SKILL WORKSHOP: AMIRIS

open **A**gent-based **M**arket model for the
Investigation of **R**enewable and **I**ntegrated energy **S**ystems

Christoph Schimeczek, Institute of Networked Energy Systems

WELCOME

Motivation
Market Modelling with AMIRIS

Transformation to **renewable-dominated** energy system

> Rising shares of fluctuating renewable energies
> Alignment of supply and demand challenging
> Refinancing uncertain

Energy systems are **complex systems**

> Market actors' behaviour under uncertainty
> Interdependencies of actors
> Emergent and non-linear effects

Aim

- Understand **market effects** of renewable energy integration
- Consider **actors' behaviour**, uncertainty and market distortions caused by regulatory framework
- Develop **policy instruments** to incite system-friendly investment and operational decisions

Motivation
Market Modelling with AMIRIS

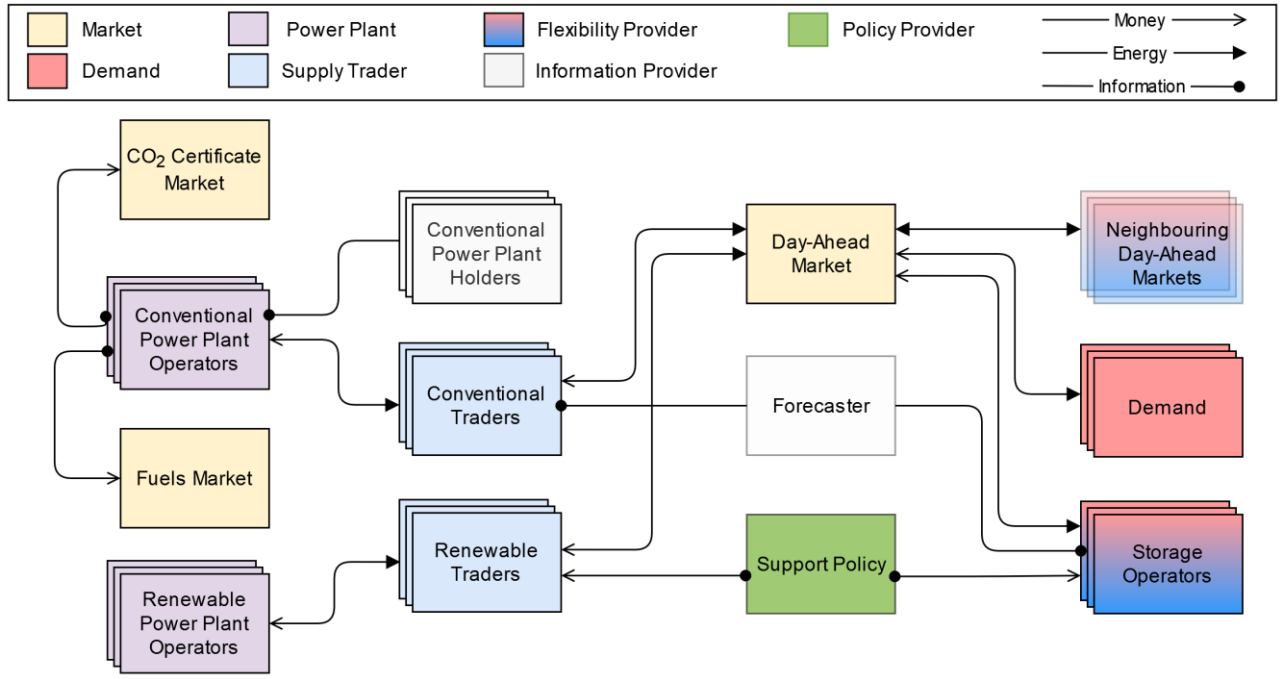
- Simulate trading and operation of power generation plants and flexibility options
- Model business-oriented behaviour under uncertainty
- Temporal resolution: ≤ hourly
- Spatial resolution: market zone(s)

Input

- Power plant park
- RES-E feed in potential
- Demand
- Efficiencies
- Availabilities
- Fuel prices
- CO_2 prices

Output

- Electricity prices
- Plant dispatch, FLH
- Market values
- System costs
- Costs for support instruments
- CO_2 emissions



Federal Ministry of Education and Research

Federal Ministry for Economic Affairs and Climate Action

Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz

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WHO ARE YOU?

AMIRIS: AGENTS

AMIRIS
Agent Types

Markets
- Determine prices

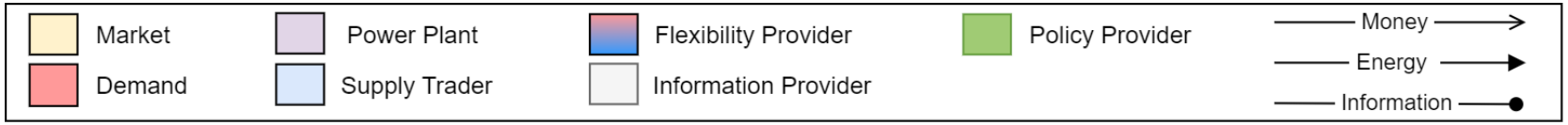
Plant operators
- Control power plants

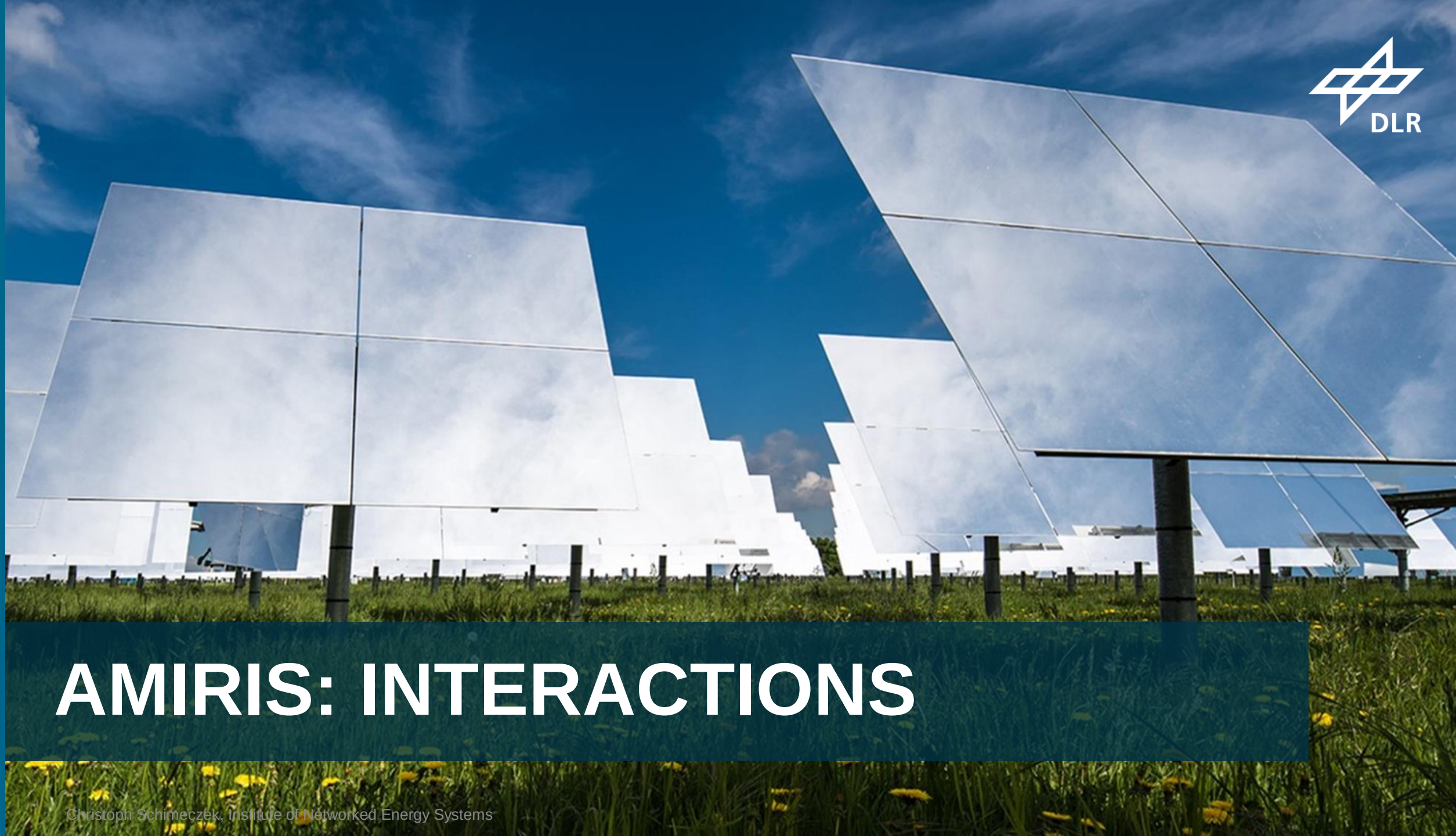
Traders
- Fulfil marketing strategies

Flexibility providers
- Optimise dispatch

Information provider
- Create forecasts

Policy
- Provide support





AMIRIS: INTERACTIONS

AMIRIS Interactions

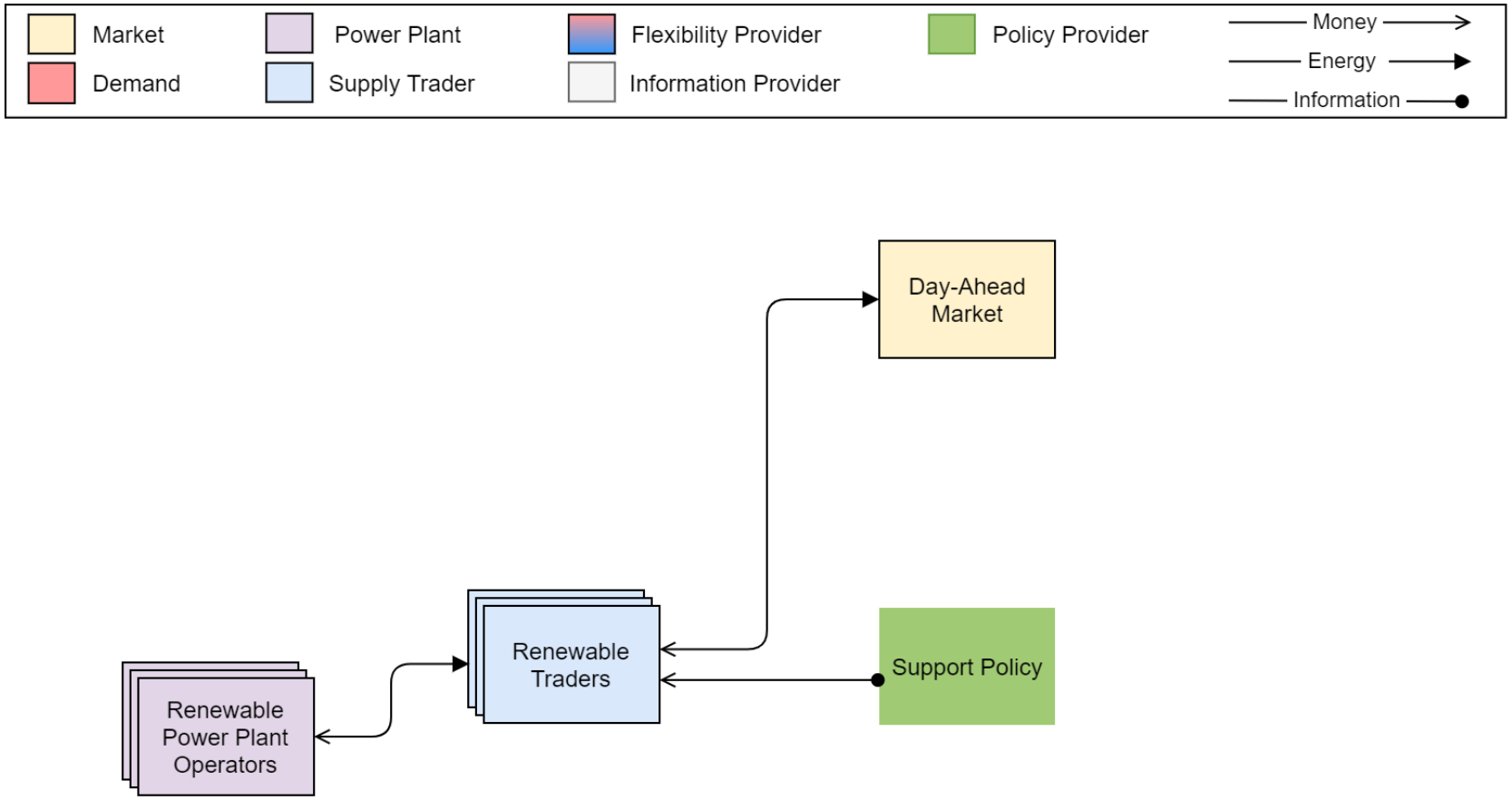
Renewables

Power Plant Operator
- Calculate marginal cost
- Dispatch power plants

Renewable Trader
- Create bid
- Request support

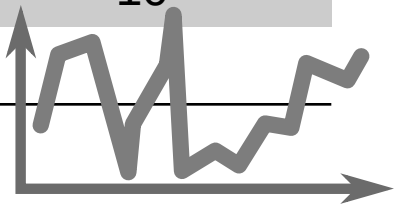
Support Policy
- Calculate support tariffs
- Provide support funding

Day-Ahead Market
- Clears Market



Renewables
Power Plant Operator

Input parameter	Value
EnergyCarrier	WindOn
InstalledPowerInMW	1000
OpexVarInEURperMWH	10
YieldProfile	



Actions

1) *Calculate power potential*
2) *Calculate marginal costs*
3) *Send marginals to Trader*
4) *Receive assignment*
5) *Dispatch plants*

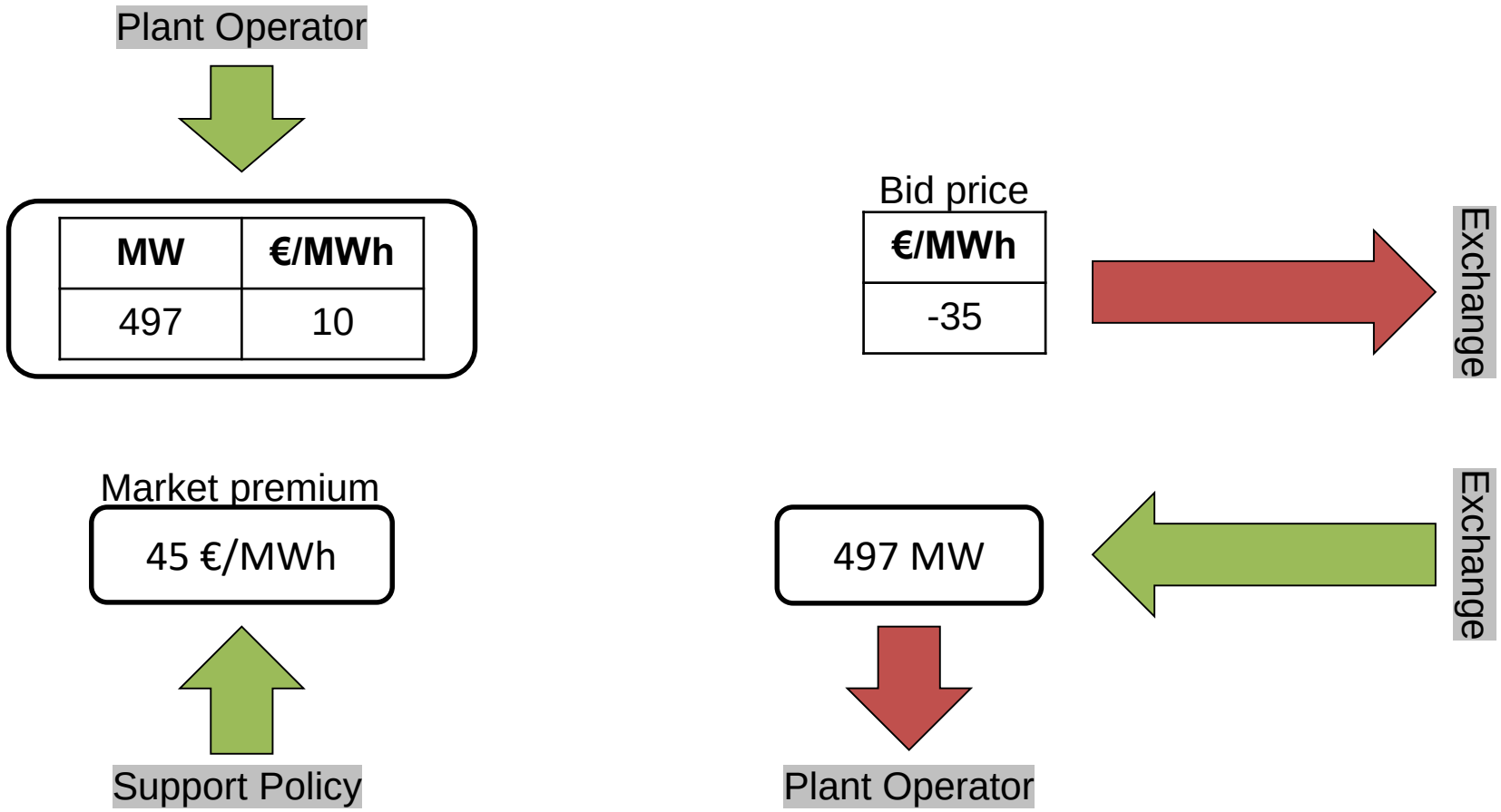
MW	€/MWh
497	10

497 MW

Renewables
Trader

Actions

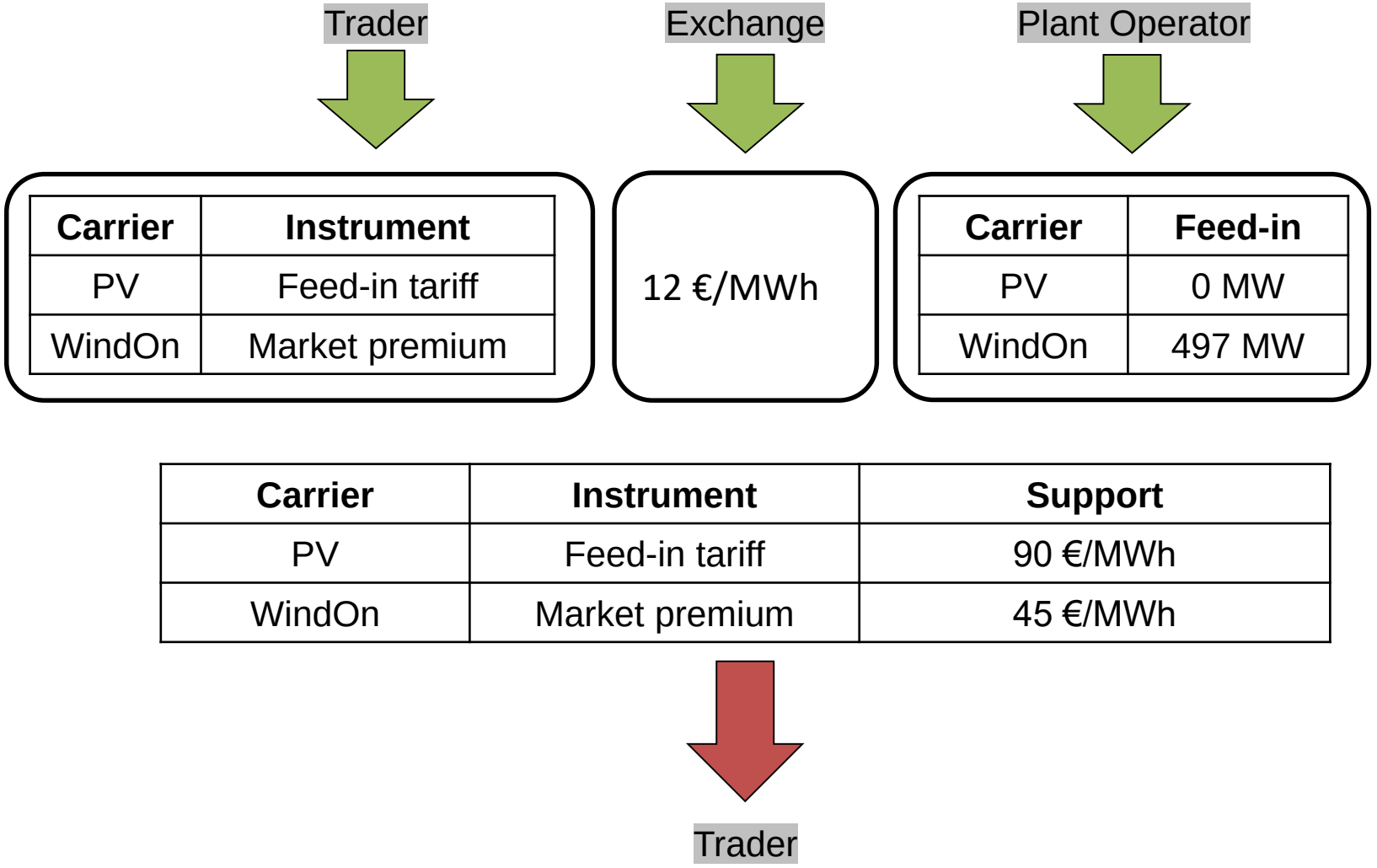
1) *Receive marginal costs*
2) *Check support instrument*
3) *Derive bid*
4) *Send bids to Exchange*
5) *Receive awards*
6) *Forward power to operator*



Renewables
Support Policy

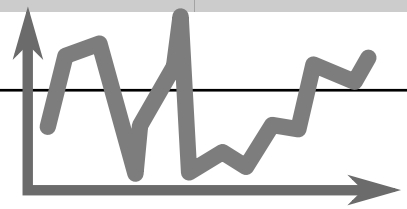
Actions

1) *Register clients*
2) *Track power prices*
3) *Track feed-in potentials*
4) *Calculate variable tariffs*
5) *Provide support*



Demand
Trader

Input parameter	Value
ValueOfLostLoad	3000
DemandSeries	



Actions

1) Create bid

2) Send bid(s) to Exchange

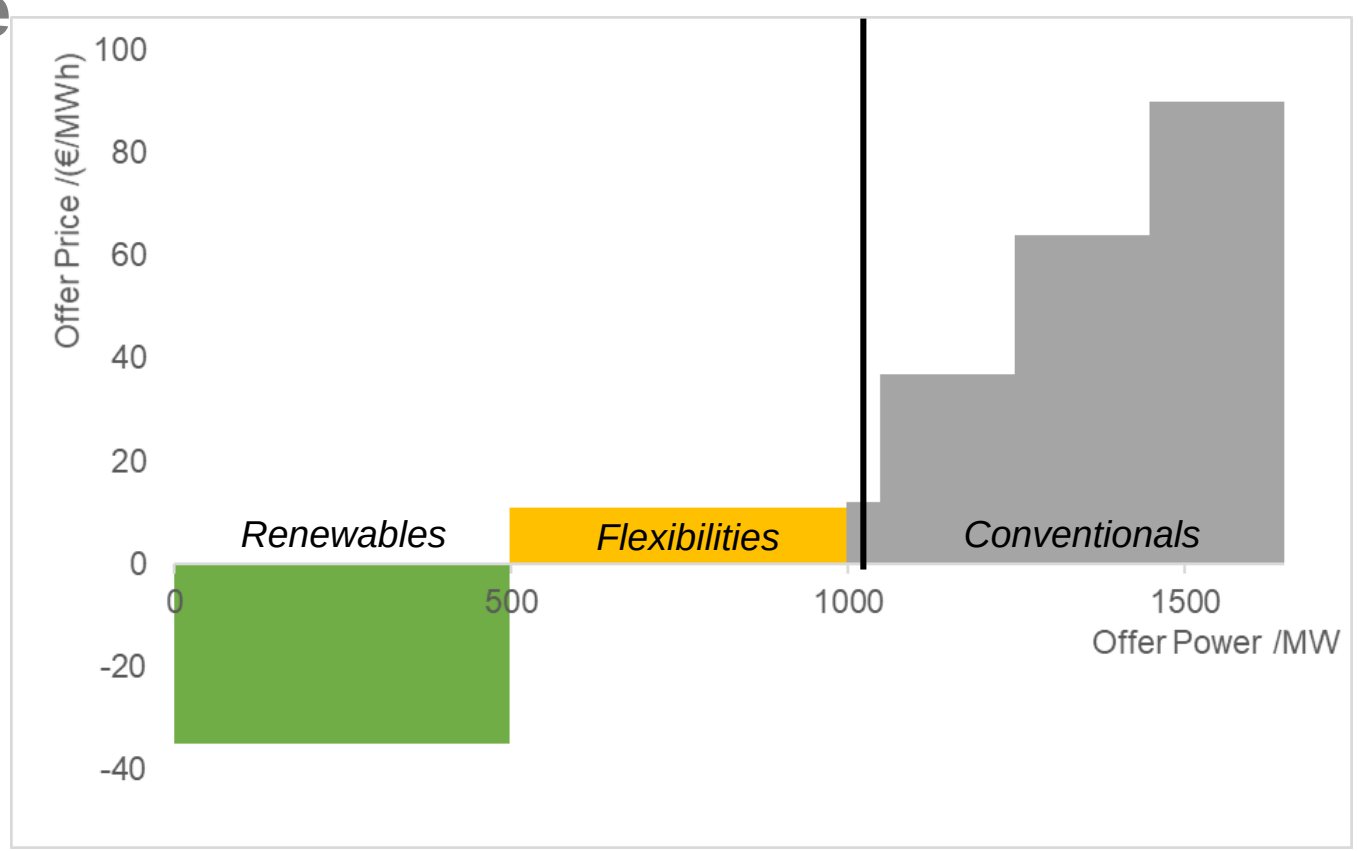
MW	€/MWh
1017	3000

Exchange

Energy Exchange
Market Clearing

Actions

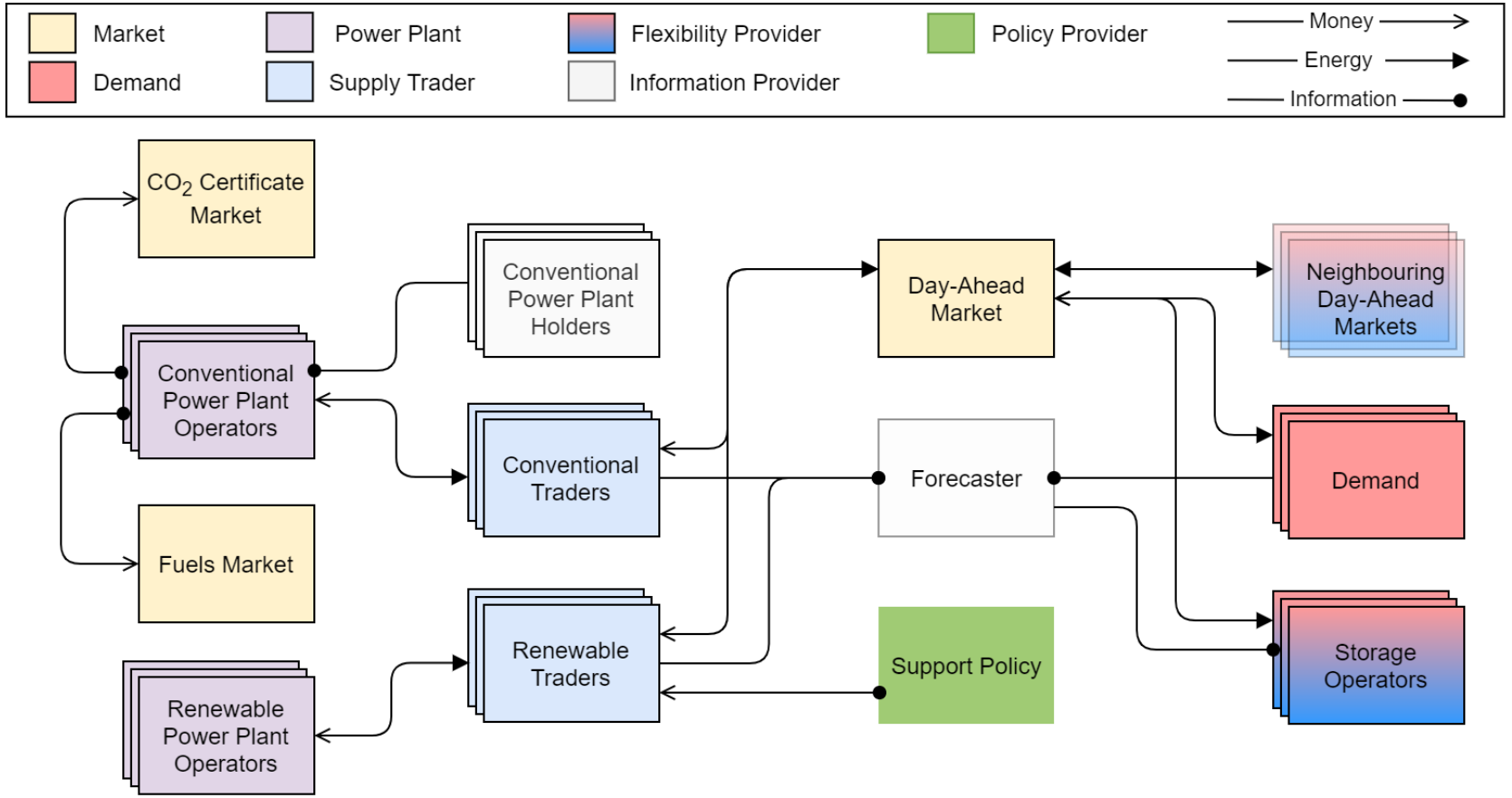
1) *Receive bids*
2) *Clear market*
3) *Send awards*



MW	€/MWh
497	12
500	12
20	12

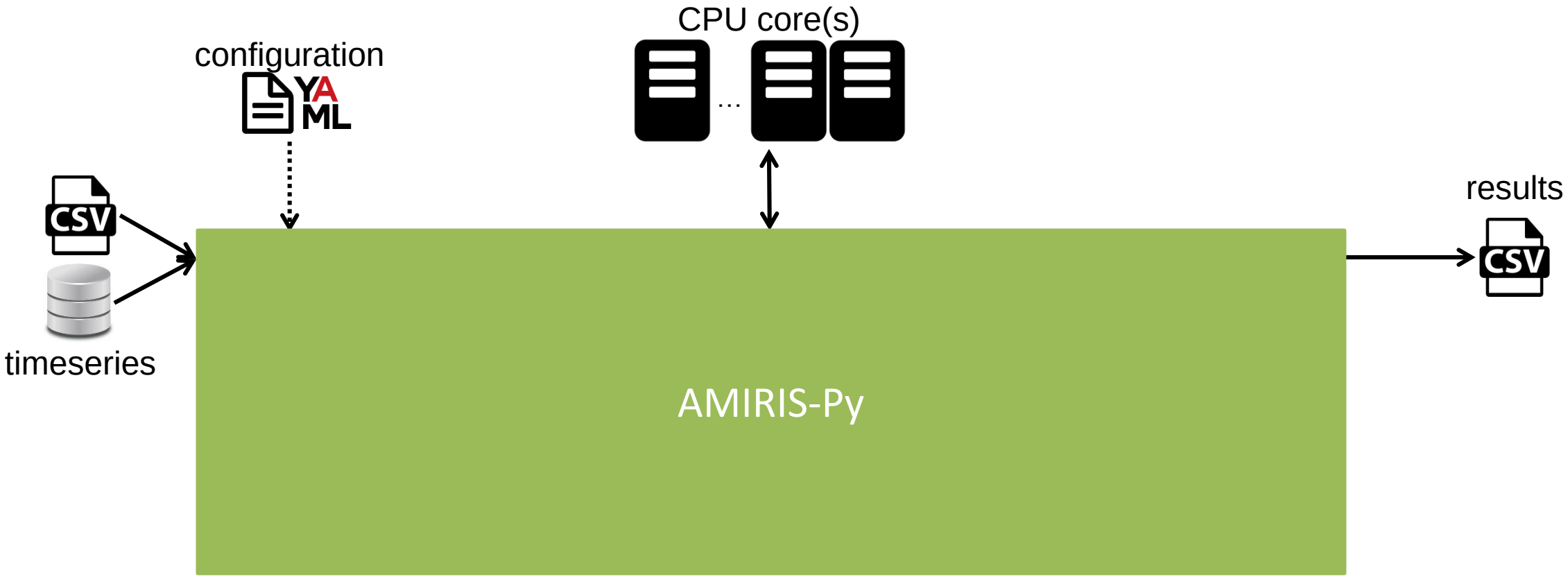
Trader

AMIRIS Agents
Overview

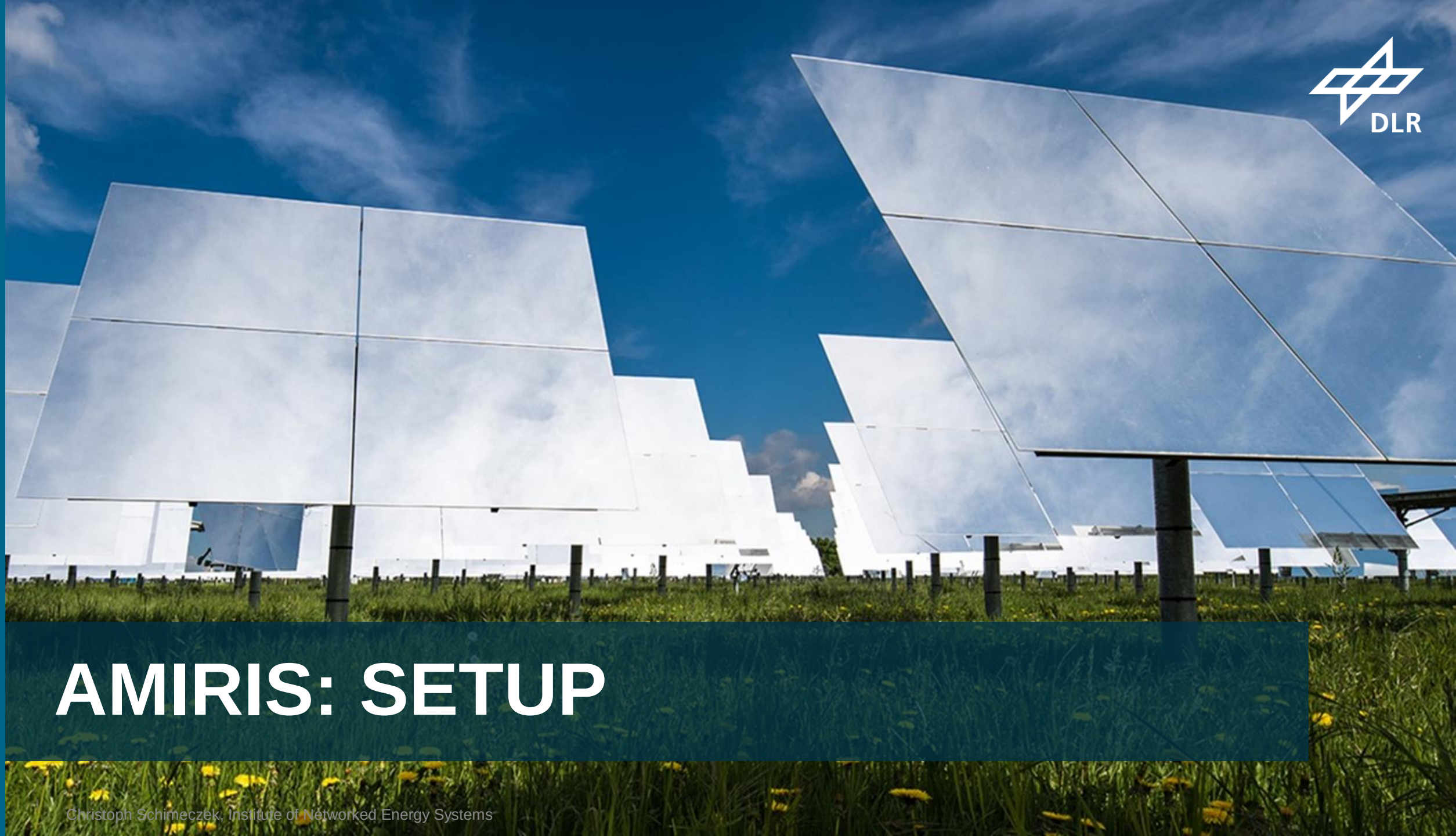


AMIRIS is based on FAME

*open **F**ramework for distributed **A**gent-based **M**odelling of **E**nergy systems*



FAME-Core: https://joss.theoj.org/papers/10.21105/joss.05087
FAME-Io: https://joss.theoj.org/papers/10.21105/joss.04958



AMIRIS: SETUP

Setup
Requirements

- Java JDK 11

```
(base) PS C:\> java --version
openjdk 11.0.9.1 2020-11-04
OpenJDK Runtime Environment AdoptOpenJDK (build 11.0.9.1+1)
OpenJDK 64-Bit Server VM AdoptOpenJDK (build 11.0.9.1+1, mixed mode)
```

  - Obtain from, e.g., https://adoptium.net/

- Python 3.8 / 3.9

```
(base) PS C:\> python --version
Python 3.9.7
```

  - Obtain from, e.g., https://github.com/conda-forge/miniforge#mambaforge

Setup
Python environment

- Create environment

```
(base) PS C:\> mamba create -n AmirisEnv python=3.8
```

- Activate environment

```
(base) PS C:\> conda activate AmirisEnv
```

- Install *amirispy*

```
(AmirisEnv) PS C:\> pip install amirispy
```

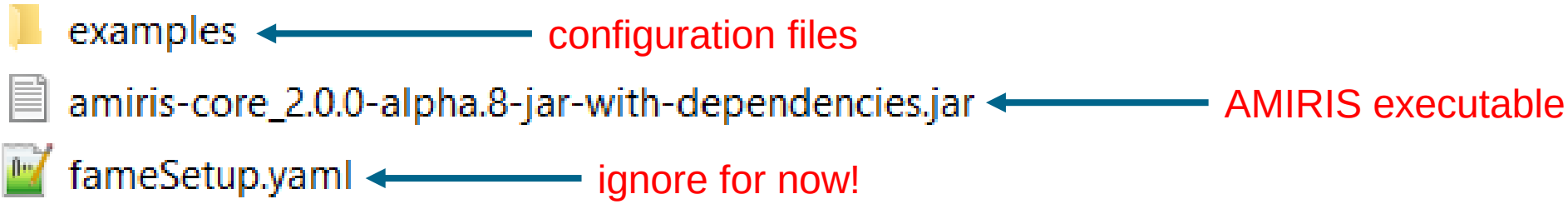
- Create folder:

```
(AmirisEnv) PS C:\> mkdir amiris; cd amiris
```

- Install *AMIRIS*:

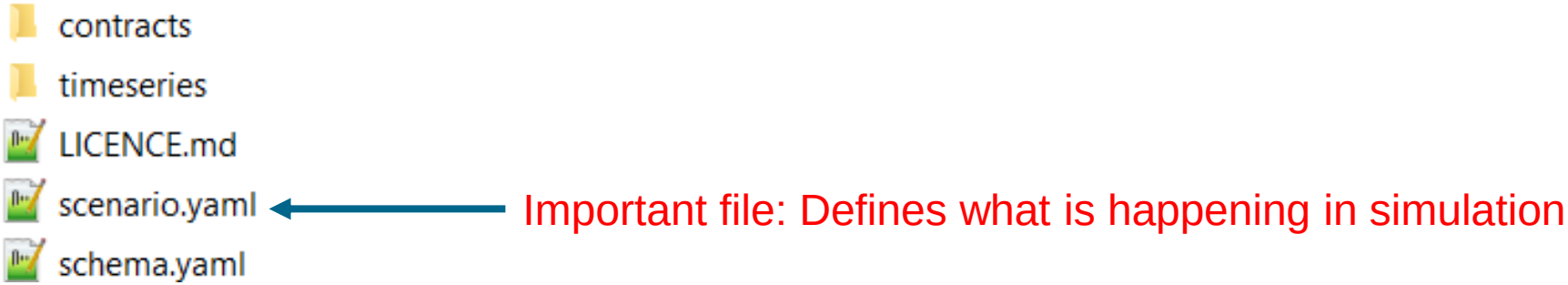
```
(AmirisEnv) PS C:\amiris> amiris install
```

Setup
Files



examples/

Examples/Simple/



Setup
Run AMIRIS

```
(AmirisEnv) PS C:\amiris> amiris run
usage: amiris run [-h] --jar JAR --scenario SCENARIO
                  [--output OUTPUT]
amiris run: error: the following arguments are required: --jar/-j, --scenario/-s
```

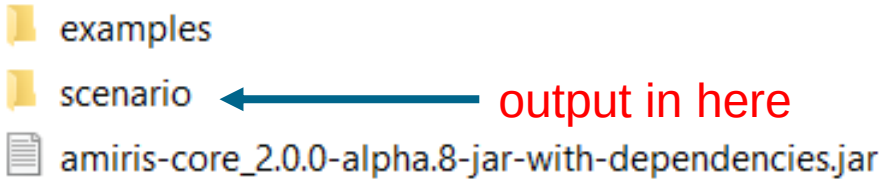
Required arguments

- -j AMIRIS executable
- -s Scenario file

```
(AmirisEnv) PS C:\amiris> amiris run -j .\amiris-core_2.0.0-alpha.8-jar-with-dependencies.jar
 -s .\examples\Simple\scenario.yaml
```

Console output

```
14:18:38 – PRINT – Start running AMIRIS
Starting up 1 processes.
Warm-up completed after 1 ticks.
04.10.2023 14:18:39:: Simulation completed! Ran 219 ticks in 258 ms
14:18:40 – PRINT – Successfully executed AMIRIS. See your results in '.'
```



Setup
Redirect output

```
(AmirisEnv) PS C:\amiris> amiris run -h
usage: amiris run [-h] --jar JAR --scenario SCENARIO [--output OUTPUT]

optional arguments:
  -h, --help            show this help message and exit
  --jar JAR, -j JAR     Path to 'amiris-core_<version>-jar-with-dependencies.jar'
  --scenario SCENARIO, -s SCENARIO
                        Path to a scenario yaml-file
  --output OUTPUT, -o OUTPUT
                        Directory to write output to
```


use this

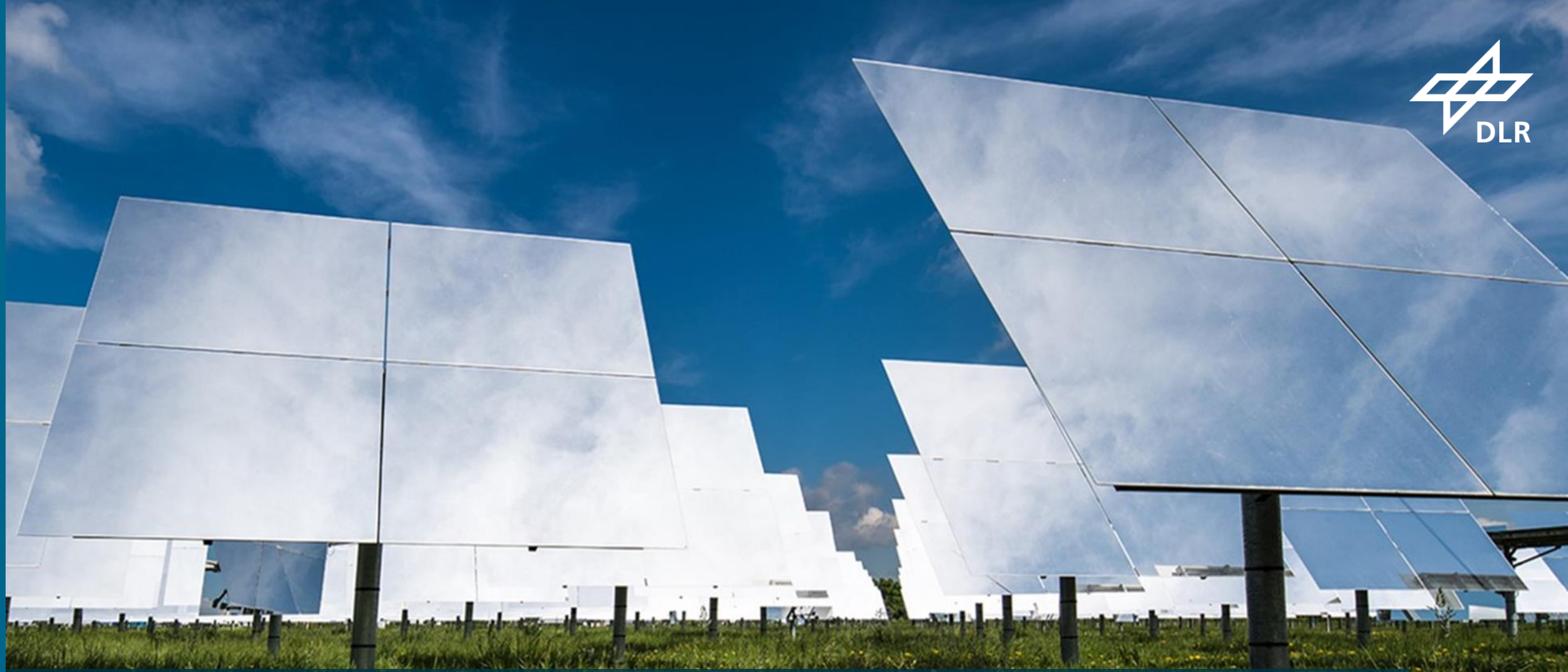
```
(AmirisEnv) PS C:\amiris> amiris run -j .\amiris-core_2.0.0-alpha.8-jar-with-dependencies.jar
 -s .\examples\Simple\scenario.yaml -o simple
```

output now in here

Setup
Results

- ConventionalPlantOperator.csv
- ConventionalPlantOperator_DispatchedP...
- ConventionalPlantOperator_VariableCost...
- ConventionalTrader.csv
- DemandTrader.csv
- EnergyExchange.csv
- NoSupportTrader.csv
- VariableRenewableOperator.csv

AgentId	TimeStep	TotalAwardedPowerInMW	ElectricityPriceInEURperMWH
1	01.01.2021 00:00	12431	267.4721054
1	01.01.2021 01:00	11416	262.9066734
1	01.01.2021 02:00	11163	260.8119727
1	01.01.2021 03:00	11036	257.4786831
1	01.01.2021 04:00	11192	256.4702082
1	01.01.2021 05:00	12177	256.2193284
1	01.01.2021 06:00	12685	256.2193284
1	01.01.2021 07:00	15222	259.7771467
1	01.01.2021 08:00	16491	260.2935264
1	01.01.2021 09:00	17125	257.9859146
1	01.01.2021 10:00	17378	255.7190453
1	01.01.2021 11:00	16997	255.4696391
1	01.01.2021 12:00	16237	257.2258181
1	01.01.2021 13:00	15476	256.4702082
1	01.01.2021 14:00	15222	259.5197279
1	01.01.2021 15:00	14968	262.3798356
1	01.01.2021 16:00	15095	265.3039864
1	01.01.2021 17:00	15729	265.8426993
1	01.01.2021 18:00	16491	264.7674623
1	01.01.2021 19:00	17505	263.1708901
1	01.01.2021 20:00	18012	260.035079
1	01.01.2021 21:00	17251	250.822094
1	01.01.2021 22:00	16744	0
1	01.01.2021 23:00	14968	0



PARAMETERISATION

Parameterisation

Scenario: Main config file to bundle all simulation properties

Open: examples/Germany2019/scenario.yaml

scenario.yaml

schema	*definition of valid agent and contract structures*
general properties	*simulation start/end time, random seed*
variables	*YAML anchors, optional*
agents	*which agents have what parameters*
contracts	*how and when agents interact*

The name „scenario.yaml“ is arbitrary and can be changed.

*You can split the scenario.yaml into separate files, e.g. schema, contracts, etc., and join them using **!include**, see https://gitlab.com/fame-framework/fame-io#split-and-join-multiple-yaml-files*

Parameterisation
General Properties

- Define
  - start and end of simulation
  - which random seed to use

```
GeneralProperties:
  RunId: 1          <-- ignore
  Simulation:
    StartTime: 2018-12-31_23:58:00
    StopTime: 2019-12-31_23:58:00
    RandomSeed: 1
  Output:           <-- ignore
```

*FAME's time definition **always** uses 365 days / 8760 hours per year, see also https://gitlab.com/fame-framework/wiki/-/wikis/architecture/decisions/TimeStamp*

YAML is indentation-based (2 spaces)

Parameterisation
Agents

- Define
  - agents
  - their type, ID, and attributes.
- Supported data types:
  - integer, floating point, enums, timeseries
- Supported structures
  - Any combination of block, list, flat
- Structure of attributes
  - depends on type of agent
  - is defined in schema

In YAML, dash is used to denote lists

```yaml
Agents:
  - Type: EnergyExchange
    Id: 1
    Attributes:
      DistributionMethod: SAME_SHARES
      GateClosureInfoOffsetInSeconds: 11

  - Type: CarbonMarket
    Id: 3
    Attributes:
      OperationMode: FIXED
      Co2Prices: "./timeseries/co2_price.csv"

  - Type: FuelsMarket
    Id: 4
    Attributes:
      FuelPrices:
        - FuelType: LIGHNITE
          Price: 5.00
          ConversionFactor: 1.0
        - FuelType: NATURAL_GAS
          Price: "./timeseries/natural_gas_cost.csv"
          ConversionFactor: 1.0
```

Time series attributes also support a single value.

*Every agent **must** have a unique ID within the simulation. This is how agents address each other.*

Parameterisation
Timeseries

Open: examples/Germany2019/timeseries/co2_price.csv

- Use case: time-dependent input

- File Format
  - Timestamp – semicolon – (dot-separated) floating point value

- Timestamps Format
  - YYYY-MM-DD_hh:mm:ss
  - Refer to simulation time **!not!** UTC
  - Idea: Easily reapply timeseries from one year to another

- Missing data: AMIRIS will interpolate

timestamp value

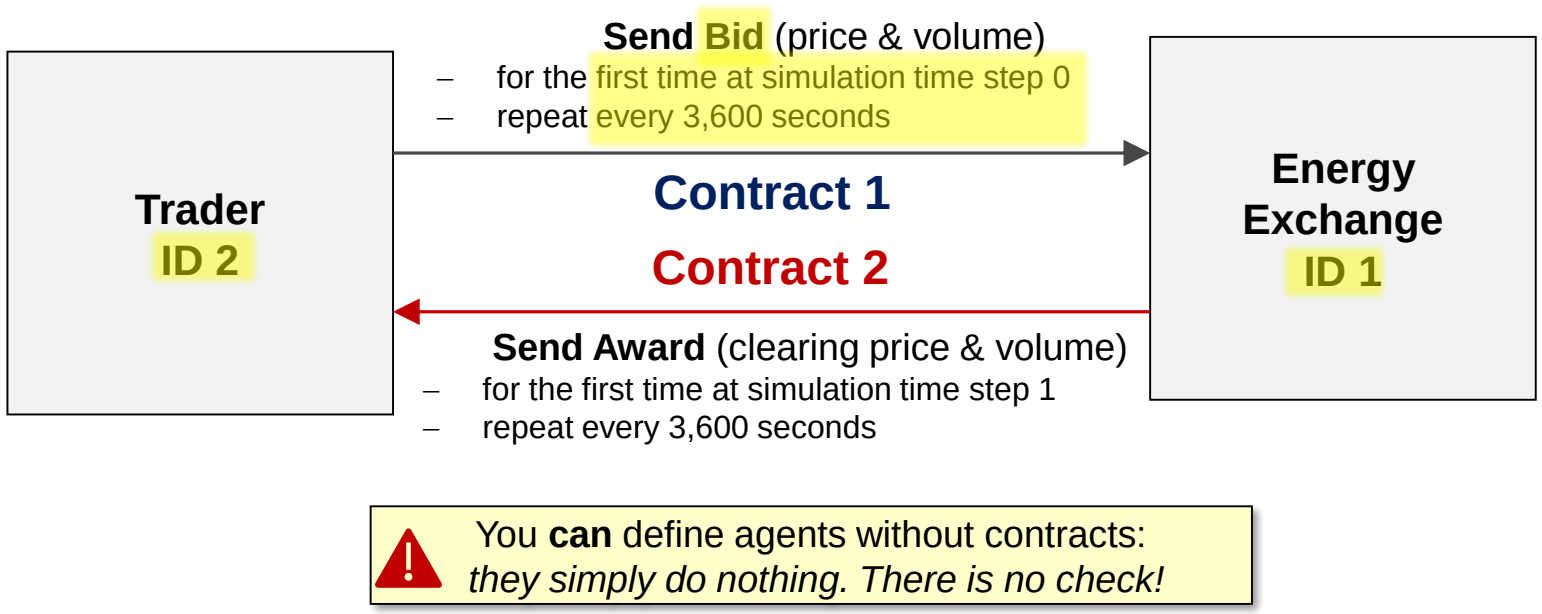
```
2019-01-07_00:00:00;23.01
2019-01-08_00:00:00;22.4
2019-01-10_00:00:00;21.4
2019-01-14_00:00:00;21.95
2019-01-15_00:00:00;22.55
2019-01-16_00:00:00;22.72
2019-01-17_00:00:00;23.55
2019-01-21_00:00:00;24.22
2019-01-22_00:00:00;24.42
2019-01-24_00:00:00;24.6
2019-01-28 00:00:00;23.01
```

Additional columns (even empty) are not allowed and need to be removed.

Lines with empty time or value are not allowed and need to be removed.

Parameterisation
Contracts

Define **when** agents send **what** data to **which** other agents



You **can** define agents without contracts:
they simply do nothing. There is no check!

Parameterisation

Contracts: Advanced

Open: examples/Germany2019/contracts/conventionals.yaml

- Simulations often require *many* contracts!
- Contracts are often *similar*!
- Short notations available:
  - 1:N → one sender to multiple receivers
  - N:1 → one receiver from multiple senders
  - M:M → m senders, each to **one** of m receivers

- Sender / receiver lists *repeat* often!
- Use YAML anchors to replace similar lists
  - Define: &anchorName <something>
  - Reference: *anchorName

```yaml
AgentGroups:
  - &builders  [2000, 2001, 2002, 2003, 2004, 2005]
  - &traders   [1000, 1001, 1002, 1003, 1004, 1005]
  - &operators [500, 501, 502, 503, 504, 505]
  - &exchange 1
  - &carbonMarket 3
  - &fuelsMarket 4
  - &forecaster 6

Contracts:
################################
# -- PlantBuildingManagement -- #
################################
  - SenderId: *builders
    ReceiverId: *operators
    ProductName: PowerPlantPortfolio
    FirstDeliveryTime: -60
    DeliveryIntervalInSteps: 31536000

##############################
# -- Forecast Preparation -- #
##############################
  - SenderId: *forecaster
    ReceiverId: *traders
    ProductName: ForecastRequest
    FirstDeliveryTime: -26
    DeliveryIntervalInSteps: 3600
```

anchors

comment

reference

Parameterisation
Schema

Open: examples/Germany2019/schema.yaml

- Defines
  - types of agents
  - their contract products
  - their attributes
  - attribute types
  - if attributes are mandatory / lists
  - attribute value restrictions

```
- Type: EnergyExchange
  Id: 1
  Attributes:
    DistributionMethod: SAME_SHARES
    GateClosureInfoOffsetInSeconds: 11
```

```
AgentTypes:
  EnergyExchange:
    Attributes:
      DistributionMethod:
        AttributeType: enum
        Mandatory: true
        List: false
        Values: [ 'SAME SHARES', 'RANDOMIZE' ]
      GateClosureInfoOffsetInSeconds:
        AttributeType: integer
        List: false
        Mandatory: true
    Products: [ 'Awards', 'GateClosureInfo' ]
```

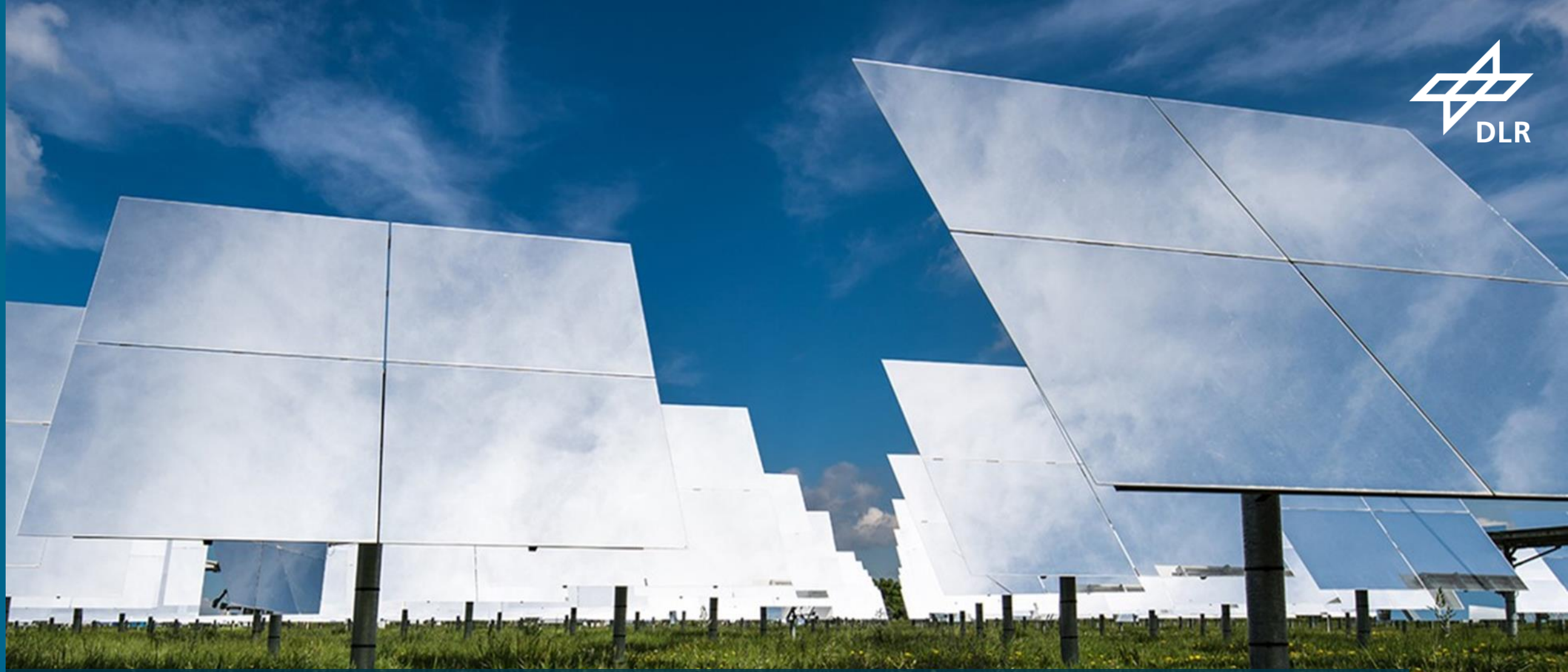
Use to look up agent attributes & related types, see also https://gitlab.com/dlr-ve/esy/amiris/amiris/-/wikis/Classes/Classes

Do not tamper with this – it is derived from Java code and used to validate scenario inputs.

GERMANY 2019: BASE SCENARIO

GERMANY 2019: HIGH GAS PRICE

GERMANY 2019: EXTRA PV



FINAL REMARKS

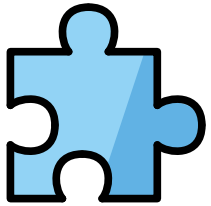
AMIRIS
Following FAIR4RS Principles

Findable

- DOI
- Wikipedia
- COMSES
- HECI
- OEP
- openmod
- Website

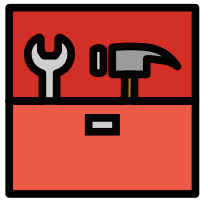
Accessible

- GitLab
- PyPI
- Zenodo



Interoperable

- API
- Workflow tools
- CSV
- YAML



(Re-)usable

- Apache 2.0
- REUSE
- Wiki
- Javadoc
- Win/Mac/Linux
- Scalable (H)PC

will upload presentation here

Key Indicators

Users

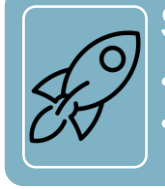
- 12 confirmed external user
- 4 bugs reported

PhD candidates

- 4 internal
- 3 external

Visibility

- 14k views on Wikipedia
- 9k views on openmod



Software

- 39 releases
- 60k downloads

Barker et al. (2022). 10.1038/s41597-022-01710-x

AMIRIS
Application Ideas

- Apply to your market zone
- Look at effects of different
  - weather years
  - policy schemes
  - fuel prices
- Assess
  - system cost,
  - market prices
  - agent refinancing

Comparison of Support Schemes for Renewables: German Case Study of project TradeRES,
Friday, 15:50h, Room 3

Use AMIRIS

Use AMIRIS
- Report difficulties
- Ask questions in forum
- Create / publish scenarios
- Cite AMIRIS at JOSS

Make us enhance AMIRIS
- Report issues / bugs
- Post ideas in forum
- Make feature requests

Enhance AMIRIS yourself
- Improve / modify agents
- Sign Contributor License Agreement
- Make pull requests

Get in contact: amiris@dlr.de

*Ask us **questions**!*

*Join forces with us in a **project**!*

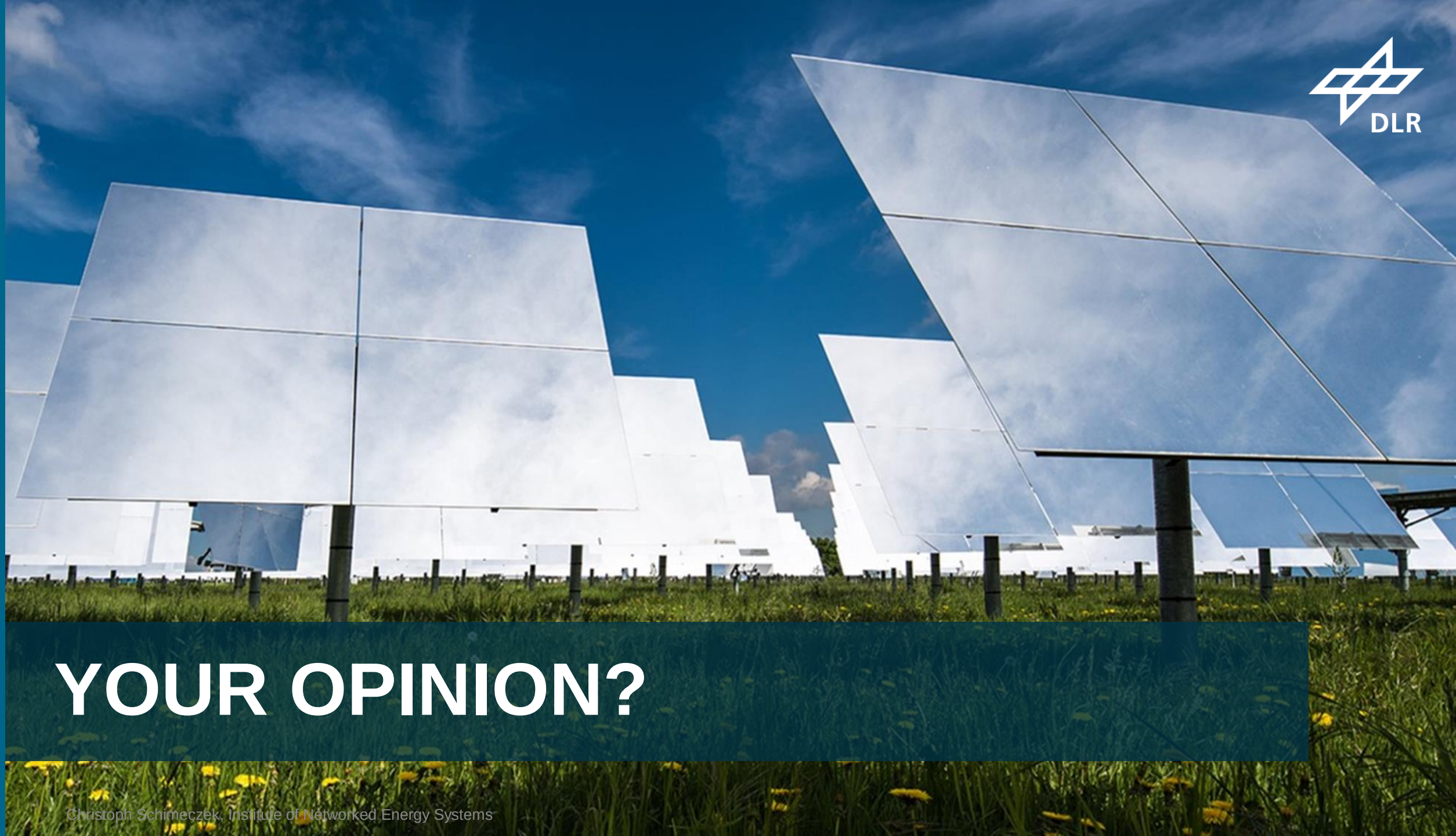
*Discuss modelling **ideas**!*

*Get **insights** on latest projects!*

***Collaborate** with us on extensions!*

Visit our website

Christoph Schimeczek, Institute of Networked Energy Systems



YOUR OPINION?

Imprint

Topic:	Skill Workshop: AMIRIS
Date:	October 5th 2023
Author:	Christoph Schimeczek
Institute:	Institute of Networked Energy Systems
Images:	DLR (CC BY-NC-ND 3.0)