

# How High is High Enough? Assessing Financial Risk for Vertical Farms Using Imprecise Probabilities

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## Supplementary Data

Supplementary data is separated into two sections, UK and Japanese case study. The data for each study includes full-tables for farm characteristics, capital costs and operational costs. These are included within a model inputs table that were the direct inputs to the financial risk model. The UK case study also includes a suggested interventions subsection that notes the modifications to inputs.

### 1. UK Case study

The UK case study data is contained within a spreadsheet called ‘Current\_Financial\_Model\_FU\_v1.xlsx’ in the mode library which is executed by the model script: main\_pba\_UK\_Farm.py. The pilot and full-scale production are considered by the model and are therefore detailed within the tables for this section.

#### 1.1 Farm Characteristics

UK Farm characteristics are detailed in Table S7.

**Table S7.** Farm characteristics for the pilot and full-scale UK farm

Characteristic	Pilot production (year 1)	Full production (year 2)	Unit
<b>Real Estate</b>			
Facility size	220	220	m2
Facility height	3	3	m
Space utilisation	27	27	%
Growing space	59	119	m2
<b>Systems</b>			
Growing system	ZipGrow Racks, 8' towers	ZipGrow Racks, 8' towers	
Grow levels	30 towers per rack	30 towers per rack	
Number. of racks	8	16	
Stacked growing area	196	392	m2
Number of lights	128	256	
Lighting system	Intravision Spectra LED Blade Single Sided	Intravision Spectra Blade Single Sided	
Light wattage	100	100	W
Energy price	0.073-0.108	0.073-0.108	£/kWh
Water price	0.002	0.002	£/L

Annual electrical consumption	127,170	224,255	kWh
<b>Labour</b>			
Number of direct labourers	2	3	people
Number of indirect staff	1.5	3	people
Direct labour hours per week	20	20	hours per person
Direct hourly cost	9.50	9.50	£/hour
<b>Crop: Lettuce</b>			
Annual yield	3,900-5,500	8,800-10,800	kg/year
Harvest weight	0.1	0.1	kg
Photoperiod	16	16	hours
Product 1 weight	0.3	0.3	kg
Customer segmentation	85	15	-
Unit prices	7.50	3	-
Packaging cost	1.50	0.85	£/unit
<b>Attributes*</b>			
Business model	Hybrid	Wholesale	
Grower experience	Medium	High	
Automation level	None	Medium	
Climate control level	Medium	High	
Lighting control level	Medium	High	
Nutrient control level	Medium	High	
CO2 enrichment	No	Yes	
Biosecurity level	Medium	High	

\*Definition of input is detailed in method statement in the supplementary material

## 1.2 Capital Costs

The capital costs for both the pilot and scaled-up production are detailed in Table S8. Total costs are reflective of Table 5 in the manuscript.

**Table S8.** Pilot and full-scale farm data for UK case study

Capital costs	Pilot farm (year 1)	Full-scale farm (year 2)	Total	Unit
<b>Construction</b>				
Structure	0	0	0	£
Finishing	350	3,500	3,850	£
Appliance	750	3,500	4,250	£
Management costs	3,600	5,429	9,029	£
Electrical infrastructure	5,520	2,500	8,020	£
Real estate	0	0	0	£
Total construction costs	10,220	14,929	25,149	£
<b>Systems</b>				
Growing system cost	28,296	32,775	55,071	£
Lighting system cost	37,440	49,725	87,165	£
HVAC system cost	700	2,000	2,700	£
Miscellaneous cost	9,548	2,000	9,548	£
Total equipment cost	67,984	86,500	154,484	£
Total capital costs	78,204	101,429	179,633	£

### 1.3 Operational characteristics and costs

The operational characteristics and costs are detailed in Table S9. These values are reflective of Table 6 in the main manuscript.

**Table S9.** Operational characteristics and costs

	Pilot VF	Full-scale VF	Unit
Grants and other funding	89,000	128,000	£
Operational Expenditure			
Rent	0	0	£/year
Staff costs (non-direct labour)	60,750	83,214	£/year
Insurance	1,551	1,551	£/year
Distribution	27,860	31,594	£/year
Other costs	729	1346-5,980	£/year
Total OpEx	75,210	108,998	£/year
Cost of goods sold			
Direct labour staff	2	3	No. of people
Wages	19,758	29,637	£/year
Growing media	1,255-1,752	2,509,-3503	£/year
Seeds and nutrients	3,628-7674	7,255-15,344	£/year
Total electricity cost	9,340-13,731	15,929-23,416	£/year
Water consumption	7358-10272	14713-20539	L
Water price	0.002	0.002	£/L
Water cost	30-190	60-381	£/year
Total COGS	53,787-70,839	78,371-104,362	£/year
Other fixed costs			
Depreciation and Amortisation	10,208	20,417	£/year
Tax rate	0	0	%
Working capital	197,000	63,409	£
Loan amount	158,000	-	£
Loan tenure	7	5	years
Loan interest	5	5	% per year

### 1.4 Model inputs

The inputs to the model are detailed in Table S10 and can be found within the model library as “Current\_Financial\_Model\_FU\_v1.xlsx” on the inputs sheet. As the spreadsheet does not propagate uncertainty until processed by main\_pba\_UK.py, several lines of code manually input uncertainty:

```
scenario.electricity_price = minmaxmean(0.0734, 0.1079, 0.09065)
```

```
light_improvement = minmaxmean(0.5, 0.8, 0.65)
```

```
water_use = pba.mmms(1325, 8325, 3730, 2039)
```

**Table S10.** Model inputs from Current\_Financial\_Model\_FU\_v1.xlsx

#	Code	Input	Unit
1	start_date	01/02/2021	Date
2	facility_size_pilot	220	currency
3	percent_production_area_pilot	0.27	m <sup>2</sup>
4	growing_levels_pilot	1	%

5	weight_unit	kg	%
6	growing_area_multplier	2	# of levels
7	no_lights_pilot	128	Weight unit
8	packaging_cost_pilot	£1.50	Multiplier
9	packaging_cost_full	£0.85	# of lights
10	other_costs_pilot	2.0%	£
11	farm_type	Basement	£
12	business_model	Hybrid	%
13	grower_exp	Medium	-
14	automation_level	Low	-
15	climate_control	Medium	-
16	lighting_control	Medium	-
17	nutrient_control	Medium	-
18	system_type	ZipRack	-
19	system_quantity	8	-
20	light_system	Intravision Spectra Blade Single Sided - J	-
21	growing_media	Rockwool	# of racks
22	ceiling_height	4	-
23	insulation_level	High	-
24	roof_type	Flat roof	Metres
25	co2_enrichment	No	-
26	structure_type	N/A	-
27	water_price	£0.002	-
28	electricity_price	£0.07	-
29	labour_improvement	5%	£
30	percentage_renewable_energy	0%	£
31	biosecurity_level	Medium	%/year
32	loan_amount	£158,000.00	%
33	tax_rate	0%	-
34	loan_interest	5%	£
35	loan_tenure	7	%
36	loan_type	Standard	%
37	crop_typ1	Lettuce (Farm Urban Mix)	Years
38	crop1_percent	100%	Type
39	crop1_system	Drip Tower	Crop type
40	crop1_harvest_weight	0.1	% of system space
41	crop1_product_weight	0.3	System type
42	crop1_customer_percent	85%	Kg
43	crop1_price1	£7.50	Kg
44	crop1_price2	£3.00	%
45	crop_typ2	Lettuce (Farm Urban Mix)	£
46	crop2_percent	0.0%	£
47	crop2_system	Drip Tower	Crop type
48	crop2_harvest_weight	0.1	% of system space
49	crop2_product_weight	0.45	System type
50	crop2_customer_percent	100%	Kg
51	crop2_price1	£9.50	Kg

52	crop2_price2	£0.00	% of system space
53	crop_typ3	Basil - Genovese	£
54	crop3_percent	0.0%	£
55	crop3_system	Drip Tower	Crop type
56	crop3_harvest_weight	0.075	%
57	crop3_product_weight	0.075	System type
58	crop3_customer_percent	100%	Kg
59	crop3_price1	£1.50	Kg
60	crop3_price2	£0.00	%
61	crop_typ4	None	£
62	crop4_percent	0%	£
63	crop4_system	Drip Tower	Crop type
64	crop4_harvest_weight	0.5	% of system space
65	crop4_product_weight	0.5	System type
66	crop4_customer_percent	0	kg
67	crop4_price1	£7.50	kg
68	crop4_price2	£7.50	%
69	vadded_products_multiplier	1	£
70	education_multiplier	1.15	£
71	tourism_multiplier	1.15	Multiplier per year
72	hospitality_multiplier	1	Multiplier per year
73	vadded_avg_revenue_y1	£ -	Multiplier per year
74	education_avg_revenue_y1	£-	Multiplier per year
75	tourism_avg_revenue_y1	£-	£/month
76	hospitality_avg_revenue_y1	£-	£/month
77	monthly_rent_y1	£-	£/month
78	monthly_distribution_y1	£2,322	£/month
79	monthly_rent_y2	0	£/month
80	monthly_distribution_y2	2632.853131	£/month
81	delivery_msalary	£1,500.00	£/month
82	farmhand_msalary	£1,500.00	£/month
83	parttime_wage	£9.50	£/month
84	ceo_msalary	£2,025.00	£/month
85	hgrower_msalary	£1,560.00	£/month
86	marketer_msalary	£2,025.00	£/month
87	scientist_msalary	£2,025.00	£/month
88	salesperson_msalary	£1,560.00	£/month
89	manager_msalary	£2,025.00	£/month
90	admin_msalary	£624.00	£/month
91	ceo_count_y1	0	£/month
92	hgrower_count_y1	0	£/month
93	marketer_count_y1	0.5	People
94	scientist_count_y1	0	People
95	salesperson_count_y1	0	People
96	manager_count_y1	1	People
97	delivery_count_y1	0	People
98	farmhand_count_y1	0	People
99	admin_count_y1	0	People

100	parttime_count_y1	173.32	People
101	ceo_count_y2	0	People
102	hgrower_count_y2	1	People
103	marketer_count_y2	1	People
104	scientist_count_y2	0	People
105	salesperson_count_y2	0	People
106	manager_count_y2	1	People
107	delivery_count_y2	0	People
108	farmhand_count_y2	0	People
109	admin_count_y2	0	People
110	parttime_count_y2	259.98	People
111	insurance_pilot	129.25	People
112	insurance_full	£129	People
113	capex_pilot	£78,204.00	People
114	capex_full	£179,633.00	£
115	capex_lights	£87,165.00	£
116	capex_facilities	£67,319.00	£
117	capex_building	£8,100.00	£
118	target_productivity_space	90	kg/m <sup>2</sup>
119	target_productivity_energy	0.07	kg/kWh
120	target_productivity_labour	6	kg/man-hour
121	target_productivity_water	0.5	kg/L
122	target_productivity_nutrients	500	kg/kg
123	target_productivity_volume	130	kg/m <sup>3</sup>
124	target_productivity_plants	800	No. of plants per m <sup>2</sup>
125	target_productivity_CO2_emit	500	kg/kg
126	target_productivity_CO2_miti	50000	kg/kg
127	target_productivity_CO2_net	-1000	kg/kg
128	Integrated pest management	No	Yes/No
129	pest_detection	No	Yes/No
130	electrical_backup	No	Yes/No
131	currency	GBP	Currency
132	percent_production_area_full	27%	%
133	energy_type	Average UK energy mix	-
134	grants_rev_y0	89000	£
135	grants_rev_y1	128000	£
136	grants_rev_y2	0	£
137	grants_rev_y3	0	£
138	grants_rev_y4	0	£
139	grants_rev_y5	0	£
140	grants_rev_y6	0	£
141	grants_rev_y7	0	£
142	grants_rev_y8	0	£
143	grants_rev_y9	0	£
144	grants_rev_y10	0	£
145	grants_rev_y11	0	£
146	daily_energy_consumption	102.652383	kWh
147	other_costs_full	0.02	kWh

1.5 Results

Full result tables including probability bounds can be found in the model folder (<https://github.com/GaiaKnowledge/VerticalFarming>) as results\_UK.xlsx. The graphs can be generated by executing the script 'main\_pba\_UK\_Farm.py' Graphs for additional metrics not found in the main manuscript are shown in Figures S3-S11.

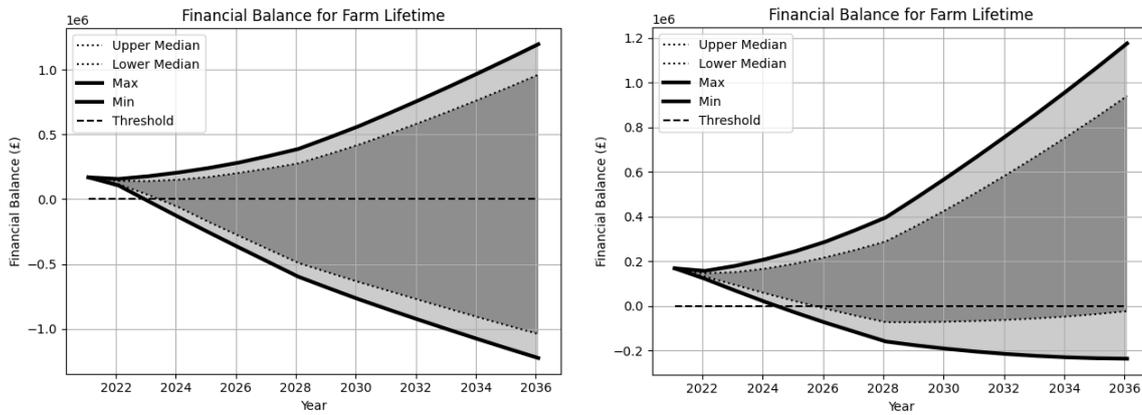


Figure S3. UK vertical farm financial balance with risk and opportunities (on the left) and without risk and opportunities (on the right).

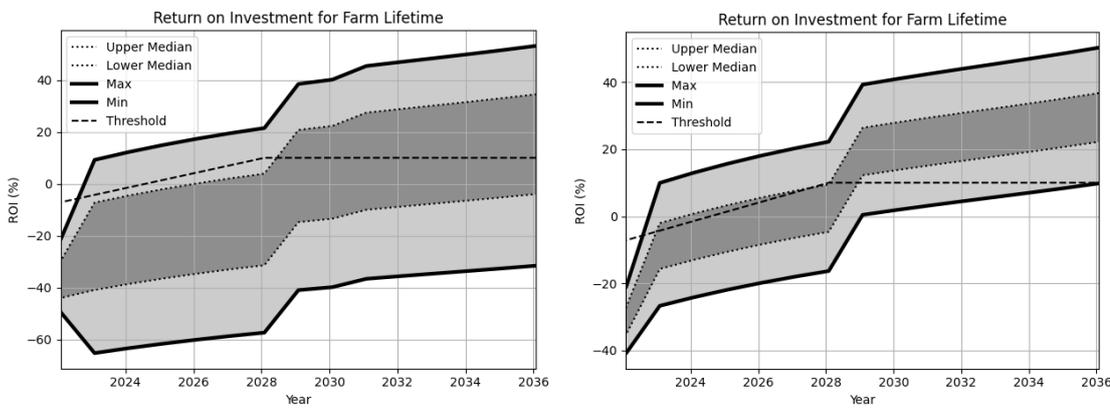


Figure S4. UK vertical farm return on investment with risk and opportunities (on the left) and without risk and opportunities (on the right).

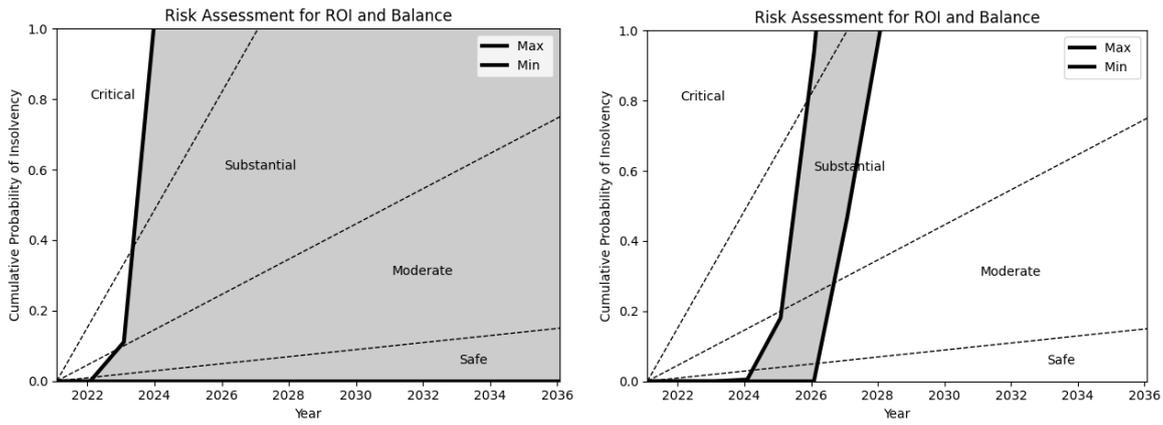


Figure S5. UK vertical farm risk profile with risk and opportunities (on the left) and without risk and opportunities (on the right).

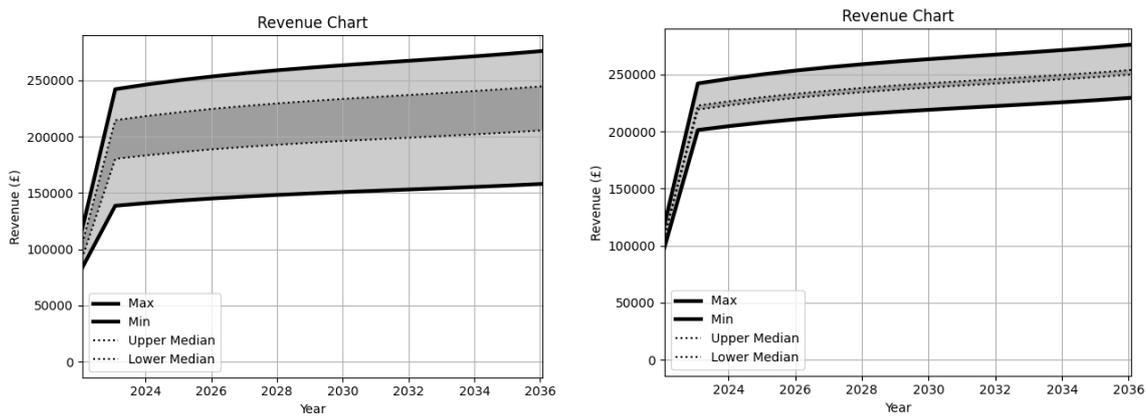


Figure S6. UK vertical farm revenue with risk and opportunities (on the left) and without risk and opportunities (on the right).

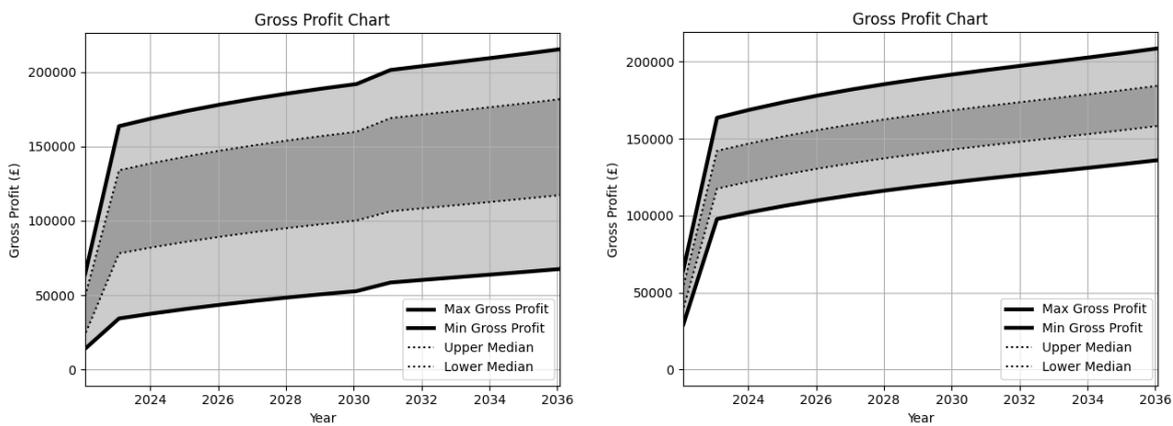


Figure S7. UK vertical farm gross profit with risk and opportunities (on the left) and without risk and opportunities (on the right).

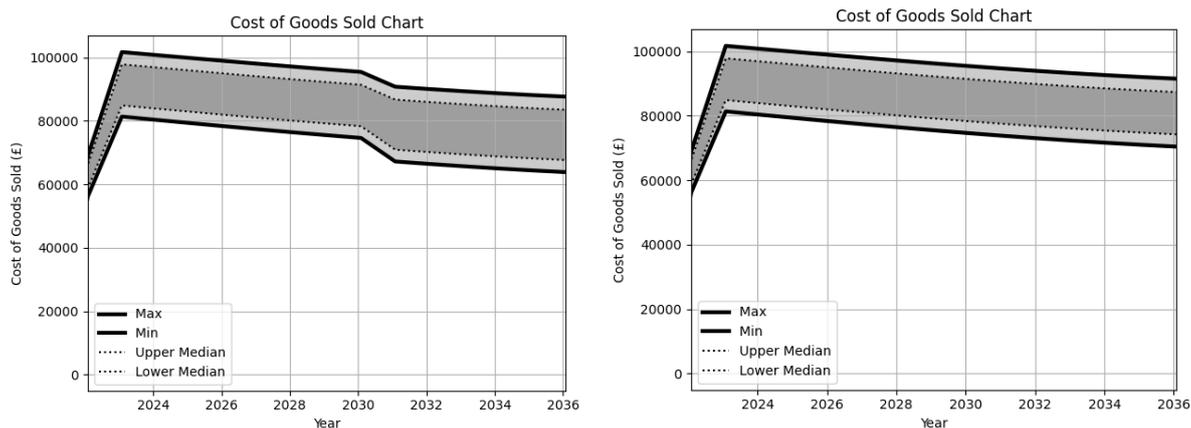


Figure S8. UK vertical farm cost of goods sold with risk and opportunities (on the left) and without risk and opportunities (on the right).

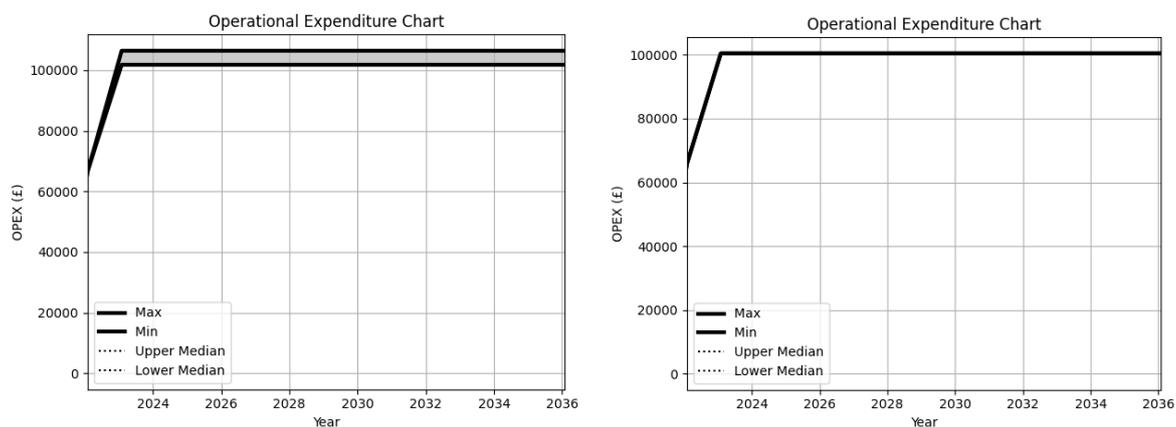


Figure S9. UK vertical farm operational expenditure with risk and opportunities (on the left) and without risk and opportunities (on the right).

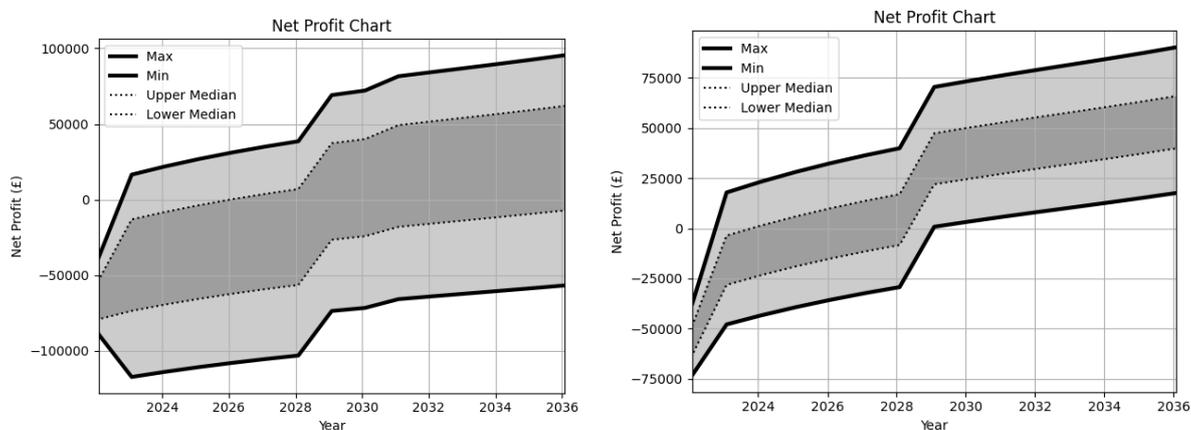
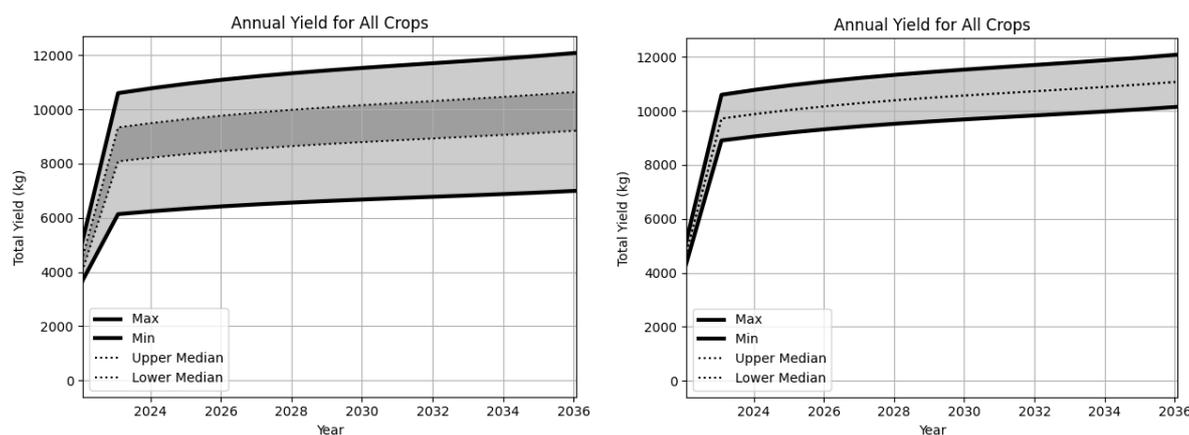


Figure S10. UK vertical farm net profit with risk and opportunities (on the left) and without risk and opportunities (on the right).



**Figure S11.** UK vertical farm annual yield with risk and opportunities (on the left) and without risk and opportunities (on the right).

1.6 Suggested interventions

The suggested interventions in Section 5.3 of the article are manually implemented to the model (<https://github.com/Gai-aKnowledge/VerticalFarming>) within the code (Lines 146 to 164) of 'main\_pba\_UK\_Farm\_interventions.py'. The changes made are detailed in Table S11. The results for these changes can be found in the same folder as 'results\_UK\_post.xlsx'.

**Table S11.** Interventions made to the UK farm.

Intervention	Input change	Result
Tailor nutrient solution to lettuce	Nutrient control: <i>medium to high</i>	Improved yield and produce quality
Provide carbon dioxide enrichment	CO2 enrichment: <i>no to yes</i>	Improved yield and produce quality
Improve climate control through HVAC system	Climate control: <i>low to medium</i> . Additional 5-20% energy costs	Improved yield and reduced risk of pathogens and pests
Alter packaging solution with digital information	Reduce cost from £1.00 to £0.70 per unit	Reduced unit costs
Adopt robust biosecurity protocol requiring more regular cleaning of the systems	Biosecurity control: <i>medium to high</i>	Reduced risk of pathogen outbreaks
Use efficient distribution channels by focusing on bulk customers	Distribution unit costs are reduced by 50%	Reduced unit costs
Acquire further capital funding for proposed improvements	£100,000 grant in year 2	£20,000-30,000 additional capex
Utilise load shifting to optimise electricity prices [1]	From (£0.073, 0.108) to (£0.073, 0.085)	Reduced unit costs
Introduce tours of the farm with a dedicated tour guide	£2000 revenue per month (10% increase/ year) and tour guide salary budgeted	Increased revenue
Account for higher expenses associated with CO2, nutrient solution, biosecurity and tour marketing	From 2% to 5% of salaries	Increased costs

These have been manually implemented as code as follows within 'main\_pba\_UK\_Farm\_interventions.py'.

""INPUTS CHANGED FOR AFTER INTERVENTIONS""

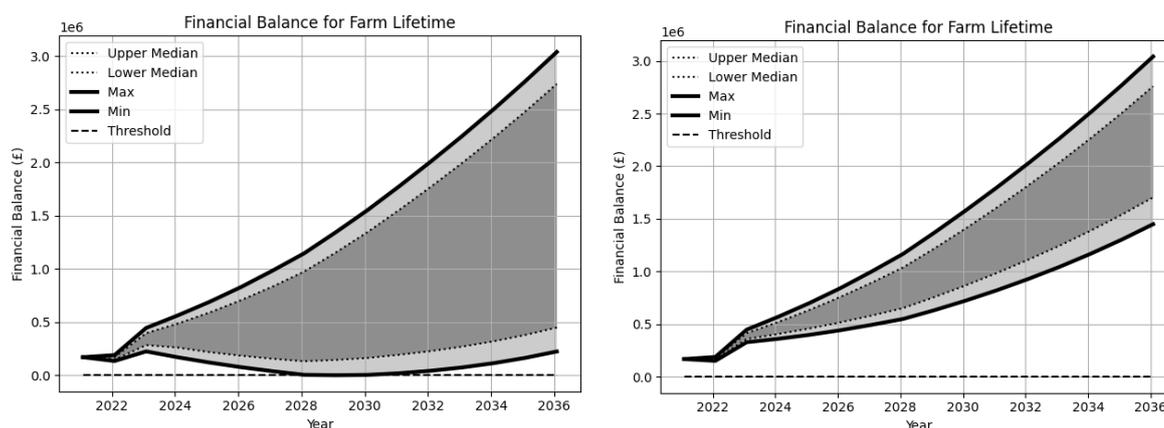
```

scenario.capex_full += 30000
HVAC_multiplier = 1.2
sales_person.count_pilot = 1
admin.count_full = 1
scenario.climate_control = 'Medium'
scenario.nutrient_control = 'High'
scenario.co2_enrichment = 'Yes'
scenario.packaging_cost_full = 0.60
scenario.packaging_cost_pilot = 1
scenario.monthly_distribution_y2 = scenario.monthly_distribution_y1
scenario.tourism_avg_revenue_y1 = 2000
scenario.tourism_multiplier = 1.1
scenario.grants_rev_y2 += 100000 #pba.Pbox(pba.I(75000,100000))
scenario.electricity_price = minmaxmean(0.0734, 0.085, 0.079)
scenario.other_costs_full = 0.05
scenario.biosecurity_level = 'High'

```

### 1.7 Post-Intervention Results

Full result tables including probability bounds can be found in the model folder (<https://github.com/GaiaKnowledge/VerticalFarming>) as results\_UK\_post.xlsx. The graphs can be generated by executing the script 'main\_pba\_UK\_Farm\_interventions.py'. Graphs for additional metrics not found in the main manuscript are shown in Figures S12-S20.



**Figure S12.** UK vertical farm post-intervention financial balance with risk and opportunities (on the left) and without risk and opportunities (on the right).

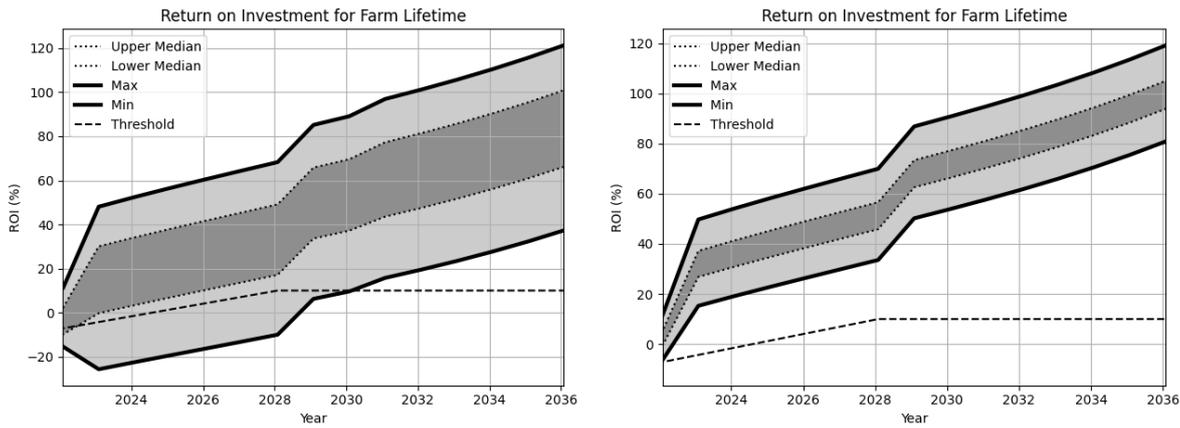


Figure S13. UK vertical farm post-intervention return on investment with risk and opportunities (on the left) and without risk and opportunities (on the right).

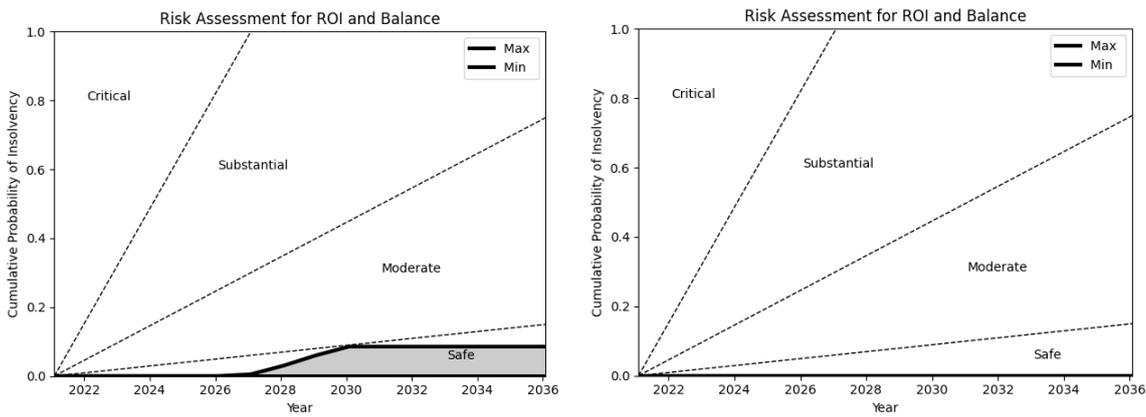


Figure S14. UK vertical farm post-intervention risk assessment with risk and opportunities (on the left) and without risk and opportunities (on the right).

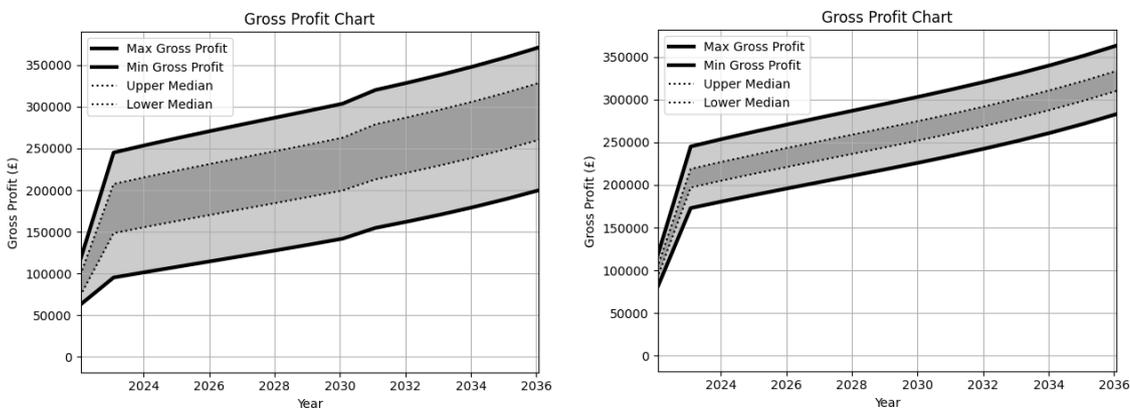


Figure S15. UK vertical farm post-intervention gross profit with risk and opportunities (on the left) and without risk and opportunities (on the right).

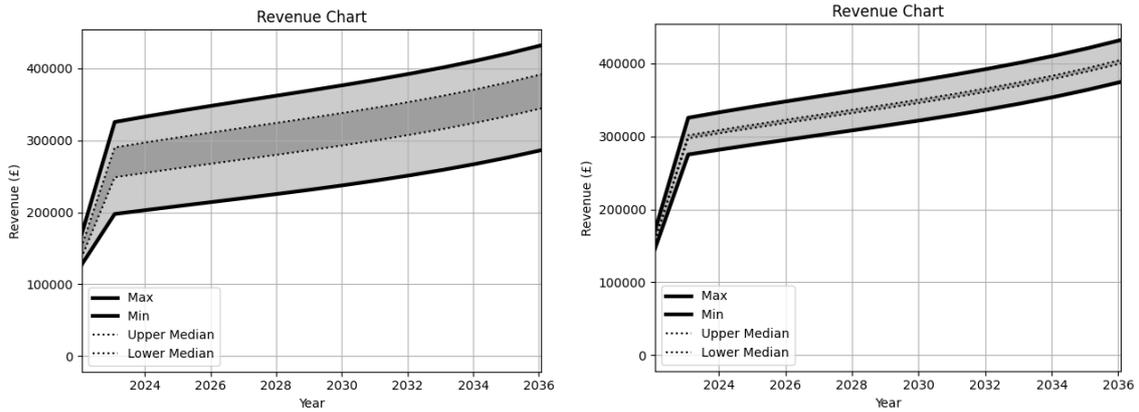


Figure S16. UK vertical farm post-intervention revenue with risk and opportunities (on the left) and without risk and opportunities (on the right).

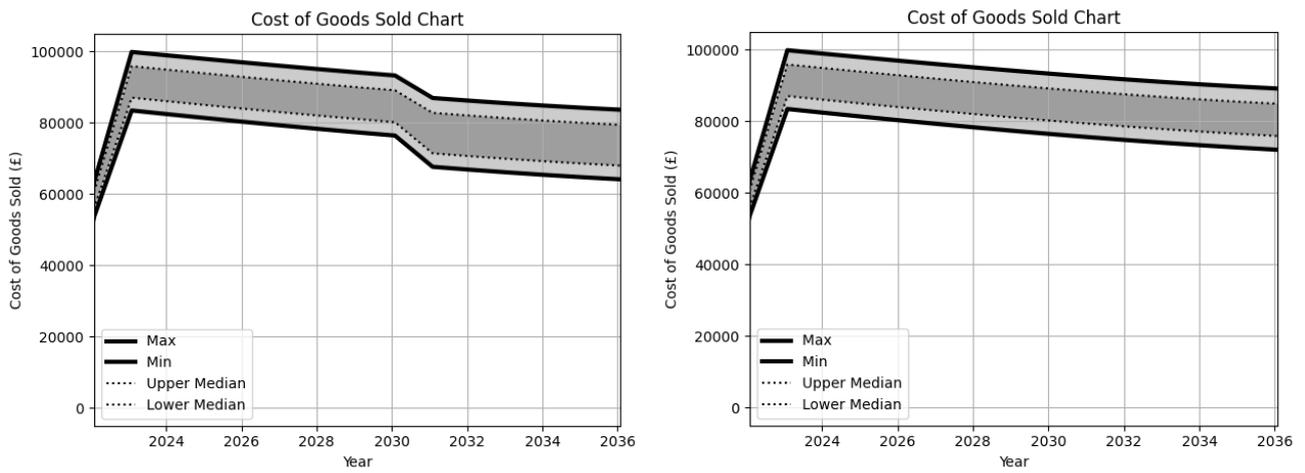
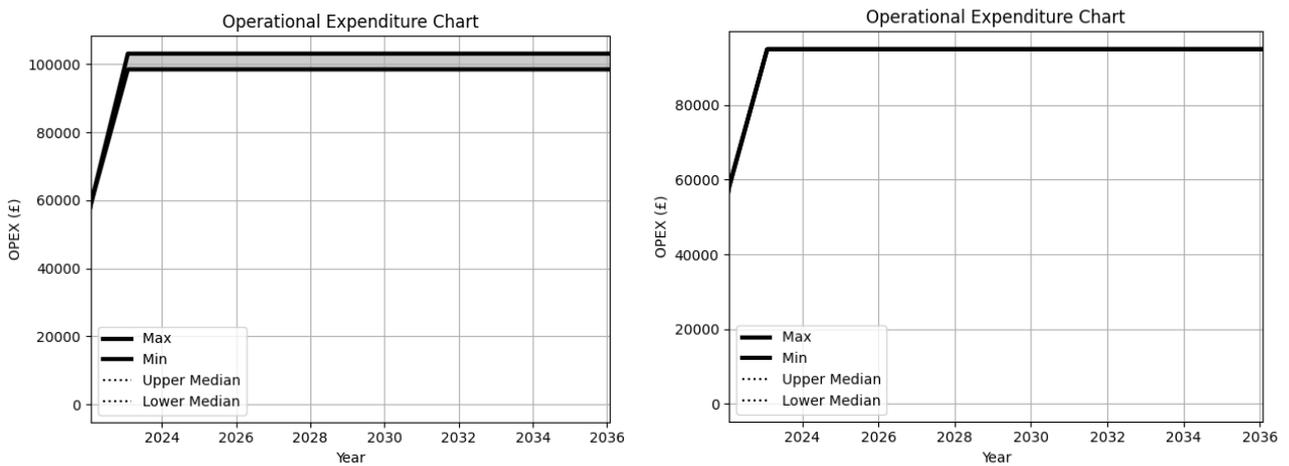
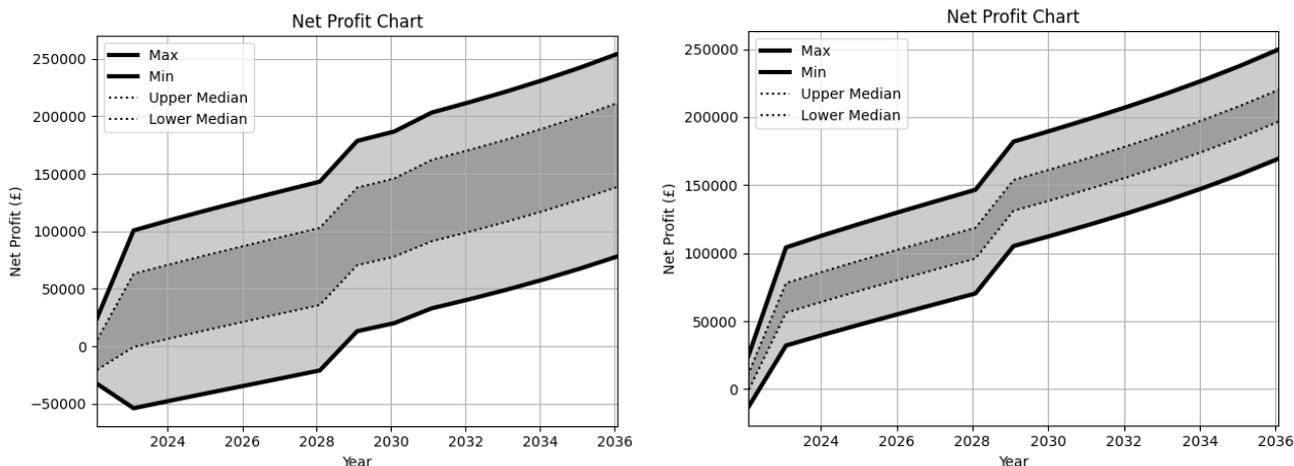


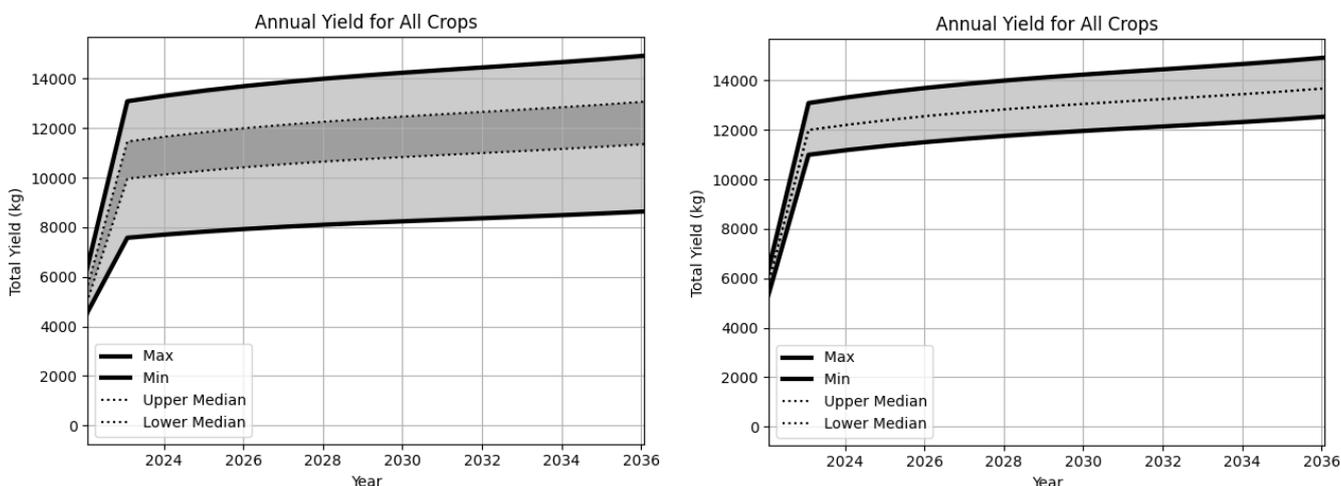
Figure S17. UK vertical farm post-intervention cost of goods sold with risk and opportunities (on the left) and without risk and opportunities (on the right).



**Figure S18.** UK vertical farm post-intervention operational expenditure with risk and opportunities (on the left) and without risk and opportunities (on the right).



**Figure S19.** UK vertical farm post-intervention net profit with risk and opportunities (on the left) and without risk and opportunities (on the right).



**Figure S20.** UK vertical farm post-intervention annual yield with risk and opportunities (on the left) and without risk and opportunities (on the right).

### 1. Japanese Case study

The Japanese case study data is contained within a spreadsheet called 'Current\_Financial\_Model\_JP\_PFAL.xlsx' which it executed by the model script: main\_pba\_JP\_PFAL.py. The inputs are based on the case study provided in full within the book chapter, Smart Plant Factory, Chapter 6 [2]. Values have been converted at a rate of 1 USD = 0.72 GBP (at the time of analysis). The farm only runs at full-production without a pilot farm included. The farm details are summarised within the tables of this section.

#### 2.1 Farm characteristics

Japanese Farm characteristics are detailed in Table S12.

**Table S12.** Farm characteristics for Japanese case study (adapted with permission from [2]).

Characteristic	Japanese Hypothetical Farm	Unit
Real Estate		
Facility size	1000	m <sup>2</sup>
Facility height	3.5	m
Space utilisation	36.4	%
Growing space	364	m <sup>2</sup>
Systems		
Grow levels	6 shelves	
Number. of racks	241	
Stacked growing area	2184	m <sup>2</sup>
Number of lights	5784	
Light wattage	32	W
Energy price	0.090-0.100	£/kWh
Annual electrical consumption	1,676,052	kWh
Labour		
Number of direct labourers	9	people
Number of indirect staff	5	people
Direct labour hours per week	42	hours per person
Direct hourly cost	7.34	£/hour
Crop: Lettuce		
Annual yield	116,640	kg/year
Harvest weight	0.09	kg
Photoperiod	16	hours
Product weight	1	kg
Customer segmentation	100	% to customers
Unit prices	8.64	£/unit
Packaging cost	0.05	£/unit
Attributes*		
Business model	Wholesale	
Grower experience	High	
Automation level	Medium	
Climate control level	High	
Lighting control level	High	
Nutrient control level	High	
CO2 enrichment	Yes	
Biosecurity level	High	

## 2.2 Capital costs

The capital costs for production are detailed in Table S13. Costs are reflective of Table 5 in the manuscript.

**Table S13.** Japanese farm capital costs (adapted with permission from [2]).

Capital costs	Japanese Hypothetical Farm	Unit
Construction		
Finishing	114,775	£
Appliance	108,000	£
Management costs	0	£
Electrical infrastructure	25,200	£

Real estate	0	£
<u>Total construction costs</u>	247,975	£
Systems		
Growing system cost	747,072	£
Lighting system cost	538,804	£
HVAC system cost	56,160	£
Miscellaneous cost	0	
<u>Total equipment cost</u>	1,342,037	£
<u>Total capital costs</u>	1,590,012	£

### 2.3 Operational characteristics and costs

The operational characteristics and costs are detailed in Table S14. These values are reflective of Table 6 in the main manuscript.

**Table S14.** Operational characteristics and costs (adapted with permission from [2]).

Production costs	Japanese Hypothetical Farm	Unit
<u>Operational expenditure</u>		
Rent	69,120	£/year
Staff costs (non-direct labour)	171,888*	£/year
Distribution	106,691	£/year
Other costs*	8,594*	£/year
<u>Total OpEx</u>	356,293	£/year
<u>Cost of goods sold</u>		
Direct labour costs	142,689	£/year
Growing media	14,818	£/year
Seeds and nutrients		
Packaging	2905	£/year
Total electricity cost	150,844	£/year
Water cost	N/A	£/year
<u>Total COGS</u>	375,192	£/year
Other costs		
Depreciation	162,454*	£/year
Working capital	2,160,000	£
Loan amount	0	£
Loan tenure	0	years
Loan interest	0	% per year

### 2.4 Model inputs

The inputs to the model are detailed in Table S15 and can be found within the model library as “Current\_Financial\_Model\_JP\_PFAL.xlsx” on the inputs sheet. As the spreadsheet does not propagate uncertainty until processed by main\_pba\_JP\_PFAL.py, several lines of code manually input uncertainty:

```
scenario.electricity_price = pba.Pbox(pba.I(0.09,0.1))
nutrients_cost = [0, 39815, 39815, 39815, 39815, 39815, 39815, 39815, 39815, 39815, 39815, 39815, 39815, 39815, 39815]
HVAC_multiplier= 1
light_improvement = minmaxmean(0.5, 0.8, 0.65)
```

**Table S15.** Model inputs for Japanese PFAL (adapted with permission from [2]).

#	Code	Input	Unit
1	start_date	01/02/2021	Date
2	facility_size_pilot	1000	currency
3	percent_production_area_pilot	0.364	m <sup>2</sup>
4	growing_levels_pilot	6	%
5	weight_unit	kg	%
6	growing_area_multitplier	1	# of levels
7	no_lights_pilot	5784	Weight unit
8	packaging_cost_pilot	£0.05	Multiplier
9	packaging_cost_full	£0.05	# of lights
10	other_costs_pilot	5.0%	£
11	farm_type	Plant Factory	£
12	business_model	Wholesale	%
13	grower_exp	High	-
14	automation_level	Medium	-
15	climate_control	High	-
16	lighting_control	High	-
17	nutrient_control	High	-
18	system_type	Bespoke (add your own)	-
19	system_quantity	241	-
20	light_system	Japanese Case Study	-
21	growing_media	Sponge	# of racks
22	ceiling_height	3.5	-
23	insulation_level	High	-
24	roof_type	Flat roof	Metres
25	co2_enrichment	Yes	-
26	structure_type	N/A	-
27	water_price	£0.000	-
28	electricity_price	£0.09	-
29	labour_improvement	5%	£
30	percentage_renewable_energy	0%	£
31	biosecurity_level	High	%/year
32	loan_amount	£2,160,000.00	%
33	tax_rate	0%	-
34	loan_interest	0%	£
35	loan_tenure	0	%
36	loan_type	Standard	%
37	crop_typ1	Lettuce - heads	Years
38	crop1_percent	100%	Type
39	crop1_system	NFT	Crop type
40	crop1_harvest_weight	0.09	% of system space
41	crop1_product_weight	1	System type
42	crop1_customer_percent	100%	Kg
43	crop1_price1	£8.72	Kg
44	crop1_price2	£0.00	%
45	crop_typ2	Basil - Lemon	£
46	crop2_percent	0.0%	£

47	crop2_system	Drip Tower	Crop type
48	crop2_harvest_weight	0.075	% of system space
49	crop2_product_weight	0.075	System type
50	crop2_customer_percent	100%	Kg
51	crop2_price1	£1.50	Kg
52	crop2_price2	£0.00	% of system space
53	crop_typ3	Basil - Genovese	£
54	crop3_percent	0.0%	£
55	crop3_system	Drip Tower	Crop type
56	crop3_harvest_weight	0.075	%
57	crop3_product_weight	0.075	System type
58	crop3_customer_percent	100%	Kg
59	crop3_price1	£1.50	Kg
60	crop3_price2	£0.00	%
61	crop_typ4	None	£
62	crop4_percent	0%	£
63	crop4_system	NFT	Crop type
64	crop4_harvest_weight	0.5	% of system space
65	crop4_product_weight	0.5	System type
66	crop4_customer_percent	0	kg
67	crop4_price1	£7.50	kg
68	crop4_price2	£7.50	%
69	vadded_products_multiplier	1	£
70	education_multiplier	1.1	£
71	tourism_multiplier	1.15	Multiplier per year
72	hospitality_multiplier	1	Multiplier per year
73	vadded_avg_revenue_y1	£-	Multiplier per year
74	education_avg_revenue_y1	£-	Multiplier per year
75	tourism_avg_revenue_y1	£-	£/month
76	hospitality_avg_revenue_y1	£-	£/month
77	monthly_rent_y1	£5,760.00	£/month
78	monthly_distribution_y1	£8,891	£/month
79	monthly_rent_y2	5760	£/month
80	monthly_distribution_y2	8890.9184	£/month
81	delivery_msalary	£1,500.00	£/month
82	farmhand_msalary	£1,500.00	£/month
83	parttime_wage	£7.34	£/month
84	ceo_msalary	£ 2,600.00	£/month
85	hgrower_msalary	£2,200.00	£/month
86	marketer_msalary	£1,800.00	£/month
87	scientist_msalary	£2,000.00	£/month
88	salesperson_msalary	£1,560.00	£/month
89	manager_msalary	£2,200.00	£/month
90	admin_msalary	£624.00	£/month
91	ceo_count_y1	1	£/month
92	hgrower_count_y1	1	£/month
93	marketer_count_y1	1	People
94	scientist_count_y1	1	People

95	salesperson_count_y1	0	People
96	manager_count_y1	0	People
97	delivery_count_y1	0	People
98	farmhand_count_y1	0	People
99	admin_count_y1	1	People
100	parttime_count_y1	1620	People
101	ceo_count_y2	1	People
102	hgrower_count_y2	1	People
103	marketer_count_y2	1	People
104	scientist_count_y2	1	People
105	salesperson_count_y2	0	People
106	manager_count_y2	0	People
107	delivery_count_y2	0	People
108	farmhand_count_y2	0	People
109	admin_count_y2	1	People
110	parttime_count_y2	1620	People
111	insurance_pilot	0	People
112	insurance_full	£0	People
113	capex_pilot	£1,590,012.00	People
114	capex_full	£1,590,012.00	£
115	capex_lights	£538,804.00	£
116	capex_facilities	£803,233.00	£
117	capex_building	£247,975.00	£
118	target_productivity_space	90	kg/m <sup>2</sup>
119	target_productivity_energy	0.07	kg/kWh
120	target_productivity_labour	6	kg/man-hour
121	target_productivity_water	0.5	kg/L
122	target_productivity_nutrients	500	kg/kg
123	target_productivity_volume	130	kg/m <sup>3</sup>
124	target_productivity_plants	800	No. of plants per m <sup>2</sup>
125	target_productivity_CO2_emit	500	kg/kg
126	target_productivity_CO2_miti	50000	kg/kg
127	target_productivity_CO2_net	-1000	kg/kg
128	ipm	No	Yes/No
129	pest_detection	No	Yes/No
130	electrical_backup	No	Yes/No
131	currency	GBP	Currency
132	percent_production_area_full	36	%
133	energy_type	Average UK energy mix	-
134	grants_rev_y0	0	£
135	grants_rev_y1	0	£
136	grants_rev_y2	0	£
137	grants_rev_y3	0	£
138	grants_rev_y4	0	£
139	grants_rev_y5	0	£
140	grants_rev_y6	0	£
141	grants_rev_y7	0	£
142	grants_rev_y8	0	£

143	grants_rev_y9	0	£
144	grants_rev_y10	0	£
145	grants_rev_y11	0	£
146	daily_energy_consumption	1630	kWh
147	other_costs_full	0.03	kWh

2.5 Results

Full result tables including probability bounds can be found in the model folder (<https://github.com/GaiaKnowledge/VerticalFarming>) as results\_JPFA.xlsx Results are visualised graphically in Figures S21-S29. The graphs can be generated by executing the script 'main\_pba\_JP\_PFAL.py' Graphs for additional metrics not found in the main manuscript are shown in Figures S21-S29.

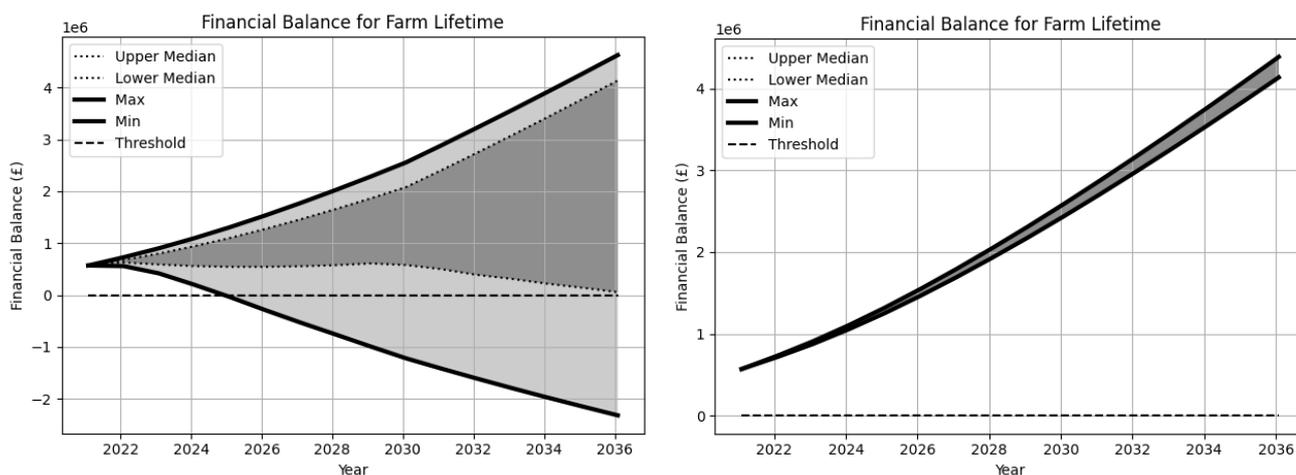


Figure S21. Japanese PFAL financial balance with risk and opportunities (on the left) and without risk and opportunities (on the right).

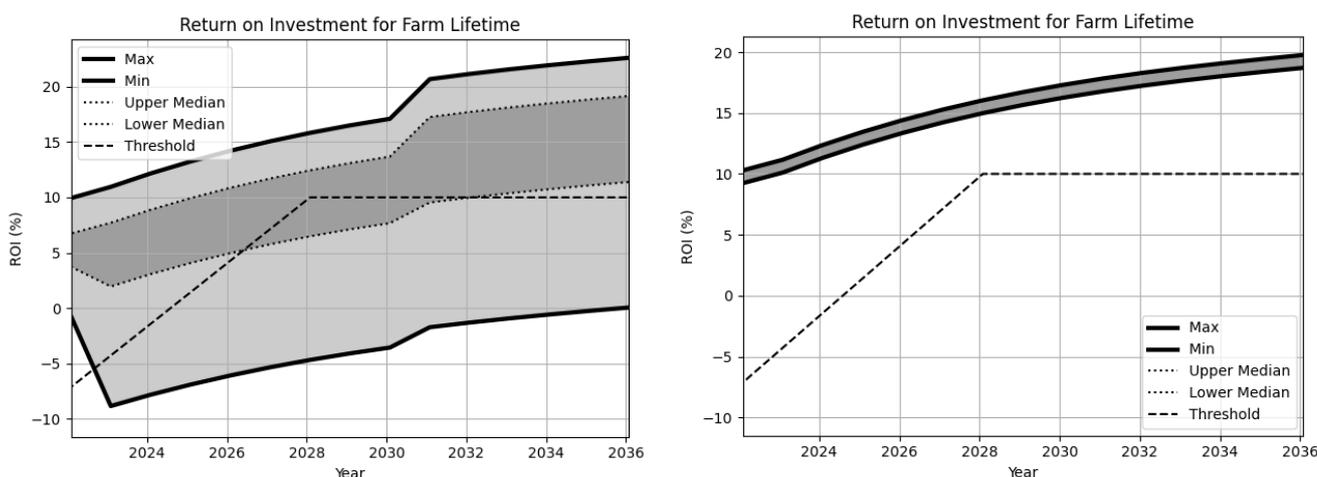


Figure S22. Japanese PFAL return on investment with risk and opportunities (on the left) and without risk and opportunities (on the right).

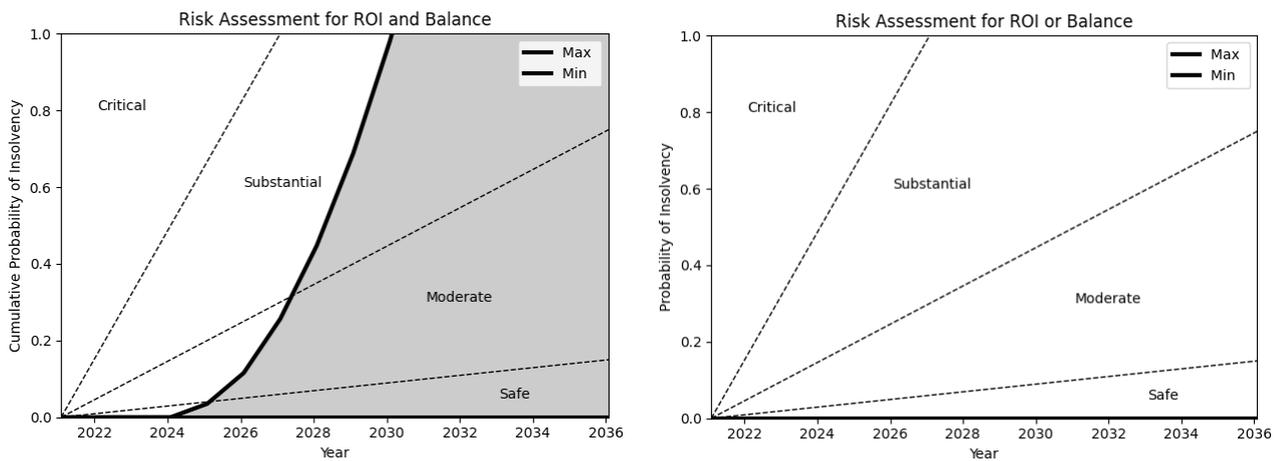


Figure S23. Japanese PFAL risk profile with risk and opportunities (on the left) and without risk and opportunities (on the right).

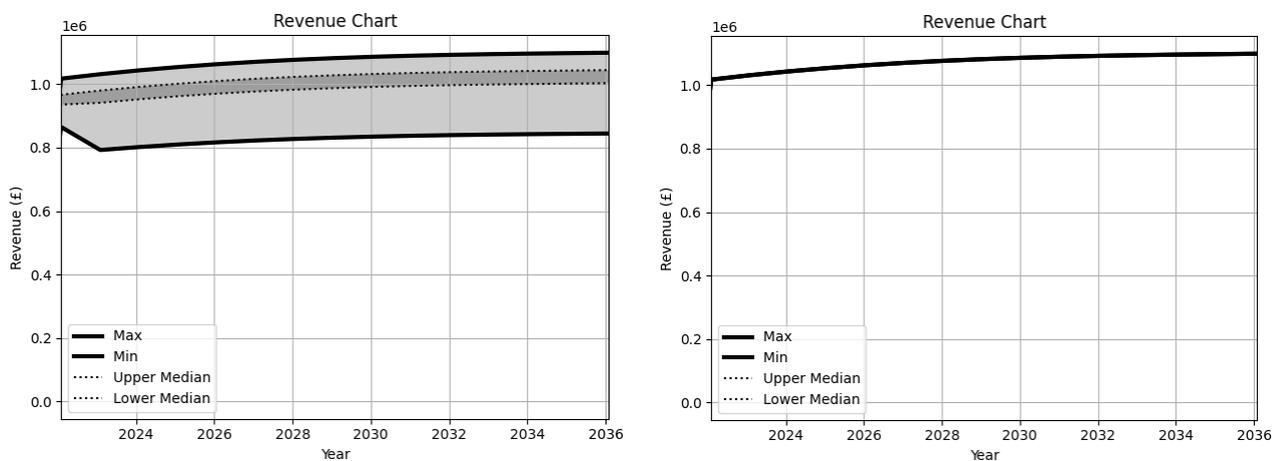


Figure S24. Japanese PFAL revenue with risk and opportunities (on the left) and without risk and opportunities (on the right).

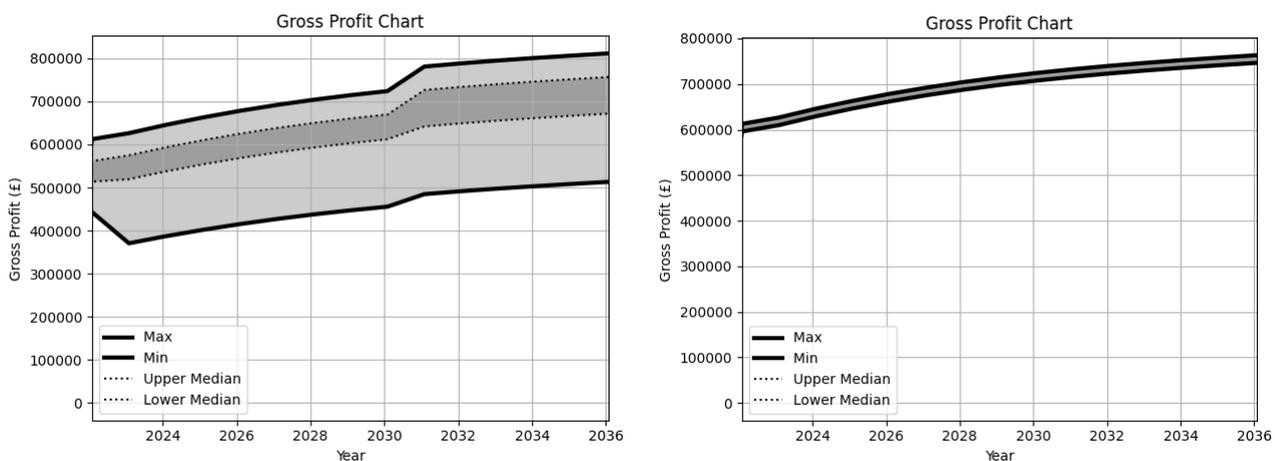


Figure S25. Japanese PFAL gross profit with risk and opportunities (on the left) and without risk and opportunities (on the right).

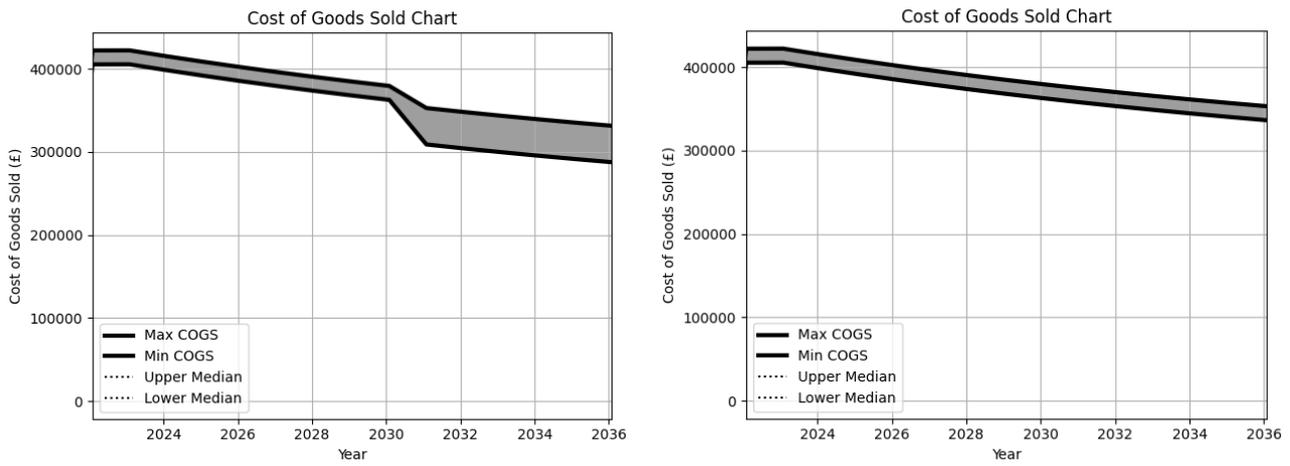


Figure S26. Japanese PFAL cost of goods sold with risk and opportunities (on the left) and without risk and opportunities (on the right).

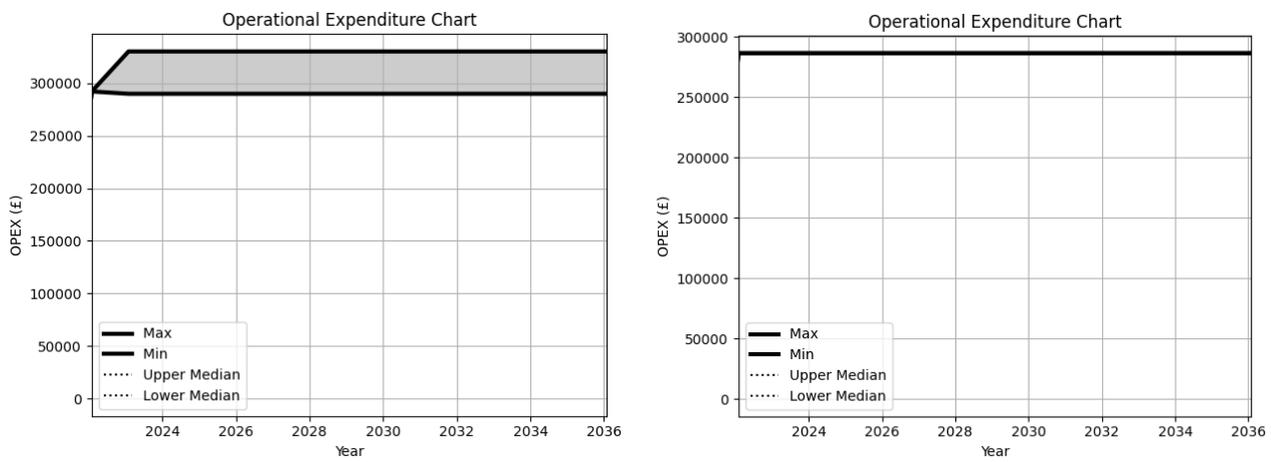


Figure S27. Japanese PFAL operational expenditure with risk and opportunities (on the left) and without risk and opportunities (on the right).

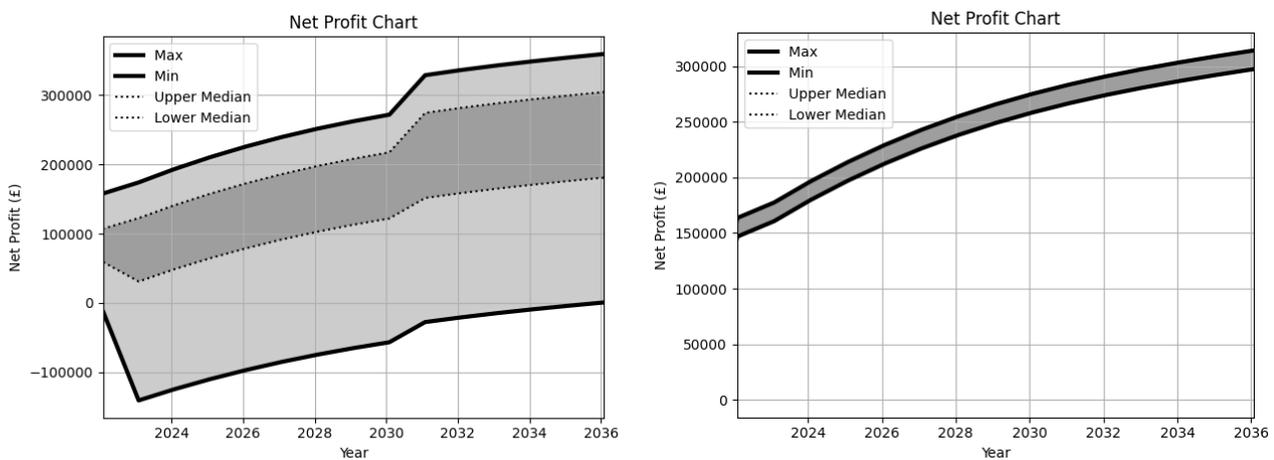
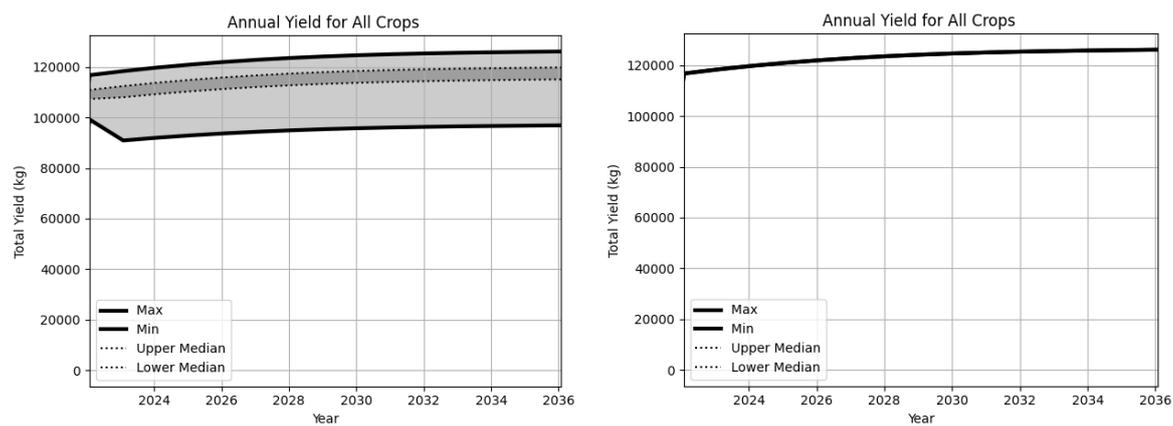


Figure S28. Japanese PFAL net profit with risk and opportunities (on the left) and without risk and opportunities (on the right).



**Figure S29.** Japanese PFAL annual yield with risk and opportunities (on the left) and without risk and opportunities (on the right).

## References

1. Avgoustaki, D. D. and Xydis, G. "Energy cost reduction by shifting electricity demand in indoor vertical farms with artificial lighting," *Biosystems Engineering*, vol. 211, pp. 219–229, 2021.
2. Uraisami, K. Business Planning on Efficiency, Productivity, and Profitability. In *Smart Plant Factory*, T. Kozai, Ed. Springer: Berlin/Heidelberg, Germany, 2018.