Analyzing Nursery Production Systems for Environmental Impact Potential and Cost

UK
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College of Agriculture, Food and Environment

Dewayne L. Ingram, PhD
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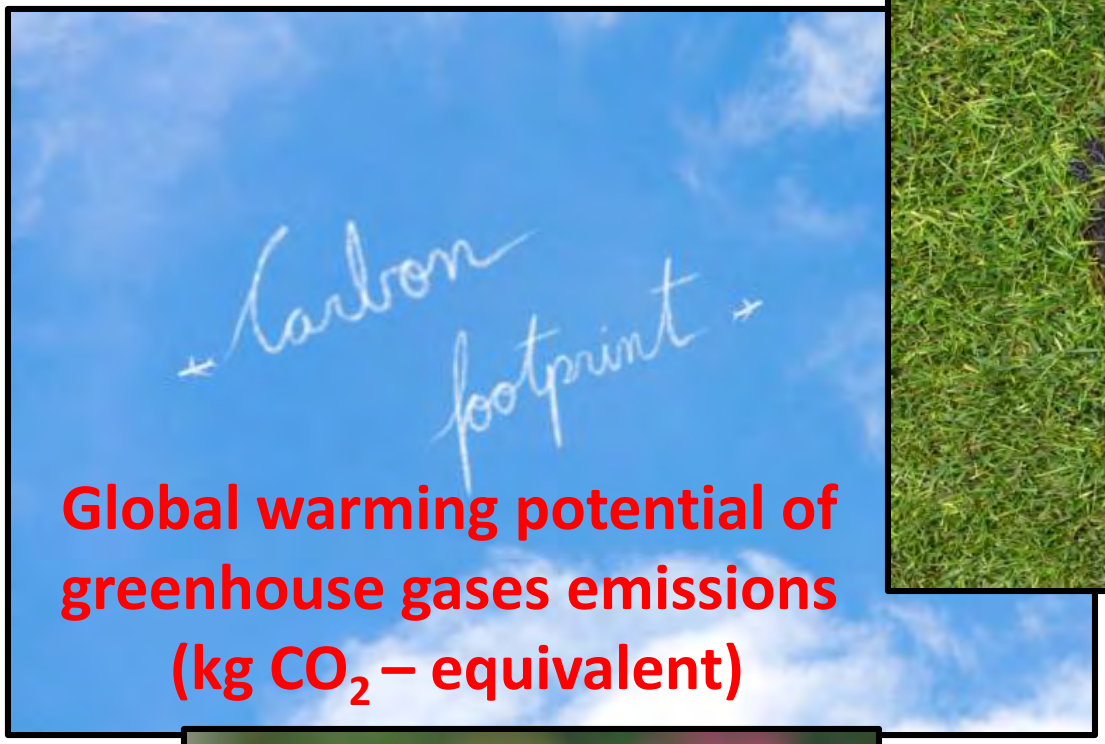
carbon
footprint

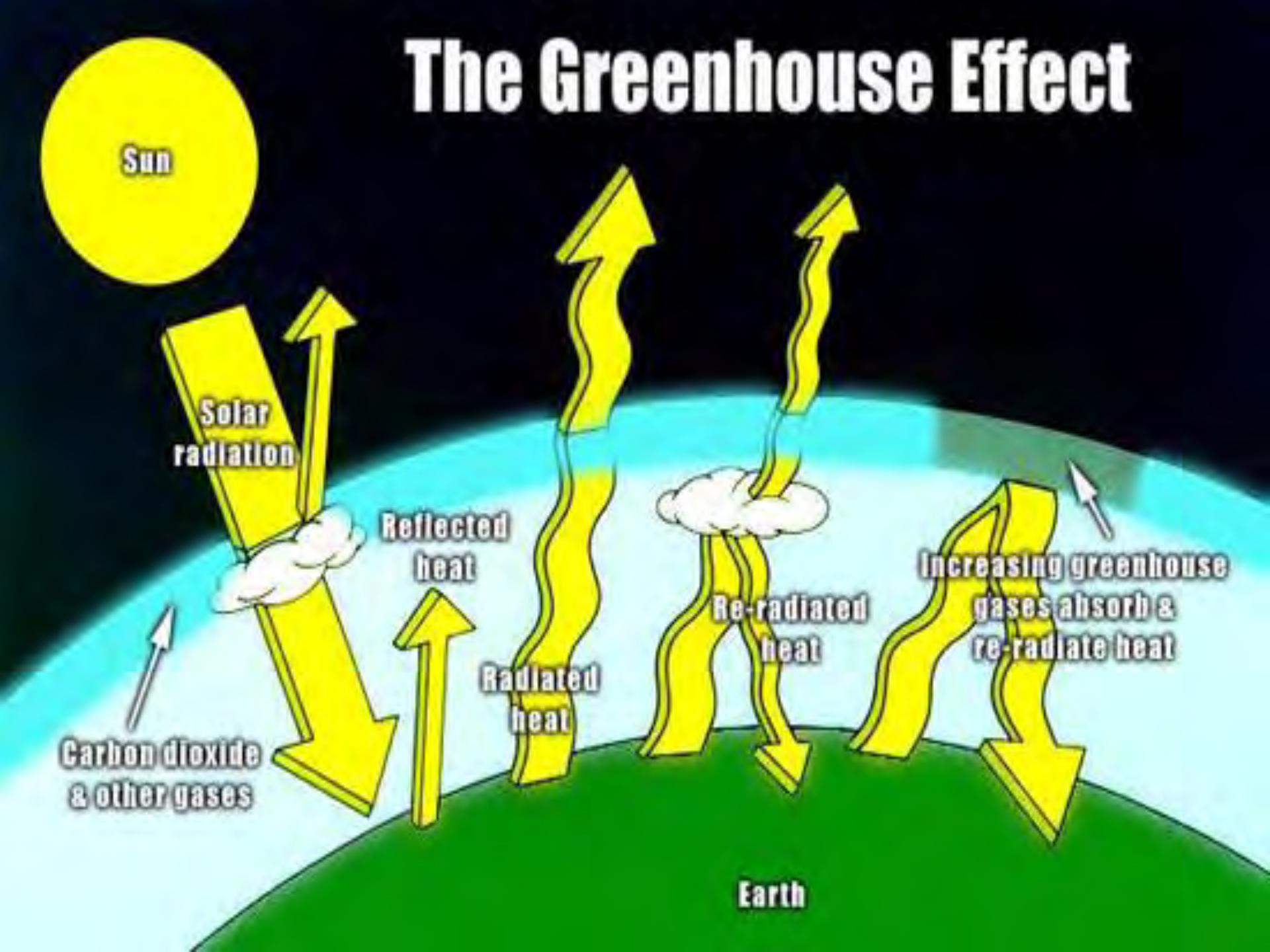


Global warming potential of greenhouse gases emissions (kg CO_2 – equivalent)

Summary of scientific basis for role of CO_2 in climate change

- Human activity is emitting large amounts of CO_2
- CO_2 concentration in atmosphere is increasing
- CO_2 and other greenhouse gases traps thermal radiation

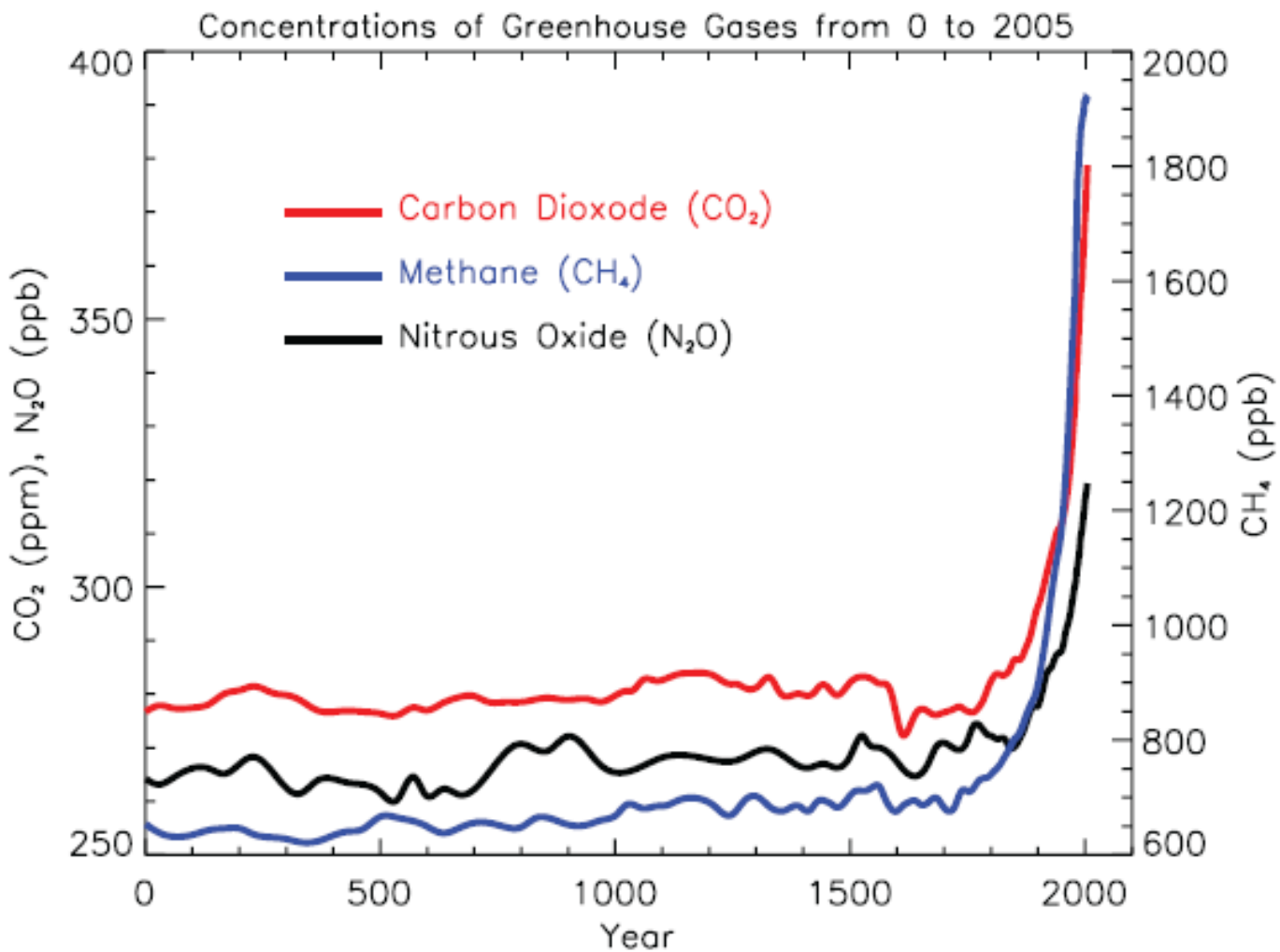
The Greenhouse Effect



Greenhouse Gas Emissions have Global Warming Potentials, GWP_{100}

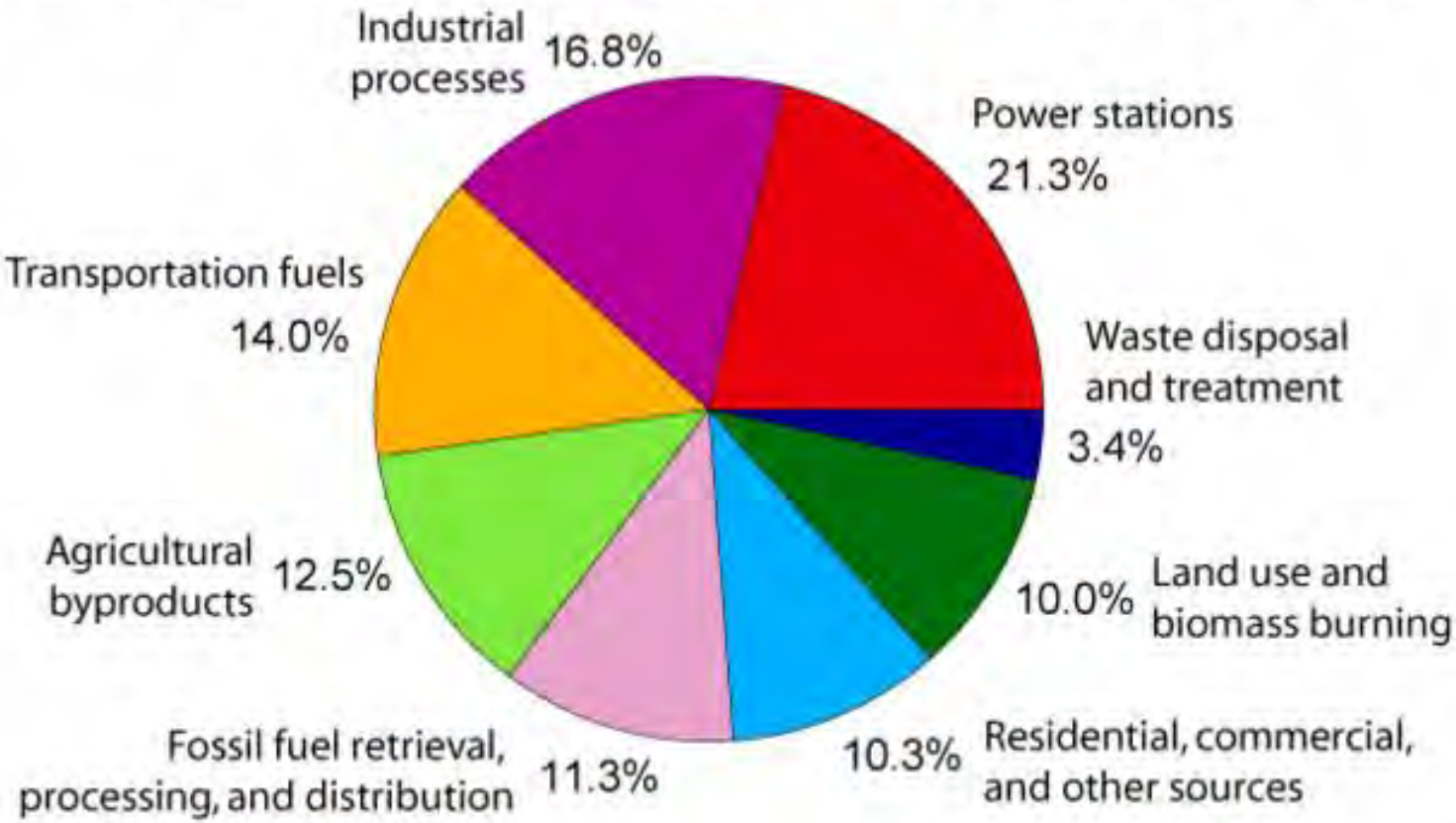
- The GWP of CO_2 is set at 1
- The GWP of N_2O is 296
- The GWP of CH_4 is 23

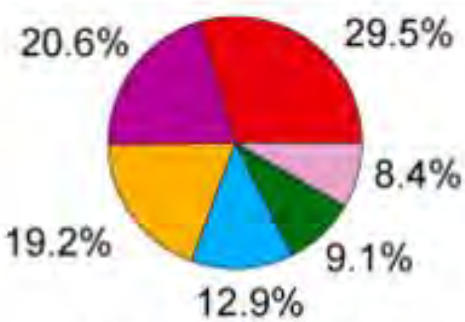
Atmospheric concentrations of important greenhouse gases



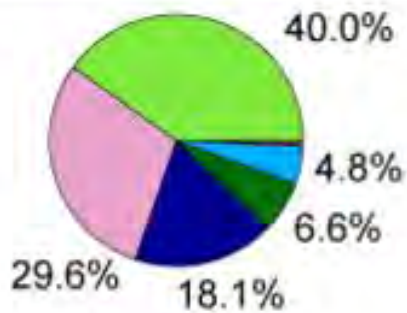
IPCC. FAQ

Annual Greenhouse Gas Emissions by Sector

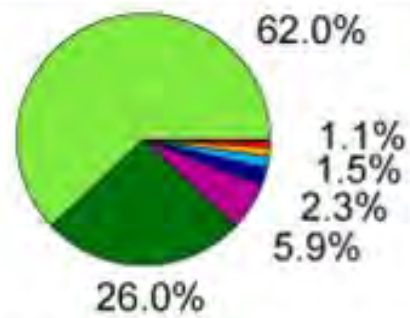




Carbon Dioxide
(72% of total)



Methane
(18% of total)



Nitrous Oxide
(9% of total)

Life Cycle Assessment:

A research tool to study the environmental impacts of products and processes

…a few reported carbon footprints

…complete life cycle

- Six-pack of beer…… 3.7 kg CO_2e
- Gallon jug of milk…… 3.4 kg CO_2e
- Timberland winter boots…… 54.0 kg CO_2e
- 2-Liter bottle of Coca Cola…… 0.5 kg CO_2e
- ½-gallon carton of orange juice… 1.7 kg CO_2e

Production of Trees and Shrubs

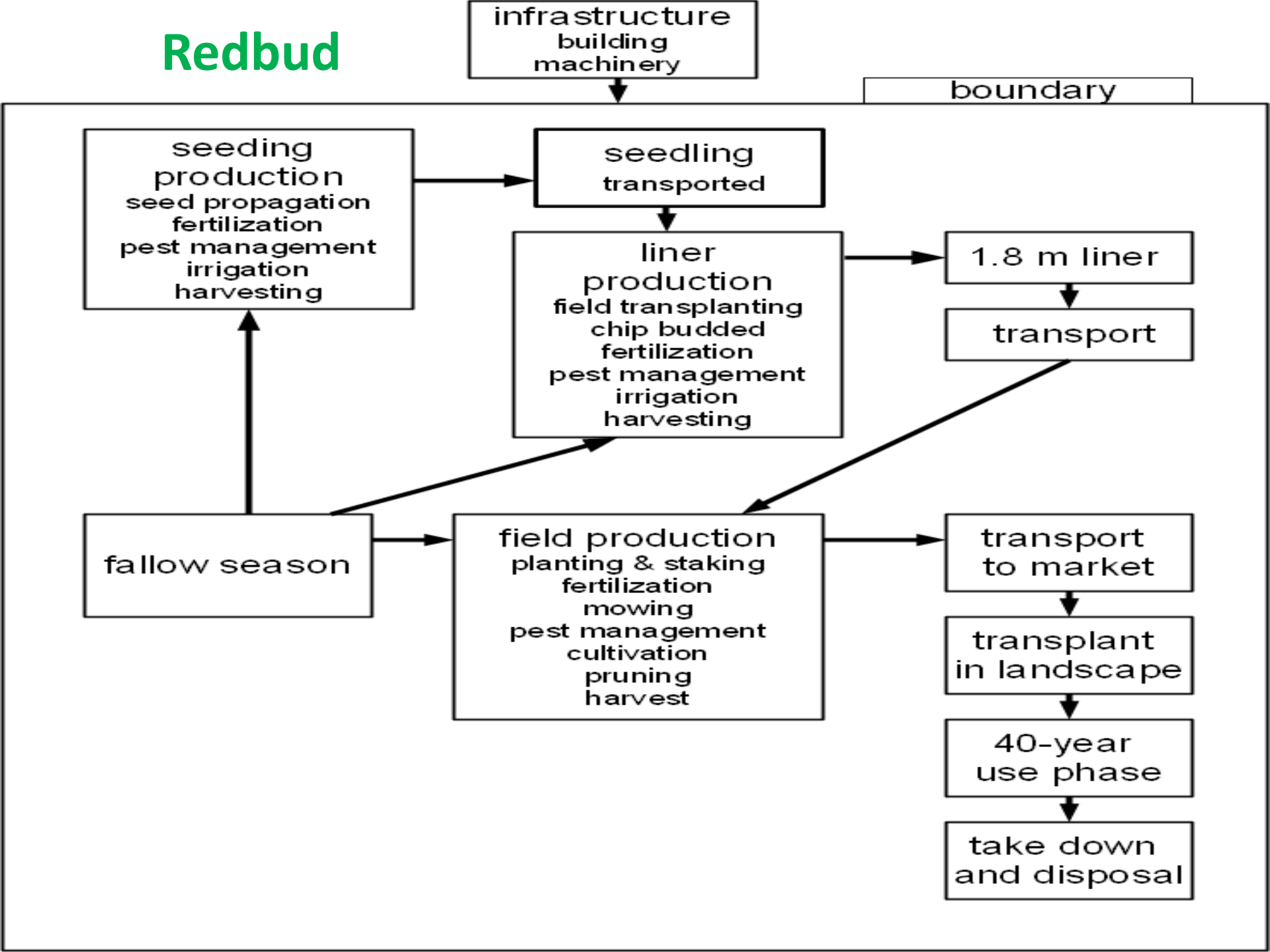
- 2011… Red Maple (B&B)
- 2012… Colorado Blue Spruce (B&B)
- 2012-13… Redbud (B&B)
- 2014-15… Field-grown shrubs (B&B)
- 2015… Pot-in-pot
- 2016… Container-grown shrubs
- 2017… Greenhouse foliage and annuals

Inventory the System

Life Cycle Inventory

- Every material used
- Every chemical used
- Each equipment use
- Energy inputs
- Labor inputs

Redbud


infrastructure
building
machinery
boundary
seeding production
seed propagation
fertilization
pest management
irrigation
harvesting
seedling
transported
liner production
field transplanting
chip budded
fertilization
pest management
irrigation
harvesting
1.8 m liner
transport
fallow season
field production
planting & staking
fertilization
mowing
pest management
cultivation
pruning
harvest
transport to market
transplant in landscape
40-year use phase
take down and disposal

Redbud Field Production

Input Material	Product/A	Product per marketable tree (kg)	GWP (kg CO_2e / kg)	GWP per marketable tree (kg CO_2e)
Sudex seed	40	0.025199	4.0670	0.1024861
Pre-plant Ag lime	2000	1.259972	0.5862	0.7386461
Fertilizer (15-15-15)	1300	0.818982	1.4325	1.1731916
Bambo stake	800	0.244444	0.1818	0.0444400
Fescue in middles	11.25	0.007087	4.0670	0.0288242
Wire basket (cnt)	720	0.652000	1.2927	0.8428541
Trunk protector (cnt)	720	0.011352	0.4700	0.0053353
Transplant (cnt)	800	1.111111	0.6073	0.6747600

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Redbud Field Production

	Product/A	Active ingredient per marketable tree (kg)	GWP (kg CO_2e / kg a.i.)	GWP per martketable tree (kgCO_2e)
Surflan	115.2	0.002291	23.0832	0.0528751
Goal	57.6	0.001145	23.0832	0.0264375
Roundup (glyphosate)	86.4	0.001465	33.3424	0.0488309
Bifendrin	87	0.000507	18.6864	0.0063211
Discus	15	0.000738	18.6864	0.0000966

Redbud Field Production

Equipment Use	hrs/A	hrs per marketable tree	fuel per marketable tree (Gal)	GWP (kg CO_2) per marketable tree
Chisel plow	2	0.002778	0.011499	0.1314622
Disk (2 times)	2	0.002778	0.011499	0.1314622
Apply Ag lime	0.5	0.000694	0.002875	0.0328655
Seed sudex	1.3	0.001806	0.007474	0.0854504
Plow	1	0.001389	0.005749	0.0657311
Rototill	0.75	0.001042	0.004312	0.0492983
Transport liners to field	0.25	0.000347	0.000229	0.0026362
Transplant liners	1	0.001389	0.005749	0.0657311
Sow fescue in middles	0.5	0.000694	0.001437	0.0164597
Stakes to field	0.5	0.000694	0.000457	0.0052723
Irrigation	9.6	0.013333	0.059616	0.6814912
Apply fertilizer (3 yr)	1.5	0.002083	0.001372	0.0158169
Cultivate (4 times in 3 yr)	4	0.005556	0.011499	0.1316776
Apply herbicide (3 yr)	3	0.005556	0.003658	0.0421784
Apply Glyphosate (3yr)	3	0.004167	0.002743	0.0316338
Apply insecticides (3 yr)	1.5	0.000694	0.001437	0.0493791
Mow (3 yr)	6	0.000769	0.001592	0.0182323
Digging with tree spade	48	0.066700	0.279590	3.1964104
Loading in field	36	0.050000	0.194041	2.2186659
Hauling from the field	36	0.050000	0.206977	2.3663185
Unloading and loading	36	0.050000	0.194041	2.2186659
Removal of culls	6.7	0.009259	0.035934	0.4108641
Haul culls from field	3.3	0.004630	0.005080	0.0583418

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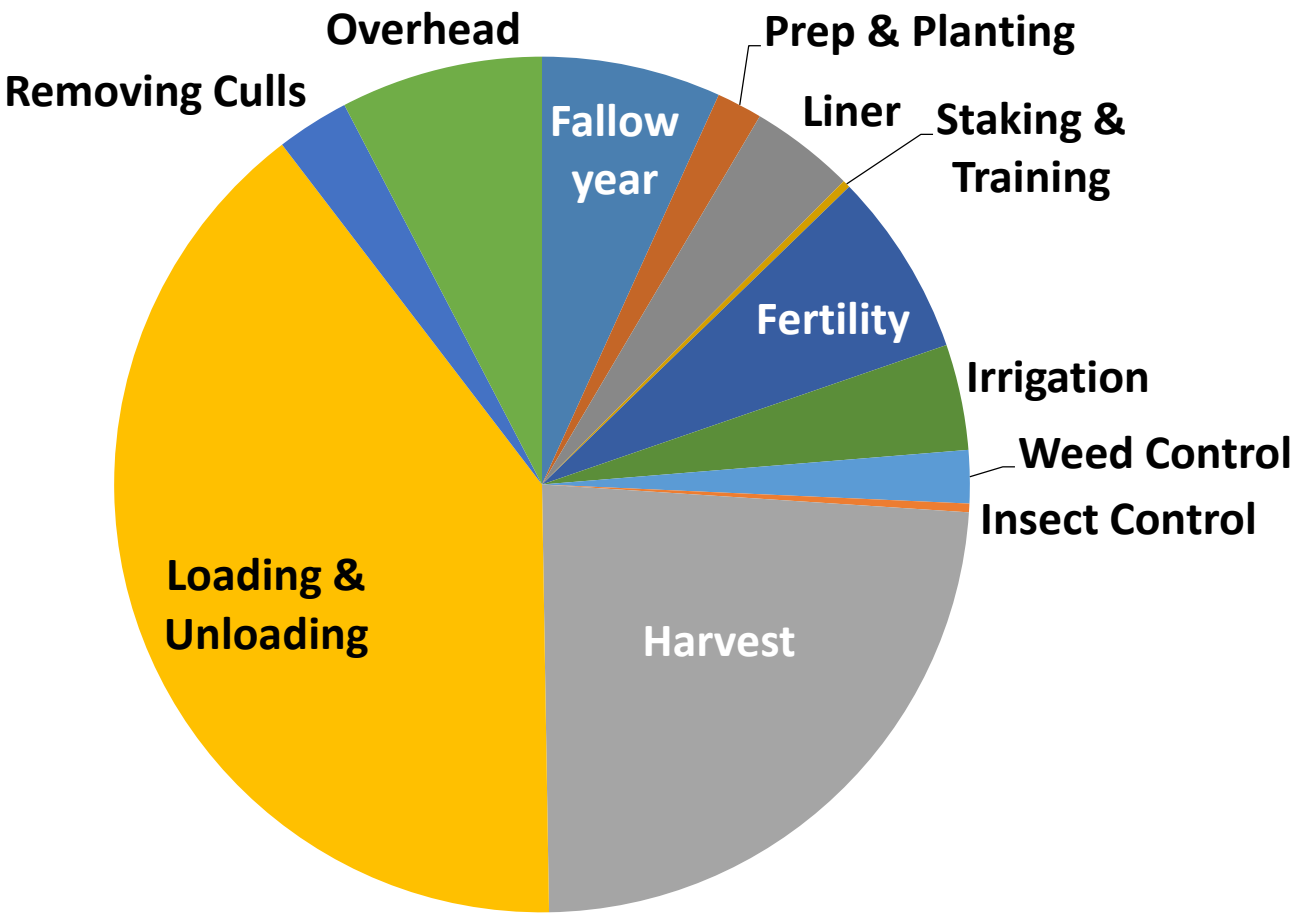
Relative GWP of input materials and equipment use during redbud field production phase (seed-to-gate)

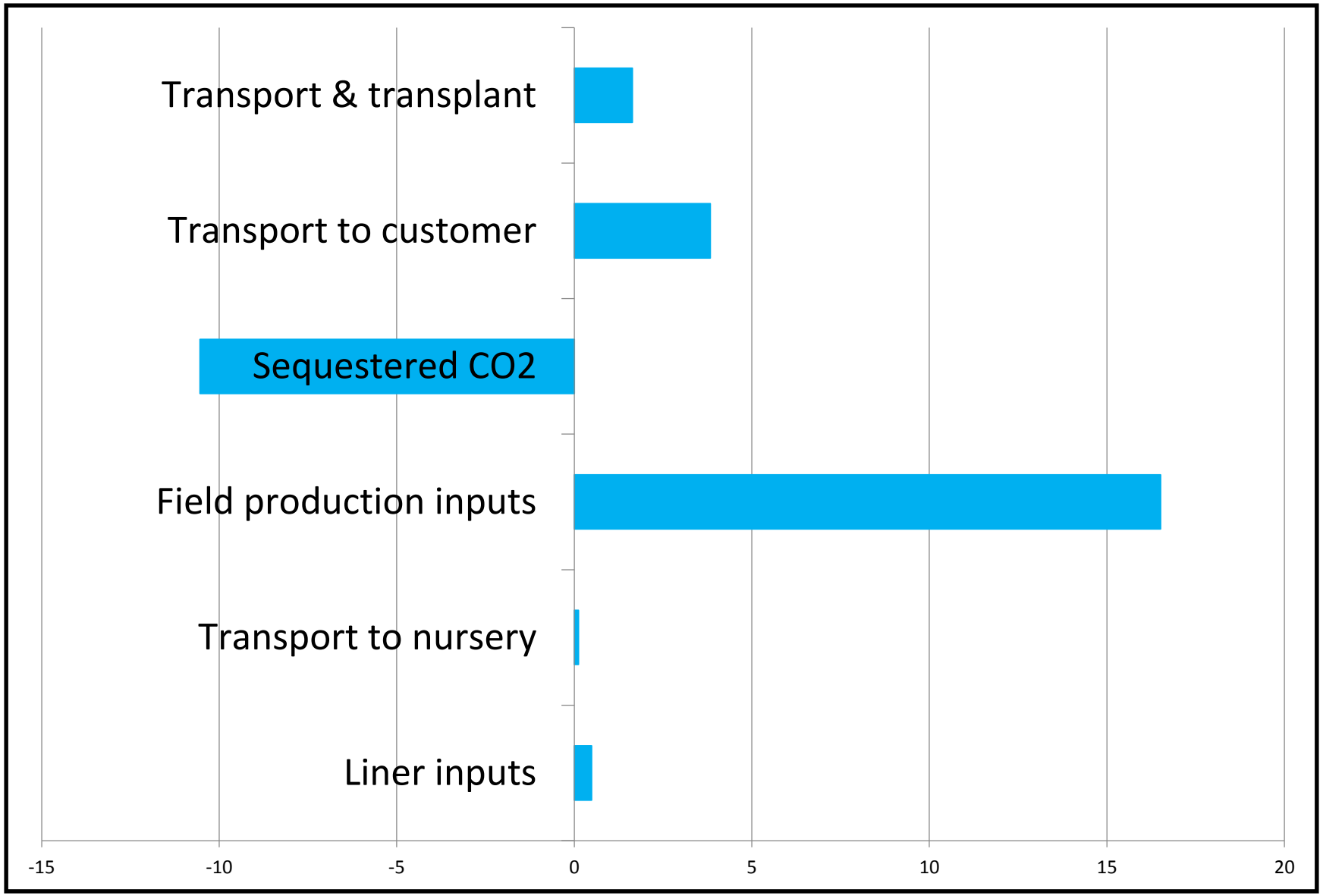
(kg CO_2e / tree)



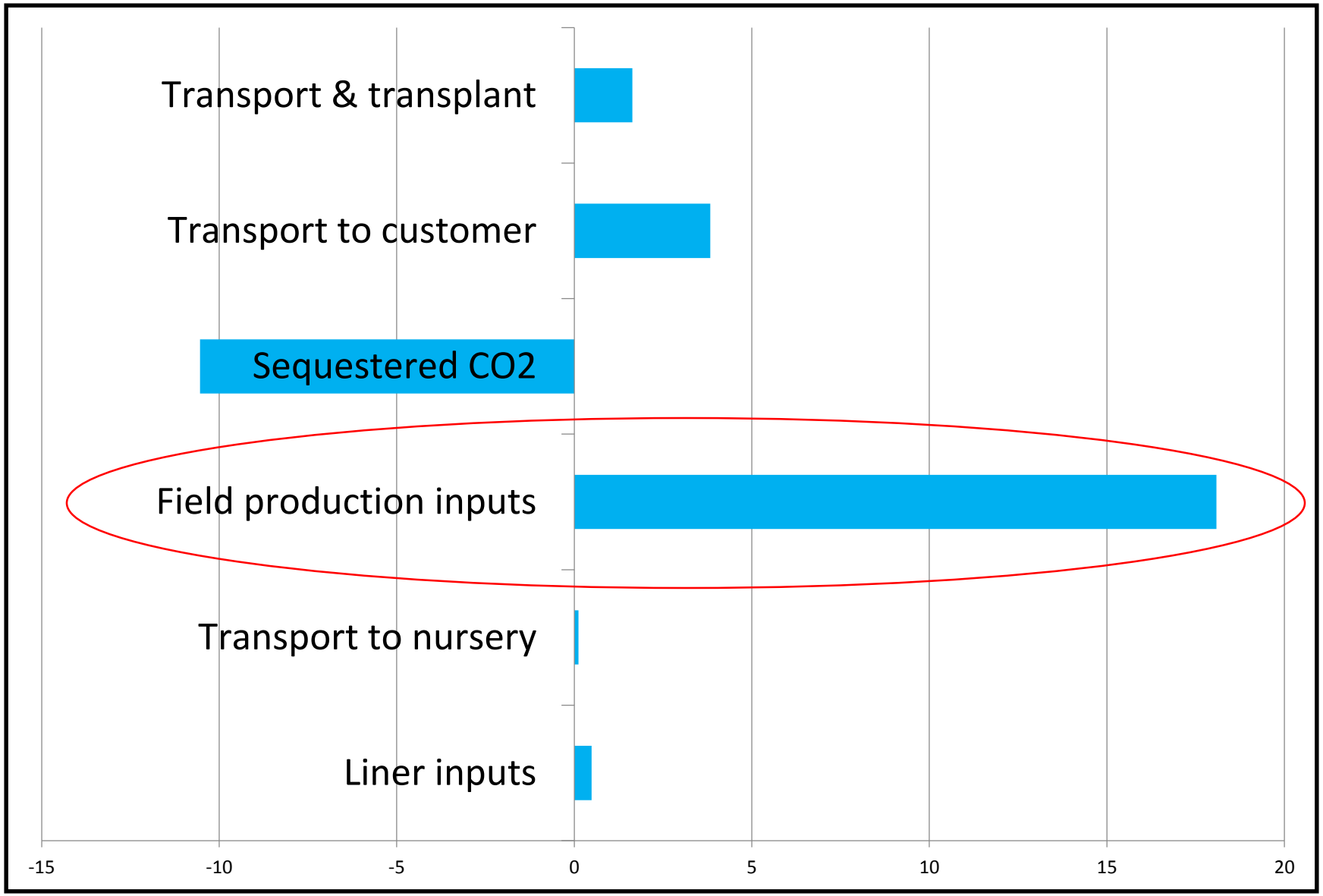
Transport and Transplanting of Tree

- Transport 240 miles to customer, 120 trees/load
- Transport another 20 miles to the landscape site
- Tractor with boom positioned the tree for transplanting

Redbud


Transport & transplant
Transport to customer
Sequestered CO2
Field production inputs
Transport to nursery
Liner inputs
-15
-10
-5
0
5
10
15
20

Redbud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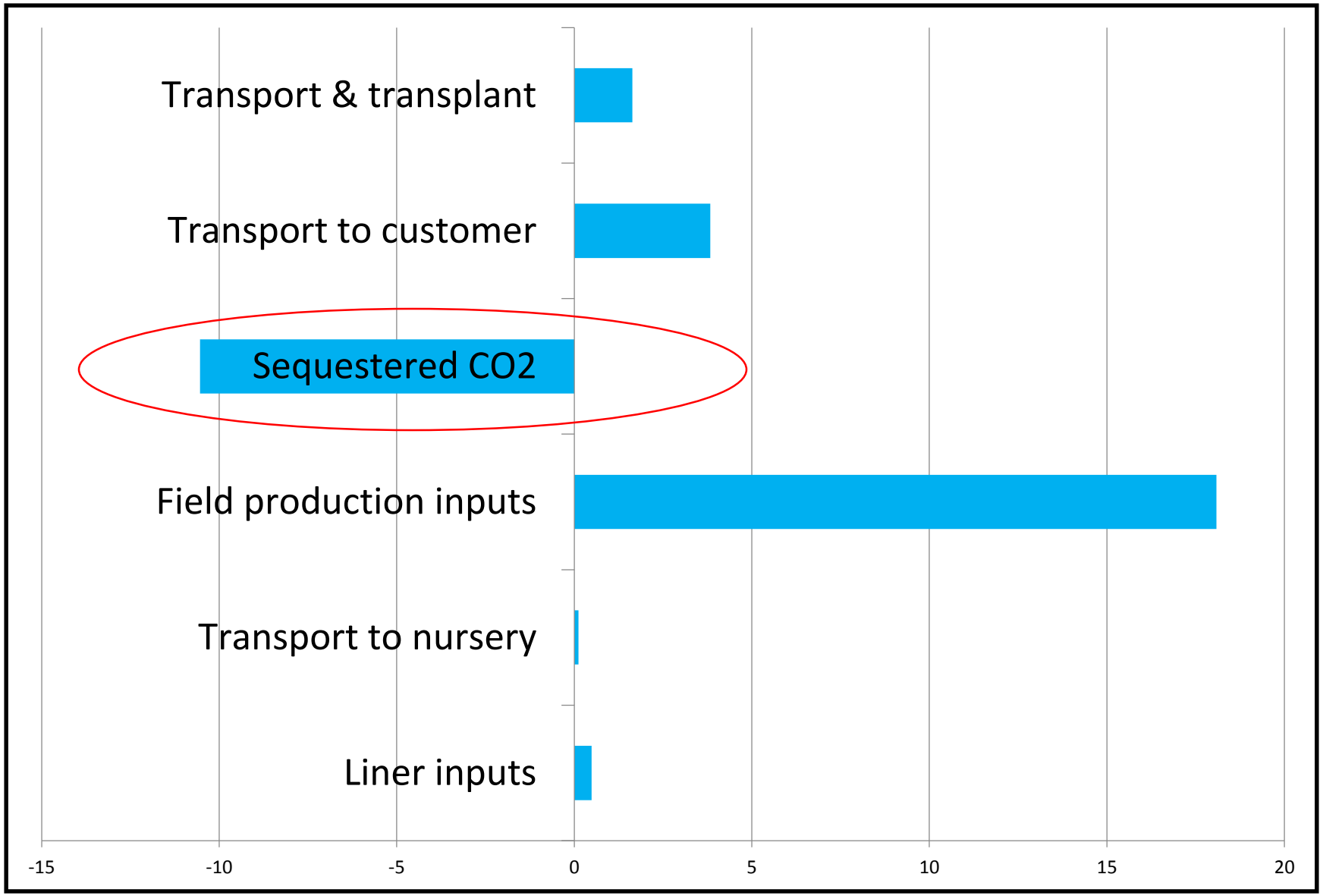
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0
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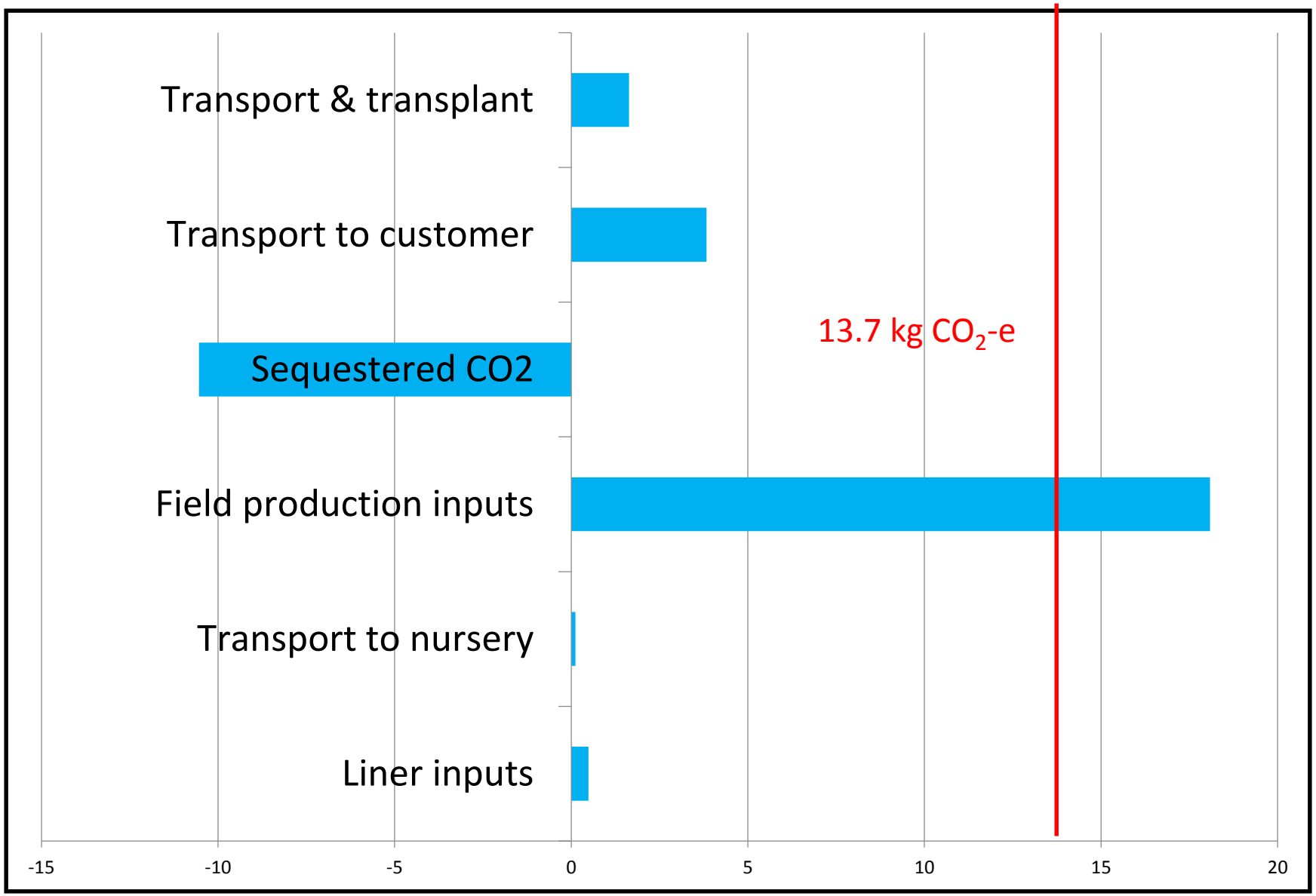
10
15
20

Redbud


Transport & transplant
Transport to customer
Sequestered CO2
Field production inputs
Transport to nursery
Liner inputs
13.7 kg CO_2-e
-15
-10
-5
0
5
10
15
20

Tree Species and "System" Comparisons

(kg CO_2e)

	Blue Spruce	Red Maple	Redbud
Liner - inputs	0.013	0.115	0.153
Liner - equipment use	0.021	0.311	0.169
Liner transport	0.008	0.105	0.123
Liner nursery overhead	0.001	0.005	0.157
Field Production - inputs	3.467	2.878	3.649
Field Production - equipment use	13.069	10.146	12.016
Field nursery overhead	0.581	1.083	1.304
Sequestered C in production	-9.000	-12.100	-10.539
Transport to landscaper	2.434	4.565	3.831
Transport to site & transplant	3.142	3.766	3.202
Propagation-to-landscape	**13.6**	**10.3**	**13.7**

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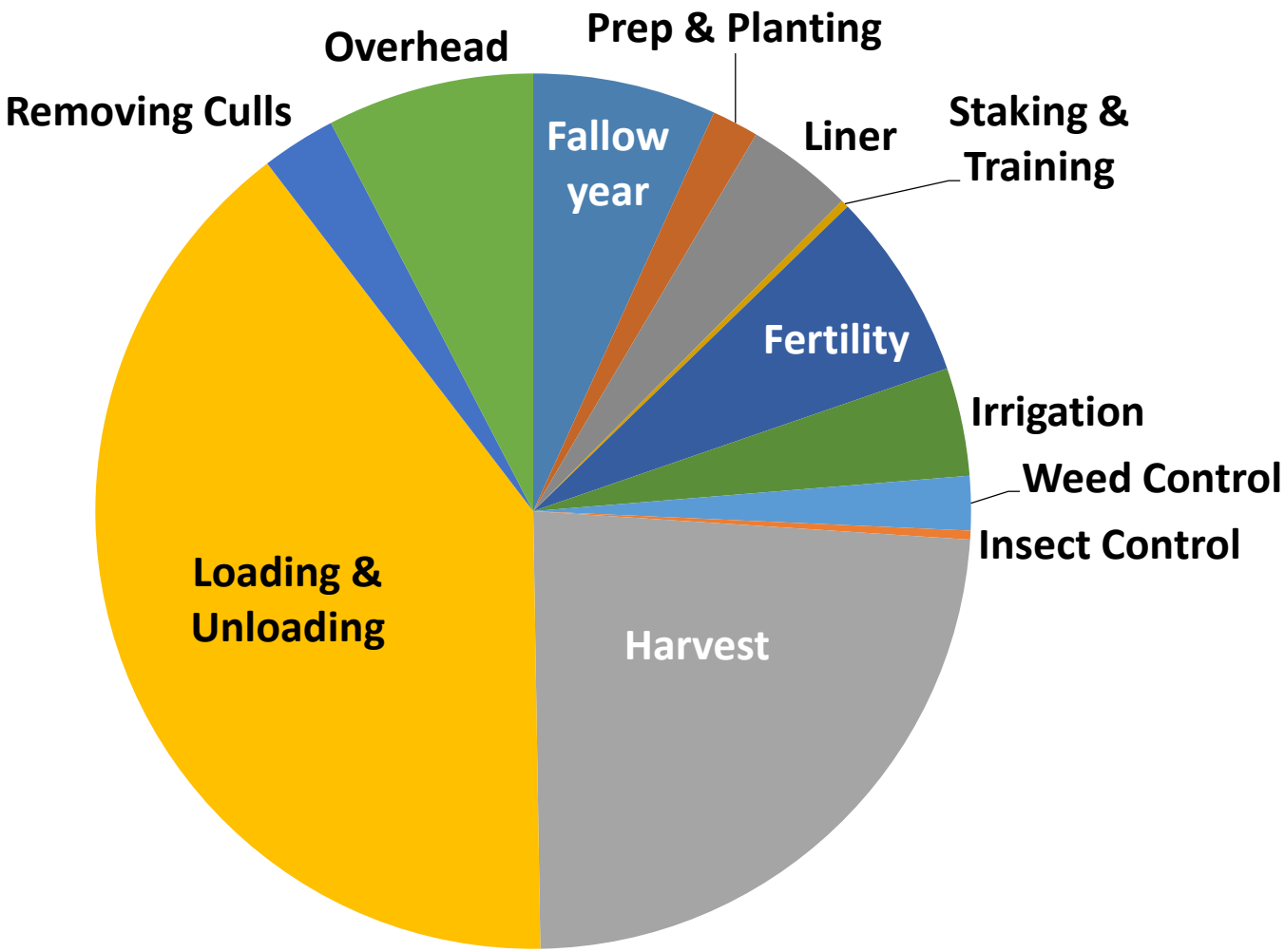
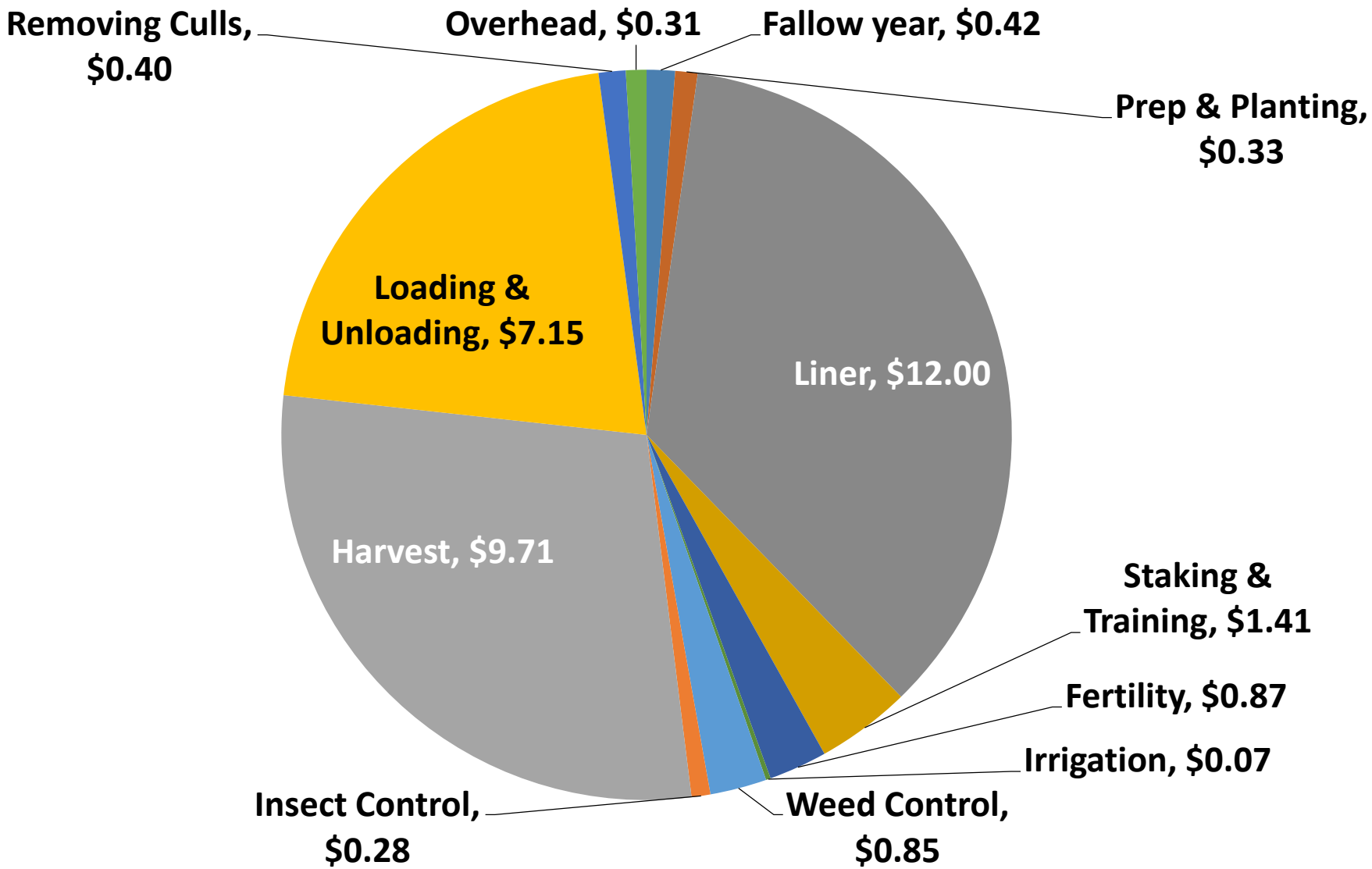


Collaboration with Dr. Charlie Hall

Relative cost of materials, labor and equipment use during redbud field production

($)



Farm-Gate GWP
and
Variable Costs of field-grown trees are closely related…

Primarily due to
<u>equipment use</u>

“so what”
can be addressed by
“what if”
using the models

What if…. for redbud

it took 4 years in the field vs 3 years

Increase cutting-to-landscape carbon footprint by

4% to 14.1 kg CO_2e

Add $0.77 to the cost of each tree

What if…. for redbud

the cull rate was 15% instead of 10%

Increase seed-to-gate carbon footprint by

9% or 0.619 kg CO_2e

Add $1.42 to the cost of each tree

What if…. for redbud

reduce fertilizer by 1/3

Decrease cutting-to-landscape carbon footprint by

0.396 kg CO_2e

Reduce cost $0.28

What if…. for redbud

Product shipping distance was reduced by 1/3 to 160 miles

<u>Decrease</u>

cutting-to-landscape carbon footprint by

16% to 11.4 kg CO_2e

Save $2.60 per tree

What if…. for redbud

Transported 100 trees / load to landscaper instead of 120

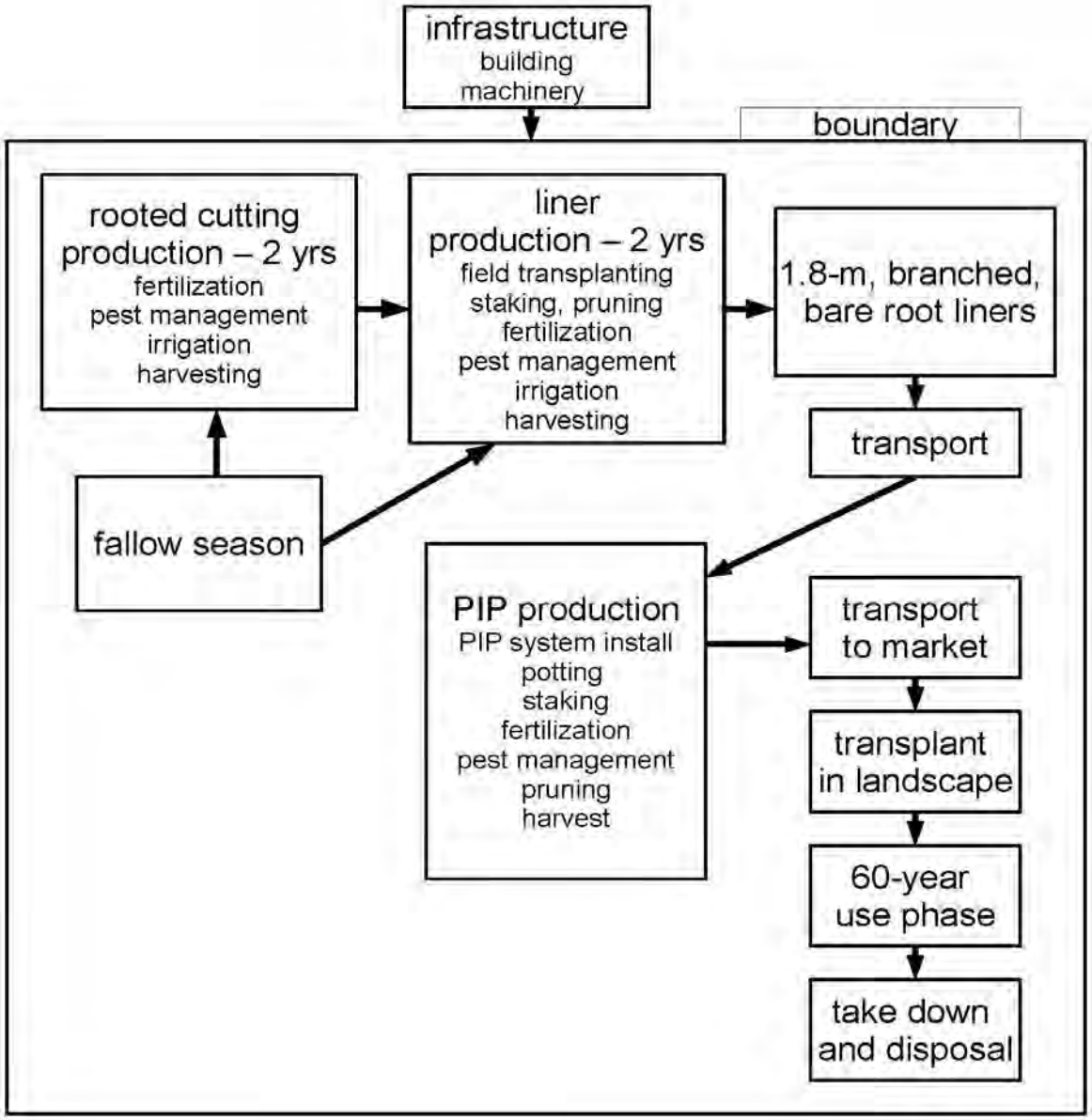
<u>Increase</u>

cutting-to-landscape carbon footprint by

5% to 14.5 kg CO_2e

Cost by $1 per tree

#25 PIP red maple life cycle protocol



Red Maple PIP Production

Activity / Components	Materials GWP (kg CO_2e)	Equipment GWP (kg CO_2e)	Total GWP (kg CO_2e)
PIP system installation	0.3184	0.9610	1.2794
Irrigation system installation	0.0433	0.0000	0.0433
Landscape fabric	2.4029	0.0000	2.4029
Insert/growing container	3.8250	0.0000	3.8250
Substrate	3.3033	0.2603	3.5636
Potting liners	1.4204	0.0044	1.4248
Transport containers to field	0.0000	0.2109	0.2109
Staking and training	0.2020	0.0000	0.2020
Irrigation	0.0000	0.2159	0.2159
Apply fertilizer (15-9-12)	1.4515	0.0000	1.4515
Apply herbicides	0.0775	0.0000	0.0775
Scouting & apply insecticides	0.0154	0.0515	0.0669
Transport from field	0.0000	0.2109	0.2109
Loading into truck/trailer	0.0000	0.0829	0.0829
Energy overhead		0.2595	0.2595
Total GWP	**13.0597**	**2.2574**	**15.3171**

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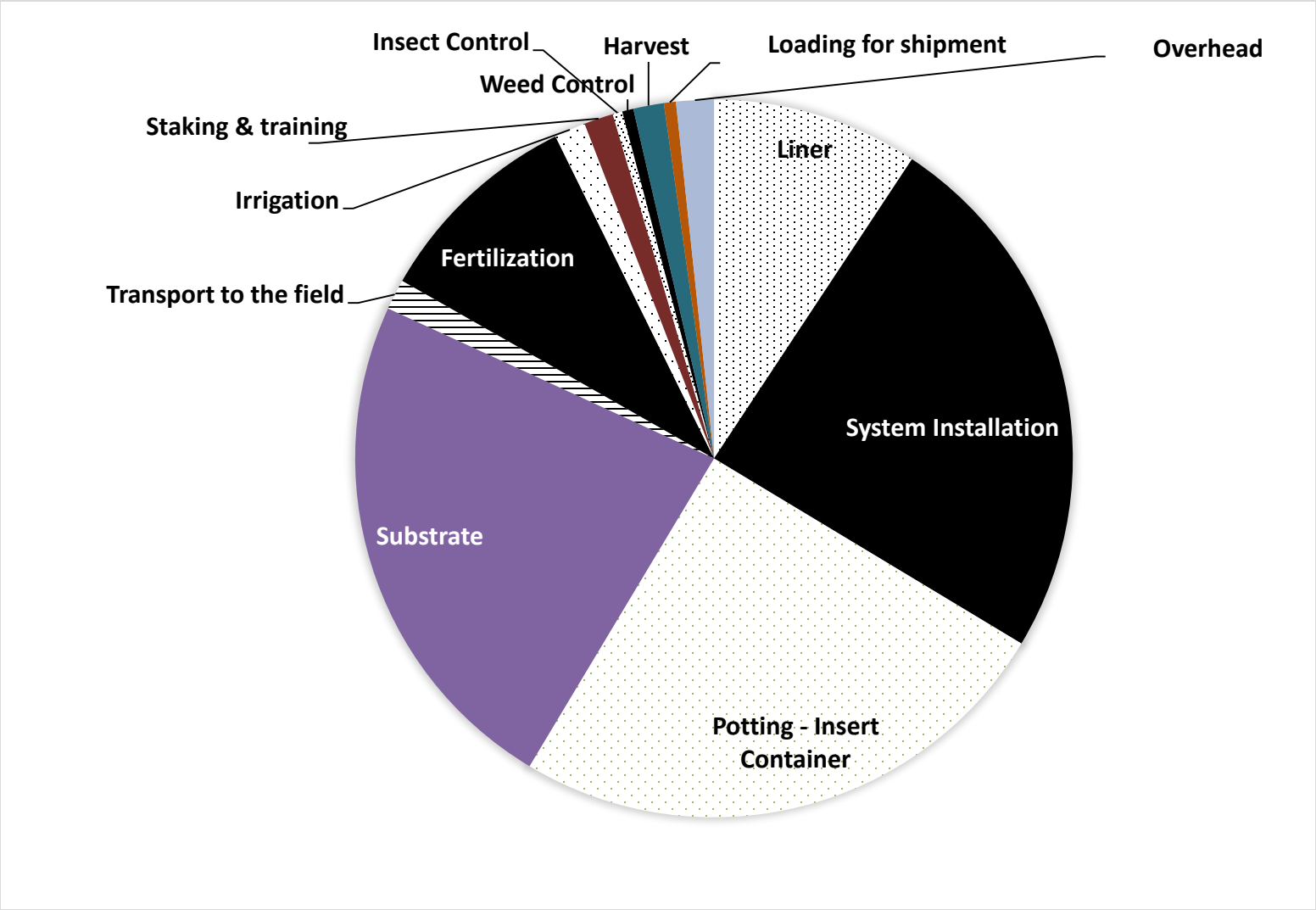
Irrigation	0.0000	0.2159	0.2159
Apply fertilizer (15-9-12)	1.4515	0.0000	1.4515
Apply herbicides	0.0775	0.0000	0.0775
Scouting & apply insecticides	0.0154	0.0515	0.0669
Transport from field	0.0000	0.2109	0.2109
Loading into truck/trailer	0.0000	0.0829	0.0829
Energy overhead		0.2595	0.2595
Total GWP	**13.0597**	**2.2574**	**15.3171**

Relative GWP of red maple PIP production components in a #25 container (cutting-to-gate)

(kg CO_2e / tree)



Carbon sequestration during production

15.317 CO_2e emissions during production

- 4.575 CO_2e sequestered, weighted for 100 yr

10.742 CO_2e Carbon Footprint (GWP) at gate

Red Maple PIP Production

Variable costs ($)

Activity / Components	Material Costs ($)	Equipment Costs ($)	Labor Costs ($)	Total Costs ($)
PIP system installation	0.9435	0.4495	1.8913	3.2843
Irrigation system installation	0.0000	0.0000	0.0000	0.0000
Landscape fabric	1.2600	0.0000	0.0125	1.2725
Insert/growing container	11.8500	0.0000	0.0000	11.8500
Substrate	3.9683	0.1230	0.0827	4.1739
Potting liners	22.0000	0.1727	2.0048	24.1775
Transport containers to field	0.0000	0.1919	1.9578	2.1498
Staking and training	0.8000	0.0000	2.9237	3.7237
Irrigation	0.0000	0.0653	0.4277	0.4930
Apply fertilizer (15-9-12)	1.1112	0.0000	0.0908	1.2020
Apply herbicides	0.1246	0.0025	0.0470	0.1741
Scouting & apply insecticides	0.1790	0.0674	0.2158	0.4622
Transport from field	0.0000	0.1919	1.9578	2.1498
Loading into truck/trailer	0.0000	0.0212	0.2707	0.2918
Energy overhead		0.0830		0.0830
Total Costs	**42.2365**	**1.3685**	**11.8827**	**55.4877**

Red Maple PIP Production

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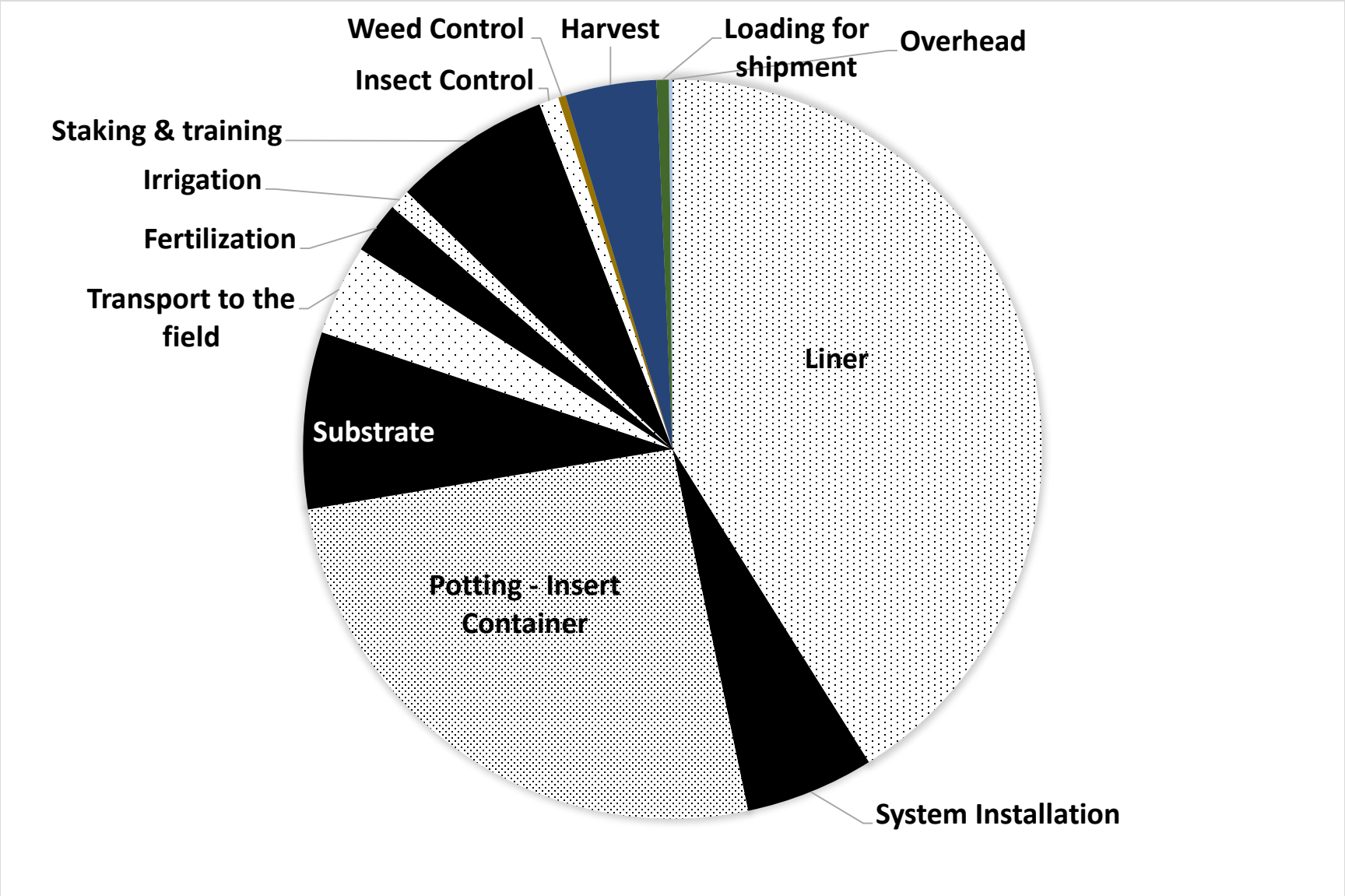
Energy overhead		0.0830		0.0830
Total Costs	**42.2365**	**1.3685**	**11.8827**	**55.4877**

Variable Costs [input materials, equipment use and labor] for #25 red maple PIP production (cutting-to-gate) ($)



What if…. 300 #25 containers were in each truck load instead of 225

decrease cutting-to-landscape carbon footprint by

0.63 kg CO_2e

Reduce cost by $0.87 per tree

2-inch caliper red maple tree

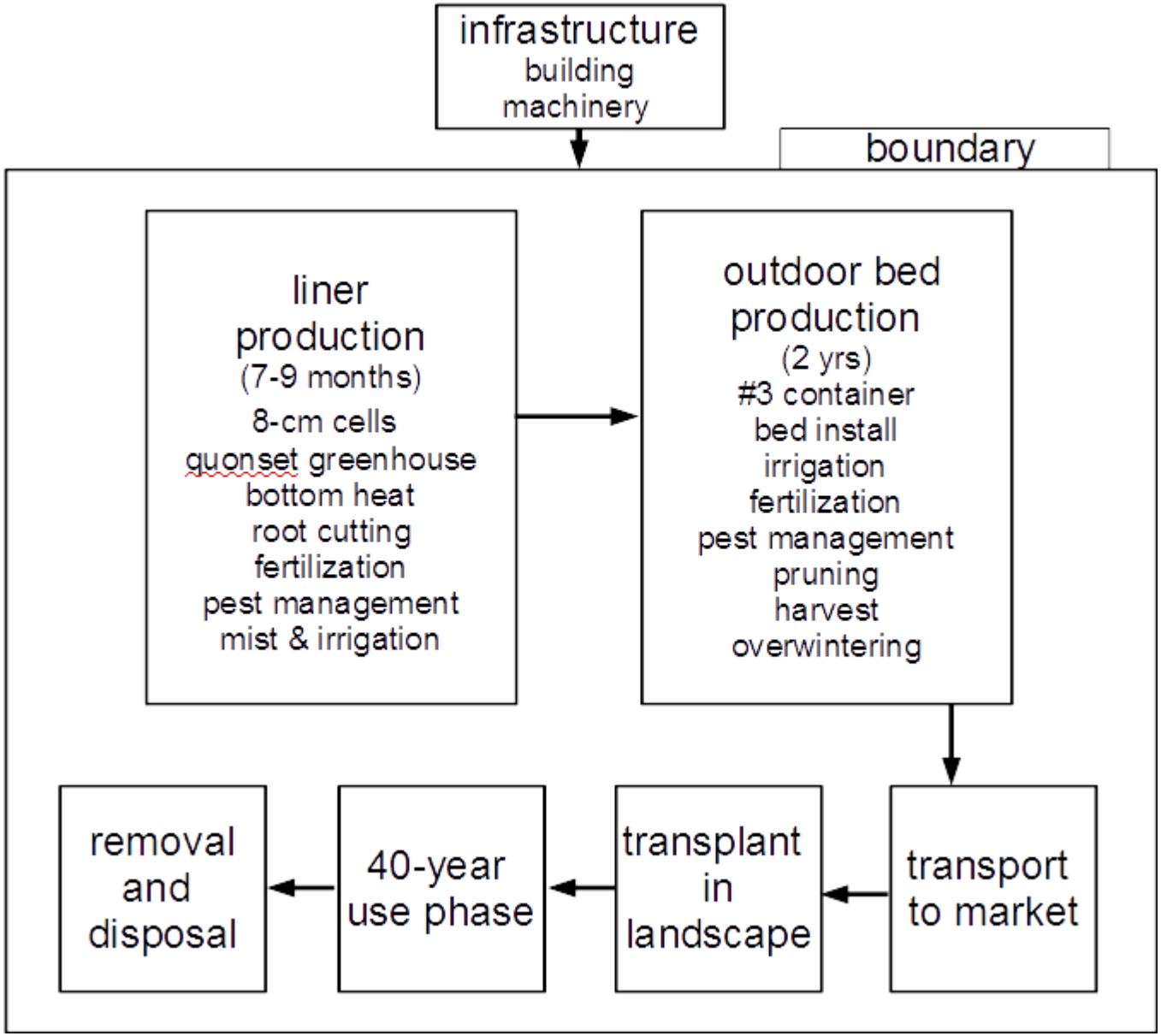
Pot-in-Pot Production

Component	GWP (kg CO_2e)	Variable Cost ($)
Rooted cutting stage	**0.0814**	**$0.3511**
Liner stage	**1.2784**	**$5.3856**
PIP nursery stage	**15.3171**	**$55.4877**
TOTAL - farm gate GWP & Cost	**10.7421**	**$55.4877**
Postharvest stage		
Transport tree to customer	2.6268	$3.4667
Transport tree to landscape	2.2837	$1.9023
Planting in the landscape	0.0000	$21.2010
Subtotal - postharvest stage	**4.9105**	**$26.5700**
TOTAL cutting to landscape	**15.6527**	**$82.0576**

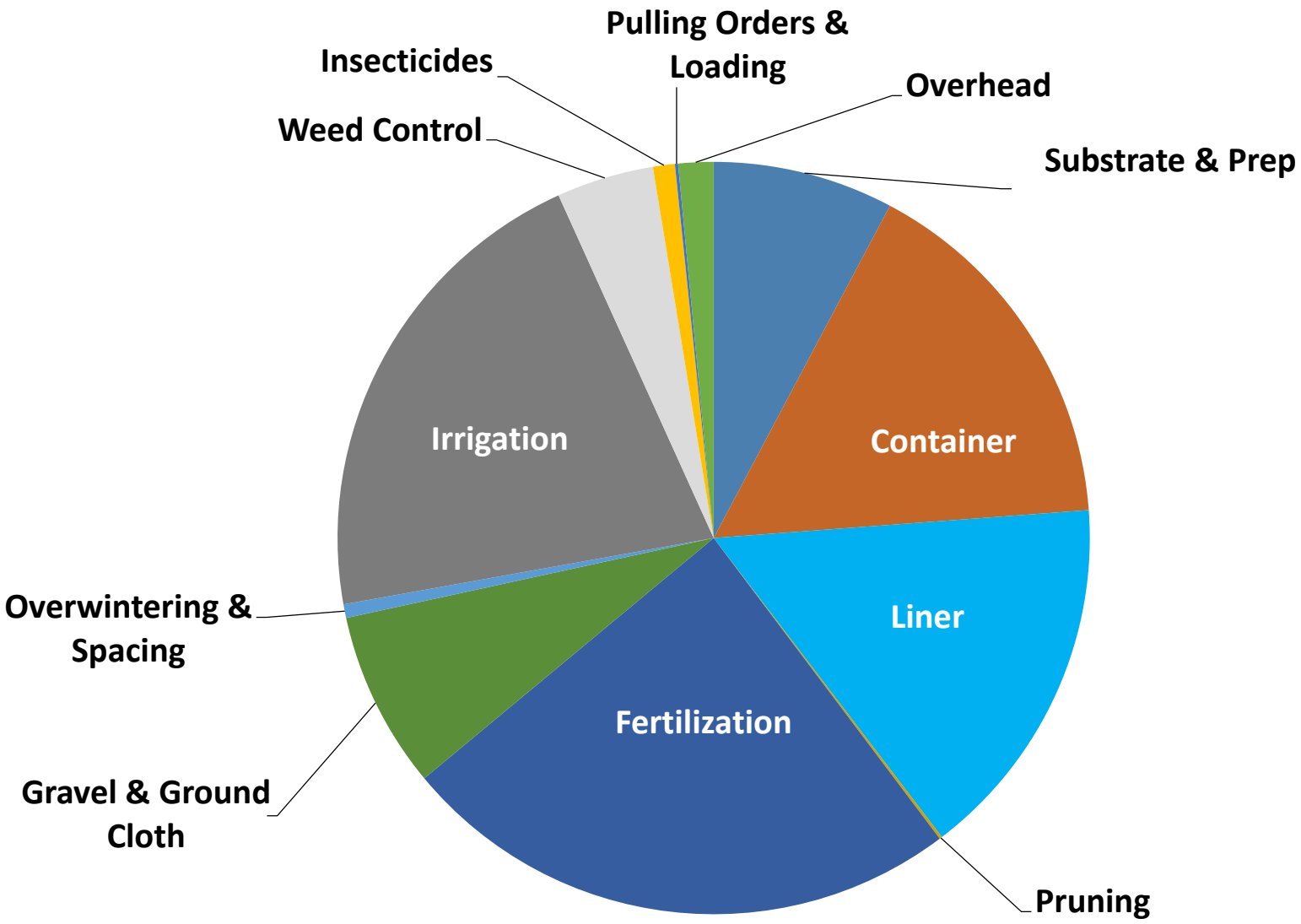
Field Production

Component	GWP (kg CO_2e)	Variable Cost ($)
Rooted cutting stage	**0.0128**	**$0.0986**
Liner stage	**0.4885**	**$2.6421**
Field Production stage	**17.0730**	**$36.6583**
TOTAL - farm gate GWP & Cost	**12.4980**	**$36.6583**
Postharvest stage		
Transport tree to customer	4.6560	$6.2400
Transport tree to landscape	2.8544	$2.3777
Planting in the landscape	0.9194	$22.1499
Subtotal - postharvest stage	**8.4298**	**$30.7676**
TOTAL cutting to landscape	**20.9278**	**$67.4260**

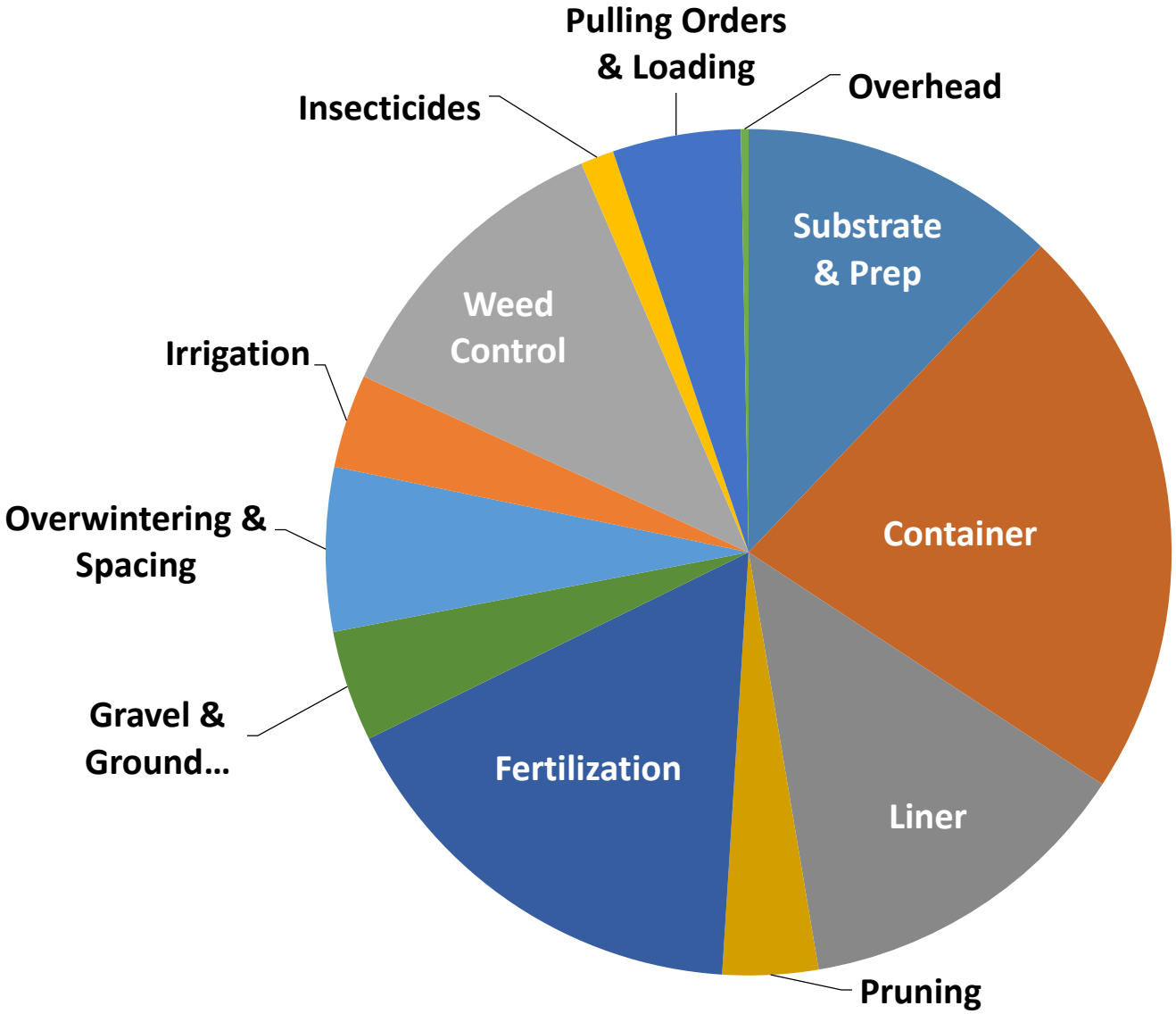
#3 I.c. 'Bennett's Compacta' life cycle protocol



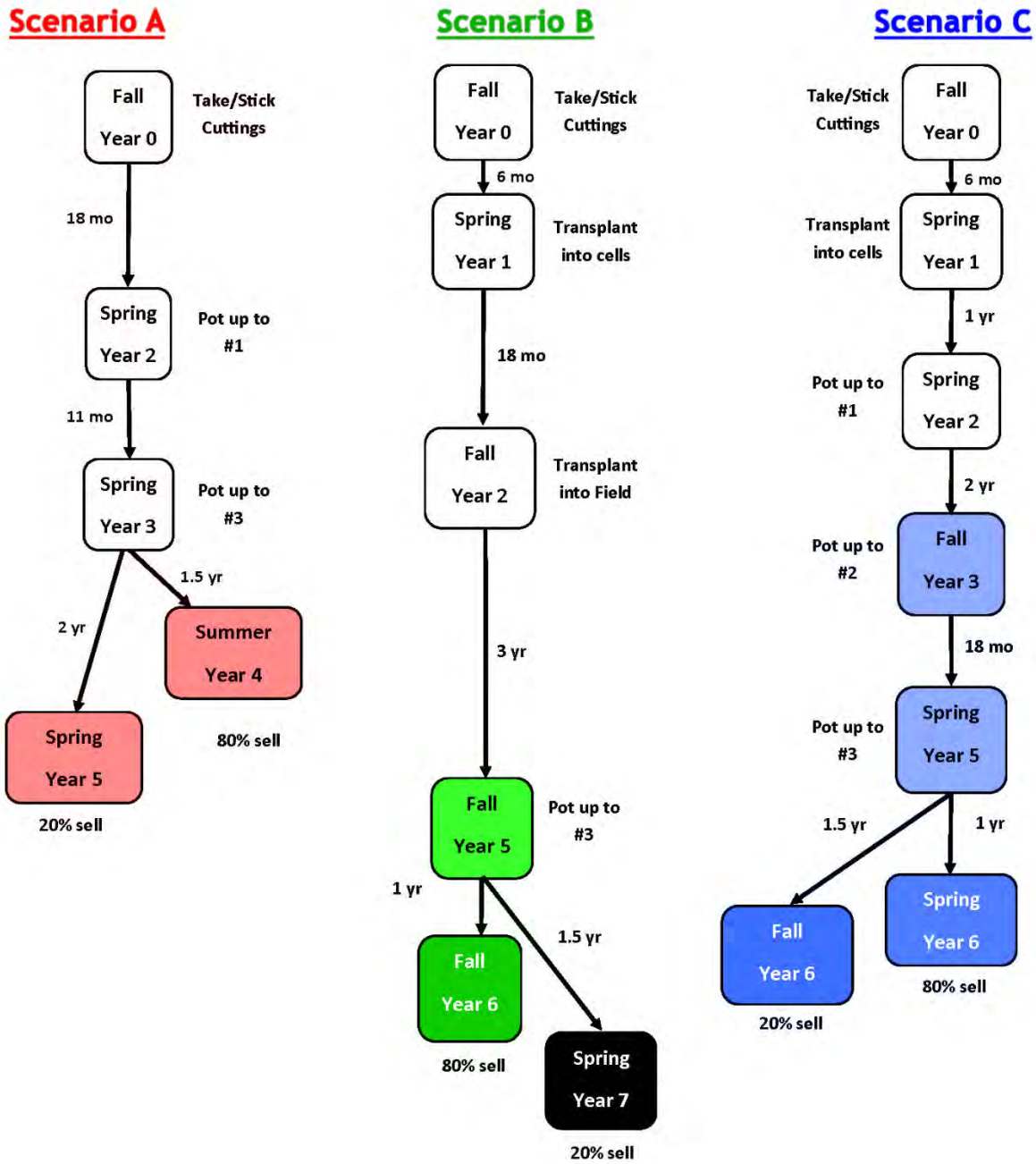
GHG emissions of #3 l.c. 'Bennett's Compacta' - East Coast Production Components (cutting-to-gate)

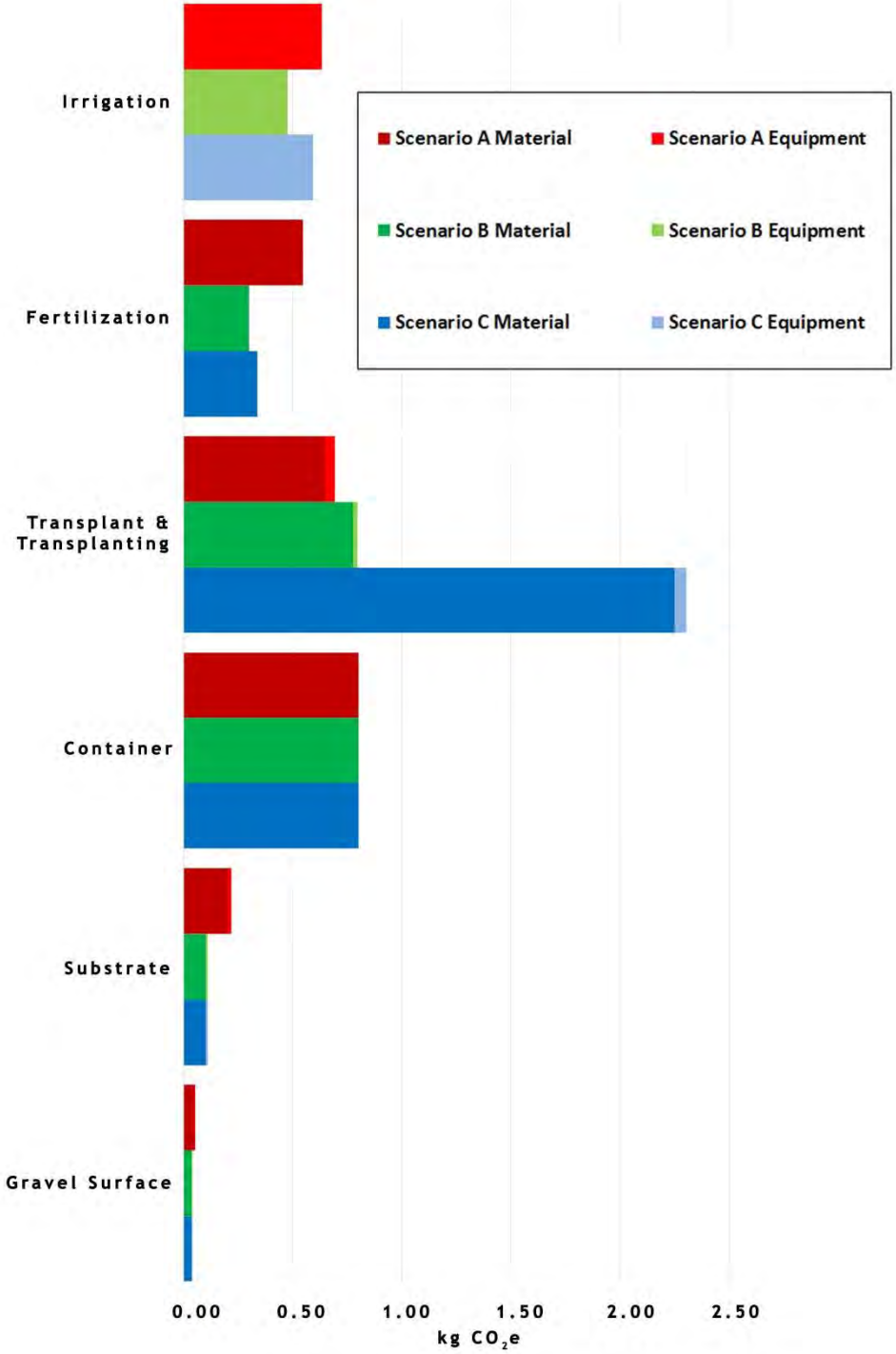


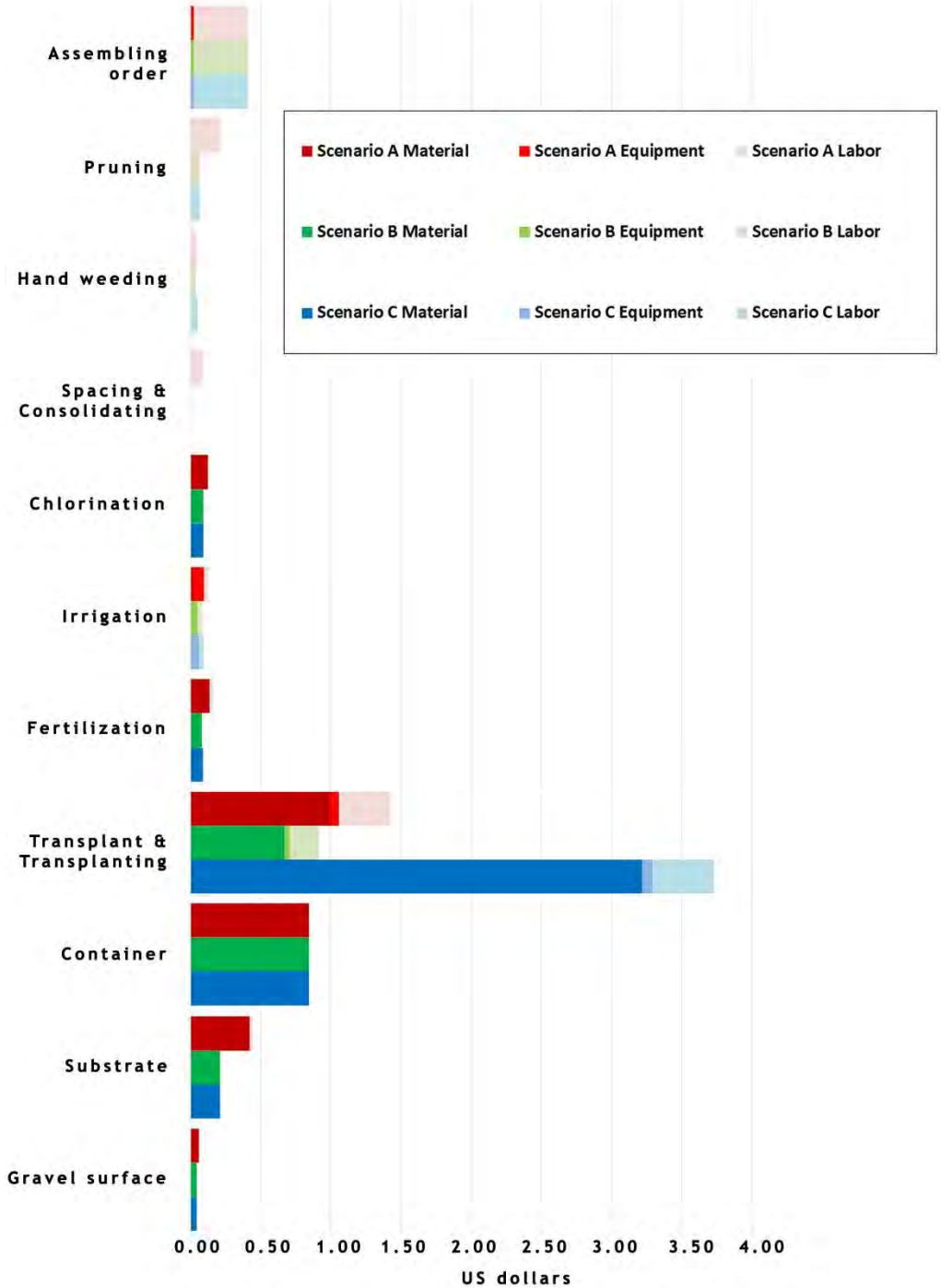
Variable Costs of #3 l.c. 'Bennett's Compacta' – East Coast Production Components (cutting-to-gate)



#3 Boxwood Alternative Production Scenarios on the West Coast


Scenario A
Fall Year 0
Take/Stick Cuttings
18 mo
Spring Year 2
Pot up to #1
11 mo
Spring Year 3
Pot up to #3
1.5 yr
2 yr
Summer Year 4
Spring Year 5
80% sell
20% sell
Scenario B
Fall Year 0
Take/Stick Cuttings
6 mo
Spring Year 1
Transplant into cells
18 mo
Fall Year 2
Transplant into Field
3 yr
Fall Year 5
Pot up to #3
1 yr
1.5 yr
Fall Year 6
Spring Year 7
80% sell
20% sell
Scenario C
Take/Stick Cuttings
Fall Year 0
6 mo
Transplant into cells
Spring Year 1
1 yr
Pot up to #1
Spring Year 2
2 yr
Pot up to #2
Fall Year 3
18 mo
Pot up to #3
Spring Year 5
1.5 yr
1 yr
Fall Year 6
Spring Year 6
20% sell
80% sell


Irrigation
Fertilization
Transplant & Transplanting
Container
Substrate
Gravel Surface
Scenario A Material
Scenario A Equipment
Scenario B Material
Scenario B Equipment
Scenario C Material
Scenario C Equipment
0.00
0.50
1.00
1.50
2.00
2.50
kg CO_2e


Assembling order
Pruning
Hand weeding
Spacing & Consolidating
Chlorination
Irrigation
Fertilization
Transplant & Transplanting
Container
Substrate
Gravel surface
Scenario A Material
Scenario A Equipment
Scenario A Labor
Scenario B Material
Scenario B Equipment
Scenario B Labor
Scenario C Material
Scenario C Equipment
Scenario C Labor
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
US dollars

What we are learning

- Knowing more about the CF and variable costs of individual operations helps managers increase efficiency.
- A few inputs and processes in production account for most of the CF and variable costs.
- Plants provide many ecosystem services, including sequestration of carbon

SCRI - Clean Water^3

Reduce, Remediate, Recycle

USDA NIFA

United States Department of Agriculture

National Institute of Food and Agriculture

Horticultural Research Institute

The AmericanHort Foundation

UK Nursery and Landscape Fund

…a family of industry endowments

University of Kentucky

College of Agriculture, Food and Environment

TEXAS A&M UNIVERSITY