DuckDB as backend to build optimization models in JuMP.jl

JuMP-dev 2026

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Summary

- Linearise indices by storing them as tables
- Separate indices creation from model creation
- Use DuckDB to facilitate data manipulation

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TulipaEnergyModel.jl circa Dec 2023

- Energy System Optimization
- Time blocks instead of time steps: `1:2, 3:6, 7:7, 8:9`, etc.
- Each flow is defined on a time block:

  ```
  @variable(_, flow[e in edges, timeblocks[e]])
  ```

- Each balance equation happens for another time block:

  ```
  @constraint(_, cons[a in assets, timeblocks[a]], _)
  ```

- `flow[e, block_var] * intersect(block_var, block_cons)`

Issues

- Sparse containers
- “Sum-if problem”

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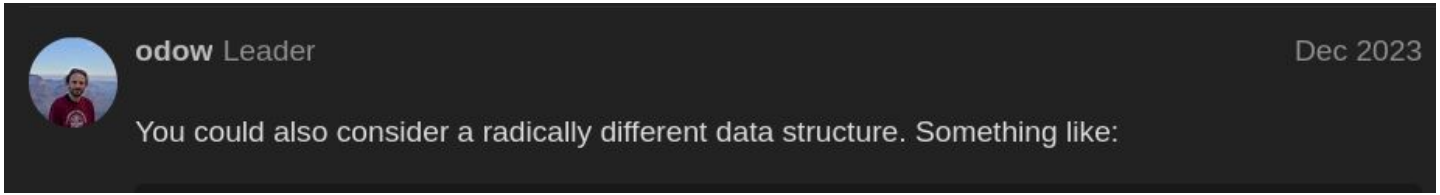
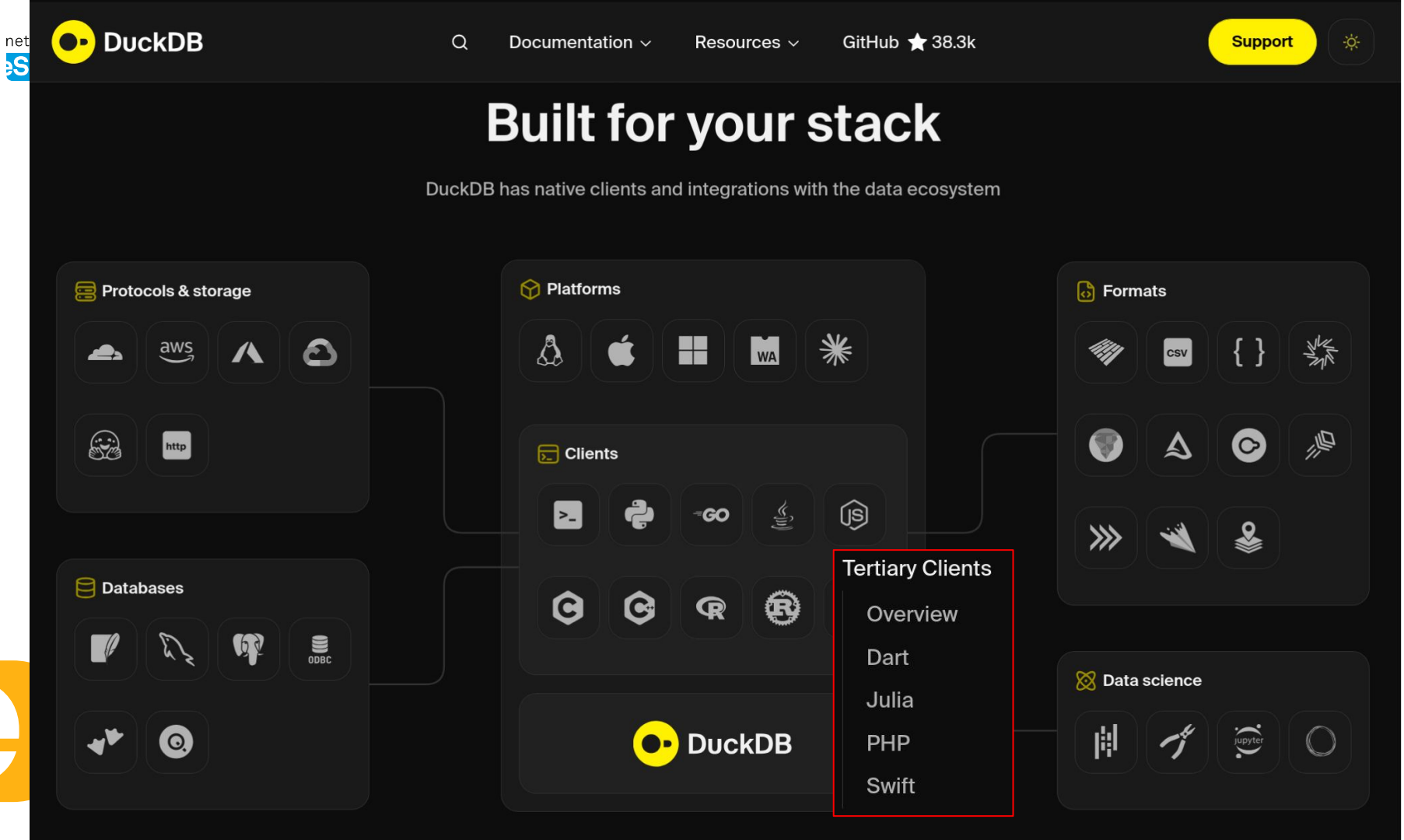
- Sparse containers
- “Sum-if problem”

Solution



- Linearized indices
- Separate indices creation from model creation


DuckDB
Documentation
Resources
GitHub 38.3k
Support
Built for your stack
DuckDB has native clients and integrations with the data ecosystem
Protocols & storage
aws
http
Platforms
WA
Formats
CSV
Clients
GO
Databases
ODBC
DuckDB
Tertiary Clients
Overview
Dart
Julia
PHP
Swift
Data science
jupyter

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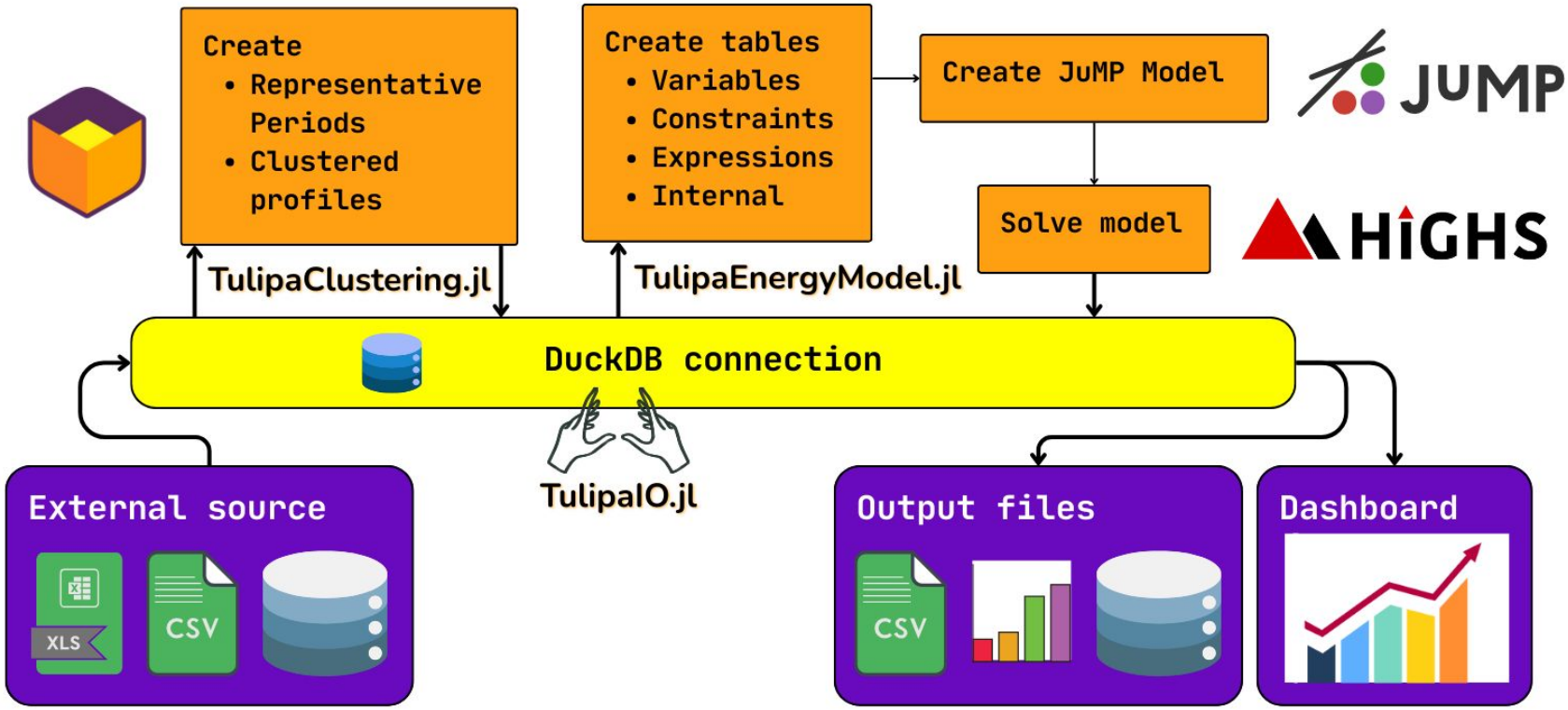
Tulipa ecosystem overview



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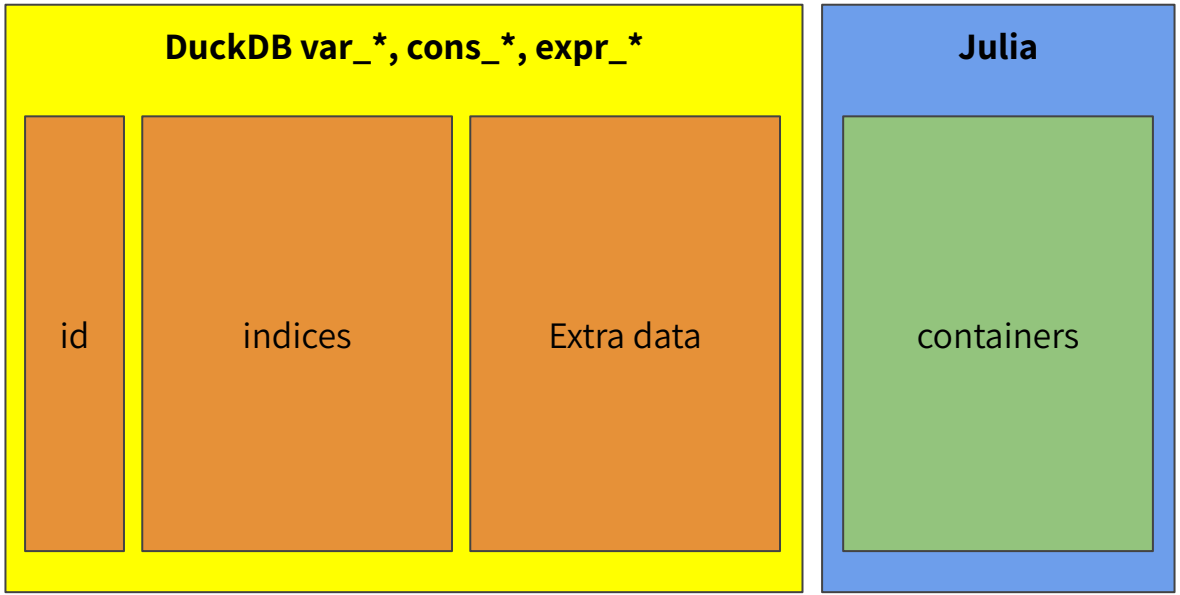
Indices and containers



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Pipeline

Input tables

```
-- SQL

CREATE OR REPLACE edges AS FROM
read_csv('edges.csv');

CREATE OR REPLACE edge_resolution AS FROM
read_csv('edge_resolution.csv');

…
```

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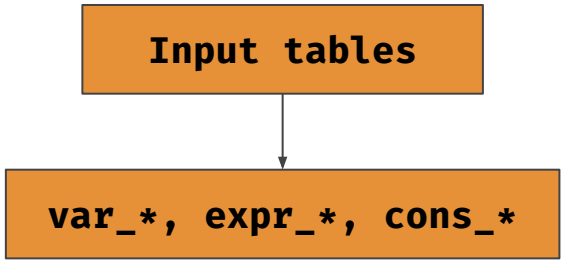
Pipeline




```
-- SQL

CREATE SEQUENCE var_id START 1;

CREATE OR REPLACE var_flow AS (
  SELECT
    nextval('var_id') AS id,
    edges.src_node_id AS src_node_id,
    edges.dst_node_id AS dst_node_id,
    … AS time_block_start
  FROM edges
  LEFT JOIN edge_resolution
    …
);
…

CREATE OR REPLACE cons_balance AS (
  SELECT
    …
    ARRAY_AGG(...) AS incoming_ids,
    …
  FROM …
);
```

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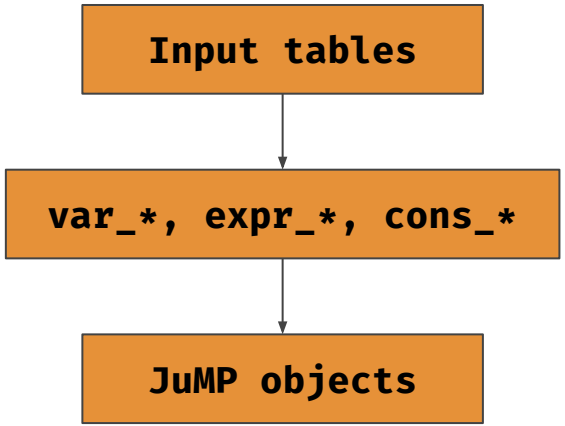
Pipeline




```julia
# Julia

sql(s) = DuckDB.query(connection, s)

var_flow = model[:var_flow] = [
  @variable(
    model,
    lower_bound = 0.0,
    base_name = "flow[$(row.id)]",
  )
  for row in sql("FROM var_flow")
]

model[:cons_balance] = [
  @constraint(
    model,
    sum(
      var_flow[id] for id in row.incoming_ids
    ) == sum(
      var_flow[id] for id in row.outgoing_ids
    )
  )
  for row in sql(“FROM cons_balance”)
]
```

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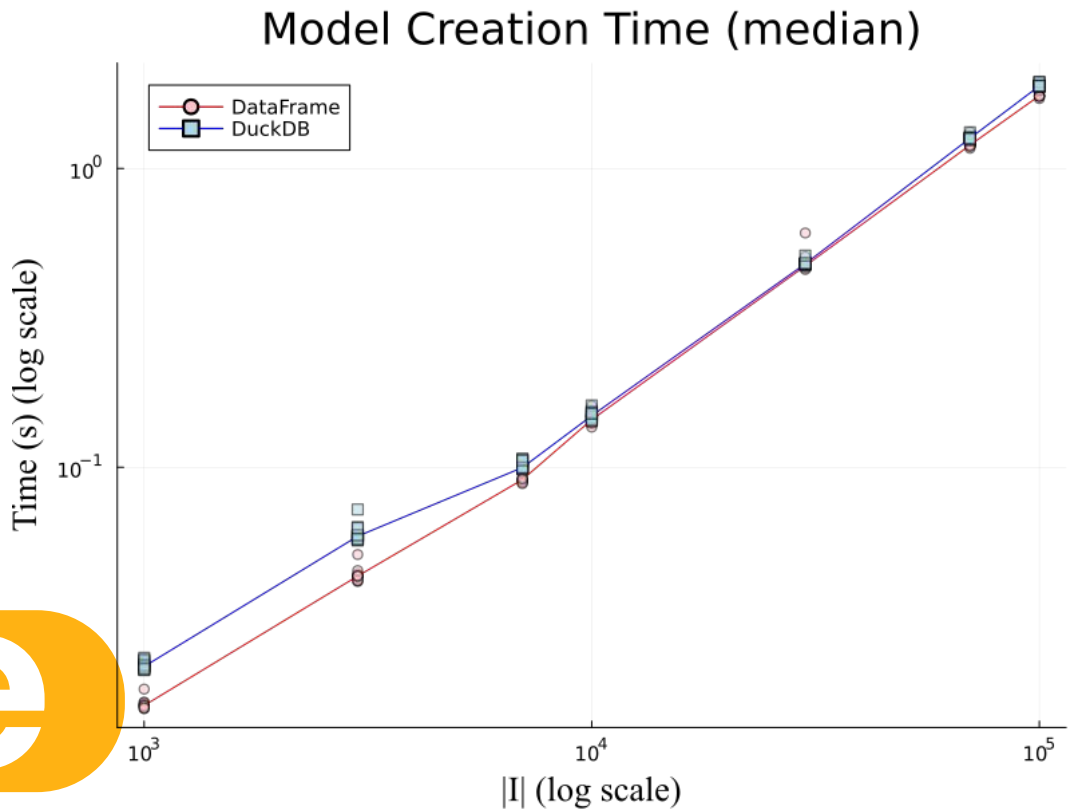
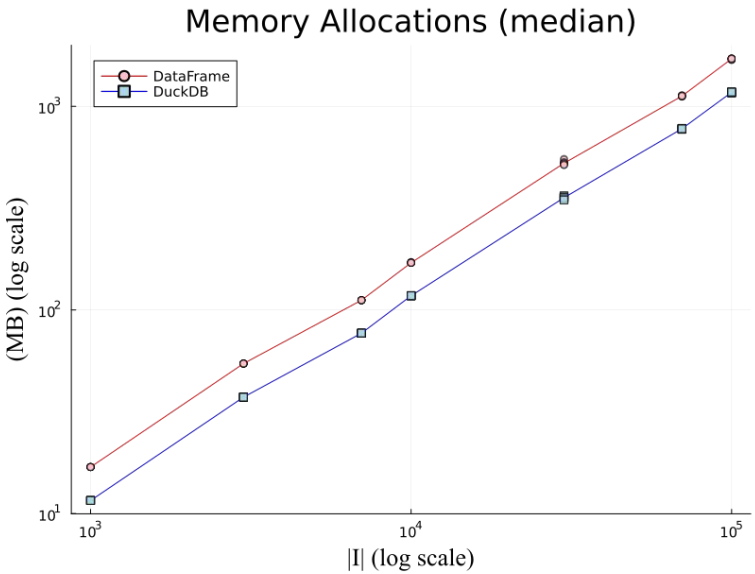
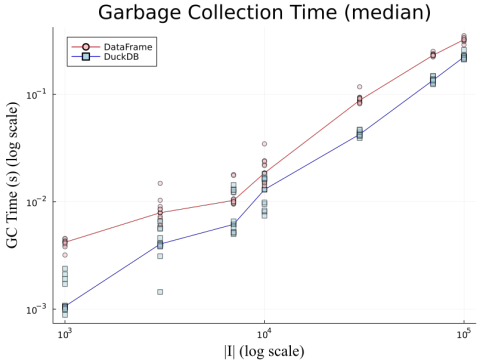
https://github.com/TulipaEnergy/2025-juliacon-poster

IJKLM problem







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Pros and cons

+ Model creation speed is similar to **DataFrames.jl** (same **Tables.jl** backend)
+ Data ops in SQL => less memory and faster
+ Easier to integrate in a more complex pipeline
+ Same indices can be used for other frameworks
- Requires SQL knowledge for modeling
- Loses JuMP indexing (but lookup can be created)
- DuckDB.jl has limited support and dynamically dispatches

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Thanks


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