A Life Cycle Assessment of Energy and Greenhouse Gas Emissions for Almond Production in California

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Research Objectives

- **Quantify** net life cycle greenhouse gas (GHG) **emissions** and **energy** use in California almond production..
  - Stage 1: Field to Farm Gate
  - Stage 2: Hulling and Shelling
- Why do these calculations matter?
  - Consumer and retailer demand, particularly in Europe for "carbon footprints" (another phrase for life cycle GHG assessment)
  - Potential AB32 Carbon Offsets
  - Understand energy use over the production life cycle to improve efficiency and mitigate energy-related costs

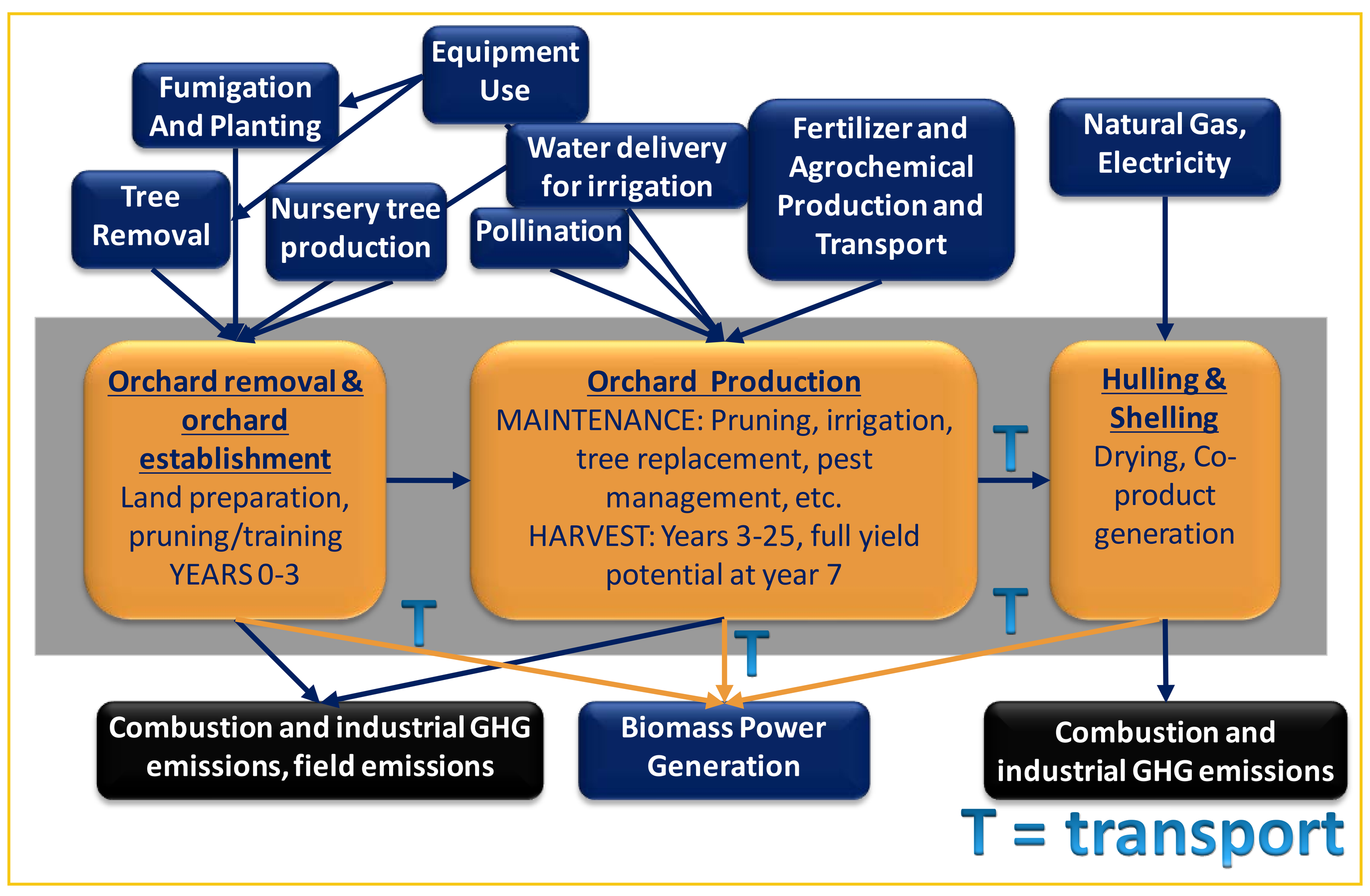

Figure 2. Simplified LCA model for almond production.

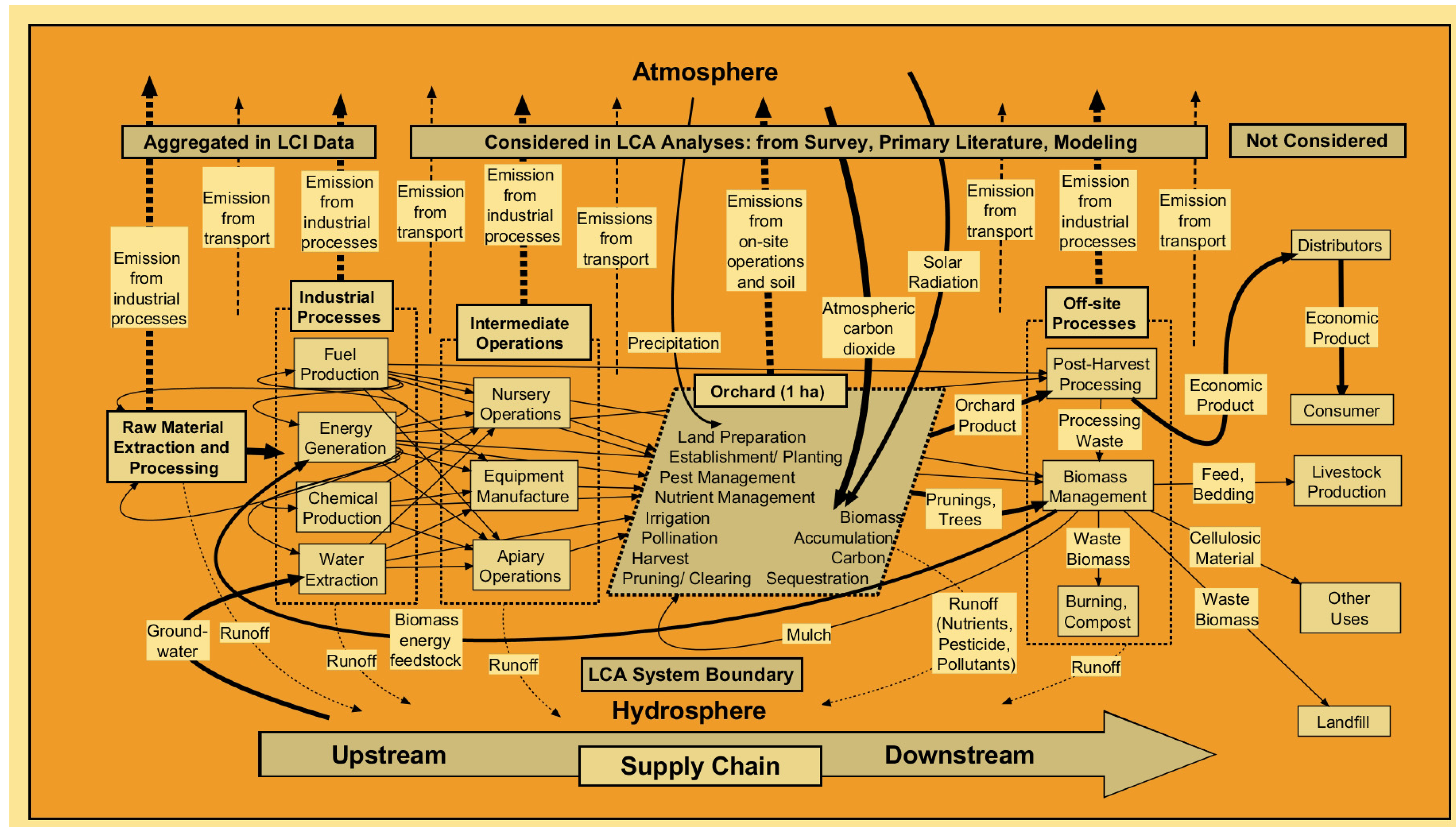

Figure 1. Life cycle inputs and outputs in the almond production system and relationship to environmental flows and reservoirs

Life Cycle Assessment

- **Life Cycle Assessment** (LCA) evaluates the environmental flows (energy and material **inputs** and pollution and product **outputs)** over a system's life cycle. In this study, environmental flows associated with the almond production life cycle were measured from **nursery** to **farm gate**, and from farm gate through **hulling and shelling**.

Methods

Input, **yield**, and **operations** data were gathered from UC Davis Department of Agriculture and Resource Economics cost/return studies, farmer and operator survey, literature review, and collaboration with other researchers.

Emissions and **energy** use data for industrial processes were collected from Life Cycle Inventory (LCI) databases provided by GaBi 4, Ecoinvent, and USLCI.

Greenhouse gas emissions are expressed as **100-year Global Warming Potential (GWP)**, calculated according to Intergovernmental Panel on Climate Change (IPCC) guidelines.

Cogeneration potential was calculated from tree mass at orchard clearing and pruning mass, based on a logarithmic growth model.

Fuel combustion emissions are calculated using the California Air Resources Board (CARB) OFFROAD modeling tool.

Upstream impacts of producing fuels, chemicals, and other inputs were modeled using life cycle inventory data from the commercial databases *GaBi Professional DB* and *Ecoinvent*

Soil emissions in response to management and nutrient inputs are estimated using IPCC Tier 2 calculations.

Results

- **Potential** greenhouse gas **offsets** represent a significant proportion of total almond production emissions (excluding processing and distribution).
- The bulk of energy use and emissions are derived from **nutrient management** – particularly from **production** of **nitrogen fertilizers,** and from **irrigation**. These are **hotspots** for improvements in energy efficiency, and resource efficiency actions
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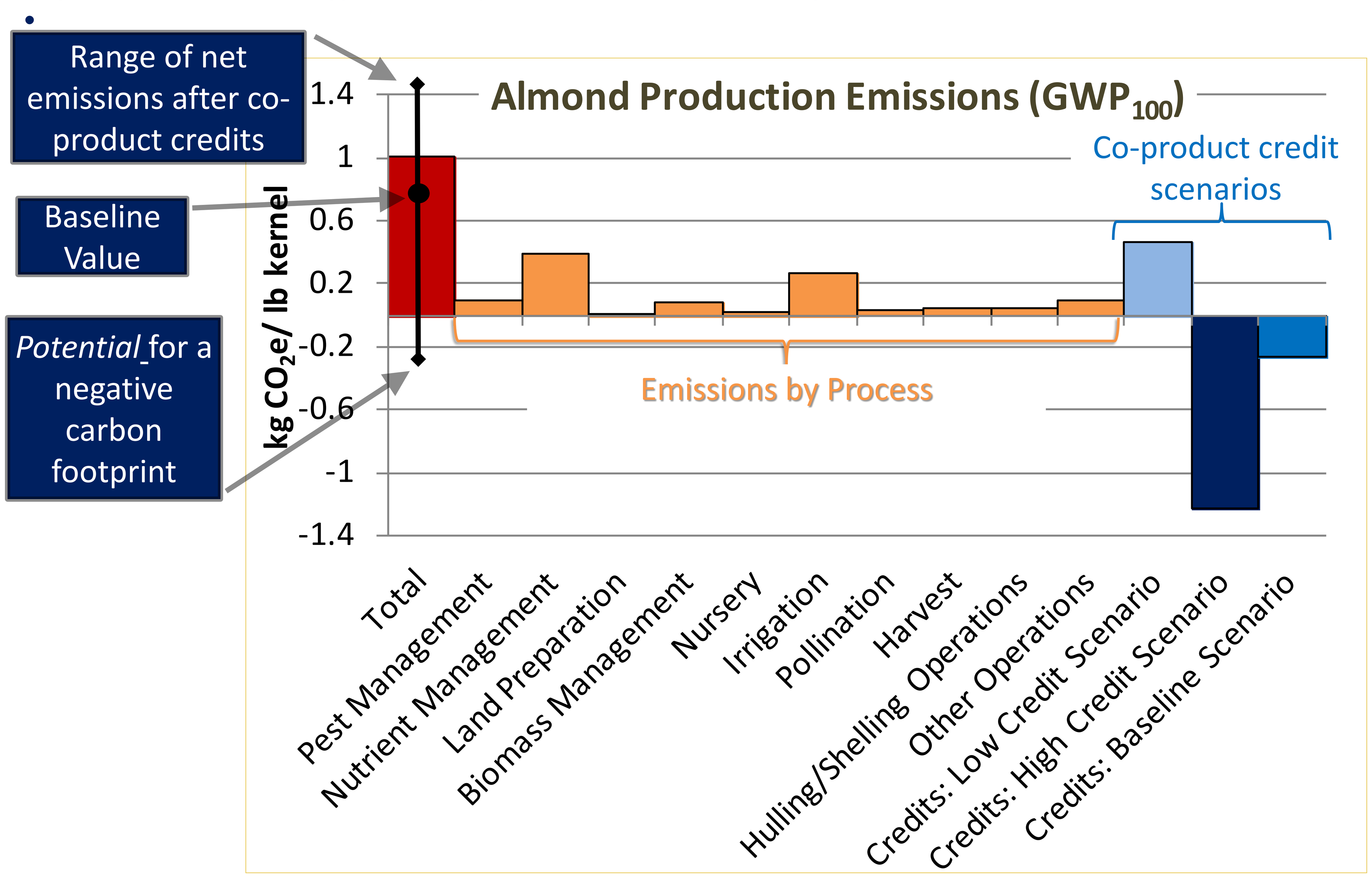

Figure 4. Life cycle GHG emissions by process

Table 1. Life cycle GHG and Energy by Category, Baseline Values

Per acre (over 25 year life span)	Production	Field	Transport
Energy (MJ)	606,405	26,889	95,437
GWP_{100} (kg CO_2eq)	28,824	8,875	6,534
Per pound of kernel	**Production**	**Field**	**Transport**
Energy (MJ)	13.82	0.61	2.17
GWP_{100} (kg CO2eq)	0.66	0.20	0.15