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IMPROVING ENERGY AND RESOURCE EFFICIENCY IN GREENHOUSE CULTIVATION IN KOSOVO PROJECT

DELIVERABLE # 3: OPTIMAL TECHNOLOGICAL PACKAGES FOR GREENHOUSES

July 2019 (revised August 2019)

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IMPROVING ENERGY AND RESOURCE EFFICIENCY IN GREENHOUSE CULTIVATION IN KOSOVO

DELIVERABLE # 3: OPTIMAL TECHNOLOGICAL PACKAGES FOR GREENHOUSES SURVEYED

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TABLE OF CONTENTS

ACRONYMS

CEA	Controlled Environment Agriculture
CO_2	Carbon Dioxide
GIZ	Gesellschaft für Internationale Zusammenarbeit
EF	Exhaust fans
GH Operator	Greenhouse Operator
IPM	Integrated Pest Management
IRT	InfraRed Transmitting
IS	Insect Screen
ITP	Innovation and Technology Park
ha	Hectare
KCBS	Kosovo Center for Business Support
kWp	Kilowattpeak
LM	Linear Meter
MAFRD	Ministry of Agriculture, Forestry and Rural Development
m^2	Meter squared
NFT	Nutrient Film Technique
PE	Ployethylene
pH	Potential of Hydrogen
PV	Photovoltaic
RV	Roof Ventilation
R-Value	Resistance to heat flow through a given thickness of material
SQ	Status Quo
USAID	United States Agency for International Development
VET	Vocational Education and Training

BACKGROUND

The Improving Energy and Resource Efficiency in Greenhouse Cultivation in Kosovo program (the Program) is a USAID-funded, 13-month long project that is designed to research and bring to light improvements in technologies for greenhouse cultivation in Kosovo and how to finance them in two primary areas: (1) Renewable Energy Technologies; and (2) Hydroponics; in a format that is accessible, practical and usable for Kosovo's greenhouse operators.

The hypothesis is that if technologies for reducing energy costs, reducing natural resource use (energy/water) and improving energy reliability in greenhouse production in Kosovo are better understood by greenhouse operators, combined with a better understanding of how to finance these technologies, then greenhouse operators in Kosovo will be more likely to uptake these technologies and the overall efficiency of greenhouse production in Kosovo will be improved.

The Program will:

1. Conduct an overview, sampling 10 greenhouses in Kosovo
2. Develop an assessment of application of renewable energy technologies and hydroponics in Kosovo
3. Develop Optimal Technological Packages for the 10 greenhouses sampled
4. Create a Toolkit for greenhouse operators in Kosovo of technologies for renewable energy and hydroponics, providing practical guidance on potential options for how to source financing for these technologies
5. Provide support to select greenhouse operators in accessing finance
6. Produce a Study Report compiling data and information gathered from activities 1-5 above

During the period March 4-16, 2019, project experts conducted on-site, field-based research at 10 greenhouse operations in Kosovo, in order to better understand the technologies currently used by greenhouse farmers in Kosovo and the challenges they face in their greenhouse operations. See Program Deliverable # 1 for further details.

In May 2019, the Team developed and submitted an Assessment of Renewable Energy Technologies and Hydroponics in Kosovo Greenhouse Operations report (see Program Deliverable #2).

During June 2019, reflecting the findings and recommendations from Deliverables #1 and #2, as well as findings and recommendations in the draft version of this report (Deliverable #3), Crimson proposed to the Kosovo Center for Business Support (KCBS) that they work together to select 10 greenhouse operators in Kosovo North to participate in a demonstration project, whereby sensors to monitor humidity and temperature in greenhouses will be installed in their greenhouse operations (see section "Environmental Monitoring Sub Package" below for a discussion of the importance of environmental monitoring in greenhouse operations). The sensors have been ordered and are being provided by Crimson as cost share to this Program. It is expected that the 10 greenhouse operators in Kosovo North will be selected in August 2019. Each greenhouse selected will have humidity and temperature sensors both inside the greenhouse and outside, and the data will be transmitted wirelessly. The greenhouse operators will be able to monitor humidity and temperature from their mobile phones.

This report covers item # 3 of the Program, the development of Optimal Technological Packages for the 10 greenhouses sampled and builds on the first two Program deliverables.

This report is organized as follows: the next section presents study assumptions, followed by the Optimal Technological Packages for each of the 10 greenhouse operators, and an analysis of costs and pay back periods. The subsequent section of the report provides relevant detail on the technological packages. This is followed by a recommendations and observations section. Annex I is an overview of the methodology used for determining the economic benefits of the technological packages. Annex II provides detail on the computer modeling done on cooling.

RECOMMENDED TECHNOLOGICAL OPTIONS FOR EACH OPERATOR

The section below outlines recommended packages (technological options) for the 10 Greenhouse Operators surveyed. The quantity and complexity of technological options recommended for each operator is based on the Team's perception of each farms' resources and organizational capacity. It should be noted that installation costs were **not included** in the estimated capital costs, and for US based priced items, shipping costs were not included either. It should also be noted that price quotes were obtained in May/June of 2019 and these prices are subject to change.

Relevant detail on the technological options recommended for each Operator (e.g., "Insect Protection Sub Package"; "Hydroponic Starter Kit") can be found in the Section "Detail on Technological Sub Packages". We have considered seven technological sub-packages under three categories: renewable energy; hydroponics; and ancillary equipment (see table below). The packages have been designed to provide greenhouse operators in Kosovo with a menu of technological options for increasing operational efficiency and production in their greenhouse operations.

Renewable Energy Packages
Solar PV System Sub Package
Hydroponic Packages
Hydroponic Starter Sub Package
Hydroponic Crop Sub Package
Ancillary Equipment Packages
Greenhouse Ventilation Sub Package
Environmental Monitoring Sub Package
Insect Protection Sub Package
Spring Planting Jumpstart Sub Package

Table 1: Overview of Packages

Assumptions:

Since the Operators' greenhouses and tunnels vary greatly in size, orientation, age, materials and other factors, the Team has created the technological packages assuming a standard 1,000 m^2 greenhouse with dimensions of 25 m x 40 m with a sidewall of height of 2.5 m and a roof peak of 4 m (Figure 1). Using this standard, the Team estimated costs per 1,000 m^2 and then translated those costs to the dimensions of each operation. It is important to note that site-specific calculations will be required for each operation if they proceed with the ventilation sub package.

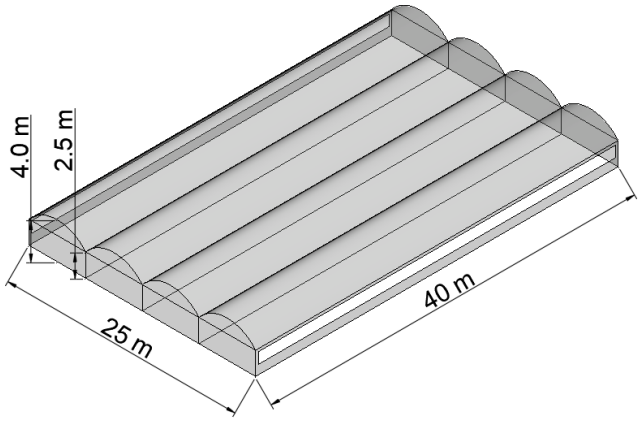

Figure 1: Isometric view of 1000 m^2 greenhouse dimensions

If implemented correctly, the recommended sub packages will improve the growing environment in the operators' greenhouses; however, it is impossible to quantify exactly how much of an improvement there will be or the exact value of this improvement. This is due to a variety of factors ranging from climate conditions, human application, and final pricing on equipment. The analysis section for each greenhouse operator below explains this further.

OPERATOR 1: HALIM BAFTIU

Farm Size Greenhouse Size	3 ha 5000 m^2
Crops Grown	Tomatoes Peppers Cucumbers Strawberries Lettuce Ornamental Plants
Operational Needs	Ventilation Pest Monitoring Increased production of all crops

Table 2: Profile of Operator 1

Recommended Technological Options:

Mr. Baftiu operates six greenhouses and tunnels totaling 5,000 m^2 in size. The Team recommends that one greenhouse be upgraded with the advanced ventilation sub package for hydroponic strawberry cultivation. The other greenhouses should incorporate the basic ventilation sub package in addition to the incorporation of insect protection, environmental monitoring and the Spring Jumpstart sub packages[1] to allow for early production. The Team also recommends a hydroponic starter sub package for this farm, since it would enable them to widen the variety of ornamental plants that they are cultivating.

Technology	**Qty[2]**	**Total Cost**
Insect Protection Sub Package	5	€1,325
Environmental Monitoring Kit (10 sensors, 1 gateway required)	See note, left	€528
Spring Planting Jumpstart Sub Package	5	€8,725
Solar PV System Sub Package	1	€7,500
Basic Ventilation Package - Roof Vents	4	€1,872
Advanced Ventilation Sub Package - Roof Vents + Exhaust Fans	1	€5,000
Hydroponic Crop Kit	1	€13,204
Hydroponic Starter Kit	1	€5,250
	Estimated Total Cost:	€43,404

Table 3: Estimated Capital Costs of Recommended Packages for Operator 1

Operational Costs:

Electricity will be required to run ventilation equipment, soil heating cables, pumps for hydroponics, the monitoring system and dosing equipment for hydroponics. Depending on the design of the PV system and connection to the grid, some of these expenses will be offset, but the exact degree cannot be determined. All equipment should last about 5 years, minimum, but some parts may need replacement sooner. These expenses should be relatively minor. Nutrients and Integrated Pest Management (IPM) will be a reoccurring cost for the hydroponic system and will likely average €2,000 - €2,500 per year.

Analysis:

It is estimated that the hydroponic strawberry system will provide additional revenue of €4,913. Additionally, due to the other improvements afforded to the additional 4,000 m^2 of greenhouse area, there may be an estimated increase in revenue of €0.96 per m^2 which would translate to €3,840 of additional revenue per year. The hydroponic starter kit will provide opportunities for seedling production and sales should provide €600 in additional revenue. The estimated total revenue from these

[1] Note that this operator already has an additional plastic ceiling layer in at least one of his greenhouses so not all elements of this package may be required.
[2] Quantity of 1,000 m^2 units.

improvements in year 1 is €9,353. Without grant funding, the payback period is estimated at approximately 4.6 years.

OPERATOR 2: IZET KASTRATI

Farm Size Greenhouse Size Tunnels	4 ha 1500 m^2 2 x 250 m^2
Crops Grown	Peppers Cucumbers Lettuce
Operational Needs	Ventilation Pest Monitoring Increased production of all crops

Table 4: Profile of Operator 2

Recommended Technological Options:

Mr. Kastrati operates a 1,500 m^2 greenhouse comprised of 10 bays. Mr. Kastrati emphasized production issues due to pests, frosts, and ventilation. Specifically, Mr. Kastrati discussed spider mites on cucumbers as a primary problem. Mr. Kastrati expressed interested in experimenting with hydroponic systems. The following packages are recommended:

Technology	**Qty**[3]	**Total Cost**
Insect Protection Sub Package	2	€530
Environmental Monitoring Kit (1 gateway & 5 sensors)	See note, left	€308
Spring Planting Jumpstart Sub Package	1.5	€2,618
Advanced Ventilation Package - Roof Vents + Exhaust Fans (for Greenhouse)	1.5	€7,500
Solar PV System Sub Package	1.5	€11,250
Basic Ventilation Package - Roof Vents (for tunnels)	0.5	€234
Hydroponic Starter Kit	1	€5,250
	Estimated Total Cost:	€27,690

Table 5: Estimated Capital Costs of Recommended Packages for Operator 2

[3] Quantity of 1,000 m^2 units.

Operational Costs:
Electricity will be required to run ventilation equipment, soil heating cables, lights and the pump for the hydroponic starter kit and environmental monitoring system. Depending on the design of the PV system and connection to the grid, some of these expenses will be offset, but the exact degree cannot be determined. All equipment should last about 5 years minimum but some parts may need replacement sooner. These expenses should be relatively minor. Nutrients for the hydroponic starter kit will likely average €300- €600 per year depending on the intensity of use.

Analysis:
The improvements in ventilation, environmental monitoring and insect protection will lead to an estimated increase in revenue of €1.08 and €0.96 per m^2 in the greenhouse and tunnels respectively. The hydroponic starter kit should provide additional revenue and this amount cannot be predicted but an assumption of €300 is being made, meaning a total revenue increase of €2,400 annually. Without grant funding, the payback period is estimated at approximately 11.5 years.

OPERATOR 3: NEXHAT MORINA

Farm Size Greenhouse Size Tunnels	1.1 ha 4,200 m^2 8 x 250 m^2
Crops Grown	Spinach Cucumbers Tomatoes
Operational Needs	Ventilation Frost Protection Tuta Protection

Table 6: Profile of Operator 3

Recommended Technological Options:
Mr. Morina is operating a 4,200 m^2 greenhouse with a 2.5 kW solar PV system in Mamusha. During the Team's visit to his facility, Mr. Morina expressed disinterest in hydroponic techniques due to lack of knowledge and expertise. The Team observed manual sidewall vents used for ventilation but no mechanical ventilation. While Mr. Morina does have a solar PV system, this system is not big enough to support the ventilation needs of the greenhouse. The following packages are recommended:

Technology	**Qty**[4]	**Total Cost**
Insect Protection Sub Package (for greenhouse and tunnels)	6	€1,590
Environmental Monitoring Kit	See	€616

[4] Quantity of 1,000 m^2 units.

(1 gateway & 12 sensors)	note, left	
Spring Planting Jumpstart Sub Package	4	€6,980
Advanced Ventilation Sub Package- Roof Vents + Exhaust Fans (for Greenhouse)	4.5	€22,500
Solar PV System Sub Package	4.5	€33,750
Basic Ventilation Package - Roof Vents (for tunnels)	2	€936
	Estimated Total Cost:	€66,372

Table 7: Estimated Capital Costs of Recommended Packages for Operator 3

Operational Costs:
Electricity will be required to run ventilation equipment, soil heating cables, lights and the environmental monitoring system. Depending on the design of the PV system and connection to the grid, some of these expenses will be offset, but the exact degree cannot be determined. All equipment should last about 5 years minimum, but some parts may need replacement sooner. These expenses should be relatively minor.

Analysis:
The improvements in ventilation, environmental monitoring and insect protection will lead to an estimated increase in revenue of €1.08 and €0.96 per m^2 in the greenhouse and tunnels respectively. This amounts to a revenue increase of €8,852, annually. Without grant funding, the payback period is estimated at approximately 7.5 years.

OPERATOR 4: REXHEP KRYEZI

Farm Size Greenhouse Size Tunnels	3 ha 2 ha total 20 x 250 m^2
Crops Grown	Tomatoes Cucumbers Spinach
Operational Needs	Ventilation Pest Monitoring Increased production of all crops

Table 8: Profile of Operator 4

Recommended Technological Options:
Mr. Kryezi has numerous greenhouses and tunnels totaling 2.5 ha. The Team recommends implementing the Solar PV sub package and the advanced ventilation sub package in one 0.45 ha greenhouse and the basic ventilation sub package in the others. Insect protection should be implemented in all greenhouses

and environmental monitoring where possible. Additional recommendations include the Spring Planting Jumpstart sub package for all greenhouses.

Technology	Qty[5]	Total Cost
Insect Protection Sub Package	25	€6,625
Environmental Monitoring Kit (1 gateway & 12 sensors)	See note, left	€616
Spring Planting Jumpstart Sub Package	10	€17,450
Advanced Ventilation Sub Package Roof Vents + Exhaust Fans (for Greenhouse)	4.5	€22,500
Solar PV System Sub Package	4.5	€33,750
Basic Ventilation Sub Package - Roof Vents (for tunnels and additional greenhouses)	20.5	€9,594
Estimated Total Cost:		€90,535

Table 9: Estimated Capital Costs of Recommended Packages for Operator 4

Operational Costs:
Electricity will be required to run ventilation equipment, soil heating cables, lights and environmental monitoring system. Depending on the design of the PV system and connection to the grid, some of these expenses will be offset but the exact degree cannot be determined. All equipment should last about 5 years minimum but some parts may need replacement sooner. These expenses should be relatively minor.

Analysis:
The improvements in ventilation, environmental monitoring and insect protection will lead to an estimated increase in revenue of €1.08 and €0.96 per m^2 in the greenhouse and tunnels respectively. This amounts to a revenue increase of €24,108 annually. Without grant funding, the payback period is estimated at approximately 3.8 years.

OPERATOR 5: EKREM DURAKU

Farm Size Greenhouse Size	4 ha 0.3 ha
Crops Grown	Spinach Lettuce Cucumbers Peppers

[5] Quantity of 1,000 m^2 units.

Operational Needs	Ventilation Pest Monitoring Increased production of all crops

Table 10: Profile of Operator 5

Recommended Technological Options:

Mr. Duraku expressed a strong interest in learning about hydroponics and incorporating technology in his operation wherever possible. The team recommends a hydroponic starter kit in addition to the advanced ventilation sub package in one of his greenhouses. The other greenhouses should be upgraded with the basic ventilation sub package. All areas should be upgraded with insect protection, environmental monitoring and the jumpstart planting sub packages.

Technology	**Qty**[6]	**Total Cost**
Insect Protection Package	3	€795
Environmental Monitoring Kit (1 gateway & 10 sensors)	See note, left	€528
Spring Planting Jumpstart Package	3	€5,235
Basic Ventilation Package - Roof Vents (for Greenhouse)	2	€936
Advanced Ventilation Package - Roof Vents + Exhaust Fans (for Greenhouse)	1	€5,000
Solar PV System Package	1	€7,500
Hydroponic Starter Kit	1	€5,250
	Estimated Total Cost:	€25,244

Table 11: Estimated Capital Costs of Recommended Packages for Operator 5

Operational Costs:

Electricity will be required to run ventilation equipment, soil heating cables, lights and pump for the hydroponic starter kit and the environmental monitoring system. Depending on the design of the PV system and connection to the grid, some of these expenses will be offset, but the exact degree cannot be determined. All equipment should last about 5 years minimum, but some parts may need replacement sooner. These expenses should be relatively minor. Nutrients for the hydroponic starter kit will likely average €300- €600 per year, depending on the intensity of use.

Analysis:

The improvements in ventilation, environmental monitoring and insect protection will lead to an estimated increase in revenue of €1.08 and €0.96 per m^2 in the greenhouse and tunnels respectively. This amounts to a revenue increase of €3,000 annually. The hydroponic starter kit should provide additional revenue; an exact amount cannot be predicted but an assumption of €300 is being made,

[6] Quantity of 1,000 m^2 units.

meaning a total revenue increase of €3,300. Without grant funding, the payback period is estimated at approximately 7.6 years.

OPERATOR 6: ARMEND KRASNIQI

Farm Size Greenhouse Size	1 ha 350 m^2
Crops Grown	Plant starts Lettuce Cucumbers
Operational Needs	Heating for seeding propagation

Table 12: Profile of Operator 6

Recommended Technological Options:

Mr. Krasniqi has an agricultural degree and works as an agricultural consultant in addition to operating a small farm with his father. A main element of his business is raising seedlings for sale to local gardeners. The Spring Planting Jumpstart Sub Package will allow him earlier seedling production and the Hydroponic Starter Kit will allow for year round seedling production (if desired) and a wider array of plants to be produced. Mr. Krasniqi might also be an ideal person to help other farmers with their Hydroponic Starter Kits, should assistance be required.

Technology	**Qty**[7]	**Total Cost**
Environmental Monitoring Kit (1 gateway, 3 sensors)	See note, left	€220
Spring Planting Jumpstart Sub Package	0.5	€873
Basic Ventilation Sub Package - Roof Vents (for Greenhouse)	0.5	€234
Hydroponic Starter Kit	1	€5,250
	Estimated Total Cost:	€6,577

Table 13: Estimated Capital Costs of Recommended Packages for Operator 6

Operational Costs:

Electricity will be required to run soil heating cables, lights and pump for the hydroponic starter kit and the environmental monitoring system. The amount of these expenses directly relates to their frequency and duration of use and cannot be predicted. All equipment should last about 5 years minimum, but some parts may need replacement sooner. Nutrients for the hydroponic starter kit will likely average €300- €600 per year, depending on the intensity of use.

[7] Quantity of 1,000 m^2 units.

Analysis:
The improvements in ventilation, environmental monitoring and insect protection will lead to an estimated increase in revenue of €0.96 per m^2 in the greenhouse. This amounts to a revenue increase of €336 annually. Additionally, the hydroponic starter kit will provide Mr. Krasniqi with the ability to produce seedlings year round or cultivate micro greens or baby salad products. The additional revenue from these ventures cannot be predicted but an assumption of €600 is being made, meaning a total additional revenue of €936. Without grant funding, the payback period is estimated at approximately 7 years.

OPERATOR 7: NASIM MORINA

Farm Size Greenhouse Size	0.7 ha 1,000 m^2 (x2)
Crops Grown	Strawberries Lettuce Tomatoes
Operational Needs	Ventilation Pest Monitoring Increased Strawberry Production

Table 14: Profile of Operator 7

Recommended Technological Options:

Mr. Morina operates 2 greenhouses, each 1,000 m^2 in size. One greenhouse is currently growing strawberries while the other is dedicated to lettuce in the cool season and tomatoes in the warmer season. He also has outdoor production of strawberries. Mr. Morina expressed a strong interest in implementing hydroponic strawberry production at his farm. Additionally, due to his agricultural degree, the Team feels that he is qualified to manage such a system.

Technology	**Qty**[8]	**Cost**
Insect Protection Sub Package	2	€530
Environmental Monitoring Kit (Reduced due to no WiFi - no gateway required; 6 sensors only)	See note, left	€280
Spring Planting Jumpstart Sub Package	1	€1,745
Basic Ventilation Sub Package - Roof Vents	1	€468
Advanced Ventilation Sub Package - Roof Vents + Exhaust Fans	1	€5,000

[8] Quantity of 1,000 m^2 units.

Solar PV System Sub Package	1	€7,500
Hydroponic Crop Kit	1	€13,204
	Estimated Total Cost:	€28,727

Table 15: Estimated Capital Costs of Recommended Packages for Operator 7

Operational Costs:
Electricity will be required to run ventilation equipment, soil heating cables, pumps for hydroponics, the monitoring system and dosing equipment for hydroponics. Depending on the design of the PV system and connection to the grid, some of these expenses will be offset, but the exact degree cannot be determined. All equipment should last about 5 years minimum, but some parts may need replacement sooner. These expenses should be relatively minor. Nutrients and IPM will be a reoccurring cost for the hydroponic system, and will likely average €2,000 - €2,500 per year.

Analysis:
It is estimated that the hydroponic system will provide additional revenue of €4,913. Additionally, due to the other improvements afforded to the additional 1,000 m^2 of greenhouse area, there may be an estimated increase in revenue of €0.96 per m^2 which would translate to €960 of additional revenue per year. The estimated total revenue from these improvements in year 1 is €5,873. Without grant funding, the payback period is estimated at approximately 4.9 years.

OPERATOR 8: YLBER KUQI

Farm Size Greenhouse Size	~2,500 m^2 200 m^2 tunnel
Crops Grown	Unknown
Operational Needs	N/A

Table 16: Profile of Operator 8

Recommended Technological Options:
None. This operator has only one small 200 m^2 tunnel and it is used for home consumption. The most meaningful sub package would be for ventilation, but since this tunnel is so small, it could be that local air flow is sufficient to ventilate. WiFi is not available at this site so the environmental monitoring is not an option.

OPERATOR 9: ISMAJL DURAKU

Farm Size Greenhouse Size Tunnels	13 ha 700 m^2 2 x 150 m^2

Crops Grown	Tomatoes Cucumbers Peppers Spinach
Operational Needs	Ventilation Insect Protection

Table 17: Profile of Operator 9

Recommended Technological Options:

Mr. Duraku operates one greenhouse for growing higher quality vegetables for sale at his retail store (the rest of his production is outdoors for wholesale). His farm site is not connected to the grid, so neither the Advanced Ventilation sub package or the PV sub package can be recommended. The Team recommends the basic greenhouse ventilation sub package, due to the lack of grid connection. If there is a grid connection in the future and the PV sub package is possible, then the mechanical ventilation sub package would be recommended instead of the basic ventilation sub package.

Technology	**Qty**[9]	**Total Cost**
Insect Protection Sub Package	1	€265
Environmental Monitoring Kit (no WiFi - no gateway required - only 5 sensors with bluetooth connection)	See note, left	€220
Spring Planting Jumpstart Sub Package	1	€1,745
Basic Ventilation Sub Package - Roof Vents	1	€468
Estimated Total Cost:		€2,698

Table 18: Estimated Capital Costs of Recommended Packages for Operator 9

Operational Costs:

Without connection to the grid, heating cables will not be used and there should be no operational expenses. All equipment should last about 5 years minimum but some parts may need replacement sooner.

Analysis:

Mr. Duraku's greenhouse of 700 m2 area should experience an improvement in performance with an approximate value of €0.96 per m^2. This translates to €672 in increased annual revenue. Without grant funding, the payback period is estimated at approximately 4 years.

OPERATOR 10: SELMON SHALA

[9] Quantity of 1,000 m^2 units.

Farm Size Greenhouse Size Tunnels	10 ha 1.2 ha 0.08 ha
Crops Grown	Tomatoes Cucumbers Peppers Lettuce
Operational Needs	Pest Monitoring Ventilation Technology Upgrades

Table 19 Profile of Operator 10

Recommended Technological Options:

Mr. Shala operates numerous greenhouses and would like to upgrade the technology in them. The Team suggests full mechanical ventilation upgrades in all of his greenhouses and the basic roof ventilation in the tunnels. Additionally, Mr. Shala should incorporate environmental monitoring and insect protection in all of his greenhouses.

Technology	**Qty**[10]	**Total Cost**
Insect Protection Sub Package	12	€3,180
Environmental Monitoring Kit (1 gateway & 15 sensors)	See note, left	€748
Spring Planting Jumpstart Sub Package	12	€14,460[11]
Basic Ventilation Package - Roof Vents (for tunnels)	1	€468
Advanced Ventilation Package - Roof Vents + Exhaust Fans (for greenhouses)	12	€60,000
Solar PV System Sub Package	12	€90,000
Estimated Total Cost:		€168,856

Table 20: Estimated Capital Costs of Recommended Packages for Operator 10

Operational Costs:

Electricity will be required to run ventilation equipment, soil heating cables, lights and environmental monitoring system. Depending on the design of the PV system and connection to the grid, some of these expenses will be offset, but the exact degree cannot be determined. All equipment should last about 5 years minimum but some parts may need replacement sooner. These expenses should be relatively minor.

[10] Quantity of 1,000 m² units.

[11] Mr. Shala has a second layer of plastic in many of his greenhouses so the cost for the jumpstart packages has been reduced accordingly.

Analysis:
The improvements in ventilation, environmental monitoring and insect protection will lead to an estimated increase in revenue of €1.08 and €0.96 per m^2 in the greenhouse and tunnels respectively. This amounts to a revenue increase of €13,728 annually. Without grant funding, the payback period is estimated at approximately 12.3 years.

DETAIL ON TECHNOLOGICAL SUB PACKAGES

RENEWABLE ENERGY PACKAGE

Solar PV System Sub Package

The Solar PV sub package is designed to generate electricity to operate any mechanical devices associated with agribusiness operations.[12] Possible uses include greenhouse exhaust fans, environmental monitoring equipment, irrigation pumps for wells and hydroponic systems, monitoring and control systems for hydroponic production, soil heating cables and the hydroponic starter kit which includes lights, pumps and heating elements. The team estimates that the majority of Solar PV power generation would go towards the operation of exhaust fans, which will help alleviate the overheating of Kosovo greenhouses in the summer months (and which can be linked to the Greenhouse Ventilation Sub-Package and Environmental Monitoring Sub Package).

Figure 2 below shows the distribution of fan (ventilation) operations hours throughout the year. As would be expected, ventilation / fan operation is most needed in the summer months.

[12] While the Team initially original considered solar PV, solar hot water (solar hot water for radiant heat) and biomass (biomass for heating) technologies, during the field study stage, it became clear that both biomass heating and solar hot water for radiant heat of un-insulated greenhouse facilities in Kosovo is simply not feasible from a cost perspective, especially when considering the limited number of days that heating would be needed for Kosovo greenhouse operations (see Deliverable # 2 for more information). We have therefore focused our recommendations on solar PV, which could be used on a year-round basis to power mechanical operations of greenhouses.

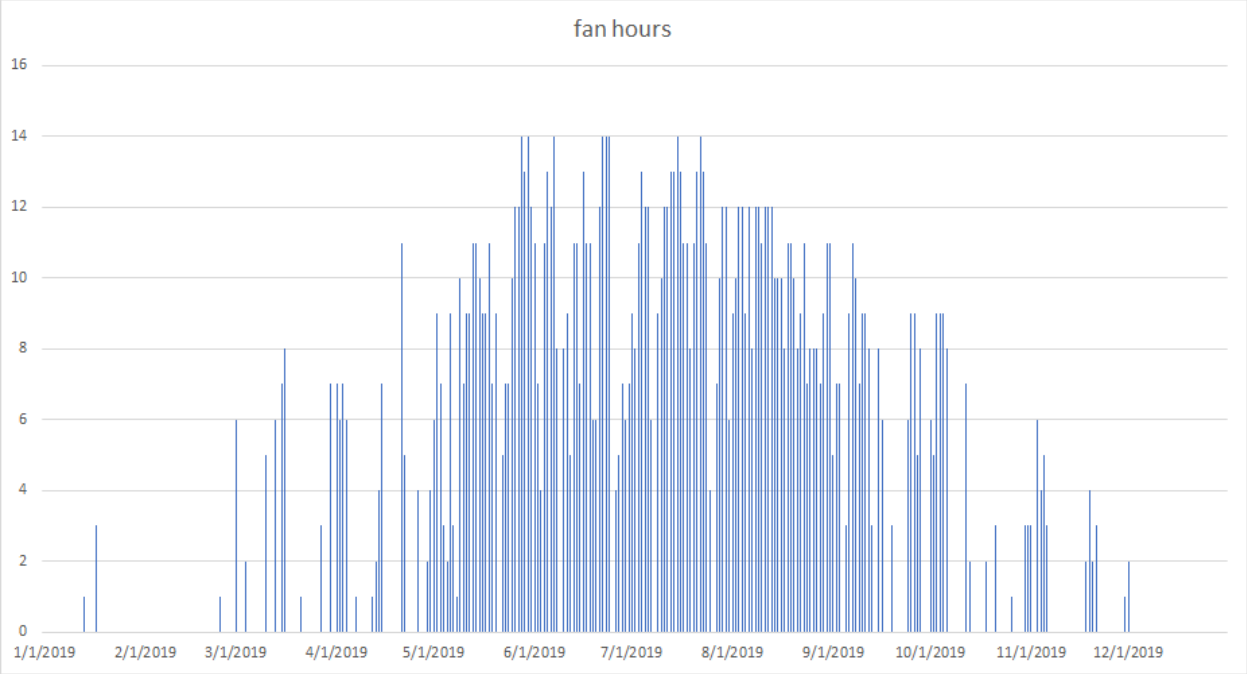

Figure 2: Average running hours per day of ventilation fans throughout the year

From the energy analysis modeled, a 20 kWp system would be required to provide *all* the electricity needed for the ventilation system year round. This system would be very inefficient from a cost perspective and the payoff time would be greater than 25 years.

Therefore, our recommendation for greenhouse operators that are connected to the grid (all but one of the 10 greenhouse operators surveyed -- operator # 9 -- are connected to the grid) is a 10 kWp system, that could cover *most* of an operation's ventilation needs as well as some other mechanical needs, with any excess power injected back to the grid, through Kosovo's net metering scheme[13].

Assuming a 1,000 m^2 greenhouse, a 10 kWp system is recommended.[14] The estimated cost, including installation, for a 10 kWp is approximately €7,500 and the payback period is roughly 6-7 years, assuming that the operator is connected to the grid and able to take advantage of net metering.

Components	Total Cost
PV System- grid connected	€7,500

Table 21: Cost of PV System

[13] Net metering allows a user to use electricity generated from a PV system anytime, not only when it is generated. What this means is that a smaller PV system can be created to cover the majority of the greenhouse operation's energy requirements and the grid can serve as a backup for the additional energy needed at peak times.

[14] System size is an economically viable size to cover a large percentage of energy needs for ventilation for a 1000 m^2 greenhouse.

HYDROPONIC PACKAGES

Hydroponic Starter Sub Package

The hydroponic starter sub package is a hydroponic system for seedling production. This system is designed for operators who have an interest in learning about hydroponic agriculture and implementing it in their operations. The starter kit is a commercially available system called a GrowRack. It is a complete kit, easy to operate and a good way for operators to begin learning and using hydroponic systems in an easy to operate format.

The benefits to this system include:

- An easy to manage hydroponic system, optimal for operators starting out in hydroponics
- The system that can be used year round for seedling production (if enclosed in an insulated area of a greenhouse)
- Could be used for cultivation of other specialty crops such as micro greens.

Operational expenses for this system include: power for lights, a small pump, a heater for the reservoir, nutrients, plugs for plants and chemicals to balance the system pH.

Figure 8: The GrowRack Seedling Production System

Components	Total Cost
Grow RackSystem & components	€5,250[15]

Table 22: Cost of GrowRack Seedling Production System

Components	Total Cost
GrowRack System	€4,000

[15] This cost is US based pricing and does not include shipping or assembly costs. The production system comes unassembled and it is assumed that it will be assembled by the operator in conjunction with a technical expert so that the operator will learn how to maintain the system. Shipping costs may be significant and are not included.

GrowRack Add-on Package (nutrients, media, fans, timers, pH equipment, etc.), plus reservoir water heater	€750
Insulated greenhouse area for GrowRack	€500

Table 23 Component Cost Breakdown

Hydroponic Crop Sub Package

The hydroponic crop sub package is a hydroponic system for strawberry production specifically.[16] This system is designed for operators who are currently cultivating strawberries and have an understanding of their management. Additionally, it is for operators that have expressed interest in using hydroponics and have the capacity to do so.

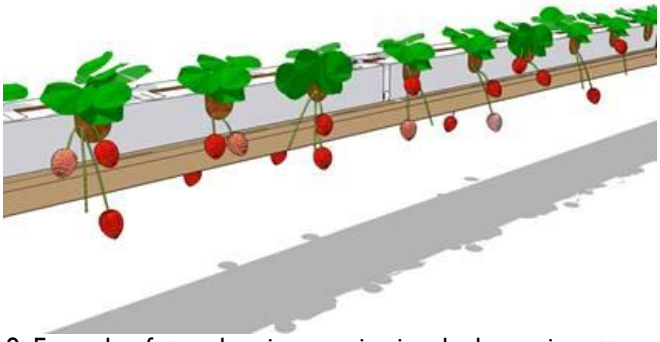

Figure 9: Example of strawberries growing in a hydroponic gutter system.

System	Capital Cost per LM	Total Capital Cost	Value of production[17] (Low Yield)	Value of production[18] (High Yield)	Estimated added profit for 1000 m2 greenhouse"
Strawberry (Mapal System[19])	€15	€13,204	€3,652	€8,662	€4,913[20]

Table 24: 1000 m^2 greenhouse, 880 linear meters of gutter system, 7 plants per linear meter

Components	Total Cost
Grow System, plants & all components	€13,204

Table 25: Cost of Hydroponic Crop Package

ANCILLARY EQUIPMENT PACKAGES

Greenhouse Ventilation Sub Package

[16] Strawberries were chosen as an optimal crop for beginning hydroponic production because the value of strawberries versus the other crops currently cultivated is high and because strawberries are a perennial crop so system can be in place year round.

[17] 0.6 kg/ plant x 6160 plants= 3696 kg(low) x 0.9 €/kg (67%) 1.5 €/ kg (33%)= 1.098 €/kg x 0.9 (less wastage)= €3,652

[18] 1.2 kg/ plant x 6160 plants= 7392 kg (high) x 0.9 €/kg (33%) 1.5 €/ kg (67%)= 1.302 €/kg x 0.9 (less wastage)= €8,662

[19] Mapal is an Israeli brand that is sold by Magan-Mak, a greenhouse supply company in North Macedonia. This is the closest hydroponic supplier to Kosovo.

[20] See Appendix 1 for explanation of how this value was calculated.

Proper ventilation of greenhouses is essential to productivity of greenhouse operations. The greenhouses that were observed in Kosovo are at the lower end of the spectrum in regards to technological sophistication (see Deliverable #1 for further detail). These greenhouses function in the cooler months to trap heat and allow for cultivation sooner than is permitted outdoors. They contain limited ventilation and thus, in the summertime, create sub-optimal growing conditions for crops, i.e., overheat. This heat can stress, shock or kill the crops being cultivated in the greenhouse, resulting in reduced yields. Numerous operators reported this problem due to a lack of ventilation.

Generally, when greenhouses are not mechanically ventilated, their longest side should be perpendicular to the prevailing wind to increase natural ventilation. Figure 3 illustrates greenhouses in Mamusha oriented in many directions, which means not all are optimally oriented for ventilation purposes.

No ventilation other than sidewall vents was observed in any of the greenhouses visited, even though ventilation is poor in all except the smallest tunnels. One reason this may be the case is that the greenhouses were installed by construction companies rather than greenhouse companies, in contrast to what occurs in the U.S. and many other countries. These companies simply construct greenhouses, but do not understand the balance of temperatures or how air should flow in the structures that they are building. Greenhouse companies specialize in not only greenhouse construction but also the appropriate design and orientation for airflow and temperature management.

Figure 3: Overhead view from Google of Mamsuha. Greenhouses with numerous different orientations can be seen. Naturally ventilated greenhouses such as these should generally be oriented with the longest side perpendicular to the prevailing winds.

Computer modeling (see Annex II) was performed to determine the number of "cooling hours" that would be required in the existing single layer polyethylene (PE) greenhouses versus the same greenhouses with different types of ventilation systems. Based on the results of the computer modeling, two ventilation sub packages were created:

1. ***Basic Ventilation Sub Package - Incorporates Roof Vents***
2. ***Advanced Ventilation Sub Package - Incorporates Exhaust Fans and Roof Vents***

The Basic Ventilation Package reduces the daily hours that plants are in suboptimal conditions from 10.4 to 4.9 hours. The Advanced Ventilation Sub Package is more expensive, but reduces the daily hours that plants are in suboptimal conditions from 10.4 to 2.9 hours. This should result in significantly higher yields for fruiting crops due to reduced stress, reduced pollen death and reduced fruit abortion that were a result of the elevated temperatures in the poorly ventilated greenhouses.

The costs associated with implementing this are described below. It is important to note that each ventilation scenario will be different, depending on the exact size of the greenhouse, its orientation and local conditions. The number and placement of fans will vary. The costs described below are approximate for a 1,000 m^2 greenhouse.

Component	Quantity & Cost	Lifespan & Sourcing Information
Basic Ventilation Package Roof/Ridge Vents	Assuming a 25 x 40 m greenhouse, sidewall vent area is approximately 156 m^2. This same area should be created in roof vents. The cost is €3 per m^2 for a motorized system so total cost is €468 (A manual system using chains is €2.5 per m^2)[21]. A motorized system may require electrical upgrades/ modifications on site at greenhouses and these costs cannot be estimated. Total Cost: €468	Mechanical system for opening and closing vents should last for at least 10 years. Motorized systems will likely fail sooner. If not maintained correctly or if excessive moisture intrusion, challenges may occur after 2-3 years.
Advanced Ventilation Package Exhaust Fans plus Roof Vents	67 m^3/ per second (142,000 ft^3/min) of ventilation is recommended. This will require 6 large exhaust fans with a total cost including fan, housing, shutters and thermostats of approximately €4,500. Total Cost for the advanced package includes Roof Vents also: €5,000[22]	Fans are high quality and should last 10 years or longer.

Table 26: Costs of Ventilation Sub Packages

[21] Cost information provided by Ismet Babaj in e-mail correspondence. Cost information is from a local greenhouse fabricator and is from June 2019.

[22] Pricing is from Magan-Mak, a greenhouse supply company in North Macedonia. Magan-Mak estimates that installation, electrical cables and control panels would cost an additional €3,000 per installation, but this will vary by greenhouse. A controller is also required and that pricing has not been determined.

Figure 4: Exhaust fan for greenhouse. A 1,000 m^2 greenhouse would require seven to eight 48" diameter fans to exhaust air at one exchange per minute.

Economic Benefits of Ventilation Sub-Package:
The value per m^2 of the ventilation sub-package will vary based on the type of package chosen, the existing site wind and environmental conditions, crops being grown and other factors. It is estimated that the value ranges from €0.15 - €0.30 per m^2 of greenhouse area.

Environmental Monitoring Sub Package

Greenhouse monitoring equipment allows operators to have a more accurate understanding of what their plants are experiencing in the greenhouse environment. As discussed above, excess heat can greatly stress plants resulting in changes in flavor (bitterness in lettuce) or a lack of fruit production (tomatoes, peppers & cucumbers). For example, at 32 C, tomato pollen will die and fruit will not set. 32 C is easily reached in Kosovo greenhouses each summer. Peppers can suffer damage at lower temperatures. Excess humidity can lead to fungus and mold issues. There is an ideal balance of temperature and humidity based on crop type and without monitoring equipment, observing this and making appropriate adjustments is impossible.

Greenhouse Environmental Monitoring Demonstration Project

During June 2019, Crimson proposed to the Kosovo Center for Business Support (KCBS) that they work together to select 10 greenhouse operators in Kosovo North to participate in a demonstration project, installing humidity and temperature sensors at their greenhouse operations. This demonstration project will allow operators to monitor the conditions of their greenhouses from their mobile phones. The sensors are being provided by Crimson as cost share to this Program.

During observations of greenhouse operators, none of the operators were actively monitoring temperature. A couple of the operators had small thermometers and/or hygrometers hanging in greenhouses, but none were actively recording or using this information for decision making purposes.

Monitoring equipment comes in many styles and price ranges but simple systems that can deliver smartphone alerts are available for a few hundred dollars if there is WiFi available near the greenhouse.

Figure 5: These sensors and gateway made by SensorPush are a low cost way to monitor environmental conditions.

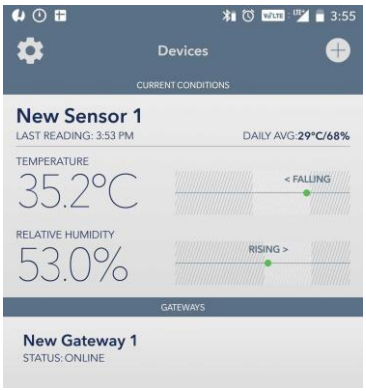

Figure 6: Operators can easily monitor greenhouse conditions on their smartphones from anywhere they have service.

Potential Benefits

1. Growers will have increased understanding of their crop environment.
2. Growers will have increased tools to adjust their crop environment to optimize for production.
3. Growers can get notifications on their phone to alert them to dangerous conditions (elevated temperatures, humidity, low temperatures, etc.) and take appropriate action before crop damage is sustained.
4. Agricultural extension agents can use data collected by sensors to help growers diagnose problems and better understand regional conditions in Kosovo, in addition to drawing correlations between climatic conditions and incidences such as pest outbreaks, etc.

Potential Drawbacks

1. There will be a learning curve to understand how sensors work, where they should be placed, etc.
2. If sensors are not correctly calibrated, operating off faulty information would be problematic.

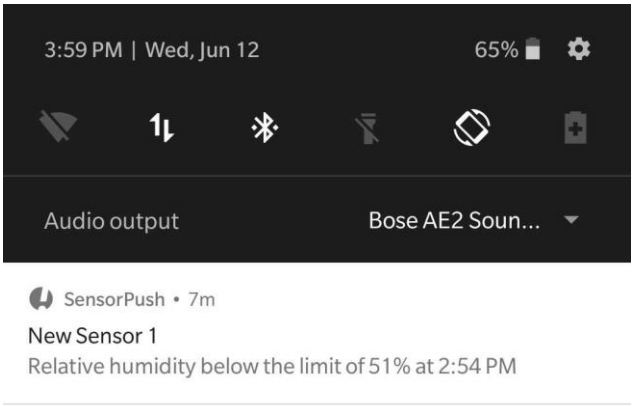

Figure 7: Sensor notification of a user set threshold being exceeded.

Components	Total Cost Range
Temperature/humidity sensors (3), wireless gateway (1)	€220[23]

Table 27: Cost to incorporate Environmental Monitoring Package: 1,000 m^2 Greenhouse

Component	Quantity	Cost & Lifespan Information
Temperature/ humidity Sensors	A 1000 m^2 greenhouse, would require 2 sensors inside the greenhouse and 1 outside (per farm). A small tunnel, 200 m^2, would only require 1 sensor inside plus 1 outside (per farm).	Sensors cost approximately €44 (U.S. price via Amazon[24]). Sensors should provide value for many years (5-10) with almost no operational costs other than battery replacement once per year.
Wireless gateway	One gateway would be required per operation. Having WiFi on site is a requirement for the gateway and sensors to function.	A wireless gateway[25] costs €88 (allows sensors to be monitored from anywhere). Each gateway can service an unlimited number of sensors. There is no operational cost for the gateway other than a small amount of electricity to power. This device should last for numerous years.

Table 28: Cost breakdown

The economic benefits of this package cannot be measured independently, but a discussion of the overall benefits are outlined in Appendix 1.

Insect Protection Sub Package

Insect Screen

[23] This is a U.S. based price so additional shipping costs would apply but the Team has spoken with the company and they said that on a large order (30 gateways plus 100+ sensors) then a 30% discount would apply.

[24] Here is the retail link: https://www.amazon.com/SensorPush-Wireless-Thermometer-Hygrometer-Android/dp/B01AEQ9X9I/ref=sr_1_2?crid=1258WASI8KGBM&keywords=sensorpush+gateway&qid=1560301039&s=gateway&sprefix=sensorpush%2Caps%2C220&sr=8-2

[25] https://www.amazon.com/SensorPush-G1-WiFi-Gateway-Anywhere/dp/B01N17RWWV/ref=sr_1_1?crid=1258WASI8KGBM&keywords=sensorpush+gateway&qid=1560301218&s=gateway&sprefix=sensorpush%2Caps%2C220&sr=8-1

Insect screen is a type of netting that is used to cover all the openings of a greenhouse to prevent entrance of insects. Insect screening comes in many different sizes based on the insect pests that are most problematic. Insect screening has an estimated use life of 3 years. Operators in Kosovo mentioned tuta absoluta, thrips, spider mites, and aphids as significant insect pests.

Of the pests mentioned, thrips is the smallest and if thrips control is a priority then netting should have holes not larger than 0.15 mm (192 micron) to keep thrips out. Tuta absoluta is the pest of highest risk and infestations can completely wipe out tomato crops. The insect screen for Tuta control can have much larger holes because it is to prevent the entrance of the moths, which are 10 mm in size and can fly up to 100 km.

Potential Benefits of Insect Screens

The main benefit of insect screen is that it keeps insect pests out which results in several secondary benefits to producers. These are:

- Increased production and quality of cucumbers (thrips) and tomatoes (tuta) resulting in more saleable product and increased revenue.
- Reduced need to apply pesticides saving money for the producer and likely also positively affecting operator, soil and consumer health.

Potential Drawbacks of Insect Screens

Incorporating insect screen will reduce "natural ventilation" (ventilation based on wind and air currents from differences in air temperature). All operators surveyed use natural ventilation via sidewall vents for their greenhouses. The installation of insect screen will reduce the ventilation capacity of the sidewall vents by approximately 30%[26]. Additionally, it would no longer be prudent to open doors at greenhouse ends which would provide entrance points for insects. Except in extremely small tunnels or greenhouses with exceptionally consistent wind/ air flow, additional ventilation will be required (this is discussed in the ventilation section).

Pest Monitoring

Pest monitoring equipment is a very inexpensive method of monitoring and limited control of pest populations in greenhouses.

Two types of traps that are recommended are:

- Basic sticky cards which trap flying insects such as thrips, aphids, fruit flies and more.
- Pheromone traps for tuta absoluta (for tomato growers)

[26] This reduction in air flow is based on insect screen with holes that are 1.5 mm x 1.5 mm in size. This size of insect screen is available affordably in Kosovo and is sufficient to control Tuta and may help with aphids also. This insect screen should not provide a significant improvement in thrips or spider mite control. Spider mites may be windborne but often are tracked into greenhouses on worker clothes and shoes.

Figure 8 Trap with pheromones for tuta absoluta pest

Benefits & Drawbacks of Pest Monitoring

These traps allow for monitoring of pest issues in a greenhouse. Of the greenhouses observed, only 1 had a basic sticky card (Operator 7). Pest monitoring is critical to understand what pests are present, the level of incidence and when to take additional control measures. It is much easier to spot pests in traps than on plants and thus operators who do not use traps are usually only aware of the pest infestation when it reaches a level which is already destructive. There are no drawbacks to pest monitoring.

Components	Total Cost
Insect screen, tuta pheromone traps (18), sticky cards (45)	€265

Table 29: Approximate cost per 1,000 m^2 Greenhouse for Insect Protection Sub Package

Component	Quantity	Cost, Lifespan & Sourcing Information
Insect Screen	A 1000 m^2 greenhouse, measuring 25 x 40 m, would require approximately 185 m of screen[27].	The cost to purchase insect screen locally (sourced from Turkey) is approximately 0.45 €/m^2 or a total cost of approximately €85. A 3 year lifespan is assumed for this product.[28] (local sourcing)
Tuta pheromone traps	A 1000 m^2 greenhouse would require 2 traps. Assuming changing traps twice over the summer, then €6 traps would be required per season. For 3 years, 18 would be required.	The cost is €7.5 per pheromone trap. For 18 traps the total price would be €135. The lifespan of these traps depends on the level of infestation. (local sourcing)
Sticky Cards	It is beneficial to locate these every 200 m^2, so assume 5 cards per 1000 m^2 with 2	The lifespan of these traps depends on the level of infestation. The cost for sticky cards is

[27] (40+25) x 2 x 1.4 m (opening width = 1.2 m) = 182 m^2. Based on a greenhouse measuring 40 m x 25 m.

[28] There is a Dutch product from Svensson that retails for €4.06 per m^2. This may have a significantly longer lifespan and may be worth the additional investment. This product has smaller holes and will result in a further reduction in airflow so adjustments to ventilation packages should be made if this type of product is incorporated.

	changes means 15 per year per greenhouse.	likely €1 each. It is good to change these 2x per year to observe pests in each season or when heavily infested. A total of 45 cards would be needed. (local sourcing)

Table 30: Cost breakdown of Insect Protection Sub Package

Economic Benefits of the Insect Protection Sub Package

The economic value of the benefits provided by this sub package range from €0.03 - €0.08 per m² of greenhouse area. This means that value for a 1,000 m² greenhouse will range from €30 - €80. This means that operator payback is between 1 - 3 years. Details of how this value was calculated can be found in Appendix 1.

Spring Planting Jumpstart Sub Package

Seedling Production Heating System

Many operators had challenges with protection of seedlings from cold. Seedlings may be killed, stunted or simply delayed due to cold weather. Operators used simple items such as light bulbs to heat seedling areas. This heating system is a package of items that allows operators to begin seedling production earlier and ensure that seedlings don't suffer damage from cold weather. The package consists of the following:

- Soil heating cables[29] (2)
- Temperature control unit[30]
- Steel hoops for tunnel creation (locally available)
- Polypropylene fleece for insulation (locally available)

The package should allow for the creation of approximately 15 m² of heated seedling production area (1 m wide x 15 m long) or 11,250 seedlings[31].

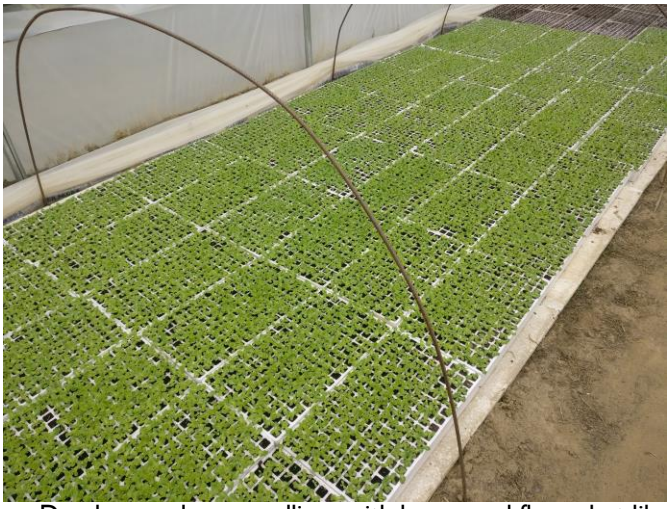

Figure 9: Operator 5, Ekrem Duraku, produces seedlings with hoops and fleece but like the other producers, has no viable heating source.

[29] https://www.greenhousemegastore.com/supplies/seed-starting/heat-mats-cables/soil-heating-cable?returnurl=%2fsupplies%2fseed-starting%2fheat-mats-cables%2f%3fgclid%3dcj0kcqjwxylobrcxarisaef16-tpbomjel8fwba5wfo6dpr0chabcrha2lmwxzplbqtjj0ectl1vlkyaank-ealw_wcb

[30] https://www.hummert.com/unit-heaters/redi-heat-thermostat-42083500

[31] Assuming 750 seedlings per m²

Benefits & Drawbacks of the Seedling Production Heating System

- Earlier seedling production allowing for an earlier crop and greater revenue
- Higher quality seedling production leading to improved yields from crop
- More consistent germination and seedling quality meaning less expenses on seeds

The only drawback is the energy cost of operating this system, but that should not be significant in comparison to the benefits gained from earlier planting and increased crop revenue.

InfraRed Transmitting Plastic Mulch

Plastic mulch is used in agriculture for numerous reasons. Firstly, it is an easy way to control weeds without the need for herbicide application. Secondly, it will aid in heating the soil creating a warmer environment for plants, which is especially critical in the springtime. Finally, it helps with moisture retention by reducing evaporation.

Figure 10: A typical Kosovo greenhouse using black plastic mulch with a lettuce crop.

Black plastic mulch does not let light reach the ground and thus inhibits the growth of weeds. Similarly it blocks much of the solar radiation and thus only warms the ground slightly. Clear plastic allows for much more solar radiation to pass, warming the ground more (beneficial to plants during cooler months of the year) but it also allows light to pass which means that weeds will grow underneath the plastic, which is not desirable.

InfraRed Transmitting (IRT) plastic is a type of hybrid plastic mulch, which combines the benefits of black and clear plastic into one. IRT plastic has the weed blocking properties of black plastic but allow more solar radiation to pass resulting in a warmer soil mass. This is very important for spring planting and is one strategy to allow greenhouse growers to plant slightly earlier in the season.

Benefits & Drawbacks of InfraRed Transmitting Plastic Mulch

The benefits of using InfraRed Transmitting Plastic (IRT) mulch vs. black plastic mulch is an increased soil temperature during the day and a slow release of that thermal energy at night, warming the ground area and allowing for earlier planting. Ideally this plastic is used in conjunction with a fleece (discussed below) to retain this heat at the plant area. The drawback is that IRT mulch is more expensive than plastic mulch by €0.03 - €0.05 per m^2.

Frost Protection/Fleece

Frost protection is a requirement for earlier planting to avoid damage to plants due to a spell of cold weather. One simple method to increase frost protection is by using fleece to cover plants. Fleece is actually a polypropylene blanket that covers crops and helps to retain heat stored in the ground near the plants. Fleece comes in different thicknesses, levels of light transmission and degrees of protection. Fleece type should be chosen based on historical low temperatures.

In Mamusha, for example, cold night lows reach -7 C in February and -4 C in March[32]. It would be ideal to have frost protection that protects to -7 C (20 F). In Peja, the cold nights are more extreme with February temperatures drop to -10 C and -5 C in March[33].

Greenhouse Plastic (Additional Layer)

Greenhouses are made of different glazing materials. Some are glass, some are polycarbonate, and others, like the ones in Kosovo are made of plastic sheeting. Each material has a certain insulative value. Plastic sheeting has a minimal insulative value but if a second layer of plastic is added, then a layer of air is trapped between the two layers of plastic, providing much greater insulative value. This is demonstrated in the image below as seen at Operator 10 in Peja. This second sheet of plastic is "retractable" and will be retracted by operators as temperatures rise in the late spring.

Figure 11: This greenhouse displays a second layer or plastic for added insulative value.

Computer modeling was performed on the combined benefits of incorporating an additional layer of Greenhouse Plastic to the roof and adding IRT Plastic at the soil layer to determine the number of "heating hours[34]" that would be required in the existing single layer PE greenhouses versus the same greenhouses with the IRT mulch and the additional plastic layer. Modeling showed that the single sheeting greenhouses would have a heating hour requirement of 409 hours (5 C threshold). With the addition of the second layer of plastic sheeting and the IRT mulch, the heating hour requirement drops significantly as shown in the Table 31 below.

[32] https://www.meteoblue.com/en/weather/forecast/modelclimate/mamu%C5%A1a_kosovo_788187

[33] https://www.meteoblue.com/en/weather/forecast/modelclimate/pe%C4%87_kosovo_787157

[34] Heating hour is defined as a period of time in which the temperature in the greenhouse is below the temperature threshold requiring supplementary heating to meet said threshold. Because the point of the additional heat retention is to allow for earlier planting of hot weather crops (tomato, pepper, cucumber), computer modeling was done for the months of February, March and October. October was modeled because an early frost can interfere with these crops in their late season.

	Status Quo (5 C temp threshold)	Status Quo (0 C temp threshold)	With Plastic Layer & IRT Mulch (5 C temp threshold)	With Plastic Layer & IRT Mulch (0 C temp threshold)
Heating hours	409	31	360	6
Heat requirement (W/m^2)	73.9	26.5	47.6	4.5

Table 31: Heating requirements across different sheeting covers

Components	Total Cost
Seedling production heating system (per 15 m^2 area), IRT mulch, add'l plastic layer & Frost Protection (1,000 m^2)	€1260

Table 32: Cost to incorporate Spring Planting Jumpstart Package: per 15 m^2 seedling area and 1,000 m^2 Greenhouse

Component	Quantity & Cost	Lifespan & Sourcing Information
Seedling production heating system- soil heating cables (2), temperature control unit (1), steel hoops for tunnel creation, polypropylene fleece for insulation	Thermostat plus 2 heating cables - each 61 meters (200') €450 Fleece to -10 C, 30 m^2, €6 (locally available @ €0.2 per m^2) Steel hoops for tunnel creation, 15 hoops, €2 each, €30	Should last 5 - 10 years if used correctly.
IRT plastic mulch: 1000 m^2	€50	One season
Frost Protection: -10 C- 1000 m^2	€200	5+ years
Plastic sheeting	€510 total includes: €400 plastic sheeting €50 480 m wire €60 labor: 3 people 1 day	3+ years

Table 33 Cost breakdown & Lifespan of Heating Materials

Economic Benefits of Spring Planting Jump Start Sub Package

It is estimated that the economic benefit of earlier planting that this package allows will provide value of €0.16 - €2.93 per m^2. The economic benefits of the packages are described more precisely in Appendix 1.

FINAL OBSERVATIONS & RECOMMENDATIONS

The team feels that agriculture in Kosovo is at an inflection point. It can continue its current ways of farming, or it can embrace technological and sustainability integration to help it take a giant leap forward. This opportunity must be seen on two levels: first, at a granular level with specific incentives and technological packages to help farm operators. Second, at the macro level where systematic changes should be encouraged to develop and transform the entire agricultural sector.

On the granular level, all sub packages recommended by the Team should provide measurable benefits to Kosovo farmers and their implementation is highly encouraged. The greenhouse ventilation sub-package and both hydroponic sub-packages have a higher capital costs (likely requiring at least partial grant funding)[35]. Additionally, the hydroponic sub-packages come with a steep learning curve to optimize their use. The Solar PV sub-package has high capital costs, but low operational costs and in some cases, if combined with net metering, could be financed commercially, while in other cases, would likely require at least partial grant funding for uptake. The Insect Protection sub-package, the Environmental Monitoring sub package and the Spring Planting Jumpstart sub package are all affordable and easy to implement.

At the macro level there are opportunities to connect Kosovo agriculture with local developing sustainable industries, which will allow both to thrive and help transform the entire agricultural sector. There is a well developed solar energy industry that can provide local RE technological solutions to farmers. Solar solutions can provide a reliable source of electricity and long-term operational savings for farmers. However, the up-front capital costs of these systems can be high and that is why the team suggests net metering solutions that will provide energy savings year round to the operators.

Hydroponic technologies can increase production and provide a higher level of control over the quality of produce. However, similar to the renewable energy technologies, the high capital costs of these systems can be a barrier for farmers. For a successful introduction of hydroponics in Kosovo, there should simultaneously be efforts to develop the market for higher quality produce (both domestically and for export) and to develop the technical capacity of greenhouse operators in the region. The team feels that the hydroponic sub packages recommended are appropriate to begin these efforts.

At the macro level, the team feels there would be great benefit to installing a large scale demonstration hydroponics facility for training purposes. Prime Contractor Crimson discussed the possibility with GIZ of installing a demonstration hydroponics facility in one of the buildings of the Innovation and Technology Park (ITP) being implemented at the former German KFOR base in Prizren. The ITP is planned to support entrepreneurship, ICT, agriculture, VET and non-formal education, science and research, and tourism and culture. Sub Contractor Agritecture confirmed that the building was suitable for a self-contained (room within a room), working hydroponics system that could be used for training as well as producing high value products year round. As the ITP moves forward, we will continue discussions with GIZ.

Most of the farmers interviewed, and most farmers in Kosovo, are older and are not very tech savvy. They are also quite conservative and tend to be committed to traditional farming. Many farmers were unsure who would take over their farms when they are no longer able to operate them. Soon it will be important to attract the younger generation into agriculture, which can be supported by incorporating new methodologies and technologies. In order to attract younger people into agriculture, it will be critical to provide training and capacity building in the most modern methods and technologies, including RE and hydroponics. It would be helpful to implement agricultural training centers in main growing areas in Kosovo to overcome the knowledge and skill gaps, especially with the new technologies. The plan for

[35] In 2018, approximately €3M were given as grant funding to 91 greenhouse operators in Kosovo, through grants provided by the Ministry of Agriculture, Forestry and Rural Development (MAFRD).

ITP in Prizren includes just such a center. This center could include training on the utilization of solar PV, solar thermal, biomass, hydroponics, ventilation, monitoring, insect protection, early planting, etc. These centers will provide both training and inspiration to the area farmers. One component of the training can be hydroponics. Trials should also be conducted at these facilities with new crop varieties, new methods of production and different pest management strategies. These centers could also function as seedling production facilities, producing high quality seedlings for Kosovo farmers, further improving their yields.

Kosovo also has opportunities to develop an agritourism sector, which can include hydroponics. Creative applications of hydroponics may be a viable means of boosting its uptake in Kosovo.

APPENDIX 1 – METHODOLOGY & ASSUMPTIONS

Methodology of Determining Economic Benefits of Proposed Packages

As it is not possible to predict or model exactly how much an operator will benefit from the recommended sub packages, the Team has made the following conservative estimates to quantify these benefits.

Benefits of Spring Planting Jumpstart Package

Several operators discussed the price increase they received at the beginning of the season, as shown below. This one consideration, specifically for the Spring Planting Jumpstart Package, is the value of earlier crop production.

Operator	Crop	Early Season Price	Mid Season Price	Price % increase for early season
1	Tomato	0.7 €/kg	0.4 €/kg	75%
1	Salad Cucumber	0.8 €/kg	0.3 €/kg	166%
1	Peppers	1.0 €/kg	0.6 €/kg	66%
1	Strawberry	3.0 €/kg	1.5 €/kg	100%
2	Peppers	1.5 €/kg	0.5 €/kg	200%
2	Salad Cucumbers	1.0 €/kg	0.4 €/kg	150%
4	Gherkin Cucumber	0.6 €/kg	0.3 €/kg	100%
			Average early season increase:	122%

Table A: Early season price increase noted by some of the operators

The average price bounce for early season crops was 122%, which is highly significant. While it is not possible to predict exactly how much of the crop would translate to early season prices for each operator after incorporation of the Spring Jumpstart Planting Package, the below is a range of values that were considered.

Current profit levels observed in greenhouse operations ranged from 2.5 - 6 €/m^2. The Spring Jumpstart Planting Package will provide a higher percentage of crop sold in the "early season" and a higher price for that crop as shown in the table below.

"early season" bump- increased value	25%	50%	75%	100%
Increased percentage of crop sold at "early season" prices	5%	10%	15%	20%
additional % profit	6.25%	15.00%	26.25%	40.00%

Table B: Estimates of additional profit for operators due to increased early season sales

The early season bump, depending on the value of the bump and the amount of crop sold as early season, should range from a minimum of 6.25% to a maximum of 40%. This translates to an additional profit per m^2 of a minimum of 0.16 € and a maximum of 2.93€ as shown in the table below.

Profit per m^2	2.5 €	4.25 €	6 €
With 6.25% bump	2.66 €	4.52 €	6.38 €
With 40% bump	3.72 €	6.32 €	8.93 €

Table C: Range of profit per m^2 with bump due to early season sales increase

Benefits of Insect Protection Sub Package

Operators that we spoke with were not able to give specific information on crop losses due to insects but most estimated it as being 2-3% of their crop. For tomato growers they additionally reported that incidence of Tuta absoluta was increasing and in many countries, crop loss ranges from 50-100%. Assuming a 2% loss of crop due to insects and that the insect package cuts that loss in half, then the value is essentially equal to a 1% increase in production plus reduced expenses on pesticides and other control measures. If we assume a 1.25% increase in production at current profit levels, this will mean the following:

Profit per m^2	2.5 €	4.25 €	6 €
1.25% bump	0.03 €	0.05 €	0.08 €

Table D: Range of profit increase per m^2 with bump due to Insect Protection Package

Benefits of Environmental Monitoring and Ventilation Sub Packages

These two packages should be seen as working together since there isn't a huge amount of value of having one without the other. Improved ventilation, as described earlier, will benefit operators most during the mid to late summer months. This is due to improved fruit development (peppers, cucumbers, strawberries and tomatoes) during the summer months. (Reduced temperatures should also help reduce insect pressure as insects reproduce more rapidly at higher temperatures). The exact benefit to operators will vary based on each specific greenhouse, local weather conditions and the crop being produced but crop production should increase between 5-15%. Using 10% as a fair estimate, we see the following benefits in economic value.

Profit per m^2	2.5 €	4.25 €	6 €
Summer profit per m^2 [36]	1.5 €	2.1 €	3 €
10% bump	0.15 €	0.21 €	0.30 €

Table E: Range of profit increase per m^2 with bump due to Environmental Monitoring and Ventilation Packages

Total value of benefits:

Summing all the benefits, we find that incorporation of the packages described offer the following benefits per in profit per m^2:

[36] Summer profit level was calculated at 50% of overall profit since that is the time when the market is "flooded" with product and operator revenue drops significantly.

Profit per m^2	2.5 €	4.25 €	6 €
Low value	+0.34 €	+0.53 €	+0.76 €
High value	+1.40 €	+2.33 €	+3.31 €

Table F: Total increase in profit per m^2 due to packages

Per m^2 of greenhouse, the additional profit per year would range from 0.34€ to €3.31. In deciding which value to use of the above, the following options are available:

- Average value: €1.44
- Tossing out highs and lows and then finding average: €1.26
- Median value: €1.08

For this analysis we have chosen the most conservative figure, the median value, €1.08 increased value per m^2. This is the estimated revenue increase of all improvements. In many instances there is a recommendation for the basic ventilation package, which will mean lesser ventilation benefits and a reduced benefit per m^2. It is estimated that this will reduce the benefit by approximately €0.12 and reduce the increased value per m^2 to €0.96. It should be kept in mind that the benefit levels suggested here and used in calculations are extremely conservative and actual benefits may exceed these values. Only through solid data collection focused on agribusiness finances will the true value of these integrations be determined.

Benefits of Hydroponic Crop Sub-package

- Hydroponic systems provide a higher yield per plant than in ground systems in Kosovo.
    - According to the two operators which cultivate strawberries, their yields average 1.45 kg/m^2 /year. 4.5 plants are planted per m^2 so yield is 0.32 kg per plant.
    - A 1,000 m2 greenhouse will thus yield 1,450 kg per year. At an average value of €1.2 per kg, then the total value provided is approximately €1,740.
    - Plants growing in hydroponic systems should average 0.9 kg per plant (a minimum of 0.6 kg and a maximum of 1.2 kg, as shown in the scenarios in the table 24).
    - A 1,000 m2 greenhouse can support approximately 880 linear meters of gutters with 7 plants per linear meter. At an average yield of 0.9 kg per plant, this greenhouse will yield 5,544 kg. At an average value of €1.2 per kg, then the total value provided is approximately €6,653.

The increased value provided by the hydroponic production system is approximately €4,913.

Benefits of Hydroponic Starter Kit package

The hydroponic starter kit is primarily focused as a learning tool for the operators. That said, two of the four operators that were recommended to receive this package sell plant seedlings or live plants (operators 1 & 6) and this kit could provide significant value to them as a way to propagate plants year round or grow and sell unique plants that are not normally available. For these two operators, it is assumed that the kit will provide revenue of €50 per month or €600 per year. For the other two operators, it will provide value as another option for early seedling propagation and could provide value if these operators decide to sell seedlings or cultivate other high value crops such as micro greens in the system, so it is assumed that they will provide less revenue, €25 per month or €300 per year.

Benefits of Solar PV package

The solar PV package will allow Kosovo farm operators to run mechanical devices on their farm essentially for free, up to the amount of electricity that is generated. It does not matter what these devices are or what time of day or year they are operated.

The 10 kvp Solar PV package can produce a maximum of 14,000 kWh per year. At Kosovo's average electricity rates of 0.70 Euro/cents per kWh, this would provide an annual value of 980 Euro per year. If exhaust fans are used in conjunction with the implementation of the PV system, these fans will run for approximately 1,500 hours and consume around 7500 kWh/year. This would mean 6,500 kWh of free energy consumption (around 455 Euro/year), which could either be injected back into the grid or used for the Operator's other mechanical needs.

APPENDIX 11 – DETAIL ON COMPUTER MODEL TO DETERMINE COOLING HOURS FOR VENTILATION SUB PACKAGE

Computer modeling was performed to determine the number of "cooling hours" that would be required in the existing single layer polyethylene (PE) greenhouses versus the same greenhouses with different types of ventilation systems. There are three different types of equipment that factor into the cooling hour results: roof ventilation (RV), exhaust fans (EF), and insect screen (IS). Different combinations of these systems were modeled to illustrate the amount of cooling hours needed.

The maximum temperature threshold was set at 27 C for the computer modeling. While plants will survive at much higher temperatures than 27 C and un-ventilated greenhouses often reach temperatures of 45-50 C in summer months, 27 C is an approximate upper limit temperature before these plants will get stressed.

The computer model looked at the following scenarios:

1. Status Quo (SQ): 1000 m^2 greenhouse with single layer PE glazing and sidewall vents opening to a maximum of 1.2 m.
2. SQ + Roof Ventilation (RV): This incorporates a ridge vent or other type of roof opening of equal area to that of the sidewall openings.
3. SQ + Insect Screen (IS): The status quo greenhouse but with the incorporation of the insect screen covering sidewall vents[37] which reduces the natural ventilation process.
4. SQ + IS + RV (RV Scenario): The same as scenario 2 but with insect screen covering the sidewall vents.
5. SQ + IS + RV + Exhaust Fans (EF Scenario): This incorporates exhaust fans in the roof area that will exhaust approximately 67 m^3 per second or approximately the entire volume of air in the greenhouse per minute.

Scenario	SQ	RV	IS	RV Scenario	EF Scenario
Cooling Hours Required	940 hrs	438 hrs	1223 hrs	776 hrs	258 hrs
Average hours per day in suboptimal conditions	10.4	4.9	13.6	8.6	2.9

Approximate total and daily cooling hours during summer months (June, July, August)

[37] Assumes a 50% ventilation reduction from the insect screen. The exact characteristics of the insect screen that is locally available are unknown.

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