Conceptual Modeling of Seasonal Storage

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Abstract

A high-level conceptual model for storing renewable energy to cope with seasonal variations.

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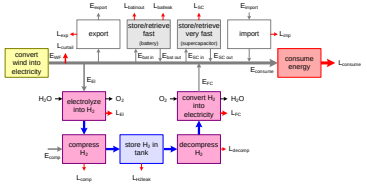
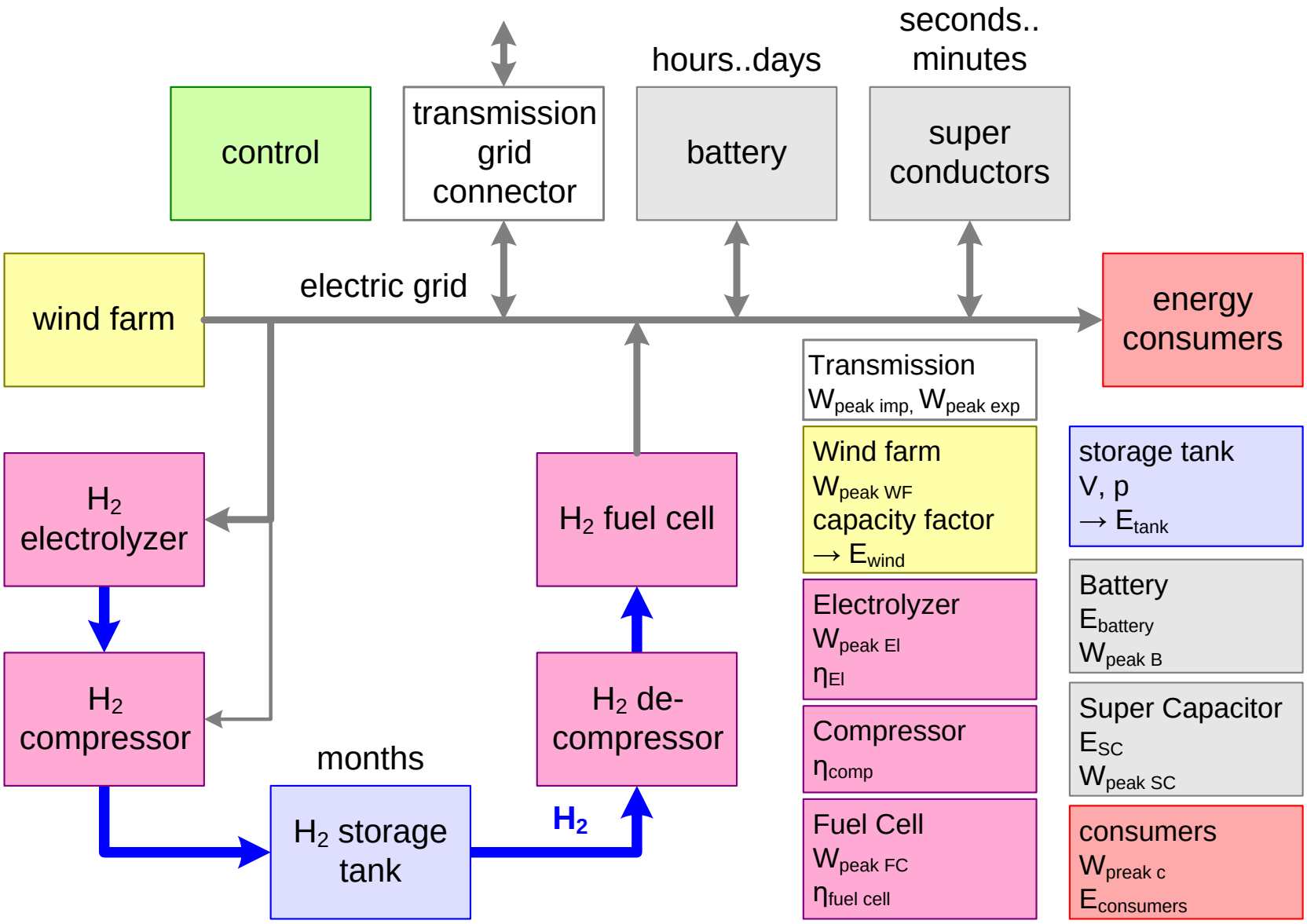
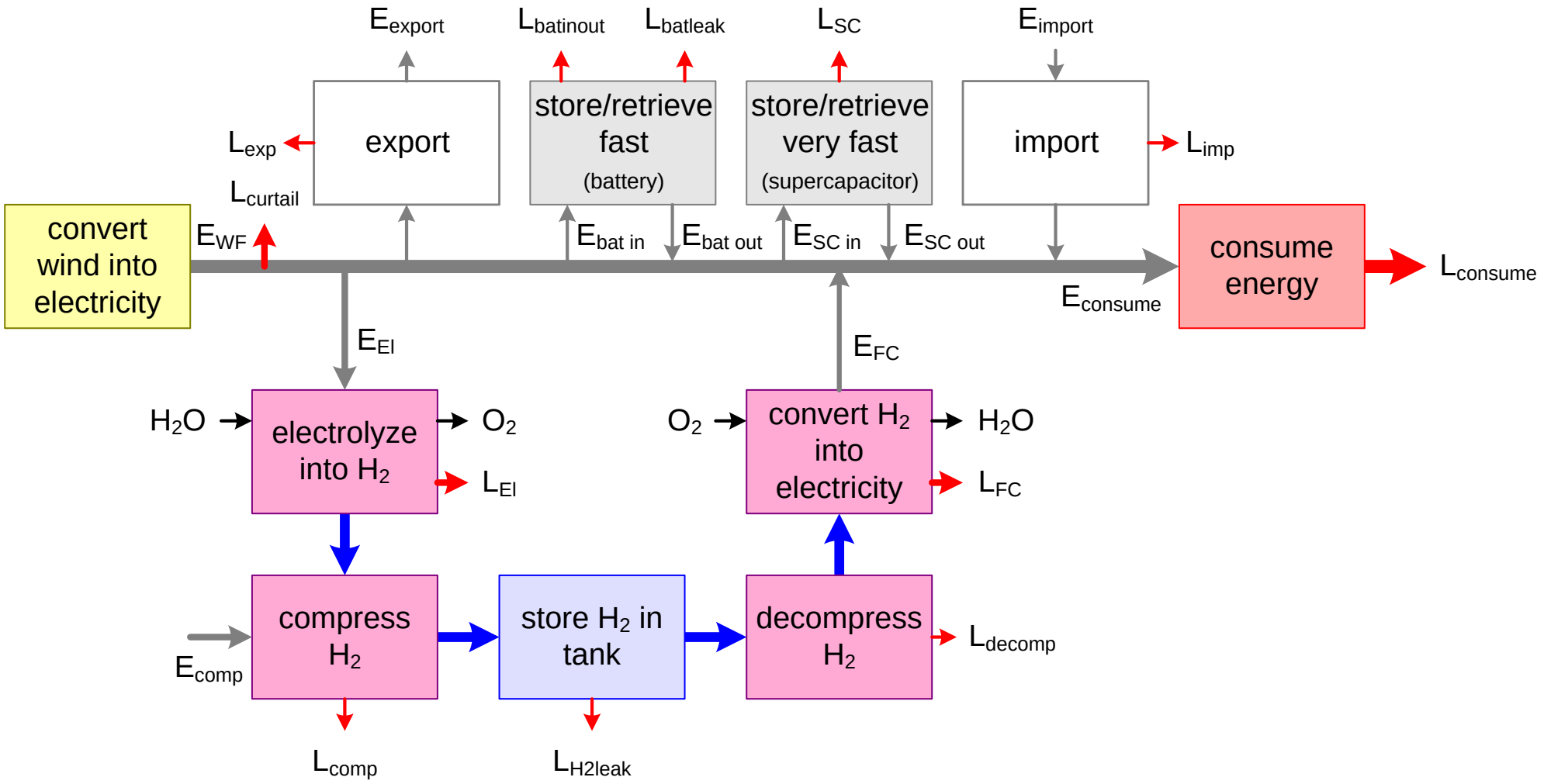


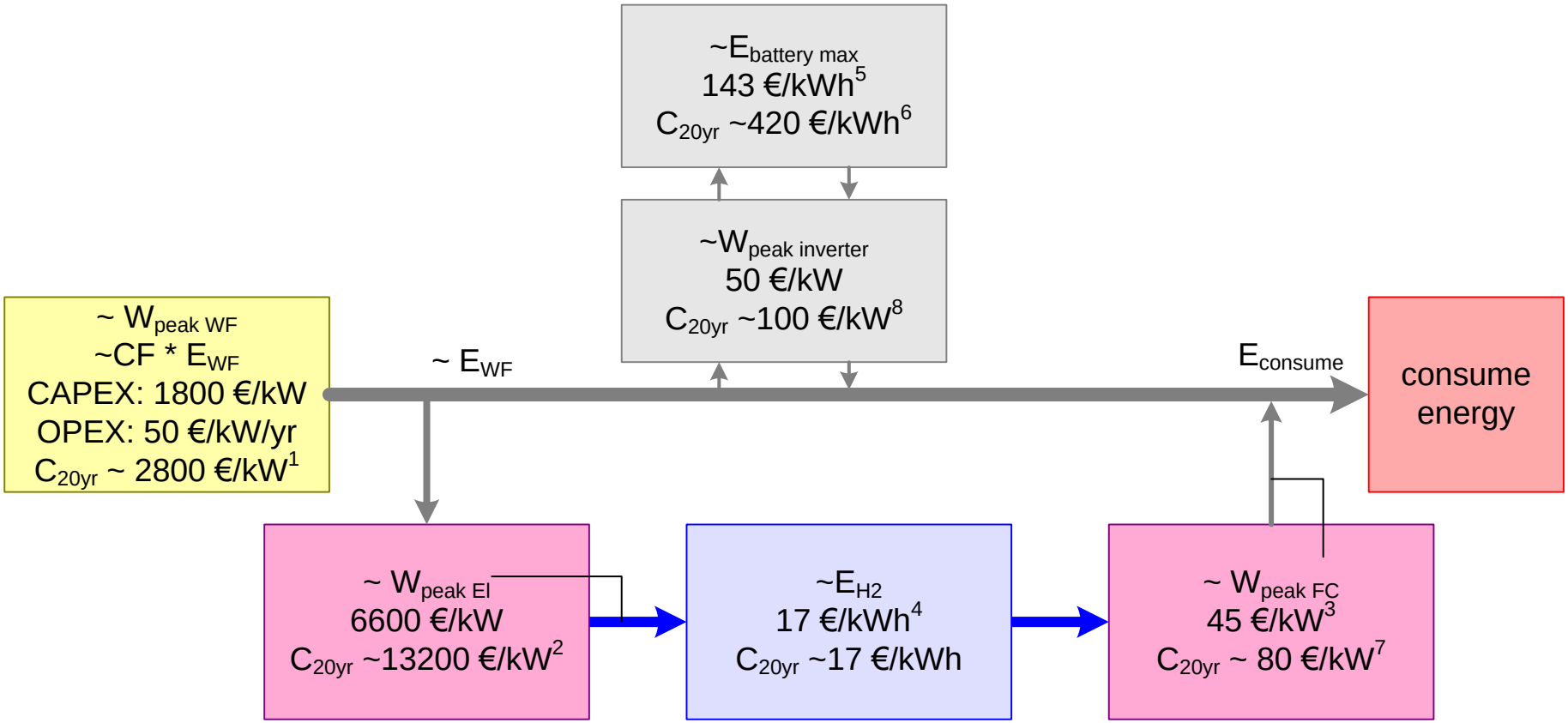
Block Diagram



Functional Model

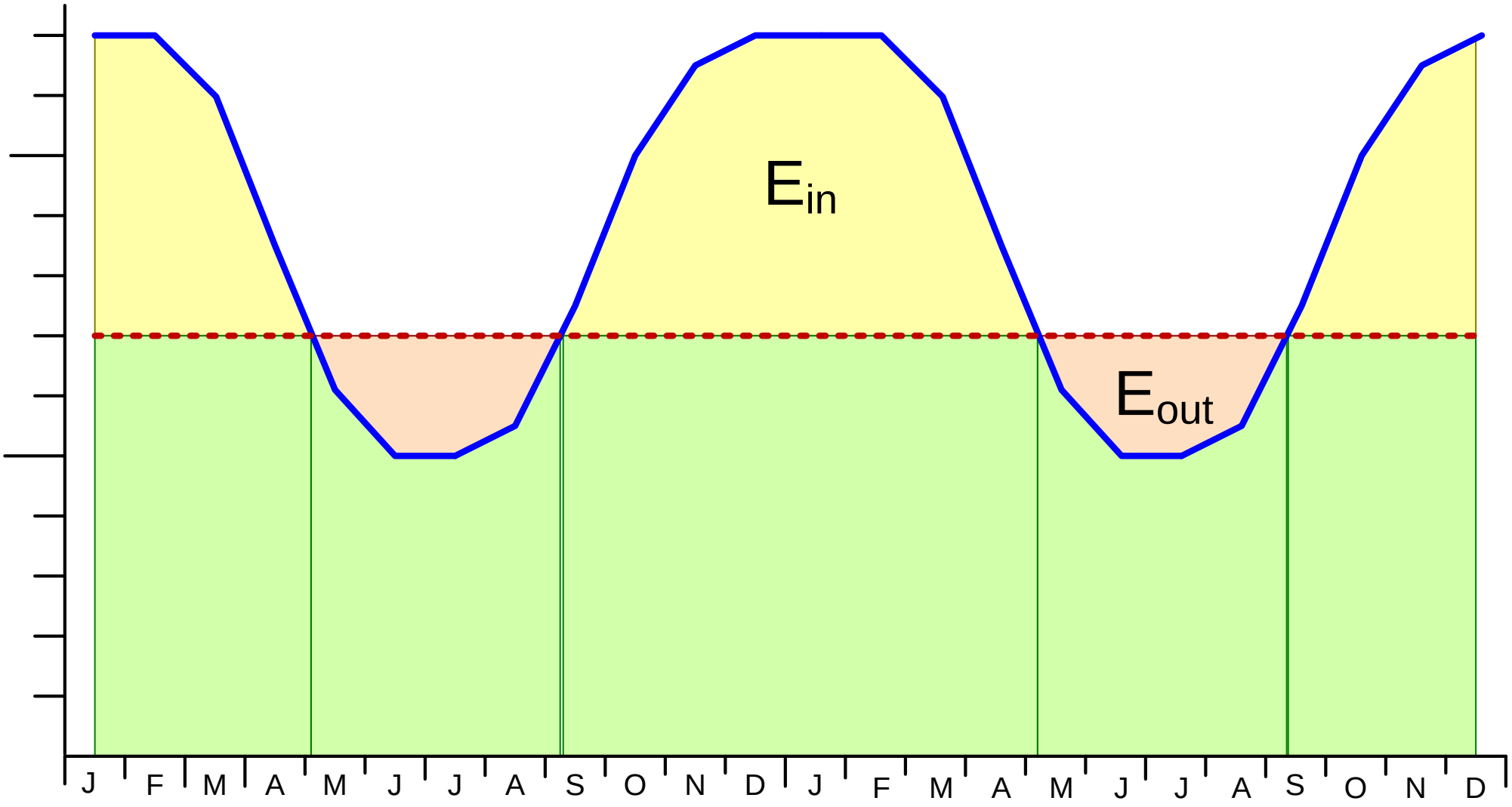


Cost Model

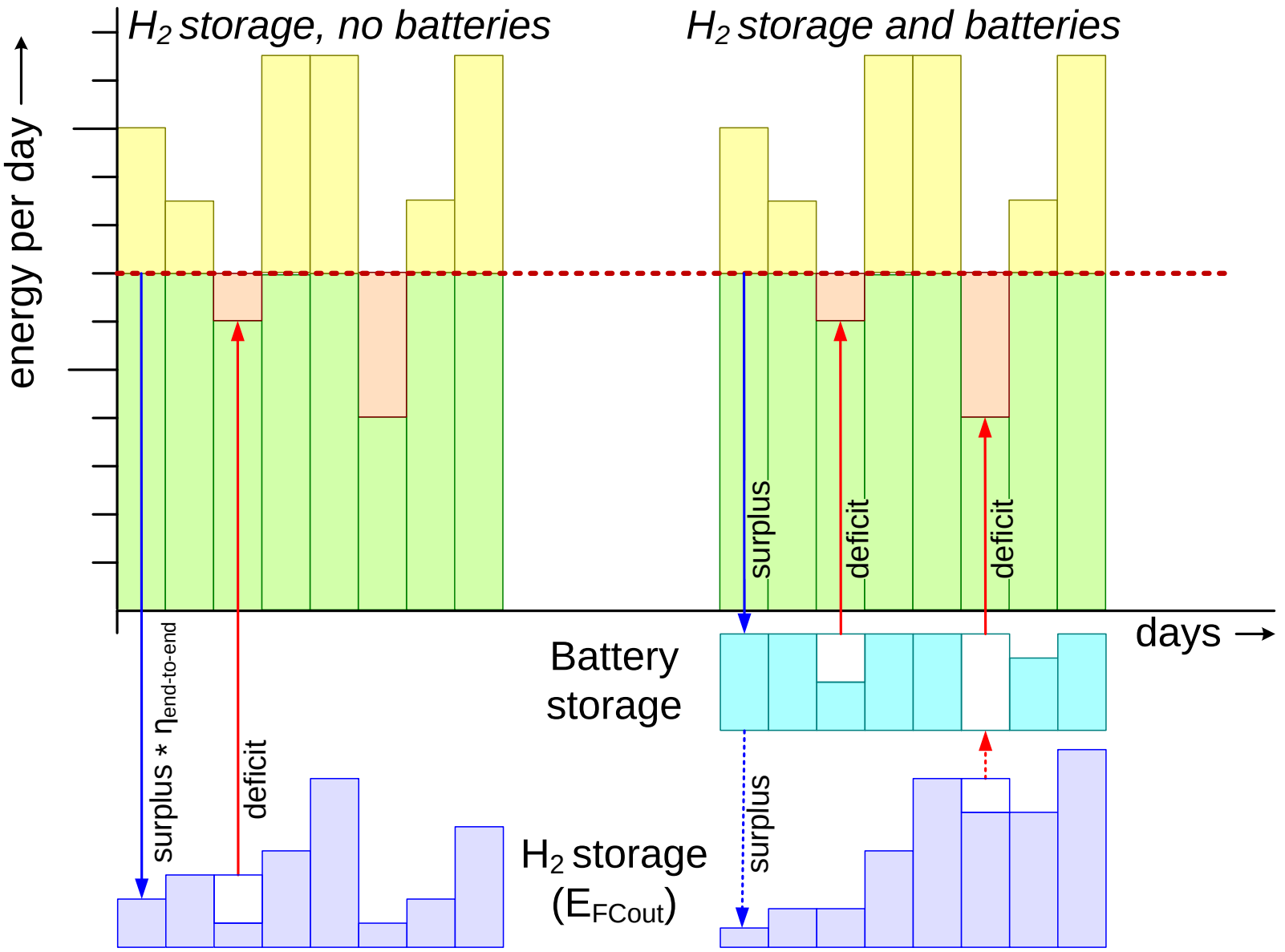


[1] https://www.pbl.nl/sites/default/files/downloads/pbl-2019-costs-of-offshore-wind-energy-2018_3623.pdf
[2] using 10 k$ for 1 KG H_2 in 24 hrs, 33.33kWh/Kg H2, and 0.92 €/$, 30000 hrs ~= 10 years https://pv-magazine-usa.com/2020/03/26/electrolyzer-overview-lowering-the-cost-of-hydrogen-and-distributing-its-productionhydrogen-industry-overview-lowering-the-cost-and-distributing-production/
[3] https://www.energy.gov/eere/fuelcells/fact-month-april-2018-fuel-cell-cost-decreased-60-2006
[4] https://energypost.eu/the-lowdown-on-hydrogen-part-1-transportation/
[5] https://www.greencarcongress.com/2019/12/20191204-bnef.html
[6] 1000 full cycles, let's assume 7 years, https://www.forbes.com/sites/arielcohen/2020/12/30/teslas-new-lithium-ion-patent-brings-company-closer-to-promised-1-million-mile-battery/
[7] 40000 hours at −35 °C to 40 °C, ~12 years https://en.wikipedia.org/wiki/Fuel_cell
[8] assuming 10 years https://www.nrel.gov/docs/fy19osti/72399.pdf

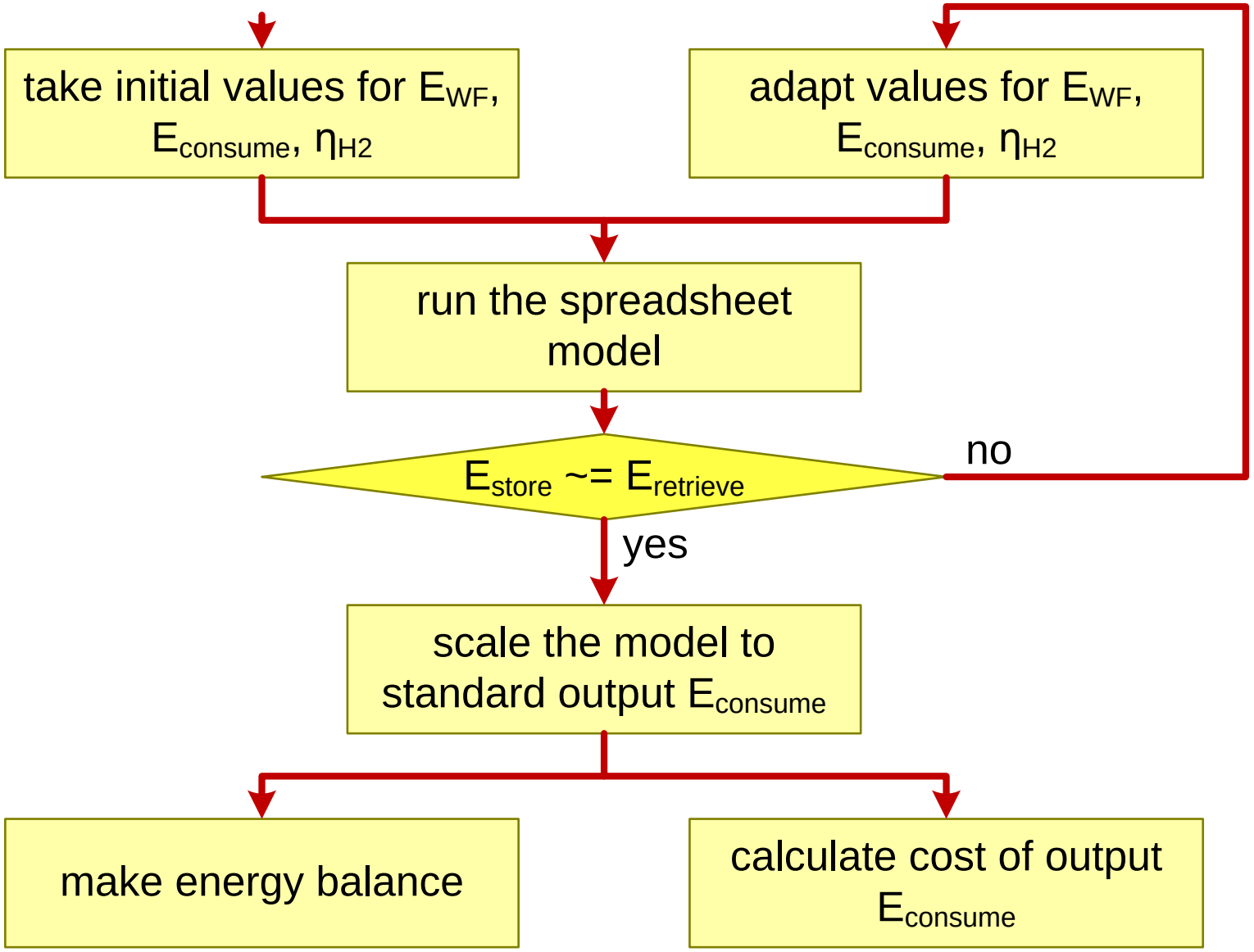
Idealized production and Consumption



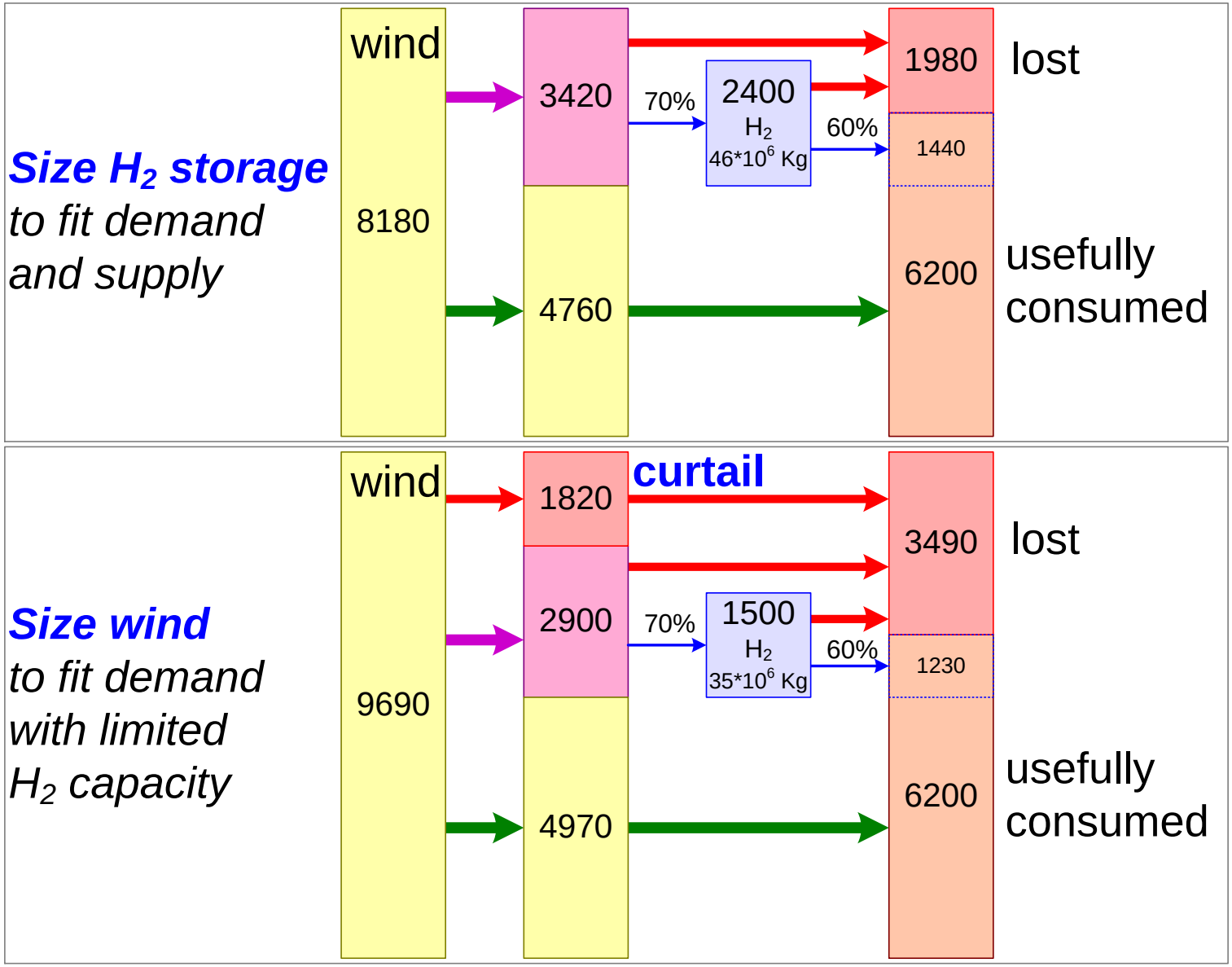
Zooming in on Days



Simulation Workflow

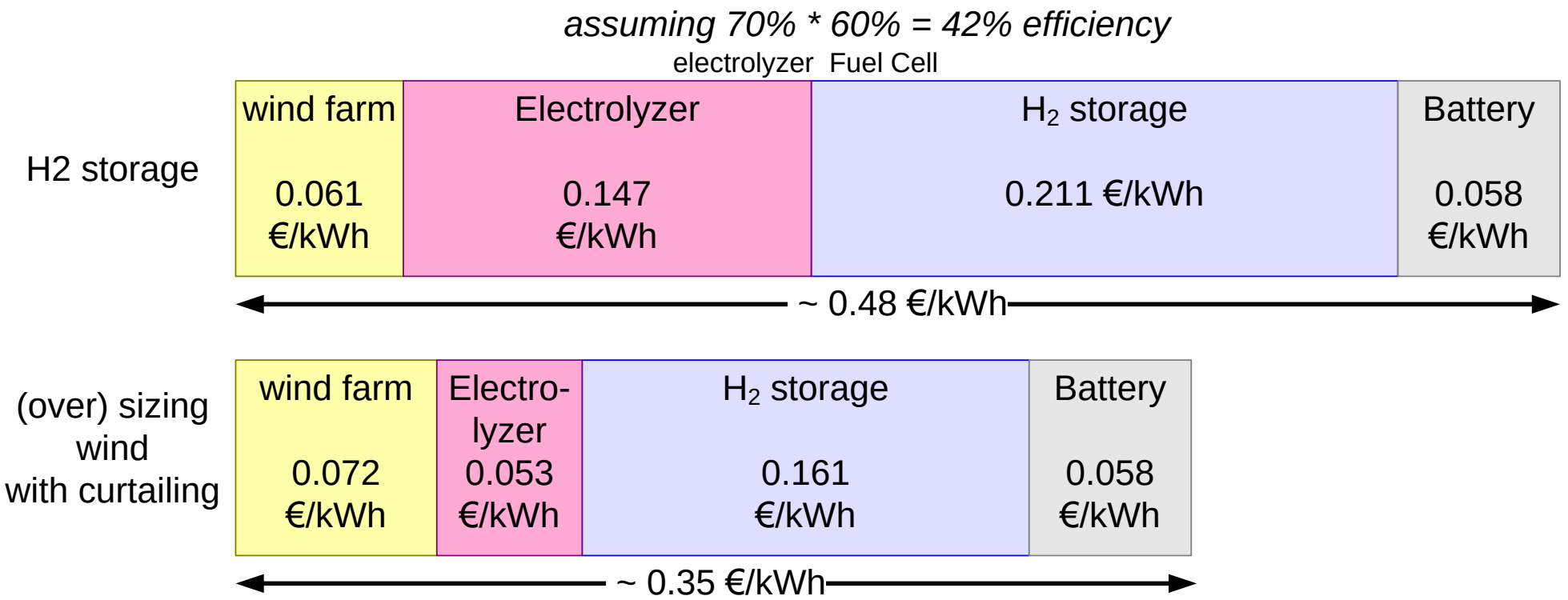


Energy Balance for H2 storage only

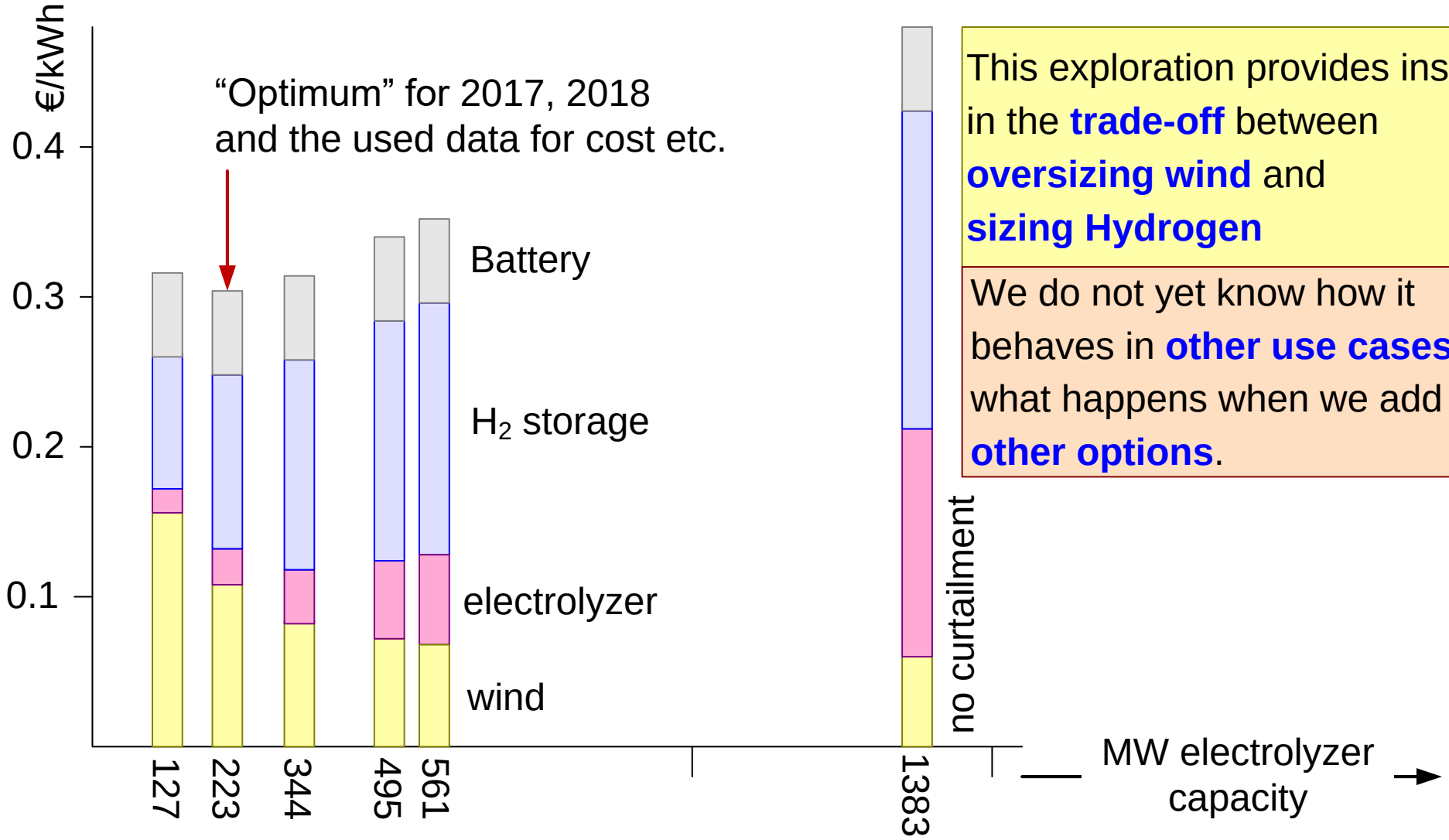


all numbers
GWh/year

Energy Cost for H2 storage only



Energy Cost as Function of H2 Size



This exploration provides insight in the **trade-off** between **oversizing wind** and **sizing Hydrogen**

We do not yet know how it behaves in **other use cases**. Or what happens when we add **other options**.

Simulation for H2 storage only

wind trace data

year	day	production
2018	1	44214
2018	2	39969
2018	3	51687
2018	4	19293
2018	5	15842
2018	6	26849
2018	7	14014
2018	8	43098
2018	9	50887

use

- daily use

21370

surplus

22844
18599
30317
-2077
-5528
5479
-7356
21729
29517

convert

* η_{H2}

50%

store/retrieve

delta	storage
11422	700000
9300	709300
15159	724458
-2077	722382
-5528	716854
2740	719593
-7356	712237
10864	723101
14759	737860

aggregated production

	2017	2018
jan	1179179	842549
feb	849591	1221703
mar	881203	1134683
apr	653040	863695
may	571785	503499
jun	322225	544853
jul	351038	522236
aug	618113	746528
sep	832528	710308
oct	968051	946287
nov	1270278	710351
dec	1041645	1100137
unscaled	9538677	9846828

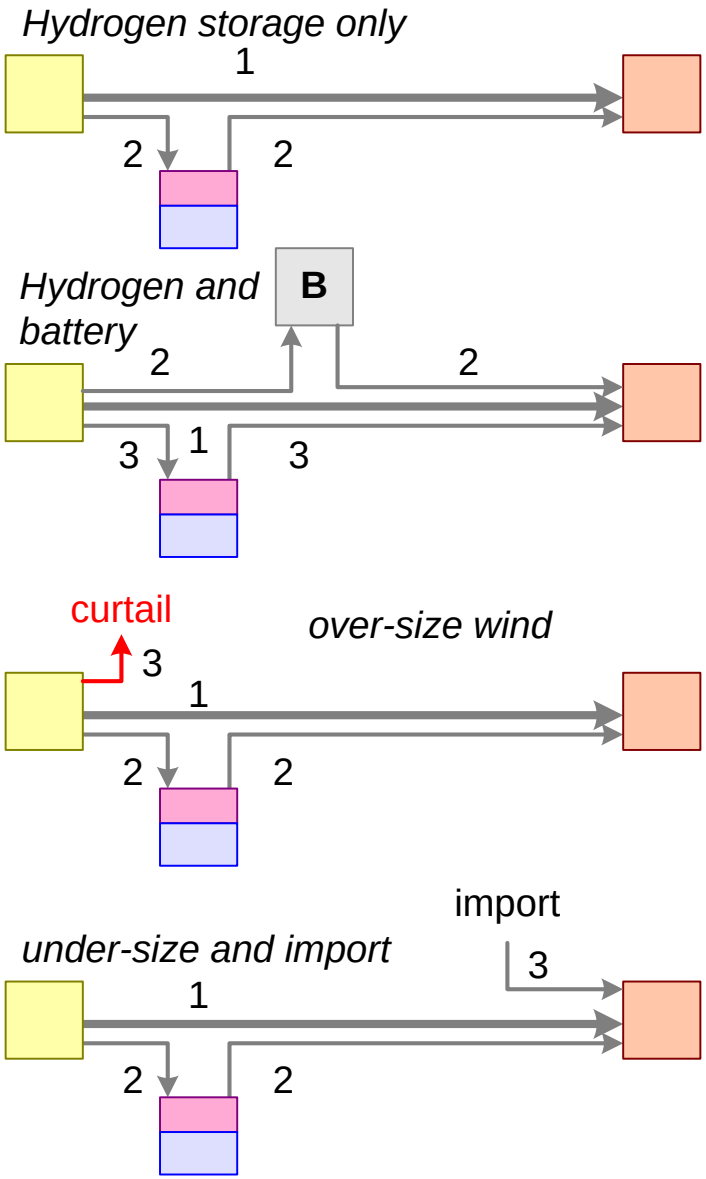
aggregated surplus

surplus +		surplus -	
2017	2018	2017	2018
583321	337872	-66607	-157789
316200	669854	-64965	-46508
368354	536118	-149616	-63901
209203	310924	-197259	-88325
100599	114026	-191280	-272992
78620	122038	-397491	-218281
49842	125676	-361270	-265906
159892	242967	-204244	-158904
319105	262903	-127673	-193691
425785	389846	-120199	-106025
659014	232856	-29831	-163602
466746	530776	-87566	-93105
3736680	3875856	-1998003	-1829028

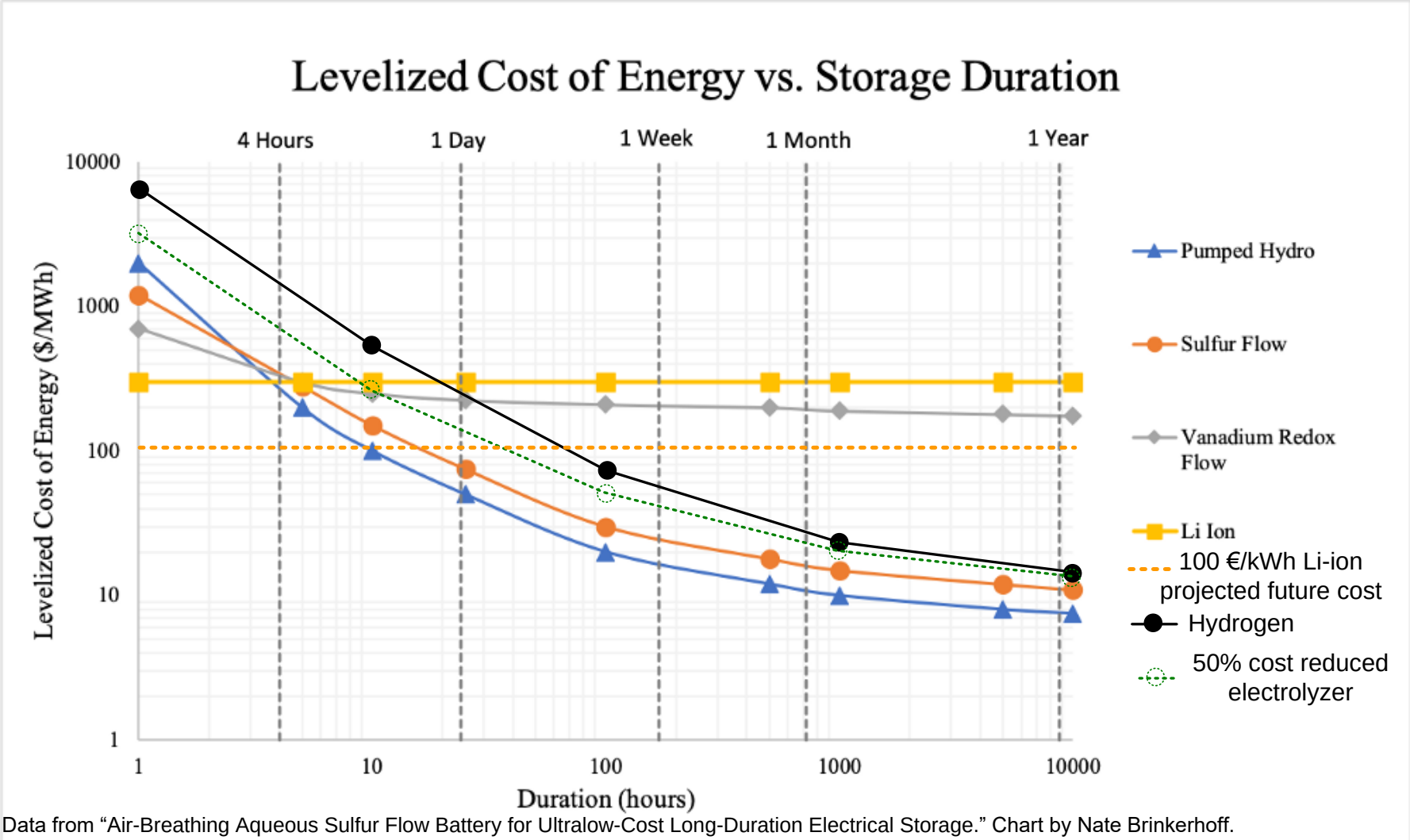
aggregated store/retrieve

store		retrieve	
2017	2018	2017	2018
291660	168936	-66607	-157789
158100	334927	-64965	-46508
184177	268059	-149616	-63901
104601	155462	-197259	-88325
50300	57013	-191280	-272992
39310	61019	-397491	-218281
24921	62838	-361270	-265906
79946	121483	-204244	-158904
159553	131452	-127673	-193691
212892	194923	-120199	-106025
329507	116428	-29831	-163602
233373	265388	-87566	-93105
1868340	1937928	-1998003	-1829028

Scenarios


Hydrogen storage only
1
2
2
Hydrogen and battery
B
2
2
3
1
3
curtail
3
over-size wind
1
2
2
import
3
under-size and import
1
2
2

Comparing Storage Options



Data from “Air-Breathing Aqueous Sulfur Flow Battery for Ultralow-Cost Long-Duration Electrical Storage.” Chart by Nate Brinkerhoff. from https://cleantechnica.com/2020/04/25/how-long-can-lithium-ion-energy-storage-actually-last/

We added: using 10 k$ for 1 KG H_2 in 24 hrs, 33.33kWh/Kg H2, and 0.92 €/$, 30000 hrs ~= 10 years https://pv-magazine-usa.com/2020/03/26/electrolyzer-overview-lowering-the-cost-of-hydrogen-and-distributing-its-productionhydrogen-industry-overview-lowering-the-cost-and-distributing-production/ and [4] https://energypost.eu/the-lowdown-on-hydrogen-part-1-transportation/ : 6600 €/kW and 17 €/kWh