



Electrification of the Chemical Industry

# Electrification technologies: Business cases and time-to-market

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# Electricity demand Outlook

Sector Reference	2016			2030		
	[PJ]	[TWh]	[%]	[PJ]	[TWh]	[%]
<b>Built environment</b>						
NEV17	201	56	49	189	53	47
"AoA/WuR"	206	57		189	53	
"Gasunie"	208	58		200	56	
<b>Industry</b>						
NEV17	123	34	30	119	33	30
"Regeerakkoord"	123	34		164	46	
"Robuust voor de toekomst"	123	34		244	68	44
<b>Mobility</b>						
NEV17	7	2	2	13	4	3
"Sub-group EV"	7	2		35	10	6
<b>Agriculture</b>						
NEV17	33	9	8	34	9	9
<b>Energysector</b>						
NEV17	36	10	9	35	10	9
<b>Water and waste processing</b>						
NEV17	8	2	2	9	3	2
<b>Total</b>						
NEV17	<b>408</b>	<b>113</b>	<b>100</b>	<b>399</b>	<b>112</b>	<b>100</b>
Max	<b>415</b>	<b>115</b>		<b>557</b>	<b>156</b>	

Towards 2030 demand for electricity seems to be stable or show limited growth:

- No increase in Built Environment, including heat pumps
- Small increase in Mobility
- Potential doubling of electricity demand in Industry, depending on electrification scenario

Electricity demand  
112 -156 TWh

# Electricity Production outlook

Jaar: 2030												
Scenario	PBL-notitie "Kosten Energie- en Klimaattransitie in 2030 - Update 2018". Pakket "Transitie, zelfde reductie" <sup>1</sup>			Werkagenda Elektriciteit - 19 april 2018 (Versie 2.0)								
				Scenario 49%			Scenario 55%			Scenario Plus		
Eenheid	GW	TWh	Mton CO2	GW	TWh	Mton CO2	GW	TWh	Mton CO2	GW	TWh	Mton CO2
Wind op zee	12	54	0	12-14	45-59	0	14-16	59-68	0	16-19	68-79	0
Wind op land <sup>2</sup>	6	18	0	6-10	19-29	0	10-13	29-39	0	13-15	39-48	0
Zon-PV	30	30	0	21-23	21-22	0	23-26	22-26	0	29-34	30-35	0
Biomassa	0	0	0	0-3	0-19	0	0-3	0-19	0	4	28	0
Nucleair	0,5	4	0	0,5	4	0	0,5	4	0	0,5	4	0
WKK	2	5	0*	2	5	0*	2	5	0*	2	5	0*
Hoogoven-en cokesovengas	1	4	9	1	4	9	1	4	9	1	4	9
Gas	?	10	3	?	?	?	?	?	?	?	?	?
Import	?	37**	0	?	37**	0	?	37**	0	?	37**	0
Export	?	-37**	0	?	-37**	0	?	-37**	0	?	-37**	0
<b>Totaal</b>	<b>51,5***</b>	<b>125</b>	<b>12</b>	<b>43-54***</b>	<b>98-142***</b>	<b>?</b>	<b>53-62***</b>	<b>123-165***</b>	<b>?</b>	<b>66-76***</b>	<b>179-203***</b>	<b>?</b>
<b>Totaal - niet weersafhankelijk</b>	<b>3,5***</b>	<b>24</b>	<b>12</b>	<b>3,5-6,5***</b>	<b>14-33***</b>	<b>?</b>	<b>3,5-6,5***</b>	<b>14-33***</b>	<b>?</b>	<b>7,5***</b>	<b>42***</b>	<b>?</b>

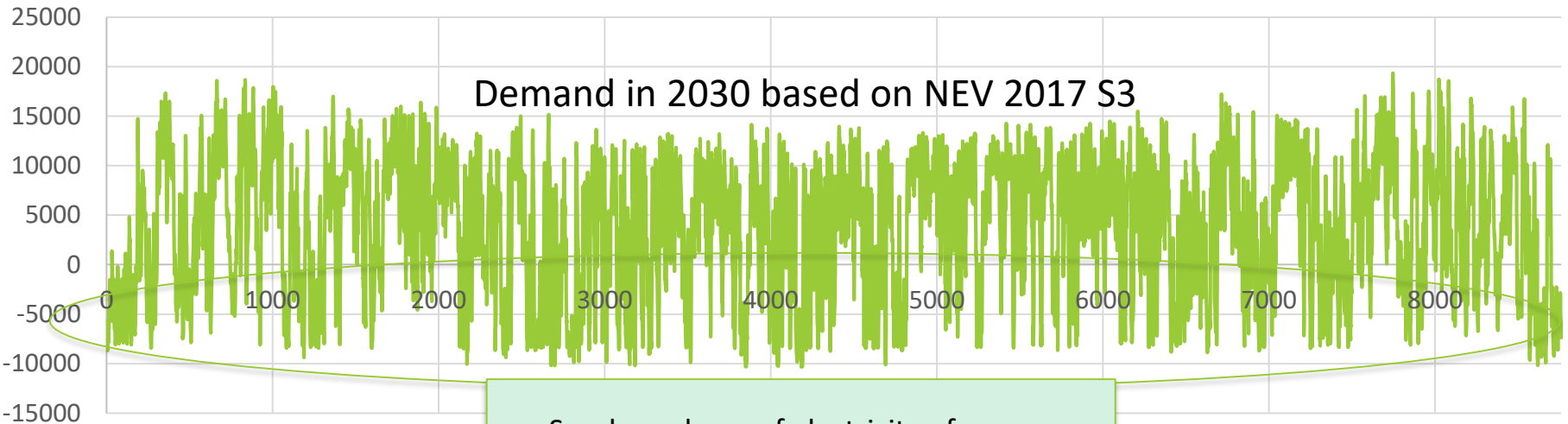
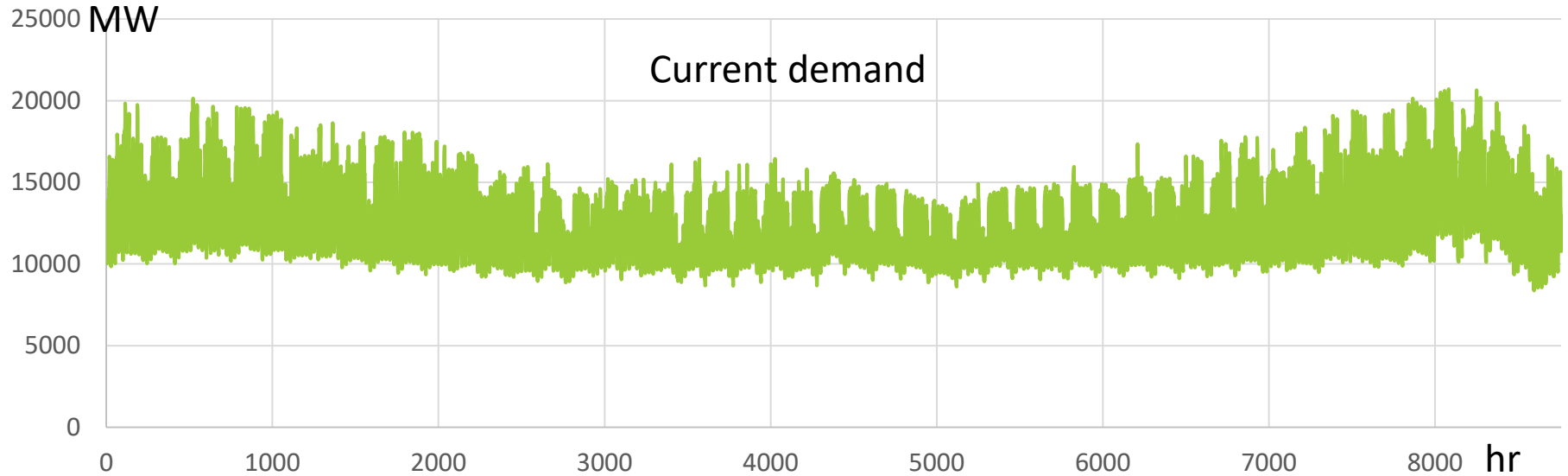
\* CO2 emissies gerekend bij de industrie \*\* Op basis van NEV 2017 \*\*\* Exclusief gas, import/export, en eventuele curtailment  
<sup>1</sup> Cijfers zijn deels op basis van basispad NEV2017 voorgenomen beleid; de illustratieve pakketten zijn niet doorgerekend in het NEV-instrumentarium  
<sup>2</sup> Extra wind op land is in het pakket voor de helft meegenomen

Electricity Production 125 -204 TWh  
(Approx: 100 – 160 TWh from renewables)

- › TWh produced from sustainable energy sources could be sufficient, but...
- › Weather dependency will increase & 'adjustable power capacity' will decrease

# Demand Curve Evolution/revolution

## increase renewables



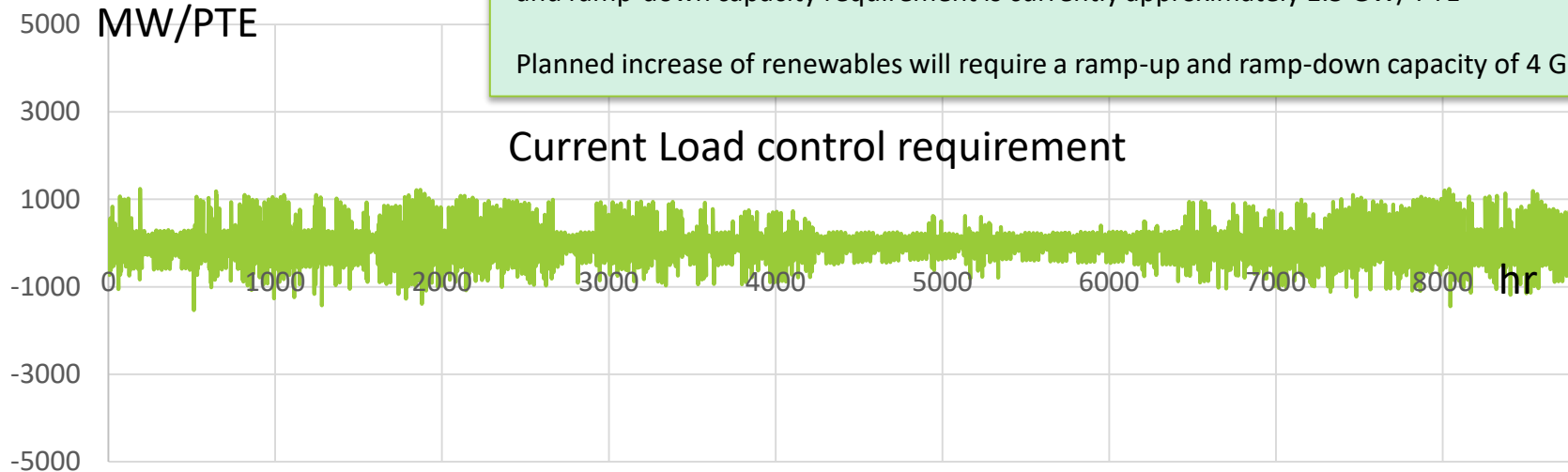
Surplus volume of electricity of approx  
15 TWh (54 PJ)

# Load control requirement

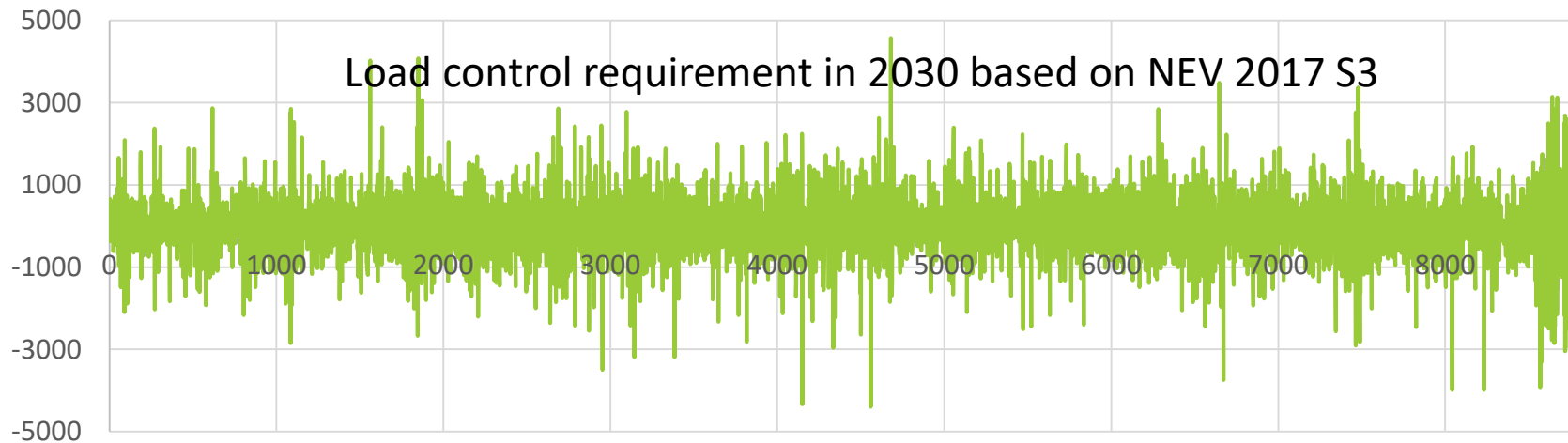
Currently there is a need for ramp-up and (slightly less) ramp-down capacity. Maximum ramp-up and ramp-down capacity requirement is currently approximately 1.5 GW/ PTE

Planned increase of renewables will require a ramp-up and ramp-down capacity of 4 GW/ PTE

Current Load control requirement



Load control requirement in 2030 based on NEV 2017 S3



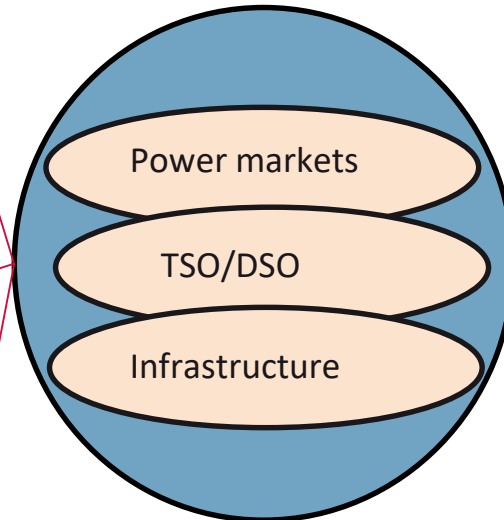
# Future power system flexibility

## Flexibility Needs

Demand variability  
& uncertainty

Significant increase of  
fluctuating renewables  
Decrease of adjustable power

Power plant delivery obligations  
& grid requirements



## Flexibility Sources

Dispatchable Power Plants (zero  
emission)

### Conversion:

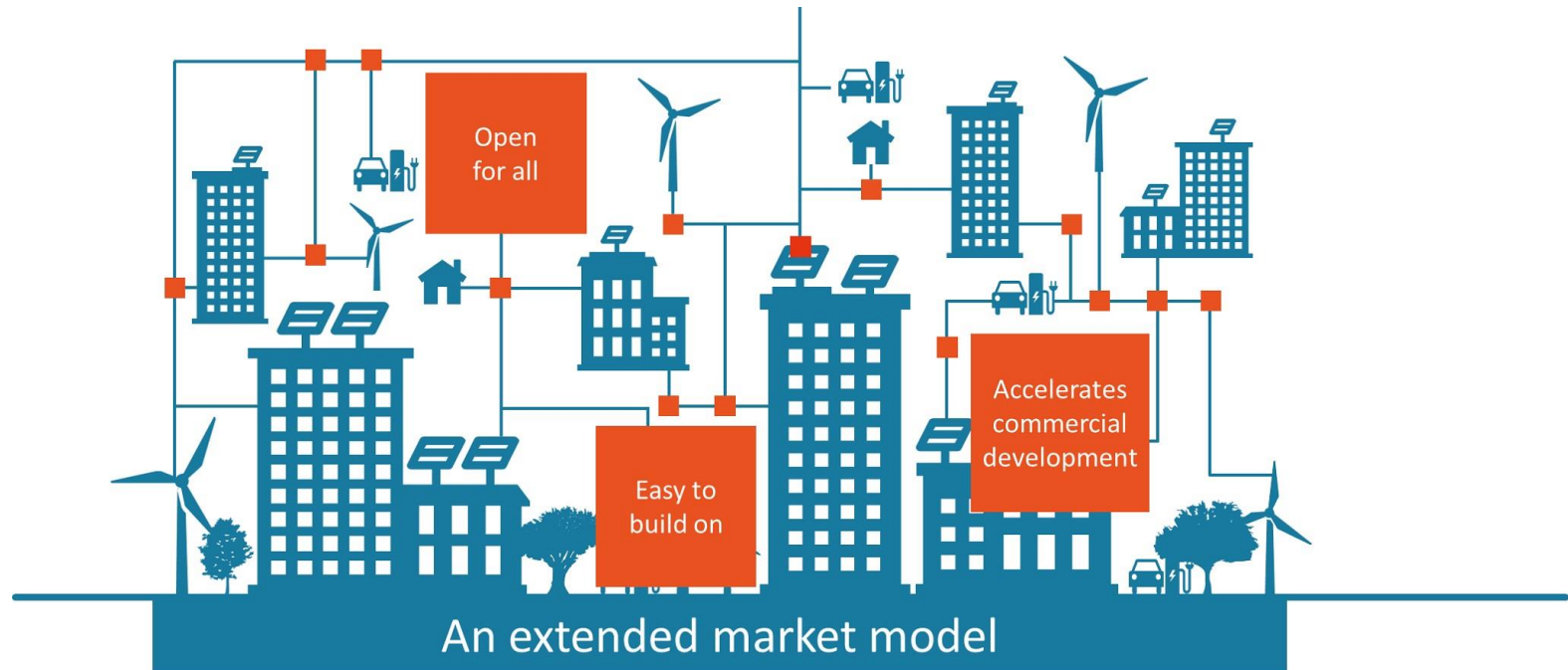
- ✓ Power to Heat/Cold
- ✓ Power to Gas  
(hydrogen/methane)
- ✓ Power to Chemicals / Fuels

Storage: power and heat

Interconnection

# Surplus of renewable energy opportunity for the industry.

In 2030 there is a surplus volume of approx 15 TWh that might be used for different applications. Demand side response (prosumer) and storage (power and heat).



Source : Usef (flexibility frame work)

# Facts and figures

System capacity E-grid (20 GW)<sup>1</sup>

System capacity NG- grid (350 GW)<sup>1</sup>

Renewable capacity in 2030 (50 - 60 GW)

Energy infrastructure (spatial model analyses / cost optimisation)

Primary energy use in 2018: 3147 PJ



Electricity production 378 PJ (11% renewable)<sup>2</sup>

2030

Significant share of renewable electricity production 300 PJ

Fossil based production (Natural gas 6 GW) 100 PJ

Storage of renewable energy 60 PJ

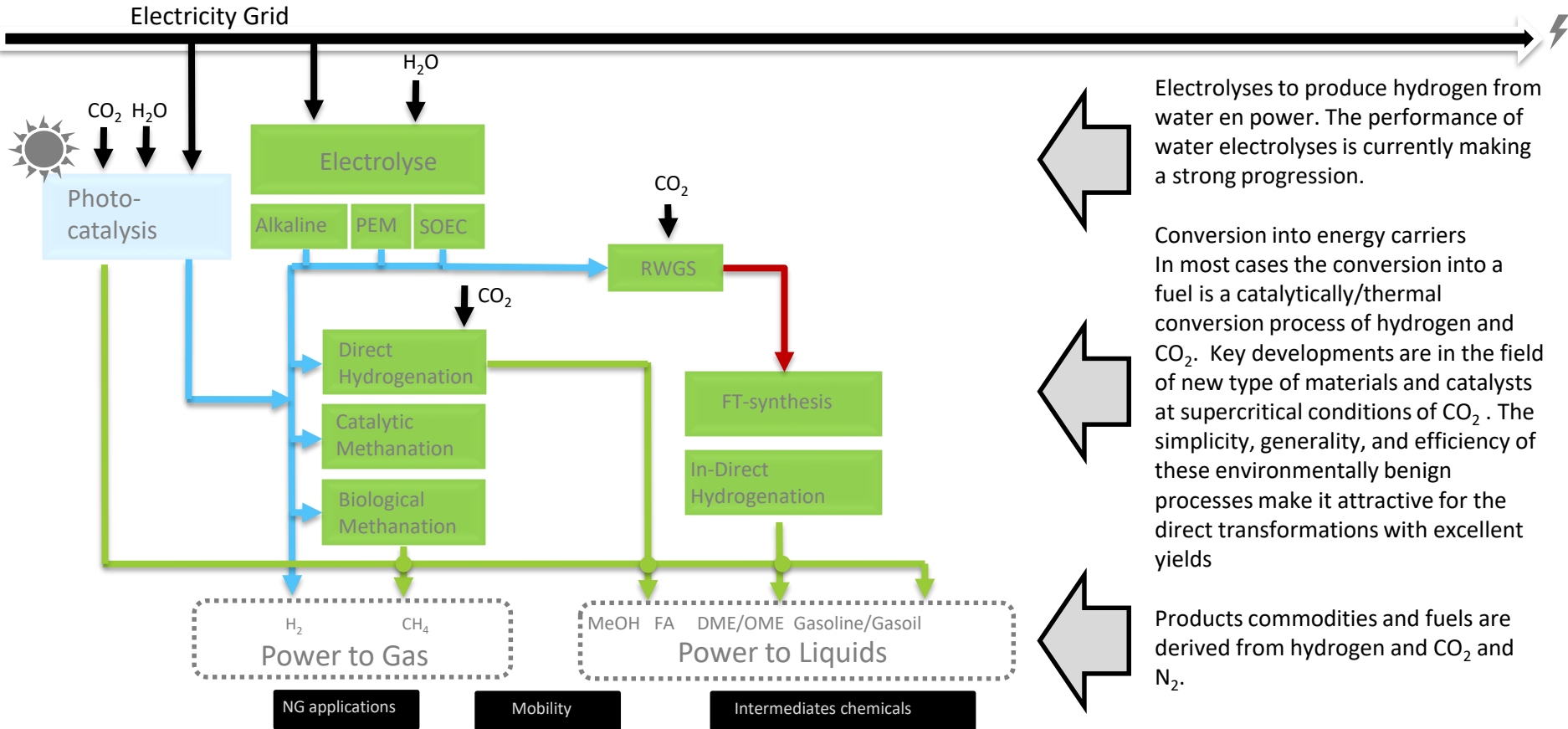
System balancing and storage of electricity is required to maximise optimal use of renewables.

Smart use of the (surplus) volume of renewable electricity is required and use of existing energy infrastructure

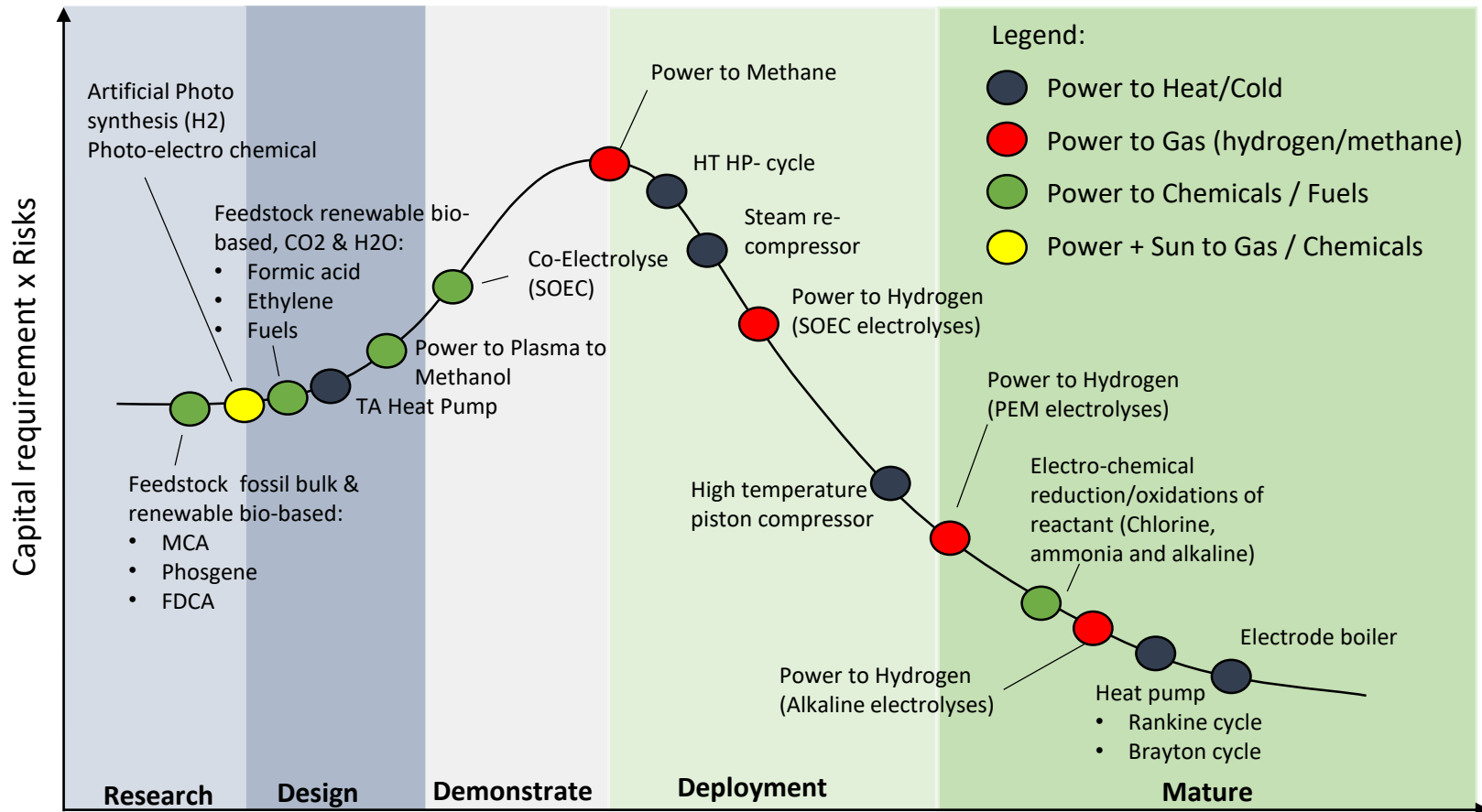
1: Gasunie / Tennet

2: EBN infographic 2018

# Technology pathways for hydrogen

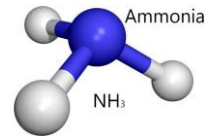
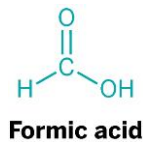
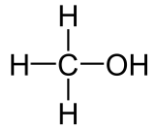


# Technology Maturity curve

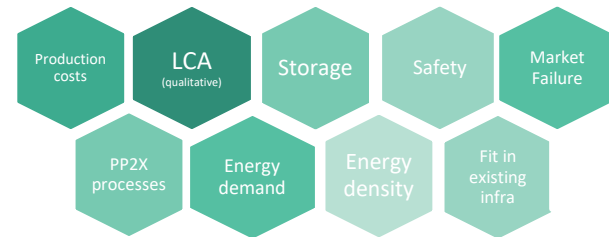


# Inventory of relevant pathways

- › Make shortlist of most relevant molecule



- › Assess energy carriers by concept framework



- › Mapping on relevant markets and applications

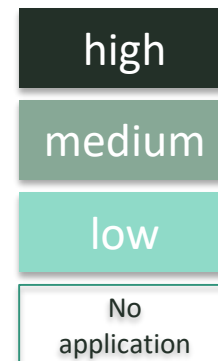


# Shortlist of relevant energy carriers

	Indirect, Power-2-X	Direct, Power-2-X
Liquid hydrogen		
Pressurized hydrogen		
Ammonia		
Methanol		
Methane		
Hydrogen peroxide		
OME		
DME		
Formic Acid		

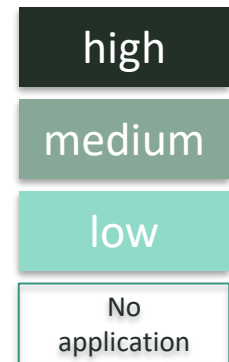
# Current functions of H2 markets

	Feedstock	HT heat	LT heat	Transmission	Electricity
Chemical industry	high				
Refineries	high	low			
Steel	medium	low			
Mobility				low	
Electricity					low
Built environment			low		low
Paper					
Food	low				



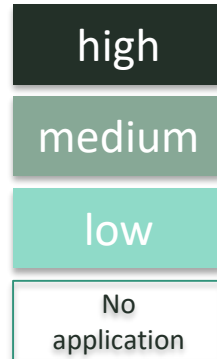
# Future Power-2-Gas markets

	Feedstock	HT heat	LT heat	Transmission	Electricity
Chemical industry	high	medium	low	No application	low
Refineries	high	No application	low	No application	low
Steel	medium	No application	low	No application	low
Mobility	No application	No application	No application	high	No application
Electricity	No application	No application	No application	No application	high
Built environment	No application	No application	high	No application	low
Paper	No application	No application	high	No application	No application
Food	high	No application	high	No application	No application



# Mapping of molecules on functions

	Feedstock	HT heat	LT heat	Transmission	Electricity
Liquid hydrogen	high	high	high	high	high
Pressurized hydrogen	high	high	high	high	high
Ammonia	high	low	low	medium	high
Methanol	high	low	low	low	low
Methane	high	high	high	high	high
Hydrogen peroxide	high	low	low	low	low
OME	high	low	low	high	low
DME	high	low	low	high	low
Formic Acid	high	low	low	medium	low



# Shorter term technology options

## Short term (2017- 2030)

### Power 2 Heat

- Heat pumps (low temperature applications)
- Mechanical Vapor Recompression (dryers)
- Electro boilers

The market for heat pumps are challenging and are mostly heat driven. A hybrid approach might be considered although there might be a limited direct impact on the core production process.

The business case for MVR salt drying purposes is very promising and MVR's are commercial available.

The market for electro boilers are challenging and are mostly heat driven. Therefore a hybrid approach might be required to minimize the impact on the core production process. Electro boilers are commercial available.

### Power 2 Gas

- Alkaline/ PEM electrolyzers (H<sub>2</sub> - refineries)
- Alkaline/ PEM electrolyzers (H<sub>2</sub> - transportation)

Hydrogen applied at refineries might qualify as a renewable energy source, according to the RED2, and short terms already financial attractive.

The application of Hydrogen for local transportation purpose is very interesting on the longer term. Although the business case is weak, there might be special local conditions such as grid support which can contribute to the business case.

### Power 2 Liquids

- Co- electrolyzers
- Hydrogen catalytically/thermal conversions (for transportation fuels)

The business case for indirect production of synthetic fuels requires a strong incentive to become economic attractive. Currently several Power to Methanol demonstration projects are ongoing and there is strong lobby for green- or bio-Methanol.

CO-electrolyses technology is currently in pre-commercial scale available, the industrial scale is rather small and requires demonstration pilot plants.

# Thanks

