

# Engineered Bamboo for Sustainable Construction

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## Carbon Stocks and Footprints of Bamboo Products

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# Bamboo products: various usages

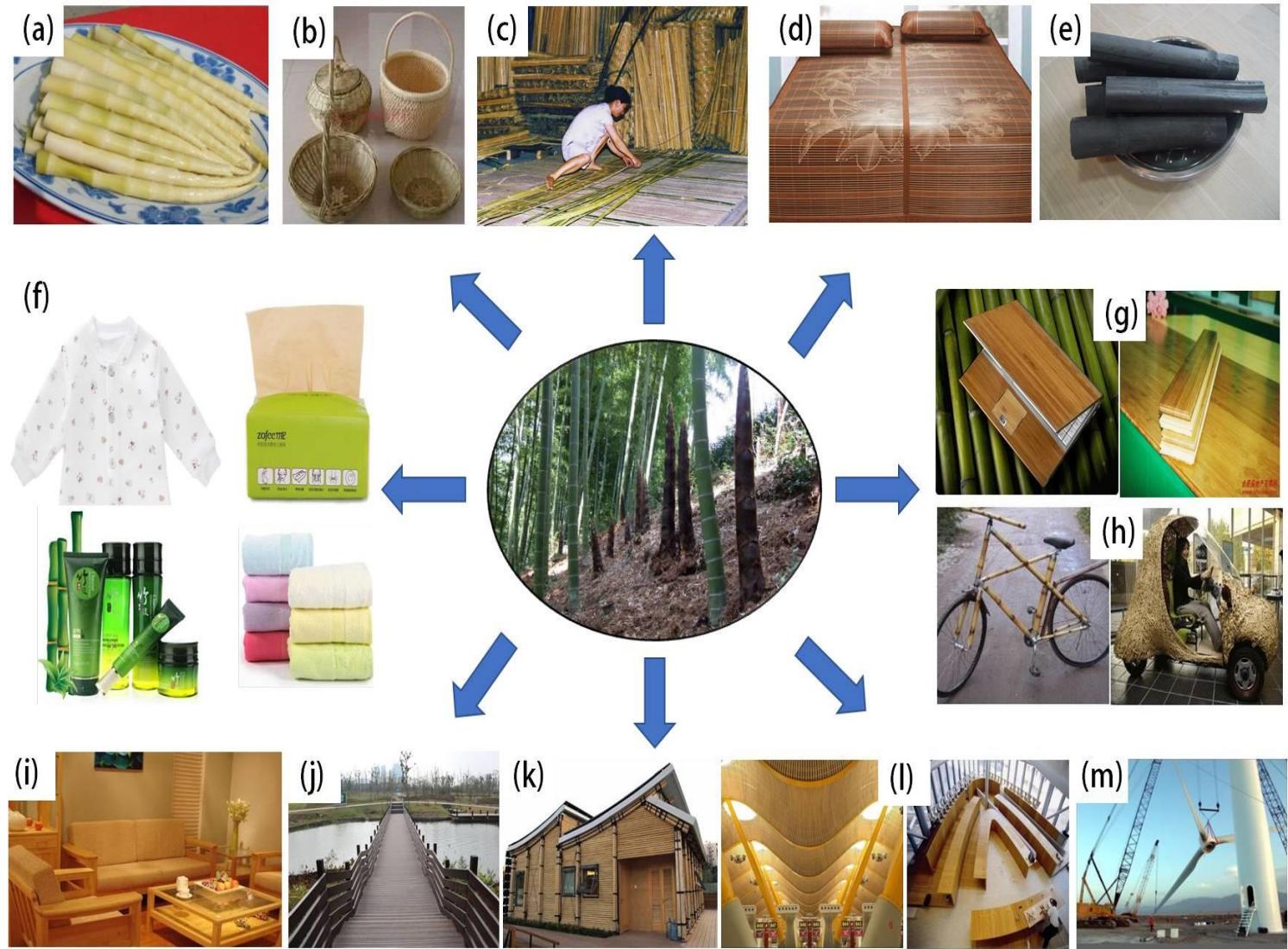
## Bamboo production:

10 billion dollars per year

## Bamboo products:

more than 2000 varieties

- (a) bamboo shoots;
- (b) bamboo weaving;
- (c) bamboo slabs;
- (d) bamboo mats;
- (e) bamboo biochar;
- (f) bamboo-fiber fabric, facial tissues, and makeup;
- (g) bamboo decorative material;
- (h) bamboo vehicle;
- (i) bamboo furniture;
- (j) bamboo floor;
- (k) bamboo buildings;
- (l) bamboo waiting hall;
- (m) bamboo wind turbine blades.



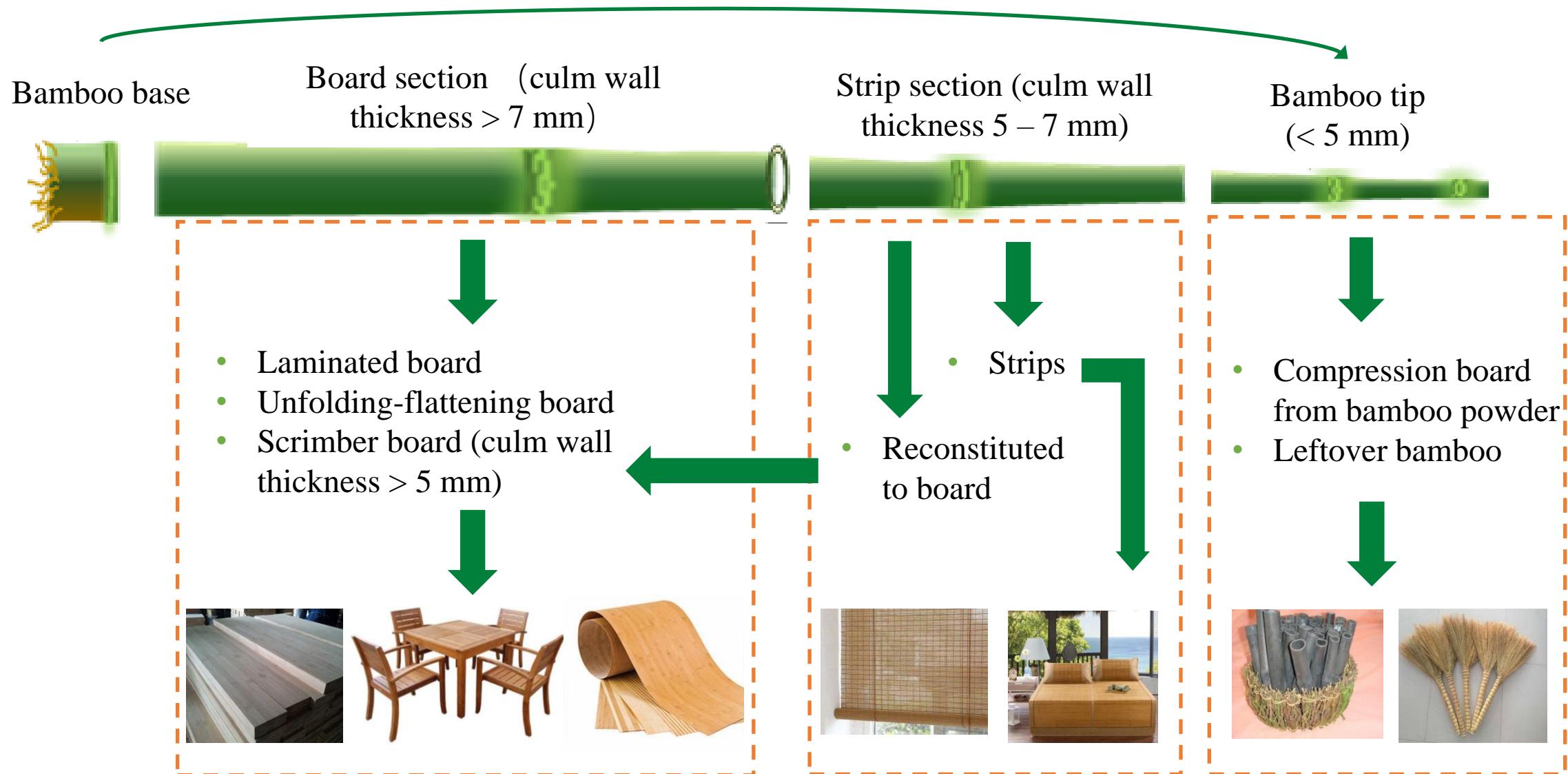
# Carbon footprints of bamboo products



From 2011 to 2016, we:

- investigated 105 bamboo manufacturers in 4 provinces in China (Zhejiang, Fujian, Jiangxi, Sichuan)
- measured 1098 logged bamboo culms
- traced and measured the whole technological processes of bamboo production
- measured carbon footprints of 9 bamboo products in 5 categories.

# From a standing bamboo culm to products



## 3 main technologies

Laminated

Unfolding-flattening

Reconstituted

Laminated board

Unfolding-flattening board

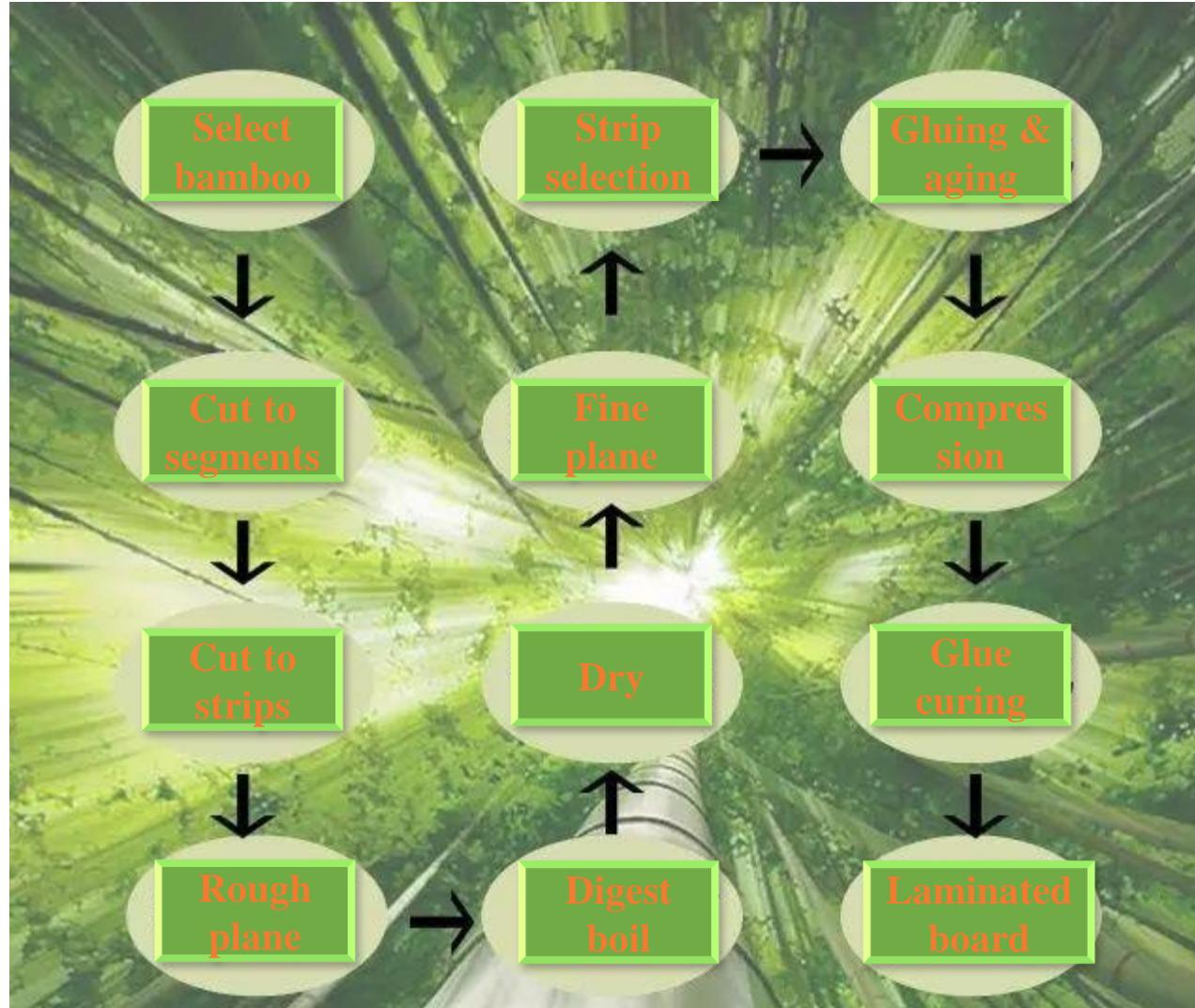
Scrimber board

Drawn bamboo threads

Sliced bamboo board

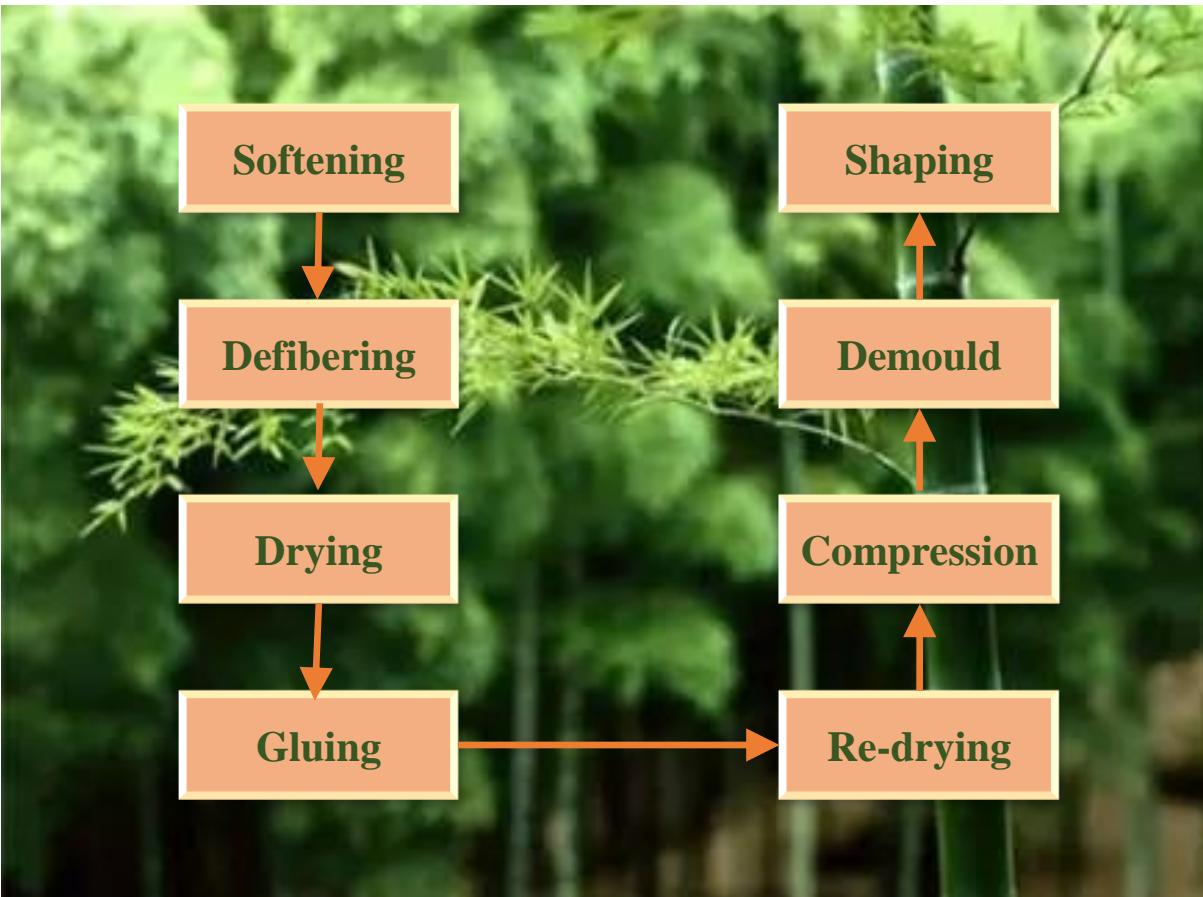
# 1<sup>st</sup> Main technology:

## Laminated technology

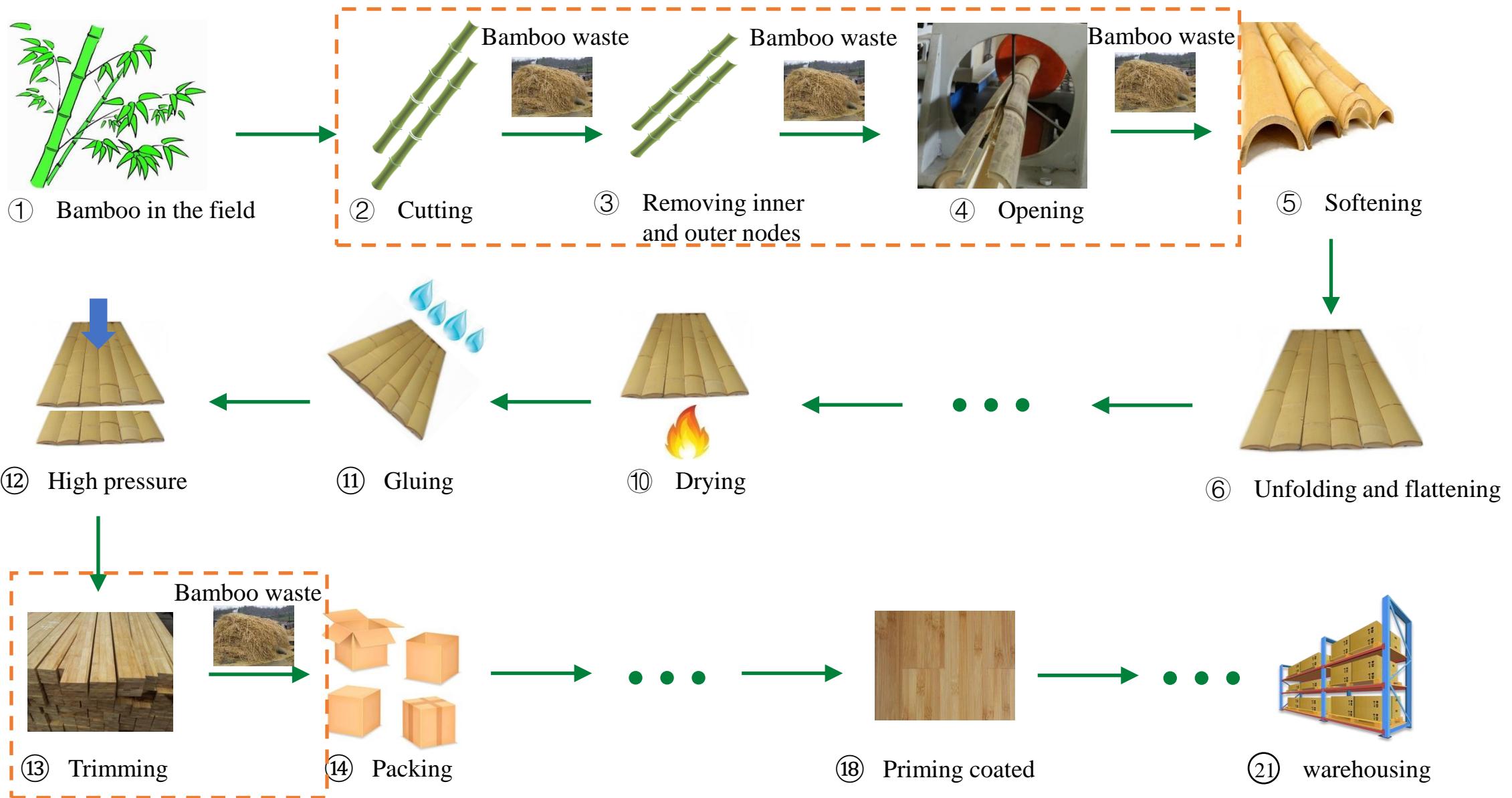


## 2<sup>nd</sup> Main technology:

### Reconstituted technology



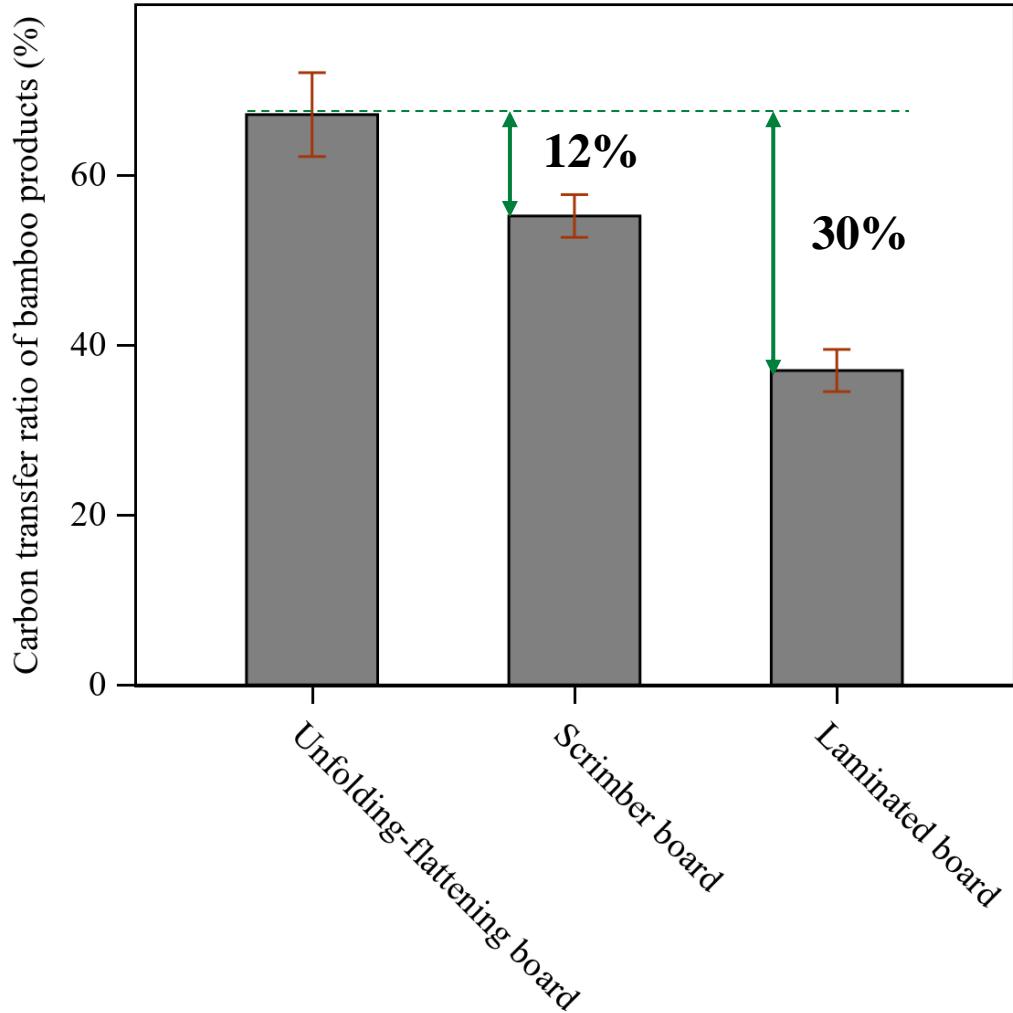
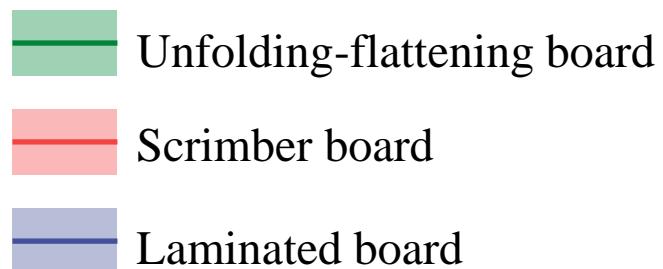
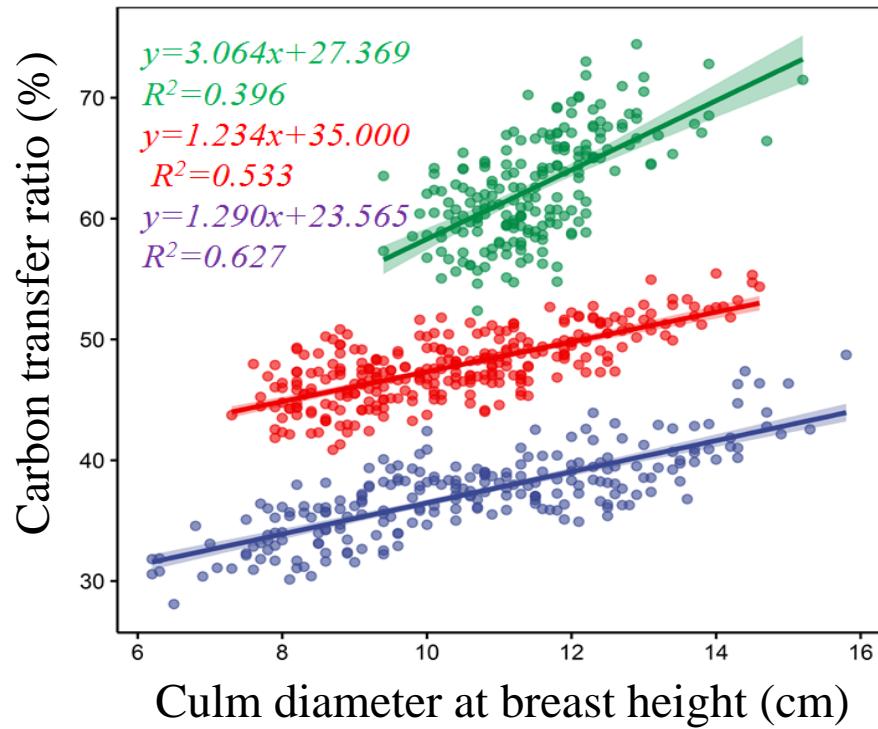
### 3rd Main technology: unfolding-flattening (bamboo floor with green bark)



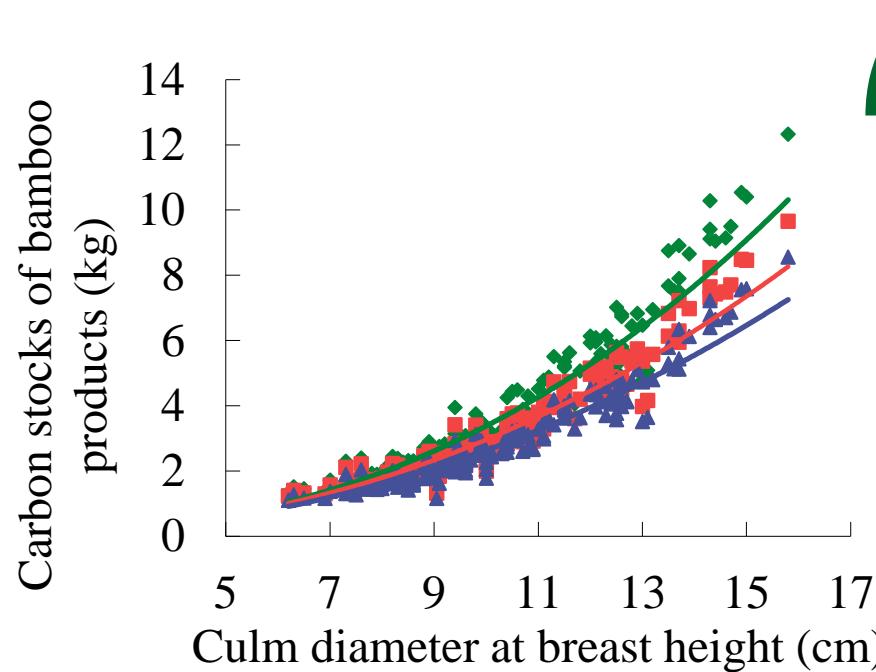
# Carbon emission: unfolding-flattening bamboo floor

Process	Power consumption	Operation time of machine	Idle operation of machine	Carbon transfer	Carbon emission for producing 1 m <sup>3</sup> board	Percentage emission
Unit	Kw h <sup>-1</sup>	s	s	%	kg	%
① Cutting	4.5	4	10	100	0.88	1.01
④ Open	3	16	6 times	100	0.38	1.18
⑤ Softening	1.5	60	2 times	120	0.29	0.33
⑥ Unfolding/flattening	14	47	20	100	4.32	4.92
⑧ Remove color	35.1	48	12	81.54	10.59	12.06
⑩ Drying	1.5	432000	0	100	0.42	0.48
⑬ Trimming	4.5	4	10	100	1,24	1.41
⑮ Rough-plane	19.5	20	3	54.02	33.46	38.1
⑯ Fine-plane	15	17	3	67.1	22.02	25.08
⑰ Primary coated	1.5	0.5	3	100	0.12	0.13
...						
Summary					87.8	100

# Carbon transfer ratio of bamboo products: effects of culm diameters and Technological types



# Upscaling carbon stocks of bamboo products to national level



- ◆ Unfolding-flattening board (high-tech)
- Scrimber board (traditional)
- ▲ Laminated board (traditional)



**Step 1:** Carbon stocks of bamboo products from 3 technologies:

- ◆  $C_i = 0.0123 \times D_i^{2.4584}$
- $C_i = 0.0169 \times D_i^{2.2445}$
- ▲  $C_i = 0.0161 \times D_i^{2.2146}$

**Step 2:** Weibull distribution of bamboo culm diameter:

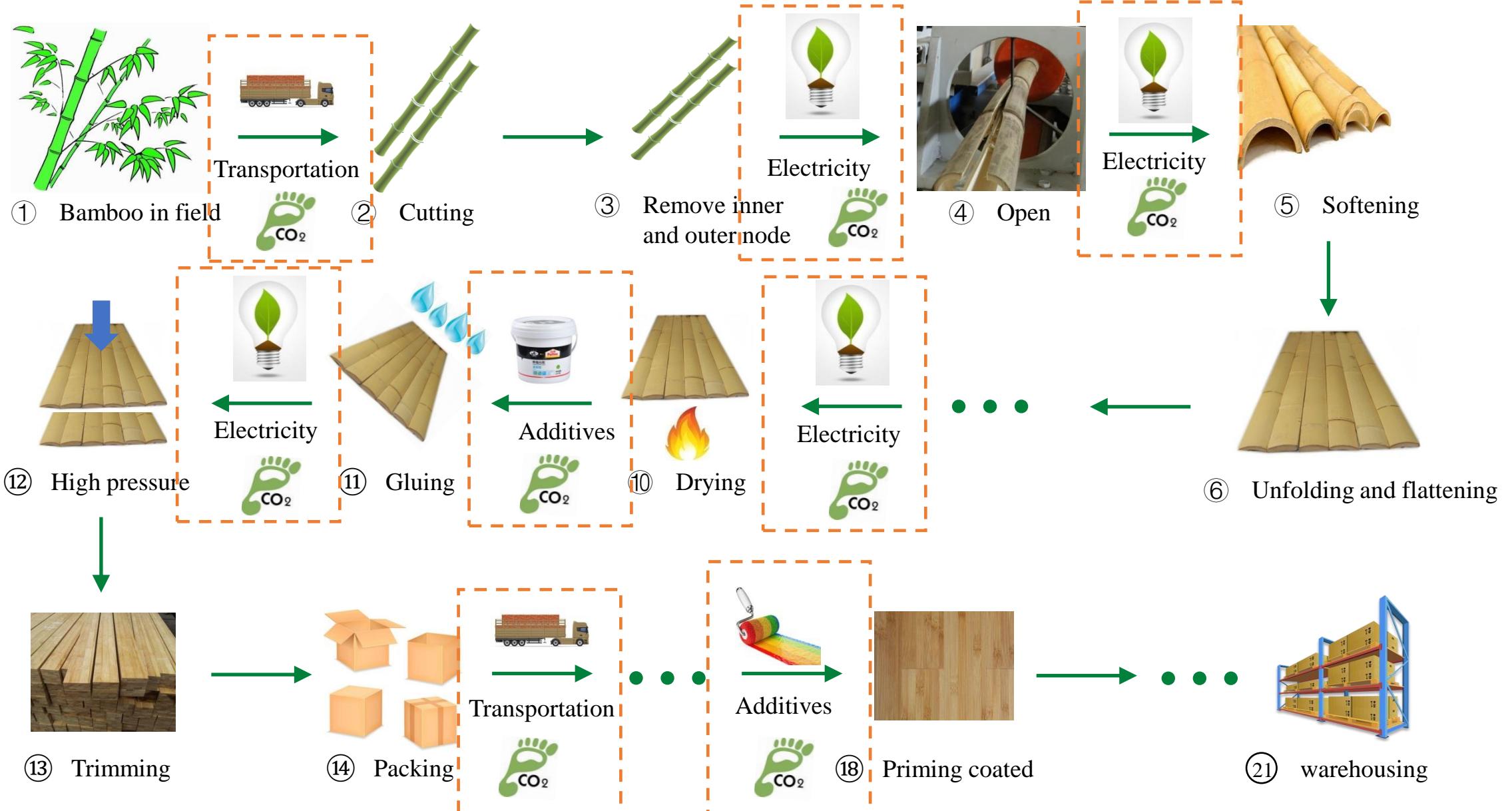
$$f(D, \theta) = \left(\frac{D - 1.3367}{7.442}\right) 3.606 \frac{3.606}{D - 1.337} e^{-\left(\frac{D - 1.337}{7.442}\right) 3.606}$$

**Step 3:** Cumulated carbon stocks of bamboo products derived from bamboo culms with diameter range of 5 to 15 cm:

$$C_{product} = \sum_{i=5}^{15} (N \times f(D_i, \theta) \times c_i)$$

Results: based upon **1.9 billion** bamboo removals in **2015**, we predicted that a national level of carbon flux into bamboo products is **319,200 ton C year<sup>-1</sup>**.

# Technological processes: unfolding-flattening bamboo floor with green bark



# Carbon emission of unfolding-flattening bamboo floor with green bark

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## (Additives)

Process	Additives	Carbon emission factor	Amount of additive for 1 m <sup>3</sup> board	Carbon emission for producing 1 m <sup>3</sup> board	Ratio of emission
Unit	-	kg kg <sup>-1</sup>	kg	kg	%
Gluing	Adhesive	0.6	27.44	16.47	51.75
Primary coated	Oil paint	0.6	0.41	0.25	0.78
Waxing	Paraffin	0.2	0.41	0.08	0.25
Packing	Carton	0.9	16.69	15.03	47.22
Summary				31.82	100

# Carbon footprints of unfolding-flattening bamboo floor with green bark

	Item	Carbon footprint (kg)*	Footprint count
	Transportation	31.2	yes
	Electricity	87.8	yes
	Additives	31.8	yes
	Bamboo waste	232.2	no
Carbon stock (assumed 20 years of usage)		168.8	
Carbon footprint		-17.9	→ Carbon uptake product

\* The amount of carbon footprint for 1 m<sup>3</sup> bamboo floor.

# Carbon footprints of 9 investigated products

Bamboo products	Specification	Theoretical life span	Carbon footprint
	mm*mm*mm	Year	kg m <sup>-3</sup>
Unfolding-flattening floor with green bark	1200*137*18	20	-17.91
Unfolding-flattening chopping board	360*240*17	8	114.55
Unfolding-flattening chopping board	380*280*18	8	130.38
Bamboo scrimber flooring for outdoor use	1860*137*20	20	3.83
Bamboo scrimber flooring for indoor use	910*127*14	20	51.58
Sliced bamboo veneer	2500*450*0.6	20	152.60
Bamboo curtain	1500*3.5*1.5	15	118.06
Bamboo mat	1500*2.5*2.5	15	152.27
Bamboo carpet	1500*4.5*2.0	15	112.22

# Conclusions

- **Culm diameter** and **production technology** are two main factors influencing carbon transfer ratio.

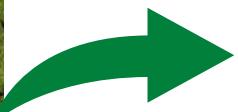


*Dendrocalamus gigantous*,  
Bogor Botanical Garden, Indonesia



Unfolding-Flattening floor

- A predicted large amount of national level of carbon stocks in bamboo products based on carbon transfer ratio and Weibull distribution of bamboo diameters, which implied **a potentially huge carbon pool of bamboo products**.



Ecosystem carbon flux of Moso bamboo monitored by the eddy covariance tower in Anji, Zhejiang

Photo by Jinhe Fu, INBAR

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**Thank you for your attention!**

