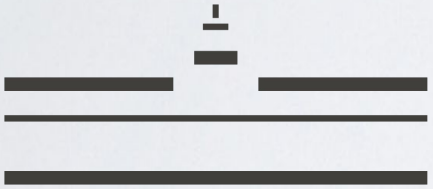
Shared Energy Storage and Neighbourhood Energy Exchange:

A Smart Neighbourhood Simulation Environment



Westfälische Wilhelms-Universität Münster

Michael Biech, Timo Bigdon, Christian Dielitz, Georg Fromme, Anne Remke

Outline

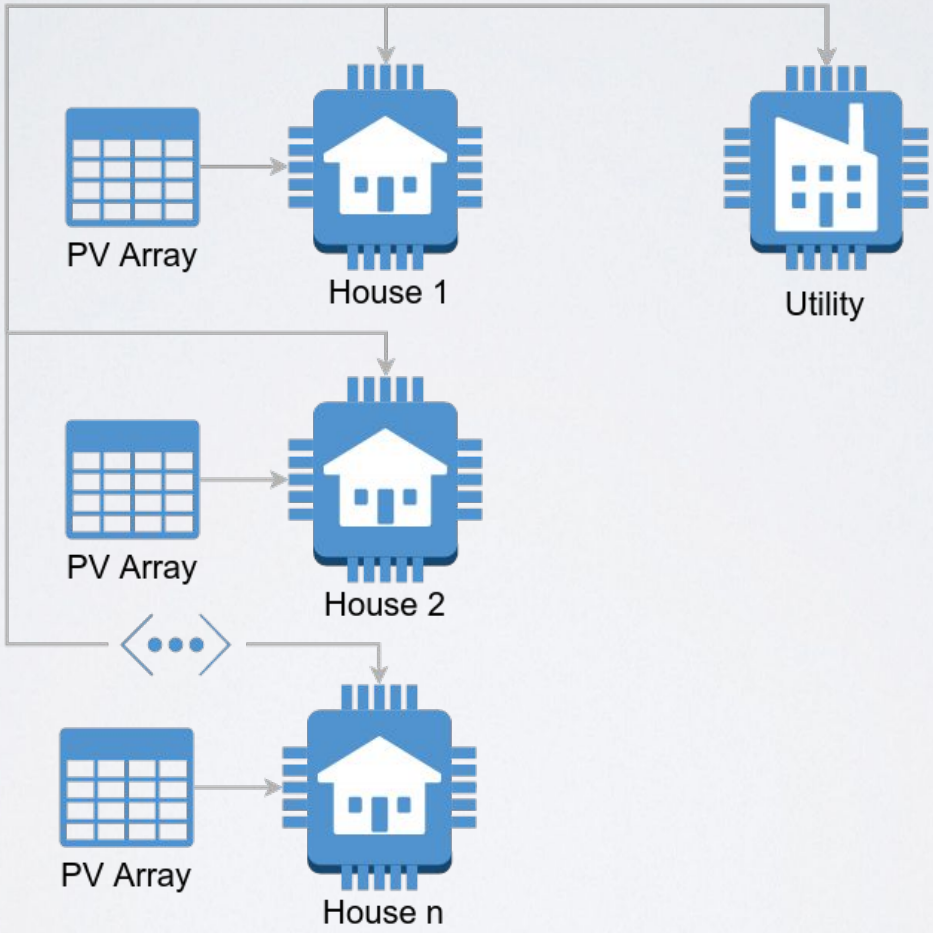
Motivation

Model Implementation

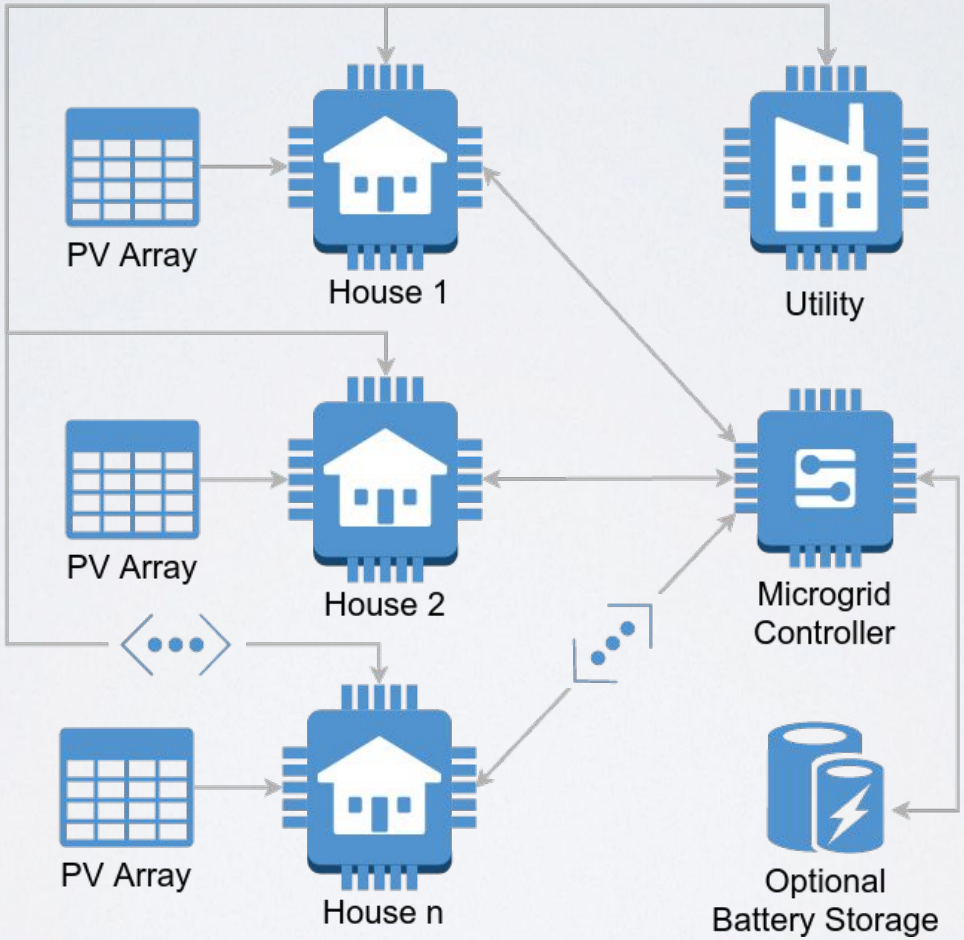
Simulation Results

Open Questions and Conclusions

How can we make the most of locally produced electricity?



Energy production and consumption times don't align optimally



Central Questions

Increased use of locally generated energy?
Financial viability / advantage?

Take into account:
Feed-in tariff (EEG)
PV installation dates
Internal / neighbourhood trade
Consumption / production (NEDU, PVWatts)
Battery capacity

Model Implementation

Versatile simulation tool
Implemented in MATLAB / Simulink
Wide array of options

Developed with German / Dutch market in mind
but flexible regarding other markets

Houses

	Solar panel size (m²)	Yearly power demand (kWh)	Date of PV installation (MM-YYYY)
1	25	3500	05-2013
2	17	2870	01-2012
3	32	5800	12-2015
4	12	3280	08-2007
5	15	4096	04-2015

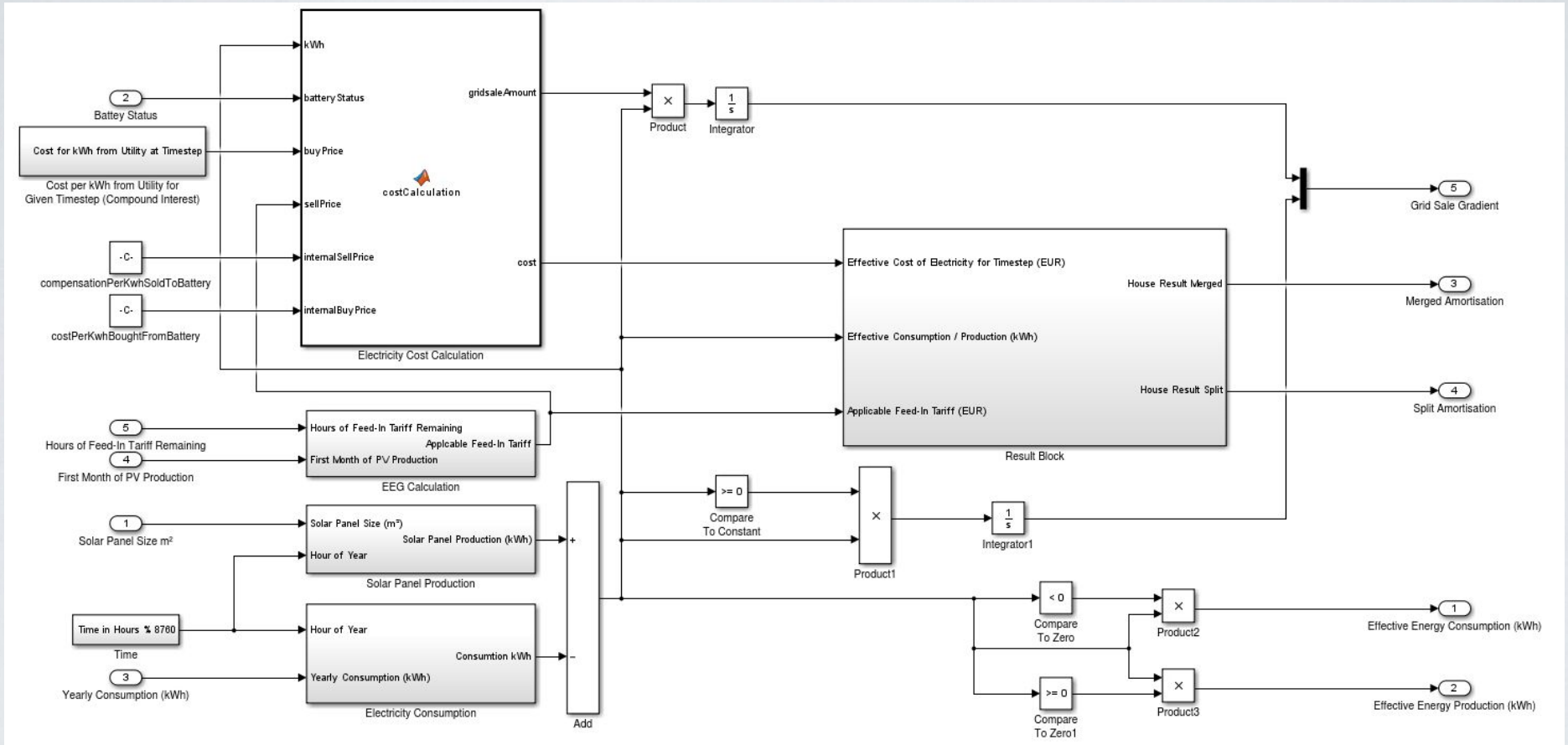
Add house | Remove selected house

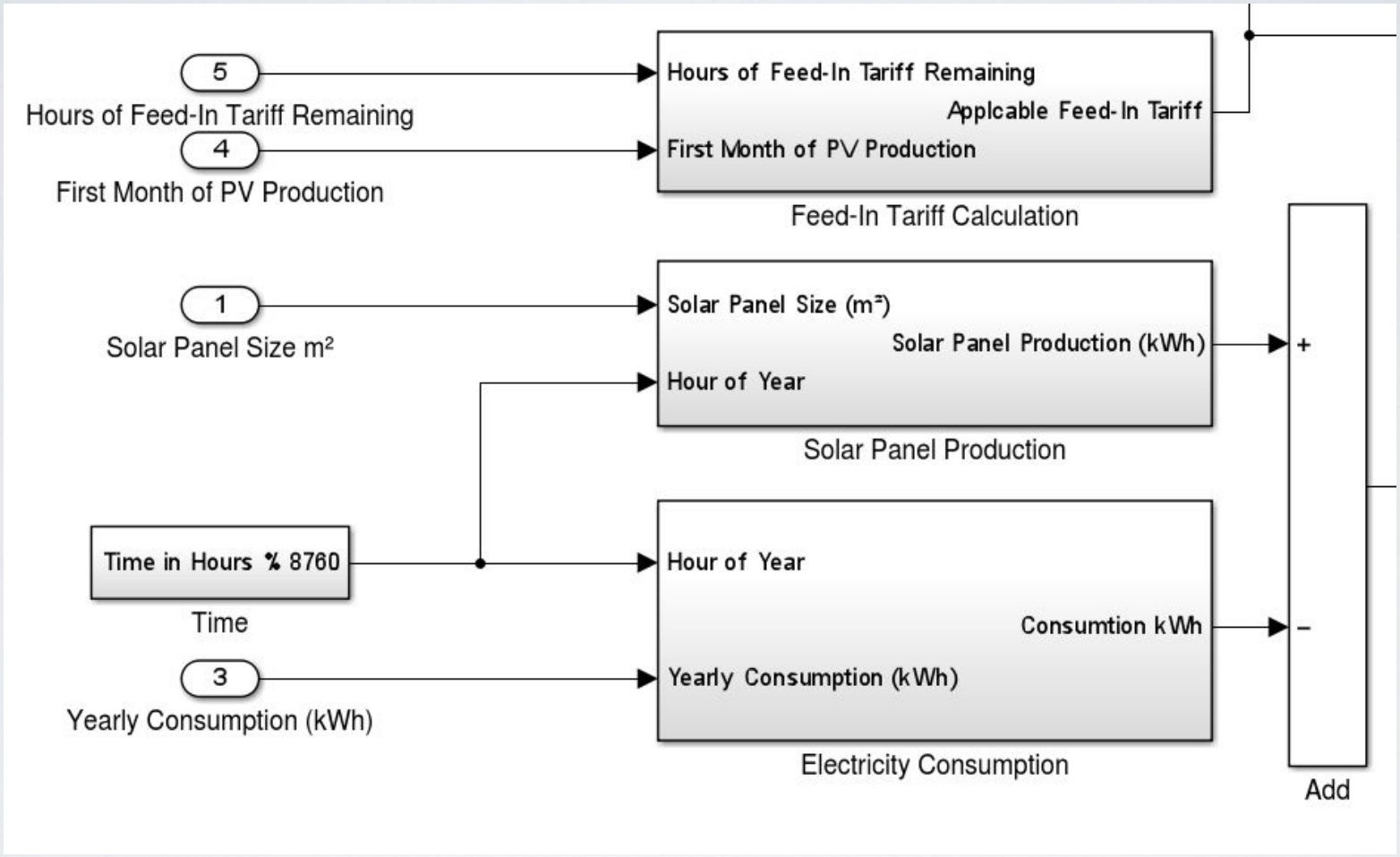
Simulation settings

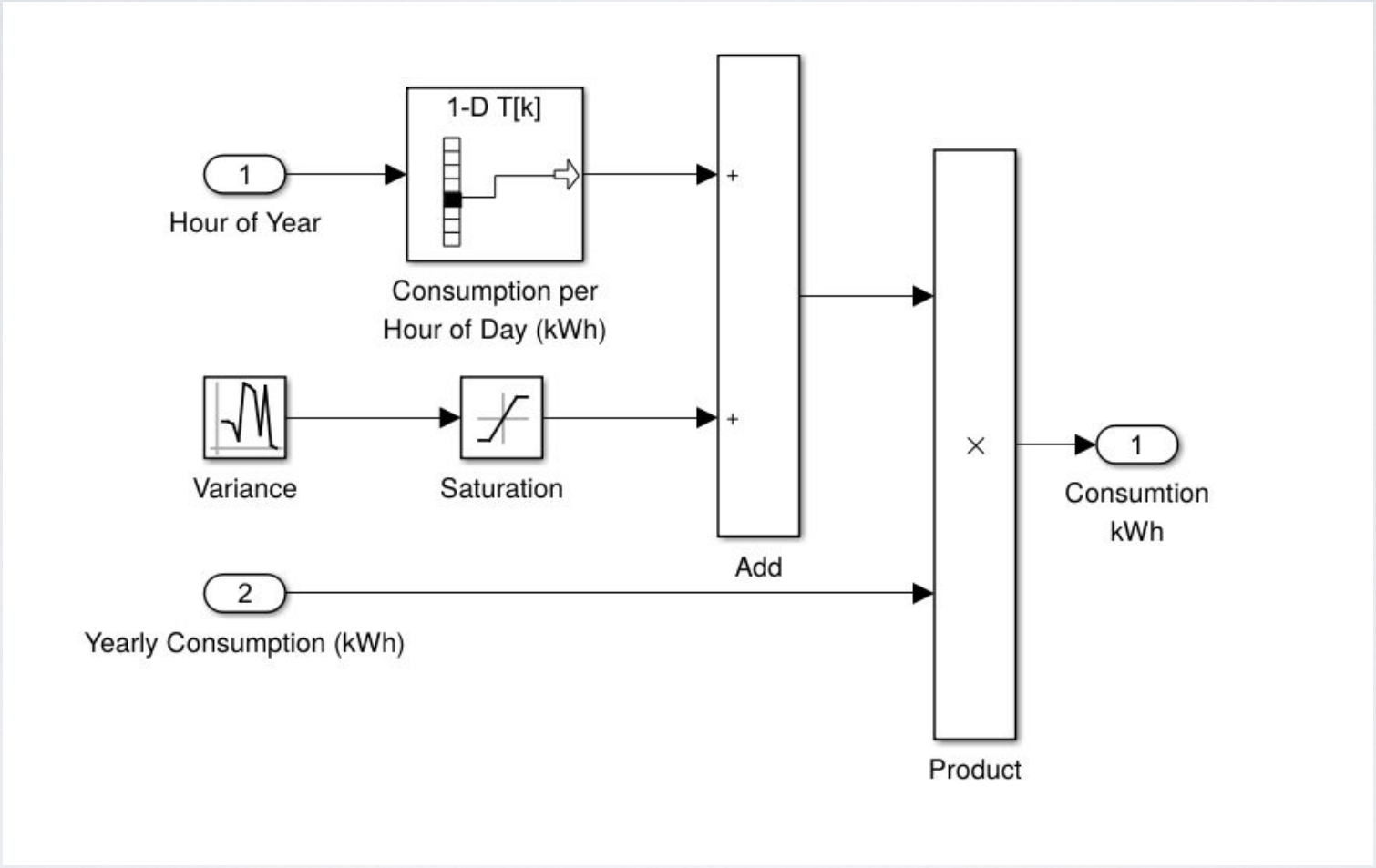
Battery cost per kWh	500	€
Battery capacity	7	kWh
One-time cost	1000	€
Initial cost per kWh from utility	0.2881	€
Annual change of cost per kWh from utility	3.4	%
Date of battery installation	01-2016	MM-YYYY
Solar panel efficiency	16	%
Cost per kWh received from micro grid controller	0.18	€
Compensation per kWh handed off to micro grid controller	0.18	€
Duration of simulation	15	year(s)

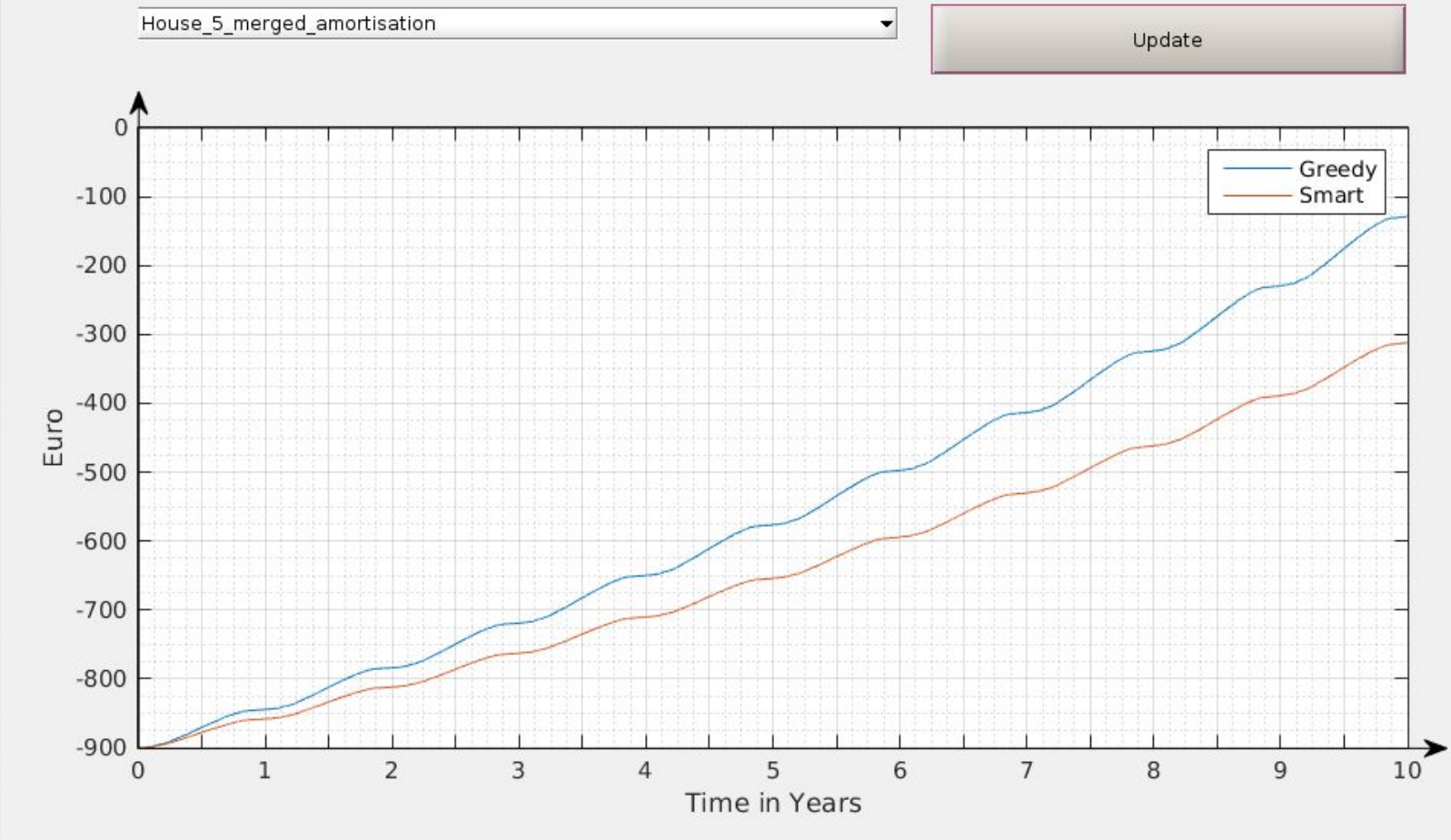
Create simulation (This might take a considerable amount of time!)

Display Output GUI (Please only click this once the simulation has finished!)

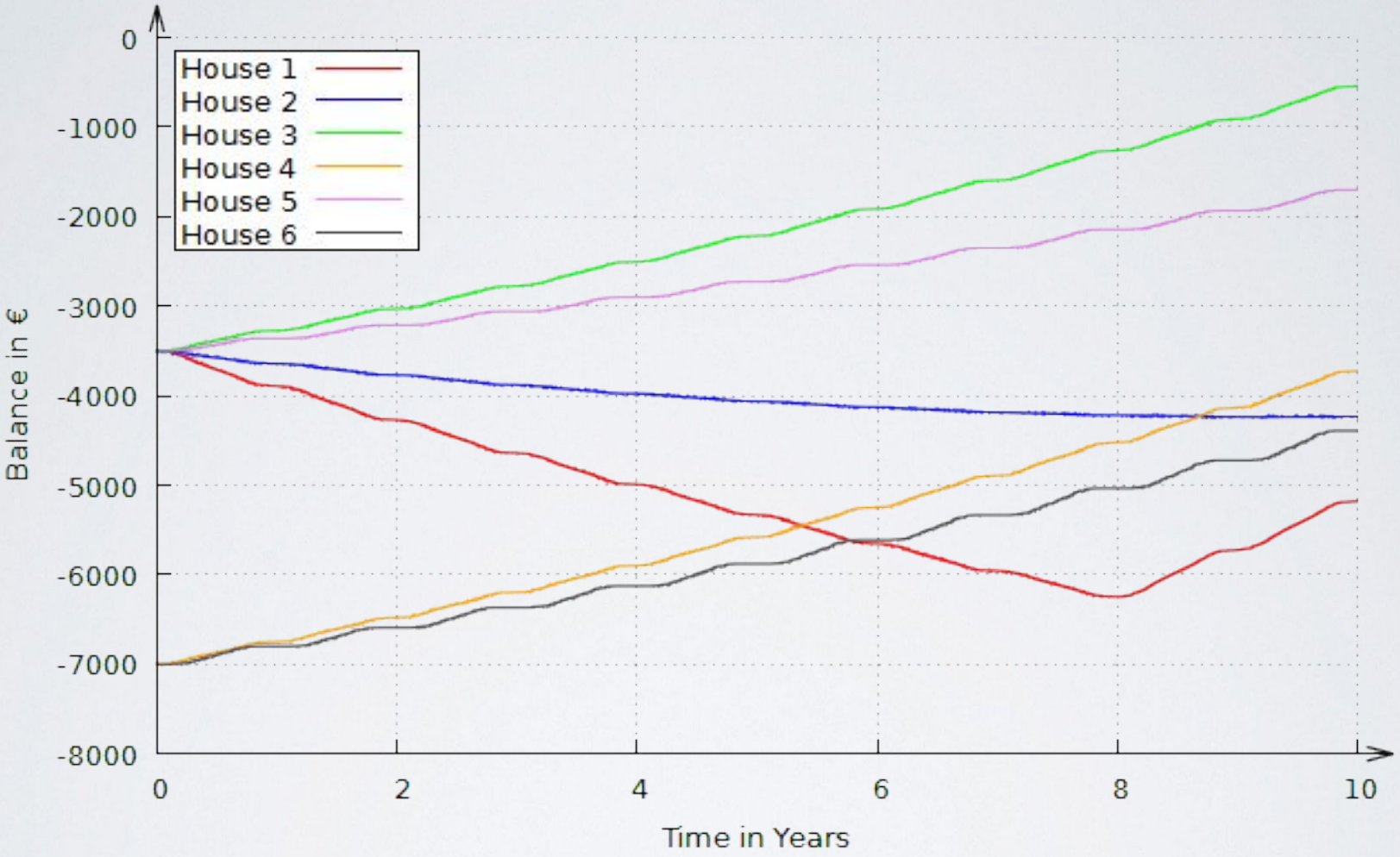

kWh
battery Status
buy Price
sellPrice
internalSellPrice
internalBuyPrice
gridsaleAmount
cost
costCalculation
Electricity Cost Calculation
2
Battey Status
Cost for kWh from Utility at Timestep
Cost per kWh from Utility for Given Timestep (Compound Interest)
-C-
compensationPerKwhSoldToBattery
-C-
costPerKwhBoughtFromBattery
Product
Integrator
Effective Cost of Electricity for Timestep (EUR)
Effective Consumption / Production (kWh)
Applicable Feed-In Tariff (EUR)
House Result Merged
House Result Split
Result Block
5
Grid Sale Gradient
3
Merged Amortisation
4
Split Amortisation
5
Hours of Feed-In Tariff Remaining
4
First Month of PV Production
Hours of Feed-In Tariff Remaining
Applcable Feed-In Tariff
First Month of PV Production
EEG Calculation
1
Solar Panel Size m²
Solar Panel Size (m²)
Solar Panel Production (kWh)
Hour of Year
Solar Panel Production
Time in Hours % 8760
Time
3
Yearly Consumption (kWh)
Hour of Year
Consumtion kWh
Yearly Consumption (kWh)
Electricity Consumption
Add
>= 0
Compare To Constant
Product1
Integrator1
< 0
Compare To Zero
>= 0
Compare To Zero1
Product2
Product3
1
Effective Energy Consumption (kWh)
2
Effective Energy Production (kWh)


5
Hours of Feed-In Tariff Remaining
4
First Month of PV Production
Hours of Feed-In Tariff Remaining
Applcable Feed-In Tariff
First Month of PV Production
Feed-In Tariff Calculation
1
Solar Panel Size m²
Solar Panel Size (m²)
Solar Panel Production (kWh)
Hour of Year
Solar Panel Production
Time in Hours % 8760
Time
3
Yearly Consumption (kWh)
Hour of Year
Consumtion kWh
Yearly Consumption (kWh)
Electricity Consumption
+
−
Add


1-D T[k]
1
Hour of Year
Consumption per
Hour of Day (kWh)
+
+
Variance
Saturation
Add
×
1
Consumtion
kWh
2
Yearly Consumption (kWh)
Product

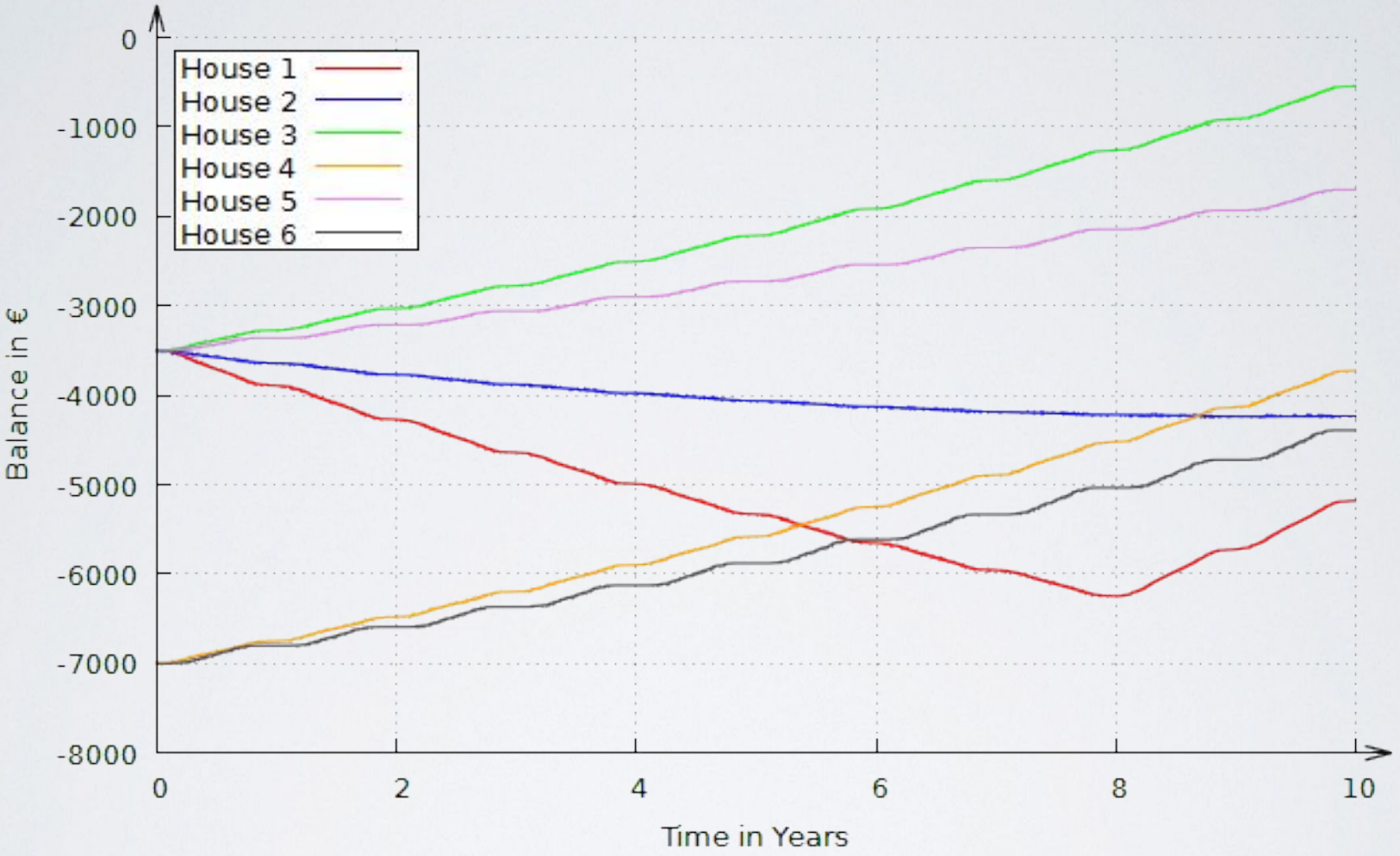

House_5_merged_amortisation
Update
Greedy
Smart
Euro
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
0
1
2
3
4
5
6
7
8
9
10
Time in Years

Amortisation without internal trade



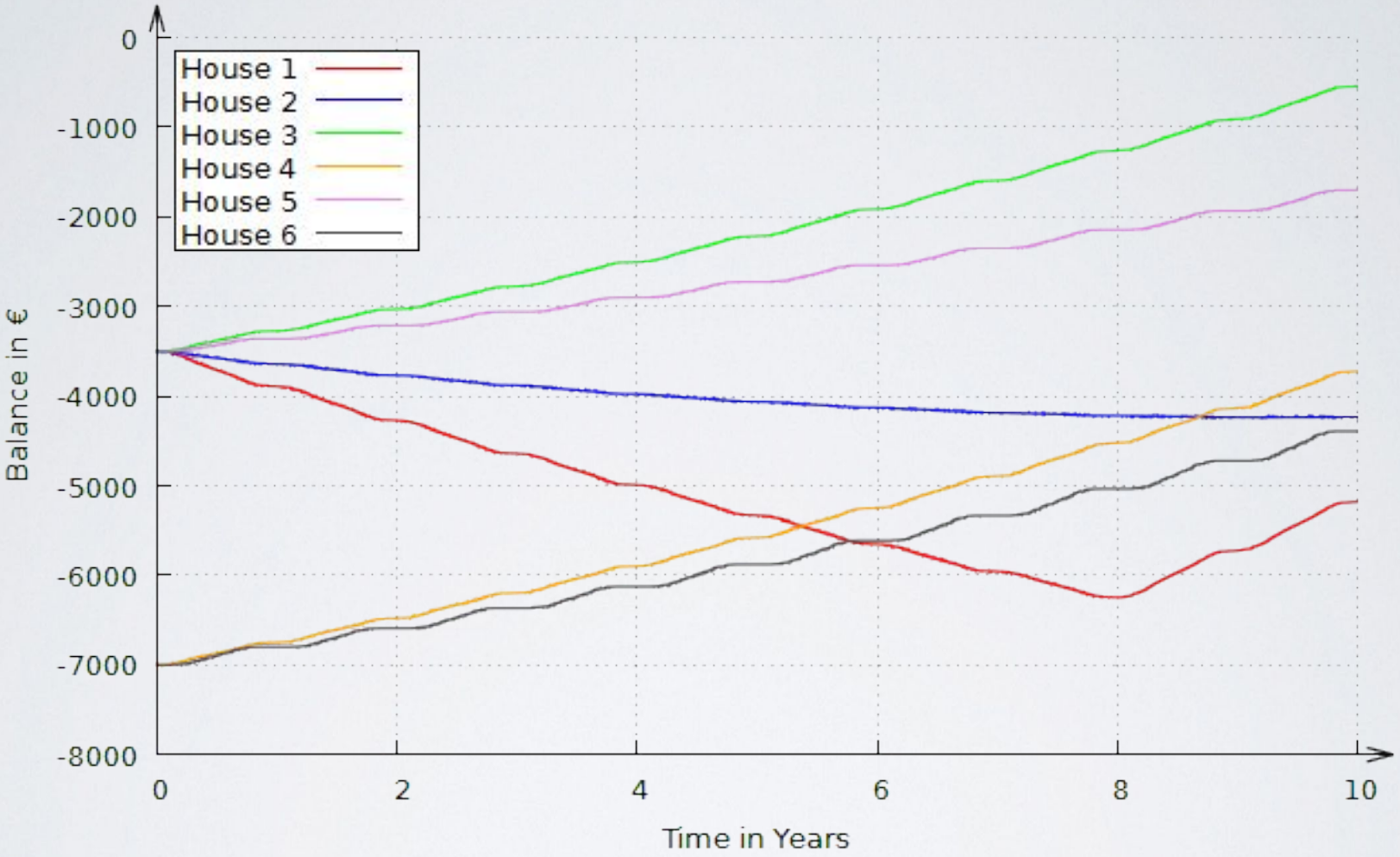
House 1: Consumption: 5,000 kWh p.a., PV: 40 m², Installation Date: 01-2004, Battery Capacity: 7 kWh

Amortisation without internal trade



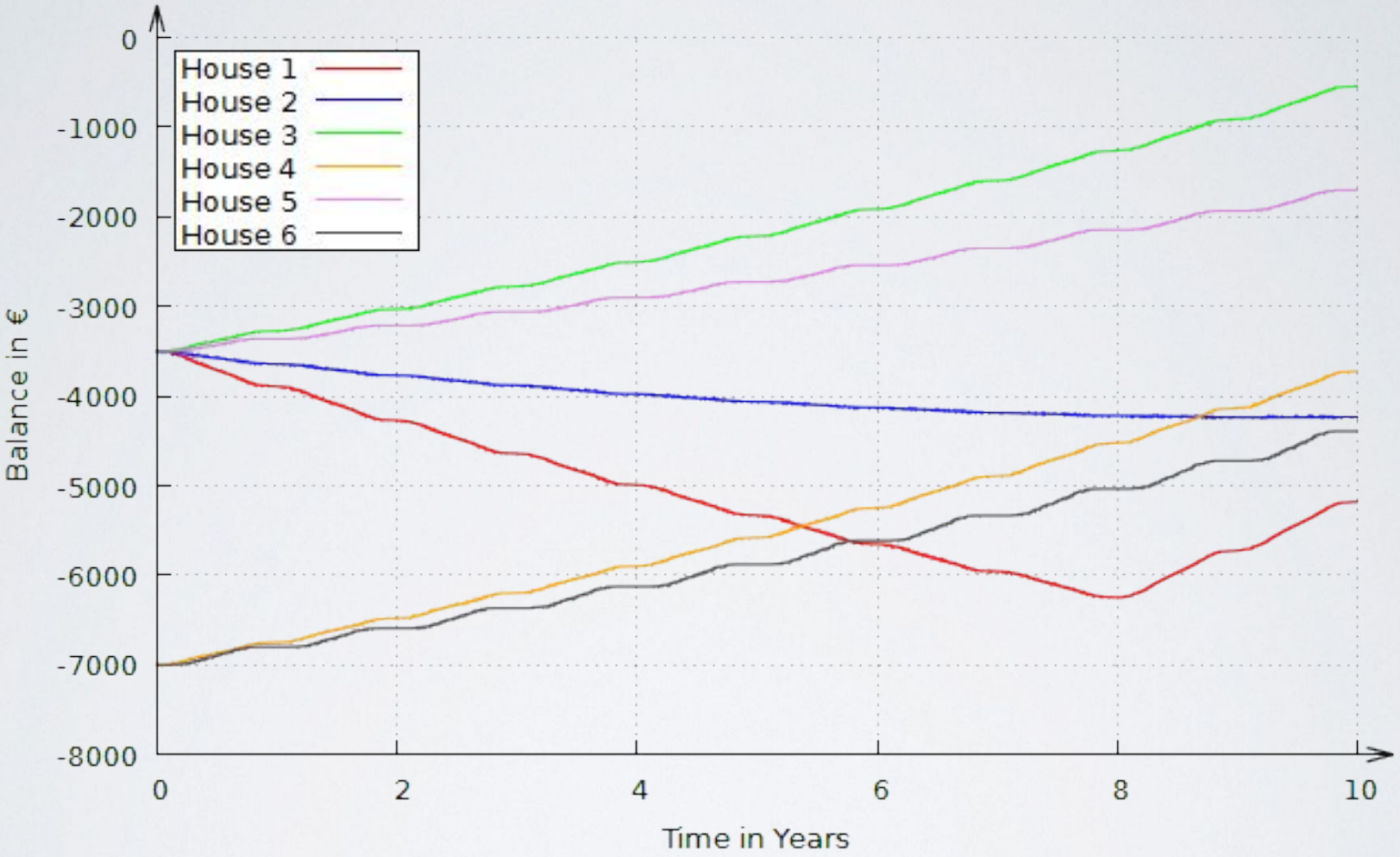
House 2: Consumption: 5,000 kWh p.a., PV: 40 m², Installation Date: 01-2010, Battery Capacity: 7 kWh

Amortisation without internal trade



House 3: Consumption: 5,000 kWh p.a., PV: 40 m², Installation Date: 01-2015, Battery Capacity: 7 kWh

Amortisation without internal trade



House 4: Consumption: 5,000 kWh p.a., PV: 40 m², Installation Date: 01-2015, Battery Capacity: 14 kWh

Internal trade in 3-house neighbourhood

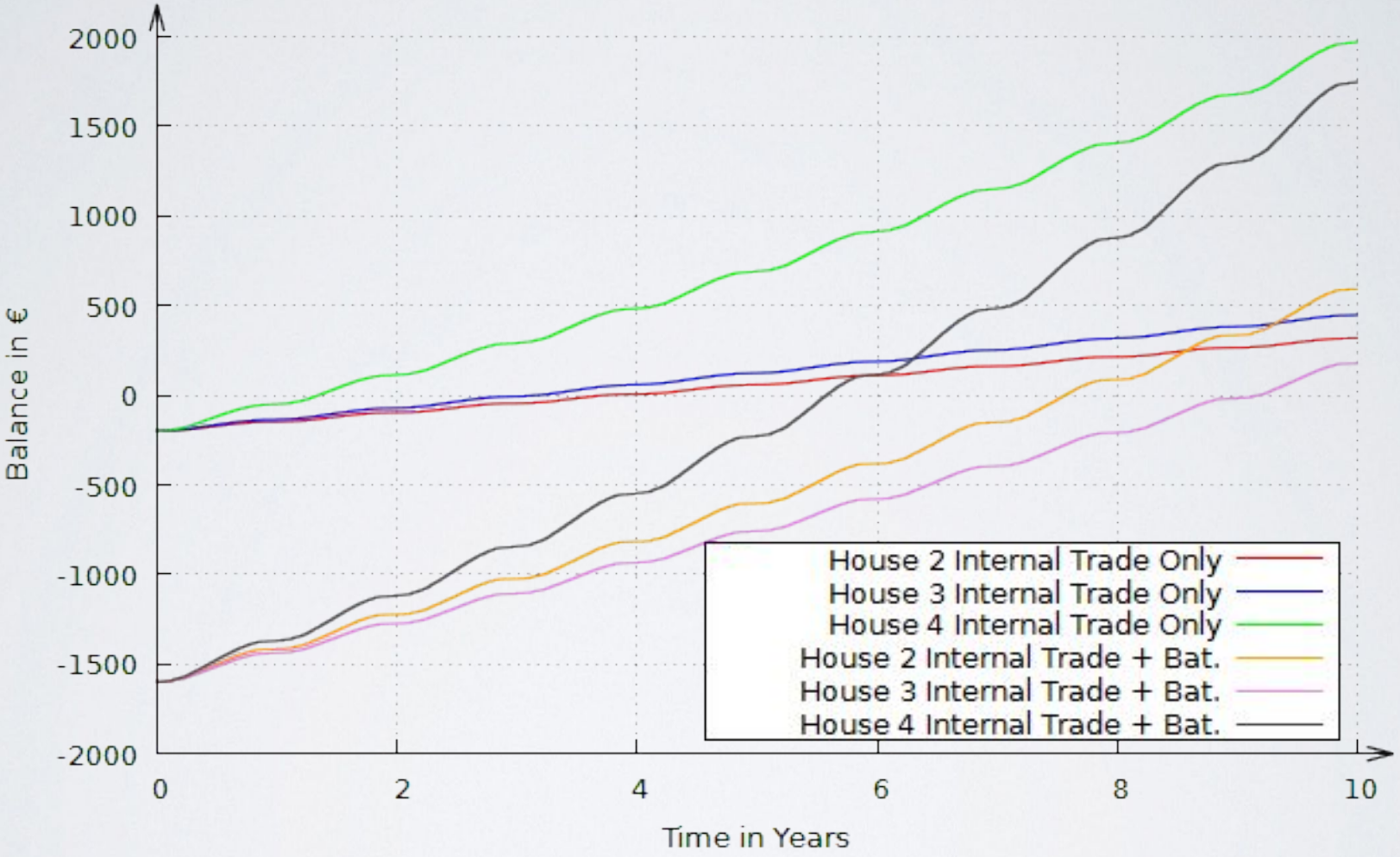
House 1: PV: 35 m², consumption p.a.: 4200 kWh
House 2: PV: 45 m², consumption p.a.: 6000 kWh
House 3: PV: 40 m², consumption p.a.: 3200 kWh

Amortisation in 5-house neighbourhood 3 with, 2 without PV

Specific setup:

Identifier	Consumption p.a. (kWh)	PV Size (m^2)
House 1	4,200	35
House 2	6,000	45
House 3	3,200	40
House 4	5,000	0
House 5	5,500	0

Amortisation in 5-house neighbourhood 3 with, 2 without PV



Conclusions

Smaller Feed-In-Tariff ⇒ Greater Amortisation

Time until amortisation does not depend on battery capacity in a linear fashion

Neighbourhoods including houses without PV lead to increase in internal trade

Future and Related Work

Non-linear battery models (KiBaM) [6]

Internal trade model (Ilic et al.) [7]

Scheduling and optimisation

Consumption patterns (ongoing work)

Analyses / Optimisation [1, 2, 3]

Velik [4]

VIMSEN (van der Burgt et al.) [5]

Thank you! — Questions?

[1] Y. Guo, M. Pan, and Y. Fang, ‘Optimal Power Management of Residential Customers in the Smart Grid’, IEEE Transactions on Parallel and Distributed Systems, vol. 23, no. 9, pp. 1593–1606, Sep. 2012.

[2] P. Samadi, A.-H. Mohsenian-Rad, R. Schober, V. W. S. Wong, and J. Jatskevich, "Optimal Real-Time Pricing Algorithm Based on Utility Maximization for Smart Grid", in 2010 First IEEE International Conference on Smart Grid Communications (SmartGridComm), 2010, pp. 415–420.

[3] N. G. Paterakis, I. N. Pappi, J. P. S. Catalao, and O. Erdinc, "Optimal operational and economical coordination strategy for a smart neighborhood", in PowerTech, 2015 IEEE Eindhoven, 2015, pp. 1–6.

[4] R. Velik, "Battery Storage versus Neighbourhood Energy Exchange to Maximize Local Photovoltaics Energy Consumption in Grid-Connected Residential Neighbourhoods", International Journal of Advanced Renewable Energy Research, vol. 2, no. 6, 2013.

[5] J. van der Burgt, G. Sauba, E. Varvarigos, and P. Makris, "Demonstration of the smart energy neighbourhood management system in the VIMSEN project", in PowerTech, 2015 IEEE Eindhoven, 2015, pp. 1–6.

[6] M. R. Jongerden and B. R. Haverkort, "Battery Modeling", Centre for Telematics and Information Technology, University of Twente, Enschede, info:eu-repo/semantics/report TR-CTI, Jan. 2008.

[7] D. Ilic, P. G. Da Silva, S. Karnouskos, and M. Griesemer, "An energy market for trading electricity in smart grid neighbourhoods", in 2012 6th IEEE International Conference on Digital Ecosystems Technologies (DEST), 2012, pp. 1–6.