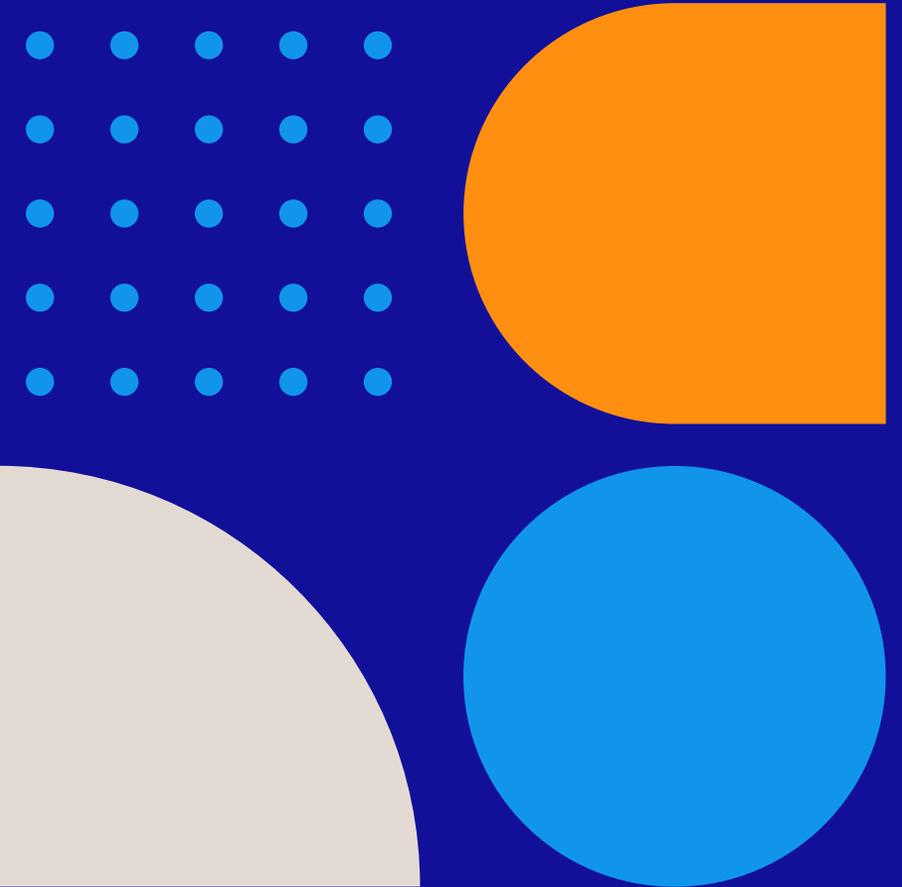


Ein Weg zu hoher Zuverlässigkeit von Systemen eines Netzbetreibers

Tim Digel

Netze BW | BOBKonf | 14.03.2025







Strategische Geschäftsfelder des EnBW Konzerns



Nachhaltige Erzeugungsinfrastruktur

- Erzeugung und Vermarktung von Strom aus erneuerbaren Energien und konventionellen Kraftwerken
- Fernwärmeerzeugung
- Speicherung von Gas
- Handel mit Strom und Gas, CO₂-Zertifikaten und Brennstoffen



Intelligente Infrastruktur für Kund*innen

- Vertrieb von Strom und Gas
- E-Mobilität
- Telekommunikation
- Heimspeicher für Solarstrom



Systemkritische Infrastruktur

- Verteil- und Transportnetze für Strom und Gas
- Wasserversorgung
- Erbringung netznaher Dienstleistungen



Netze BW

Ein Unternehmen der EnBW



Systemkritische Infrastruktur

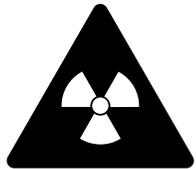
- Verteil- und Transportnetze für Strom und Gas
- Wasserversorgung
- Erbringung netznaher Dienstleistungen



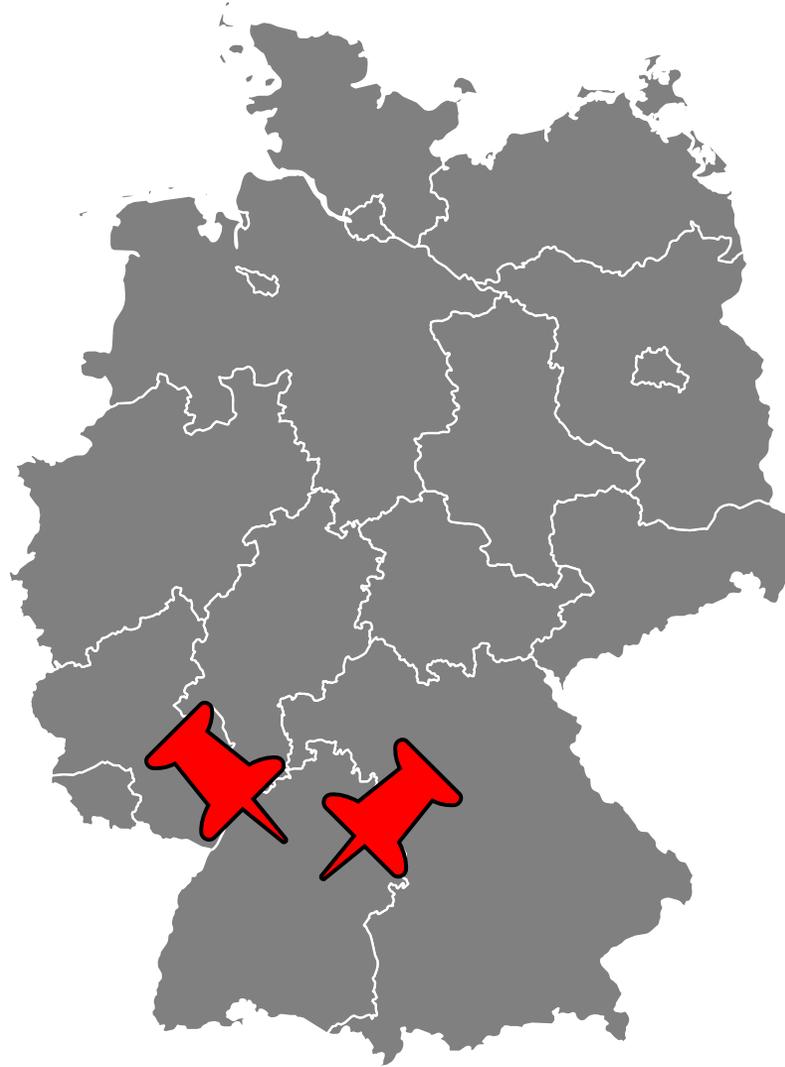




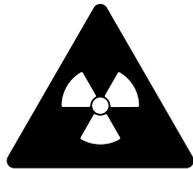
Quelle Bilder: enbw.com



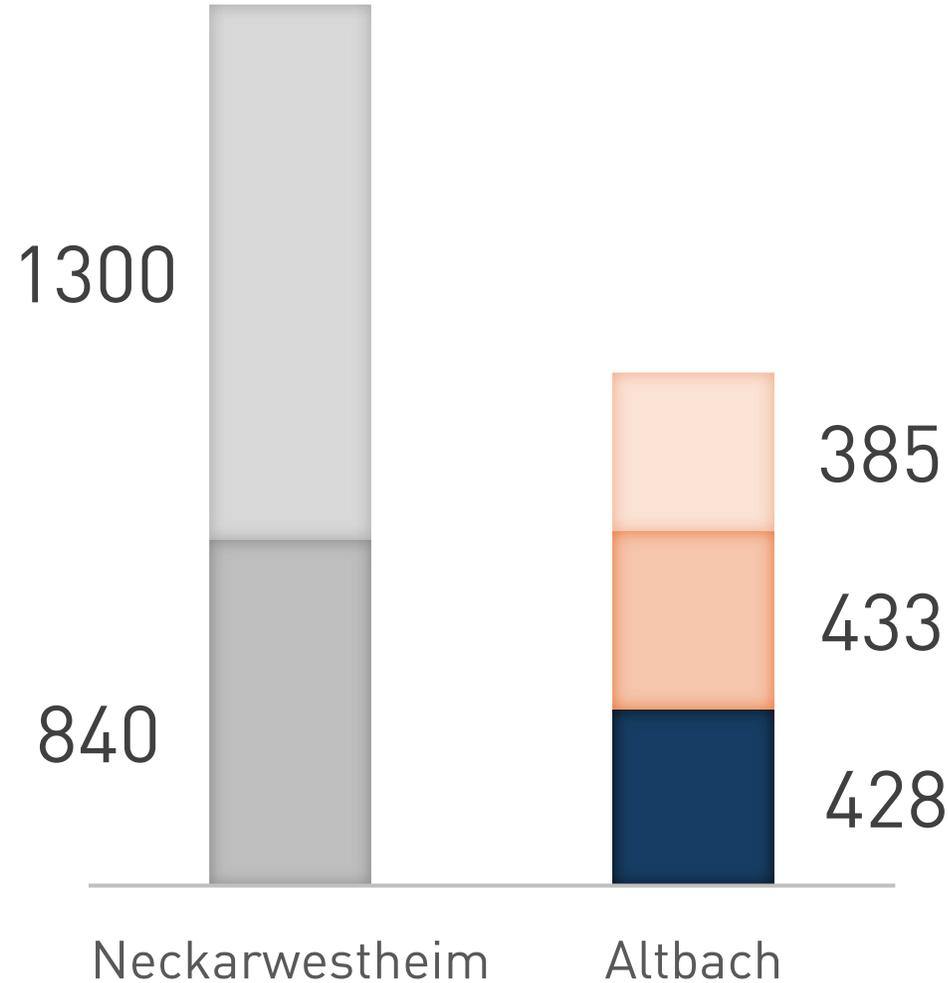
Neckarwestheim



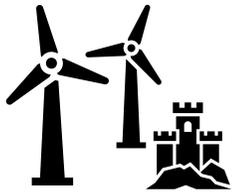
Altbach



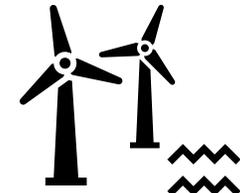
Neckarwestheim



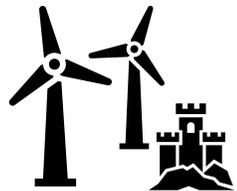
Altbach



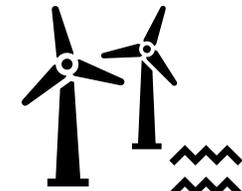
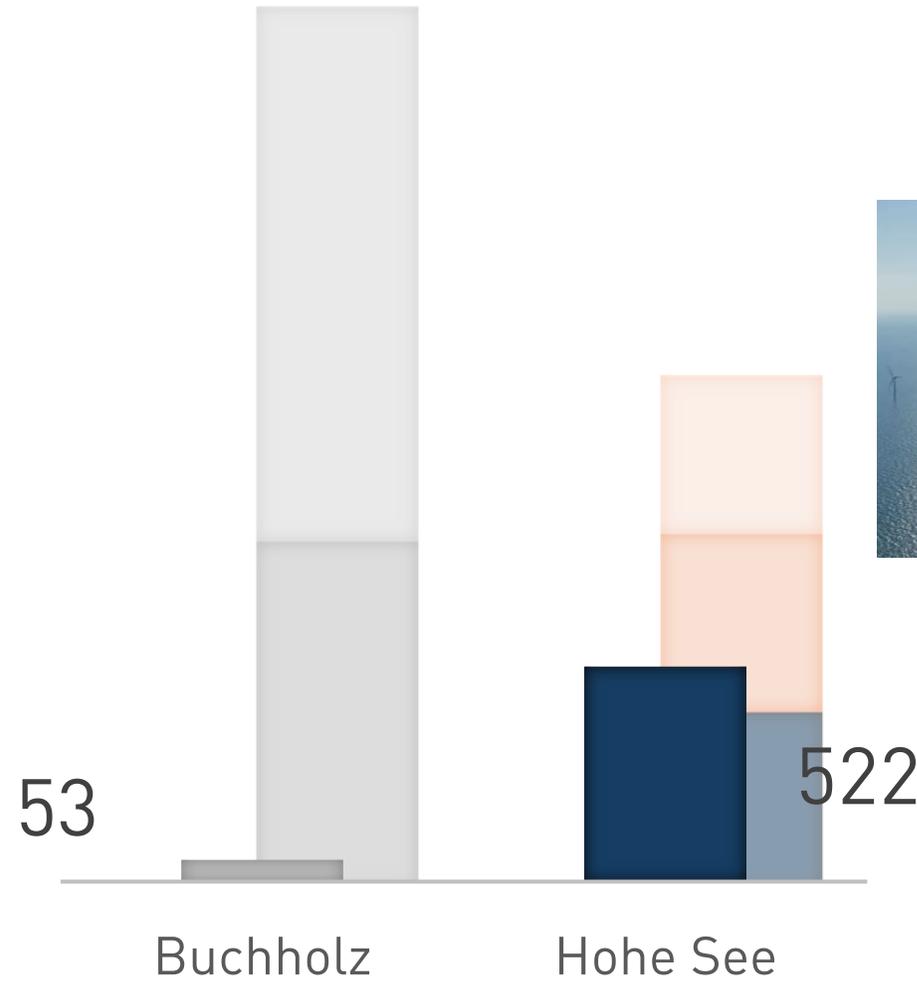
Buchholz



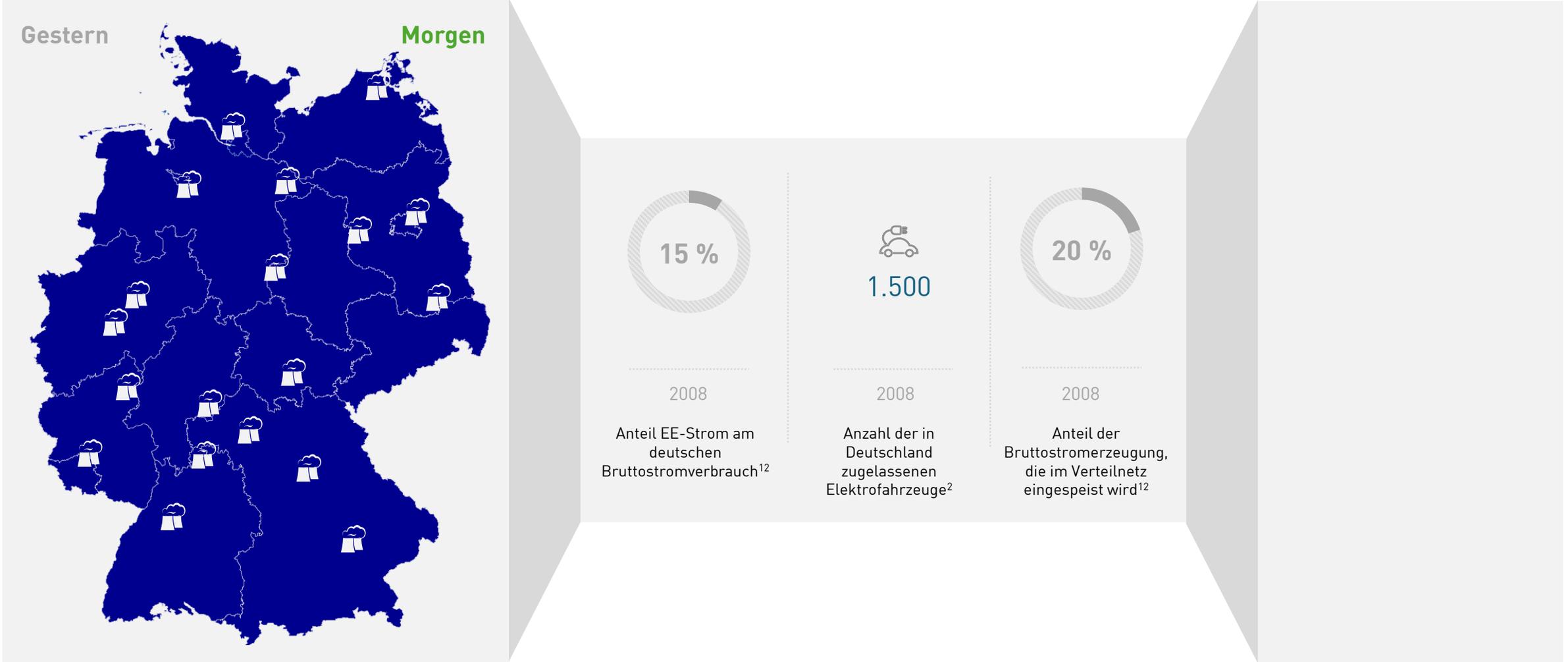
Hohe See



Buchholz



Hohe See

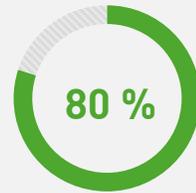
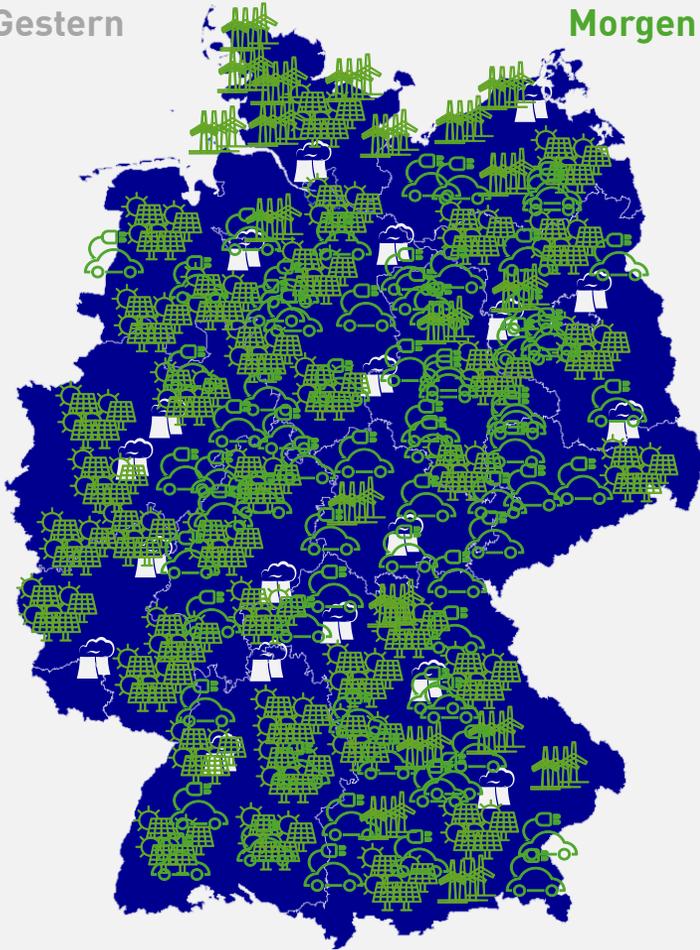


1 Strommix Deutschland 2008 (statista) – 20% im Verteilnetz setzen sich aus EE und sonstigen Energieträgern zusammen

2 Abschätzung auf Basis der Zahlen der Studie „Energiesystem Deutschland 2050“ vom Fraunhofer ISE (2013), ca. 80% aus fluktuierende EE, ca. 7% aus kleinen bis mittleren KWK-Anlagen und ca. 3% aus Wasserkraft

Gestern

Morgen



2050

Anteil EE-Strom am
deutschen
Bruttostromverbrauch¹²



2050

Anzahl der in
Deutschland
zugelassenen
Elektrofahrzeuge²



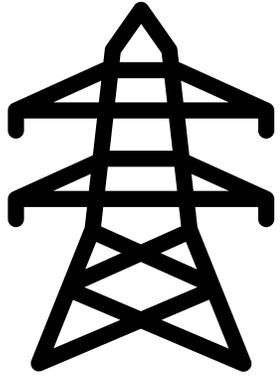
2050

Anteil der
Bruttostromerzeugung,
die im Verteilnetz
eingespeist wird¹²

Die
Energiewende
findet im
Verteilnetz
statt.

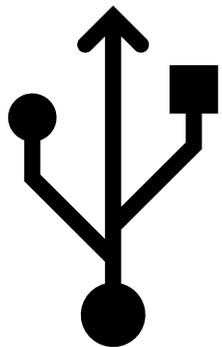
1 Strommix Deutschland 2008 (statista) – 20% im Verteilnetz setzen sich aus EE und sonstigen Energieträgern zusammen

2 Abschätzung auf Basis der Zahlen der Studie „Energiesystem Deutschland 2050“ vom Fraunhofer ISE (2013), ca. 80% aus fluktuierende EE, ca. 7% aus kleinen bis mittleren KWK-Anlagen und ca. 3% aus Wasserkraft



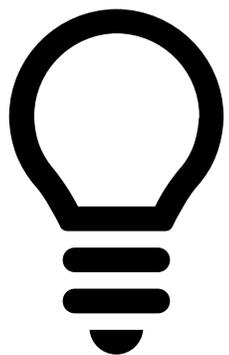
110 kV
220 kV
380 kV





10 kV
20 kV
30 kV

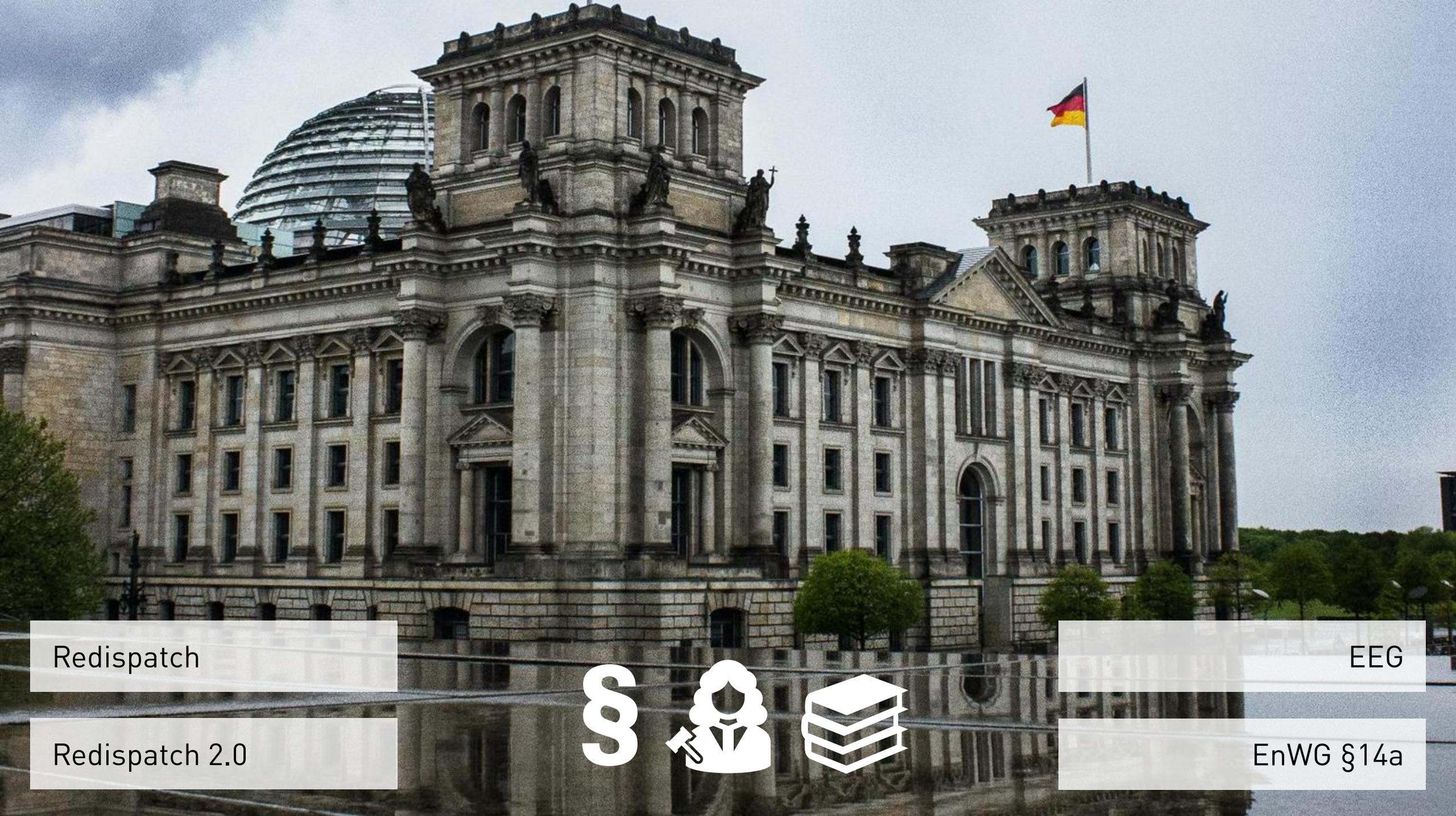




400 V



Quelle Bild: netze-bw.de



Redispatch

Redispatch 2.0

EEG

EnWG §14a





Export ab Element anfordern

Suchen...



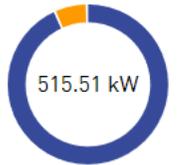
Netzgruppe	UW	UW Trafo	UW Abgang	UST/SST	NS Abgang	Anschlussobjekt	Zählpunkt
---	ACHER	T101	J06F	AHKRR-E-UST-001	AHKRR_006_06-07-08-09	502136257	DE007214792350000000000000872342
RT	BLEIB	T102	J15P	AHKRR-E-UST-002	AHKRR_006_06-07-08-10		
SW	BOLBA			AHKRR-E-UST-003			
GE	BREIS			AHKRR-E-UST-004			
VI	BRUNM			AHKRR-E-UST-005			
OR	BUEHL			AHKRR-E-UST-006			
BL	DENZL			AHKRR-E-UST-007			
STU	EICHS			AHKRR-E-UST-009			
WS	ENDIN			AHKRR-E-UST-010			
GR	FSTET			AHKRR-E-UST-011			
GN	FWEIS			AMOLT-E-UST-002			
BR	GENGN			AMOLT-E-UST-003			
TNG	GRAUD			BICKS-E-UST-002			
	GUTAC			BICKS-E-UST-003			
	HERBO			BICKS-E-UST-006			

Informationen zur Auswahl

Umspannstation AHKRR-E-UST-006 [Im GIS öffnen >](#)

Techn. Platz der UST AHKRR-E-UST-006	UST-Name Kleinhartäcker	UST-Eigentümer EnBW
Trafostufung ---	Ablisedatum 2017-05-31	Bemessungsleistung 400 kVA
Spannung OS/US ---	Ablisewert 97 kVA / 140 A	Auslastung 24.0%

Summe der installierten EEG Leistung Summe der install. Verbrauchsmittel ↔



Träger	Anzahl	Leistung
Solaranlage	16	481.51 kW
BHKW	1	34.00 kW

Anzahl der versorgten Betriebsmittel Datenstand und -qualität ↔

Betriebsmittel	Anzahl
Anschlussobjekte	23
Zählpunkte	58
Anlagen	17

SWWE_UW-BESTE_X-T101



SWWE_UW-BESTE_X-T101

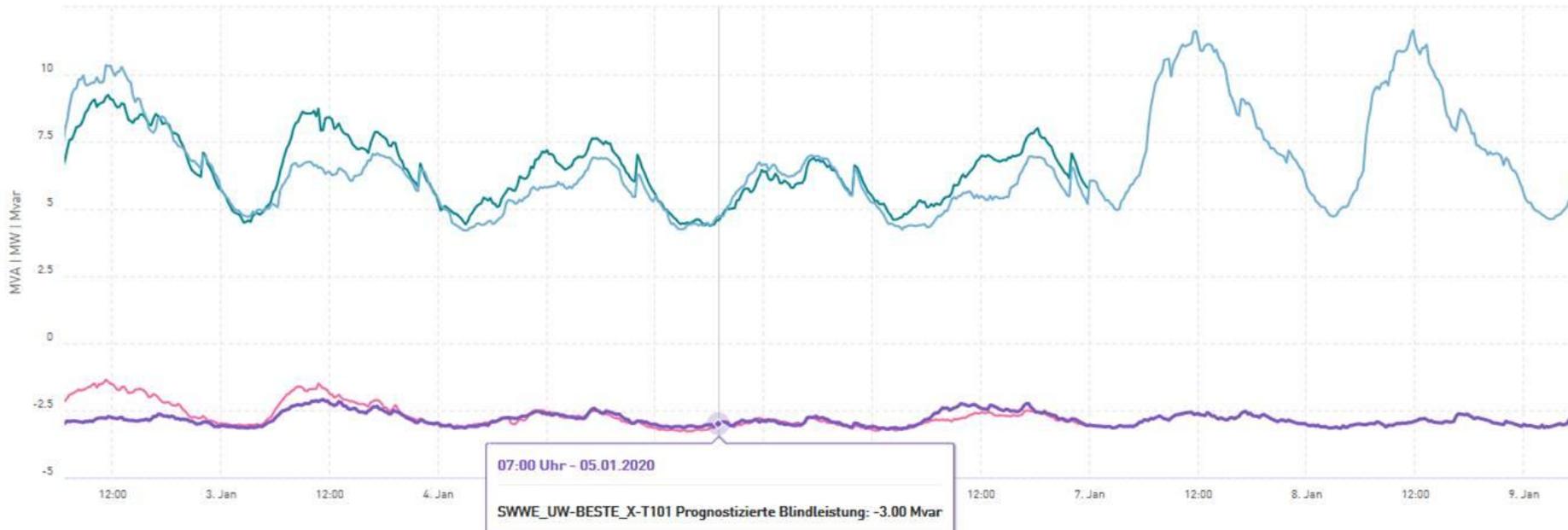
Prognose zuletzt aktualisiert: Di, 07.01.2020 00:00 Uhr

Diagramm Min/Max Werte

Von 17.12.2019 bis 14.01.2020

6 h 12 h 1 Tag 2 Tage 7 Tage

S gem S prog P gem P prog Q gem Q prog



07:00 Uhr, 05.01.2020

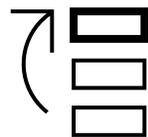
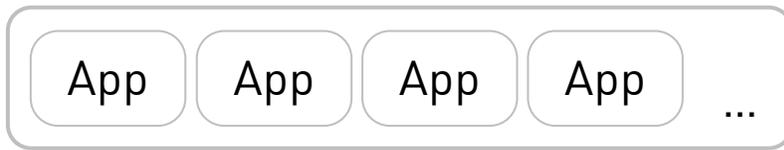
Betriebsmittel

SWWE_UW-BESTE_X-T101	
Prognose	Gemessen
S 5.612 MVA	S 5.470 MVA
P 4.745 MW	P 4.576 MW
Q -2.997 Mvar	Q -2.997 Mvar





React



Event Sourcing

2018

1 **Git-Repo** (Mono-Repo)



Single Deployment



CI

Continuous Integration

CI-Durchlauf ca. 60-70 Minuten
(> 8000 Unit-/Integrationstests)

CD

Continuous Deployment

CD-Durchlauf ca. 30 Minuten



2018



2022

Zahlreiche Datenbanken



neo4j

GraphDB



influxdb

mnesia
DETS

Infrastructure as Code




HashiCorp
Terraform

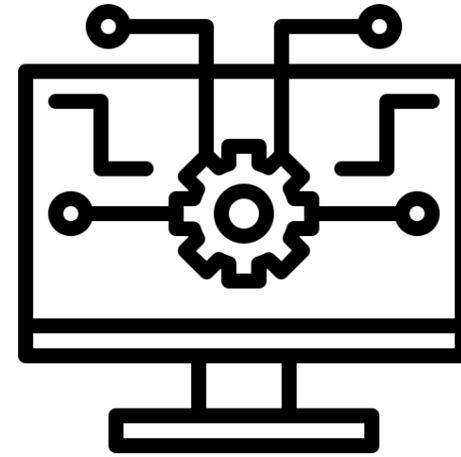

ANSIBLE

2018 ...

2022

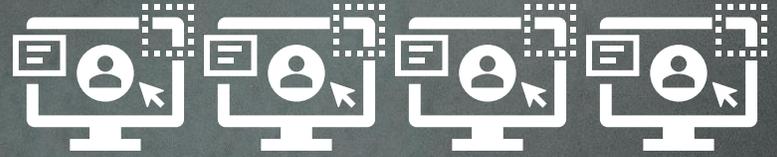
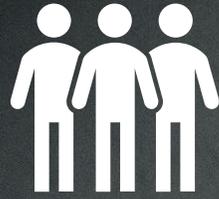
Viele Schnittstellen

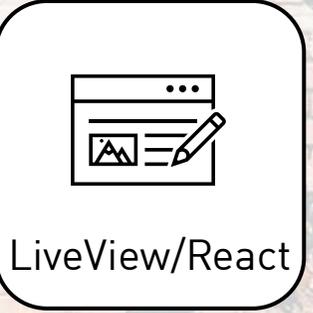
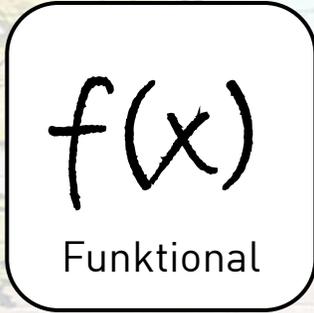
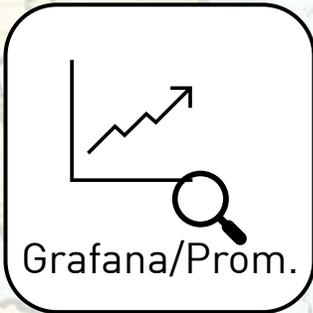
Konsumieren & Bereitstellen
Unternehmensintern & - extern



#NETZlive

2018 ... 2022









CI & CD

Erst spät umgesetzt



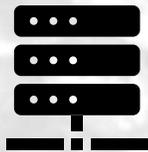
1 Git-Repo (Mono-Repo)

Lange Laufzeit **CI & CD**



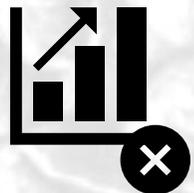
Single Deployment

Hohe Downtime



Viele Technologien

Viele statische Server & Betriebsaufwand



Skalierung

Kaum möglich für einzeln Komponenten



Moving Forward
BOLD PROJECTIONS

2022 ...

Redispatch-Prozess

Immer wichtiger durch Zubau
erneuerbare Energien



Zukünftig **automatisierte Steuerung**
erforderlich (Mengengerüst steigt)





Security



Verschiedene **Security-Bewertung**
für verschiedene Produkte

Hohe **Uptime** notwendig



A woman with dark hair, wearing a dark dress, is carrying a large stack of cardboard boxes. She is looking to her right. The background shows an office environment with a window, a desk, and a white door.

Lastspitzen auffangen
(Hoher Datenfluss)

Zukünftig **automatisierte Steuerung**
erforderlich (Mengengerüst steigt)

Redispatch-Prozess
Immer wichtiger durch Zubau
erneuerbare Energien

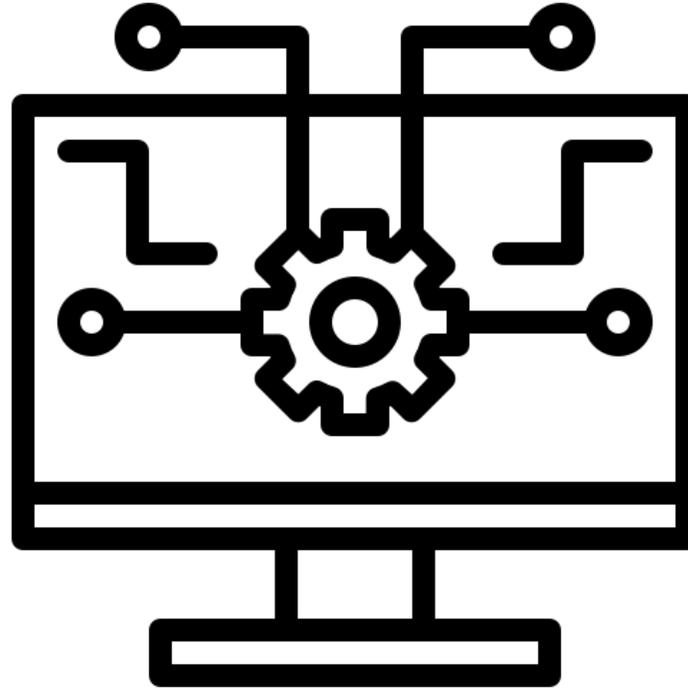
Hohe **Uptime** notwendig

Verschiedene **Security-Bewertung**
für verschiedene Produkte

2022

2023

2024

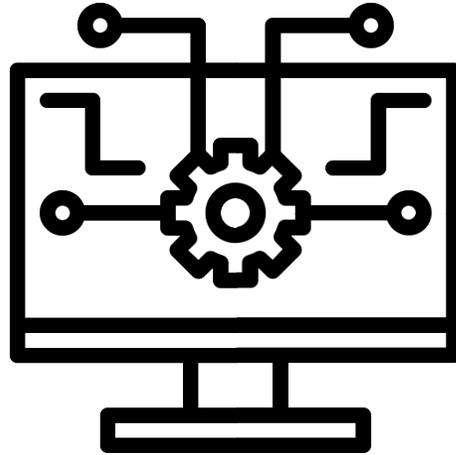


#NETZlive

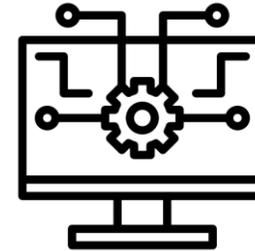
2022

2023

2024



#NETZlive



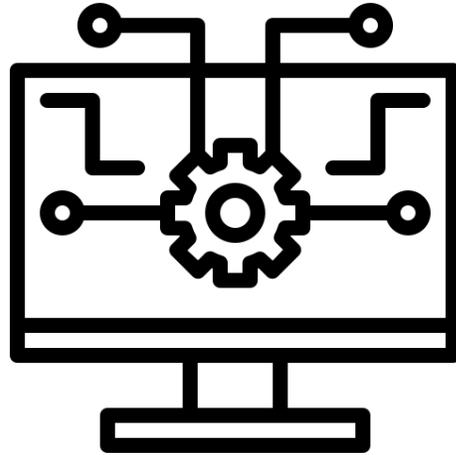
#BMH

Betriebsmittelhierarchie

2022

2023

2024

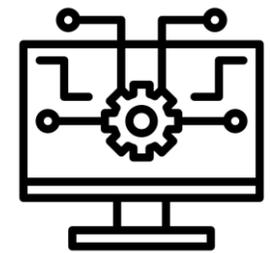
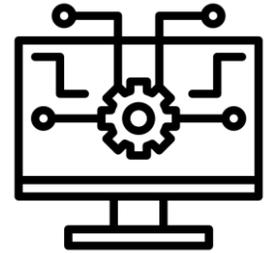
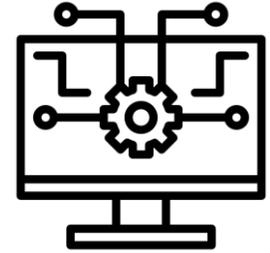


#NETZlive

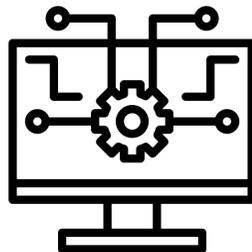
#NETZkoordinator
Schaltungen im HS-Netz

#BMH
Betriebsmittelhierarchie

#NETZzeitreihenauskunft
Anzeige von Zeitreihendaten



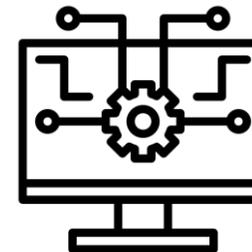
2022



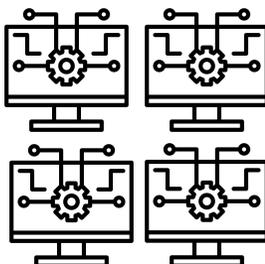
#NETZlive

#NETZkoordinator

Schaltungen im HS-Netz



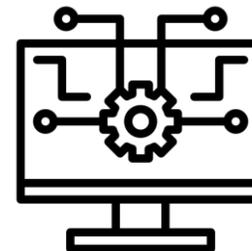
2023



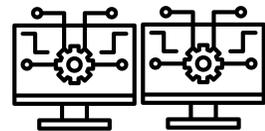
17 unabhängige
Teilanwendungen

#BMH

Betriebsmittelhierarchie

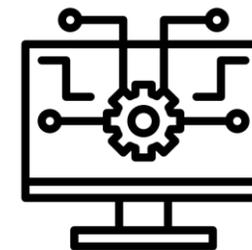


2024

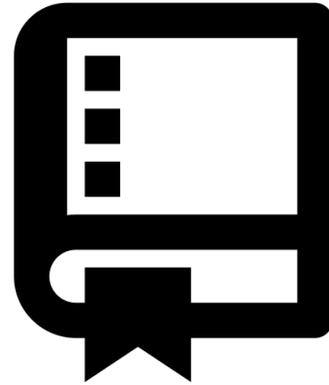


#NETZzeitreihenauskunft

Anzeige von Zeitreihendaten



1 Git Repo (Mono-Repo)



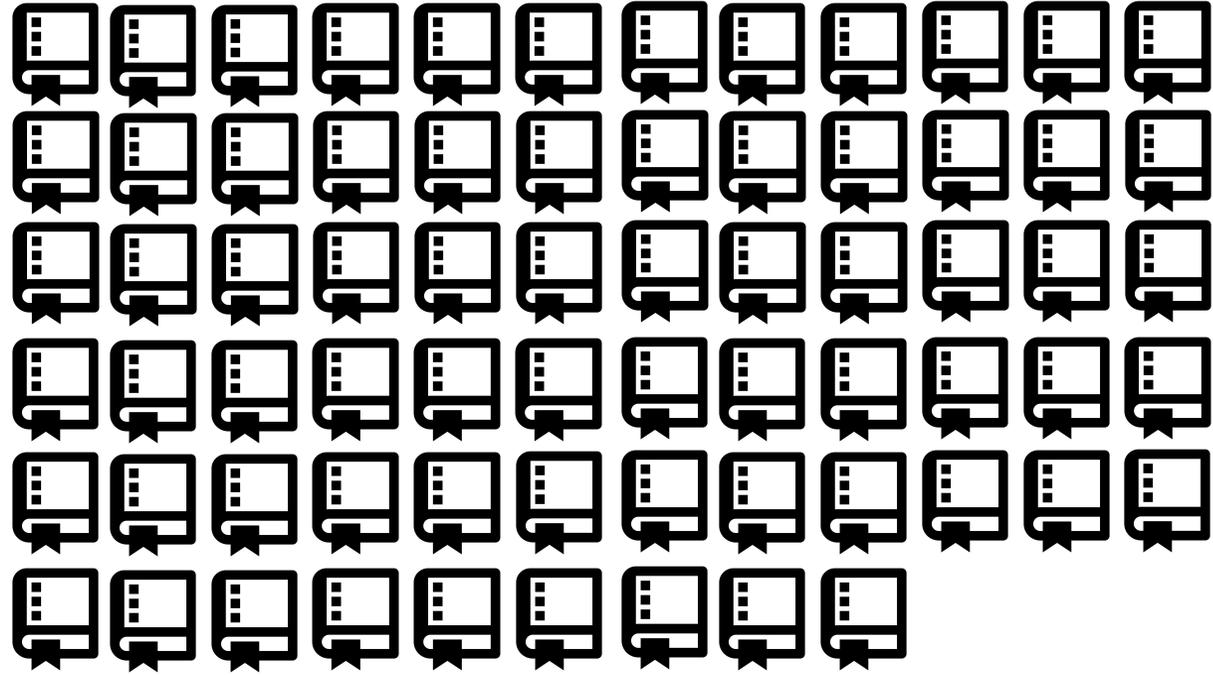
git

```
git filter-repo --path apps/<app>  
git filter-branch --subdirectory-filter apps/<app> -- -- all
```

68 Git Repos



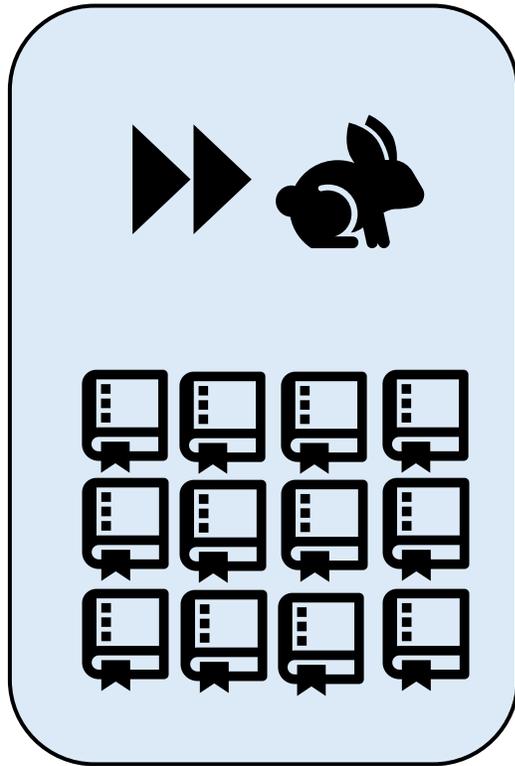
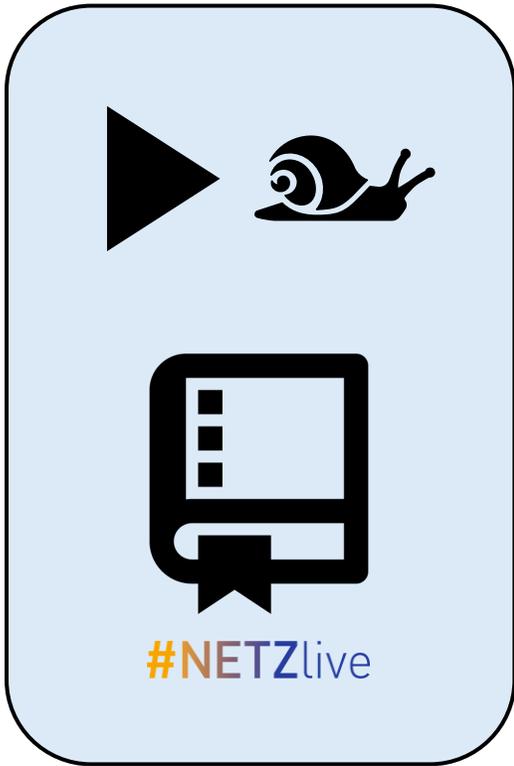
git



```
git filter-repo --path apps/<app>  
git filter-branch --subdirectory-filter apps/<app> -- -- all
```

Automatisierung mit Workflows

CI/CD werden schneller



CI

Continuous Integration

.github/workflows/elixir_ci.yml

```
name: CI
...
jobs:
  cache:
    ...

  all-jobs:
    runs-on: ubuntu-latest
    needs: [cache]
    steps:
      - uses: actions/checkout@v4
      - name: Setup elixir
        ...
      - name: Mix compile
        run: MIX_ENV=test mix compile --warnings-as-errors

      - name: Run Tests & Check Coverage
        id: run-tests
        run: mix test --cover

      - name: Check Format
        run: mix format --check-formatted

      - name: Check Credo
        run: mix credo --all --all-priorities --ignore-checks
              todo,fixme

      - name: Check Dialyzer
        run: mix dialyzer --force-check
```

Hex Paket bauen

Workflow/Github Release



EnBWAG / netzlive.shared

Code Issues Pull requests 3 Actions Projects Wiki Security Insights Settings

← Package
v2.11.0 #85

- Summary
- Jobs
 - cache
 - release
- Run details
 - Usage
 - Workflow file

Triggered via release last month	Status	Total duration	Artifacts
DerTim1 published v2.11.0	Success	1m 54s	1



release / doc summary

Docs

Documentation published to dev.netzlive-stage.netze-bw.de/docs/netzlive_shared/2.11.0.

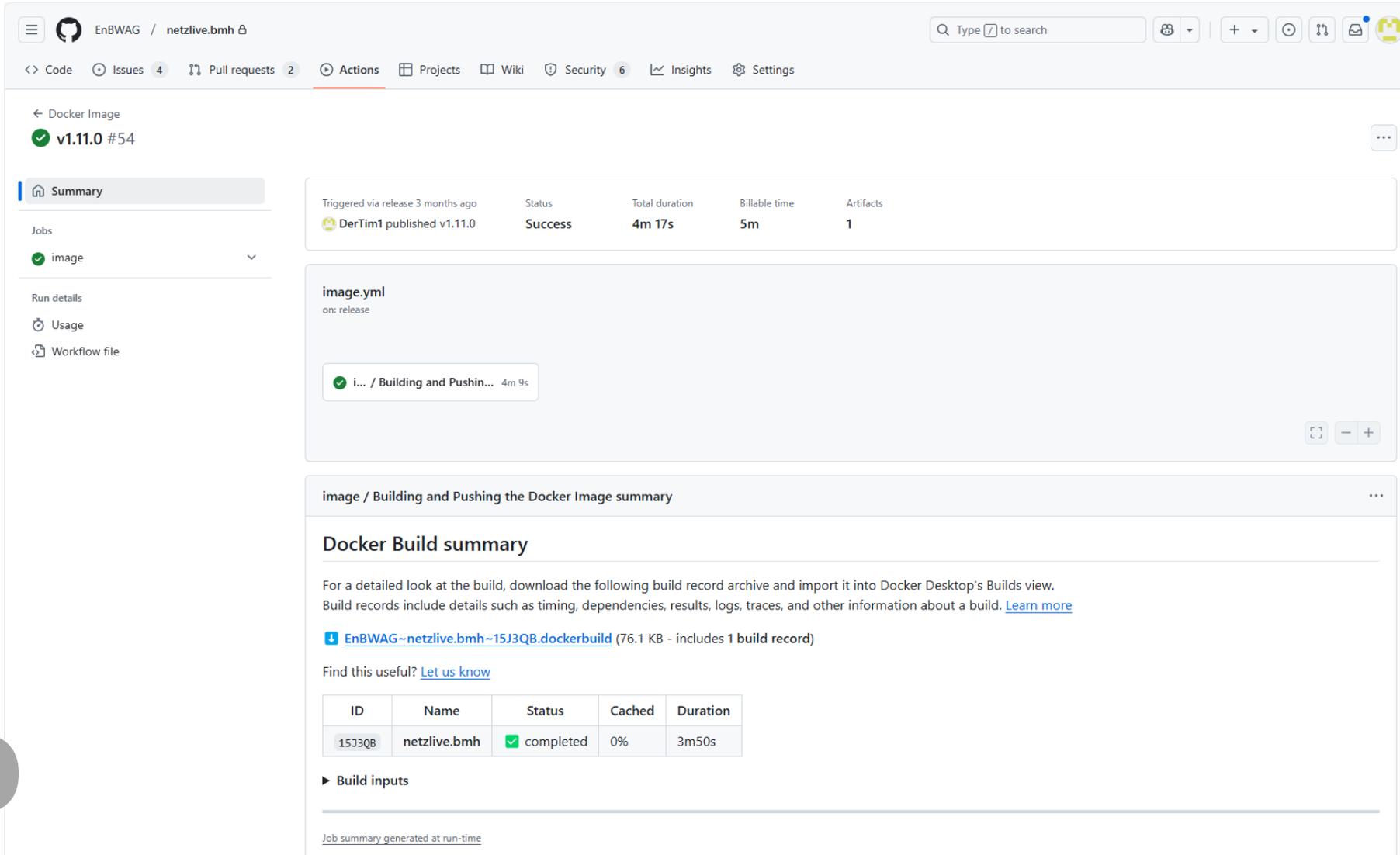
Job summary generated at run-time



Continous Deployment

Docker Images bauen

Workflow/Github Release



The screenshot shows the GitHub Actions interface for a workflow named "image" in the repository "EnBWAG / netzlive.bmh". The workflow is triggered by a release and has completed successfully. The summary section provides details about the build process, including the Docker build summary and a table of build records.

Triggered via release 3 months ago

Triggered via	Status	Total duration	Billable time	Artifacts
DerTim1 published v1.11.0	Success	4m 17s	5m	1

image.yml
on: release

i... / Building and Pushin... 4m 9s

image / Building and Pushing the Docker Image summary

Docker Build summary

For a detailed look at the build, download the following build record archive and import it into Docker Desktop's Builds view. Build records include details such as timing, dependencies, results, logs, traces, and other information about a build. [Learn more](#)

[EnBWAG~netzlive.bmh~15J3Q8.dockerbuild](#) (76.1 KB - includes 1 build record)

Find this useful? [Let us know](#)

ID	Name	Status	Cached	Duration
15J3Q8	netzlive.bmh	completed	0%	3m50s

► Build inputs

Job summary generated at run-time

CD

Continous Deployment

Deployments Workflow

EnBWAG / netzlive.bmh

Code Issues 4 Pull requests 2 Actions Projects Wiki Security 6 Insights Settings

Deployment BMH Prod

Deployment of Branch v1.12.1 to Env Prod #36

Re-run all jobs

Summary

Jobs

- deployment

Run details

- Usage
- Workflow file

Manually triggered last month	Status	Total duration	Artifacts
tiemens -> 81430fb v1.12.1	Success	7m 40s	-

deploy_to_prod.yml
on: workflow_dispatch

```
graph LR; A[deployment / ... / Prod 24s] --> B[deployment / baseit 29s]
```

deployment / baseit summary

BaseIT KAT0 Change

- Change *Netzlive Betriebsmittelhierarchie neues Release: v1.12.1* with id 355848 created.
- Status of Change changed from *Neu* to *Freigegeben*.
- Status of Change changed from *Freigegeben* to *Erfolgreich*.

Job summary generated at run-time

Deployment protection rules

Reviewers, timers, and other rules protecting deployments in this run

Event	Environments	Comment
DerTim1 approved last month	Prod	

CD

Continuous Deployment



#NETZkoordinator

Schaltungen im HS-Netz

Betriebsmittelhierarchie - NETZlive

Suchen...

Netzgruppe	UW	UW Trafo	UW Abgang	UST/SST	NS Abgang	Anschlussobjekt
BL						
BR						
GE						
GN						
GR						
OR						
RT						
SW						
VI						
WS						
unverknüpft						

Dashboard - Netzkoordinator

Filter speichern | Filter wiederherstellen | Filter zurücksetzen

Datumsbereich: Beginn 07.02.2025, Ende 07.05.2025

Netzgruppen: Daxlanden, Esslingen, Engstlatt, Blau, Braun, Gelb, Grau, Orange, Grün Nord, Grün Süd, Schwarz, Stuttgart, Weiß, Violett, Rot

Maßnahmenanträge

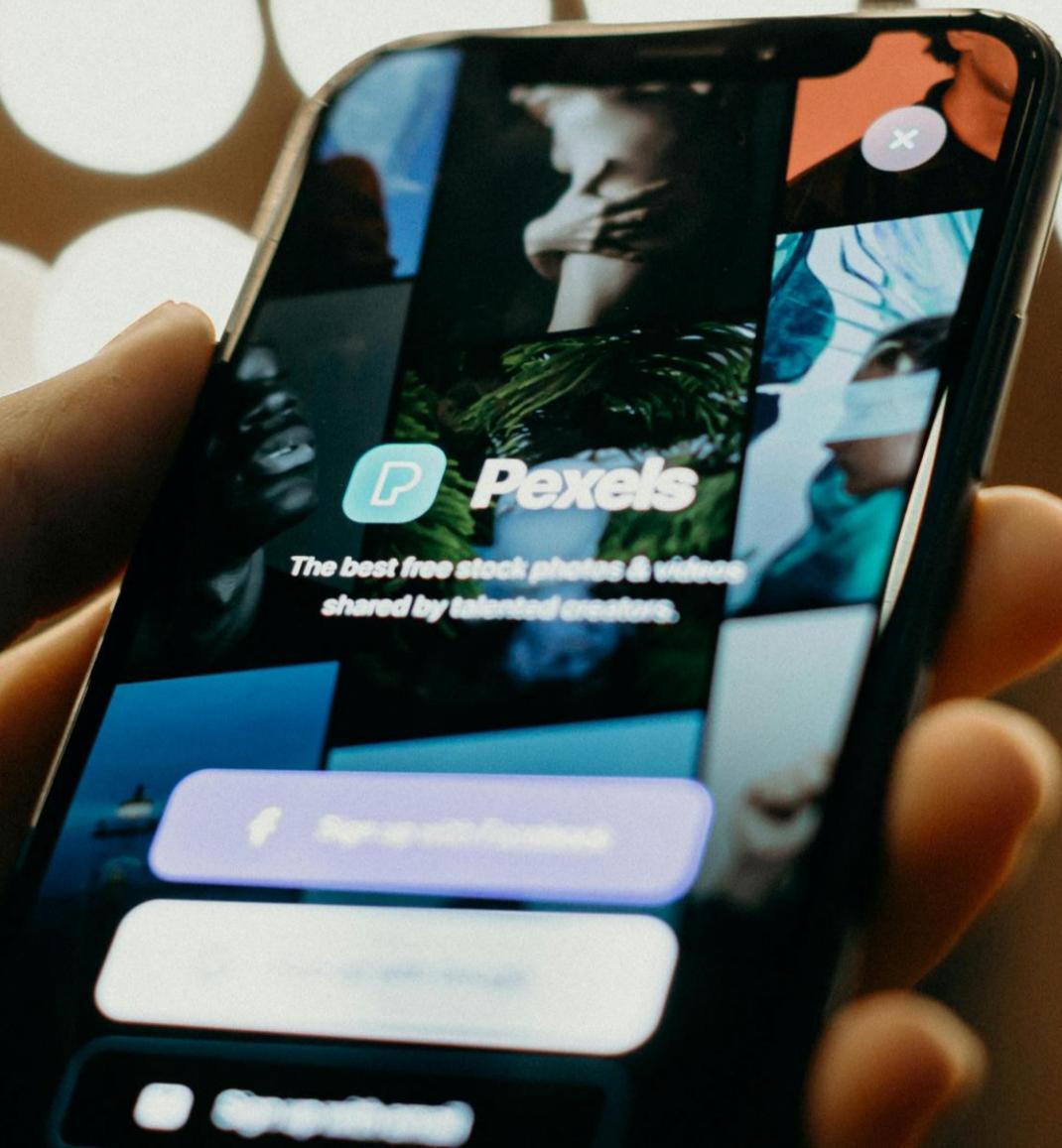
Name	Beginn (MA)	Ende (MA)	VE-Bereich	Spannungsebene
[Loading Indicator]				

Zeilen pro Seite: 50 | 0-0 von 0

#BMH

Betriebsmittelhierarchie

Universaler **Login**





Apps formieren einen
Erlang Cluster



```
Terminal
td@luke:~/P/netzlive/netzlive main+*± n remote stage netzkoordinator
```

Apps formieren einen **Erlang Cluster**

```
Terminal
td@luke:~/P/netzlive/netzlive main+*± n remote stage netzkoordinator
Will connect to netzkoordinator STAGE remote console. Press CTRL+C twice to disconnect.
Erlang/OTP 26 [erts-14.2.5.5] [source] [64-bit] [smp:8:8] [ds:8:8:10] [async-threads:1] [jit:ns]

Interactive Elixir (1.16.3) - press Ctrl+C to exit (type h() ENTER for help)
iex(netzkoordinator-6fdd6c7f66-7r6qc@netzkoordinator-web.netzlive.svc.cluster.local)1>
Node.list() ■
```

Apps formieren einen **Erlang Cluster**

```
Terminal
Will connect to netzkoordinator STAGE remote console. Press CTRL+C twice to disconnect.
Erlang/OTP 26 [erts-14.2.5.5] [source] [64-bit] [smp:8:8] [ds:8:8:10] [async-threads:1] [jit:ns]

Interactive Elixir (1.16.3) - press Ctrl+C to exit (type h() ENTER for help)
iex(netzkoordinator-6fdd6c7f66-7r6qc@netzkoordinator-web.netzlive.svc.cluster.local)1> Node.list()
[: "framework-8946b7f68-r2v2k@10.3.16.128",
 : "nls-importer-6bb68547df-c5snn@nls-importer-web.netzlive.svc.cluster.local",
 : "redispatch-0@redispatch-web.netzlive.svc.cluster.local",
 : "congestions-0@congestions-web.netzlive.svc.cluster.local",
 : "bmh-587886cc84-vt7cj@bmh-web.netzlive.svc.cluster.local",
 : "forecast-f7f5d869-4v8tj@forecast-web.netzlive.svc.cluster.local",
 : "framework-8946b7f68-q9cbx@10.3.16.151",
 : "token-management-74c88bb994-2cc7h@token-management-web.netzlive.svc.cluster.local",
 : "time-series-schedules-7dd78cccf8-kknz6@time-series-schedules-web.netzlive.svc.cluster.local",
 : "netzkoordinator-ms-7c74ff5844-krs8g@netzkoordinator-ms-web.netzlive.svc.cluster.local",
 : "zeitreihenauskunft-8454496c47-r9vtk@zeitreihenauskunft-web.netzlive.svc.cluster.local",
 : "netzlive-0@netzlive-web.netzlive.svc.cluster.local",
 : "grid-state-0@grid-state-web.netzlive.svc.cluster.local"]
iex(netzkoordinator-6fdd6c7f66-7r6qc@netzkoordinator-web.netzlive.svc.cluster.local)2> █
```

Apps formieren einen **Erlang Cluster**

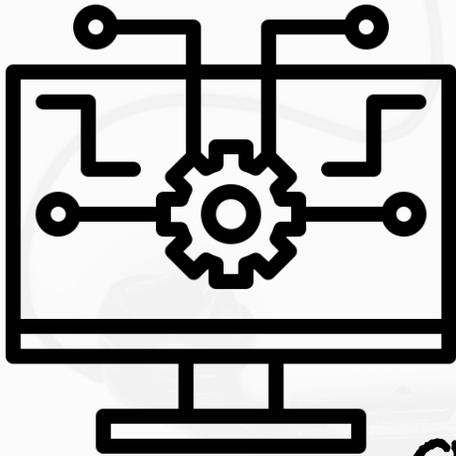


Bereitstellung von Funktionen als
Cluster-Services

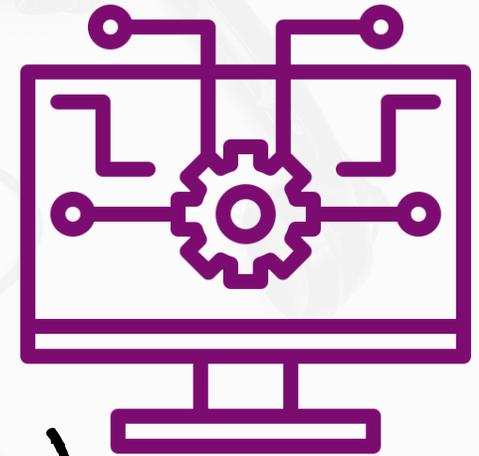


$f(x)$

$h(x)$

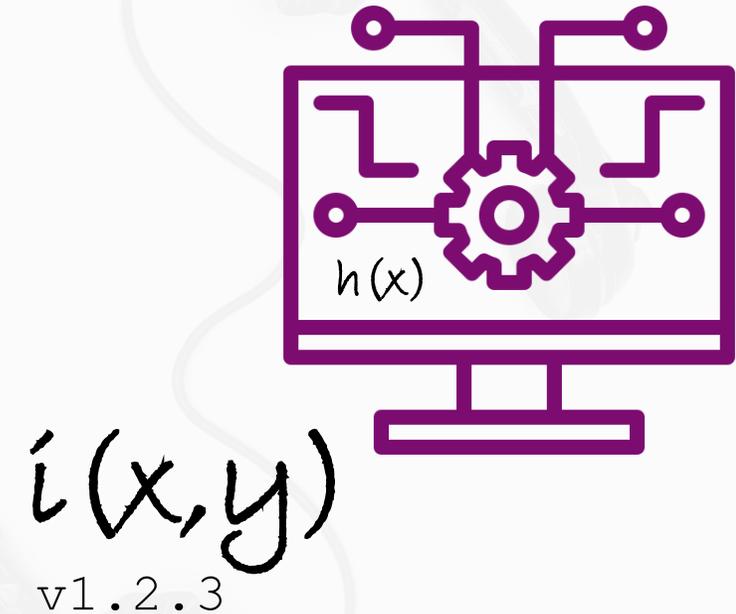
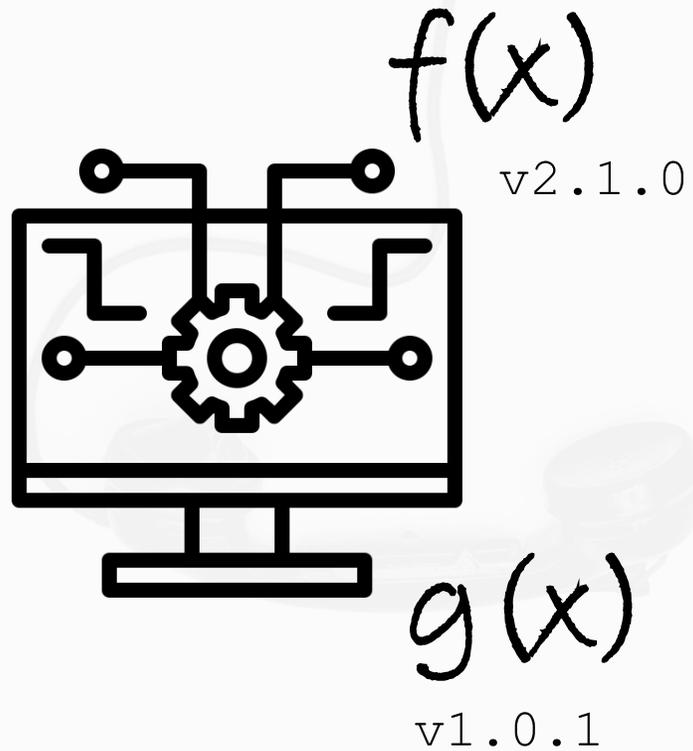


$g(x)$



$i(x, y)$

Bereitstellung von Funktionen als
Cluster-Services



Bereitstellung von Funktionen als
Cluster-Services

```
defmodule BMH.Service.InfoV1 do
  @moduledoc """
  BMH release information offered as a netzlive service
  """

  use Netzlive.Cluster.Service,
    name: __MODULE__,
    version: "1.0.0",
    retry_after: 1000,
    retry_limit: 10

  defapi(release_version(),
    to: BMH.ReleaseInfo
  )

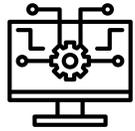
  defapi(release_notes(),
    to: BMH.ReleaseInfo
  )

  defapi(release_build_time(),
    to: BMH.ReleaseInfo
  )
end
```

f(x)

v2.1.0

           	<p>+ Netzlive</p> <hr/>	<p>1.1.1 Thu, 16 Jan 2025 10:10</p>
	<p>+ Betriebsmittelhierarchie</p> <hr/>	<p>1.12.1 Mon, 13 Jan 2025 13:18</p>
	<p>+ Congestions</p> <hr/>	<p>1.1.0 Tue, 17 Dec 2024 19:58</p>
	<p>+ Forecast</p> <hr/>	<p>1.4.2 Wed, 8 Jan 2025 15:06</p>
	<p>+ Framework</p> <hr/>	<p>1.2.0 Tue, 17 Dec 2024 15:32</p>
	<p>+ Grid-State</p> <hr/>	<p>1.7.3 Thu, 16 Jan 2025 11:31</p>

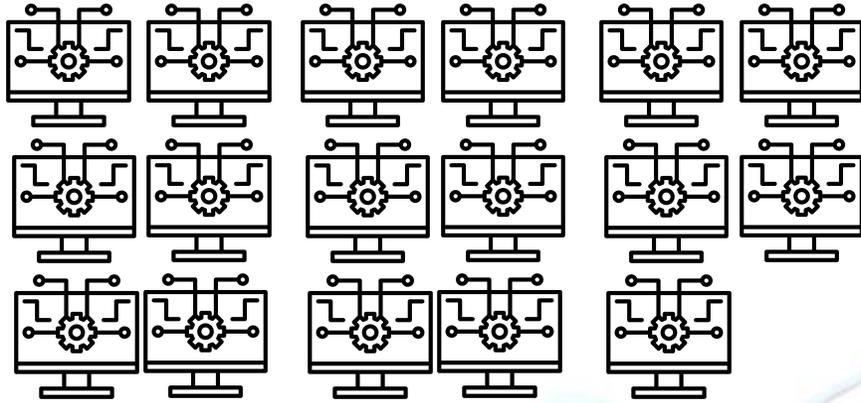


#NETZlive

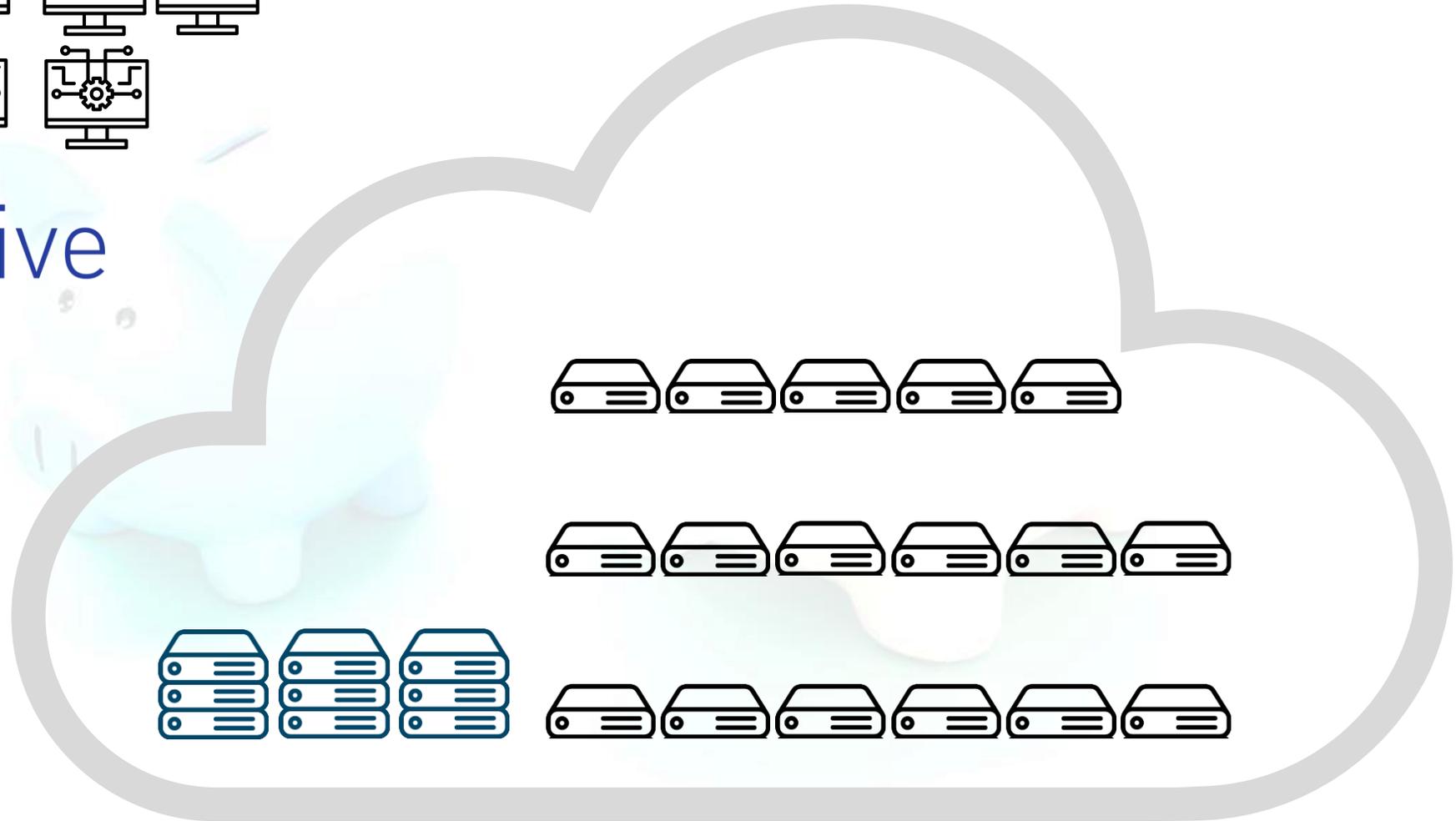


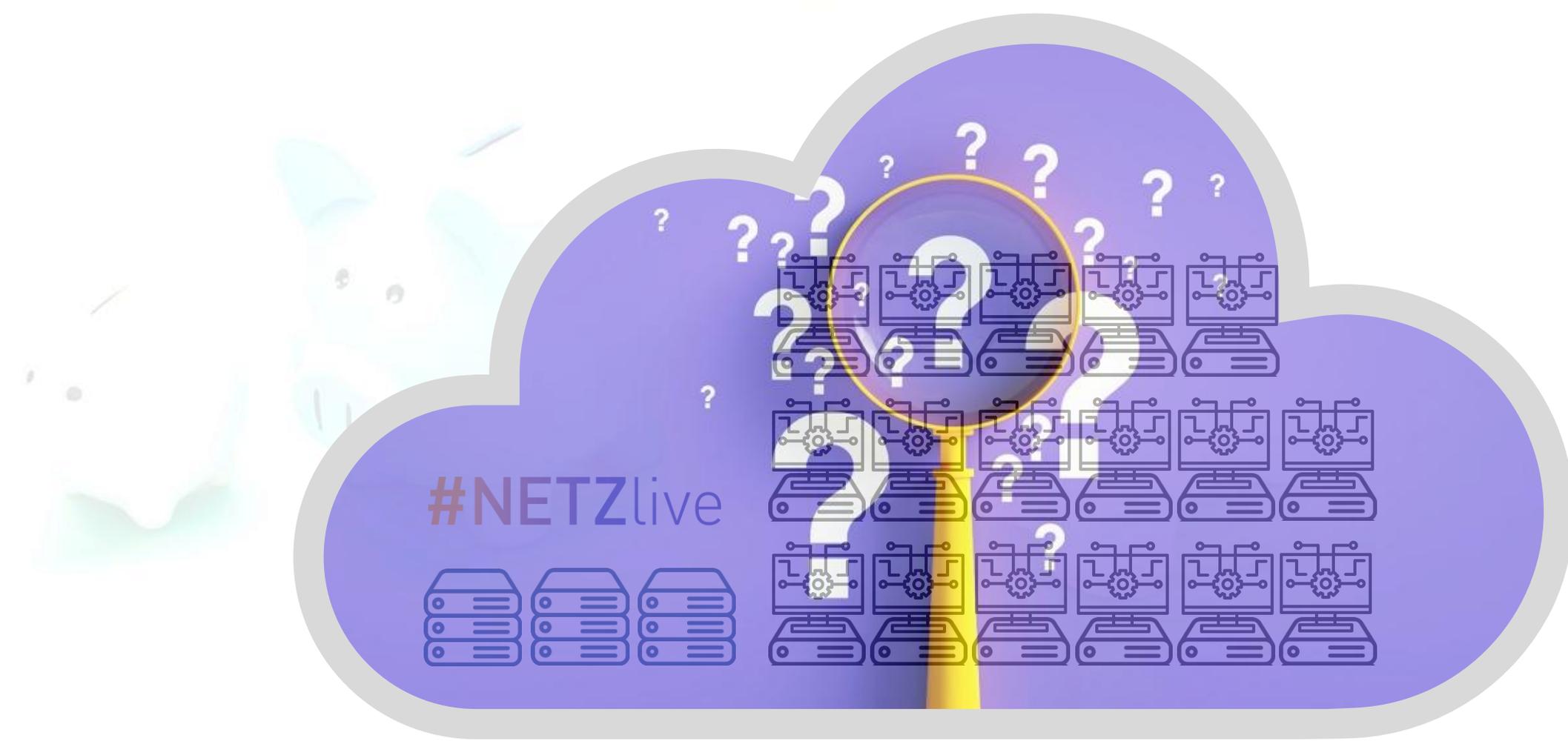
#NETZlive



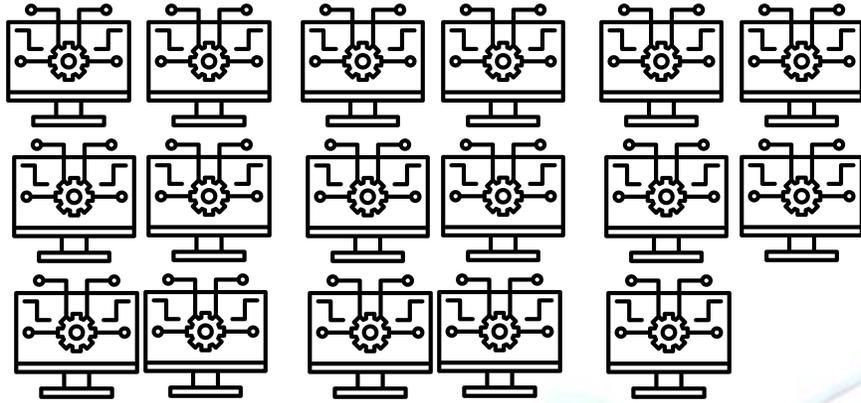


#NETZlive

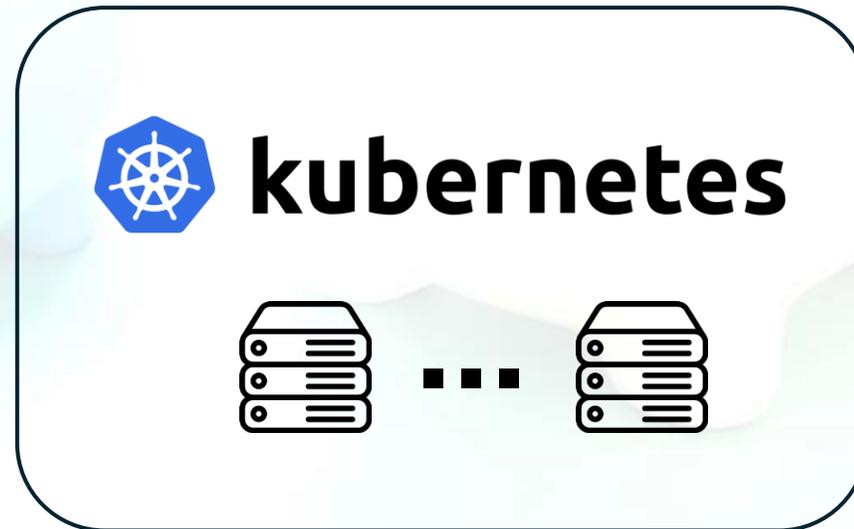
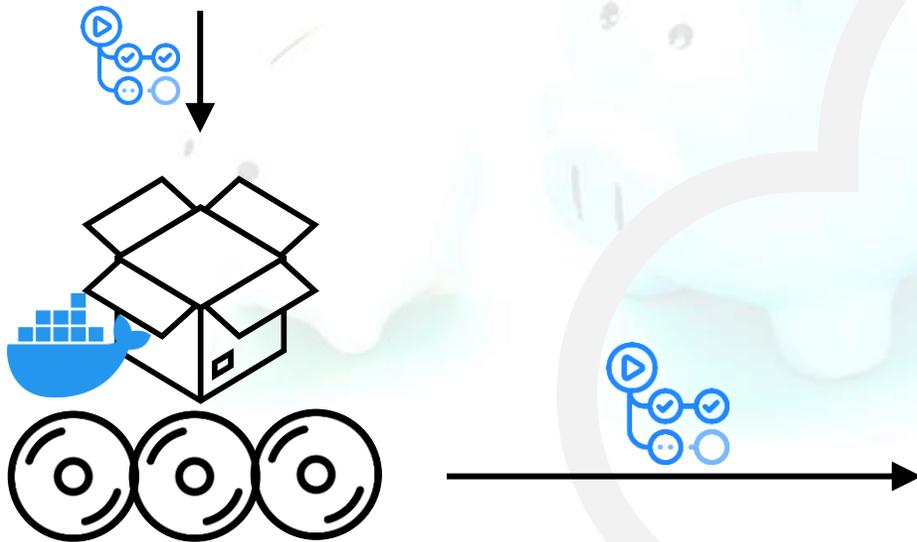


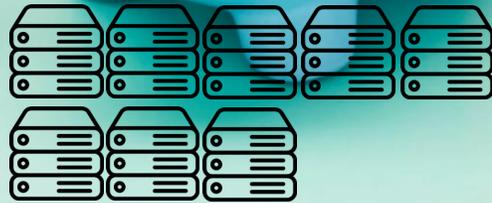
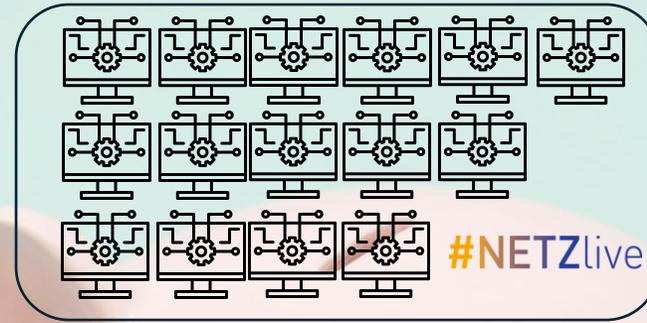
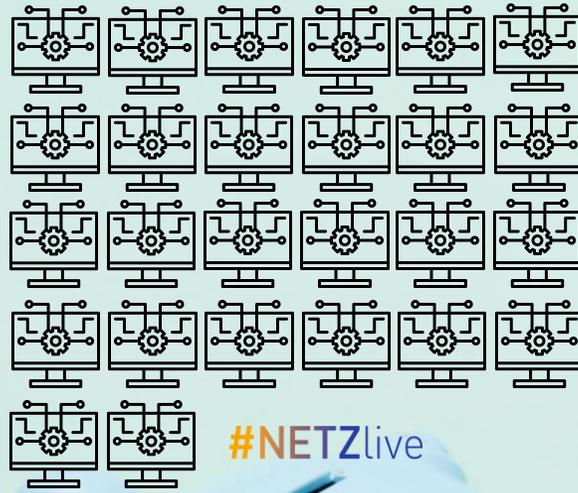


#NETZlive



#NETZlive





2025

2022



PEO Adlied

MAERSK

MAERSK
SEALAND

MAERSK

MAERSK
SEALAND

MAERSK

CRONOS

EVERGREEN

EVERGREEN

MAERSK

MAERSK
SEALAND

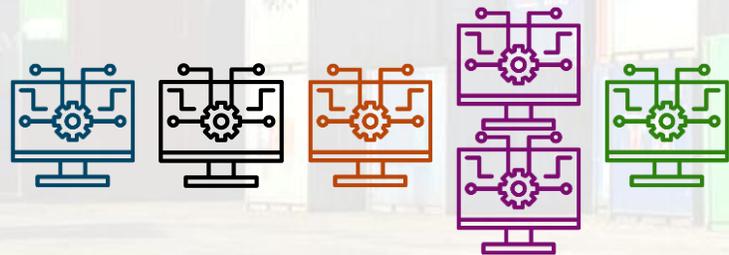
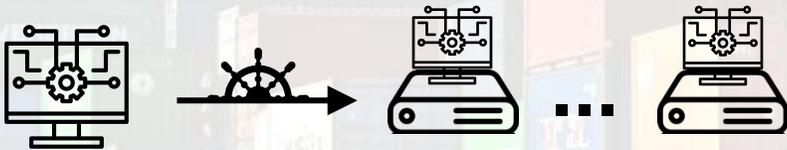
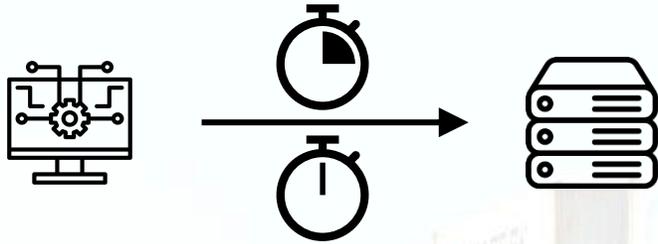
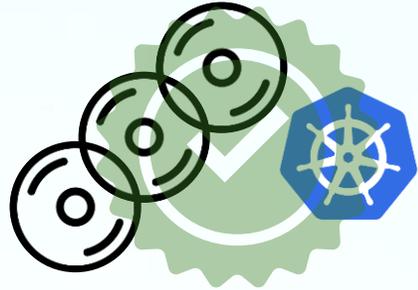
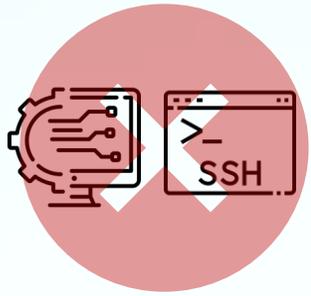
EVER
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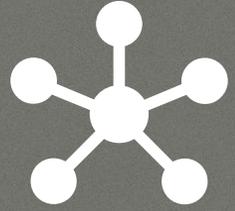
NYKU
4383 20 5

MSKU 653 817 5
4261

MSKU 632 775 5
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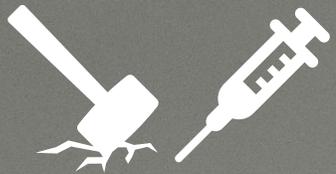




Clustering
Out of the Box

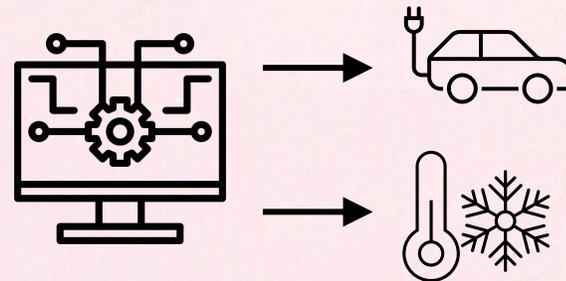
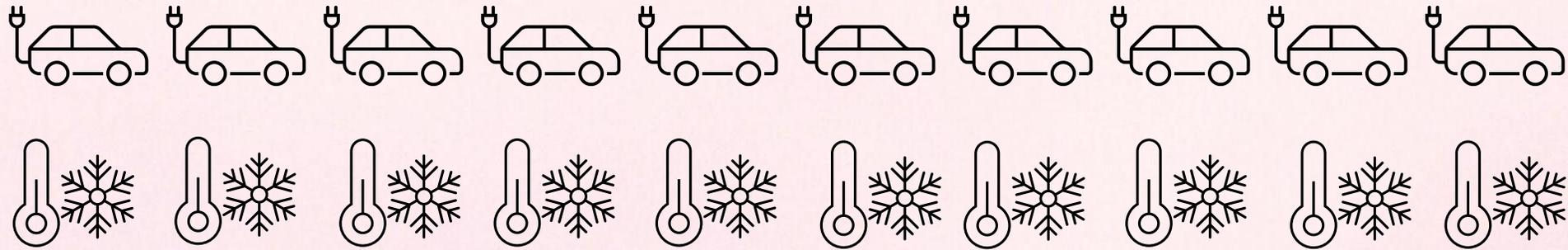


Gutes Tooling
mix, Hex (private Registry), ...

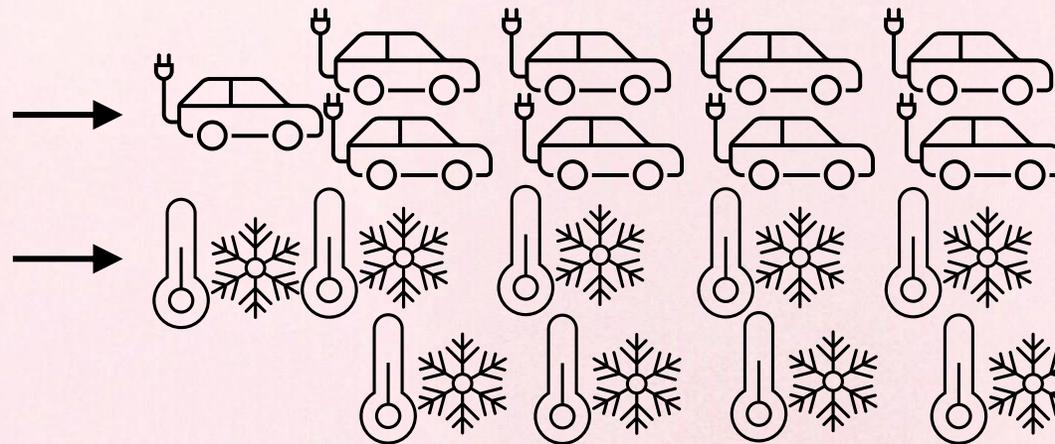
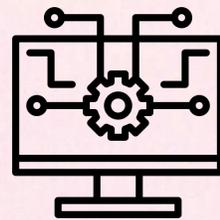


Hohe intrinsische **Stabilität**
Erlang Prozess Modell

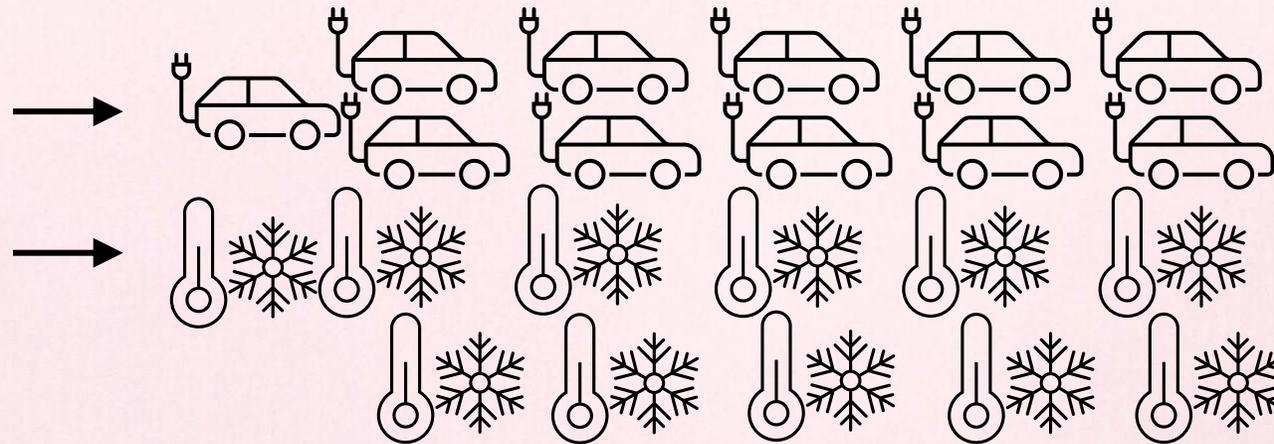
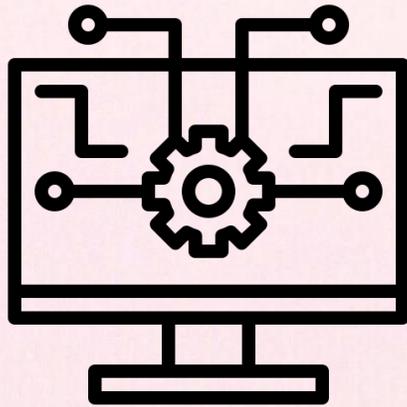




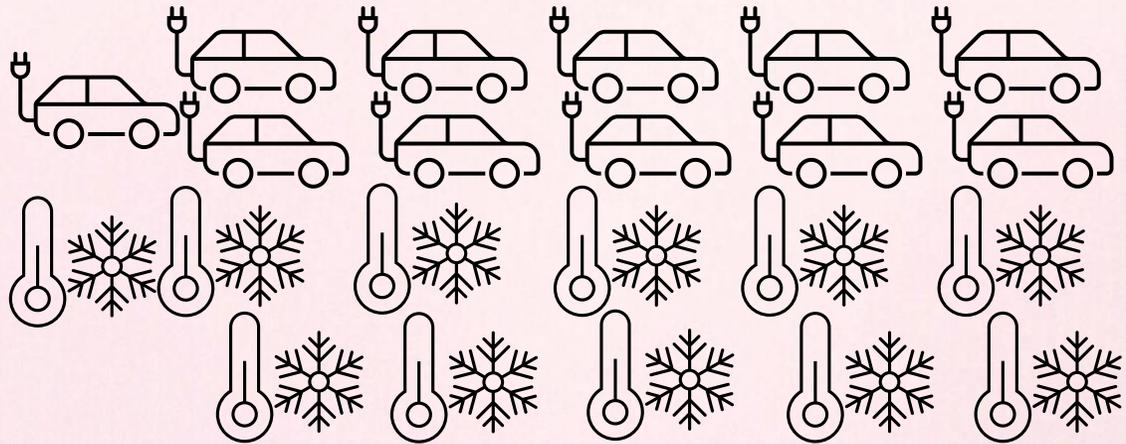
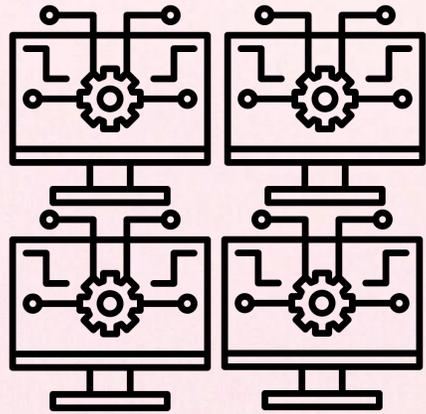
N₁ E₁ X₈ T₁



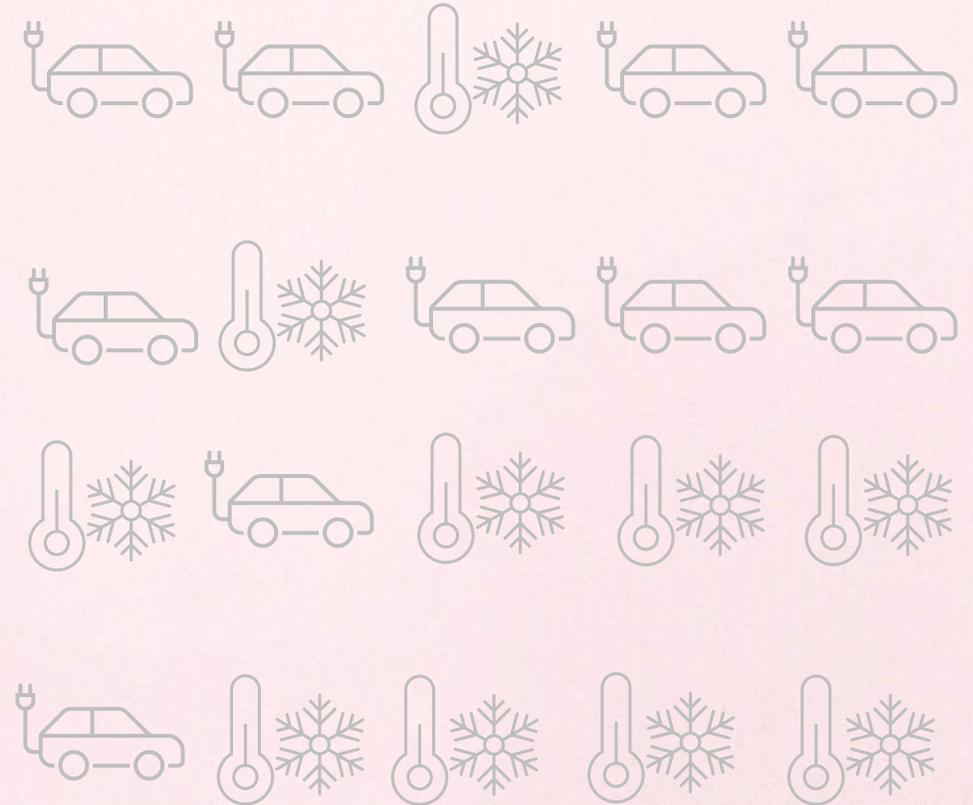
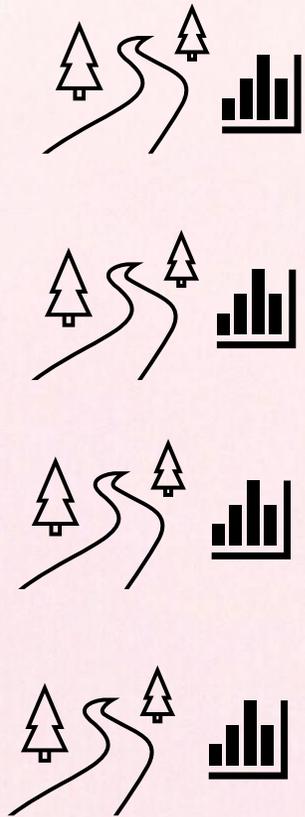
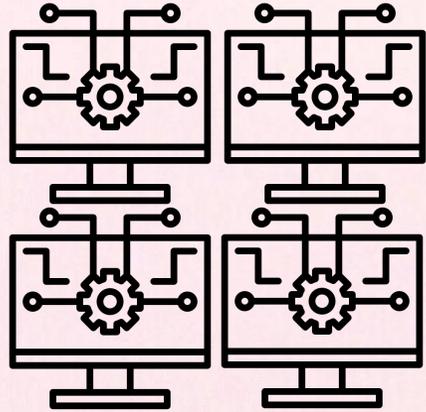
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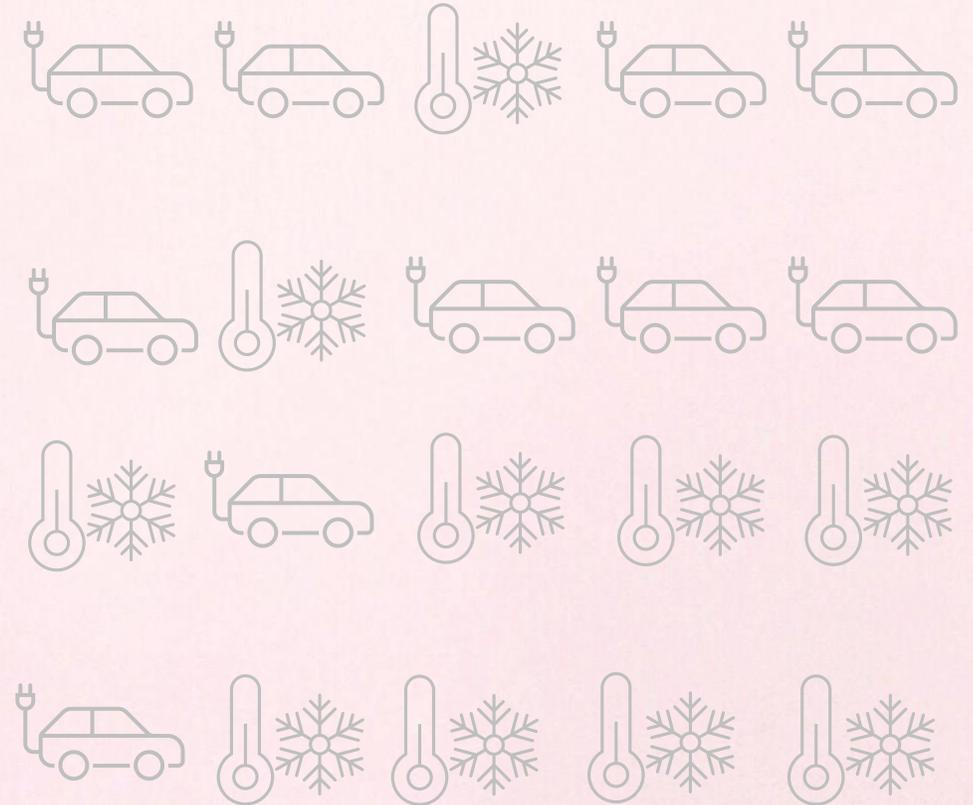
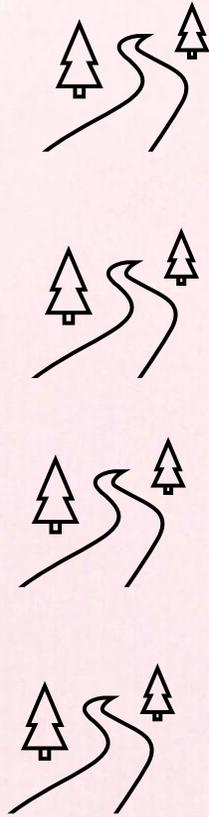
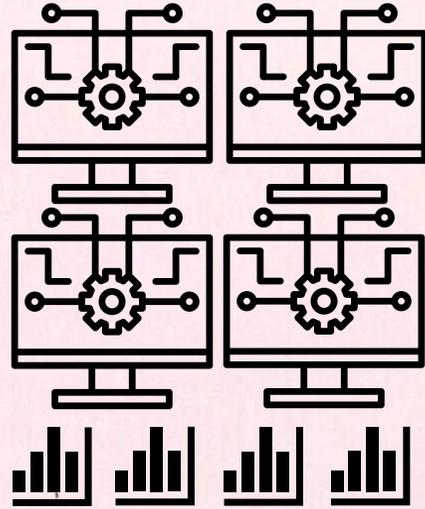
N₁ E₁ X₈ T₁



N₁ E₁ X₈ T₁



N₁ E₁ X₈ T₁





Redispatch nimmt weiter zu
Mehr Steueraufwand



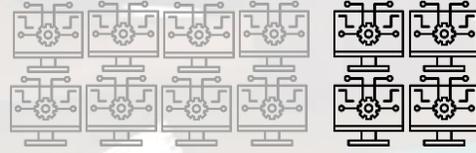
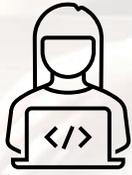
24/7



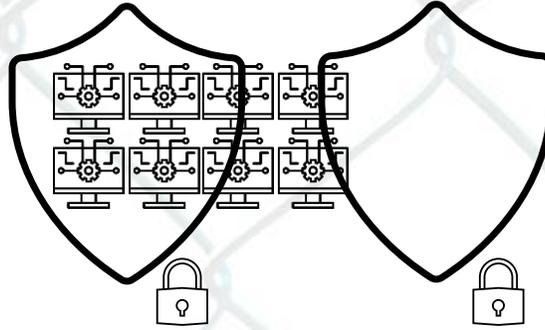
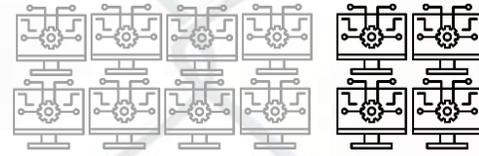
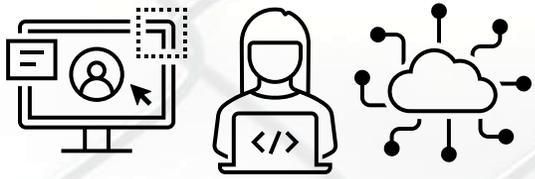
Anzahl Erzeugungsanlagen steigt
Mehr kleine Anlagen







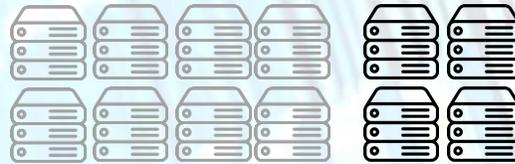
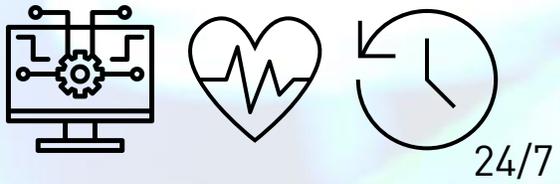
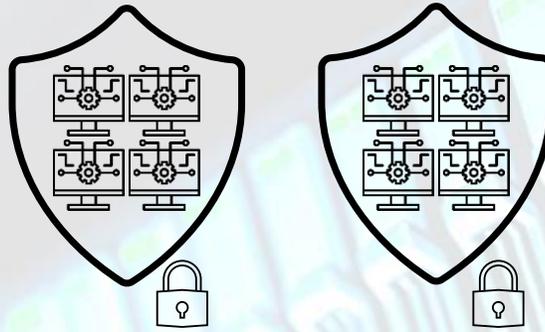
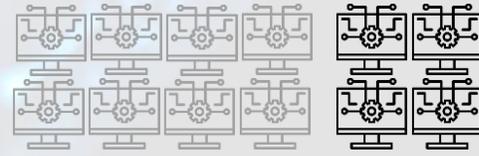
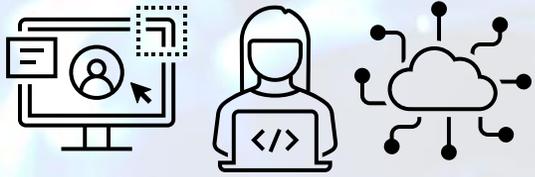


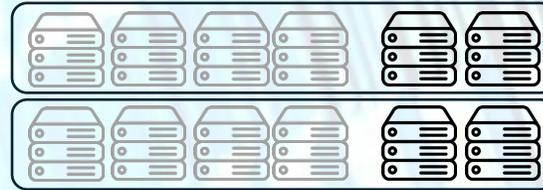
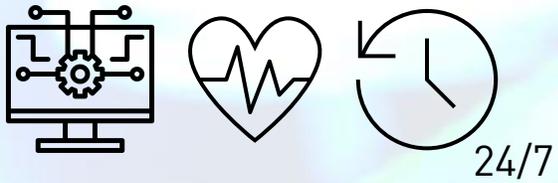
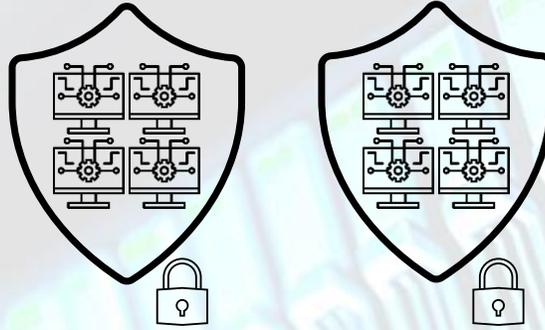
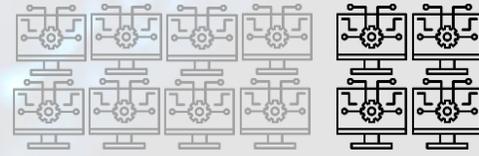
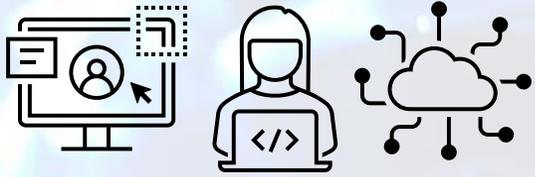




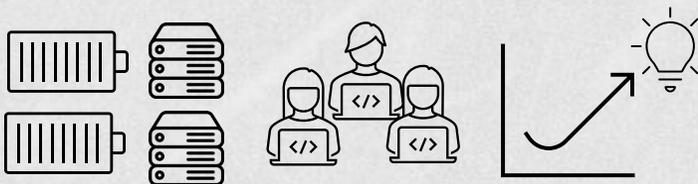
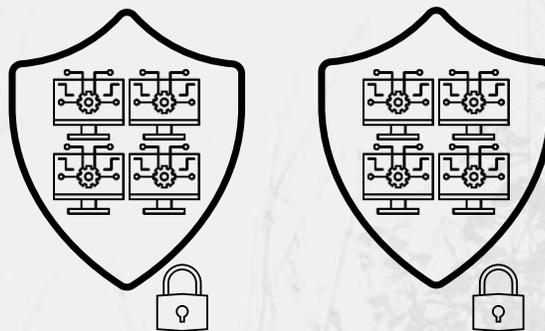
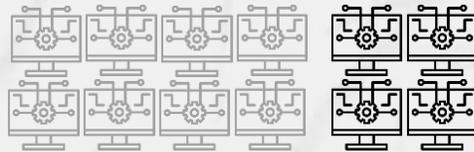
24/7













Elixir/Phoenix



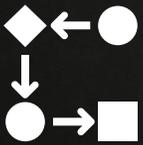
Erlang



Kubernetes



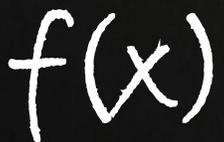
Terraform



Microservices



Workflows (CI/CD)



Funktional



Event-Sourcing



v1.0.1

Versionierung



State of the Art



Technologiezuschnitt

TIME

FOR

CHANGE

