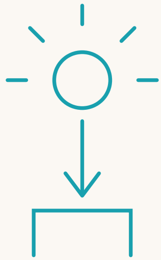
KARNOT ENERGY SOLUTIONS



Heat Pumps for CFOs

What your energy bill is really telling you

THE NO-JARGON GUIDE

- Up to three-quarters off your energy bill
- Cash in your pocket from month one
- Future-proof natural refrigerants

BOOK ONE · A PLAIN-ENGLISH GUIDE
Karnot Energy Solutions Inc. · Pangasinan, Philippines

START HERE

FOR THE PERSON WHO SIGNS THE CHEQUE

The whole book in ninety seconds

If you read nothing else, read this page. The rest of the book simply explains why every line of it is true.

> *You are paying good money for heat you could be getting mostly for free. A heat pump is the machine that collects it — and a bank will fund the whole thing, so you make money from the first month without spending your own cash.*

THE IDEA IN ONE LINE

It's an aircon, running backwards

Your aircon takes heat out of a room and dumps it outside. A heat pump does exactly the same thing, backwards: it takes heat out of the outside air and puts it into your hot water, your process, or wherever you need it. It's the same proven machine you already trust and service every day — just pointed the other way.

WHY IT COSTS SO LITTLE TO RUN

The air is the fuel

The fuel isn't electricity — it's the air around your building, which is full of free heat all year round in this climate. The heat pump only collects it. You pay a small electricity bill to run the pump; you pay nothing for the air. About three-quarters of the heat arrives free. You buy the last quarter.

THE MONEY LINE

An electric heater turns ₱1 of power into ₱1 of heat. A Karnot heat pump turns ₱1 into about ₱4 — because three of those four pesos come free, out of the air.

WHAT A FINANCE TEAM ACTUALLY WANTS TO KNOW

Cash in your pocket from month one

You don't write a cheque. A green bank loan covers the equipment, and the fuel you stop buying is worth more each month than the loan repayment — so cash flow goes *up* from the very first month. Here is a real Karnot project, anonymised, with its actual figures:

YOU PAY THE BANK

₱23,842

green loan, each month

YOU STOP BUYING FUEL

₱57,868

diesel no longer burned

IN YOUR POCKET

₱34,026

every month, from month one

A real, anonymised Karnot project — a Philippine food processor. Equipment financed over 60 months; the full workings are in Chapter 15.

SO, IN FOUR LINES

- **It's a backwards aircon** — it moves heat instead of burning fuel to make it.
- **The air is the fuel** — about three-quarters of your heat arrives free.
- **₱1 of power buys about ₱4 of heat** — up to three-quarters off the bill.
- **The bank funds it** — and you are cash-positive from the first month.

THE ONE NEXT STEP

Send us your last electricity or diesel bill. We measure your building first and put *your* numbers — savings, payback and a financed cash-flow like the one above — in writing, before you spend a peso. **Then you decide.**

What's inside

Sixteen short chapters. We start with who we are, then build the physics one small idea at a time — each from something you already know — until you can see exactly how the machine works and why it saves you money. Every chapter opens with the money at stake and ends with what it means for your bill.

HEAT PUMPS FOR CFOS

BOOK ONE · OPENING

Why We're Called Karnot

00

Our name is two great physicists fused into one. It tells you exactly what this company does — and what this little book is about to teach you.

> *Two hundred years ago, a handful of people worked out the rules that govern all heat, all engines, all cooling — the rules your electricity bill still obeys today. We named our company after two of them. This is their story, and yours.*

THE METER READING · WHY THIS MATTERS TO YOU

You don't need to love physics to run a profitable business. But the people who quietly understand these old rules are the ones who stop overpaying for energy. This book hands you that understanding, one small step at a time. **By the end you'll read your own bill the way an engineer does — and see the money hiding in it.**

THE NAME

Kelvin and Carnot

Say our name slowly: **Kar-not**. It's a deliberate joining of two names from the dawn of thermodynamics — the science of heat and how to put it to work.

The first is **Sadi Carnot**, a young French engineer who, in 1824, sat down and worked out the absolute limit of how good any heat engine could ever be — the ceiling set by nature itself, long before anyone had built a decent one. Every engine, every fridge, every heat pump on earth lives under the ceiling Carnot found.

The second is **Lord Kelvin** — a Scottish physicist, born William Thomson, who built on Carnot's work, gave us the absolute scale of temperature still used in every laboratory, and helped turn these ideas into the engineering that powered the modern world.

One found the limit. The other gave us the measuring stick. Fuse their names and you get a company whose whole purpose is to build machines that get as close to nature's limit as the real world allows — and to *measure* honestly how close. That's Karnot.

K+C

THE THERMAL FATHERS

Carnot (1796–1832) & Kelvin (1824–1907)

Carnot died young, at 36, his great work barely noticed in his lifetime. Kelvin lived long, was knighted, and was buried beside Isaac Newton. Between them they laid the foundations of everything in this book. We carry both names so we never forget that good engineering starts with respect for the rules — and honest measurement of the results.

WHAT WE ACTUALLY DO

A business, in one paragraph

Here's the plain version, before any physics. Karnot is a Philippine company, based in Pangasinan, that builds machines to make your business's heating, cooling and hot water far cheaper — using the warm air around you, the sun above you, and storage so you can use that energy after dark. We use natural, future-proof refrigerants instead of the man-made gases now being banned. And we measure your building first, so the savings are proven before you spend.

That's the whole business. The rest of this book explains *why it works* — gently, one idea at a time — so that when someone offers to cut your energy bill by up to three-quarters, you'll understand exactly how, and know it isn't a trick.

> *THE MONEY LINE*
>
> *Our name is a promise: build close to nature's limit, and measure it honestly. For you, that promise shows up as a smaller bill you can actually understand.*

HOW TO READ THIS BOOK

One small step at a time

You don't need to read fast or remember formulas. Each chapter does just one small thing, and starts from something you already know — a cold drink, a pressure cooker, a tricycle engine, the sweat on your skin. By the end the machine will feel obvious, almost simple. That's the point. The physics was settled long ago. What's new is that you can finally buy it, made here, and keep the savings.

BEFORE YOU TURN THE PAGE

- **Karnot = Kelvin + Carnot** — two founders of the science of heat.
- **Carnot found nature's limit; Kelvin gave us the measuring stick.** We build close to the limit and measure honestly.
- **The business, plainly:** cheaper heating, cooling and hot water from air, sun and storage — natural refrigerants, survey first.
- **This book teaches you why it works** — one small, familiar step at a time.

PART ONE

The Rules of the Game

Seven small ideas about heat. Each one from something you already know. Together they explain everything.

HEAT PUMPS FOR CFOS

PART 1 · CHAPTER 1

01

Heat Always Travels Downhill

Before any heat pump, any aircon, any chiller — there is one rule the universe never breaks. And it is quietly draining your bank account right now.

> *If you remember one thing from this whole book, make it this: heat moves on its own from hot things to cold things, and never the other way round. Everything we build is just clever engineering around that single stubborn fact.*

THE METER READING · WHY THIS IS YOUR MONEY

In most Philippine businesses, the machines that make things hot or cold — aircon, refrigeration, water heating — eat the biggest share of the electricity bill. Every idea in this chapter answers one question you can take to your accountant: **are we spending money to move heat the smart way, or burning cash fighting nature?** By the end of this book you'll read your own bill and know the answer.

START WITH WHAT YOU KNOW

You already understand this

Buy a hot coffee and leave it on the table. Come back in an hour. It's cold. You did nothing — the heat left the cup by itself and spread into the cooler room.

Now take a cold soft drink out of the fridge on a hot afternoon. Leave it on the table. Come back in an hour. It's warm, and sweating. Again you did nothing. This time the heat went the other way — from the warm room into the cold bottle.

See the pattern? In both cases heat flowed from the hotter place to the cooler one. Coffee to room. Room to bottle. It always picks that direction. You have never once seen a coffee on the table get hotter while the room got colder. It simply doesn't happen.

THINK OF IT LIKE WATER

Heat behaves like water on a hill. Water runs **downhill** by itself — it never climbs back up unless a pump pushes it. Heat is the same: it runs "downhill" from hot to cold on its own, and only goes "uphill" from cold to hot if a machine does the work. Remember that word — *pump* — because it's hiding in the name of our whole business.

GIVING IT A NAME

Temperature is the hill

So what decides which way is "downhill" for heat? **Temperature.** Temperature is just how hot or cold something is — and the bigger the gap between two things, the faster heat rushes between them.

Put a pan on a strong flame and it heats fast, because the flame is much hotter than the pan. Put the same pan in front of an electric fan and it cools slowly, because the air is only a little cooler. Big gap, fast flow. Small gap, slow trickle. No gap, and heat stops moving — the two things are the same temperature and settle down.

RC

THE PEOPLE BEHIND THE RULE

Rudolf Clausius (1822–1888)

A German physicist who, in 1850, was the first to write the rule down plainly: heat cannot flow on its own from a colder body to a hotter one. It sounds obvious once you hear it — but stating it clearly was the foundation everything in this book is built on. We'll meet him again when we talk about why fridges need electricity.

WHY THIS MATTERS FOR COOLING

Cooling is just taking heat away

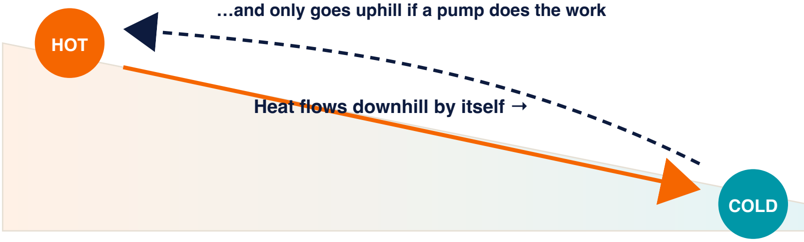
Here's the idea that trips most people up, so read it slowly. **There is no such thing as "cold."** Cold is not a thing you add to a room. Cold is simply what's left when you take heat *away*.

When your aircon "makes the room cold," it isn't pumping cold in. It's grabbing the heat already in your room and carrying it outside — which is why the box on the wall outside blows hot air. That hot air is your room's heat, thrown out. The room feels cooler because it now holds less heat than before.

THE MONEY LINE

An aircon doesn't make cold. It moves heat from where you don't want it to where you don't mind it. Heating and cooling are the same job — and a machine that does both at once is doing two jobs on one bill.

That last point is the quiet secret at the heart of Karnot. If cooling is really just *moving heat from one place to another*, then the heat you throw away when you cool one room is real, usable heat. Instead of dumping it outside, you could catch it and use it to heat your water for free. One machine, two useful jobs, one flow of energy. We'll build all the way up to exactly that. But it starts here, with heat going downhill.



Heat runs downhill on its own. A heat pump is the machine that pushes it back up — that is the whole story of this book.

A FIRST LOOK AHEAD

So what is a heat pump?

You already have the answer. A **heat pump** is a machine that uses a little electricity to push heat *uphill* — from a cooler place to a warmer one, against its natural direction. That's the only reason it needs power at all. Left alone, heat would never climb. The pump makes it climb.

Your fridge is a heat pump. So is your aircon — in fact a heat pump is simply **an aircon running backwards**: instead of throwing heat out of a room, it gathers heat from the outside air and puts it to work heating your water. The big difference with Karnot's machines, which we'll get to, is what we make them *do* with that heat, and what we use to carry it. But the engine underneath — push heat uphill — is the same in all of them.

BEFORE YOU TURN THE PAGE

- **Heat always moves from hot to cold** on its own — never the reverse without help.
- **Temperature is the slope.** A big gap means heat flows fast; no gap means it stops.
- **Cold is not a thing.** Cooling means removing heat and carrying it somewhere else.
- **A heat pump pushes heat uphill** — that pushing is the only reason it uses energy. The heat it throws away is free money if you catch it.

HEAT PUMPS FOR CFOS

PART 1 · CHAPTER 2

02

You Can't Get Something for Nothing

Energy never disappears. Every peso you spend on power ends up somewhere — and the whole game is making sure it ends up working for you, not escaping out the door.

> *There is a second rule, just as stubborn as the first: energy cannot be created or destroyed. It only changes its clothes. So when your bill is high, the energy didn't vanish — you can follow it, find where it went, and stop the waste.*

THE METER READING · WHY THIS IS YOUR MONEY

Every kilowatt-hour on your bill is energy you bought. It all goes somewhere — into useful heating and cooling, or leaked out through a hot roof, an open cold-room door, or a machine throwing away heat you could have used twice. **Because energy can't disappear, every peso of waste is findable.** That single fact is what makes an energy survey worth far more than it costs.

THE RULE, IN ONE BREATH

Energy just changes form

Petrol in a tricycle becomes movement, heat, and noise. Electricity in a bulb becomes light and warmth. Rice in your body becomes the energy to work all day. In every case the energy didn't appear from nowhere and it didn't disappear — it changed from one form into another. Add it all up before and after, and the totals match.

This is the First Law of thermodynamics, and it's the most reassuring rule in this whole book. It means nothing is hidden. If your electricity bill is high, that energy went *somewhere* specific. You can chase it down.

THINK OF IT LIKE YOUR CASH DRAWER

At the end of the day, the money in your drawer plus the money you paid out has to equal what you started with plus what came in. If it doesn't balance, you don't shrug — you find where it went. Energy is exactly the same. It always balances. So when the bill is bigger than the work being done, there's a leak, and a leak can be found and closed.

WHERE THE MONEY ESCAPES

Following the heat out the door

Picture a cold-storage room for mangoes. You pay electricity to keep it cold — that is, to keep pulling heat out of it. But heat is always trying to flow back in from the warm air outside (remember Chapter 1: it runs downhill, into the cold). Every time the door opens, warm air pours in. Every gap in the insulation lets heat seep through the walls. Sunlight on the roof drives heat down into the room.

All that leaked-in heat, your refrigeration has to pull back out again — and you pay for every bit of it. The energy isn't lost; it moved from the hot outside into your cold room, and your bill is the receipt. Close the leaks and the bill drops, because there's less heat to remove.

FOR THE CURIOUS

Engineers split this into "the First Law" (energy is conserved — totals always balance) and the practical art of an energy audit (tracing where it flows). The two ideas you'll hear are *heat gain* (heat leaking into a cold space you're paying to cool) and *heat loss* (heat escaping a hot tank you're paying to heat). Both are just energy changing address — and both are money.

JJ

THE PEOPLE BEHIND THE RULE

James Prescott Joule (1818–1889)

An English brewer's son who ran careful experiments in his family's brewery. He proved that work and heat are two forms of the same thing — that stirring water with a paddle warms it by an exact, measurable amount. The unit of energy is named the *joule* in his honour. Every figure on your electricity bill is counted in his units.

THE GOOD NEWS IN THE RULE

Waste heat is just heat at the wrong address

Here's where the First Law turns from a warning into an opportunity. Many machines throw heat away as a by-product. A big aircon dumps heat outside. A refrigeration system dumps heat off the back. That heat didn't disappear — it's real energy, and it's free, because you already paid for it once.

A normal business pays twice: once to cool a space (throwing heat outside), and again to heat water with a separate machine. But if heating and cooling are the same job seen from two ends — which is exactly what

Chapter 1 told us — then the heat thrown away by cooling could be caught and used to make your hot water. You'd pay once and get both.

This is precisely what Karnot's CO_2 machines are built to do: cool your process and heat your water at the same time, from one flow of energy. The industry calls it heat recovery. We call it not paying for the same energy twice. We'll come back to it properly in Chapter 10.

THE MONEY LINE

Every peso of energy you buy ends up somewhere. The question that decides your bill is simple: did you use it once and throw it away, or catch the waste and use it twice?

BEFORE YOU TURN THE PAGE

- **Energy can't be created or destroyed** — it only changes form, and it always balances.
- **A high bill isn't a mystery.** The energy went somewhere specific, so waste can always be found.
- **Leaks are money.** Heat seeping into a cold room, or out of a hot tank, is energy you paid for, escaping.
- **Waste heat is free heat.** Catching it and using it twice is the heart of how Karnot saves you money.

HEAT PUMPS FOR CFOS

PART 1 · CHAPTER 3

03

The Three Ways Heat Sneaks In

Heat has exactly three ways to get into your cold room or out of your hot tank. Once you can name them, you can stop them — and each one you block is money saved.

> *Heat is always trying to move (Chapter 1) and it never disappears (Chapter 2). So where does it actually sneak through? There are only three doors it can use. Learn the three, and you can shut them.*

THE METER READING · WHY THIS IS YOUR MONEY

Most of what you pay to cool a space is spent fighting heat that leaked in — and most of that leak is avoidable. A better-sealed door, a shaded roof, a bit more insulation: small fixes that cut the work your machines have to do, every hour of every day. **Before you buy a bigger machine, it's often cheaper to stop the heat getting in.** This chapter shows you where to look.

DOOR ONE

Conduction — heat creeping through solid walls

Hold a metal spoon in a hot cup of coffee and the handle soon gets warm. The heat crept along the metal, from hot end to cold end, through the solid itself. That's **conduction** — heat travelling through a material by touch, passed from one part to the next.

Your cold room loses the battle this way through its walls. Warm outside, cold inside, and heat creeps straight through the solid wall to even things out. Thick insulation is simply a material that conducts heat very *badly* — it slows the creep to a trickle. That's the whole job of insulation: to be a poor conductor, so less heat sneaks through.

THINK OF IT LIKE A CROWD PASSING BUCKETS

Conduction is like a line of people passing water buckets hand to hand. In metal, the line is tightly packed and fast — heat races through. In foam insulation, the people are spread far apart and slow — the buckets barely move. Same idea, different speed. Choose a "slow crowd" material for your walls and less heat gets through.

DOOR TWO

Convection — heat carried by moving air

Open the door of a cold room on a hot day and you feel the warm air pour in — you can almost see it. That warm air carries its heat bodily into the cold space. That's **convection** — heat carried from place to place by a moving fluid, usually air or water.

This is the leak that opens and closes all day. Every time a forklift drives through, every time a door is propped open "just for a minute," a wave of warm, moist outside air rolls in, dumps its heat, and your refrigeration has to pull it all out again. Strip curtains, air curtains, and simply keeping doors shut are cheap weapons against convection — and they work the moment they're fitted.

DOOR THREE

Radiation — heat beamed straight from the sun

Stand in direct sun and you feel warmth on your skin even though the air may be cool. That heat travelled to you as invisible rays, straight from the sun, through empty space — no touching, no moving air needed. That's **radiation** — heat that travels as a beam, like light.

For a Philippine building, the roof is where this bites. Tropical sun beats down on the roof all day, the roof soaks up the rays and heats up, and that heat then conducts down into the rooms below. A reflective roof coating, shade, or a ventilated roof space turns much of that beam away before it ever becomes your problem.

JF

THE PEOPLE BEHIND THE RULE

Joseph Fourier (1768–1830)

A French mathematician who, in the 1820s, worked out the exact laws of how heat conducts through solids — the maths every engineer still uses to size insulation. He also was among the first to describe how the atmosphere traps the sun's warmth, the idea we now call the greenhouse effect. Two centuries on, his equations decide how thick the walls of your cold room should be.

WHY NAMING THEM PAYS

Three doors, three cheap fixes

The reason this chapter matters to your bill is simple: every machine in this book has to fight whatever heat sneaks in. The less that gets in, the smaller and cheaper the machine can be, and the less it costs to run. So before sizing any equipment, a good engineer first asks where the heat is getting in — and very often the cheapest saving is a door seal, a roof coating, or some insulation, not a new machine at all. That's exactly what a survey looks for, as we'll see in Chapter 14.

THE MONEY LINE

Heat has three doors — through the walls, on the moving air, and beamed from the sun. Every door you shut means a smaller machine, a smaller bill, every hour, for free.

BEFORE YOU TURN THE PAGE

- **Conduction** — heat creeping through solid walls. Beaten by insulation (a poor conductor).
- **Convection** — heat carried in on moving warm air. Beaten by sealing doors and using curtains.
- **Radiation** — heat beamed from the sun onto your roof. Beaten by shade and reflective coatings.
- **Shut the doors first.** Stopping heat getting in is usually cheaper than buying a bigger machine.

HEAT PUMPS FOR CFOS

PART 1 · CHAPTER 4

04

Temperature, and the Size of the Hill

The further uphill you push heat, the harder the pump works and the more you pay. The size of the temperature gap is the size of your bill.

> *In Chapter 1 we said heat runs downhill, and a pump pushes it uphill. Now the key question for your wallet: how steep is the hill? Because the steeper it is, the more electricity the pump needs — and steepness is just the gap in temperature.*

THE METER READING · WHY THIS IS YOUR MONEY

A heat pump that only has to lift heat a little way sips electricity. One asked to lift it a long way gulps it. This is why a cold store at minus twenty costs far more to run than a chiller at plus five, and why making water scalding hot costs more than making it just warm. **Matching the temperature to what you actually need — no colder, no hotter — is one of the easiest savings in the building.**

FIRST, WHAT TEMPERATURE REALLY IS

How hard the tiny pieces are jiggling

Everything is made of tiny pieces — molecules — far too small to see, and they're always jiggling. **Temperature is simply how hard they're jiggling.** In hot water the molecules are bouncing about wildly; in cold water they're jiggling gently; in ice they're barely shuffling. Heat is that jiggling energy, and temperature is the measure of it.

When you warm something up, you're making its molecules jiggle harder. When you cool it, you're stealing some of that jiggle away. There's nothing more mysterious to it than that.

THINK OF IT LIKE A DANCE FLOOR

A hot object is a crowded dance floor with everyone jumping hard. A cold one is the same floor late at night, people barely swaying. "Cooling" the floor means calming people down — taking energy out. And there's a limit: you can't dance less than completely still. That dead-stop point, where all jiggling stops, is the coldest anything can ever be.

THE COLDEST POSSIBLE

Absolute zero, and Kelvin's scale

Because cold is just *less* jiggling, there's a hard floor: the point where the jiggling stops completely. Nothing can be colder than that. Scientists call it **absolute zero**, and it's about minus 273 degrees Celsius — far colder than anything on Earth.

Lord Kelvin — half of our name — built the temperature scale that counts up from that absolute floor. Engineers use his scale because it measures the *real* amount of heat energy in something, with no confusing negative numbers. You don't need to use it, but it's nice to know that the "K" in our company name is standing quietly in every calculation an engineer makes.

BACK TO YOUR BILL

The taller the hill, the harder the pump works

Now the part that costs money. A heat pump moves heat from a cooler place to a warmer one. The bigger the gap between those two temperatures, the steeper the hill, and the harder the pump must work to climb it.

Cooling a room to a pleasant 24 degrees on a 32-degree day is a gentle slope — a small gap, easy work, cheap. Freezing a cold store down to minus 20 on that same hot day is a mountain — a fifty-degree gap — and the machine works far harder for every unit of heat it shifts. Same with heating: warming water to a comfortable wash temperature is easy; driving it up to steam is a long, expensive climb.

> FOR THE CURIOUS
>
> This is Carnot's insight from 1824, in plain words. He proved that the best any heat-moving machine can ever do depends only on the two temperatures it works between — the smaller the gap, the higher the possible efficiency, with a ceiling set by nature that no engineering can beat. It's why the single most powerful way to cut a refrigeration bill is often to *not over-cool*: every extra degree colder than you truly need makes the hill taller and the bill bigger.

THE PRACTICAL LESSON

Ask for exactly what you need

The money lesson is wonderfully simple. Don't make the hill taller than it has to be. If your product is safe at minus 18, don't run the store at minus 25 "to be sure" — you're paying a steep premium for those needless degrees. If your process needs water at 60, don't heat it to 80. A good survey checks every setpoint in the building and asks: is this gap bigger than it needs to be? Each degree you give back is money, every hour, forever.

THE MONEY LINE

The temperature gap is the steepness of the hill, and the steepness is your bill. Ask for exactly the temperature you need — never colder, never hotter — and the pump works less and you pay less, around the clock.

BEFORE YOU TURN THE PAGE

- **Temperature is how hard the molecules jiggle.** Heating adds jiggle; cooling steals it.
- **There's a coldest possible — absolute zero** — and Kelvin's scale counts up from it. The "K" in Karnot.
- **The bigger the temperature gap, the harder the pump works** and the more you pay.
- **Don't over-cool or over-heat.** Every needless degree makes the hill taller and the bill bigger.

HEAT PUMPS FOR CFOS

PART 1 · CHAPTER 5

05

The Magic of Boiling

Water doesn't always boil at 100 degrees. Change the pressure and you change the boiling point — and that single trick is the hinge the whole machine turns on.

> *This is the most important chapter in the book, so we'll go slowly. Everything a heat pump does rests on one surprising fact: by squeezing or releasing a fluid, you can choose the temperature at which it boils. Master this one idea and the machine falls into place.*

THE METER READING · WHY THIS IS YOUR MONEY

You can't see this trick on your bill, but it's the reason the bill can fall by three-quarters. Controlling boiling with pressure is how a heat pump grabs heat from cool air and releases it into hot water — moving heat uphill cheaply. **Understand this chapter and every saving in the rest of the book stops being a sales claim and starts being obvious.**

THE SURPRISE

Boiling point isn't fixed

Most of us learn that water boils at 100 degrees. True — but only at sea level. Take a pot of water up a high mountain and it boils at a lower temperature, because the air pressing down on it is thinner. This is why cooking takes longer in the mountains: the water is boiling, but it's cooler, so food cooks more slowly.

Go the other way — squeeze the water under higher pressure — and it boils *hotter*. That's exactly what a pressure cooker does. By trapping steam and raising the pressure inside, it pushes the boiling point well above 100 degrees, so the food cooks faster in hotter water.

THINK OF IT LIKE A PRESSURE COOKER, BECAUSE IT IS ONE

Every Filipino kitchen knows the pressure cooker. Lock the lid, the pressure rises, and the water inside gets hotter than it ever could in an open pot — that's why the *nilaga* is done in half the time. Loosen the valve, the pressure drops, and it boils cooler again. A heat pump is doing the very same thing on purpose, over and over: squeeze to boil hot, release to boil cold. That's the whole trick.

WHY BOILING MATTERS SO MUCH

Boiling soaks up heat; the reverse releases it

Here's why boiling, of all things, is the key. When a liquid boils into a gas, it *drinks in* a large amount of heat from its surroundings — far more than just warming the liquid does. And when a gas turns back into a liquid, it *gives that heat back out*. (We'll see exactly why in the next chapter.)

So if you could make a fluid boil in a cold place — drinking in heat there — and then condense back to liquid in a warm place — dumping the heat out there — you'd have carried heat from cold to hot. From low to high. Uphill. That is a heat pump. And the way you control where it boils and where it condenses is by controlling the pressure.

PUTTING IT TOGETHER

Boil cold here, condense hot there

Now picture the special fluid inside a heat pump — the refrigerant. It's chosen so that it boils at very low temperatures, far below water. Let it sit at low pressure next to the cool outside air and it boils, drinking in heat from that air even though the air feels merely warm to you. The gas it becomes is now carrying that heat.

Then a pump squeezes that gas hard. High pressure means a high boiling point — so now the same fluid will happily condense back to liquid at a high temperature, hot enough to heat your water. As it condenses, it dumps out all the heat it collected, plus the energy from the squeeze. Heat has moved from the cool air into your hot water. Release the pressure and the cycle begins again.

WC

THE PEOPLE BEHIND THE RULE

William Cullen (1710–1790)

A Scottish doctor who, in 1748, gave the first public demonstration of artificial refrigeration — by letting a fluid boil at low pressure and watching it pull so much heat from the surrounding air that a little ice formed. He didn't build a machine from it, but he proved the principle this whole industry stands on: boiling a fluid makes cold. Two and a half centuries later, your cold store runs on his observation.

THE MONEY LINE

Squeeze a fluid and it boils hot; release it and it boils cold. That one trick lets a machine carry heat uphill from cheap, cool air into valuable hot water — and that is why your bill can fall by three-quarters.

BEFORE YOU TURN THE PAGE

- **Boiling point depends on pressure.** High pressure boils hot (the pressure cooker); low pressure boils cold (the mountain top).
- **Boiling drinks in a lot of heat;** condensing back gives it out again.
- **Boil cold in one place, condense hot in another,** and you've carried heat uphill — that's a heat pump.
- **Pressure is the control knob.** Squeeze and release to choose where heat is grabbed and where it's released.

HEAT PUMPS FOR CFOS

PART 1 · CHAPTER 6

06

Solid, Liquid, Gas

There's a huge amount of hidden heat in simply changing from liquid to gas — far more than in warming the liquid up. That hidden heat is the real engine inside every heat pump.

In the last chapter we used boiling to carry heat. Now we'll see why boiling is so powerful: a phase change — liquid to gas, or back — moves an astonishing amount of heat for the size of the thing. This hidden heat is the secret muscle of the whole machine.

THE METER READING · WHY THIS IS YOUR MONEY

The reason a small heat pump can shift so much heat — and a small thermal store can hold so much — comes down to this hidden heat in a phase change. It's also, as we'll see in Chapter 7, where most of the free energy in our humid air is hiding. **Understand phase change and you understand why so little electricity moves so much heat.**

THE THREE STATES

How tightly the pieces hold hands

Everything can exist as a solid, a liquid, or a gas. Water is the example we all know: ice, water, steam. The difference is just how tightly the tiny molecules hold onto each other. In a **solid** they're locked together in a rigid grip — ice holds its shape. In a **liquid** they've loosened enough to slide past one another — water flows. In a **gas** they've let go entirely and fly apart to fill the room — steam.

To move from solid to liquid to gas, you have to loosen those grips, and loosening grips takes energy. That energy is heat. To go back the other way, the grips re-form and the heat comes back out.

THE SURPRISE

Breaking the grip costs far more than warming

Here's the part that surprises people. Warming water from cool to nearly boiling takes a certain amount of heat. But turning that same hot water into steam — just breaking the last grip, with no rise in temperature at all — takes *several times more heat again*. The temperature doesn't even go up while it boils; all the energy goes into tearing the molecules apart from each other.

This hidden heat — the heat swallowed up changing from liquid to gas, without changing the temperature — is the giant of the heat world. It's called *latent heat*, meaning "hidden." It's hidden because your thermometer doesn't see it: the temperature sits still while a huge amount of energy pours in.

THINK OF IT LIKE SWEAT ON YOUR SKIN

Why does sweating cool you down? Not because the sweat is cold — it's body temperature. It cools you because as each drop of sweat *evaporates* — turns from liquid to gas — it drinks a big gulp of heat straight from your skin to break its molecular grip. That gulp is latent heat, and it's why a breeze on damp skin feels so cooling. Your own body uses the exact trick a heat pump uses.

WHY THE MACHINE LOVES IT

Big heat, small package

Now you can see why a heat pump uses boiling and condensing rather than just warming and cooling a fluid. Because the phase change carries so much hidden heat, a small amount of refrigerant, boiling and condensing over and over, can shift an enormous amount of heat. You get a lot of heat moved for a small, compact machine. That's latent heat doing the heavy lifting.

The same fact powers thermal storage. A material that melts and freezes at a useful temperature can store a great deal of heat or cold in a small space — far more than just warming up a tank of water — because of the hidden heat locked in the phase change. That's exactly the principle behind Karnot's iSTOR thermal batteries, and the coconut-based FLX material in development: store energy in the melting and freezing, not just the warming, and a compact module holds a surprising amount. We'll return to it in Chapter 13.

FOR THE CURIOUS

The numbers are striking. Warming a kilogram of water by one degree takes about 4 kilojoules. But boiling that kilogram of water into steam takes about 2,260 kilojoules — over five hundred times as much, all hidden in the phase change with no temperature rise. This is why steam burns are so severe, why sweat is so effective, and why a phase-change thermal store packs far more into its volume than a plain water tank.

THE MONEY LINE

The hidden heat of turning liquid to gas is several times larger than the heat of warming it. That hidden muscle is why a small machine moves so much heat — and why a compact thermal store can run your business after dark.

BEFORE YOU TURN THE PAGE

- **Solid, liquid, gas** differ in how tightly the molecules grip each other.
- **Breaking the grip (boiling) swallows far more heat** than just warming the liquid — and the temperature doesn't even rise.
- **This hidden heat is called latent heat.** Sweat cooling your skin is latent heat at work.
- **It's the machine's secret muscle** — moving big heat in a small package, and storing big energy in a small tank.

HEAT PUMPS FOR CFOS

PART 1 · CHAPTER 7

The Ocean of Energy in Our Air

07

The warm, humid Philippine air you walk through every day is a vast, free reservoir of heat. A heat pump's real job is simply to dip into it — and the amount on offer is staggering.

> *We've built every piece. Heat runs downhill; energy is conserved; boiling and phase change move huge amounts of heat. Now let's point it all at the thing that surrounds you for free: the air. Because there is far more usable energy in it than almost anyone imagines.*

THE METER READING · WHY THIS IS YOUR MONEY

A heat pump doesn't make heat — it gathers heat that's already in the air, for free. The only thing you pay for is the gathering. This chapter shows you just how much free heat is flowing past your building every hour. **Once you see the size of the reservoir, the "₱4 of heat for ₱1 of electricity" stops sounding too good to be true — and starts sounding obvious.**

THE HIDDEN WARMTH

Even "cool" air is full of heat

Air doesn't feel like fuel. But remember Chapter 4: heat is just the jiggling of molecules, and the air's molecules are jiggling plenty at 32 degrees. There's real, gatherable warmth in it — and the warmer the air, the more there is. The Philippines, blessed with warm air all year, sits on a richer reservoir than a cold European country ever gets.

And there's a second, bigger store hiding in our air, thanks to Chapter 6. Philippine air is *humid* — thick with water vapour. That vapour is water that has already paid the huge latent-heat price to become a gas. Coax a little of that moisture back toward liquid and it gives that hidden heat back. So our humid air carries two stores at once: the ordinary warmth, and a much larger hidden store locked in the moisture.

LET'S COUNT IT

The number in 10,000 cubic metres an hour

Let's put a real figure on it. Picture a fairly ordinary air flow for a commercial machine: **10,000 cubic metres of air every hour** passing across the heat pump's coil — roughly the air in a small warehouse, drifting past each hour.

That air weighs around 11,500 kilograms an hour. Now we harvest a modest slice of its heat — cool it by about 5 degrees and wring a little of the moisture out of it. Working the figures carefully for typical Philippine conditions (around 32 degrees, humid), here's what that slice contains:

~16 kW from cooling the air just 5 °C (the ordinary warmth)
~86 kW from wringing out a little moisture (the hidden latent heat)
~100 kW total free heat harvested from that one air stream
5× more heat hiding in the moisture than in the warmth itself

Around **100 kilowatts of heat** — gathered from air you would otherwise let drift straight past your building. Look at the split: the moisture alone carries five times more heat than the temperature does. That's Chapter 6's hidden latent heat, showing up as real money in our humid climate. The air is not "a bit warm." It's an ocean.

FOR THE CURIOUS

These are worked estimates for stated conditions (≈32 °C, high humidity, cooling the stream ~5 °C and removing a little moisture); real figures vary with weather, airflow and the machine. The key engineering point: in humid tropical air the *latent* heat in the moisture dwarfs the *sensible* heat of temperature — here roughly five to one. It's why air-source heat pumps perform so well in the Philippines, and why dehumidifying and heat-pumping are really two views of the same job. The total energy merely *carried* past in that stream is larger still — on the order of 250–270 kW-equivalent — of which we skim only a sensible, sustainable slice.

WHY THIS CHANGES THE MATHS

You pay for the bucket, not the river

Now the COP claim makes sense. To gather that ~100 kW of free heat from the air, the heat pump's compressor might use only around 25 kW of electricity — the cost of running the pump that does the gathering and squeezing. Out comes roughly 100 kW of useful heat for 25 kW of electricity paid: four units of heat for one unit of power. The other three-quarters came free, out of the ocean of air.

This is the river-and-bucket from earlier, now with numbers. You're not paying to *make* the heat. You're paying only to *lift* it out of an enormous free reservoir that the Philippine climate keeps topped up all year round. Your hot, humid weather — the thing that makes cooling expensive — is the very thing that makes this reservoir so rich.

THE MONEY LINE

Ten thousand cubic metres of Philippine air an hour holds around 100 kilowatts of harvestable heat — most of it hidden in the moisture. A heat pump pays only to dip into that ocean. The climate fills it for free.

BEFORE YOU TURN THE PAGE

- **Even "cool" air is full of gatherable heat** — and warm, humid Philippine air is especially rich.
- **Most of the energy hides in the moisture** (latent heat) — here about five times the warmth itself.
- **One ordinary air stream carries ~100 kW of free heat** an hour, ready to be harvested.
- **You pay only to lift it out** — about a quarter of the energy you get back. That's where COP 4 comes from.

PART TWO

How the Machine Works

Now you have the rules, the machine itself is easy. Four parts, one loop, and the number that proves it pays.

HEAT PUMPS FOR CFOS

PART 2 · CHAPTER 8

08

The Refrigeration Loop, Step by Step

Four parts, one sealed loop, going round and round. You now know every idea inside it — so let's walk the whole machine, one step at a time.

> *This is the moment everything clicks together. A heat pump is just four parts in a loop, and you already understand what each one does. Walk around the loop once and you'll never look at a fridge, an aircon, or your energy bill the same way again.*

THE METER READING · WHY THIS IS YOUR MONEY

Every machine that heats or cools your business runs this exact loop — your fridge, your aircon, your cold store, and every Karnot heat pump. When you can see the loop, you can see where energy is gathered for free and where it's wasted. **This is the picture that lets you judge any quote, any salesman, any machine — including ours.**

THE CAST

Four parts, and what each one does

The whole machine is four parts joined in a sealed loop, with the refrigerant (our heat-carrying courier) flowing round forever. Here they are, in plain terms:

The evaporator — where the refrigerant boils and drinks in heat. This is the cold part. It sits where you want to take heat *from*: the outside air (for heating) or inside your cold room (for cooling).

The compressor — the pump, the only part that uses real electricity. It squeezes the gas, raising its pressure and its temperature. This is the muscle that pushes heat uphill.

The condenser — where the refrigerant condenses back to liquid and dumps its heat out. This is the hot part. It sits where you want to deliver heat *to*: your hot water, or the outside air (for cooling).

The expansion valve — a tiny nozzle that lets the high-pressure liquid suddenly release. The pressure drops, and so the boiling point drops, getting the refrigerant cold again, ready to start over.

THE JOURNEY

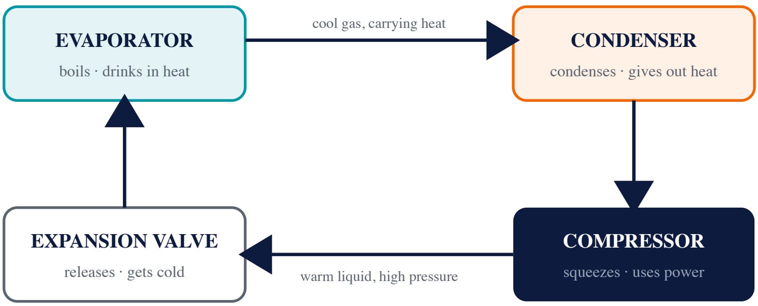
One trip around the loop

Now walk the courier around the loop. Start it as a cold, low-pressure liquid entering the **evaporator**. Here it meets the warm outside air (the ocean of energy from Chapter 7). Because it's at low pressure, it boils at a very low temperature (Chapter 5) — so it boils, drinking in a big gulp of heat from the air as it does (the latent heat of Chapter 6). It leaves as a cool gas, now carrying that heat.

Next it reaches the **compressor**. The compressor squeezes it hard. Now it's a hot, high-pressure gas — squeezed so tightly its boiling point is now very high. This is the only step where you spend real electricity.

On it goes to the **condenser**. Here the hot gas meets your water, which is cooler than the now very-hot gas. So the gas condenses back to liquid, dumping out all the heat it gathered from the air *plus* the energy from the squeeze. Your water gets hot. The refrigerant leaves as a warm, high-pressure liquid.

Finally it passes through the **expansion valve** — a sudden release. The pressure drops, the boiling point drops with it, and the refrigerant turns cold again, ready to enter the evaporator and start the whole journey over. Round and round, thousands of times an hour.



The loop runs clockwise: boil and gather heat (left), squeeze (bottom-right), release heat into your water (top-right), drop the pressure (bottom-left), repeat.

THINK OF IT LIKE A DELIVERY RIDER

Picture a rider who collects warm *pandesal* from a bakery on the cool edge of town and delivers it to a café in the centre. He loads up where it's cool (evaporator), rides hard to get there (compressor — the effort), drops off the warm load where it's wanted (condenser), then rides back empty and relaxed (expansion valve) to load up again. The only fuel you buy is the effort of the ride. The bread — the heat — was waiting there for free.

THE MONEY LINE

Four parts, one loop: boil and gather free heat, squeeze, release the heat where you want it, reset. The only thing you pay for is the squeeze — everything else is the free heat from the air, doing your work.

BEFORE YOU TURN THE PAGE

- **Evaporator** — boils the refrigerant and drinks in free heat (the cold part).
- **Compressor** — squeezes the gas; the only part using real electricity.
- **Condenser** — condenses the gas and delivers the heat to your water (the hot part).
- **Expansion valve** — drops the pressure to get cold again, and the loop repeats. Same loop in every fridge, aircon and heat pump.

HEAT PUMPS FOR CFOS

PART 2 · CHAPTER 9

09

Three Pesos of Heat for One Peso of Power

A heater turns one peso of electricity into one peso of heat. A heat pump turns one peso into three or four. This single difference is the whole reason to read this book.

> *You've seen the loop gather free heat from the air. Now we put a number on how good a deal that is — one simple number your accountant will care about more than any other in this book.*

THE METER READING · WHY THIS IS YOUR MONEY

An electric water heater gives you ₱1 of heat for every ₱1 of electricity. A Karnot heat pump gives you about ₱4 of heat for the same ₱1 — because most of the heat is lifted free from the warm air (Chapter 7). **That is up to 75% off your heating bill, every single month.** Same hot water. A quarter of the cost.

THE CONTRAST

Making heat versus moving it

An electric heater works by force. Push electricity through a coil, the coil resists, and that struggle makes heat. It's honest but expensive: one unit of electricity in, one unit of heat out. You can never get more than you paid for. Diesel and LPG boilers are the same story — you only get back the energy locked in the fuel, minus what goes up the chimney.

A heat pump doesn't make heat at all. It *moves* heat that already exists in the air (Chapter 7) into your water — and moving is far cheaper than making. The electricity isn't used to create the heat; it only runs the compressor that gathers it and pushes it uphill (Chapter 8). The heat itself is free, taken from the ocean of air around you.

THINK OF IT LIKE A WATER BUCKET

Making heat with an electric coil is like filling a bucket by hand, cup by cup — slow, and every cup costs you. A heat pump is like using a small pump to lift water from a river that's already there. You pay only for the little pump, not for the water. The river is the warmth in the air, and in the Philippines that river runs warm all year.

THE ONE NUMBER

COP — your return on energy

Engineers measure this deal with one simple number: **COP**, the Coefficient of Performance. It just means: for every 1 unit of electricity you put in, how many units of heat do you get out?

An electric heater has a COP of 1 — one in, one out. A Karnot iHEAT heat pump runs at a COP of about **4 to 5**. One unit of electricity in, four to five units of heat out. Think of COP as the return on your energy: a peso spent on a heater returns a peso of heat, but a peso spent through a heat pump returns four. No bank offers that.

SC

THE PEOPLE BEHIND THE RULE

Sadi Carnot (1796–1832)

The young French engineer who gave us half our name. In 1824 he worked out the absolute ceiling on how efficient any heat-moving machine could ever be — set purely by the two temperatures it works between (Chapter 4). Carnot showed there's a limit nature won't let you beat. Karnot's whole job is to build machines that get as close to that ceiling as the real world allows.

WHAT IT MEANS FOR YOU

The same hot water, a quarter of the bill

Put it in pesos. Suppose your business spends ₱100,000 a month heating water with electric coils or an LPG boiler. Swap to a heat pump running at COP 4, and you need roughly a quarter of the energy for the same hot water. That's a path to cutting tens of thousands of pesos off that bill every month — money that was leaving your business and now stays in it.

And because the savings start the moment the machine is switched on, the system begins paying for itself immediately. We'll put real numbers on that in Chapter 15. For now, hold onto the headline: you are buying the same hot water you already buy, for a fraction of what you pay today.

THE MONEY LINE

A heater turns ₱1 of electricity into ₱1 of heat. A Karnot heat pump turns ₱1 into about ₱4. That is the entire investment case in one sentence — and it is true from the first day.

BEFORE YOU TURN THE PAGE

- **Burning fuel can only return what you put in.** Heaters and boilers are capped at one-for-one.
- **A heat pump moves free heat from the air** instead of making heat — so it returns far more than it costs to run.
- **COP is the number that matters.** Karnot heat pumps run at COP 4–5: four to five units of heat per unit of electricity.
- **The Philippine climate makes this better, not worse** — warm air means a higher COP and up to 75% off your heating bill.

HEAT PUMPS FOR CFOS

PART 2 · CHAPTER 10

10

One Machine, Two Jobs

If cooling makes waste heat, and heating needs heat, why pay for both separately? Karnot's machines do both jobs at once, from a single flow of energy — and that's where the savings get serious.

> *Back in Chapter 1 we said heating and cooling are the same job seen from two ends. Now you have the loop to prove it. A heat pump always makes a cold side and a hot side at the same time. The clever move is to use both.*

THE METER READING · WHY THIS IS YOUR MONEY

Most businesses pay two bills: one to cool a process, and another to heat their water — never noticing that the cooling machine is throwing away exactly the heat the water heater is paying to make. **Use one machine for both, and you pay once for two results.** For a business that needs cold *and* hot at the same time — a hotel, a restaurant, a food plant, a dairy — this can be the single biggest saving in the building.

THE THING NOBODY NOTICES

Every cooler is also a heater

Look back at the loop (Chapter 8). The evaporator makes a cold side; the condenser makes a hot side. Always. They come as a pair — you cannot make one without the other. A normal aircon makes cold for your room and dumps the matching heat outside, wasted. A normal chiller makes cold for your process and throws the heat away off the back.

That thrown-away heat is real, useful heat (Chapter 2) — and you already paid to produce it. The waste isn't the heat; the waste is *dumping* it. If, at that very moment, some other part of your business needs heat — hot water for the kitchen, warm water for washing, heat for a process — then the heat you're about to throw away is exactly what they're about to pay to make.

THINK OF IT LIKE A SARI-SARI STORE THROWING AWAY ICE WATER

Imagine a store that sells cold drinks, tipping out buckets of perfectly good chilled water all day — while the carinderia next door boils the kettle again and again for hot water. Two businesses, two bills, and the answer was sitting right between them. Karnot's machine is the pipe that connects the two: the cold side cools the drinks, the hot side makes the hot water, one machine, one bill.

DOING BOTH AT ONCE

Simultaneous heating and cooling

Karnot's CO_2 machines are built precisely to use both ends at the same time — what the industry calls simultaneous heating and cooling, and what your accountant should call buy-one-get-one-free. The cold side chills your cold room or your process; the hot side, instead of being wasted outdoors, heats your water to high temperatures. One flow of energy, two useful jobs delivered together.

When a machine does this, its value for money soars. You're no longer judging it on heating alone or cooling alone — you're getting both outputs from one electricity bill. This is why, for the right business, the combined performance can be extraordinarily high, as we'll see with the numbers in the next chapter.

FOR THE CURIOUS

When you count both the cooling *and* the heating a single machine delivers from one unit of electricity, the combined "useful energy per unit of power" can be very high indeed — Karnot's design figures for an iHEAT CO_2 system show heating at COP 4.67 and cooling at COP 3.60, which together give a combined effective performance above 8. That number only appears because nothing is thrown away: both ends of the loop are put to work.

THE MONEY LINE

Every cooling machine is secretly a heater too. Use both ends at once and you pay a single electricity bill for two results — often the biggest single saving a hotel, restaurant or food business can make.

BEFORE YOU TURN THE PAGE

- **A heat pump always makes a hot side and a cold side together** — you can't have one without the other.
- **A normal machine wastes one of them.** The thrown-away heat is exactly what your water heater pays to make.
- **Karnot's CO_2 machines use both ends at once** — simultaneous heating and cooling from one flow of energy.
- **For businesses needing hot and cold together, this is often the biggest saving** — two results, one bill.

HEAT PUMPS FOR CFOS

PART 2 · CHAPTER 11

11

Going Transcritical — the CO_2 Story

Carbon dioxide makes an unusual refrigerant — it behaves differently from all the others. And in the Philippine climate, paired with heat recovery, that difference becomes an advantage worth real money.

This is the most technical chapter, and the most rewarding. CO_2 doesn't play by the normal boiling-and-condensing rules at high temperature — it goes "transcritical." That sounds complicated, but it gives Karnot's machines a special power: making very hot water while cooling, exactly what a hot country needs.

THE METER READING · WHY THIS IS YOUR MONEY

Transcritical CO_2 is why a Karnot machine can take the waste heat from your cooling and push your water all the way up to washing- and process-temperatures — not just lukewarm. In Philippine conditions, with that heat actually used rather than dumped, these systems reach a heating performance around **4.5** and a combined heating-and-cooling figure far higher. **For a hotel, dairy or food plant, that's the difference between a good saving and a transformational one.**

A QUICK RECAP

The normal rule, and CO_2's exception

Normally (Chapter 5) a refrigerant boils to grab heat and condenses to release it, with pressure choosing the temperatures. That works because every fluid has a clear line between "liquid" and "gas." But every fluid also has a special point — its *critical point* — above which that line vanishes. Push past it and the fluid is neither a normal liquid nor a normal gas; it's a strange in-between state that's part-way to both.

Most refrigerants have a high critical point, so they spend their whole life comfortably below it, condensing normally. **Carbon dioxide is unusual: its critical point is low** — easily passed in everyday operation. So when a CO_2 machine releases its heat, it often does so *above* the critical point, in that strange in-between state. That's what "transcritical" means: the machine crosses the critical point on every loop.

THINK OF IT LIKE A KETTLE THAT NEVER QUITE STOPS STEAMING

A normal refrigerant releasing heat is like steam condensing on a cold window — it gives up its heat all at one fixed temperature, then it's done. Transcritical CO_2 is different: as it releases heat it *glides* smoothly down through a whole range of high temperatures rather than dumping it all at one. That gliding is the secret — because it can hand over heat across a range, it's brilliant at heating water from cool all the way up to hot, in one pass.

WHY IT SUITS US

The tropical twist

Here's the honest engineering, because a CFO deserves it straight. On its own, CO_2's transcritical behaviour is usually called a *weakness* in hot countries: when the outdoor air is hot, a CO_2 machine struggles to dump its waste heat to that hot air, and its cooling efficiency drops. Many engineers would tell you CO_2 is better suited to cold climates.

But that judgement assumes you're *throwing the heat away*. Karnot doesn't. We recover it (Chapter 10). And the moment you actually *want* that high-grade heat — for hot water, for a process — CO_2's "weakness" flips into its greatest strength. Its gift for producing very hot water is exactly what a Philippine hotel or food plant needs every day. The heat it struggles to dump to hot air is heat you were going to pay to make anyway. So you capture it, and the supposed disadvantage becomes free high-temperature hot water.

FOR THE CURIOUS

This is why context decides everything. Judge a transcritical CO_2 system on cooling alone in hot weather and the numbers look ordinary. Judge it on cooling *plus* the high-temperature heat it recovers — which in a hot, humid country you genuinely use — and it shines. Karnot's design figures for tropical operation show heating performance around 4.5 and, with simultaneous cooling counted too, a combined effective performance well above 8. CO_2 also reaches very low temperatures cleanly for cold storage, and it's a natural refrigerant with one of the lowest climate impacts there is — the subject of the next chapter.

THE KARNOT MACHINES

iHEAT and iCOOL

This is the engineering behind two of Karnot's product families. **iHEAT** is the high-temperature heat pump — it makes hot water and process heat, and the CO_2 versions can drive water to high temperatures using exactly this transcritical behaviour. **iCOOL** is the CO_2 refrigeration side — cold storage and process cooling down to very low temperatures, with a refrigerant that has one of the lowest climate impacts of any. Put together on a site that needs both, with the heat recovered rather than wasted, they deliver the combined performance no single-purpose machine can match.

THE MONEY LINE

CO_2's quirk of making very hot water is a drawback only if you waste the heat. Recover it — as Karnot does — and in a hot, humid country that quirk becomes free high-temperature hot water, lifting heating performance to around 4.5 and combined performance far beyond.

BEFORE YOU TURN THE PAGE

- **CO_2 goes "transcritical"** — it crosses its critical point and releases heat across a glide of high temperatures, ideal for making hot water.
- **On its own in hot air that's usually a weakness** — it struggles to dump waste heat.
- **But Karnot recovers that heat,** so the weakness flips into free, high-grade hot water — exactly what a tropical business needs.
- **iHEAT (hot) and iCOOL (cold)** are built on this, reaching ~4.5 heating performance and far higher combined.

PART THREE

The Karnot System, and the Money

You understand the machine. Now the four things that turn it into cash in your hand.

HEAT PUMPS FOR CFOS

PART 3 · CHAPTER 12

12

The Refrigerant Question

The fluid inside the loop — the courier that carries the heat — used to be a detail for engineers. Today, which one you choose is a question for the person who signs the cheques.

> *You've met the refrigerant all through Part 2 — the fluid that boils and condenses round the loop. For decades the industry used man-made chemicals that are now being restricted worldwide. Buy the wrong one today and you could own a machine that's costly to refill and hard to service for years.*

THE METER READING · WHY THIS IS YOUR MONEY

The refrigerant inside your equipment is now a business risk. The old man-made gases are being phased down, which pushes their price up and their supply down — some cost over ₱60,000 a kilogram and rising. **Choose a machine built around a natural refrigerant and you sidestep all of it:** cheap to refill, not facing a ban, and worth more when you come to sell the business.

THE OLD CHEMISTRY

The man-made gases, and why they're going

For most of the last century the courier was a family of man-made chemicals — first CFCs, then HFCs, the gases many know as "Freon." They worked well. The problem is what they do when they leak.

Two problems turned them from convenient to costly. First, when they escape into the sky, many trap heat thousands of times more strongly than ordinary carbon dioxide — so even a small leak does outsized damage, and governments have agreed worldwide to phase them down. Second, some belong to a group nicknamed "forever chemicals" (you may see the letters PFAS) because they don't break down in nature, and regulators are moving to restrict the whole family. The detail matters less than the direction: **the man-made refrigerants are on the way out, and everyone in the industry knows it.**

FOR THE CURIOUS

The phase-down of high-warming HFCs is driven by the Kigali Amendment to the Montreal Protocol, which the Philippines has joined. Separately, Europe's chemicals agency (ECHA) is assessing a broad restriction on PFAS substances, with technical committee opinions issued in 2025. None of this happens overnight — but the planning horizon for any equipment you buy today runs straight into it. As supply tightens, the price of refilling an HFC machine only goes one way: up.

THINK OF IT LIKE A FUEL THAT'S BEING BANNED

Imagine buying a delivery truck that runs on a fuel the government has already said it will phase out. The truck works fine today. But each year the fuel gets scarcer and pricier, fewer mechanics will touch it, and when you try to sell the truck nobody wants it. That's an HFC machine. A natural-refrigerant machine runs on a "fuel" that isn't going anywhere.

THE NATURAL ANSWER

Propane and CO_2 — older, simpler, here to stay

The way out isn't a newer man-made chemical. It's going back to natural substances used before the synthetic ones took over — which modern engineering has made safe and efficient. Karnot builds on two:

R290, which is propane. The same gas family as your cooking gas, refined for refrigeration. It's a superb heat carrier — part of why Karnot's iHEAT heat pumps reach COP 4 to 5. Its impact on the climate is tiny, and it costs a fraction of the man-made gases to buy.

CO_2, which is R744. Ordinary carbon dioxide — the gas in your soft drink. It's completely non-flammable, has one of the lowest climate impacts of any refrigerant, and (as Chapter 11 showed) works beautifully for cooling and for making hot water. Karnot's iCOOL refrigeration and its combined heat-and-cool machines run on it.

Neither is affected by the phase-downs. Neither faces a PFAS ban. Both are cheap to refill. This is what "the world is choosing sides" means — half the industry is squeezing a few more years out of the old chemistry, and the other half is building on natural refrigerants. Karnot has chosen.

THE HONEST TRADE-OFFS

What we won't hide

We won't pretend natural refrigerants have no downsides — a CFO deserves the whole picture. Propane is flammable, like the LPG already in most kitchens; so it's used in small, sealed amounts in outdoor units, engineered to strict European safety standards. CO_2 runs at high pressure, which demands well-made components. Both are solved problems — Karnot's European partners have thousands of units running safely on these refrigerants. The point is simply that the safety is engineered in, not wished away.

THE MONEY LINE

The refrigerant inside your machine is now a balance-sheet decision. A natural-refrigerant system is cheap to refill, safe from coming bans, and still valuable in ten years. The man-made alternative is a slow, rising cost you can avoid entirely.

BEFORE YOU TURN THE PAGE

- **The refrigerant is the courier** that carries heat round the loop — and which one you pick now matters for years.
- **Man-made refrigerants are being phased down** — for warming the climate and as "forever chemicals" — making them costlier and harder to service.
- **Natural refrigerants are the way out.** Karnot uses R290 (propane) for heating and CO_2 for cooling — cheap, future-proof, high-performing.
- **The trade-offs are real but solved** — engineered to European safety standards, with thousands of units already running.

HEAT PUMPS FOR CFOS

PART 3 · CHAPTER 13

13

Catching the Sun, Keeping It After Dark

The Philippines has the sunshine the rest of the world envies. The trouble is the sun clocks off at six. The real prize isn't making solar power — it's storing it cheaply until you need it.

> *A heat pump already turns ₱1 into ₱4 of heat. Run it on your own solar power instead of grid power and the sums get better still. But solar only shines by day, and most businesses run into the night. The answer is storage — and the cheapest storage isn't a battery at all.*

THE METER READING · WHY THIS IS YOUR MONEY

Most Filipino businesses with solar only cover about a fifth of their bill, because the sun stops and they've nowhere to keep the power. Add storage and you use your own cheap solar morning, noon and night — instead of buying dear grid power after dark or selling your surplus back for a pittance. **Storage is the missing piece that turns a small solar saving into a big one.**

THE PROBLEM WITH SOLAR ALONE

The sun clocks off at six

Solar panels are wonderful and cheaper every year. But they only make power when the sun is up. A hotel, a cold store, a factory — these run in the evening, overnight, before dawn. So a business with only panels finds its solar covers the easy midday hours and leaves the expensive evening hours to the grid.

Worse, at midday the panels often make *more* than the business can use, and that surplus gets sold back to the grid for far less than it costs to buy back at night. You're giving away cheap power by day and buying dear power by night. The gap between the two is money lost. This is why Karnot doesn't sell you solar panels. As the website puts it: **we sell the missing piece that lets your solar actually work** — the storage that holds your midday sunshine until your evening shift needs it.

THINK OF IT LIKE A WATER TANK ON A FARM

Rain falls when it falls, not when your crops are thirsty. A good farmer doesn't let the rain run away — they catch it in a tank and release it when needed. Solar is your rain: it pours down at midday whether you need it or not. Storage is the tank. Without a tank you use what falls right now and waste the rest. With a tank, every drop works.

TWO WAYS TO STORE

Store electricity, or store heat and cold

There are two ways to keep that midday energy, and the cheaper one surprises most people.

Store electricity in a battery. Karnot's iVOLT pairs solar inverters with battery banks built from $LiFePO_4$ — a chemistry chosen for the tropics because it won't catch fire even in high heat, and lasts thousands of cycles. The batteries fill at midday and run your business after dark. Proven, and sized to your real load rather than a regulatory cap.

Or — cleverer, and often far cheaper — store heat and cold directly. Here's the insight that changes the maths: most businesses aren't really trying to store electricity. They're trying to store hot water, or coldness for a chiller. And storing energy *as heat or cold* costs roughly five to ten times less per unit than storing it in a lithium battery.

FOR THE CURIOUS

Storing energy as heat skips a wasteful round-trip. To store solar in a battery and later make heat, you go sunlight → electricity → chemistry → back to electricity → heat, losing a little at every arrow. But if you simply run your heat pump at midday on free solar and store the *heat* in an insulated tank, you cut out the battery entirely. And thanks to Chapter 6's hidden latent heat, a phase-change store — like Karnot's iSTOR — packs far more into its volume than a plain water tank, up to three times more compact.

THE KARNOT PIECES

iVOLT, iSTOR, and a coconut battery

Put together, the kit is straightforward. **iVOLT** is the solar inverter and lithium battery side — for the energy you genuinely need as electricity. **iSTOR** is thermal storage — compact phase-change modules that bank heat or cold from your midday solar to release at night, far more cheaply than a battery. And the heat pump itself becomes a store: run it on solar at noon, fill an insulated tank, draw hot water all evening for almost nothing.

Then there's the piece that's purely Philippine. **FLX is a thermal battery made from coconut.** A natural wax from Philippine coconut stores heating and cooling at high density — no lithium, no rare earths, no imported chemistry. Local material, made locally, supporting local jobs. FLX is still in development and not yet quoted to customers — but it's the direction of travel, grown in the next province rather than shipped across an ocean.

INVISIBLE WORK

The system decides when to use what

You don't want to be flicking switches to manage all this. Karnot's iSAVE system watches your equipment and quietly does the juggling — charging storage when the sun is strong, drawing it down when power is dear, even shifting your heaviest use away from the priciest hours of the day. To you it just looks like a smaller bill. We'll see in the next chapter how iSAVE also measures and proves your savings.

THE MONEY LINE

Solar makes the power. Storage decides whether you keep it or give it away. Storing heat and cold directly — not just electricity — is up to ten times cheaper, and it's how your midday sun pays your evening bills.

BEFORE YOU TURN THE PAGE

- **Solar alone leaves money on the table** — it shines by day, but your business runs into the night.
- **Storage is the missing piece.** It holds your cheap midday power until the expensive evening hours.
- **Storing heat and cold beats storing electricity** for most businesses — up to 10× cheaper per unit (iSTOR, and coconut-based FLX, in development).
- **iVOLT, iSTOR and iSAVE work together** so it all happens automatically — you just see a smaller bill.

14

First We Measure

A good doctor doesn't prescribe before examining the patient. Before Karnot sells you a single machine, we measure your building — because the survey usually finds money you're already losing.

> *You can't manage what you don't measure. Most businesses have never seen where their energy actually goes — only the total at the bottom of the bill. A survey opens the box, shows you the waste, and proves the savings before you spend a peso on equipment.*

THE METER READING · WHY THIS IS YOUR MONEY

A Karnot energy survey starts from around ₱40,000 — and routinely finds more than that in waste you pay for every month. It tells you exactly which machines are eating your bill, how much a heat pump would save, and what your payback would be — in writing, before you commit. **It turns "I think this will save money" into "here is the proof."** No CFO should sign off equipment without it.

WHY MEASURE FIRST

The bill only tells you the total

Your electricity bill is a single number. It doesn't tell you the old chiller is running twice as hard as it should (a too-tall hill, Chapter 4), or that the boiler is the biggest single drain, or that a cold-room door seal is letting heat in all day (a convection leak, Chapter 3). It's like being handed only the grand total of a month's spending with no breakdown — you know it's too high, but not where to cut.

A survey breaks the total apart. It measures what each major machine actually draws, when it draws it, and how efficiently it's working. Only then can anyone honestly say what a change would save. Anyone who quotes you savings without measuring first is guessing — and you'd be buying their guess.

> THINK OF IT LIKE A MEDICAL CHECK-UP
>
> A careful doctor takes your blood pressure, runs the tests, and reads the results before prescribing anything. A bad one sells you the medicine first and checks later. Karnot is the careful doctor: we examine your building, find what's actually wrong, and only then recommend the treatment — sized to your real condition, not a one-size-fits-all guess.

WHAT A SURVEY FINDS

The leaks add up faster than you'd think

Remember Chapter 2: energy can't disappear, so every peso of waste is findable. A survey is that search, done properly. It typically turns up a boiler or electric heater a heat pump could replace at a quarter of the running cost; refrigeration throwing away heat that could be making your hot water for free (Chapter 10); equipment running flat-out overnight when nobody needs it; and quick fixes — a door seal, a setpoint, a bolt-on retrofit — that pay for themselves in weeks.

That last one matters. Not every recommendation is a big purchase. Karnot's iMESH, for example, is a bolt-on retrofit that boosts the efficiency of cooling equipment you already own, with a short payback.

Sometimes the cheapest saving is fixing what you have before adding anything new.

LK

THE PRINCIPLE BEHIND THE PRACTICE

Lord Kelvin (1824–1907)

The other half of our name. Kelvin once said, in effect, that until you can measure something and put a number on it, your knowledge of it is thin and unsatisfactory. That's the spirit of an energy survey — and of this whole company. Feelings about your bill are not a plan. A measured breakdown is. It's fitting that the man who gave us the measuring stick stands behind the chapter on measuring.

THE HONEST PROMISE

The numbers come before the sale

The reason Karnot leads with a survey isn't ceremony — it's that the savings are real enough to put in writing in advance. You get a clear picture of what you spend now, what you'd spend after, what the equipment costs, and how fast it pays back. If the numbers don't work for your building, you'll know before spending on anything big. That's the opposite of a hard sell. It's proof first, purchase second. And on larger sites, the measuring never stops: iSAVE keeps watching, using the machine's own sensors to track savings, and may also help you qualify for utility incentives or carbon credits where those programmes are available.

THE MONEY LINE

A survey from around ₱40,000 routinely finds more than that in monthly waste — and turns the whole decision from a leap of faith into a signed-off business case. Measure first; the savings prove themselves.

BEFORE YOU TURN THE PAGE

- **Your bill only shows the total.** A survey breaks it apart and shows where the money actually goes.
- **Savings quoted without measuring are guesses.** Karnot measures first, then proves the case in writing.
- **The survey pays for itself** — it routinely finds more waste than it costs, including quick fixes like iMESH retrofits.
- **Measuring continues after install.** iSAVE tracks savings and may help you qualify for utility incentives or carbon credits where available.

HEAT PUMPS FOR CFOS

PART 3 · CHAPTER 15

15

Cash Back From Month One

Here is the move that makes a finance team lean forward: borrow the full cost from a green bank loan, and the fuel you stop buying more than covers the repayment — cash in your account from month one, none of your own money down.

> *You now understand the whole machine. Heat goes downhill; energy never disappears; a heat pump returns ₱4 for every ₱1. Now the part a CFO has been waiting for: you can install one without spending your own cash — borrow against the savings, and the project puts money in your account from the very first month.*

THE METER READING · THE WHOLE POINT, IN ONE BOX

Here is the move that changes everything for a finance team. A green bank loan covers 100% of the equipment. The monthly fuel saving is *bigger* than the monthly loan repayment — so from month one the project is cash-positive. You put in nothing, and money lands in your account every month while the bank is still being paid. **This isn't a cost to be recovered. It's positive cash flow from day one, funded by someone else.**

THE IDEA THAT FLIPS THE DECISION

Don't spend your cash — borrow against the savings

Most owners assume a new system means a large cheque up front. It doesn't have to. Because the savings are large, steady and predictable, a bank will lend you the full cost — and you repay that loan out of the money you're now *not* sending to the diesel supplier. The savings service the debt. Your own capital never leaves the business.

And here's the part that makes a finance director smile: the monthly saving is larger than the monthly repayment. So you're not waiting years to break even — you're cash-positive from the first instalment, with the surplus landing in your account every month while the loan runs. When the loan finishes, the whole saving becomes yours.

A REAL KARNOT PROJECT

A food processor in Metro Manila

Let's use a real example — a food processor in Metro Manila, anonymised but with its actual numbers. The business was burning diesel to pre-heat its boiler feedwater. Karnot proposed a single iHEAT R290 heat pump to do that pre-heating instead, recovering free heat from the air rather than buying fuel.

The system costs about **₱1.18 million**. It cuts the diesel bill by **₱694,000 a year** — a 76% saving on that fuel cost. Bought outright, it pays for itself in 1.7 years. But the owner didn't pay a peso up front. Here's what happened when they financed it instead, over 60 months at 8% a year through a Philippine green-energy loan:

YOU PAY MONTHLY	
₱23,842	
green loan instalment	
YOU SAVE MONTHLY	
₱57,868	
diesel no longer burned	
IN YOUR POCKET	
₱34,026	
every month, from month one	

Read that again, because it's the whole point of the book in three numbers. The bank is paid ₱23,842 a month. The fuel saving is ₱57,868 a month. The difference — **₱34,026 — is positive cash flow into the business, every month, starting the month it switches on.** The owner spent nothing and is better off immediately.

THINK OF IT LIKE A TENANT WHO PAYS MORE THAN YOUR MORTGAGE

Imagine buying a small unit with a bank loan, and a reliable tenant moves in paying rent that's higher than your monthly repayment. You put down nothing meaningful, the tenant covers the loan, and you pocket the difference from day one — then own the unit outright at the end. The heat pump is that tenant. The "rent" is the fuel you stop buying; it more than covers the loan, and after five years the asset — and the whole saving — is yours.

THE TEN-YEAR PICTURE

What it does to the balance sheet

Stretch it over the asset's life and the case gets stronger. For the first five years the loan is being repaid, yet the business still banks over ₱400,000 of net cash a year. From year six the loan is gone and the entire saving — nearly ₱700,000 a year — stays in the business. Here is the whole story on one page:

Year	Energy saved	Loan repaid	Net cash to you
1	₱694,417	₱286,104	₱408,313
2	₱694,417	₱286,104	₱408,313
3	₱694,417	₱286,104	₱408,313
4	₱694,417	₱286,104	₱408,313
5	₱694,417	₱286,104	₱408,313
6	₱694,417	— paid off —	₱694,417
7	₱694,417	— paid off —	₱694,417
8	₱694,417	— paid off —	₱694,417
9	₱694,417	— paid off —	₱694,417
10	₱694,417	— paid off —	₱694,417
Total	**₱6,944,173**	**₱1,430,520**	**₱5,513,653**

Illustrative cash-flow on system cost ₱1,175,850, annual saving ₱694,417, 60-month finance at 8% p.a., 10-year asset life. Final terms subject to lender approval.

Over ten years the project puts **₱5.5 million of net cash** onto the business's books — having required none of the owner's own money to start. That is the difference between thinking of this as a purchase and thinking of it as what it really is: a financing decision that generates cash.

FOR THE CURIOUS — THE ARITHMETIC, SO YOU CAN REDO IT

The numbers are simple enough to check on a phone. **The loan:** borrowing ₱1,175,850 over 60 months at 8% a year gives a monthly instalment of ₱23,842 (the standard loan-payment formula — any bank calculator gives the same). **The saving:** the heat pump cuts annual fuel cost from about ₱917,000 to about ₱223,000 of electricity — a saving of ₱694,417 a year, or ₱57,868 a month. **The monthly surplus:** ₱57,868 saved – ₱23,842 repaid = ₱34,026 positive, every month. **Over five years** that surplus is ₱34,026 × 60 = about ₱2.04 million; **years six to ten** add the full ₱694,417 × 5 = ₱3.47 million; **total ₱5.51 million.** The debt-service coverage — saving divided by repayment — is about 2.4 times, comfortably above any bank's minimum, which is exactly why these projects get approved.

WHERE THE MONEY COMES FROM

Philippine green-loan options

This isn't a special favour — it's a whole category of lending built for exactly this. Several Philippine banks run preferential "green" or "sustainable energy" loan programmes, priced a little below ordinary commercial rates and designed to fund energy projects that pay for themselves. In broad terms:

The **Development Bank of the Philippines** runs a Sustainable Energy Finance Programme aimed at agri-industrial and food projects — typically funding most of the equipment cost over a five-to-ten-year term. **LandBank** offers a similar sustainable-energy investment loan, often the easiest route if you already bank there. And **BPI**'s sustainable development finance is a fast commercial route for established businesses with an existing relationship. Rates and terms vary and are set by the bank, not by Karnot — but they exist, they're real, and they're priced for precisely this kind of self-funding project.

FOR THE CURIOUS — A TAX SWEETENER

There's an extra layer most owners miss. Under the Energy Efficiency and Conservation Act (Republic Act 11285), qualifying energy-efficiency equipment can be eligible for accelerated depreciation and certain import-duty relief — which improves your after-tax cash flow on top of the savings already shown. Your accountant can confirm what applies to your situation; it's worth asking the question before you file.

OR SIMPLER STILL

If you'd rather not borrow at all

Not every business wants a loan on the books. So Karnot also offers **Energy-as-a-Service**: we install and maintain the whole system at zero upfront cost, you buy nothing, and you simply pay a monthly energy bill that's lower than what you pay today. The savings fund the equipment behind the scenes, you keep the difference, and you carry none of the capital or the risk. Three doors, then — buy it outright, finance it with a green loan, or pay as you save — and all three leave you better off from month one.

THE MONEY LINE

Finance the system with a green loan and the fuel you stop buying more than covers the repayment — ₱34,026 a month into the business from day one in our real Metro Manila example, ₱5.5 million over ten years, with none of your own cash at risk.

WHERE TO BEGIN

One measurement, then a decision

You don't have to decide anything today except the first, small, sensible step: measure. Book a site survey (Chapter 14). Let Karnot examine your building, find the waste, and put the savings, the payback and a financed cash-flow exactly like the one above in writing for *your* premises — your actual numbers, ready to hand to your bank's credit officer. Then you choose how to start. Every month you wait is a month of net cash flow you would otherwise have been banking.

THE WHOLE BOOK, IN FIVE LINES

- **Heat moves; it isn't made.** A heat pump lifts free heat from the air and returns ₱4 for every ₱1 — up to 75% off.
- **Natural refrigerants future-proof the machine** — cheap to run, safe from bans, still valuable in ten years.
- **Solar plus cheap thermal storage** keeps your midday sunshine working into the night.
- **A survey proves your numbers first** — and routinely finds more waste than it costs.
- **Borrow against the savings** and the project is cash-positive from month one — ₱34,026/month in our real example, with none of your own money down.

The physics has been settled for two hundred years — since Carnot and Kelvin, the two names we carry. What's new is that you can finally buy it, made in Pangasinan, fund it with someone else's money, and watch it put cash on your balance sheet from the first month. The first step is simply to measure. Everything after that is just deciding how much money you'd like to keep.