

38 Energy Models A First Review

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Denmark



Background

- Wanted to investigate:

*How Can Ireland Integrate the Most Renewable Energy
Into It's Energy System*

- To do this I wanted to create a model of the Irish Energy-System
- Found it difficult to identify what options were available
- Very briefly explored the options available



Background

- After arriving in AAU, I began working with Henrik Lund and Brian Vad Mathiesen
- Extensive history of energy planning in the department
- A lot of experience with other models
- Decided to collaborate to create a review paper:
A review of computer models used for analysing the integration of renewable energy into energy-systems



The Review Paper

- Goal

A review of computer models used for analysing the integration of renewable energy into energy-systems

- Methodology

- Send a survey to model developers (15th Jan – 18th Mar)
- Prepare a short overview of each model
- Compare models

- Result

- “*A Signpost Paper*” for renewable-energy analysis



Today

- Results obtained last week
- These are some of the initial statistics that have been taken from the survey answers
 1. General Information
 2. Typical Application
 3. Technologies Considered
 4. Renewable Energy



Part 1

General Information

Models
Contacts
Number of Downloads/Sales
Costs
Versions To Date
Training



Part 1

General Information

Models
Contacts
Number of Downloads/Sales
Costs
Versions To Date
Training



Energy Models

Number	Energy Model	Contact	Number	Energy Model	Contact
1	Aeolius	Dominik Möst	21	MARKAL/TIMES	Gary Goldstein
2	Balmorel	Hans Ravn	22	Mesap PlaNet	Fiona Baumhögger
3	BCHP Screening Tool	Mike MacDonald	23	MESSAGE	Volker Krey
4	COMPOSE	Morten Boje Blarke	24	National Energy Modelling System	Paul Kondis
5	E3database	Werner Weindorf	25	ORCED	Stanton Hadley
6	E4cast model	Dr Arif Syed	26	ObjECTS-MiniCAM	Son H. Kim
7	EMCAS	Guenter Conzelmann	27	PERSEUS	Dominik Möst
8	EMINENT	Raquel Segurado	28	PRIMES	P. Capros
9	EMPS	Nils Flataboe	29	ProdRisk	Birger Mo
10	EnergyPLAN	Henrik Lund	30	RAMSES	Sigurd Lauge Pedersen
11	energyPRO	Anders N. Andersen	31	RETScreen	Kevin Bourque
12	ENPEP-BALANCE	Guenter Conzelmann	32	SimREN	H.Lehmann
13	GTMax	Guenter Conzelmann	33	SIVAEL	Jens Pedersen
14	H2RES	NEVEN DUIC	34	STREAM	Alexandros Filippidis
15	HOMER	Tom Lambert	35	TRNSYS	Matt Duffy
16	HYDROGEMS	Øystein Ulleberg	36	UniSyD	Dr Jonathan Leaver
17	IKARUS	Dag Martinsen	37	WASP	Ahmed Irej Jalal
18	INFORSE	Gunnar Boye Olesen	38	Wilmar Planning tool	Peter Meibom
19	Invert	Michael Stadler			
20	LEAP	Charles Heaps			

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20	LEAP	Charles Heaps			

Number of Downloads/Sales

Not Available	0	1-20	20-100	100-1000	1000+	Amount
Balmorel	EMINENT	Aeolius	EMCAS	EnergyPLAN	BCHP Screening Tool	2,000
E4cast model	PRIMES	COMPOSE	EMPS	energyPRO	HOMER	28,000
H2RES		E3database	ENPEP-BALANCE	Invert	LEAP	5,000
HYDROGEMS		IKARUS	GTMMax	MARKAL/TIMES	RETScreen	187,320
ORCED		INFORSE		MESSAGE		
SimREN		Mesap PlaNet		ObjECTS-MiniCAM		
STREAM		National Energy Modeling System		TRNSYS		
UniSyD		PERSEUS		WASP		
Wilmar Planning tool		ProdRisk				
		RAMSES				
		SIVAEL				

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UniSyD		PERSEUS		WASP		
Wilmar Planning tool		ProdRisk				
		RAMSES				
		SIVAEL				

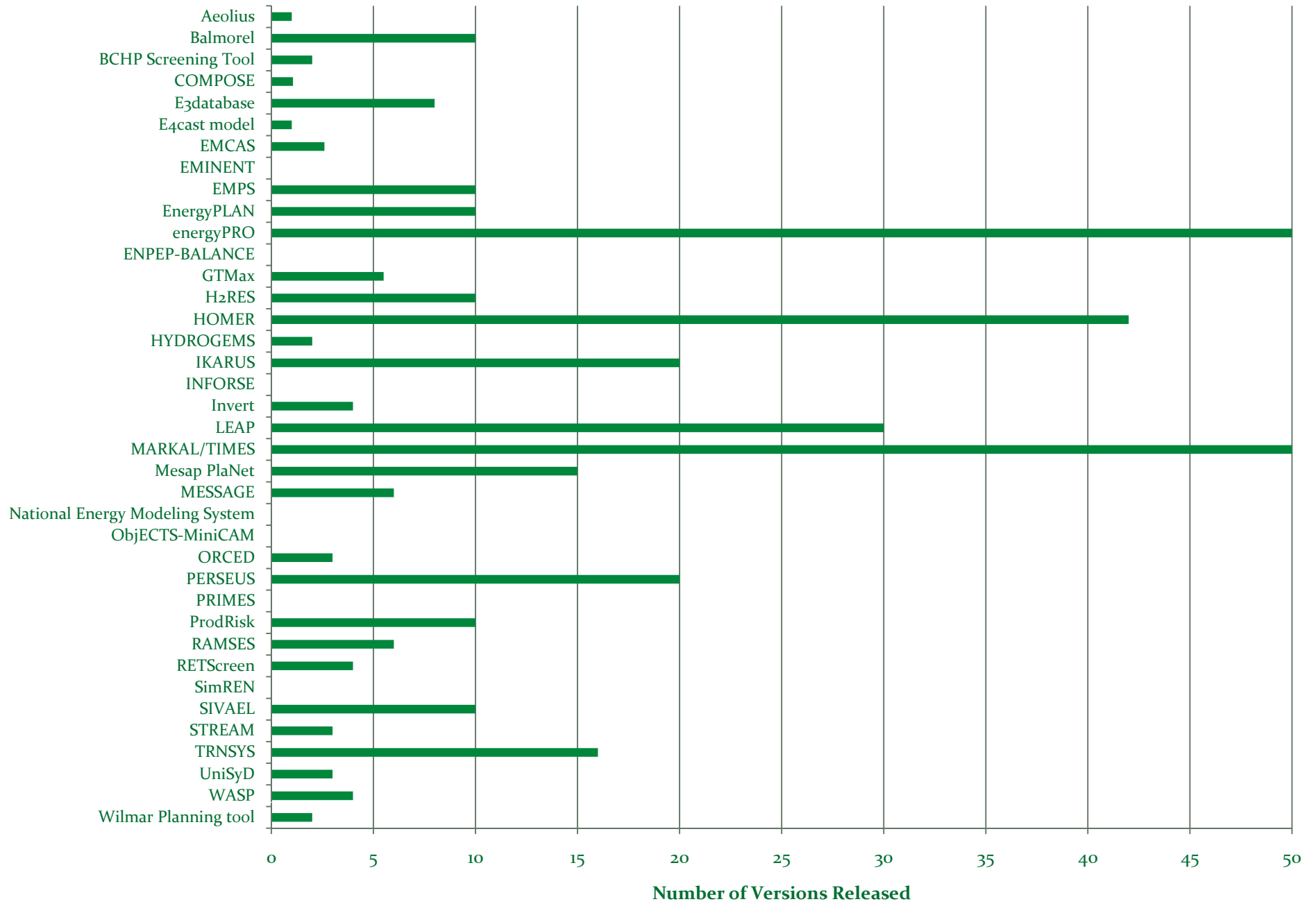
Cost

Not Available	Not For Sale	Free	Free With Conditions	Cost	Amount (US\$)
Aeolius	EMINENT	Balmorel	LEAP	E3database	\$20,000
EMCAS	INFORSE	BCHP Screening Tool	MESSAGE	E4cast model	\$1,500 per day
GTMx	RAMSES	COMPOSE	SIVAEL	EMPS	\$78,000
H2RES		EnergyPLAN	WASP	energyPRO	\$2,700 to \$5,600
PERSEUS		ENPEP-BALANCE		HYDROGEMS	\$5,500
PRIMES		HOMER		IKARUS	\$250
ProdRisk		Invert		MARKAL/TIMES	\$5,000 to \$20,000
UniSyD		National Energy Modeling System		Mesap PlaNet	\$11,500
Wilmar Planning tool		ObjECTS-MiniCAM		SimREN	Depends on projects
		ORCED		TRNSYS	\$4200 Comm. \$2100 Edu.
		RETScreen			
		STREAM			

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		STREAM			

Versions Released



Part 2

Typical Application

Feasible Regions
Typical Regions
Time Step
Longest Time-Duration



Part 2

Typical Application

Feasible Regions
Typical Regions
Time Step
Longest Time-Duration



Feasible Regions Vs. Typical Regions

- ***Feasible Regions:*** The regions that the model is CAPABLE of modelling
 - This is not discussed here due to the level of detail that is required.
- ***Typical Regions:*** The regions that the model is most COMMONLY used for



Typical Regions Considered

Number	Energy Model	Typical Region	Number	Energy Model	Typical Region
1	Aeolius	National/State/Regional	21	MARKAL/TIMES	National/State/Regional
2	Balmorel	International	22	Mesap PlaNet	National/State/Regional
3	BCHP Screening Tool	Single-Project Investigation	23	MESSAGE	Global
4	COMPOSE	Single-Project Investigation	24	National Energy Modelling System	National/State/Regional
5	E3database	Not Applicable	25	ORCED	National/State/Regional
6	E4cast model	National/State/Regional	26	ObjECTS-MiniCAM	Global and Regional
7	EMCAS	National/State/Regional	27	PERSEUS	International
8	EMINENT	National/State/Regional	28	PRIMES	National/State/Regional
9	EMPS	International	29	ProdRisk	National/State/Regional
10	EnergyPLAN	National/State/Regional	30	RAMSES	International
11	energyPRO	Single-Project Investigation	31	RETScreen	User Defined
12	ENPEP-BALANCE	National/State/Regional	32	SimREN	National/State/Regional
13	GTMax	National/State/Regional	33	SIVAEI	National/State/Regional
14	H2RES	Island	34	STREAM	National/State/Regional
15	HOMER	Local/Community	35	TRNSYS	Global
16	HYDROGEMS	Single-Project Investigation	36	UniSyD	National/State/Regional
17	IKARUS	National/State/Regional	37	WASP	National/State/Regional
18	INFORSE	National/State/Regional	38	Wilmar Planning tool	International
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17	IKARUS	National/State/Regional	37	WASP	National/State/Regional
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19	Invert	National/State/Regional			
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Time Step vs. Duration

- The Duration is the length of time that the model can simulate
- The Time-Step is the steps used
- Example: EnergyPLAN uses a **1 hour time-step** over a **1 year duration**
- Time Step: This will not be discussed here due to the detail required



Longest Time-Duration

1 Year	Multiple Years	20-50 Years	2050	50+ Years	No Limit	Not Applicable
Aeolius	EMPS	Balmorel	IKARUS	ENPEP-BALANCE	COMPOSE	E3database
BCHP Screening Tool	ProdRisk	E4cast model	PRIMES	INFORSE	EMCAS	
EMINENT	TRNSYS	energyPRO		MESSAGE	GTMMax	
EnergyPLAN		Invert		ObjECTS-MiniCAM	H2RES	
HOMER		MARKAL/TIMES			LEAP	
HYDROGEMS		National Energy Modelling System			Mesap PlaNet	
ORCED		PERSEUS			SimREN	
SIVAEL		RAMSES				
STREAM		RETScreen				
Wilmar Planning tool		UniSyD				
		WASP				

Longest Time-Duration

1 Year	Multiple Years	20-50 Years	2050	50+ Years	No Limit	Not Applicable
Aeolius	EMPS	Balmorel	IKARUS	ENPEP-BALANCE	COMPOSE	E3database
BCHP Screening Tool	ProdRisk	E4cast model	PRIMES	INFORSE	EMCAS	
EMINENT	TRNSYS	energyPRO		MESSAGE	GTMMax	
EnergyPLAN		Invert		ObjECTS-MiniCAM	H2RES	
HOMER		MARKAL/TIMES			LEAP	
HYDROGEMS		National Energy Modelling System			Mesap PlaNet	
ORCED		PERSEUS			SimREN	
SIVAEL		RAMSES				
STREAM		RETScreen				
Wilmar Planning tool		UniSyD				
		WASP				

Part 3

Technologies Considered

Energy-System Sectors
Generation Technologies
Renewable-Energy Technologies
Storage and Conversion Technologies
Transport Technologies
Focus on Any Particular Technology
Grid Dynamics



Part 3

Technologies Considered

Energy-System Sectors
Generation Technologies
Renewable-Energy Technologies
Storage and Conversion Technologies
Transport Technologies
Focus on Any Particular Technology
Grid Dynamics



Specific Technologies - Yes

Energy Model	Focus
Aeolius	Focus on the impact of fluctuating energy carriers (wind, PV) on the conventional electricity system.
BCHP Screening Tool	CHP
COMPOSE	Cogeneration with electric boiler or compression heat pump
E4cast model	Wind power
EMPS	Hydro power
HYDROGEMS	RE/H2-based stand-alone power systems
Invert	Heat pumps, conventional heating-systems, solar thermal, etc.
ProdRisk	Hydro power



Part 4

Renewable Energy

Ability to Simulate 100% RES
RES penetrations to date



Can Model Simulate a 100% RES System?

Number	Energy Model	100% RES	Number	Energy Model	100% RES
1	Aeolius	Yes	21	MARKAL/TIMES	Yes
2	Balmorel	Yes	22	Mesap PlaNet	Yes
3	BCHP Screening Tool	No	23	MESSAGE	No
4	COMPOSE	No	24	National Energy Modelling System	No
5	E3database	Yes	25	ORCED	No
6	E4cast model	Yes	26	ObjECTS-MiniCAM	Yes
7	EMCAS	Yes	27	PERSEUS	Yes
8	EMINENT	No	28	PRIMES	No
9	EMPS	Yes	29	ProdRisk	Yes
10	EnergyPLAN	Yes	30	RAMSES	No
11	energyPRO	Yes	31	RETScreen	Yes
12	ENPEP-BALANCE	Yes	32	SimREN	Yes
13	GTMax	Yes	33	SIVAEI	Yes
14	H2RES	Yes	34	STREAM	Yes
15	HOMER	Yes	35	TRNSYS	Yes
16	HYDROGEMS	Yes	36	UniSyD	Yes
17	IKARUS	Yes	37	WASP	Yes
18	INFORSE	Yes	38	Wilmar Planning tool	Yes
19	Invert	Yes			
20	LEAP	Yes			

% of Electricity to Date from RES

Number	Energy Model	% Electricity Demand	Number	Energy Model	% Electricity Demand
1	Aeolius	60	21	MARKAL/TIMES	80
2	Balmorel	50	22	Mesap PlaNet	100
3	BCHP Screening Tool	0	23	MESSAGE	70
4	COMPOSE	25	24	National Energy Modelling System	32
5	E3database	100	25	ORCED	50
6	E4cast model	100	26	ObjECTS-MiniCAM	100
7	EMCAS	20	27	PERSEUS	100
8	EMINENT	60	28	PRIMES	50
9	EMPS	100	29	ProdRisk	100
10	EnergyPLAN	100	30	RAMSES	60
11	energyPRO	100	31	RETScreen	100
12	ENPEP-BALANCE	20	32	SimREN	100
13	GTMmax	20	33	SIVAEL	100
14	H2RES	100	34	STREAM	50
15	HOMER	100	35	TRNSYS	0
16	HYDROGEMS	50	36	UniSyD	95
17	IKARUS	30	37	WASP	20
18	INFORSE	100	38	Wilmar Planning tool	50
19	Invert	100			
20	LEAP	100			

% of Heat to Date from RES

Number	Energy Model	% Heat Demand	Number	Energy Model	% Heat Demand
1	Aeolius	0	21	MARKAL/TIMES	80
2	Balmorel	50	22	Mesap PlaNet	100
3	BCHP Screening Tool	0	23	MESSAGE	60
4	COMPOSE	0	24	National Energy Modelling System	5
5	E3database	100	25	ORCED	0
6	E4cast model	100	26	ObjECTS-MiniCAM	20
7	EMCAS	0	27	PERSEUS	50
8	EMINENT	40	28	PRIMES	100
9	EMPS	0	29	ProdRisk	0
10	EnergyPLAN	100	30	RAMSES	60
11	energyPRO	100	31	RETScreen	100
12	ENPEP-BALANCE	20	32	SimREN	100
13	GTMMax	0	33	SIVAEL	80
14	H2RES	80	34	STREAM	80
15	HOMER	100	35	TRNSYS	0
16	HYDROGEMS	50	36	UniSyD	90
17	IKARUS	15	37	WASP	0
18	INFORSE	100	38	Wilmar Planning tool	50
19	Invert	100			
20	LEAP	100			

% of Transport to Date from RES

Number	Energy Model	% Transport Demand	Number	Energy Model	% Transport Demand
1	Aeolius	0	21	MARKAL/TIMES	60
2	Balmorel	10	22	Mesap PlaNet	100
3	BCHP Screening Tool	0	23	MESSAGE	55
4	COMPOSE	0	24	National Energy Modelling System	12
5	E3database	100	25	ORCED	0
6	E4cast model	100	26	ObjECTS-MiniCAM	50
7	EMCAS	0	27	PERSEUS	0
8	EMINENT	0	28	PRIMES	20
9	EMPS	100	29	ProdRisk	0
10	EnergyPLAN	100	30	RAMSES	0
11	energyPRO	100	31	RETScreen	0
12	ENPEP-BALANCE	20	32	SimREN	100
13	GTMMax	0	33	SIVAEL	0
14	H2RES	100	34	STREAM	20
15	HOMER	0	35	TRNSYS	0
16	HYDROGEMS	10	36	UniSyD	55
17	IKARUS	20	37	WASP	0
18	INFORSE	100	38	Wilmar Planning tool	50
19	Invert	100			
20	LEAP	100			

100% RES To Date

1. E3database
2. E4cast model
3. EnergyPLAN
4. energyPRO
5. INFORSE
6. Invert
7. LEAP
8. Mesap PlaNet
9. SimREN



Typical Regions for 9 100% RES Models

Number	Energy Model	Typical Region	Number	Energy Model	Typical Region
1	Aeolius	National/State/Regional	21	MARKAL/TIMES	National/State/Regional
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20	LEAP	National/State/Regional			

Questions or Feedback?



Part 3

Technologies Considered

Energy-System Sectors
Generation Technologies
Renewable-Energy Technologies
Storage and Conversion Technologies
Transport Technologies
~~Focus on Any Particular Technology~~
~~Grid Dynamics~~



Energy Sectors Considered

Energy Sector	% of Models
Electricity Generation	97.4%
Individual House-Heating	51.3%
District Heating	71.8%
Transport	61.5%
Industry	59%
Other	51.3%



Generation Technologies

Generation Technology	% of Models
Thermal Power Plants	94.9%
CHP	92.3%
Nuclear Power Plants	74.4%
Biomass Power Plants	92.3%
Other	61.5%



Renewable Technologies

Renewable Technology	% of Models
Wind	94.9%
Hydroelectric	84.6%
Wave	51.3%
Tidal	43.6%
Solar Thermal	69.2%
Photovoltaic	84.6%
Geothermal	74.4%
Other	35.9%



Storage and Conversion Technologies

Storage & Conversion Technology	% of Models
Pumped-Hydroelectric Energy Storage	64.1%
Battery Energy Storage	56.4%
Compressed-Air Energy Storage	35.9%
Hydrogen Production	51.3%
Hydrogen Storage	41.0%
Hydrogen Consumption	43.6%
Other	28.2%
None	7.7%



Transport Technologies

Storage & Conversion Technology	% of Models
Internal-Combustion Vehicles	41.0%
Battery-Electric Vehicles	48.7%
Intelligent Battery-Electric-Vehicles	28.2%
Vehicle to Grid (V2G)	35.9%
Hydrogen Vehicles	38.5%
Hybrid Vehicles	25.6%
Rail	35.9%
Aviation	35.9%
Other	38.5%
None	35.9%

