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# Reducing E-Waste: Repurposing Old PCs and Laptops into Sustainable NAS Systems

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***Abstract*** **-** The global rise in electronic waste (e-waste) has impacted the world's economy and brought about significant environmental challenges. These challenges have highlighted the necessity for innovative strategies for once thought obsolete technologies into sustainable storage systems. We have explored how outdated hardware can be repurposed into functional, energy-efficient Network Attached Storage (NAS) systems to help reduce potential e-waste. Using Open Source Software and minimum system requirements, we have created customizable storage solutions that breathe life back into outdated hardware and promote sustainability within the ever-evolving tech industry.

***Keywords*****:** NAS, Open Source Software, Storage, Sustainable.

## 1. Introduction

As global technological advancements progress and reliance on newer electronics intensifies, the frequency of disposal of outdated technology has escalated. This has resulted in a significant increase in worldwide e-waste, which has lately been reported to be unprecedented [1]. Traditional methodologies for recycling are insufficient, necessitating the evaluation of other approaches to address this escalating issue. The primary objective of our investigation is to repurpose obsolete equipment, which would often be discarded, into usable and energy-efficient Network Attached Storage (NAS) systems.

A NAS is a device linked to a WiFi router, specifically engineered for file storage and enabling data transfer among all devices on the same network. A NAS is highly adaptable and might require minimal hardware components or be upgraded with more advanced ones [2]. A simple device such as a Raspberry Pi with a connected storage drive could be utilized this way. Another advantage of utilizing a NAS is that the stored data is typically available from any location globally, making it a good alternative to cloud storage. It provides complete control over the data and enables the scaling of storage space according to individual requirements [2].

To achieve our objectives, we have utilized discarded office equipment that was repurposed as a NAS device. This study delineates each phase of the procedure for constructing this device and also presents the tangible outcomes of this conversion, including the device's practical applications and its beneficial environmental impact when used on a larger scale.

The remainder of the paper is structured as follows: Section 1 has presented the rationale and context for the study, Section 2 provides a comprehensive overview of the technologies employed in our project, Section 3 delineates the essential hardware and software components required for the experiment, In section 4 we illustrate each phase of implementation and the operational project accompanied by testing components, Section 5 presents the outcomes obtained from our experiment, and in Section 6 our conclusion is presented.

## 2. Background Overview

Network Attached Storage systems are centralized file storage solutions that simplify data management across connected devices. It is commonly used for file storage, media streaming, and backups for data redundancy. For example, many small businesses use NAS systems to store project files, allowing team members to access the files without having to rely on other forms of delivery methods such as flash drives and emails. These systems can act as private cloud servers that offer secure remote access to files with the benefit of being cost-effective. It also offers advantages such as parallel I/O, incremental scalability, and lower operating costs [3].

Beyond traditional storage roles, NAS systems can be customized to run other open source software. Many open source software can run on outdated hardware, reducing e-waste by turning old computers into functional servers. Older desktops can be repurposed to address various needs, from providing centralized media servers for households to acting as cost-effective hosts for small businesses. Redundant Array of Inexpensive Disks (RAID) technology involves tying together several hard drives into one to improve performance, data redundancy, or both. It protects data by spreading it out across several disks to ensure that, upon the failure of one disk, data may still be recovered; it enhances speed because data can be read and written simultaneously across multiple drives. Common RAID Level in NAS is RAID 0-Striping: Performance increase, with no data redundancy. RAID 1-Mirroring: The same data is written for two drives for redundancy. RAID 5-Striping with Parity: A very efficient balance between redundancy and performance. In this, the failure of one disk does not lead to any data loss. RAID 6-Double Parity: Can support up to two disks in redundancy. RAID 10 (1+0) combines high performance with redundancy, combining RAID 1 and RAID 0. RAID in NAS delivers such vital features as data availability, security, and better performance within storage environments.

### 2.1. NAS Operating Systems

Network Attached Storage systems (NAS) employ specialized operating systems engineered to manage storage resources and facilitate smooth network-based data access. Numerous operating systems (OS) are available for use in Do It Yourself (DIY) builds; we briefly examine some of the most common ones. Typically, these operating systems are open-source and available at no cost; however, a notable exception is UnRAID, which requires a paid license. It is acclaimed for its user-friendliness and offers the capability to create containers, along with access to thousands of applications and plugins, including encryption utilities, AI tools, security services, and game servers. This operating system would be advantageous for individuals prepared to incur additional expenses or for small enterprises. An alternative noteworthy choice is the OpenMediaVault operating system, commonly utilized with lower-end devices such as mini-PCs and obsolete laptops, attributed to its minimal hardware demands. Despite its minimal requirements, it is replete with numerous capabilities, including Docker containers and support for ZFS and various other file systems. Lastly, we identified the selected software for our project, which is TrueNAS Core. TrueNAS Core is meticulously engineered for data archiving and is well regarded for its stability as the most popular Open Source Operating System. While somewhat less impressive than its counterpart TrueNAS Scale, it nonetheless offers substantial functionality and security features, including the implementation of OpenZFS and numerous plugins that enhance its capabilities [4].

### 2.2. Software in NAS Systems

Repurposing outdated hardware into functional NAS systems relies on selecting and configuring software that maximizes the potential of aging components. The software must be lightweight, efficient, and capable of running on hardware with limited processing power and memory. Open Source NAS operating systems like TrueNAS, OpenMediaVault, and UnRAID offer robust solutions for transforming old machines into reliable storage hubs. These NAS operating systems provide features such as file-sharing protocols (SMB, NFS, FTP), user management, and remote access capabilities. Additionally, they allow for easy integration of features like media servers and backup automation, catering to diverse user needs. For example, OpenMediaVault, built on Debian Linux, offers a user-friendly web interface for configuring storage, managing permissions, and monitoring system performance.

Energy efficiency is another critical factor addressed by NAS software. Many operating systems include power-saving modes and features such as scheduled shutdowns or disk spindowns to reduce energy consumption. Security is equally prioritized, with built-in tools for encrypting data, managing user access rights, and setting up firewalls. The choice of software directly impacts the system's scalability, performance, and ease of use. With the proper configuration, even hardware deemed obsolete by modern standards can be a cost-effective, sustainable alternative to commercial storage solutions. This step is foundational in creating a versatile NAS system and complements the integration of advanced tools like Docker for further functionality.

### 2.3. Docker and Its Role in Repurposing Old Hardware for NAS Systems

The software side of repurposing old computers into NAS systems involves selecting an efficient NAS operating system such as TrueNAS, OpenMediaVault, UnRAID, Ubuntu Servers, and more. It also involves configuring file-sharing protocols, securing data, and utilizing energy-saving features. You can also extend functionality by integrating media servers, Docker containers, and virtualization. With these software aspects, we can effectively create a sustainable and valuable NAS system from old hardware, reducing e-waste and maximizing resource utilization [5] [6].

In transforming outdated computers into efficient NAS systems, Docker plays a pivotal role in enhancing the software capabilities and versatility of the repurposed hardware. Docker containers provide a lightweight and portable environment to run applications, enabling consistent performance across different setups without the overhead of traditional virtual machines. By leveraging Docker, even older machines can efficiently host modern software applications required for advanced NAS functionalities [5].

Docker’s ability to isolate applications within containers ensure that resources are utilized optimally, which is critical when working with hardware with limited processing power or memory. Containers can host various applications, such as file servers, media servers, or backup tools, all operating independently yet cohesively. This modularity allows users to expand or modify the NAS system's capabilities without extensive reconfiguration.

Additionally, Docker's scalability makes it ideal for NAS systems, especially when paired with microservices architecture. For example, a repurposed machine could run containers for file sharing, media streaming, and data synchronization, each as a separate service. Additional services can be deployed in new containers with minimal resource conflicts as needs grow. This approach not only maximizes the use of existing hardware but also reduces energy consumption, aligning with our project’s goal of minimizing e-waste.

Studies highlight Docker's efficiency compared to traditional virtual machines, showing that containers reduce resource overhead while maintaining strong application isolation, making them highly suitable for energy-efficient setups [4]. By integrating Docker, repurposed NAS systems gain enhanced functionality and flexibility, bridging the gap between sustainability and modern technological demands. This makes Docker an essential tool in redefining the potential of obsolete hardware for environmentally friendly storage solutions [5].

### 2.4 File Systems in NAS Software

The choice of file system is critical in NAS software, as it determines how data is stored, accessed, and managed. Modern NAS systems often utilize advanced file systems like ZFS (used in TrueNAS) and Btrfs (used in Rockstor) for their features. ZFS provides data integrity through checksums, snapshots for point-in-time recovery, and efficient data compression. Similarly, Btrfs offers flexible volume management, data deduplication, and error detection. These file systems ensure reliability, scalability, and optimal performance, making them ideal for sustainable storage solutions [5] [7].

## 3. Implementation Requirements

Although technology constantly evolves, TrueNAS, an open-source operating system designed for NAS, can play a pivotal role in reducing e-waste by repurposing outdated hardware. Our hardware consists of an obsolete GDC Projector Server with 2GB DDR3 RAM and an Intel Core 2 Quad CPU. This hardware is generations behind what is now considered entry-level and no longer meets the minimal requirements of the latest Windows operating systems. Computers such as this are often regarded as e-waste as they are perceived as having no purpose today, but using TrueNAS, we gave this outdated system a new purpose as a NAS system. While external hard drives provide convenience, this NAS system with proper software configurations, can provide fail-safe to prevent loss of data in case of disk failures.

Secondly, we employed the use of a dedicated QNAP NAS server with some of the newest components available. This server runs on a Quad Core ARM Cortex CPU and 8GB DDR4 RAM. The price range of this type of server can vary between $500 and $800. At this price range, a dedicated NAS system can be a hefty financial investment for many. Meanwhile, an old PC can range anywhere between $0 and $50 depending on where one looks, considering that many of these computers are now obsolete. The QNAP NAS server will run its dedicated NAS software provided by QNAP, and our repurposed system will run TrueNAS with a 1GB network and 300-watt power supply.

## 4. Methodology Employed

NAS systems can function as effective storage solutions based on their physical dimensions and energy usage. By utilizing an obsolete projector server that previously operated on a customized version of Linux, we may repurpose its components to function as a NAS system. Despite the availability of specialized NAS systems, we can evaluate the performance of both our repurposed system and the dedicated NAS system. We measured power usage using a wattmeter during idle and operational modes and compared their efficiency.


Fig. 1: Theater Server Rack.

Fig. 1 above illustrates the repurposed projector server. (Images of the theater's server rack and QNAP graphical user interface are omitted for security purposes.)

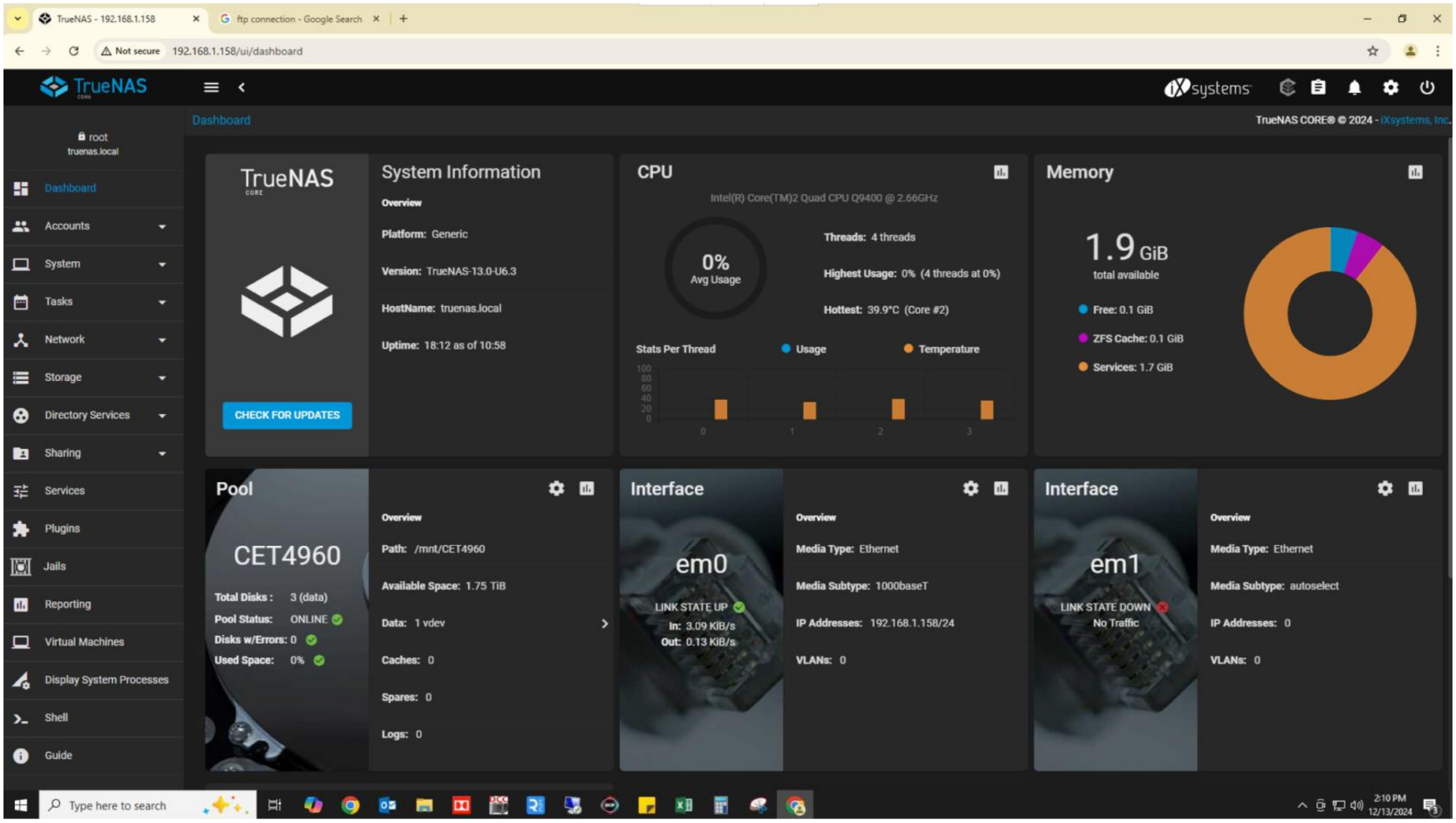


Fig. 2: TrueNAS Dashboard.

Fig. 2 above illustrates the converted projector server using TrueNAS, along with its dashboard. The dashboard indicates that the system operates with 2GB of RAM and an Intel Core 2 Quad CPU, last upgraded in 2008.

## 4.1. Testing Conditions

To provide the most accurate measurements, both systems were running in a climate controlled server room provided by a local movie theater. The environmental conditions were set to 68°F with proper ventilation and airflow to reduce humidity which could potentially affect the system's performance. Aside from the temperature of the room, both systems were connected to the same Uninterruptible Power Supply (UPS) to provide stable power and prevent any spikes or drops during testing. The network cards in both systems were rated for 1GB with both connected to the same network infrastructure with equal bandwidths. Finally, both systems were set to be transferring the same files (125GB) to the same computer at individual tests to ensure maximum bandwidth.

## 4.2. Data Collection

To measure the power consumption of the systems we made use of two wattmeters. Since both systems were connected to the same UPS, it was not necessary to calibrate the wattmeters since the UPS provides a stable flow of power. Once our systems were up and running we recorded the wattage of each system during their idle states, with no workload being performed on either system. Once ready, we conducted the file transfer of our 125GB file, which should take approximately 15-20 minutes to complete on both systems. At this phase, each system were running at peak loads, providing us with the highest power readings on our wattmeter. We present the recorded of all our findings in the next section.

## 5. Results

Both NAS systems were under load for about the same amount of time with our system completing the 125GB transfer in approximately 20 minutes. The QNAP NAS server beat our time by one minute completing the transfer in approximately 18 minutes. The performance was similar but the difference is most apparent in power consumption. The graph below details the typical wattage during the transfers in two-minute intervals.

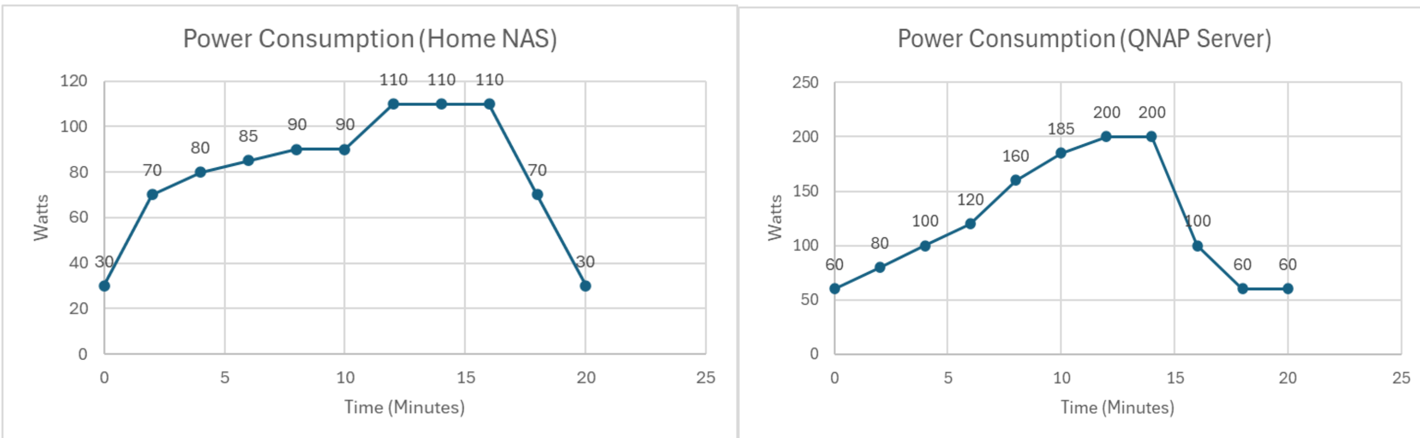


Fig. 3: Power Consumption graphs of both NAS Systems.

From Fig. 3 in the graphs above we can notice the idle wattage of both NAS systems, with our system consuming approximately 30 Watts and the commercial QNAP Server consuming approximately 60 watts. This idle wattage is typical considering that both systems must be continuously running for users to access their data at a moment's notice. Their transfers were done separately to ensure that their maximum one gigabit bandwidth wasn't shared between both systems. Once the transfer starts, both systems are utilizing their four hard drives to write the data into their ZFS file systems. Since our system is using outdated components, the maximum wattage consumed is about 110 Watts; meanwhile the QNAP consumes almost double the amount for a rather insignificant speed difference. On average, our system consumed approximately 80 Watts through its entire transfer while the QNAP server's average was 120 Watts. Although the QNAP had newer components, being used strictly as a NAS, it performed similarly to our Home Server that used outdated parts. This is because the QNAP server is limited by the bandwidth of the network. Considering that most home computers run off one-gigabit networks, the QNAP was at a severe disadvantage since it was not capable of using its 2.5 gigabit Ethernet port. The one minute difference is not a significant difference to warrant the use of this kind of commercial server in home settings. The more convenient recycled PC performed similarly while also consuming significantly less wattage.

Strictly from a power consumption standpoint, our home server consumes 30 watts, which if ran continuously for one month in NYC at twenty-eight cents per kWh, is approximately $6.05. With the QNAP server that would equate to $12.10 per month, this could be an impactful difference for one's electrical expenses [9]. Essentially, one would be paying double the price for a NAS system that has similar performance to an outdated machine. Instead of discarding this outdated hardware and increasing the load of e-waste, one can create a NAS system that performs just as efficiently as a brand new machines.

Repurposing this obsolete equipment offers significant practical benefits, including energy and cost savings, while also addressing the growing e-waste issue. The United States discards about 300 million electronic goods annually, of which less than 20% gets recycled [3]. The U.S. Environmental Protection Agency (EPA) believes that over 30 million of these devices are likely to be outdated PCs. This experiment, corroborated by research, demonstrates that repurposing existing PCs is more efficient than purchasing new ones for similar reasons. If we could persuade even a small fraction of one million devices each year to adopt our methods and repurpose obsolete equipment instead of discarding them, it would conserve energy equivalent to that consumed by 3,600 houses in the United States annually. This will also prevent the generation of about 10,000 to 25,000 tons of environmentally detrimental E-waste [1].

## 6. Conclusion

The findings of our study highlights the potential of repurposing outdated hardware to create sustainable and cost-effective NAS systems. By transforming obsolete computers into functional storage solutions, individuals can significantly reduce e-waste while achieving performance comparable to commercial alternatives. The repurposed NAS system demonstrated lower power consumption, making it an economically viable option for home users operating on a budget. The cost savings in energy consumption alone and the minimal investment in recycled hardware present a compelling case for this approach. Furthermore, our study emphasizes that outdated machines can meet modern data storage and transfer needs with the proper configuration and use of open-source NAS software such as TrueNAS. Features like energy-efficient operations and file system reliability position repurposed systems as an environmentally and economically friendly alternative. We have also demonstrated the beneficial environmental effects of implementing our system using the suggested technique we gave, supporting our overarching objective of minimizing E-waste. This aligns with the broader goal of promoting sustainability in the tech industry while offering practical storage solutions for personal or small business use.

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