

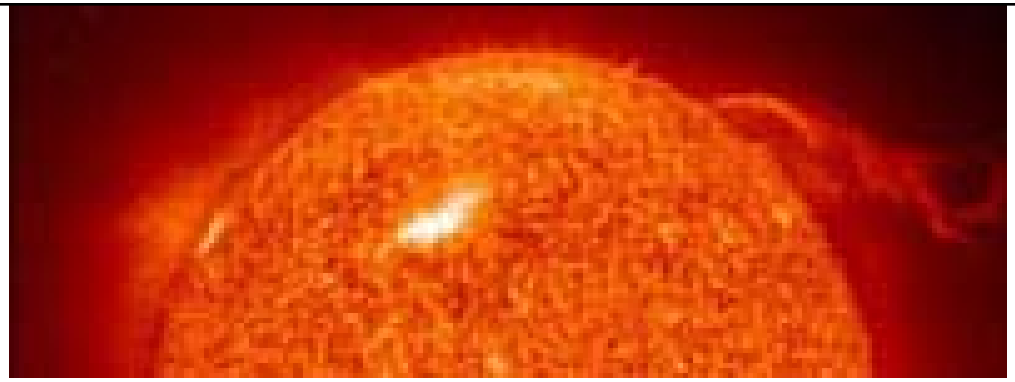


Energy, Power and Electricity

– They are NOT the same –

(OK, so what are they…)

Gordon Howell, P.Eng.

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v5 2011 May 02

What is Energy?

- In any discussion about energy and power, it is really important for us to understand is the very significant difference between the two.
- Energy can neither be created nor destroyed…
  energy merely flows… from areas of high "pressure" to areas of low "pressure", and from one form to another.
- All energy on planet earth originated in our sun at some point in time and was produced by the process of nuclear fusion (the merging of atoms).
- There are several forms of energy:
  - Electrical energy (in electricity) (electrical pressure = voltage)
  - Thermal energy (in heat) (thermal pressure = temperature)
  - Mechanical energy (in motion) (mechanical pressure = force)
  - Chemical energy (in elements) (chemical pressure = …?)

What Is Electricity?

- Electricity is NOT power
- Electricity is NOT energy
- Electricity IS electronic charges (the charge of which is measured in coloumbs)
- Electricity CONTAINS energy (not power) and we know how to extract it

just like

- Gasoline is NOT power
- Gasoline is NOT energy
- Gasoline IS a fuel (the volume of which is measured in litres)
- Gasoline CONTAINS energy (not power) and we know how to extract it

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Energy *vs.* Power – they are NOT the same

- Energy and power are not the same at all...
- Let’s look at the units that describe energy and power...

Energy *vs.* Power – they are NOT the same

- **Energy** = power x time (power multiplied by time)
  - energy is the ability to do work
  - the ability to move an object over a distance

Energy *vs.* Power – they are NOT the same

- **Energy** = power x time
  - the ability to do work
  - the ability to move an object over a distance

Analogy

- Like **distance**

Energy *vs.* Power – they are NOT the same

- **Energy** = power x time
  - the ability to do work
  - the ability to move an object over a distance
- It is measured in
  - joules (J)

Analogy

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Analogy

- Like **distance**
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- **Power** = energy / time (energy divided by time)

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Analogy

- Like **distance**
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- **Power** = energy / time
  - is the flow of energy (the amount of energy used at any moment in time)

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- Like **speed**
  - is not distance
  - is the "flow" of distance

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- **Power** = energy / time
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- It is measured in
  - joules per second = watts (W)
    J / s

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Energy *vs.* Power – they are NOT the same

- **Energy** = power x time
  - the ability to do work
  - the ability to move an object over a distance
- It is measured in
  - joules (J)
  - kilowatt-hours (kWh) = power x time
    (kWh means “thousand x watts x hours”)

Analogy

- Like **distance**
  - measured in metres (m)

- **Power** = energy / time
  - is the flow of energy
    (the amount of energy used
    at any moment in time)
- It is measured in
  - joules per second = watts (W)
    J / s

- Like **speed**
  - is not distance
  - is the “flow” of distance
  - measured in m/s

Electricity – what do we buy?

- When we buy electricity,
  we buy electrical **energy** (which is measured in kWh).
- We do **not** buy electrical power (which is measured in kW).
- Look at our electricity bills and our electricity prices
  and we will see kWh, not kW.
- kWh means “thousand x watts x hours”…
  - Forgetting the little “h” in kWh is **NOT** good and leads to mass confusion.
  - **Energy is NOT “kW / h”, it is “kW x h”**
  - **Power is NOT “kW / h”, it is “kW”** (= thousands of joules per second)

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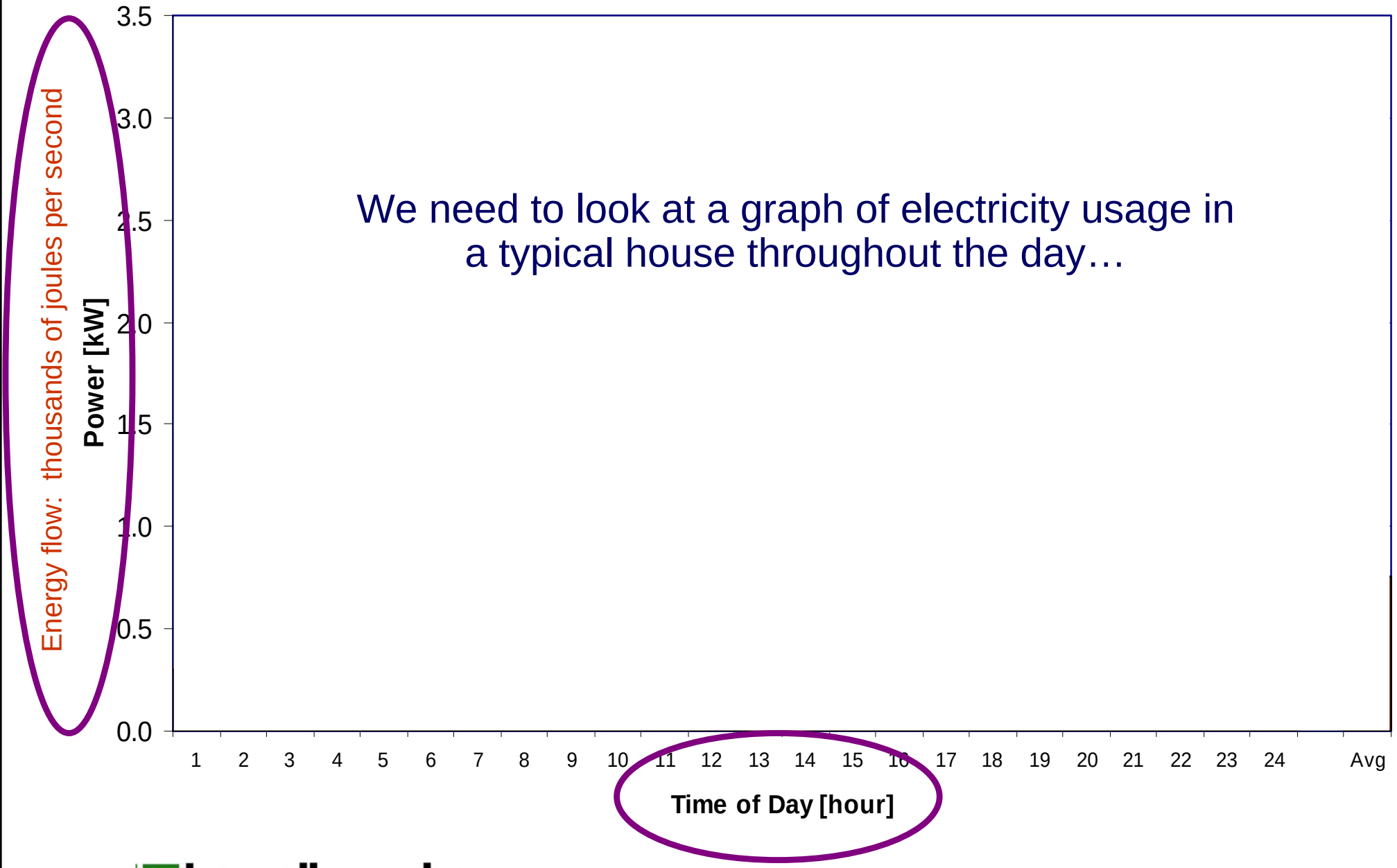
Power (of any sort) and Time



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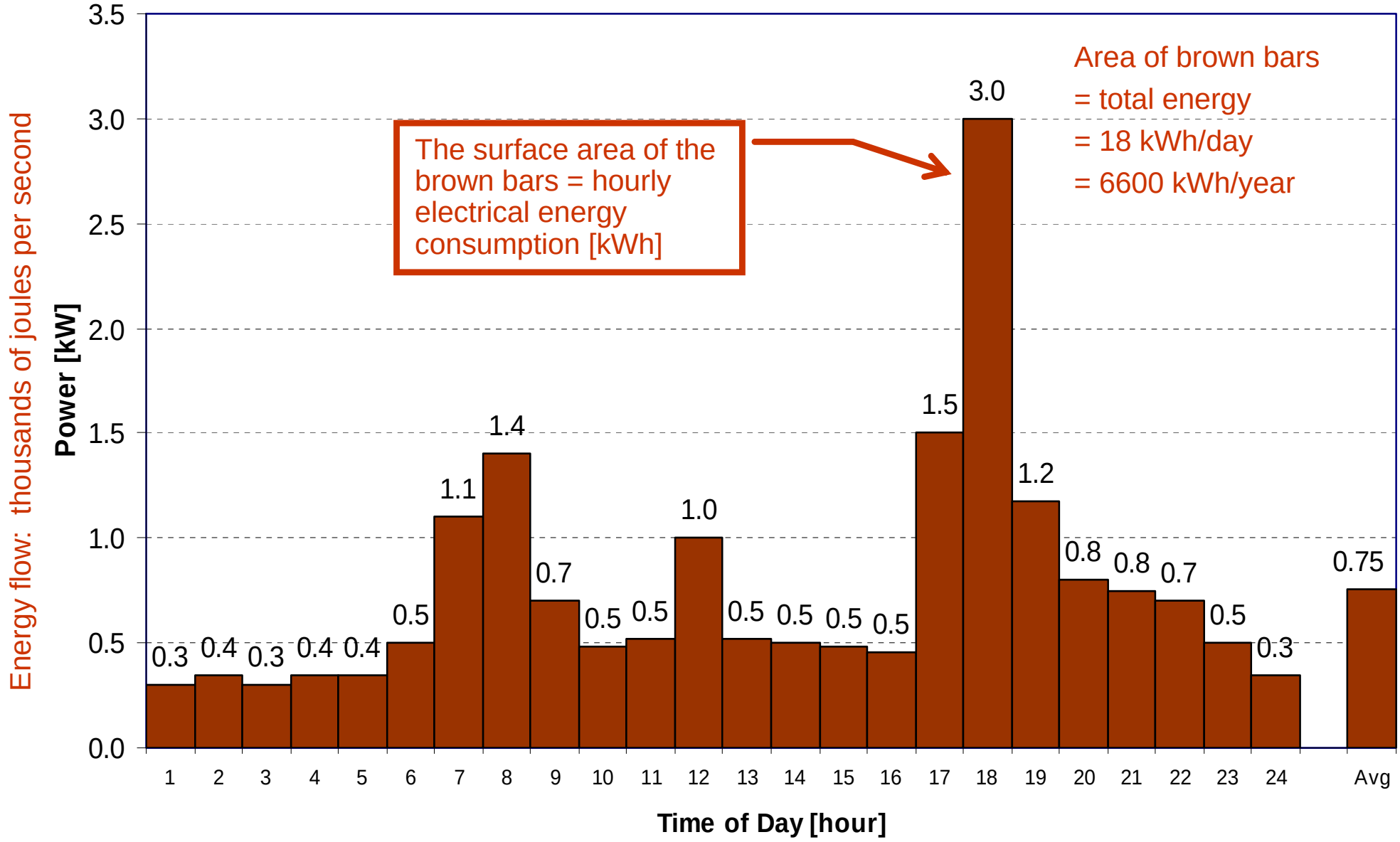
Electrical Energy



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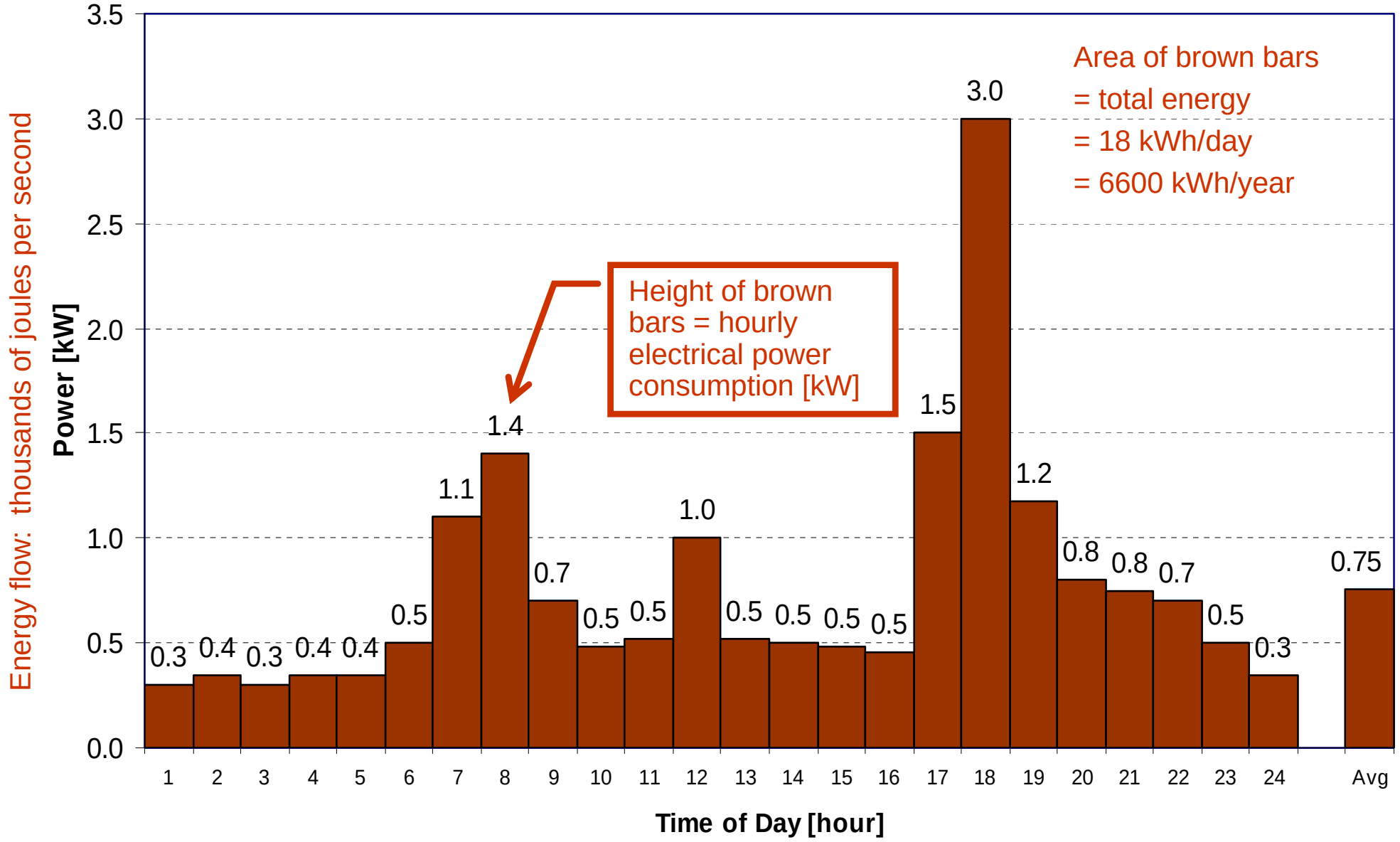
Electrical Power



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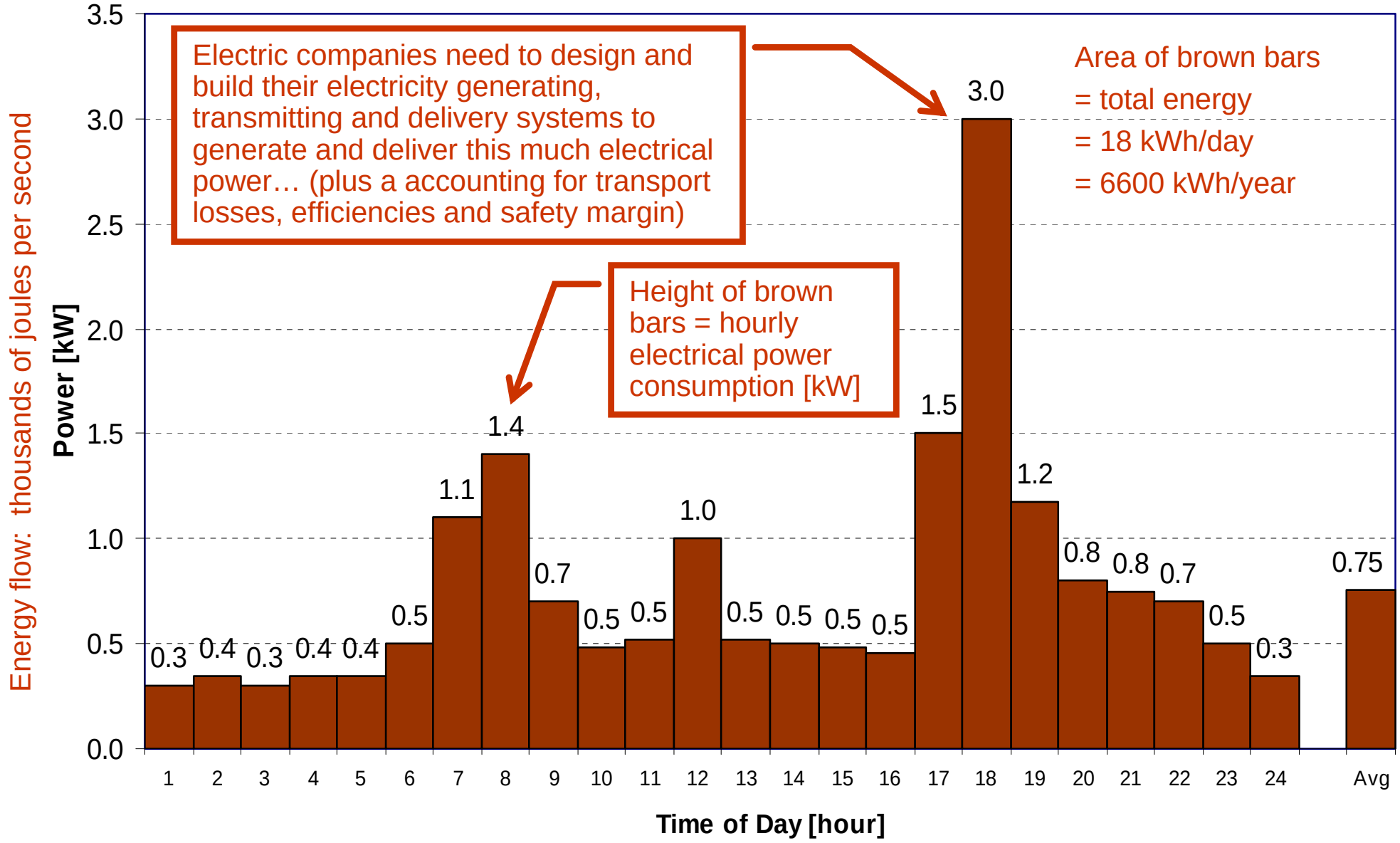
Electrical Power Capacity



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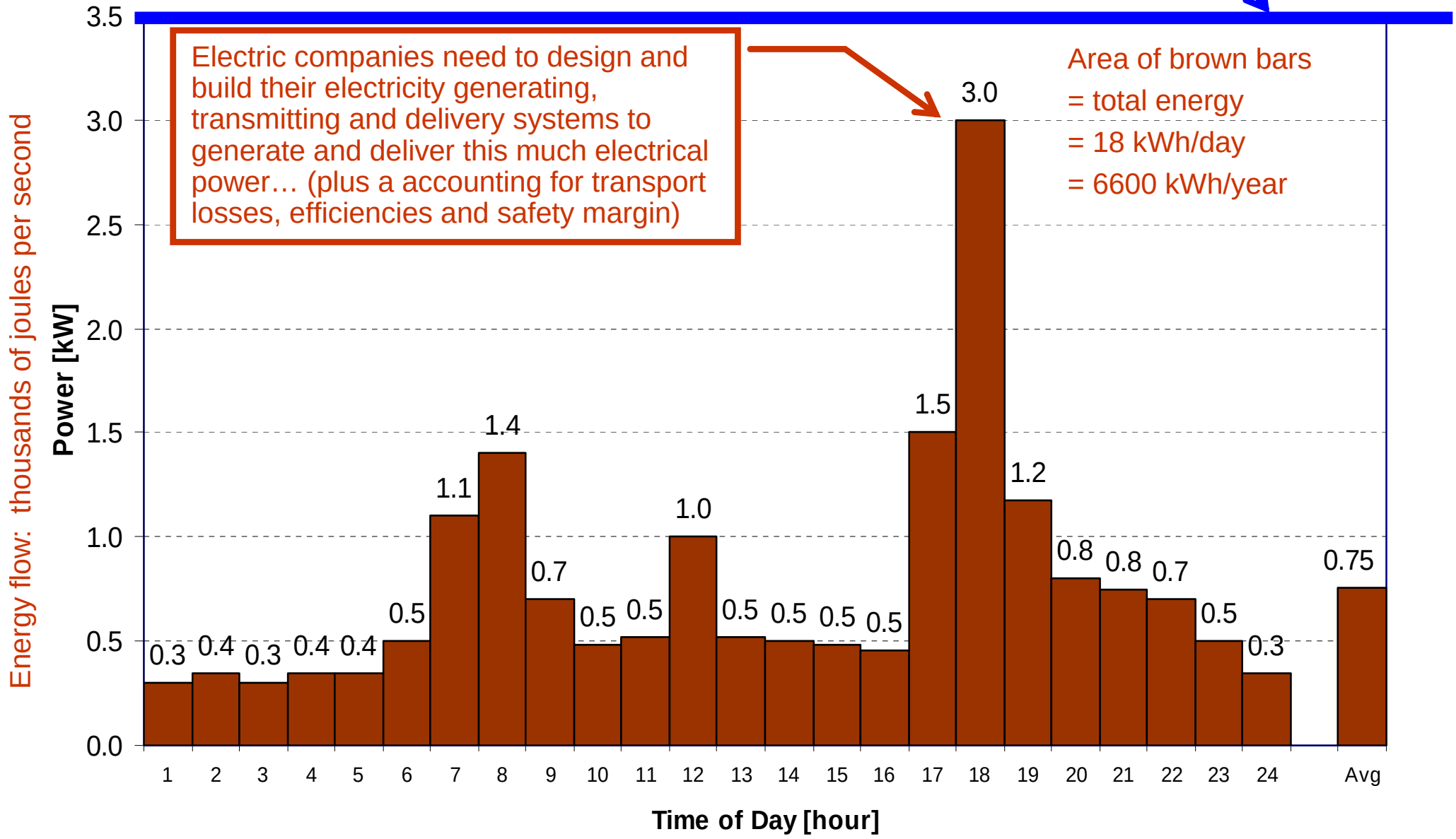
Electrical Power Capacity

The capacity of the electricity generating, transmitting and distribution system



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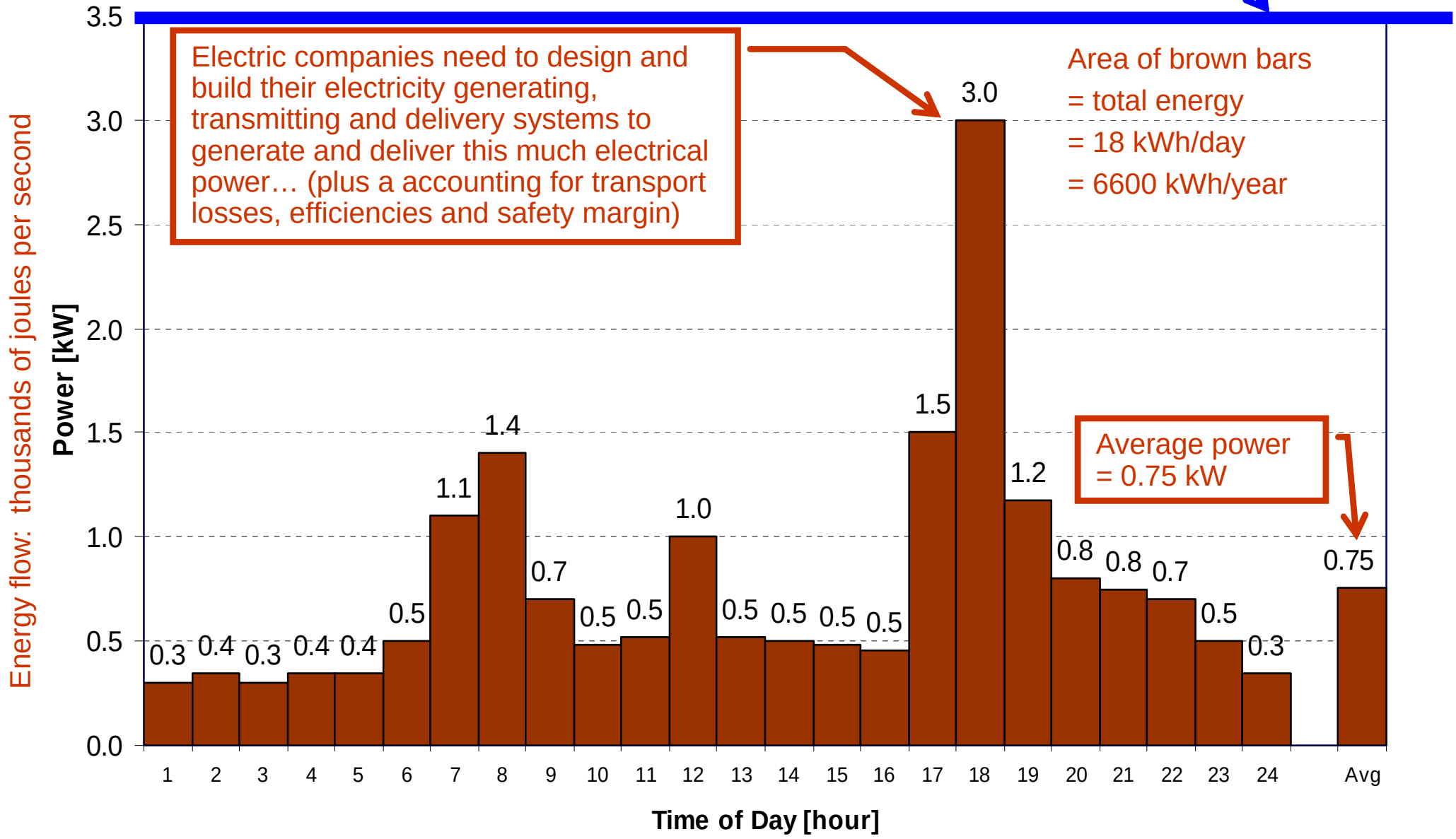

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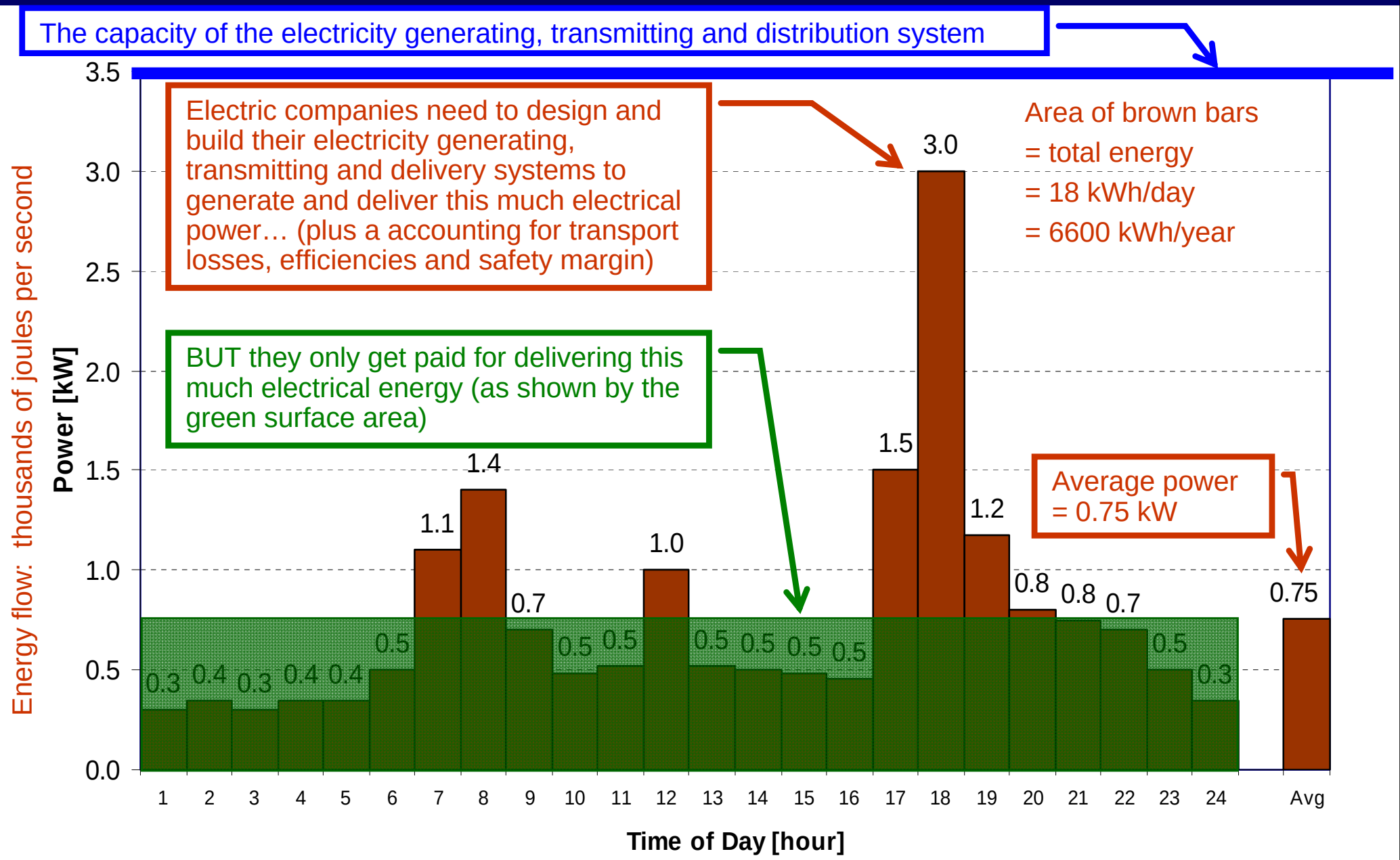
Electrical Energy Revenue



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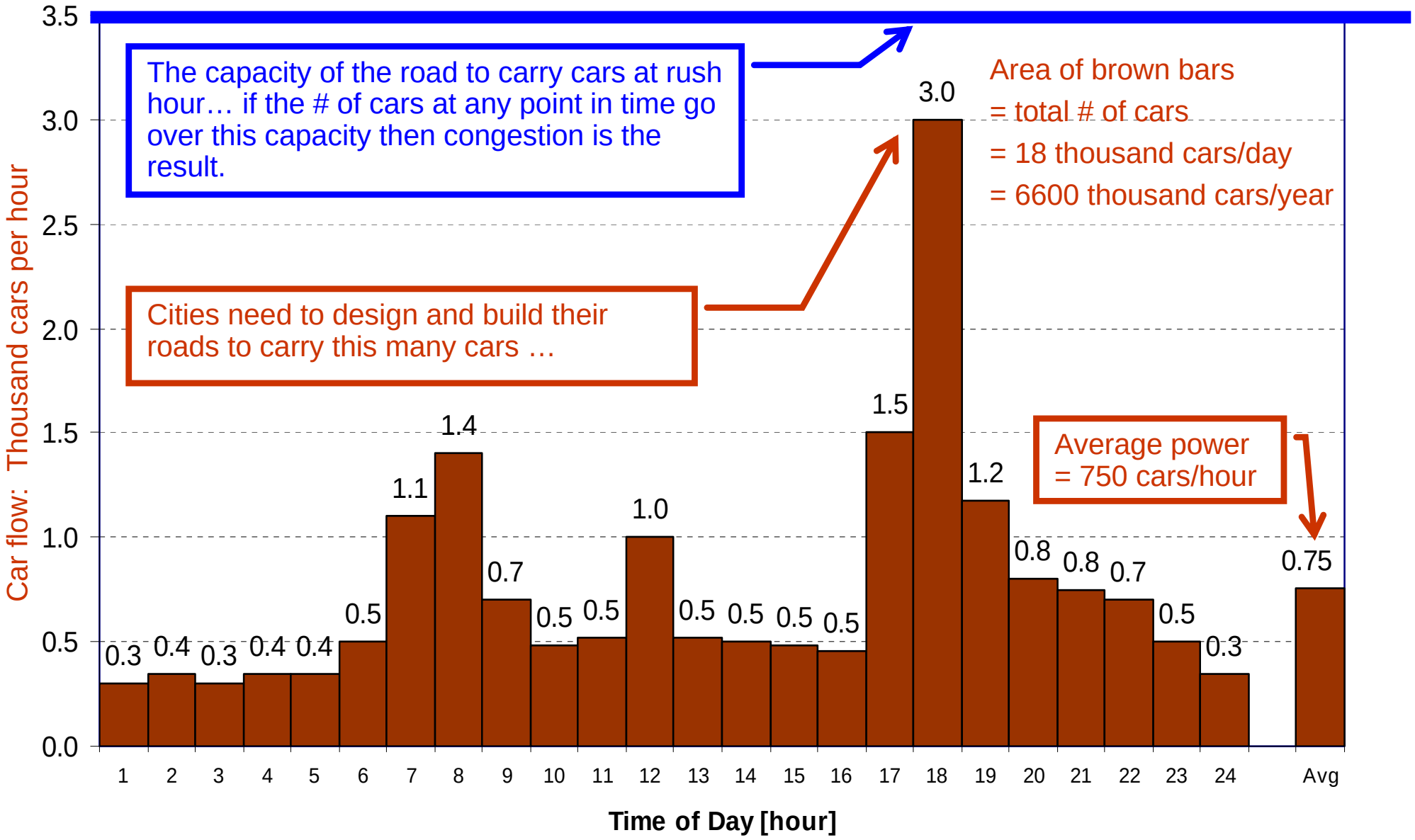
Analogy to Roads…



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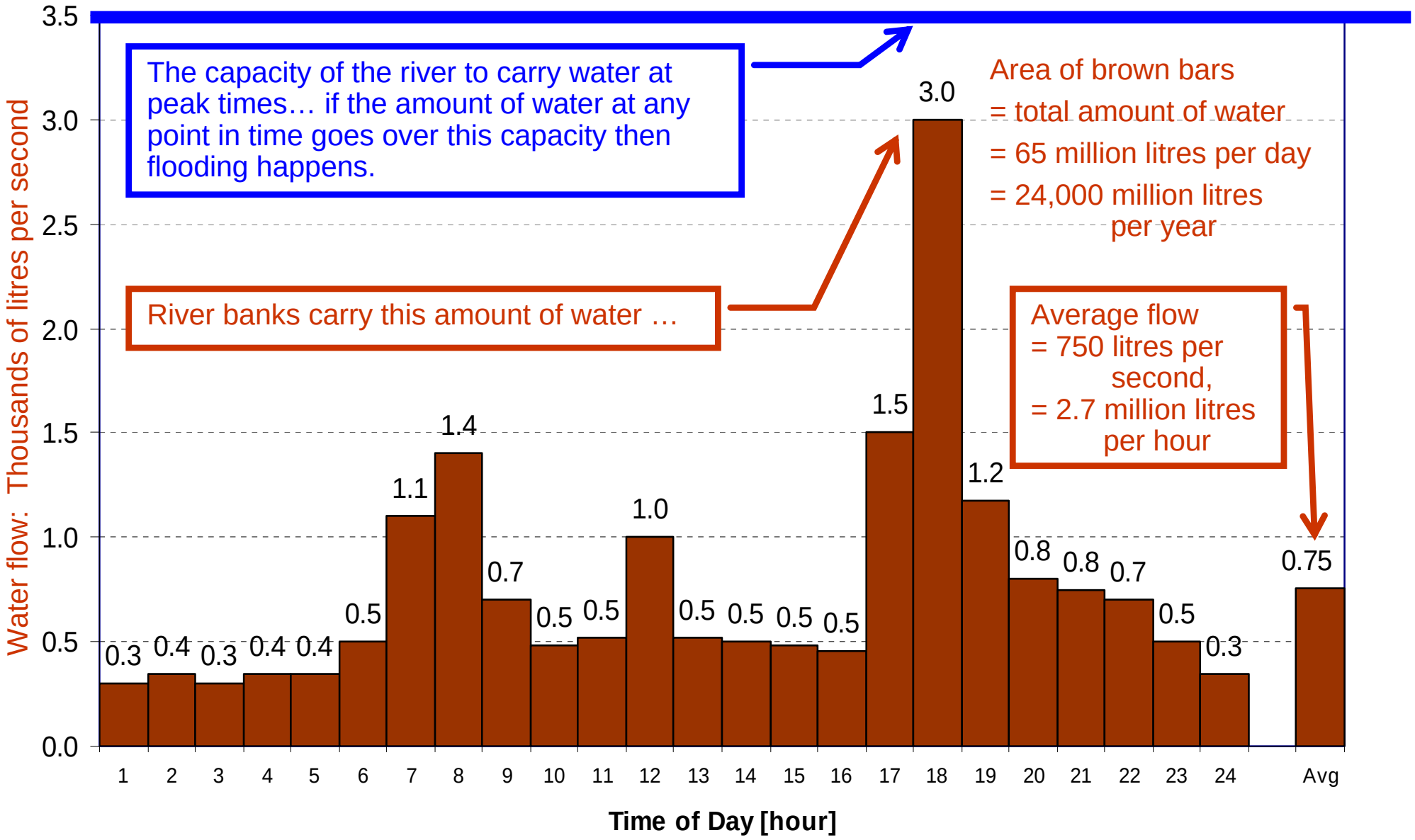
Analogy to Rivers…



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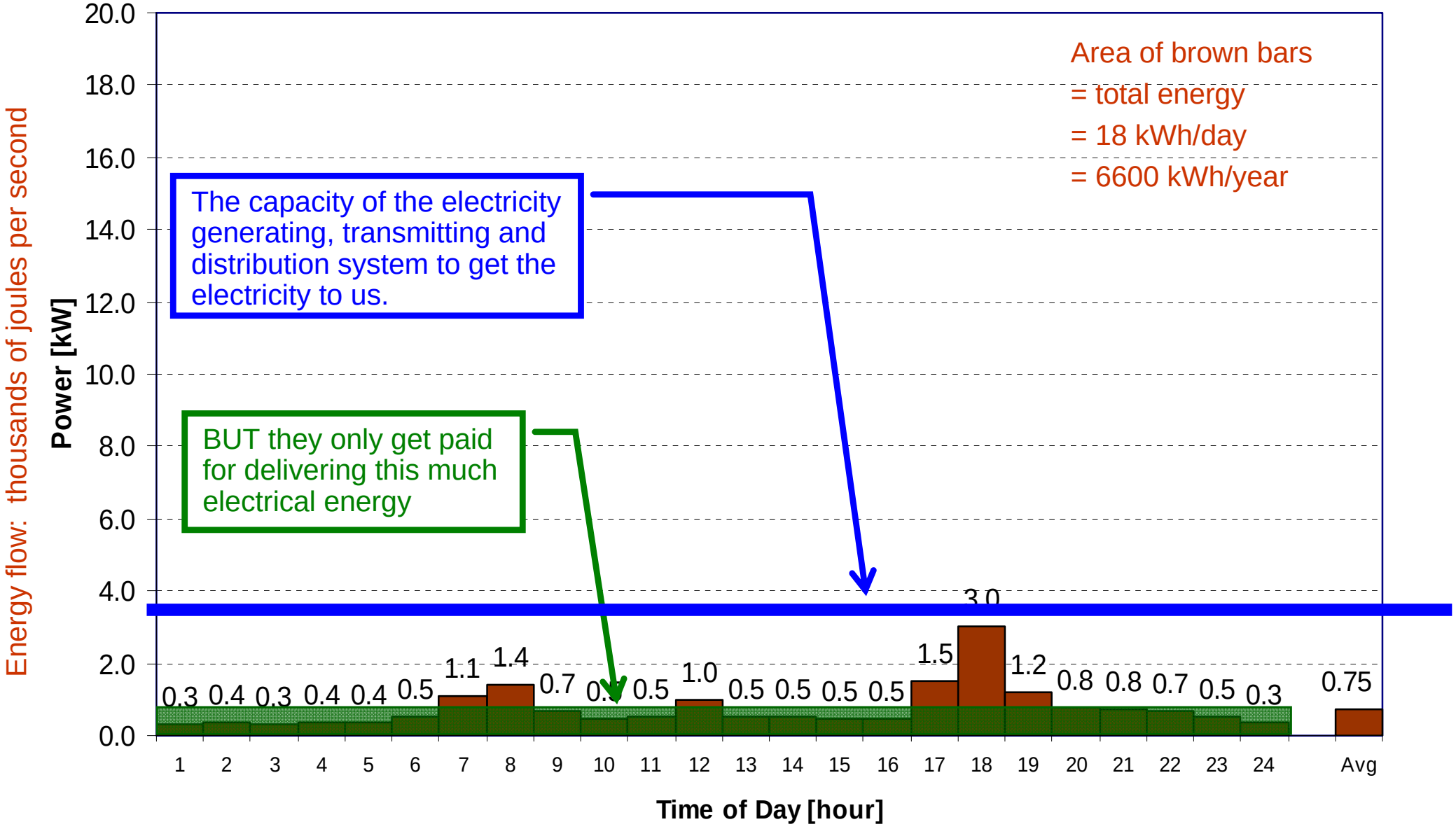
Daily Energy Chart – different power scale



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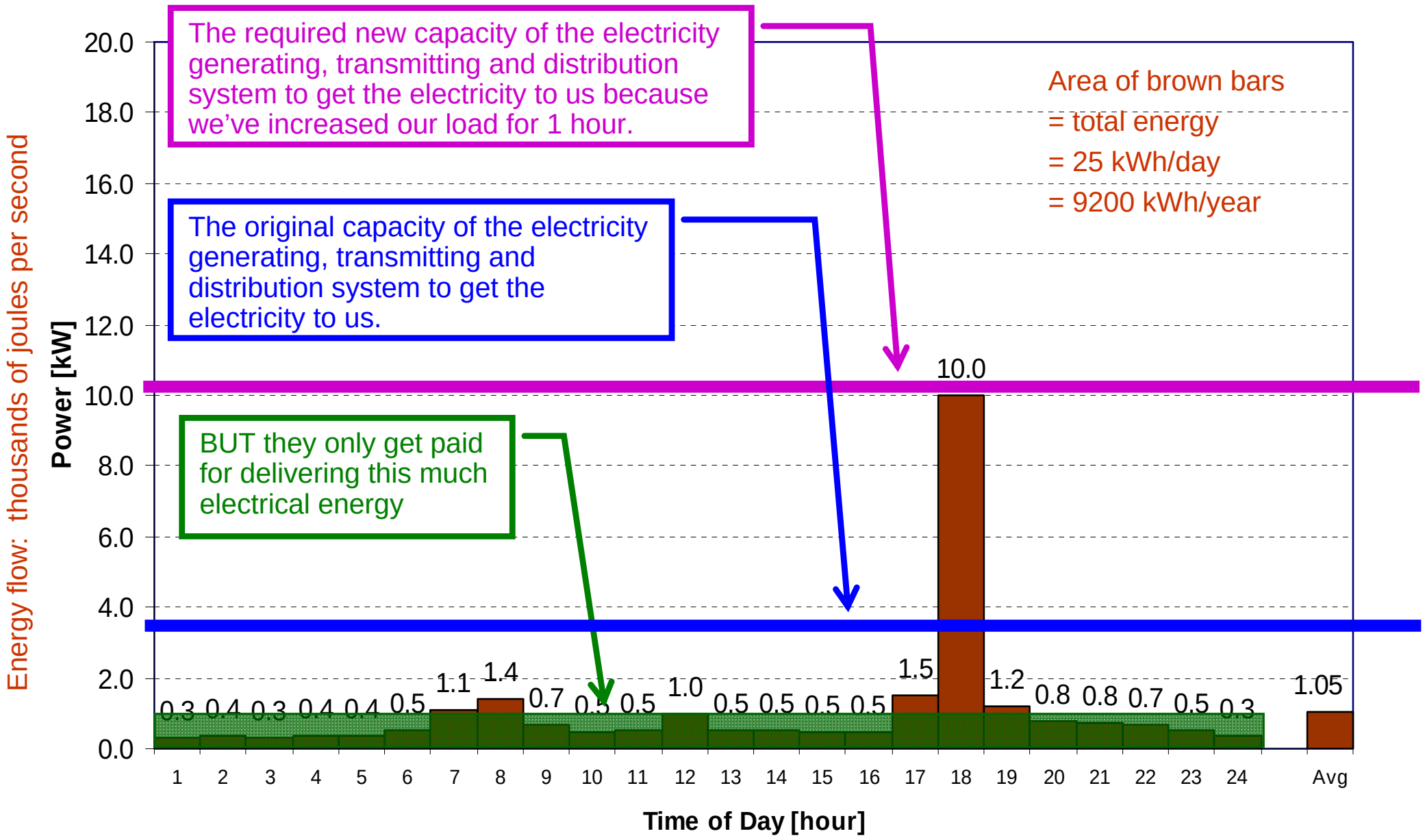
Turning Our Electric Stove On Full Power



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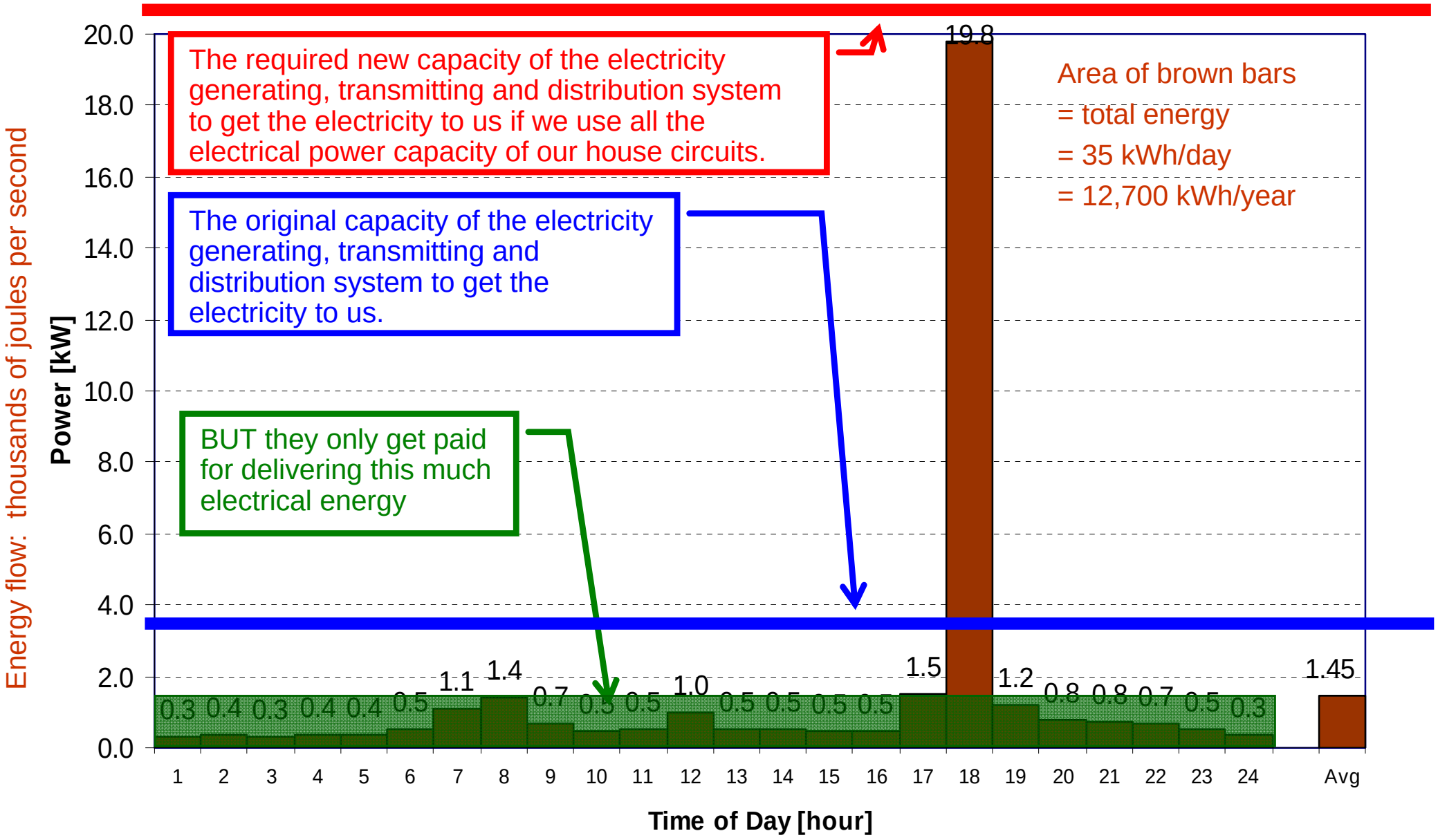
Ability of Our House Main Breaker To Supply



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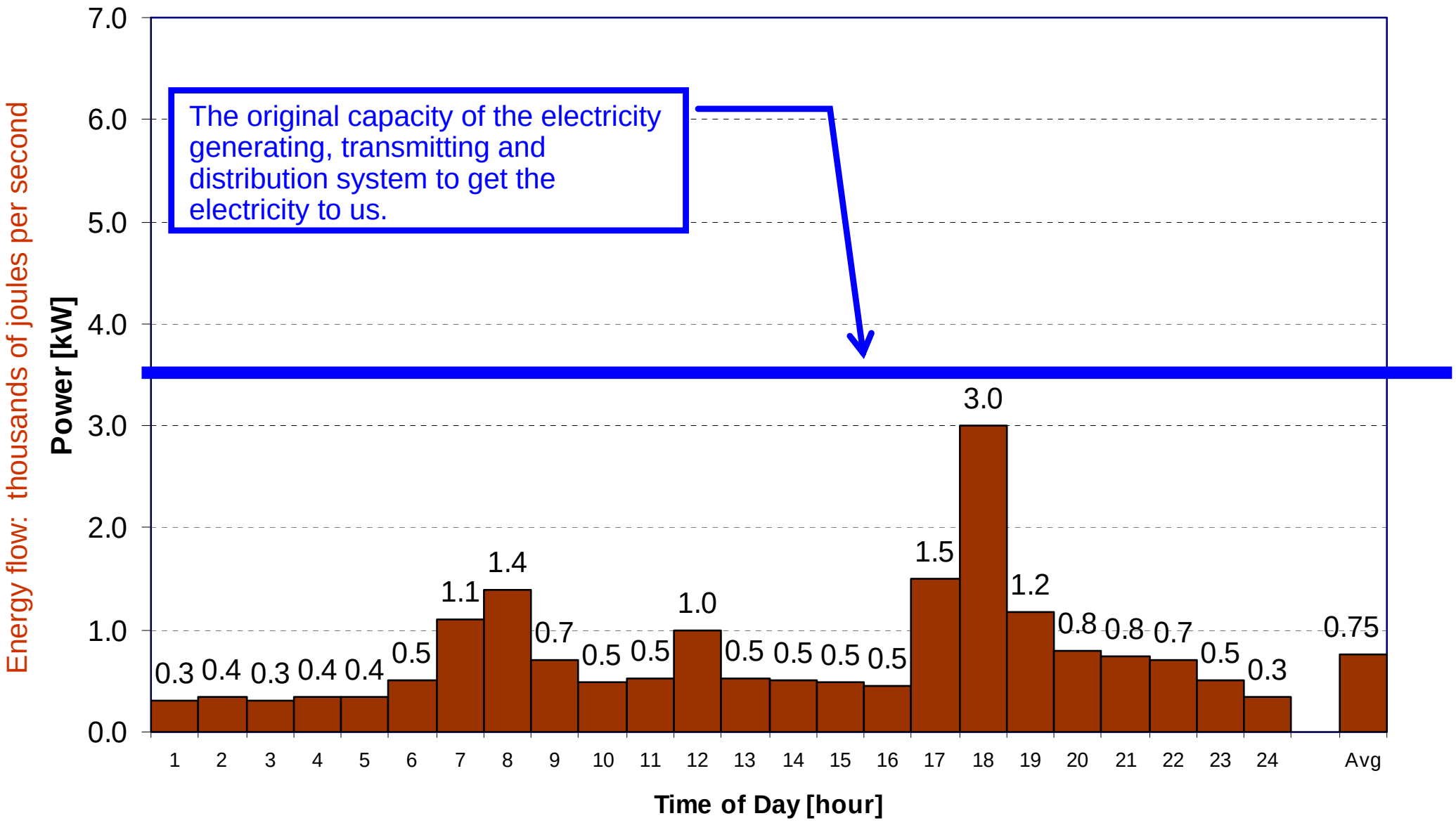

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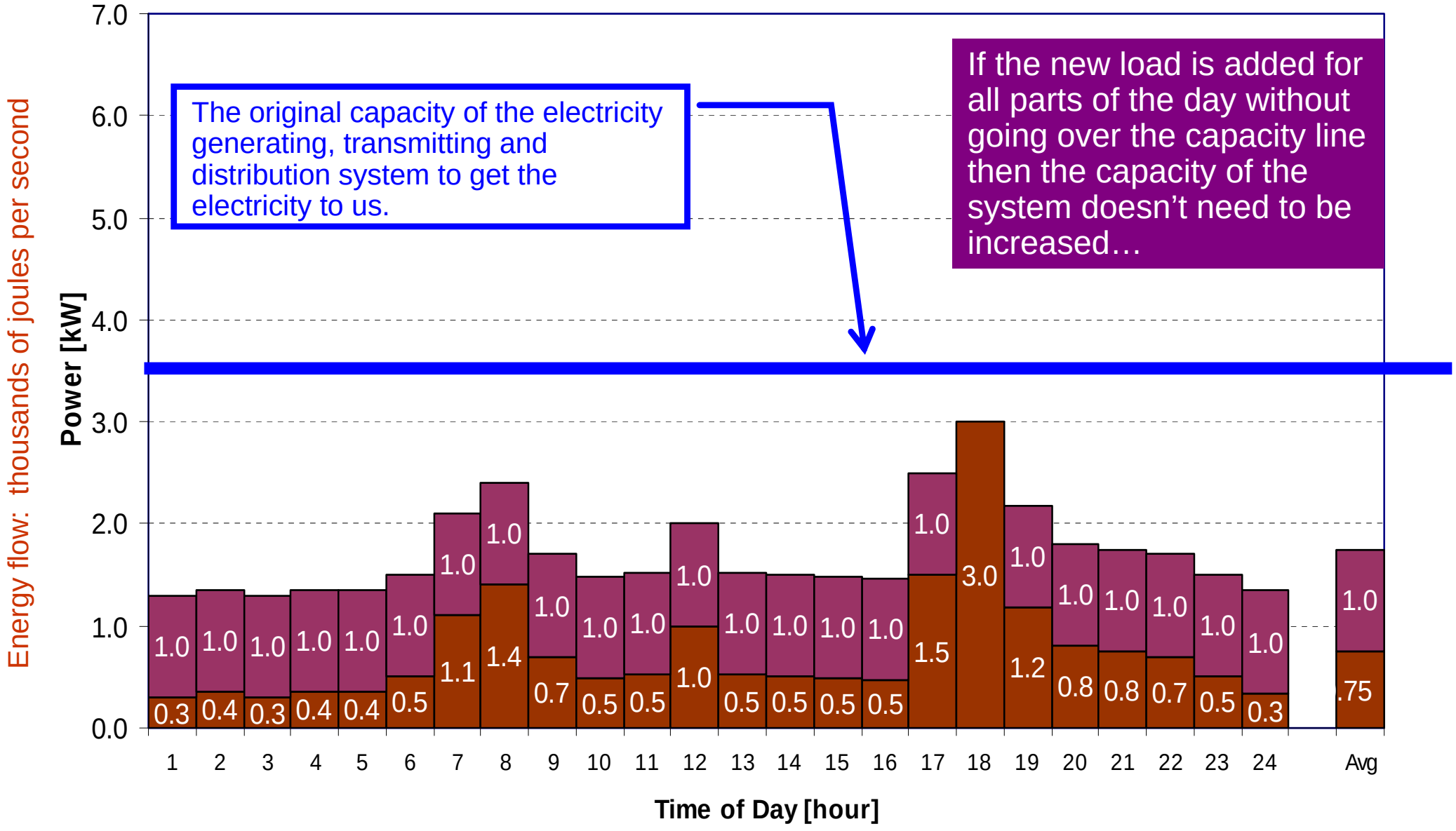
Add A New Electrical Load…



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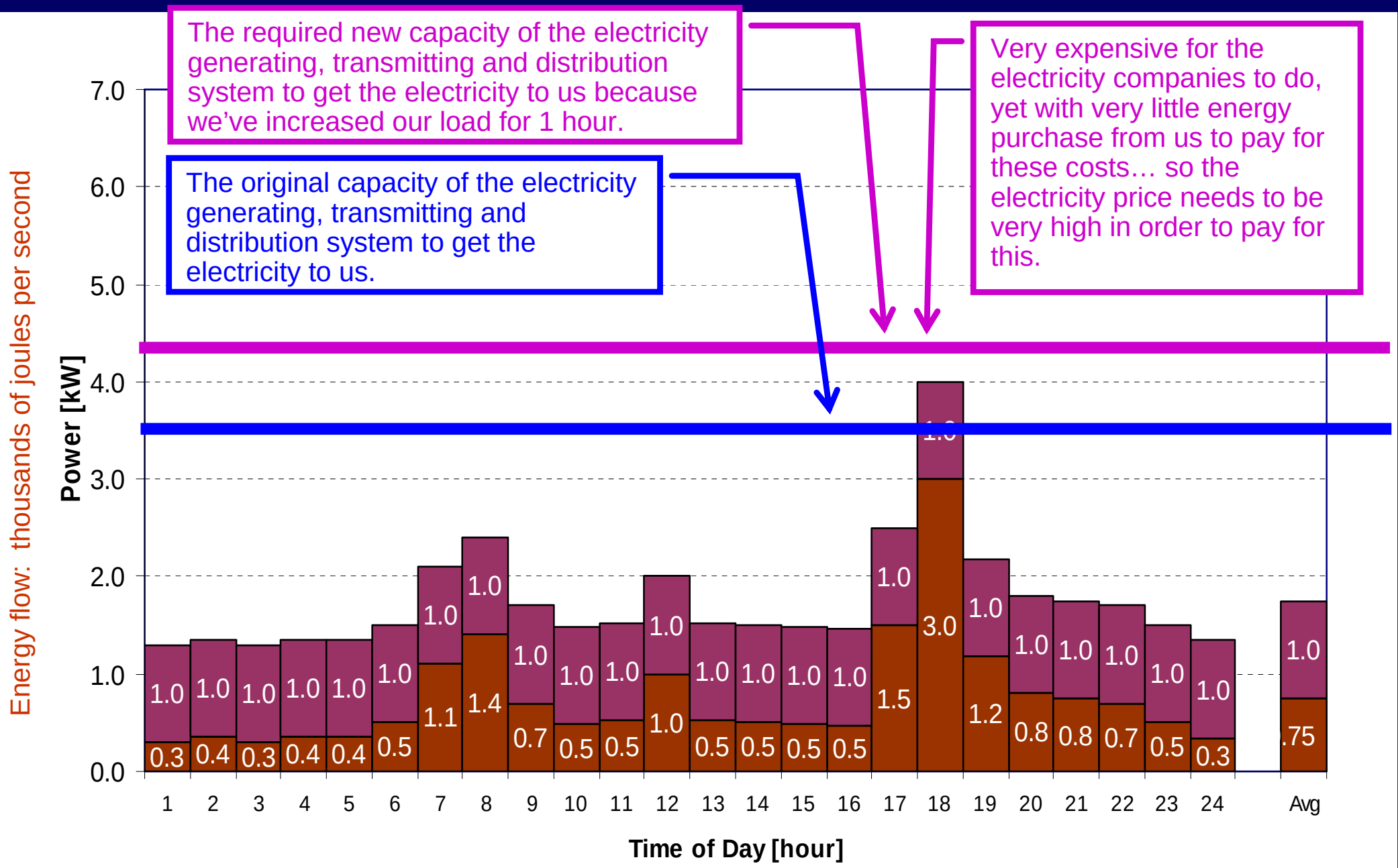

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All Energy Supply Systems…

- Very important to understand as we discuss energy supply **systems**
- **ALL** energy supply **systems**
  - electrical grid
  - fuel grid (natural gas, propane, Diesel, gasoline)
  - electrical systems, heating systems, motive systems

  need to have a **reliable**:

1. source of **energy**
2. and **flexible** source of **power** capacity
3. system to **store** energy (you can't store power you can only deliver it)
4. system to deliver energy **and** power
5. system to provide **backup** power (not energy) in the case of failure
6. system to provide **backup** energy (not power) in the case of running out of energy (energy supply systems usually do not run out of energy, but they can and do fail to provide power)

What provides the services?

Electricity generators	Reliable		Flexible	Reliable			
	Energy Source	Power Source	Power Source	Energy Storage	Energy & Power Delivery	Backup Power	Backup Energy
Electricity grid (as a whole, regardless of generator mix)	X	X	X	X	X	X	X
Baseload (boilers fired by nuclear, coal, methane, oil)	X	X		X			X
Hydro-electric dams	X	X	X	X		X	
Solar PV and wind	X						
Methane turbines & fuel cells (natural gas, biogas, biomass)	X	X	X	X		X	X
Energy storage devices (batteries...)		X	X	X		X	

- And many other, very technical, ancillary grid services are needed too: power factor correction, VAr support, voltage support, black start...

Example: Electricity Grid in Alberta

1. Source of **energy**
   - volume of coal, natural gas, water, wood
2. Source of **power**
   - flow of coal, natural gas, water, wood through the generating system (conveyor belts, pumps, pipes, steam or water turbines, generators, controls)
3. System to **store** energy
   - piles of unburned coal and wood, caverns of unburned natural gas, water behind a dam (because we don't have a system to store massive amounts of electrical energy)
4. System to **deliver** energy and power
   - transmission and distribution lines, sub-stations, controls, monitors
5. System to provide **backup** power (because all generators can and do crash)
   - spinning reserve, operating reserve
6. System to provide **backup** energy
   - not needed. There are no energy source issues.

- Will it run out of energy?
  - yes, in ~1000 years at current consumption rates and energy reserves
- Will it run out of power?
  - no because a lot of effort is spent in system planning to ensure reliability
  - but it is always under the threat of running out of power (not energy) because new demand (not necessarily load) can be connected faster than new generation

Example: Natural Gas Grid in Alberta

1. Source of **energy**
   - volume of natural gas
2. Source of **power**
   - flow of natural gas through the extraction and processing system (pumps, pipes, steam turbines, generators, controls)
3. System to **store** energy
   - caverns of unburned natural gas (because we don't have a system to store massive amounts of heat energy)
4. System to **deliver** energy and power
   - trunk and distribution pipelines and pumps, valves, controls, monitors
5. System to provide **backup** power (because all equipment can and does crash)
   - backup pumps
6. System to provide **backup** energy
   - electricity grid. Energy sources are a long-term issue but not short-term.

- Will it run out of energy?
  - likely within 20 to 25 years
- Will it run out of power?
  - no because a lot of effort is spent in system planning to ensure reliability
  - I don't know it well enough to suggest whether it is under the threat of running out of power…

Example: A car

1. Source of **energy**
   - volume of gasoline
2. Source of **power**
   - engine
3. System to **store** energy
   - fuel tank
4. System to **deliver** energy and power
   - engine, fuel system
5. System to provide **backup** power (because all equipment can and does crash)
   - none, it is sized to more than meet usual demand. It is usually sized to even meet irresponsible demand!
6. System to provide **backup** energy
   - none on board. Backup is provided by society through fuelling stations.

- Will it run out of energy?
  - yes, every 600 to 900 km due to driver choices and system design
- Will it run out of power?
  - yes, due to driver error, traffic conditions or mechanical failure

Example: Electricity Grids in Whitehorse and Juneau

1. Source of **energy**
   - volume of water, volume of Diesel fuel
2. Source of **power**
   - flow of water, flow of Diesel fuel through the generating system (pumps, pipes, water turbines, engines, generators, controls)
3. System to **store** energy
   - lakes of water, tanks of fuel (because we don't have a system to store massive amounts of electrical energy)
4. System to **deliver** energy and power
   - transmission and distribution lines, sub-stations, controls, monitors
5. System to provide **backup** power (because all generators can and do crash)
   - multiple Diesel engines equivalent to total capacity of hydro stations
6. System to provide **backup** energy
   - Diesel fuel and engines

- Will it run out of energy?
  - it runs out of water energy every spring and so has to use Diesel energy
- Will it run out of power?
  - not under current conditions, but there is a big threat of running out of power if new mines come on line – this is always a system planning issue full of trials

Example: An off-grid solar PV system

1. Source of **energy**
   - solar radiation
2. Source of **power**
   - battery bank
3. System to **store** energy
   - battery bank
4. System to **deliver** energy and power
   - wiring, inverter, switches, charge controller
5. System to provide **backup** power (because all generators can and do crash)
   - only if a fuel generator is also part of the system
6. System to provide **backup** energy
   - Fossil-feedstock fuel, but only if a fuel generator is also part of the system

- Will it run out of energy?
  - no
- Will it run out of power?
  - yes, if the demand is greater than the inverter's capacity to deliver
  - yes, if user choices are greater than for what the system was designed and so the battery drains out of energy

Example: A grid-connected solar PV system

1. Source of **energy**
   - solar radiation
2. Source of **power**
   - electricity grid
3. System to **store** energy
   - the electricity grid's energy storage means
4. System to **deliver** energy and power
   - wiring, inverter, switches, charge controller and electricity grid
5. System to provide **backup** power (because all generators can and do crash)
   - the electricity grid
6. System to provide **backup** energy
   - the electricity grid, but only required if user choices are greater than system design

- Will it run out of energy?
  - no
- Will it run out of power?
  - yes during an electrical outage on the grid

…we hold the future in our hands

It is important that we understand what is real…

…so we don't get blown away by self-serving myths from vested interests…

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We welcome any feedback, questions, suggestions, comments and challenges to anything we present.

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