

# System Architecture Support for Green Enterprise Computing

Maria Kazandjieva

Chinmayee Shah, Ewen Cheslack-Postava,  
Behram Mistree, Philip Levis

Stanford University

Computing systems account for an estimated **13%** of the electricity use of office buildings. [DoE]

This amounts to about **2% of the total electricity** consumption in the US.



Greetings from

NEW



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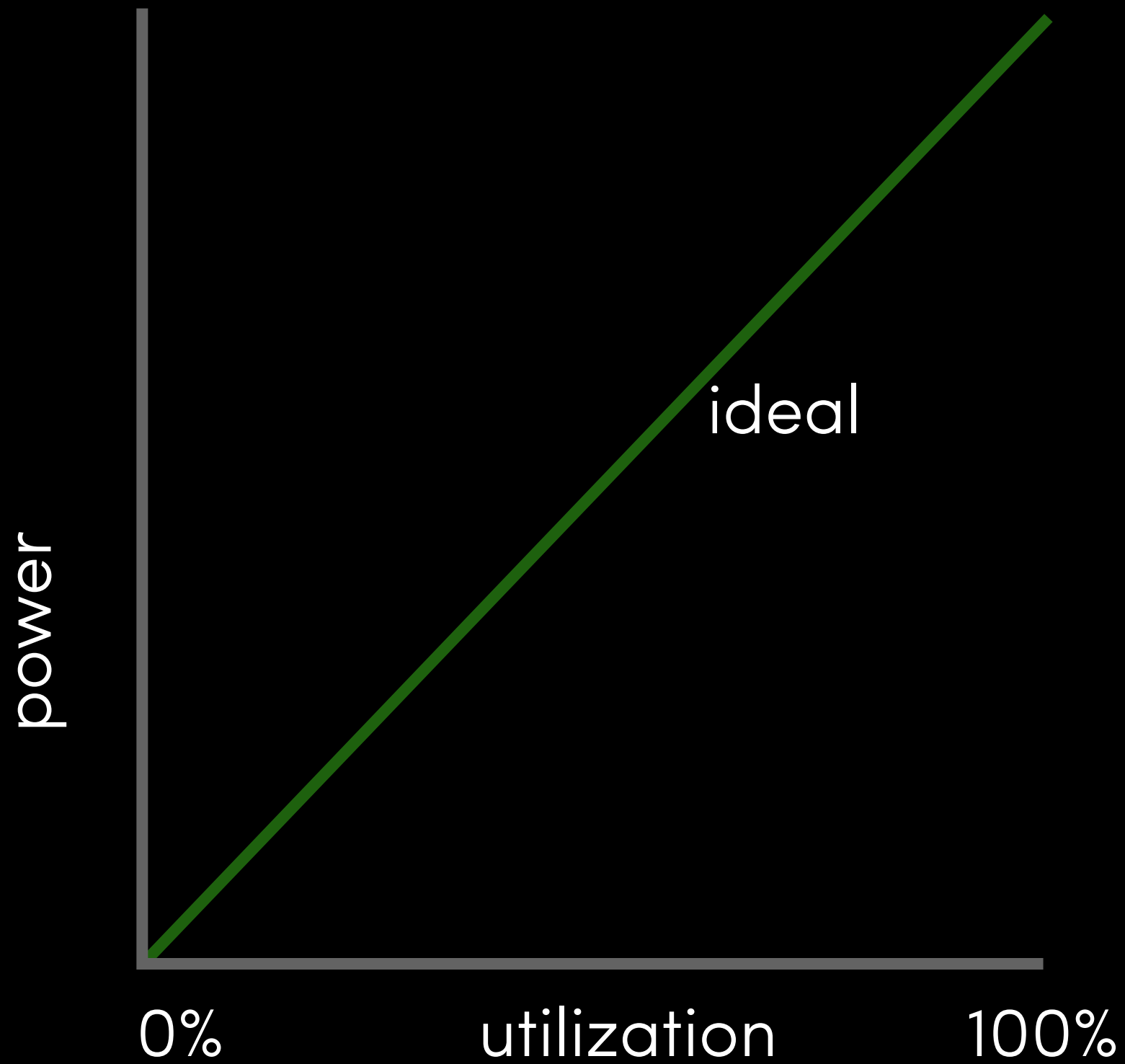
Office PCs spend the majority of their time at very low CPU utilization.

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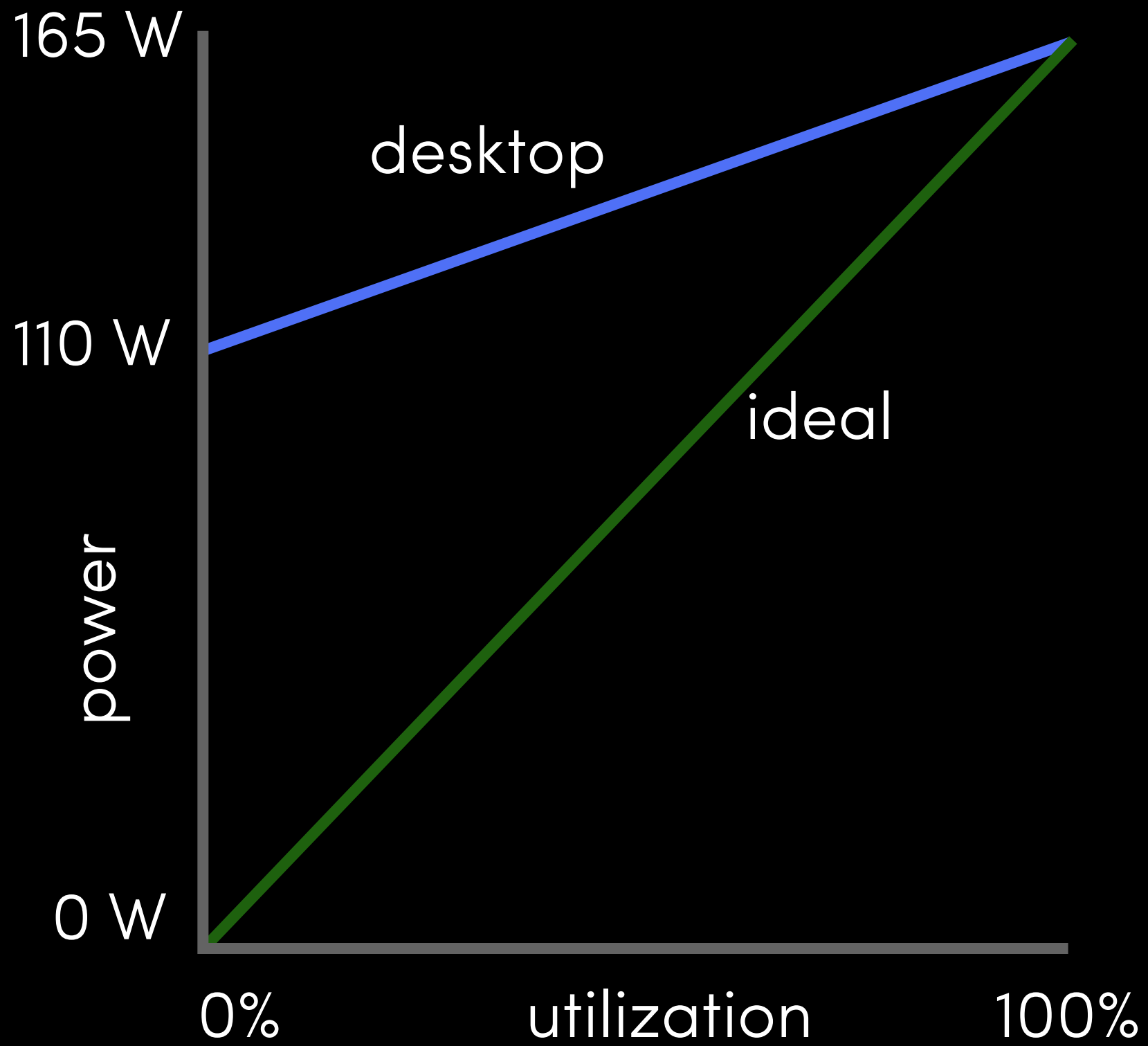
Machine	Percentile CPU		
	5	50	95
Dell Optiplex 745	1%	9%	58%
High-end custom-built	0%	1%	57%
Dell Precision T3400	0%	4%	29%
HP Pavillion Elite m9250f	0%	0%	25%
Dell Precision T3400	0%	1%	13%
Dell Inspiron 530	1%	1%	8%
Dell Precision T4300	0%	1%	7%

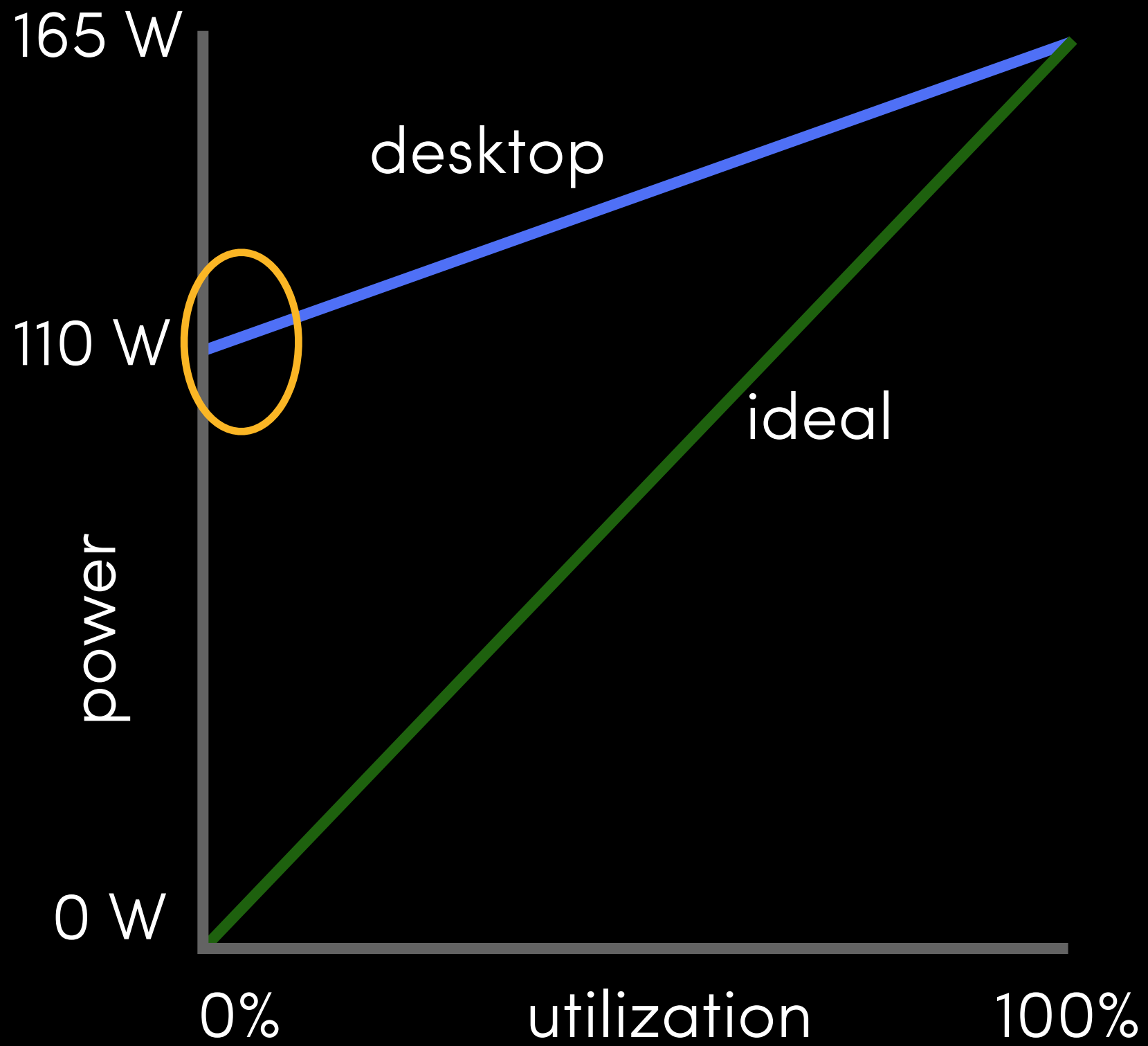
two-thirds of office PCs have CPU < 10%  
75% of the time

- ① Why is low desktop utilization a problem?
- ② What about other, greener hardware?
- ③ A hybrid solution
- ④ Takeaways









Hardware is not power-proportional

so

low utilization means a lot of waste.

# Hardware: Thin Clients

No local compute resources

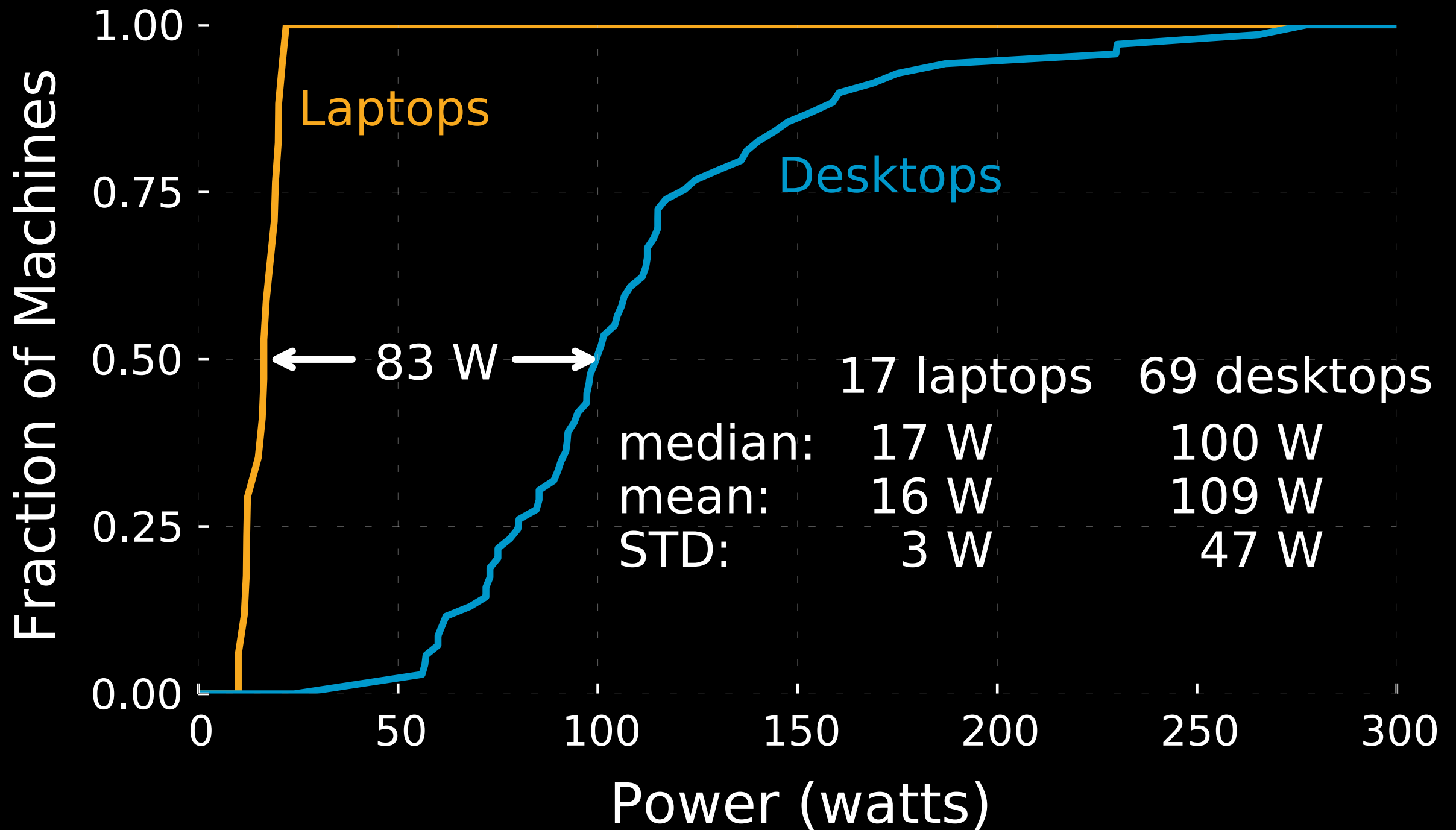
Displays the GUI of a remote machine.

15–20 watts for client itself

10–15 watts server share



# Hardware: Laptops





## Laptops

performance << desktops

## Thin Clients

not suitable for all workloads

Laptop power  $\approx$  Thin Client power

- ① Why is low desktop utilization a problem?
- ② What about other, greener hardware?
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- ④ Takeaways

A hybrid compute architecture can save as much energy as a thin client without sacrificing performance.

# Anyware

combines

low-power clients

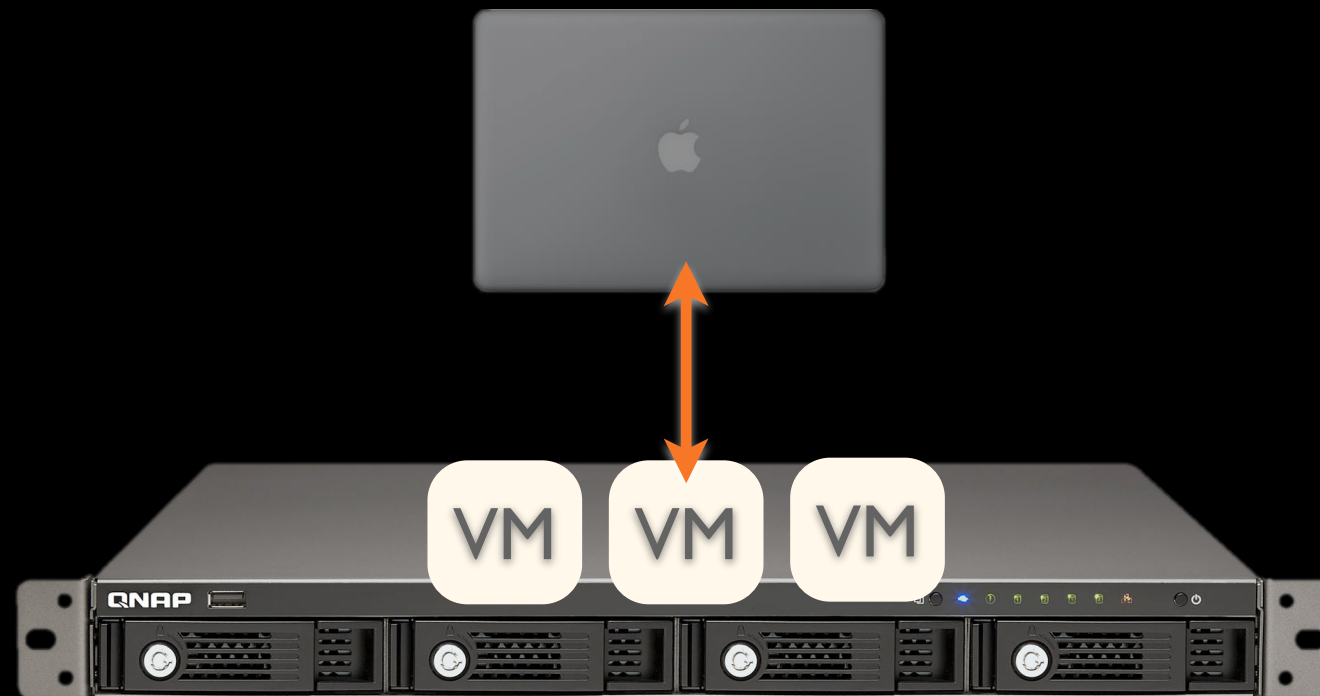
with

a high-end shared server.



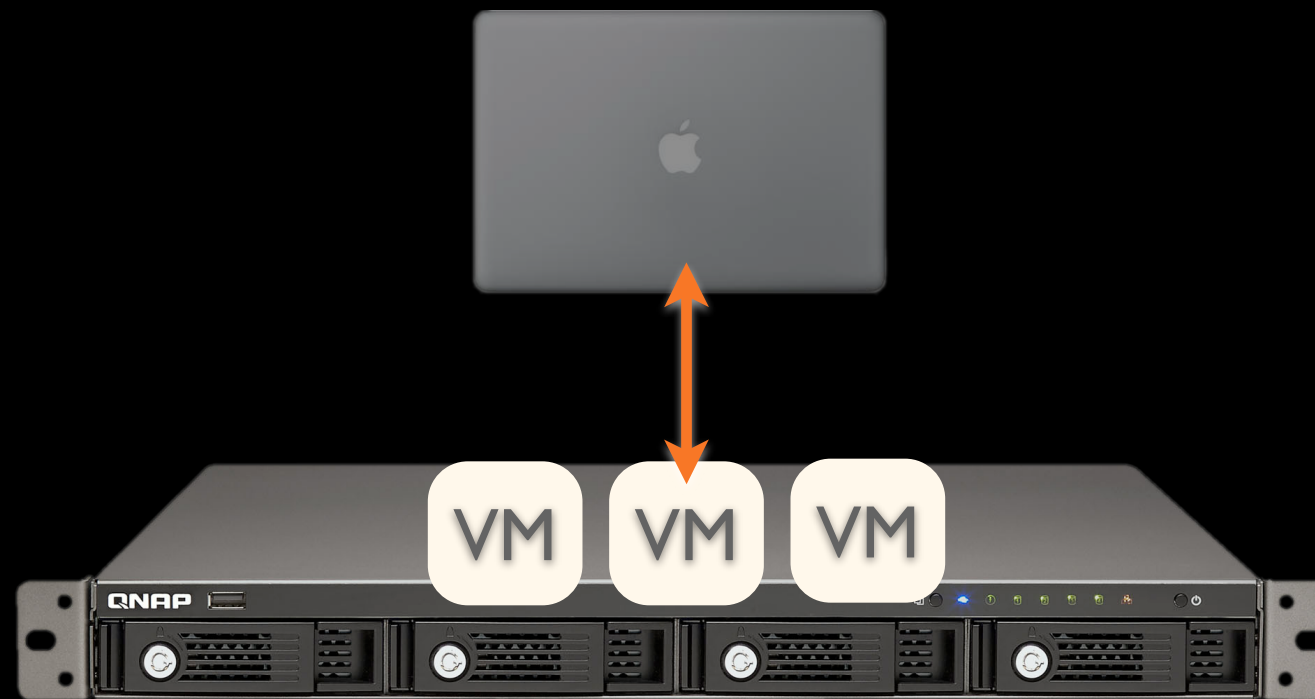
# Anyware

low-power client



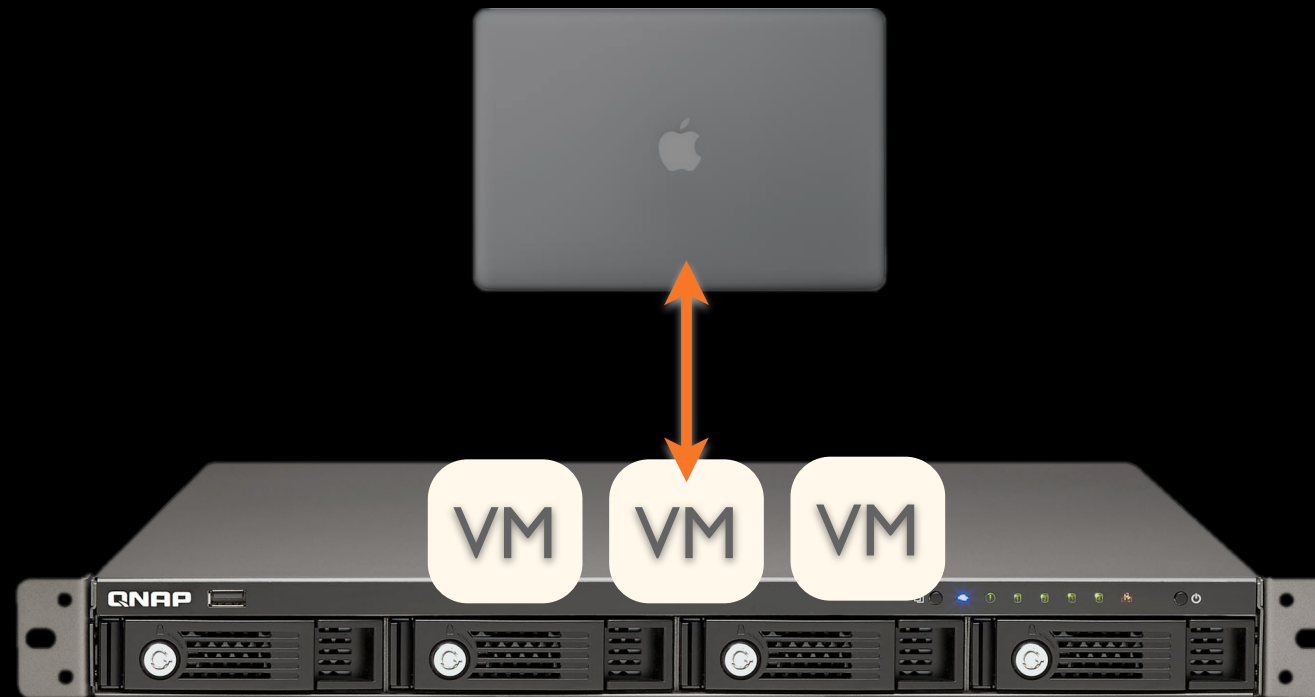
high-end shared server

1. Double-click to watch a **video**



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2. Decide to use local resources to play the video

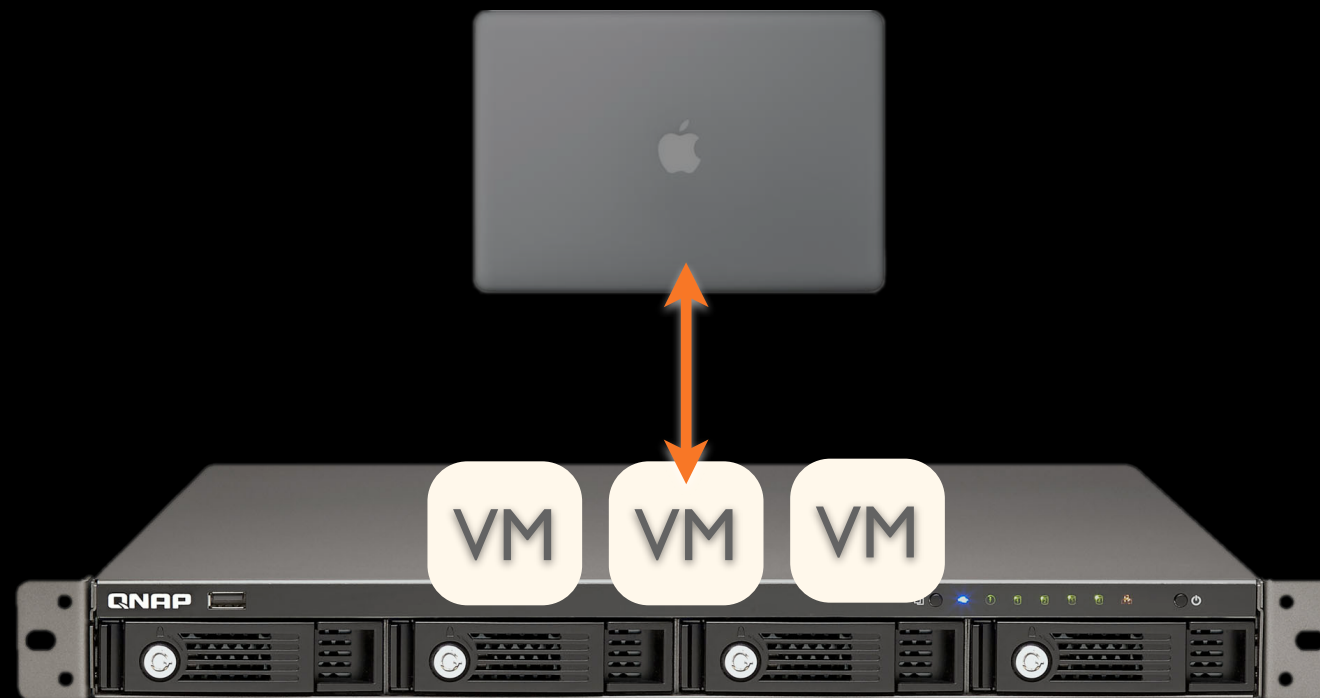


1. Double-click to watch a **video**

2. Decide to use local resources to play the video



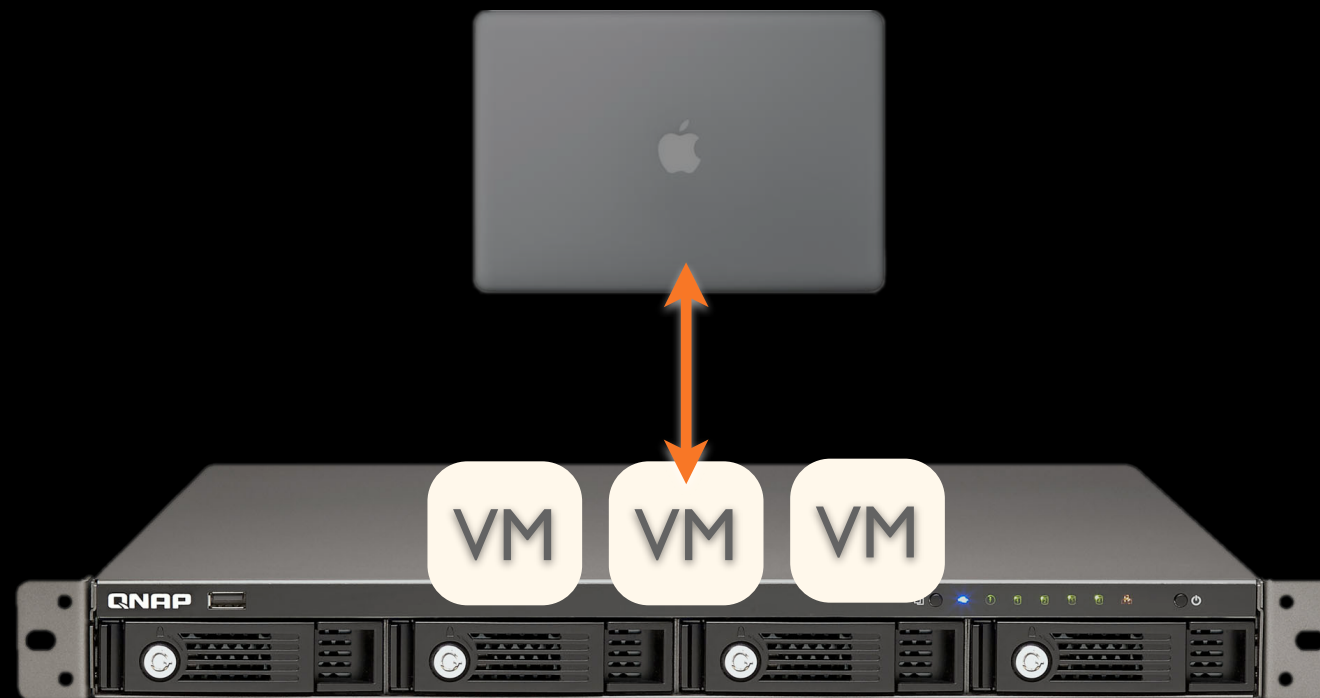
1. Double-click to edit an **image**





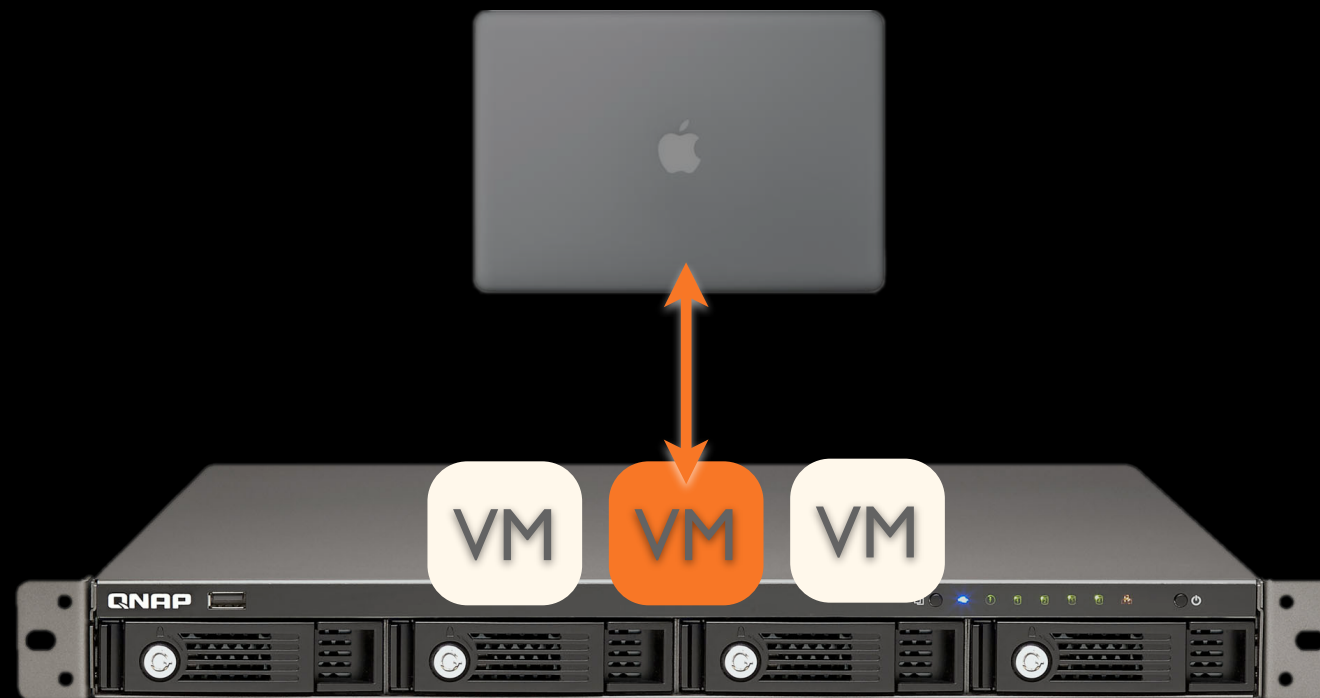
1. Double-click to edit an **image**

2. Decide to offload the task



1. Double-click to edit an **image**

2. Decide to offload the task



How do we build Anyware so  
that

it is invisible to the user

and

it does not require application or OS changes

and

it is practical and easy to setup?



create a bare-bones VM that matches the client OS and architecture



create a bare-bones VM that matches the client OS and architecture



connect the VM and client via SSH and export the VM windowing system





create a bare-bones VM that matches the client OS and architecture



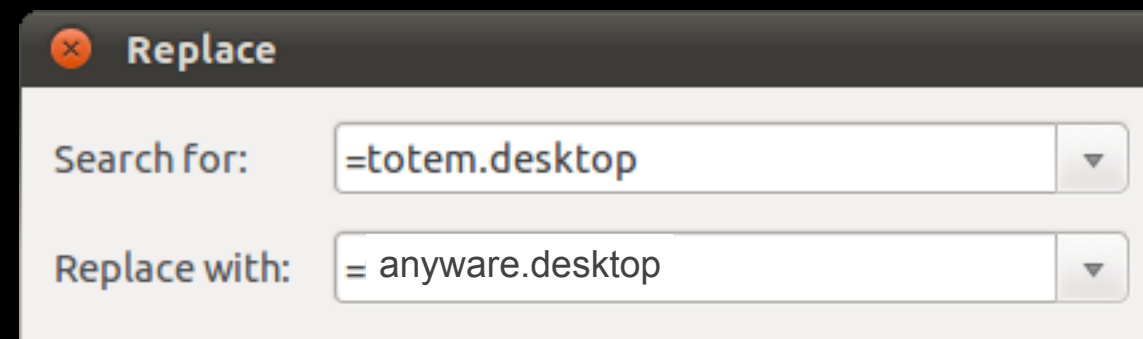
connect the VM and client via SSH and export the VM windowing system



identify files and folders that the client will export to the VM via a networked FS

Offload complete  
program execution.

Do so in user space by  
intercepting MIME type  
association.



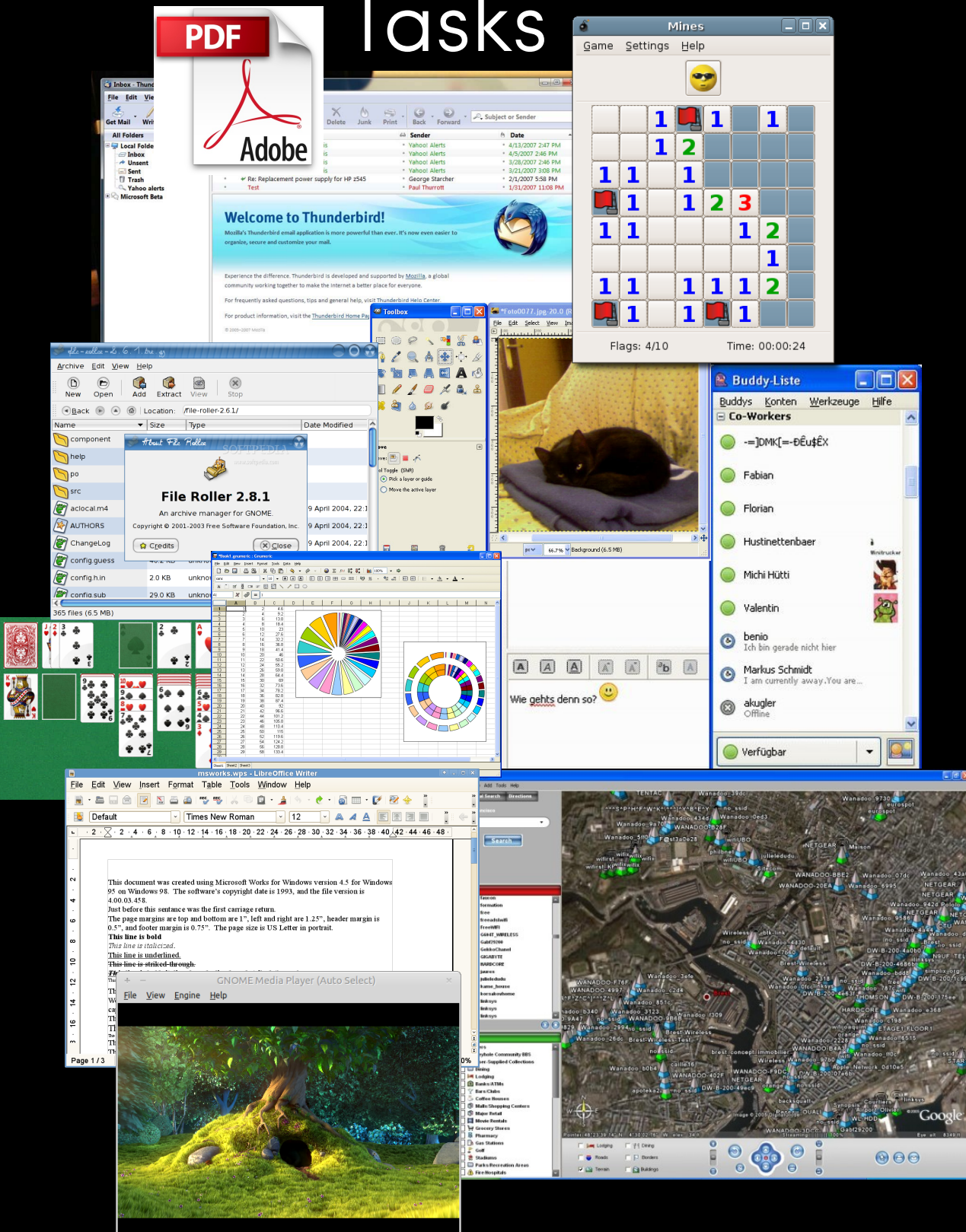
# But wait,

Who will decide where  
task are executed?

Will remote execution  
impact user experience?

# User Study

## Tasks



## Application Features

instructions executed

IPC

cache misses

X drawing calls

local: data read

remote: network data in/out

# Qualitative Results

From a user perspective, the majority of applications perform similarly, regardless of whether they run on a laptop or on a remote VM.

Tasks that are data— or graphics—heavy, have visibly worse performance when executed remotely.

A logistic regression model suggests a small set of workload features are indicative of where a task should be executed.

Remote

number of instructions

Mb sent from client to VM

Local

Mb sent from VM to client

number of subprocesses

# Hardware Setup



4-core, 2.4 GHz  
4 GB RAM  
256 GB SSD

2-core, 1.6 GHz  
4 GB RAM  
256 GB SSD



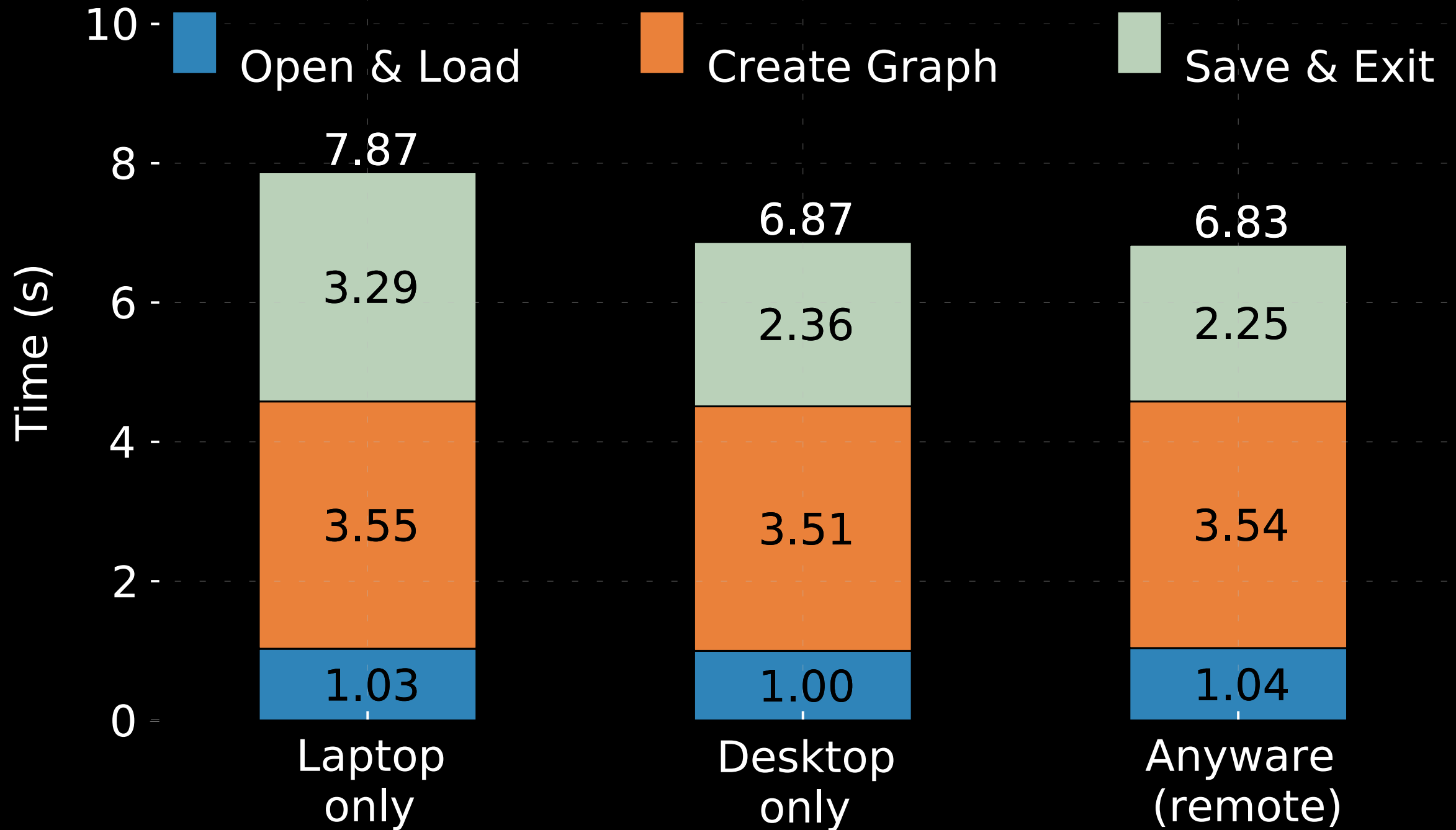
12-core, 3.0 GHz  
48 GB RAM  
7200 RPM HDD



four cores  
4 GB RAM

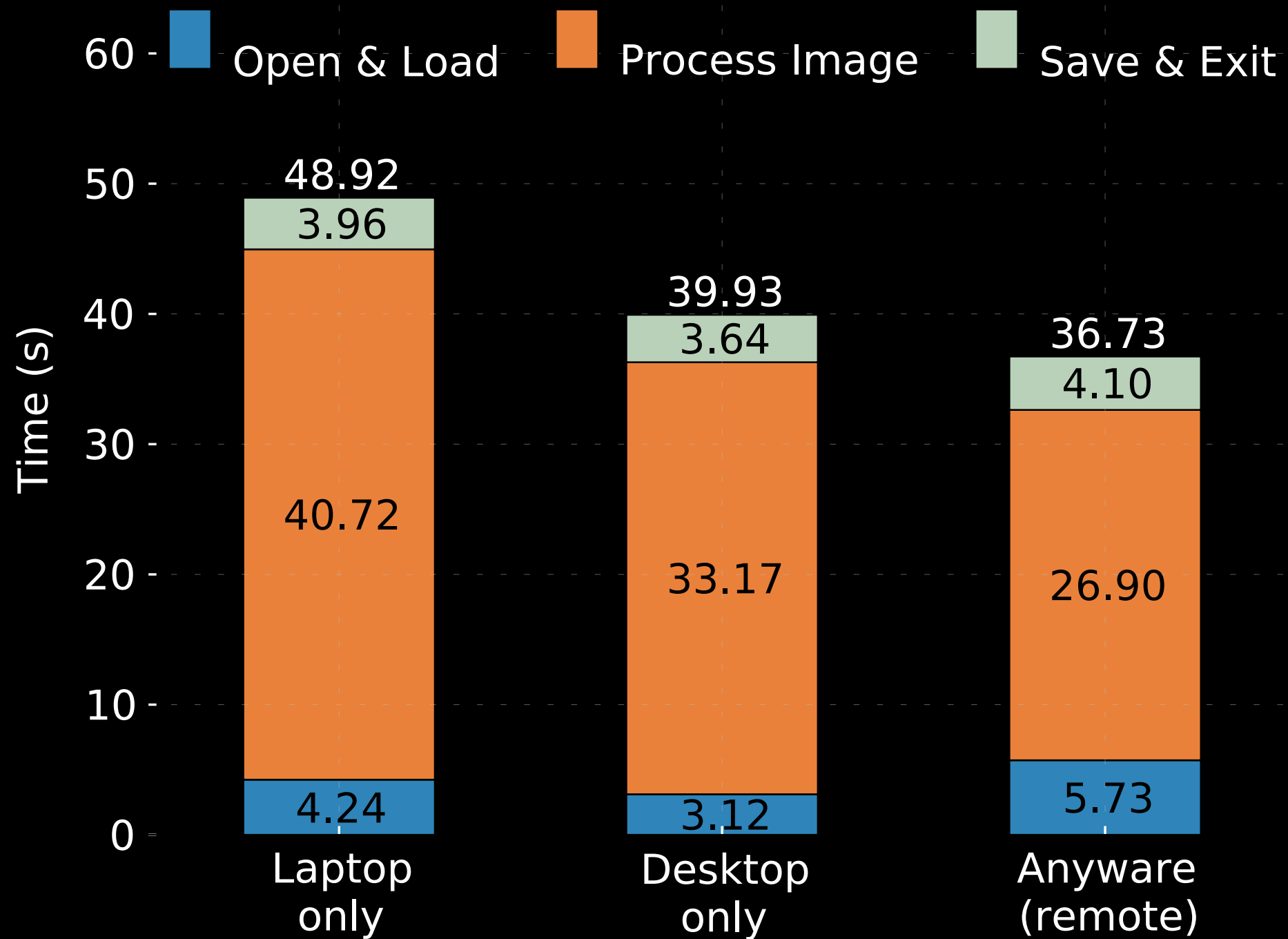


# Spreadsheet Task

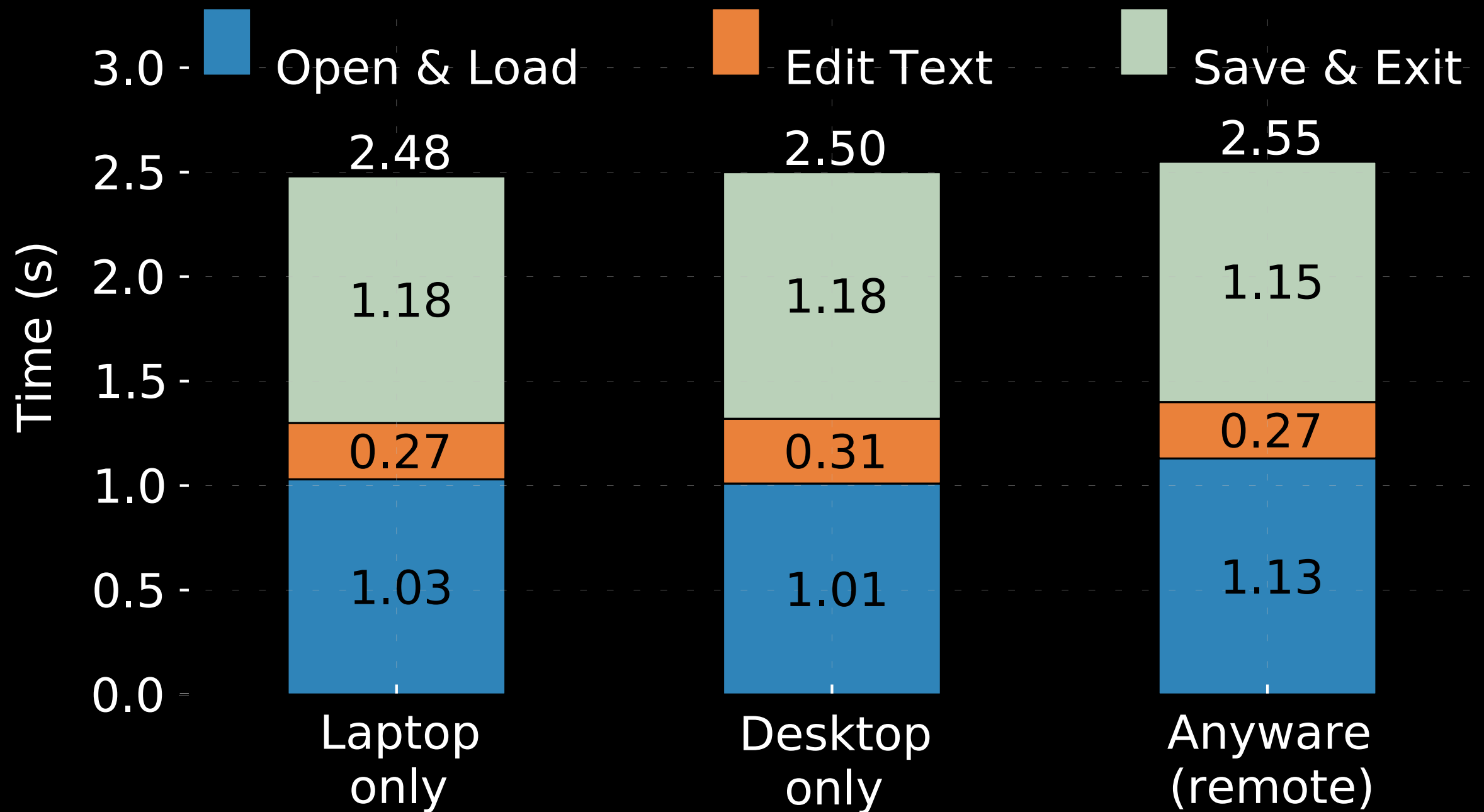


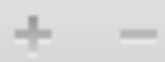


# Image-processing Task



# Text Edit Task





GNOME Media Player (Auto Select)



File View Engine Help



Time:



0:31/7:08



Playlist

# A Video Workload

	desktop	Anyware	
		local	remote
frames not displayed	0%	0%	32%

# A Video Workload

	desktop	Anyware	
		local	remote
frames not displayed	0%	0%	32%

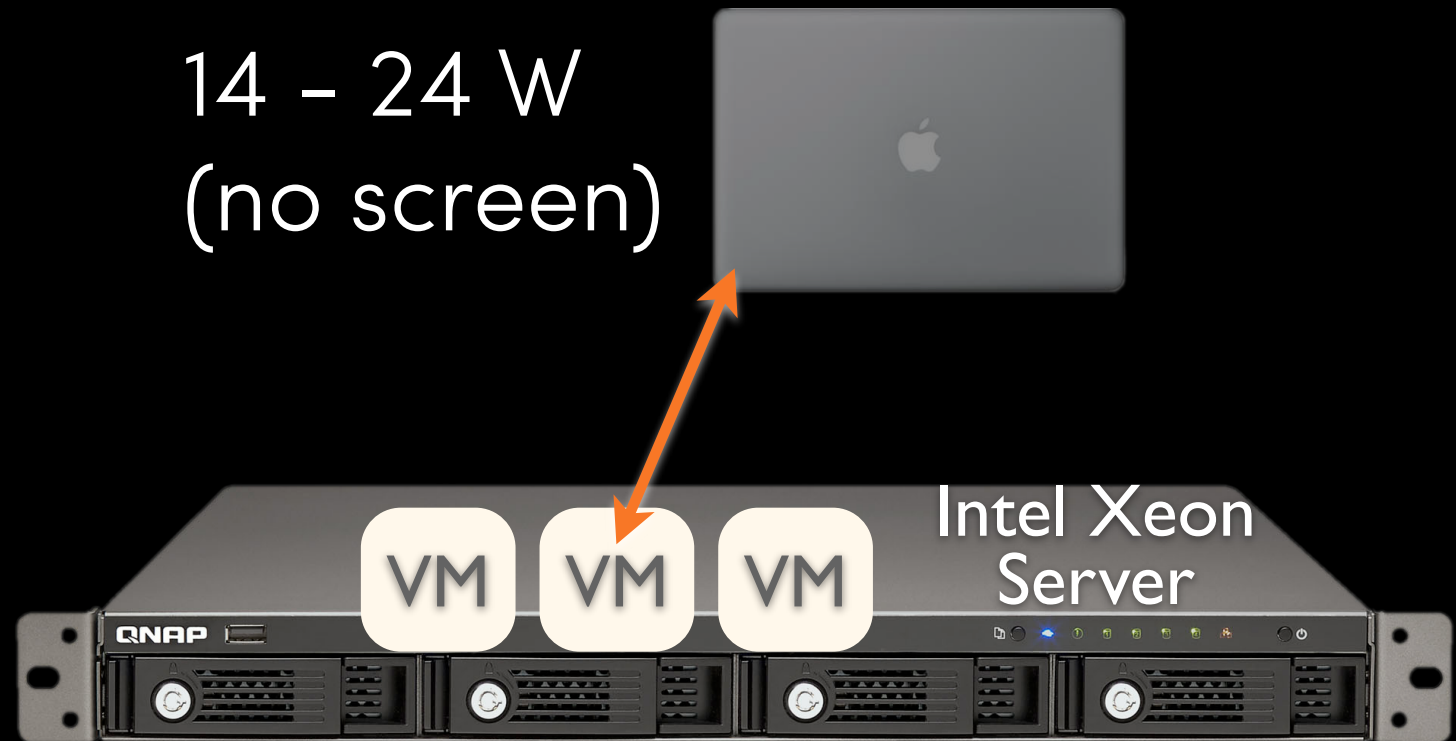
Anyware will choose to run this locally



# Energy Evaluation



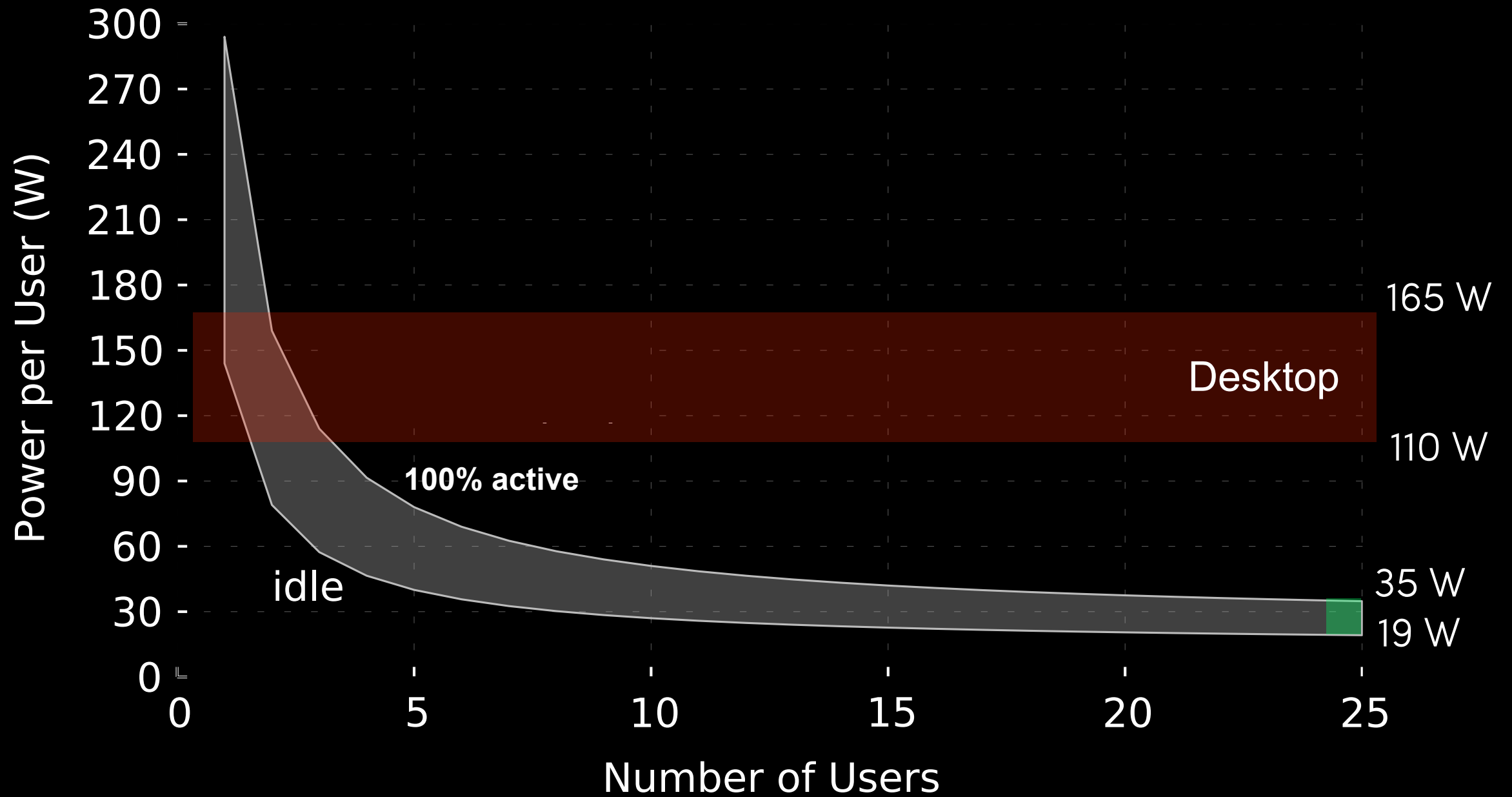
110 - 165 W



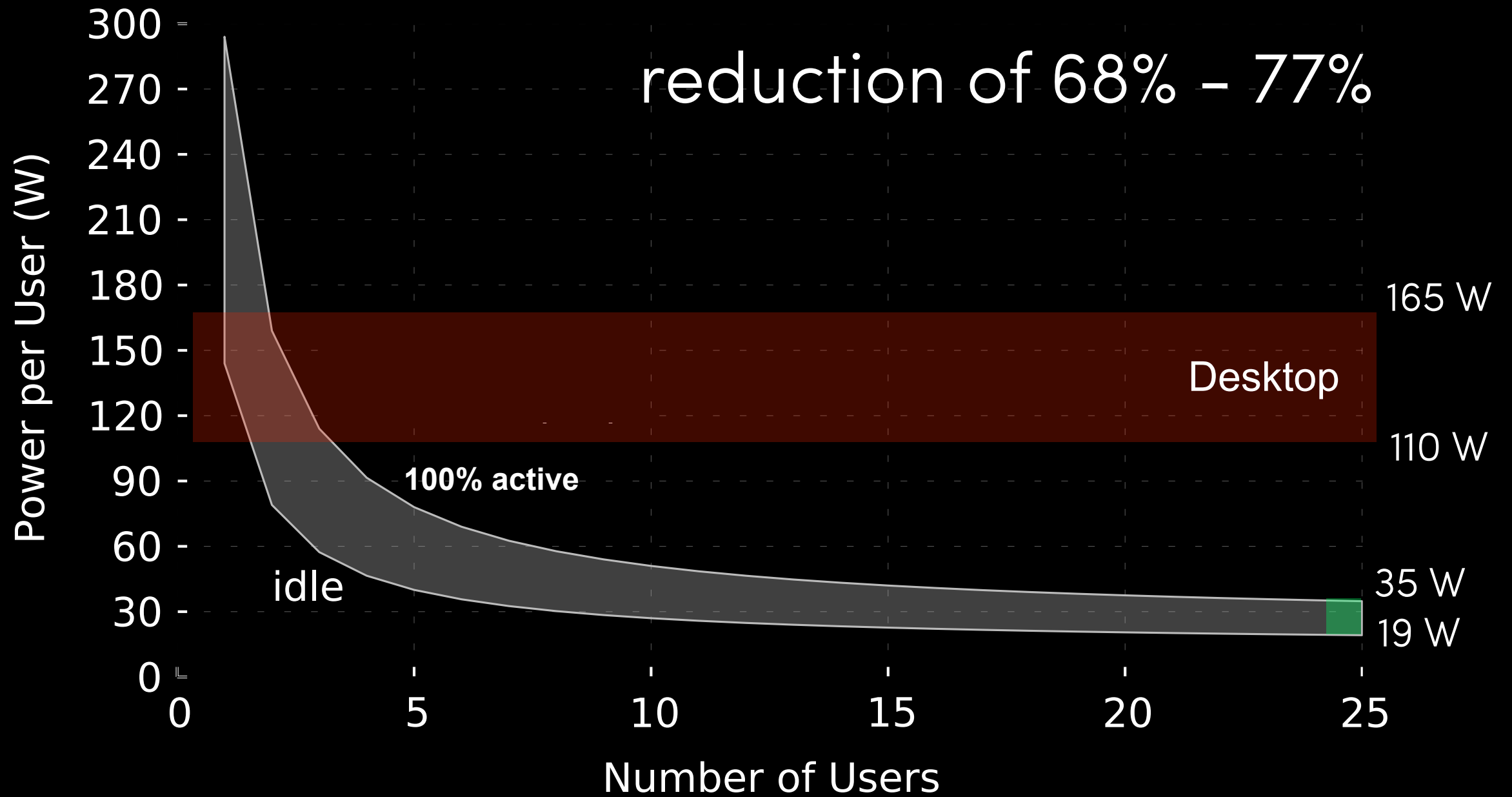
130 - 270 W

VM 5 - 11 W  
(assuming 25 VMs)

# Energy Evaluation



# Energy Evaluation





# Anyware

A **practical** system that uses established techniques

to

provide performance **comparable** to that of desktops

while

**reducing energy** costs by ~70%

# Final Thoughts

The computing design space is large and the trade-off between power and performance is not linear.

# Final Thoughts

Time to rethink the needs of enterprise computers:

**local:** graphics, I/O, network, memory

**remote:** cpu, memory