one actor per stakeholder group to have a complete picture for the TIS analysis. Finally, the research process needs to be adapted to the analysis of multiple market applications for the same technology. In the case of this research, this was done since the beginning, by collecting literature data for the most suitable market applications for sustainable greenhouse technologies in Morocco. Further on throughout the interview process questions were asked to the interviewees, like: '*Could you name some market applications for Sustainable Greenhouses? Do growers know for what application to use the technology and know-how to grow this product?'.* These types of questions have helped the author in collecting some primary data regarding the market applications and checking if there is any alignment with the available literature. Once a wide range of data was collected from different stakeholders, the most feasible market applications for Sustainable greenhouses were selected. The implications started when the author had to categorize the data collected for the different market applications. This was because the information had to be easily understandable and visualizable for the reader. A way to overcome this obstacle was the implementation of tables throughout the analysis process. The tables had a double objective, firstly to highlight the barriers/factors for the singular market applications. Secondly, as a summary for the reader to gain a more straightforward idea of which were the key take-out for each market application.

The same method has been used for the NIS, where each one of them was mostly relevant for each singular market application.

General Reflections on the TIS

Within this section, a more general reflection of the building block framework by Ortt & Kamp (2022) is presented. As mentioned, the TIS framework helps in understanding the context around innovation through the analysis of the seven building blocks and influencing conditions. Overall the framework in practice has demonstrated great ability in capturing the dynamicity and complexity of the socio-technical system. However, after having carried out a study with the use of such a framework, the author has identified some points for improvement.

Firstly, as already mentioned in the previous section, the paper written by Ortt & Kamp (2022) is very straightforward, as it guides the reader in the practical understanding of how to use the framework with two case examples. The paper does not mention how the study should be conducted in the case of an investigation for the same technology but for different market applications. Keyout, that could be helpful to expand the area of the relevance of the framework. Because the same technology with different market applications might have different TIS, thus different barriers to the large-scale diffusion of the technology within the market. Similarly, it goes for the lack of guidance in the choice of the status (e.g. complete, partially complete, incomplete) of the building blocks and influencing conditions. Leaving the choice to the author's perspective the labelling of building blocks as a barrier. This in the long run, according to the author's opinion, might hamper the validity of the framework. Thus, it would be suggested implementation of a yardstick of judgement to develop an objective guideline for the future framework users so that the building block/influencing conditions status evaluation would be more impartial.

Secondly, the current framework **lacks in explicitly addressing the environmental factors** of innovation as a distinct building block or influencing factor. The framework is relying on the indirect capture of some sustainability-related aspects within the building blocks and influencing factors. The accountancy of the sustainability within an innovation could be included within the '*Product performance and quality'* building block, which could include some criteria, like for the case of Sustainable greenhouses, the water and energy efficiency. Or within the '*Macro-economic and strategic aspects'* influencing condition, with the inclusion of governmental policies or economic incentives to promote sustainability. However, with the pressing effects of climate change and the increasing need for mitigative technologies. The environmental aspect cannot be undervalued when developing and analysing the technology diffusion on the national scale. Especially because, according to the author, the lack of sustainability aspects within an innovative technology can seriously hamper its diffusion of it on the national landscape. For instance, in the specific case of Sustainable greenhouses in Morocco. If the technology would have not fit within the sustainability requirements, it could not be a solution for Morocco. This is because there would be a lack of a final product market, as the international market could be sold products which fit within the sustainability regulations set by the importing countries. Moreover, if the technology would have not been sustainable it would have not limited the use of water, which is the first reason the Moroccan government for the technology implementation.
Therefore, this could be seen as a potential limitation of the TIS framework. Fortunately, this limitation could be overcome by the author's framework in **four different ways**. Firstly, a new building block could be introduced, which could be named '*sustainable development'*. The characteristic of this building block is that it explicitly integrates sustainable considerations throughout the process of technological innovation. This building block could ensure that the innovation is aligned with the national/international sustainability targets and could contribute to the national long-term sustainability goals. The building block would be incomplete/missing if it does not reach the sustainability requirements, thus a barrier could be formed, and further work would be needed to solve it. The inclusion of such building block could encourage companies in thinking proactively and directly (rather than indirectly for another building block)

in contributing to sustainable development and resource optimization. Secondly, the author could expand an already existing building block to explicitly include sustainability. For instance, the '*product performance and quality* 'could be changed to '*Product performance, quality and sustainability*' this would ensure the integration of the sustainability aspect, although in minor terms. Thirdly, the sustainability considerations could be made more explicit with the introduction of a new influencing condition, in a similar way as the one proposed for the development of a new building block. Finally, the limitation could be overcome by using the framework alongside another sustainability framework such as a social-LCA or the triple bottom-line framework. In any of these four cases, it would be highly recommended for the TIS framework authors to collaborate with sustainability experts and seek inputs to refine and enhance the framework on how sustainability could be included in it in the most effective way possible. With the incorporation of one or more of the suggested measures, the framework could be easily adapted to overcome its potential limitation, which limits the consideration of the sustainability element within a breakthrough technology by companies.

Thirdly, in this study, the use of the TIS framework was more complex than usual. On the one hand, because of the analysis of Sustainable greenhouse for multiple market applications. On the other, the introduction of such breakthrough technology within the Moroccan national market is caused by the **technology transfer** from the Netherlands to Morocco. The push of the Netherlands for the technology implementation in Morocco is not minor. Therefore, the TIS framework had to be used meticulously to embody relevant data. That is because the TIS evaluates technological diffusion **at a national leve**l. Thus, in this case, the framework was not taking into account the technology transfer between the two countries, therefore it had some limitations in the identification of the contextual differences among the Netherlands and Morocco. Some examples of cultural differences were the differences within the political systems and cultural norms. However, these limitations were overcome by the author with the inclusion of the Netherlands first in the stakeholder analysis (Chapter 4), then in the inclusion of both Moroccan and Dutch stakeholders throughout the primary data collection process, to not have a one-side perspective of the story and lack of barrier validation. As already mentioned above, this has led to a limited amount of actors interviewed per stakeholder group but simultaneously the capturing of more diverse perspectives. What is more, the analysis of the building blocks and influencing conditions had to be adapted in the writing style to ensure the reader's understanding of the discrepancies and agreements between the two nations in the statements for the evaluation of the TIS components' status. With the adoption of this measure, the author has deepened the analysis by considering two-sided perspectives and has expanded the area of relevance of the framework, as the role played by the international actors in the technology transfer is a key component for the speed-up of the technology diffusion and solving of the barriers. However, it was not always possible for the author to include some aspects of the motivation of the Netherlands for the technological adoption which did not refer to the economic aspects, but to national strategies. An example of this is the topic of *Green Colonialism*, which is discussed in the conclusion of the study and not considered within the TIS analysis. At this point, it is important to note that if the study's goal would have been to investigate the technological transfer only and the relations of the two countries the TIS framework would not be enough. In any case, since the purpose of the research was not to investigate this, it is statable that the TIS framework possesses enough capacity to capture the international influences for Sustainable greenhouse diffusion in Morocco. The TIS capacity to do so has to bear in mind the inclusion of multiple perspectives from a diverse range of actors to develop a more comprehensive analysis of technological transfer alongside technological diffusion.

Fourthly, with the aim of primary data gathering the author had to develop specific questions regarding the building blocks and influencing conditions depending on the interviewed actor. Sometimes when more general questions were asked, such as: '*Can you think of any barrier to the large-scale diffusion of sustainable greenhouses (SG) in Morocco?'.* The interviewee was limiting himself by mentioning only one barrier. Therefore, some barrier-specific follow-up

questions investigate the presence of some other obstacles to diffusion. An example is: *'Do you believe that the high starting costs could be a barrier? Will the change in technology affect the product price?'.* Thus, it was up to the author to have extra care not to overestimate the presence of certain barriers.

In conclusion, when analysing the socio-technical system around a breakthrough innovation there are a lot of factors to consider. However, the TIS framework by Ortt & Kamp (2022) manages to capture their dynamism with great accuracy from a company perspective.

Chapter 8: Conclusion & Discussion

This chapter aims at answering the main research question, to do so an overview of the four sub-questions is presented. Furthermore, this chapter reflects on the theory of Green colonialism related to the diffusion of sustainable greenhouses in Morocco. Finally, it concludes with an analysis of the study's limitations and the author recommendations for further research.

8.1 SQ1:

What could be the barriers hampering the large-scale diffusion of Sustainable Greenhouses in Morocco?

By answering this sub-question the author has identified through the use of desk research and primary data collection and analysed with the TIS framework, by Ortt & Kamp (2022), the barriers hampering the large-scale diffusion of the three different market applications of Sustainable greenhouse in Morocco. The *greatest barriers* to overcome are summarized in the following Table (32):

Table 32: list of the biggest Sustainable greenhouse large-scale diffusion barriers

Barriers	Explanation
Product price	High initial investment costs, long ROI
Innovation-specific institutions	Lack of long-term vision and shared vision with other Moroccan actors.
Customers	Are hesitant toward the adoption of a new innovation
Network formation & coordination	Lack of collaboration among the big exporting companies
Complementary products & services	For some market application is not present the infrastructure to supply the Sustainable greenhouse with the required water and energy.

Be noted, these were not the only obstacles to the diffusion of sustainable greenhouses in Morocco, as the scale of these barriers depends on the different market applications. From the analysis carried out in Chapter (5), it could be seen that Sustainable Greenhouse for market application 1 presents fewer barriers to large-scale diffusion. Apart from the international incentivization, this is because the Moroccan growers have more experience with this crop, thus they have more knowledge. Sustainable greenhouse for all of the three market applications do not present a barrier within the *product performance and quality* building block, this is because the technology meets the necessary requirements to compete with its market competitors. Regarding the *Product price* building block, this is the **biggest** barrier for all three market applications. Because on one side there is a rising price in material costs and on the other side growers are facing a smaller return with the current horticultural production, making it harder to save up for a future technological switch. For these reasons, 99% of the growers do not possess enough capital for an immediate technological switch and cannot get easy access to mortgages or government funding (Tailored niche introduction strategy presented in 8.3). This last issue brings us to the *Innovation-specific institutions* building block. Barrier to large-scale diffusion for all three market applications, is generated by the lack of long-term governmental vision leading to the lack of goal-oriented subsidies and legislation. Due to these barriers within the building block, it is evident that it is missing real and strong economic support to encourage the technological switch from the government. Contradictory point because there is a great interest and effort put by the Moroccan government in the introduction

of Sustainable greenhouses. Another barrier is present within the *Customer* building block for all three market applications, caused by the hesitancy toward the adoption of the technology because of the high product price and lack of knowledge regarding the technology. Another obstacle within this building block which represents a major barrier for Sustainable greenhouse for tomato production (MKTA1) is the lack of a final product market. With the quota on the export of tomatoes, many Moroccan growers refuse to adopt the technology because incapacitated to sell their final product. What is more, the difficulty to sell the final product abroad is caused by a barrier present within the *Network formation & Coordination.* This is the lack of collaboration among the different companies, preventing them to develop a national value chain and a selling association to penetrate together the international market. This with the lack of alignment between the companies and the government encourages the formation of another obstacle to Sustainable greenhouse large-scale diffusion for all of the three market applications.

To conclude, it **would be recommended** to the reader that wants to gain a deeper insight into the different building blocks to read Chapter (5). It is important to note that a greater amount of primary data was collected for Sustainable greenhouse for tomato production (MKT1), thus the barriers for this market application are the most validated ones. In the following chapter, which answers Sub-question 2, the author takes a closer look at the factors influencing barrier formation.

8.2 SQ2:

What is the status of the influencing conditions that are impacting the incomplete building blocks?

The purpose of this sub-question was to evaluate the influencing factors impacting the status of the building blocks, thus, understanding the factors causing the barriers for the different market applications determined in SQ2. It was of **utmost importance** for the research, to cautiously analyse these influencing conditions, as they were providing fundamental elements for the understanding of the underlying causes for the barrier formation and to better develop the Niche introduction strategies. Similarly, to the previous sub-question, the TIS framework by Ortt & Kamp (2022) is used, as well as primary and secondary data collection for the validation of the factors. The *greatest influencing conditions* impacting the barriers for the different sustainable greenhouses market applications are summarized in Table (33) below:

Table 33: List of the main influencing factors affecting the status of the barriers to large-scale diffusion

Influencing conditions	Explanation	Influenced barriers
Knowledge and awareness of the technology	There is a lack of knowledge on how to use the technology for specific market applications	Production system, Complementary products and services, Network formation and coordination, Customers
Natural, human and financial resources	There is a lack of skilled/unskilled labour force as well as a lack of capital of investment	Product price, Complementary products and services, Customers
Socio-cultural aspects	There is a lack of long-term perspective	Network formation and coordination, Customers
Competition	There is a strong competition with low land costs	Production system, Network formation and Coordination

To be noted, these were not the only influencing conditions to the barriers of diffusion of sustainable greenhouses in Morocco, as the scale of influence of each factor was varying

depending on the different market applications. For instance, **because there is a greater push** for sustainable greenhouse adoption for market application 1 there is a greater knowledge of the technology for the *knowledge and awareness of the technology (KNAW)* component. However, for Market Application 3 this building block has a greater influence on the *customer's* building block. In any case, despite their degree of influence the KNAW component surely impacts the Customers because the lack of knowledge within the technology increases the skepticality toward the adoption of the *customers* and prevents the knowledge share among the different actors leading to a barrier formation in the *Network formation and coordination* building block. The *Natural, human and financial resources* component has a strong influence on all three market applications. This is because the lack of human skilled/unskilled workforce makes them more expensive for companies to hire people. The lack of natural resources instead has an impact on the product price because the material price will rise similarly goes for water or gas if the government decides to build further infrastructures to sustain the Sustainable greenhouse operations (Complementary products and services building block). The *Socio-cultural aspects* influencing condition which is relatively a strong influence for all three market applications, because it is affected by the high age of the growers. It has an impact on the customers as some growers are not aware of the benefits that the technology could bring them and might prefer to go for a shorter-run alternative (which in most cases is not sufficient). This component has an impact on the Network formation and coordination building block, especially for Sustainable greenhouse for tomato production (MKTA1), as companies are prevented from establishing a strong network among themselves. The competition is fairly strong for Sustainable greenhouses, many companies prefer to purchase further land or to go for smaller technological improvements. This has an influence mainly on the *production system* as with a lower technological adoption, there will be a slowdown in the development of national technology due to the decrease in demand.

In conclusion, it **would be recommended** to the reader that wants to gain a deeper insight into the different influencing conditions to read Chapter (5). However, the study of the influencing conditions has provided the author with enough data on the context around the barrier to develop more specific Niche introduction strategies. These were developed with the answer in Sub-question 3, which is investigated in the following section.

8.3 SQ3:

What could be the potential niche introduction strategies to be adopted by Sustainable Greenhouses companies to overcome these barriers?

After having analysed the context around innovation, the following sub-question aims at formulating the most fitting Niche introduction strategies that will give companies some guidelines on how to overcome the presented barriers and prepare for large-scale diffusion. As for the other sub-questions, the strategies are formulated for the three different market applications of sustainable greenhouses. In Chapter (6), the strategies for adoption have been divided into two parts, one company oriented and another governmental. To speed up the technology adoption/diffusion strategies designed for companies are not enough. For this reason, according to the author, a clarification of what strategies the government had to adopt was needed. As already mentioned, some of the strategies were used from the paper of Ortt et al., (2015) others were specifically developed for this case by the author. However, this **study has been pushed one step forward** by emphasizing the influences between the different Niche introduction strategies. Additionally, these cannot be introduced in random order, but rather following a precise order to ensure the greatest probability of success of the individual strategies. The first ones to be introduced are the Demo and Develop (DD) and Educate (ED) niche strategies, these need to be adopted simultaneously to build showcase demonstration greenhouses within universities and demonstration centres to generate interest and develop know-how abilities through **showing**. Then the Redesign (RD) and Gradual

implementations (GI) strategies have to be adopted to ensure both the design of Moroccan technologies cheaper to build and suitable to the country's environmental conditions. What is more the GI strategy, would lead to a step-by-step implementation which is feasible for 99% of the growers, with low ROI times. This strategy could be joined by the *Subsidized* niche strategy (SUB), for the development of tailored subsidies to speed up the technology adoption. Once the Moroccan actors have gained enough know-how from the DD and ED strategies, it is key to adopt the Network creation strategy (NTW), this would help in developing among the different growers a network of knowledge share, which will give a further boost in the technology diffusion. Furthermore, with this strategy, a **decentralized knowledge creation environment** will be established, which will make fertile ground for the adoption of the other two strategies: *Infrastructure and service* (INS) and *Common Market* (CM). Fundamental for the development of infrastructures to sustain the running operations of the greenhouses and the generation of a national market for international products trade.

As mentioned, the above strategies have to be adopted by companies. However, further action is needed from the government to encourage technology diffusion and speed up the overcoming of the barriers. These comprehend a shared vision between the companies and the government, the simplification of the bureaucracy, and the development of a follow-up programme to technology adoption to ensure the correct use of the technology. In conclusion, it **would be recommended** to the reader that wants to gain a deeper insight into the different niche introduction strategies to read Chapter (6). It is worth noticing how the strategies focus majorly on **education/knowledge share through showing** and the development of **clear and goal-oriented** subsidies from the government side.

8.4 SQ4:

How effective is the TIS framework in the analysis of the context around Sustainable Greenhouses companies?

The aim of this sub-question was to reflect on the use of the TIS framework by Ortt & Kamp (2022) for the case of sustainable greenhouse large-scale diffusion in Morocco. For the first time, it is analysed the effectiveness of the TIS framework for multiple market applications and in the case of technology transfer from one country to another.

Firstly, it is summed up the reflection of the first point. As already mentioned in Chapter (7), for the case of this study there were required different TIS frameworks to analyse the various market applications of the same technology. This method is not always applicable but has found relevance within this research because although the technology is the same, the internal structure of the sustainable greenhouses and their operations were changing. Leading to a different type of knowledge of operation and production systems required per market application. By doing this the author has managed to expand the area of validity of the research, therefore increasing the study's generalizability capacity. Additionally, this allowed the researcher to interview a wider range of stakeholders, key to have a wider picture of the technology and the socio-economic aspects around it. However, this required an adaptation of the framework, data collection, data analysis and writing process (further explained in Chapter 7).

Regarding the second point, because the Sustainable greenhouse technology is pushed toward adoption from the Netherlands to Morocco it was important to analyse the effectiveness of the TIS in the case of technology transfer. To do so, the conduction of interviewees with more stakeholders (from both the Netherlands and Morocco) has guaranteed more diverse perspectives and enhanced the quality and quantity of data collected. Similarly, for the previous case, the data collection, data analysis and writing process had to be adapted. Specifically, major attention has been put to the writing process as the author had to highlight the discrepancies and agreements between the two nations. As explained in Chapter (7), the

TIS framework for this case was quite effective, as the international factors could fit within the influencing conditions. However, if the study's goal would be to investigate the technological transfer the TIS framework would not be enough. In any case since the purpose of the research was not to investigate this, it is statable that the TIS framework possesses enough capacity to capture international influences for Sustainable greenhouse diffusion in Morocco.

If the effectiveness of the framework is to be analysed, it is necessary to address its limitations. The first limitation pertains to the necessity of inclusion of various market applications for the same innovative technology within the paper by Ortt and Kamp (2022). This would involve explaining when and how the TIS can be used to study different market applications, along with providing guidelines. The second limitation involves the incorporation of a yardstick of judgment to develop an objective guideline for future framework users. This would ensure a more impartial evaluation of the status of building blocks and influencing conditions. The third limitation is the inclusion of a new building block or influencing conditions that explicitly address environmental factors. Chapter 7 presents four different implementation options for this purpose. Currently, the framework relies on indirectly capturing sustainability-related aspects, which restricts the consideration of sustainability concepts in new technologies by companies.

In conclusion, this section provides an overview of the analysis conducted to evaluate the effectiveness of the TIS framework in this study. If readers wish to dive further into this topic, **it is recommended to refer to Chapter (7).** Overall, the TIS framework has demonstrated a remarkable ability to capture the dynamic nature of various factors, making it an ideal tool to address the research question. However, it is strongly advised that the authors of the framework consider the recommendations for improvement, as they would contribute to expanding the framework's relevance.

8.5 Main Research Question:

How can Sustainable Greenhouses, for horticulture, diffuse on a large-scale in Morocco?

By answering the presented sub-questions, the author has identified the barriers to large-scale diffusion for each of the three market applications, has evaluated the factors influencing the barrier formation and has developed some Niche introduction strategies to help companies overcome the obstacles to diffusion. However, from the conducted analysis it can be statable that the barriers that Sustainable Greenhouse companies would have to overcome to diffuse on the Moroccan national level are not a few. This was supported by building block analysis, conducted in Chapter (5), which indicates how most of the framework components are incomplete, due to: the limited access to resources, the lack of knowledge and expertise, the limited demand for sustainable high-tech greenhouse products and the limited access to financing options making it hard for companies to access to secure funding to support the implementation. All of these are elements that are having a detrimental impact on the plan of technology large-scale diffusion in the short-run.

The application of Sustainable greenhouse for tomato production would find an easier way within the Moroccan market. This is because the knowledge transfer between the Netherlands and Morocco has started for the implementation of such technology specifically for the case of this market application, to sustain the European tomato horticultural production within the winter period. Moreover, the network of knowledge sharing regarding this market application is more established. In any case, apart from the numerous amounts of the mentioned barriers to be overcome, this application presents another problem which resides within the end-costumers, because of the quota. From this research, it appears that there is a lack of a final product market, as the importing countries (such as the EU) have developed a quota to protect their local production. Therefore, many Moroccan growers decide to not implement

sustainable greenhouses for this market application, because if they do not export their produced products, they will never be able to have a return on the investment made.

Beyond this market application there are two additional potential uses for sustainable greenhouses, but these face more significant barriers to widespread adoption. The first application is sustainable greenhouse cultivation for soft fruit production (market application 2). Although this application could be beneficial for producing high-value crops, the market for soft fruits is already saturated. Consequently, less emphasis has been placed by the government and stakeholders on developing a network for knowledge sharing and acquiring the necessary expertise to effectively operate such operations.

The second potential application is sustainable greenhouse for herb production (market application 3). However, this particular application encounters the greatest obstacles to large-scale diffusion. The primary challenge lies in the lack of water and energy infrastructure in the main production areas. Additionally, the costs associated with transitioning to greenhouse cultivation for herbs would only be justified if a market for the final product is sufficiently established.

When discussing horticultural production in water-scarce countries like Morocco, the question arises: Can the implementation of sustainable greenhouses limit water consumption while still increasing or maintaining food production levels? While this study does not provide a definitive answer, there is significant controversy among the interviewed actors regarding this issue.

Some actors believe that given the limited water resources, Morocco should refrain from producing and exporting horticultural products and instead focus on being an exporter of technology and knowledge. On the other hand, there are actors who disagree with this viewpoint. They believe that Morocco should continue producing and exporting horticultural products, even in the face of water scarcity. They argue that sustainable greenhouses can help address the water shortage by reducing water consumption and improving water management practices. Moreover, the Moroccan government is actively promoting and financing the diffusion of greenhouse technology, considering it a potential solution to water scarcity.

The conflict of interest in the diffusion of greenhouse technology in Morocco is evident. Dutch companies have economic incentives to make Morocco dependent on their technology imports and increase their profit margins by buying and re-selling their horticultural products. Meanwhile, the Moroccan government is not restricting the adoption of this technology but rather encouraging its use as a means to tackle water scarcity.

In any case, although there is a great push from the Moroccan government to the introduction of sustainable greenhouses, the research has shown that there is an evident lack of goal-oriented objectives and subsidies to speed up the horticultural transition. For this reason, in Chapter (6), the author presented some strategies for the companies but even for the government to help and encourage the transition from the early stages of technology diffusion, to overcome the grower's skepticality through showing, encouraging knowledge share and increasing the investment within R&D.

8.6 Validation of the results

At the end of the study, the author had the chance to validate the research results with a well-known external professor of technology and innovation from the Rotterdam School of Management. Throughout the brief examination, there were several discussion points. Firstly, although the professor agreed with the depicted status of the building blocks for sustainable greenhouse large-scale diffusion in Morocco, the status of the ‘product performance and

quality' has raised a debate. The professor suggests that this building block should be considered partially incomplete, due to the technology's limitations for some market applications (e.g. too expensive in running operations) and the lack of awareness among the different growers of its benefits. However, the author disagreed with these statements.

On the one hand, there have been included the analysis of the most feasible market applications (based on interview results) in which the technology could be successfully adopted. For instance, it was not proposed as a market application for sustainable greenhouse bean production as it would not be economically feasible to sustain its running operations.

On the other hand, the author believed that the *product performance and quality* building block should represent the technology's intrinsic characteristics, regardless of whether people possessed sufficient knowledge to maintain its quality and performance. This aspect was addressed within the influencing condition building block of *knowledge and awareness of the technology.*

Regarding the Validation of the Niche Introduction Strategies (NIS) and the topic of Green colonialism, the professor agreed on the necessity to produce more components locally in Morocco to reduce international independence. However, the professor also acknowledged the near impossibility of achieving full technological independence as each state globally relies on the import of some technology or materials.

The professor agreed on the *Educate NIS*, emphasizing the importance of collaboration between universities and companies. Even if, show-case high-tech greenhouses were built on university campuses, they lacked knowledge on how to grow tomatoes, for this reason, it is important the expertise of growers, that need to be part of the knowledge share and development.

Regarding the *Common Market NIS*, the professor agreed on the necessity of the development of a common national value chain to export their produced products abroad. Nevertheless, the quota reduction for tomatoes exports to the European Union, would not be possible because the European government needs to protect the interest of its growers and producers.

To conclude, the discussion conducted with an external professor was a useful step further to validate the final results of the conducted research.

8.7 Reflection on the research contributions

To the literature

This research fills up the knowledge gap presented in Chapter (1). In fact, this study adds by analysing the diffusion pattern of Sustainable High-tech greenhouses from a company perspective in Morocco. Therefore, this study can help in providing **relevant scientific insights** to sustain sustainable greenhouse companies throughout their pathway to diffusion in Morocco. Considering the company perspective on this matter is crucial as innovation often emerges from individuals, companies, and markets.

To the TIS framework

This research has expanded the applicability of the TIS framework by Ortt & Kamp (2022), for two reasons.

Firstly, it has investigated the barriers to large-scale diffusion to various market applications of the same technological innovation. This study provides an overview of the barriers for three

different market applications, allowing the reader the possibility to evaluate which market application fits the most the Moroccan landscape.

Secondly, it has evaluated the case of a technology transfer from one country to another, which was not done before. The results, prove that the framework can be used to capture the dynamicity of the complex international technology transfer. However, it requires the inclusion of a stakeholder analysis, major care in maintaining a systemic perspective and extra effort from the author in finding relevant actors to be interviewed from each involved country.

Finally, the research contributes to the Building Block framework by adapting the research by providing some suggestions to expand the framework area of relevance.

8.8 Reflection on Green Colonialism for technology diffusion in Morocco

Due to the increasing food demand for export, Morocco is innovating its horticultural sector by transitioning to Sustainable greenhouse technology. However, this ambitious goal does not come without any problems, which are encountered in multiple aspects of technology implementation. For instance, the high energy and water requirements for horticultural production, while the country is already encountering nationwide water scarcity. Or also the fact that local communities are suffering from the consequences of decreased water availability, alongside the increasing cases of land converted into horticultural farms for food production.

In 2008, Morocco developed the 'Green Morocco Plan' (GMP) with the aim of increasing agricultural production to improve Morocco's trading ability. One of the goals of this strategy was the expansion of the drip irrigation system by 550.000 hectares (WBG, 2021; ORMVA, 2021). According to Collas (2022), the socio-economic benefits coming from the GMP are indisputable. Nevertheless, the effects of the water drip irrigation expansion led to agricultural intensification and an increase in national water consumption.

The evidence presents that Morocco's horticultural production primarily benefits foreign countries rather than its own population. These circumstances raise concerns about whether the development of horticulture in Morocco, even if sustainable, perpetuates the power dynamics of its colonial past and represents another instance of green colonialism: 'the exploitation of resources of the Global South by Global North for their green agendas' (Lee, 2022). An example, of a predominant phenomenon coming with green colonialism in the case of Morocco, is the *lingering power relations*. This is the idea that Western countries seek to impose their neoliberal doctrines on postcolonial nations in the name of technological advancement. Leaving international companies tied to developing countries, preventing them from gaining complete independence. Often this pattern is carried in the name of the Western environmental imaginary arguing that local people mishandle their resources (Lee, 2022). In the specific case of Morocco, multinational companies are competing to make food production more sustainable, as investing in transition within the country is more profitable than pursuing the same projects within their own borders (Haag, 2022). Throughout the study, it was highlighted how Dutch Company 2 stated that Morocco will not ever gain technology independence, with sustainable greenhouse adoption, from the Netherlands. Thus, the introduction of such technology would make it harder to liberate Morocco from Western influences in food production. Another example of green colonialism is *land dispossession* for food production, infrastructure development or energy generation (Fairhead et al., 2012).

To conclude, it was of utmost importance for the author to reflect on green colonialism, however, due to the nature of the research and the time constraints, the reflection of green colonialism for sustainable greenhouse diffusion in Morocco needs further research and study. Even because the relevant research on the exploitation of countries in the global south for

horticultural production is a recent phenomenon and thus scarce information is provided. Nevertheless, it is clear that colonial power structures are still dominant up to this date. Thus, to prevent old colonialist practices from reoccurring, one must analyse the effects of green colonialism when considering technology implementation in developing countries.

8.9 Limitations

This section presents the limitations of the study.

Firstly, it was in the author's interest in maintaining a systemic perspective throughout the duration of the whole study. To do so, the author has interviewed 17 actors coming from different stakeholder groups. Although the amount of interviewees is decent and all of the interviewed actors cover an important role and detain a high level of knowledge/involvement within the project, they are spread among eight different stakeholder groups (four per nation). Thus, for instance, there were interviewed only two Moroccan and two Dutch researchers. Hence why, the insights gained from them might be limited, and some further interviews with some other actors might have strengthened or lowered some of the barriers/influencing conditions, by providing some more diverse perspectives and enhancing the quality and quantity of the data.

Secondly, another limitation is the time constraint. In fact, although the author's consistency in the work, further desk or primary research was not possible due to the lack of time and resources. Additionally, the analysis of sustainable greenhouses for three different market applications required the analysis with three different TIS frameworks. Therefore, for some market applications, the author managed to gather more data than for others.

Thirdly, the results provided by this research have been depicted by the data collected at a specific moment. Thus, the analysis of the building blocks for sustainable greenhouses in Morocco is static and does not capture the changes in the socio-technical system over time. To overcome this limitation, it would be required to integrate a longitudinal perspective into the analysis. This approach enables a deeper understanding of the system's dynamics and how it changes over time.

Fourthly, although the author has put extra care into limiting this factor, it is important to remind the reader that because the semi-structured interviews were conducted in English, French and Arabic, there could have been some misinterpretation of some of the questions from the interviewee side.

To conclude, as already mentioned in Chapter (7) the adaptation of the research process for multiple market applications can be a limiting factor because dependent on the ability of the researcher. As well as the selection of the building block/ influencing condition status, as no clear guideline was presented by the authors of the TIS framework Ortt & Kamp (2022).

8.10 Recommendations for further research & findings generalizability

Within this section are given some recommendations on how to overcome the limitations presented in the paragraph above and some suggestions for further research.

Among the presented limitations, the first one could be overcome by maintaining the systemic perspective but by interviewing more actors per stakeholder category. This would increase the quantity and maybe the quality of the collected data by gathering more opinions regarding the barriers and influencing conditions from multiple perspectives. This limitation could be overcome as well by the expansion of the available time for data collection/analysis. The third

limitation is hard to overcome as the socio-technical system is in a state of perpetual change, both in the short and long term.

Here are presented some recommendations for further research. Firstly, a longitudinal study could be carried out, this would help understand the evolution of the TIS framework over time. Especially, in the case of this research, the inclusion of a longitudinal study could help clarifying the dynamics of technology transfer and the factors that could limit or encourage technology diffusion. What is more, if this is not going to be the last study on the application of the TIS framework for technology transfer from one country to another, there it could be studied the results among the longitudinal studies and a cross-comparative analysis could be made to improve the framework by seeking common patterns in the technology diffusion. Secondly, further research could be conducted on the topic of **Green Colonialism**. Thus, it could be interesting to investigate the influence of multinational companies on, firstly, the Moroccan government and then the technological diffusion of Sustainable greenhouses. Thirdly, the use of niche introduction strategies could be combined with **Game Theory**. This could be used to understand how companies can better interact within a market or solve the lack of alignment between the companies and the government. Finally, another study could be carried out for the understanding of whether the introduction of sustainable greenhouses (although with water management technologies) in countries like Morocco can help in diminishing / not increasing the waste of water resources.

According to Goodman (2008), generalizability is applied in qualitative research when results coming from a sample of participants can apply to a wider population. In the case of this research which is focused on the barriers to the large-scale diffusion of Sustainable greenhouses in Morocco. The data was collected by a sample of 17 participants, and by literature research.

With this mentioned, how representative is the data collected from the interviewers and desk research in relation to the Moroccan sustainable greenhouse ecosystem? To ensure the generalizability of the research under this aspect, the author has interviewed actors from five different stakeholder groups to have a more systemic perspective. What is more, the actors were coming from both Morocco and the Netherlands to not have a one-sided perspective. In some of the cases, the data gathered was backed up by some literature research on the Moroccan or global level. This has ensured a stronger generalizability of the research.

Regarding, on what scale the results gathered for the case of Morocco could be generalizable for the case of other North-African countries? It is important to remind the reader that this study is specific to the Moroccan social, political, cultural and economic characteristics. Nevertheless, the findings of this research could be relevant for company managers in other countries, that might take some points of reflection based on the research results.

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Chapter 10: Appendix

Appendix A: The diffusion of Innovation theory

The Diffusion of Innovation Theory, developed by Rogers, it is a milestone within the literature regarding technology diffusion because of the importance given to the time element (Lundbland et al., 2003). In fact, there have been identified, by the author, three components of it: the innovation-decision process, the adopter categories and the rate of adoption (Rogers, 1995). The five different categories of adoption of a technological element are shown in Figure (22). It is noticeable how these categories show the extent to which an individual is inclined to adopt new ideas as compared to other members of the social systems. In most cases adoption is not immediate, this is because some people might be more skeptical / conservatives /or less risk taking than others.

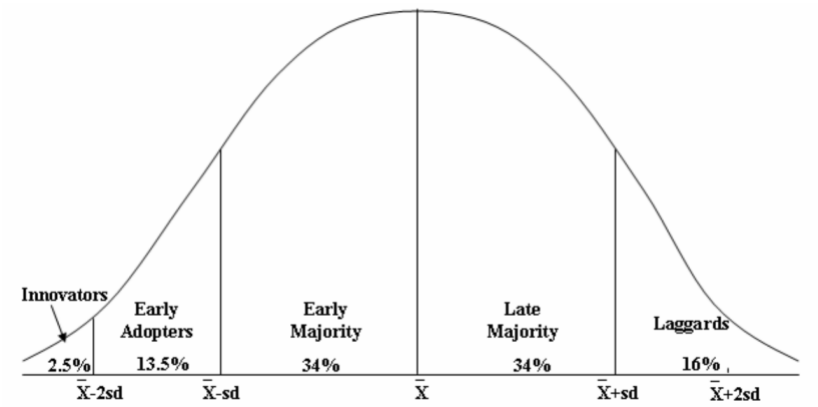

Figure 22: Rogers stages of technological adoption (Rogers, 2003)

According to Rogers (2003), the adoption of the innovation it is shown by an S-shaped curve, demonstrating that initially only a small number of individuals adopt the innovation, however, as time passes and more people adopt it, the rate increases. This can be seen with the diffusion of the radio and the television (Ortt, 2004). Nevertheless, it happens many times that a breakthrough technology faces a disappointing number of adopters, which do not reflect the optimistic expectations of the S-curve. This is because, according to Ortt (2004), S-curve model hardly captures the early-stages of diffusion of a breakthrough technology, not showing the erratic patterns after the first market introduction. This was the case with the fax technology, it took 16 years from its invention to its first market introduction which followed an erratic process of diffusion (Ortt, 2004). Hence it was necessary to develop a framework showing the patterns of development and diffusion of breakthrough technologies. This was done with the introduction of three phases in the diffusion process.

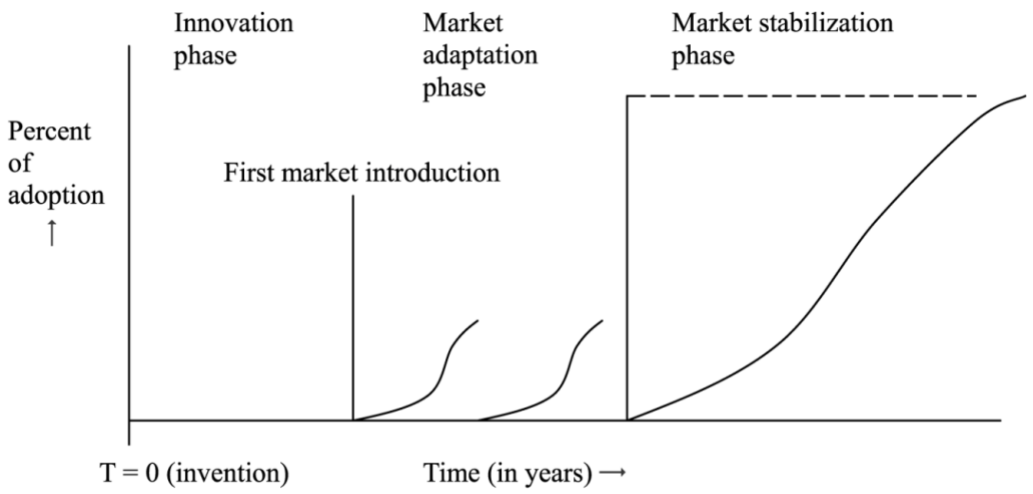

Figure 23: Rogers technological innovation diffusion phases (Ortt, 2010)

Where the innovation phase goes from the invention of the technology to its first market introduction, there is no average length for this stage as it can vary drastically depending on the technology. Through this stage research institutes and universities play a central role. Once the product has been introduced within the market, the market adaptation phase starts, this is the most critical stage due to the complex interaction among many factors which may hamper the technology's large-scale diffusion (Ortt, 2010). Within this stage the market is unstable, in fact the pattern of diffusion may face introductions and declines until when the technology takes off to the large-scale diffusion within the market stabilization phase, which ends when the technology is substituted. It is noticeable from Figure (23) that the S-curve it is present only in the last phase of this model (Ortt, 2004). Most of the time organisations, struggle in defining the right introduction strategy within the niche market, resulting in an organisation's "extinction" or dilatation of the market diffusion time. It is noticeable how with the adoption of an effective niche strategy, breakthrough innovations can be introduced in the market.

To better understand the socio-technical context, in the following chapter, the Technological Innovation System (TIS) is explained. This will be useful for the understanding of how the niche strategies work.

Appendix B: The technological innovation system

In the early 1990s researchers and practitioners began to recognize the growing importance of technology and information in shaping society. At the same time, researchers and practitioners began to realize that technology and information were not neutral but were shaped by social and cultural factors, and that their interaction with society was complex and dynamic. Moreover, during a transition, both technological and social innovations are interdependent and continually influence each other. Technological advancements lead to social change and vice versa, demonstrating the intertwined nature of these innovations. According to multiple authors transitions are long term and complex processes because resistant to change. Throught the 1990s and the 2000s researches and policy makers, that were studying the socio-technical system, have developed terms such as "Transition Management" (TM) and "Strategic Niche Management" (SNM) aiming to generate some instruments to manouvre transitions (Kemp 1998, Loorbach 2007). Niche development it is a key component, Schot (1992) argued that, especially for sustainable innovations, often no clear niche market exist. Thus, this market would have to be created with a process of co-evolutions with institutions. For instance, by encouraging their development with in-favour public policies or tax exemptions, until they gain momentum for diffusion. The main question

that scholars wanted to investigate into was: " Why a certain innovation was a success or a failure?" (Raven, 2010). However, according to Raven (2005), the SNM is analysed by scholars as a policy tool, meaning that it is mostly applied for "ex-post analysis of transition experiments in niches to inform policy makers for future sustainability policies".

However, it was believed that it is needed the development of a framework that is capable to transfer to actors involved in transitions the practical "how to do it" guidelines, which the current SNM, TM and socio-technical analysis is not doing (Raven, 2005). Furthermore as previously mentioned, these studies have been conducted to help policy makers to develop policies to encourge technological diffusion. Thus according to Ortt and Kamp (2022) this "policy perspective is causing a lack of attention for the strategies of companies in the socio-technical system". Hence the authors have developed a framework which combines the integration of perspectives from two distinct areas of research to deepen the investigation, while using the TIS to formulate niche introduction strategies from a company perspective, rather than a governamental perspective.

In the next paragraph is introduced the TIS framework developed by Ortt and Kamp (2022). The unique aspect of this framework is its integration of perspectives from two distinct areas of research to deepen the investigation of the context around the technology during the adaptation phase, to develop a effective niche-introduction strategies.

Appendix C: The History of Sustainable greenhouses

Quite surprisingly the concept of growing plants in an environmentally controlled space dates back to 37 CE, hence during Roman times, where artificial methods have been implemented to grow some crops all year round for Emperor Tiberius. Already back then, plants were planted on carts to move them to the daily sun and back inside into protected houses, called Specularia, during colder nights (Nemali K. et al., 2022). Only in 1450, a Korean royal physician has documented back again the use of protected agriculture. His manual pointed out the use of an underfloor heating system, to grow citrus plants. Simultaneously, in Italy during the sixteenth century, structures similar to the modern greenhouses were built, to create favourable environments for the many tropical plants brought by explorers. Only in the 19th century, greenhouses faced a large-scale diffusion in Europe, with the aim of growing exotic plants, which were requiring more tropical conditions. A large role, in the large- scale diffusion of this technology, was played by universities, due to the growth of botany. This technology was named differently in countries depending on its use. For instance, in France they were called "orangeries", and they were built to protect fruit trees, like oranges or lemons, from winter colder temperatures (Nemali K. et al., 2022). The southern side of these buildings was prevalently made of glass windows to allow the sunlight in. Throughout this period there have been many structural design improvements in greenhouses, led by technological enhancements. Indeed, in Japan, it was applied on a small scale from the 1880s onwards. Multiple universities did start researching advanced cultivation methods with the use of artificial light sources, which have subsequently led to sharp improvements in lighting efficiency. Nowadays, the use of Greenhouses is not anymore limited to crop production, but it is used to produce ornamentals, medical and aromatic plants. The Netherlands and Israel, along with having considerable greenhouses areas, are two of the greatest greenhouse technology innovators and suppliers. The current development of greenhouses technology aims at upgrading the technological advancements to reduce environmental impacts while maintaining a high level of crop production (Achour Y. et al., 2021).

Appendix D: List of technological components

External technologies

The first pillar of the developed technological map for sustainable greenhouses is 'external technologies'. These technologies are not designed for greenhouses, but are a key component for maximizing efficiency and sustainability within the sustainable greenhouse system, while reducing their overall environmental impact. In fact, these components can be sourced from multiple fields, from renewable energy to waste management and water management. These elements, analysed below, provide the foundation for sustainable greenhouse design and operation.

Technology	Function
Renewable Energy Sources and Electrical Installations	Greenhouses require a lot of energy to operate, and renewable energy sources such as solar and wind power can reduce the environmental impact of greenhouse operations (Giuliano Vox et al., 2010).
Dynamic Microclimate Control Systems	Climate control systems are crucial for maintaining the ideal growing conditions for plants inside the greenhouse, and advanced systems can reduce energy consumption and greenhouse gas emissions (Albright, 2002).
Water installations	Water installations are a critical component of sustainable greenhouse systems as they play a key role in reducing water consumption and optimizing irrigation practices. Various water conservation techniques are utilized to achieve this goal (Stanghellini et al., 2017).
Waste management systems	This system should ensure in reducing the waste of water, energy and materials within a sustainable greenhouse (Giuliano Vox et al., 2010).

Technological elements

Technology	Function
LED Lighting Systems	LED lighting systems are energy-efficient and can provide the specific light spectrum required for plant growth, reducing energy usage and optimizing plant growth (Berkovich Yu et al., 2017).
Natural lighting system	The architecture and design of the greenhouse building has to ensure enough daylight concentration, to maximise the level of sunlight absorption of the crops (Giuliano Vox et al., 2010).
Biological Pest Control Methods	These methods involve the use of natural predators and parasites to keep pests under control. One approach is introducing pollinators, while another is planting trap crops to attract pests away from valuable crops (Giuliano Vox et al., 2010).

Hydroponic Systems	Is considered one of the most sustainable greenhouse cropping practices. Research has demonstrated that this technique significantly reduces water and fertilizer usage, thereby decreasing environmental pollution caused by over-irrigation (Giuliano Vox et al., 2010).
Substrate culture system	This cultivation method is a type of soilless cultivation, which includes the use of a substrate for plant growth instead of soil (e.g. rockwool and peat) (Giuliano Vox et al., 2010).
Water culture system	There are three primary water culture systems used in plant cultivation: aeroponics, floating raft systems, and NFT (Giuliano Vox et al., 2010).
Advanced Sensors and Monitoring Systems	Sensors and monitoring systems can provide real-time data on temperature, humidity, lighting, water usage, and other variables. This is done to maximise crop production and reduce waste of resources (Giuliano Vox et al., 2010).
Energy Efficient Heating Systems	Greenhouse heating systems are essential to maintain the optimal temperature for plant growth. There are four types of greenhouse heating systems: hot water, steam, hot air, and infrared (Giuliano Vox et al., 2010).
Cooling Systems	Especially in hotter countries there is an increasing need of removing large quantity of heat from greenhouses. the most commonly used and affordable method of cooling greenhouses is evaporative cooling. This technique cools down the greenhouse by using the natural process of water evaporation (Giuliano Vox et al., 2010).
Heating and Ventilation Systems	The aim of this technology is to limit the excessive rise of temperature and humidity. In fact an abset ventilation during summer day would result in a loss of the crops due to high temperatures (Giuliano Vox et al., 2010).
Pollinators	Pollinators such as bumble bees, butterflies and other insects; play a key role in greenhouses to increase the crop yields and quality (Giuliano Vox et al., 2010).

Infrastructural technologies

Technology	Function
Greenhouse Design and Construction materials	The structure has to be built with the appropriate covering materials, because these play an important role in the development of the right microclimate to allow the crops to thrive. Sustainable greenhouses

	aim at introducing covering materials aimed at reducing the amount of heating and cooling needed (Giuliano Vox et al., 2010).
Smart Grid Systems	These technologies would increase their benefits with the integration of a smart grid which can optimize energy consumption by managing the energy production and storage (Giuliano Vox et al., 2010)
Waste Treatment Systems	Waste management systems can minimize waste production and maximize waste reuse and recycling, reducing the environmental impact of greenhouse operations (Giuliano Vox et al., 2010)
Data Management and Control Systems	Data management and control systems can provide real-time data on greenhouse operations, allowing for optimization of resource usage and greenhouse conditions (Giuliano Vox et al., 2010).
Road network	An efficient road network is necessary for the transportation and delivery of crops to customers, as well as for the commute of workers and technicians to the facility (Giuliano Vox et al., 2010).

Appendix E: Transcript/Summary of interviews with Dutch actors

Dutch Researcher 1:
Based on your knowledge, what are currently the barriers to diffusion for SG in Morocco?

According to me apart from the high-initial investment required for the switch of technology, the supply-chain to the costumer could be a barrier to diffusion for the technology. Therefore it is hard to have access to the consumer the whole year round, but if it would be possible have contracts for the produced products from europe throughout the whole year more growers would be encourage in making a long term investment.

Could you please tell me more about this “long term mentality” of the growers? Is it missing?

There are two different type of growers the big ones and the smaller ones. Both of them are part of the APEFEL group, although some growers might be more involved than others. Regarding the first one, they have a longer term vision, whilst the second ones do low investment returns by instead purchasing innovative technologies and prefer to purchase more land, which on the long term is turning out to be unsustainable.

Are there any policies, law or regulamentations that could hinder / encourage the diffusion of the technology on a national scale?

I do not know of any policies or laws that may hinder the diffusion of this technology. Even because in Morocco there is a growing issue with water usage. Therefore there are a greater amount of laws which are pushing the growers to adapt with the use of desalination plants and other similar technologies.

Do Moccan growers/company have enough knowledge on SG technology (product, production system, services and maintenance)?

No Moroccan growers do not have enough knowledge on the technology. What they are doing right now is building pilot greenhouses, where they grow tomatoes to learn about the technology. In these cases the pilot greenhouses are at least one hectare big.

What are in your opinion the best market applications for SG in Morocco, apart from cucumbers and tomatoes?

I would say blueberries, raspberries and strawberries, these are already produced on a small scale. These products detain more value per kg, in fact some farmers are switching their production from tomatoes to raspberries. Flowers as well could be grown in Morocco then transported to the Netherlands. However everything will depend on the supply chain, how it is structured. It is important to understand that the market of these other produced products in Morocco will not be as big as the one for tomatoes.

Surely one of the biggest barriers for SG are the high initial investment costs, are there any other human/natural factor that may influence the diffusion of the technology on a large-scale?

It could be the knowledge of english, but a lot of work has been put in by the government and I believe that in the coming 10/15 years it is not going to be an issue. However it is necessary to bring the long term perspective to the growers, to train young people in the use of the technology. Furthermore there should be a step by step action by the government, this might be seen as a barrier as it is needed to have a clear vision of where they want to go on the long term.

What is the mentality of the growers regarding the introduction of SG?

I believe that right now there is already an open discussion among the growers regarding the technology. This is because the country it is facing an economic growth, which is making them diversify the crops produced and encouraged to get closer to european standards of production.

Dutch Researcher 2:

Could you tell me more about your knowledge and involvement within the Moroccan context?

I have been involved with a Moroccan project now for two years, more specifically with the local universities and guiding the development of the center of excellence, whose purpose is to introduce knowledge on a high tech sustainable greenhouse technology.

What's the main advantage you think from the Dutch side and what's the main advantage from the Moroccan side in this collaboration?

Well the main advantage from the Moroccan side is water saving. So there they have quite a big basin underneath the soil from the Atlas Mountains, which provides the water for the entire region. However since a few years the agricultural or horticultural side has grown, as well as exports. This has simultaneously caused an increase in pressure on water resources. So the Moroccan government needs to start issuing regulations or start helping the growers to use less water. This is like a double sided blade. On the one hand, they're very happy that there's more economy and more money being made with the horticultural products that are sent to Europe during the wintertime. On the other hand, due to the increase pressure on the water resources the Moroccan government has contacted the Dutch government, to learn on how more food could be grown while using less resources.

In your opinion what are the current obstacles to the diffusion of SG in Morocco?

According to me the main one is Finance. For instance if I am a farmer and I produce 15kg of tomatoes per square meter that would bring be around 20 euros revenue. If I would decide to implement a new technology, or even a new component, in most of the cases I would not have enough money to make a full installation, and simultaneously I would not be able to get a loan for it either. So instead of trying to decrease the resource used by improving the technology, farmers decide to buy more land and expand their production with the use of low-tech greenhouses.
Another barrier could be cultural. There is not a great culture in saving up to use better technology, and most of the farmers feel no current pressure on the water shortage as they take the water from under the ground. So in most of the cases they do not care if that is bad for the future as they want “to eat now”. It should be proven and shown to them that by using higher technology they will get greater yield, increase quality and decrease consumption.
In this last case, there should be an immediate action from the government with subsidizations of water improvements systems and regulations which limit the water use. This would allow farmers that have adopted sustainable greenhouses to produce more with lower costs, beating the smaller growers.
To conclude, it is both a financing issue as well as a cultural issue. There is a limitation in the scale up of groups, as banks do not want to take many risks.

What is the best type of coverage you would suggest in Morocco? (plastic or glass)

I would recommend the plastic film. The glass one is very good to use for research purposes, so you don't want to have to replace the plastic in the middle of the trial. So that's basically the only reason why we suggested use glass. What is more above the 50 degrees of latitude it would be suggested the glass type of greenhouse, whilst below those the plastic film ones.

Will the change in technology affect the product price?

I believe that the price of the product, if it is going to be exported, will increase as there would be an increase in quality. However I think that the price per kg for some crops like tomatoes would not change much, so you will have the same prices but you would increase your production.

What do you believe are, based on your knowledge, the best market applications for SG in a dry climate like Morocco?

Of course in Morocco tomatoes, cucumber and bell pepper are the main types of crops grown. Surely Sustainable greenhouses could be used for herb production, like mint. Because the production with the use of such technology increases there is a possibility to grow almost everything. You should be checking regarding the possibility to grow cannabis, for medical purposes in Morocco, regarding the legislation. Morocco is one of the countries that has a monopoly on saffron, however the problem with this crop is that only a few mg per each plant is sold, therefore the costs might be too high.

Do you believe that SG technology has enough quality and performance to satisfy the growing needs in Morocco?

Yes it does. Even if It would depend on the type of investment it is made, as when you start investing in such technology you need to look at 15 years ahead.

What happens when a components breaks in a SG in Morocco?

It is important to develop a value chain cluster, so that when a component breaks the company can speak with the partner nearby. The international suppliers will venture out in those countries and supply the primary chain. This is what happens at the beginning, and although many international companies would not like that (because it would not be as profitable for them), Morocco at some point would have to develop its own cluster. Therefore to do that it is important to teach and train them, so that they can further develop this sector.

Do Moccan growers/company have enough knowledge on SG technology (product, production system, services and maintenance)? Are Moroccan people aware of the technology?

That is a good question. Most of the Moroccan farmers do not have enough knowledge on how to operate these high-tech greenhouses. Therefore we cannot just build the greenhouses for them as they would not know how to use them in the best possible way. This is why we are collaborating with the CEH, to share the knowledge and most importantly to show them what installations do what and what effect do they have. Validating and Proving. This is the first step. Meanwhile the second step is to make them use the right equipment for their local use. For instance, steel gutter might be more expensive so it might be needed to use a bamboo one or use the local available materials. And hopefully more locals would start developing a better material or a better use or a better market application for the technology, ideating a new cluster. The key thing is not to talk to them about the technology but actually showing it. To conclude, yes Moroccan growers are aware of the technology but most of the times is financially unattendible.

Are there any-socio cultural factors that may slow down the adoption of the technology? are there some actors that are skeptical about the adoption of this technology?

One that comes to my mind is the knowledge of English. Even if I believe that in the coming 10/15 years it will be well known in the country as I have noticed major efforts in increase its use by the current government. Further to this, I believe that there is a lot of skepticism among the Moroccans.

What is the greatest technological competitor to SG in Morocco? More specifically, how does the current farming methods affect the diffusion of SG in Morocco?

I believe that to reach High-tech, it is needed in most of the cases the introduction to small improvements. 1% of the entrepreneurs in Morocco has the possibility to an immediate shift to high-tech greenhouses, for the rest 99% there are no financial capabilities to do so. For them it is important to make the change slowly, bit by bit. This is even because they do not have enough knowledge on the technology, so it would be better for them to build on 1 hectar higher technology greenhouse to learn how to use it first, because everything in the production would be different.

But wouldn't this slow down the adoption of the technology?

In my opinion it would make it faster, as the growers will talk with other growers and will show the improvements they have made with the introduced technology and the advantages they have noticed. Therefore it is important for them to understand which is the component that could have the greatest impact at the lowest cost. Based on my knowledge, the best thing to be introduced is water recycle, this would be a great improvement. This would mean managing the root zone and with it its diseases. The next step is climate control, thus the introduction of screening windows to keep out the sun, keeping the temperature low. The next one is humidity,

with the introduction of ventilation. So if you introduce all of these components within a plastic greenhouse, you already have developed a sustainable greenhouse.

What is in your opinion the best way to overcome the mentioned barriers?

I think the best way is to validate and prove. To show the growers how the technology works. This will surely take a lot of time and effort but it is the only way, in my opinion, to do it. Regarding the financial barrier, I would include small improvements till the reaching of a fully high tech sustainable greenhouse. I would make them calculate the ROI for these improvements themselves, so that they could make their own choices. Furthermore, the government should improve the financial system, so that it would be easier to have the money. For instance, in Holland you could take off the depreciation of your greenhouse from taxes.

Dutch Company 1:
Could you tell me briefly about your knowledge within the Moroccan context ?

I did a lot of research for the Moroccan industry, Moroccan horticulture, the impact cluster and what types of companies there are. More specifically how they interact with each other, but also the differences in culture, this helped me understand a lot of insight and background information on how the Moroccan industry is acting.

What is the aim of this collaboration between the Dutch and Moroccan government/ institutions?

One of them, of course, is the war in the Ukraine, which has had an incredible impact on gas pricing. This has made the farmers decide that it was unsustainable to keep on growing food during the winter in the Netherlands as a lot of energy is needed to heat their greenhouses, which now requires higher prices. Even before the war the margins were very small, very tight for greenhouse farmers.
So what you see is that they look for alternatives in production during winter time. Therefore there has been an increasing interest in moving the production from Europe to Morocco due to economic interests. At the same time this is a good opportunity for Morocco to innovate, to make a better use of their resources and expand their knowledge within the field. Especially now where the population is increasing and countries are starting to face the first impacts of climate change.

Can you think of any barrier to the large-scale diffusion of sustainable greenhouses (SG) in Morocco?

Well, I think there are two main barriers and the first one is knowledge. When you introduce higher technologies, you also need to have more in depth knowledge of the crop and how the crop reacts under different circumstances. So that doesn't mean that the current level of knowledge is low. But what you see is that the current level of knowledge on Moroccan farmers is relatively low compared to the experience and knowledge of the Dutch farmers. However, to operate Sustainable greenhouses you need to bring that knowledge level to a higher level so that they also understand how they can influence the crops by different conditions. This is because this type of greenhouses have many components which needs some knowledge in application, for instance they need to know how to use the internal weather, climate controls computers and so on, to create the best conditions for the crops. So knowledge is a very important issue which is which could hinder the diffusion of sustainable high tech greenhouses. Still regarding the knowledge, another problem is the language, as in Morocco, most of the people do not speak a fluent english. Moreover, for instance the Dutch farmers are open towards each other they share their information. They talk to each other on how to improve technologies or the challenges they face etc. And it makes also that they create and

culture and community possibly in which they share information and get on a continuous knowledge improvement by knowledge sharing. And that is that is not a culture in Morocco. So there is there is a difference in culture, there is a difference in language and that could also hinder the knowledge exchange extension from an another sense for from the Netherlands to watch Morocco, but also it could hinder the internal the knowledge exchange within community Moroccan communities.

The second barrier is for me the access to finance. When you look for a funding for high tech greenhouses as a banker, you easily say well, we need at least 30% on equity and 70% can be organized by loans. Or if I think of an international investment, outside the Netherlands, I'd say it could be required a 40% own equity and 60% of loans. The problem is that when you are a small scale farmer or when you have low tech greenhouses, you don't have possibly huge amounts of own equity. So on one side there is the problem of farmers that do not have a great equity. On the other hand what you see in many African countries is that banks do not understand agriculture. And what I mean by they do not understand agriculture is what they see are earnings fully depending, in most of the cases, by one season crop. That means that for example, in January, you need to invest in seeds in the in the greenhouse equipment in, in labor in crop protection, etc. So there is a strong cash out for most of the season and no cash in. From March to to August, there is cash in and what you but also cash out because you still have your labor costs. And what you see is that you make the margins at the end of the season so that's possibly from August to November, December. So in the banking industry in many African countries is not not used to this kind of cycles, they don't have experience in it, and they don't know how to finance them and they don't know how to monitor now. And what you also see is that a lot of farmers don't have actual data available in which they can prove how the cycle runs. So that makes it also very difficult that there is less access to finance that is on one side caused by the low equity. While on the other side that the farmers are not able to show or to demonstrate the banking industry their history figures. Meanwhile the banking is not able to understand them in the right way and to entertain them and translate them towards financing opportunities.

Is it true that Moroccan farmers prefer to buy more land rather than improve their production methods?

What you see is in in Morocco is that the density, the number of people per square km is quite low, and there is a lot of open space available in land prices are quite low. So that makes it also easier to extend expansion, current production and to buy more land instead of improving their production methods. On the other hand, when you look from water perspectives there is an upcoming problem with the climate change. And when you have low tech infrastructures, your water management and water consumption is very high per kg of crop produced

During the given lecture, you said that all the components for sg needed to be imported from the EU, do you believe that how the EU centralized supply-chain could hinder the large-scale diffusion of SG in Morocco? Shall it have to be shifted the production in Morocco for some components?

I believe that what you see in, for example, in the Netherlands is that the western area is still avery located area where production supply, trades, etc is centralized. My expectations for Morocco are that when the industry will become more and more professional, you will find similar situations also in Morocco, nearby the production location so wherever farmers can buy the broken components for example. For instance, in Ethiopia they have developed to overcome this problem at the beginning to encourage and ensure the diffusion of the technology the development of a service delivery model. This is an input supplier with storage.

And what about the road network in Morocco, do you think this could be a problem in terms of delivering the components for the greenhouses?

No, the routes in Morocco are quite good. However a big issue could be the delivery of water and electricity, therefore the infrastructure to deliver these necessities.

In your opinion, how does the current awareness of how and where to apply SG in the Moroccan market affect the development of the technology? (What are the possible market applications of the technology in Morocco)

Well, the most common crops in Morocco are tomatoes, bell pepper, cucumber and eggplants. I think the production of soft fruits could be possible, but I feel like the market is almost saturated. I would produce herbs too in Morocco, although the internal of the greenhouse would have to be different. Nevertheless, especially for these last two more specific market application it is necessary to build customer relations since the beginning, therefore ensure the development of a strong sale and distribution channel

What is the greatest competitor for SG technology diffusion in Morocco?

In the case of Morocco when talking of SG I would build them as a plastic type of greenhouse rather than a glass type of greenhouse, due to economic reasons, as the first one is more economic viable. Even because in my opinion in most of the cases it is not about “the box” but the technicians that work in it. Only the technician inside the greenhouse in which you can manage the watering, the fertilization, the biological pest control but also the climate and you have a situation which can highly increase the yield while reducing the amount of resources needed per kg produced.

How do you believe the knowledge barrier could be overcome?

Through education and training and knowledge sharing. So it is import not only to educate but also to demonstrate because I could tell you, for example, “well here it is aglass greenhouses, you're here to grow with them because they bring you the highest yields”. But in this case the growers would not be convinced it is necessary to show them, therefore demonstrating the difference in yield per meter square and of water usage. Furthermore, I think what's very important is to try to create those communities in which farmers can share their knowledge and their experiences but also their challenges. Which is not very common in Morocco as people are not used to this type of open dialogues.

How would you overcome the financing barrier?

What you see is when there are innovations is that the local government is convinced on the added value of the innovations so that they set some grants, especially in the startups phase. We all currently we all facing some transitions in in our communities, and to speed up the process of transitions the government says has to set funds to be invested. The government needs to be convinced that this is the direction in which they want to go, they want to transition to a more sustainable horticultural production. Simultaneously, the banking industry need to be lined up. They need to understand what greenhouse farming is and how they can can judge or they can have a look at funding applications or financing applications and how they can monitor and evaluate the process during during the loan is running. And what I see currently in the Netherlands because I'm also working at (BANK NAME), this bank is facing also challenges in financing innovations. And this is because we don't have historical data on innovation. So what we are trying to do currently is looking at venture capital or private equity, who wants to invest in social responsible programs or projects to get them at least funded in

the first stage, so that as soon as we have data available we have historical data available that the bank can take over the loans in loan for the long term.

Dutch Company 2:
Could you introduce yourself/ your company and what is it doing in Morocco?

He has been working within the horticulture and floriculture sector for his whole life. In XXX, he has founded the a company which delivers engineering and project management solutions to the greenhouse industry. Some of the main activities are design, supply and installation of the greenhouses. They have built a high-tech greenhouse for 1 crop in Agadir in the Centre of Excellence (CEH). This greenhouse is 1hectare big, without mechanical cooling, with water desalination plants. What is more, the company is currently building a 'showcase' greenhouse in Agadir.

To your knowledge which are the obstacles to spread SG in Morocco?

He has given a various number of barriers for the diffusion of the technology in Morocco. The first one is the mentality of the growers, as according to him a long term perspective is missing. The second barrier is the high-initial investment required. The third barrier could be the supply-chain to the costumers, which is missing.

Could you dive more into the first barrier you have mentioned?

According to him because the current greenhouse technology is profitable on the very short term many growers, because of the lack of a long term vision might be more resistant to change. It continued saying that, there could be two different types of high-tech greenhouses that could be implemented: a glass or a plastic covered greenhouse. The first one are 30% more expensive to build, and the return on the investment (ROI) is seen after 5 years. Whilst the ROI for plastic high-tech greenhouse is 3 years. If a moroccan company would implement a plastic greenhouse rather than a glass greenhouse is because sometimes the long-term perspective is missing, as the plastic ones require a greater maintenance than the other one. For instance, the glass greenhouse can operate for 20 years without stop; whereas the plastic greenhouse has to stop every 2-3 years to replace the plastic coverage with a new one. This would mean for the grower to stop the production and pay for the newly implemented plastic and workforce. All this is translated in economic loss. I think that resources are not really the problem here, but the expect return on investment is, the entrepreneur can increase their capital more easy to invest e.g. in stocks, so they are not really prepared to invest in more sustainable (water- and energy saving) technologies like high-tech greenhouses. The reason is that damage to the environment (such as depleting fossil and water resources) is not included in the cost price of agricultural projects. Such thing can only be solved by changing to legalization, forcing companies to apply true pricing. So now the grower simply thinks I know that I will earn money the way I am growing now. If I invest millions in a new greenhouse and I have a return of investment which is at least 10 years, then he considers this as too much of a risk. In many european countries there is regulation in place forcing companies to save energy and wateruse. I think, but I am not sure, that such legalization is not yet in place in Morocco.

In your opinion which could be the best way to overcome the high-initial investment required for the switch of the technology?

According to him the Moroccan government needs to develop a local regulation to invest in the innovative technology, with the implementation of national subsidies to cover the high costs. Furthermore, the government should force the companies to treat the water after use and recycle it, as it is a lacking resource in Morocco. The investment in CAPEX is just high, it

maybe is a little higher than growers in Netherlands, since some parts of the high tech greenhouse have to be imported so there will be additional import duties and transport costs.We should also not forget that the hightech level which we see in the Netherlands very slowly in 100 year timeframe came to where it is today. Maybe this giant leap for Moroccan growers simply is too big (at least without governmental support).

Do you believe that how the EU centralized supply-chain could hinder the large scale diffusion of SG in Morocco? Shall it have to be shifted the production in Morocco for some components? If so, how?

The steel construction, the aluminium parts for glazing, the glass and many parts can be produced in Morocco in case there will be enough demand for hightech greenhouses. For the more sophisticated or specialized parts, like software, drive mechanisms, pumps, drip irrigation, these will continue to be imported from the Netherlands. As long as there will be only a few greenhouses 80% of the value of the greenhouse investment has to be imported. When the market for hightech greenhouses will grow, the share of import can decrease to a 30%.

Is the Dutch/Moroccan production system able to produce large quantities of SG with sufficient quality and performance?

This should be no problem, if there is a strong strategic cooperation between Dutch and Morrocan companiees.

Because you have worked within Morocco, would you believe that there it could a language barrier? (many people do not speak english, so they might not know how to operate the greenhouse)

In China and Russia many greenhouse were built in last 15 years, language and culture barriers are certainly there, but will not be crucial for the development of greenhouses.

Based on your knowledge, which do you think are the best market applications for the technology in Morocco?

He said that according to him the technology in Morocco should be used to produce food such as tomato, cucumber and pepper. Another market application for the technology is the production of soft food, like blueberry and strawberries. He would not use the technology to produce flowers, because he is against the use of high amount of resources for something that does not feed a growing population.

How does the current competition in the agricultural sector affect the spread of the technology?

The greatest competitor to SG are the Mexican type of greenhouse (or the Canarian greenhouses), coming from Turkey. Many growers do not switch to high-tech greenhouses because the canary ones are still profitable for them. So, according to him, the greatest competitor to SG are slow improvements to the Canarian greenhouses.

Do you believe that the current high-tech greenhouse technology has enough quality and performance, when compared to competing technologies, to satisfy the growing needs in Morocco?

To my opinion the biggest challenge for cultivation of greenhouse vegetables such as tomato and blueberry is to grow them with:

1. A minimum of water use, which makes it inevitable to grow on growing gutters and irrigation and drain water disinfection equipment, where we can recycle and disinfect the drain water. Investment in these techniques are more easy to get return on investment, since you will save on nutrients. In the current situation excess irrigation water is discharged to the soil (pollution). Governmental regulation can help to stimulate the application of water saving techniques.

2. Minimum or no use of pesticides with application of biological crop control. This requires a closed environment which the Moroccan growers in fact already have in their nethouses.

3. An increased productivity and product quality. To obtain this they have to invest in plastic/glass greenhouses with at least sophisticated ventilation equipment in such a way that humidity levels at all time can be controlled and occurrence of fungi can be prevented. Fungi occurrence is one of the bigger enemies when Morrocco wants to keep serving more distant EU and UK markets.

Which could be, in your opinion the best way to show the advantages of this breakthrough innovation and overcome the barrier?

It is necessary to show the advantages that the technology could bring, this could be done with the help of the universities and 'innovative' companies, so that the people and other companies would be encouraged to switch. He has mentioned the case of Spain, in the Almeria region, that even banks were not believing in the switch to a high-tech greenhouse, so the government had to intervene.

Dutch Company 3:

The actor started by defining the greatest barriers to large scale diffusion for sustainable greenhouses in Morocco. As the first one the actor has mentioned the costs of switching, as in the NL there is a situation where land is not that available, prices are high, so we are forced to invest in improving the production per square meter. Whlist in Morocco, the land is quite available, which means that the grower has a choice between either invest in a high-tech Greenhouse or expand the production by buying more land. This costs barrier is caused by some other reasons, firstly the raw materials prices have risen quite a lot in the last year. So that's a big cause. Usually, the workers to build the greenhouse are an expense too, although what is usually done is sending a Dutch supervisor that works with a local crew. Therefore, the people that are going to invest within the technology have to know that they are going to make profits within a year or two.

Another barrier is the lack of knowledge on what a high-tech greenhouse can bring them. Because the investment is going to be higher for a SG but the water use will be reduced and greater yields as wells as a higher turnover comes with it. If they would understand this it would be much easier to diffuse the technology, but most of the time they just see it as a high starting investment cost. The reason behind this knowledge barrier is because the need for development in Morocco is starting now, now they are pushing themselves to produce, for example, more tomatoes, because they see a market pull from the EU as we cannot fill the market demand of this product during winter, this is because of the increased costs of production in EU. It's true that the paths now are not very straightforward so that might be one of the reasons why they do not want to invest within the technology. A third barrier are the sales, because there is a limitation in the amount of products a Moroccan grower could sell to the EU market, in fact I spoke once with a grower that has told me "I can produce more but I

cannot sell it in the European market, so why shall I make such an investment". Therefore, if some of these retail barriers could be reduced more people would be keen in boosting their production. If Moroccan growers decide to sell their products to the EU market usually happens through European Trade Organizations, thing that might be a bit unclear to the growers now and makes it harder too to invest in a new technology. What usually happens is that companies come together under a cooperative so that they have more power.

The actor continued talking about the water and energy infrastructures built in Morocco, it was said that greenhouses would not use a lot of electricity for the lightning, but they would use it more for humidification and / or ventilation. Currently the actor believes that the grid is not suited to satisfy such demand. The government needs to finance this type of infrastructure, as well as the water desalination plants to encourage the growers in not taking the water from below ground level but developing a closed system instead where the water recirculates within the facility.

The stakeholder mentioned that with the introduction of SG there's going to be a sort of a shift where some growers decide to go into high tech greenhouses and some growers decide to remain in their current way of growing, those last ones will provide for local markets. With time a big Association will be developed, who has direct contact with retailers in Europe and who can export directly their high quality product to Europe and make a decent amount of profit on that. Alongside with that you will have the local growers who are on the national markets providing the local people with their products. Currently there is no Moroccan grower association for the EU. This could be as well a barrier, as I will not be able to produce a product which is in between the regulations. If I make the investment of a high tech greenhouse I will have to produce very high quality products that fit within the EU market regulations otherwise it would not be convenient for me to make the investment to remain on the national market.

So if you are a Moroccan grower, the first thing you would have to make is an investment plan to know in how many years you are going to get the investment back. While analyzing that you need to check if there is a market to sell the products. If there is not I would not make the investment as it would be a big risk. Unless the risk diminishes with time, for instance, currently there is a growing a pathway where Dutch Growers Association, go into Morocco to find good growers and tell them we will develop with you and you can put your products in our catalogue and we'll sell them towards the retailers. This could be an efficient pathway for the Moroccan growers. In Europe, the amount of food produced is either remaining stable or going down, therefore there is a growing need, which could be filled by Moroccan growers if they can link up with Dutch associations, which is already happening as there is definite exchange between knowledge and an already visible improvement in quality and yield.

The stakeholder started talking about the collaboration among the different growers in morocco, and how it affects the knowledge share. It was mentioned that most of the growers are internally focused so they do what they do and sharing knowledge is not that common. In the NL growers have access to all type of data's, whereas in Morocco no. But the actor believes that very soon they will start understanding the value of that and start asking 'Why are you doing this?'. The actor currently believes that there is a mistrust between the growers, even if it would be suggested to have an afternoon every two weeks where they would either discuss or they would visit each other with each other's facilities and then discuss how they could improve each other's facilities. It is important to mention that Moroccan growers are very keen on getting new information. So, there is a culture where they are looking for information, but not necessarily with the other competitors / neighbours. They are more open to information coming from outside, because they understand that some other countries are further ahead in the development curve.

The actor continued by highlighting the lack of knowledge of English from most of the growers, although they have a very good knowledge of French and Spanish. This could be a barrier but

not a unsurmountable one it is very easy to overcome. Even because the growers believe in seeing, so if they can see the technology and see how to use it, they will understand it. You cannot just throw manuals at them. At the same time it is necessary to train them, even in the case they would decide to introduce mid-tech greenhouses it is important to train these mid level managers and workers, because currently there are not enough people that know how to use it.

It is important to note that these high-tech greenhouse technologies have some lay down, especially for the energy use for cooling in Morocco, for instance during winter natural gas should be used for the heating. So the questions that arises here, does Morocco have any natural gas resources? If so do they have the pipe system developed? It is important that they have a stable source of energy to fuel the greenhouses. The actor continued by mentioning that the best type of technology for Morocco would be plastic greenhouses, where you will have to replace the layer every 4 years, so the operational expenses are higher. The change to this type of technology is of leads to a 40% improvement if they start from the canarian type of greenhouses.

Within these greenhouses I would sell cash crops, eggplants, tomatoes cucumbers, herbs and soft fruits. For this one there is a growing market as the labour price is very low and they can be transported quite easily, and I believe that the growers have a very good knowledge on the market applications for the different types of greenhouses. But they might not know very well about the set up for a softfruit greenhouse and some other crops, that is why it is important to demonstrate. In any case all of the components will have to be shipped from EU, they will build many different warehouses, for instance if something breaks within my greenhouse I have a technician that comes within 30 minutes, it needs to be in the same way for Morocco.

To sell the products to the EU some of the supermarkets or gross associations require the use of some greenhouse technologies, and the respect of some values like (e.g. ISO 9001, ISO 17,001 ; no child labor, good practices. Sustainability..), therefore some moroccan growers are even forced to move to these type of applications.

The actor concluded by saying how these barriers could be overcomed. It was said that the EU should play a role by the open up the markets and reduce export barriers. So they actually allow individual or group growers from market to sell directly on the market. Either that or the growers would make an association to incorporate more and more growers and sell together. Regarding the knowledge I believe the most important thing is to show and demonstrate with practical examples and cases.

Dutch Grower 1:

The actor started talking about his experience within horticulture, how he works within this field for over 25 years, within crop protection and biological pest control. In the last 17 years, this actor has worked internationally, 4 years in Morocco, this experience in particular is quite interesting as I have noticed since the start the interest from Moroccan growers in the in improving the technology. So there is a collaboration because from the Dutch side there is the energy crisis and from the Moroccan side there is a seek to improvement. In holland it is a platform of technological and products distribution, we are great producers and great exporters thanks to our advanced logistic. Whlist Morocco not only is very close to the EU but it is a great producing country, especially during the winter times. There are of course many challenges like the water scarsity, but with the adoption of new technologies this problem could be tackled. So an interest to enter the Moroccan market from the Netherlands there has always been even if I have to say it is being speed up by the war in Ukraine, it was surely a trigger, but there are already some dutch businesses working in Morocco since 20 years now. But another trigger is the increase of labour costs in EU, which do not make the production profitable anymore.

The actor started talking about a great challenge for horticulture in Morocco, which is the increase in the taxation of the horticulture. With an increase in the VAT, so the production is become much more heavily taxed than it was. But for some crops, like tomatoes, I still have great margins of income in Morocco, that may allow a grower to continue on investing in horticulture, however if I compare the margins now with the ones of 15 years ago there is a big difference, that is why it is needed to innovate and produce more to maintain higher profit margins. The best technology to be implemented in Morocco is the one that can tackle the different limiting parameters that influence production in the periods of winter blues.
The actor continued talking about the infrastructures in Morocco, saying that the road and the logistic infrastructure is very well developed, believing it even better than some european countries. The most lacking one is the energy infrrastacture, as Morocco does not have any gas, oil. The country in the last 20 years have been implementing renewables.

One of the barriers for the switch in technology is the market, because you can produce more to export especially during winter times, where moroccan farmers get better deals. Of course all of the products have to withstand within the standards and regulations of the European market otherwise they could try to sell the product to the national market. However, the problem is that Moroccans are limited in the export due to the quota setted, so if you have these limitations its harder for farmers to make the investment in a new technology, due to the European protectionism. This is something which is blocking the development and diffusion of this technology. So the only reason why the growers might switch in technology is for entering the european market, so if there is a market there is a development of the industry. Another thins is that

The collaboration among the grower is important not only for knowledge share but also to build together some packing facilities, but sometimes there is competition on price. Last 15 year there has been a switch towards english, because they want to increase their indipendence from France.
The actor regarding the knowledge on operations within a high-tech greenhouses said ‘before you get to drive a license, you have to learn driving.’ The transfer of technology does not have to be only for the hardware part but for the software part too. When I was working in Morocco, I tell you that the first two / three years it's knowledge transfer and making the system understandable. So the you need to invest in transferring the knowledge. Explain how to do how the tools are working. How to work with them how to analyze the data , because yeah, it's it's because we're moving from doing the observation to analyzing data. I have to say that when I was working in there changing the mindset is the most difficult part because people are used to a certain system and now you tell them to change them. So people are afraid because they do not understand how the technology works and do not have any experience with it. This is valid for any technology you implement. People have to get familiar with it, knowing how to use it. That was why the impact cluster was developed with a demonstration greenhouse put in place in the Institute where we can showcase let's say the added value or the different technologies and tools we are using. To show them.
Within a high tech greenhouse in Morocco you could grow tomatoes, soft fruits, beans and herbs. Even if beans are highly labor intensive so I do not know if it could be profitable to move into a higher tech greenhouse. For all of these products there is already a very good market established.
The problem of the tomatoes is that in Morocco people do not eat cherry tomatoes the ones consumed in Europe, that is why with the quota it could be a limit to produce more of these products. Regarding the herbs they are sold as well for the local market, but the soft fruits are majorly exported and not many of them remain on the local market. The actor believes that the Moroccan have a very good knowledge on how to grow and take care of these crops, within the Moroccan environmental conditions. What is lacking is the knowledge of the hardware.

Appendix F: Summaries of the interviews with Moroccan actors

Moroccan researcher 1:

The actor has given a great picture of the current situation in Morocco, highlighting how there is a massive decrease in the groundwater level by 2 meters per year, how mostly of the products produced in Souss-massa are for export, and how the price of water has gone up in the last years. According to this actor the main barrier to the diffusion of SG are the high costs, in fact it would be very expensive for the growers to implement such technology. Currently the different research centers and universities are collaborating in the development of cheaper alternatives, which although they might not have the same efficiency of the Dutch technology can be a good starting point for improving production and reduce resource use. The university offers short courses of formations to growers that want to learn on how to use high-tech greenhouses. This is done with the use of lectures and practical demonstrations, by showing. This was the main reason for building a full glass high tech greenhouses in the university campus, to show. In fact, the main goal of the Hassan II university is to research, share knowledge and connect the different actors among different fields. By being in direct contact with a wide variety of growers, the actor has noticed how there is a lack of knowledge for the use of the technology, in fact he stated that "many times happen that the farmers use the technology in the wrong way". This does nothing more than increasing the skepticality of certain growers in the introduction of such technology, after mentioning this he highlighted the importance of the demonstrative greenhouse in campus to show them in practices how the technology works and that the growers with its implementation could increase their yield. The stakeholder has mentioned the english barrier, that although some of the growers speak good english most of the smaller growers do not speak any. Despite this, every grower have a good knowledge of French. Another problem mentioned by this actor is the lack of workforce for the greenhouse production, but only for some market applications (e.g. soft fruits). The actor said "there is not only a lack of workers but there is also a lack of workers with the knowledge on how to use the technology". This is a big issue but the university is trying to do its part, although the greatest role is played by the agricultural department. Regarding the competitors to the diffusion of high-tech greenhouse, the actor mentioned that many growers prefer to buy more land rather than investing in technologies that want to improve the yield per meter square. The actor continued mentioning that in the Souss-Massa region there is a highly developed infrastructure for water and energy, but in some more rural areas in Morocco it is not as good as in this area. Whereas the road infrastructure is highly developed in the whole of Morocco. Currently the government is improving the water infrastructure with the building of more desalination plants, but there is a continuos discussion between the government and some growers for the materials and technologies that should be subsidies, he suggested to put on finance the water management technologies and climate management technologies. The actor continued stating that many farmers do not have any knowledge on how to make a business plan, and that smaller farmers do not have any knowledge on how to get an investment. Therefore what happens is that they get helped by agricultural banks which 'should' be involved in the project. Another issue that has been highlighted is that many farmers have their piece of land fragmented. The actor than started talking about the university and the infrastructures built in the last years. Firstly an in campus incubator has been built which is going to become active in the coming year, then the greenhouse built by HortiXS which works have started 1.6 years ago and they are going to end by September 2023.
For some types of market applications the use of this technology cannot be applied as the price will be higher and the company will not be competitive on the market.

Moroccan Researcher 2:

According to this actor the main barrier to diffusion to high-tech greenhouse technology is the price barrier as many growers do not see the point of making such an investment because they are still profitable with the technology they are using right now. It was said ' Currently 95% of farmers have less than 5 hectare and they cannot afford to implement high-tech greenhouses'. This stakeholder has put major emphasis on the fact that is necessary to

develop an ad-hoc solution for Morocco. The case of high-tech greenhouses have to be adapted within the Moroccan context, as it is not possible to continue on importing the technology from EU as it would cost a lot not only on the import itself but for its maintenance too. Therefore it would be better to develop a cheaper local technology: 'to adopt the technology to our reality'. Similarly goes for the crop production it is important to analyse the market application of the technology, the adoption of new technology should be flanked with the development of new crops that fit within the Moroccan circumstances. The use of such technology would fit different market applications according to the region, for instance the north of the country,in the area of Rabat ,there is the biggest market for the soft fruit production, over 15k hectares, whilst the area of Agadir it is more diffused the production of tomatoes. However it is important to state that each produced crop should not be water intensive. The price of a worker to pick up the horticultural products within a greenhouse has increased a lot, what is more when a big grower finds some good workers he keeps them for himself, leaving the smaller growers with a lack of pickers. That is why many growers are starting to hire women within their greenhouses, they work harder and they do not complain. Furthermore they are paid in the same way man are.
The actor has continued saying that the main technological components that need to be adopted within the Moroccan context is the heat insulation for the winter temperatures as well as sensor for monitoring. Most of these technologies are not expensive but in most of the cases people do not have the knowledge to use such technology. Furthermore currently there are people that have the knowledge on how to fix the Canarian type of greenhouses in Morocco, but there are not too many people that know how to fix a problem within a high-tech greenhouse in Morocco.

Moroccan Grower 1:

The author started by introducing the growers association by saying that they gather the producers and exporters of Morocco. This is the greatest growers association of Morocco owned by the companies not by the governament, this association includes a research centre named CTT created in 2005, with a total of 8 greenhouses. The actor started talking about the water problem and how it was perceived. Starting mentioning that moroccans have been mis-using water by giving 'as much as they can to the plant' as most of the people thought that this was the best way to water a crop. The stakeholder then mentioned how there it has been an increase in the price of the materials to build a greenhouse in morocco, therefore at the moment it is very expensive even to build a low tech one. This is because some of the components are imported too, therefore if a component breaks it needs to be imported from the EU, as currently there are no companies that produce such components in Morocco, but with the passing of time and the diffusion of such technology new companies will be formed in Morocco and the import of the technology from EU will be reduced. The actor than mentioned that his fear is that there is a lack of market, that although a grower produces a lot of products because the quota on tomato he would be unable to export them. Moroccan growers cannot export as much as they want as they are competitors of the Spanish and Dutch producers (e.g. Moroccan growers are not allowed to sell the tomatoes to the EU market all year round to not harm the EU producers) . When exporting products from Morocco to Europe there are a lot of challenges to overcome, this is why it would be important to enhance the local consumption . In fact the actor stated 'We need to produce and sell locally, we need clear agreements which do not change with a change in government'. However to implement such technologies there it must be a strong support from the government, which there is not at the moment, this is because the government does not understand that from 2015 to 2022 the costs of production have doubled. Therefore before developing a producer objective a government objective has to be developed, as the government posses enough founds to support the diffusion of this type of technology. Currently this objective is lacking, even because many times the objective from the government side and the APEFEL side are not shared.
Regarding Dutch companies that are entering the moroccan market to sell the technology, the actor said that they are surely playing an important role in the encouragement of the diffusion

of the technologies and that most farmers and companies are open to gain knowledge and expertise regarding the thing they do not know. However, he has highlighted how there is mainly a strong economic interest from their side. Most Moroccan growers are not skeptical but they are hesitant, that is why we have built the CTT, to show them the greenhouses, we bring the growers here and we show them the technology, the yield and we convince them to adopt this technology. The growers trust us because we give them the real answer to their questions. If the technology does not work we will tell them that it does not work, we have no reason to lie to them because this centre is owned and funded by farmers. What is more currently more and more farmers have started connecting with each other and working closer together. This is because the farmers are starting to understand that they are not direct competitors, in fact they meet even some times in caffe's to talk with each other and share knowledge. What the actor is noticing is that if a farmers sees another farmer introducing some new technology, he wiil jump in and introduce it too.
This actor has made an important affirmation ' Morocco should not produce and export any horticultural products because there is a lack of water in the country. Morocco should produce the technology and export the knowledge on how to grow some types of crops but not produce any.' The actor continued saying how many other relevant actors agreed in this affirmation. He concluded that in Morocco greenhouses are used to produce tomatoes, beans, pepper and soft fruits.

Moroccan Grower 2:

This actor started by mentioning his connection with the university and APEFEL. The main horticultural products that this grower produces is beans, furthermore he buys and re-sells seed to international market. This farmer is a medium size grower with 5 hectare production. Straight after this was mentioned the stakeholder made the joke ' I would rather have half an hectare with dutch technology than 5 hectares with mine'. The stakeholder continued saying that the products that beans that he produces are fully exported and sold to EU (Holland, Spain and Germany), as there is no market in Morocco for such horticultural products as it is not in the culture to eat this product type. Once the product is produced it is sent to the packing company, that once the products is packed sells it to the supermarkets. The grower highlighted that he produces beans all year round as there is not quota for the export of beans. However, they have to reflect certain parameters of shape otherwise they cannot be sold to the EU market. This growers has remarked how the crops that he produces in not highly profitable to a level that would allow him to switch to higher technology, currently there are some subsidies from the government but they are not enough to change technologies. The current subsidies relate to water irrigation and the building for the greenhouse of 1k euros. Then the stakeholder has said that many farmers do not know how to go through the bureaucratic process to ask for these funds, that is why some governmental offices have been established to help the growers to fill up the papers. Similarly, it was said that many farmers do not have any knowledge of English, but all of them speak french. Then it was said that the younger generation of farmers speak english. The grower has mentioned his collaboration with other farmers and how they have a shared programme, in fact, many times some farmers come to see his technology and to share knowledge with him. The grower pointed out that there is no lack of workers, especially for the picking, this growers higher women, that are trained in a day and they brought to work for the same wage as males workers. This grower mentioned that since the implementation of pipe irrigation he has noticed an increase in water use of 30%, for then saying that he uses the dam water rather than the desalinated one as it is 7 times more expensive. Then it was said that the plastic coverage of the greenhouses was used for 5 years and then he did not know what it was done with it once changed. He was really happy of the engagement of the Netherlands in the diffusion of better technology, to then mentioned that he visits greentech in the Netherlands every year to learn on how to improve his production, it was said ' It is very easy to have a connection with dutch companies as they show me everything and it is easy to communicate with them. Even if sometimes they try to sell me things, but I will only buy what I really need, so I do not fall in their tricks'. There is a growing collaboration among the mroroccan universities and the Netherlands, even if I do not benefit

from this, I know that some young people do, now I do not know if the knowledge these students are gaining is ever going to be applied to Morocco. The actor concluded by stating that he does not perceive water scarcity as a problem as the main concern is the yield.

Moroccan Gov-act. 1:

The actors started by talking about the federation that works within the water management of the groundwater, waste water, desalination plant and water harvesting. The director has highlighted that Morocco is current facing a double problem: the increase of water use in agriculture and the facing of the first effects of climate change on the nation. This is increasing the water stress. To fight this the government is working in the development of dams and water infrastructure across the whole nation. In fact it is planned that by 2040, three more dams are going to be built. The actor mentioned on how the deficit of water is bringing people together, in fact there is a growing debate with people from different roles such as APEFEL and the agricultural department. It is important to mention that this office is trying to push among the different growers the use of more sustainable irrigation methods, for instance the use of drip irrigation, but there is a continuos work to try to find the best technologies to subsidize for the farmers, in fact there is a strong collaboration with the NEXUS (water, food and energy). However, the actors has mentioned that it is up to the national committee the final decision for which technology has to be subsidized. For the areas where the water infrastructure is lacking, there are some farmers associations, which are subsidized by the agricultural department to build a common water network to encourage a more responsible use of water and to ensure water delivery to the farmers. However what is currently happening is that this division does not give the money directly to the farmers, but the farmers have to make the investment by themselves (e.g. to build a water basin for their greenhouses) and then the money will be refunded. It is up to the Agricultural department the managing of the fundings, which are allocated according to the reachment of the requirements set. Once that the farmer implements the technology, is not checked individually, if he knows how to use it, but it would be necessary to check the water balance of the crop. Regarding the farmers that has experienced an increase in water use by 30%, that could be due to more extreme environmental conditions brought by climate change. This actor believes that the farmers have a good understanding of the technology and knows well how to use it. According to this actor has stated that the barrier to diffusion is high costs for the equipment , as well as the higher water costs as due to the high costs to build the infrastructure the water is more expensive, for instance over 30% of farmers are not connected to the water infrastructure. However, this actor is working closely with the university Hassan II in Agadir to educate the new generations regarding the problem of water scarcity.

Moroccan Gov-act. 2:

The actor started by introducing the work done by this office, which takes care of disease control for imported and exported products. This governamental actors is made up by 10 offices spread across Morocco, this is done to ensure the quality of the products entering in Morocco and the quality and respect of standards of the exported products from Morocco. According to the country a company wants to export to there are some different regulations that have to be followed. If a grower is looking for a market in which to export its products, we ensure the communication among the growers to help him enter in the market, this is done with the help of seminars and the collaboration with APEFEL. This is done also to help the farmers to be updated with the always changing regulations, which are becoming tighter and tighter. In Morocco the introduction of High-tech greenhouses could be used to produce tomatoes, citrus and in the north area of Morocco the production of Soft fruits. The introduction of such technology may help in increasing the yield and reduce the amount of products that do not fit within the EU regulations and standards of shape. The products sold to the Moroccan market are aswell very controlled but not as strictly as for the EU market. However the introduction of such technology might help in reduce the costs of the products which due to covid and the worsen the environmental conditions got worse.

Moroccan Gov-act. 3:

This actors started by introducing the work was carried in the agricultural incubator in Agadir. It was stated that the centre had 35 start-ups, for which each one has an office in the building for 18th months, once they scale-up they could move to a techno-park. The aim of this centre is to develop innovative projects while mobilize fundings to help companies to scale. Currently there are 5 start-ups within this facility that relate to the greenhouse sector but only for the data analysis technology development. Hence there is no start-up that aims to produce greenhouse components but only software development. The actor has explained the key role of this centre is the introduction and diffusion of new agricultural technologies in Morocco, and how in most of the cases when a new agricultural innovation had to be introduced in Morocco, farmers were skeptical, that was why according to the stakeholder it was important to develop training programmes to actors to show them how to use the technology and to show the advantages that they will be getting while using it. It was stated ' We are encouraging and training the population in the use of the technology. Therefore we aim at spreading awareness and training'. The actor continued by stating that due to the long history of water scarcity in Morocco he perceived that saving water lies within the cultural history of people in Morocco, in fact many villages used to build water basins to collect water from rainfall since centuries in Morocco. Regarding the barriers to diffusion for the technology, the actor has mentioned as a main one the costs, stating 'if the farmers had the technology for free they would use it'. This price barrier is due to the increased costs of the materials due to the pandemic, and even because most of these materials are imported from the EU. Simultaneously along side the price barrier, there are the subsidies, which are hard to get due to the bureaucratic process. This unfortunately is not up to the incubator, however they are working along side the national office and APEFEL to understand which is the best way to encourage the diffusion of the greenhouse technology, therefore another aim of this incubator is to help overcoming the administrative problem. According to the actor the use of high-tech greenhouses could fit for the production of the following market applications: tomatoes, cucumber, bananas, flowers and beans. When it was asked to this actor how it was perceived the dutch investment and participation in the diffusion of such greenhouse technology, it was said that if the NL and any other european countries would like to enter in the Moroccan market by organising some programmes or by making any kind of investment they would be welcome. The interview concluded with the actor saying that Morocco is facing an economic growth and that will encourage the diffusion of high-tech plastic greenhouses in Morocco, in fact it was said that in around 40 years time there is going to be a full switch to this type of technology. However what may slow down the diffusion of the technology is the low investment in innovation in Morocco, in fact it was said ' While in the Netherlands the investment in innovation is around 3-4% of the GDP in Morocco is around the 0.7% of the GDP'. So if we do not invest in research how can we develop?'.

Moroccan Gov-act. 4:

The actor started by introducing the work that was conducted within this governamental office, of which the main goal is the application of the 'Green generation' plan, which aims at developing the human wellbeing, the sustainability of agricultural practices in Morocco and the encouragement of young generations of entrepreneurs. Regarding the last point, this is one of the biggest challenges for moroccan agriculture as most of the growers are people of high age, therefore it is necessary to try to encourage young people to start new companies within the horticultural sector. It is of great importance the collaboration among this organ and the universities to overcome this barrier, as this will help in bringing new ideas and to show to the farmers how to use some new technologies. Another obstacle that might slow down the diffusion of such technologies is the lack of development of an easier bureaucratic procedure to allow and facilitate farmers to start their companies, this is because it can be hard to get some help from banks. According to this actor there is a psychological barrier too, as some of the growers might not believe in the benefits of these technologies, this is not because they are not open indeed but if it is shown to them that such technology can bring certain positive impacts in their yield they will surely invest money in there, for the ones that have an

economical availability to do so. The price of water is a problem in Morocco, currently the farmers pay 3.2 dirhams for 1m3 of ground water, as 0.2 is for the taxes and 3 dirhams for the energy to pump it up. The actor continued stating that once a technology is subsidized, no more action from the government is taken and the adoption of this technology is left to the market. Regarding the collaboration among the different international actors, the actors expressed that the cooperation is welcome but it is needed a co-ordination to bring the actors together toward the same objective. Together with the help of the universities and incubators an exchange of information is created, so that we can show the dutch technologies to our growers. Currently Morocco is one of the first countries to be highly affected by water scarcity, but this problem is going to be more common in the coming years worldwide. In fact it is important to find the right balance between the produced products and the exports as we cannot put too much weight on our water resources. We are trying to encourage a more sustainable use of water and diffusion of new technologies with some legislations, for instance it is now prohibited to increase the land area expansion in Morocco for farmers. Therefore if they want to produce more they should be using higher technologies.

Moroccan Company 1:

The actor has started explaining how each country has its own regulations and product standards that is why this company focusses only for the export of tomato products only in UK. The stakeholder continued mentioning how there is a quota that Morocco has to follow for the export of tomato products, this quota is only for the export of tomatoes. Then it was said that before producing more horticultural products it is necessary to be sure that there is a market established for this product, otherwise growers / companies would make an investment ending up to sell the same quantity of products. What the company that works for does is selling tomatoes directly to supermarkets across the whole UK, she has mentioned that within her company there are a lot of people that have enough knowledge on how to operate high tech greenhouses. The actor continued saying that big growers are keen to adopt technological improvement, but regarding the smaller growers there is price barrier as the technologies are quite expensive to implement. Currently the government of agriculture is subsidizing different technologies (e.g. drip irrigation, the structure of greenhouses)(e.g. for the drip irrigation the government helps by paying around 30% of the final costs) and its trying to help the growers with financial advices, in fact the actor mentioned that there has been an increase of people hired to work in bureaucracy to help the smaller growers. The stakeholder said that in the case of export to UK there are not only standards to be respected within the physical characteristics of the product but there have been imposed some sustainability requirement for the product production that have to be certified otherwise the product cannot be sold in the market. The actor mentioned that, the greenhouses are not recycling the water due to the lack of knowledge on how to use that type of technology and the costs to implement. Continued suggesting the government to start some procedures to limit the water use by investing in more sustainable cultivation methods like high-tech greenhouses to help the farmers to switch to this technology. This actor was following some courses within the university of Agadir Hassan II, which are helping managers, growers, employees to formate and develop a model to manage technology. In fact there has been established a collaboration among the companies and the university to ensure training and consultancy. Furthermore, the actor mentioned how growers are facing water restrictions, as with the implementation of the desalination plants water is again available in the area but the price has increased 4 times. In fact now growers pay 5 dirhams (0.50 euros) for water coming from the desalinations plants. Currently, there is a good water infrastructure in the ware of souss massa, but it lacks in many other areas, in fact in some cases the private sector takes action more than the government to build these infrastructure.

Moroccan Company 2:

The actor started talking about the market, mentioning that most of the products are exported to the EU especially to Germany, Netherlands and United kingdom. This stakeholder has put major emphasis on the quote ‘ In Morocco we produce to export not to feed the population’,

even with a change in technology this would be done only to export more and sell to the EU. This is because the agriculture is the most important sector for Morocco, and we cannot stop producing because of the lack of water. Is like you tell the Saudi Arabians to stop pumping oil because of climate change, impossible, they would never do that. Currently we are using a quite high amount of water to produce tomatoes we use around 60 liter of water per kg of tomatoes, it is indeed needed to reduce this quantity of water used. But the diffusion of the technology could take 10, or even more years. This fully depends on the cost of the technology, as most of the growers would be very happy to invest in this type of technology but it is very expensive. Fortunately with the growing competition among greenhouse producers you can easily find nowadays companies that sell the same product for cheaper, this could help the adoption of the technology. The stakeholder made an example that if he had 6 hectares of canary greenhouses he would be able to switch only 2% of them to high-tech sustainable greenhouses. The actor highlighted the impossibility to convert to the new technology immediately due to this price barrier, so the solution would be to include some step by step improvements. Another barrier is the lack of training in fact the actor said an arabic quote ' if you do not understand something, that thing is opposed to you' to indicate the Morccan skepticallity to adoption of knew technologies, but that is only because they do not know about this technology. For example, currently there is only one person that has enough knowledge, one engineer or technician, for 20 hectares. This is not enough, to manage well the whole area, more people are needed. Similarly there is a lack of people that speak english, especially the growers, the actor said that there arre more growers that speak spanish rather than english. The actor continued saying that for some people formations is still important, in fact this stakeholder after 20 years this actor keeps on following courses at the university of Agadir to learn how to improve farm managing skills. The products that this actor would produce within a sustainable greenhouses are tomatoes, because morocco is the perfect country to grow them and they have a lot of experience on the crop, followed by soft fruits. It is important to note that a change in techno would lead to an increase of the costs of production, an increase in maintenance costs and harvesting costs therefore the costs of the crops are going to be higher. The current technology is imported from the EU, currently Moroccan people do not know how to fix the technology but this actor put major emphasis on a point ' In Morocco we are growers since always, we are not stupid when we talk about knowledge on how to grow crops. And I can guarantee you that if any farmer would purchase a higher tech greenhouse it would be purchased only after he knows perfectly how to run it and how to fix it. Therefore if the technology, once implemented breaks, we are not going to be dependent from the EU, because before importing and investing in it we have to understand how to fix it and use it.' Currently there are many technologies that are subsidized by the government.

The actor continued mentioning how for the smaller-medium growers there is no competition and there is a lot and continuos knowledge share. But for the greater corporations, the confidentiality comes in, therefore there is not much knowledge share with them. There is a lack of workers, especially pickers, depending on the season and for the type of crops grown. For instance the higher paying crops pickers are the following: soft fruits, vegetables, citrus. The thing is that is not an easy job and many people refuse to do it, for instance no student ever works in these greenhouses during weekends. Regarding the selling process the actor said that ' all the routes bring to Rome' , there are three different way you can sell a product to EU. The first one is to produce for a supermarket, the second one is to work with a supplier of a supermarket which puts their label on the product or the third one is that you work with a contractor for the EU market, which leaves your label to the product and takes 8% of the monetary value and then they sell it o the supermarket. The actor concluded by talking about the quota for tomatoes to the EU and cucumbers (to UK only) and if you exceed it you have to pay a gut.

Moroccan Company 3:

The company this actor works for counts for over 60 thousand employees. All the yield that is harvested is exported to the EU apart from the 5% which is sold locally. We are talking about

over 120 thousand tones of tomatoes, of over 300 varieties. The same goes for herbs, most of them are produced for export. The company that this actor is working in, to remain competitive on the international market, invested continuously in innovation. For instance, in 2014 there were built 1.2 hectares of high-tech plastic greenhouses were built, for which the actor is not particularly enthusiastic as he said that they do not produce more earnings than the other greenhouses. Another example of innovation within the company is the greenhouse they are building now with a closed system of water recycling. This is because of the high maintenance costs and the high water/ energy costs. The water costs are high because they are using the water from the desalination plant. However the company firmly believes in innovation, they have a department of R&D and they work with EU companies (from the NL) to implement new technologies.

The actor continued by stating that Morocco is facing an economic growth, and is becoming more and more relevant within the tomato export market, in fact the actor communicated that this last May, Morocco reached the position of 3rd Worldwide exporter of tomatoes. To stay within this market it is important to have sustainability certifications and have a strong network of collaboration with customers and clients to reach the desired requirements.

Regarding the competition, the actor confirmed that there is a strong one especially among the 3 big companies and exporters in Morocco, therefore there is a lot of confidential data which is not shared. However the company the actor is working in confirmed that there is a collaboration with the government and some associations.

The actor concluded how within his company there is no lack of know how and there is no lack of workforce. the best solution for morocco, according to this actor, is small improvements over time, for instance to improve variation they have increased the roof height within some greenhouses from 5 mt to 6.5mt and there were already some results shown.