The True Costs of Electric Roasting

Roast Summit – October 24, 2024

The True Costs of Electric Roasting

Be Wary of Misleading Statements

- *Selecting a roasting machine **based upon energy efficiency** or **CO2 emission** is currently **close to impossible**.*
- *Only in some cases is **energy consumption indicated in the technical documentation** of a machine.*
- *In rare cases, the electric consumption of the motors and other components will be included. **Emission values are even harder to come by.***
- *A lack of information about the conditions under which consumption and emission figures apply **makes it impossible to estimate** how much energy is actually needed to roast a kilogram of green coffee on a given machine and with the intended roast result.*

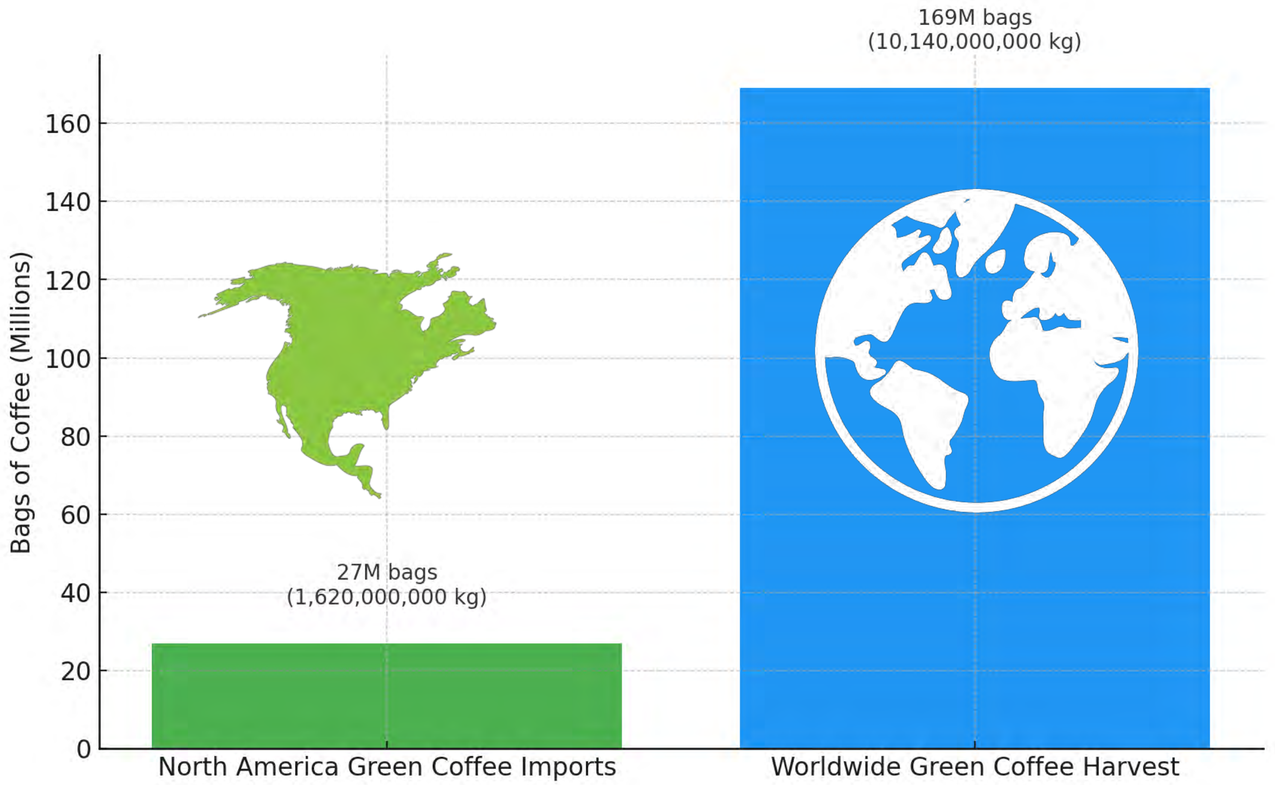
Today We Will Cover:

1. True Cost of Operating an Electric Roaster
2. Calculating Utility Consumption for Roasters
3. CO2 Emissions During Coffee Roasting
4. Key Variables Influencing Utility Use and CO2 Generation
5. Debunking Misinformation to Make Informed Decisions

Understanding the Market

For those working in agricultural supply chains, the challenges remain significant, given the diverse direct and indirect emissions occurring throughout the value chain.

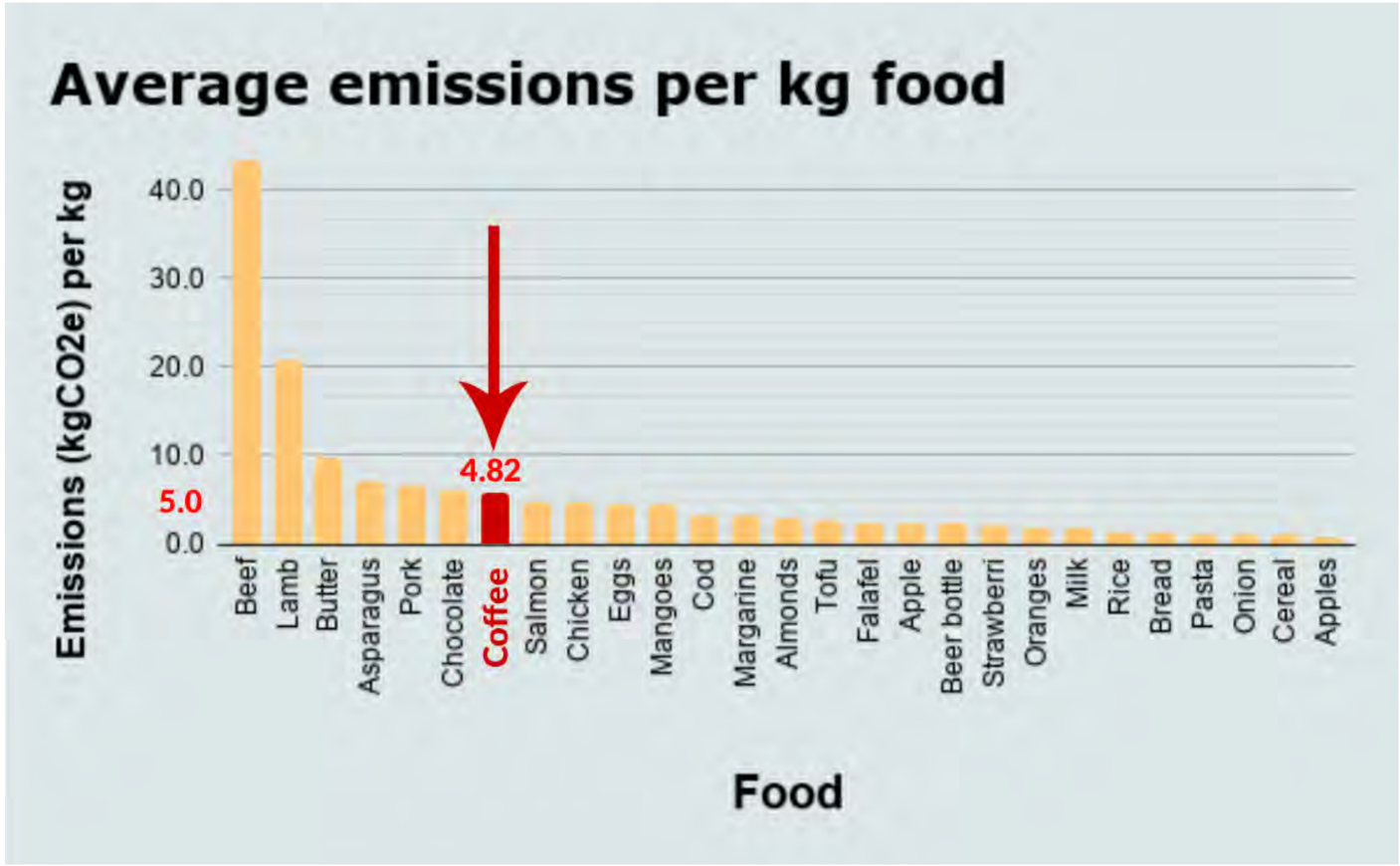
Annual Import vs. Worldwide Harvest of Green Coffee



Overall, it can be estimated that the total carbon footprint across the entire supply chain is approx. 4.82 kg CO_2 /kg green coffee.

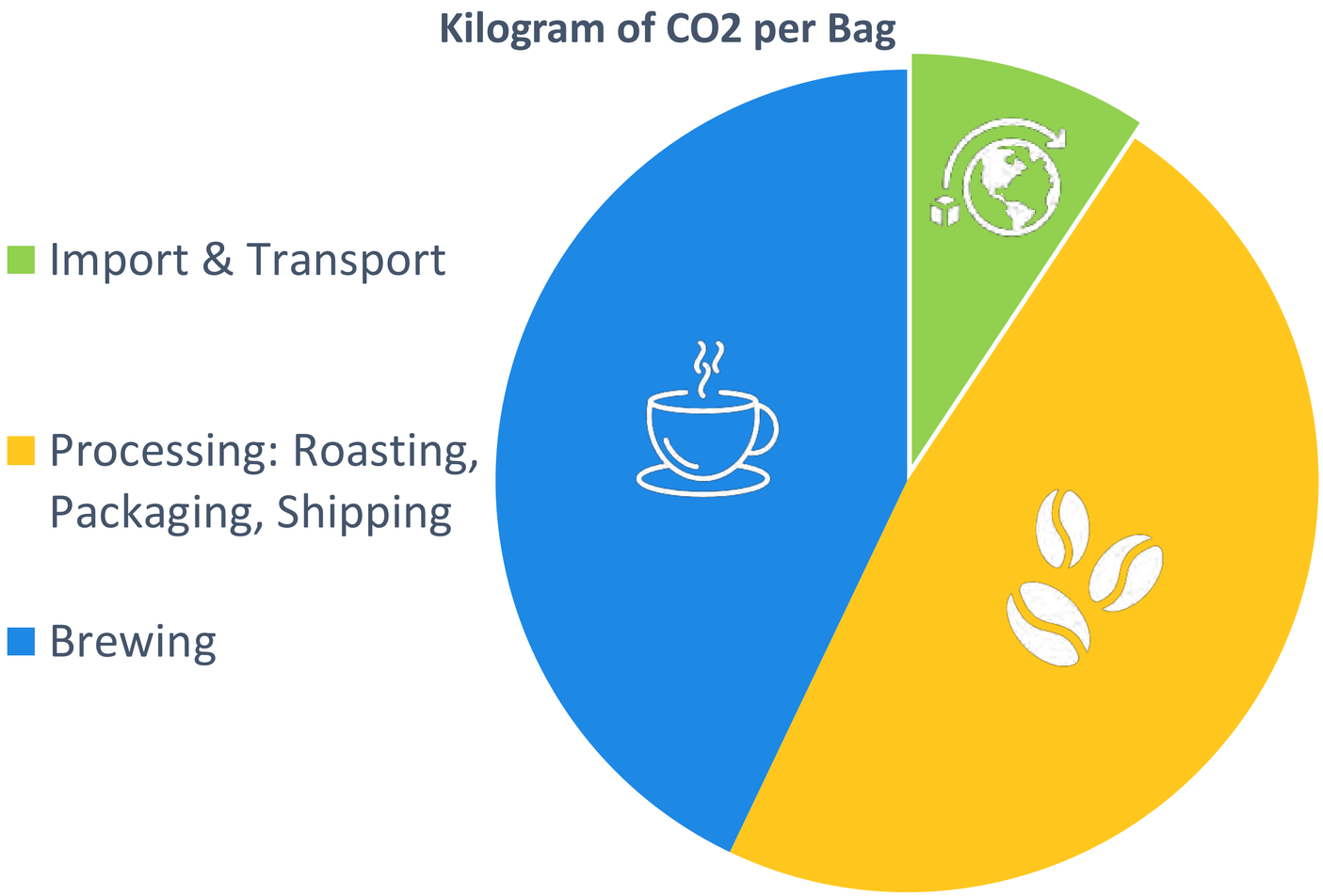
The coffee value chain is considered to have a "very high intensity" carbon footprint.

Comparing Coffee Carbon Footprint with other Food Applications



Overall, it can be estimated that the total carbon footprint across the entire supply chain is approx. 4.82 kg CO_2 /kg green coffee.

Carbon Footprint across Coffee Value Chain



Import of green coffee from country of origin and transport to roaster generates approximately **27Kg of CO_2 per bag**

•or 0.45 Kg CO_2 /Kg green coffee

Processing of green coffee including Roasting, Packaging and Shipping generates

138 Kg CO_2 /bag or

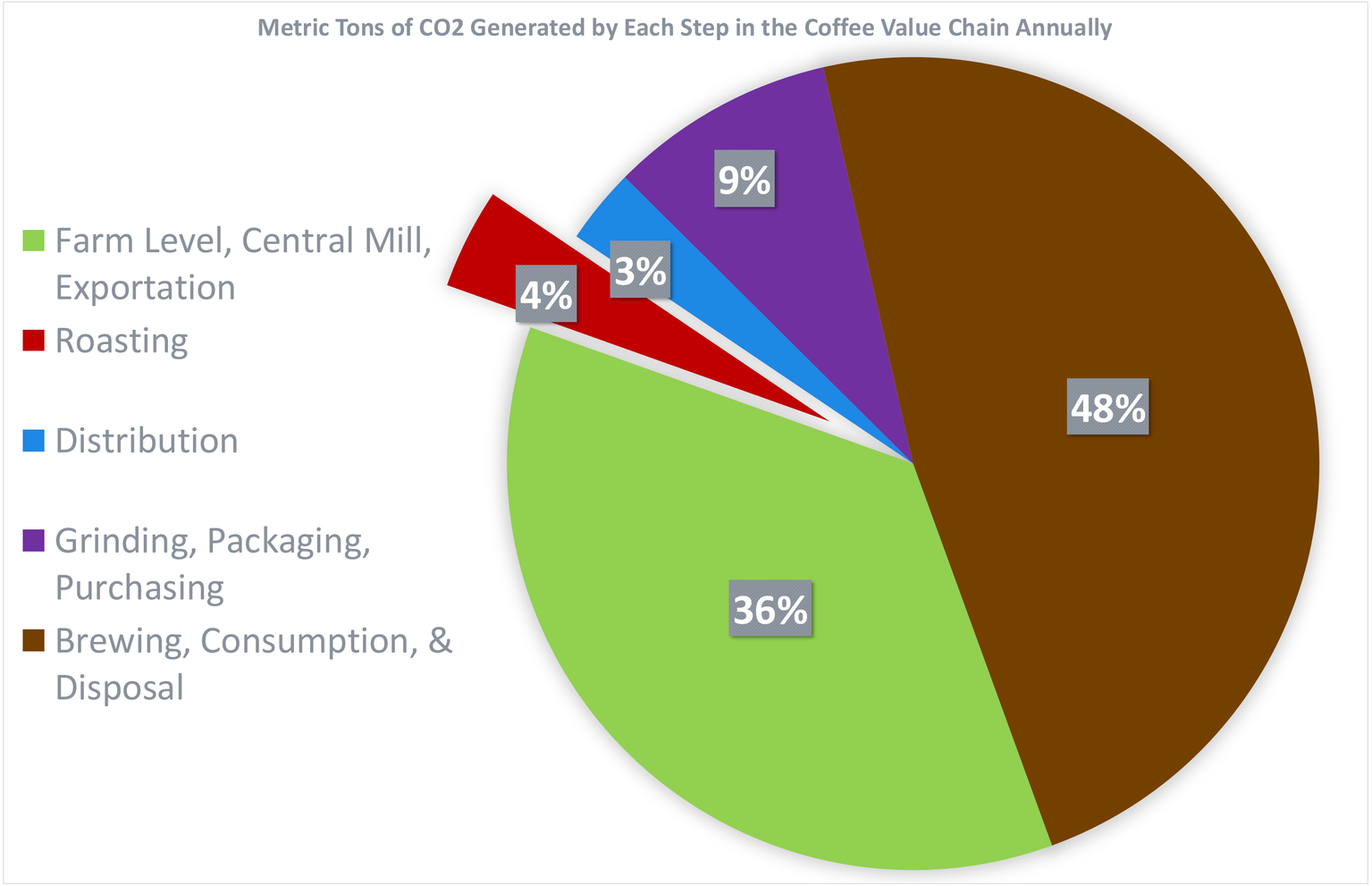
•2.3 Kg CO_2 /kg green coffee

Brewing of coffee generates **124 Kg CO_2 /bag or**

•2.07 Kg CO_2/ kg green coffee

Overall, the total carbon footprint across the entire supply chain is approx. 4.82 kg CO_2 /kg green coffee.

CO2 Generated on the Journey of the Bean



- **Coffee processed through the coffee value chain annually:** 1.620 billion kg
- **CO2 generated by the entire coffee value chain annually:** 7,808,000 metric tons CO2 generated
- ***Roasting alone creates 312,336 metric tons of CO2 Annually***

North American Coffee Market

TOP
(400KG)

Less Than 10 Roasters in North America
Capacity approx. >10,000 kg/hr.

REGIONAL
(280KG-400KG)

Less than 25 Roasters in Capacity
approx. 2,000-9,000 kg/hr.

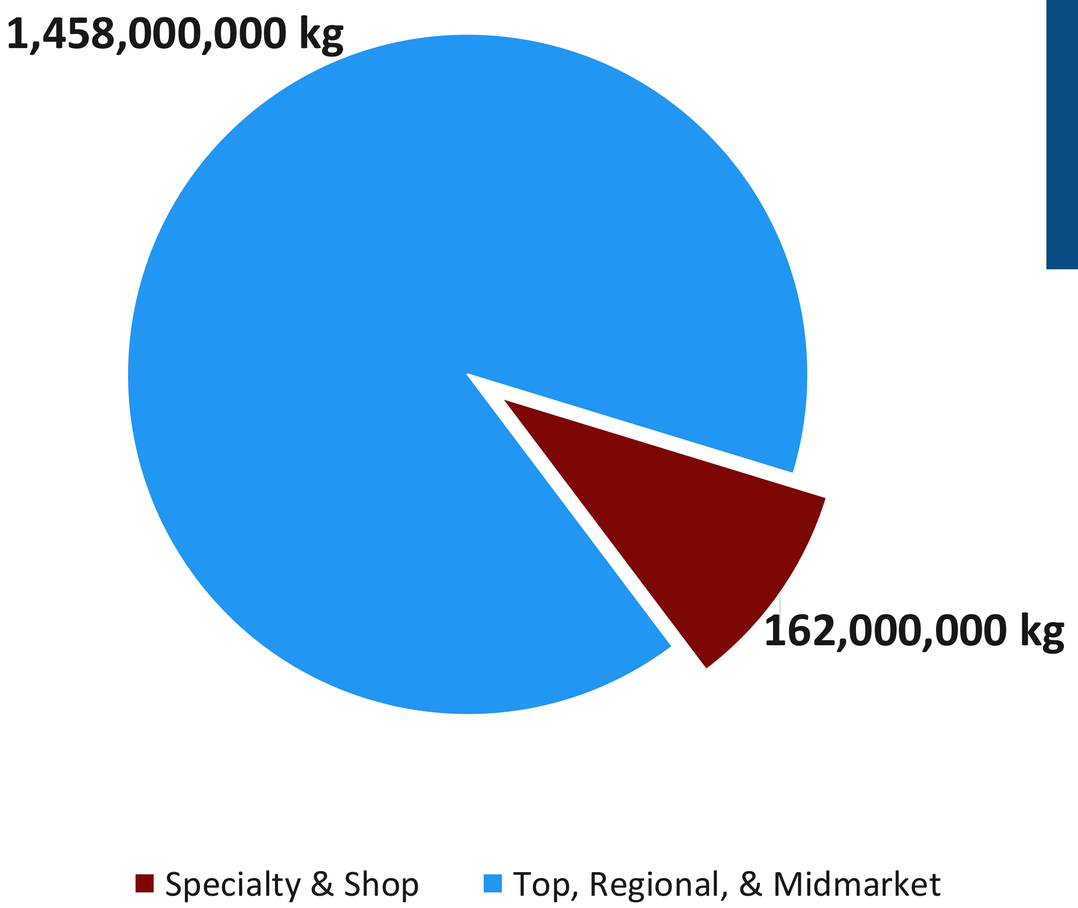
MIDMARKET
(70KG-280KG)

100+ Roasters
Capacity approx. 500-2,000 kg/hr.

SPECIALTY & SHOP ROASTERS
(1KG-70KG per batch)

Approx. 6,000 Roasters
Batch Capacity approx. > 1-70 kg

North American Coffee Market



Nano and Specialty Roasters process less than 10% of all coffee imported and roasted.

Assuming:
4 batches /hr. 4 hours/day 4 day/week 52 weeks/year
Total Batch – 3328 batches/year

Batch Sizes:	Operating Roasters	Processing Capacity
1kg – 3328kg/year	3,100	31 mill. Kg
3kg – 10,000kg/year		
5kg – 17,000kg/year	600	10 mill. Kg
12kg – 40,000kg/year	2,175	87 mill. Kg
25kg – 83,000kg/year	200	17 mill. Kg
35kg – 116,000kg/year	150	17 mill. Kg
Total		**approx. 6,225**

162 mill. Kg of coffee roasted annually within Specialty/Shop Roasters)

Micro & Nano Roasters contribute the least amount of C02. These roasters are strong advocates of environmental concerns.

Electric Roasters Through Time

Electric Roasters have been on the market for 40+ years

Historically, the primary purpose of a table-top roaster has been as a sample roaster to roast, cup, and score green coffee as part of the green coffee selling process.

Nano Roasters

Bellwether Coffee

STRONGHOLD

LINK

PROBAT

DIEDRICH ROASTERS

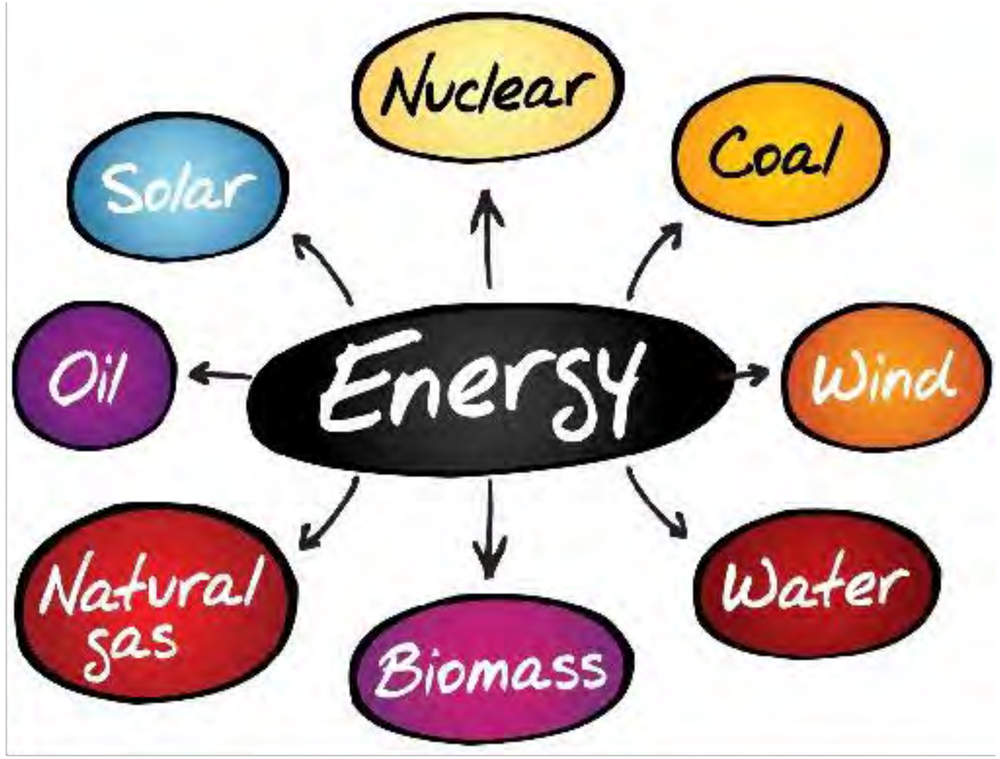
Understanding the Sources of Electricity

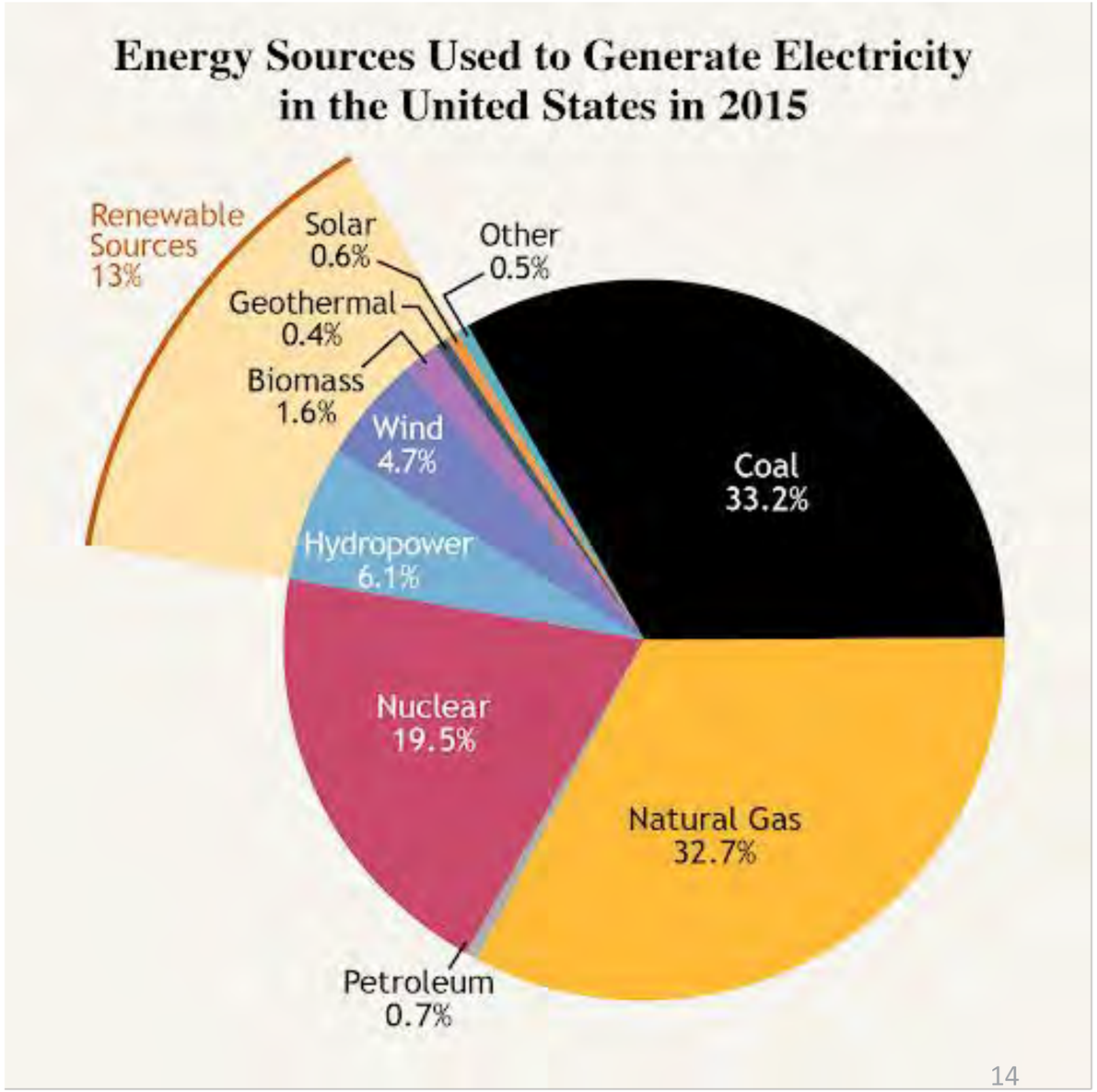
Electricity is not always “clean” energy.

While electricity is often viewed as a cleaner alternative, especially in the push for sustainability, the reality is more complex.

The environmental impact of electric roasters depends heavily on how electrical plants generate electricity.

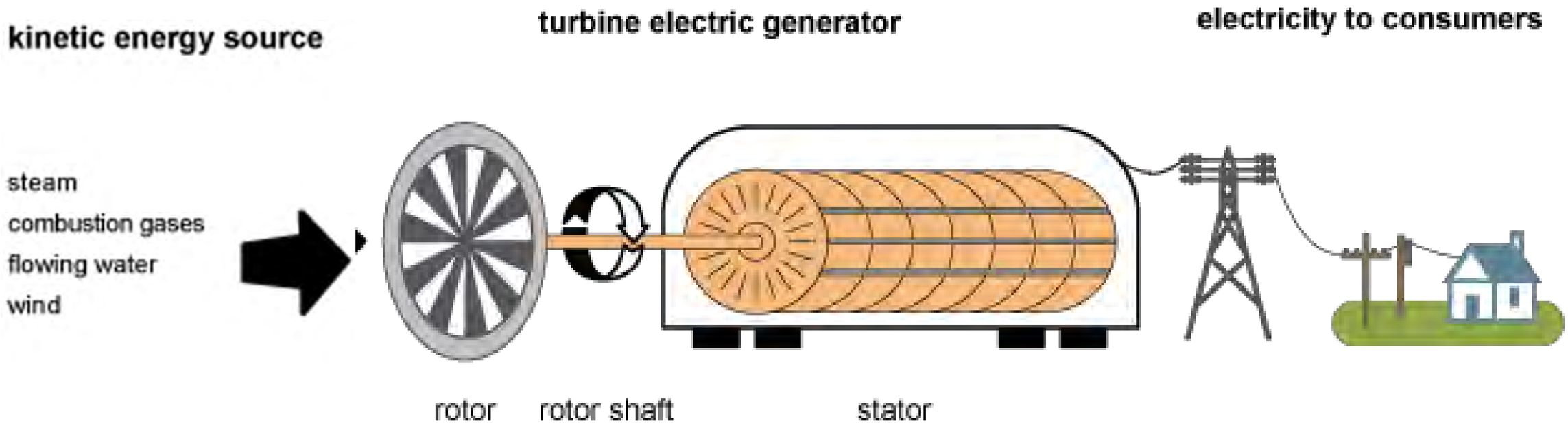
Where Is Your Power Coming From?





How is Electricity Generated?

Electricity Generation from an Electric Turbine



Source: US Energy Information Administration

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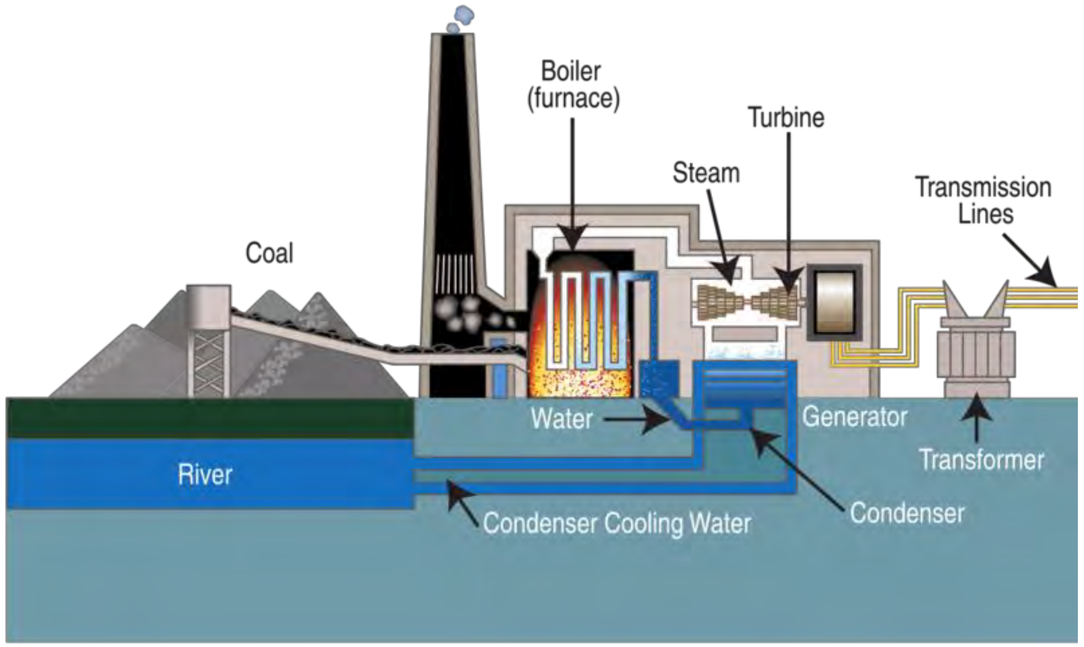


Fossil Fuels Used to Generate Electricity

In 2023, fossil fuels were used to generate about 60% of electricity in the United States.

Amount of fossil fuels used to generate electricity varies by type of fuel in 2023:

Coal:

1.14 pounds per kWh

Natural Gas:

7.42 cubic feet per kWh

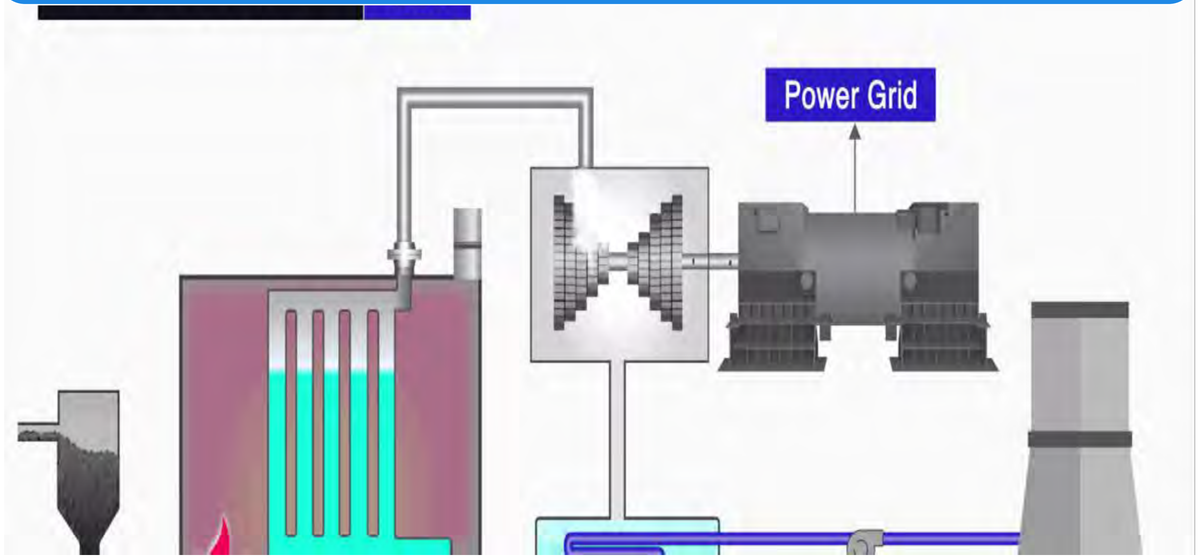
Petroleum Liquids:

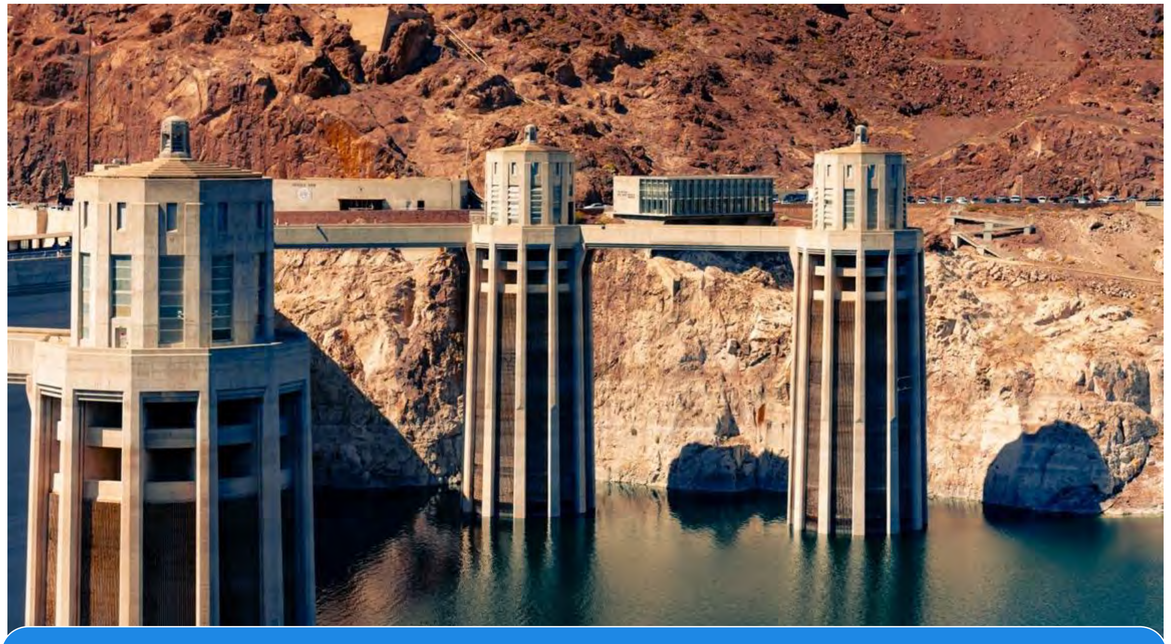
0.08 gallons per kWh

Petroleum coke:

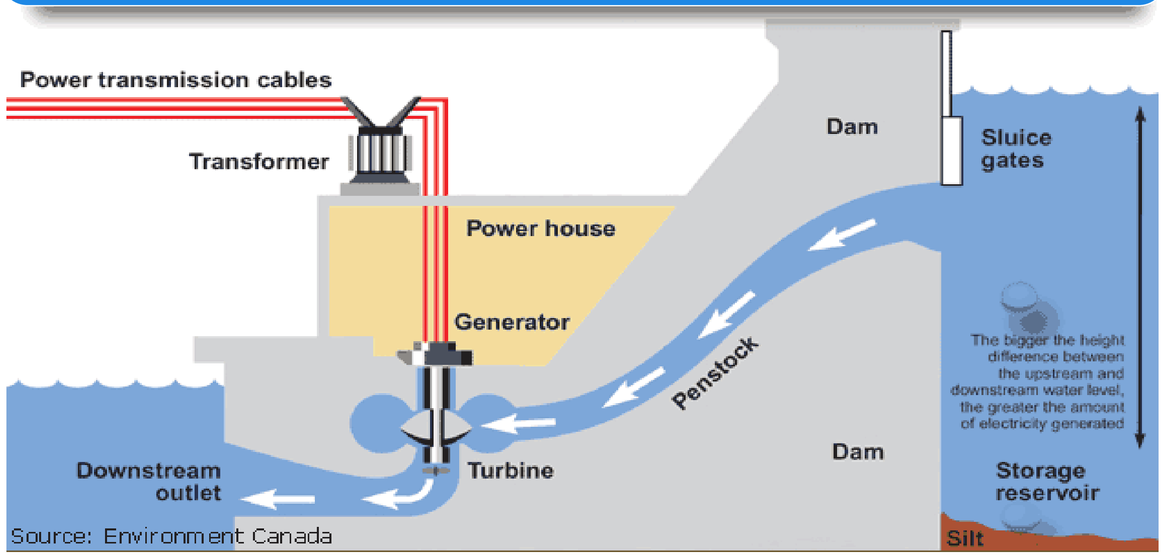
0.85 pounds per kWh

Coal Fueled Thermal Power Plant





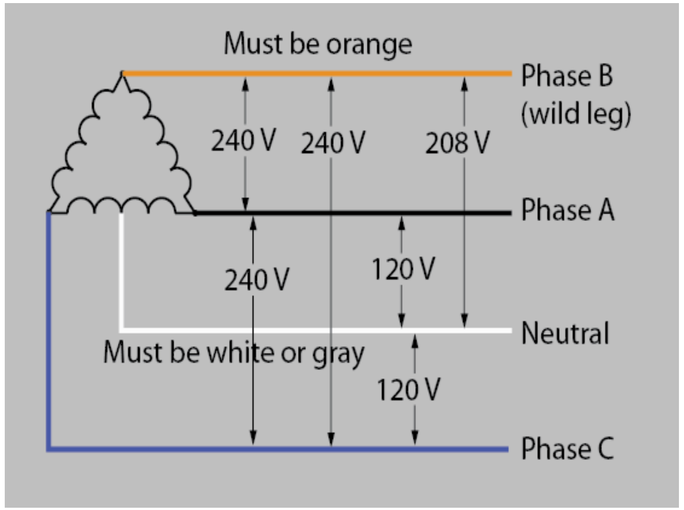
Hydro Electric Power Plant



Electrical Phases

Important Electrical Considerations for Roasting Coffee

US Electrical Services to a Home



US Standards

- 240V power is used in the US and parts of the world.
- **Homes:** 240V power is used in the US and parts of the world.
- 120 / 240V 1 Phase,
  3-Wire is the standard for homes
- **Small Buildings with Large Loads**: 240V 3-Phase Open Delta

Single-Phase vs. 3-Phase

What it Means for Roasting

SINGLE PHASE

Standard: Single-Phase

Works for small-batch roasters.

- **Common Use**: Found in most homes.
- **Voltage**: 120V or 240V.
- **Appliances**: Suitable for small, everyday devices.

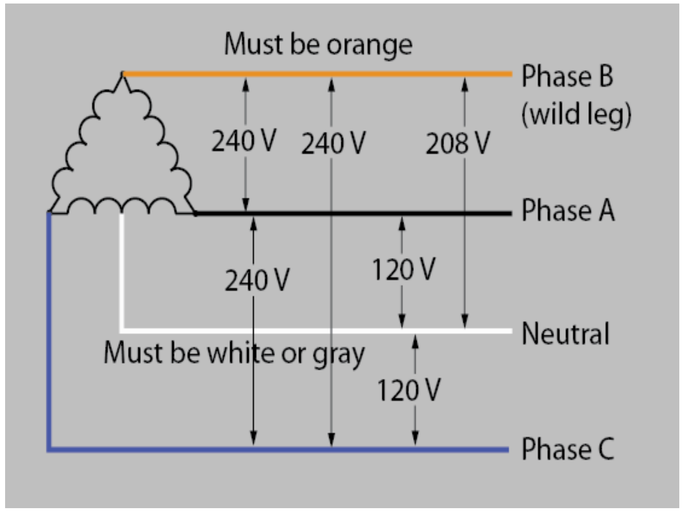
3-PHASE

Required for large-capacity roasters.

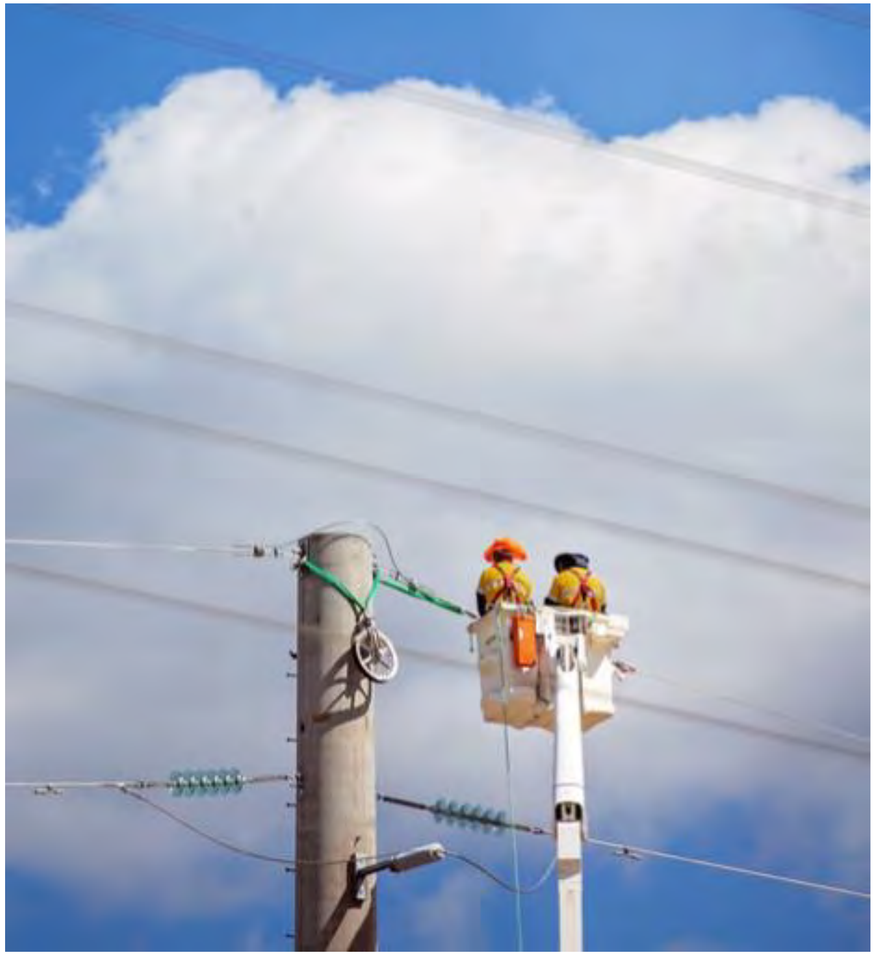
(5 kg batch size and larger)

- **Common Use**: Used in commercial/industrial settings.
- **Voltage**: 208V, 240V, or 480V.
- **Appliances**: Powers heavy-duty machines like large coffee roasters.

How do you get 3-Phase Electricity to your Residential Shop?



Facility Planning for Electrical Needs: Location & Distance Matter!



Can you even get 3-Phase power to your facility?

- **Zoning:** Industrial zones will have access to 3PH; residential zones likely won't.
- **Distance to Nearest 3PH Source:** Costs rise with longer distances.
- **Upgrades Required:** Check if the existing electrical infrastructure needs significant upgrades (panels, transformers).
- **Permitting:** Local regulations may require specific electrical permits, adding to costs.
- **Installation Method:** Underground vs. overhead wiring impacts costs, with underground being more expensive.
- **Power Demand:** Higher energy requirements may need larger transformers and equipment.
- **Utility Provider Policies:** Each utility company has different fees and guidelines for new 3PH installations.

Understanding Utility Requirements

How much will it cost to bring 3-PH Electricity to your Facility?

SAMPLE QUOTE

3-Phase Hookup to Roasting Facility

Install and Hookup 3-PH Electrical Power
500 feet from source to facility
Does NOT Include Tree trimming or Land Clearing

SERVICES	FEES
Power Line Installation	**$5,000 - $12,500**
Meter box/can	**$500 - $3,500**
Transformer Installation	**$3,000 - $20,000**
Trenching costs	**$2,500-$6,000**
Electrician ($200/hr - 80 hrs.)	**$16,000**
Panel & Breakers	**$5,000**
Permits	**$200**

ESTIMATED COST FOR 500 FEET

$32,000-63,200

Estimate depends on local labor rates, equipment specifications, and the distance from the nearest power source.

Before You Purchase a Roaster:

Do Your Homework

- What are your production/revenue goals?
- Do you have an existing shop/facility?
- How is your location zoned? (residential, commercial, industrial)
- Do you need 1-Phase or 3-Phase power based on your production goals?
- How does a nano/tabletop support your business goals?

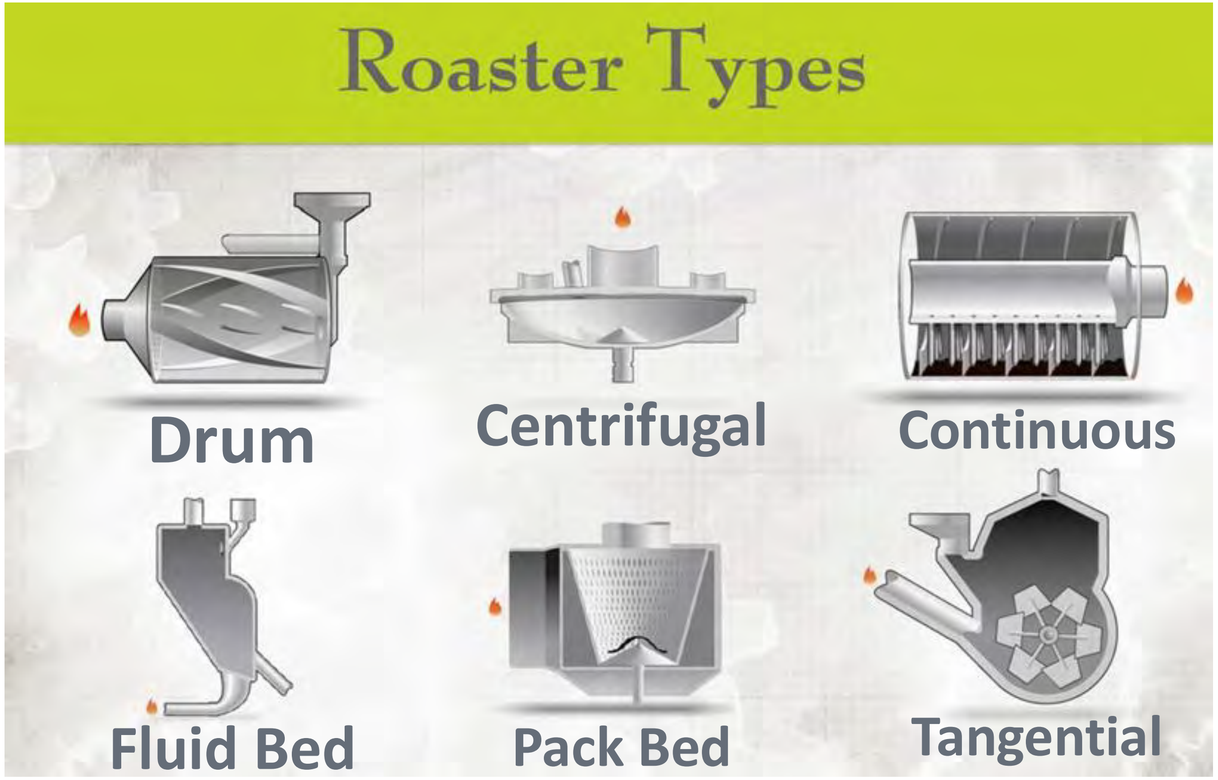
Understanding Utility Operating Costs & Calculations

Be Wary of Misleading Statements

- *Selecting a roasting machine **based upon energy efficiency** or **CO2 emission** is currently **close to impossible**.*
- *Only in some cases is **energy consumption indicated in the technical documentation** of a machine; usually only the consumption of the heating source itself is given.*
- *In rare cases, the electric consumption of the motors and other components will be included. **Emission values are even harder to come by.***
- *A lack of information about the conditions under which consumption and emission figures apply **makes it impossible to estimate** how much energy is actually needed to roast a kilogram of green coffee on a given machine and with the intended roast result.*

We will find answers to these statements

Variables that Determine Energy Consumption Figures



- Roasting Technology
- **Burner Rating** – Calculation depends on:
  - Roast air temperature to the beans
  - Specific Airflow for the roast system
  - Specific heating capacity of air

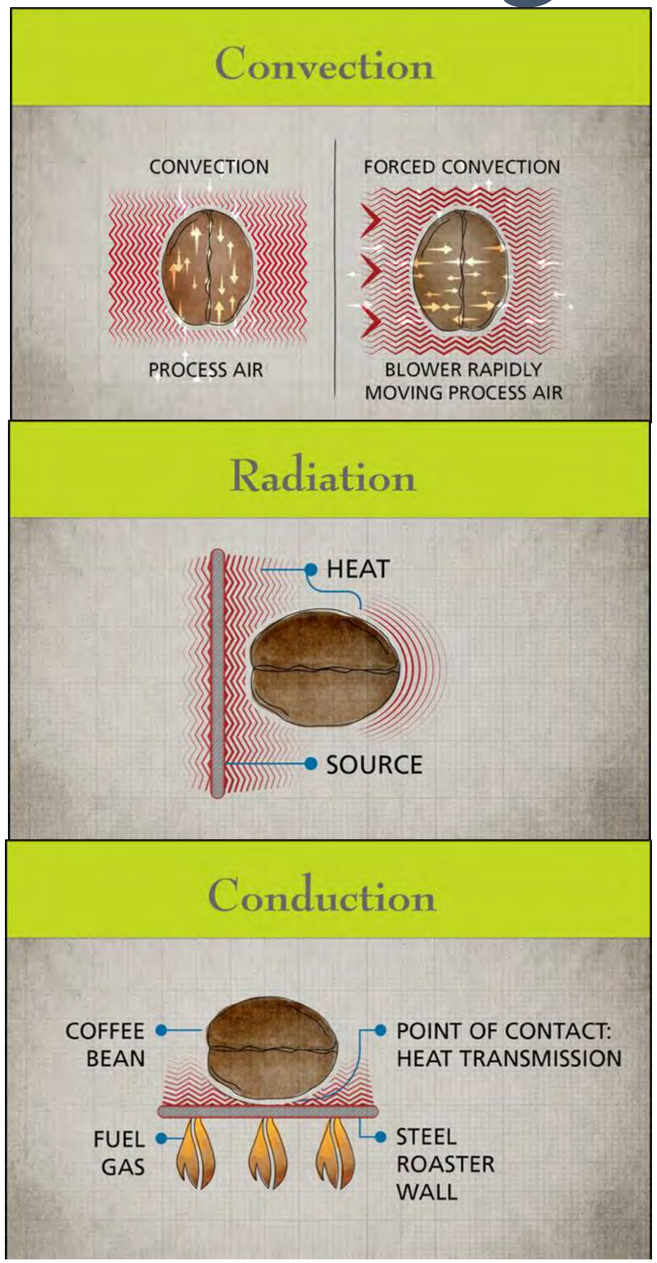
$$Q = V \times cpm \times (T_2 - T_1)$$

Burner Rating is NOT the same as Usage
The bigger the roaster - the more efficient
The smaller the roaster - the less efficient

How much air can be pulled through Roast Chamber?

At best – you can achieve 220 lb of green require 125,000 BTU
Equal to 568 BTU/lb of green coffee

Coffee Heating Requirements Per Batch



- Bean Sensible
- Water Sensible
- Water Latent
- Heat Loss from System
- Fuel
- Combustion Air
- Vent Gas Loss

How can a bean so small pack such power?

CO_2 Generated by Roasting

lb. CO_2/lb. of Green Coffee

Light Roast generates 0.165 lbs CO_2

Medium Roast Generates 0.2 lb CO_2

Dark Roast Generates 0.242 lb CO_2

Operating Cost Comparison Calculations

- Burner ratings & specific air volume requirements
- Consider roasting variables

Cost NG $/cu.ft.	$ 0.01	Based on North Idaho Prices	Example Calculations Gas = [Btu/hr]/[Btu/cu.ft.]*[$/cu.ft]*70% Electricity = [KW]*[1hr]*[$/KWH]*70%
Cost LPG $/cu.ft.	$ 0.05		Based on Idaho Prices Subject to change for each location, coffee type, and degree of roast
Cost KWH $/KWH	$ 0.1011		

Operating Cost Comparison

Natural Gas Roaster vs. Electric Roaster

3 kg Batch Size

Example Calculations
Gas =
[Btu/hr]/[Btu/cu.ft.]*[$/cu.ft]*70%
Electricity =
[KW]*[1hr]*[$/KWH]*70%

Natural Gas Operated

Burner rated capacity: 30,000 Btu/hr.
Heating Value: 1020 Btu/cft.
Average costs of gas across the nation: $0.01/cft.

Actual usage of NG during roasting of a batch of coffee 21,000Btu/hr.
Hourly capacity of Roaster: 23.1 lbs. of green coffee

21,000BTU/hr./1020BTU/cu.ft. = 20.59 cu.ft. x $.01/cuft =

Costs of Roast/hour: $0.21/hr.

Electrically Operated

Burner rated capacity: 30,000 Btu/hr.

Average costs of KWh. across the nation: $0.1011/KWh

Actual usage of KWh during roasting of a batch of coffee 6.157KWh/hr.
Hourly capacity of Roaster: 23.1 lbs. of green coffee

6.157kW/hr. x $.1011KWh =

Costs of Roast/hour: $0.64/hr.

Operating Cost Comparison
Natural Gas Roaster vs. Electric Roaster

Electricity is a more
Expensive way to Roast

12 kg
Batch Size

25 kg
Batch Size

Example Calculations
Gas = [Btu/hr]/[Btu/cu.ft.]*[$/cu.ft]*70%
Electricity = [KW]*[1hr]*[$/KWH]*70%

*See Appendix for Full Calculations

Natural Gas Operated

Average costs of gas across the nation:
$0.01/cu.ft.

Hourly capacity of Roaster:
approx. 92.4 lbs. of green coffee

Costs of Roast/hour:
$0.63/hr.

Electrically Operated

Average costs of KWh across the nation:
$0.1011/KWh

Hourly capacity of Roaster:
approx. 92.4 lbs. of green coffee

Costs of Roast/hour:
$1.84/hr.

Natural Gas Operated

Average costs of gas across the nation:
$0.01/cu.ft.

Hourly capacity of Roaster:
approx. 192.5 lbs. of green coffee

Costs of Roast/hour:
$1.03/hr.

Electrically Operated

Average costs of KWh. across the nation:
$0.1011/KWh

Hourly capacity of Roaster:
approx. 192.5 lbs. of green coffee

Costs of Roast/hour:
$3.11/hr.

Calculation Summary

- Burner ratings & specific air volume requirements
- Consider roasting variables

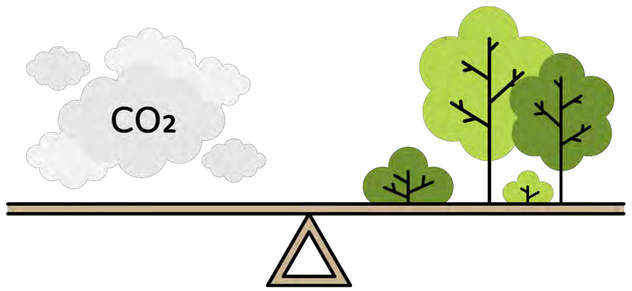
			Example Calculations Gas = [Btu/hr]/[Btu/cu.ft.]*[$/cu.ft]*70% Electricity = [KW]*[1hr]*[$/KWH]*70%	
Cost NG $/cu.ft.	$ 0.01	Based on North Idaho Prices	Based on Idaho Prices Subject to change for each location, coffee type, and degree of roast	
Cost LPG $/cu.ft.	$ 0.05			
Cost KWH $/KWH	$ 0.1011			
Roaster Size Batch Capacity	Burner Capacity Btu/Hr	Electric Heat Capacity KW	NG $/HR	KWH $/HR
3	30,000	9	$ 0.21	$ 0.64
5	50,000	15	$ 0.35	$ 1.06
12	90,000	26	$ 0.63	$ 1.84
25	150,000	44	$ 1.03	$ 3.11
35	300,000	88	$ 2.06	$ 6.23

Understanding CO2 Generation in the Roasting Process

CO2 and Sustainability

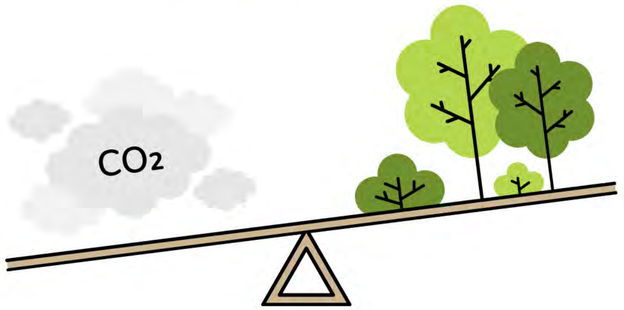
IDEAL

CARBON NEUTRAL



REALITY

CARBON NEUTRAL



DEFINITION OF CARBON NEUTRAL

- Achieving a net-zero carbon footprint by **balancing CO2 emissions with removal or offset efforts**
- **Carbon *reduction* alone** would not meet the term of being “carbon neutral.”

NET ZERO ≠ ZERO CO^2 EMISSIONS

59.12 g CO2 per cup of coffee
The equivalent of driving your car ~2km

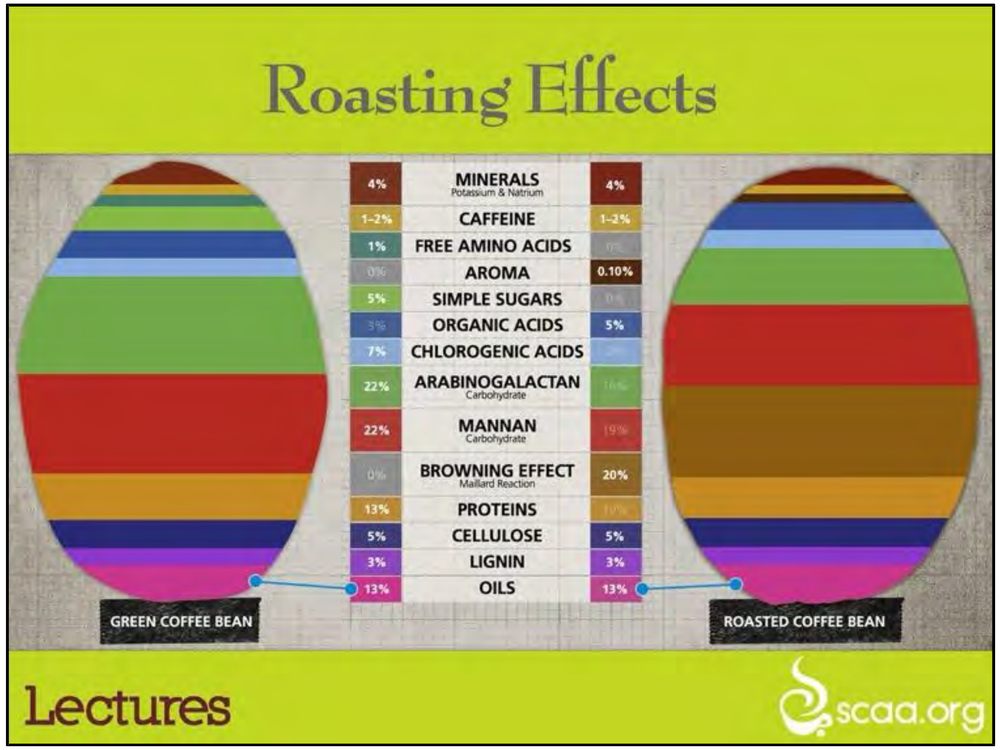
Total Carbon Footprint from Bean to Cup:

59.12 g CO2 per Cup

How are Hydrocarbons Generated

In coffee roasting, hydrocarbons are generated as part of the thermal decomposition of organic compounds in coffee beans.

Coffee consists of
11% Moisture
89% Dry substance (60% are carbohydrates)



Hydrocarbons HC+O2 in the presence of temperature generates CO2

- **Hydrocarbons (HC)** combined with oxygen at specific temperatures will yield carbon dioxide (CO_2) plus water.
- Using a catalyzer, e.g.: (platinum palladium) a substance to accelerate the rate of chemical reactions
- **$HC + O_2 \rightarrow H_2O + CO_2$**
- At elevated temperatures, the molecules of HC + Oxygen have sufficient energy to react directly with each other to form carbon dioxide.
- VOCs are converted to CO_2 and H_2O
- **$HC + O_2 \xrightarrow[500-900F^{\circ}]{Thermal} H_2O + CO_2$**

Generating CO2 even on Electric Roasters

- Carbon Dioxide gas is formed during roasting and pyrolysis. CO2 does not exist freely in green coffee beans.
- At least 1% of green coffee is given off as CO2 gas during roasting and pyrolysis.
- Darker roasts give about 2% of CO2.
- The rate of carbon dioxide gas evolved rises rapidly as the rate of water loss falls off.
- Different coffees give different rates of CO2.

Here’s what we’ve established in understanding CO2 Generation in the Roasting Process:

- ✅ We’ve defined carbon neutral
- ✅ We’ve defined how CO2 is generated

w we need to determine how CO2 is generated through combustion of gas.

Calculating CO2 Production

Lighter Roast: 330 lb of CO2 generated by 2,000 lb of Green Coffee

Medium Roast: 400 lb of CO2 generated by 2,000 lb of Green Coffee

Darker Roast: 480 lb of CO2 per 2,0000/green coffee

Gas for Thermal Energy :
400 lbs./ton of Coffee = 0.2 lbs. CO2/lb. of Green Coffee
(3 Kg Batch Roaster)

Using assumption of medium roast moving forward

Natural Gas Operated Roaster

3 kg
Batch Size
Hourly Capacity
Approx. 23.1 lb. of Green Coffee

CO2 comparison using different fuel sources

3 kg Batch Roaster

The total generation of CO2 when roasting coffee is 0.2 lb./lb. of green coffee.

3 kg Roaster C02 Generated Per Batch:

3 kg batch = 6.6 lb x3.5 roasts per hour = 23.1 lb./hr x 0.2lb./lb. = 4.62lbs CO2/hr.

Exotherm/Pyrolysis CO2 depending on type of coffee, degree of roast, and moisture content of the beans

0.01 - 0.09 lb CO2/lb of green coffee

(For further calculations we use .05 lb CO2/lb of green coffee.)

Exotherm: **23.1 lb. green/hr. x .05 lb. CO2/lb = 1.155 lb CO2/hr.**

*See CO2 Spreadsheet in Appendix for Calculations

4.62lbs CO2/hr. – 1.155lbs CO2/hr.
= 3.47 lbs CO2/hr.
for combustion of NG

Calculation includes combustion of fossil fuel and the CO2 developed during Exotherm/Pyrolysis phase of the roast

CO2 comparison using different fuel sources

3 kg batch Roaster - Approx. 23.1 lb. of Green Coffee

Electric Operated Roaster

Burner rated capacity: 9.0 KW
9KWh x 0.7 = 6.3
Actual usage of Electric Power during roasting for a batch of coffee 6.3 KWh

CO2 generated during roasting:
1.1lb CO2 /KWh x 6.3KWh = 6.93 lbs. of CO2/hr.

Exotherm: **23.1lbs green/hr. x .05lbs CO2/lb = 1.155lbs CO2/hr.**
Total CO2 produced : 1.155lbs + 6.93lbs = 8.085 lbs CO2/hr.

With electricity, you are generating higher CO2 than roasting on natural gas.

*See CO2 Spreadsheet in Appendix for Calculations

Calculation includes combustion of fossil fuel and the CO2 developed during Exotherm/Pyrolysis phase of the roast.

Example Calculations

$CO2_{Overall} = CO2_{Heating} + CO2_{Coffee}$

CO_2 comparison using different fuel sources

3 kg Batch Roaster

Gas

Total CO_2 Produced:

4.62 lb. CO_2/hr.

Batch

Electricity

Total CO_2 produced:

8.085 lb. CO_2/hr.

CO2 Production Comparison Calculations

COFFEE Exotherm lb CO2 / lb Coffee	0.050
LPG lb CO2/cu.ft.	0.352
NG lb CO2/cu.ft.	0.121
AVG Electricity Generation lb CO2/KWh	1.1

Example Calculations
Gas = [Btu/hr]/[Btu/cu.ft.]*[lb CO2/cu.ft]*70%
Electricity = [KW]*[1hr]*[lb CO2/KWH]*70%

Example Calculations
CO2_Coffee = [Batch Capacity in lbs] * [0.05 lb CO2/lb coffee] * [3.5 batches/hr]

Example Calculations
CO2_Overall = CO2_Heating + CO2_Coffee

CO2_Heating
ONLY CO2 generated from heating source

CO2_Coffee
ONLY CO2 generated from coffee exothermic process

CO2_Overall
CO2 from heating plus CO2 from coffee exothermic proces

Roaster Size Batch Capacity	Burner Capacity Btu/Hr	Electric Heat Capacity KW	NG Only [lb CO2/hr]	Electric Only [lb CO2/hr]	Coffee Exotherm Only [lb CO2/hr]	**NG Overall [lb CO2/hr]**	**Electric Overall [lb CO2/hr]**
3	30000	9	3.46	6.93	1.16	**4.62**	8.09
5	50000	15	5.78	11.55	1.93	**7.70**	13.48
12	90000	36	13.86	27.72	4.62	**18.48**	32.34
25	150000	75	28.88	57.75	9.63	**38.50**	67.38
35	300000	105	40.43	80.85	13.48	**53.90**	94.33

Venting, Smoke, VOCs, EPA

- **Airflow and Coffee Roasting**: Roasting relies heavily on heated air to process coffee beans.
- **Venting the Roaster**: Heated air carries smoke, odors, and VOCs out of the roaster, requiring proper venting.
- **Emission Concerns**: Even small-scale roasting generates smoke, odors, and VOCs.
- **Environmental Oversight**: Nano and small roasters typically operate below the threshold of EPA regulation.
- **Filters and Emissions**: Filters help reduce odors but do not eliminate VOCs.
- **Regulatory Guidance**: For larger operations, consult the **EPA** or local agencies to understand regional regulations.

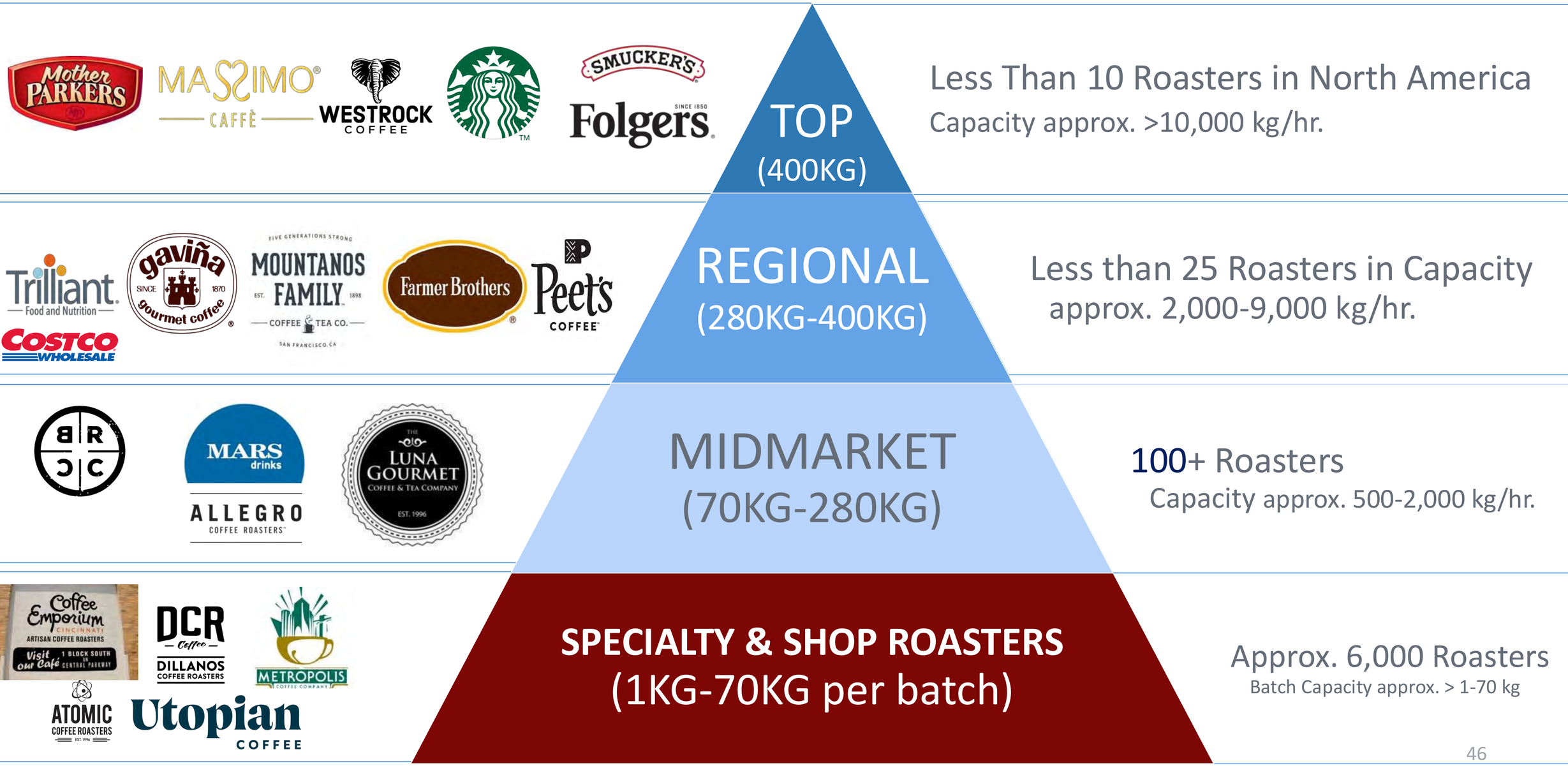
Electric Roasters: Key Takeaways

Electric Roasters have been on the market for 40+ years

It’s more expensive to roast on electric at scale

CO2 Consumption is higher

North American Coffee Market



Household vs. Commercial/Industrial

Most of the Coffee Roasted is Commercial/Industrial

Nano and Specialty Roasters process less than 10% of all coffee imported and roasted.

How does electric roasting fit into your roasting facility & production process big picture?

Key Considerations

Please be aware:

- **Operational and Setup-Costs:** Electric operated roasters are more expensive than gas operated roasters
- **Carbon Footprint:** You are not eliminating the carbon generated in producing electricity that powers the roaster.
- **Carbon Generation in Roasting:** Electric roasting does not eliminate CO2 generation when roasting.

Other considerations:

- Shop design and arrangement
- How does a nano/tabletop support your business goals?
- What experience are you creating for your customers?
- Nano/tabletop is a great marketing tool
- Not applicable for sustainable production
- Misinformation can cost you
- Do your homework
- Look to reliable sources

The True Costs of Electric Roasting
Questions?

CO2 Production

COFFEE Exotherm lb CO2 / lb Coffee	0.050
LPG lb CO2/cu.ft.	0.352
NG lb CO2/cu.ft.	0.121
AVG Electricity Generation lb CO2/KWh	1.1

Example Calculations
Gas = [Btu/hr]/[Btu/cu.ft.]*[lb CO2/cu.ft]*70%
Electricity = [KW]*[1hr]*[lb CO2/KWH]*70%

Example Calculations
CO2_Coffee = [Batch Capacity in lbs] * [0.05 lb CO2/lb coffee] * [3.5 batches/hr]

Example Calculations
CO2_Overall = CO2_Heating + CO2_Coffee

CO2_Heating
ONLY CO2 generated from heating source

CO2_Coffee
ONLY CO2 generated from coffee exothermic process

CO2_Overall
CO2 from heating plus CO2 from coffee exothermic proces

Roaster Size Batch Capacity	Burner Capacity Btu/Hr	Electric Heat Capacity KW	NG Only [lb CO2/hr]	Electric Only [lb CO2/hr]	Coffee Exotherm Only [lb CO2/hr]	**NG Overall [lb CO2/hr]**	**Electric Overall [lb CO2/hr]**
3	30000	9	3.46	6.93	1.16	**4.62**	8.09
5	50000	15	5.78	11.55	1.93	**7.70**	13.48
12	90000	36	13.86	27.72	4.62	**18.48**	32.34
25	150000	75	28.88	57.75	9.63	**38.50**	67.38
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