# $f_{CASP}$: a Forgetting Operator and its Application to Energy Distribution Under a Goal-Directed ASP Decision Model

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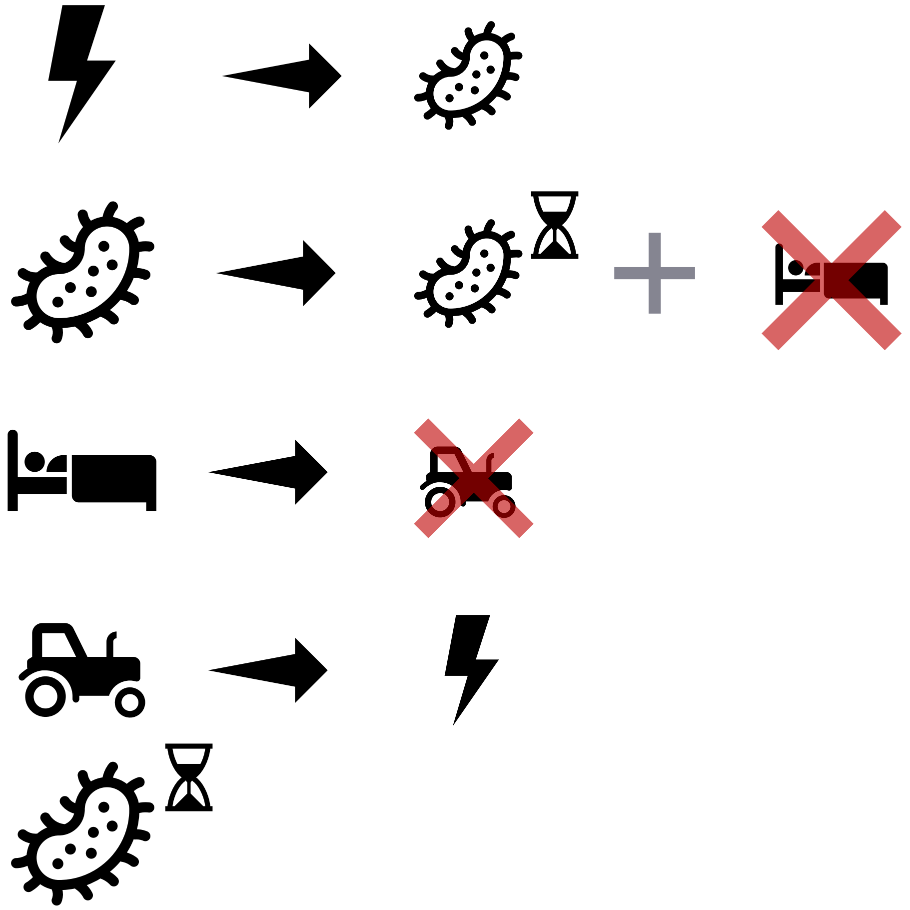
# Introduction

- **Decision models** can automate the allocation of crucial resources in cooperative/competitive contexts.
  - We can use **ASP** to program decision models.

```
energy_pepe :-
    sick_pepe.
sick_pepe:-
    past_sick_pepe,
    not rest_pepe.
rest_pepe :-
    not machine_pepe.
machine_pepe :-
    energy_pepe.
past_sick_pepe.
```



# Introduction

- Decision models can automate the allocation of crucial resources in cooperative/competitive contexts.
  - We can use ASP to program decision models.
- Explainability is needed to ensure trustworthiness.
  - ASP programs/models can provide justifications.

```
1.  energy_pepe :-
2.      sick_pepe.
3.  sick_pepe:-
4.      past_sick_pepe,
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6.  rest_pepe :-
7.      not machine_pepe.
8.  machine_pepe :-
9.      energy_pepe.
10. past_sick_pepe.
```

Model: { energy_pepe, ... }

Justification:

```
energy_pepe :-
  sick_pepe :-
    past_sick_pepe,
    not rest_pepe :-
      machine_pepe :-
        chs(energy_pepe).
```

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  - We can use **ASP** to program decision models.
- **Explainability** is needed to ensure trustworthiness.
  - ASP programs/models can provide justifications (in NL).

```
energy_pepe :-
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rest_pepe :-
    not machine_pepe.
machine_pepe :-
    energy_pepe.
past_sick_pepe.
```

Model: { energy_pepe, ... }

Justification:

```
energy_pepe :-                    Pepe gets electric power, because
  sick_pepe :-                    Pepe is sick, because
    past_sick_pepe,               Pepe was sick yesterday, and
    not rest_pepe :-              there is no evidence that Pepe has rested, because
      machine_pepe :-             Pepe has used the machine, because
        chs(energy_pepe).         it is assumed that Pepe gets electric power.
```

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- However, the justifications (and the models) may expose private and confidential information.

```
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Justification:

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```

Sensitive information

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# Introduction

- However, the justifications (and the models) may **expose** private and confidential information.
- So, we must **protect** these sensitive information:
  a) By **manipulating** the justification.

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Model: { energy_pepe, ... }

Justification:

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  ~~sick_pepe :-~~
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- However, the justifications (and the models) may **expose** private and confidential information.
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  b) Applying **forgetting** (removing predicates in ASP programs).

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# Introduction

- However, the justifications (and the models) may expose private and confidential information.
- So, we must protect these sensitive information:
  a) By manipulating the justification.
  b) Applying forgetting (removing predicates in ASP programs).

We present $\mathbf{f_{CASP}}$, a forgetting technique based on s(CASP) that removes predicates in ASP programs with Denials.

# Background: ASP and s(CASP)

- Answer Set Programming is based on the stable model semantics:
  - Supports non-stratified negation (even loops).
  - May provide multiple models.
  - We extend ASP with double default negations (not not).

- s(CASP) is a goal-directed interpreter of ASP with Constraints:

2

solves negated atoms 'not p(X)' against **dual rules**

provides **justifications** in natural language

can **manipulate** the justifications (#show and --short)

# $f_{CASP}$: Design

$f_{CASP}$ removes predicates from ASP programs with denials:

- Supports even and odd loops.
- Based on s(CASP) dual rules.
- Implemented as part of s(CASP).

The $f_{CASP}$ algorithm consists of 4+1 steps:

1. Add auxiliary predicates (neg_x).
2. Generate the simplified dual rule(s) using s(CASP).
3. Forget the predicate and its negation.
4. Clean extra clauses and add double negations.
5. (Optional) Transform double negations.

- Could be extended to support variables and constraints.

# $f_{CASP}$: Implementation

```
f_casp([Pred|Preds], P_0, P_Forgetting, Flag) :-
        transform_even_loops(Pred, P_0, P_1a, Neg_Pred),        % Step 1
        add_clauses_if_needed(Pred, P_1a, P_1b),
        delete_auto_calls(Pred, P_1b, P_1c),
        generate_dual(Pred, P_1c, Dual_Rule),                    % Step 2
        forget_pred(Pred, Dual_Rule, P_1c, P_3),                 % Step 3
        restore_even_loop(Neg_Pred, P_3, P_4a),                  % Step 4
        restore_facts_missing(P_4a, P_4b),
        f_casp(Preds, P_4b, P_Forgetting, Flag).                 % Repeat 1,2,3,4
f_casp([], P_Forgetting, P_Forgetting, 0).                       % Skip Step 5
f_casp([], P_Forgetting, P_sCASP, 1) :                           % Step 5
        transform_double_negations(P_Forgetting, P_Scasp).
```

- Available at [https://gitlab.software.imdea.org/ciao-lang/sCASP](https://gitlab.software.imdea.org/ciao-lang/sCASP)

# $f_{CASP}$: Usage instructions

- To apply $f_{CASP}$, just run s(CASP) using the following flag:

--forget = LIST[/F]

List of predicates to be forgotten

F = 0 skip step 5
F = 1 (default) execute step 5

- E.g.: scasp energy.pl --forget='sick_pepe'

DEMO

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# $f_{CASP}$: Example

- Forgetting ‘sick_pepe’.

Original program:

1. energy_pepe :-
2. sick_pepe.
3. sick_pepe:-
4. past_sick_pepe,
5. not rest_pepe.
6. rest_pepe :-
7. not machine_pepe.
8. machine_pepe :-
9. energy_pepe.
10. past_sick_pepe.

{ energy_pepe, sick_pepe, past_sick_pepe, not rest_pepe, machine_pepe }

$f_{CASP}$ {sick_pepe}:

1. energy_pepe :-
2. past_sick_pepe,
3. not rest_pepe.
4. rest_pepe :-
5. not machine_pepe.
6. machine_pepe :-
7. energy_pepe.
8. past_sick_pepe.

{ energy_pepe, past_sick_pepe, not rest_pepe, machine_pepe }

# Preliminary validation through examples

- Example with double negations from Berthold et al. 2019 :

Original program:

```
q :- not not q,
        b.
a :- q.
c :- not q.
```

{c}

$f_{CASP}$ {p,q}:

```
a :-  not neg_1,
        b.
c :- not not neg_1.
neg_1 :- not not neg_1.
neg_1 :- not b.
```

{c, neg_1}

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# Preliminary validation through examples

- Comparing the required auxiliary predicates ($f_{AC}$ vs. $f_{CASP}$):

Original program:

```
q :- not not q,
        b.
a :- q.
c :- not q.
```

{c}

$f_{CASP}$ {p,q}:

```
a :-  not neg_1,
        b.
c :- not not neg_1.
neg_1 :- not not neg_1.
neg_1 :- not b.
```

{c, neg_1}

$f_{AC}$ {p,q}:

$a$ :- $b$,
$\quad\quad \delta_q$.
$c$ :- not $\delta_q$.
$c$ :- not $b$.
$\delta_q$ :- not not $\delta_q$.

{c}  $\{c, \delta_q\}$

# Comparison between forgetting operators

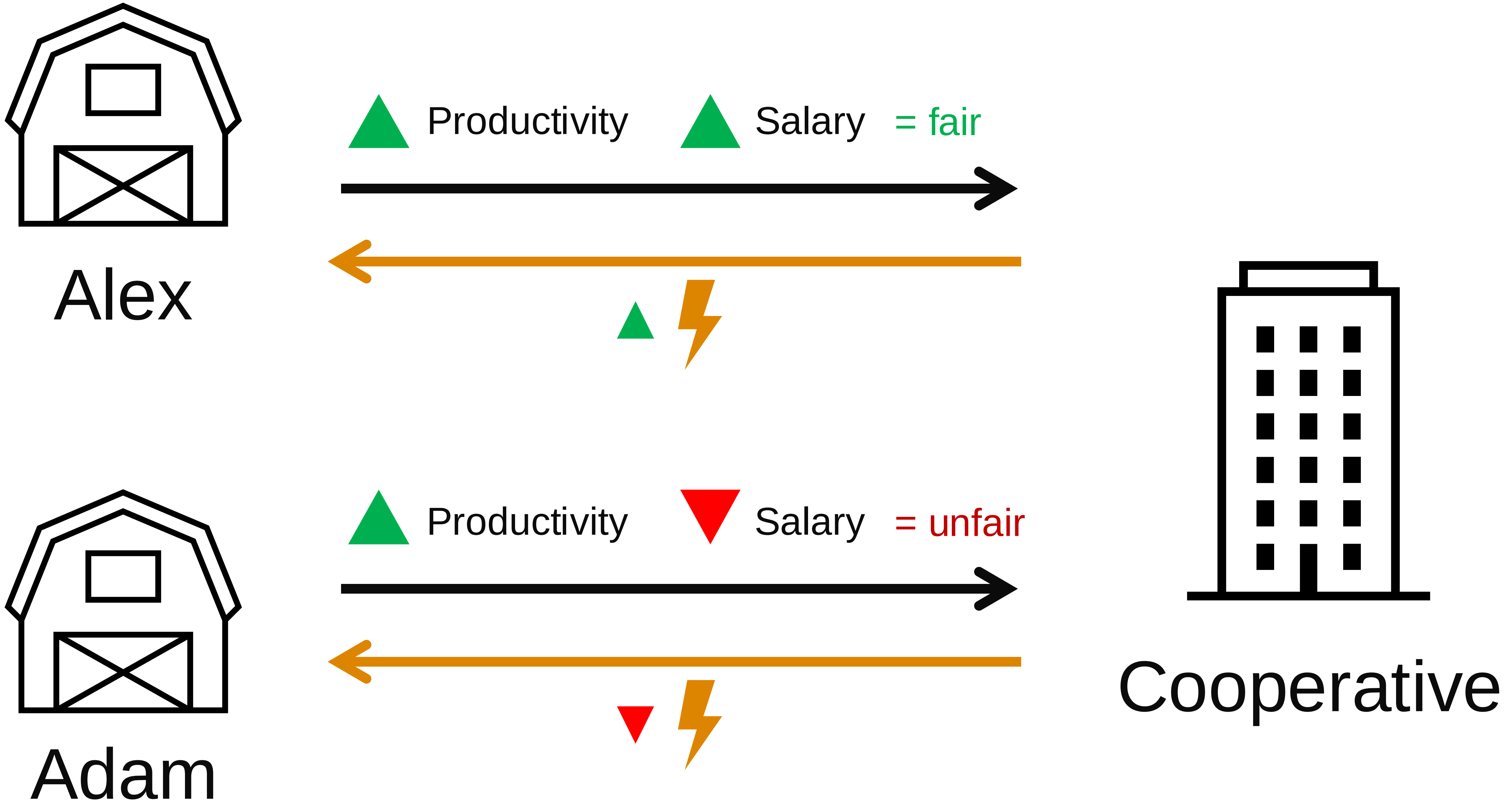
| | (UP) | (SP) | Loops | Commutative | Predicates | Constraints |
|---|---|---|---|---|---|---|
| $f_{SU}$ | ✓ | x | ✓ | x | x | x |
| $f_{SP}$ | ✓ | Limited | x | x | x | x |
| $f^*_{SP}$ | ✓ | Limited | ✓ | ✓ | x | x |
| $f_{AC}$ | ✓ | ✓ | ✓ | ✓ | x | x |
| $f_{CASP}$ | ✓ | ✓ | ✓ | ✓ | WiP | WiP |

# Transparent and fair energy assignment applying $f_{CASP}$

- Consider local power generation managed by an agricultural cooperative to provide an alternative energy supply.
- Its assignment can encourage better practices if we base the energy distribution criteria on human-values.
  - E.g., on a fair income for agricultural workers.
- But to rely on the decision process, the members want an explanation.

However, the explanation of a decision must not expose members' trade secrets.

# Transparent and fair energy assignment applying $f_{CASP}$



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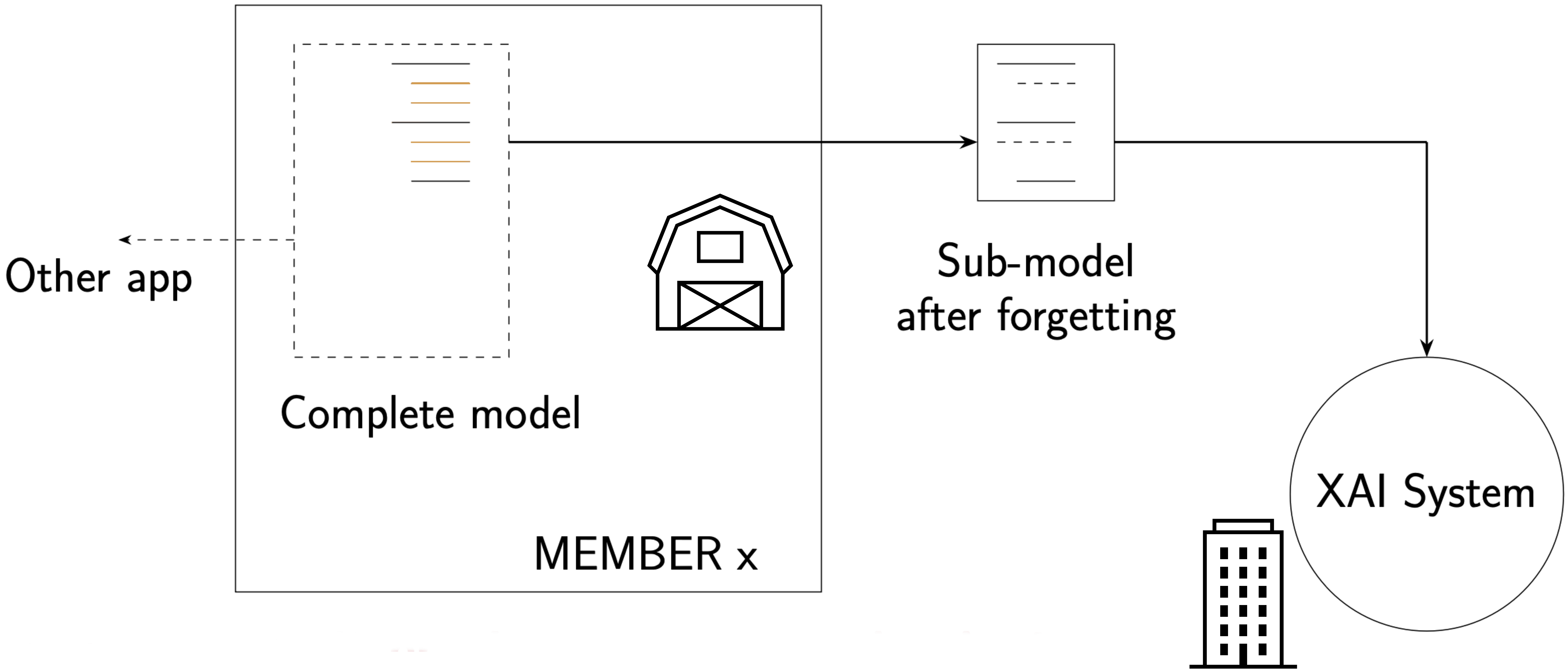

# Transparent and fair energy assignment applying $f_{CASP}$

## Cooperative program:

```
percentages([alex(PercentageAlex), ...]):-
    fair_income_alex(PointsAlex),
    fair_income_adam(PointsAdam),
    ...
    ponder(PointsAlex, Max, PercentageAlex).

fair_income_alex(PointsAlex):-
     salary(bea, Salary),
     ...
     productivity(bea, Productivity),
     ...
fair_income_adam(PointsAdam), :-
    ...
```

## Alex's program:

```
over_40_bea :- not neg_over_40_bea.
neg_over_40_bea :- not over_40_bea.

generational_renewal(bea,0) :- over_40_bea.
generational_renewal(bea,100) :- not over_40_bea.

salary(bea,Salary) :-
        base_salary(bea,S0),
        generational_renewal(bea,S1),
        holiday_worked(bea,S2),
        Salary is S0+S1+S2.
```

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# Transparent and fair energy assignment applying $f_{CASP}$

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        Salary is S0+S1+S2.
```

business secrecy
(salary supplements)

# Transparent and fair energy assignment applying $f_{CASP}$

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        base_salary(bea,S0),
        generational_renewal(bea,S1),
        holiday_worked(bea,S2),
        Salary is S0+S1+S2.
```

After forgetting sensitive predicates:

```
neg_1 :- not neg_2.
neg_2 :- not neg_1.

salary(bea, Salary) :-
        S0 = 900,
        neg_2,
        S1 = 0,
        S2 = 0,
        Salary is S0 + S1 + S2.

salary(bea,Salary) :-
        S0 = 900,
        neg_1,
        S1 = 100,
        S2 = 0,
        Salary is S0+S1+S2.
```

# Transparent and fair energy assignment applying $f_{CASP}$

## Original justification

```
percentages([adam(10.13), alex(29.27), ...]) :-
  ...
  fair_income_alex(1.08) :-
      salary(bea,900) :-
            base_salary(bea,900),
            generational_renewal(bea,0) :-
              over_40_bea :-
                not neg_over_40_bea :-
                  chs(over_40_bea).
            holiday_worked(bea,0),
            900 is 900+(0+0).
      productivity(bea,1040) :-
            ...
  fair_income_adam(0.74) :-
      ...
```

## After manipulating the justification

```
percentages([adam(10.13), alex(29.27), ...]) :-
  ...
  fair_income_alex(1.08) :-
      salary(bea,900) :-
         900 is 900+(0+0).
         ...
```

## After forgetting sensitive predicates

```
percentages([adam(10.13), alex(29.27), ...]) :-
...
  fair_income_alex(1.08) :-
      salary(bea,900) :-
         neg_2 :-
           not neg_1 :-
             chs(neg_2).
         900 is 900+(0+0).
         ...
```

## Conclusions

- We have presented and evaluated $f_{CASP}$, a forgetting operator that:
  - Supports **even loops**
  - Can be extended to support **predicates and constraints**
- We have applied $f_{CASP}$ to achieve a **fair (and trustworthy)** energy distribution decision model.

## Future work

- **Extend it with** variables, arithmetic constraints and recursive predicates.
- Determining and **proving formally** the $f_{CASP}$'s forgetting properties.
- **Splitting CASP programs** based on their predicate stratification.

# thank you

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