Education

Green Storage Technologies and Your Bottom Line

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Abstract

Green Storage Technologies and Your Bottom Line

- A number of green technologies and processes have emerged in the last several years. The green meme has raced up the hype curve in record time. The EPA is doing an "ENERGY STAR" Storage Spec. What to make of it all? This tutorial takes a dollar-and-cents view of the various technology and process areas, helping you prioritize your acquisition planning and attention. We cover green storage technologies, the importance of efficient facilities, and recent developments in ENERGY STAR regulation of the storage sector.

Outline

- What does "green" mean to data center operators?
- Power and Energy
- Where does all the energy go?
- Storage and energy
- The big rocks
- Other topics

What does "green storage" mean to data center operators?

- It means reducing the data center footprint of storage
  - in space
    - less equipment to put in place
  - in energy
    - more energy-efficient equipment
    - less equipment to power and cool
    - more efficient cooling and power management
  - in administrative costs
    - less equipment to buy, manage and EOL
- In other words, MONEY

How much is “green” worth?

- More than you think!
- Facilities: over ½ total energy cost, sometimes
  - mW* data center ~= $100/hr = $876K/yr
  - Taking PUE** from 2.5 to 1.25 saves ½ of energy bill
- Servers: over ½ total energy cost, sometimes
  - Anecdotal increases in efficiency of 3:1
- Storage: over ½ total energy cost, sometimes
  - Storage software optimizations are key

* mW megaWatt
** PUE defined later

Power and energy

- Power
  - Instantaneous load (kW)
  - Peak power used in plant sizing
    - e.g. wiring, transformers, CRAC units, fans, UPSs etc.
  - Rewards for reducing peak load
    - reduced demand charges
- Energy
  - Power over time (kWH)
  - This is what metered rates are for
    - rates may vary during the 24/7/365 period

Check out SNIA Tutorial:

Green Storage: The Big Picture

Where does all the energy go?

Power to Data Center

UPS / Power Conditioning

Power losses

"Useful Work"

Cooling

IT Equipment

(Only major power loss sources are shown)

What do we mean by IT equipment?

Power to
IT Equipment

IT Equipment

Servers (about 60%)

Networking (about 10--20%)

Storage (about 20--30%)

YMMV!

PUE

- "Power Usage Effectiveness"

$$\frac{\text{Power to Data Center}}{\text{Power to IT Equipment}}$$

- Historically 2.25 to 3.0 and even higher
  - Because IT work transforms power into heat, which must be eliminated, and air conditioners are not 100% efficient...
  - 2.0 means 50% of the power is being lost or used for cooling
- Modern best practice asymptote is around 1.25
  - 80% of the power gets delivered to IT equipment

Putting numbers on the diagrams

Power to Data Center

2792kW

UPS / Power Conditioning (85% efficiency) 364kW

Cooling (at 70% eff.) 1428kW

1000kW

"Useful Work"

Servers – 600kW
Networking – 100kW
Storage – 300kW

PUE = 2.8

Typical Historical Figures

Putting numbers on the diagrams

Power to Data Center
1250kW

Flywheel UPS
(96% efficiency)
50kW

Adaptive Cooling
200kW

Best Practice 2010 Figures

1000kW
"Useful Work"

Servers – 600kW
Networking – 100kW
Storage – 300kW

PUE = 1.25

What do those numbers mean?

- 1 mW IT power = $876,000 / year
  - at $0.10 per kWh, and ignoring demand charges
  - (ignoring power factor too, because the utility eats that)
- With a PUE = 2.8 → $2,452,800
- With a PUE = 1.25 → $1,095,000

- Power delivery cost ("tax") to deliver that $876K of energy per year
  - PUE = 2.8 : $2453K - $876K = $1577K tax / yr
  - PUE = 1.25 : $1095K - $876K = $219K tax / yr

Energy OPEX vs. CAPEX

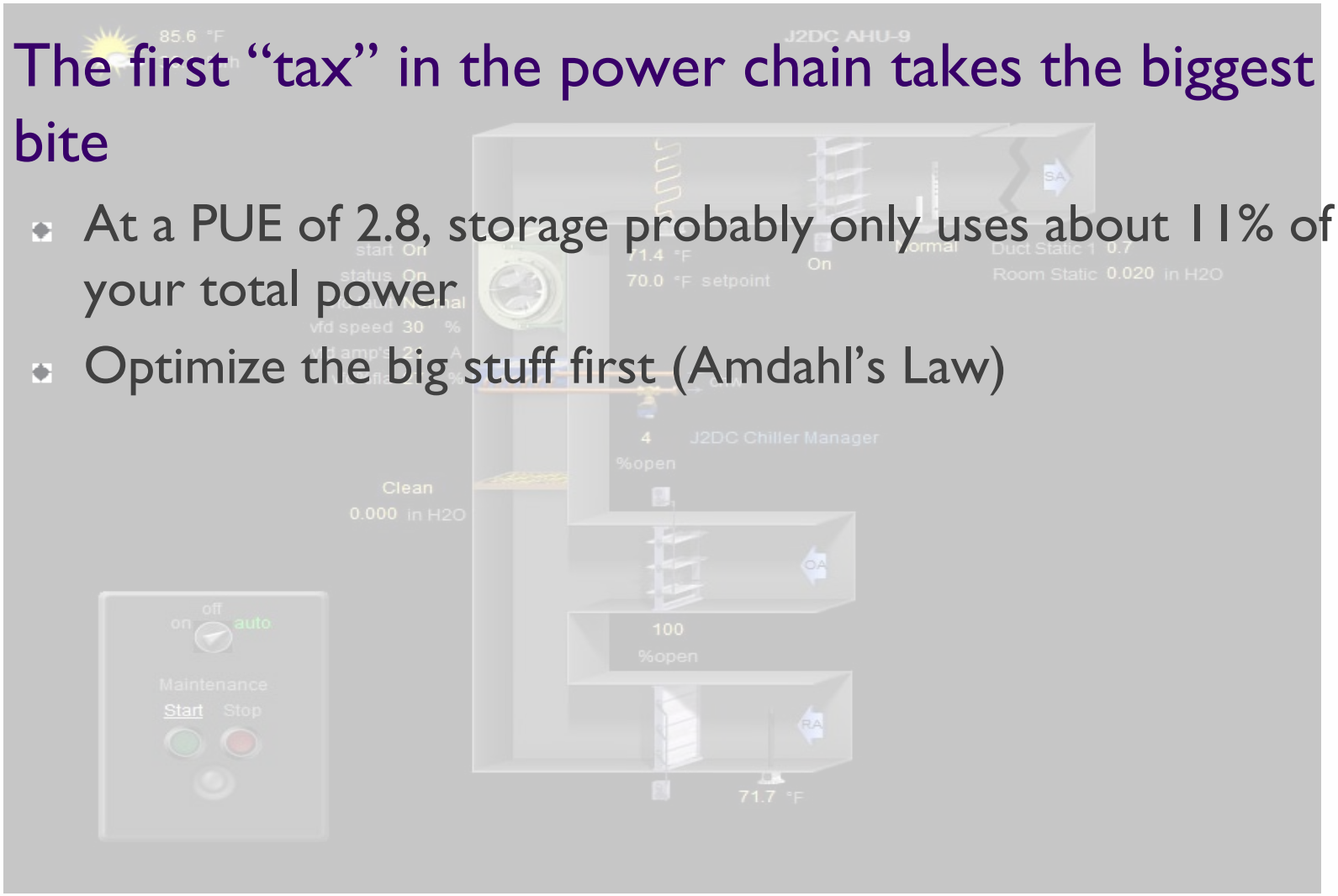
- Compare the "tax" to cost of equipment (that drinks 1 mW)
  - 2,500 1U servers: $2M - $4M
    - $1,500K wasted over 5 years is significant
    - $1.5M / $2M = 75% of CAPEX
  - FC arrays (~30,000 disks): probably $30M
    - The tax is still $1,500K, but it's not as big relative to CAPEX
    - $1.5M / $30M ~= 5% of CAPEX
- So the urgency of a facilities upgrade is in part dependent on your server ratio
  - More servers, less storage → upgrade may be more urgent
  - More storage, fewer servers → upgrade may be less urgent

Facilities Technologies

- Covered in more detail in past tutorials
  - See "Technologies for Green Storage" at www.snia.org/education/tutorials/2009/fall#green
- Flywheel UPS
- Air handling systems (use of outside air)
- Variable speed fans
- Hot aisle / Cold Aisle technologies
- Monitoring and feedback control systems
- Spam filtering (!)

Why am I just talking about facilities?

- The first "tax" in the power chain takes the biggest bite
  - At a PUE of 2.8, storage probably only uses about 11% of your total power
  - Optimize the big stuff first (Amdahl's Law)



But this is a Storage conference!

- Okay, let's talk about storage
- Four basic strategies
  - Make the equipment more power-efficient
    - Power supplies, fans, drive speeds, etc.
  - Use less redundancy
    - Delta snapshots, advanced RAID
  - Commit less space
    - Thin provisioning
  - Squeeze more data into available space
    - Data deduplication, compression

Power efficiency

- Capacity vs. high performance drives
- ILM / HSM
- MAID
- Tape
- SSDs
- Power supply and fan efficiency
- Disk drives

Capacity vs. high performance drives

- Capacity
  - focused on GB/watt at idle
    - 1 TB SATA: 12W
    - 4 x 250 GB FC: 64W
  - also tend to have better $/GB
  - NOTE: power use is theoretically quadratic with respect to rotational speed
    - Use the slowest drives that will fit your needs
- Performance
  - focused on seek time
    - 1 TB SATA: 12 – 15 ms
    - 300 GB FC: 3 – 4 ms
  - also designed for higher RAS * environments

* RAS = Reliability, Availability, Security

ILM / HSM *

- Exploit cost differences between storage tiers
  - Idea: automatically move data to an appropriate storage platform at each period in its lifetime
  - Tier change must have substantial value to make the overhead worth it
    - Cost of ILM/HSM system
    - Cost of administration
    - Cost of data movement
- Practice
  - Storage declines in value as it ages
  - Manual movement of data sets
- New wrinkle
  - Footprint considerations preclude keeping older gear

* ILM = Information Lifecycle Management
  HSM = Hierarchical Storage Management

MAID (Massive Array of Idle Disks)

- Idea: spin down disks when not in use
  - Pros
    - Disks use no power when spun down
    - > 50% power savings at idle
  - Cons
    - Most data near-online (access times of several seconds)
    - Background disk housekeeping difficult
    - Often the same data center sizing requirements (UPSs, CRAC units, PDUs etc.), but these are used at lower efficiencies
    - Impending competition from SSDs
    - Competition from tape
  - Best practice: spin down spares
    - Savings = the percentage of spares you're running

Power efficiency: Tape

- Still the best, energy-wise
  - Pros
    - Tapes use no power when inactive
    - > 90% power savings at idle
  - Cons
    - Data is at best near-online (access times of several seconds)
    - Not a random access format
    - Lack of true resilience to format failure
      - Redundant Array of Independent Tape, anyone? (RAIT)

Check out SNIA Tutorial:

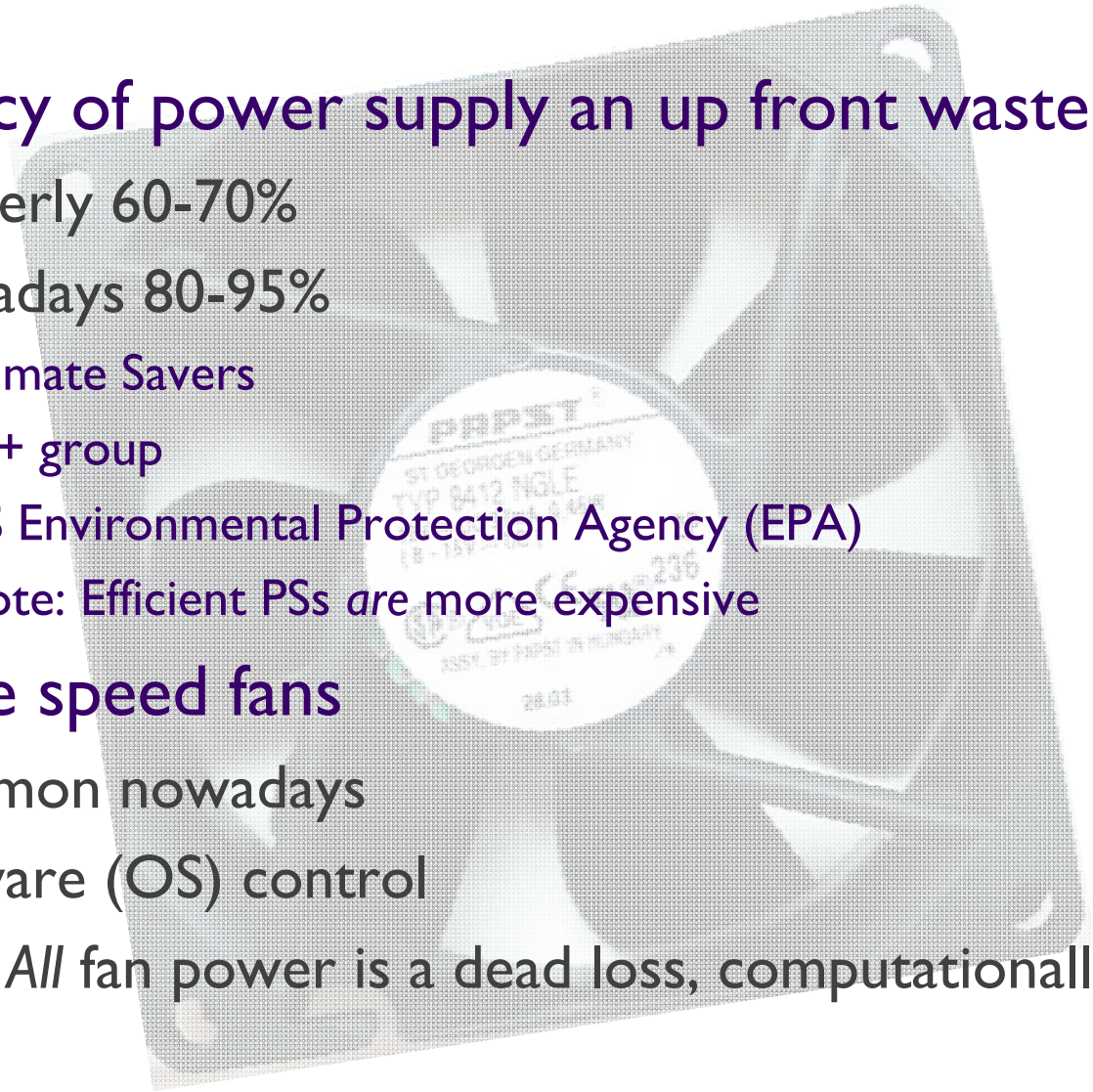
Introduction to Data Protection: Backup to Tape, Disk and Beyond

SSDs (Solid State Disks)

- Usually refers to FLASH-based disks
  - Pros
    - Great READ performance
    - At rest power consumption = 0
    - No access time penalty when idle (cf. MAID)
    - No need to keep some disks spinning (cf. MAID)
  - Cons
    - WRITE performance may be < mechanical disks
    - Cost >> mechanical disks except at very high perf points
    - Wear leveling requires a high space overhead
  - Note: these dynamics changing rapidly with time
    - SSSI – SNIA Solid State Storage Initiative

Check out the SNIA Tutorials in the Solid State Storage (SSS) Tutorial track

Power supply and fan efficiencies



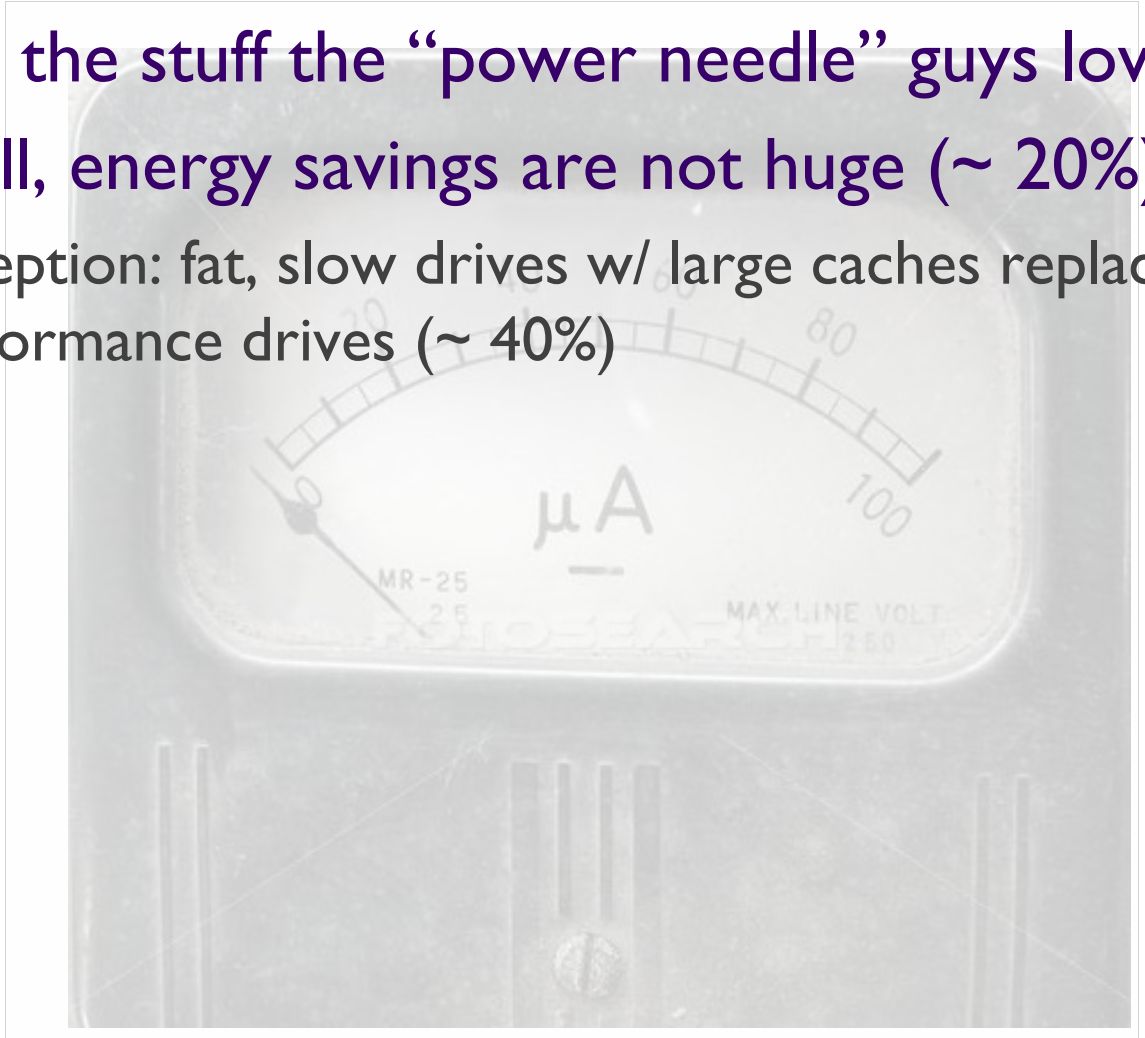
- Efficiency of power supply an up front waste
  - Formerly 60-70%
  - Nowadays 80-95%
    - Climate Savers
    - 80+ group
    - US Environmental Protection Agency (EPA)
    - Note: Efficient PSs *are* more expensive
- Variable speed fans
  - Common nowadays
  - Software (OS) control
  - N.B. *All* fan power is a dead loss, computationally

Spinning disk drives

- Test results – SNIA Green Storage TWG (Technical Working Group)
  - Drives at "idle" – meaning no I/O to the array – use 85% or more of the power they use under load
  - Larger arrays may even use more power at idle than when under load
    - Many workloads are less intensive than housekeeping operations that get kicked off when the array is idle
  - Slower drives (SATA) use much less power
- Best practice – SATA drives fronted by large caches
  - Except in ultra-high-performance and high-bandwidth scenarios
  - Fairly significant energy savings – up to about 40%
    - Solid State people would like to help you get rid of the other 60% too, but the CAPEX economics aren't there at this point

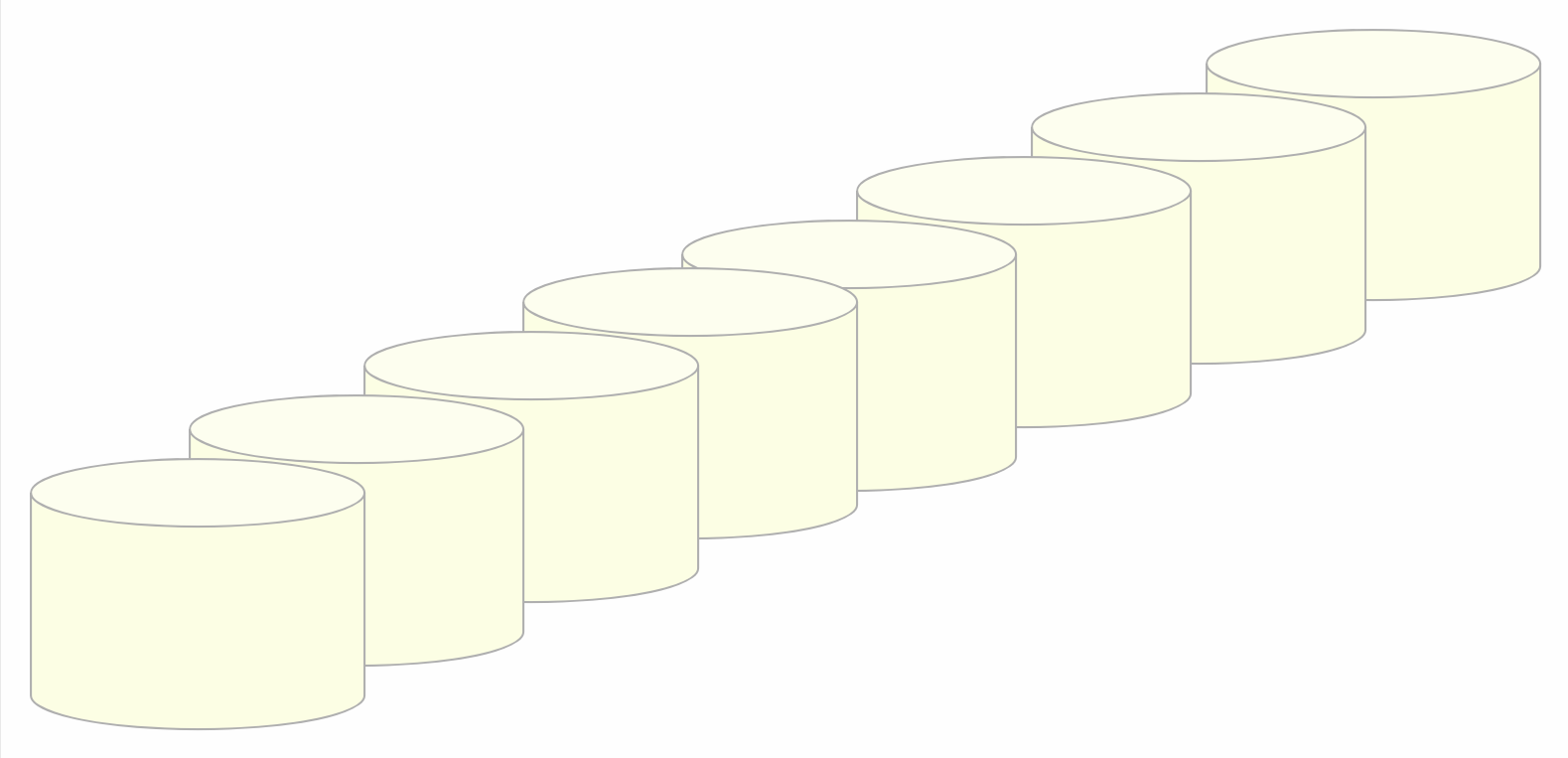
Power efficiency: Summary

- This is the stuff the "power needle" guys love
- Overall, energy savings are not huge (~ 20%)
  - Exception: fat, slow drives w/ large caches replacing high-performance drives (~ 40%)

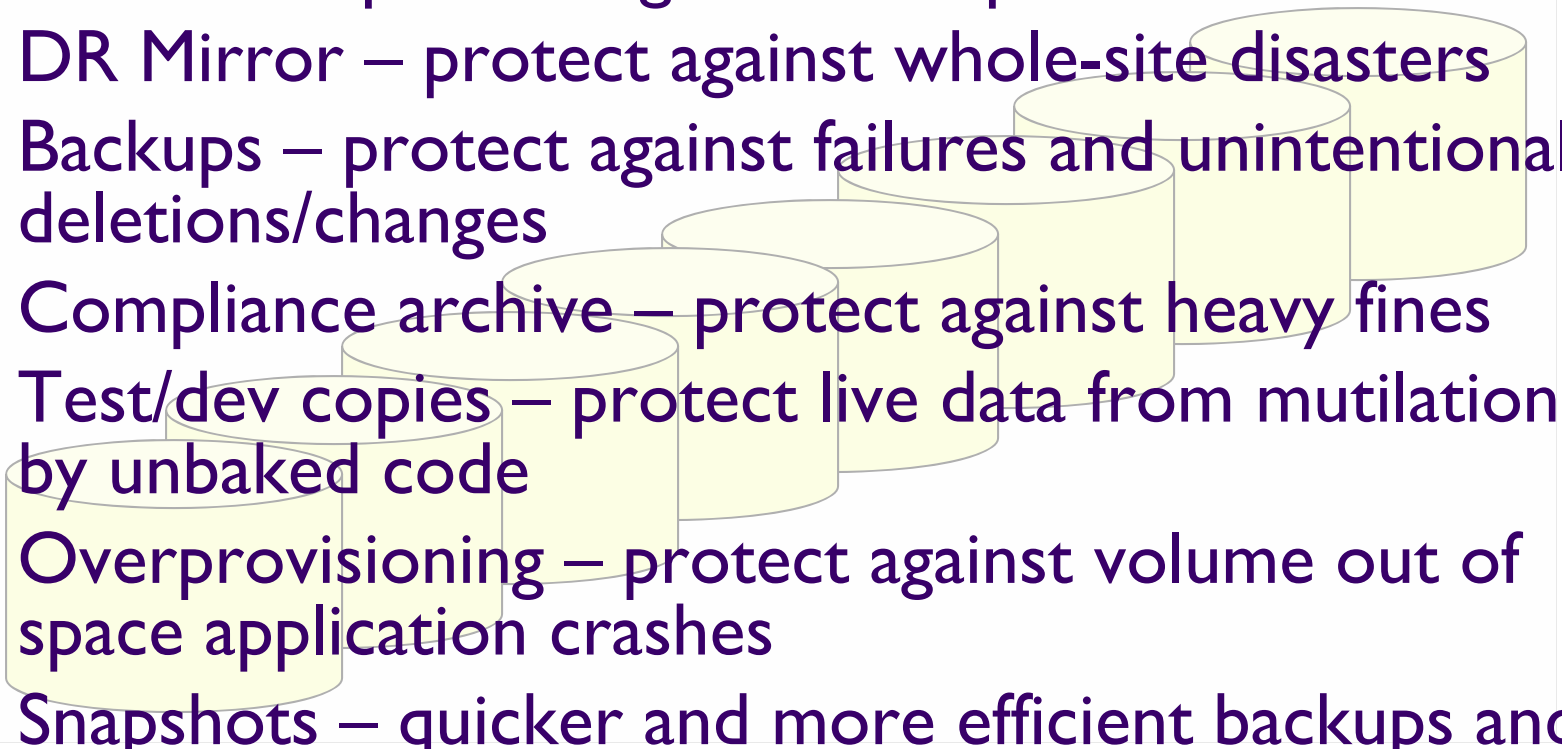


Less redundancy

- High value storage uses redundancy heavily
- Many enterprise applications also use redundancy

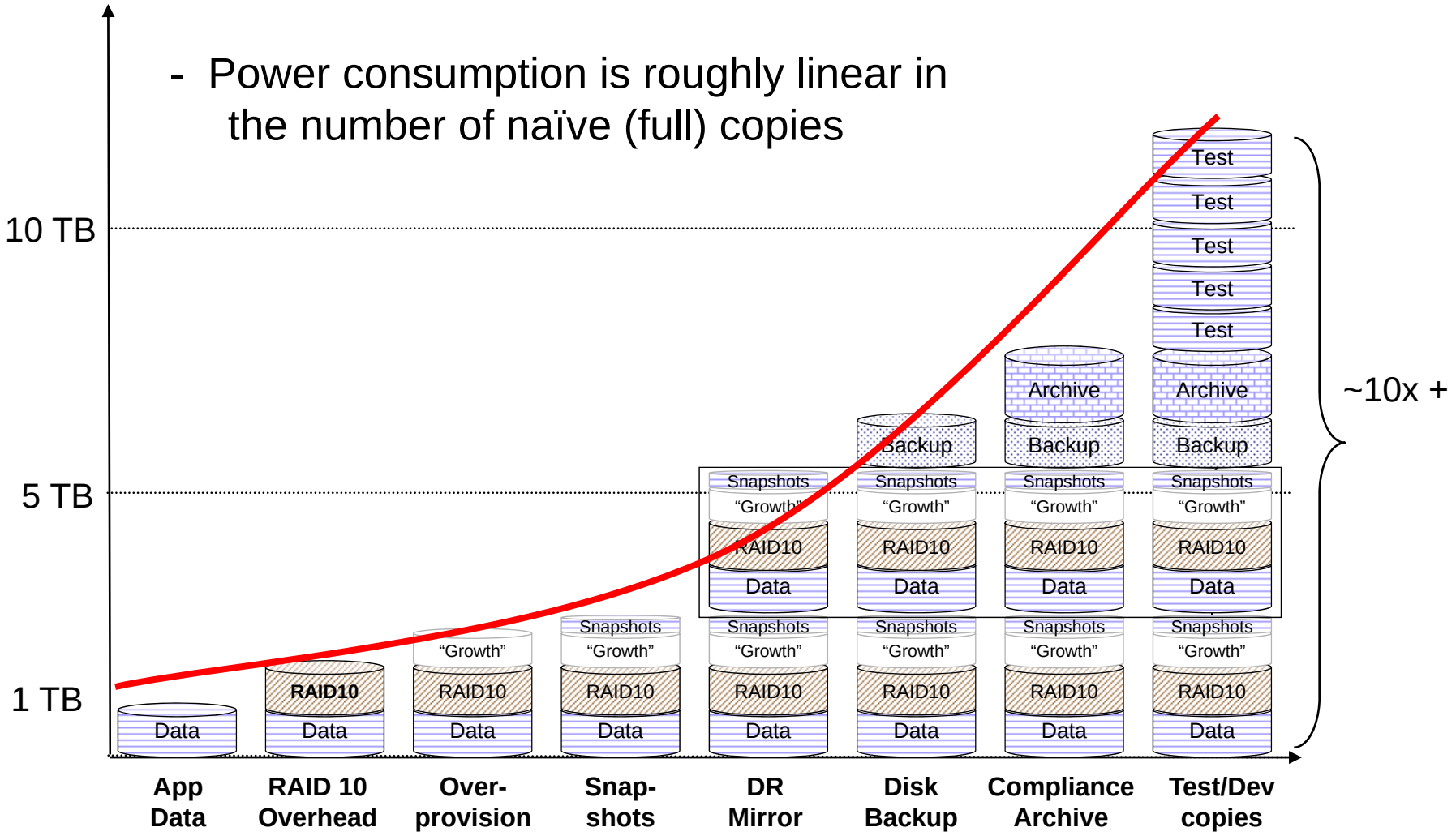


Need for redundancy



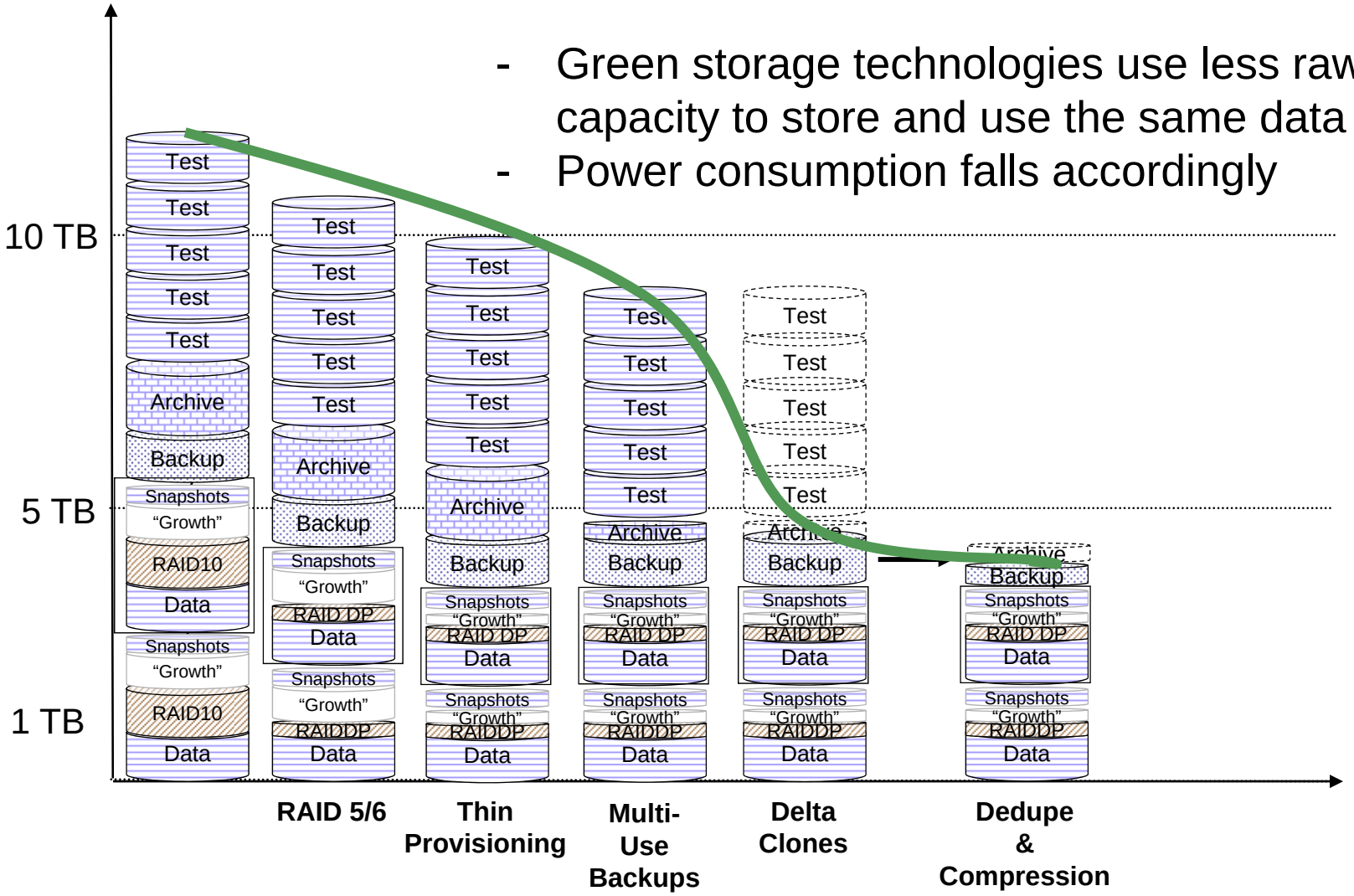
- RAID 10 – protect against multiple disk failures
- DR Mirror – protect against whole-site disasters
- Backups – protect against failures and unintentional deletions/changes
- Compliance archive – protect against heavy fines
- Test/dev copies – protect live data from mutilation by unbaked code
- Overprovisioning – protect against volume out of space application crashes
- Snapshots – quicker and more efficient backups and PIT (point in time) copies

Result of redundancy



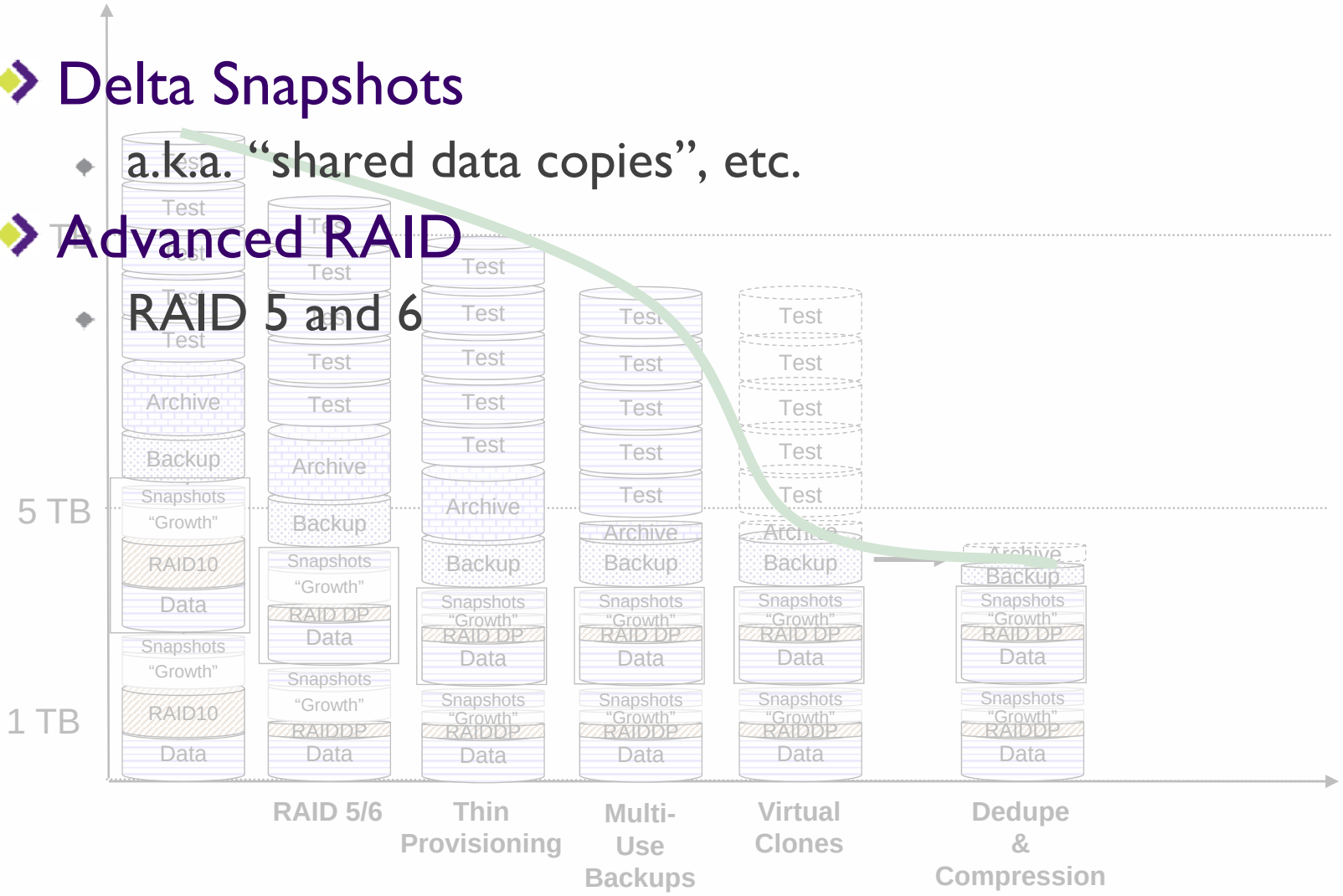
Effect of green technologies

- Green storage technologies use less raw capacity to store and use the same data set
- Power consumption falls accordingly



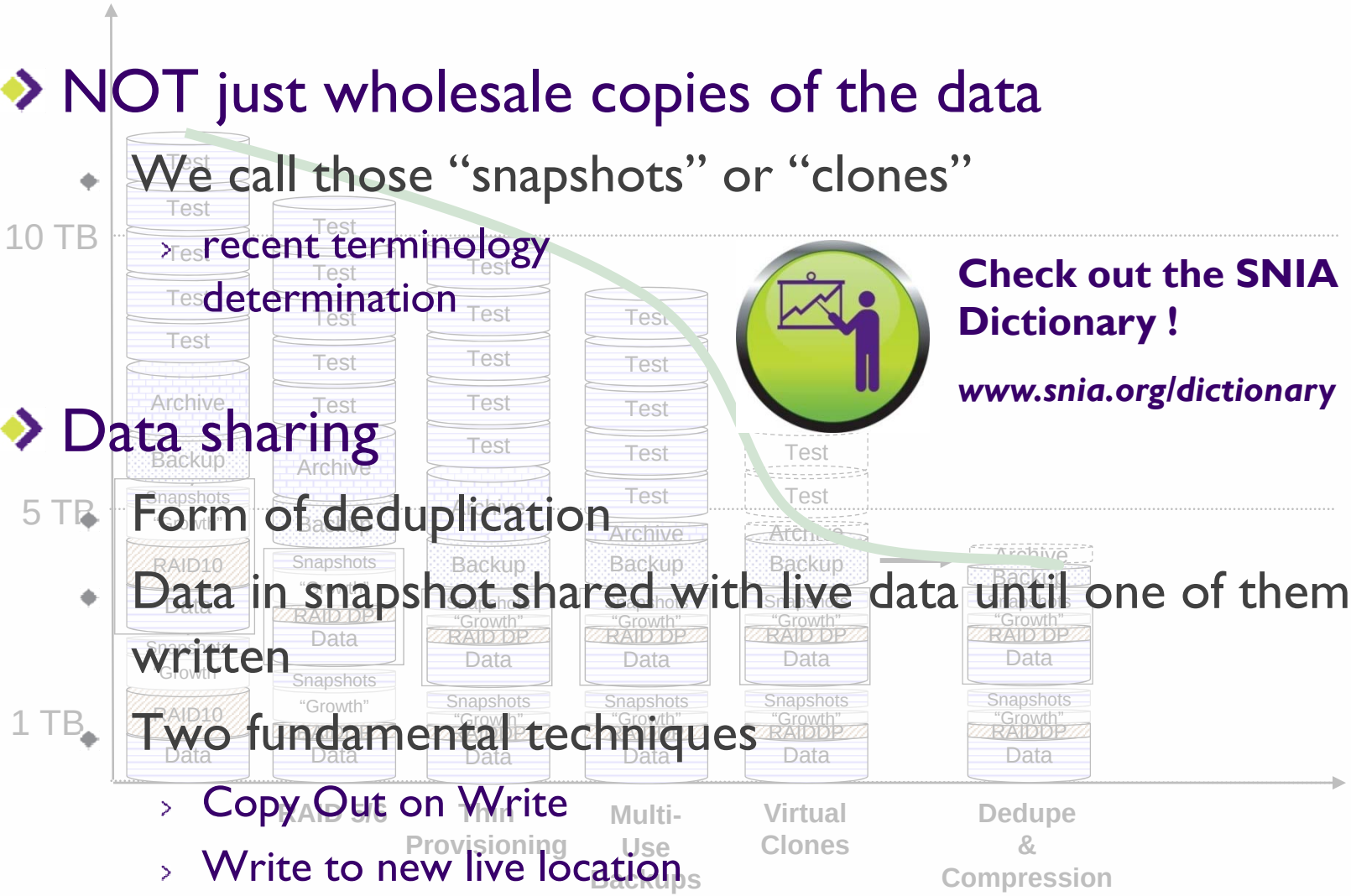
Less redundancy: techniques

- Delta Snapshots
  - a.k.a. "shared data copies", etc.
- Advanced RAID
  - RAID 5 and 6



Delta snapshots

- NOT just wholesale copies of the data
  - We call those "snapshots" or "clones"
    - recent terminology determination
- Data sharing
  - Form of deduplication
  - Data in snapshot shared with live data until one of them is written
  - Two fundamental techniques
    - Copy Out on Write
    - Write to new live location

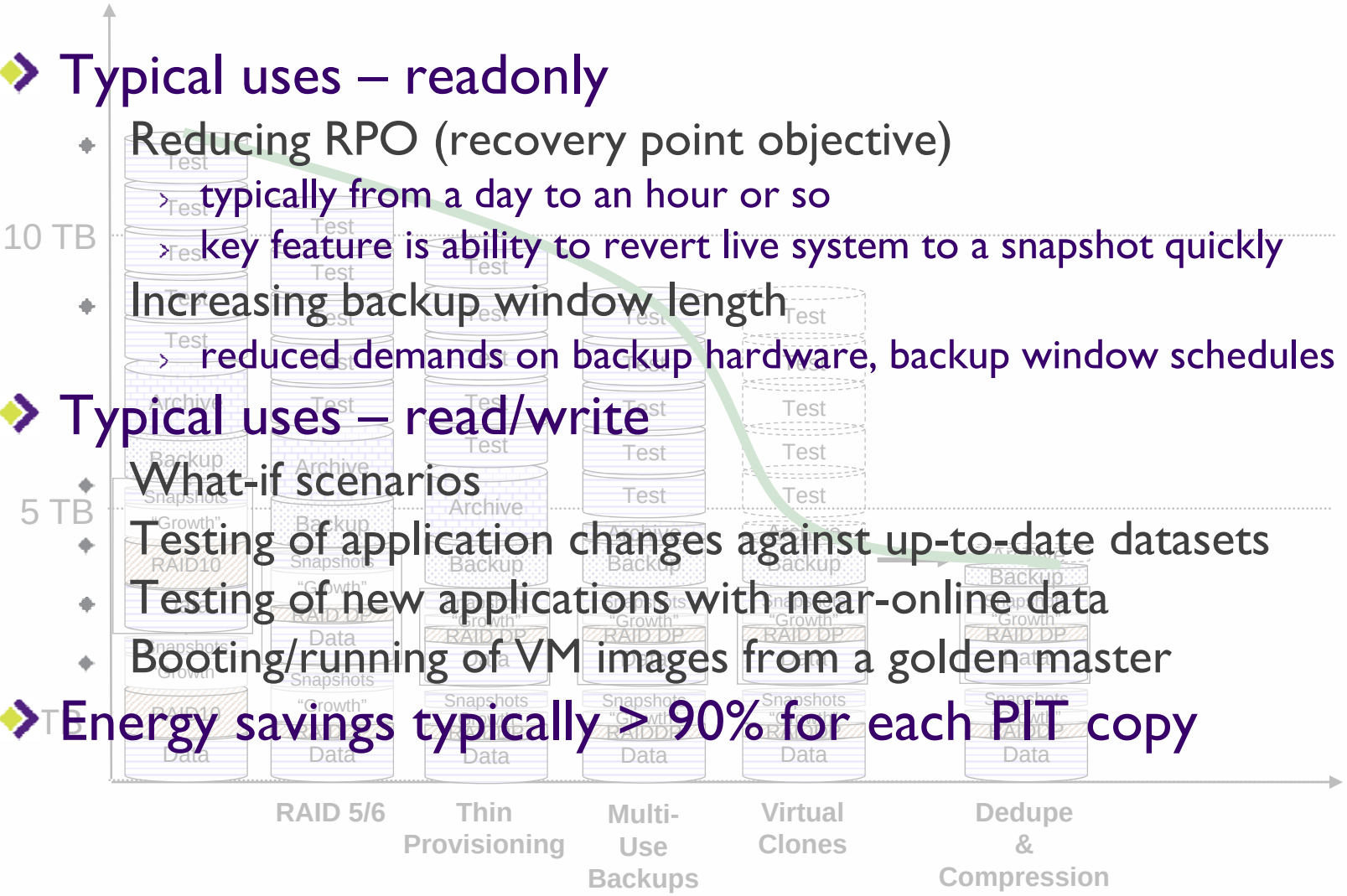


Check out the SNIA Dictionary !

www.snia.org/dictionary

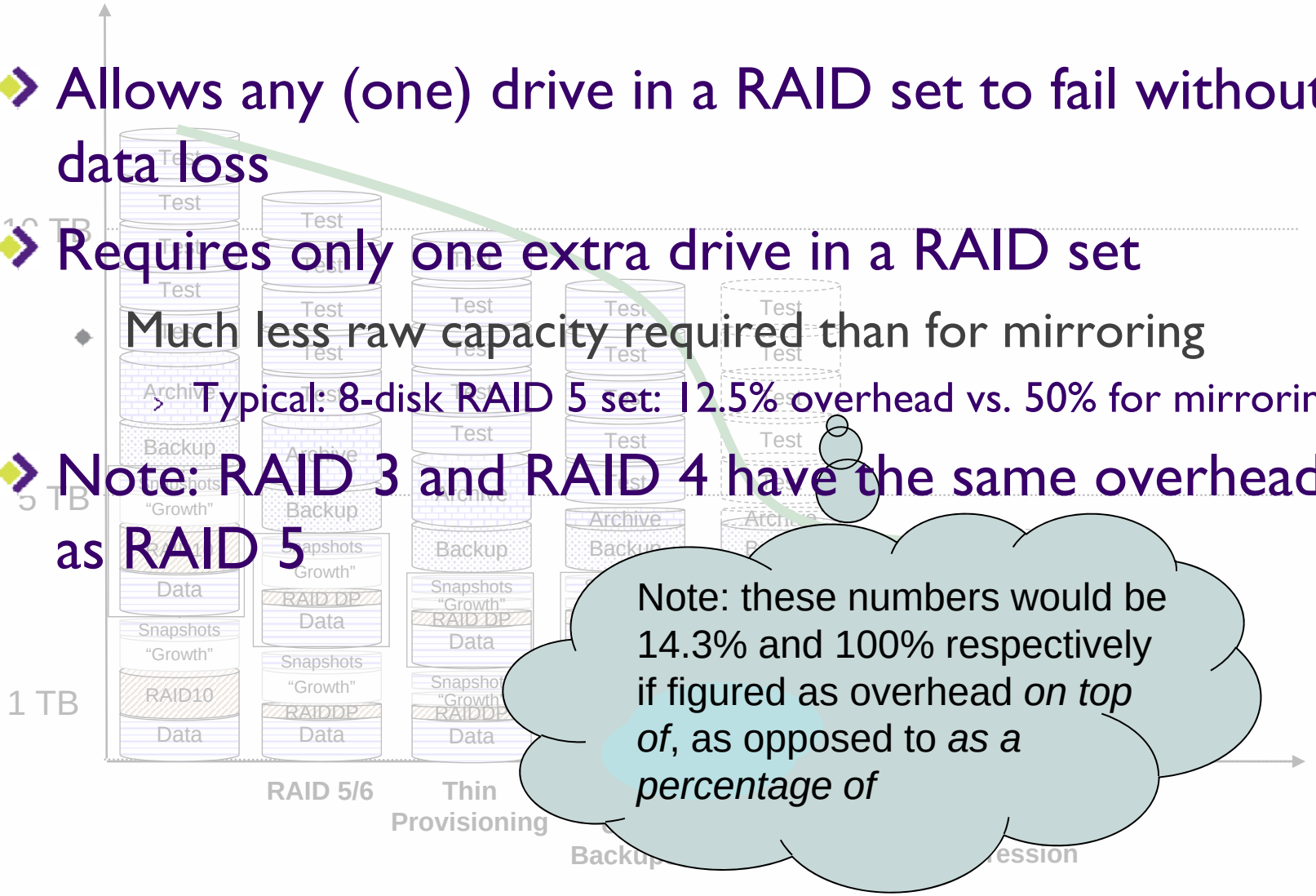
Delta snapshots

- Typical uses – readonly
  - Reducing RPO (recovery point objective)
    - typically from a day to an hour or so
    - key feature is ability to revert live system to a snapshot quickly
  - Increasing backup window length
    - reduced demands on backup hardware, backup window schedules
- Typical uses – read/write
  - What-if scenarios
  - Testing of application changes against up-to-date datasets
  - Testing of new applications with near-online data
  - Booting/running of VM images from a golden master
- Energy savings typically >90% for each PIT copy



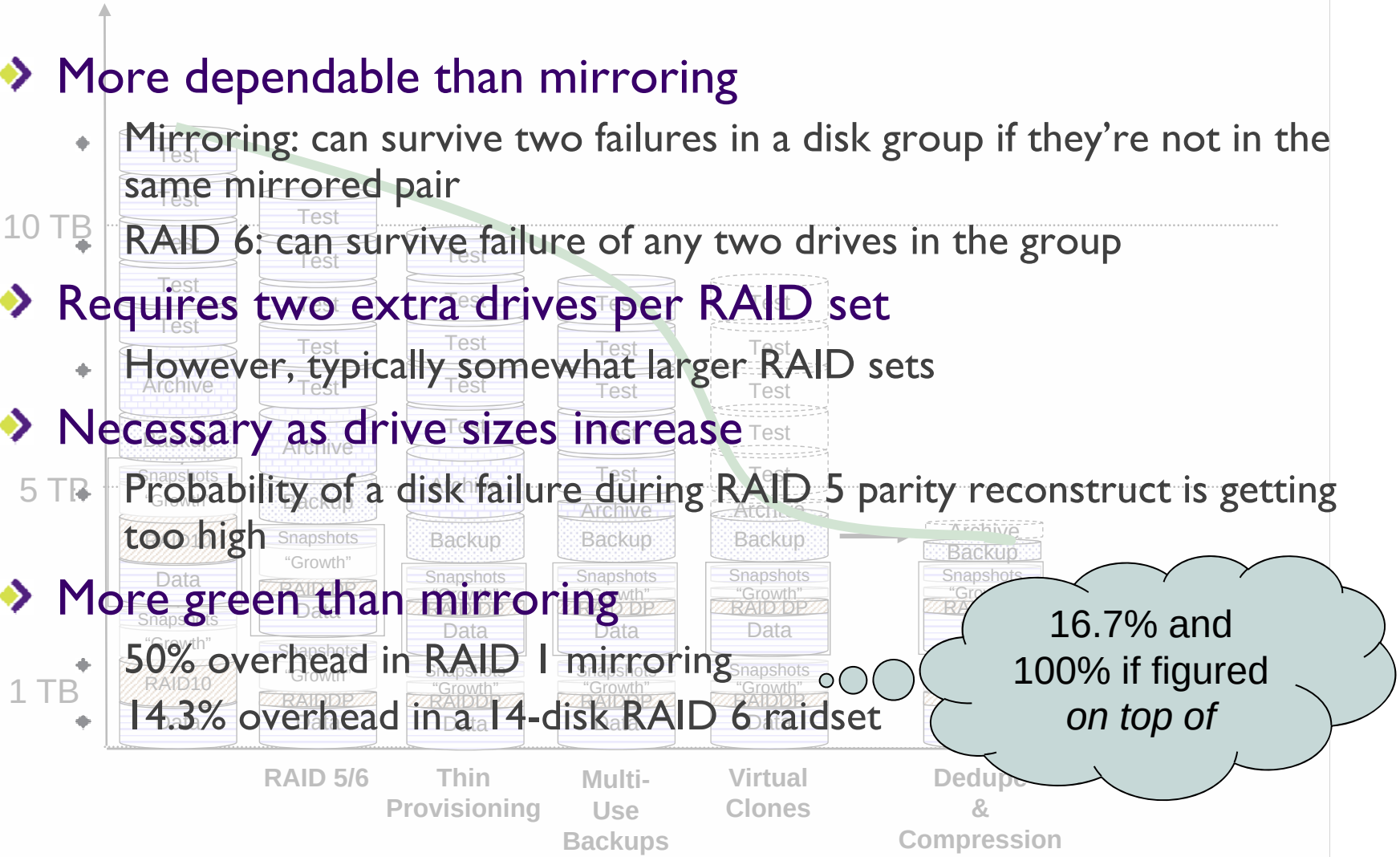
RAID 5

- Allows any (one) drive in a RAID set to fail without data loss
- Requires only one extra drive in a RAID set
  - Much less raw capacity required than for mirroring
    - Typical: 8-disk RAID 5 set: 12.5% overhead vs. 50% for mirroring
- Note: RAID 3 and RAID 4 have the same overhead as RAID 5



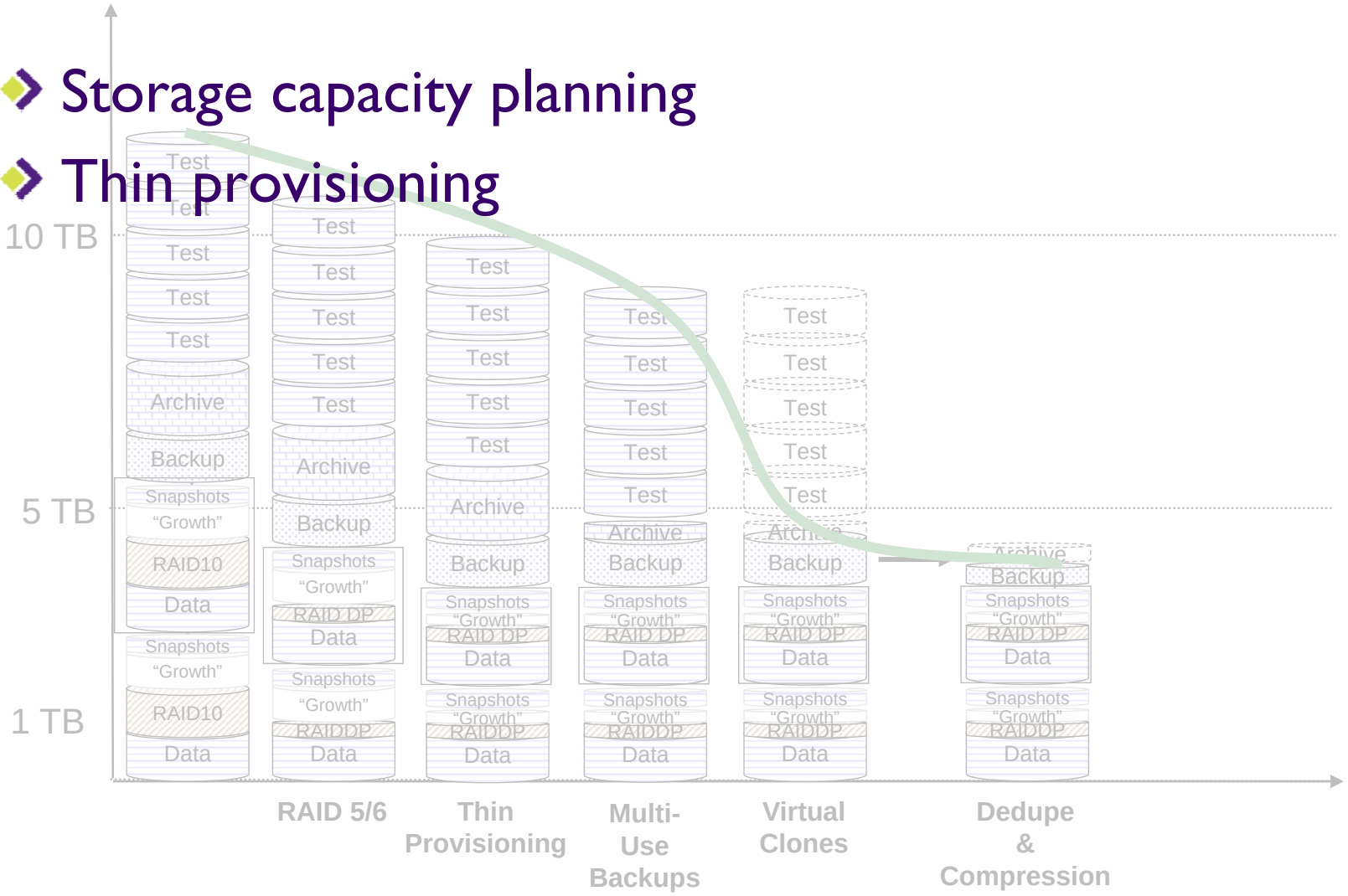
RAID 6

- More dependable than mirroring
  - Mirroring: can survive two failures in a disk group if they're not in the same mirrored pair
  - RAID 6: can survive failure of any two drives in the group
- Requires two extra drives per RAID set
  - However, typically somewhat larger RAID sets
- Necessary as drive sizes increase
  - Probability of a disk failure during RAID 5 parity reconstruct is getting too high
- More green than mirroring
  - 50% overhead in RAID 1 mirroring
  - 14.3% overhead in a 14-disk RAID 6 raidset



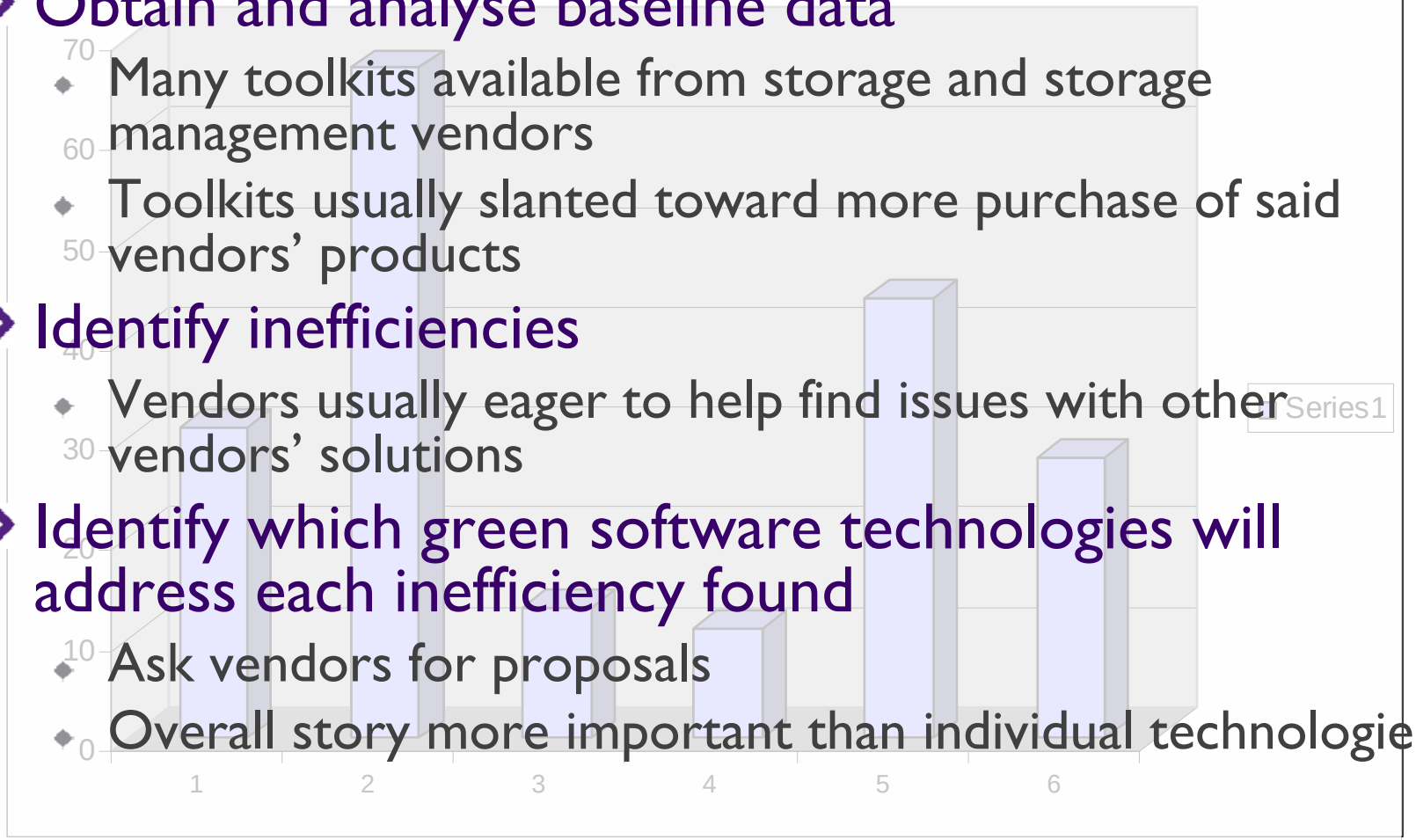
Committing less space

- Storage capacity planning
- Thin provisioning



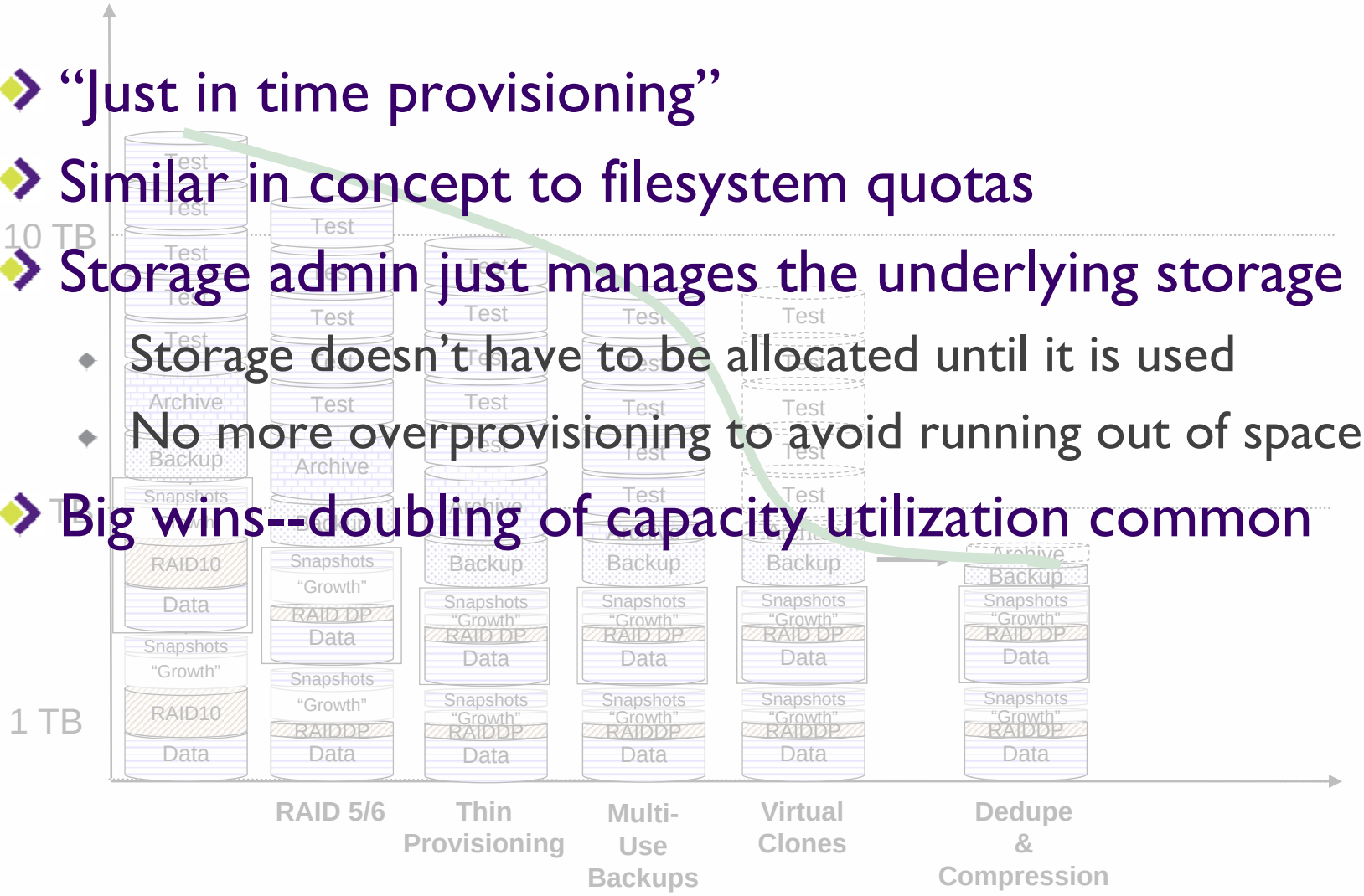
Storage capacity planning

- Obtain and analyse baseline data
  - Many toolkits available from storage and storage management vendors
  - Toolkits usually slanted toward more purchase of said vendors' products
- Identify inefficiencies
  - Vendors usually eager to help find issues with other vendors' solutions
- Identify which green software technologies will address each inefficiency found
  - Ask vendors for proposals
  - Overall story more important than individual technologies



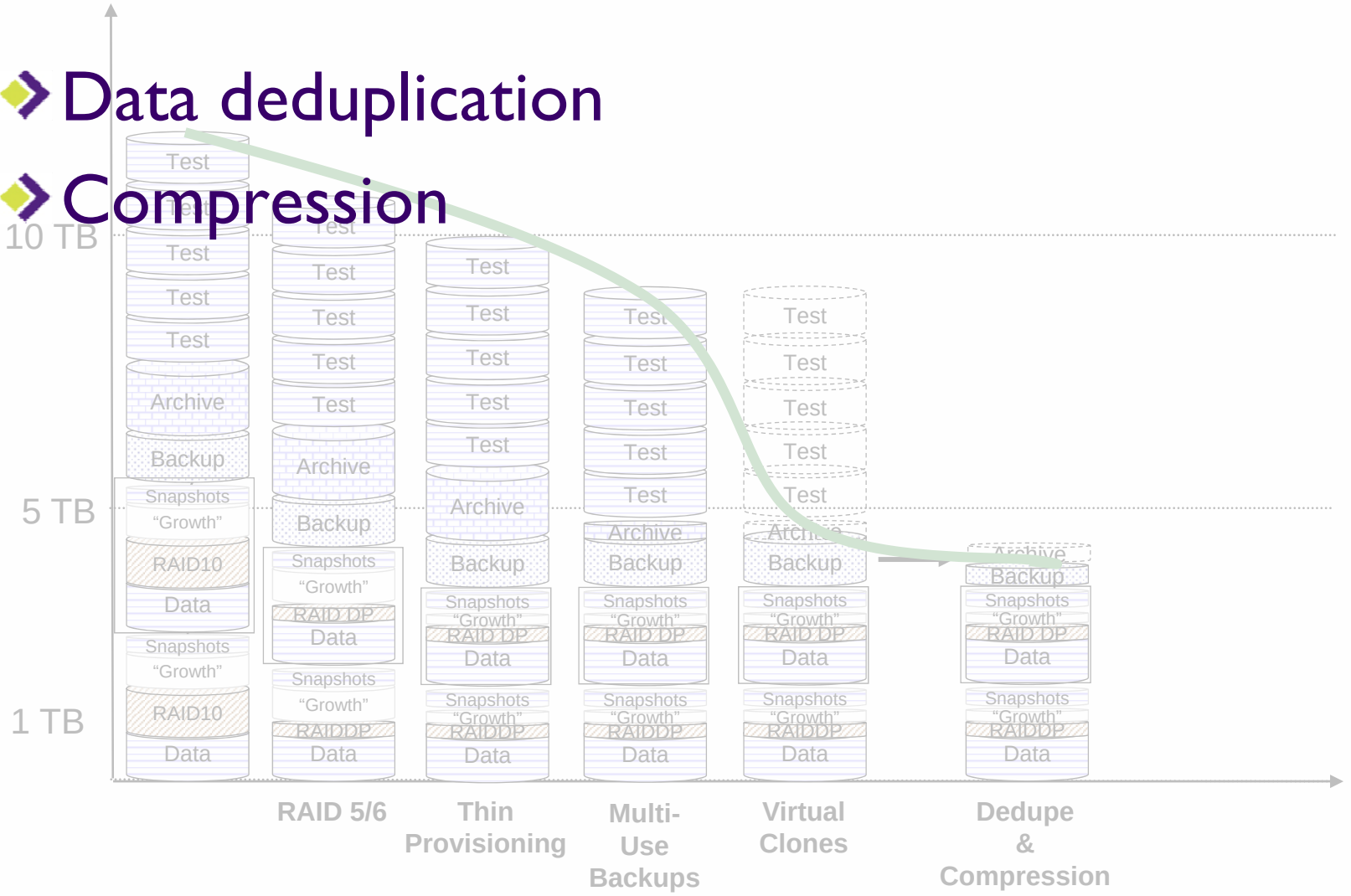
Thin provisioning

- "Just in time provisioning"
- Similar in concept to filesystem quotas
- Storage admin just manages the underlying storage
  - Storage doesn't have to be allocated until it is used
  - No more overprovisioning to avoid running out of space
- Big wins--doubling of capacity utilization common



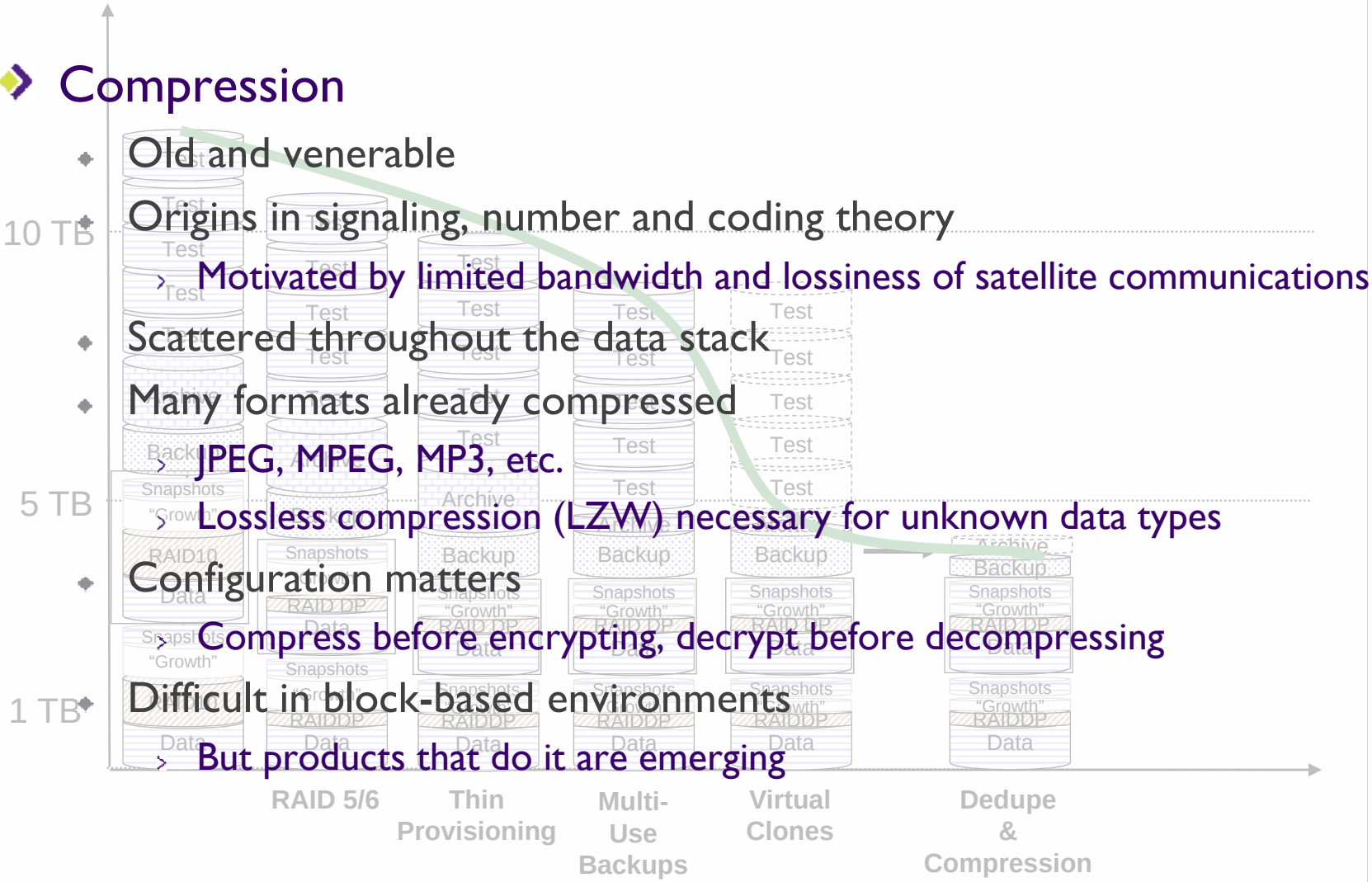
Squeezing in more data

- Data deduplication
- Compression



Compression

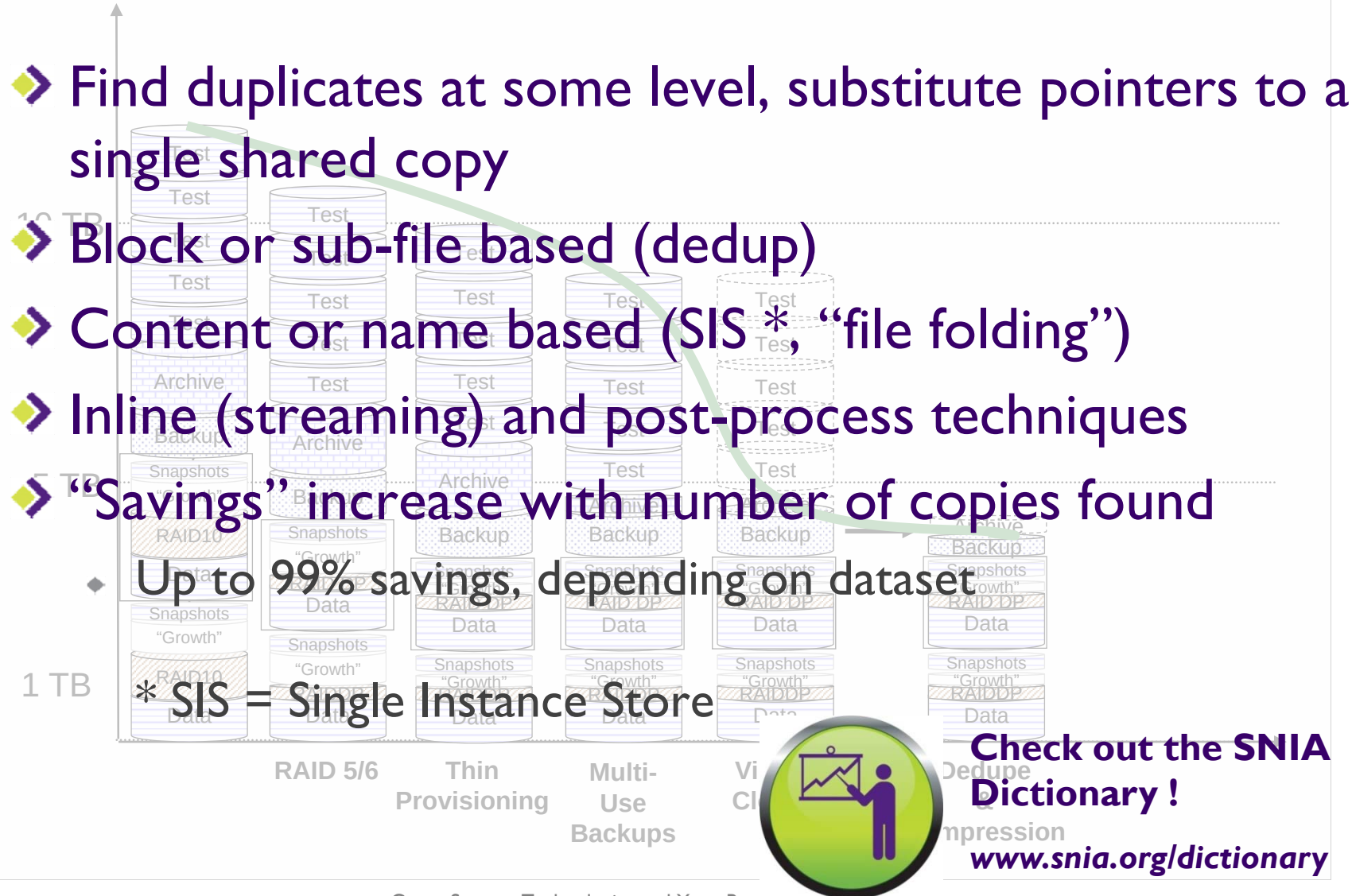
- Compression
  - Old and venerable
  - Origins in signaling, number and coding theory
    - Motivated by limited bandwidth and lossiness of satellite communications
  - Scattered throughout the data stack
  - Many formats already compressed
    - JPEG, MPEG, MP3, etc.
    - Lossless compression (LZW) necessary for unknown data types
  - Configuration matters
    - Compress before encrypting, decrypt before decompressing
  - Difficult in block-based environments
    - But products that do it are emerging



Deduplication and SIS

- Find duplicates at some level, substitute pointers to a single shared copy
- Block or sub-file based (dedup)
- Content or name based (SIS *, "file folding")
- Inline (streaming) and post-process techniques
- "Savings" increase with number of copies found
  - Up to 99% savings, depending on dataset

* SIS = Single Instance Store



Check out the SNIA Dictionary !

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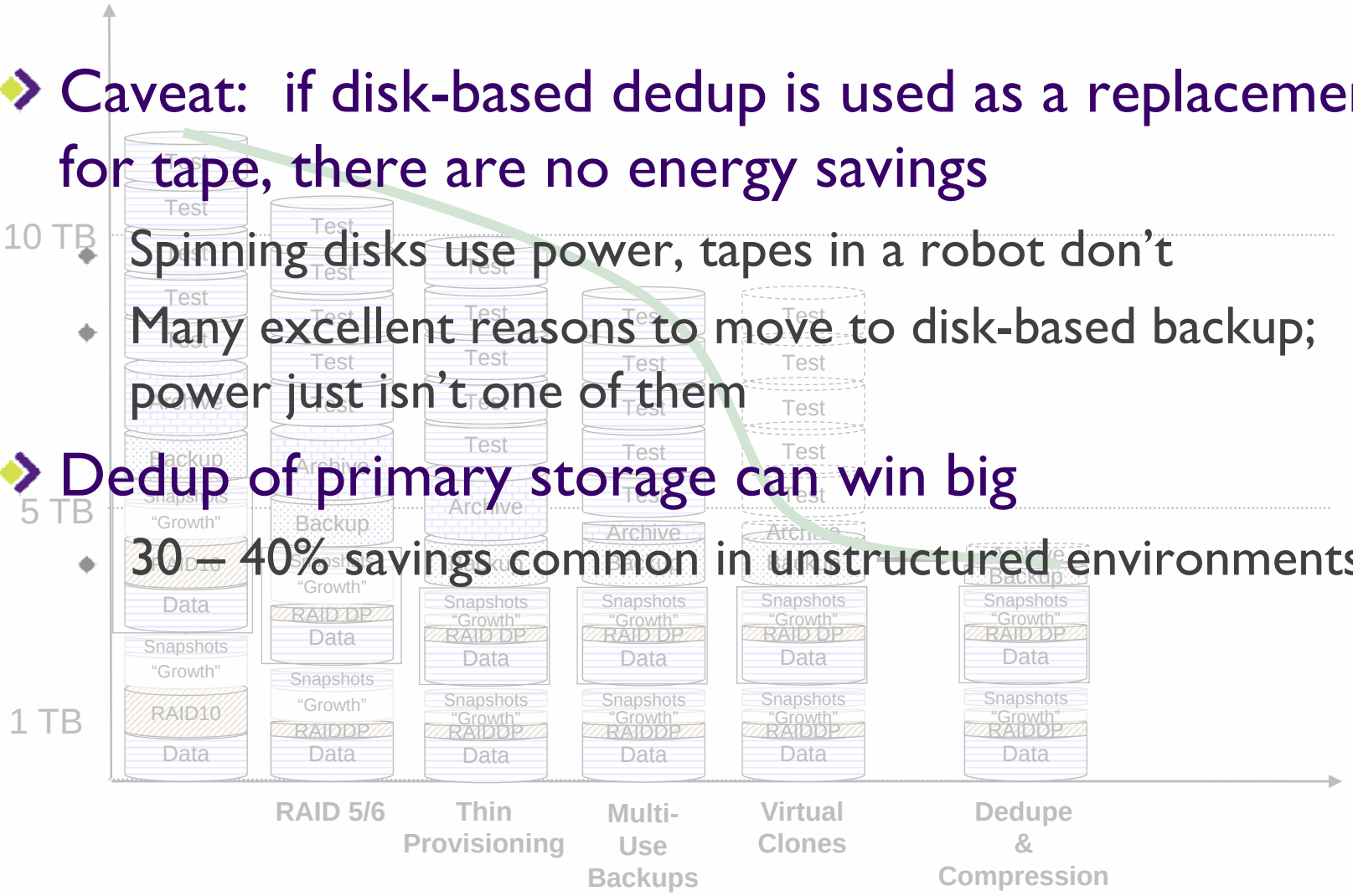
Dedup and energy

- Caveat: if disk-based dedup is used as a replacement for tape, there are no energy savings
  - Spinning disks use power, tapes in a robot don't
  - Many excellent reasons to move to disk-based backup; power just isn't one of them
- Dedup of primary storage can win big
  - 30 – 40% savings common in unstructured environments



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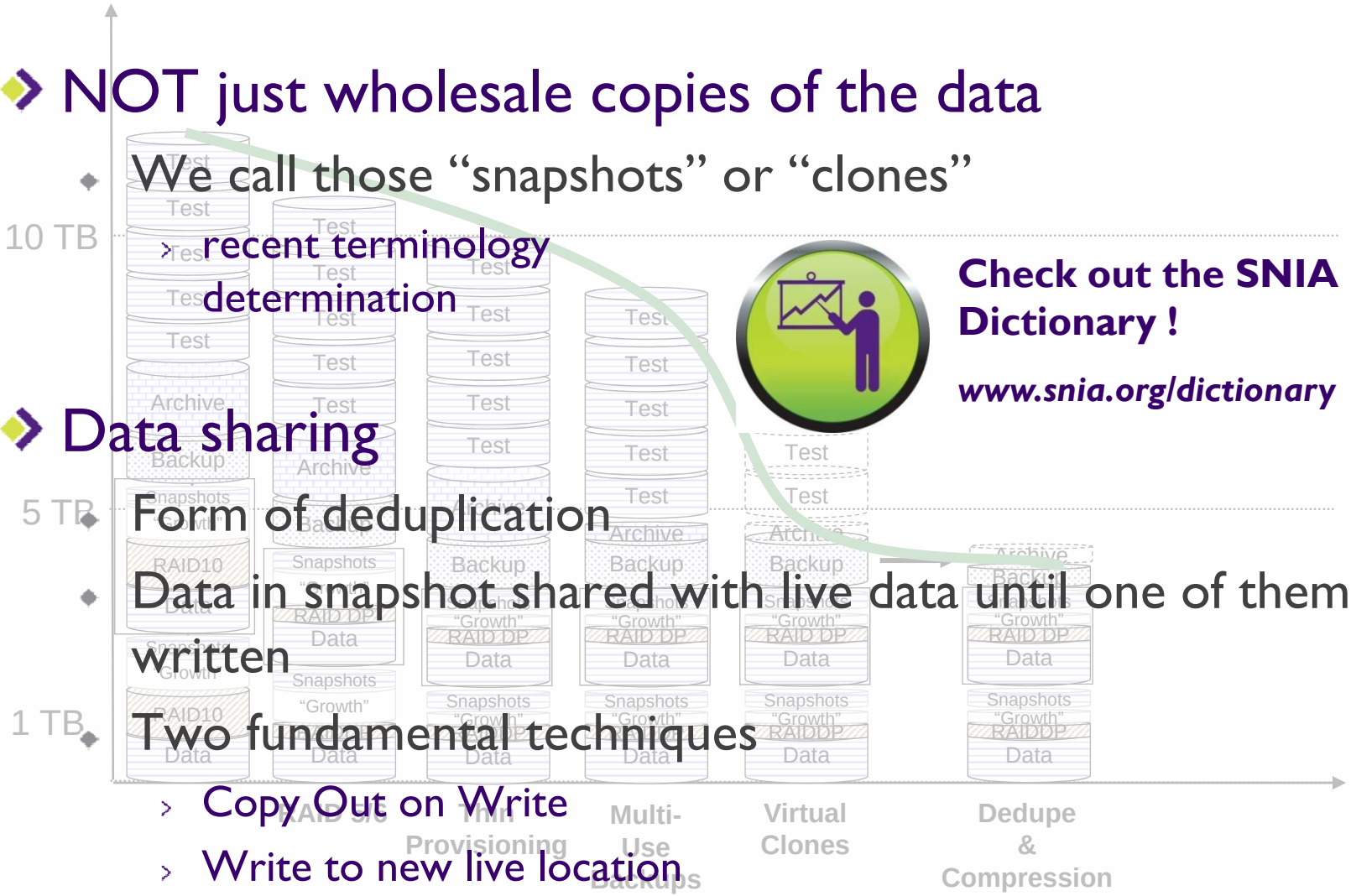

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Savings calculations

- Facilities power savings
- Equipment power savings
- Capacity savings
  - Dedup and compression
  - Thin provisioning
  - Delta snapshots, advanced RAID

Typical savings

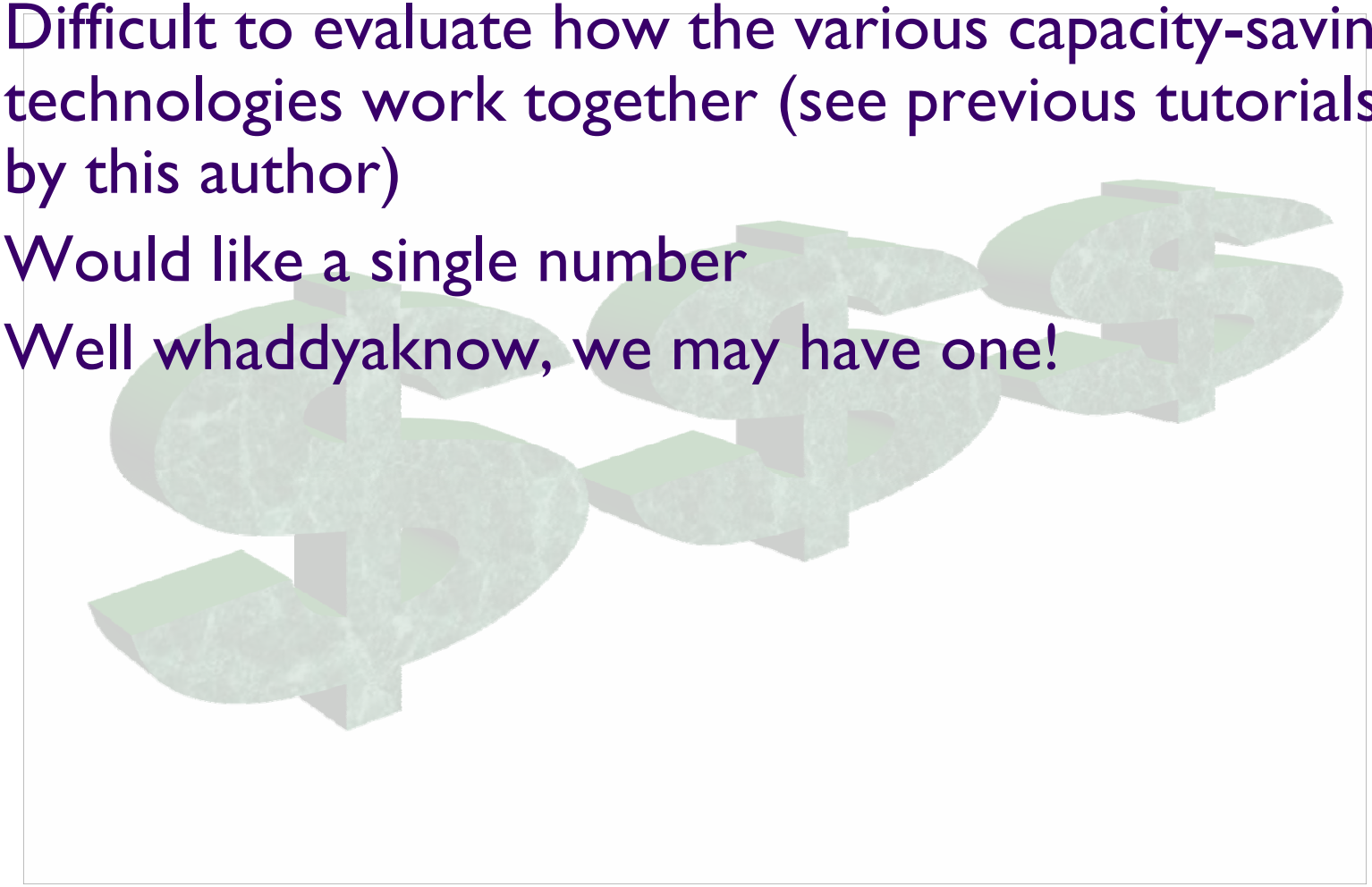
- Facilities
  - ~50% typical when moving to state of the art
- Equipment power savings
  - 20 – 30% overall (EPA says low 20's)
- Capacity savings
  - Dedup and compression
    - Primary storage (unstructured data): 25 – 40%
    - Secondary storage (streaming compression only): 50%
  - Thin provisioning
    - Move from 30% used to 80% used
  - Delta snapshots, advanced RAID
    - Savings linear in the # of snapshots
    - 10 – 20% overhead for RAID 5/6 vs. 50% for RAID 1/10

And the heavy hitters are...

- Facilities
  - ~50% typical savings when moving to state of the art
- Thin provisioning
  - 160% improvement in capacity utilization often achievable
- Advanced RAID
  - 40% reduction in disk requirements
- Fat slow drives
  - ~85% energy savings per unit data
  - Mind the performance caveat though!
- Tape (incl. streaming compression)
  - still the champ energy wise

Problems with measuring gains

- Difficult to evaluate how the various capacity-saving technologies work together (see previous tutorials by this author)
- Would like a single number
- Well whaddyaknow, we may have one!



Storage efficiency

- A way to look at--and actually measure--overall gains
- Three key quantities
  - How much data did I store?
  - How much unused usable space do I have left?
  - How much raw capacity did I start out with
- Ratio of the first two to the third is my *storage efficiency*
  - Storage efficiency = $\frac{\text{size of data + free space}}{\text{raw capacity}}$

Storage Efficiency - definitions

- Raw capacity
  - What the manufacturer says
- Formatted (usable) capacity
  - Raw capacity minus system overhead
  - Anything that can be assigned by the storage admin for application-level use
- Assigned capacity
  - Nominal size of a thin provisioned container
  - Can exceed formatted capacity
- Effective capacity
  - Amount of data that has been crammed into a container plus leftover free space
- Storage efficiency
  - Effective capacity / raw capacity

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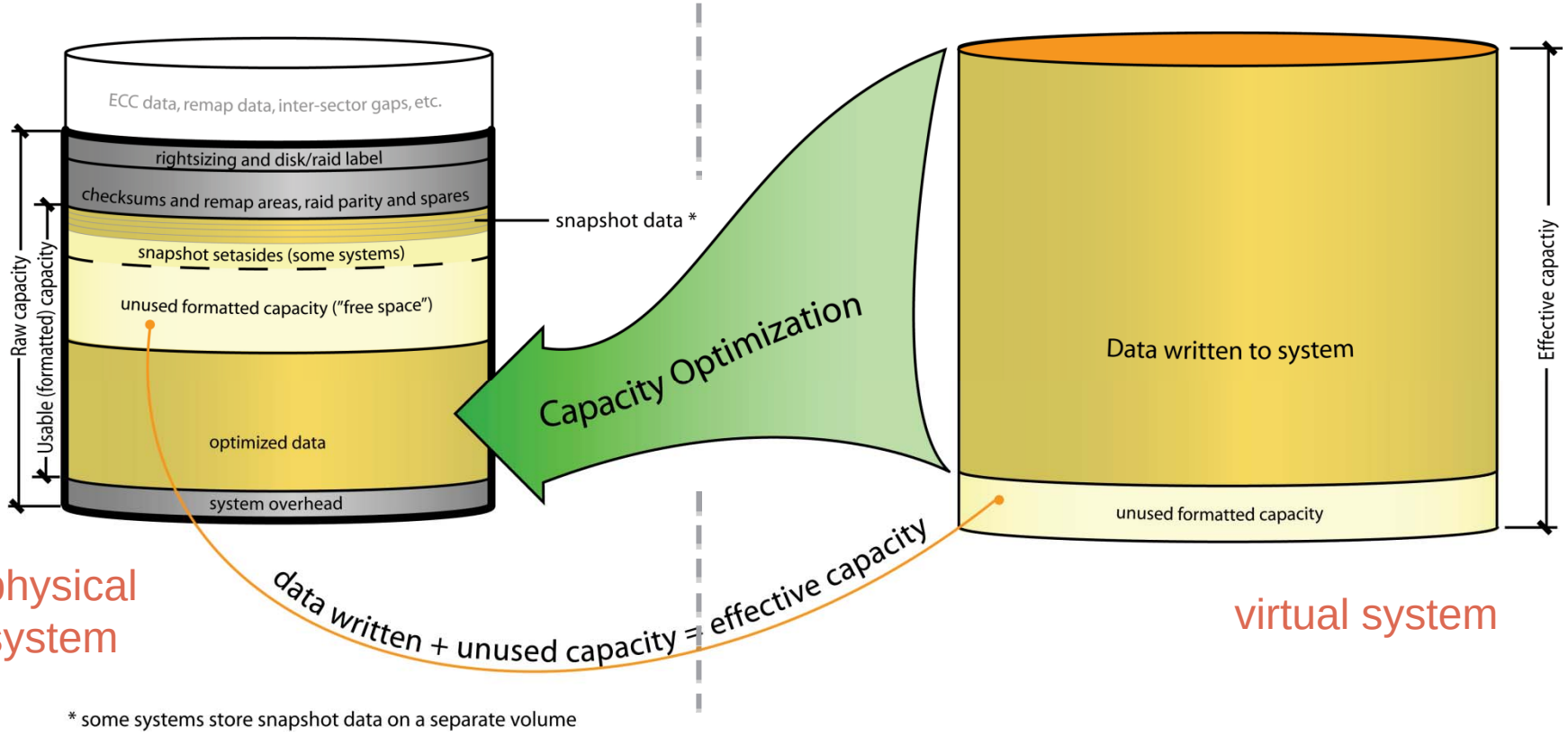
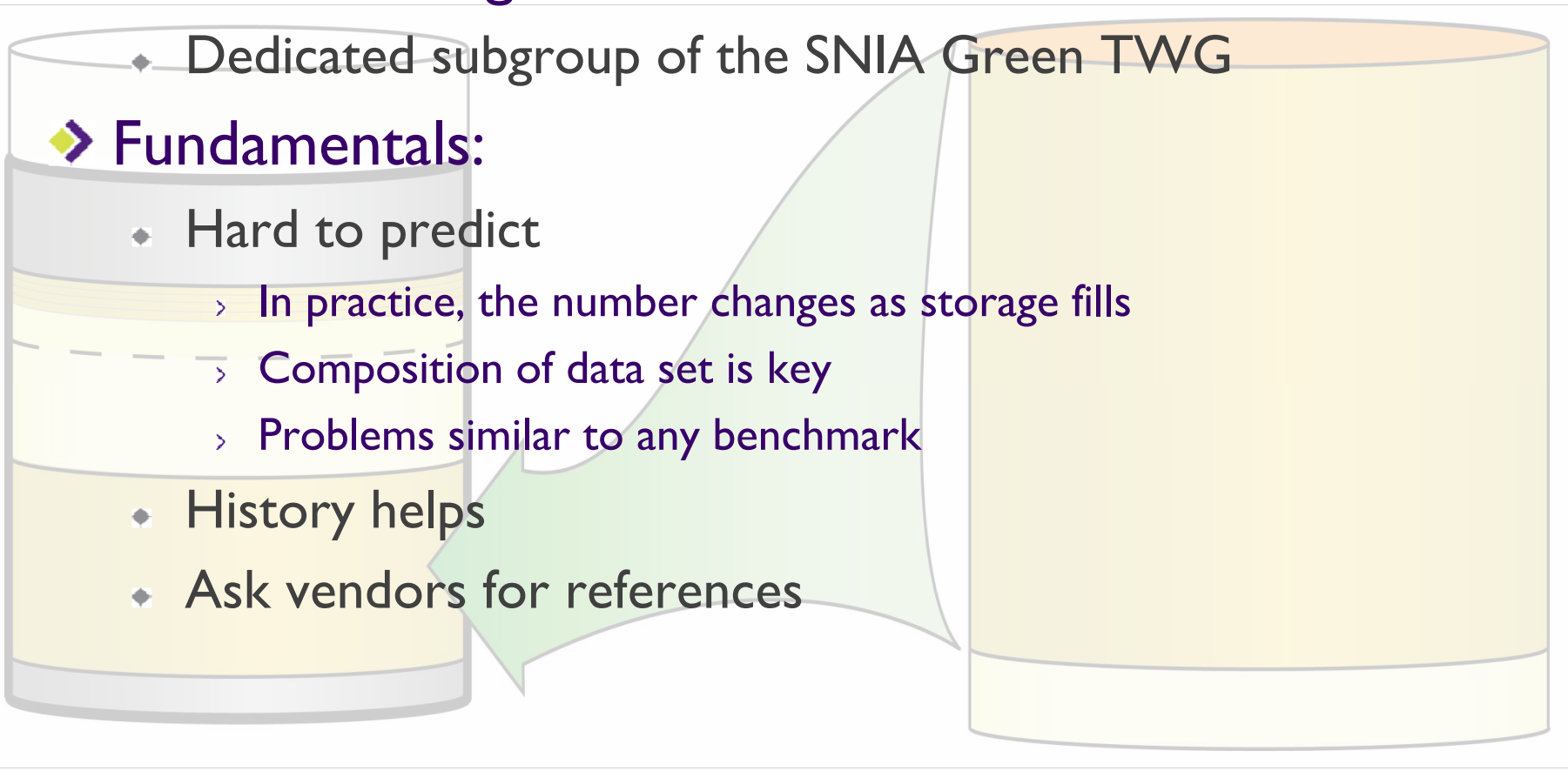
Storage Efficiency - illustration



$$\text{Storage Efficiency} = \frac{\text{Effective Capacity}}{\text{Raw Capacity}}$$

Storage efficiency – how to measure?

- We're working on it
  - Dedicated subgroup of the SNIA Green TWG
- Fundamentals:
  - Hard to predict
    - In practice, the number changes as storage fills
    - Composition of data set is key
    - Problems similar to any benchmark
  - History helps
  - Ask vendors for references



Takehome: the heavy hitters

- Facilities
  - Resources: The Green Grid, DOE
- Thin provisioning
  - Your kit probably has it: USE IT!
  - Document and compare before and after utilization, if possible
- Fat slow drives
  - Archive data, 2nd tier storage
  - Greatly expanded possibilities when fronted by large cache
    - Most unstructured data
    - Structured data with medium or low performance requirements
- Advanced RAID
  - If your vendor says RAID 6 doesn't work, it means they don't have it
- Tape
  - Oldie but goodie

Q&A / Feedback

- Please send any questions or comments on this presentation to *trackgreenstorage@snia.org*

Check out our other SNIA Green Tutorials!

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