Scaling Agriculture to Meet Increasing Marketplace Demand

Agriculture Trade Show Workshop

January 2015

Problem: How to Scale?

Ways to Scale Production

- Diversification
- Year round growing
- Increased acreage under production
- Use of technologies

How to Scale Sustainably:

- Economically
- Environmentally

What does scaling sustainably look like?

Solar Power

Wind Power

Biomass Fuels

Minimizing Inputs

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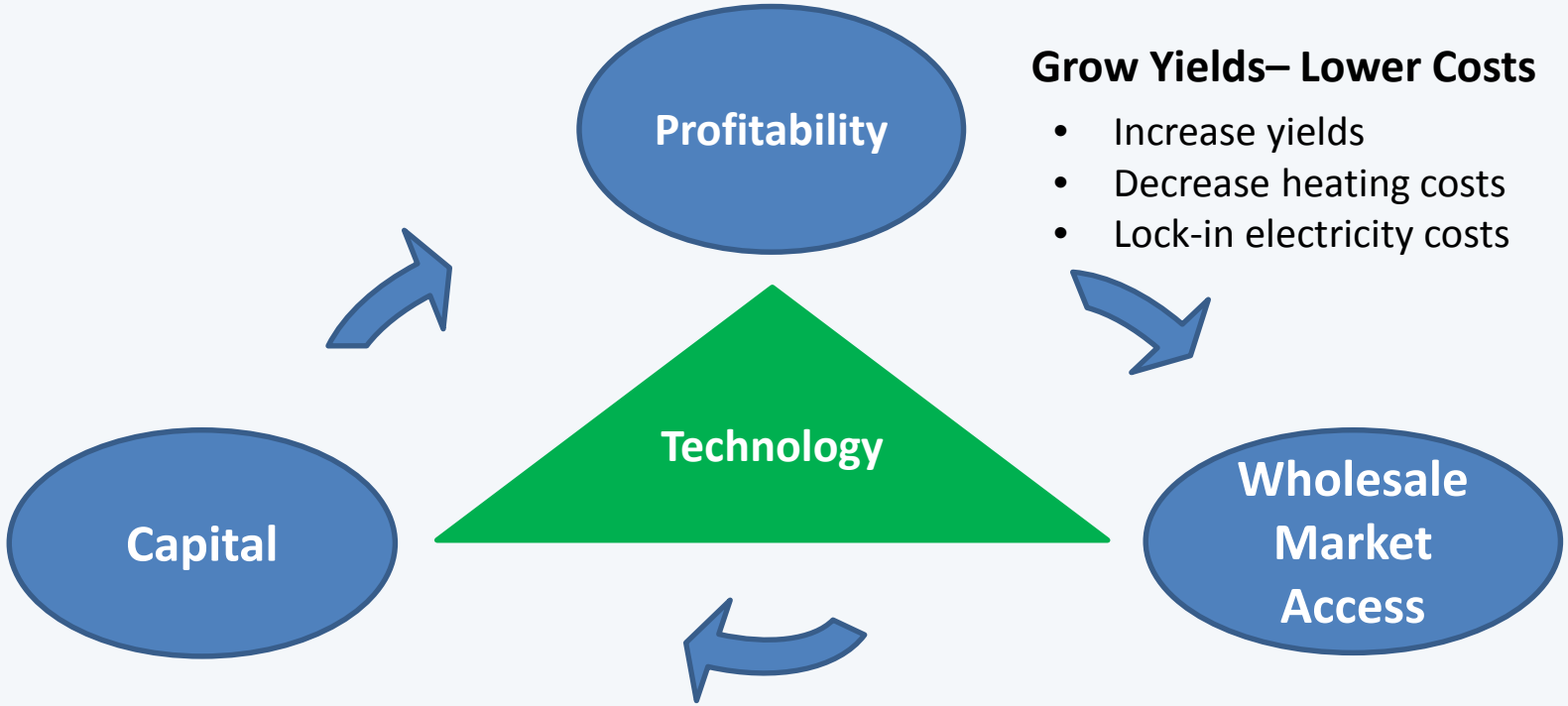
Many Dynamics Dictate Scale



Grow Yields– Lower Costs

- Increase yields
- Decrease heating costs
- Lock-in electricity costs

Lower Risks- Predictable Returns

- Increase capital availability
- Decrease capital cost

Improve Scale - Cost - Consistency

- Increase Volume @ lower cost
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Various technologies can in crease profitability, open up wholesale markets and increase access to capital

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Technologies to Improve Sustainability

Heating

- Insulation
- Energy Screens
- Solar Heating
- Electric Heat Pumps
- Biomass

Lighting

- LED Lighting
- HPS/ Plasma

Structures

- High Tunnels
- Dual Poly Greenhouse Design
- PV Glazing
- Composite Framing

Production

- Multi-cropping
- Hydroponics
- Aquaponics
- CO_2 Enrichment

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Technology In Focus- Heating

Overview

- In Maine, greenhouses require more heating, less cooling.
- Heat is up to 11-15% of total costs.
- Insulation and energy curtains can save up to 75% on heating costs.
- Solar heat gain can be retained with thermal mass.
- Electric heat pumps up to 350% efficient; other heating systems less than 100% efficient.
- Biomass has high upfront cost but lower l-t costs for those with a wood lot

Implications

- Design greenhouses differently: insulate better to retain more heat.
- First minimize heat load with design and insulation, then choose heating system.
- Plan for thermal mass in floor or north wall to reduce lifetime heating costs.
- Electricity likely to be a cost-effective heating energy source.
- Biomass, heat pumps both have grants and tax credits available

Better insulation, thermal mass and electric heat pumps likely to be more cost-effective heating approach than conventional heating systems.

Technology Specifics: Heating

Rank	Technology	Description	Benefits
1	Perimeter insulation	Insulation along perimeter of greenhouse	• Lower heating cost
2	HAF fans	Horizontal air flow fans distribute heat evenly	• Lower heating cost • Higher yields
3	Heat curtain	Insulating material that covers crops at night	• Lower heating cost
4	Heat pump	Electric heat pump	• Lower heating cost • Pollution prevention
5	Passive Solar Greenhouse	East-west oriented greenhouse with insulated north wall and passive solar heating	• Lower heating cost • Less risk of crop loss
6	Active Solar Heating	Blowing hot air through thermal storage	• Lower heating cost • Less risk of crop loss
7	Radiant Floor Heating	Heat distribution system that heats from below	• Lower heating cost • Easier to insulate

Fuel Type	Heat Pump Electricity	Natural Gas	Wood	Cooking Oil	Heating Oil	Propane	Resistance Electricity
Demand / ft^2	4 W	4 W	4 W	4 W	4 W	4 W	4 W
Fuel / ft^2 yr	11.68 kWh	1.33 therms	0.009 cords	1.33 gal	1.08 gal	1.45 gal	35.04 kWh
Cost / ft^2 yr	$1.75	$2.13	$2.28	$2.40	$3.76	$4.07	$5.26

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Technology Specifics: Structures

Greenhouses

	Hoop House	Polycarbonate Greenhouse	Glass Greenhouse	PV Greenhouse
Glazing R-Value	1.25	1.4 – 1.7	1	1.5-1.7
Installed Cost / ft^2	$4.50 - $7.00	$9 - $12	$10 - $15	$13 - $20 (depending on PV % coverage)
Annual Cost / ft^2	$0.63 – 0.97**	$0.63 – 0.84**	$0.30 – 0.50	$0.52 – 0.80
Energy Curtain	Difficult	Yes	Yes	Yes

Multi-use Structures

	Fabric Building	Composite PV	Conventional
Pros	Easy to move	Electricity generation	Aesthetics
	Low Cost	Strength / Long life	Easy to permit and insure
		Aesthetics	
Cons	Unfamiliar to some code enforcers and insurers	Unfamiliar to some code enforcers and insurers	Difficult to move
	Aesthetics	More Expensive	Most Expensive (No revenue, high installed cost)

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Technology In Focus - Lighting

Overview

- Winter light levels in Maine are below the recommended Daily Light Integral for most crops.
- Plant response to light is complex, depending on heat and CO2 levels.
- LED lights can operate on 25% of the electricity for the same output of useful light.
- Costs of LED are less than half of what they were two years ago
- LED lighting is an active area of research with rapid improvements

Implications

- Supplemental lighting can boost productivity. If you are heating then try lighting
- Determining the optimal level of supplement lighting can be difficult.
- If capital constrained non-LED lights still worthwhile. Although expensive way to heat.
- Producers who are sensitive to increases in energy costs may choose to invest now in LED lighting.

LED lighting is becoming more main stream for providing supplemental lighting. Up to 12-16 hours to be optimal

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Technology Specifics: Production

Multiple Cropping

- Two or more crops in the same area/season.
- Accelerated crop rotations
- Controlled environment for faster crop rotations/production
- Also intercropping and companion planting

Hydroponics

- Growing in water without soil.
- Recup capital costs through high-value products
- Increased yields, decreased pest and disease costs
- Light, temperature, humidity, and irrigation are controlled; nutrients are recycled
- Can cost ~$10/sqft with gross returns of $10-25/sqft
- Overcomes poor/contaminated soil and lack of land

Carbon Dioxide Enrichment

- Increasing CO2 from 400 to 1,000 ppm has been shown to enhance plant growth.

3-D Agriculture

- Growing crops above each other
- Challenge is managing light: choose shade-tolerant species/mushrooms, or low-angle baskets
- Supplemental lighting – while expensive is worthwhile as more crops are produced at the margin

Aquaponics

- Integration of aquaculture/hydroponics, produces animal protein and plants
- Capital intensive

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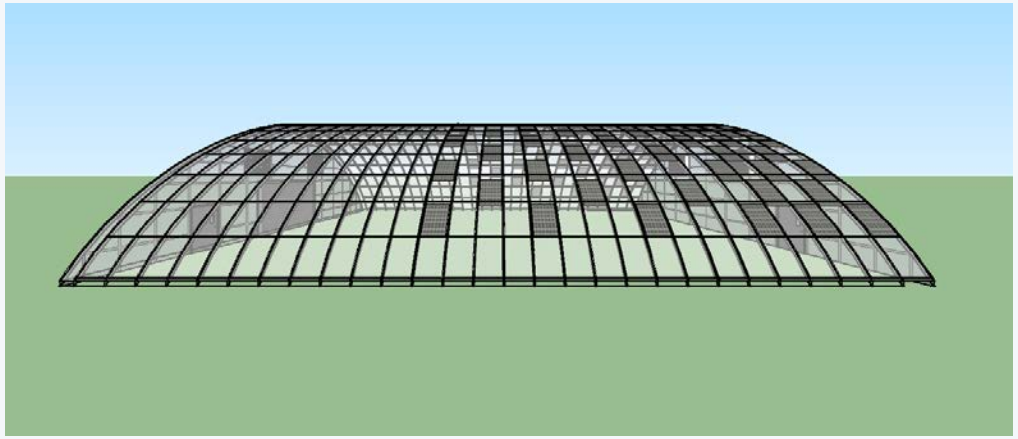
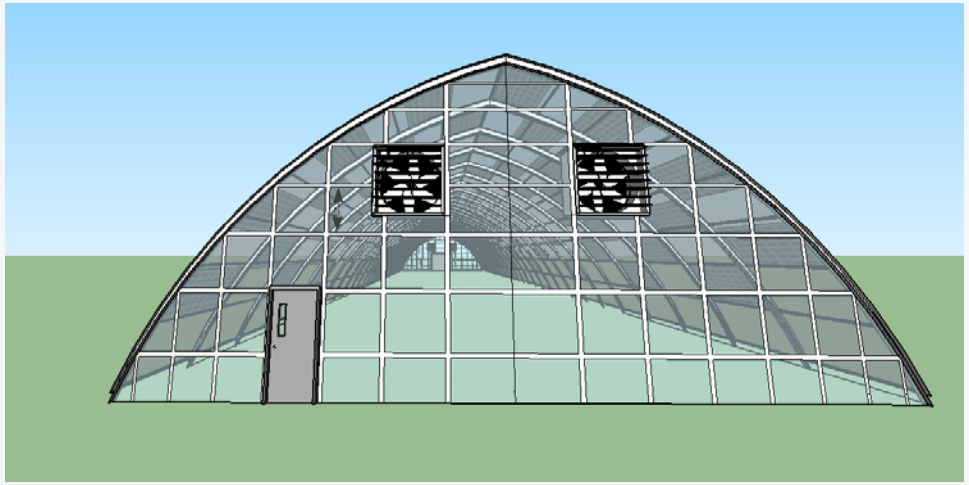
Integrated Photovoltaic Greenhouse

Season Extension or Year Round Use





Investment Type	Gross $ / sf	Profit $/ S.f.
Ground Mount Solar Farm	$ 1.57	$ 1.40
Open Field Agriculture	$ 1.00	$ .50
Controlled Environment Growing	$24.00	$ 6.00
Controlled Environment Growing and Solar	**$ 31.87**	**$ 7.20**

Features and Benefits

- 5500 sf structure
- 47’ wide x 20’ high

Applications

Multi-purpose-

- Greenhouse in Spring and Summer and Fall
- Use as a wood kiln
- Animal production structure
- Cold crop in winter

Integrated Solar allows you to realize additional revenue streams from your investment

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Examples from Bari, Italy

- 150,000 s.f. installation
- 1.5 gigawatt hours
- Strawberries, Basil, Mint, Green beans, chili peppers, flowers
- Opaque polysillicon panels: 8 w/s.f. covering all south facing exposure
- Need to study morphology and physiology

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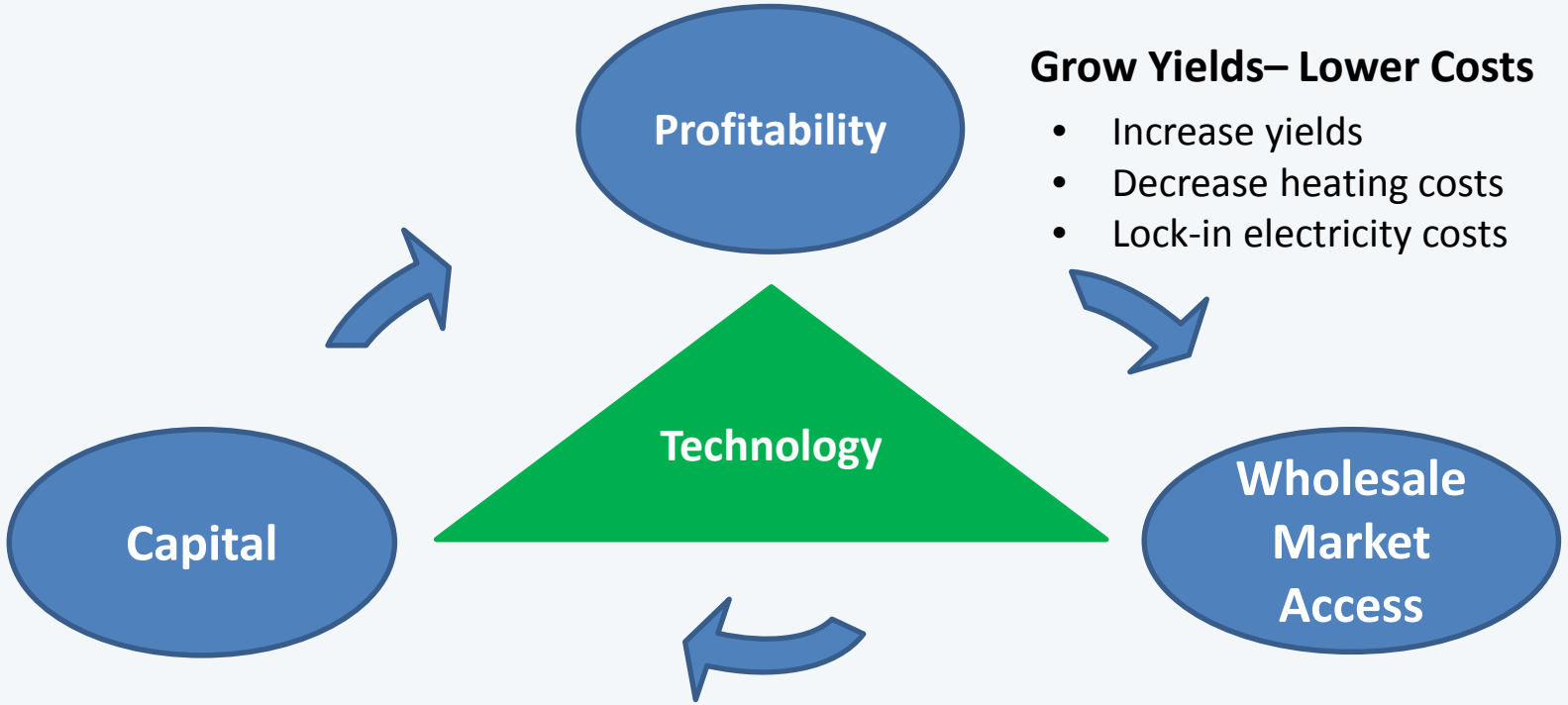
Key Ingredients to Scaling Production



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Market Channels

	Direct to Consumer	Direct Wholesale	Wholesale
	Farm Stand, CSAs, Farmers Markets	Restaurants, Stores, Institutions	Distributor
Prices as % of Retail	100%	75-80%	50-65%

2011 Study by USDA – Percent of Farms Selling Local Sales

	Small Farms (< $50,000 gross sales)	Medium Farms ($50,000 - $250,000 gross sales)	Large Farms (>$250,000 gross sales)
Direct to Consumer Only (%farms)	72.1%	46.5%	31.0%
Direct Wholesale Only (% farms)	33.7%	10.4%	37.1%
Both (%farms)	16.6%	43.0%	31.9%
Average Gross Annual Sales	$7,800 local food sales $640/acre	$70,000 local food sales $1,310/acre	$770,000 >$3,000/acre

Direct and Intermediated Marketing of Local Foods in the United States study in 2011.

Local: Producer Consumer Connection, Community, Distance - 50 – 100 miles

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Financial Models are Evolving

Outright Ownership End user purchases the system outright, and benefits from all incentives, tax credits, energy production, and rent. Need have tax appetite.	**Community Solar** Array is owned by collaborative entity. Owners share in tax credit or a 3rd Party investors take part to take advantage of tax equity if required.
Crowd Funded 3rd parties outside community provide loans for an expected return in the 7-9% range Mosaic, Co-op are good examples	**Partnership Flip** End user enters into a partnership with tax equity investor. Revenue is shared amongst partners, with the "flip" of ownership once % return is met.

Key Ingredients:

- Net Metering Makes all of these happen
  - Up to 10 meters associated to an array (ME).
  - MA, RI, CT, VT all have virtual net metering
- Host wants to build/Use it/Energy Consumers who will buy electricity /Investors looking for solar investment/Need someone for Tax Credits

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Where to obtain capital?

- USDA – REAP
  - Grants available for 25% of project costs for biomass and heat pumps, solar/wind
  - Loan guarantees available for up to 75% of total project costs
- Traditional Financial Institutions
  - FAME, Farm Credit, CEI, etc.
- Conservation Funds

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Thank you!

Technology Specifics: Heating

Heating Options

- Passive Solar Heating
- Active Solar Heating
- Electric Heat Pumps
- Combustion Boilers
- Combustion Furnaces
- Electric Boilers and Furnaces
- Unit Heaters
- Heat Mats
- Heat Lamps
- Radiant Floor Heat
- Ventilating, Cooling and Refrigerating
- Root Zone Heating
- HAF fans
- Combined Heat and Power
- Livestock
- Anaerobic Digesters
- Automated Climate Control
- Sidewall Natural Ventilation
- Ridge Ventilation
- Open Roof Ventilation
- Evaporative Cooling Pads
- Fog Coolers
- Heat Pumps
- Refrigerators and Freezers
- Insulation
- Mechanical End Vents

Recommended Approach: Heat Curtain

	High Heat Greenhouse	Low Heat Greenhouse
Heat Curtain Cost	**$8,640**	**$11,520**
Projected Savings Rate	**50%**	**40%**
Annual Heat Savings	**$7,700**	**$198**
Simple Payback	**1.12 years**	**58.18 years**

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Technology Specifics: Heating

Insulation

- Value of insulation depends on heat load and energy costs.
- Insulated glazing can save up to 67% of heating costs.
- As insulating value increases, light transmission decreases.
- Retractable heat curtains can save up to 50% in heating costs, without diminishing light transmission.
- Insulation around perimeter and in north wall can provide payback in less than 2 years.

Best insulation approach likely to be insulating perimeter and north wall, while using heat curtain to reduce heat loss through glazing.

- Investment in insulation is warranted to support cold-weather production, especially when faced with rising fuel costs.
- Need to balance light loss and insulating value for target crop.
- Insulation should be installed around perimeter and on north wall.

18

Technology Specifics: Heating

Energy Sources: Comparative Cost

Most affordable heating energy source (besides solar).

Greenhouses in Maine are often heated with #2 heating oil

Least affordable heating energy source.

Fuel Type	Heat Pump Electricity	Natural Gas	Cooking Oil	Wood	Heating Oil	Propane	Resistance Electricity
Fuel Units	kWh	Therm	Gallon	Cord	Gallon	Gallon	kWh
Fuel Price / Unit	$0.15	$1.70	$1.80	$250.00	$3.50	$2.82	$0.15
Fuel BTU / Unit	3,412	100,000	112,000	15,000,000	139,000	91,500	3,412
Fuel Price / MMBTU	$43.96	$17.00	$16.07	$16.67	$25.17	$30.82	$43.96
Efficiency	300%	90%	80%	70%	80%	90%	100%
Effective $ / MMBTU	$14.65	$18.89	$20.09	$23.81	$31.47	$34.24	$43.96

Energy costs as of March 2013 in CMP service territory.

Low ⟷ Relative Cost ⟷ High

Technology In Focus - Production

Overview

- Heat and light requirements of high value crops may force switch to low value crops in winter.
- Hydroponics and aquaponics both require electricity and ability to carefully control growing environment.
- Effect of supplemental lighting is limited by availability of CO2 for plant development.
- Combining strategies and technologies increases production faster than costs.

Implications

- Multi-crop production, e.g. greens in winter and tomatoes rest of year, may generate best return on technology investment.
- Hydroponics and aquaponics good match for greenhouse with PV glazing.
- CO2 enrichment should be considered if supplemental lighting is used to get up to 2X production.
- Investing in technology to increase scale of year-round production will lead to higher net incomes.

Investments in intensive year-round production that build scale will lead to higher net incomes.

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Technology Specifics: Lighting

Lighting Technology	Incandescent	High Intensity Discharge	Fluorescent	Light Emitting Diode	Light Emitting Plasma
Efficiency	Low	Varies	High	High	High
Life (hours)	2K	24K	20K - 100K	50K	30K
Toxic	No	Yes	Yes	No	Yes
Heat	High	High	Medium	Low	High
Start Time	Fast	3-5 min	Medium	Instant	45 seconds
Restrike	Fast	15-20 min	Fast	Instant	2 minutes
Cost / lamp	Low	Medium	Medium	High	High

Findings from 2013 Feasibility Study:

- LED lighting should be considered as a viable option Maine
- LEDs can reduce energy costs by 80%
- Opportunities for maximizing growing potentials
- LED products are experiencing dramatic price reductions which should favor their adoption

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