



2050 Calculator Extensions - Electricity System

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Outline

- Background information
- Electricity system balancing
- Grid system
- Reserve margin
- Loss of load

Background Information

Electricity in Taiwan :

- Relies on energy imports
- No international connection
- Highly depends on fossil fuel (77% of electricity supply)
- Nuclear power accounts for 17% of supply, highly controversial at present
- Volatile renewables accounts for 1%
- Demand peaks in summer afternoon
- Industrial sector is the biggest consumer



Fig: Taiwan grid system map (Source: Taipower)

Background Information

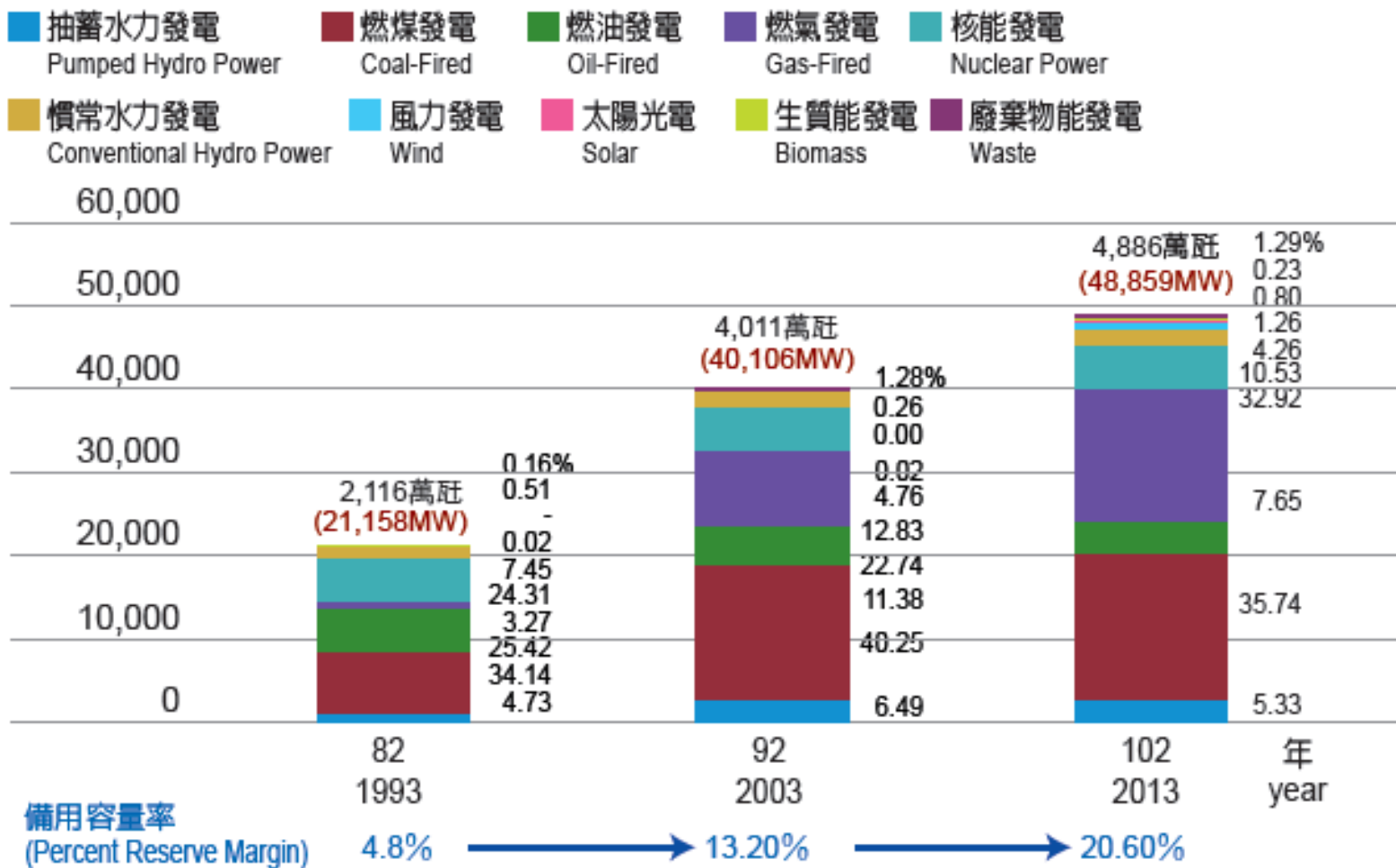
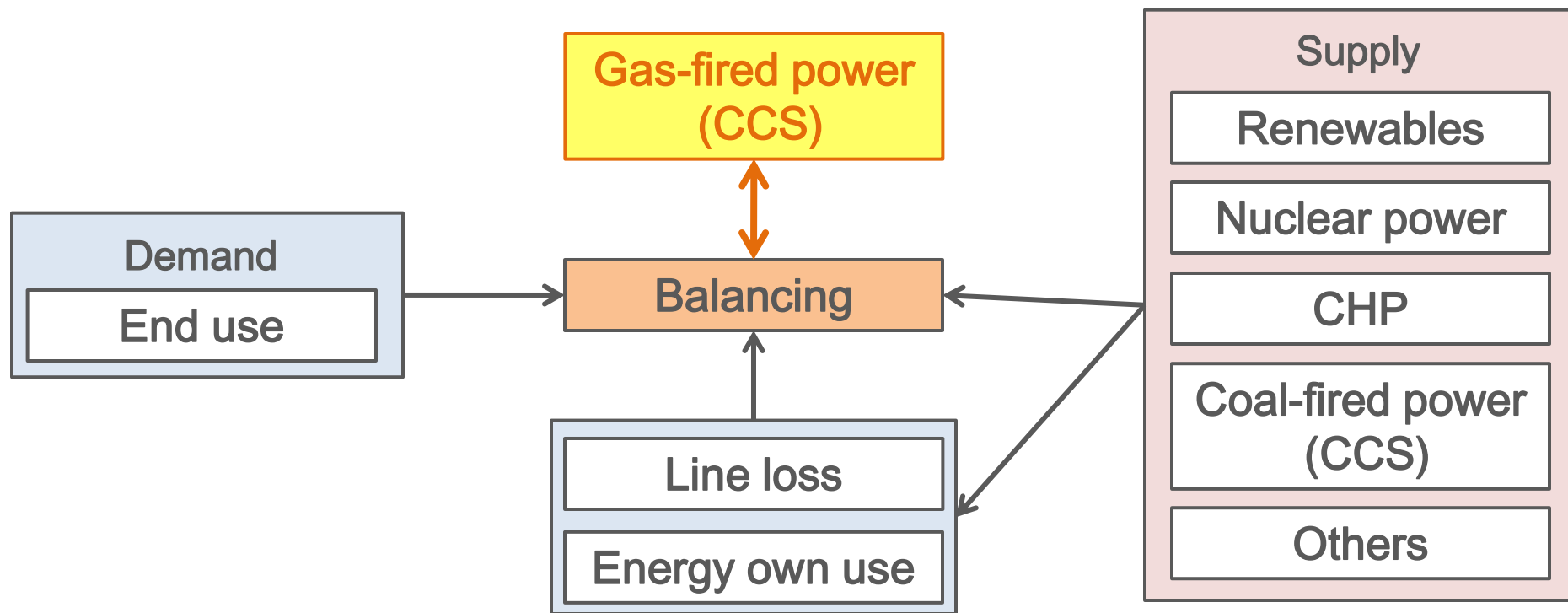


Fig: History Taiwan power supply structure (Source: BOE)

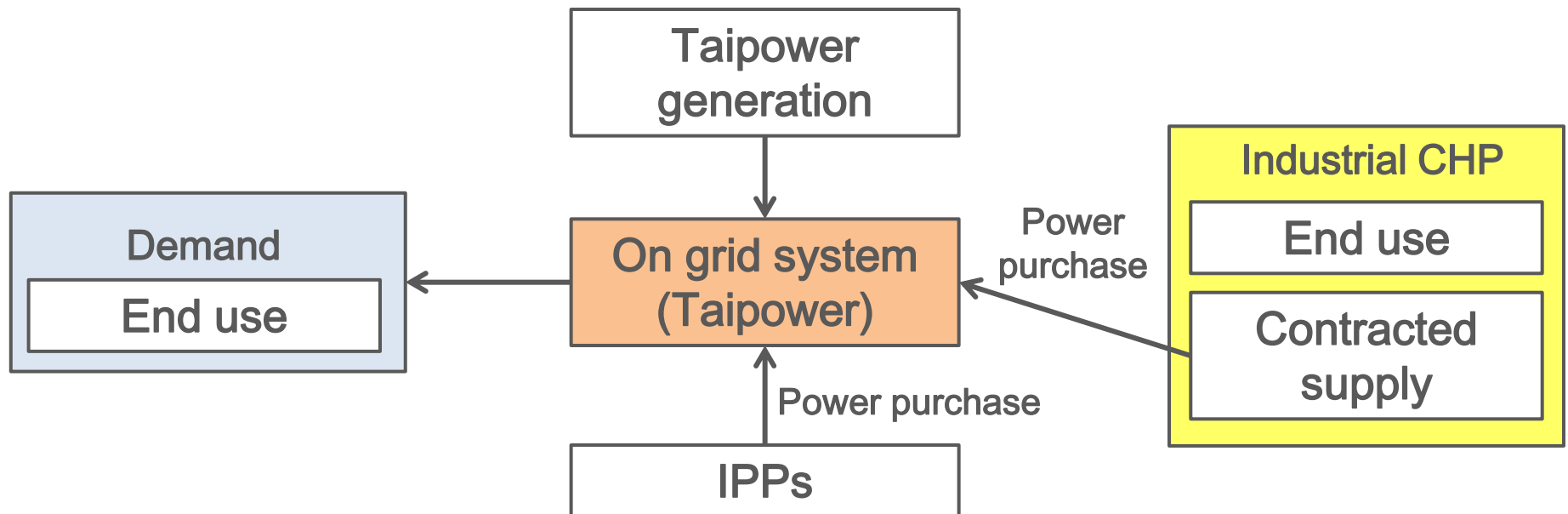
Electricity system balancing

- **Yearly** supply and demand balancing
- **Gas-fired power** plants take the role in balancing the supply and demand (shortage and oversupply still may happen)



Grid system

- State-owned company Taipower operates the grids and most plants
- **CHP** accounts for 16% power supply nationally, but only 22% of its generation was supplied to grid
- All electricity generation is separated into **on-grid** and **off-grid** supply in the model

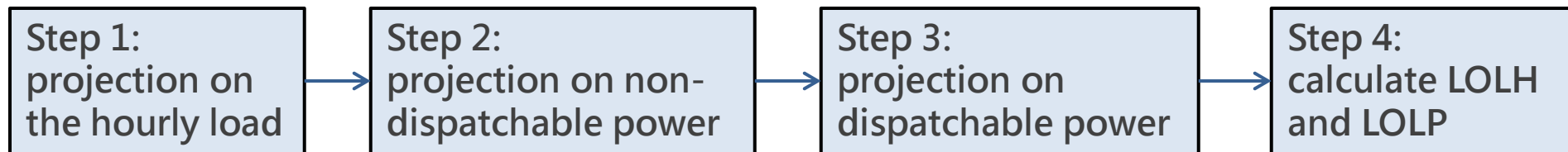


Reserve Margin

- An index to evaluate the electricity security and reliability
- Equation: $(\text{Net Peaking Capability} - \text{peak load}) / \text{peak load}$ (%)
- only calculates the supply and demand **on the grid at peak**
- Current goal is to keep above 15%
- **Peak load projection** is derived from **yearly average load projection** divided by **yearly load factor** (normally 69% - 72%)
- **Net peaking capability** is derived from summing up all plants' peaking supply capacity. Peak capacity factor:
 - Thermal power plant: 94% - 98%
 - Wind power: 5%
 - Solar PV: 27%
 - Industrial CHP: 24%

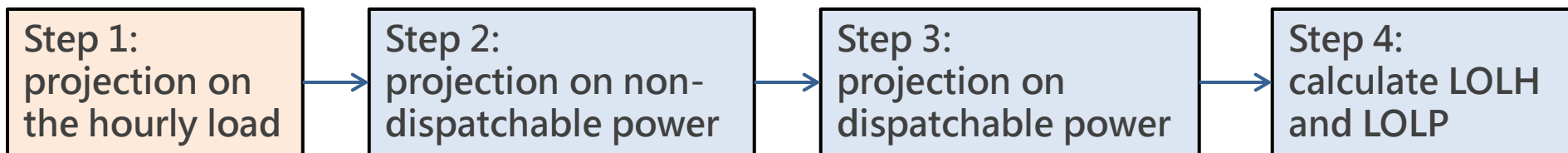
Loss of load

- Use the real load records to project loss of load
- Based on the 2012 data because the weather pattern in the year is representative (hot in July, several typhoons in August)
- The excel based model could not handle 8760 hours simulation, so we take only top 100 peaking hours in simulating (all in summer)
- Does not take into account demand management measures
- Steps:





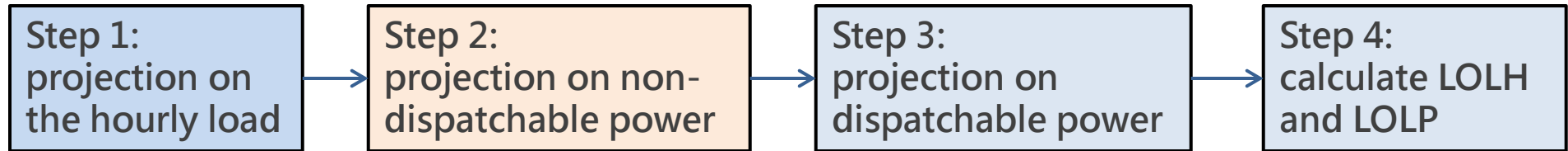
Loss of load



日期	小時	2012	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	
		Avg. load	24.102	26.350	26.853	27.331	27.744	28.122	28.606	29.030	29.420	29.762	30.049	30.288	31.881
		multiplier	1	1.093	1.114	1.134	1.151	1.167	1.187	1.204	1.221	1.235	1.247	1.257	1.323
2012/6/1	1	23060	25212	25692	26150	26545	26907	27370	27775	28149	28476	28751	28979	30503	
2012/6/1	2	22503	24603	25072	25518	25904	26257	26709	27105	27469	27788	28056	28280	29766	
2012/6/1	3	21960	24009	24467	24902	25279	25624	26065	26451	26806	27118	27379	27597	29048	
2012/6/1	4	21668	23690	24141	24571	24943	25283	25718	26099	26450	26757	27015	27230	28661	
2012/6/1	5	21535	23544	23993	24420	24790	25127	25560	25938	26287	26593	26849	27063	28485	
2012/6/1	6	21306	23294	23738	24160	24526	24860	25288	25662	26007	26310	26564	26775	28182	
2012/6/1	7	21924	23969	24426	24861	25237	25581	26021	26407	26761	27072	27334	27551	28999	
2012/6/1	8	23126	25283	25765	26224	26621	26983	27448	27854	28229	28557	28832	29062	30589	
2012/6/1	9	25650	28043	28577	29086	29526	29929	30444	30895	31310	31674	31979	32234	33928	
2012/6/1	10	27012	29532	30095	30631	31095	31518	32061	32535	32973	33356	33678	33946	35730	
2012/6/1	11	27709	30294	30872	31421	31897	32331	32888	33375	33823	34216	34547	34822	36652	
2012/6/1	12	28336	30980	31571	32133	32619	33063	33632	34130	34589	34991	35329	35610	37482	
2012/6/1	13	27067	29592	30156	30693	31158	31582	32126	32602	33040	33424	33746	34015	35803	
2012/6/1	14	28500	31159	31753	32319	32808	33255	33827	34328	34789	35193	35533	35816	37699	
2012/6/1	15	28715	31394	31993	32562	33055	33505	34082	34587	35052	35459	35801	36086	37983	
2012/6/1	16	28623	31293	31890	32458	32949	33398	33972	34475	34939	35345	35686	35970	37861	
2012/6/1	17	28360	31006	31597	32159	32646	33091	33660	34159	34613	35019	35366	35644	37529	
2012/6/1	18	27657	30237	30814	31362	31837	32271	32826	33312	33763	34169	34520	34816	36703	
2012/6/1	19	27837	30434	31014	31567	32044	32481	33040	33529	34000	34421	34788	35099	36988	
2012/6/1	20	28226	30860	31448	32008	32492	32935	33502	33998	34479	34914	35291	35600	37491	
2012/6/1	21	27660	30241	30817	31366	31840	32274	32830	33316	33774	34183	34533	34824	36717	
2012/6/1	22	26699	29190	29747	30277	30735	31153	31690	32159	32599	33000	33351	33643	35538	
2012/6/1	23	25444	27818	28349	28853	29290	29689	30200	30647	31060	31429	31754	32026	33923	
2012/6/1	24	24651	26952	27465	27954	28377	28764	29259	29692	30091	30441	30735	30979	32879	

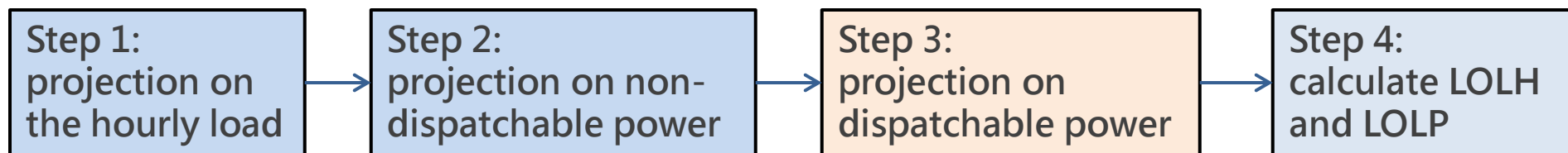
Use the on-grid hourly records in 2012 to project future hourly load

Loss of load



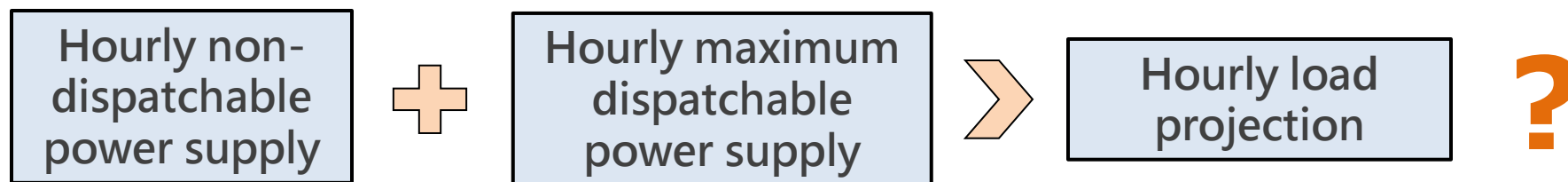
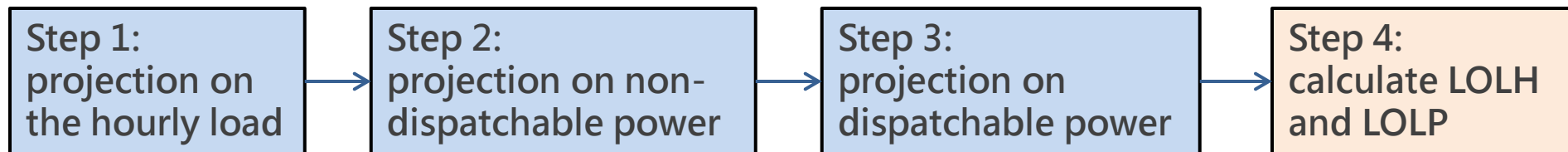
- non-dispatchable power is mainly **volatile renewables**, the capacity varies according to the scenario
- **Solar PV, onshore wind, and hydro-power (includes pumped-hydro)**
 - Assume the hourly output (load factor) is the same as the 2012 records, which have reflected availability
- **Offshore wind, geothermal power and ocean power**
 - No real records
 - Project the hourly output based on the 2012 meteorological records or give a constant for all, then multiply their assumptions on availability

Loss of load



- **Thermal power**
 - Assume capacity factor remain at the their peak (96%-98%), then multiply a assumption on availability (97%)
- **CHP**
 - Assume the hourly output (load factor) is the same as the 2012 records
- **Fuel cell battery and electric vehicles**
 - Assume capacity factor remain at 45% for fuel cell batteries
 - For EV, calculator the number of vehicles, grid connection rate, feedback efficiency, ratio of discharge, discharging time and so on.

Loss of load



- Loss of load hours (LOLH)
- Loss of load probability (LOLP)
- Expected Demand Not Served(EDNS)

Loss of load

- Simulation results

Reference scenario

	2015	2020	2025	2030	2035	2040	2045	2050
LOLH (hours)	28.0	-	37.0	79.0	32.0	8.0	2.0	-
LOLP	1.0%	0.0%	1.3%	2.7%	1.1%	0.3%	0.1%	0.0%
EDNS(GWh)	6.0	-	14.3	59.8	17.9	3.2	0.2	-
Renewable capacity(%)	10.6%	13.5%	19.7%	24.3%	26.6%	28.5%	30.1%	31.8%
Renewable generation(%)	4.0%	5.2%	7.7%	10.8%	13.1%	15.4%	17.7%	20.0%
Reserved margin	10.4%	15.8%	9.0%	7.8%	9.9%	11.8%	13.6%	14.9%
Total capacity(GW)	42.1	47.7	49.7	56.1	60.7	65.3	69.9	74.7

Reference scenario, PV L2 -> L3, wind L2 -> L3

	2015	2020	2025	2030	2035	2040	2045	2050
LOLH (hours)	24.0	-	17.0	41.0	12.0	4.0	1.0	-
LOLP	0.8%	0.0%	0.6%	1.4%	0.4%	0.1%	0.0%	0.0%
EDNS(GWh)	4.8	-	6.6	29.7	7.2	1.7	0.1	-
Renewable capacity(%)	10.9%	15.2%	27.1%	35.2%	41.5%	45.1%	44.8%	45.2%
Renewable generation(%)	4.2%	6.1%	12.0%	18.3%	26.4%	32.8%	33.7%	33.4%
Reserved margin	10.4%	16.1%	10.8%	11.5%	14.8%	17.5%	19.1%	20.5%
Total capacity(GW)	42.2	48.6	54.7	65.5	76.2	85.0	88.4	92.9

Loss of load

- Simulation results

Reference scenario, PV L2 -> L3, wind L2 -> L3, coal L3 -> L2

	2015	2020	2025	2030	2035	2040	2045	2050
LOLH (hours)	24.0	-	17.0	163.0	184.0	229.0	296.0	382.0
LOLP	0.8%	0.0%	0.6%	5.6%	6.3%	7.9%	10.2%	13.2%
EDNS(GWh)	4.8	-	6.6	208.6	315.7	458.3	696.2	1,046.1
Renewable capacity(%)	10.9%	15.2%	27.1%	36.3%	43.8%	48.5%	49.2%	50.6%
Renewable generation(%)	4.2%	6.1%	12.0%	18.3%	26.4%	32.8%	33.8%	34.5%
Reserved margin	10.4%	16.1%	10.8%	7.2%	6.6%	5.5%	3.7%	2.0%
Total capacity(GW)	42.2	48.6	54.7	63.5	72.2	79.0	80.4	82.9

Reference scenario, PV L2 -> L3, wind L2 -> L3, 4th nuclear power plant shut down

	2015	2020	2025	2030	2035	2040	2045	2050
LOLH (hours)	29.0	25.0	260.0	238.0	117.0	60.0	30.0	13.0
LOLP	1.0%	0.9%	9.0%	8.2%	4.0%	2.1%	1.0%	0.4%
EDNS(GWh)	6.9	7.2	296.4	365.3	154.2	61.3	23.0	11.2
Renewable capacity(%)	11.3%	16.1%	28.5%	36.7%	43.0%	46.6%	46.2%	46.5%
Renewable generation(%)	4.2%	6.1%	12.0%	18.3%	26.4%	32.8%	33.8%	34.5%
Reserved margin	10.2%	9.2%	4.2%	5.2%	8.8%	11.7%	13.5%	15.1%
Total capacity(GW)	40.9	45.9	52.0	62.8	73.5	82.3	85.7	90.2