



**Nordic Folkecenter**  
for Renewable Energy



# The New role of the Farm: from Agriculture to Energy

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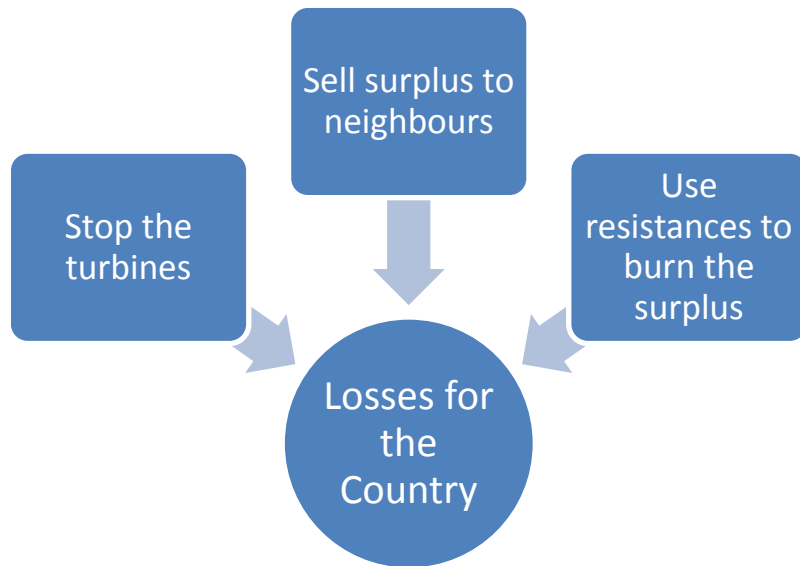
**How can we increase our energy production  
and at the same time reduce our CO2  
emissions?**



## Background of the Study

The problem of surplus:

**139%**  
26 July 2015



Source: Energinet.dk





## Background of the Study



### Danske vindmøllejere får tyske penge for at stoppe produktionen

En overbelastning af el-nettet har fået tyskerne til lommerne.

«Danish Wind turbine owners get german money for stopping the production»

*Finans.dk*

200 Million Euro to  
stop 37 GWh  
November 2015

Electrical resistance  
burning 15 kW every  
hour



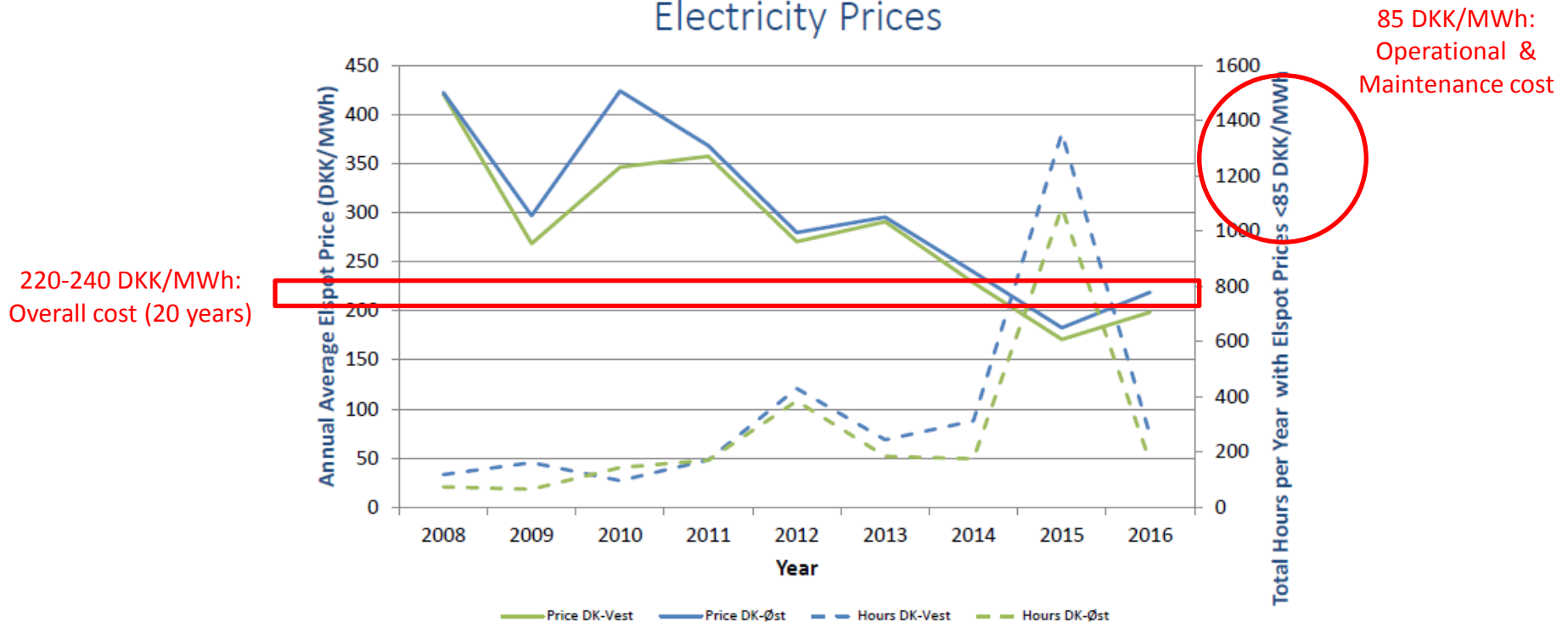
*climatetechwiki.org*





## Background of the Study

### Evolution of the Danish Spot Market Electricity Prices



Source: The Danish Wind Turbine Owners' Association:



## Background of the Study

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1 571 000  
cattles

13 173 000  
pigs

429 487 000  
Tonnes/year

- 196+ Biogas plants installed;
- 95,8 MW installed (2015);
- 1.14 TWh/year produced (2010);





## A Real Case Scenario

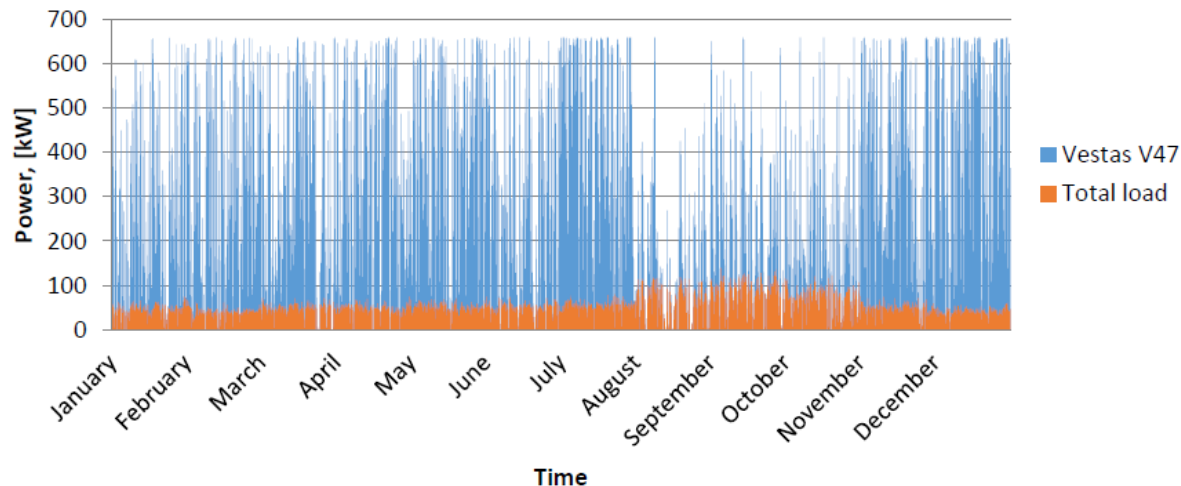
### Wind turbine: Vestas V47, 660 kW

- Average production: 1.8-2.0 GWh/year;
- Installation: 2000;
- Expected lifetime: Extra 14-15 years;

### Biogas installation:

- 6000 m<sup>3</sup>/day (2 digesters x 3000 m<sup>3</sup>);
- 65% CH<sub>4</sub> content;
- Approx. 4 GWh/year production;
- Input: 70 tons/day of waste;

### **Vestas V47 power output and load variation**





## A Real Case Scenario



Vestas 660 kW, max output: 2.2 GWh/year  
@ 0.256 DKK/kWh = 563,200 DKK/year  
@ 0.180 DKK/kWh = 396,000 DKK/year

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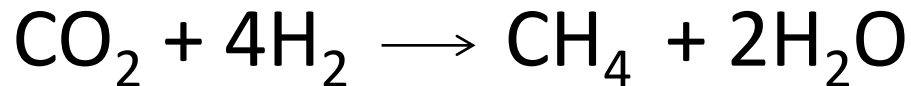
Biogas installation, max output: 2,190,000 m<sup>3</sup>/year  
Current production (2015): 3.58 GWh/year  
@ 1,23 DKK/kWh = 4,403,400 DKK/year





## A Real Case Scenario

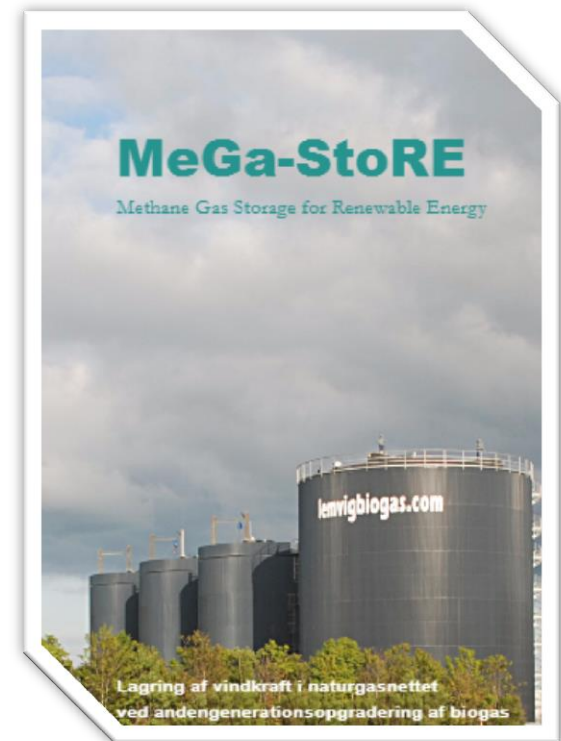
Sabatier Reaction:



Increase  $\text{CH}_4$  up to 50% = 2x  $\text{CH}_4$  quantity

More technical information:

- <http://methan.dk>
- <http://www.lemvigbiogas.com/MeGa-stoREfinalreport.pdf>





## A Real Case Scenario

The technology is there, but...

- Theoretical minimum electricity consumption: 2,94 kWh/Nm<sup>3</sup>;
- Standard electricity consumption: 4,5-6,0 kWh/Nm<sup>3</sup>;



**USE SURPLUS ELECTRICITY!**



## A Real Case Scenario

Methane content [%]	MAN+Deutz Consumption [m <sup>3</sup> ]	Excess [m <sup>3</sup> /year]	Total AEP [kWh]	Cash inflow [DKK/year]	P <sub>out</sub> new engine [kW]
65.0	2,452,707.85	0.00	4,642,980.93	5,710,866.55	0.00
67.5	2,361,866.82	0.00	4,811,443.55	5,918,075.56	0.00
70.0	2,277,514.44	0.00	4,979,906.16	6,125,284.58	0.00
72.5	2,198,979.45	0.00	5,148,368.78	6,332,493.60	0.00
75.0	2,125,680.14	64319.86	5,331,204.89	6,557,382.02	18.59
77.5	2,057,109.81	132890.19	5,515,980.75	6,784,656.32	39.68
80.0	1,992,825.13	197174.87	5,700,756.60	7,011,930.62	60.77
82.5	1,932,436.49	257563.51	5,885,532.46	7,239,204.92	81.86
85.0	1,875,600.12	314399.88	6,070,308.31	7,466,479.22	102.96
87.5	1,822,011.55	367988.45	6,255,084.16	7,693,753.52	124.05
90.0	1,771,400.12	418599.88	6,439,860.02	7,921,027.82	145.14
92.5	1,723,524.44	466475.56	6,624,635.87	8,148,302.12	166.24
95.0	1,678,168.53	511831.47	6,809,411.73	8,375,576.42	187.33
97.5	1,635,138.57	554861.43	6,994,187.58	8,602,850.72	208.42
99.0	1,610,363.74	579636.26	7,105,053.09	8,739,215.30	221.08





## A Real Case Scenario

Before upgrading



$$WT1_{revenue} = 1,533,671.12 \frac{kWh}{year} \cdot (0.023 + 0.157) \frac{DKK}{kWh} \rightarrow 276,061 \frac{DKK}{year}$$

$$Biogas_{revenue} = 4,637,966.69 \frac{kWh}{year} \cdot 1.23 \frac{DKK}{kWh} \rightarrow 5,704,699 \frac{DKK}{year}$$

**5,980,760 DKK/year**

$$WT1_{revenue} = (8,760 - 2,863)h \cdot 175 kW \cdot 0.18 \frac{DKK}{kWh} \cdot 68\% \rightarrow 126,300 \frac{DKK}{year}$$

$$Biogas_{revenue} = 6,809,411.73 \frac{kWh}{year} \cdot 1.23 \frac{DKK}{kWh} \rightarrow 8,375,576 \frac{DKK}{year}$$

**8,501,876 DKK/year**

**+42.15%**



After upgrading



## The Transport Scenario: Fleet

- 3 x Volvo trucks. Consumption: 1.8 km/L. Km: 50,000/year

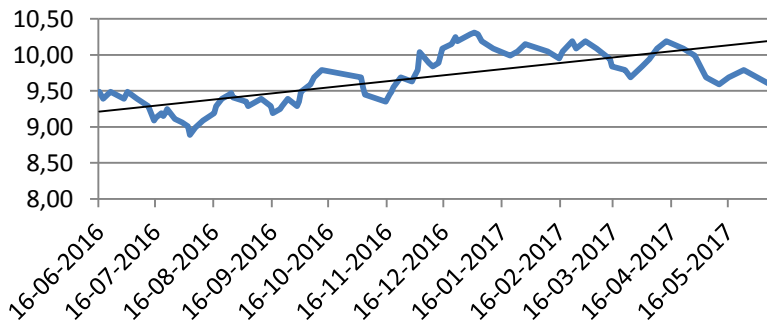
**803,333 DKK/Year**

- 14 x tractors + additional farming machines

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copyright

### Diesel Price to the Consumer

Source: eof.dk



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## The Transportation Scenario: Fleet

- No need for quick filling station, meaning considerable reduction in costs;
- Being a fleet, it is possible to charge the vehicles in the night;
- Daily average mileage per vehicle: 137 km;
- Current consumption: 77 L/day/vehicle;
- Total current consumption: 231 L/day;
- Needed gas/day: 231 m<sup>3</sup>;



2 x 143 m<sup>3</sup>/day time-fill stations  
Ca. 100,000 \$

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Source: [nyserda.ny.gov](http://nyserda.ny.gov)





## Comparison

### Not Upgrading

#### Wind:

2,100,000 kWh/year @  
(0.023+0.157)Dkk

378,000 dkk/year

#### Biogas

4,642,980 (65%) @ 1.23 DKK

5,710,865 dkk/year

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**Total:** 6,088,865 DKK/year  
917,494 \$/year

### Upgrading to 99% CH<sub>4</sub>

#### Wind:

114,918 dkk/year

#### Biogas

7,045,735(99%) @ 1.23 DKK

8,666,254 dkk/year

#### Investment

2.730.250 dkk

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**Total:** 6,050,922 Dkk (Year 0)  
8,781,172 Dkk/year  
1.32 M\$/year

### Upgrading to 99% CH<sub>4</sub> + transport

#### Wind:

114,918 dkk/year

#### Biogas

6,767,307(99%) @ 1.23 DKK

8,323,787 dkk/year

#### Savings from fuel

803,330 dkk/year

#### Investment

3,098,803 dkk

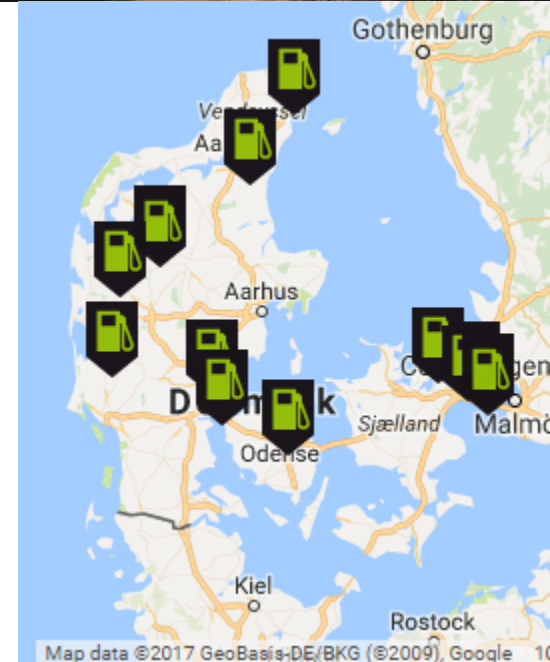
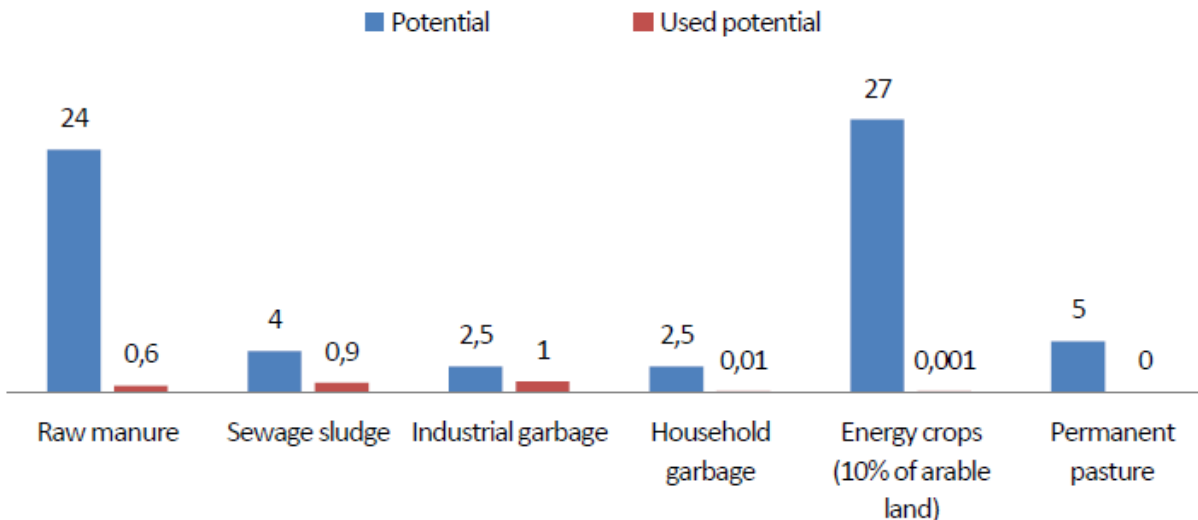
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**Total:** 6,143,232 Dkk (Year 0)  
9,242,035 Dkk/year  
1.39 M\$/year



## Impact on Denmark

### Potential energy production through biogas (in PJ/year)



Source: [gasbiler.info](http://gasbiler.info)

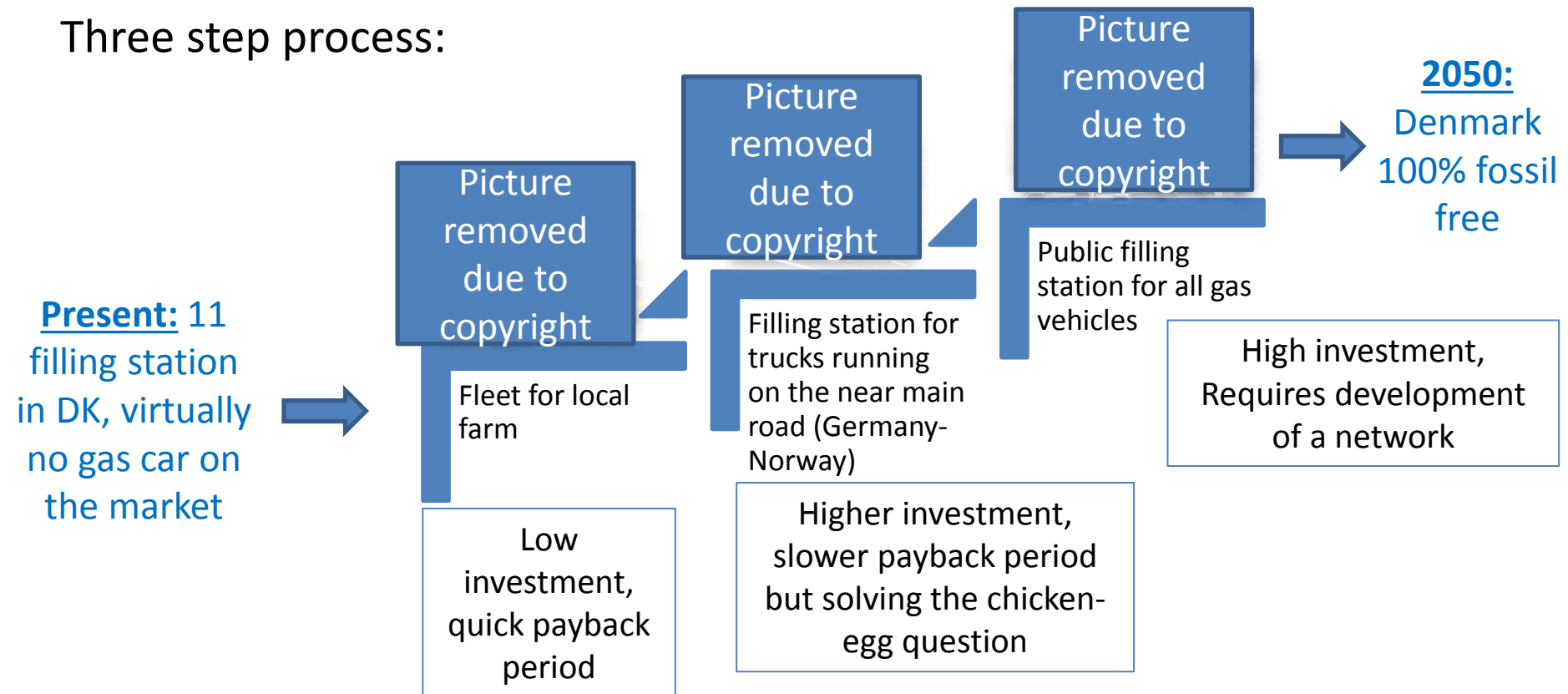
**18.05 TWh/year potential  
with current technology**

Source: "Biogas in Denmark – a potential energy source with benefits for the environment", p.6,



## Recommendations

Three step process:







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# Thank you!



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[www.folkecenter.net](http://www.folkecenter.net)



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