IRENA
International Renewable Energy Agency

IRENA FlexTool

Modelling different flexibility options

IRENA 2020

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Flexibility options according to IRENA

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Flexibility needs to be harnessed in all sectors of the energy system

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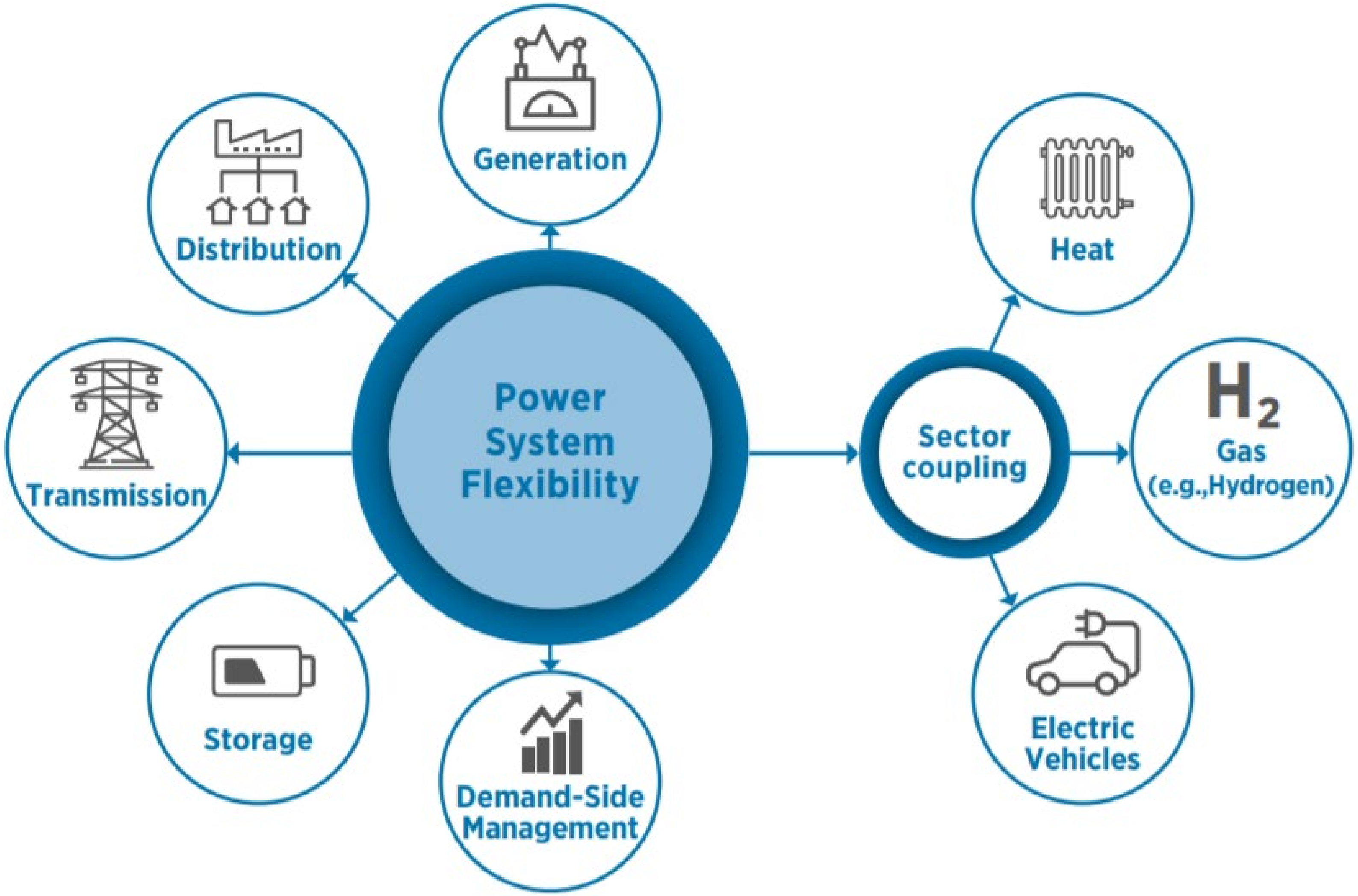

Generation

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Modelling flexible thermal generators in IRENA FlexTool

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- Technical characteristics of generation are defined in “**unit_type**”:
  - **For example:** efficiency, ramping capability, minimum stable load, start up costs, min up and down times…

unit type	efficiency	min load	eff at min load	ramp up (p.u. per min)	ramp down (p.u. per min)	O&M cost/MWh	availability	max reserve	inertia constant (MWs/MW)	fixed cost/kW/year	inv.cost/kW	inv.cost/kWh	fixed kW/kWh ratio	conversion eff	startup cost	min uptime (h)	min downtime (h)	eff charge	self discharge loss	lifetime	interest	annuity	non synchronous
Engine_gas	0.46	0.20	0.43	0.20	0.20	2.0	1.00	1.00	2.00	30	600				0.50	4.00				35	0.08	0.086	0
CC_oil	0.40	0.50	0.35	0.05	0.05	2.5	1.00	1.00	3.00	50	800				1.00		5.00			35	0.08	0.086	0

- Then in “**units**” specific country or node capacity and fuels of those unit types are defined:

		Choose one input option (none, fuel, cf profile, inflow **or** input grid+node)					Output #1																
unitGroup	unit type	fuel	cf profile	inflow	input grid	input node	output grid	output node	capacity (MW)	invested capacity (MW)	max invest (MW)	storage (MWh)	invested storage (MWh)	max invest (MWh)	storage start	storage finish	reserve increase ratio	use efficiency time series	fix unit generation	use_min_generation	use_max_generation	use_min_online	inflow multiplier
Fossil	Engine_gas	nat_gas					elec	nodeA	1500		5000									1			
Bio	ST_bio	biomass					elec	nodeB	500		0												
Geo	Geothermal	geo_heat					elec	nodeB	200		0												
PV	PV		PV				elec	nodeB	300		500						0.10						

Modelling hydropower generators in IRENA FlexTool

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- **Run-of the-river hydro**
  - Similar to defining a thermal generator with some changes, but in addition
  - Define time series of **natural inflows** (MWh/h) in “ts_inflow” sheet
  - Assign it to hydro-ROR unit in “units” sheet by selecting inflow input option
  - Define inflow multiplier (1 as default) in “units” sheet
  - Now the unit will be similar to a VRE generator using ts_inflow instead of ts_cf

- **Hydro with reservoir:**
  - In addition to run-of-river hydro,
  - Define value for “storage (MWh)” parameter in “units” sheet
  - Optionally define storage start, storage finish

Transmission

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Transfers, 1/2

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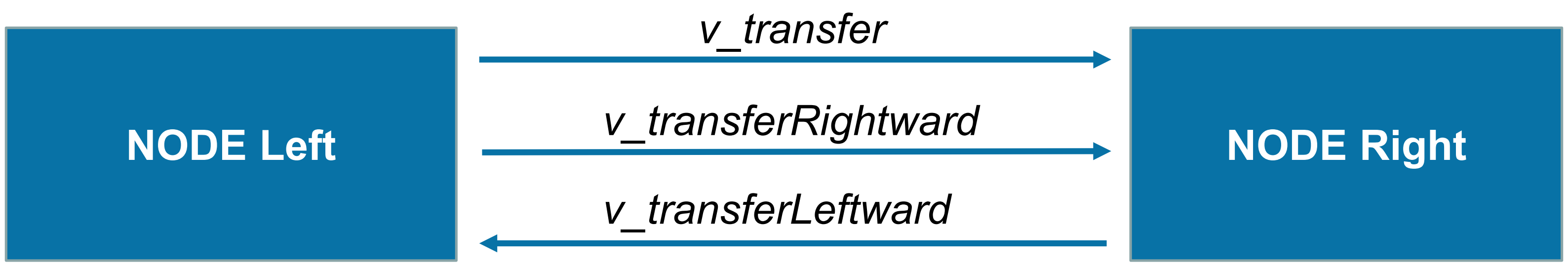
- **Transfers** between nodes are defined in "**nodeNode sheet**"
  - Both nodes have to be from the same grid
  - Existing transfer links can have different capacity to different direction
  - Future investments will always have equal capacity to both directions

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	grid	node1	node2	cap.rightward (MW)	cap.leftward (MW)	invested capacity (MW)	max invest (MW)	loss	inv.cost/kW	lifetime	interest	annuity	HVDC	color in results
2	elec	nodeA	nodeB	150	150		0	0.01	100	50	0.08	0.082	0	
3	elec	nodeB	nodeC	100	100		0	0.01	100	50	0.08	0.082	0	

nodeNode sheet

Transfers, 2/2

- **Transfer with losses** requires at least two variables
  - A linear equation with ‘loss x transfer’ would mean that in the other direction loss is actually a gain
- The loss can be used to make the **model ‘leak’**
  - Instead of curtailing VRE, the model can dissipate energy by transferring in two directions at once
  - Can be controlled only with a binary variable (not allowed in FlexTool)
- Hence, **three variables**: transfer, transfer rightward and transfer leftward
  - Transfer does not contain loss
  - Transfer rightward allows losses and helps to limit the leakage
  - Transfer leftward helps to limit the leakage further



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Electricity Storage

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Modeling electricity storage in IRENA FlexTool

- Electricity storage is defined in "**unit_type**" sheet, with few additions compared to other generators:
  - Efficiency (%) – Discharging efficiency
  - Eff.charge (%) – Charging efficiency
  - Self discharge loss (% of content per hour) – if any

- In "**units**" sheet the following is defined:
  - Capacity (MW) – Installed capacity in MW
  - Storage (MWh) – Maximum storage capacity in MWh
  - Storage start/finish – Initial and final state of the storage

- If storage type is pumped hydro storage it is possible that the unit has a natural inflow, which could be defined in "**ts_inflow**" sheet

Investment mode for batteries

Two options: Fixed P/E ratio or free optimisation

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Option 1: Fix power to energy ratio

- Model the batteries with a fixed power to energy ration, this is to say, with a fixed discharge duration (*e.g.*, 2 hours or 4 hours batteries
- **Only investment cost required is the one to invest in energy (battery cells)**
- In this example the model would only consider 1 hour duration batteries in optimisation

unit type	inv.cost/kW	inv.cost/kWh	fixed kW/kWh ratio
battery		80	1.000

Option 2: Free optimisation of power and energy

- It is also possible to optimise separately power and energy
- In this case there is no need to defined a P/E ratio but an investment cost for power (inverter) and energy would be required

unit type	inv.cost/kW	inv.cost/kWh	fixed kW/kWh ratio
battery	20	80	

Demand response

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Modeling demand response in the IRENA FlexTool

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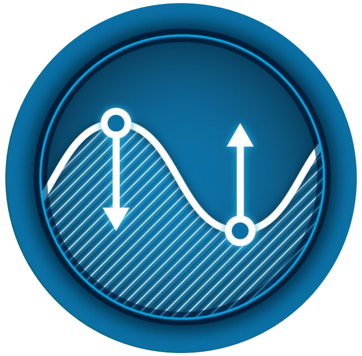
- Demand response is defined in "**unit_type**" sheet, as if it was a generator. Defined as:
  - **Demand response increase** – Generator with negative price and empty charging efficiency
  - **Demand response downwards** – Generator with positive price and efficiency



unit type	efficiency	min load	eff at min load	ramp up (p.u. per min)	ramp down (p.u. per min)	O&M cost/MWh	availability	max reserve	inertia constant (MWs/MW)	fixed cost/kW/year	inv.cost/kW	inv.cost/kWh	fixed kW/kWh ratio	conversion eff	startup cost	min uptime (h)	min downtime (h)	eff charge	self discharge loss	lifetime	interest	annuity	non synchronous
demand_incr				1.00	1.00	-15.0	1.00	1.00										1.00		10	0.08	0.149	0
demand_decr	1.00			1.00	1.00	100.0	1.00	1.00												10	0.08	0.149	0

- In "**units**" sheet the following is defined:
  - Capacity (MW) – If the demand response is an increase then negative maximum capacity and if it is to decrease then positive

		Choose one input option (none, fuel, cf profile, inflow **or** input grid+node)					Output #1		
unitGroup	unit type	fuel	cf profile	inflow	input grid	input node	output grid	output node	capacity (MW)
Dem_inc	demand_incr						elec	nodeC	-30
Dem_dec	demand_decr						elec	nodeC	40

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Electric Vehicles

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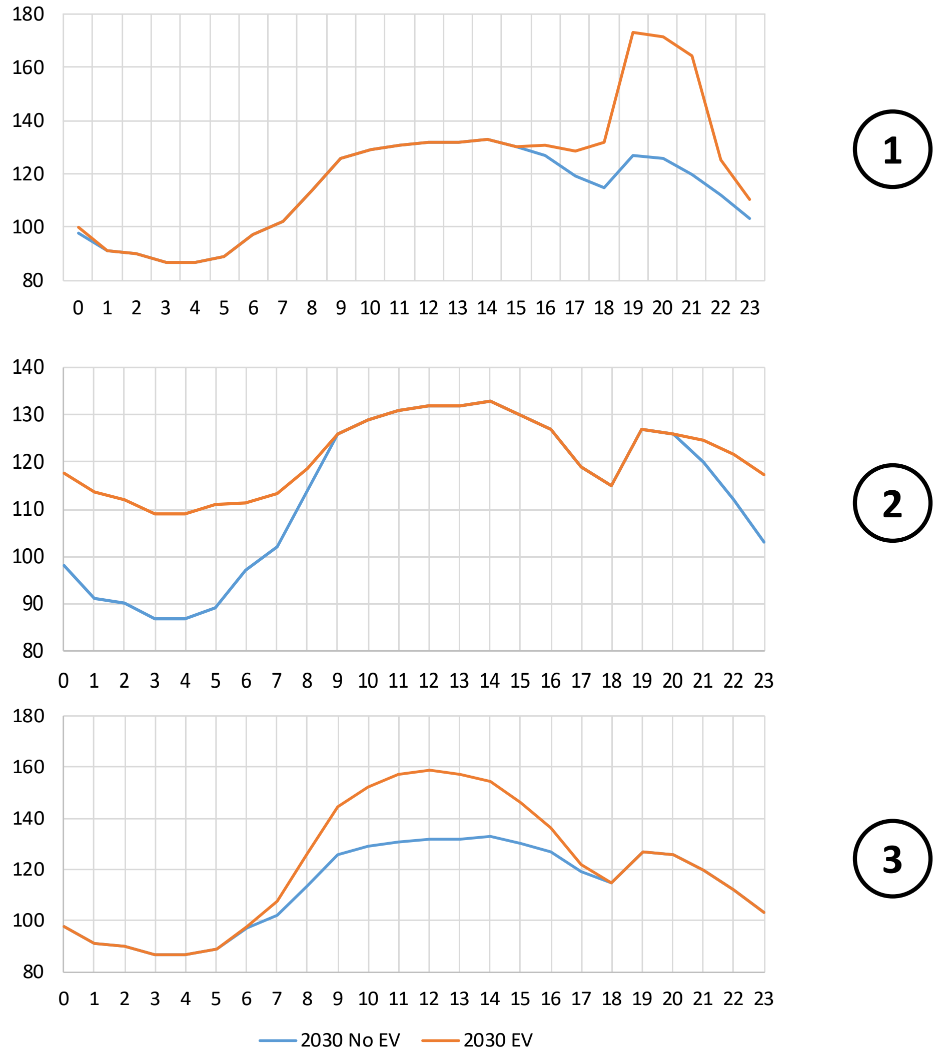
Modelling unidirectional charging of EVs

Pre-calculating demand profiles

- EVs as predefined demand profiles that are added on top of the original demand curve

- Three charging scenarios:
  1. Evening uncontrolled charging
     - As soon as EVs arrive home, they charge at maximum power
  2. Night controlled charging
     - Charge is distributed along the night
  3. Day controlled charging
     - Charge coincides with the solar PV profile

- **In FlexTool**: Sum these profiles to the demand curve and add it in "**ts_energy**" sheet



Modelling Vehicle-to-Grid in FlexTool (V2G)

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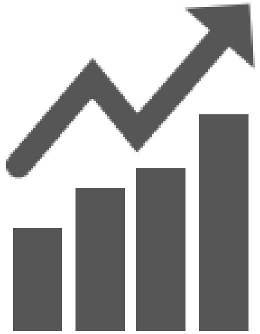
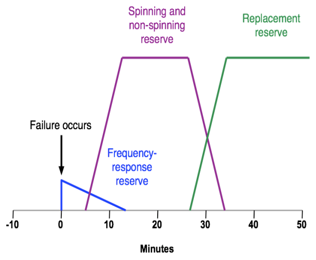
Electromobility Grid



Demand

- Defined demand profile in “ts_energy” sheet
- This demand would represent discharge of battery because of mobility
- We need to estimate this demand



Reserves

- Define reserve profile in “ts_reserve” sheet
- This is used to represent the amount of EVs that are connected to grid in a time period
- Existing software to estimate this

Define a unit that transfers energy from mobility grid to electricity grid and vice versa

$$P_{tot} = \alpha * \sum P_{Chargers}$$

$$E_{tot} = \alpha * \sum E_{battery}$$

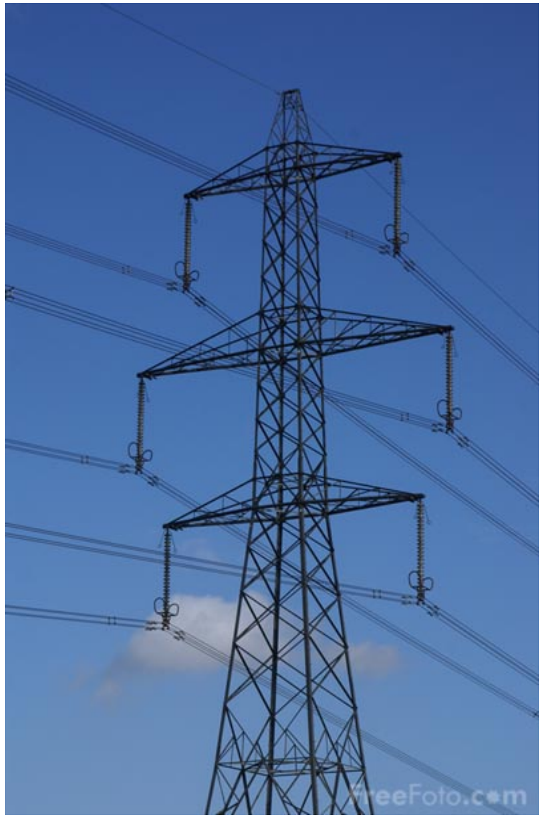
$$\alpha = Simultaneity\ factor$$

Discharge →

← Charge

→ Ancillary services →

Electricity Grid



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Power-to-heat

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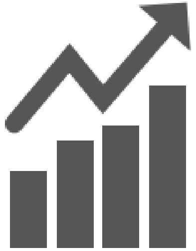
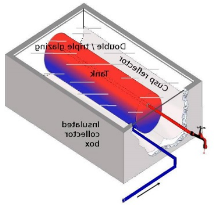
Modelling Power-to-heat in IRENA FlexTool

Heat Grid



Demand

- Defined demand profile in "ts_energy" sheet
- This demand would represent heat demand in system



Thermal Storage

- Defined exactly the same as electricity storage but in heat grid (see slides on electricity storage)
- Usually use the property: "self-discharge loss"

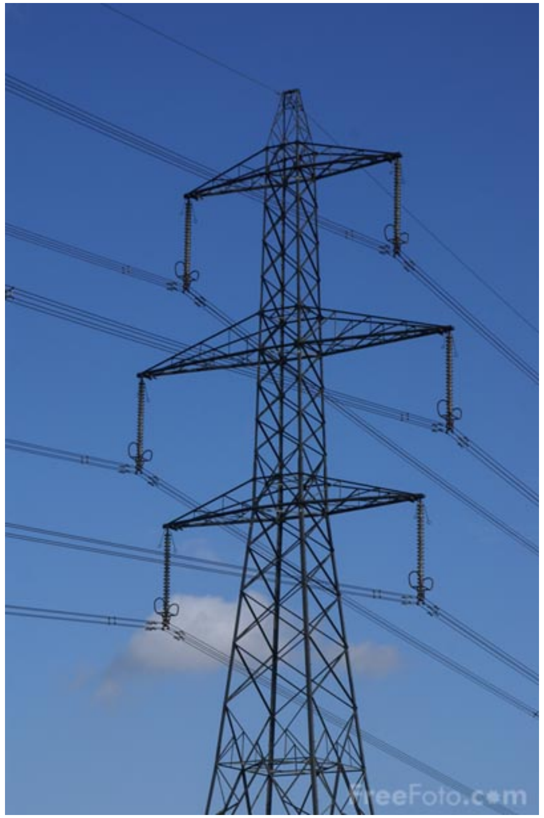
Direct heat devices

- Defined exactly the same as a generator but in heat grid (see slides on generators)
- Examples: solar thermal, gas boilers, etc.

Power-to-heat devices

(NEXT SLIDE)

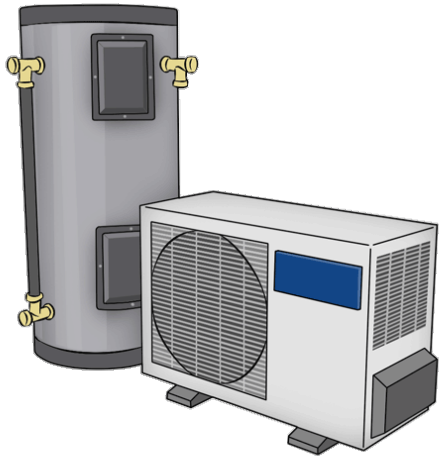
Electricity Grid



Power-to-heat devices in IRENA FlexTool

- Power-to-heat devices can be heat pumps or electric boilers that convert electricity to heat
- Defined similar to generators with some peculiarities:
  - Static efficiency – Defined directly in “unit_type” sheet as “conversion_eff”

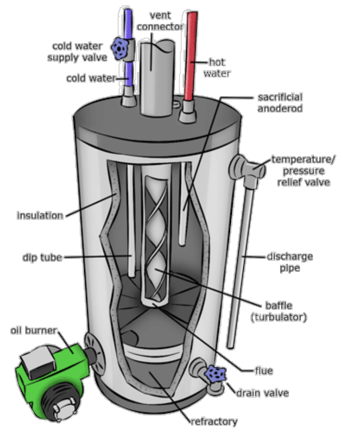
unit type	efficiency	min load	eff at min load	ramp up (p.u. per min)	ramp down (p.u. per min)	O&M cost/MWh	availability	max reserve	inertia constant (MWs/MW)	fixed cost/kW/year	inv.cost/kW	inv.cost/kWh	fixed kW/kWh ratio	conversion eff	startup cost	min uptime (h)	min downtime (h)	eff charge	self discharge loss	lifetime	interest	annuity	non synchronous
heat_pump				1.00	1.00		1.00	0.50			1000			2.50						40	0.08	0.084	1



  - Dynamic efficiency – Activate option in “units” sheet and then define it in “ts_unit” sheet

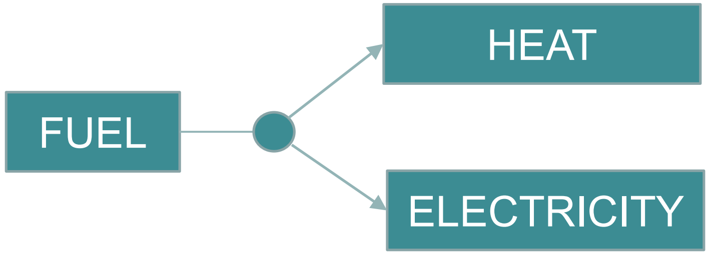
use efficiency time series	fix unit generation	use_min_generation	use_max_generation	use_min_online	inflow multiplier
			1	1	
1					

	grid	heat
	node	heatA
	unit	heat_pump
	unit_ts_param	efficiency
Time		
t0000		2.50
t0001		2.60
t0002		2.70
t0003		2.80
t0004		2.90
t0005		3.00



- **IMPORTANT**: Define electricity as input grid and heat as output grid in the “units” sheet

Advanced modelling of CHP units



- A CHP unit is a unit that can produce both heat and electricity
- There is typically a relationship between heat and electricity production, being one of the outputs limiting the other

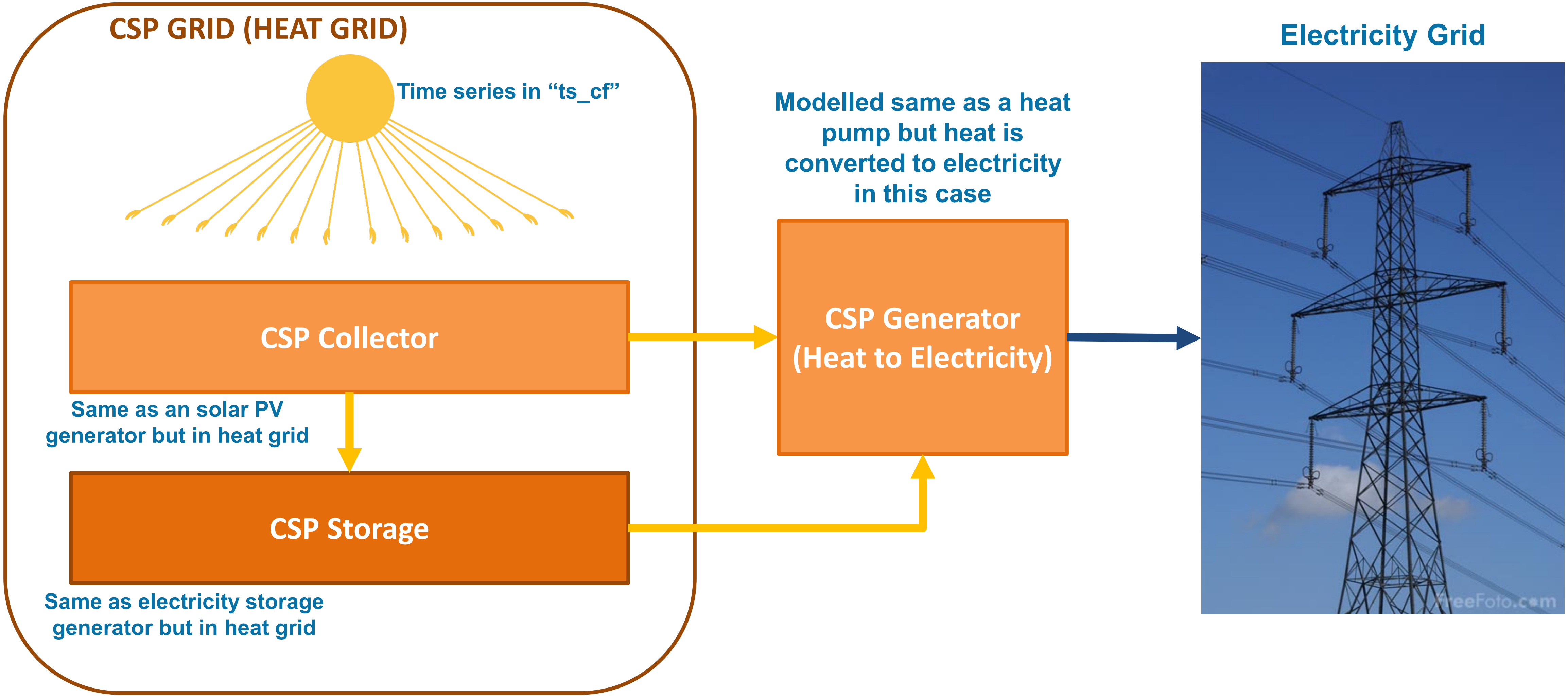
- Technical characteristics are defined in “unit_type” as any other generator
- Then in the “units” sheet we define
  - Output 1: Electricity
  - Output 2: Heat
  - Relationship between outputs 1 and 2 (user define coefficients)
    - Inequality constraints $O_2 \geq a_1 * O_1 + b_1$ and $O_2 \leq a_2 * O_1 + b_2$
    - Equality constraint $O_2 = a_3 * O_1 + b_3$
  - Fuel consumption increase coefficient due to Output 2

Optional output #2 (with parameters)									
output2 grid	output2 node	output2 eq coeff	output2 eq constant	output2 gt coeff	output2 gt constant	output2 lt coeff	output2 lt constant	output2 max capacity (MW)	fueluse increase eq x output2
heat	heatA			1.40	-100	2.00	100	800	0.10

- For more information see IRENA FlexTool 2.0 Methodology slides on units with two outputs

Special case – Modelling CSP units in FlexTool

- CSP is represented in the FlexTool as an additional single node grid with zero demand
- The CSP grid is interconnected with electrical grid at a specific node



Power-to-hydrogen

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Modelling Power-to-hydrogen in IRENA FlexTool

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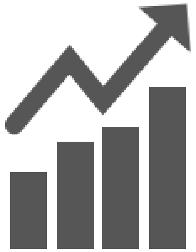
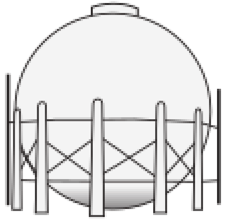
Hydrogen Grid



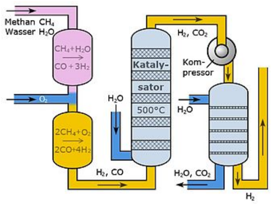
Demand

- Defined demand profile in “ts_energy” sheet
- This demand would represent hydrogen demand in the system



Hydrogen Storage

- Defined exactly the same as electricity storage but in hydrogen grid (see slides on electricity storage)
- In FlexTool a hydrogen network with different nodes could also be modelled



Other production methods

- In hydrogen grid other methods of hydrogen production can also be modelled in a simplified way
- Examples: steam methane reforming (SMR)

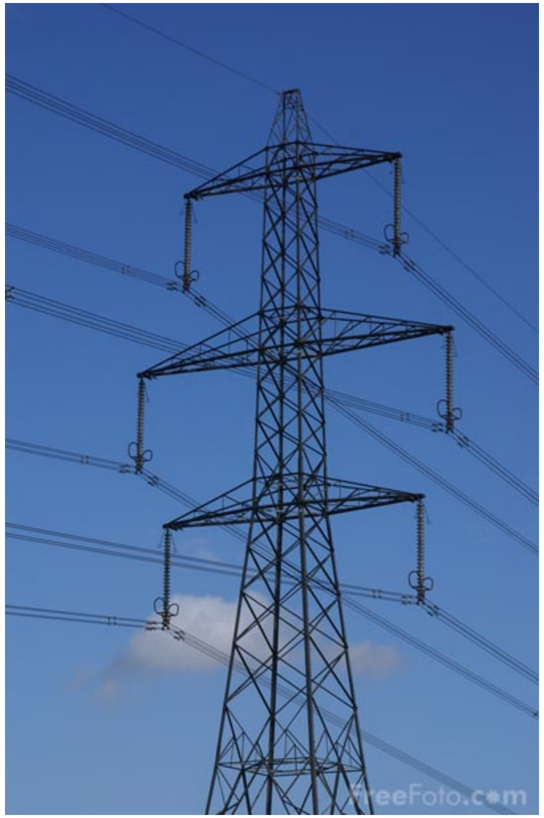
Electrolyser

(NEXT SLIDE)

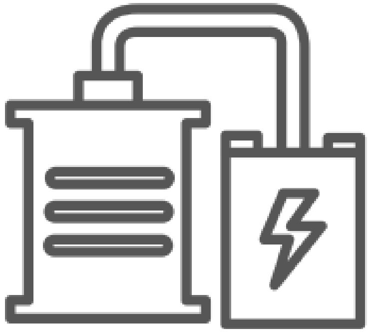
Fuel Cell

(NEXT SLIDE)

Electricity Grid

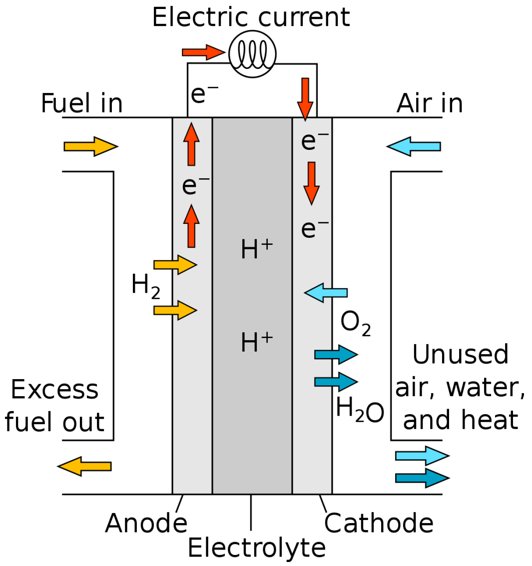


Electrolysers and Fuel Cells



- Unit that absorbs electricity and converts it to hydrogen to be used in that grid
- In “**unit_type**” define the main characteristics of the electrolyser depending on its chemistry
  - For example: efficiency (“**conversion eff.**”), ramping capabilities, lifetime, etc.
- In “**units**” define installed capacity per node as with generators
- Main issue with electrolysers today is lack of real data about their characteristics

- Unit that absorbs hydrogen and converts it back to electricity
- In “**unit_type**” define main characteristics of the fuel cell. Note that efficiency is also “**conversion eff.**”
- In “**units**” define installed capacity per node as with generators
- Likewise we can model a gas turbine or any other generator that uses hydrogen as an input



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