1. WHY BACKUP ENERGY IS SURVIVAL — NOT CONVENIENCE

In Wyoming, backup power is about:

- Freeze prevention
- Water security
- Medical equipment reliability
- Food preservation
- Communications
- Heating system support
- Loss of power in winter = system cascade failure.

Backup energy must be:

- Redundant
- Load-prioritized
- Cold-rated
- Fuel-planned

Why Power Failure Is the Most Common Modern Emergency

Key Points:

- The grid fails more often than any other large-scale emergency.
- Causes:
  - Ice storms
  - High winds
  - Equipment failure
  - Vehicle strikes on poles
  - Substation fires
  - Overload during extreme temperatures

Power outages are not rare — they are statistically routine.

In Wyoming specifically:

- High winds
- Heavy snow load
- Rural infrastructure
- Long repair distances

This isn't collapse fantasy — it's infrastructure reality.

Key Line:

"We don't prepare for collapse first. We prepare for disruption."

Inconvenience vs. Collapse

Define the Difference:

Inconvenience:

- No TV
- No microwave
- Internet down
- Coffee maker doesn't work

Operational Disruption:

- Fridge warming
- Furnace blower off
- Water pump stops
- Garage door inoperable

Survival Threat:

- Heat loss in winter
- Frozen pipes
- Medical devices offline
- Food loss over multiple days

Most outages start as inconvenience.
They become survival problems when duration increases.

Preparedness reduces escalation.

The Redundancy Principle (Rule of 2–3 Systems)

You should have:

1. Primary power backup (generator OR solar)
2. Secondary recharge method
3. Manual fallback option

Examples:

- Generator + stored fuel
- Solar + battery bank
- Portable power station
- Propane heat backup
- Manual cooking method

Key Concept:

"One system is a plan. Two systems are resilience."

If a generator fails and you have no secondary plan — you're exposed.

Redundancy prevents single-point failure.

Comfort Loads vs. Survival Loads

Draw a clear line.

Survival Loads:

- Heat source
- Refrigerator/freezer
- Medical equipment
- Water system
- Lighting (minimal)

Operational Loads:

- Communications
- Charging devices
- Security systems

Comfort Loads:

- TV
- Microwave
- Gaming systems
- Decorative lighting
- Extras

Explain:

Most people oversize generators to power comfort.

Smart planning powers survival first.

Have students mentally rank their loads.

Discussion Prompt + Engagement

Ask:

"What are the first 5 things in your home that stop working in a power outage?"

2. UNDERSTANDING ELECTRICAL LOADS

Key Terms

1. Watt (W) = Instantaneous power draw
2. Watt-hour (Wh) = Power over time
3. Kilowatt-hour (kWh) = 1,000 Wh
4. Amp-hour (Ah) = Battery storage capacity
5. Voltage (V) = Electrical pressure

3. CRITICAL LOAD IDENTIFICATION

Tier 1 – Survival Loads

Well pump

Furnace blower

Medical devices

Refrigerator (winter optional if outside temp allows)

Tier 2 – Operational Loads

Freezer

Lighting

Router/Comms

Security system

Tier 3 – Comfort Loads

TV

Microwave

Coffee maker

Applicance	Running Watts	Surge Watts	Running Hours
Well pump	1000-1500	3000-4000	0.5-1 hours
Deep well pump	1500-2200	4500-6000	0.5-1 hours
Furnace Blower	400-800	1200	4-8 hours
Boiler Pump	80-200	400	6-10 hours
Fridge	100-200	600	8 hours
Chest Freezer	150-300	700	6-8 hours
LED Light	8-12 watts		4-6 hours
Router	10-20 watts		24 hour
Coffee Maker	800-1200		.25 hours
Microwave	1000 watts	1000 watts	0.2 hours

Step-by-Step Load Calculation Procedure

1. **Step 1: Identify Running Wattage**

   - Use appliance label or manufacturer specification.

2. **Step 2: Determine Realistic Daily Run Time**

   - Winter operation differs from summer operation.

Furnace and pumps increase significantly in sub-zero temperatures.

3. **Step 3: Calculate Daily Watt-Hours**

Formula:

   - Watts × Hours Used = Watt-Hours (Wh)

Example:

Furnace blower

   - 600W × 6 hours = 3,600 Wh

4. **Step 4: Add All Daily Loads Together**

Example:

Well pump: 1,200 Wh

Furnace: 3,600 Wh

Refrigerator: 1,200 Wh

Lights: 300 Wh

Total = 6,300 Wh

5. **Step 5: Add Safety Buffer**

Add 20–25% for inverter losses and inefficiencies.

6,300 × 1.2 = 7,560 Wh required per day

<u>Voltage Conversion Reference</u>

To convert Watt-Hours to Amp-Hours:

Wh ÷ System Voltage = Ah

System Voltage

Formula

- 12V

  Wh ÷ 12

- 24V

  Wh ÷ 24

- 48V

  Wh ÷ 48

Example:

- 7,560 Wh ÷ 48V = 157.5 Ah per day

<u>Formula: Watts x Hours Used+= Watt Hours</u>

Appliance		Watts		Hours Used		Daily need
Well pump						
Fridge						
Furnace						
Lights x 2						

Total Daily Wh= _____

Add 20% safety buffer: Total x 1.2 = _____

BATTERY SIZING

Step 1: Convert Wh to Amp-Hours

- Formula: Wh ÷ System Voltage = Ah per day
- Example: 6,000 Wh ÷ 48V = 125 Ah/day

Step 2: Autonomy Goal

- How many days without sun or wind?
- Wyoming winter minimum: 2 days
- 125 Ah × 2 = 250 Ah

Step 3: Depth of Discharge

- Lithium (80% usable):
- 250 ÷ 0.8 = 312 Ah bank required

WORKSHEET 2 – BATTERY BANK

- Daily Wh: _____
- System Voltage: _____
- Ah per Day: _____
- Autonomy Days: _____
- Total Ah Required: _____
- Battery Chemistry: _____
- Final Bank Size: _____

1️⃣ 12-Volt Systems

Overview

- Most common in RVs, small cabins, mobile setups

- Lower cost entry point

- Limited scalability

Best Use Case

✓ Small emergency backup
✓ Single battery system
✓ Low loads (lights, router, small fridge)
✓ Under ~1,500 watts inverter size

Not Ideal For

✗ Whole-home backup
✗ Large inverters (>2000W)
✗ Long cable runs (high amperage = thick expensive wire)

Why?

Power (Watts) = Volts × Amps

If you need 2000W:

- At 12V → 2000 ÷ 12 = **166 amps**

- High amps = large cables, voltage drop, heat

How to Wire a 12V System

Battery Bank

- 12V batteries wired **in parallel** to increase capacity

- Positive to positive

- Negative to negative

Solar

- 12V charge controller

- Panels wired in parallel (if using PWM controller)

- Or higher voltage array stepped down with MPPT

Generator Integration

- Generator → 120V AC → Battery charger → 12V battery bank
  OR

- Hybrid inverter/charger handles both

Wind

- 12V wind turbine controller

- Dump load required (to prevent overcharge)

2️⃣ 24-Volt Systems

Overview

Mid-size residential systems. Good balance of efficiency and cost.

Best Use Case

✔ Moderate home backup
✔ Inverters 2,000–4,000W
✔ Well pumps (small)
✔ Furnace + fridge + lights

Why It's Better Than 12V

2000W load:

- 2000 ÷ 24 = **83 amps**

Half the amperage of 12V → smaller cables, less loss.

How to Wire 24V

Battery Bank

Two 12V batteries wired **in series**:

- Positive of Battery 1 → Negative of Battery 2
Remaining free terminals = 24V output

To increase capacity:

- Create multiple 24V strings

- Then wire those strings in parallel

Solar

- 24V MPPT charge controller recommended

- Panels wired in series to increase array voltage

Generator

- 24V inverter/charger system

- Generator feeds inverter AC input

- Inverter charges batteries automatically

Wind

- 24V turbine + diversion controller

- Dump load mandatory

3️⃣ 48-Volt Systems (Residential Standard)

Overview

This is the modern standard for serious home backup and off-grid homes.

Best Use Case

✓ Whole-home backup
✓ 4,000W–15,000W inverters
✓ Large well pumps
✓ Electric heating backup
✓ Scalable solar arrays

Why 48V is Superior for Homes

5000W load:

- 5000 ÷ 48 = **104 amps**

At 12V that would be 416 amps (unsafe, impractical).

Lower amps =

- Smaller wire

- Less heat

- Higher efficiency

- Safer system

How to Wire 48V

Battery Bank (Lead Acid Example)

Four 12V batteries wired in **series**:
B1+ → B2-
B2+ → B3-
B3+ → B4-
Free terminals = 48V output

Multiple 48V strings can be paralleled for capacity.

Lithium Systems

Many 48V systems use:

- Rack-mounted 48V LiFePO4 batteries

- Internal BMS

- Simplified wiring

Generator Integration (48V System)

Generator →
Inverter/Charger (48V rated) →
Battery Bank

Inverter automatically:

- Powers loads

- Charges batteries

- Switches to battery during outage

Common hybrid inverter brands used in 48V systems:

- Victron Energy

- OutBack Power

- Schneider Electric

- EG4 Electronics

Quick Comparison Table

System	Best For	Max Practical Inverter	Cable Size	Scalability
12V	Small backup	~2000W	Very Large	Poor
24V	Mid backup	~4000W	Moderate	Fair
48V	Whole home	15kW+	Smaller	Excellent

When NOT to Use Each

Avoid 12V if:

- Running well pump

- Running furnace blower long term

- Planning to scale later

Avoid 24V if:

- Planning whole-house backup

- Running >4kW regularly

Avoid 48V if:

- Only powering small shed

- Budget extremely tight

- Minimal loads

Practical Recommendation (Wyoming Context)

For a home running:

- Well pump

- Furnace blower

- Fridge + freezer

- Lights

- Router

A **48V system with a 6–10kW inverter** is ideal.

12V is survival backup.
24V is transition.
48V is infrastructure.

Core Wiring Architecture (All Systems)

Battery Bank →
DC Disconnect →
Fuse/Breaker →
Inverter →
AC Load Panel (critical loads subpanel)

Solar/Wind →
Charge Controller →
Battery Bank

Generator →
Inverter AC Input

Critical Safety Notes

- Always fuse between battery and inverter.

- Use proper gauge cable for amperage.

- Install DC disconnect.

- Ground system properly.

- Wind systems require dump load.

- Lithium requires compatible inverter and BMS.

GENERATOR STRATEGY

Generators are not primary systems. They are:
- Battery chargers
- Surge load handlers
- Emergency recovery tools

Generator Sizing

Continuous load example:
- Well pump (1,000W)
- Furnace (600W)
- Fridge (200W)
   Total = 1,800W

Add surge buffer → minimum 3,000W generator

Fuel Planning

Example: Generator uses 0.75 gallons/hour
Runs 2 hours/day = 1.5 gallons/day

7-day outage = 10.5 gallons

Plan 2× → 21 gallons minimum

WORKSHEET 3 – GENERATOR PLAN

Continuous Load: _____ W
Surge Load: _____ W
Generator Size: _____ W
Fuel Use Per Hour: _____
Hours Per Day: _____
7-Day Fuel Needed: _____

SOLAR & WIND STRATEGY

Solar Sizing

If winter sun = 4 usable hours/day

Required Wh ÷ 4 = panel watts needed
Example: 6,000 Wh ÷ 4 = 1,500W
Add inefficiency → 1,800–2,000W array

Wind Advantage in Wyoming

Wind works:
At night
During storms
When solar fails
Hybrid systems reduce generator dependence.

LOAD SHEDDING STRATEGY

When battery hits 50%:

☐ Shut freezer
☐ Reduce lighting
☐ Delay water pumping

When battery hits 30%:
☐ Essential loads only
☐ Start generator cycle

FAILURE SCENARIO DISCUSSION

Scenario: 3 cloudy days, no wind, 20°F temperatures.
Battery at 35%.
What shuts off first?

FINAL WORKSHEET – PERSONAL SYSTEM PLAN

My Daily Wh Need: _____
Battery Bank Size: _____
Solar Array Target: _____
Generator Size: _____
Fuel Stored: _____ gallons
Days Sustainable: _____
Backup Heat Source: _____