

Carbon-Aware Systemd Timers

Masterarbeit

December 3, 2024

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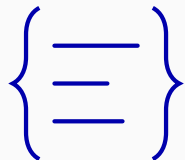


Lehrstuhl für Informatik 4
Systemsoftware



Friedrich-Alexander-Universität
Technische Fakultät

Carbon Emissions

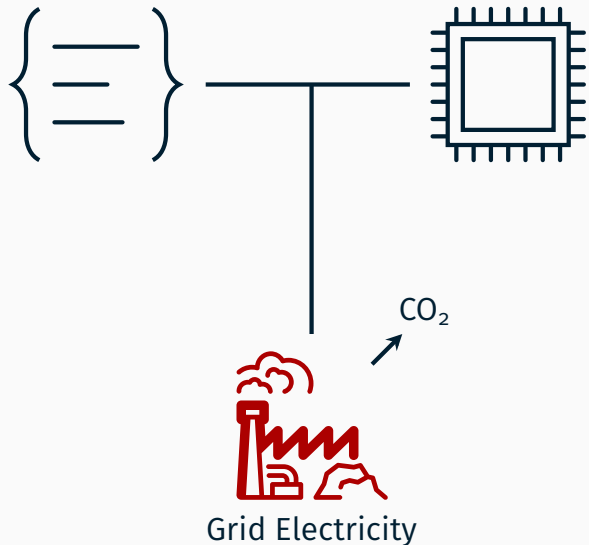


Software

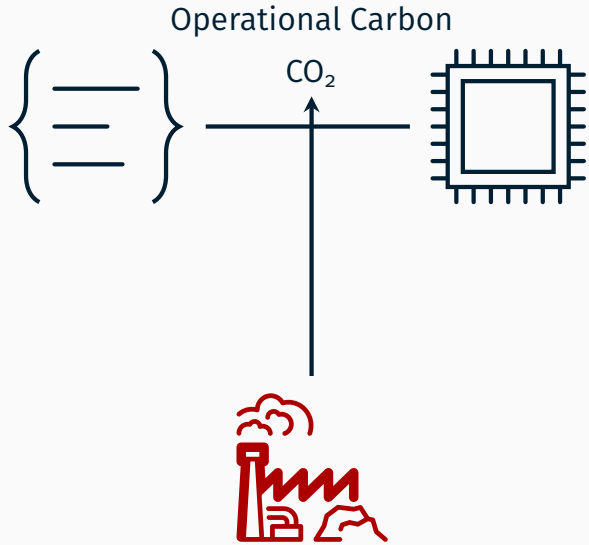
Carbon Emissions



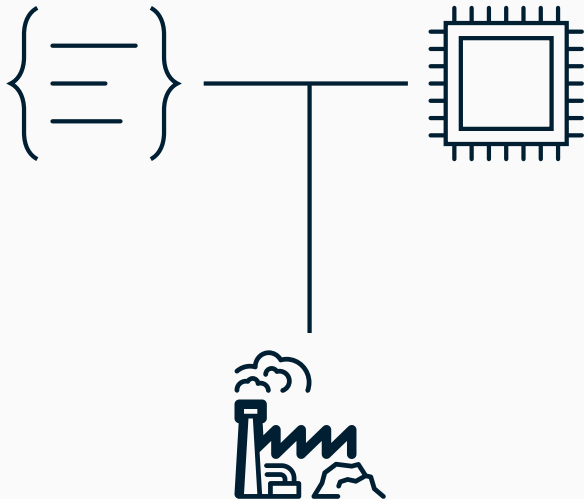
Carbon Emissions



Carbon Emissions



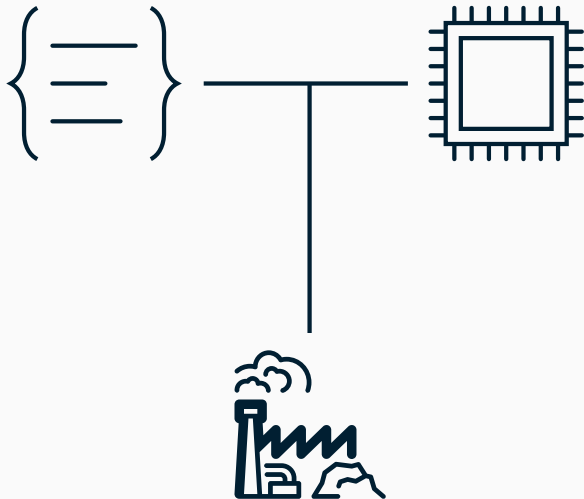
Motivation



Electricity Usage
by Datacenters
 $130TWh_{2018}$



Motivation



Electricity Usage

by Datacenters

$130TWh_{2018}$

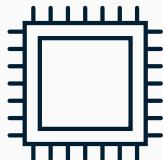
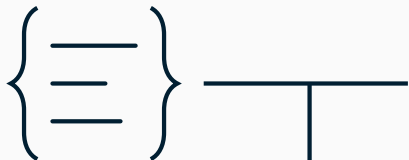


by Desktop Computers

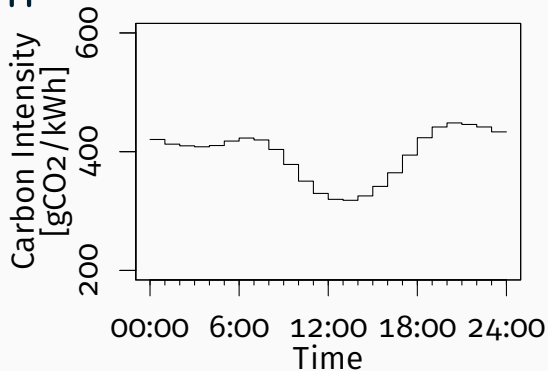
$132TWh_{2013}$



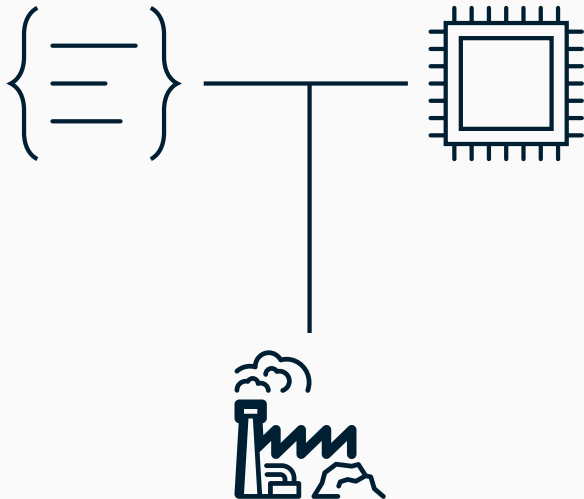
Motivation



Carbon Savings up to 29%



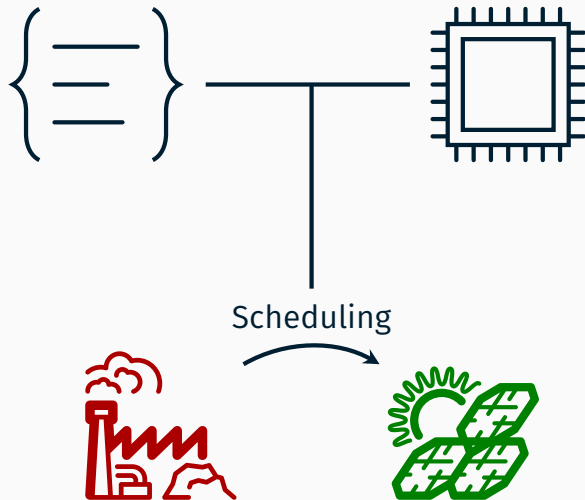
Goal



Goal:

- Reduce emissions
- on single machines
- with low effort

Approach



Goal:

- Reduce emissions
- on single machines
- with low effort

Carbon-Aware Scheduling

Temporal Shifting

Compatible Tasks

Carbon Emission Reductions

System Management Implementation

Summary

Carbon-Aware Scheduling

Datacenters vs. Single Machines

Datacenter

Scheduling Strategy:

- Geographic Shifting ✓
- Power Modeling ✓
- Temporal Shifting ✓

Datacenters vs. Single Machines

Datacenter Single Machines

Scheduling Strategy:

Geographic Shifting



Power Modeling



Temporal Shifting



Datacenters vs. Single Machines

Datacenter Single Machines

Scheduling Strategy:

Geographic Shifting	✓	✗
Power Modeling	✓	✗
Temporal Shifting	✓	✓

Environment:

Carbon Forecast Availability	✓
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Datacenters vs. Single Machines

Datacenter Single Machines

Scheduling Strategy:

Geographic Shifting



Power Modeling



Temporal Shifting



Environment:

Carbon Forecast Availability



Datacenters vs. Single Machines

Datacenter Single Machines

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Geographic Shifting	✓	✗
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Environment:

Carbon Forecast Availability	✓	✗
System Management	Custom	

Datacenters vs. Single Machines

Datacenter Single Machines

Scheduling Strategy:

Geographic Shifting



Power Modeling



Temporal Shifting



Environment:

Carbon Forecast Availability



System Management

Custom

Systemd

Datacenters vs. Single Machines

Datacenter Single Machines

Scheduling Strategy:

Geographic Shifting	✓	✗
Power Modeling	✓	✗
Temporal Shifting	✓	✓

Environment:

Carbon Forecast Availability	✓	✗
System Management	Custom	Systemd

Task Specification:

Deadlines	Fix
Resource Requirements	Fix

Datacenters vs. Single Machines

Datacenter Single Machines

Scheduling Strategy:

Geographic Shifting	✓	✗
Power Modeling	✓	✗
Temporal Shifting	✓	✓

Environment:

Carbon Forecast Availability	✓	✗
System Management	Custom	Systemd

Task Specification:

Deadlines	Fix	Unknown
Resource Requirements	Fix	Flexible

Temporal Shifting

Compatible Tasks



systemd

Utilize systemd timer



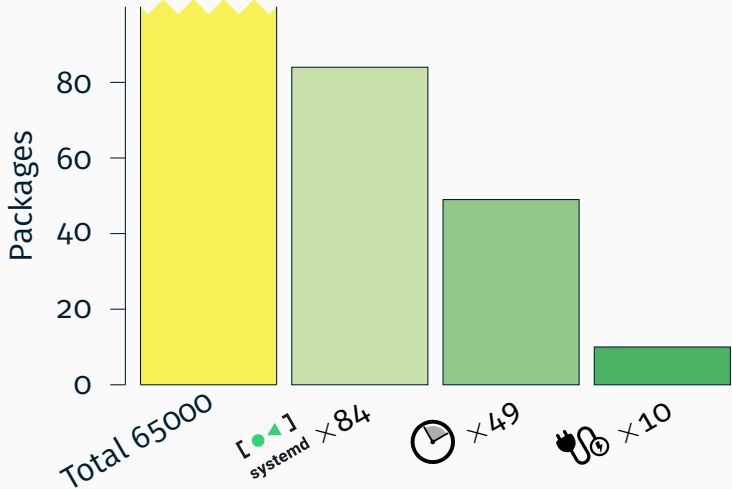
Delayable without impact on functionality



Electricity consumption high enough to allow carbon savings

Compatible Tasks in Debian

[● ◀]
systemd



Compatible Tasks in Debian

[● ◀]

systemd

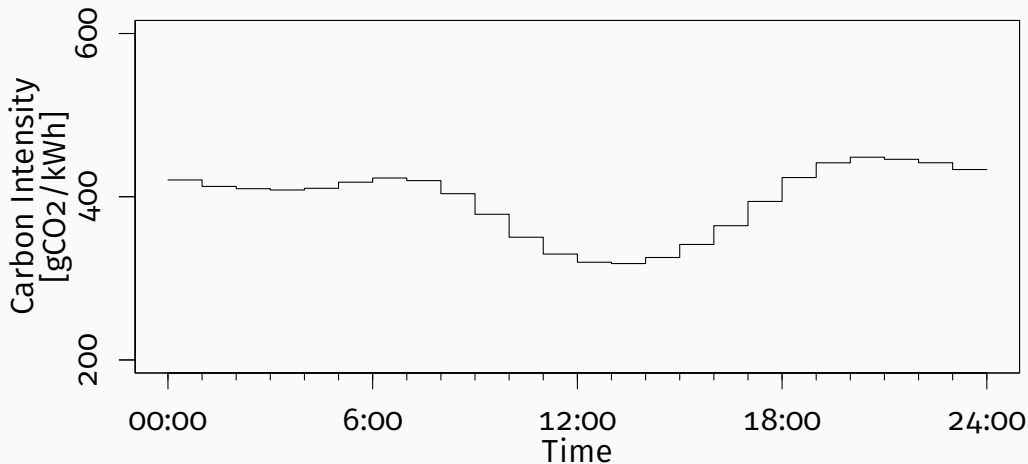


Package	Task	Frequency
borgmatic	backup	Day
btrbk	backup	Day
postgresql-common	backup+data checks	Day-Week
btrfsmaintenance	data checks	Month
e2fsprogs	data checks	Week
ocsinventory-agent	data checks+updates	Day
util-linux	data checks	Week
zfsutils-linux	data checks	Week-Month
apt	updates	Day
podman	updates	Day

- Borg Backup
- 45m Execution Duration
- Scheduled Daily
- Simulated across the full year 2023

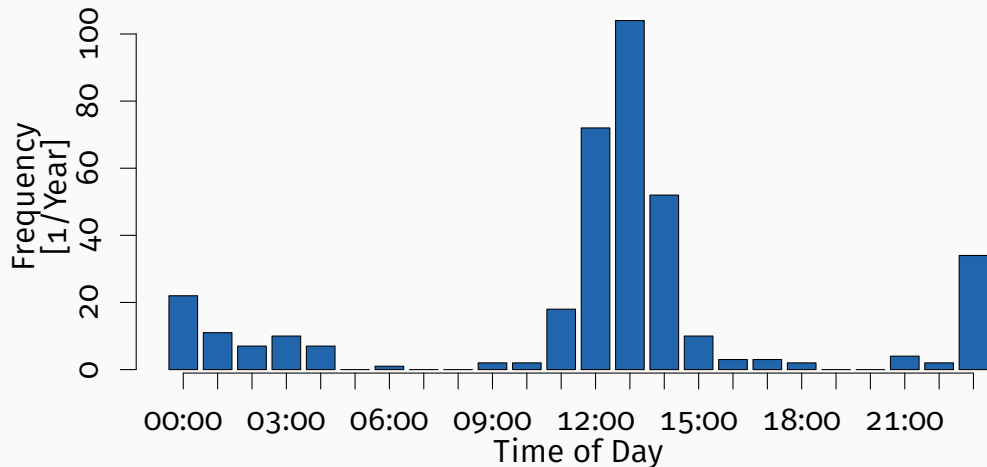
Carbon Intensity

Baseline Scheduling at 13:00 achieves
24% reduction in Carbon Emissions.



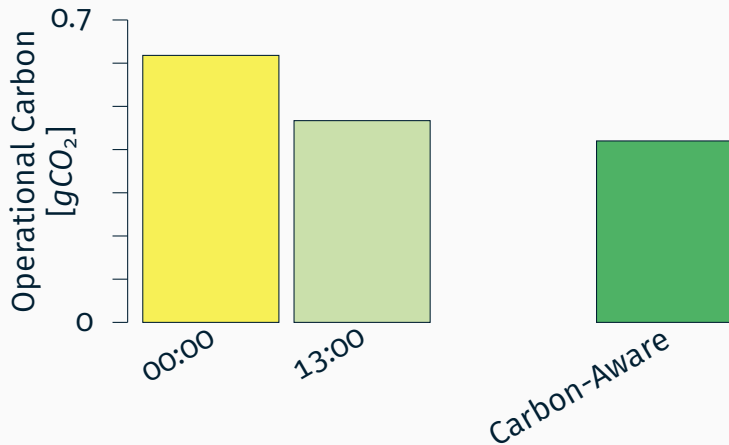
Carbon Intensity

Time of minimal Carbon Intensity **varies**.



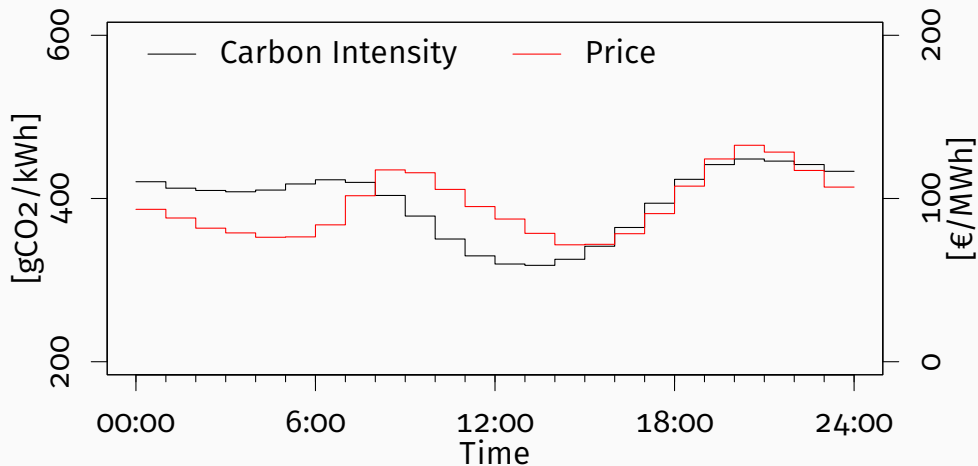
Carbon Emission Reductions

Carbon-Aware Scheduling achieves
32% reduction in Carbon Emissions.



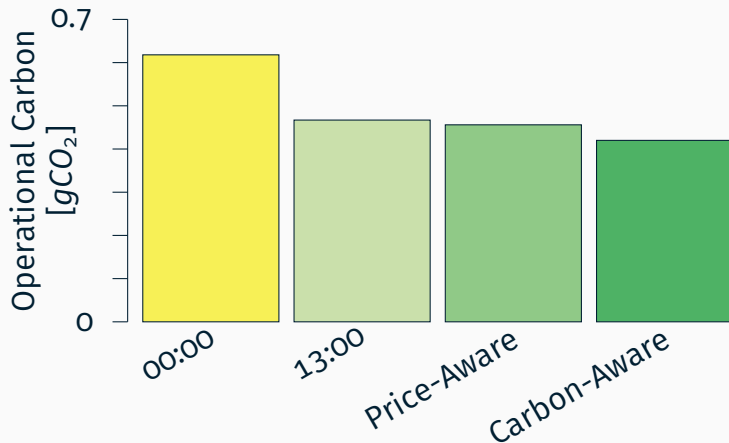
Day-Ahead Electricity Prices

Day-Ahead Prices follow **similar** patterns as Carbon Intensity.



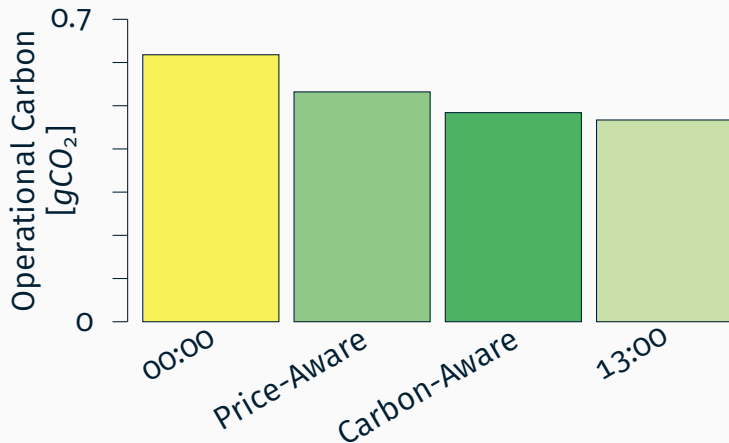
Carbon Emission Reductions

Price-Aware Scheduling performs comparable to Optimal **Unaware** Scheduling.



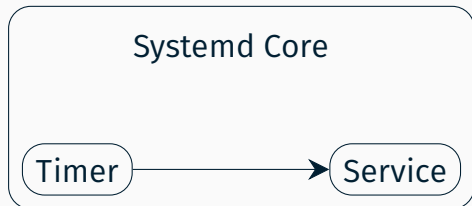
Carbon-Aware Scheduling

Emission Reductions while avoiding
core office hours (9:00-17:00)

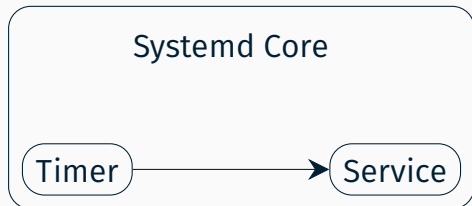


System Management Implementation

Systemd Modules

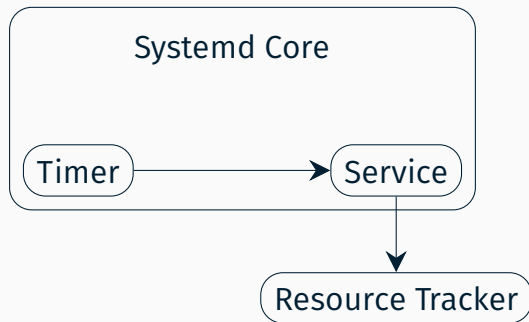


Systemd Modules



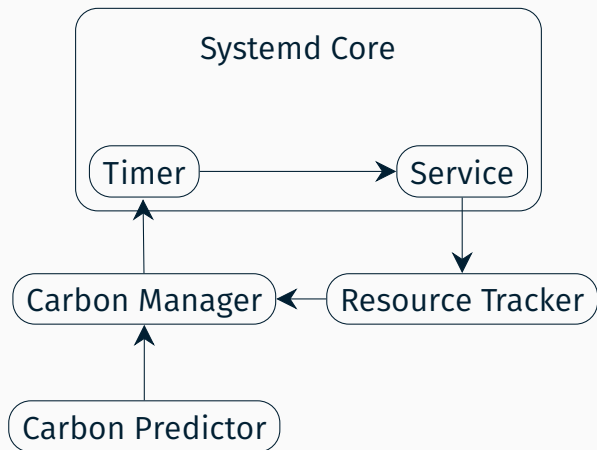
Carbon Predictor

Systemd Modules

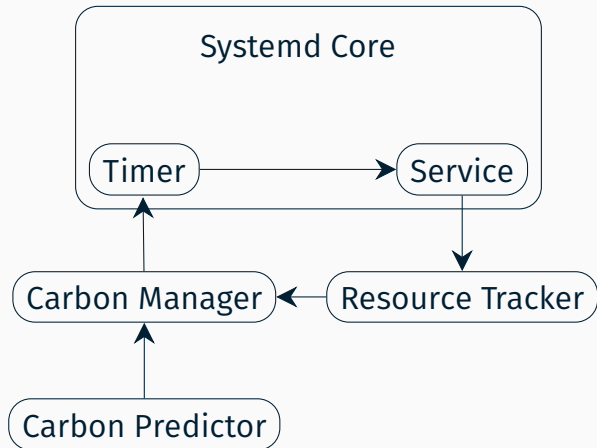


Carbon Predictor

Systemd Modules

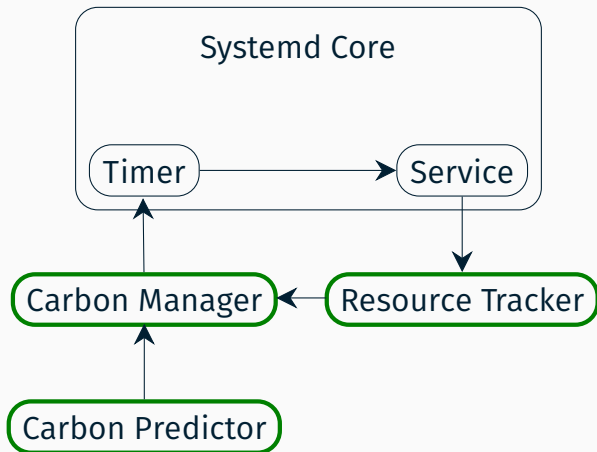


Systemd Modules



Benefits:

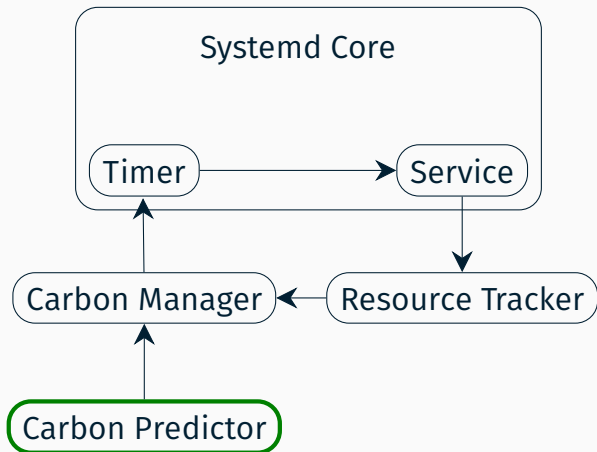
Systemd Modules



Benefits:

- Adaptability

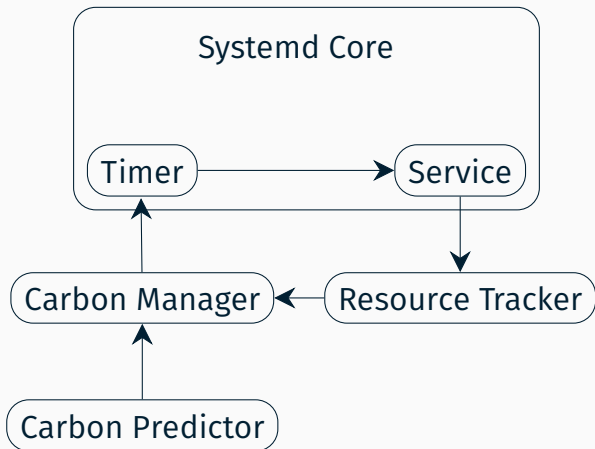
Systemd Modules



Benefits:

- Adaptability
- Abstraction from Region

Systemd Modules

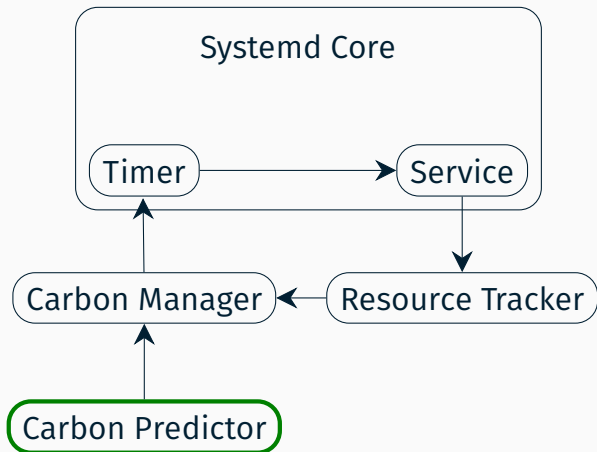


Benefits:

- Adaptability
- Abstraction from Region

Requirements:

Systemd Modules



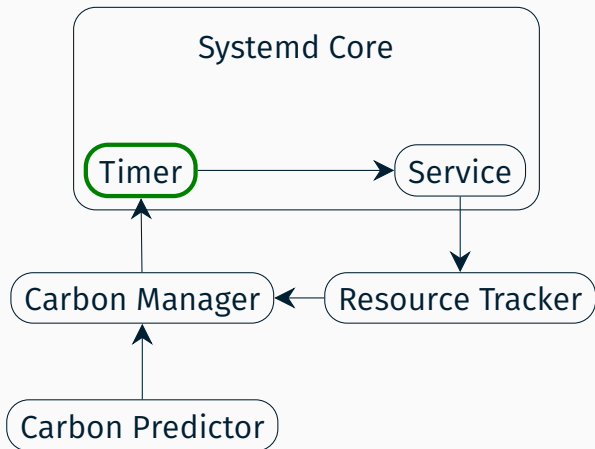
Benefits:

- Adaptability
- Abstraction from Region

Requirements:

- Forecast Access

Systemd Modules



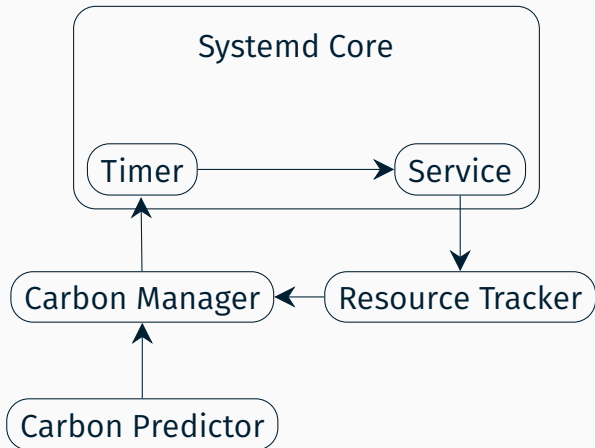
Benefits:

- Adaptability
- Abstraction from Region

Requirements:

- Forecast Access
- Marked Compatible Tasks

Systemd Modules



Benefits:

- Adaptability
- Abstraction from Region

Requirements:

- Forecast Access
- Marked Compatible Tasks

Summary

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Reduce emissions



on single machines



with low effort



Summary

✓ Reduce emissions



32% Reduction

□ on single machines



□ with low effort



Summary

✓ Reduce emissions



32% Reduction

✓ on single machines



Systemd

□ with low effort



Summary

✓ Reduce emissions



32% Reduction

✓ on single machines



Systemd

✓ with low effort



Requires only Forecast Access

Carbon-Aware Systemd Timers

Future Work

- Freely available Carbon Intensity Forecasts
- System Load Prediction
- Support Long-Running Interruptible Tasks
- Support Manual Tasks