Customer request analysis for designing & construction

(Consulting Report)

27th Sep 2023

Pakistan Agriculture Research Council/KOPIA Pakistan Center

This report is the basis report for designing and constructing the most efficient and practical greenhouse within the given budget by reflecting local location conditions and user demands in relation to the construction of a new seed potato multiplication demonstration greenhouse on the site of the Pakistan Agricultural Research Institute located in Islamabad, Pakistan.

Summary

○ The location of the new greenhouse for seed potato multiplication is adjusted in harmony with the existing primary and secondary greenhouses within B16-1 and B16-2 blocks in the PARC site at 33 north latitude, 73 east longitude, and 500M above sea level.

○ The smart greenhouse recommends a venlo-type structure with a double roof in a span connected to two 8m wide buildings because it improves the light environment by minimizing the shade area in the greenhouse.

○ In this type of greenhouse, the middle and auxiliary bracing of the inter-column truss structure are installed to reinforce the structure.

○ The greenhouse is designed so that the night temperature in winter was over 10℃, and the daytime temperature in summer was less than 30℃.

○ To this end, PO-based vinyl with thick and invincible properties is first employed as a thermal covering, and a thermal curtain and a light-shielding curtain are double used in the horizontal direction of the greenhouse, and also a thermal curtain is employed in the vertical direction.

○ The remained heat load is covered using a radiant heat electric heater. The total heat load might be about 150,000 kcal/hr per as a max.

○ Ventilation in the greenhouse is designed to be opened and closed using Rack & Pinion at the front end of the ceiling, and the side windows are designed to be operated flexibly in four seasons. In addition, internal circulation fans and exhaust fans will be used to induce internal air circulation and forced ventilation.

○ In addition to ventilation, a shading agent is applied to the outside of the vinyl coating to reduce the amount of light energy entering the room (usually around 30%), thereby reducing the amount of cooling load, and using an indoor horizontal shading film (usually around 80%).

○ After that, cooling is cooled using a Fog generator and an exhaust fan at the bottom of each growing beds, and it is expected that the indoor

temperature can be controlled at a level of about 25~27℃. When potatoes will be grown, an additional 3 degrees temperature drop is expected due to the evapotranspiration of the crops.

○ Reliable controller is recommended to implement an optimal greenhouse environment, and a control logic of temperature and humidity should be employed. All data and control situations must be stored and transmitted in real time, and the alarm function must be activated quickly in case of control failure.

○ A cycling aeroponic system is formed by properly mixing a certain amount of waste liquid (1/3 level) and a newly prepared culture medium (2/3 level) along with an automatic preparation function.

1. Condition of a Location

1.1 Longitude from North Pole

○ The location where the new greenhouse will be built is at 33°40'17" north latitude, an area with mild winters and a lot of solar radiation in the summer.

1.2 Latitude from the East

○ The location where the new greenhouse will be built is at 73°07'19" east longitude, an open area with no mountains nearby and an area that is almost unaffected by sunrise and sunset.

1.3 Altitude Above Sea Level

○ The location where the new greenhouse will be built is approximately 503 m above sea level, making it an advantageous area for growing crops in the summer.

1.4 Ground Slope

○ The new greenhouse will be located next to the NIGAB laboratory and on a site about 12.6 ac (1.5 ha) in land numbers B15, B16-1, and B16-2.

○ This land is 250m long and has a slight slope of about 3m (1.2% slope).

○ It is considered suitable for installing a free-fall rainwater reservoir on the western edge of the land using this slope



<Figure1> Planned Site of KOPIA Smart Farm Complex

2. Layout of Existing Greenhouse and New Greenhouse

2.1 Existing Greenhouse

2.1.1 Single-type Greenhouse

○ Greenhouse layout : Length 42m x width 8 m = 220 m^2

○ Greenhouse quantity : 2 greenhouses

○ Cultivation facility : 4 aeroponic system bed

○ Internal facility : Exhaust fan, circulated nutrient separate supplier

○ Covering material : 1 layer of plastic cover, 2 layers of insulation cover

2.1.2 Venlo-type greenhouse

○ Greenhouse layout : Length 52m x width 16 m = 832 m^2

○ Greenhouse quantity : 1 greenhouses

○ Cultivation facility : 16 aeroponic system bed

○ Internal facility : Exhaust fan, circulation fan, circulated nutrient separate supplier

○ Covering material : 1 layer of plastic cover, horizontal insulation curtain, vertical insulation curtain, fan heater

2.1.3 Screenhouse

○ Screenhouse layout : Length 100m x width 8 m = 800 m^2

○ Screenhouse quantity : 3 screenhouses

○ Cultivation system : Soil cultivation

○ Internal facility : Liquid supply

○ Covering material : White mesh 1 layer



<Figure 2> The Whole View of 1st, 2nd Greenhouse



<Figure 3> The Whole View of 2nd Screenhouse

2.2 New Greenhouse

2.2.1 Venlo-type Greenhouse

○ Greenhouse layout : Length 50m x width 18 m = 900 m^2

○ Greenhouse quantity : 2 greenhouses

○ Cultivation system : 16 aeroponic system bed

○ Internal facility : Exhaust fan, circulation Fan, circulated nutrient separate supplier

○ Covering material : 1 layer of plastic cover, horizontal insulation curtain, vertical insulation curtain, electricity heater

2.2.2 Screenhouse

○ Screenhouse layout : Length 100m x width 8 m = 800 m^2

○ Screenhouse quantity : 32 screenhouses (8 units, 1 unit consists of 4 linked screenhouses)

○ Cultivation system : Soil cultivation (6 ridges / screenhouse, high ridge & plastic mulching cultivation)

○ Internal facility : Fertigation system(venturi method A,B solution liquid preparation)

○ Covering material : White mesh 1 layer (0.16 x 0.16 mm mesh)

2.3 Infrastructure (Further Additional Construction)

○ Reservoir : Length 50m x width 2 m x depth 1m = 100 m^2 (100tons)

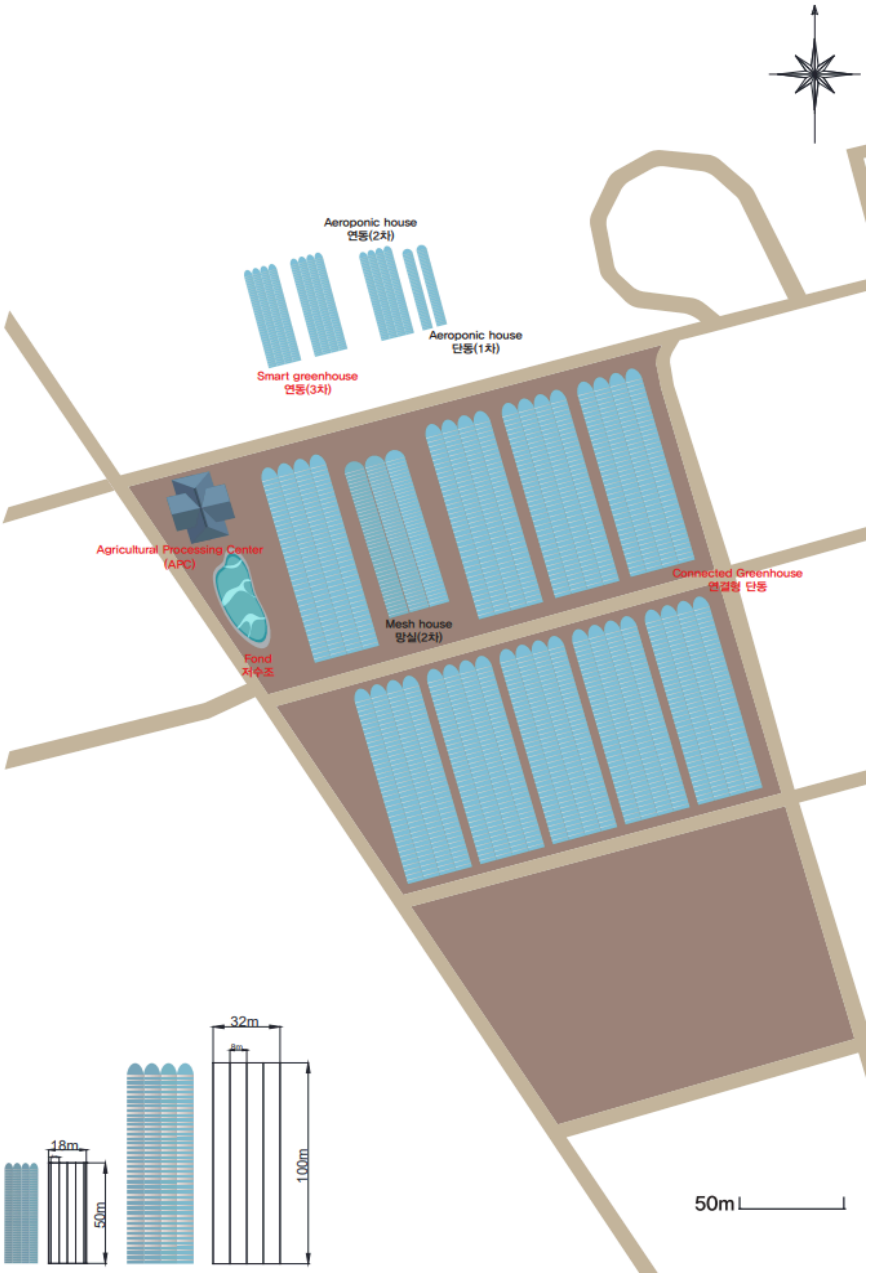
○ Electricity : For venlo-type greenhouse 80 kw x 2 greenhouses + for screenhouse = 300 kw (surgy way)

○ Solar electricity generation and recharge : Length 100m x width 8 m = 800 m^2

(100KW production, 80kw electricity storage, net mattering)

○ Fence for security : About 1000 m x height 2.5 m

○ Agricultural Processing Center (APC) : Processing, cold storage



<Figure 4> Facility Layout in the Seed Potato Multiplication Smart Farm Complex

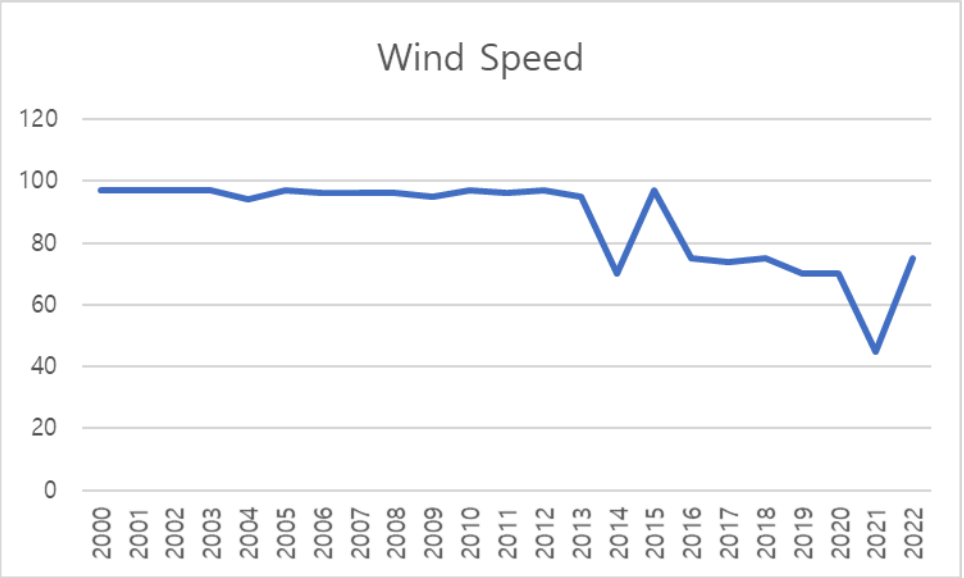
3. Type of Greenhouse

3.1 Construction of Venlo-type Greenhouse

○ Venlo-type plastic greenhouse : Span 8 m x 2 linked greenhouse x side height 4.5m x length 50m

○ Middle beam : Truss structure and bracing

○ Characteristic : Wind load 30m/sec (108km/h)



<Figure 5> Maximum Wind Speed Trend in Smart Farm Complex for the Past 20 Years (2000~2022; NASA)

○ Open & close method of vertex window : Rack & pinion way on the top site

○ 1 layer of plastic covering for the vertex window, 2 layers of horizontal curtain (1 for insulation and 1 for light-shading)

○ 1 layer of windproof wall for both side windows (1m slope structure from the greenhouse column) and 1 layer of vertical insulation curtain

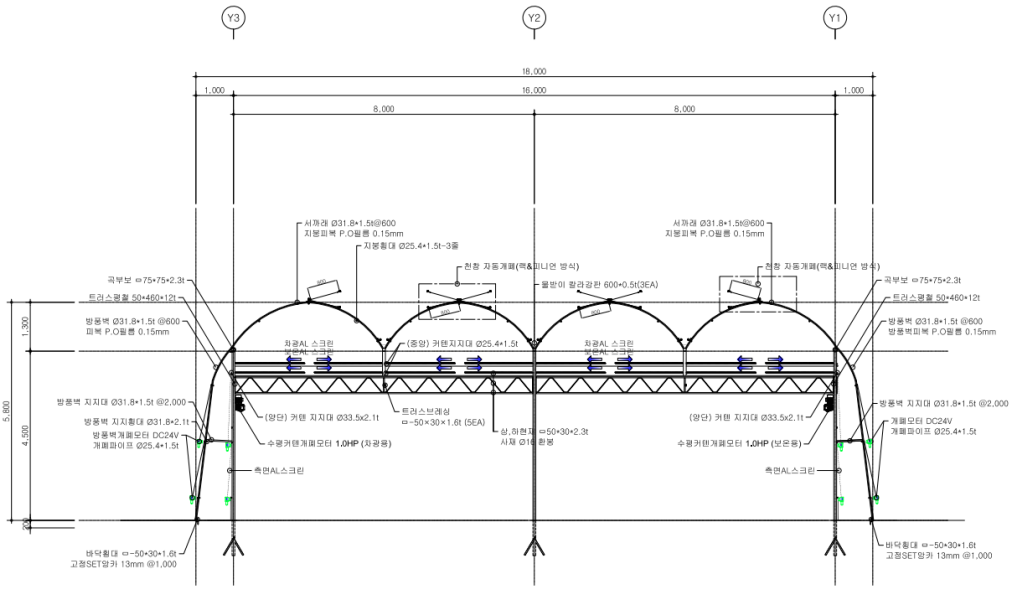
○ Internal circulation fans : 4 fans(60W)/greenhouse x 2 rows = 8 fans(320W), vertical reflux type circulation fans

○ Exhaust fan : 4 fans(200W) x front & backside = 8 fans(1,600W), hydraulic exhaust fans

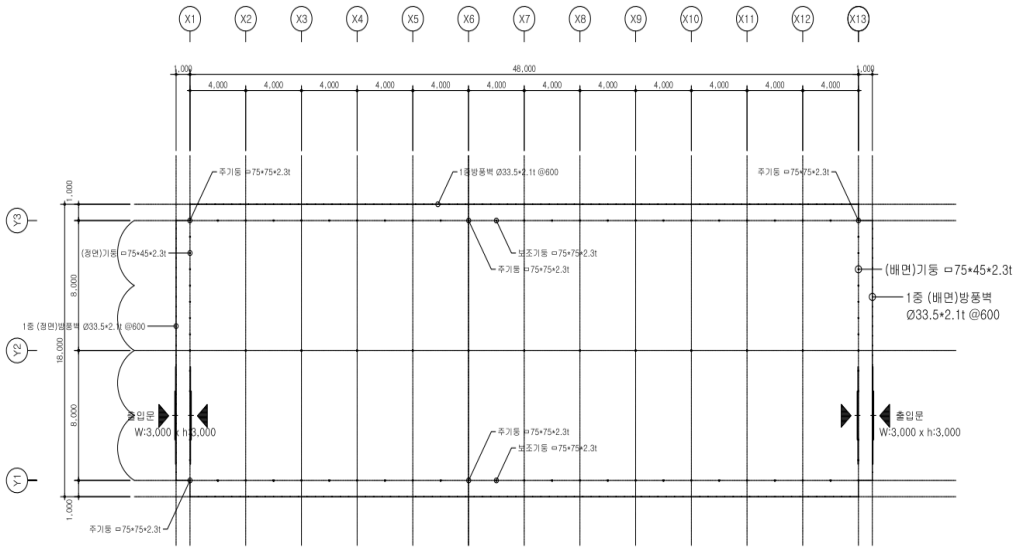
○ Heating facility : 80KW power receiving facility, radiant heat type

heating pipe in 4 rows

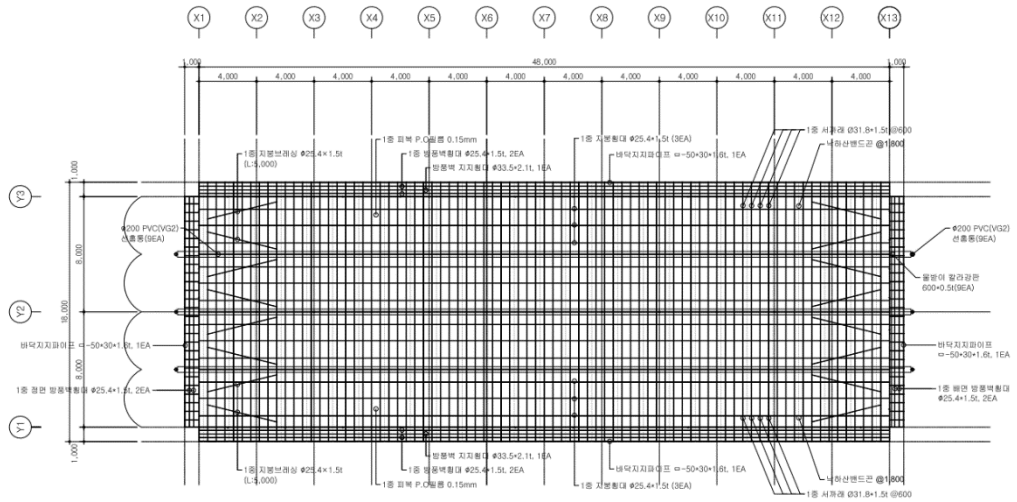
○ Fog generator : Installation of fog (200um level) at a height of 50cm at intervals of 2m



<Figure 6> Main Front View of Venlo-type Greenhouse



<Figure 7> Cross-Sectional View of Venlo-type Greenhouse Ground Floor



<Figure 8> Cross-Sectional View of Venlo-type Greenhouse Roof

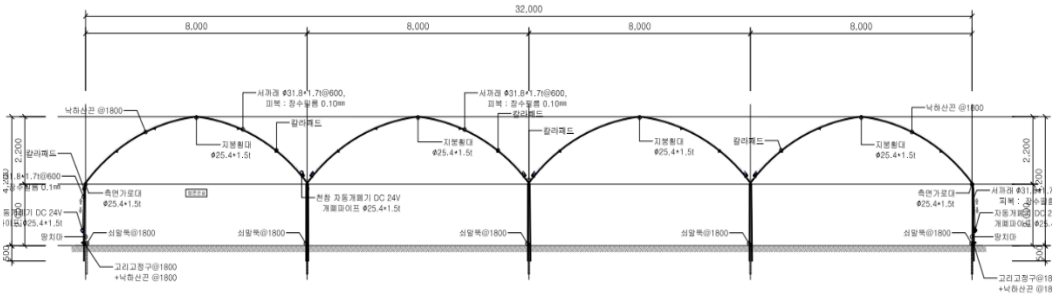
3.2 The Structure of a Single-type Greenhouse

○ Single greenhouse type : Width 8 m x length 100 m x side height 2 m x rafter 60 cm

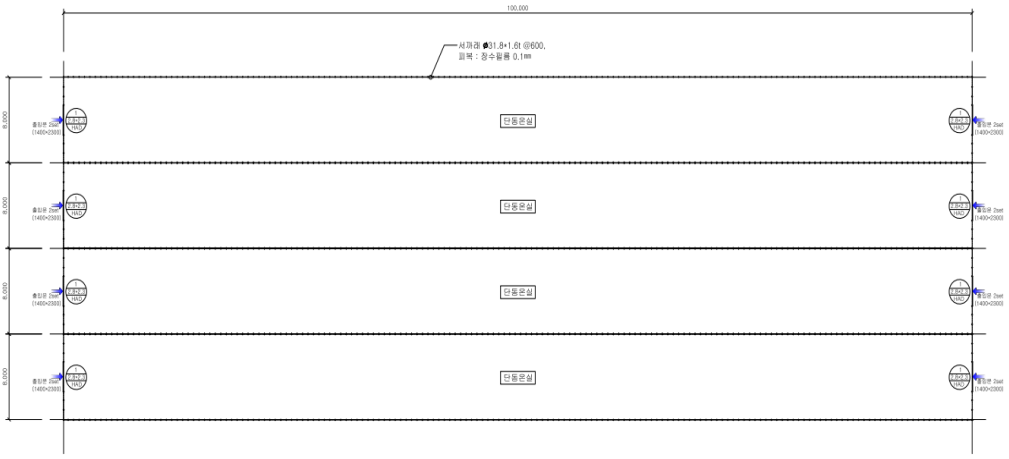
○ Venlo-type greenhouse by single greenhouse : Link 4 of each single greenhouse and set up drainage material

○ Covering material : 0.16 x 0.16 mm white mesh, middle greenhouse fixed in 4 rows with Pad & Spring, side greenhouses fixed in 5 rows

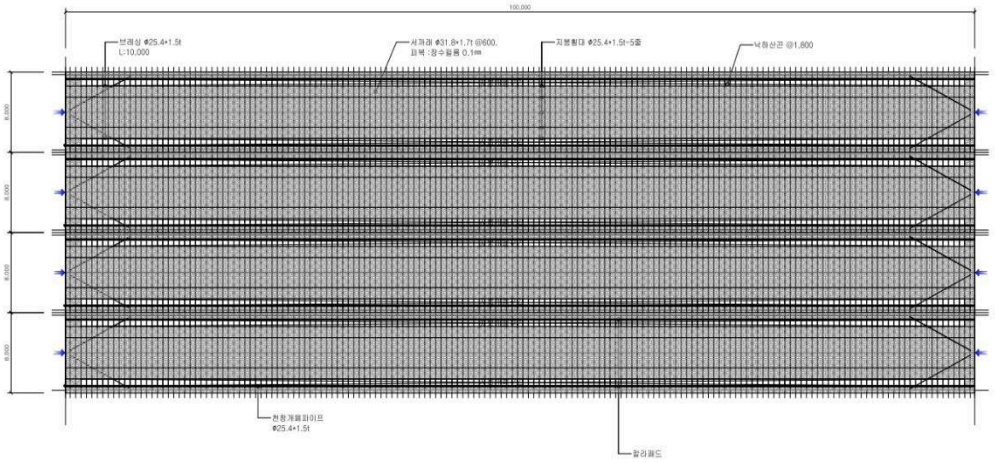
○ Wind load : Designed based on instantaneous wind speed 30m/s



<Figure 9> Main Front View of Single Type Greenhouse



<Figure 10> Cross-Sectional View of Single Type Greenhouse Ground Floor



<Figure 11> Cross-Sectional View of Single Type Greenhouse Roof

4. Insulation and Heating

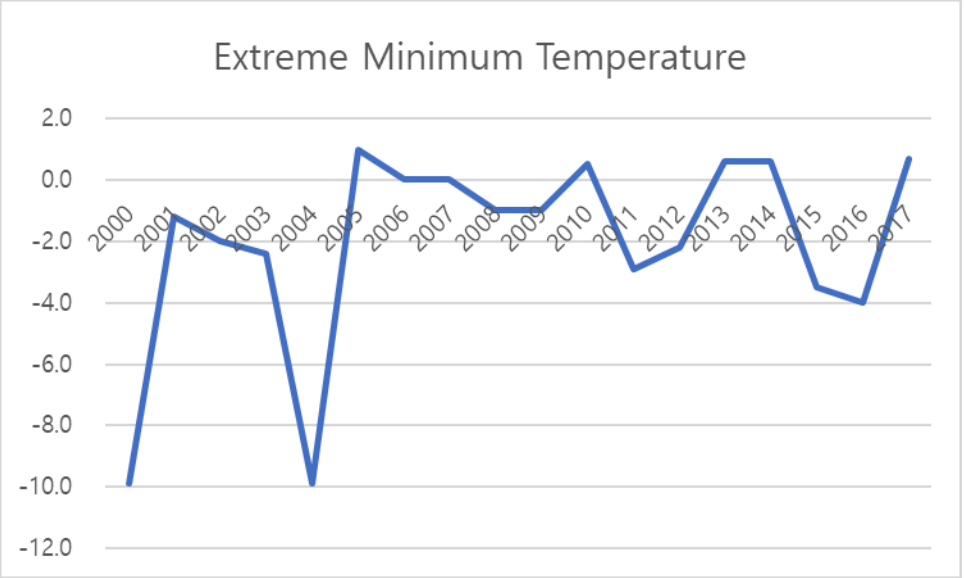
4.1 Extreme Minimum Temperature Through Last 20 Years

○ Table 1 shows the weather data for the past 20 years where the greenhouse will be located

<Table 1> Annual Climate Values of KOPIA Greenhouses Site in NARC

Year	Ave. Temp.	Max. Temp.	Min. Temp.	Relative Hum.	Wind Speed
	℃	℃	℃	%	km/h
2000	23.5	43.8	3.9	54.2	97
2001	22.0	30.1	9.2	57.0	97
2002	22.3	50.6	8.9	55.7	97
2003	23.2	44.4	-4.6	62.1	97
2004	22.4	41.1	0.0	63.6	94
2005	21.1	46.6	-9.9	62.0	97
2006	22.5	43.0	-1.2	61.8	96
2007	22.2	46.0	-2.0	60.5	96
2008	21.9	40.0	-2.4	60.6	96
2009	22.2	45.5	-9.9	56.0	95
2010	23.0	44.5	1.0	57.6	97
2011	22.6	42.5	0.0	61.0	96
2012	22.3	45.0	0.0	56.3	97
2013	22.2	45.5	-1.0	62.5	95
2014	21.7	43.5	-1.0	61.8	70
2015	21.5	43.0	0.5	63.5	97
2016	22.9	43.0	-2.9	60.4	75
2017	22.8	46.0	-2.2	59.4	74
2018	22.4	44.0	0.6	58.6	75
2019	16.9	38.2	0.6	69.1	70
2020	21.7	42.1	-3.5	61.4	70
2021	22.3	44.3	-4.0	54.7	45
2022	23.0	42.7	0.7	54.6	75

○ Rerise cycle based on 10-years : -5.0 ℃ (-5.0 ℃ based on return period of 10 years)



<Figure 12> The Extreme Minimum Temperature Distribution of Smart Farm Complex over the Past 20 Years (2000~2022; NASA)

4.2 Required Inner Temperature

○ Seed potato G1-stage greenhouse

○ Inner temperature recommendation: At least over 12 ℃

4.3 Facilities Surface Area

○ Floor area : 800m^2 (250py)

○ Side height of Venlo-type greenhouse : 6m

○ Surface area excluding floor : 3,064m^2

4.4 Covering Materials

○ Ingredient : Polyolefin (External cover: PO film), Thickness : 0.15 mm

○ Specification : Non-droplets

○ Warranty : 5 years

4.5 Insulation method

○ Upper part of horizontal curtain(energy curtain) : Aluminum vapor deposition film heat retention 80%, light shading rate 40%

○ Lower part of horizontal curtain(Light-shading) : Aluminum vapor deposition film heat retention 40%, light shading rate 60%

○ Vertical curtain (energy curtain) : Aluminum vapor deposition film heat retention 80%, light shading rate 40%

4.6 Maximum Heating Load

○ Calculation formula : Q = A x U x (Tin – Tout) x (1 – f)

A : Greenhouse surface area

U : Heating factor(5.3kcal)

Tin : Internal Temperature of greenhouse (10℃)

Tout : External Temperature of greenhouse(refer to the attachment of Islamabad annual temperature)

f : Heat saving rate (60%)

○ Estimated as about 150,000 kcal / h 800m^2

4.7 Calculation of Heating Capacity

○ 230,000 Kcal/h 800m^2 based on 67% electrical energy thermal efficiency

○ 36 KW power consumption based on 6,500 Kcal / 1KW(ignoring mobile power)

4.8 Seasonal Heating Load

○ Assuming heating season from October to February of the following year, based on Islamabad weather data for the past 3 years

○ 36 KW x 12 h x 150 days =64,800 KW

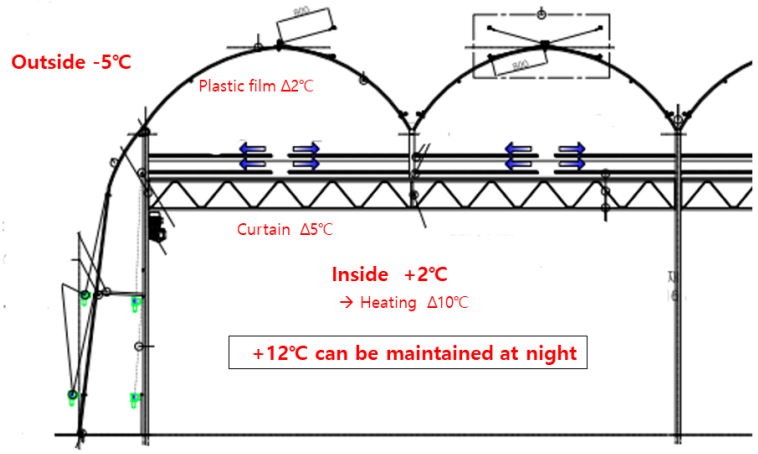
○ Assuming 13 Rupees per 1KW, the estimated cost of heating during the period is 840,000PKR / year

4.9 Heating System

○ Energy source : Electricity(transmission tower or ESS for power storage)

○ Radiant heat type heating element

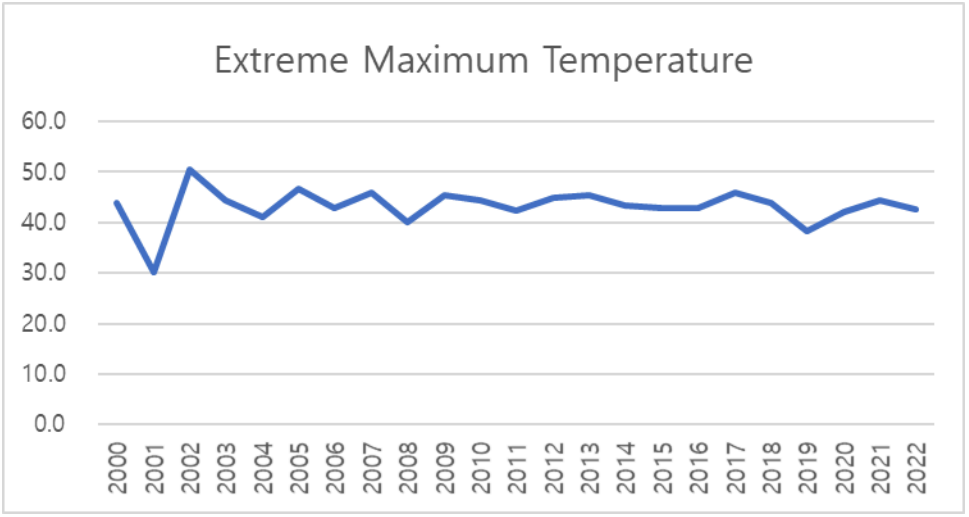
○ Four-row deployment method at 10cm intervals in four directions, north, south, east and west



<Figure 13> Conceptual Diagram of Insulation and Heating

5. Ventilation and Cooling

5.1 Extreme Maximum Temperature Through Last 20 Years



<Figure 14> The Extreme Maximum Temperature distribution of Smart Farm Complex over the Past 20 Years (2000~2022; NASA)

○ Rerise cycle based on 10-years : + 40.0 ℃ (+38.0 ℃ based on return period of 10 years)

5.2 Required Inside Temperature

○ Seed potato G1-stage

○ Inner temperature at least below 25 ℃

5.3 Ventilation Rate

○ Natural ventilation : Width 60cm x length 50m x both sides x 2 greenhouse = 120 m^2 (affected by external wind speed)

○ Exhaust by force: 27cm x 2 hp x both sides x 2-linked greenhouse = 10min / cycle

5.4 Shading Materials

○ Ingredient : Calcium carboxylate

○ Shading : 30% of light-shading

○ Effect : Cooling 5℃

○ Warranty : 120 days

5.5 Shading Method

○ Lower part of horizontal curtain(light-shading curtain) : Aluminum vapor deposition film, heat retention 40%, light shading rate 60%

○ Combined with warming curtain

5.6 Maximum Cooling Load

○ Calculation Formula : Q = A x U x (Tout – Tin) x (1 – f)

A : Greenhouse surface area

U : Turn rate(7.0kcal)

Tout : External temperature of greenhouse(refer to the attachment of Islamabad annual temperature)

Tin : Internal temperature of greenhouse (25℃)

F : Light-shading rate (30%)

○ 450,000 kcal / h 800m^2

5.7 Cooling Method

○ Spray ultra-fine particles(Fog & Fan 200 um) 40L/minute on the bottom 50cm proportion of the cultivation

○ 25KW power consumption based on 6,500kcal per 1KW(ignoring mobile power)

○ Effect : Cooling effect by generating evaporative heat at about 5 ℃

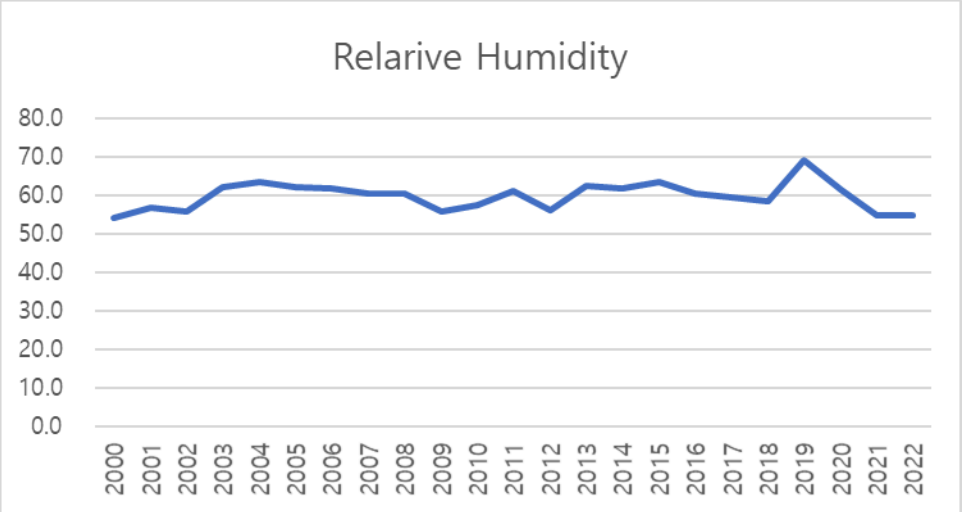
○ During cultivation : Lowering 3℃ separately due to plant transpiration

5.8 Seasonal Cooling Load

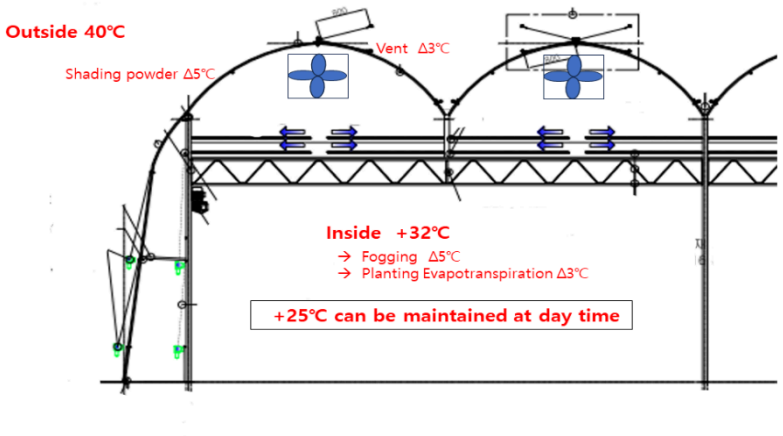
○ Assuming the cooling season is from May to October, based on Islamabad weather data for the past 3 years

○ 25 KW x 12 h x 180 days =54,000 KW

○ Assuming 13 Rupees per 1KW, estimated cost of cooling during the period is 701,700 PKR / year



<Figure 15> Relative Humidity Distribution of the Smart Farm Complex over the Past 20 Years (2000~2022; NASA)



<Figure 16> Conceptual Diagram of Ventilation and Cooling

6. Smart Control System

6.1 Factors for Environment Control

○ Ventilation : Vertex window, Side window, Curtain, Exhaust fan

○ Circulation : Circulating fan

○ Heating : Heater

○ Cooling : Fogging

○ Nutrient solution(Culture Medium) : Preparation, Supply, Return

6.2 Factors for Environmental Data Collection

○ External data : Temperature, Humidity, Light amount, Precipitation, Wind direction, Wind Speed

○ Internal data : Temperature, Humidity, CO_2, Light amount

○ Nutrient solution data : EC, pH

6.3 Control Decision

○ Nutrient solution supply scheduled control by using integrated solar radiation

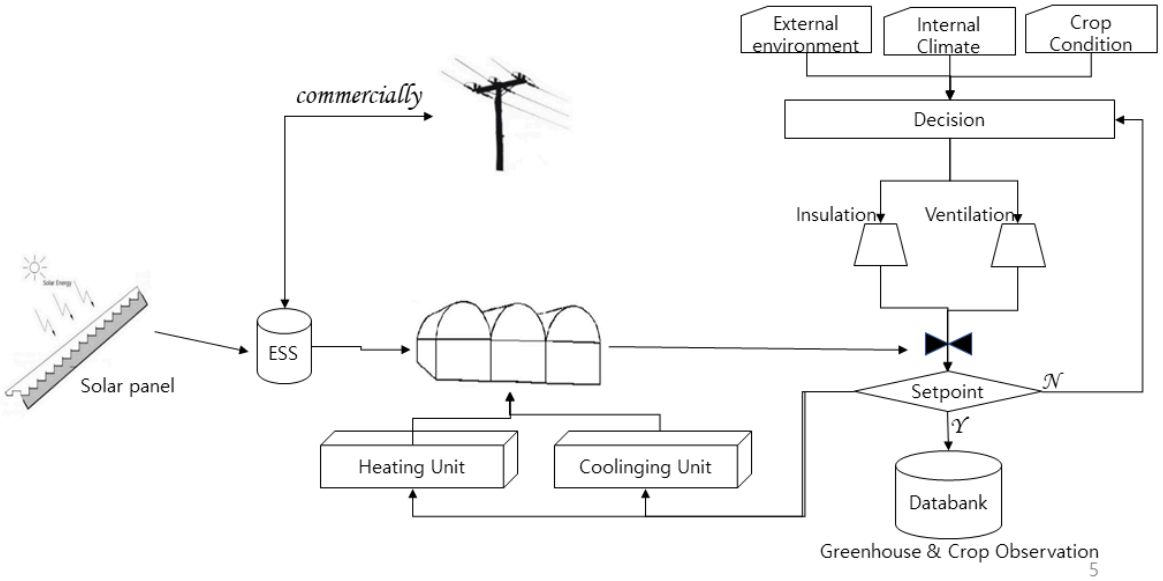
○ Circulating fan : Inducing 24-hour air flow

○ Ventilation window, curtain : proportional control method by vent setpoint

○ Temperature and humidity complex control to keep Absolute Humidity(AH) at the level of 50 ~ 55 % during daytime, 80~85% during night time

○ Setpoint change function by remote control

○ Establishing a weekly internal environmental management strategy and implementing it



<Figure 17> Smart Farm Control System Configuration

7. Aeroponic System

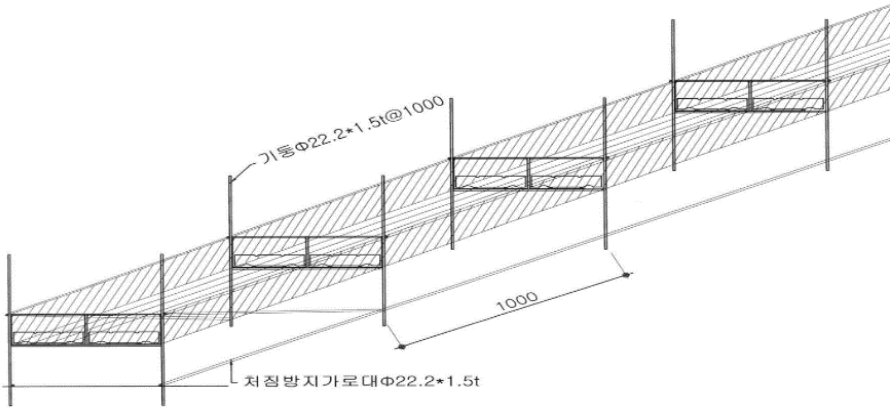
7.1 Arrangement of Water Tanks

. Size of Individual Water Tanks: 10 m

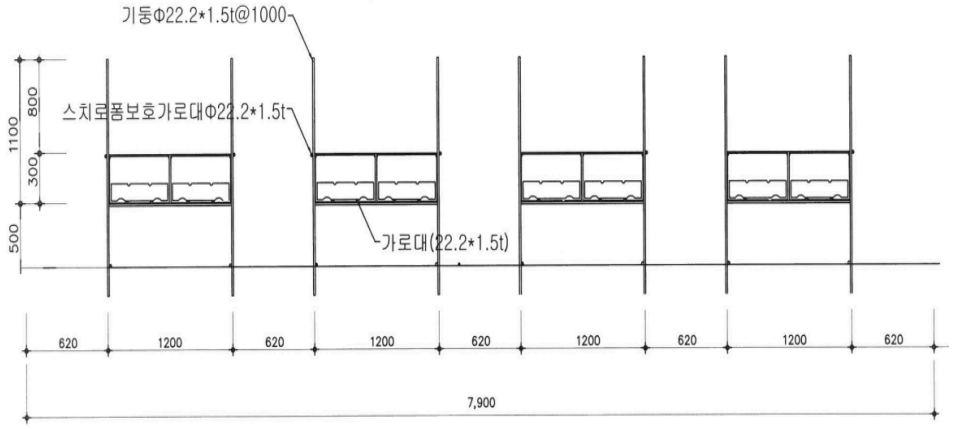
. Number of Water Tanks per Greenhouse: 4 columns x 4 sector = 16ea

. Height of Cultivation Water Tanks: 30 cm

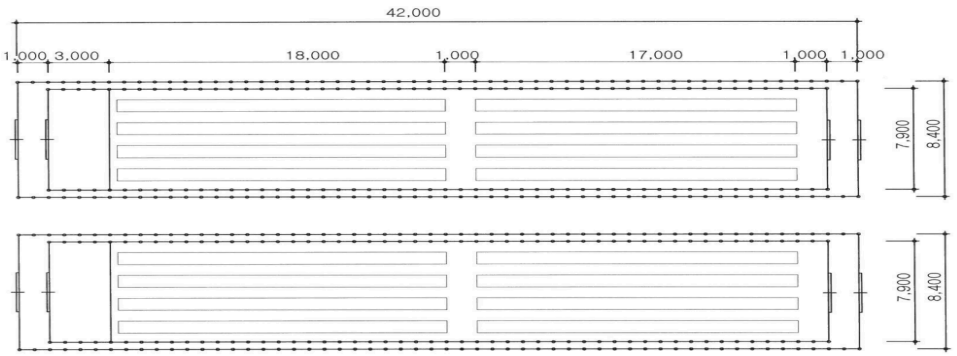
. Slope of Cultivation Water Tanks: 3%



<Fig.18> Aerial View of Aeroponic Beds



<Fig.19> Detailed View of Aeroponic Beds



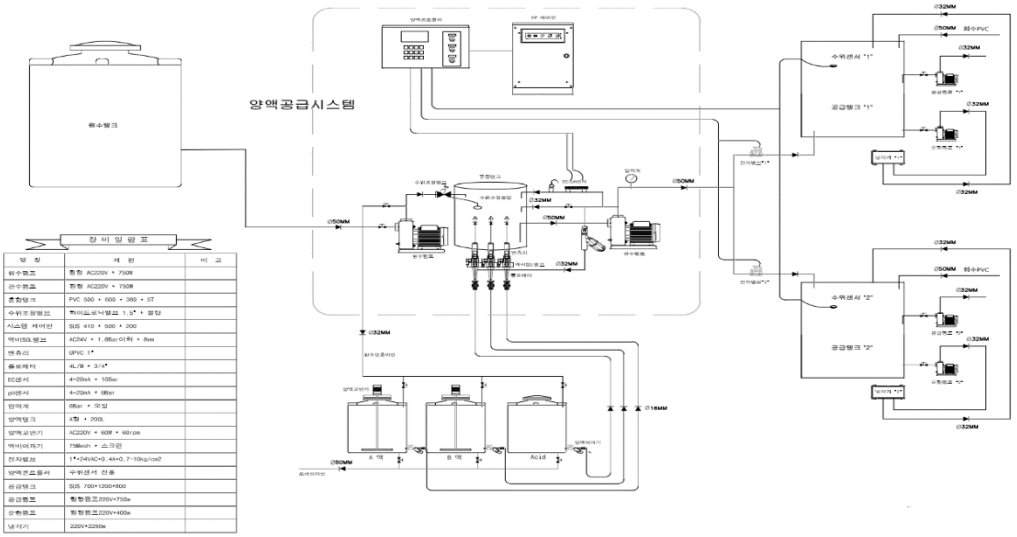
<Fig.20> Aeroponic Beds Plan

7.2 Nutrient Supply and Drainage Management System

○ Nutrient supply: Time control and solar radiation control options

○ Nutrient solution Mixing: Mix the nutrient solution using a metering pump from two tanks (Tank A and B), each containing 1 ton of concentrate diluted to 100 times the volume

○ Drainage handling: Drainage is located near the nutrient supply tank, and the system is designed to maintain a mixing ratio of 7:3 between the nutrient solution and drainage.



<Fig.21> Overview of Nutrient Solution Preparation System

arate): Sorting facility, Cold storage, Cleaning room, etc.