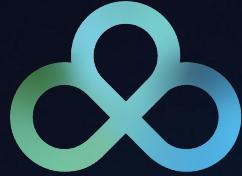


# PostgreSQL in Kubernetes: Can I trust it for Day 2 operations?



# Can I migrate PostgreSQL from public DBaaS to Kubernetes with ~ Zero Downtime?





**EDB**

Postgres® for the AI Generation



# CloudNativePG: the past, the present, the future

KCD Denmark

Wednesday, 20th November

**Gabriele Bartolini**

VP, Chief Architect, Kubernetes at EDB



# Gabriele Bartolini

VP, Chief Architect of Kubernetes at EDB

PostgreSQL user since ~2000

Ex 2ndQuadrant (co-founder)

PostgreSQL Contributor

DoK Ambassador

DevOps evangelist

Open source contributor

- Barman (2011)
- CloudNativePG (2022)



Blog: gabrielebartolini.it   @\_GBartolini\_

# Agenda

- Introduction
- The Past
- The Present
- The Future
- Conclusions





# Introduction

# What is PostgreSQL?

The world's most advanced database. Also known as **Postgres**. URL: postgresql.org

- **100% Open Source**
  - Widely used, extremely robust, and feature-rich.
- **Extensible and Customizable**
  - Support for custom data types, functions, and procedural languages.
- **Advanced features**
  - Includes replication, partitioning, full-text search, and JSON support.
- **ACID-Compliant**
  - Ensures Atomicity, Consistency, Isolation, and Durability for transactions.
- **Strong Community Support**
  - Backed by a large, active global community.

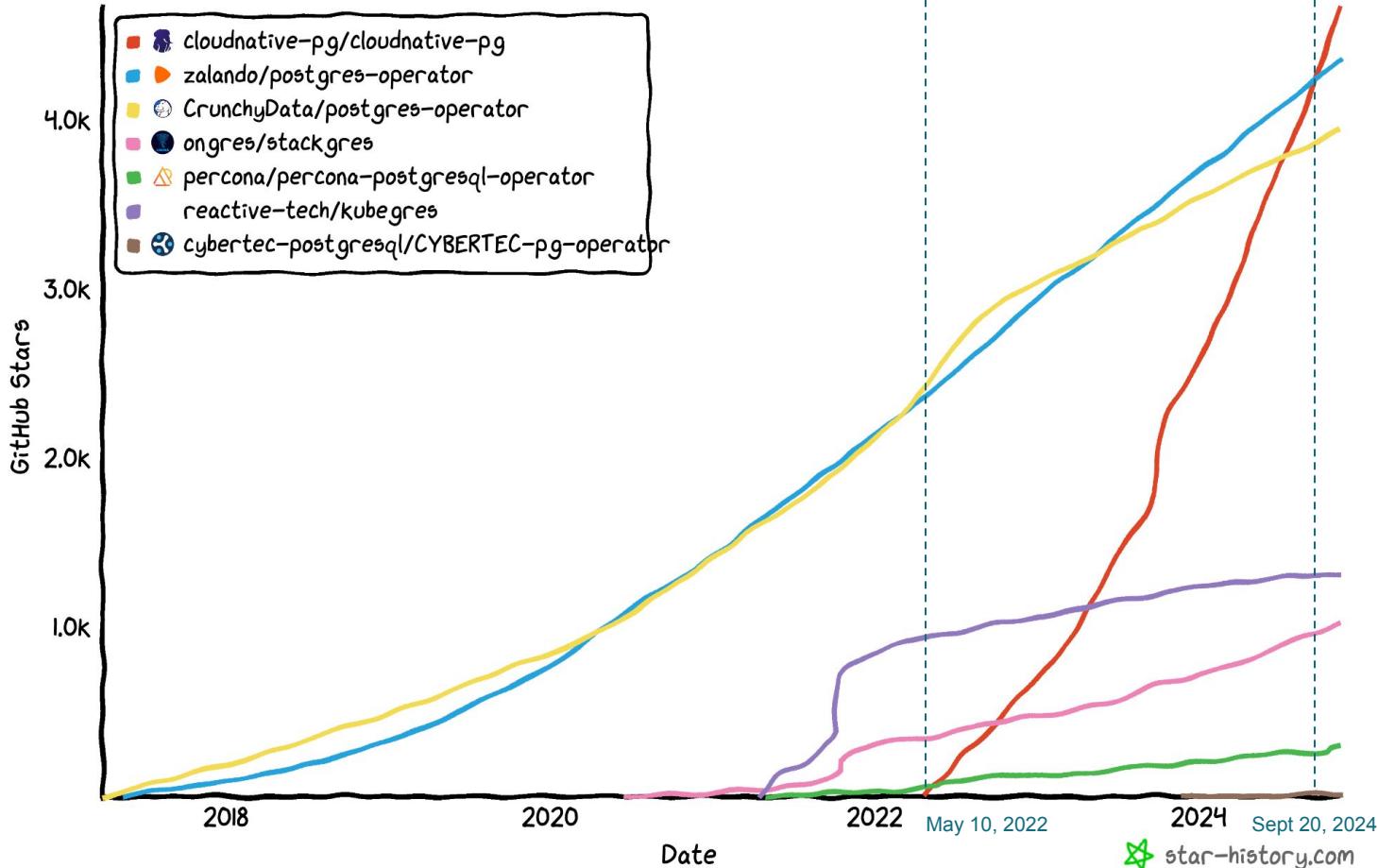


# Kubernetes operators for PostgreSQL

Operator	Year	Technology	License	Copyright	Governance	Commits year avg	Stars
Crunchy PGO	2017	Based on Patroni and Statefulsets	Apache 2.0	Company	Company	~ 165	4.0k
Zalando	2018	Based on Patroni and Statefulsets	MIT	Company	Company	~ 100	4.4k
Stackgres	2020	Based on Stolon and Statefulsets	AGPL 3.0	Company	Company	~ 615	1.3k
Percona ( <i>forked from Crunchy</i> )	2021	Based on Patroni and Statefulsets	Apache 2.0	Company	Company	~ 250	300
Kubegres	2021	Kubernetes native with Statefulsets	Apache 2.0	Company	Company	~ 10	1.3k
<b>CloudNativePG</b>	2022*	<b>Kubernetes native with PVC</b>	Apache 2.0	Community	<b>Vendor Neutral</b>	~ 800	<b>4.7k</b>
Cybertec ( <i>forked from Zalando</i> )	2023	Based on Patroni and Statefulsets	Apache 2.0	Company	Company	~ 270	12



# Star History



864 days (2y 5m)  
4260 stars

Sept 20, 2024  
CloudNativePG  
has reached the  
#1 spot for the first  
time, surpassing  
Zalando's  
PostgreSQL  
operator—a major  
milestone that  
highlights the  
growing impact  
and recognition of  
the project within  
the cloud-native  
ecosystem.



# CloudNativePG, aka CNPG

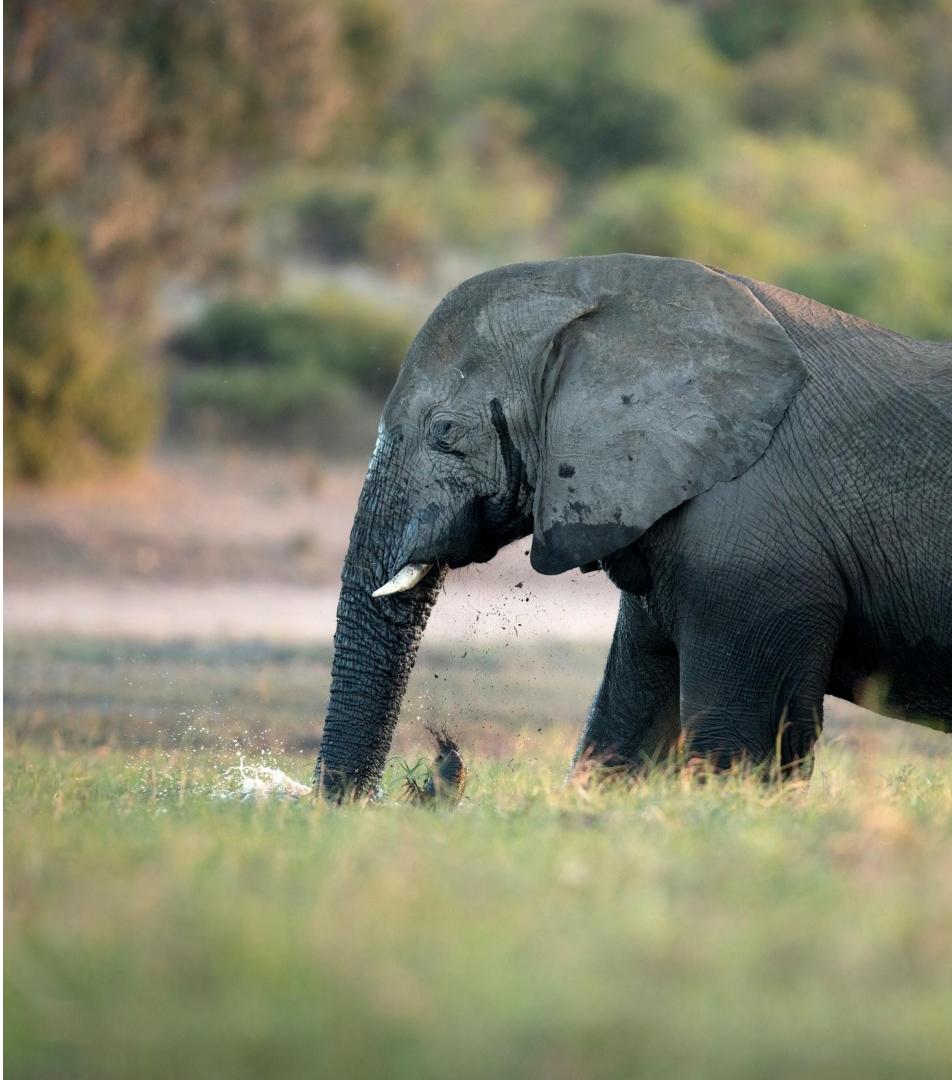
Kubernetes native database and “Level 5”, Production ready operator

- Adopted by EDB, IBM, Google, Azure, Tembo, ...
- Open source (May 2022)
  - Apache License 2.0
  - Vendor neutral, openly governed, **always free**
  - Originally created by EDB (2019 by 2ndQuadrant)
  - CNCF Sandbox application (Sept 2024, second attempt)
- Multiple installation methods:
  - K8s manifests
  - Helm chart
  - OperatorHub.io (OLM)
- ~3.6k commits
- ~4.7k stars on Github (#1 Postgres operator)
- ~60M downloads on Github (~2 years)



[github.com/cloudnative-pg](https://github.com/cloudnative-pg)





# The past

# First impressions last

Kubernetes was initially focused on stateless workloads



**Kelsey Hightower**   
@kelseyhightower

...

Kubernetes has made huge improvements in the ability to run stateful workloads including databases and message queues, but I still prefer not to run them on Kubernetes.

[Traduci il Tweet](#)

3:04 PM · 13 feb 2018



**Kelsey Hightower**   
@kelseyhightower

Kubernetes supports stateful workloads; I don't.

3:26 PM · 13 feb 2018



# Evolution of PostgreSQL in containers

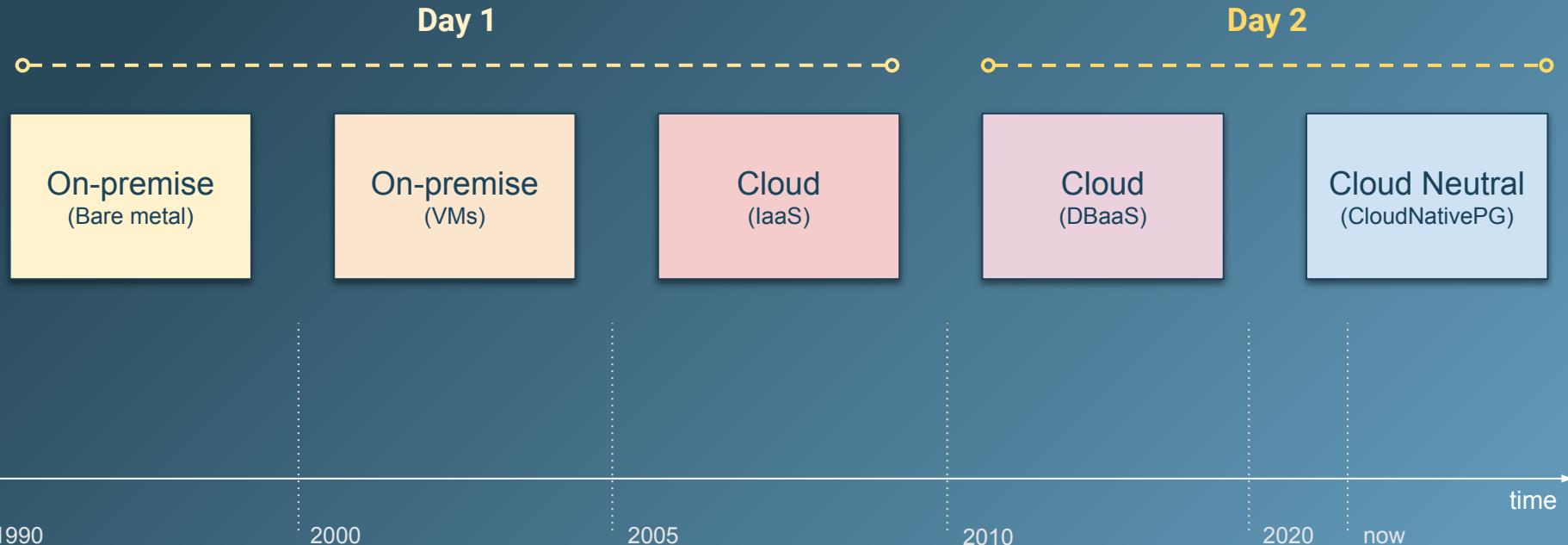
From Docker system containers to Kubernetes native databases with CloudNativePG

- **2013/3:** Docker is released. Postgres runs mainly for testing in system containers
- **2015/7:** Kubernetes 1.0 is released. Stateless applications only.
- **2016/11:** Operator pattern by CoreOS
- **2017/3:** Crunchy Data releases the first Postgres operator based on Patroni
- **2017/12:** Statefulsets are introduced in Kubernetes 1.9 (*1 year after beta in 1.5*)
- **2018/8:** Zalando releases their operator
- **2019/4:** Local persistent volumes are introduced in Kubernetes 1.14
- **2019/8:** The Cloud Native initiative at 2ndQuadrant begins (*under my lead*)
- **2021/2:** EDB launches Cloud Native Postgres
- **2022/5:** EDB open sources CloudNativePG
- **2024/9:** CloudNativePG is submitted to the CNCF Sandbox for the second time
- **2024/10:** CloudNativePG reaches 4500 stars on GitHub (#1 Postgres operator)

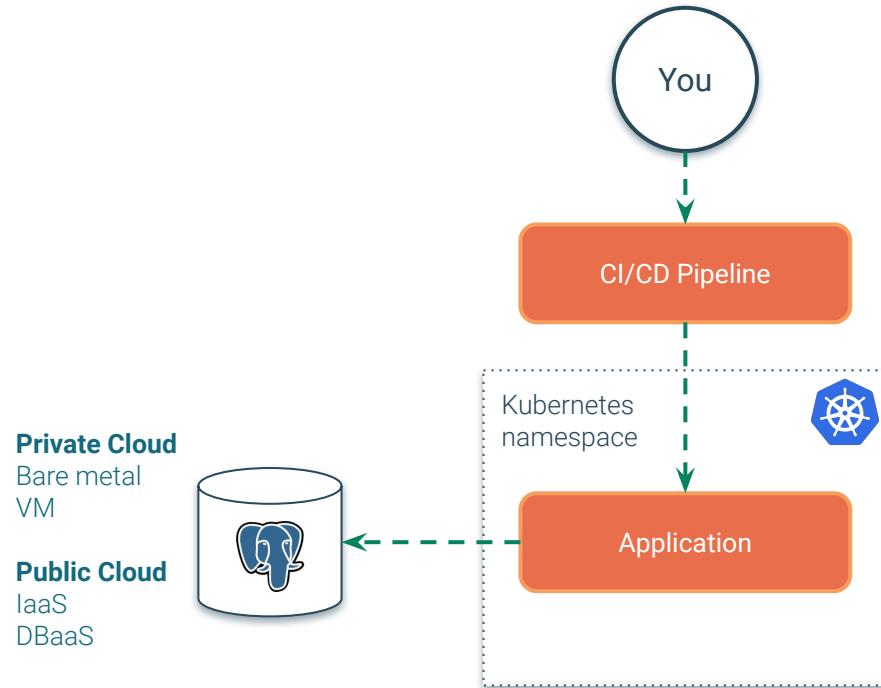


# The evolution of Postgres use cases

From Handcrafted PostgreSQL to Cloud-Neutral Automation with GitOps & K8s



Database outside your Kubernetes cluster  
**(Bare metal, VM, IaaS, and DBaaS approaches)**



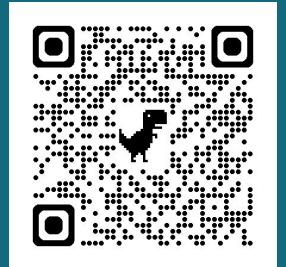


# The present

**"Kubernetes has come a long way from  
'no way I would run a database on Kubernetes' to  
'I'm running databases at petabyte scale with  
automated rolling upgrades.'"**

Michelle Au - Google Engineer, Kubernetes Storage

**June 25, 2024**



“Every single place where **Red Hat OpenShift** runs is where our customers are deploying **IBM software** that’s powered and backed up by **EDB Postgres for Kubernetes**.

I believe we’ve **tripled the adoption rate** since the inception of the **CloudNativePG** open source project, which is proof of how **rock solid** the technology is.”

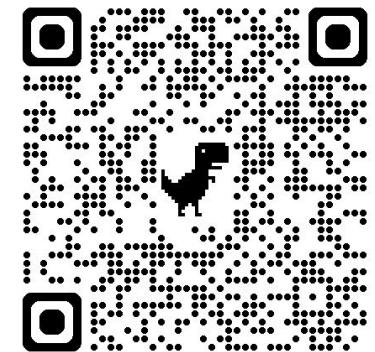
Piotr Godowski, CTO at IBM Krakow Software Lab

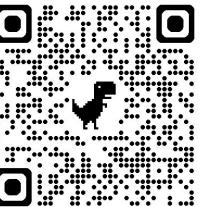
read the  
full story



# Kubernetes Just Turned Ten: Where Does PostgreSQL Stand?

Recommended reading from gabrielebartolini.it





# Data on Kubernetes Community

Databases are #1 workload in Kubernetes



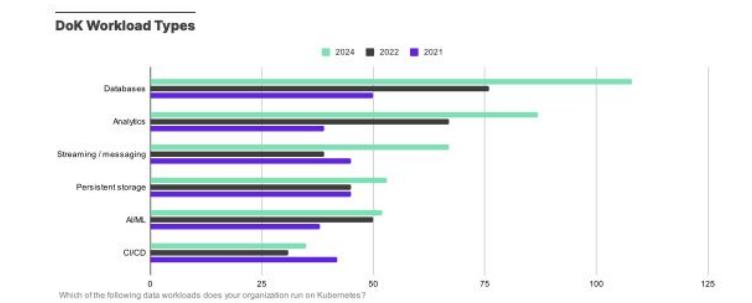
The Future of DBaaS on Kubernetes - M. Logan, S. Pronin, D. Sigireddi, G. Bartolini  
Kubecon NA 2024 - Panel

RESEARCH REPORT

**Data on Kubernetes 2024**

Beyond Databases: Kubernetes as an AI Foundation

November 2024



## Database Workloads: The Steady Foundation

Databases continue to be the cornerstone of DoK deployments. For the third consecutive year, databases remain the most common DoK workload, demonstrating the platform's reliability for critical data services. The consistency in database workload adoption demonstrates:

1. Platform Reliability: Organizations trust Kubernetes for critical data services.
2. Operational Standardization: Growing comfort with running databases on Kubernetes.
3. Deployment Confidence: Increased willingness to run production database workloads.



# Cloud **Neutral** PostgreSQL

Achieve cloud neutrality with the CloudNativePG stack (K8s, Postgres and CNPG)

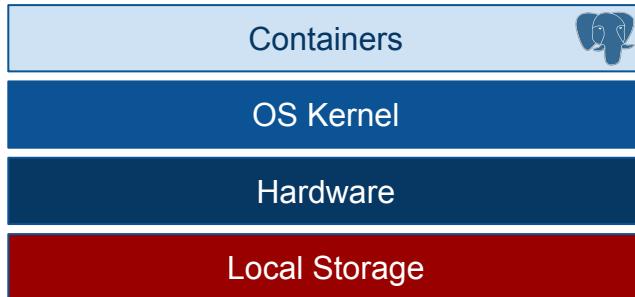
- Leverage infrastructure portability of Kubernetes, even on-prem!
  - **Private**, public, multi-cloud, **hybrid cloud**
- Provide internal/external DBaaS services with CloudNativePG
  - Extend **Day-2 operations** to PostgreSQL with CloudNativePG
  - Implement **IaC** and **GitOps** for your PostgreSQL databases
- Fully exploit PostgreSQL for data portability
  - **European Data Act**
  - **Streaming replication**, both physical and logical
- Cattle vs Pets? no ... Elephants!
  - Bare metal with local storage for **shared nothing architectures** and reduced **VM costs!**
  - **Isolate PostgreSQL workloads** with node taints (physical) and affinity rules (logical)
- Free from any form of vendor lock-in



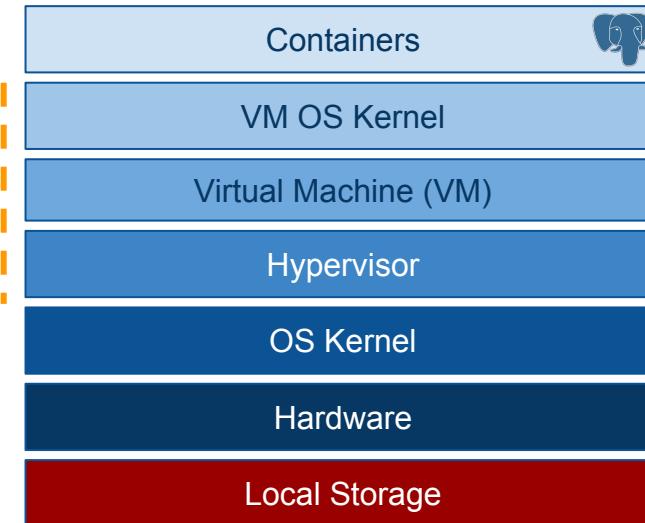
# You can run Kubernetes on bare metal nodes

With locally attached and dedicated storage. Migrating “Postgres on VMs” to CloudNativePG on bare metal Kubernetes nodes.

## Bare metal



## VMs



# The main features of CloudNativePG

Overview of CloudNativePG's main features covering through Day 2 operations

- High Availability and Self-Healing
- Support for local PVCs
- Managed services for rw and ro workloads
- Continuous backup (including snapshots)
- Point In Time Recovery (incl. snapshots)
- Scale up/down of read-only replicas
- “Security by default”, including mTLS
- Native Prometheus exporter
- Logging to stdout in JSON format
- Rolling updates, incl. minor Postgres releases
- Synchronous replication
- Online import of Postgres databases
- Separate volume for WALs
- Postgres tablespaces, including temporary
- Replica clusters and distributed topologies
- Declarative role management
- Declarative hibernation
- Declarative fencing
- Connection pooling
- Postgres extensions (pgvector, PostGIS, ...)



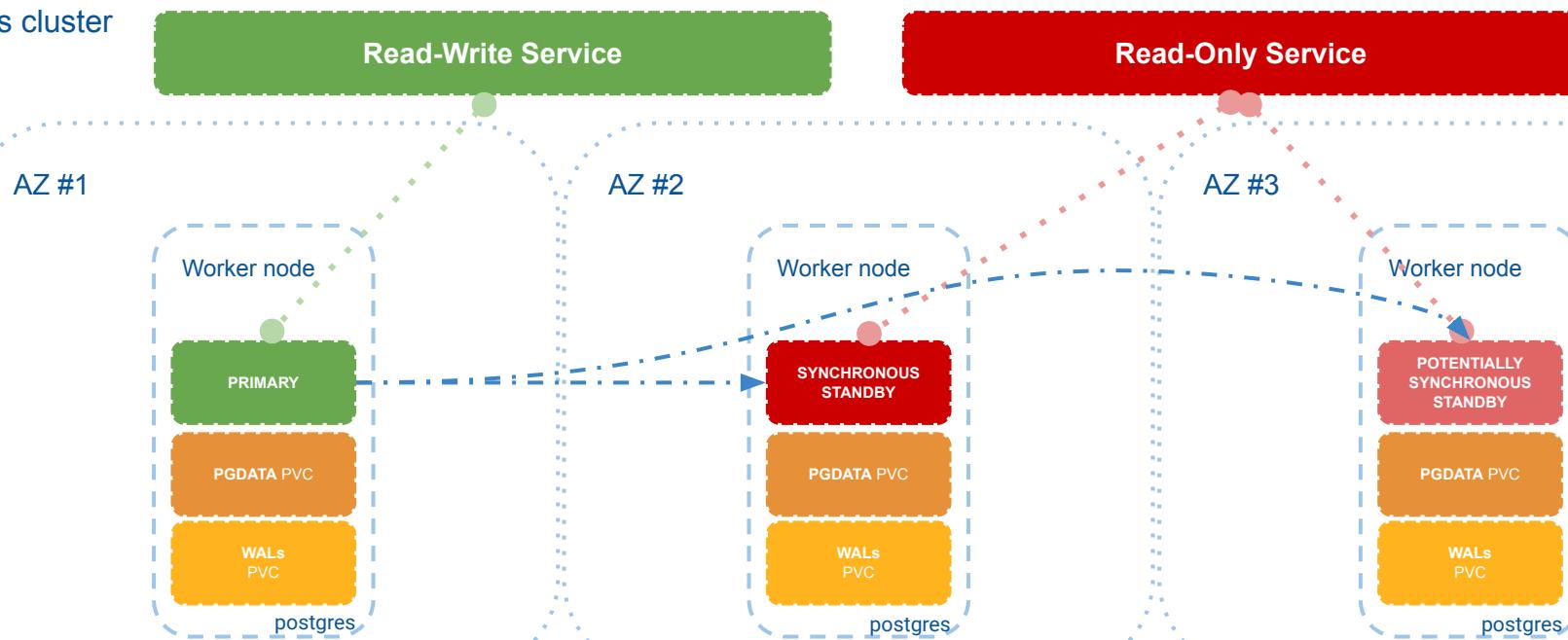
# The PostgreSQL `Cluster` resource

```
apiVersion: postgresql.cnpq.io/v1
kind: Cluster
metadata:
  name: clapton
spec:
  instances: 3
  affinity:
    nodeSelector:
      node-role.kubernetes.io/postgres: ""
  postgresql:
    synchronous:
      method: any
      number: 1
    storage:
      size: 40Gi
    walStorage:
      size: 10Gi
```



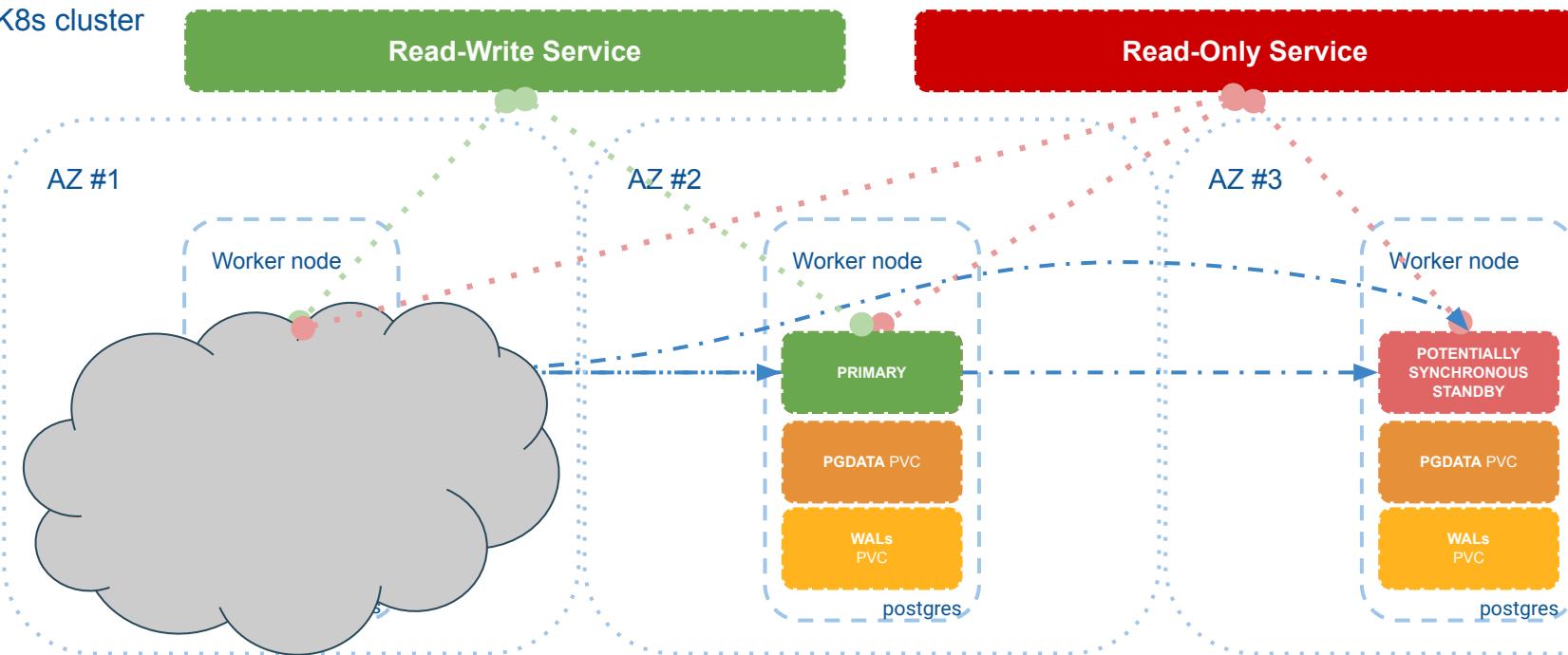
# Highly Available PostgreSQL Cluster

K8s cluster

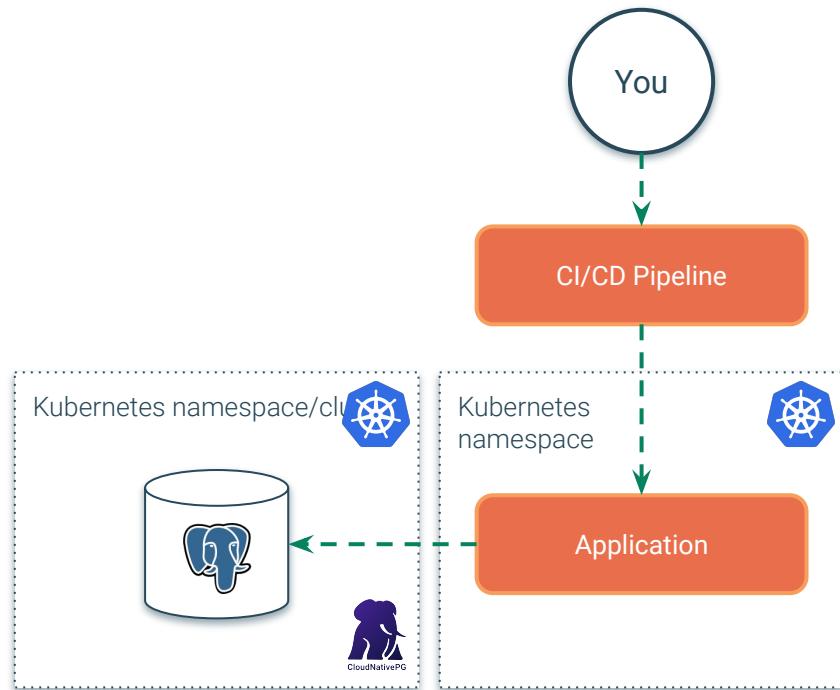


# Automated failover (HA with very low RTO)

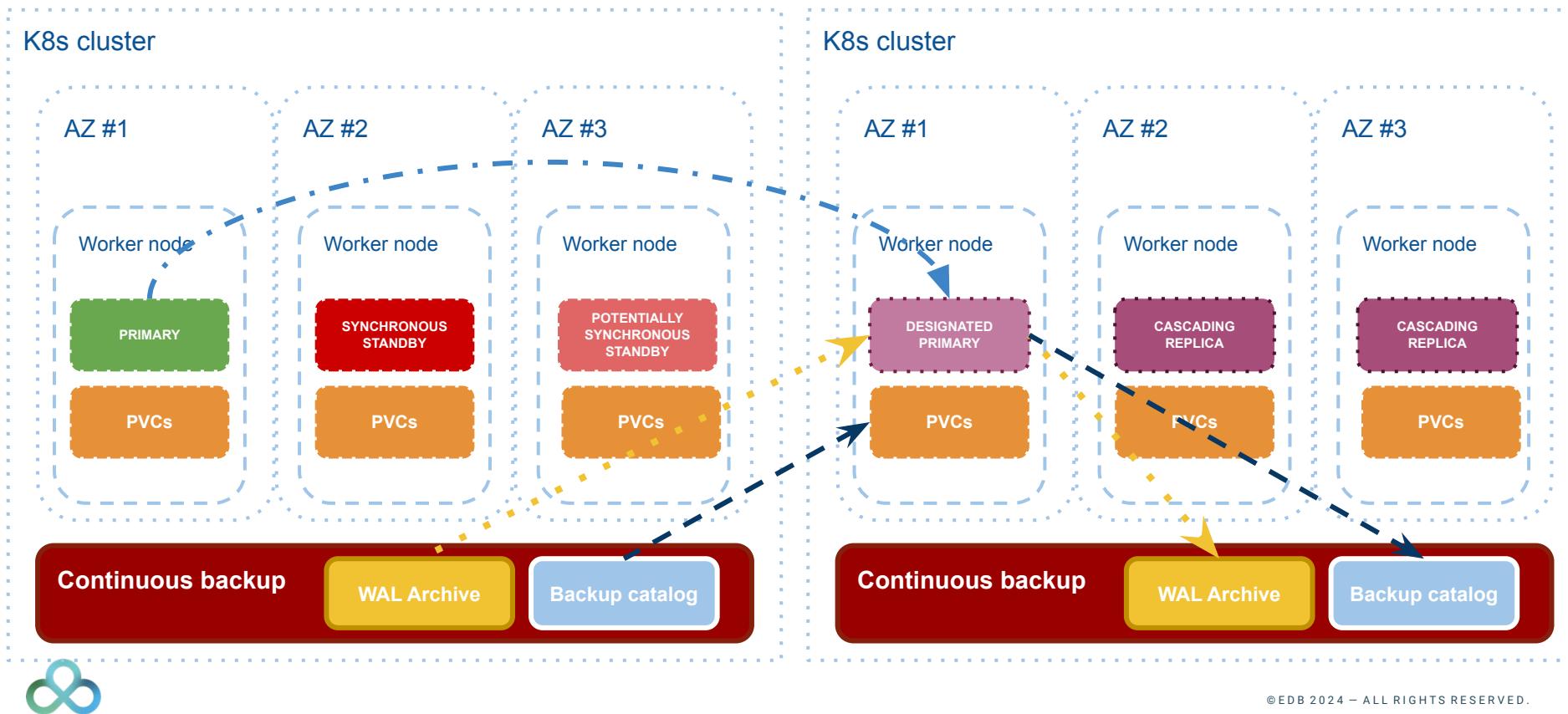
K8s cluster



Database outside your Kubernetes namespace  
**(CloudNativePG internal DBaaS approach)**



# Symmetric architecture on 2 Kubernetes clusters





# Suggested reading from the CNCF blog

The image shows the cover of a blog post. On the left, there is a teal-colored sidebar containing the title and author information. On the right, there is a photograph of a modern building's corner, featuring a glass facade and a light-colored brick or concrete structure.

**Recommended architectures for PostgreSQL in Kubernetes**

BY GABRIELE BARTOLINI

**CLOUD NATIVE COMPUTING FOUNDATION**





# The future

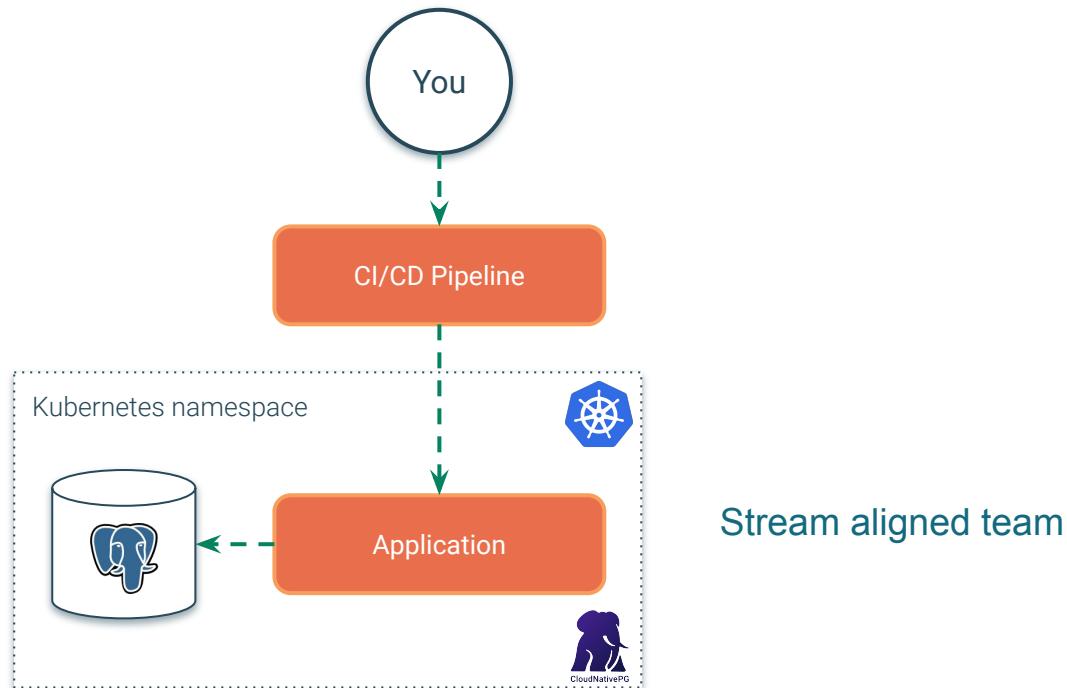


# Suggested reading from my blog

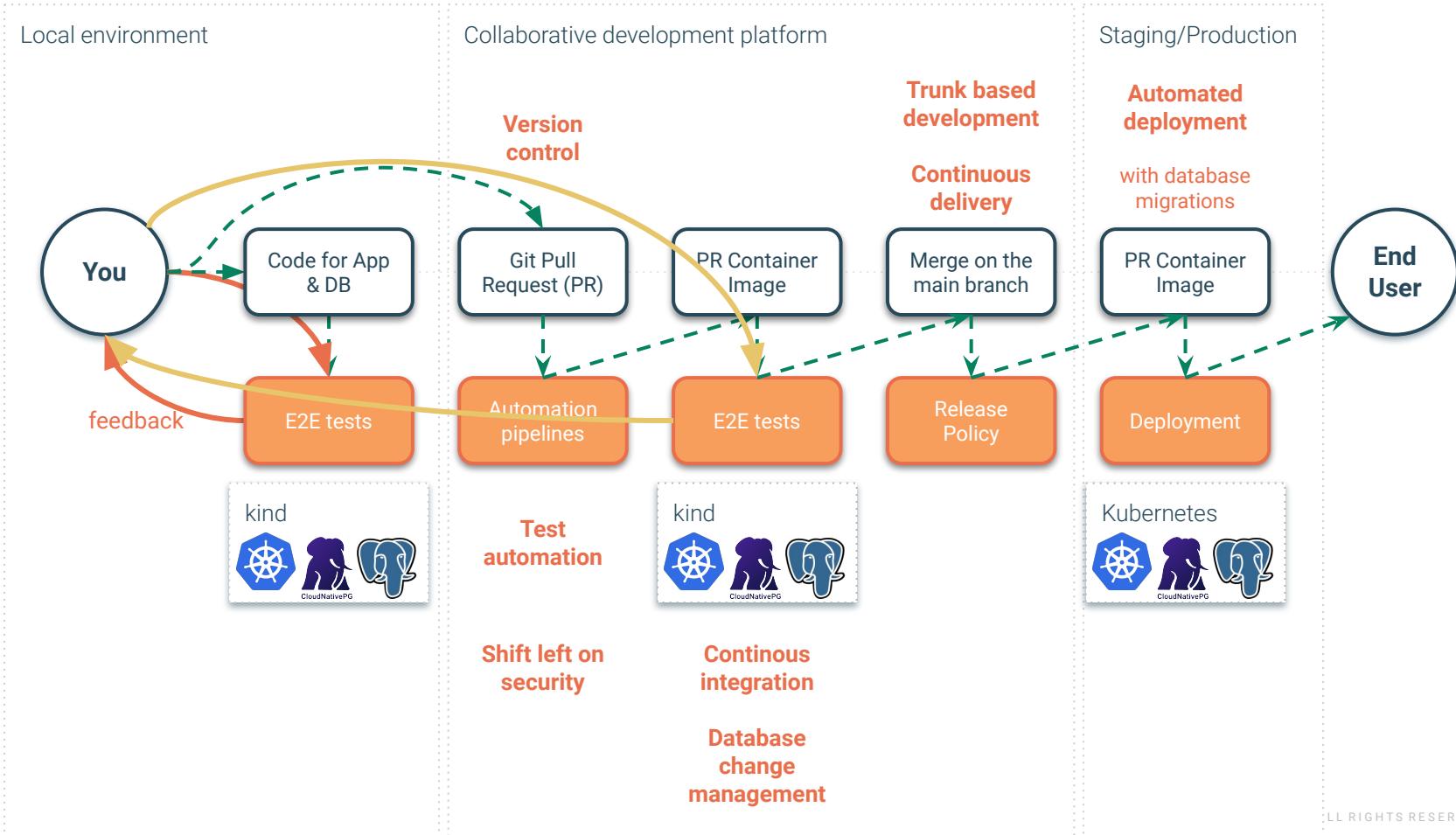
Maximizing Microservice Databases with Kubernetes, Postgres, and CloudNativePG

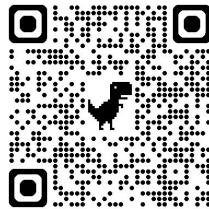


Database inside your Kubernetes namespace  
**(CloudNativePG microservice database)**



# DevOps capabilities, CloudNativePG databases and automated pipelines





# CloudNativePG's submission to the CNCF Sandbox

If you use CloudNativePG, please support our application

The screenshot shows a GitHub issue page for the "cnf / sandbox" repository. The issue is titled "[Sandbox] CloudNativePG #128". The main content of the issue includes:

- Application contact emails:** A list of email addresses: gabriele.bartolini@enterprisedb.com, leonardo.cecchi@enterprisedb.com, francesco.canova@enterprisedb.com, marco.nenciarini@enterprisedb.com, armando.ruocco@enterprisedb.com, p.scorsolini@gmail.com, jonathan.gonzalez@enterprisedb.com
- Project Summary:** CloudNativePG is a Kubernetes native database platform for PostgreSQL.
- Project Description:** CloudNativePG is a comprehensive platform designed to streamline the management of PostgreSQL databases within cloud-native environments based on Kubernetes. The main component is the CloudNativePG operator. CloudNativePG automates the entire lifecycle of PostgreSQL clusters—from deployment to maintenance—while ensuring high availability, disaster recovery, and self-healing capabilities. Built with a "security-by-default" mindset, it integrates advanced security measures, along with robust observability features like Prometheus metrics and Grafana dashboards for monitoring.

On the right side of the issue page, there are several sidebar sections:

- Assignees:** No one assigned
- Labels:** New (purple button), Storage (green button)
- Type:** No type
- Projects:** Sandbox Application Board (selected, with a status dropdown menu showing "New")
- Milestone:** None





# Roadmap

What lies ahead

- `Database` resource (declarative database management)
- `Publication` and `Subscription` resources (declarative logical replication)
- `Role` resource (declarative role management)
- Spread rolling upgrades
- CloudNativePG Interface (CNPG-I) to extend the operator
- Barman Cloud support as a CNPG-I plugin
- `VolumeGroupSnapshot` support
- Improve Postgres to manage extensions using immutable container images
- Declarative PostgreSQL major upgrades

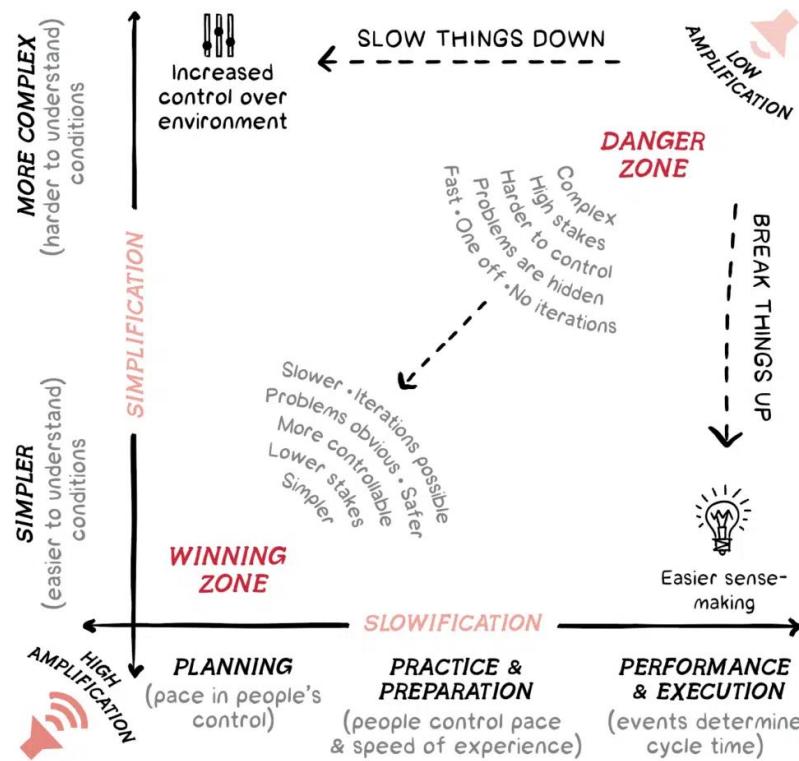
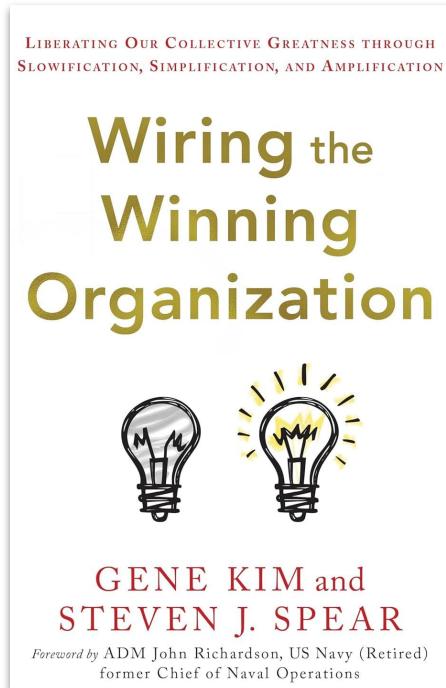


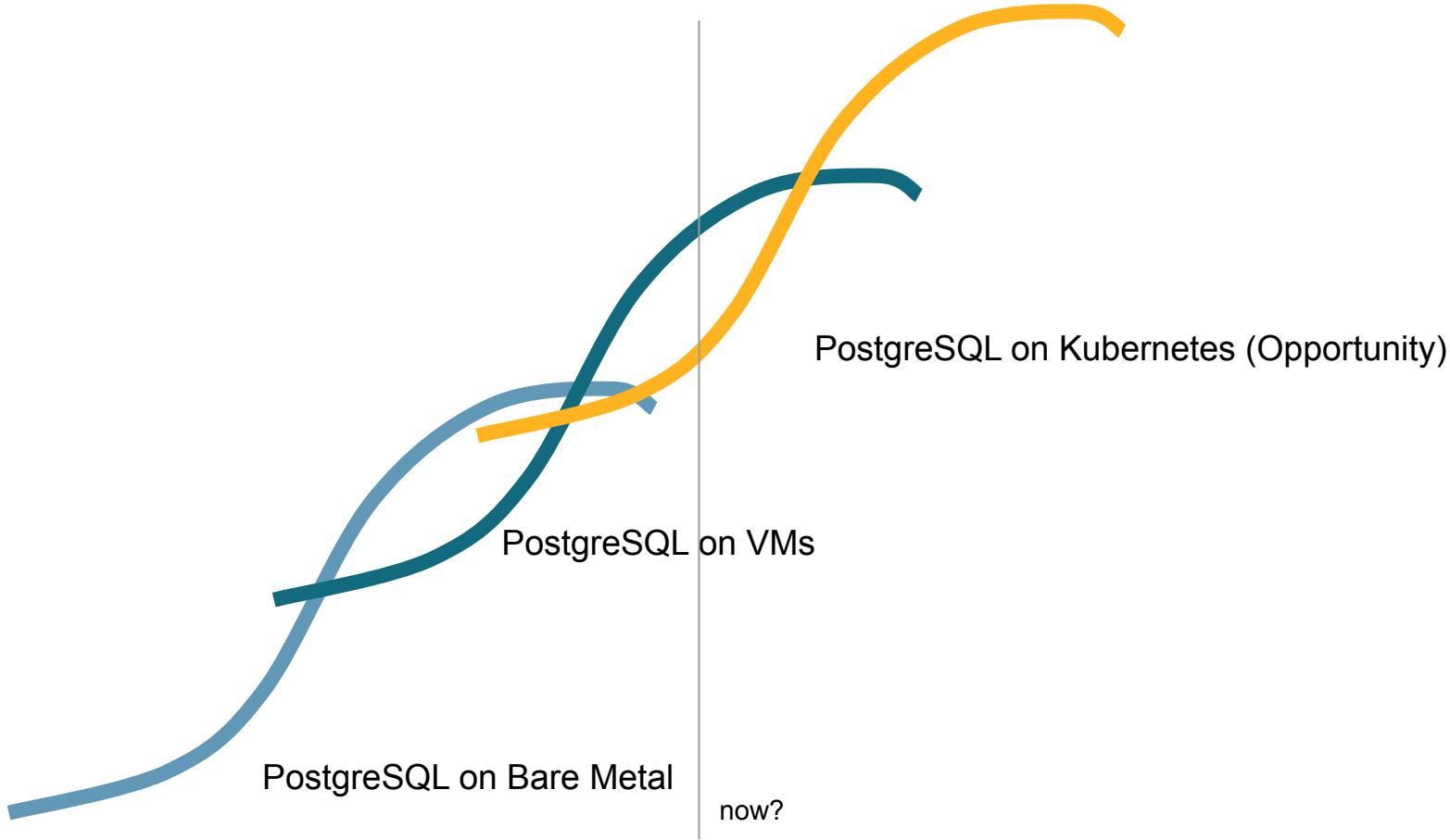


# Conclusions

# “Slowification”, Simplification, Amplification

Kubernetes is a way to **simplify** complex IT problems through modularisation





# Cattle or pets? Better ... herds



"Pinnawala orphanage provides a lifeline to the orphaned baby elephants and orphaned elephants lost in the wilderness" by Puviraj Diluckshan



# Key take aways

Your opportunity to run Postgres databases in Kubernetes starts today

- From “Kubernetes is stateless” to “Databases are #1 workloads”
- PostgreSQL is the most popular database
- CloudNativePG is the most popular operator for Postgres
- CloudNativePG is still in the first phase of adoption:
  - Internal/External DBaaS with Kubernetes (Dev separate from Ops)
  - Migration of VMs to bare metal K8s for license cost savings
  - ~0 cutover migrations/upgrades to CNPG via logical replication
- Second phase of adoption: microservice databases (true DevOps)
- Cloud Neutrality for PostgreSQL databases
- Focus on outcomes and **people** more than technologies
  - Social circuitry, Slowification, Simplification and Amplification (*Kim and Spears*)
  - T-shaped profiles and multi-disciplinary teams to spread cognitive load



# Thank you

## Maintainers

- Gabriele Bartolini
- Francesco Canovai
- Leonardo Cecchi
- Jonathan Gonzalez
- Marco Nenciarini
- Armando Ruocco
- Philippe Scorsolini

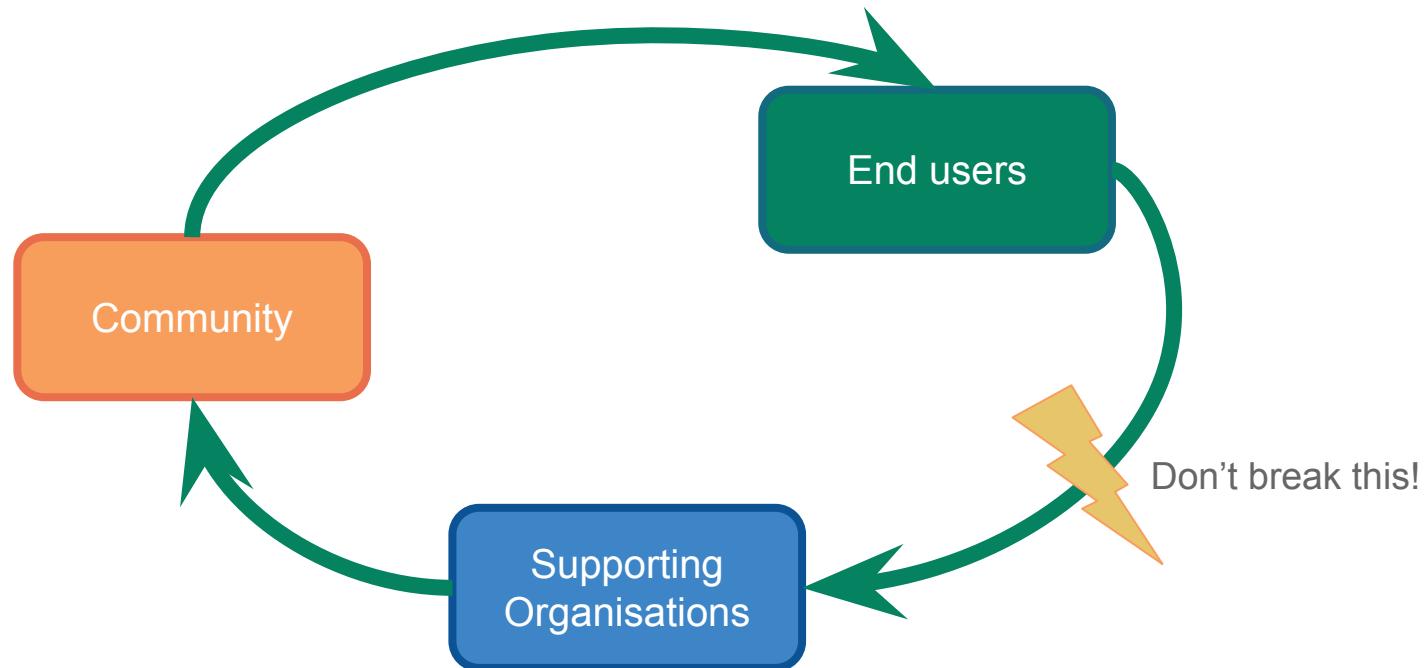
**All the contributors, users and community members**

## EDB

For generously donating the intellectual property for this project and for their decades of invaluable contributions to the broader PostgreSQL ecosystem.

# The virtuous cycle of open-source software sustainability

Help us innovate through open-source software!



# Questions?

Join **CNPG** now!

**Visit EDB booth!**



gabrielebartolini.it @\_GBartolini\_



Creators of  **CloudNativePG**

[enterprisedb.com](http://enterprisedb.com)

[cloudnative-pg.io](http://cloudnative-pg.io)

[postgresql.org](http://postgresql.org)

[dok.community](http://dok.community)

