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FOREST CARBON OFFSETS – MARKET EXPANSION, RESEARCH GAPS AND MODELING NEEDS

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Presented at: Southern Forest Assessment Consortium 2022 Annual Meeting
August 10. Durham, NC

What is Driving Market Participation?

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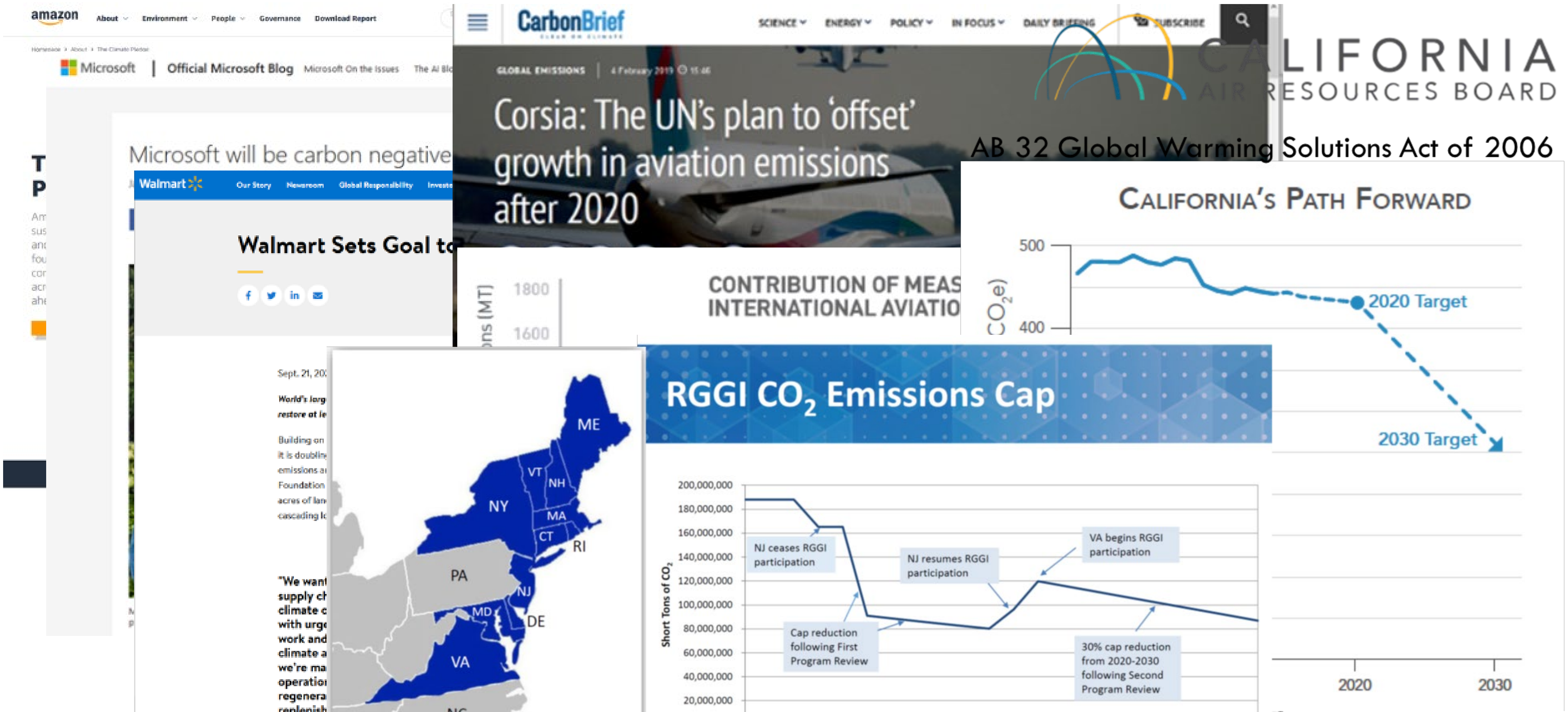
Corporations   Airlines   State/Regional



Types of Projects

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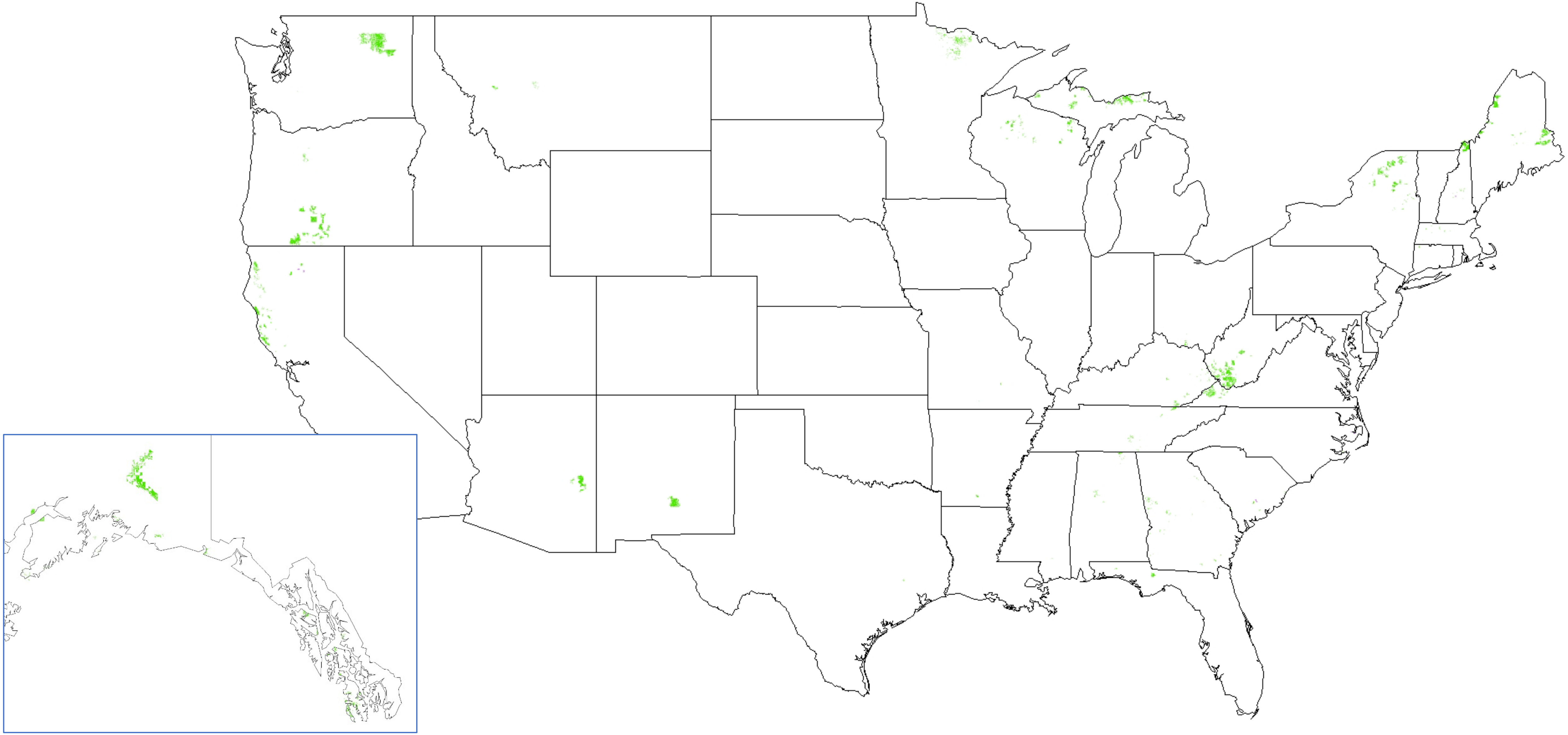
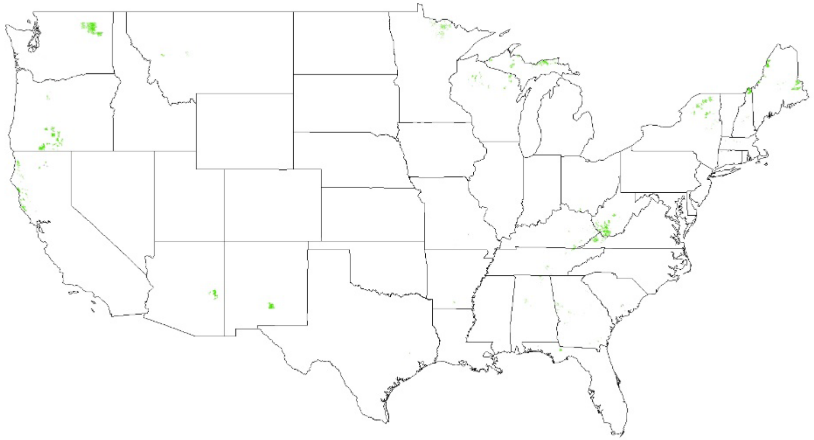
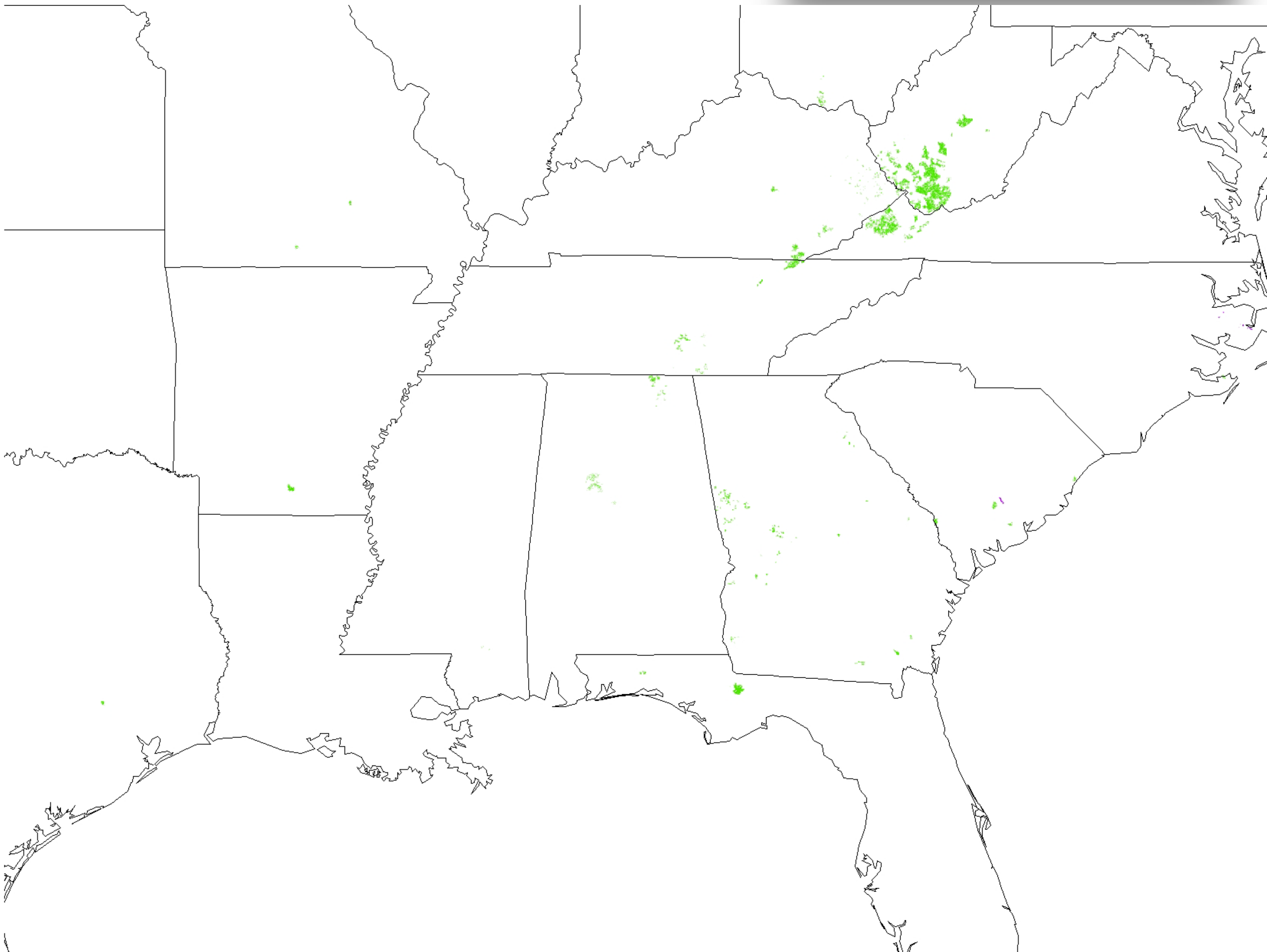
- California Air Resources Board (CARB or ARB)
  - Program: Regulatory program in the state of California
- Climate Action Reserve (CAR)
  - Registry with Programs: Biggest movement lately is Mexico
- American Carbon Registry (ACR)
  - Registry with Programs: Biggest US non-ARB improved forest management (IFM) program
- Verified Carbon Standard (VCS or Verra)
  - Registry with Programs: Biggest international registry – not much in terms of US IFM

Where are these projects - ARB?

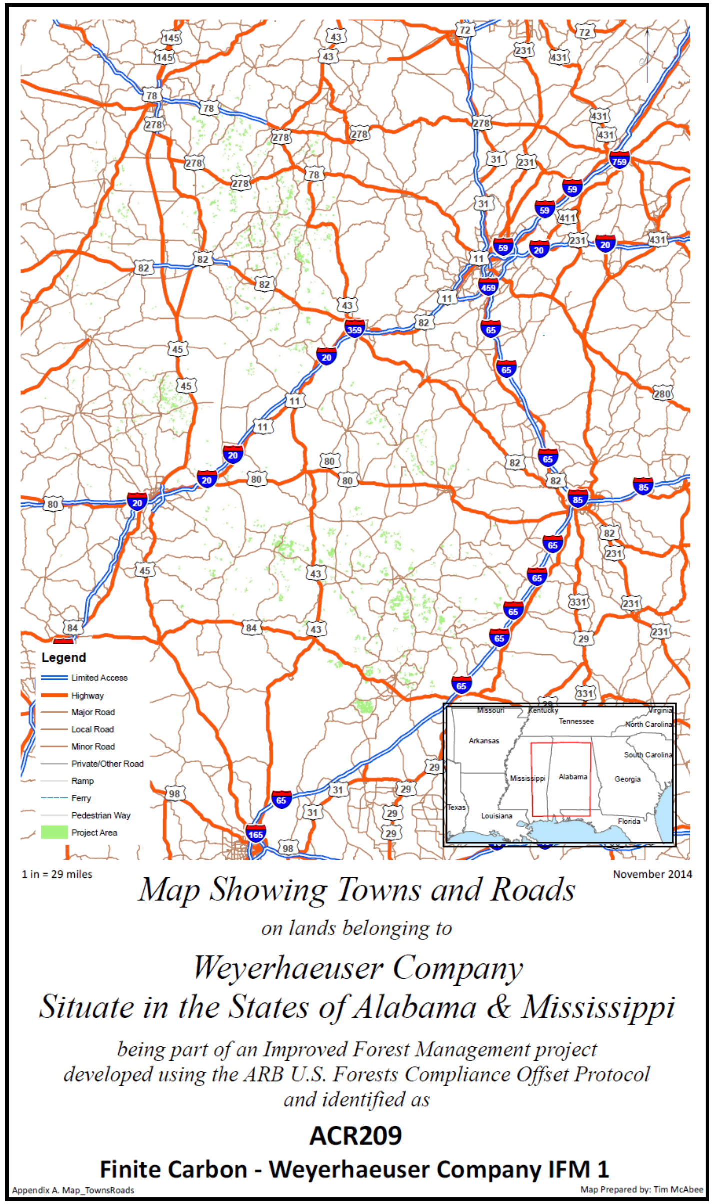


Where are these projects?





Where are these projects - ARB?



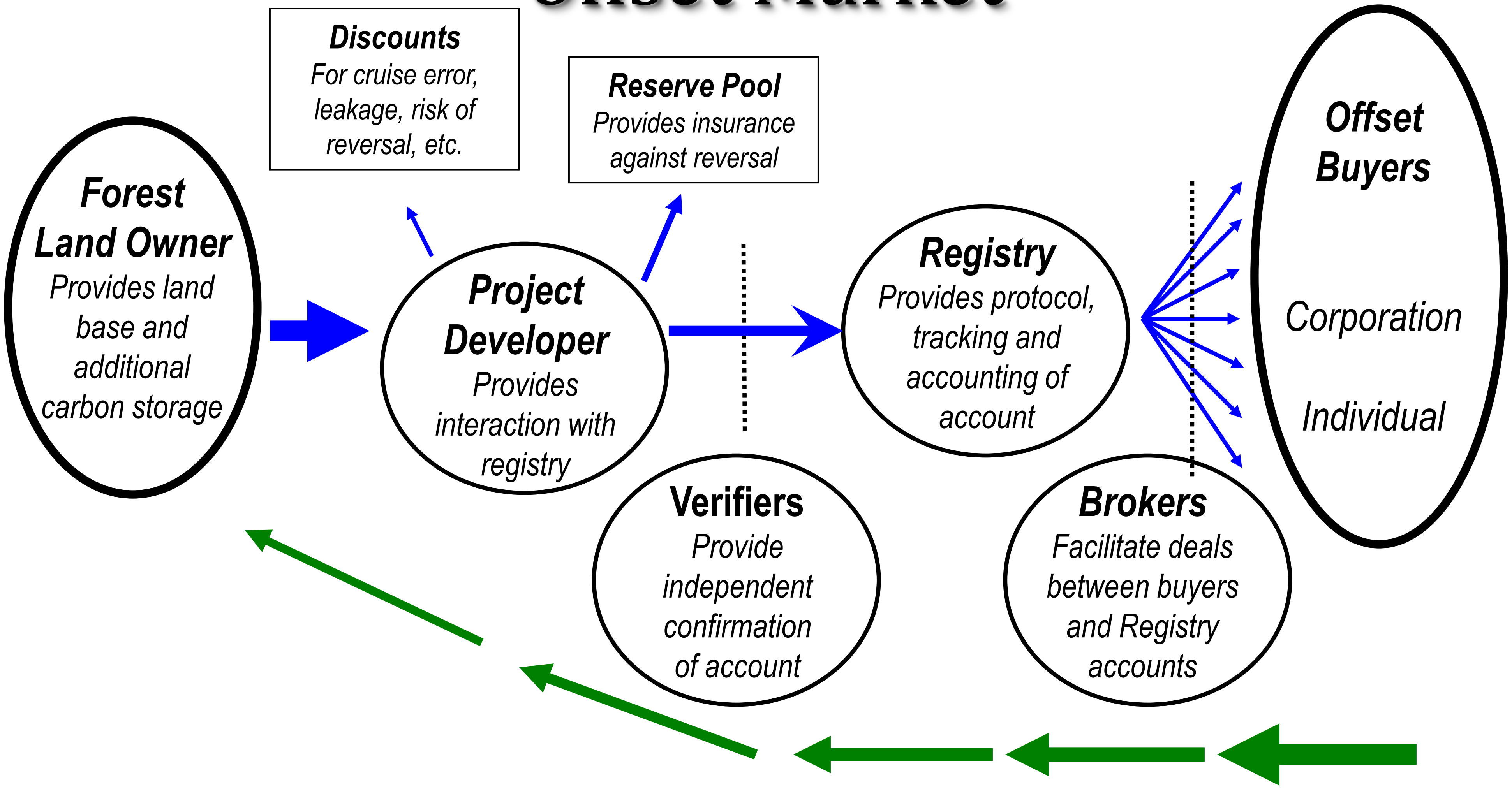
ACR209 – Weyco project not on map

It was listed in 2014, but never a project

Alabama – 3 projects

1) ARB - TCT Birmingham IFM Project
2) ARB - Finite Carbon – Stevenson AL IFM
3) ACR - Bluesource – Sharp Bingham

Following CARBON and MONEY through an Offset Market



How ARB IFM (*Improved Forest Management*) Works

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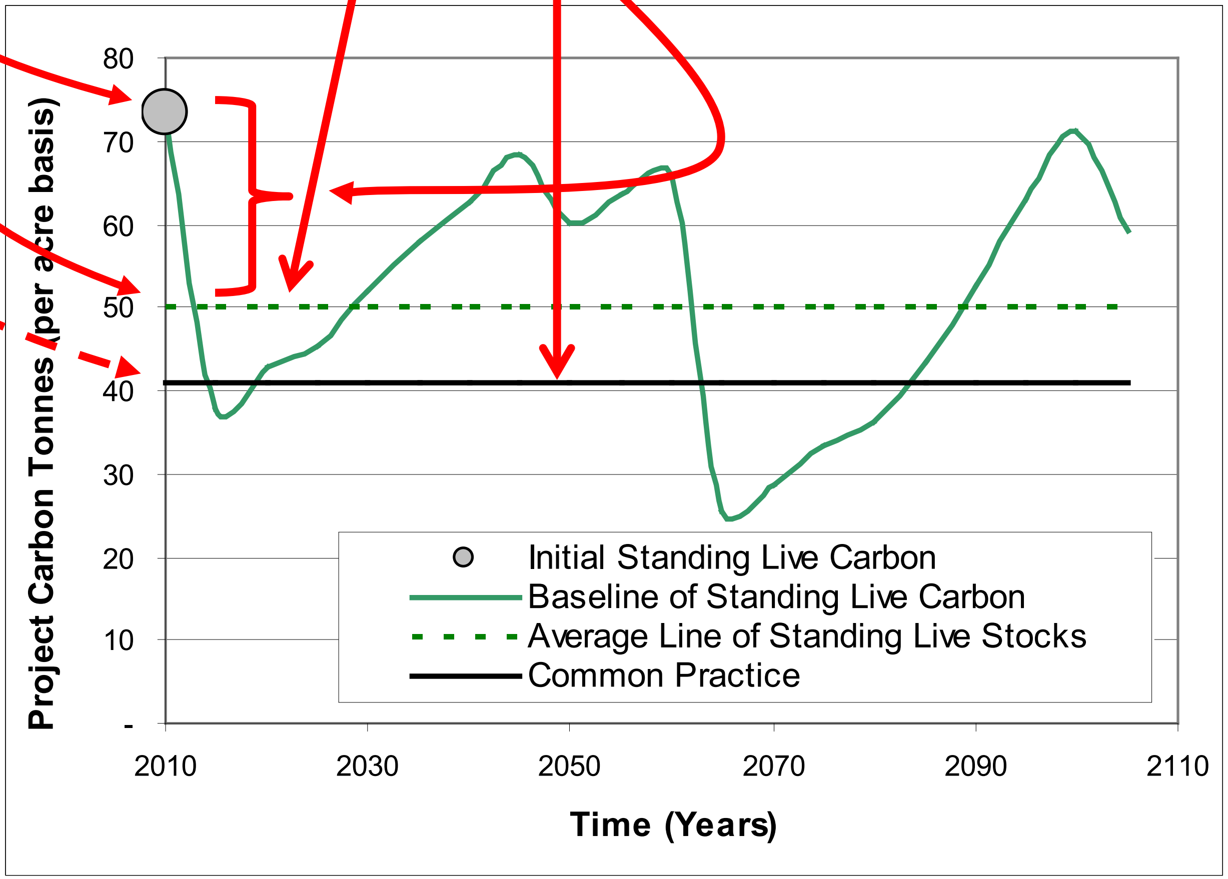
5. Landowner gets a one-time allocation for carbon above Common Practice

3. Conduct a 100 year harvest schedule *(legal and economically viable of course)*

2. Determine CAR Common Practice for your region / forest type

This Average Line

Must be above this Common Practice Line



CLIMATE ACTION RESERVE

California Environmental Protection Agency AIR RESOURCES BOARD

How ARB IFM (*Improved Forest Management*) Works

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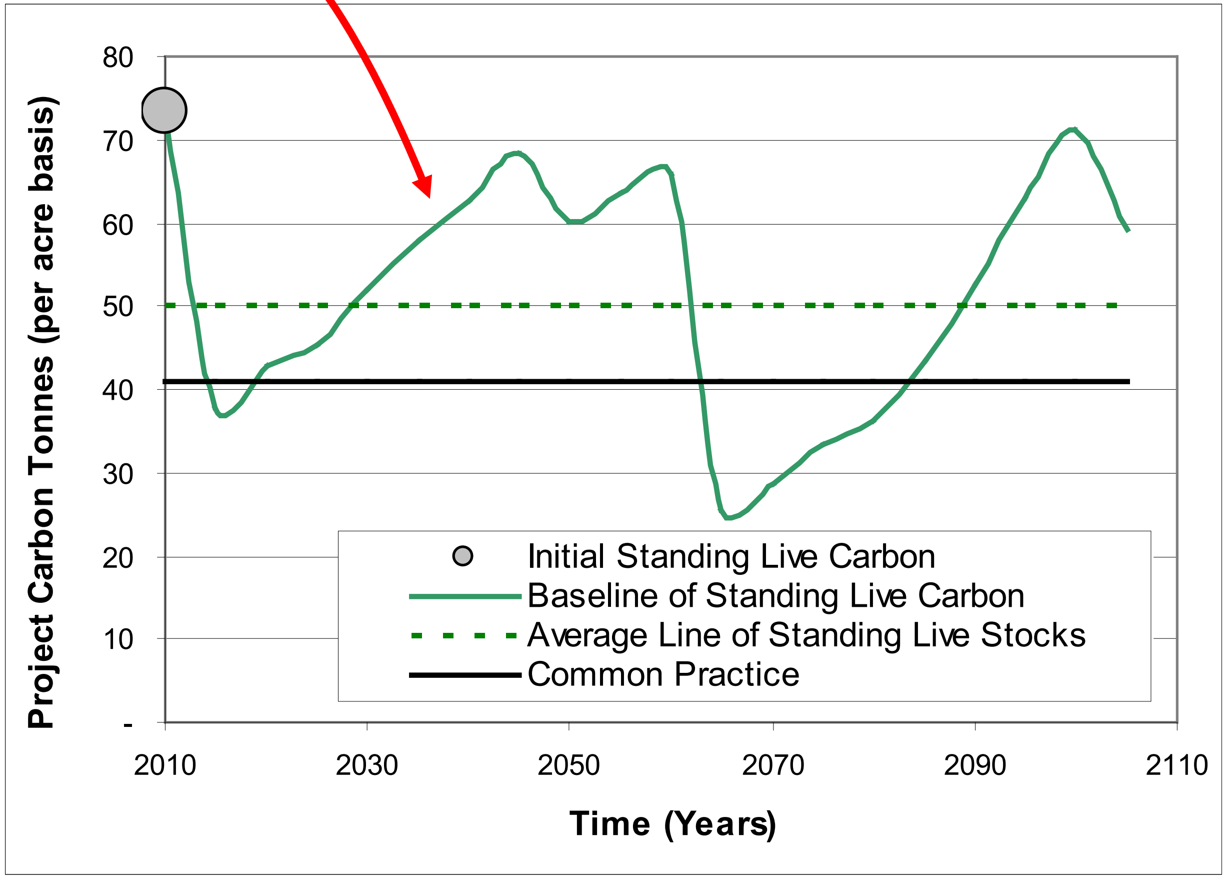
1. When you conduct this 100-year harvest schedule

2. You also average the removals for use in the Harvested Wood Products determination
   - Average of storage in wood products over a 100 year timeframe

3. If you harvest less than this amount in a reporting period, you will be assessed a penalty (reduction in offsets) due to leakage



CLIMATE ACTION RESERVE

California Environmental Protection Agency
AIR RESOURCES BOARD

Stand Type 1

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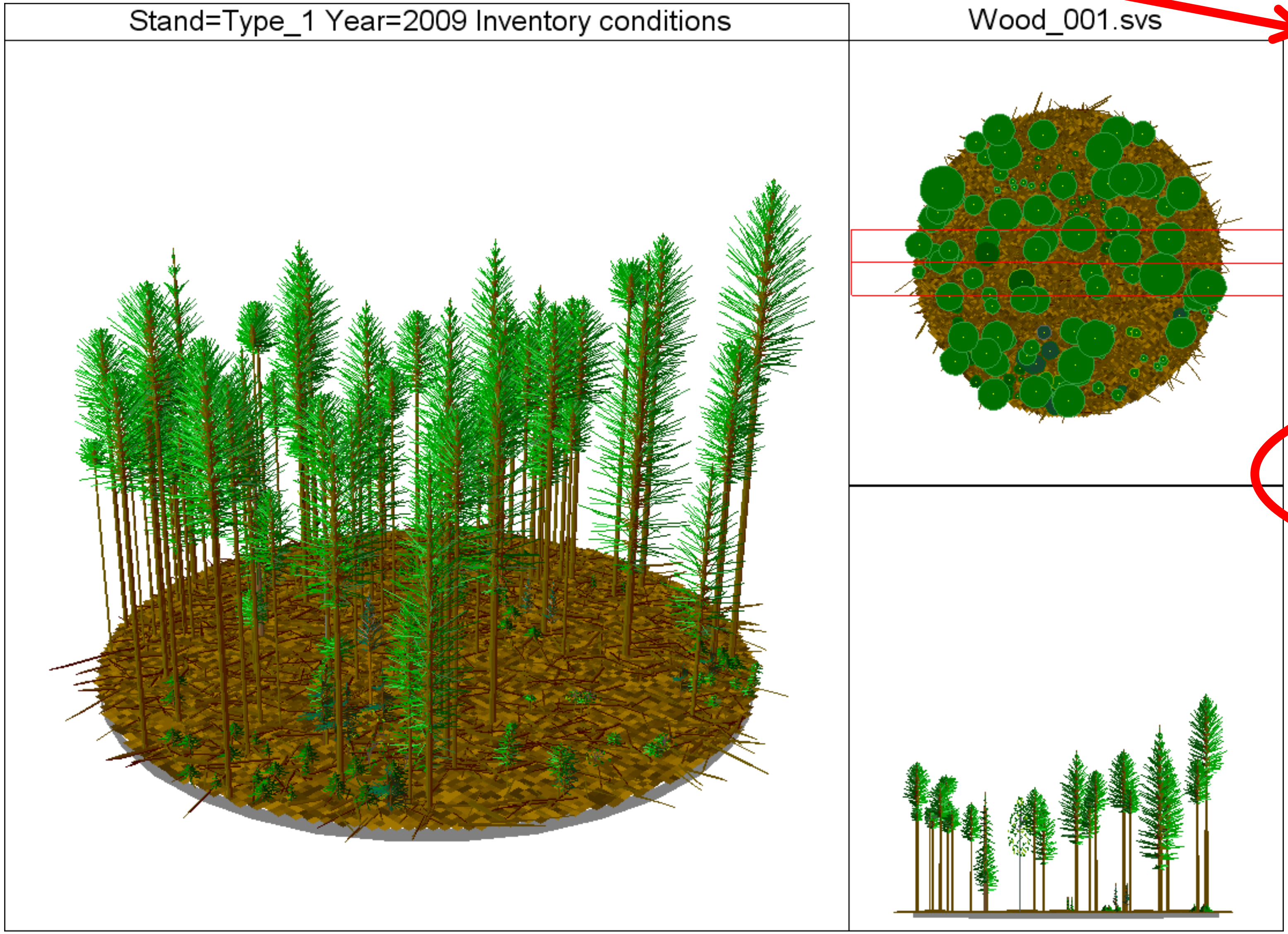
Carbon Stock based on this number



5194 Total Cubic ft / acre

Accumulating 7.3 tons / acre of CO_2 per year

Carbon Flux is what we care about

Stand Type 2

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Lower Stock

740 Total Cubic ft / acre

Accumulating 19.21 tons / acre of CO_2 per year

Higher Flux

Types of Projects

Avoided Conversion (AC)

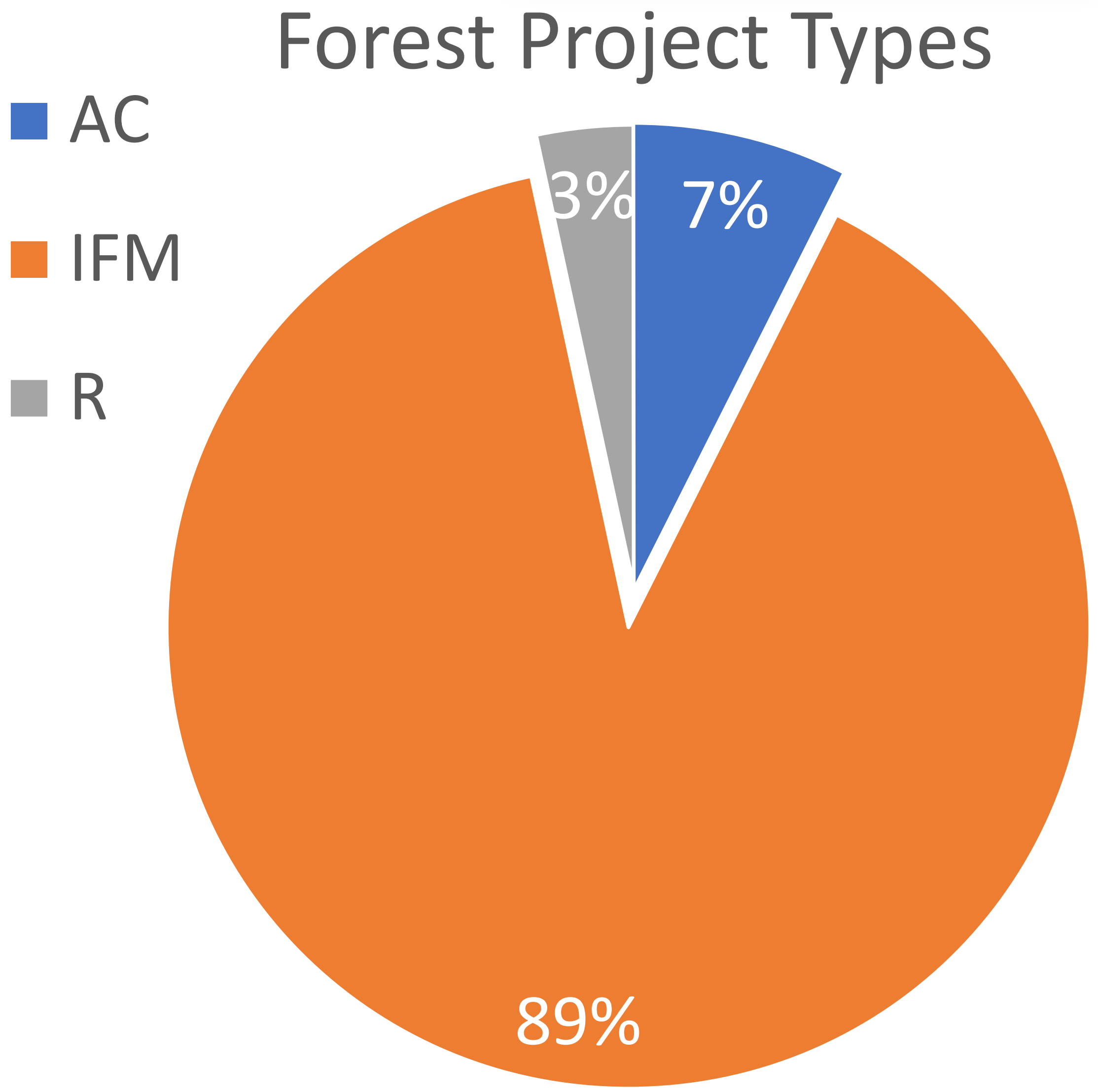
- Forests prevented from being converted to non-forested land

Improved Forest Management (IFM)

- Forest management that increases and maintains a certain level of carbon stocking

Reforestation R

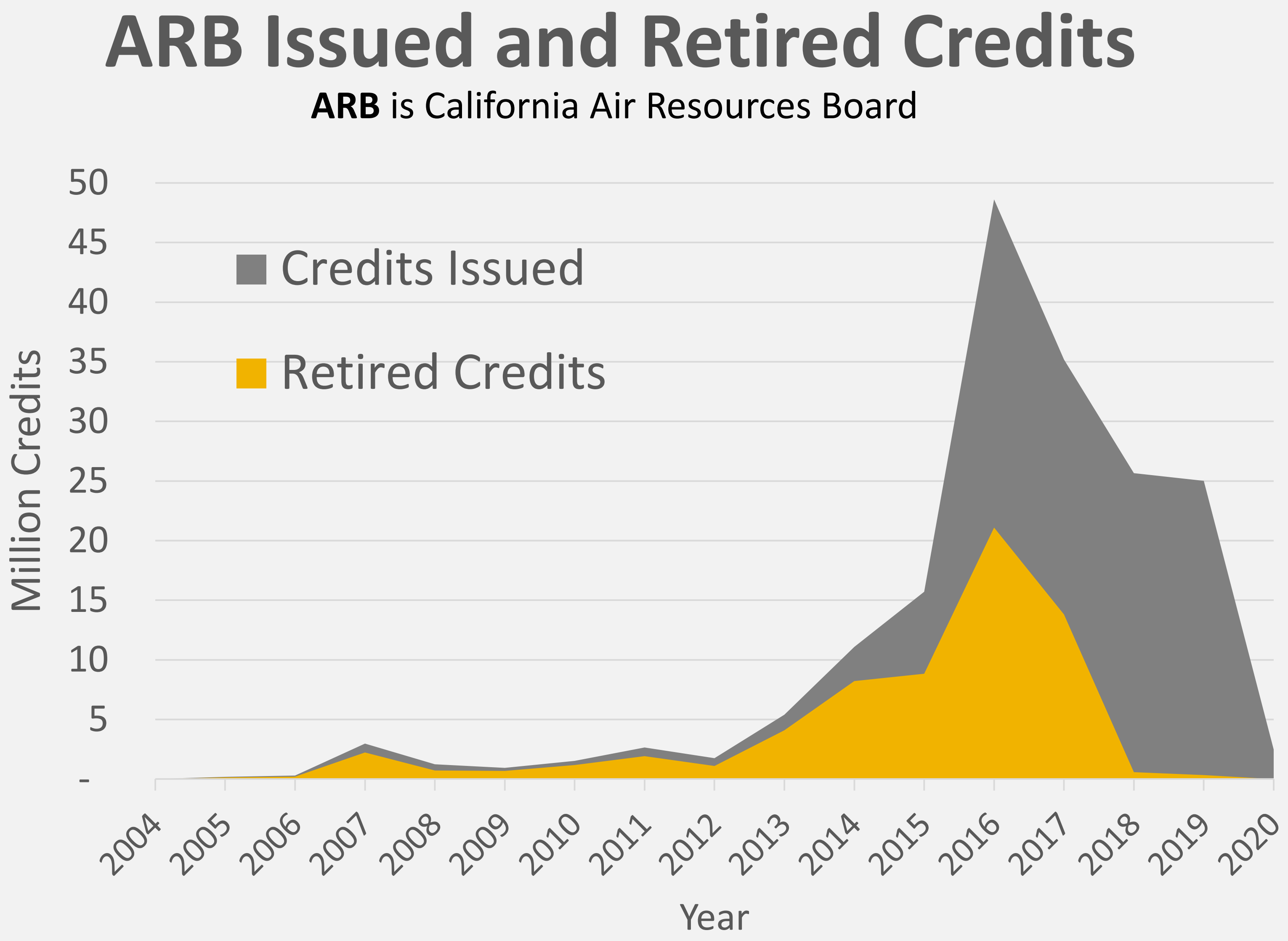
- Converting non-forested land into forested land



US FOREST CARBON OFFSET CREDITING

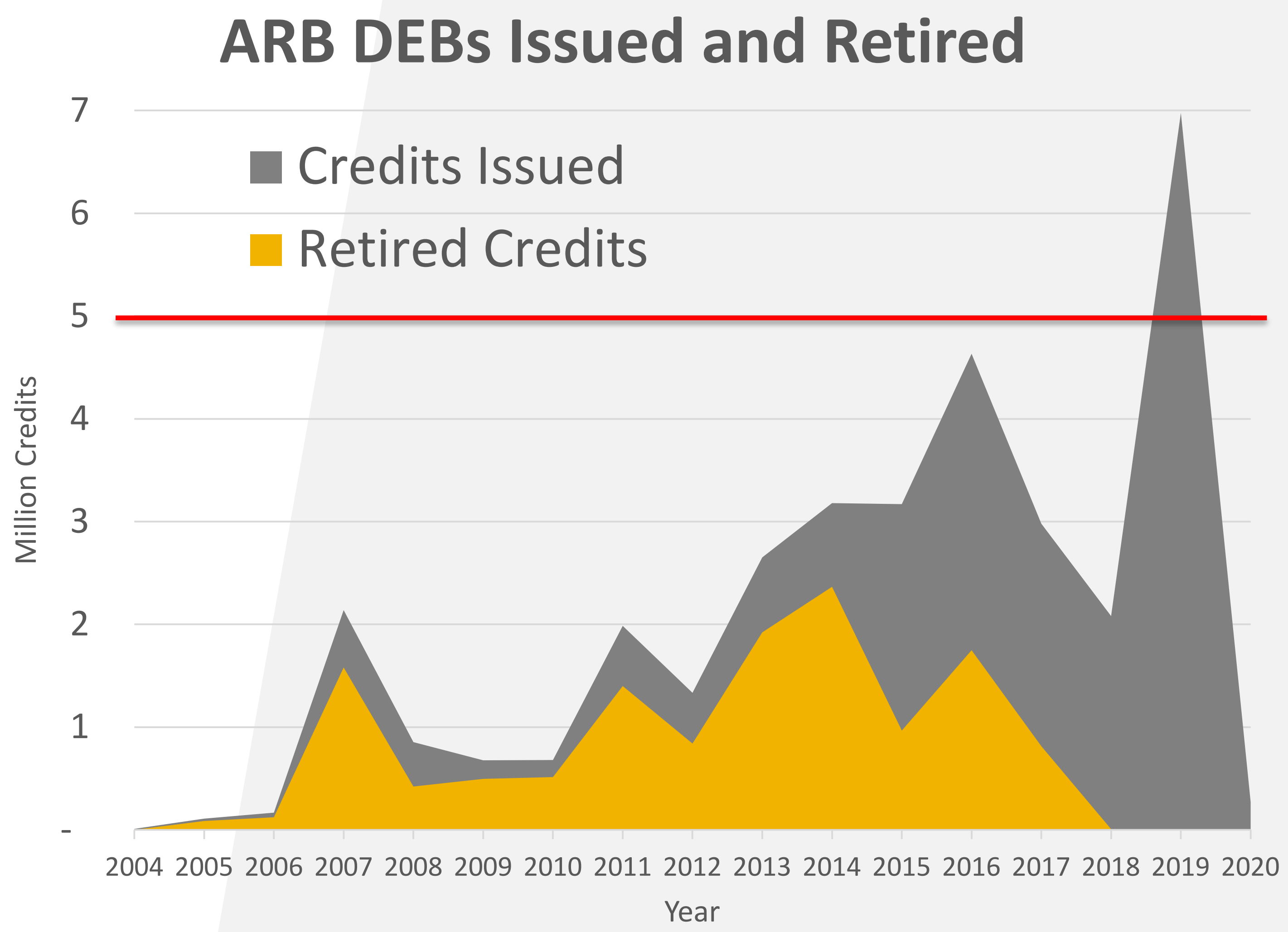
<u>Issued credits:</u>
represents one metric ton of CO_2 from the atmosphere

<u>Retired credits</u>:
purchased credits that are taken off the market, so the purchaser can claim to have reduced emissions

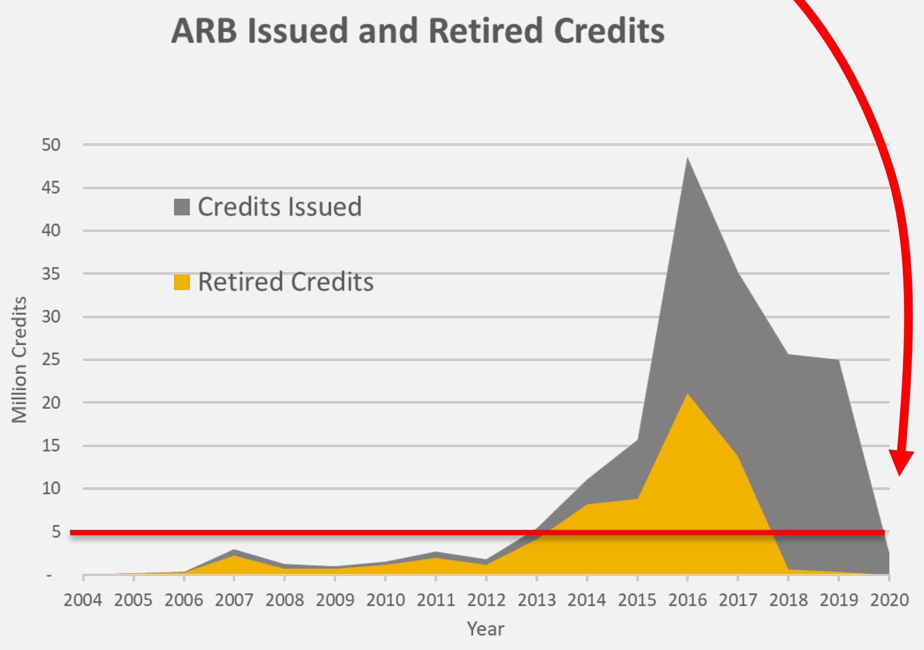


DIRECT ENVIRONMEMNTAL BENEFITS (DEBS)

To the State Of California *requires the reduction or avoidance of any air or water pollutant that could negatively affect the state of California (Assembly Bill 398 (AB 398; Chapter 135, Statutes of 2017))*



Prior slide (all ARB credits) for reference

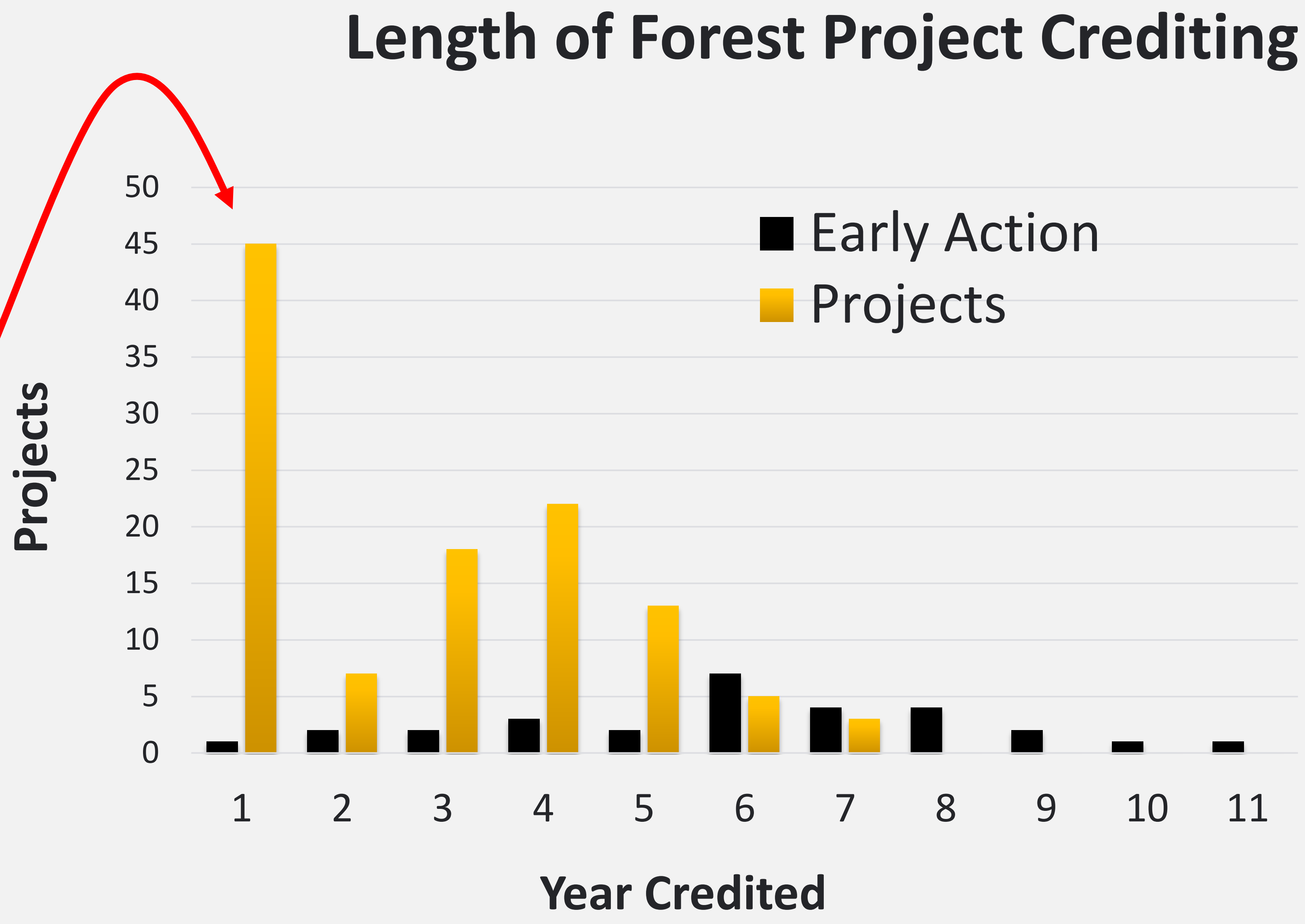


NUMBER OF CREDITING PERIODS *(ARB ONLY AGAIN)*

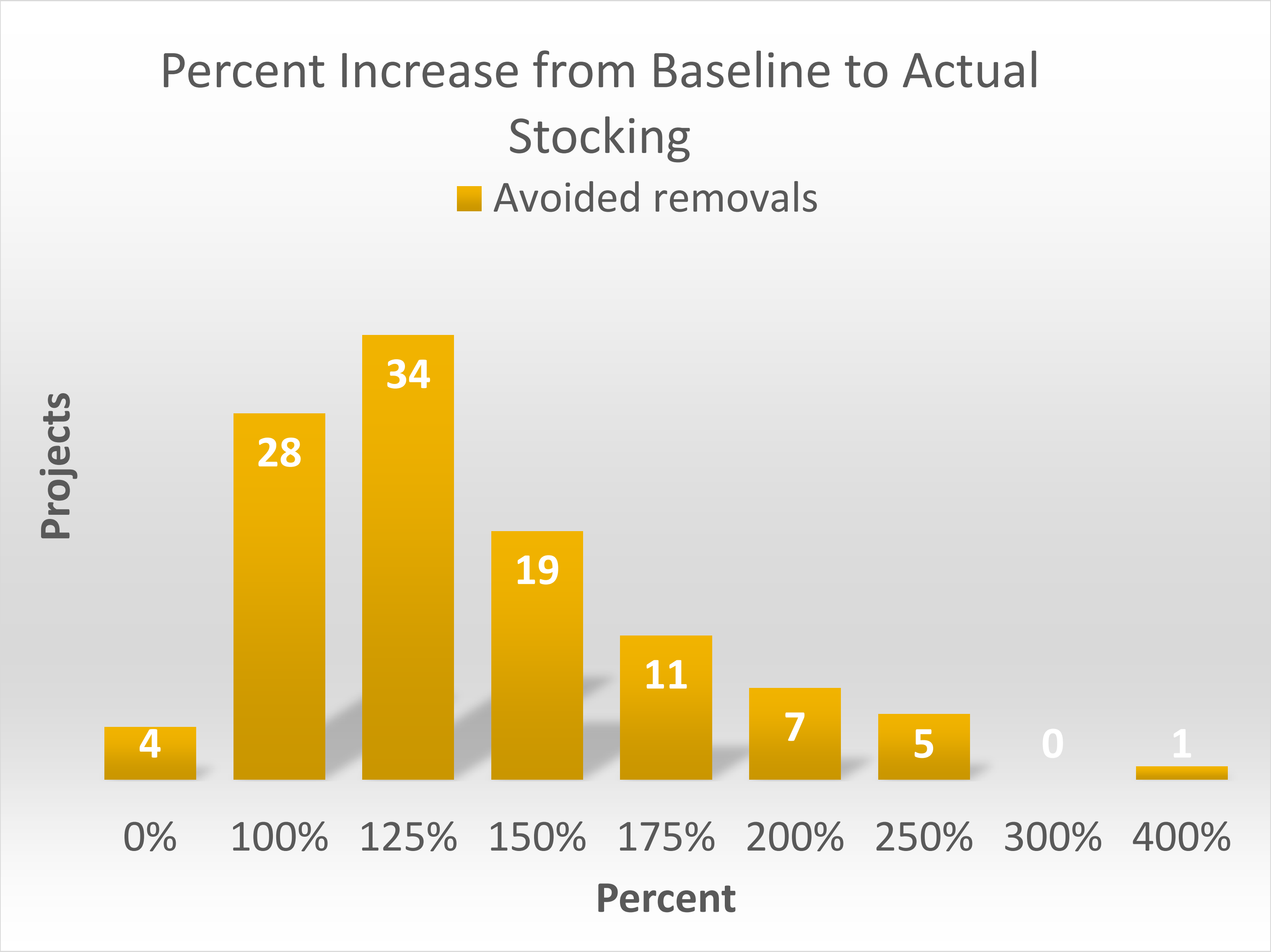
Could be projects that just began (or are in the verification process)

Or

Could be projects that monetized avoided emissions credits only



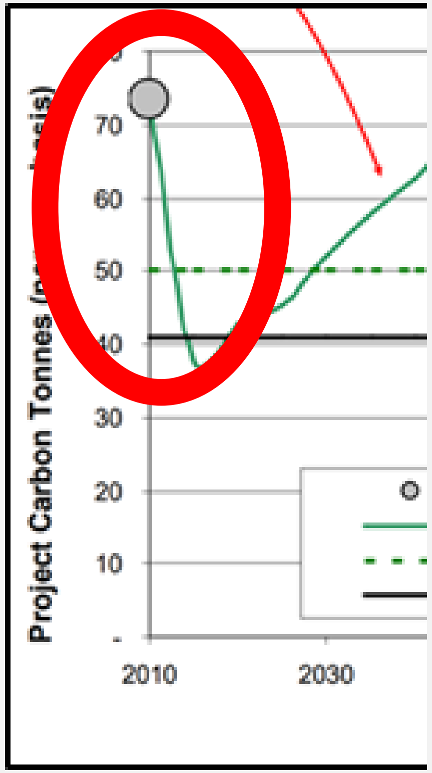
US FOREST CARBON OFFSET STOCKING



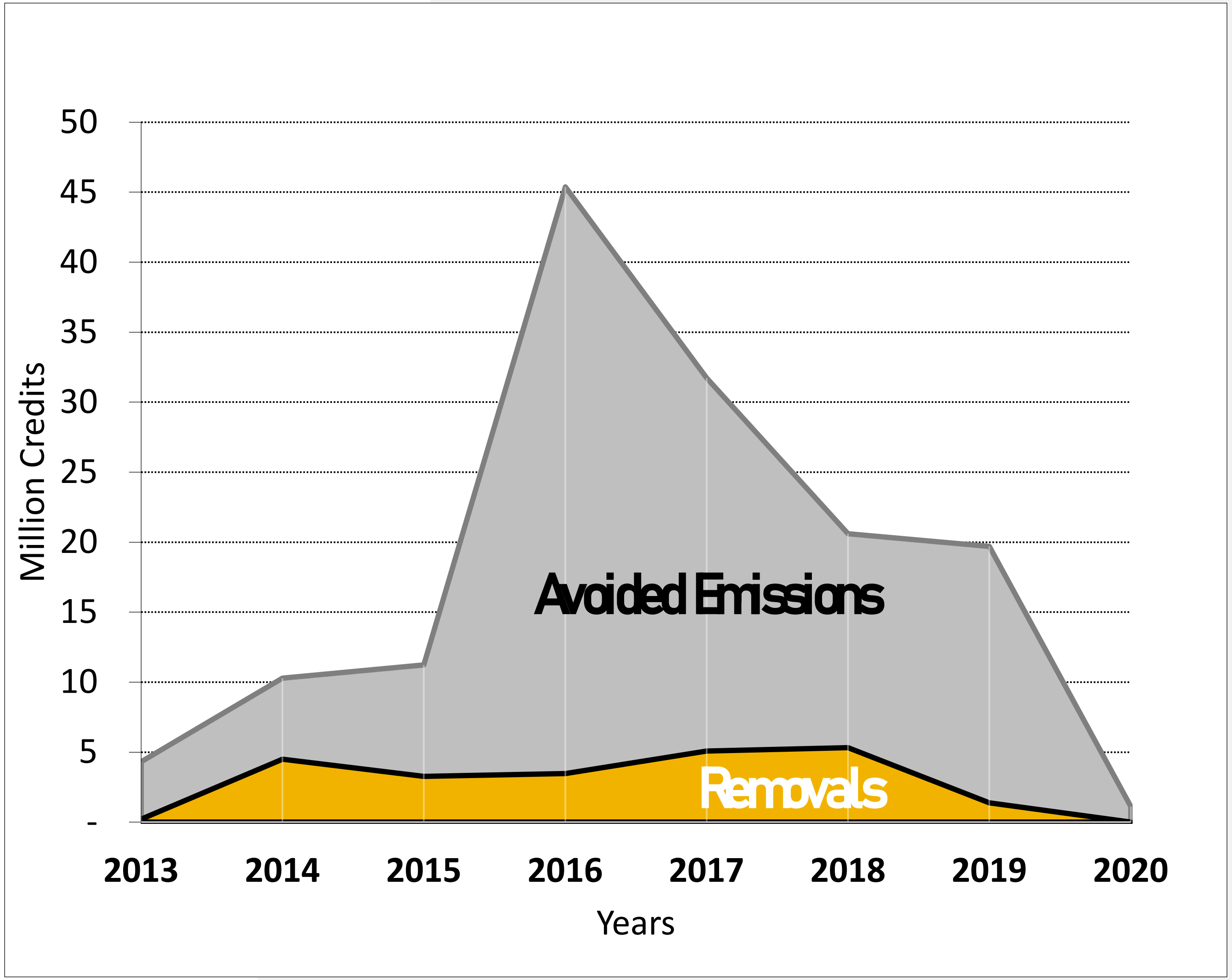
ARB only here *(yet again)*

This graph shows the percent increase from the projected stocking to the actual stocking recorded.

(not including early action)



AVOIDED EMISSIONS VERSUS REMOVALS BY CREDITS



Avoided Emission Offsets: Initial credits issued, usually larger number because of previously established timber

Removal Offsets: Credits that are issued yearly due to yearly growth of the project area

ACTIVE MANAGEMENT – WHO IS HARVESTING?

Looking just at ARB

- **37% of all projects**
  - *That is 56 projects harvesting*
- 38.6% of IFM *(Improved Forest Management)*
- 45% of AC *(Avoided Conversion)*
- 0% of R *(Reforestation)*

Leakage

- **20% in ARB** – not assessed on avoided emissions at time of crediting
- **40% on most ACR** – assessed against all crediting

Most leakage values based in some way on:
Murray, B. et al. 2005. Greenhouse Gas Potential in U.S. Agriculture and Forestry. United States Environmental Protection Agency Report EPA 430-R-05-006. 154p.

BUFFER POOL CONTRIBUTION - RISK

The risk rating represents...

- Financial risks
- Natural disaster risks
- Social risks
- Management risks.

Average Risk Rating is 17.5%

Looking Back

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Research Gaps And Modeling Needs

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2018

REFLECTIONS/EXPERIENCES IN FOREST CARBON OFFSET MARKETS

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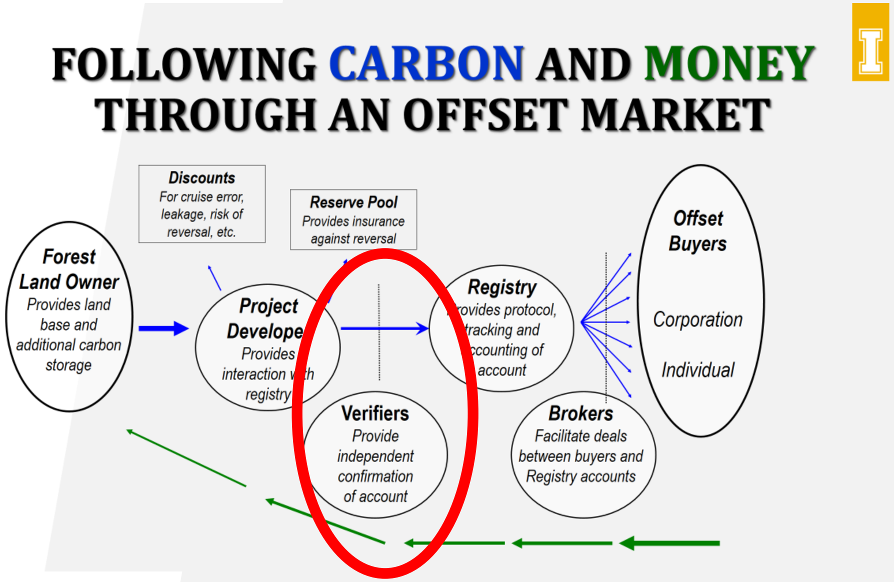
Presented at: WFE Annual Meeting
Olympia, WA, 5 June 2018

CARBON MARKET PROCESS SIMPLIFICATION



- Reliability (aka Verification)
  - Too many "These go to 11" moments
  - In other words – no room for common sense
- Do all projects need to go through an onerous verification process
  - What about sampling projects (verify only some)
- What role do small woodland owners have in the market?
  - Is there a way to monetize activities known to improve the carbon balance of a forest property?

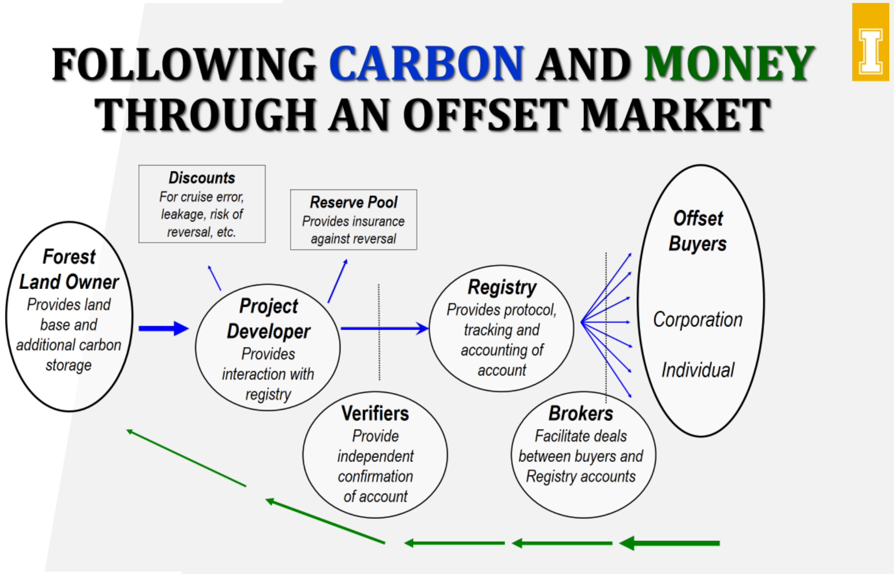
CARBON MARKET RESEARCH NEEDS

- There appears to be a lack of coordination/collaboration between the carbon researchers and carbon practitioners.
  - There is even a communication gap (Example BC Forest Carbon SSP, vs IPCC SSP)

What can the research community do to help?

- Leakage
  - The Brian Murray 20% in entrenched, but not necessarily appropriate
  - We can do better *(hint: the leakage is not constant, it depends on carbon market participation)*
- Permanence
  - Do we need permanence? *(is **forestry** the problem we are trying to solve?)*
  - Why 100 years anyway? *(would you get better participation and thus emissions reductions with shorter contracts?)*

CARBON MARKET PROCESS JUSTIFICATION



- Why are the rules what the rules are?
- Additionality
  - Should NGOs, Industry, and family owners have the same baseline?
  - Should outside money have a non-forestry baseline? (invest instead in equipment upgrades at poorly performing facilities

Fast Forward to Now

Same old story:

- But worse----
- Now we have NCX, FFCP, ACR Canada, CAR Mexico…
  - Landowners are confused
  - Academia is confused
  - Project developers are confused
  - Worse yet – offset buyers are confused
- Market “watchdogs” are popping up all over
  - And they are confused too

Can we simplify

Simplify

- Don’t focus on stocks – they don’t matter
  - Only the interaction with the atmosphere matter

- Only 2 Concepts
  1. **Reliability** – the emissions reduction (*or sequestration*) must be additional and that includes onsite and offsite effects (*so leakage*)
  2. **Durability** – they also need to stick around (*or we need to account for the project timeframe*) through reserve pools or discounting

Forest Carbon Quantification Consortium

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Forest Carbon Quantification Consortium (FCQC)
FOREST OFFSET MARKET TARGETED RESEARCH

Forest Carbon Quantification Consortium
2022 Summer Workshop

May 17, 2022
Raleigh, NC
Stateview Hotel and Conference Center*

Send participation inquiries to : glatta@uidaho.edu

Workshop Agenda:

Report Results from Year 1 Leakage and Permanence Studies
Discuss Priorities for Year 2 and Beyond

Forest Carbon Quantification Consortium – Research and Analytics Addressing Market and Policy Challenges in Offset Program Design and Implementation
Greg Latta (Univ. of Idaho), Adam Daigneault (Univ. of Maine), Christopher Galik and Justin Baker (North Carolina State Univ).

The Forest Carbon Quantification Consortium (FCQC) is a collaborative focused on economic approaches to evaluate market and policy issues that affect forest carbon offsets. FCQC leverages research capabilities at multiple research institutions and provides a flexible funding mechanism to accomplish research objectives targeted at bolstering scientific credibility to a rapidly developing voluntary forest carbon offset (FCO) market

*this will be a hybrid meeting – call-in information will be provided to meeting participants

MAINE

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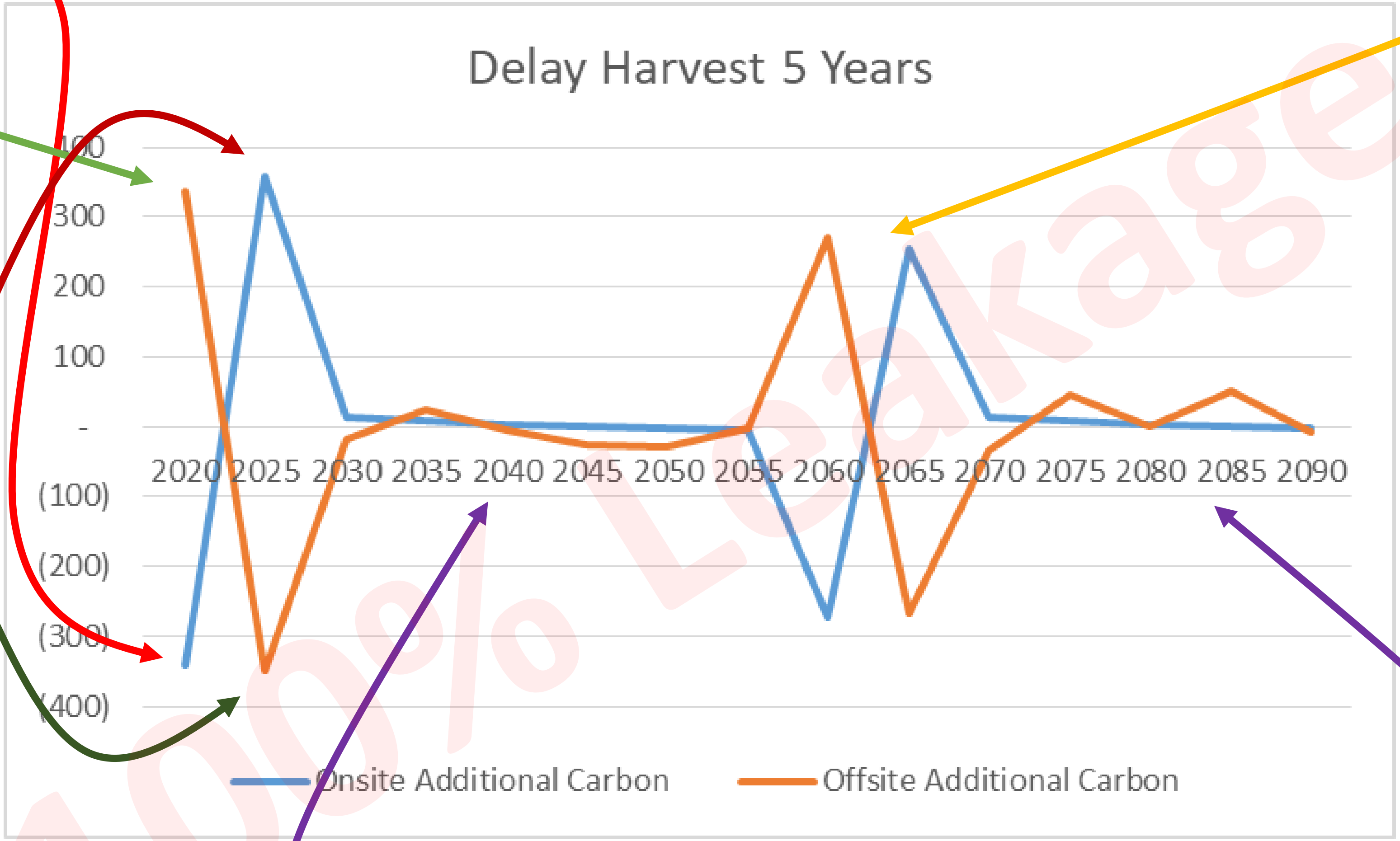
1. FCQC – Forest Carbon Quantification Consortium (Greg Latta (Univ. of Idaho), Adam Daigneault (Univ. of Maine), Christopher Galik and Justin Baker (North Carolina State Univ))

Delaying Single Harvest

1) Initial onsite reduction in emissions when harvest delayed on 5000 acres
2) Offsite response in same period
3) Second period we cut the stand and therefore there is an increase in onsite emissions
4) And reduction offsite as the harvest displaced offsite harvesting

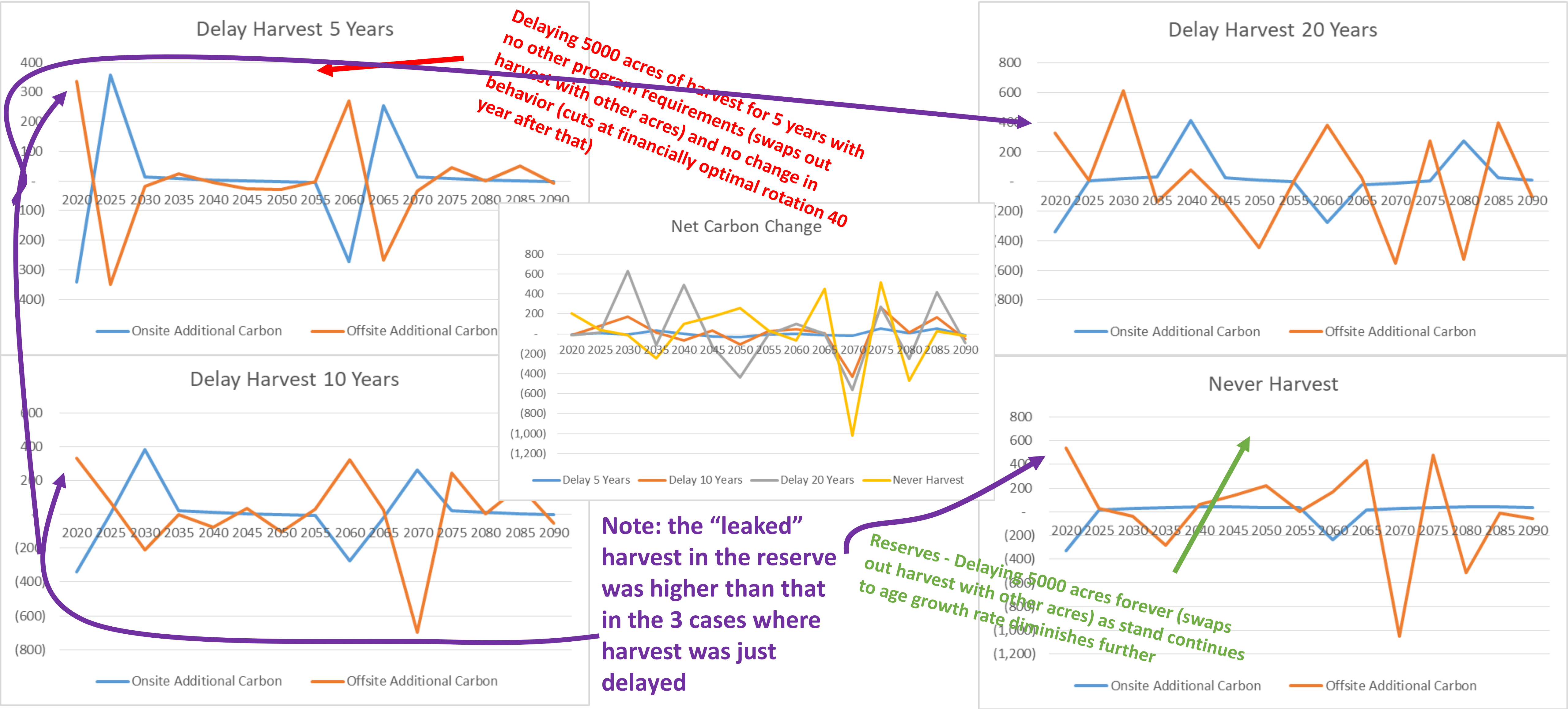
Same compensating harvests occur when the regenerated stand is harvested again



Not much going on outside of the harvest shifting periods

(because no payment for sequestration (only avoided emissions))

Delaying Single Harvest – Part2



Issues with that approach *– focus on the old stuff*

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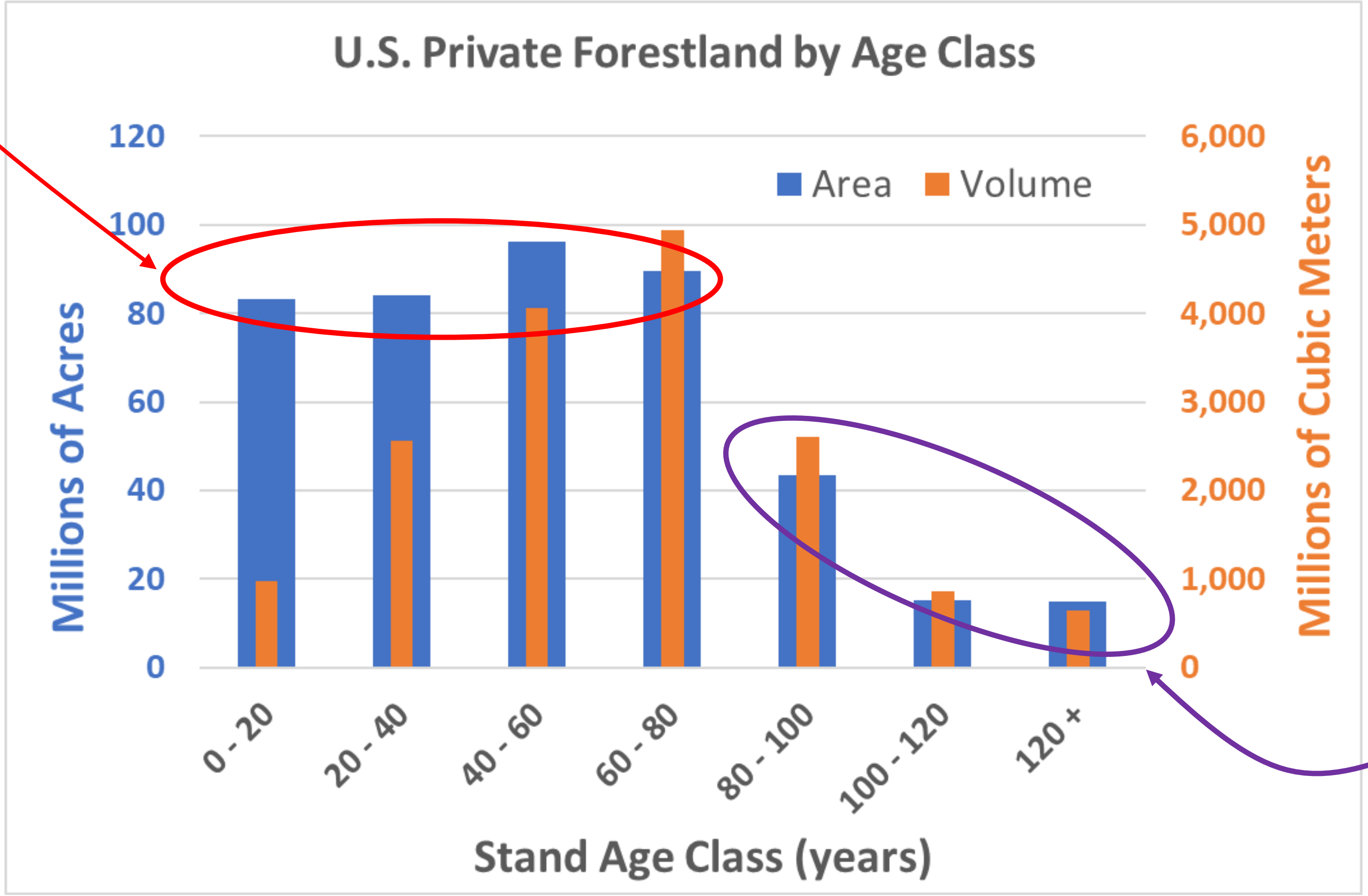
- There is a lot of harvestable material on private forest land in the US

Most actively managed land in 0-80 acre classes *(fairly evenly distributed)*



80 years plus land –

- 17% of the area and 24% of the volume
- That's 4.1 billion cubic meters
  - Annual harvest on all land in US is 0.35 billion cubic meters
  - So close to 12 years of volume on those older forest land
  - Only 2% of that land (and volume) shows up in the Protected Lands Database *(so it would appear harvestable)*

So: There is a lot of Slack in the system

We don't know how much of this land is not really part of the manageable land base *(riparian, inaccessible, or otherwise encumbered)*

Basic FASOM Stand Dynamics

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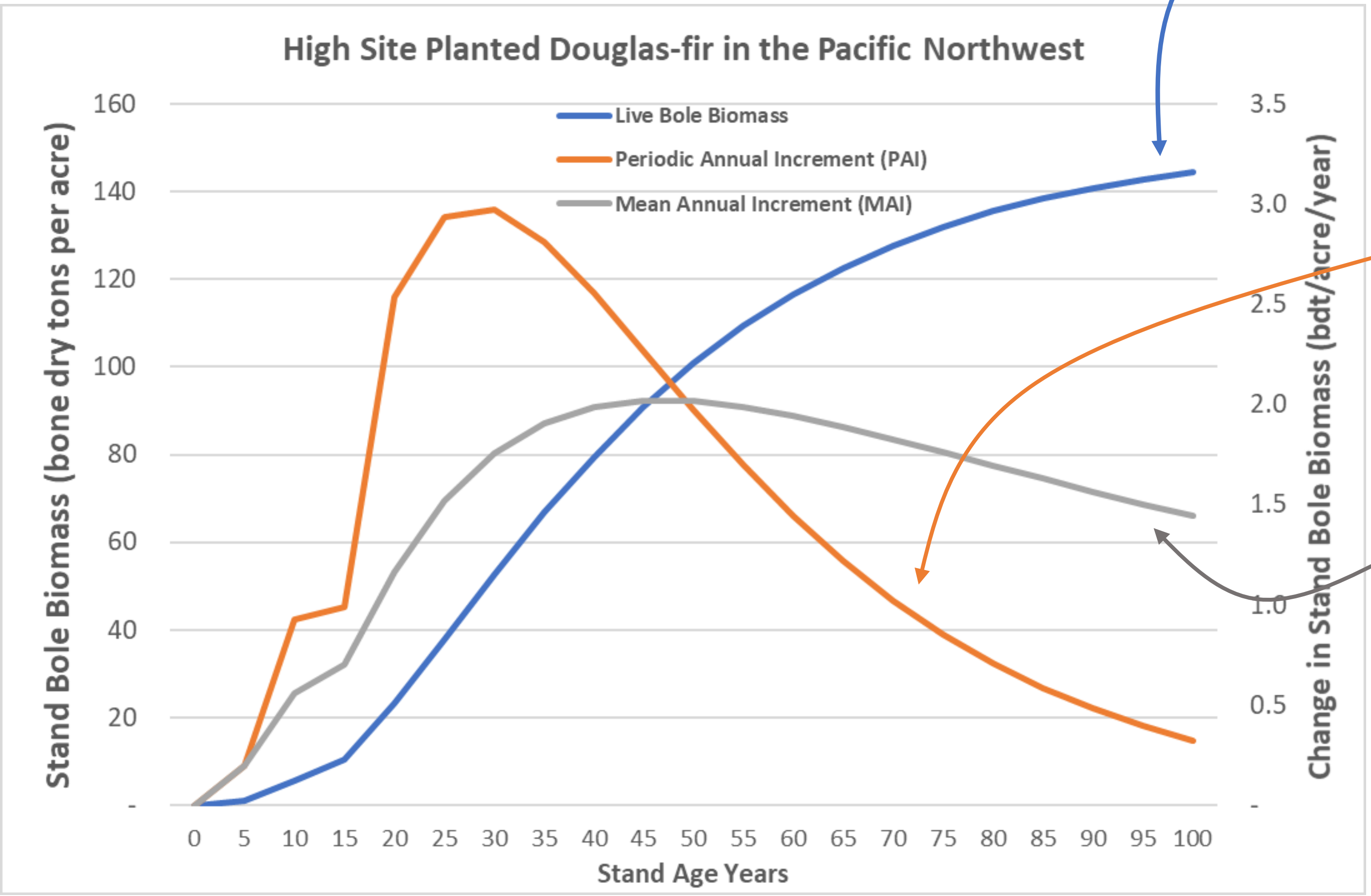


Live Bole Biomass – this is what we think of as yield in logs. It does not include small tree, tops, branches, or stump biomass

- Sigmoidal – so increasing growth rate when young and then decreasing growth when older

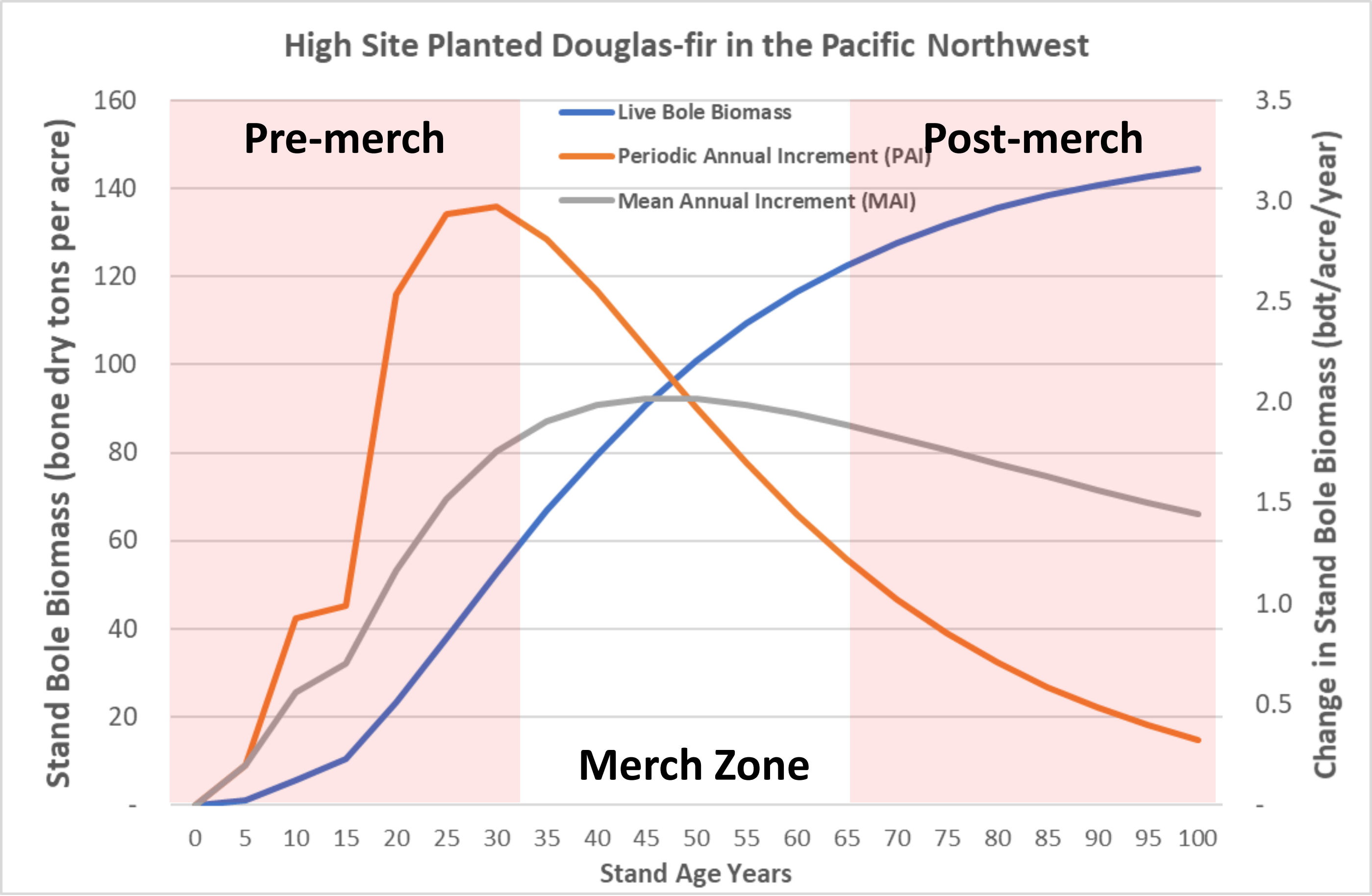
Periodic Annual Increment (PAI) – this is what we think of annual growth rate

- Peaks when the stand growth rate changes from increasing to decreasing (yield curve inflection point)

Mean Annual Increment (MAI) – this is what we think of average growth rate

- The peaks is often defined as the biological rotation age (where PAI crosses MAI)

Basic FASOM Stand Dynamics



Defining Merchantability Limits in FASOM

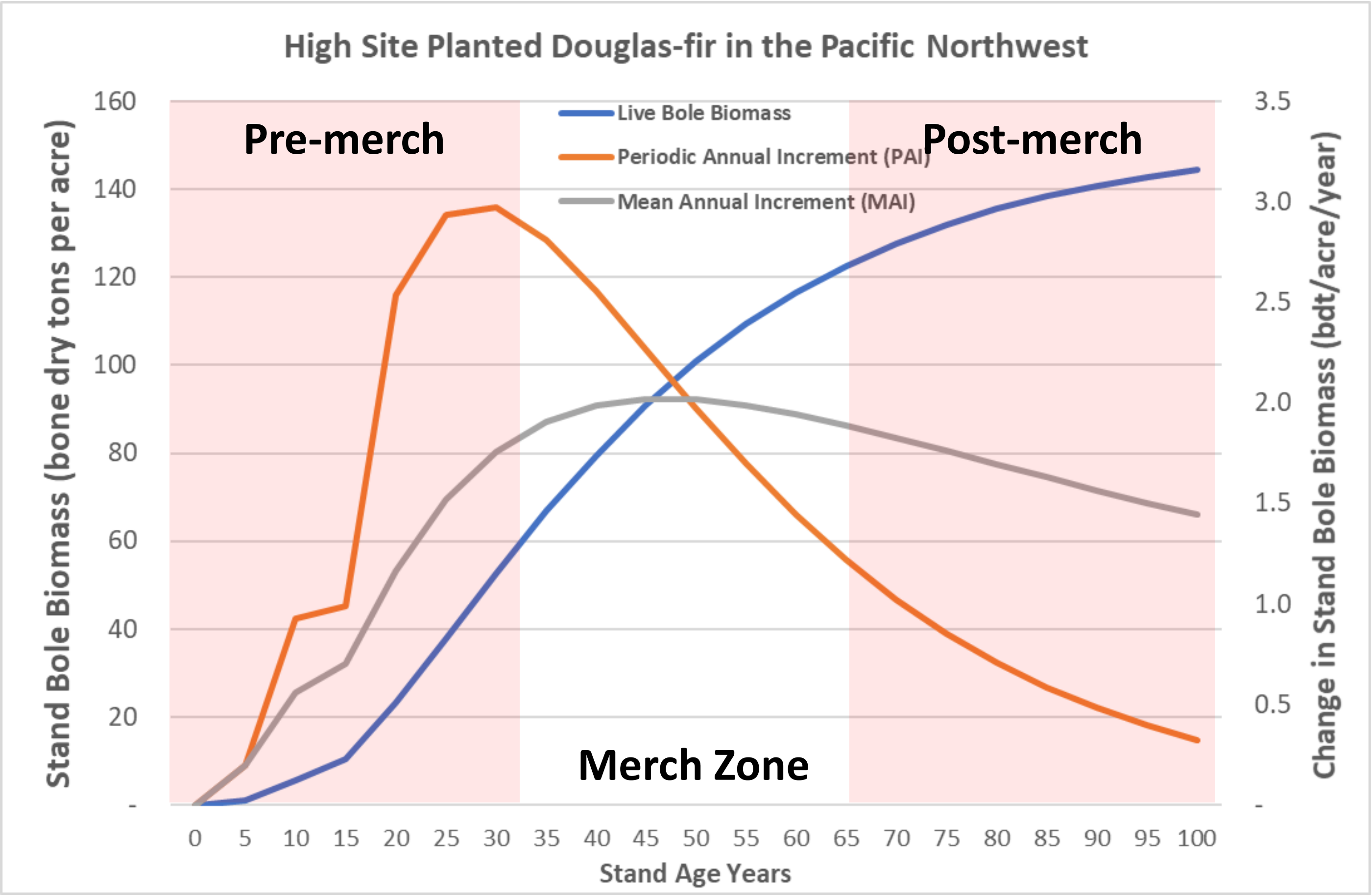
- We have always had a minimum harvest age
- What if we add a maximum harvest age?

Pre-merch – defined as younger than 2/3 of biological rotation *(here biological rotation is 50 so pre-merch limit is 33). Can't harvest stands younger than this age.*

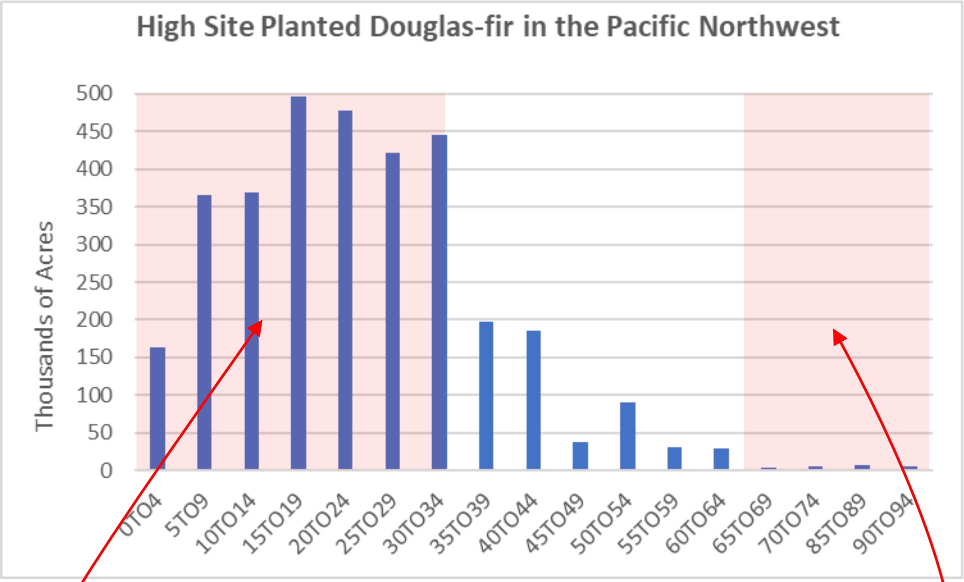
Merch Zone – defined as a range of rotations most likely used in a working forest *(so not a reserve).* Where harvesting will occur.

Post-merch – defined as younger than 2 time pre-merch age *(here biological rotation is 50 so pre-merch limit is 33 and post-merch is 66). We will experiment with harvesting stands older than this age.* Remember, we don't know how many of then are actually not harvestable.

Basic FASOM Stand Dynamics



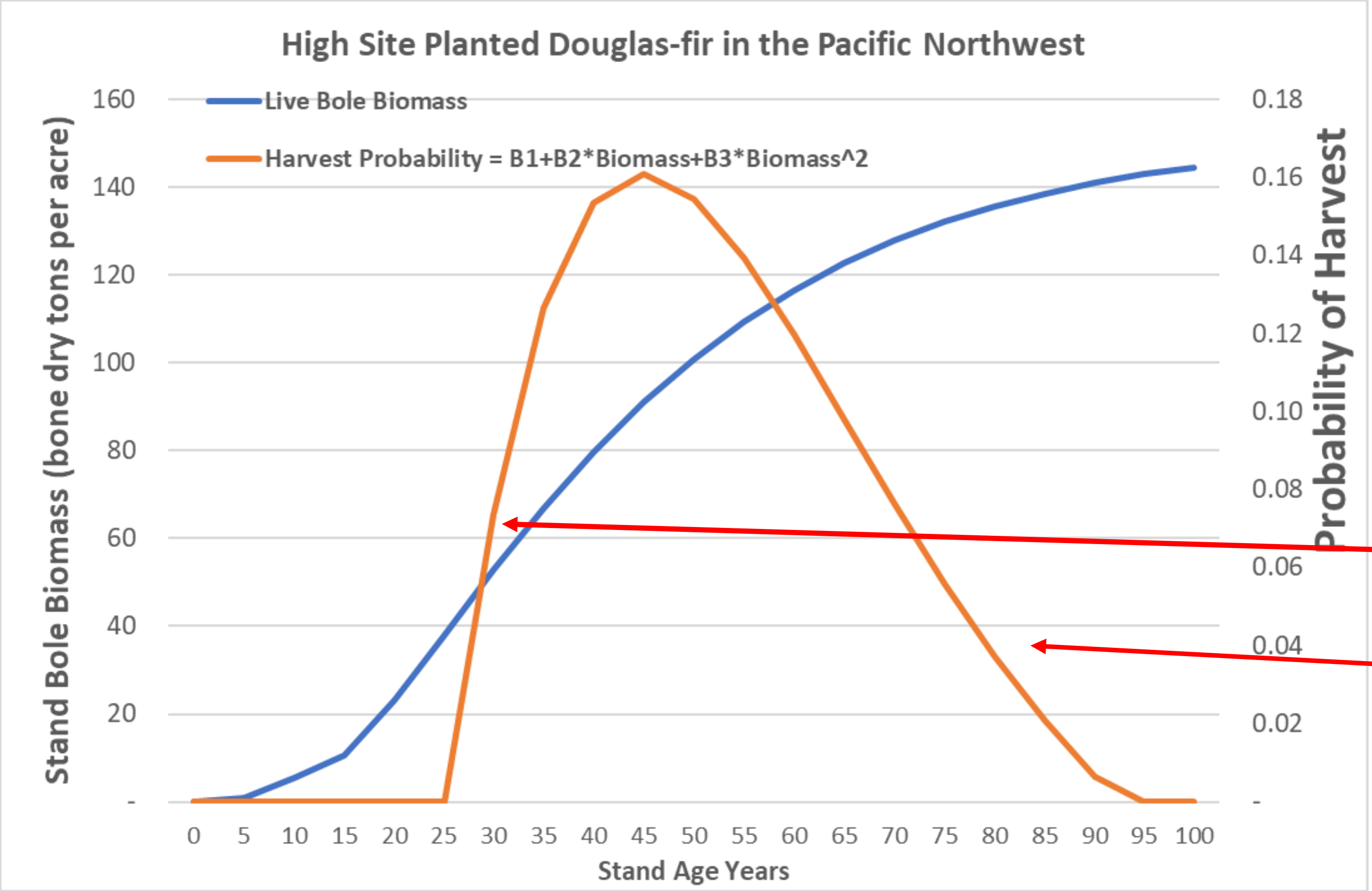
Actual Age Class Distribution in FASOM



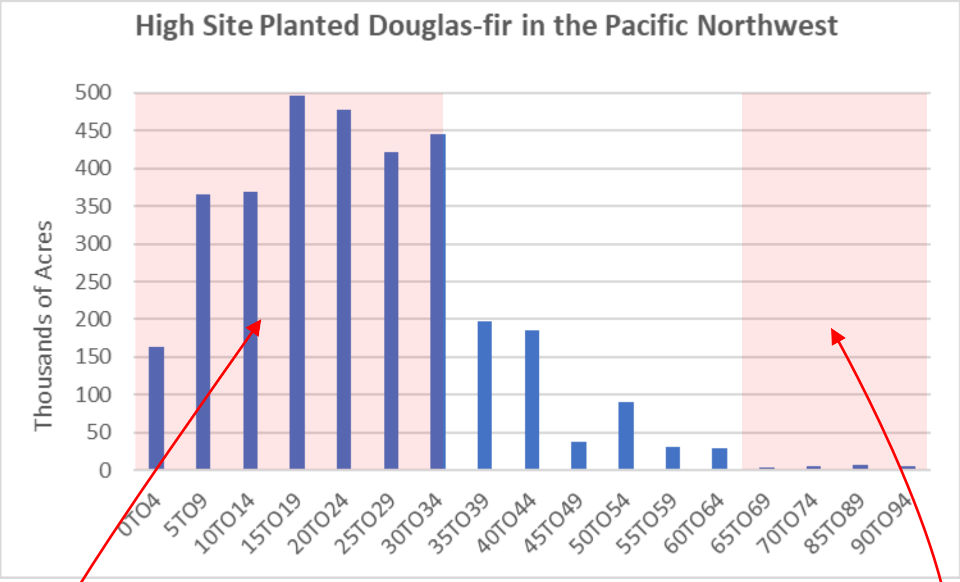
Not additional - Too young to do anything but grow *(not exactly true as there are other management options possible outside of FASOM)*

Not additional? – Possible reason for not harvesting *(not exactly true as there are other management options possible outside of FASOM)*

Harvest Probability



Actual Age Class Distribution in FASOM

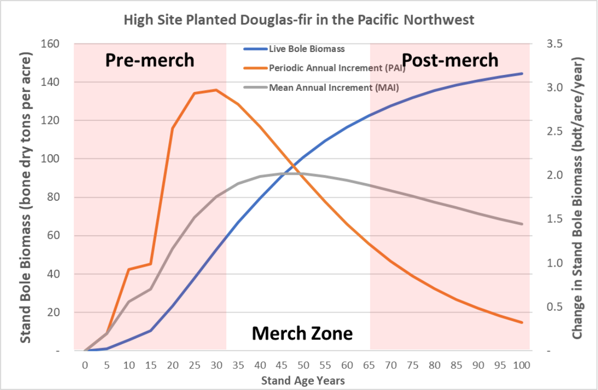


Increases as stand volume increases or as stand ages

Decreases as stand volume increases or as stand continues to age

So can we Delay Harvest in FASOM (and get meaningful output)

Not Currently – even with maximum harvest ages determined at the Region / Forest Type / Site Class level



FASOM Acres by Merchantability Class

Owner	Pre-Merch	Merch	Post-Merch
BLM	6,739,735	11,411,837	12,906,422
Ofederal	4,541,396	7,506,631	7,444,887
Private	**142,388,578**	**207,167,584**	**77,169,087**
State	15,213,991	27,394,858	14,284,514
USFS	27,614,011	55,296,615	52,531,503

We've been focusing on this as a concern ***(slack in the model)***

There are 207 million acres of harvestable (merchantable) private forest acres. Assuming 9 million acres harvested each year, that would be about 23 years worth.

So: When we move 5 thousand acres or even 1 million acres, a model like FASOM has plenty of other harvestable acres available it can replace it with

100% Leakage for Harvest Delay pretty much every time with current model formulation

Using a market mechanism *(a carbon price)* in a market model *(FASOM-GHG)*

- Use the strength of the model to inform the leakage analysis
  - In other words: use a carbon price and observe the market/resource response
  - This will be like the Wade et al. (2020) model with the Latta et al. (2011) additions allowing voluntary participation
    - So private forest owners can:
      - choose to participate in the offset market and get paid for sequestration (while also paying for emissions)
      - Or choose not to participate and not get paid or pay for sequestration and emissions.
    - To flush out that was not participating in the market anyway (non-additional) I will use \$1/tCO_2 as the base level against which to measure additionality
- Scenarios
  - 0,1,5,10,15,20,25,30,40,50,75,100 \$/tCO2 for offset market participants *(and \$0 for non-participants)*
  - Carbon Price paid only on above and below-ground live tree carbon *(so not soils, litter, or dead wood)*
  - No Harvest in Post-Merch private acres
  - Allow harvest in Post-Merch private acres

Also, a glitch in these runs not paying for harvested wood products

Wade, C.M., J.S. Baker, J.P.H. Jones, K.G. Austin, Y. Cai, A.B. de Hernandez, G.S. Latta, S.B. Ohrel, S. Ragnauth, J. Creason and B. McCarl. *In Print*. Projecting the Impact of Socioeconomic and Policy Factors on Greenhouse Gas Emissions and Carbon Sequestration in US Forestry and Agriculture. *Journal of Forest Economics*: Vol. 37: http://dx.doi.org/10.1561/112.00000545

Latta, G., D. Adams, R. Alig and E. White. 2011. Simulated effects of mandatory versus voluntary participation in private forest carbon offset markets in the United States. *Journal of Forest Economics* 17(2): 127-141.

Using a market mechanism *(a carbon price)* in a market model *(FASOM-GHG)*

Allowing Harvest in Post-Merch private acres

Marginal Abatement Cost Curve (MACC)
Steps:

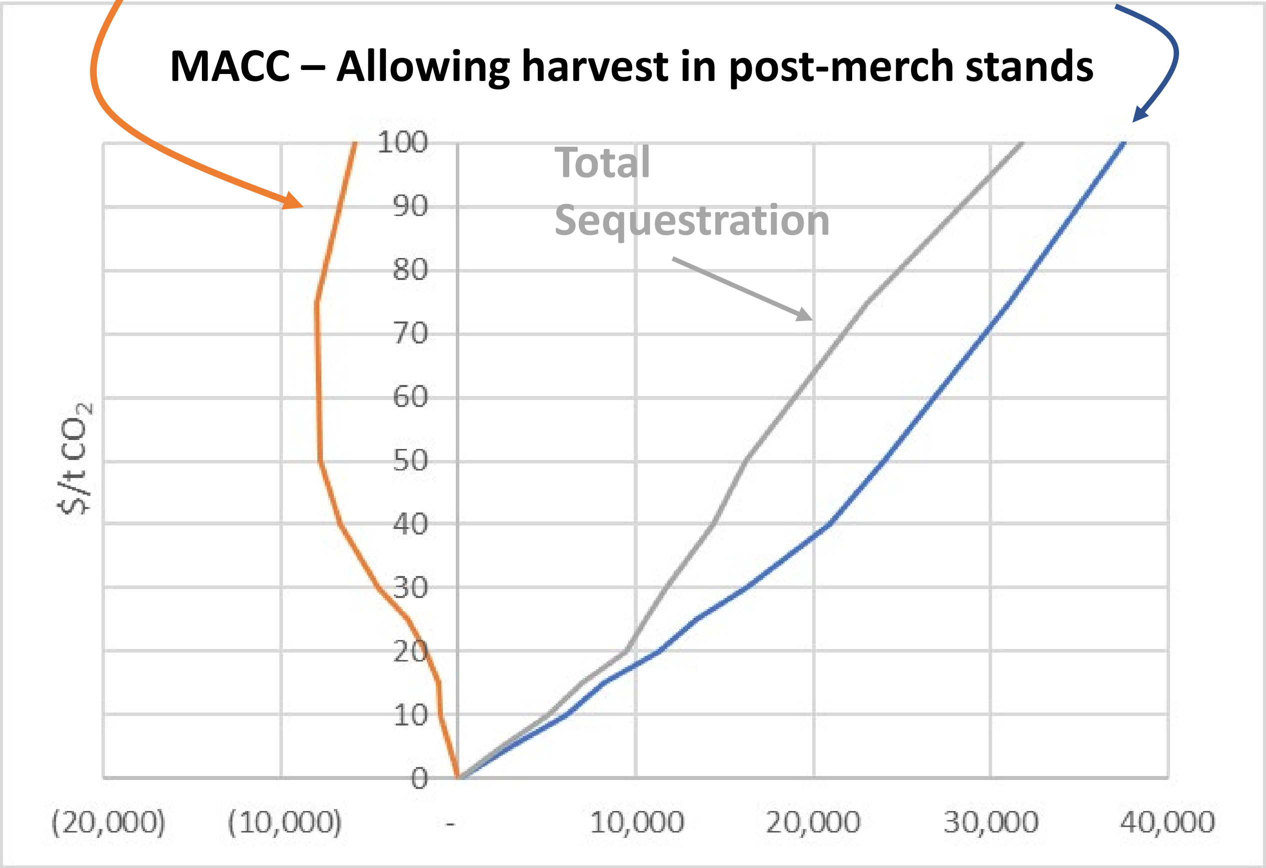
1. Run the Carbon Price Scenarios through 2090 in 5-year time periods
2. Calculate additional sequestration in each time period
3. Discount the additional carbon using 4% *(similar to Murray et al (2004))*
4. Calculate the annual annuity value that would equal the sum of the first 40 years of discounted additional carbon

$$V_0 = \frac{a * [(1+i)^t - 1]}{i * (1+i)^t}$$

V_0 is the sum of the discounted additional carbon over the first 40 years
i is the discount rate (here 4%)
t is the time period over which the annuity is calculated (here 40 years)
a is the annuity value (or a single value that could be applied annually for 40 year and give us the discounted sum of additional sequestration – it basically makes it so we have one value for each carbon price)

Non-Participants – additional emissions at each carbon price

Offset Participants – additional sequestration at each carbon price



Note: the blue line (participants) is only the above and below ground carbon. Gains in other carbon pools are part of the non-participating total.

Murray, B.C., B.A. McCarl, and H. Lee. 2004. Estimating Leakage from Forest Carbon Sequestration Programs. Land Economics 80(1):109-124.

Using a market mechanism *(a carbon price)* in a market model *(FASOM-GHG)*

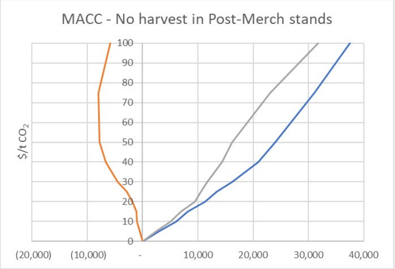
- Allowing Harvest in Post-Merch private acres

Marginal Abatement Cost Curve (MACC)
Steps:

1. Run the Carbon Price Scenarios through 2090 in 5-year time periods
2. Calculate additional sequestration in each time period
3. Discount the additional carbon using 4% *(similar to Murray et al (2004))*
4. Calculate the annual annuity value that would equal the sum of the first 40 years of discounted additional carbon
5. Calculate leakage using Equation 12 in Murray et al (2004)

$$L^T = [(PV_P - PV_T)/PV_P]*100. \qquad [12]$$

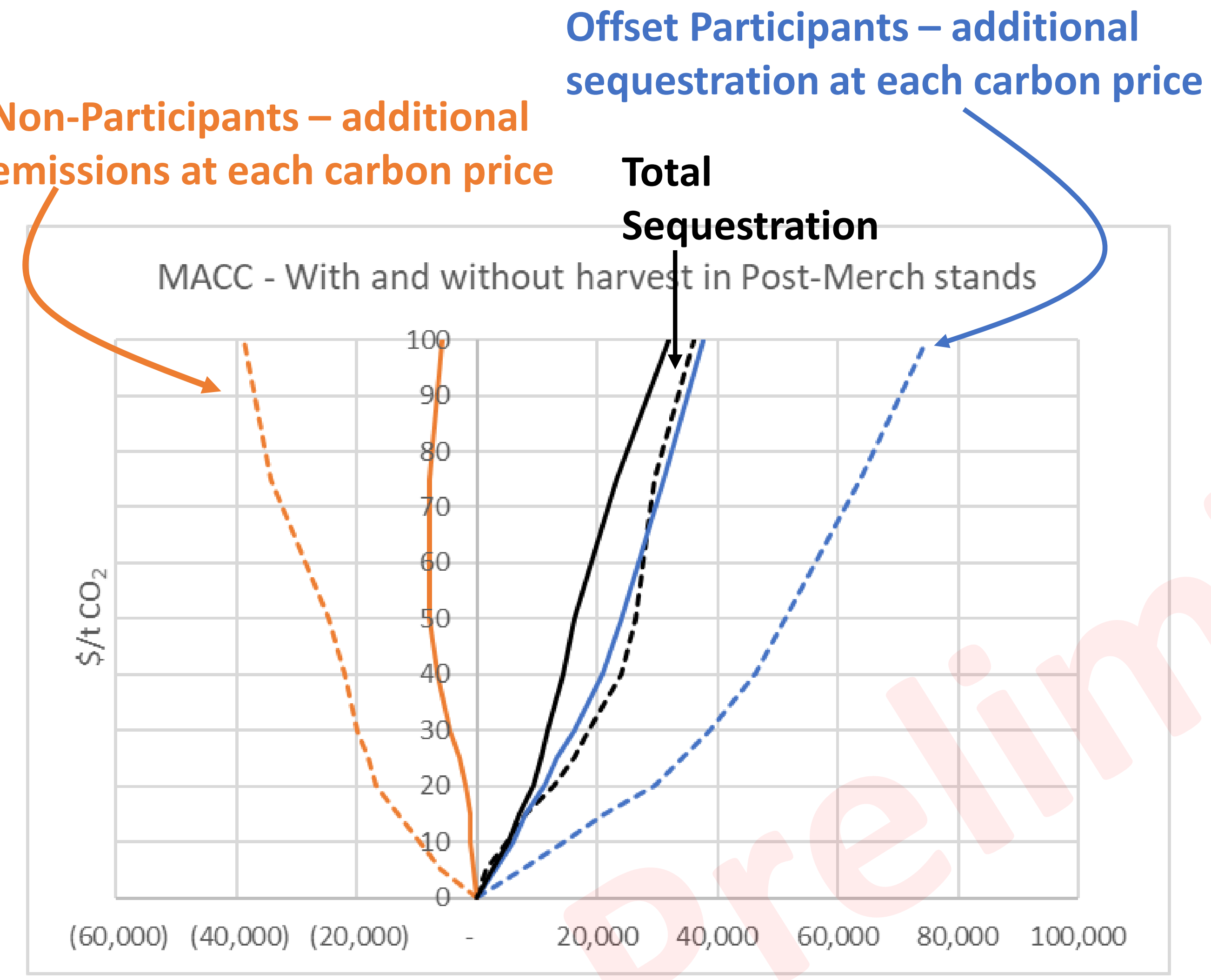
PV_P is the time-discounted present value of carbon sequestration increment on lands targeted by the policy. PV_T is the corresponding discounted value of carbon increments on all lands (targeted and non-tar-



CO_2 Price	Participants PV_P	Non-Participants	Total PV_T	Leakage L^T
	thousand tons of CO2/year			
0	0	0	0	
5	7,565	-5,990	1,574	79%
10	14,417	-9,412	5,005	65%
15	21,255	-13,134	8,121	62%
20	29,604	-16,720	12,883	56%
25	34,317	-18,119	16,199	53%
30	38,626	-20,006	18,620	52%
40	46,149	-22,072	24,077	48%
50	51,176	-24,720	26,456	48%
75	63,817	-34,374	29,443	54%
100	74,816	-38,797	36,019	52%

Murray, B.C., B.A. McCarl, and H. Lee. 2004. Estimating Leakage from Forest Carbon Sequestration Programs. Land Economics 80(1):109-124.

No Harvest in Post-Merch private acres



Without harvest allowed in post-merch stands

CO_2 Price	Participants PV_P	Non-Participants	Total PV_T	Leakage L^T
	thousand tons of CO2/year			
0	0	0	0	
5	2,976	-543	2,433	18%
10	6,078	-1,022	5,056	17%
15	8,168	-1,164	7,003	14%
20	11,282	-1,877	9,405	17%
25	13,398	-2,836	10,563	21%
30	16,213	-4,532	11,681	28%
40	20,964	-6,639	14,325	32%
50	24,006	-7,802	16,204	32%
75	31,103	-7,982	23,121	26%
100	37,561	-5,796	31,765	15%

With

CO_2 Price	Participants PV_P	Non-Participants	Total PV_T	Leakage L^T
	thousand tons of CO2/year			
0	0	0	0	
5	7,565	-5,990	1,574	79%
10	14,417	-9,412	5,005	65%
15	21,255	-13,134	8,121	62%
20	29,604	-16,720	12,883	56%
25	34,317	-18,119	16,199	53%
30	38,626	-20,006	18,620	52%
40	46,149	-22,072	24,077	48%
50	51,176	-24,720	26,456	48%
75	63,817	-34,374	29,443	54%
100	74,816	-38,797	36,019	52%

Solid lines are "No harvest in post-merch stands"

Dashed lines are "With harvest allowed in post-merch stands"

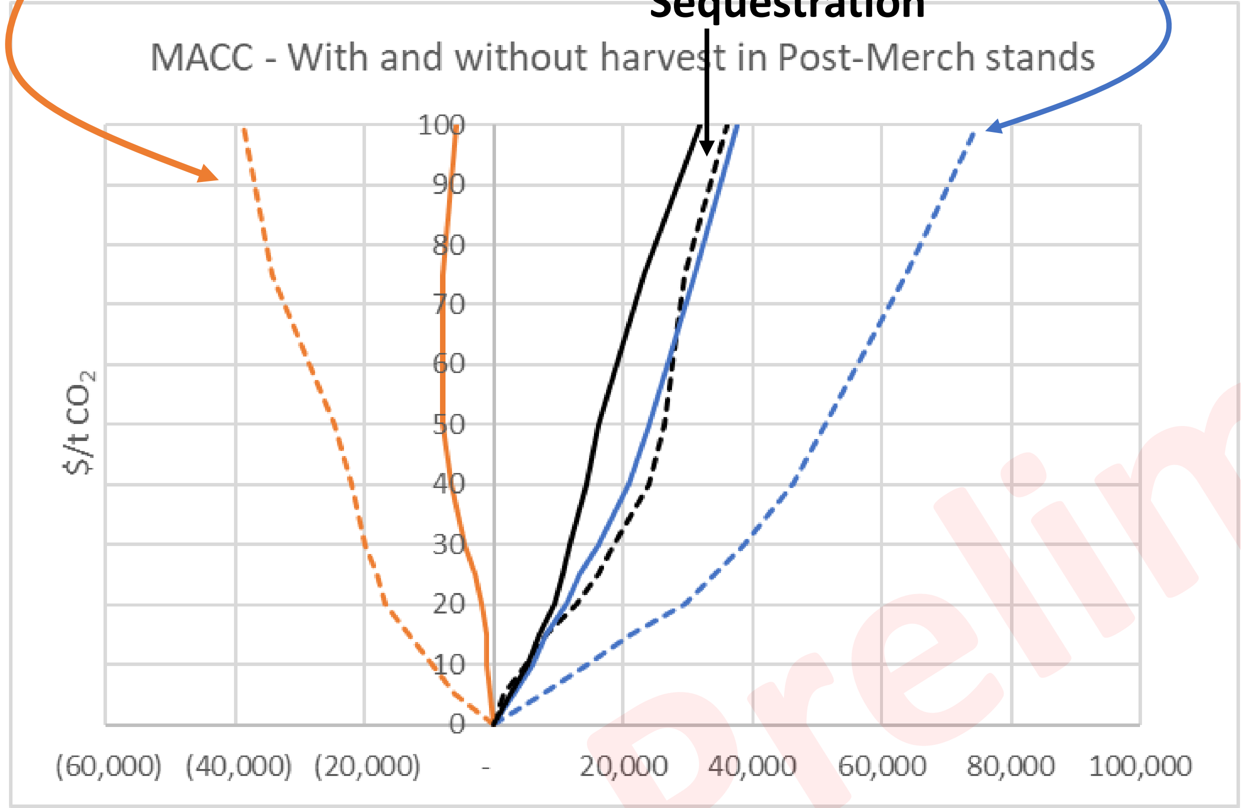
Ever-declining mitigation expectations

(or comparison with past studies)

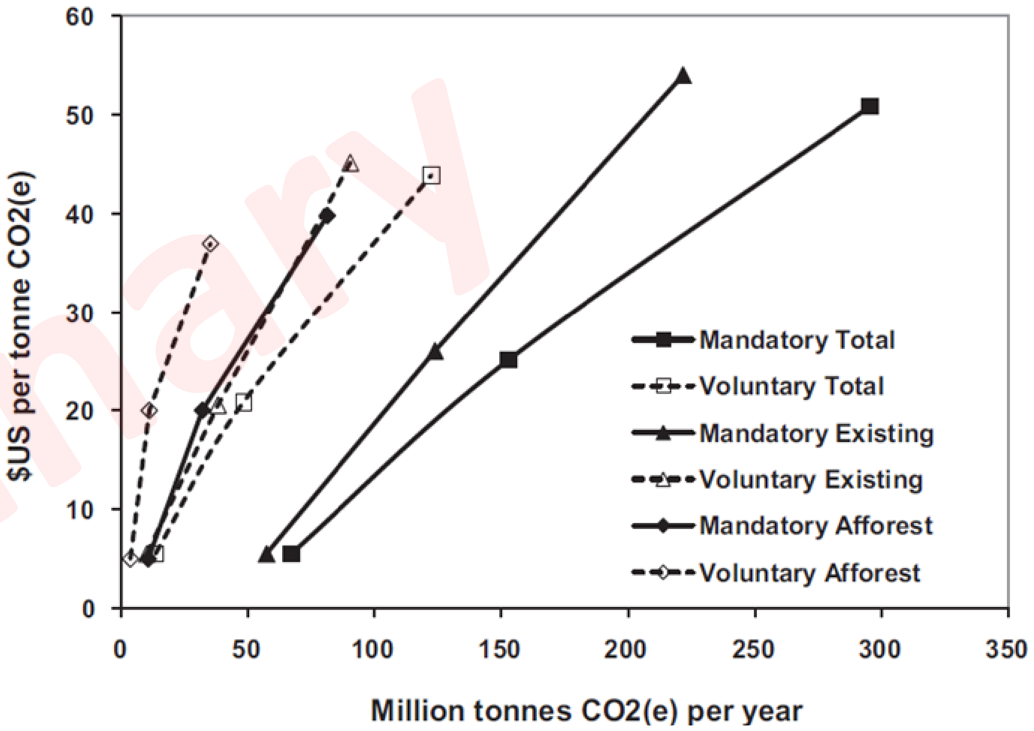
Offset Participants – additional sequestration at each carbon price

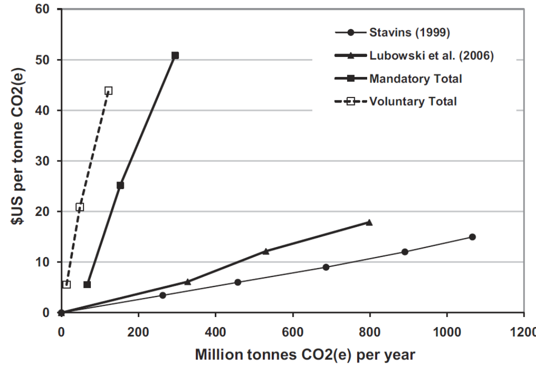
Non-Participants – additional emissions at each carbon price

Total Sequestration



G. Latta et al. / Journal of Forest Economics 17 (2011) 127–141





Solid lines are "No harvest in post-merch stands"

Dashed lines are "With harvest allowed in post-merch stands"

Single Region C-Price Scenarios

North 15 – offers option for Northeast and Lake States to enroll in carbon market for %15/tco2
South 15 – offers option for Southeast and South Central to enroll in carbon market for %15/tco2
(in each case there is no cost or penalty associated with carbon in other regions)
US 15 – all private forest landowners in US can enroll in carbon market for %15/tco2

CO_2 Price Scenario	Participants PV_P	Non-Participants In Region	Non-Participants Other	Total PV_T	Leakage within Reg	Leakage L^T
	------------------------thousand tons of CO2/year ------------------------					
0	0		0	0		
North 15	3,997	234	-2,879	1,353	-6%	66%
South 15	2,986	1,419	-2,477	1,928	-48%	35%
US 15	8,168		-1,164	7,003		14%

Preliminary – in each case, there is negative leakage (more sequestration in non live tree and unenrolled lands) within the regions and higher leakage when adding in other US regions as the industry expands there and contracts in the program region

FCQC Forest Offset Leakage Update

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This is the part where you roll your eyes and curse “models”

- *I knew this was all BS*

Remember models don’t provide answers, rather they inform the decision space

- *What did we learn?*

1. *Leakage is not an easy issue*
    - *We didn’t really learn this, but we know it is a market response*
2. *Leakage depends on how the credits are quantified (how much you take to market Methodology matters)*
3. *Leakage depends on market penetration (how much of the market is affected)*
4. *Leakage may be different for methodologies that target removals as opposed to those that target maintenance of stocks*
5. *Leakage is not constant over time (future markets are affected by current market effects)*

FCQC Forest Offset Leakage Update

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Leakage Option B

- Elasticity Route:

$$L' = \frac{100 * e * \gamma * C_N}{[e - E*(1 + \gamma * \phi)]C_R}$$

- **Pros**
  - elegant, equation-based approach
  - Handles
- **Cons**
  - Requires elasticities we don't have
  - Methodology doesn't affect it

e is the supply price elasticity
E is the price elasticity of demand
C_N is the c seq. reduction per unit of non-reserved forest
C_R is the carbon sequestration per unit of (foregone) harvest gained by preserving the reserved forest
Φ preservation parameter
γ substitutability

Murray et al. (2004) - Why go through the paper and 2005 EPA Mitigation Report scenarios if the equation was enough?

FCQC Research Priorities *(short-term after we finish the leakage work of course)*

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Harvest Probability Equations

- utilizing some localized regression techniques
  - so either GWR *(betas vary across map)* or SAR *(error varies across map)* –or hopefully not both
- Problem is we would need FIA cooperation *(location and private owner type)*
- These could be applied both within an NCX-*type* program as well as within a ARB-CAR-ACR-VCS-*type* program *(don't need it for VCS_FFCP)*

Risk in Buffer (Reserve) Pool

- First focus on fire
  - What have the actual, project emissions
- Maybe next hurricanes

U.S. FOREST CARBON MARKET PRIMER

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Policy Analysis Group

TOTAL	
Project	192
Acres	5,794,736
Credits	192,754,683

Carbon Registries

***Compliance** market set by government regulations and highly regulated — ARB*

***Voluntary** market with voluntary buyers and sellers, not as strictly regulated as compliance markets— VCS, CAR, ACR*

COMPLIANCE	
Project	149
Acres	5,338,811
Credits	180,745,973

CALIFORNIA AIR RESOURCES BOARD

VOLUNTARY	CAR	ACR	VCS
Project	11	23	9
Acres	43,966	320,799	91,160
Credits	3,066,334	8,755,048	187,328

CLIMATE ACTION RESERVE · American Carbon Registry · Verified Carbon Standard A VERRA STANDARD

ARB: 25 year crediting period with 100 years maintaining those carbon stocks

ACR: 20 year crediting period with 20 years maintaining those carbon stocks

VCS: Most used voluntary program in the world

CAR: Crediting can be valid for 100 years from the start date, then 100 years maintaining those stocks CAR Version 5.0

Principles of Offset Projects

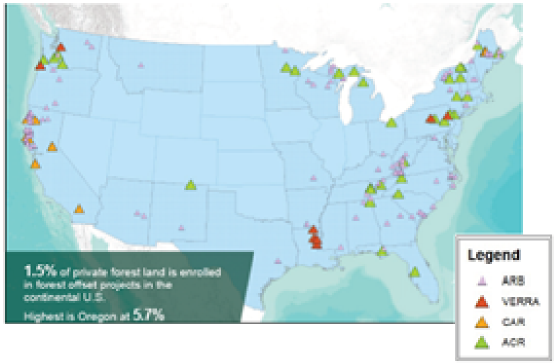
ADDITIONALLY: Project must demonstrate how it is going to increase carbon stocks in the project area.

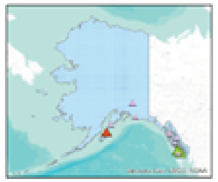
VERIFIABILITY : Projects must be verified through a third-party, sites are visited every six years and inventory reports are verified.

LEAKAGE: Occurs when the GHG reductions in one area results in the increase of GHG reductions in another area.

PERMANENCE: Must show project maintains benefits for a period of time

One Carbon Credit is equivalent to one metric ton of CO2 from the atmosphere.





Fact Sheet #12 (March 28, 2022) – Fact Sheets are based on research reports relevant to current natural resource topics.
Contributors: Daria Paxton, Undergraduate Researcher and Greg Latta, Policy Analysis Group Director
Support provided by: Adele Berklund Undergraduate Research Scholar Award

U.S. FOREST CARBON MARKET PRIMER

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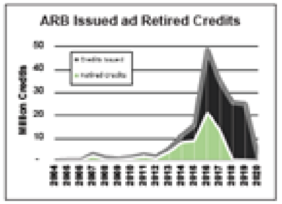
Steps for a Forest Offset Project

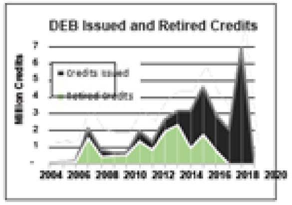
1	2	3	4	5	6
LANDOWNER	DEVELOPER	VERIFIER	REGISTRY	VERIFIED AGAIN	CREDITS ISSUED
Provides project area and management of that area	Initial project carbon inventory, quantification and documentation	Verified through an independent third party	Registry (either CAR, ACR, or VCS) provides offset tracking	The registry verifies the offset project internally	If all previous steps were approved then credits are issued to the landowner

ISSUED CREDITS: Represents one metric ton of CO_2 from the atmosphere

RETIRED CREDITS: Purchased credits that are taken off the market, so the purchaser can claim to have reduced emissions

Direct Environmental Benefits In The State Of California: requires the reduction or avoidance of any air or water pollutant that could negatively affect the state of California
(AB 398; Chapter 135, Statutes of 2017)
— Assembly Bill 398

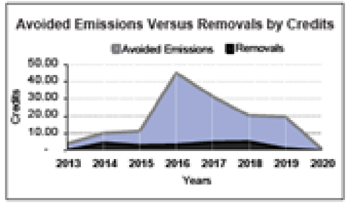




Carbon Offset Types

AVOIDED EMISSION OFFSETS: Initial credits issued, usually larger number because of previously established timber

REMOVAL OFFSETS: Credits that are issued yearly due to yearly growth of the project area

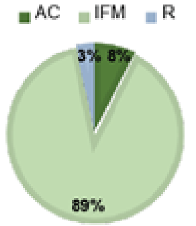


Forest Project Types

AVOIDED CONVERSION (AC): Forests prevented from being converted to non-forested land

AFFORESTATION/ REFORESTATION (R): Converting non-forested land into forested land

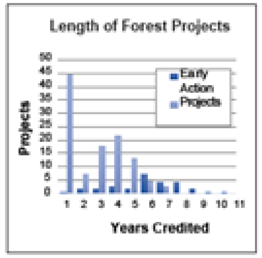
IMPROVED FOREST MANAGEMENT (IFM): Forest management that increases/ maintains a certain level of carbon stocking



ARB HARVESTING

37.6% All Projects
56 projects of 149

IFM - **38.6%** AC - **45%**
R - **0%**



Data was acquired from the ARB, CAR, and VCS public registries up to the 2020 vintage year. Completed in December 2021.

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Established by the Idaho Legislature in 1989 to provide objective analysis of the impacts of natural resource proposals.

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e-newsletter and **reports**
http://www.uidaho.edu/cnr/pag

Bonus Slide

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- For those of you who muttered "you cherry-picked your past studies" Greg

Table 2
Selected studies in the meta-regression analysis: the forest sector.

Model type	Model Name	References	Number of Estimates	Magnitude (%)	Range (%)
GEM[a]		[28] Baylis et al. (2013)	2	0.96	−10.31–7.45
GEM	CGE[c]	[29] Kuik (2014)	11	3.84	0.57–10.73
	d	[30] Alix-Garcia et al. (2012)	1	4	n/a
	e	[31] Fortmann et al. (2017)	1	4.4	−5.7–14.5
PEM[b]	f	[32] Kim et al. (2014)	1	14.85	14.8–14.9
	g	[33] Acosta-Morel (2011)	7	17.14	9–22
	h	[34] Sohngen and Brown (2004)	2	19.50	18–21
		[35] Meyfroidt and Lambin (2009)	1	22.7	n/a
PEM	FASOM[i]	[36] Murray et al. (2004)	8	25.86	−4.4–92.2
PEM	EUFASOM[j]	[37] Zech and Schneider (2019)	1	43	n/a
PEM	GCAM[k]	[38] González-Equino et al. (2017)	12	48.53	10.0–93.0
	l	[39] Sun and Sohngen (2009)	1	49.50	47.0–52.0
PEM	m	[40] Wear and Murray (2004)	3	61.80	43.3–84.4
		[41] Jadin et al. (2016)	1	68	n/a
GEM	CGE	[42] Gan and McCarl (2007)	12	75.31	42.3–95.4
PEM	EFI-GTM[n]	[43] Kallio et al. (2018)	1	76	65–87
PEM	EFI-GTM	[44] Kallio and Solberg (2018)	1	80	60.0–100.0
PEM	USFPM/GFPM[o]	[45] Nepal et al. (2013)	3	81.33	71.0–88.0
GEM	GTAP[p]	[46] Hu et al. (2014)	1	84.25	79.7–88.8
		Average		39.60	−10.31–100.0

Notes: [a] General Equilibrium Model; [b] Partial Equilibrium Model; [c] Computable General Equilibrium; [d] A simple model of household production and land allocation; [e] A matched difference-in-differences (DID) approach; [f] Leakage discount formula; [g] A Land Use Share Model; [h] Dynamic optimization model; [i] The forest and agricultural sector optimization model; [j] European Forest and Agricultural Sector Optimization Model; [k] Global Change Assessment Model from Joint Global Change Research Institute; [l] Global land use and forestry model; [m] A full econometric model of the US softwood lumber market; [n] European Forest Institute Global Trade Model; [o] US Forest Products Module and Global Forest Products Model; [p] Global Trade Analysis Project model.

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Carbon leakage in energy/forest sectors and climate policy implications using meta-analysis

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