A sustainable energy vision for Russia until 2050,
-Background note,

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This background note gives an overview of the potentials for renewable energy and energy efficiency that is used in the sustainable energy vision developed by International Network for Sustainable Energy (INFORSE) – Europe and Russian NGOs. The vision includes growth in most sectors. The growth estimates are based on expected growth in energy services (such as heateed floorspace, transport, production volume), not on forecasts of economic growth.
All comments are welcome, by email to ove@inforse.org.

Renewable Energy Potentials

Windpower:
The INFORSE-Europe Windforce report for Russia (see www.inforse.org/europe) gives a technical windpower potential of 6218 TWh/year as technical potential, divided in 2308 TWh in the European part and 3910 TWh in the Asian (Siberian) part. Other estimates give higher technical potentials; but two order of magnitude lower economic potentials, probably based on windpower economics compared with the very low power prices that Russia has and in particule used to have.

In the current version of the vision is included the technical windpower potential of the European part of Russia and 6% of the potential in the Siberian part. In this way long-distance power lines to bring power from Siberia to European Russia are not included in the vision. In this way the potentials becomes 2538 TWh. Russia has some locations with extraordinary goods windpower potentials, such as east of Murmansk. It is expected that there will be some concentration of the development in such places, and therefore a high capacity factor. As average capacity factor is used 3000 hours / year (34%). The potential windpower capacity included is then 846,000 MW.

Only a part of this potential is expected to be used in this vision:

- approx.. 100 MW in 2010
- 10,000 MW in 2020
  40,000 MW in 2030
- 100,000 MW in 2040, 12% of potential
- 170,000 MW in 2050, 20% of potential

Solar Energy
The area used for solar energy is divided between:

- Solar collectors for hot water (directly used domestically for service sector, industrial heat demand or eventually district heating) with an annual yield of 400 kWh/year (about 40% efficiency) and
- Solar electric cells (PV-cells) with an annual yield of 100 kWh/year (about 10% efficiency).

The solar heating installations can be used for low to medium temperature heat demand (below 150'C) and district heating. Normal flat-plate solar collectors will be limited to supply heat below 90’C, while higher temperatures can be achieved with use of vacuum tube solar collectors. In the current version all development is expected to be for domestic heat demands.

The use of solar energy is limited to:
- 1/3 of buildings heat demand (limited because of seasonal variation) for domestic and service sector heating
- 2/3 of low-temperature process heat (assuming equal demand throughout the year)
-15% of medium-temperature heat

To cover more than 10-15% of buildings demand for space heating and hot water will require energy storages of 1-2 months. Because of the costs of such storages, they are only included after 2040.

The market for solar energy installations in Russia is small . This is not expected to change until 2010; but the development of solar heating is then expected to start and then follow the following path:
-2010 – 2020: 500,000 m2/year (total 5 mill m^2 installed in 2020 equal to 0,04 m2/capita)
-2020 – 2030: 4,5 mill m2/year (total 50 mill.m^2 installed in 2030, equal to 0,4 m2/capita, covering 2% of domestic heat+hot water demand)
-after 2030: 15 mill. m2/year until 2040 then 16.5 mill. m2/year, leading to a total collecto area of 365 mill. m2 in 2050, equal to 2.6 m2/capita and covering 16% of domestic heat and hot water demands.

The installed area for solar electric generation (PV) is only expected to take off from 2020. After 2030 it is expected to expand strongly, leading to 2 m2/capita in 2050 (280 mill. m2 in total).

With this development, an area of 365 mill m2 will be used for solar heating and 280 mill. m2 will be used for solar electric generation in 2050. This is equal to 4.6 m2/person for solar energy use in 2050 in total. Most of this is expected to be on roofs. This area is of course not a maximum and it leaves room for additional solar installations after 2050.

Biomass

The potential for solid biomass consists of wood and straw available for energy purposes. In addition there are potentials for bio-fuel for transportation, biogas and energy plantations; these are treated separately below.
Wood is already used consederably today, mainly for domestic heating. The use was 293 PJ (81 TWh, IEA Energy Balances) in 2000, which seems to include industrial (wood) waste though it is not stated explicitly. The potential is estimated to 600 PJ (167 TWh) for the economic potential fior wood waste and straw according to N. Alkov, B. Poletaev, V. Naymov “Multi-Fuel Cogeneration Energetic Installation, Based on Stirling's Engine” - Materials of the Conference “ Renewable Energy? 2003”. Use of this potential is included in this vision for 2020 and later. Other estimations give much higher technical potentials (430 - 1220 TWh/year); but we are not certain about the sustainability of these potentials, and we have not included them.

Liquid Bio-fuel

There is a potential for liquid biofuel; but it has not been included in this vision because it is small compared with other Russian renewable energy potentials , and therefore not essential for a treansition to sustainable energy.

Biogas
For the potential for biogas (from waste water, agriculture etc.) is used the technical potential of cow manure of 71,000 million m3 biogas/year with an energy content of 1534 PJ (426 TWh)[1]. Another source (Intersolarcentre) states the technical potential to be 800-900 Twh including all sources such as landfill gas, sewage sludge etc. By taking the lower of these potential, we take a conservative estimate; but as it is a technical potential, it is not all economic with current energy prices.

There are a few working biogas plants in Russian at the moment, which we do not expect to change before 2010. Then we expect a large development of biogas, resulting in 10% of the potential utilised by 2020, growing to 60% in 2050.

Energy Crops
The potential for energy crops is dependant of the excess land of agriculture. At the moment there are large areas of unused agricultural lands that were used during Soviet Union. Therefore it is included in this vision that a land area equal to at least 7% of the 1710 mill. ha (17 mill km2) of agricultural land in Russia can be used for permament energy plants such as energy forest/energy plantation.The 7% of agricultural lands is equal to an area of 1.2 mill km2 (120 million ha). With a yield on the land of 5 tons dry matter/ha and an energy content of 4.9 MWh/ton[2] of dry matter, the corresponding energy potential is 2900 TWh = 10,500 PJ. This is well below the yields of 9-12 t/ha obtained for willow-plantations in Southern Scandinavia; but it is expected that the soil fertility is lower and that the plantations will be more extensive. Similar yields can be achieved with other fast-growing trees such as poplar.

We expect the development of energy plantations to start with 120,000 ha/year from 2010 and take off after 2030 with 25% of potential used in 2040 and later equal to use of 2.5% of the present agricultural land for energy plantations.

Geothermal energy
In several parts of Russia there is a potential for geothermal heat in deep water layers with a potential economic energy production of about 345 TWh (1242 PJ), according to 1.Z.A. Ataev. RUSSIAN REGION AND THE PERSPECTIVES OF RENEWABLE POWER ENGINEERING. Currently 0.4% of this potential is used and we assume that 1% will be used in 2020, 5% in 2030 and 40% of in 2050.
While current reported geothermal energy use is for electricity production, it is assumed that the use in the future will be mostly for heat production; but also that geothermal electricity output will increase.With this expected development geothermal energy use will be 500 PJ (139 TWh), of which 90% is for heat and 10% for electricity, increasing geothermal electricity production from 600 GWh in 2000 to 14 TWh in 2050.

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[1] From N. Alkov, B. Poletaev, V. Naymov “Multi-Fuel Cogeneration Energetic Installation, Based on Stirling's Engine” - Materials of the Conference “ Renewable Energy? 2003”

[2] Biomass includes humidity and the calorific value depends on this. As an example coniferous wood with 40% humidity has a lower calorific value of 2.9 MWh/ton, but relative to the dry matter content (60%) the lower calorific value is 4.8 MWh/ton. For beech wood with 20% humidity the lower calorific value is 4.1 MWh/ton and relative to the dry matter the lower calorific value is 5.1 MWh/ton. For straw with 15% humidity the lower calorific value is 4.0-4.2 for different types of straw and relative to its dry matter content the lower calorific value is 4.7 – 4.9 MWh/ton. As an average the (lower) calorific value is set to 4.9 MWh (17.6 GJ) / tons of dry matter.

Hydropower
The hydropower production was 591 PJ (164 TWh) in 2000 (IEA statistics). The potential for additional hydropower on small rivers has been estimated at (382 TWh), while the potential is substantially higher on large rivers. We have not included the development of hydropower on large rivers in this vision for environmental reasons. Therefore we have included a potential of 546 TWh (1966 PJ), combining existing use of hydropower, improvements of existing hydropower stations and most of the potential for hydro power expansion on small rivers.

Other renewable energy potentials
There are possibilities for ocean energies. They are not included in this vision; but they can be very important in the local and regional energy supply. The largest of these potentials are technical tidal power potentials of 272 TWh/year outside the Kamchatka region in Eastern Siberia and 229 TWh/year outside the Kola Pinisula, according to 1.Z.A. Ataev. RUSSIAN REGION AND THE PERSPECTIVES OF RENEWABLE POWER ENGINEERING.

Energy Efficiency Potentials
For the vision is used the finding that the efficiency can be increased a factor 4-10 with known technologies. This has been shown to be possible for Western European energy consuming sectors, see e.g. "Factor 10 Club" (www.factor10.de). Even though the increase of efficiency is cost effective, it will not happen by itself, as the decision-makers, e.g. the designers and manufacturers of equipment are not dedicated to supply and install energy-efficient products for a number of reasons. The increase in efficiency can be measured as decrease in the specific amount of energy used to provide a certain energy service (heated floor space, transported persons or amount of goods, amount of industrial production, use of electric appliances etc.)

For transport, electric appliances, and industrial production, energy consuming vehicles and equipment will be changed several times during the more than 40 years that the vision covers. Thus, there are not technical limitations to raise the efficiency a factor of 4 or more. The following increase in efficiency is included in the vision for industrial appliances (heat, fuels and electricity), electricity and road freight to reach a factor 4 efficiency increase 2000 - 2050:

- 2000 – 2010 5% in total (10% for road freight, domestic and service electricity use)
- 2010-2020: 2%/year (less for road freight, domestic and service electricity use)
- 2020-2030: 3%/year
- 2030-2040: 4%/year
- 2040-2050: 4.1%/year

In the transport sector the realisation of the efficiency will require a technological shift from present internal combustion engines with 15-20% efficiency to hydrogen fuel cells with >50% efficiency and electric vehicles with 60- 80% efficiency, including battery charging cycle losses. In addition is expected implementation of technologies to regain brake-energy from vehicles. This combined will allow the factor 4 increase in efficiency for road transport.

For agriculture, construction, rail, and water transport the following efficiency increases are included until 2050:
40% for agriculture,
50% for construction,
50% for rail transport (partly achieved with electrification), and

25% for navigation.
Also for these sectors the start is expected to be slow: 5% increase 2000 – 2010 for agriculture and construction and no increase in efficiency in rail transport and navigation.

Efficiency of heating
In Russia in 2000 final heat consumption in dwellings was 5,700 PJ (1,580 TWh) of which 51% was from district heating, 33% was from natural gas, only 2% from biomass (wood) and the rest from oil and coal, according to IEA statistics. In 2005 the consumption had decreased 26% to 4240 PJ of which 52% district heating and 38% gas, also according to IEA. From 2000 to 2004 the decrease was only 10% so most of the decrease happened 2004-2005, and it is fair to conclude that it is partly caused by differences in weather and maybe statistical differences, but it is assumed that at least a part is caused by more efficient houses. For thus vision we assume that the energy consumption will decrease from 2000 to 2010, in total 10%. This is a combination of a growth of floorspace of 14% (see below) and an increase in efficiency (decrease in heat consumption per m^2) of 21%.

The total heated area of dwellings was 2787 mill. m2 in 2000 increasing to 2956 mill. m2 in 2005. This corresponds to specific heat demands of respectively 570 kWh/m2 and 400 kWh/m2 in 2000 and 2005, including heating of hot water . This is well above best available technologies, and also well above present levels in Scandinavia, that partly has a climate similar to Russia. In this vision it is assumed that the specific heat consumption is gradually reduced to 165 kWh/m2 in 2050 including consumption for hot water (29% of the specific 2000-consumption) by a combination of new, efficient houses and renovations. This is still a considerably higher consumption than that of modern low-energy houses.

This gives the following specific net heat demand, compared with 2000:

2000	100%
2010	79%
2020	65%
2030	43%
2040	34%
2050	29%

The service sectors (public and private) consumed 718 PJ of heat and fuels in 2000, of which 77% came from district heating according to IEA statistics. This had grown to 1048 PJ in 2005 with all growth from 2004 to 2005 according to IEA statistics. While growth in service sector heat demand is likely, the sudden growth 2004-2005 and no growth 2000-2004 is not such a likely development.The most likely development is a change in categories between service sector and industry, that has 7 times as large consumoption if heat and fuels than the service sectors.

In this vision we assume that efficiency will develop for service sector according to the same trend as for households, while the increase 2000 - 2005 will be dealt with as an increased activity (see below).

Efficiency in Energy Supply
For energy supply we expect an increase in the conversion efficiency in the electricity and heat sector, leading to a decrease in the average loss in power and CHP plants.

For CHP plants the realised electric efficiency was 20% in 2000 and the heat use 37% resultuing in a loss including own consumption of 42%. For power-only plants the (electric) efficiency was 32% excluding own consumption. This is calculated from IEA statistics.

We assume for this vision that the power plants will be replaced in the coming years to BAT, leading to the following increases in efficiencies

We use the following efficiencies for power plants in the vision (CHP/power only):

Power plant efficiencies	2010	2020	2030	2040	2050
Electric	20%/32%*	28%/40%*	35% /47%*	43%/55%*	50/55%*
Heat	37%	42%	42%	42%	42%
Total	57%	70%	78%	85%	85%

* Figures for power-only plants.

The electric efficiencies are based on power plant efficiency data used for Danish energy planning for new plants (Danish Energy Authority, "Technology Data for Electricity and Heat Generating Plants" from www.ens.dk), with reductions due to only partial replacement of power plants. The Danish energy efficiencies data are:

Power plant efficiencies, new plants*		2010	2020 and later
Gas-fired combine-cycle, 100 – 400 MW	Electric (at 100% load)	58-62% (no heat prod.) 53-58% (full heat) 6% lower at 50% load	59-64% (no heat prod.) 54-60% (full heat) 6% lower at 50% load
	Total (at full heat)	90%	91%
Gas-fired combine-cycle, 10 – 100 MW	Electric (at full heat)	47-55% (100% load)	48-56% (100% load)
	Total (at full heat)	90%	91%
Gas engine 1-5 MW	Electric	41-44% (100% load)	as 2010
	Total	88-96%	as 2010
Large biomass-fired steam turbine plant, 400 MW	Electric	46.5% (100% load) 2.5% lower at 50% load	48.5% (100% load) 2.5% lower at 50% load
	Total	90%	as 2010
Straw-fired steam turbine, 5-15 MW**	Electric	29-30%(>75%load)	as 2010
	Total	90%	as 2010
Wood gasification, 1-20 MW	Electric	35-40% 5% lower at 50% load	37-45% 0-5% lower at 50% load
	Total	103%***	103%***

*Net efficiencies, adjusted for own consumption
** Larger installations have larger electric efficiencies
*** With flue gas condensation

Also the efficiency of the electricity network is expected to increase, with the large loss of 17% of consumption in 2000 gradually reduced to 10% in 2050.

A phase-out of nuclear power until 2030 is included in the vision.

Demand for energy services
In this model is not included an automatic link of economic development (GDP growth) and energy consumption. Instead is included expected growth of energy consuming factors, such as heated floor area, transport, production in volume, not in value. These drivers are referred to as energy service demands.

The demand for energy services (heated floorspace, transport etc.) is expected to increase as follows:

Heating (district heating + fuels):
The area of dwellings have increased from 2787 mill. m2 in 2000 to 2956 mill. m2 in 2005 (6.1 % growth), according to the Russian Committee of Statistics (internet information, http://www.gks.ru). The annual growth in the period was in the range of 1.1 - 1.35% according to the same source. In this vision we assume continued growth of 1.3%/year after 2005, until 2040. This give the following floor area realtive to 2000:

2000: 100%
2010: 114%
2020: 129%
2030: 147%
2040: 168%
2050: 191%

There is a similar area of non-residential buildings, and a large part of them are service-sector buildings. This is a high volume of service sector buildings and their area is not expected to increase as fast as residential buildings; but the increase of heat and fuel consumption of 46% 2004-2005 (IEA Energy Balances) is included in the increase 2000 - 2010.
There will be large variations with high growth in some types of private service, while public service will be more stagnant. The development is expected to be 0.5% per year until 2020 and then slow down gradually until 2050. The expected development relative to 2000 of service sector area is therefore:
2000: 100%
2010: 150%, mainly because of statistical differences
2020: 158%
2030: 163%
2040: 168%
2050: 175%

Industrial heat and fuel demand reduced 19% 2000 - 2005 while agricultural heat and fuel demand reduced 22% in the same period. This is expected to reflect an increase in efficiency combined with a stable or slightly increasing production; but the large reduction in agricultural energy demand could also partly reflect a decrease in production.

Industrial output (and related energy service demand) is assumed to double until 2050 in this vision. Because of the expected continuation of the ongoing switch from heat and fuels to electricity as industrial energy input, the heat and fuel based energy services are expected to increase to 188% of the 2000-level by 2050, while electrical energy service demand is expected to increase to 280% of the 2000-level, also by 2050. Because of the factor 4 increase in energy efficiency, the industrial energy demand is in effect decreasing because the efficiency increase is stronger than the growth in energy service demand for industry in this vision.

Agriculture, and construction are expected to continue the same level of activity that it had in 2000, measured in product volume that drives energy consumption. The trend 2000 - 2005 supports this expectation.

Electricity:

Household Sector: we expect household use of electric appliances to increase 20% more than the increase in floor space, with half of this additional increase achieved in 2010. This will lead to an energy service level in 2050 of 210% of the 2000 level.

Service sector: We also expect use of electric appliances to grow 20% more than floor space, leading to a level in 2050 of 195% of the 2000 level (150% without the statistical correction) with half of the additional growth realised until 2010 (because of the statistical correction). The high growth in heat and fuel demand of service sector 2004-2005 also appears in electricity demand, and it is therefore also included here (statistical correction).

Industrial electric energy service demand is expected to grow to 280% of the 2000-level as described above. The large increae is partly expected because of increased automisation and a shift to electricity as energy input for industry.

Construction and farming: We assume increase of 2%/year increase until 2020 (because of increased mechanisation), then stable as heat demands.The reduction in heat and fuel demands for industry 2000 - 2005 is not reflected in a reduction in electricity demand (there was a 1% increase), so the trend 2000-2005 supports this.

Transport:

In Russia the number of cars increased drastically from 75.7 cars/1000 inhabitants in 1993 to 132.4 cars/1000 inhabitants in 2000, an increase of 8%/year. The car use is expected to increase to about 220 cars/1000 inhabitants in 2010, an increase of 67% or 5%/year according to various estimates (210 - 230 cars/1000 inhabitants expected in 2010). This increase rate is expected to continue until 2020, where there would then be 350 cars/1000 inhabitants and then the rate is expected to level off to an increase of 1%/year until 2040. The increase is expected to stop in 2040 at a car fleet of 429 cars/1000 inhabitants or 3.24 times the fleet in 2000. The development after 2020 is a moderate estimate of the growth of the Russian car fleet, estimating that public transport will continue to play a large role and that traffic patterns will follow Western Europe. With a development like in the USA, the car fleet could grow to around 800 cars/1000 inhabitants almost double the number in this estimation.

Train use has increased since 2002, but decreased before (in the period 1992- 2002). The average development 2000-2006 was an increase of 1%/year. Thus, the use of passenger trains is expected to grow 1%/year from 2000 till 2050. Then it will be 1.67 times the use in 2000, or 280,000 mill. passenger km. In 1992 it was 253,000 mill. passenger km.

The use of buses has decreased in the period 2000-2006 according to public statistics; but in reality public buses were replaced by private (mini) buses, so in this vision we estimate no reduction. We assume that bus use also will remain constant in the future.

This gives the following development of personal transport relative to 2000:

	Cars	Train	Buses.
2000	100%	100%	100%
2010	167%	110%	100%
2020	265%	122%	100%
2030	293%	135%	100%
2040	324%	149%	100%
2050	324%	167%	100%

Freight transport

Train transport increased from 1,373,000 mill. ton-km in 2000 to 1,951,000 mill. ton-km in 2006, an increase of 6%/year. This increase is expected to continue until 2020 and then level off to 1%/year until 2040 and then stable.
Pipeline transport increased 1,916,000 mill. ton-km in 2000 to 2,499,000 ton-km in 2006, an increase of 4%/year. Pipeline transport is expected to follow the development in oil and gas extraction (see below).
Truck transport (mainly private trucks) is expected to grow similar to train transport.
Navigation decreased 36% 2000 - 2006. It is expected to decrease 40% from 2000 till 2010 and then remain stable.

This gives the following freight transport relative to 2000:

	Train	Truck	Pipeline	Navigation
2000:	100%	100%	100%	100%
2010:	179%	179%	118%	60%
2020:	321%	321%	124%	60%
2030:	354%	354%	114%	60%
2040:	391%	391%	97%	60%
2050:	391%	391%	95%	60%

Fuel shift
Fuel shift is in general limited to max 3%/year increase or decrease for a specific energy source in a specific sector, but the total can be more as more fuel shifts can happen simultaneously.

Fuel shift in transport is expoected to start with increased electrification of railways. After 2020 this is followed by electrification of road transport and pipelines, as well as introduction of hydrogen in road transport.
In 2030 we expect that railways will be further electrified, covering 80% of rail transport (from 60% in 2000 and 70% in 2020) while we also expect that electricity will cover 15% of energy demand on roads, via the use of electric vehicles including trolley buses. We also expect that 5% of road transport will be driven in hydrogen.
In 2040 we expect that the use of electricity in rail and road transport will increase to respectively 90% and 35%. We expect that hydrogen will cover 10% of rail energy demands and 25% of road transport energy demands.
In 2050 we expect that the railways will be fuelled as in 2040 while road transport energy will be 60% electricity, and 40% hydrogen.

Pipelines will gradually be changed from fossil energy demand to electricity.

Fossil fuels

The oil reserves in Russia are being depleted, while still at a level that allow a gradual transition to sustainable energy sources and a steady oil export for decades. The Energy Watch Group estimates that remaining oil reserves in 2005 were 105 Giga.barrels in 2005 equal to 13,900 Mtoe. With this reserve estimate, the reserve/production(R/P) ratio in 2000 would have been 50 years. Other estimates are higher (e.g. 128 Giga-barrel for an industry database named IHS). Thus we estimate the R/P ratio to 52 years in for this vision. Oil production has increased since 2000, and we estimate that extraction will follow the low scenario of official Russian forecasts until 2020, where it then will be 139% of the 2000-level. After 2020 we expect declining oil production with depletion of resources , and we expect that the production in 2050 will only be 40% of the 2000-level

The gas reserves in Russia are large. Based on an average of the reserves according to BP statistics and official Russian estimates, we assume that the Russian gas reserve in 2005 was 874,000 TWh. With this estimate, the R/P ratio in 2000 would have been 167 years. We assume that extraction will follow the low growth scenario of official Russian forecasts until 2020, where it then will be 116% of the 2000-level. Extraxtion is then expected to remain stable on that level until 2050.

Energy storages and flexible electricit consumption

High reliance on intermittent renewable energy – wind and solar- can require energy storages and flexible energy use. The total fraction of intermittent electricity production in 2020 is expected to be 3% raising to 10% in 2030, 22% in 2040 and further to 37% in 2050. After 2040 this will require special regulation either with electricity storages or with flexible elecricity consumption.

For this vision is included as flexible electricity consumption:

- hydrogen production for transport, converting 75% of electric input to hydrogen and 25% to heat for district heating.
- electric cars with batteries that can be charged at different times at night
- heat pumps that will provide heat for district heating in periods with high intermittent electricity production (mainly from windpower).

The flexible consumption will be 16% in 2040 and 25% in 2050 of electricity demand; electric vehicles not included in flexible consumption. If electric vehicles are included flexible consumption will be 38% in2050. In addition to that is included large heat pumps to change surplus electricity to heat with a factor of 3.5 (COP). This is expected to be able to fully compensate for the fluctuating production:

The heat pump expansion is expected to start after 2030 and to cover 59% of district heating demand in 2050. The heat pumps shall be combined with heat storages (hot water tanks) to store the heat from periods with high wind to periods with low winds (typically weakly storages).

For the CHP plants is recommended daily/weekly heat storages (water tanks) to de-couple electricity and heat deliveries on short-term basis. These storages can also be used for above-mentioned heat pumps.

About this note
This note was developed by Gunnar Boye Olesen, INFORSE-Europe in cooperation with Igor Babanin for the Vision2050 for Russian. Read more about the vision for other countries at www.inforse.org/europe. Please send comments to ove@inforse.org.

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