



Rapid assessment of the Climate Change Water-Food-Energy nexus in the Republic of North Macedonia

Final Report

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LIST OF ABBREVIATIONS AND ACRONYMS

CAP	Common Agricultural Policy (of the EU)
EC	European Commission
ENDC	Enhanced Nationally Determined Contributions
EU	European Union
EUR	1 Euro (European Monetary Union currency)
FAO	Food and Agriculture Organization of the United Nations
FD	Floods Directive (of the European Union)
FLW	Food loss and waste
GHG	Greenhouse gases
ha	Hectare (1 ha = 10 000 square metres)
MAFWE	Ministry of Agriculture, Forestry and Water Economy
NDC	Nationally Determined Contributions
NGO	Non-governmental organisation
RE	Renewable energy
RES	Renewable energy sources
RNM	Republic of North Macedonia
SSPI	Smart, solar-powered irrigation
UNDP	United Nations Development Programme
UNFCCC	The United Nations Framework Convention on Climate Change
USAID	The United States Agency for International Development
WFD	Water Framework Directive (of the European Union)
WFE	Water-food-energy
WFEN	Water-food-energy nexus

EXECUTIVE SUMMARY

Background information

The United Nations Development Programme (UNDP) has initiated a project on the food-energy-water nexus in the Republic of North Macedonia, aiming at supporting nexus-oriented policymaking related to climate action. The project should carry out a rapid assessment and provide identification and analysis of the specific intersectoral issues in the country, determine priority issues to be addressed, and provide preliminary recommendations regarding further analysis and possible solutions to ensure water and food security, sustainable agriculture, and energy production.

Approach and methodological steps

The water-food-energy nexus (WFEN) is a novel concept in resources management. The “nexus” term in this context refers to the sectors being inseparably linked so that actions in one policy area generally have impacts on the others, as well as on the ecosystems that natural resources and human activities ultimately depend upon. The WFEN assessment of North Macedonia in this project is based on an analysis of linkages and inter-dependences of the water, food, and energy sectors in the light of climate change. It will be prepared following methodological steps: (i) an appraisal of the current situation in WFEN-related sectors (including legislation, governance, current practices, and stakeholders), (ii) identification, and description of possible nature-based, and technical WFEN interventions, (iii) consultation with key stakeholders, (iv) preparation of final report, and (v) presentation of key findings and recommendations.

ASSESSMENT OF LEGAL AND STRATEGIC DOCUMENTS, CURRENT PRACTICES, GOVERNANCE AND STAKEHOLDERS

WFEN-relevant legislation is sector-oriented and is not fully aligned to that of EU

At present, the country does not have any specific legislation on WFEN, and none of its legal documents refer to WFEN. Water, food (agriculture) and energy issues are regulated by legislative acts that are sector-oriented and hardly consider or refer to interlinkages with other sectors and their respective legislations. However, the sectoral legislation uses the notion of rational use/management of resources (land, soil, water, energy, etc.) – and without any doubt, it strikes the right chord and provides a favourable legal setting and solid stepping-stones for the implementation of the WFEN concept and practices. The regulatory framework relevant for WFEN is still not fully aligned to that of EU, which was also highlighted in a recent EC report. The water management legislation does not fully comply with the EU Water Framework Directive and Floods Directive. Legislation on agriculture lacks environmental cross-compliance, prohibiting environmentally adverse farming practices, and linking agricultural payments to adherence to water, energy, and climate-friendly methods. Legislation on energy production and consumption is largely in line with all relevant EU energy directives, but some legal acts are still to be adopted, such as on biofuels and on energy efficiency. The same goes for legislation on climate change.

IPARD is the most WFEN-relevant programme

Among all WFEN-relevant strategies and programmes, the most comprehensive and concrete from the standpoint of WFWN – is the IPARD rural development programme, which is largely financed by the EU. Its measures are very well defined. Moreover, the programme operates according to clear procedures, including eligibility criteria and definition of eligible investments – and has a sound budget for the implementation of measures relevant for WFEN.

Modest WFEN practices

At present, the country does not have much to demonstrate in terms of implementation of WFEN-related practices. There is hardly any cultivation of energy crops used for production of renewable energy and the production of renewable energy from farm by-products is insignificant. Water is used for irrigation, but renewable energy (except electricity produced from hydropower) is rarely used in agriculture and food processing.

...and outdated irrigation systems

The most significant WFEN and climate adaptation practice is irrigation. However, it is practised using outdated water and energy-use inefficient irrigation techniques and systems, most of which are in poor conditions. Other adaptation to climate change practices in agriculture are not widely spread. Several tested adaptation techniques proved to be successful – but have not been sufficiently promoted and adopted. A national fund for financing testing of adaptation measures in agriculture (notably introduction of drought resistant species) has not yet been established and not enough resources and efforts have been invested in adaptation-related research and innovation.

Governance lacks inter-sectoral cooperation

The country has well-developed institutional structures governing food, (agriculture), water, energy, and climate sectors. Their mandates and responsibilities are well-defined, and they operate well. However, their responsibilities and activities are sector-oriented and are primarily (if not exclusively) focused on their respective sectors. This hampers the implementation of WFEN concept and practices, as these require a holistic, integral, all-inclusive approach, based on inter-disciplinary and inter-sectoral cooperation.

Sector-oriented stakeholders

None of the stakeholders are focused on promoting and/or implementing WFEN concepts and practices. They are also sector-oriented, and their efforts and activities are primarily (if not exclusively) focused on narrow, specialised sectoral interests. There is not any platform, committee, forum – or any other formal or informal structure dealing with WFEN.

Selection of proposed interventions

Proposed interventions are selected based on the findings that resulted from the (i) initial contacts and consultations made with the representatives of the North Macedonian authorities and international donors, (ii) analysis of the relevant North Macedonian legislation, strategies, and programmes, (iii) analysis of numerous studies, reports, and scientific papers on various WFEN aspects, both from North Macedonia and elsewhere, and (iv) a survey undertaken among key WFEN stakeholders. Based on the screening undertaken, three pilot programmes are proposed:

PROPOSED INTERVENTIONS

Three pilot programmes

1. Pilot programme on carbon farming
2. Pilot programme on smart, solar-powered irrigation
3. Pilot programme on reducing food loss and waste

...integrating well the three nexus sectors

All three proposed pilot programmes very well integrate the three nexus sectors: water, food, and energy – and are highly relevant for climate change (both mitigation and adaptation). All three can be applied throughout the country, regardless of the farm size, landscape, and type of production (arable, fruit, vegetables, vineyards, animal husbandry, etc.). All three pilots are scalable, replicable and their application is relatively simple. They address some of the key problems identified by relevant national strategies and programmes and are highly compatible with the EC CAP and efforts of the international donor community. Additionally, all three pilot programmes are expected to (i) demonstrate good WFEN practices, (ii) deliver a range of private and societal benefits (environmental and socio-economic), and (iii) provide evidence-based insights on the applicability of WFEN under North Macedonian conditions. The proposed pilot WFEN initiatives should also contribute to the development of human and social capital at the local, regional, and national level required to implement WFEN concepts and practices, leading to their wider uptake and upscaling.

1 BACKGROUND INFORMATION

Project rationale

The United Nations Development Programme (UNDP) has initiated a project on the food-energy-water nexus in the Republic of North Macedonia, aiming at supporting nexus-oriented policymaking related to climate action. The project implementation has been delegated to Eco Limited, a UK-based consultancy specialised in climate change projects.

Scope of work

The overall objective of the assignment is to carry out a rapid assessment of the food-energy-water nexus in the context of climate change impact in the Republic of North Macedonia. This rapid assessment should include a general identification of the specific intersectoral issues in the country, a determination of priority issues to be addressed, and preliminary recommendations regarding further analysis and possible solutions to ensure water and food security; sustainable agriculture; and energy production. In particular, the assessment should:

- Review relevant national legal and strategic documents, review the status, current practices, governance, and stakeholders related to water use in WFE sectors
- Assess interactions, trends and potential conflicts in the WFE equation, using the nexus approach
- Present and describe appropriate technical, effective governance and policy interventions in terms of optimal use of scarce water resources and their efficient use for drinking/sanitation and electricity/food productivity
- Provide a general comparison of different interventions, based on how efficiently they make use of water, energy, food/ land, employment and financial capital
- Draft recommendations for policymakers on further analysis needed and interim measures that can enhance synergies between water availability, energy generation and food production, while managing trade-offs and preventing potential conflicts
- Present the research above in a WFE Nexus Rapid Assessment Report with an executive summary for policymakers summarizing key findings and recommendations
- Present the findings and recommendations in two webinars for key stakeholders in the Republic of North Macedonia and the Western Balkans.

2 METHODOLOGY

Methodological steps

Our assessment has been prepared following six methodological steps that are shown in Figure 1. These steps include (i) an appraisal of the current situation in WFEN-related sectors) (including legislation, governance, current practices, and stakeholders), (ii) identification and analysis of interlinkages and possible conflicts between these sectors, (iii) identification, and description of possible nature-based, and technical WFEN interventions, (iv) consultation with key stakeholders, (v) preparation of final report, and (vi) presentation of key findings and recommendations.

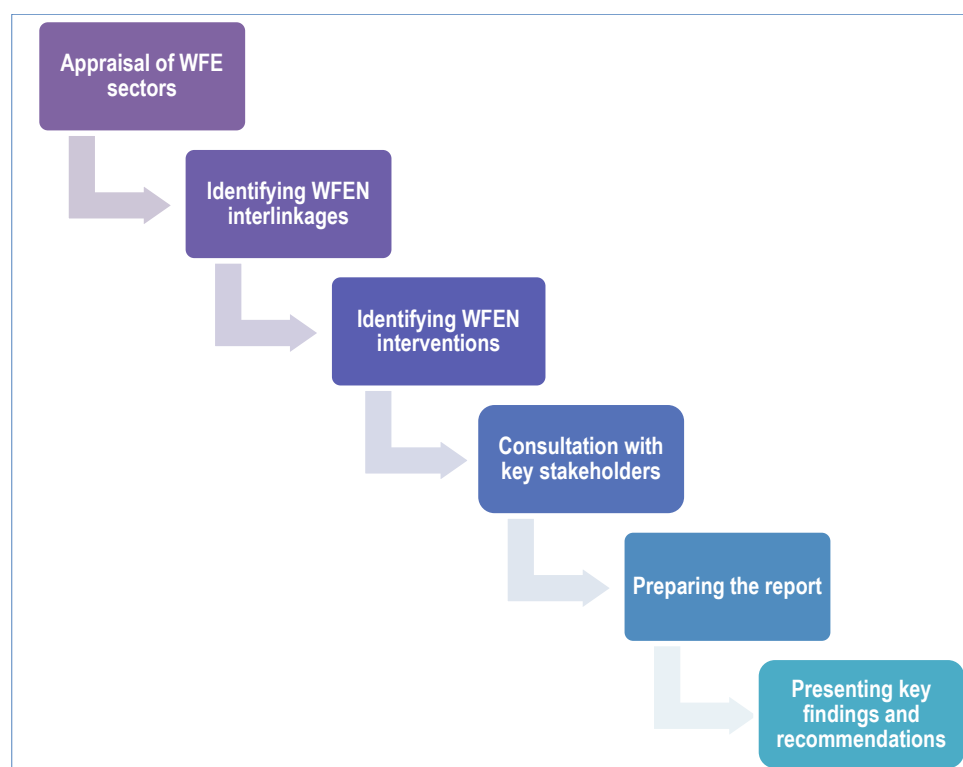


Figure 1: Methodological steps

Step 1: appraisal of WFE sectors

The first part of the nexus assessment is focused on the context analysis, providing information on the policies and strategies on water, energy, and food; governance; current practices and key stakeholders.

Step 2: identifying WFEN interlinkages

Step 2 refers to identification and assessment of interactions, trends, and potential conflicts in the WFE equation for North Macedonia. Based on the collected data, reviews of the status, current practices, identified stakeholders and governance in water, climate change, agriculture and energy sectors, interactions, trends, and potential conflicts in the nexus equation will be evaluated.

**Step 3:
identifying WFEN
interventions**

Step 3 refers to identifying and presenting appropriate interventions in terms of optimal use of scarce water resources and their efficient use for food productivity and energy production. Interventions might be nature-based or technical in nature and will be assessed considering how efficiently they make use of water, energy, food/land, and employment. Proposed nexus interventions will have a cross-sectoral dimension and will benefit more than one sector while reducing pressure on ecosystems or the environment in general.

**Step 4:
consultation with
stakeholders**

Step 4 is consultation with key stakeholders. A participatory approach is very important in the joint identification of the main nexus issues. Key stakeholders were engaged in the assessment process to build consensus on strategic issues across sectors. Involvement of stakeholders was ensured via an on-line survey and on-line consultation.

**...involving a
survey**

To support the desk study, a condensed on-line survey was prepared and sent to representatives of the relevant ministries, and several additional institutions/organizations from nexus relevant sectors. The list of these entities was determined in the communication between the consulting team and the beneficiary. The results obtained by survey and on-line consultation were used in preparing the final assessment. This process enabled bringing all the sectoral views and identified interlinkages and possible interventions into a single nexus picture, and a shared nexus understanding.

**Step 5:
Preparing the
WFEN report**

Analysis and findings of all previous steps were incorporated in the WFEN Rapid Assessment Report.

**Step 6: Presenting
key findings and
recommendations**

The findings and recommendations were presented in two webinars for key stakeholders in the Republic of North Macedonia and the Western Balkans.

3 APPRAISAL OF WATER-FOOD-ENERGY SECTORS IN NORTH MACEDONIA

3.1 Understanding of the assignment and water-food-energy nexus

Understanding of WFE nexus

The water-food-energy (WFE) nexus is a novel concept in resources management. The “nexus” term in the context of water, food and energy, according to the United Nations Economic Commission for Europe (UNECE, 2018), refers to “these sectors being inseparably linked so that actions in one policy area generally have impacts on the others, as well as on the ecosystems that natural resources and human activities ultimately depend upon”. According to the UN Food and Agriculture Organization (FAO, 2014), the added value of a nexus approach is that it “provides a cross-sectoral and dynamic perspective and that it helps us to better understand the complex and dynamic interrelationships between water, energy and food, so that we can use and manage our limited resources sustainably”.

No single, agreed-upon methodology

The nexus methodology should include identification of issues that have to be handled with the nexus approach, identification of integration and synergy issues between sectors and design, appraisal, and prioritisation of interventions. There is no single, agreed-upon methodology for the WFE nexus appraisal. In developing methodology for this rapid assessment, an analysis of the different approaches and existing methodologies has been undertaken. In particular, the methodology developed by the FAO and the one developed by the GEF-funded “Drin Project” implemented by UNDP and executed by the Global Water Partnership - Mediterranean (GWPMed), in cooperation with the United Nations Economic Commission for Europe (UNECE), has been considered and built upon. The FAO approach to WFE nexus is presented in Figure 2. Also, methodology of the assessment in the context of the Nexus Project in South-Eastern Europe, supported by the Austrian Development Cooperation (ADC) has been considered.

WFEN sectors covered

The WFEN-related sectors we cover in this project include the following:

- The water management sector relates to management of water and public water estate, protective and hydro-ameliorative water structures (notably irrigation and drainage systems), protection against water pollution and harmful effects of water.
- The food sector relates to primary agricultural production of crops and livestock, food processing, and food consumption.
- The energy sector relates to the production and distribution/supply of energy used in the food and water sector. This also includes on-farm energy production from renewable energy sources (RES) based on farm by-products.
- The climate change sector – strictly speaking, climate change is not a sector. However, in our nexus analysis we have included mitigation and adaptation aspects of climate change – as these are essential for providing a comprehensive WFEN analysis.

Table 1 provides our understanding of the WFEN matrix, showing the linkages and inter-dependences of the water, food, and energy sectors in the light of climate change.

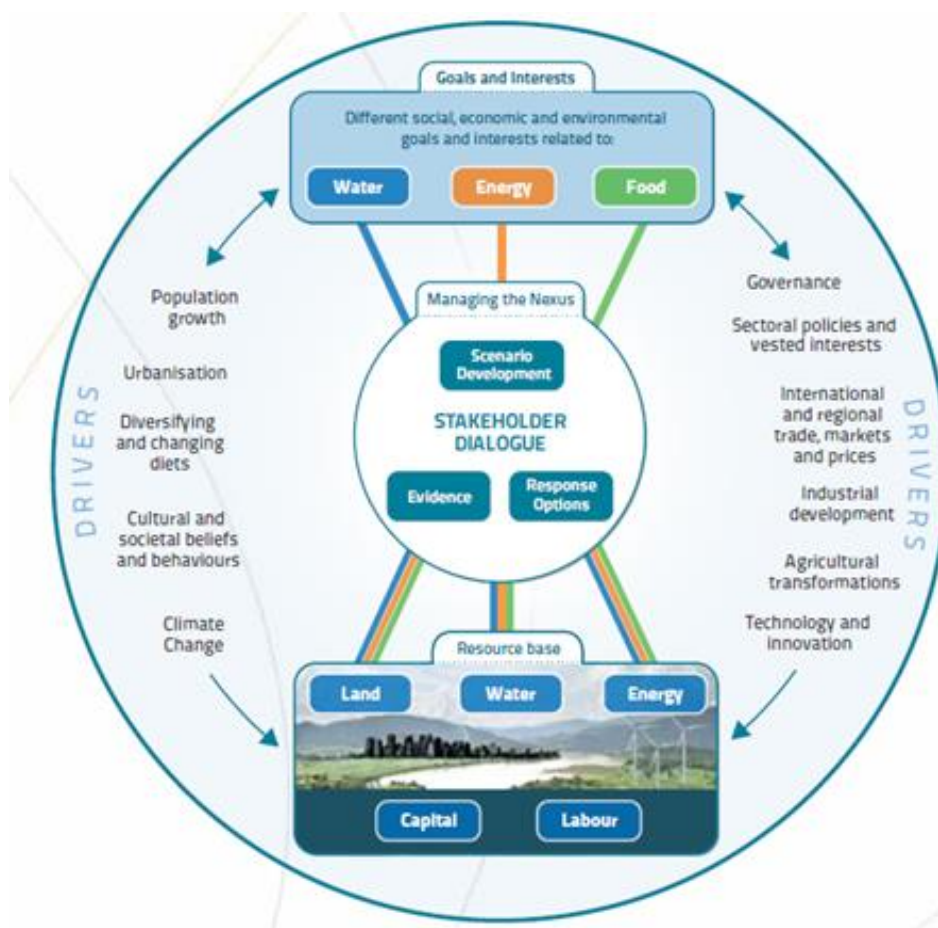


Figure 2: The FAO approach to the Water-Energy-Food Nexus (FAO, 2014)

Table 1: The water-food-energy nexus (WFEN) matrix

Sector impact	Food	Energy		Water			Climate	
	Production, processing, and consumption	Production	Consumption	Supply	Pollution	Consumption	Mitigation	Adaptation
Food ➡		Energy crops production ¹ Bioenergy production from farm by-products ²	Energy consumption ³ of agriculture, and food processing, distribution, storage, and consumption	Ecosystem services provided by agriculture, influencing water quality and quantity ⁴	Pollution by pesticides and nutrients	Crop, livestock, and food processing water consumption	Carbon sequestration in biomass and soil Use of renewable energy	Climate change calls for implementation of adaptation measures in agriculture
Energy ➡	Land use implications of biomass, wind, and solar energy production			Impact of energy policy on water resources Hydropower impacts on hydrogeomorphology, including floods	Acidification of water resulting from the combustion of fossil fuels	Water usage in energy production	Renewable energy production reducing GHG emission	Not relevant
Water ➡	Water management implications for use in agriculture (irrigation)	Water management implications for hydropower production	Energy needs of water sector				Not relevant	Water management is one of the key adaptation strategies
Climate ➡	Climate change impacts on agriculture	Climate change impacts on biomass and hydropower production	Main source of GHG emissions & cause of climate change	Climate change alters water cycles and supply	Not relevant	Climate change alters water consumption patterns		

¹ The most common ones include maize, alfalfa, perennial grasses, switchgrass, miscanthus and energy crops for liquid biofuels production, such as those used for biodiesel production (rapeseed, sunflower, soybean, etc.) and those used for bioethanol production (wheat, sorghum, and sugar cane, etc.).

² Generated from organic waste from energy crops and farm by-products, such as manure/slurry, cornhusks, grass clippings, etc.

³ Coal, oil, natural gas, firewood, geothermal, hydrogen and electricity (generated from coal, oil, natural gas, nuclear energy, hydropower, solar, wind or/and biomass)

⁴ Including groundwater recharge and purification, surface water availability and quality, mitigation of flooding in downstream areas (disaster risk reduction), climate regulation (evapotranspiration rates from soils and vegetation supporting humidity and precipitation patterns), water regulation (i.e., hydrological flow).

3.2 Legislative framework relevant to WFEN

Key legislative acts

...on food

The most relevant legislative framework regulating WFEN-related sectors in the light of climate change comprise the following key legislative acts:

- Law on Agriculture and Rural Development⁵ – this is the main law regulating agricultural production and rural development, defining national policy objectives, planning, monitoring and evaluation mechanisms, partnership with social and economic partners, measures for regulation and support of agricultural markets, direct and rural development payments, state aid in agriculture and rural development, enforcement, and control of policy implementation.
- Law on Livestock Husbandry⁶ – the law defines the goals of animal husbandry, the conditions and technologies used in livestock rearing, breeding programmes, genetic pool policies and practices, animal welfare and other aspects of livestock husbandry.

...on water management

- Law on Water Management⁷ – this law regulates the establishment, organization, modes of operation, financing and supervision of water management companies operating and maintaining irrigation and drainage and other facilities regulating hydrological regimes.
- Law on Water Management Boards⁸ – this law defines and regulates the conditions, establishment, registration procedure, operation, supervision, and termination of water management boards – associations of agricultural land users (re)constructing, managing, maintaining, and upgrading small irrigation and/or drainage systems and related water distribution networks and hydro melioration systems.

...on energy

- Law on Energy⁹ – this law regulates the objectives and mode of implementing the country's energy policy; the construction of energy facilities; the status and competence of the Energy and Water Supply Regulatory Commission of the Republic of North Macedonia (RNM); the electricity, natural gas, heat energy markets, as well as the crude oil, oil derivatives and transport fuels market; the manner and procedure for determining and fulfilling the obligations to provide a public service on the electricity, natural gas and heat energy markets, as well as the rights and obligations of energy consumers and users of energy systems; and the manner and conditions for encouraging the use of renewable energy sources. Its WFEN matrix¹⁰ is presented in Table 11.

⁵ Official Gazette No. 49/10, 53/11, 26/12, 15/13, 69/13, 106/13, 177/14, 5/15, 3/15, 83/15, 154/15, 11/16, 53/16, 120/16, 63/16, 74/17, 83/18, 7/19, 27/19, 152/19, 244/19 and 275/19.

⁶ Official Gazette No. 23/13.

⁷ Official Gazette No. 85/03, 95/05, 103/08, 1/12 and 95/12

⁸ Official Gazette No. 51/03, 95/05, 113/07, 136/11 and 95/12

⁹ Official Gazette No. 96/2018

¹⁰ Note: WFEN matrices in Appendix I and Appendix II are provided only for legislation, strategies and programmes with multiple WFEN elements.

**...on climate
change**

- Law on Energy Efficiency¹¹ - this law regulates the efficient use of the energy; energy efficiency policy; the competences of the competent Ministry for energy matters and the Energy Agency for the implementation of this law; the obligations of the public sector regarding energy efficiency and energy consumption; the energy efficiency obligation scheme and the alternative measures; energy audits of large enterprises; energy efficiency in generation, transmission, distribution and supply; the provision of energy services and the manners of financing supporting measures for energy efficiency; the energy efficiency of buildings; and the energy labelling and eco-design for energy-related products. The law also regulates the implementation of energy efficiency measures within the industrial sector, including the food processing industry.
- Ordinance on Renewable Energy Sources¹² - this regulates the definition and registration of all kinds of renewable energy sources (RES) and RE (renewable energy) production. Its WFEN matrix is presented in Table 12.
- Decree on support measures for electricity generation from renewable energy sources¹³ – this regulates the definition and categorisation of RES eligible for feed-in tariffs and registration of small-scale hydropower and hydropower energy production. Its WFEN matrix is presented in Table 13.
- Draft Law on Climate Action (or LCA) - (not adopted – in the drafting process) – this law will regulate the framework for climate action in the Republic of North Macedonia. When enacted, the law will serve as an umbrella law for all climate mitigation and adaption considerations in the country.
- Law on Environment¹⁴ - this law is the basis for environmental policy and management, thus providing guiding principles and policy instruments. It contains the fundamental environmental protection principles, which are the basis for determination of environment management procedures, which are common for all laws regulating environmental media.

**Key finding 1:
limited progress in
transposition of
the EU *acquis***

As North Macedonia aspires to EU membership, it has aligned its policy objectives with those of the *acquis communautaire*. Significant efforts and considerable progress have been made in this respect, particularly over the last couple of years. However, the country's regulatory framework is still not fully aligned to that of the EU. Many EU policies and legislative requirements have been included in the RNE regulatory framework, but the country still has a lot of work ahead, notably in terms of enforcement of what

¹¹ Official Gazette No. 32/2020

¹² Official Gazette No. 112/19

¹³ Official Gazette No. 29/19

¹⁴ Official Gazette No. 53/05, 81/05, 24/07, 159/08, 83/09, 48/10, 124/10, 51/11, 123/12, 93/13, 187/13, 42/14, 44/15, 129/15, 192/15, 39/16

has been (or will be) adopted “on paper”¹⁵. This counts for the WFEN-related sectors, too. The European Commission is of the opinion (EC, 2021a) that in “Chapter 27: Environment and climate change”, the RNM has made just “some level of preparation” and that “most of last year’s recommendations were not implemented”.

**Key finding 2:
WFEN issues are
regulated by
sector-oriented
legislation**

At present, North Macedonia does not have any specific legislation on WFEN¹⁶, and none of the legal documents refer to WFEN. Water, food (agriculture) and energy issues are regulated by legislative acts that are sector-oriented and hardly consider and refer to interlinkages with other sectors and their respective legislations. However, the sectoral legislation on water, food (agriculture) and energy, use the notion of rational use/management of resources (land, soil, water, energy, etc.) – and without doubt strikes the right chord and provides a favourable legal setting and solid stepping-stones for the implementation of the WFEN concept and practices.

**Key finding 3:
water management
legislation must be
further aligned with
EU WFD and FD**

The North Macedonia’s legislation on water management is relatively straightforward. The functioning of water boards (associations) is well regulated, providing a good base for the implementation of the WFEN-related activities. However, a better alignment with the EU Water Framework Directive (Directive 2000/60/EC) and the Floods Directive (Directive 2007/60/EC) would provide even a sounder regulatory framework for enabling the WFEN concept and practices to be implemented. These two EU Directives call for an integrated approach, based on a single system of water management, following water basin management plans and flood risk management plans considering that irrigation and drainage-related efforts respect water demand of different users and the need to reduce and manage water pollution from agricultural sources and flood hazards.

¹⁵ A good overview on the RNM’s accession efforts and achievements in harmonising its policies and legislation with EU requirements is provided in the recent EC progress report (EC, 2021a).

¹⁶ North Macedonia is not an exception in this respect. The same counts for all other countries in the World – the project team is not aware of any country with specific WFEN legislation.

**Key finding 4:
no environmental
cross-compliance
in agriculture**

The current legislation on food production (agriculture) is not yet sufficiently favourable for the implementation of WFEN concept and its practices. This is mainly because its environmental component, calling for better integration and protection of water, energy and climate in agriculture is still underdeveloped. The work on defining and enforcing environmental cross-compliance¹⁷ prohibiting environmentally adverse farming practices¹⁸, and linking agricultural payments to adherence to water, energy, and climate-friendly methods is still at an early stage of development. The problem was also highlighted in the recent ex-ante evaluation of the IPARD III programme (Ecorys, 2021).

**Key finding 5:
WFEN-friendly
energy legislation**

Legislation on energy production and consumption favours the implementation of WFEN concept and its practices. It is largely in line with all relevant EU energy directives, which as transposed as part of the obligations under the EU Energy Community. For example, the Amended National Renewable Energy Action Plan is in line with the revised binding target of 23% of energy coming from renewable energy sources by 2020 and 24% by 2025 (in 2019, North Macedonia achieved a share of only 17.5%). The Energy Law is fully aligned with the EU Renewable Energy Directive (Directive 2018/2001/EU). However, some pieces of legislation are still to be adopted, such as the Law on Biofuels, that is in the drafting phase. The same goes for the adoption and implementation of energy efficiency legislation, which the EC highlighted as a particular point for improvement (EC, 2021a).

¹⁷ Cross-compliance is an important tool for integrating environmental requirements into the EU Common Agricultural Policy (CAP). It ensures that support granted to farmers (both for production and implementation of rural development measures) contributes to promoting sustainable agriculture and the environmental objectives of the EU. In other words, environmental cross-compliance requirements make sure that public money is paid for farming that serves public policy objectives and promotes provision of environmentally related public goods and services. Environmental cross-compliance pays particular attention to, and sets a range of climate-related requirements. It is made up of:

- Statutory Management Requirements (SMRs) – a selected number of obligations incorporated in the scope of cross-compliance rules from existing EU environmental directives and regulations. SMRs are agricultural management standards (provisions) drawn from the application of relevant articles of these directives and regulations. In the context of WFEN, the most significant SMR is the Directive on the use of nitrates (Council Directive 91/676/EEC).
- Standards on good agricultural and environmental condition of land (GAEC) – calling for the implementation of farming measures aiming at mitigation of, and adaptation to climate change; protection of water against pollution by plant nutrients and pesticides; maintenance of permanent grassland; protection of soil against erosion and maintenance of soil fertility by taking care of the soil organic matter and soil structure; and protection of biodiversity and retention of landscape features.

¹⁸ Under the new CAP (2023-2027), cross-compliance requirements will be changed – new conditionality and greening systems will reflect higher green ambitions and contribute to the targets of the European Green Deal. This includes the introduction of eco-schemes, which will provide stronger incentives for climate- and environment-friendly agricultural practices. Until 2023, current measures apply, in line with the provisions of the CAP transitional regulation.

**Key finding 6:
relevant climate
legislation in
preparation**

Legislation on climate change issues is quite comprehensive, aspiring to connect relevant sectors and issues, which is quite favourable for WFEN. However, the EC is of the opinion (EC, 2021a) that “limited progress was achieved in climate change”, with “implementation in all sectors remaining a concerning issue”. But several activities to remedy this have been initiated lately. In April 2021, the Government has submitted its enhanced NDC (National Determined Contributions/ ENDC Enhanced National Determined Contributions), significantly increasing its ambition to reduce GHG emissions. Recently, the country conducted several key activities aiming at strengthening national legal and strategic framework on climate change. Currently there is no separate law on Climate Action. Climate Change issues are treated under the chapter on global issues within the Law on Environment. Preparation of the new Law on Climate Action started in February 2019, supported by the EU. The draft Law on Climate Action and first Long-term Strategy on Climate Action are in the final phase of the adoption by the Parliament. The new Law on Climate Action will, once adopted, act as an overarching climate change related legislation tool.

3.3 Strategies and programmes relevant to WFEN

**Key strategies
and programmes**

The most relevant strategies and programmes for WFEN-related sectors in the light of climate change comprise the following:

...on food

- National Strategy for Agriculture and Rural Development 2021-2027 (MAFWE, 2020) – this is the main mid-term strategic document defining goals, policies, and measures for the development of agriculture and rural areas, addressing a range of WFEN issues. Its WFEN matrix is presented in Table 14.
- Instrument for Pre-Accession Assistance for Rural Development (IPARD) Programme 2021-2027 (MAFWE, 2021) – this is an assistance programme to agriculture, rural development, and food sector, with the focus on the implementation of the *EU acquis communautaire*, preparing the country for participation in the EU Common Agricultural Policy. One of the programmes’ key objectives is adaptation to climate change and sustainable use of natural resources. North Macedonia’s IPARD comprises several measures and investments (for more details see Appendix II) focused on mitigation of, and adaptation to climate change, sustainable use and protection of water resources and more efficient use of energy in the primary agricultural sector and food processing. Its WFEN matrix is presented in Table 15.

**...on water
management**

- Plan for Investment in Water Management Infrastructure 2015-2025 (MAFWE, 2014) – this plan specifies major water management-related investment projects. According to the plan, the irrigation area should be increased by about 32,000 ha. It envisages large-scale hydro-works on the Konsko Dam, Rečani Dam, and the Raven-Rečica hydro

system; the construction of a dam on the River Slupčanska and construction of irrigation systems in the South Vardar Valley.

- Water Management Programme for 2022¹⁹ – this outlines the main water management actions in 2022.
- Irrigation and Drainage Strategy of the Republic of North Macedonia – this strategy is being prepared with the support of the UN FAO. It will define irrigation and drainage-related goals and priority investments for the period 2021-2031.

on energy...

The Strategy for Energy Development of the Republic of North Macedonia until 2040 - the strategy aims at significant reduction of energy consumption in agriculture and the food processing industry and regulates the operation of small hydropower plants. Its WFEN matrix is presented in Table 16.

**Key finding:
IPARD programme
is the most
comprehensive**

The above-listed strategies and programmes provide a good strategic framework for the implementation of WFEN concept and its practices. The goals and measures presented in these documents are largely compatible and synergistic. Among them, the most comprehensive and concrete from the standpoint of WFWN – is the IPARD programme. Its measures are very well defined. The programme operates according to clear procedures, including eligibility criteria and definition of eligible investments – and has a solid budget to finance WFEN-relevant measures. By (co)financing a range of WFEN-related investments (for more details see Appendix II) in agriculture and food processing industry, it provides a rather integrated approach to WFEN. The total IPARD public funding is worth 127,938,431 EUR, of which the EU is providing 76 percent.

3.4 Current practices relevant to WFEN

WFEN practices

Current WFEN-related practices implemented in RNM are summarised in Table 2.

¹⁹ Official Gazette No. 36/22

Table 2: The WFEN-related practices

Sector impact	Food	Energy		Water			Climate	
	Production	Production	Consumption	Supply	Pollution	Consumption	Mitigation	Adaptation
Food ➡		There is hardly any cultivation of energy crops used for production of RE ²⁰ . The same goes for RE production from farm by-products ²¹	Agriculture uses mainly fossil fuels, notably diesel. Food processing uses natural gas, diesel, and electricity. The employment of RES in agriculture and food processing is not common.	There is hardly any information about ecosystem services provided by agriculture, influencing water quality and quantity.	Pesticides and mineral fertilisers are regularly used but the data on water pollution is scarce as there is no comprehensive water quality monitoring system in place ²² .	Data on water consumption by agriculture are scarce. Irrigation is often practiced in fruit, vegetables, and grape production – but it is not modernised.	There is no reliable information on carbon sequestration in biomass and agricultural soil. The reduction of GHG emissions due to the use of RES is insignificant as these are not widely used.	The most common adaptation measure in agriculture is irrigation. Although many other measures have been tested ²³ , they are not widely used.
Energy ➡	As production of RE is marginal, land use implications of its production are not an issue.			Hydropower is widely used, producing 25% of the country's total demand for electricity.	Reliable data on the extent of acidification of water resulting from the combustion of fossil fuels are not available.	Water is widely used to produce electricity (hydropower plants).	Production of renewable energy (other than hydropower) is not widely used, so the reduction of GHG emission is insignificant.	Not relevant
Water ➡	Water management considers well irrigation and	Water management considers well the need for hydropower	Energy sector considers well the energy needs of water sector				Not relevant	Water management considers adaptation strategies.

²⁰ There is just one biomass thermal power plant, with a capacity of 0.60 MW, accounting for 0.03% of total installed capacity for production of electricity.

²¹ North Macedonia has just three biogas thermal power plants (in the Pelagonia and Polog area), with a total installed capacity of 6.99 MW, accounting for 0.34% of total installed capacity for production of electricity.

²² The EC has also highlighted this problem (EC, 2021a).

²³ More than 30 adaptation measures were tested in the period 2012-2016 through the project "Adaptation to Climate Change in Agriculture", supported by the United States Agency for International Development (USAID) and implemented by the Rural Development Network of N. Macedonia. These (among others) included the use of UV protection nets and plastic (poly)tunnels; use of inter-row mulching with peat and sawdust to reduce soil temperature; water conservation techniques; use of drought tolerant species, varieties, and substrates; changes in planting depth; application of special pruning techniques and inputs (e.g., calcium carbonate to prevent sunburn, fungus *Trichoderma harzianum*, etc.).

Sector impact	Food	Energy		Water			Climate	
	Production	Production	Consumption	Supply	Pollution	Consumption	Mitigation	Adaptation
	drainage needs in agriculture.	production, and its implications.	(hydropower production).					
Climate 	Farmers, policy makers and other actors are aware of climate change impacts on agriculture, but this is still not high enough on their agendas.	Decision makers and other actors have started considering climate change impacts on biomass and hydropower production.	Energy sector is a significant source of GHG emissions & cause of climate change – various steps have been taken (notably a shift to RES) to remedy this.	Policy makers and water users started paying more attention to climate change alterations of water cycles and water supply.	Not relevant	Policy makers and water users started paying more attention to climate change impacts on water consumption patterns.		

**Key finding 1:
modest WFEN
practices**

At present, North Macedonia does not have much to demonstrate in terms of implementation of WFEN-related practices. There is hardly any cultivation of energy crops used for production of renewable energy and the production of renewable energy from farm by-products is insignificant. Water is used for irrigation, but renewable energy (except electricity produced from hydropower) is rarely used in agriculture and food processing.

**Key finding 2:
outdated
irrigation
practices**

About 10% of the agricultural land has irrigation systems. However, these are outdated, and water and energy-use inefficient (MAFWE, 2021). Approximately 60% of the irrigated area uses sprinkler irrigation systems, while on the other 40% are surface irrigation methods are practiced. However, most irrigation systems are in poor condition. Nearly one-third are completely out of use, 22% face serious deterioration, 19% moderate deterioration and only 27% are fully serviceable (FAO, 2022). Smart, modern and resource use-efficient irrigation systems are hardly in use. There is no information on energy efficiency of the irrigation systems. Information on small-scale, low-cost, environmentally friendly irrigation schemes is scarce, but recent projects suggest that these can be successfully employed and are feasible (FAO, 2021a). Long-term investments in reconstruction and extension of dams and irrigation schemes are on the way²⁴. The Government considers the expansion and rehabilitation of existing and construction of new irrigation systems as a priority (MAFWE, 2020). The same goes for protection of water resources from adverse agricultural practices, including irrigation, and pesticide and fertiliser use. Management of livestock manure at many farms is not up to the task, leading to surface and water pollution by nutrients (FAO, 2021a).

**Key finding 3:
modest adaptation
practices**

Besides irrigation, other adaptation to climate change practices in agricultural production are not widely spread. Although several adaptation techniques proven to be successful, they are not sufficiently promoted and or widely adopted. No national fund for financing testing of adaptation measures in agriculture (notably introduction of drought resistant species) has yet been established and not enough resources and efforts have been invested in adaptation-related research and innovation (Mukaetov, D et al., 2021).

²⁴ Many of these are financed by international donors, such as rehabilitation of irrigation in Southern Vardar Valley (KfW bank), and the EU has supported a project (IPA) for construction of small irrigation systems.

3.5 Governance relevant to WFEN

Key players

The most relevant WFEN-related governance organisations in North Macedonia comprise the following²⁵:

...in the food sector

- The Ministry of Agriculture, Forestry and Water Economy (MAFWE) – oversees all agriculture and rural development-related issues. It has a complex structure, comprising 19 sectors and 62 divisions.
- The Agency for Financial Support in Agriculture and Rural Development (AFSARD) – manages financial support (payments) for all agriculture and rural development measures financed by the national and EU funds.
- The Agency for Promotion of Agricultural Development (APAD) – provides the transfer of knowledge and information to agricultural producers and other stakeholders involved in rural development.
- The State Inspectorate for Agriculture – is responsible for inspection in agriculture, rural development, fisheries, and aquaculture sectors.
- The Public Enterprise for Pasture Management – oversees the management of state-owned pastures.

...in the water management sector

- The Ministry of Agriculture, Forestry and Water Economy (MAFWE) – oversees all water management-related issues.
- The Public Water Utility Company – this organisation (in state ownership) maintains and manages irrigation and drainage systems. Besides this, there are three more public enterprises entrusted with the same tasks: Public Enterprise Streževo-Bitola, Public Enterprise Hydrosystem Zletovica-Probištip and Public Enterprise Water Economy Lisiče-Veles.

...in the energy sector

- The Ministry of Economy – is responsible for creating and implementing economic and industrial policies, including energy.
- The Energy Agency – support implementation of the energy policy by participating in the preparation of energy strategies, development plans and programs, data collection and processing and preparation of reports, encouraging the introduction of measures for energy efficiency and creation of conditions for increased use of RES for electricity production.
- The Energy and Water Services Regulatory Commission (ERC) – is an independent regulatory body that is responsible for: safe, secure and quality supply to energy consumers; environmental and consumer protection; and introduction and protection of a competitive energy market on the principles of objectivity, transparency and non-discrimination.
- The Office of the Vice President of the Government responsible for economic affairs – is the National Designated Authority (NDA)/Focal Point for interaction with the Green Climate Fund.

²⁵ A comprehensive overview of the WFEN sectors is provided in a recent (December 2021) report on climate change vulnerability and adaptation agriculture, forestry and land use (Mukaetov, D et al., 2021)

...in climate sector

- The Ministry of Environment and Physical Planning (MoEPP) – is responsible for the environmental protection, including water, soil, biodiversity, and oversees all climate change-related issues.
- National Climate Change Committee (NCCC) – is a coordination body providing high-level support and guidance for overall climate change policies.

**Key finding:
Insufficient
inter-sectoral
cooperation**

North Macedonia has well-developed institutional structures governing food, (agriculture), water, energy, and climate sectors. Their mandates and responsibilities are well-defined, and they operate well. However, their responsibilities and activities are sector-oriented and are primarily (if not exclusively) focused on their respective sectors. This problem exists even within the same institution responsible for several sectors – such as MAFWE, which (among others) oversees agriculture, rural development, and water management. The implementation of the WFEN concept and practices requires a holistic, integral, all-inclusive approach, based on inter-disciplinary and inter-sectoral cooperation. The EC has also recognised this as a problem (EC, 2021a), recommending that administrative capacities and inter-institutional coordination in the water management and environmental sectors needs to be strengthened, as well as that MAFWE and AFSARD should employ more qualified staff to manage the IPARD programme, and increase the number of staff and the technical/engineering capacity of the Energy Department in the Ministry of Economy and the Energy Agency.

3.6 WFEN stakeholders

**Key
stakeholders**

The key stakeholders representing the food (agriculture) sector are shown in Table 3. These are mainly actors involved in the Agricultural Knowledge and Innovation Systems (AKIS) – the combined organisation, knowledge flows and interactions between persons, organisations and institutions that use and produce knowledge and innovation for agriculture and interrelated fields in rural areas. Stakeholders involved in water management and energy sectors are listed in Table 4.

Table 3: Food sector stakeholders

Role / services	Name / description	Type
Research and higher education	- University of St. Cyril and Methodius ➤ Faculty of Agricultural Sciences and Food ➤ Institute of Agriculture ➤ Hans Em Faculty of Forest Sciences, Landscape Architecture and Environmental Engineering ➤ Institute of Cattle-Breeding ➤ Faculty of Natural Sciences ➤ Institute of Agricultural Economics - Faculty of Biotechnical Sciences Bitola at the University of St. Kliment Ohridski - University Goce Delčev (Štip)	Public universities and/or public research institutes
Higher education	Four higher education institutions located in Skopje, Tetovo and Ohrid	Private colleges and universities
Secondary education	Secondary agricultural schools	Public schools
Farm advisory services	- National Extension Agency - Private farm advisory services (approximately ten)	Public institution Private companies
Networking & lobbying	- National Federation of Farmers "Wines of Macedonia" Association of Wine Producers - North Macedonia's Association of Agricultural Cooperatives - North Macedonia's Association of Medical and Aromatic Plant Processors - Chamber of Commerce of North Macedonia	Farmers' associations/ NGOs
Networking, lobbying and project implementation	- Rural Development Network of North Macedonia - Local Action Groups	NGOs
Environmental protection	- Ecologist's Movement of Macedonia - North Macedonian Ecological Society - Bankwatch - Ekosvest - Environmental Research and Information Center	NGOs
Primary agricultural production	- National Federation of Farmers - North Macedonian Association of Producers - North Macedonia's Association of Agricultural Cooperatives - North Macedonia's Association of Medical and Aromatic Plant Processors - Agricultural producers	Private farms, co-operatives, and companies
Food processing	- Association of Millers and Agricultural Producers - Agricultural producers and food industry - Economic Chamber of North Macedonia	Private farms, co-operatives, and companies

Role / services	Name / description	Type
Food consumption	• Association for Consumers' Protection of North Macedonia • Food consumers	NGO Citizens
International donors and financial institutions	• Food and Agriculture Organization of the United Nations (FAO) • United Nations Office for Project Services (UNOPS) • United Nations Development Programme (UNDP) • The World Bank • Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) Office North Macedonia • KfW Development Bank in North Macedonia	

Table 4: Water and energy sector stakeholders

Role / services	Name / description	Type
Research and higher education	• University of St. Cyril and Methodius ➤ Faculty of Mechanical Engineering ➤ Faculty of Electrical Engineering and Information Technologies ➤ Institute of Power Plants and Substations	Public university and/or public research institute
Water management	• Water boards	Associations
Energy generation/ distribution/ transmission	• Power Plants of Northern Macedonia (ELEM) – publicly owned energy producer • Balkan Energy Group (BEG), District Heating Company of the city of Skopje	Public
Educational institutions	• Faculty of Mechanical Engineering Skopje • Faculty of Electrical Engineering and Information Technologies – Skopje • Institute of Power Plants and Substations	Public
International donors and financial institutions	• EBRD credit lines through commercial banks for EE renovation and RES • United Nations Office for Project Services (UNOPS) • United Nations Development Programme (UNDP) • The World Bank • Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) Office North Macedonia • KfW Development Bank in North Macedonia • Global Water Partnership-Mediterranean (GWP-Med)	International /governmental private
RES producers	• Producers of solar, wind, biomass, biogas, and biofuel-based energy	Public/private

**Key finding:
stakeholders are
also sector-
oriented**

At present, neither the available governmental, research, industry, and NGO documents (strategies, programmes, plans, project reports, research reports / papers, etc.), nor the Web pages of the above-listed stakeholders suggest that any of them is focused on WFEN concepts and practices. These organisations are also primarily sector-oriented, and their efforts and activities are primarily (if not exclusively) focused on narrow, specialised sectoral interests. There is no platform, committee, forum – or any other formal or informal structure dealing with WFEN.

4 PROPOSED WFE NEXUS INTERVENTIONS

4.1 Rationale behind proposed interventions

Based on multiple sources

We propose to implement three pilot WFEN programmes, which are selected based on the findings that resulted from the:

- Initial contacts and consultations made with the representatives of the North Macedonian authorities and international donors
- Analysis of the relevant North Macedonian legislation, strategies, and programmes
- Analysis of numerous studies, reports, and scientific papers on various WFEN aspects, both from North Macedonia and elsewhere
- A survey undertaken among key WFEN stakeholders – for more details see Appendix III and Appendix IV.

Three pilot programmes

Based on all this, we have screened several potential interventions. The three proposed pilot programmes turned to fit most of the criteria used for screening, which are presented in Table 5:

4. Pilot programme on carbon farming
5. Pilot programme on smart irrigation
6. Pilot programme on reducing food loss and waste

...integrating well the three nexus sectors

All three proposed pilot programmes very well integrate the three nexus sectors: water, food, and energy – and are highly relevant for climate change (both mitigation and adaptation). Table 6 shows the links between WFEN sectors & climate change and proposed measures. All three proposed pilots can be applied throughout the country, regardless of the farm size, landscape, and type of production (arable, fruit, vegetables, vineyards, animal husbandry, etc.). All three are scalable, replicable and their application is relatively simple. They address some of the key problems identified by relevant national strategies and programmes and are highly compatible with the EC CAP and efforts of the international donor community. Finally, two of them can also be implemented as 'no regrets' investments – as they hardly bear any significant risks.

Table 5: Performance of the three proposed pilot programmes

#	Criteria	Pilot programme on carbon farming	Pilot programme on smart irrigation	Pilot programme on food & waste loss reduction
1.	Can be applied in all climates	+	+	+
2.	Can be applied in mountain regions	+	+	+
3.	Can be applied in lowland regions	+	+	+
4.	Suits arable farmers	+	+	+
5.	Suits vegetable producers	+	+	+
6.	Suits fruit producers	+	+	+
7.	Suits vine producers	+	+	+
8.	Suits MAP producers	+	+	+
9.	Suits livestock producers	+	+	+
10.	Suits small holdings	+	+	+
11.	Suits large holdings	+	+	+
12.	Suits farmers of all age	+	+	+
13.	Suits all genders	+	+	+
14.	Identified as a problem in IPARD	+	+	-
15.	Can be financed by IPARD	-	+	-
16.	Application is simple	x	x	+
17.	It is replicable	+	+	+
18.	It is scalable	+	+	+
19.	Does not require high investments	x	-	+
20.	Compatible with international donors' actions	+	+	+
21.	Conforms with EU CAP priorities	+	+	+
21.	It is a no-regrets measure	+	x	+

+ = yes

x = moderate/neutral

- = no

Table 6: Links between WFEN sectors & climate change and proposed measures

WFEN sectors & climate	PROPOSED MEASURE		
	Carbon farming	Smart irrigation	Reducing food & waste loss
Food	Carbon in soil improves soil fertility, its water holding capacity, and suppresses pest & diseases, resulting in an increasing crop productivity and quality.	Increases crop productivity and its quality.	Increases food available for consumption
Energy	- Carbon improves soil structure, making soil easier to till, resulting in less energy required to cultivate soil. - Carbon improves soil's water retention capacity, reducing the need for irrigation, and saving energy used in irrigation.	- Uses less energy to supply irrigation water than conventional irrigation systems. - Is often powered by renewable energy sources, reducing the use of fossil fuel.	- More efficient use of energy required and stored in food - Saves energy
Water	- Carbon improves soil's water retention capacity, making farming more resilient to droughts. - Carbon in soil stimulates the work of macrofauna, whose bioturbating activity creates so-called conducting macropores in the soil, which enhance the drainage of water to deeper soil layers.	Saves water required to irrigate crops, leaving more water to be used for non-agricultural purposes.	- More efficient use of water required and stored in food - Saves water
Climate change	- Carbon sequestration in the soil contributes to climate change mitigation. - Carbon-rich soils enable farmers to better adapt to climate change.	- Is often powered by renewable energy sources, reducing GHG emissions from the use of fossil fuel. - Smart irrigation is one of the most efficient measures to help farmers to better adapt to climate change.	Contributes to mitigation and adaptation to climate change

5 CARBON FARMING

5.1 Problem

Declining soil carbon is a Europe-wide problem

Agriculture is key for reaching a climate-neutral economy because it can capture CO₂ from the atmosphere and store it in agricultural soils (EC, 2022a). However, many of today's common agricultural practices are soil carbon unfriendly, resulting in carbon quickly and easily being lost from the soil. The European Commission has identified declining soil organic matter content²⁶ as one of the most important environmental problems and causes of soil degradation, especially in southern Europe (EC, 2016). Mediterranean climates tend to have higher soil temperatures and suffer more from drought and heavy rain, speeding up the decomposition of soil organic matter and causing loss of soil nutrients. Mediterranean regions with coarse landscapes, often under sloping vineyards and soils that are left bare are more prone to erosion, which also leads to loss of soil organic matter (EC, 2016). To remedy this situation, in December 2021 the EC adopted the Communication on Sustainable Carbon Cycles (EC, 2021b), as announced in the Farm to Fork Strategy (EC, 2022b). The Communication sets out short- to medium-term actions aiming to address current challenges for carbon farming, in order to upscale this green business model that rewards land managers for taking up practices leading to carbon sequestration, combined with strong benefits for biodiversity. These include (i) promoting carbon farming practices under the Common Agricultural Policy (CAP) and other EU programmes, (ii) driving forward the standardisation of monitoring, reporting and verification methodologies to provide a clear and reliable framework for carbon farming, and (iii) providing improved knowledge, data management and tailored advisory services to land managers (EC, 2022a). Carbon farming was found to be able to contribute significantly to the EU's efforts to tackle climate change (COWI et al., 2020).

...occurring in North Macedonia, too

North Macedonian arable soils are rather poor in soil organic matter, with an average content of soil organic carbon of 1.5 percent (ranging from 0.5-3.2 percent), while soils under perennial crops have somewhat higher content: 2.66 percent of soil organic carbon (ranging from 1.0 to 4.7 percent) (Mukaetov, et al., 2021). North Macedonian agricultural soils are likely to be emitting and/or losing more carbon than they store, resulting in the loss of soil organic matter (MAFWE, 2021; Mukaetov, et al., 2021). This is primarily caused by narrow crop rotation (often mono-cropping, such as tobacco) and insufficient application of manure (MAFWE, 2021), as well as intensive soil tillage, irrational use of mineral fertilizers and insufficient application of organic fertilisers (Mukaetov, et al., 2021). The situation calls for imperative remedial action (FAO, 2021a), which has also been endorsed by the National Strategy on Agriculture and Rural Development 2021-2027 (MAFWE, 2020) and the Climate Change Vulnerability and Adaptation in Agriculture, Forestry and Land Use study prepared for the North

²⁶ Soil organic matter (SOM) contains about 58 per cent soil organic carbon (SOC).

Macedonian 4th National Communication on Climate Change (MEPP, 2020).

5.2 Importance and benefits

Importance and benefits of soil organic carbon

Soil organic matter is the organic component of soil, comprising (i) organic material from plants and animals, and (ii) material that has been converted by microorganisms in the soil at different stages of decomposition (EC, 2016). It affects the chemical, physical and biological properties of the soil and its overall health (FAO, 2005). The content of soil organic matter (SOM) is probably the most important and most comprehensive indicator of soil fertility. SOM determines soil's physical (structure, aeration, water retention), biological (biomass, biodiversity, nutrient mineralisation, disease suppression) and chemical (nutrient supply) properties. As SOM contains about 58 per cent soil organic carbon (SOC), sequestering carbon in agricultural soils has potential to mitigate carbon emissions and contributes to adaptation to climate change. SOC is vital for soil fertility, as it delivers a range of agronomic, environmental, economic and other benefits – both to farmers and society in general (EC, 2016; FAO, 2005; Feller et al., 2012; Gamajunova, 2017; Gaskell et al., 2007; Lehmann and Kleber, 2015; Manlay et al., 2007; Piccolo, 1996; Znaor and Landau, 2014). Soil organic carbon is particularly important in arid and semi-arid regions because it reduces the impact of drought by increasing water infiltration and the soil's water holding capacity²⁷ (FAO, 2005; Lal, 2020a, 2020b). Table 7 provides an overview of the expected benefits of carbon farming.

²⁷ The scientific community is divided with regard to how much water SOM can store. Most estimates suggest that that SOM holds the equivalent of 30–90 percent of its weight in moisture.

Table 7: Expected benefits of carbon farming

Benefits	Carbon farming
Agronomic & environmental	Soil organic matter plays a vital part in enhancing soil fertility and quality, providing a range of agronomic and environmental benefits on the following levels: • <u>Chemical</u>: maintains the plant nutrient cycling process (i) improving the soil's capacity to store and supply essential nutrients (such as nitrogen, phosphorus, potassium, calcium, and magnesium), (ii) retaining toxic elements, (iii) allowing the soil to cope with changes in soil acidity, (iv) helping soil minerals to decompose faster. • <u>Physical</u>: increases soil temperature and improves soil structure (i) helping to control soil erosion, (ii) increasing water infiltration and water holding capacity (also preventing also leaching), (iii) providing plant roots and soil organisms better living conditions, and (iv) enabling easier and smoother soil tillage. • <u>Biological</u>: provides primary source of carbon (i) supplying energy and nutrients to soil organisms, (ii) improving the activity of microorganisms in the soil, and (iii) enhancing biodiversity. • <u>Overall</u>: (i) captures carbon in the soil, reducing emissions of CO₂ into the atmosphere and mitigating climate change, (ii) suppresses pest and soil-borne diseases.
Economic	For farmers: • Reduced input costs: reduced fertilizer needs owing to improved nutrient cycling and reduced leaching from the rootzone; reduced pesticide needs owing to pest–predator interactions among organisms and natural biocontrol • Reduced tillage costs owing to reliance on bio tillage by macrofauna and overall better soil structure • Improved yield and crop quality For society: • Positive externality due to carbon sequestration in the soil (for more information on carbon farming externalities in the Western Balkans see for instance Znaor, 2013; Znaor and Landau, 2014)
Building human & social capital	• Carbon farming practices tend to develop new skills and capacities, adoption of new knowledge, better cooperation among stakeholders, better governance, more transparent decision making, etc. Note: this is particularly pronounced in case of collective carbon farming schemes, in which farmers, due to small plots they own, share equipment, and jointly apply for carbon farming subsidies.

**Carbon farming –
a promising
method for
preserving and
restoring SOM**

5.3 Practices increasing soil organic carbon

The so-called carbon farming is seen as a solution for declining SOM (COWI et al., 2020; EC, 2022a; Rimhanen et al., 2022; World Bank, 2012). Carbon farming is a whole-farm approach to optimizing carbon capture on working landscapes by implementing practices that are known to improve the rate at which CO₂ is removed from the atmosphere and stored in plant material and/or soil organic matter (CCI, 2022). The European Commission (EC, 2021b) defines carbon farming as a green business model that rewards land managers for taking up improved land management practices, resulting in an increase of carbon sequestration in living biomass, dead organic matter, and soils by enhancing carbon capture and/or reducing the release of carbon to the atmosphere, in respect of ecological principles favourable to biodiversity and overall natural capital. In April 2021, after a two-year study (COWI et al., 2020) the Commission published a technical handbook on how to set up and implement carbon farming in the EU, aimed at helping private actors and public authorities start up carbon farming initiatives. The study explored key issues, challenges, trade-offs, and design options. It reviewed existing schemes that reward carbon sequestration or reduced emissions in five areas: peatland restoration and rewetting; agroforestry; maintaining and enhancing soil organic carbon (SOC) on mineral soils; managing SOC on grasslands; and livestock farm carbon auditing.

**Common
carbon farming
practices**

Carbon farming practices comprise a range of good practices through combining no tillage or minimum tillage with a protective crop cover, crop rotations and application of organic manure. These practices keep the soil covered for a longer period of time, for instance with green manures (cover crops that are incorporated into the soil), maintain surface residues, roots and soil organic matter, help control weeds, enhance soil aggregation and intact large pores, in turn allowing water infiltration and reducing runoff and erosion (EC, 2016; FAO, 2005; Paulsen, 2020). In addition to making plant nutrients available, the diverse soil organisms that thrive in such conditions contribute to pest control and other vital ecological processes (FAO, 2005). Carbon farming employs a range of best technological means (e.g., crop residue management and tillage based on reduced²⁸ and conservation tillage²⁹, GIS and other digital solutions, smart water & irrigation management, smart stables, application of biochar and other soil amendments, etc.) and/or ecological means (e.g., stimulation of symbiotic N fixation and mycorrhiza, managed grazing, nutrient cycling in the rumen, multi-species cover cropping, agroforestry, conservation tillage and increasing landscape features etc.) (Paulsen, 2020; World Bank, 2012).

²⁸ With 15% to 30% residue cover on the soil (500 to 1,000 kg ha⁻¹ crop residue equivalent)

²⁹ With greater than 30% crop residue on the soil (>1,000 kg ha⁻¹ crop residue equivalent), comprising (i) no (zero) tillage, (ii) strip/minimum tillage, (iii) mulch tillage, (iv) ridge tillage, and (v) rotational tillage.

Sequestration potential

Carbon farming practices sequester carbon and/or reduce GHG emissions. Their sequestration potential in the soil is determined by a range of factors, such as climate, soil type, relief, type of production, management practices (e.g., soil tillage, crop rotation, application of manure, mineral fertilisers, lime, etc.), etc. Carbon farming practices under European conditions can typically sequester 0.1 t C ha⁻¹ yr⁻¹ to 1.5 t C ha⁻¹ yr⁻¹ (COWI et al., 2020; Hussain et al., 2021; Kurkalova, 2005; Paulsen, 2020; Piccolo, 2012; Rimhanen et al., 2022; World Bank, 2012).

Carbon farming can be practised in North Macedonia, too

Carbon farming practices that enhance soil health, maintain and/or restore SOM could be an interesting solution for the problem of declining SOM in North Macedonia, too. At present, carbon farming does not seem to be widely practiced in the country. However, North Macedonian experts are very optimistic that these practices could contribute to increasing SOM in Macedonian agricultural soils. Experts from the University of St. Cyril and Methodius³⁰ suggest that under North Macedonian conditions, the application of covers crops alone could sequester around 1.5 t C ha⁻¹ yr⁻¹ (Mukaetov, et al., 2021). Introducing fast-growing crops, such as various annual legumes, mustard, Sudan grass, other grasses, and fodder crops growing in North Macedonia can help develop biomass in a short period of time. Once sufficiently developed, this biomass can be incorporated into the soil to contribute to the soil's organic matter. Alternatively, the practice of under-sowing (e.g., alfalfa in cereals) can be applied, too.

³⁰ From the (i) Faculty of Agricultural Sciences and Food of the University, (ii) Institute of Agriculture of the University, and (iii) Hans Em Faculty of Forest Sciences, Landscape Architecture and Environmental Engineering.

6 SMART IRRIGATION

6.1 Irrigation problems

Global problem

Agriculture accounts for about 70 percent of global freshwater use, greatly contributing to the increasing global scarcity of freshwater (OECD, 2020). As the global population is expected to increase to nine billion by 2050, demand for water resources will increase by an expected 55 percent (OECD, 2022). Future demand for water by all sectors will require as much as 25 to 40 percent of water to be re-allocated from lower to higher productivity and employment activities, particularly in water-stressed regions. In most cases, such reallocation is expected to come from agriculture due to its high share of water use (WB, 2020). For Mediterranean and other dry climates, this is a huge challenge for the farmers – and those they feed. The problem is even greater as climate change is causing temperatures to soar, adding more stress to the water availability in dry regions, while irrigation itself is also adding to the problem as the agricultural sector burns huge amounts of fossil fuel such as diesel to pump water around farms (Gillman, 2017).

...fuelled also by energy crisis

Irrigation is an energy intensive activity as water pumps required to run the system consume plenty of energy. The total power needed for irrigation in southern Europe (including North Macedonia, Portugal, Spain, the south of France, Italy, Croatia, Bulgaria, Greece, Romania, and Malta) is 16 GW year (Narvarte, 2017). If this was substituted by solar power it could offset over 16 million tonnes of CO₂ a year (Narvarte, 2017). Fossil fuel and electricity prices are on rise. On the other hand, higher temperatures require more water to be pumped to fields so farmers can grow their crops. Because of all this, the imperative to practice water and energy saving irrigation techniques is actual more than ever. The use of smart, environmentally friendly irrigation technology helps farmers in climate vulnerable regions to adapt and strengthen their resilience to climate change, water scarcity and energy crises (IFC, 2016). However, the wider adoption and upscaling of smart irrigation aiming to promote highly productive yet climate-friendly agriculture requires partnership with financial institutions, donors, governments, farmers' groups, and equipment manufacturers (IFC, 2016).

N. Macedonian irrigation system requires modernisation

Although irrigation systems have been installed on approximately 14 percent of North Macedonian's utilised agricultural land (UAA), the share of the agricultural land under irrigation is several times lower than in the Mediterranean EU countries (MAFWE, 2021). In addition, due to deteriorated irrigation systems, only 2.7 percent of UAA is regularly irrigated (MAFWE, 2021). Irrational use of water for irrigation has been identified as a weakness of North Macedonian agricultural production (MAFWE, 2021), and the need to introduce more smart/drip irrigation has been highlighted by the new IPARD programme (MAFWE, 2021). In short: North Macedonia urgently needs to improve, modernise and upscale its irrigation systems. The Government has initiated several big projects, aiming at improving and installing resilient irrigation infrastructures, notably in the Bregalnica River

area and the South Vardar Valley (MAFWE, 2021), and more projects are on the way (FAO, 2021a). The IPARD programme has been financing various irrigation-related projects, including investments in on-farm irrigation facilities and equipment (such as new reservoirs, tanks, pipelines, drip-systems, mist systems, sprinkling installations, pump stations, etc.) (MAFWE, 2021).

6.2 Importance and benefits

Environmental benefits

The use of smart irrigation technologies improve crop yields through direct impacts as well as indirect ones, such as decreased soil salinity, fewer attacks from pests and diseases, and less weed competition (IFC, 2016). It also improves the quality of crops (IFC, 2016; Tamoor et al., 2021), notably in terms of the content of total soluble solids (Adu et al., 2019). The most significant environmental benefits of smart irrigation include (i) water saving, (ii) reduction of fertilisers needed (as nutrients can be dissolved in the irrigation water for uniform application), (iii) reduced energy use (because less water is needed for irrigation, which in turn requires less energy for pumping water), and (iv) refraining from fossil fuels when photovoltaics are used. Smart irrigation can help (small) farmers improve their livelihoods by reducing labour input and by allowing for a more efficient use of inputs, and by enhancing the yields and quality of the crops they grow. Moreover, it enables them to use the same amount of water to grow higher value, more water-intensive crops. Table 8 provides an overview of the expected benefits of smart irrigation.

Table 8: Expected benefits of smart irrigation

Benefits	Smart irrigation
Agronomic & environmental	• Allows farmers to grow crops with higher economic value and to obtain higher yields • By switching from furrow and sprinkler irrigation, and by practising timely irrigation, smart irrigation facilitates and enables on-farm water conservation (saving) • Reduction of uncontrolled and unmonitored groundwater consumption for irrigation due to irrigation system inefficiency • Decreased soil salinity • Plant nutrients can be dissolved in the irrigation water for uniform application, resulting in less fertiliser used • Fewer attacks from pests and diseases, and less weed competition, resulting in less pesticides and herbicides used
Economic	• Increased agriculture sector competitiveness • More profitable production (due to increased efficiency in inputs, reduced variable production costs and higher yields) • Financially (and nutritionally) better-off households.
Building human & social capital	• New skills and capacities, adoption of new knowledge, better cooperation among stakeholders, better governance – largely also due to water monitoring system involving in-situ and automated measurement devices

6.3 Smart irrigation practices

Smart irrigation systems

Smart irrigation systems are money-saving, clean-energy solutions for agricultural water management, based on weather and soil data, that minimise environmental footprint through an efficient water use. This technology relies on accurate weather forecasts and early warning systems, provided by agricultural meteorological stations that are automatically integrated with platforms for timely monitoring of key microclimatic conditions in real time, as well as on-farm sensors that measure a range of parameters in soil, air and on the crops. The sensors can detect the field soil moisture, humidity, and temperature, and provide appropriate command signals to operate irrigation pumps (Al-Ali et al., 2019). There are three main categories of smart field sensors: (i) soil-based, (ii) weather-based, and (iii) plant-mounted (Yuanzhen, 2018). These sophisticated sensors help to determine the most suitable timing for irrigation and the quantity of water required. Some smart irrigation systems are Internet of Things-based, quipped with sophisticate warning, monitoring, and control features (Al-Ali et al., 2019; Rout et al., 2018). Smart irrigation systems can also integrate and use soil, relief, vegetation, hydrological and meteorological data provided by satellites, or sensors and cameras mounted on low-flying airplanes and and/or drones. Smart features can also include a decentralized system for advanced monitoring, automated performance analysis, fault detection and reporting, all of which improve efficiency.

Smart, solar-powered irrigation systems

An advanced, and the most environmentally friendly type of smart irrigation systems are the so-called smart, solar-powered irrigation (SSPI) systems. They operate using water pumps powered by electricity obtained from the sun via solar panels (Harishankar et al., 2014). These systems are prime examples of how technological means can be employed to implement the WFEN concept in practice – because they are not only water-friendly, but also energy and climate-friendly. The SSPI systems deliver a triple win: (i) zero carbon emissions, (ii) significant water savings, (iii) and lower energy bills (Futurenviro, 2021). Photovoltaic solar modules installed to power the irrigation networks eliminate carbon emissions arising from electricity generated from fossil fuels, or from the use of diesel pumps. Smart sensors reduce the consumption of water, resulting in less energy required to pump the water. The SSPI systems can be stationary or mobile – and placed on any fields, including pastures. They are automated and independent of fossil fuel, electricity, and human labour. The pump turns itself on with the first rays of the sun and pumps water required for irrigation.

... use advanced technological and business solutions

The new generation of SSPI systems is equipped with controllers that uniquely use solar power to detect the weather and alter watering according to the conditions and the season, providing plants with the precise irrigation they need to help them thrive. Some systems run on new, clean pumping technology that stabilises the injection of energy into the system, which in turn stabilizes the irrigation process itself (Futurenviro, 2021). This technology can solve issues such as the intermittency of solar power when the sun doesn't shine and the opposite problem – overloading the network

SSPI can also be applied in North Macedonia

during peak radiation periods. When operated on larger scales, some SSPI system suppliers enter into special agreements with farmers. Farmers do not need to pay for the initial cost of the installation. Instead, they repay the initial cost through a long-term Power Purchase Agreement with the supplier of solar energy for their irrigation networks (Futureenviro, 2021). These agreements offer farmers a competitive and stable price, reducing their exposure to energy market fluctuations.

Smart, solar-powered, water and energy saving irrigation systems can also successfully be applied in North Macedonia. Experts from the University of St. Cyril and Methodius (Mukaetov, et al., 2021) suggest that replacing the commonly used petrol pumps with pumps powered by electricity and/or solar panels (photovoltaic) may be very feasible in North Macedonia, notably because it has plenty of sunshine during the periods when irrigation is mostly needed. Besides, the purchase of the required on-farm equipment can be 65 percent co-financed by the IPARD programme. However, at present, smart, climate-resilient irrigation systems are operating on just about 500-600 ha (FAO, 2021a).

7 FOOD LOSS & WASTE

7.1 Problem

How much is wasted?

Food waste is one of the biggest problems facing mankind today. Globally, an estimated one-third of all the food produced goes to waste (FAO, 2013). That's equal to about 1.3 billion tonnes of fruits, vegetables, meat, dairy, seafood, grains, and other food. In the EU, around 88 million tonnes of food waste are generated annually, which is equal to 174 kg per person (Stenmarck et al., 2016).

Where is it wasted?

Food loss and waste (FLW) occurs throughout the whole food chain, at all four levels: production, distribution, retail, and consumption. Food either never leaves the farm, get lost or spoiled during distribution, or is thrown away in hotels, grocery stores, restaurants, schools, or home kitchens.

Food loss happens:

- At the farm, because of the inadequate harvesting time, climatic conditions, practices applied at harvest and handling, and challenges in marketing produce.
- In storage, because of inadequate storage, decisions made at earlier stages of the supply chain that cause products to have a shorter shelf life.
- In transit, because of inadequate facilities and inefficient trade logistics, technical malfunctions or human error.

Food waste happens:

- In shops, because of limited shelf life, demand for food products to meet aesthetic standards in terms of colour, shape and size, and variability in demand.
- In the home and restaurants, because of poor in-home storing, poor purchase and meal planning, excess buying (influenced by over-large portioning and package sizes), confusion over labels (best before and use by), and excessive restaurant portions.

Globally, around 14 percent of food produced is lost between harvest and retail and an estimated 17 percent of total food production is wasted (FAO, 2013). At the consumers level, three types of food have been identified as being discarded: good food that has gone bad, food we think that has gone bad, but it has not, and food we know is consumable, but we simply don't want it anymore. In fact, only a small portion of the food discarded is actually inedible.

Implications of food waste

Wasted food has environmental, economic, and social implications. When food is lost or wasted, all the resources that were used to produce this food, including water, land, energy, labour, and capital, are also wasted. Some 1.4 billion hectares of land, 28 per cent of the world's agricultural area (FAO, 2013), is used annually to produce food that is lost or wasted. It could produce enough calories to feed every undernourished person on the planet.

Economic problems

Throwing away edible food represents an economic loss. In the EU, the amount of food thrown away amounts to wasting approximately 143 billion EUR annually (FAO, 2013). The food that ends up as waste also requires resources to manage its collection, transport, and disposal, the cost of which is passed on to municipal utilities and services.

Environmental problems

Wasted food that ends up in the garbage, and ultimately the landfill, produces methane, a greenhouse gas that is 21 times more potent than carbon dioxide. According to the FAO (FAO, 2013), 7% of greenhouse gases produced globally are due to preventable food waste. Food that is produced but not eaten each year consumes up a volume of water equivalent to the annual flow of the Volga River and is responsible for adding 3.3 billion tonnes of greenhouse gases to the planet's atmosphere. Food that is lost and wasted accounts for 38 percent of total energy usage in the global food system. Food wasted in the EU is responsible for 170 million tonnes of CO₂ (FAO, 2013).

Food waste in North Macedonia

There are no precise data for the amounts of food loss and waste in North Macedonia. Available data are scarce and controversial. According to some estimates (Josifovski, 2019), 40 percent of solid waste comes from food, accounting for 100,000 tonnes of waste. Agricultural surpluses create most of this waste. According to UNEP (2021), annual household food waste estimates are 172,480 tonnes or 83 kg per person. However, according to research based on a survey of 244 North Macedonian households (Bogevska et al., 2020), very little food is wasted. The result showed that 46.1 percent of the respondents throw very little food away while 23.7 percent do not throw almost anything. Most of the households throw away less than 2 percent of purchased food. The most wasted food groups are milk and dairy products, fruits, and vegetables while fish and seafood are the least wasted ones. For 55.5 percent of the respondents, their food waste value is less than 5 EUR while for 38.8 percent of them it is between 5 and 25 EUR. According to this research, North Macedonian consumers are aware about food waste but there is still a need for more information, management practices, technologies, early childhood education and behaviour change to reduce food waste that has environmental and economic impacts.

Importance and benefits

The FLW issue is at the heart of the WFE nexus. A lot of water and energy is used in the growth, storage, transportation, and consumption of food, so wasted food is also wasted water and energy. Food waste also comes at a significant cost to society. Evidently, reducing food waste has immense environmental and economic benefits. Creating a clear perception of wasted food as a source/sink for energy and water within the WFE nexus could be an effective approach towards reducing the quantities of wasted food and more efficiently managing food that is wasted. To achieve policy change on food waste, it is important to understand both the economic value of food waste and its social and environmental impacts. There is a need to increase the level of awareness in society through education and dissemination programmes aimed at all actors and stakeholders along the chain, including the consumer and wider society. Table 9 provides an overview of the expected benefits of FLW reduction.

Table 9: Expected benefits of the FLW reduction

Benefits	Reducing food & waste loss
Environmental	• Reduced pressure on land and water resources • Reduction in GHG emissions • Reduction in energy used
Economic	For farmers: • Savings in wasted labour, material resources, time and energy that go into food production. • Increase in productivity and economic results. For consumers: • Monetary savings For society: • Savings related to food waste disposal, collecting, landfills • Increased economic growth
Societal benefits	• Increased food availability for the vulnerable groups. • Increased economic growth • Increased health

7.2 Food loss and waste programmes

What is the EU doing about it?	The FLW is an important policy subject in the European union. The EU and EU countries are committed to halve per capita food waste at the retail and consumer level by 2030 and reduce food losses along the food production and supply chains (EC, 2022c). Different measures are being taken by Member States, such as the development of national strategies, adoption of legislative and non-legislative initiatives and consumer awareness campaigns. Reducing food loss and waste is an integral part of the Farm to Fork Strategy, adopted by the Commission as part of the European Green Deal. Actions include legally binding targets to reduce food waste across the EU, by end 2023, defined against a baseline for EU food waste levels set following the first EU-wide monitoring of food waste levels, and a revision of EU rules on date marking ('use by' and 'best before' dates), by end 2022. The Commission is also further integrating food loss and waste prevention in other EU policies, investigating, and exploring ways of preventing food losses at the production stage, and mobilising all players by encouraging implementation of the recommendations for action of the EU Platform on Food Losses and Food Waste (EC, 2022d).
A North Macedonian example	The FAO project "Strategies for Food Loss and Waste Reduction" (FAO, 2021b) assisted North Macedonia to reduce FLW. In particular, the project provided analysis of FLW issues, trainings and capacity building and produced educational materials. Field research on food losses in six fruit and vegetable value chains was conducted by the NGO Ajde Makedonija (FAO, 2021c). The results and recommendations provided supported the formulation and implementation of an FLW reduction programme of action.
Combination of measures	Table 10 outlines elements of a potential FLW pilot programme for North Macedonia. It considers that reduction of food loss and waste requires a set of different legislative and non-legislative measures, investments, education, and awareness campaigns. The pilot programme envisages setting up of an inter-institutional working group on FLW. This group should co-ordinate preparation of a National Food Loss and Waste Prevention Programme and Action Plan. It should also facilitate adoption of relevant FLW legislation. The FLW measures should also be adopted into other policy areas (e.g., climate, circular economy, food, and nutrition, etc.). To understand how much food is wasted and where, monitoring and measuring of the amounts of food waste generated across the entire value chain (primary production and the processing and manufacturing sectors, retail sector, restaurants and hospitality sector and households) should be set-up. Conditions for the redistribution of food to social institutions (e.g., food banks, etc.) should be created, too.
Investments	Investments to support farmers and food processors in reduction of food loss should be made available. For example, this could be machinery and equipment for composting of farm waste or equipment for processing fruit/vegetables that do not meet aesthetic standards.

**Capacity-
building and
awareness
raising**

Capacity-building and training on FLW should be organised for farmers, retailers, and the hospitality sector. An extensive awareness programme should be the backbone of reduction of food loss and waste. Awareness raising activities and campaigns on FLW could comprise:

- Advertisements and editorials in printed and social media
- Promotion of buying “ugly fruits and vegetables”
- Organising National Food Waste Day in conjunction with the International Day of Awareness of Food Loss and Waste
- Develop food and water waste calculators
- Develop teaching materials for primary and secondary schools,
- Organise competitions, e.g., recipes of using leftovers; drawing and painting competition for primary schools to raise awareness on the topic of food waste among children, etc.
- Establish anti-food-waste prize to present positive examples of such actions.

8 PILOT PROGRAMMES IN A NUTSHELL

Three pilot programmes

The three proposed pilot programmes are summarised in Table 10. All three should:

- Demonstrate good WFEN practices
- Deliver a range of private and societal benefits (environmental and socio-economic), and
- Provide evidence-based insights on the applicability of WFEN under North Macedonian conditions.

These pilot WFEN initiatives should also contribute to the development of human and social capital at the local, regional, and national level required to implement WFEN concepts and practices, leading to their wider uptake and upscaling. All three proposed pilot programmes are capacity-building oriented and practical and will have an effect after just a few years of application.

Table 10: The three pilot programmes in a nutshell

Element	Pilot programme on carbon farming	Pilot programme on smart, solar-powered irrigation	Pilot programme on reducing food & waste loss
Objective	- Sequester carbon from atmosphere into agricultural soil - Make N. Macedonian agricultural soils more resilient to drought, reducing the need for irrigation and related energy use	- Increase crop productivity per unit area and per unit of water available through efficient irrigation and reliable energy technology - To test and promote adoption of SSPI systems for farmers' adaptation to climate change impacts	- Raise awareness and educate stakeholders on food loss and waste problem - Contribute to reduction of food quantity wasted
Short programme description	The programme comprises the following key activities: - Design carbon farming measures and set-up the carbon payment scheme (subsidies) - Train trainers - Train (i) farmers how to implement the measures, and (ii) the administration how to implement the payment schemes - Develop a soil carbon calculator, estimating the soil organic matter balance – this is a practical tool for environmental impact assessment and management support in carbon farming (see for instance Brock et al., 2017) - Implement carbon farming measures - Programme outreach/dissemination - Set-up a progress monitoring programme of implemented measures (both at beneficiary and non-beneficiary sites) - Report and evaluate results achieved (incl. process and lessons learned)	The programme comprises the following key activities: - Design the programme and determine the most appropriate technological solutions to be employed - Train trainers - Train farmers about the benefits and practical uses of SSPI systems - Implement the SSPI systems in the field - Implement the programme outreach/dissemination - Set-up a progress monitoring programme of implemented measures (both at beneficiary and non-beneficiary sites) - Report and evaluate results achieved (incl. process and lessons learned)	The programme comprises the following key activities: - Set up inter-institutional working group on FLW - Set up monitoring and measuring of the amounts of food waste generated across the entire value chain - Prepare and adopt National Food Loss and Waste Prevention Programme and Action Plan - Integrate FLW measures into other policy areas - Support redistribution of food to social institutions - Capacity-building and training for farmers, retailers, and hospitality sector on reduction of food waste - Implement awareness raising activities - Report and evaluate results achieved (incl. process and lessons learned)
Preconditions	- Political will to initiate and implement the programme - An appropriate institutional setting coordinating and supervising programme implementation, monitoring, and evaluation - Secured finances to implement the programme	- Political will to initiate and implement the programme - An appropriate institutional setting coordinating and supervising programme implementation, monitoring, and evaluation - Secured finances to implement the programme	- Political will to initiate, set up and implement the programme - An appropriate institutional setting coordinating and supervising programme implementation, monitoring, and evaluation - Secured finances to implement the programme
Responsible organisation	Ministry of Agriculture, Forestry and Water Economy	Ministry of Agriculture, Forestry and Water Economy	Ministry of Agriculture, Forestry and Water Economy
Duration	5 years	5 years	5 years

Element	Pilot programme on carbon farming	Pilot programme on smart, solar-powered irrigation	Pilot programme on reducing food & waste loss
Target	200 ha managed by at least 100 farmers, cooperatives, or companies	200 ha managed by at least 100 farmers, cooperatives, or companies	Not relevant
Key performance indicators (KPI)	- KPI 1 – No. of farmers, cooperatives/companies practising carbon farming - KPI 2 – number ha under carbon farming practices - KPI 3 – annual increase in SOM content - KPI 4 – increase in SOM content after 5 years	- KPI 1 – No. of farmers, cooperatives/companies practising SSPI - KPI 2 – No. of ha under SSPI - KPI 3 – annual water saving per unit area and per crop - KPI 4 – annual energy saving per unit area and per crop - KPI 5 – increase in crop productivity per unit area and per crop - KPI 6 – quantity of reduced consumption of fossil fuel and grid-based electricity and related GHG emissions	- KPI 1 – National Programme on Food Loss and Waste Prevention adopted - KPI 2 – quantity of food redistributed to social institutions - KPI 3 – number of campaigns, schools, institutions, and people taking part - KPI 4 – number of businesses taking part in actions - KPI 5 – reduced quantity of wasted food after 5 years
Bankable investments and estimated budget	Commercial loans and/or grants will be required for: - Purchase of agricultural machinery (2 million EUR) - Purchase of GIS and other IT systems (0.5 million EUR) - Paying carbon farming subsidies (0.25 million EUR) - Training & carbon calculator development (0.25 million EUR) - Programme outreach/dissemination materials (0.25 million EUR) - Programme monitoring (soil sampling & testing, etc.) and evaluation (0.5 million EUR) - Management (0.5 million EUR) Total: 4.25 million EUR	Commercial loans and/or grants will be required for: - Purchase of SSPI-related equipment (2 million EUR) - Purchase of GIS and other IT systems & data (0.5 million EUR) - Programme outreach/dissemination materials (0.25 million EUR) - Programme monitoring and evaluation (0.25 million EUR) - Management (0.5 million EUR) TOTAL: 3.5 million EUR	- Purchase of on-farm composting machinery and equipment (1 million EUR) - Purchase of equipment for processing of fruit/vegetables that does not meet aesthetic standards (2 million EUR) TOTAL: 3 million EUR
Source of funding	International donors (EC, WB, FAO, UNDP, etc.), development cooperation (bilateral) programmes (e.g., Norwegian, Swedish, German, Japanese, USA, etc.), banks (e.g. KfW), etc.	IPARD programme, international donors (EC, WB, FAO, UNDP, etc.), development cooperation (bilateral) programmes (e.g., Norwegian, Swedish, German, Japanese, USA, etc.), banks (e.g., KfW), etc.	International donors (EC, WB, FAO, UNDP, etc.), development cooperation (bilateral) programmes (e.g., Norwegian, Swedish, German, Japanese, USA, etc.), national budget, etc.

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10 APPENDIX I: WFEN MATRICES OF KEY LEGISLATION

Table 11: Energy Law WFEN matrix

Sector impact	Food	Energy		Water			Climate	
	Production, processing, and consumption	Production	Consumption	Supply	Pollution	Consumption	Mitigation	Adaptation
Food →		Provides a legal framework for all type of energy generation, distribution, transmission, and consumption. The law regulates the relationship between energy related infrastructure and land use. This means it prohibits agricultural production if it could disrupt energy generation and transport, as well as safety of any kind.		Not relevant	Not relevant	Not relevant	Promotion and regulation of renewable energy sources	No aspects are considered
Energy →	No significant impact			The law regulates the status and competence of the Energy and Water Supply Regulatory Commission of the Republic of North Macedonia. Energy infrastructure establishment must be aligned with the rules and laws approved and adopted by the commission mentioned above.		Not relevant	Energy policy objective 10 protection of public health, the environment and mitigation of climate change from the harmful effects arising from the performance of energy activities	No aspects are considered
Water →	Not relevant	The law regulates the status and competence of the Energy and Water Supply Regulatory Commission of the Republic of North Macedonia. Energy infrastructure establishment must be aligned with the rules and laws approved and adopted by the commission mentioned above.	No significant impacts				Not relevant	Not relevant
Climate →	Not relevant	Not relevant	Energy policy objective 10 – no specific measures and details in this context	Not relevant	Not relevant	Not relevant		

Table 12: Rulebook on Renewable Energy Sources WFEN matrix

Sector impact	Food	Energy		Water			Climate	
	Production, processing, and consumption	Production	Consumption	Supply	Pollution	Consumption	Mitigation	Adaptation
Food →		Regulates the definition and registration of biomass and biogas energy production. Relevant when agriculturally based feedstock is used. However, no specific criteria related to competition with food production are provided.	Not relevant		Not relevant	Not relevant	Not relevant	Not relevant
Energy →	Regulates the definition and registration of biomass and biogas energy production. Relevant when agriculturally based feedstock is used. However, no specific criteria are provided.			Regulates the definition and registration of small hydropower and hydropower energy production. However, no specific criteria are provided.	Not relevant	Not relevant	General objective is to support the implementation of RES.	No aspects are considered
Water →	Not relevant	Regulates the definition and registration of small hydropower and hydropower energy production. However, no specific criteria are provided.	Not relevant				Not relevant	Not relevant
Climate →	Not relevant	Regulates the definition and registration of RES production systems.	Not relevant	Not relevant	Not relevant	Not relevant		

Table 13: Decree on the measures for support of the electricity generation from renewable energy sources WFEN matrix

Sector impact	Food	Energy		Water			Climate	
	Production, processing, and consumption	Production	Consumption	Supply	Pollution	Consumption	Mitigation	Adaptation
Food →		Regulates the definition and categorisation of RES eligible for feed-in tariff systems – including biomass and biogas. Relevant when agricultural based feedstock is used. However, no specific criteria related to competition with food production are provided.	Not relevant	Regulates the definition and categorisation of RES eligible for feed-in tariff systems – including hydropower.	Not relevant	Not relevant	Not relevant	Not relevant
Energy →	Regulates the definition and categorisation of RES eligible for feed-in tariff systems – including biomass and biogas			Regulates the definition and registration of small hydropower and hydropower energy production. However, no specific criteria are provided.	Not relevant	Not relevant	General objective is to support the implementation of RES.	No aspects are considered
Water →	Not relevant	Regulates the definition and categorisation of RES eligible for feed-in tariff systems – including hydropower.	Not relevant				Not relevant	Not relevant
Climate →	Not relevant	Regulates the definition and categorisation of RES eligible for feed-in tariff systems.	Not relevant	Not relevant	Not relevant	Not relevant		

11 APPENDIX II: WFEN MATRICES OF KEY STRATEGIES AND PROGRAMMES

Table 14: National Strategy on Agriculture and Rural Development 2021-2027 WFEN matrix

Sector impact	Food	Energy		Water			Climate	
	Production, processing & consumption	Production	Consumption	Supply	Pollution	Consumption	Mitigation	Adaptation
Food →		RE production is part of its Specific Goal 4 ³¹ and 32.	RE consumption is part of its Specific Goal 4 ³³ .	Water conservation is part of its Specific Goal 5. Implementation of the envisaged measures indirectly support a range of agri-ecosystem services positively influencing water quality and quantity.	Water protection is part of its Specific Goal 5 ³⁴ . Refers to compulsory water protection measures ³⁵ .	Sustainable use of water is a part of its Specific Goal 5. It calls for and supports implementation of smart irrigation techniques.	Its Strategic Goal 2 is implementation of agricultural practices mitigating climate change. Its Specific Goal 4 addresses climate change mitigation. It announces implementation of new climate programmes ³⁶ .	Its Strategic Goal 2 is implementation of agricultural practices helping the agricultural sector to adapt to climate change. Its Specific Goal 4 addresses adaptation to climate change. It announces implementation of a range of adaptation measures ³⁷ .
Energy →	Not relevant			Not relevant	Finances a range of investments reducing usage of fossil fuels, leading to less acidified water.	Finances RE production, reducing water usage in energy sector.	Finances RE production, leading to reduced GHG emission	Not relevant

³¹ It particularly aims at supporting production of renewable energy through investments in (i) solar power plants and wind farms, especially in high-mountain areas, (ii) geothermal and solar energy in horticultural sector.

³² It provides a basis for an increased rate of co-financing of by 10% for all IPARD programme investments contributing to (i) energy efficiency, (ii) production and use of green energy, and (iii) water protection (manure).

³³ It particularly addresses energy saving, energy efficiency and an increase in use of renewable energy in (i) fruit and vegetable production, and (ii) production of meat, milk, and eggs.

³⁴ Notably promotion of precision agriculture-solutions, enabling a more rational use of water and fertilisers. This will particularly be supported through the operational programmes for agricultural producer organisations and the System for Knowledge and Innovation in Agriculture (AKIS) through tailored advice and training. Another important element is co-financing schemes supporting livestock farms to meet requirements for water protection and co-financing of dislocation of farms, if required.

³⁵ These are defined by the "List of special minimum requirements for good agricultural practice and environmental protection" which also regulates the use of fertilisers and soil cultivation techniques.

³⁶ Such as "Use of bio-carbon as a carbon sink in agricultural land" and AKIS-related climate programmes comprising research projects, advisory services and mandatory training.

³⁷ Notably those tested in the period 2012-2016 through the USAID-funded project "Adaptation to Climate Change in Agriculture", implemented by the Rural Development Network.

Sector impact	Food	Energy		Water			Climate	
	Production, processing & consumption	Production	Consumption	Supply	Pollution	Consumption	Mitigation	Adaptation
Water →	An integral and efficient water management is part of its Specific Goal 4 and Specific Goal 5 ³⁸ . Requires setting-up of a “Real Estate Cadastre” ³⁹	Not relevant	Not relevant				Not relevant	Not relevant
Climate →	Recognises agriculture-related climate change problems and calls for additional efforts tackling both mitigation and adaptation (notably through irrigation and drainage).	Climate change impacts on biomass and hydropower production	Finances a range of investments reducing GHG emissions of energy used in agriculture and the food processing industry.	Finances a range of investments helping to maintain water cycles and water supply.	Not relevant	Finances a range of investments reducing alteration of water consumption patterns.		

³⁸ Including large capital investments for the rehabilitation of existing and construction of new hydro systems for irrigation and drainage aiming at improving regional availability of water during the irrigation periods, as well as flood protection. It sets a mid-term target of 144,000 ha and a long-term target of 250,000 ha (half of all arable land) of irrigated land.

³⁹ This is an inventory of all water management facilities and infrastructure built, as well as for digitalization of irrigation and drainage systems and their connection with the existing MAFWE databases and software solutions.

IPARD Programme 2021-2027

The IPARD's food-energy-water nexus specific measures and investments include the following:

- Measure – 1 “Investment in physical assets of agricultural holdings” – (i) production of energy from renewable resources for self-consumption, through processing of plant and animal products from primary and secondary biomass for production of biogas and/or biofuels, use of solar energy, wind turbines, geo-thermal energy etc, (ii) machinery and manure storage facilities preventing water pollution, (iii) purchase and/or installation of new machinery and/or equipment for environmental protection (energy efficiency, controlled climate conditions, manure handling and storage, waste and by-product treatment, water treatment etc.), including climate change mitigation (protection covers, shades etc.), including provision of electricity and/or heating using renewable resources to meet the needs of the holding for its agricultural production activities, (iv) investments in on-farm irrigation facilities and equipment (including new reservoirs, tanks, pipelines, drop-systems, mist systems, sprinkling installations, pump stations, etc. A minimum 5% of all projects financed through the Measure (financially, the most significant IPARD measure), must be spent on investments aiming at mitigating and/or adapting to climate change (compared to 1.6% in 2014 at the start of IPARD programme).
- Measure – 3 “Investments in physical assets concerning processing and marketing of agriculture and fishery products”- (i) purchase and/or installing of new machinery and/or equipment for environmental protection (energy efficiency, controlled climate conditions, waste and by-product treatment and valorisation, water/sewage treatment, processing of animal or plant primary and secondary biomass etc.), including provision of electricity and/or heating using renewable resources; (ii) construction and reconstruction of water-supply and sewage systems, pump stations, artesian boreholes, etc. on the property of the enterprise to meet the needs for food processing and marketing activities.
- Measure – 4 “Agri-environment-climate and organic farming measure” – (i) establishment of green cover of permanent crops, with the aim of preventing water pollution and contributing to the fulfilment of the requirements of the EU Water Framework Directive, and especially the Nitrate Directive and Ground Water Directive, (ii) wider crop rotations in vegetable production, aiming at preventing surface and ground water from pollution by pesticides, (iii) support to organic farming, aiming at preventing water pollution and reducing energy and water use, as well as to reducing vulnerability to climate change and to improving adaptation to climate change.
- Measure – 6 “Investments in rural public infrastructure” – (i) construction/ reconstruction/ rehabilitation and equipping renewable energy plants and public distribution installations from renewables, (ii) improvement of local public distribution networks for energy/heat supply in agricultural areas, including pastures, (iii) construction/ reconstruction/ rehabilitation of the water supply systems, installations and related facilities (e.g. purification, filtration, etc.), (iv) investments for improvement of energy efficiency in buildings used for provision of community services.
- Measure -7 “Farm diversification and business development” – grants for production and sale of energy from renewable resources (biomass, biofuel, wind and solar).

The IPARD Programme identified the following needs in terms renewable energy production and consumption:

- Need 2.3: To increase the use of energy crops and to promote use of renewable energy at farm level and at processing level as well as to increase the overall energy use from renewable resources at the national level.
- Need 3.5: To support production and use of renewable energy to protect the environment and lower the costs for electricity, heating, and cooling.

Table 15 provides an overview of the IPARD programme WFEN matrix:

Table 15: IPARD Programme 2021-2027 WFEN matrix

Sector impact	Food	Energy		Water			Climate	
	Production, processing & consumption	Production	Consumption	Supply	Pollution	Consumption	Mitigation	Adaptation
Food →		Finances RE production from (i) energy crops, (ii) farm by-products, (iii) solar panels (iv) windmills, and (v) geo-thermal sources.	Finances purchase and installation of a range of agricultural machinery and/or equipment leading to higher energy efficiency in the agricultural and food processing sectors.	Implementation of IPARD measures indirectly support a range of agri-ecosystem services positively influencing water quality and quantity.	Finances machinery for more effective application of pesticides, as well as machinery and manure storage facilities reducing and/or preventing water pollution.	Finances on-farm irrigation facilities and equipment reducing water use, as well as water-saving technologies in the food processing industry.	Finances a range of investments (notably RE production) leading to climate mitigation in agriculture and the food processing industry.	Finances a range of investments enabling crop and livestock producers to better adapt to climate change.
Energy →	Not relevant			Not relevant	Finances a range of investments reducing usage of fossil fuels, leading to less acidified water.	Finances RE production, reducing water usage in the energy sector.	Finances RE production, leading to reduced GHG emission	Not relevant
Water →	Not relevant (IPARD does not address the water management sector)	Not relevant	Not relevant				Not relevant	Not relevant
Climate →	Finances a range of investments helping the agriculture and food processing industry to mitigate climate change and adapt to it.	Climate change impacts on biomass and hydropower production	Finances a range of investments reducing GHG emissions of energy used in agriculture and the food processing industry.	Finances a range of investments helping to maintain water cycles and water supply.	Not relevant	Finances a range of investments reducing alteration of water consumption patterns.		

Table 16: Strategy for Energy Development of the Republic of North Macedonia until 2040 WFEN matrix

Sector impact	Food	Energy		Water			Climate	
	Production, processing, and consumption	Production	Consumption	Supply	Pollution	Consumption	Mitigation	Adaptation
Food →		Not relevant	The Strategy aims at significant reduction of energy consumption within the agricultural and industrial sectors. This means that food production systems can have a significant impact in reaching these objectives.	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant
Energy →	The Strategy aims at significant reduction of energy consumption within the agricultural and industrial sectors. Its energy consumption reduction objective can influence and drive change in the types of energy used in agriculture. More RES and EE implemented.			The Strategy emphasise that construction of new small hydropower plants should be carefully assessed to avoid the risk of disproportionate environmental impact compared to electricity generated. In addition to this, the capacity of the water supply systems should be used for small hydropower plants if justified based on economic and technical aspects.		Not relevant	The general objective of the Strategy is to regulate the efforts of the ENDC, to reduce GHG emissions	No aspects are considered
Water →	Not relevant	Not considered	Not considered				Not relevant	Not relevant
Climate →	Not relevant	The energy models used for setting up the quantitative objectives of the Strategy were considered and embedded.	Not relevant	Not relevant	Not relevant	Not relevant		

12 APPENDIX III: SURVEY ORGANISATION AND SURVEY QUESTIONS

Rationale behind

To better understand what is needed most in the food-energy-water nexus in North Macedonia, the project team has prepared and undertook an on-line survey. The responses received were considered when designing the WFEN interventions proposed in this document.

Survey implementation and methodology used

The survey was posted on the Survey Monkey® Internet platform (www.surveymonkey.com). It comprised ten questions. Five were closed-ended checkbox questions made up of pre-populated answer choices, of which the respondents could choose only one answer. However, at the end of each of these questions, there was a box enabling respondents to provide comments (feedback) in their own words. Four questions were matrix-type questions in which the respondents were asked a few questions in a row that have the same response options, using a Likert scale to rank them in order of importance. The last question was an open-ended question allowing the respondents to provide any additional comments in their own words. The Survey Monkey® platform system did not allow respondents to submit the survey unless all questions were answered. The original questionnaire was written in English and translated into Macedonian to enable and facilitate easier answering for Macedonian-speakers. The answers were anonymous. The questionnaire was sent by email on April 1, 2022, and a reminder was sent on April 8, 2022. The deadline for filling in the questionnaire was April 11, 2022.

Questionnaire sent to 32 organisations

The questionnaire (in English and in Macedonian language) was sent to 80 email addresses from 32 organisations⁴⁰, comprising government organisations, universities and research institutes, the chamber of commerce, businesses, international donors and banks, and NGOs:

1. Office of the Vice President of the Government of North Macedonia responsible for economic affairs / National Designated Authority
2. Ministry of Agriculture, Forestry and Water Economy
3. Ministry of Environment and Physical Planning
4. Ministry of Economy
5. Agency for Financial Support of the Agriculture and Rural Development (IPARD Agency)
6. Agency for Promotion of Agricultural Development (National Extension Agency)
7. National Hydro Meteorological Service
8. Energy Agency of the Republic of North Macedonia
9. Crisis Management Center of the Republic of North Macedonia
10. University of St. Cyril and Methodius
 - Faculty of Agricultural Sciences and Food

⁴⁰ Actually, 40 if counting different faculties and institutes of the University of St. Cyril and Methodius

- Institute of Agriculture
 - Hans Em Faculty of Forest Sciences, Landscape Architecture and Environmental Engineering
 - Institute of Cattle-Breeding
 - Faculty of Natural Sciences
 - Institute of Agricultural Economics
 - Faculty of Mechanical Engineering
 - Faculty of Electrical Engineering and Information Technologies
 - Institute of Power Plants and Substations
11. Bitola Faculty of Biotechnical Sciences at the University of St. Kliment Ohridski
 12. Goce Delčev University (Štip)
 13. Rural Development Network of North Macedonia
 14. National Federation of Farmers
 15. North Macedonian Association of Producers
 16. North Macedonian Association of Agricultural Cooperatives
 17. North Macedonian Association of Medical and Aromatic Plant Processors
 18. Association of Millers and Agricultural Producers
 19. Power Plants of North Macedonia (ELEM)
 20. Chamber of Commerce of North Macedonia
 21. North Macedonian Association for Consumer Protection
 22. Ecologist Movement of North Macedonia
 23. Bankwatch (largest network of grassroots, environmental and human rights groups in Central and Eastern Europe).
 24. Ekosvest - Environmental Research and Information Center
 25. Food and Agriculture Organization of the United Nations (FAO)
 26. United Nations Office for Project Services (UNOPS)
 27. United Nations Development Programme (UNDP)
 28. The World Bank
 29. Swiss Agency for Development and Cooperation (SDC)
 30. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) Office North Macedonia
 31. KfW Development Bank in North Macedonia
 32. Global Water Partnership-Mediterranean (GWP-Med)

**Response
rate**

Out of 80 individuals and/or organisations to whom the questionnaire was sent, sixteen (20.00 percent) filled in the questionnaire. All sixteen received responses were valid.

Below is the snapshot of the questionnaire in English:

Appendix III: Survey questions

Survey on water-food-energy nexus in North Macedonia

1. Given the scarcity of arable land at one hand, and high potential for producing renewable energy from water and sun at the other hand, is it feasible for North Macedonia to produce energy crops, especially considering competition for land with agricultural crops?

- ☐ Yes
- ☐ No
- ☐ I am not sure

Comment (if any)

2. Does Macedonian agriculture produce enough manure and silage for the expansion of biogas production?

- ☐ Yes
- ☐ No
- ☐ I am not sure

Comment (if any)

3. Do you expect that the expansion of biogas production in North Macedonia utilising manure and silage will lead to a shortage of agricultural production?

- ☐ Yes
- ☐ No
- ☐ I am not sure

Comment (if any)

4. In the light of the emerging energy crisis, which option do you consider important for Macedonian agriculture?

	Very important	Important	Low importance	Not at all important
Production of more biofuels produced from energy crops and farm by-products	☐	☐	☐	☐
Production of more renewable energy originating from wind, sun, and waterpower	☐	☐	☐	☐
Shift to less energy-intensive agricultural production methods	☐	☐	☐	☐
Introduction of higher subsidies for fossil fuels	☐	☐	☐	☐

Others (please specify)

Appendix III: Survey questions

5. The cooperation between water, food and energy sectors in North Macedonia is:

- ☐ Very good
- ☐ Sufficient
- ☐ Could be better

Comment (if any)

6. The most notable conflicts between water, food and energy sectors in North Macedonia are:

	Very important conflict	Important conflict	Conflict of low importance	Not at all important conflict
Water extraction for irrigation reduces water availability for other sectors	☐	☐	☐	☐
Food production pollutes water	☐	☐	☐	☐
Food production is energy-intensive	☐	☐	☐	☐
Food loss and waste results in water and energy loss	☐	☐	☐	☐
Land used for energy crops production jeopardizes food security	☐	☐	☐	☐

Others (please specify)

7. Which intervention in water-food-energy nexus do you consider important?

	Very important	Important	Low importance	Not at all important
Carbon farming – farming practices that are known to sequester carbon (humus) and improve water retention capacity of soil	☐	☐	☐	☐
Smart irrigation - a money-saving, clean-energy solution for agricultural water management, based on weather and soil data, that minimises environmental footprint through efficient water use	☐	☐	☐	☐
Solutions reducing food loss and waste from farm to fork	☐	☐	☐	☐

Others (please specify)

Appendix III: Survey questions

8. Which administrative set-up and coordination instruments to connect better water, food and energy sectors in North Macedonia do you consider important

	Very important	Important	Low importance	Not at all important
Governmental coordination body for water-food-energy-nexus	☐	☐	☐	☐
Multi-sector water councils	☐	☐	☐	☐
Multi-sector agriculture and rural development council	☐	☐	☐	☐
Climate change coordination body	☐	☐	☐	☐
Others (please specify)				

9. Please specify the sector you work in

- ☐ Agricultural production or food processing
- ☐ Central Government
- ☐ Local or regional Government
- ☐ University or research
- ☐ Farm advisory
- ☐ Non-governmental organisation
- ☐ Financial or donor institution
- ☐ Other

10. Any additional comments:

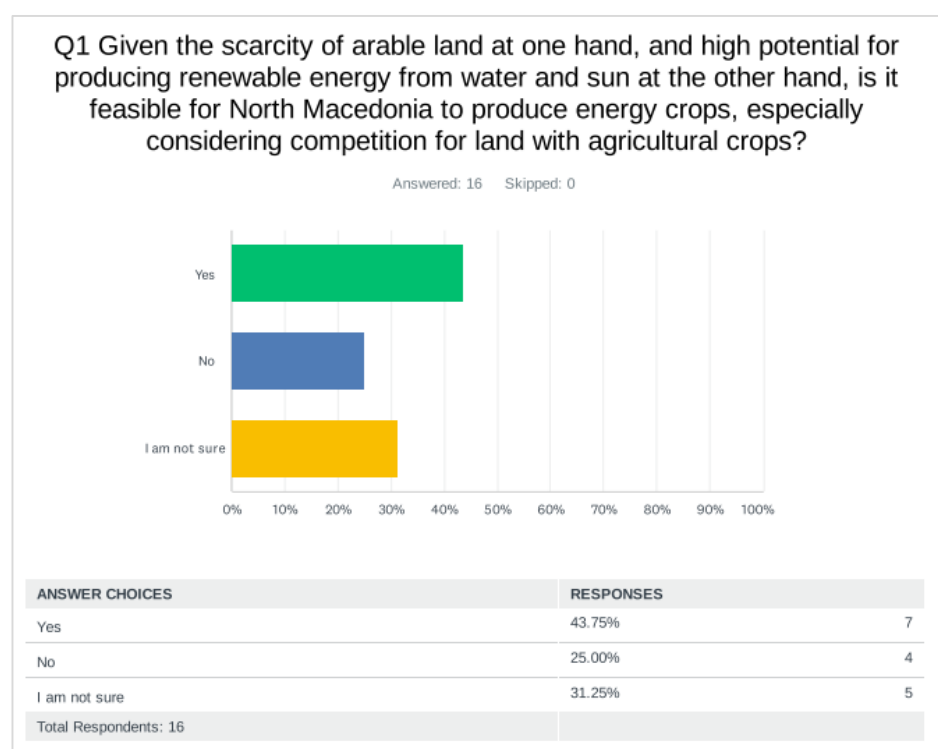
13 APPENDIX IV: SURVEY RESULTS

Key conclusions derived from the survey answers:

- Most respondents do not favour production of energy crops on agricultural land.
- None of the respondents believe that the country produces enough manure and silage that would suffice for expansion of biogas production.
- The respondents are divided regarding their expectations whether the expansion of biogas production in North Macedonia utilising manure and silage would lead to a shortage of agricultural production – no answer prevails.
- A vast majority of the respondents are of the opinion that energy production from renewable sources would make Macedonian agriculture more resilient to energy crises than pursuing other options.
- All respondents are of the opinion that the cooperation between the water, food and energy sectors in North Macedonia could be improved.
- The respondents believe that the most notable conflicts between the water, food and energy sectors in North Macedonia are (i) energy-intensive food production and (ii) food loss & waste resulting in water and energy loss.
- A vast majority of respondents are of the opinion that smart irrigation is the most suitable intervention in the water-food-energy nexus, while half of them find carbon farming to be very important, too.
- Most respondents are of the opinion that a climate change coordination body is the most suitable administrative set-up and coordination instruments to better connect the water, food, and energy sectors in North Macedonia.
- Most respondents work in a central government organisation.

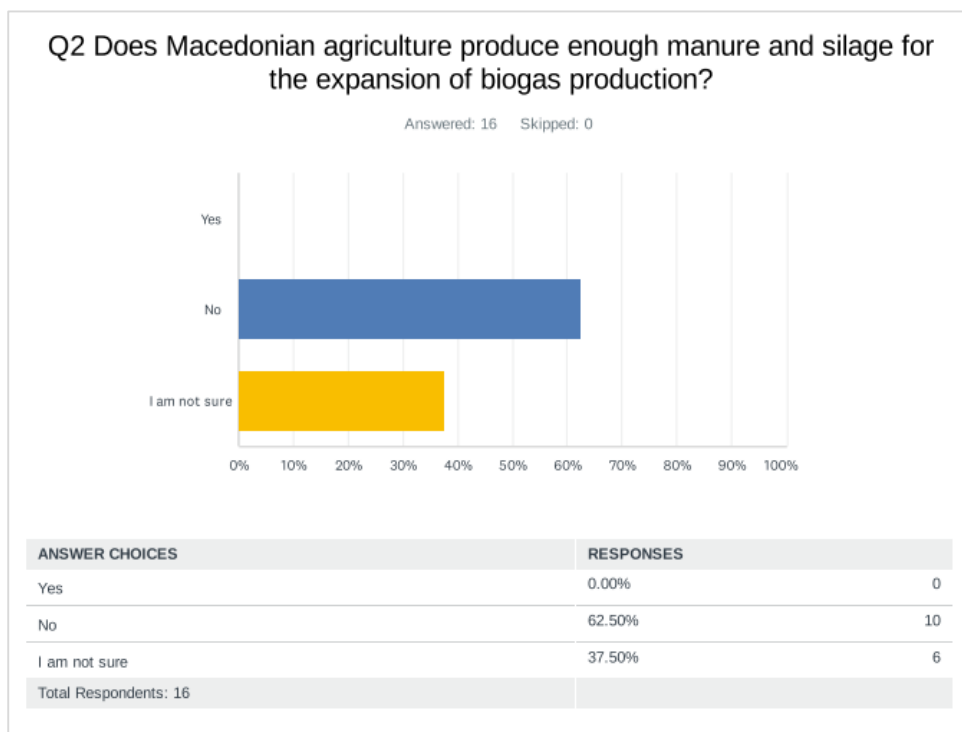
Production of energy crops is questionable

Most respondents (43.75 percent) are of the opinion that the production of energy crops in North Macedonia is feasible, despite the scarcity of arable land and the country's high potential for producing renewable energy from water and sun. However, nearly one-third (31.25 percent) are not sure about it, while a quarter (25.00 percent) don't think that the production of energy crop is a good idea. Although most participants favour production of energy crops, this opinion does not prevail, as 56.20 percent of respondents do not share it. Only one participant provided an additional answer, stating that due to a lot of sunshine and water abundance, the country has an enormous potential to generate energy from renewable sources – and that because of this it is much better and more rational to focus on that, rather than on growing energy crops on (precious) agricultural land.



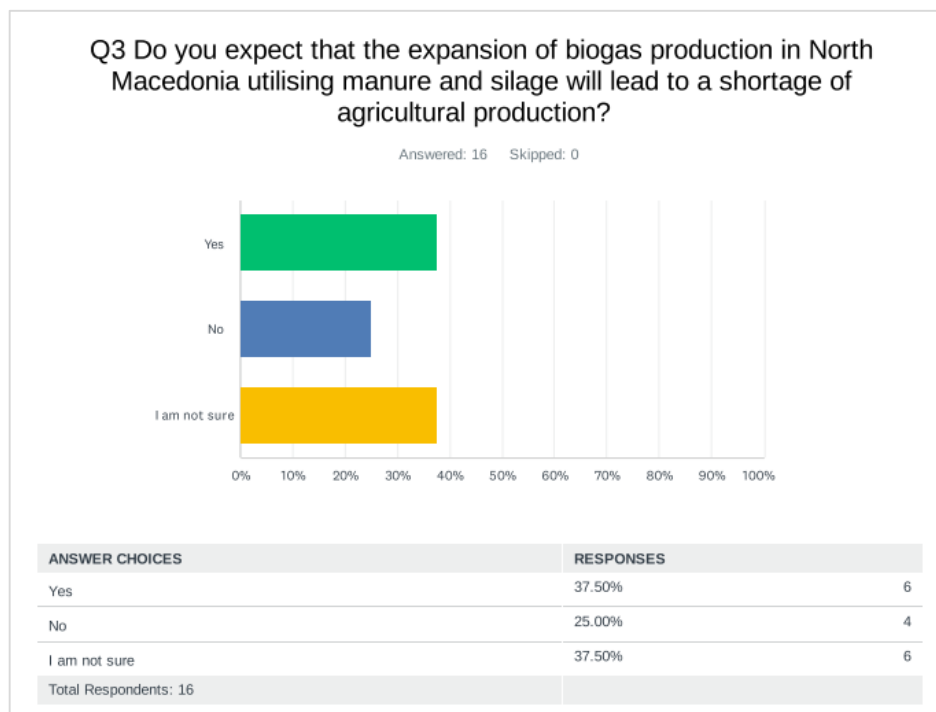
**Not enough
feedstock for
biogas production**

Majority of respondents (62.50 percent) think that North Macedonian agriculture does not produce enough manure and silage for the expansion of biogas production. However, 37.50 percent of them are not sure about it. But none is of the opinion that the country produces enough manure and silage that would suffice for the expansion of biogas production. None of the respondents provided any additional comment on this question.



Production of energy crops is questionable

The respondents are divided with regard to their expectations whether the expansion of biogas production in North Macedonia utilising manure and silage would lead to a shortage of agricultural production. As many as 37.50 percent of them believe so, but the same percentage is not sure, while a quarter of them do not expect it to cause a shortage of agricultural production. None of the respondents provided any additional comment on this question.

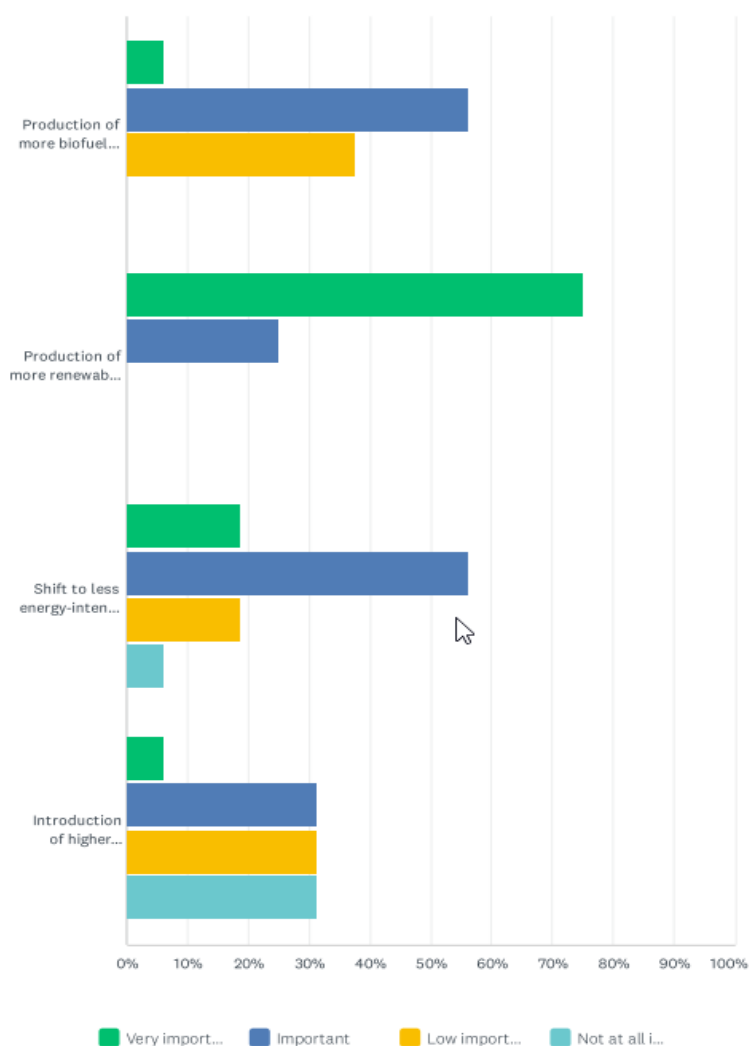


More energy should be produced from renewable sources

Considering the emerging energy crisis, a vast majority of the respondents (75 percent) are of the opinion that the most important option for Macedonian agriculture is if the country produces more renewable energy originating from wind, sun, and waterpower. As many as 56.25 percent of them find (i) production of more biofuels produced from energy crops and farm by-products, and (ii) a shift to a less energy intensive agricultural production methods to be important. The least important option is the introduction of higher subsidies for fossil fuels – only 6.25 percent of respondents find this to be very important, while 31.25 percent find it to be important, of low importance or not important at all. The responses to this question suggest that energy production from renewable sources would make Macedonian agriculture more resilient to energy crises than pursuing other options. None of the respondents provided any additional comment on this question.

Q4 In the light of the emerging energy crisis, which option do you consider important for Macedonian agriculture?

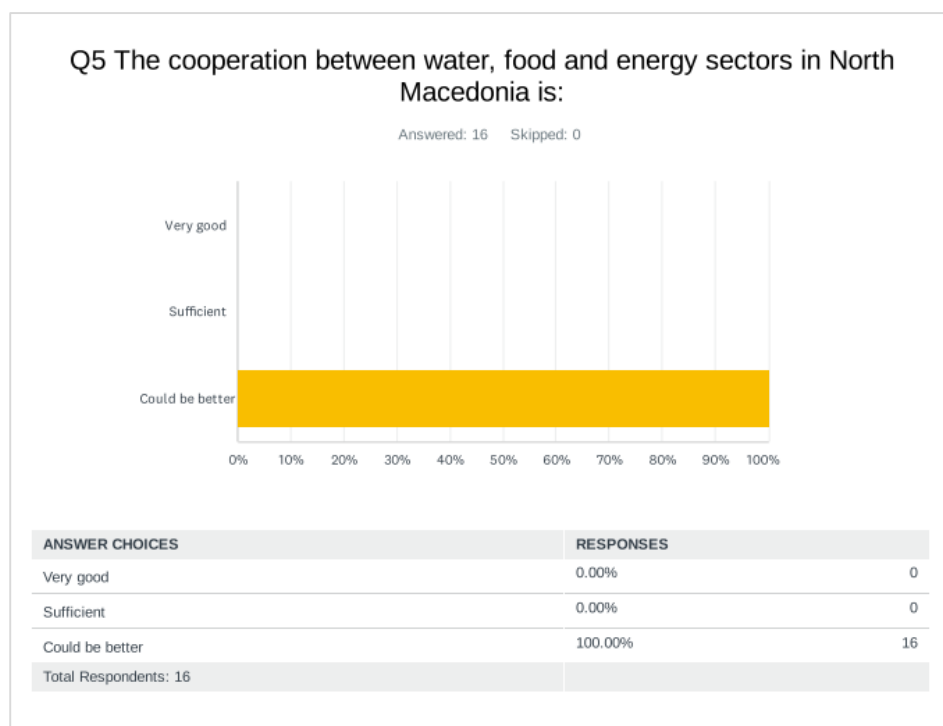
Answered: 16 Skipped: 0



	VERY IMPORTANT	IMPORTANT	LOW IMPORTANCE	NOT AT ALL IMPORTANT	TOTAL	WEIGHTED AVERAGE
Production of more biofuels produced from energy crops and farm by-products	6.25% 1	56.25% 9	37.50% 6	0.00% 0	16	2.31
Production of more renewable energy originating from wind, sun, and waterpower	75.00% 12	25.00% 4	0.00% 0	0.00% 0	16	1.25
Shift to less energy-intensive agricultural production methods	18.75% 3	56.25% 9	18.75% 3	6.25% 1	16	2.13
Introduction of higher subsidies for fossil fuels	6.25% 1	31.25% 5	31.25% 5	31.25% 5	16	2.88

Better cooperation among WFEN sectors

The answer about cooperation among the WFEN sectors is crystal clear. All respondents are of the opinion that the cooperation between the water, food and energy sectors in North Macedonia could be improved. None of the respondents provided any additional comment on this question.



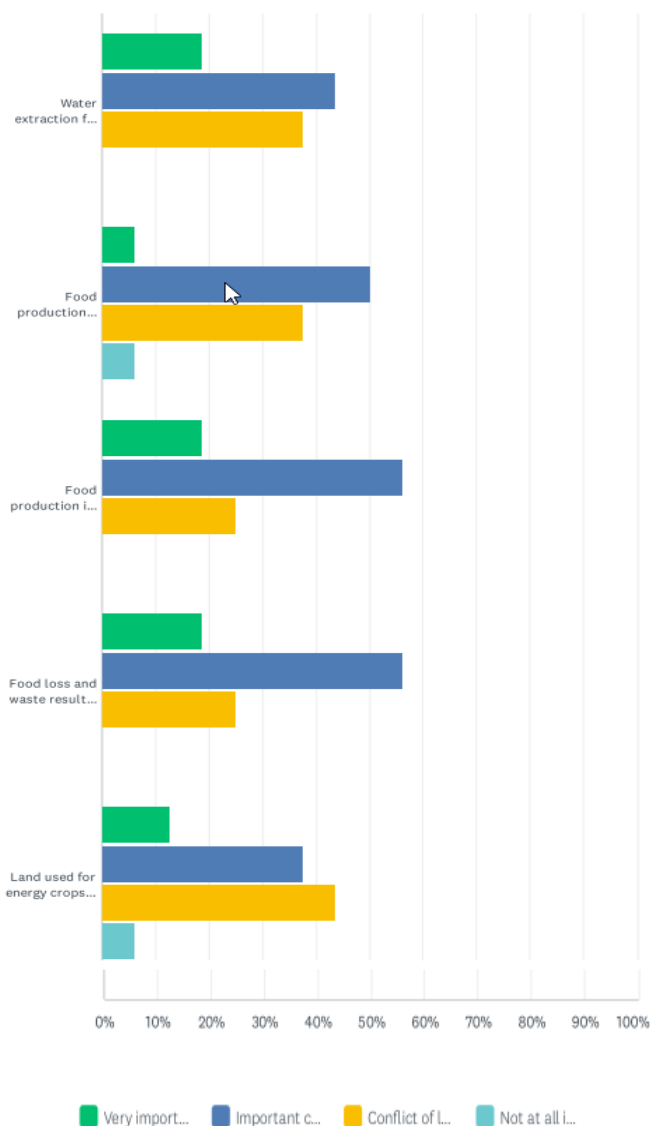
Important conflicts among WFEN sectors

The respondents are of the opinion that the most notable conflicts between the water, food and energy sectors in North Macedonia are (i) energy-intensive food production and (ii) food loss & waste resulting in water and energy loss. As many as 56.25 percent of respondents qualified these two to be as important conflicts. There are no prevailing answers regarding which conflicts are (i) very important, (ii) of low importance, or (iii) not important at all – as the answers range from 0.00 percent to 43.75 percent. Only one participant provided an additional comment on this question, stressing that land use for energy crops production threatens food security, and that this is a very important conflict.

Appendix IV: Survey answers

Q6 The most notable conflicts between water, food and energy sectors in North Macedonia are:

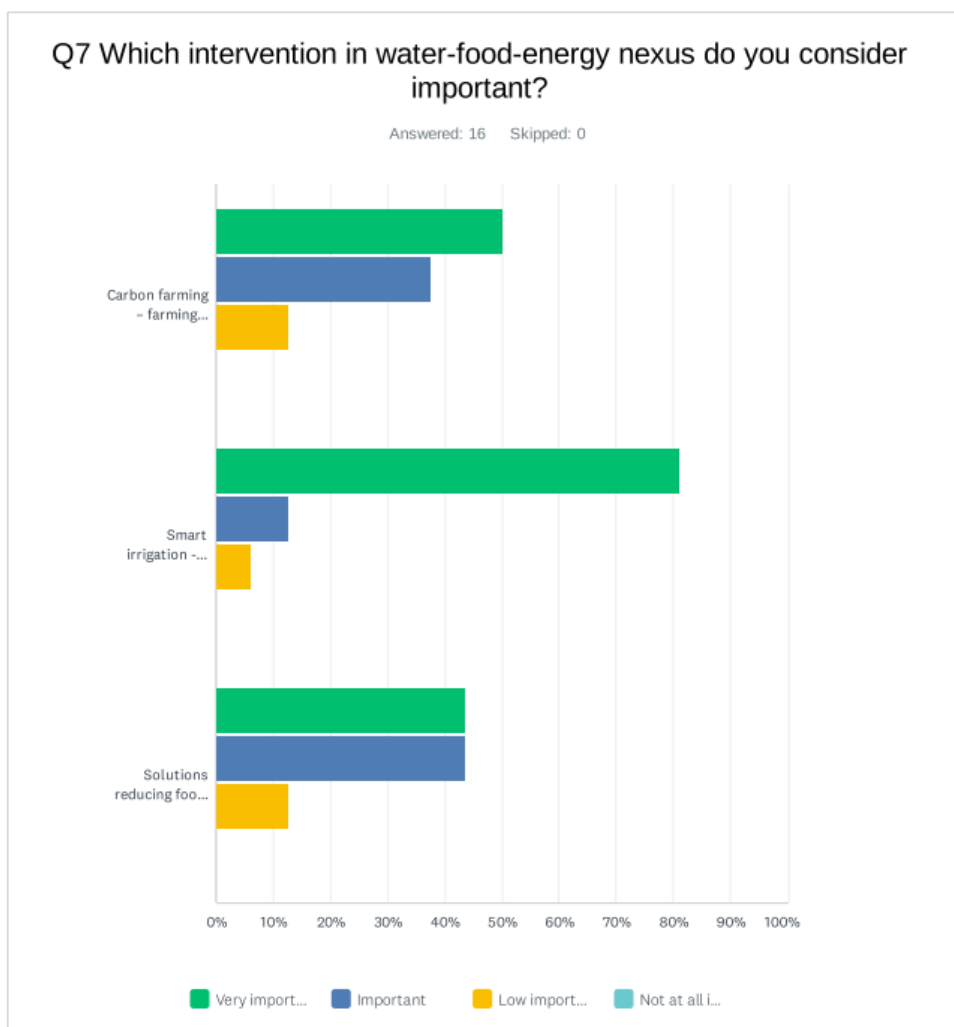
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	VERY IMPORTANT CONFLICT	IMPORTANT CONFLICT	CONFLICT OF LOW IMPORTANCE	NOT AT ALL IMPORTANT CONFLICT	TOTAL	WEIGHTED AVERAGE
Water extraction for irrigation reduces water availability for other sectors	18.75% 3	43.75% 7	37.50% 6	0.00% 0	16	2.19
Food production pollutes water	6.25% 1	50.00% 8	37.50% 6	6.25% 1	16	2.44
Food production is energy-intensive	18.75% 3	56.25% 9	25.00% 4	0.00% 0	16	2.06
Food loss and waste results in water and energy loss	18.75% 3	56.25% 9	25.00% 4	0.00% 0	16	2.06
Land used for energy crops production jeopardizes food security	12.50% 2	37.50% 6	43.75% 7	6.25% 1	16	2.44

Smart irrigation is preferred intervention

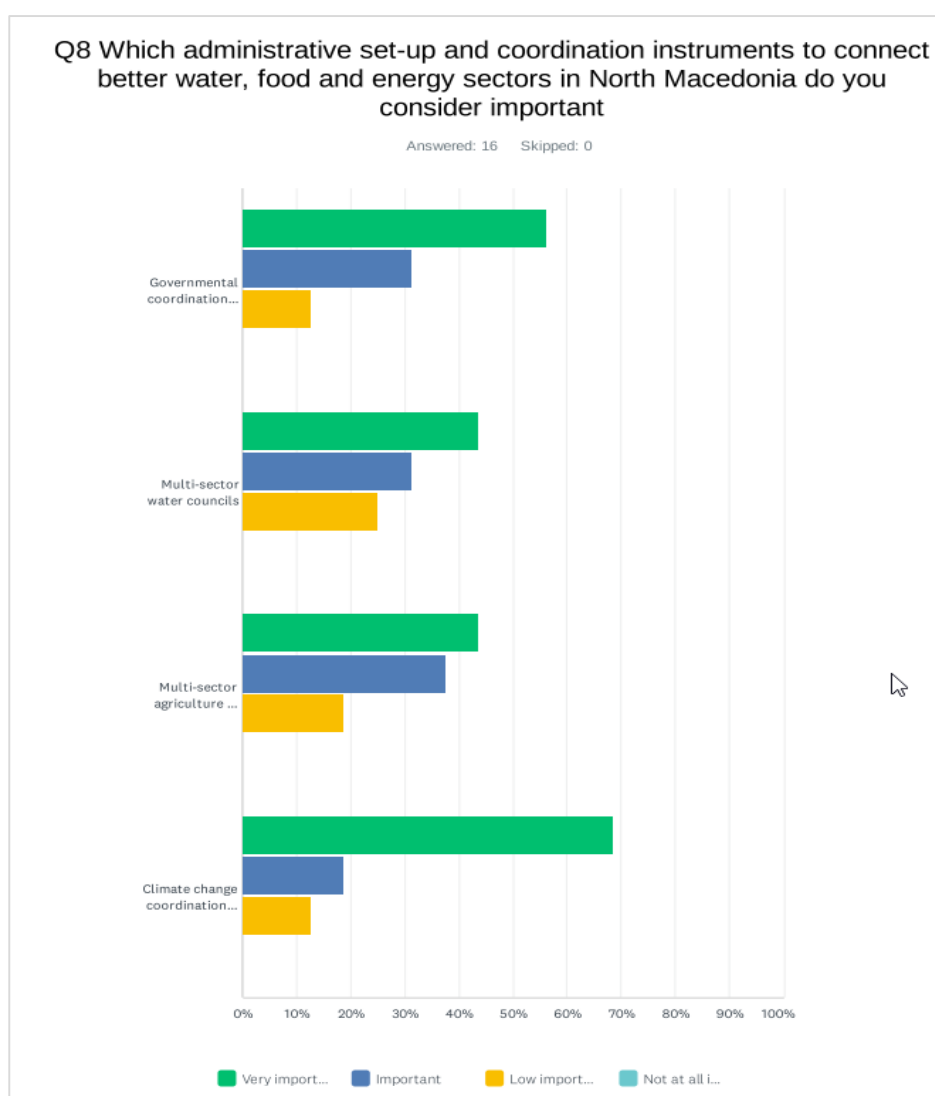
A vast majority of respondents are of the opinion that smart irrigation is the most suitable intervention in the water-food-energy nexus. As many as 81.25 percent of them qualified smart irrigation as a very important intervention, while 50% percent also did so for carbon farming. Many (43.75 percent) participants are of the opinion that solutions reducing food loss and waste from farm to fork are either very important or important. None of the three offered interventions were qualified to be of no importance at all. None of the respondents provided any additional comment on this question.



	VERY IMPORTANT	IMPORTANT	LOW IMPORTANCE	NOT AT ALL IMPORTANT	TOTAL	WEIGHTED AVERAGE
Carbon farming – farming practices that are known to sequester carbon (humus) and improve water retention capacity of soil	50.00% 8	37.50% 6	12.50% 2	0.00% 0	16	1.63
Smart irrigation - a money-saving, clean-energy solution for agricultural water management, based on weather and soil data, that minimises environmental footprint through efficient water use	81.25% 13	12.50% 2	6.25% 1	0.00% 0	16	1.25
Solutions reducing food loss and waste from farm to fork	43.75% 7	43.75% 7	12.50% 2	0.00% 0	16	1.69

A need for a climate change coordination body

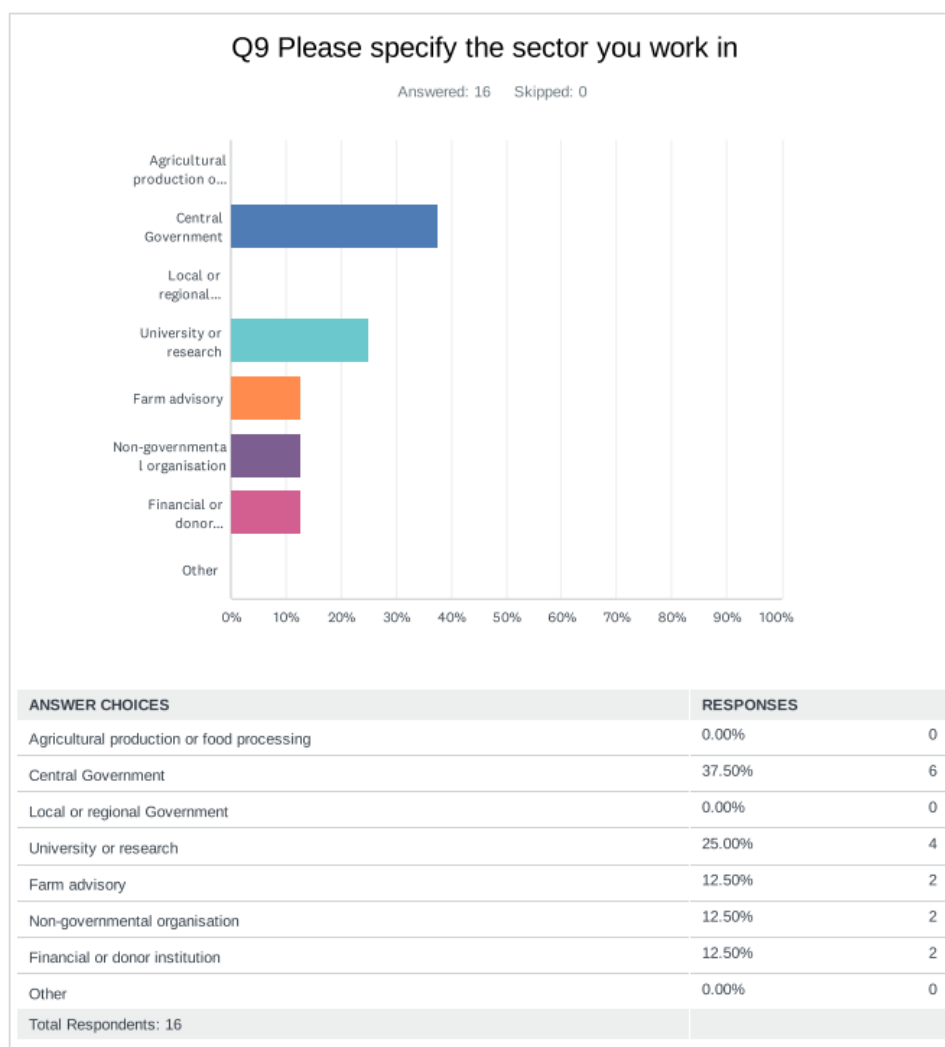
Most respondents are of the opinion that a climate change coordination body is the most suitable administrative set-up and coordination instruments to better connect the water, food, and energy sectors in North Macedonia. As many as 68.75 qualified this as a very important instrument, while 56.25 of them also did so for the need to set-up a governmental coordination body for the water-food-energy-nexus. Multi-sector water councils and a multi-sector agriculture and rural development council are considered to be very important instruments by 43.75 percent of participants. None of the respondents provided any additional comment on this question.



	VERY IMPORTANT	IMPORTANT	LOW IMPORTANCE	NOT AT ALL IMPORTANT	TOTAL	WEIGHTED AVERAGE
Governmental coordination body for water-food-energy-nexus	56.25% 9	31.25% 5	12.50% 2	0.00% 0	16	1.56
Multi-sector water councils	43.75% 7	31.25% 5	25.00% 4	0.00% 0	16	1.81
Multi-sector agriculture and rural development council	43.75% 7	37.50% 6	18.75% 3	0.00% 0	16	1.75
Climate change coordination body	68.75% 11	18.75% 3	12.50% 2	0.00% 0	16	1.44

A good mix of respondents

Most respondents (37.50 percent) work for a central government organisation. A quarter work at a university or a research institute. An equal percentage (12.50 percent) work in a (i) farm advisory organisation, (ii) non-governmental organisation, or (iii) financial or donor institution. None of the respondents works in (i) agricultural production or food processing, (ii) local or regional government, (iii) or in other sectors.



Q10 Any additional comments:

None of the respondents provided an answer to this question.